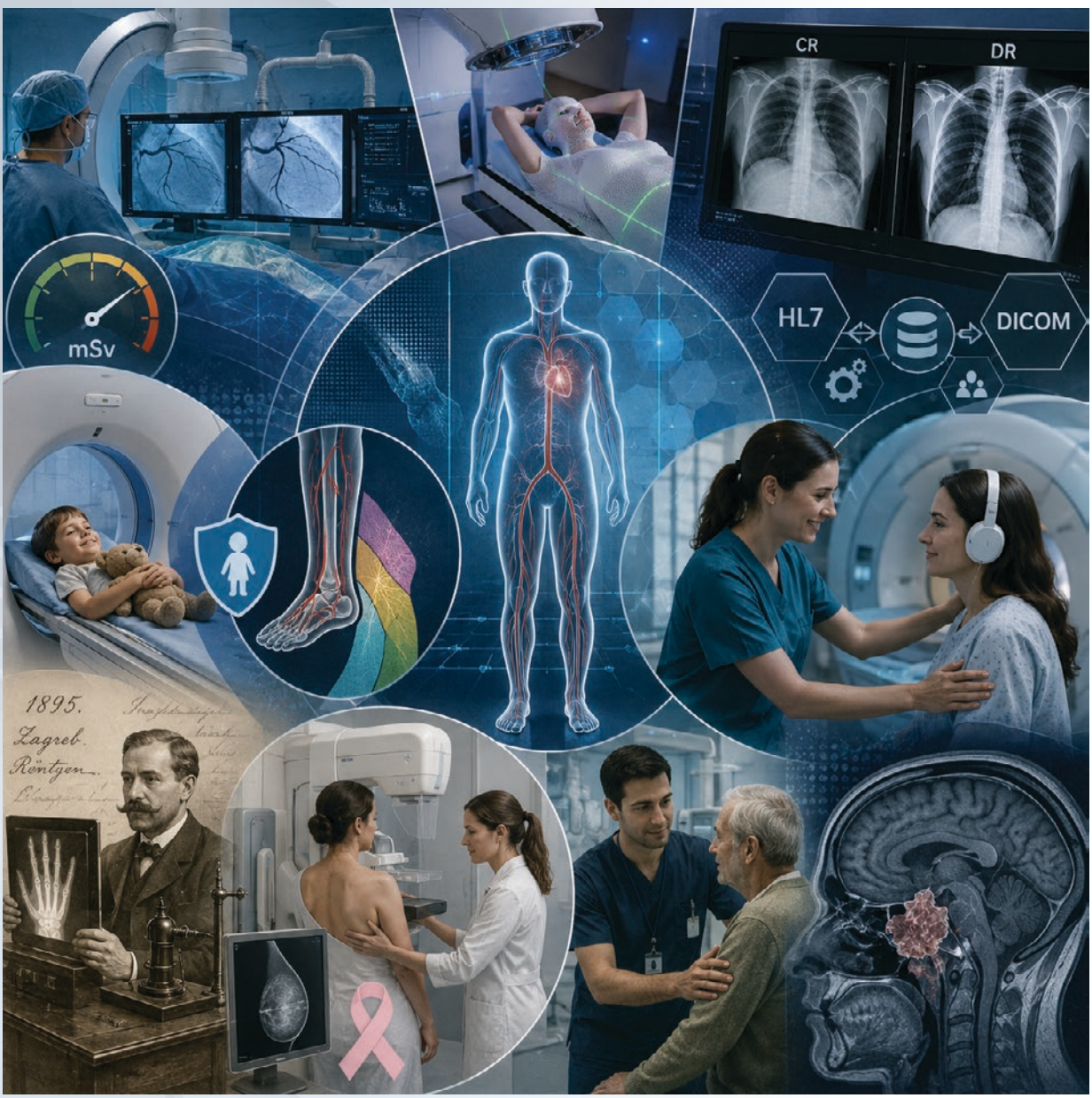
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Retrospective Analysis of Radiation Dose According to Operator Experience During Percutaneous Coronary Interventions in Acute ST-Elevation Myocardial Infarction

Assessment of Intrafractional Displacements in Surface-Guided Inspiration Breath-Hold Stereotactic Body Radiation Therapy

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Riječ urednika

Znanstveni i tehnološki razvoj radiologije oduvijek se temeljio na ravnoteži između inovacije, kliničke preciznosti i zaštite bolesnika. U jesenskom izdanju Radiološkog vjesnika (Vol. 50 No. 2, 2026.) obilježavamo izniman povijesni jubilej – 130 godina od prvih rendgenskih eksperimenata na hrvatskom tlu 1896. godine. Ova opsežna povijesno-analitička studija podsjeća nas na bogate policentrične korijene naše struke od Rijeke i Zagreba do Dalmacije, povezujući pionirski entuzijazam kasnog 19. stoljeća sa suvremenim težnjama prema globalnoj akademskoj i profesionalnoj izvrsnosti i prepoznatljivosti.

Novi broj donosi radove koji izravno odgovaraju na najsloženije izazove moderne kliničke prakse. U području intervencijske kardiologije, autori donose vrijedne izvorne podatke o utjecaju iskustva operatera na doze zračenja pri primarnim PCI zahvatima u STEMI bolesnika. U području radioterapije donosimo analizu intrafrakcijskih pomaka kod površinski vođene stereotaktičke radioterapije (SBRT) u inspiracijskom zadržavanju daha (IBH). Pitanja optimizacije zračenja i načela ALARA dodatno su produbljena usporednom analizom doza na CR i DR sustavima te sustavnim pregledom pedijatrijske CT dijagnostike, gdje se traži idealna granica između dijagnostičke vrijednosti slike i minimalne izloženosti najmlađih bolesnika.

Istodobno, tehnološka integracija različitih sustava zahtijeva i visoku razinu digitalne i procesne organizacije podataka. Kroz analizu problema interoperabilnosti HL7 i DICOM standarda te uloge nacionalnog sustava CEZIH, kao i kroz koncept angiosoma u endovaskularnom liječenju periferne arterijske bolesti, naglašena je važnost interdisciplinarnog povezivanja. Ne manje važno, ovaj broj stavlja snažan naglasak na humanu dimenziju našeg poziva – od empatije radiološkog tehnologa u ublažavanju anksioznosti i klaustrofobije kod MR pregleda, preko specifičnosti pristupa bolesnicima s mentalnim poremećajima, do standardizacije u Školi mamografskog pozicioniranja.

Posebnu vrijednost ovom izdanju daje cjeloviti program i knjiga sažetaka međunarodnog kongresa „Dani radiološke tehnologije 2026“, koji okuplja vodeće domaće i inozemne stručnjake. Vjerujemo da će vam prikupljeni radovi pružiti vrijedne znanstvene i praktične uvide te poslužiti kao poticaj za kontinuirano unaprjeđenje profesije u službi sigurnosti i dobrobiti naših pacijenata.

Glavni urednik:
Frane Mihanović

Zamjenici glavnog urednika:
Tatjana Matijaš i Velimir Karadža

A word from the Editor

The scientific and clinical evolution of medical radiology has always rested upon a delicate balance between technical innovation, diagnostic accuracy, and patient safety. In the Autumn 2026 issue of the Radiological Journal (Vol. 50 No. 2, 2026), we celebrate a momentous milestone – 130 years since the first X-ray experiments were performed on Croatian soil in 1896. This comprehensive historical-analytical study reflects on our polycentric roots across Rijeka, Zagreb, and Dalmatia, bridging the pioneering spirit of the late 19th century with our contemporary journey toward international professional excellence and recognition.

The articles featured in this issue address critical and diverse aspects of contemporary radiological sciences. In interventional cardiology, our contributors present original research examining the impact of operator experience on cumulative radiation doses during primary PCI for STEMI. In advanced radiotherapy, we present an intrafractional displacement analysis in surface-guided SBRT delivered under inspiration breath-hold (IBH). The imperative of dose optimisation is further reinforced by a comparative study of entrance surface doses between CR and DR radiography systems, alongside a rigorous review of paediatric CT protocols balancing image fidelity with radiation stewardship.

Furthermore, modern healthcare demands seamless technical and infrastructural integration. From investigating the complexities of HL7/DICOM interoperability and national CEZIH connectivity to evaluating the angiosome concept in lower extremity endovascular revascularisation, this issue underscores the power of interdisciplinary synergy. Just as importantly, our authors champion the human dimension of care: analysing the pivotal role of technologist empathy in mitigating MRI-related anxiety and claustrophobia, defining best practices for patients with mental health conditions, and elevating clinical standards through the School of Mammographic Positioning.

A significant highlight of this edition is the full program and book of abstracts for the international conference “Radiation Technology Days 2026,” showcasing our community’s vibrant scholarly engagement. We trust that the studies within these pages will provide inspiring clinical insights and reinforce our shared commitment to excellence, rigorous methodology, and patient-centred practice.

Editor in Chief:
Frane Mihanović

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Autori/ce pridržavaju sva prava. Tekstovi u časopisu odražavaju stavove autora/ica i nisu nužno stavovi uredništva niti Hrvatskog društva radiološke tehnologije.

ORIGINAL SCIENTIFIC PAPER (IZVORNI ZNANSTVENI RAD)

Retrospective Analysis of Radiation Dose According to Operator Experience During Percutaneous Coronary Interventions in Acute ST-Elevation Myocardial Infarction

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Abstract

Introduction: Primary percutaneous coronary intervention (pPCI) is the standard reperfusion treatment for patients with STEMI. The procedure involves exposure to ionising radiation and the administration of contrast media, with patient characteristics, procedural complexity, and operator experience potentially influencing the level of exposure.

Aim: To analyze the association between operator experience and radiation dose, with particular emphasis on cumulative air kerma (CAK).

Participants and Methods: A retrospective analysis was conducted on 1,140 patients with STEMI treated with pPCI between January 1, 2021, and December 31, 2025. Patients were divided according to admission troponin levels into a normal-troponin group (n = 293) and an elevated-troponin group (n = 847). Ten interventional cardiologists were categorised according to experience as senior, mid-experienced, and junior operators. CAK, fluoroscopy time, contrast media volume, age, and sex were analysed. Differences were assessed using ANOVA with Duncan's post-hoc test, while independent predictors were analyzed using multivariable linear regression.

Results: In the normal-troponin group, no significant differences were found between operator groups in CAK, fluoroscopy time, or contrast media volume. In the elevated-troponin group, operator experience was significantly associated with CAK ($F = 11.6$; $p < 0.001$), fluoroscopy time ($F = 4.2$; $p = 0.0151$), and contrast media volume ($F = 13.9$; $p < 0.001$). The highest mean CAK was recorded among junior operators (2254.2 mGy), and the lowest among mid-experienced operators (1561.5 mGy). Multivariable analysis identified sex and age as independent predictors of higher CAK, whereas operator experience was not an independent predictor. Greater operator experience was independently associated with lower contrast media use.

Conclusion: The association between operator experience and procedural parameters was most pronounced in patients with elevated troponin levels. After adjustment, CAK was primarily associated with patient characteristics, whereas contrast media use remained associated with operator experience. Optimization of pPCI should include the ALARA principle, individualized procedures, rational use of contrast media, and continuous education and supervision of less experienced operators.

Keywords: STEMI; primary percutaneous coronary intervention; cumulative air kerma; fluoroscopy; contrast media; operator experience; radiation protection.

Introduction

Acute ST-segment elevation myocardial infarction (STEMI) is a medical emergency most commonly caused by acute occlusion of a coronary artery, resulting in myocardial ischemia and necrosis. Timely restoration of coronary blood flow is the cornerstone of treatment, as the duration of ischemia directly affects the extent of myocardial damage. Primary percutaneous coronary intervention (pPCI) is the standard reperfusion treatment when it can be performed within the recommended time frame [1,2].

pPCI involves coronary angiography and, depending on the findings, interventional treatment of the coronary le-

sion. Since the procedure is performed using fluoroscopy and angiographic acquisition, the patient is exposed to ionizing radiation during the intervention. The level of exposure depends on numerous factors, including patient characteristics, the complexity of coronary anatomy, the number of treated lesions and vessels, the procedural technique, and operator experience [3–6].

Cumulative air kerma (CAK) is one of the most important indicators of patient radiation exposure during interventional procedures. In addition to CAK, fluoroscopy time is frequently used as a procedural indicator, while the volume of administered contrast media represents an important measure of the rationality and safety of the intervention.

Previous studies have shown that operator and center experience may be associated with patient radiation exposure during coronary interventions [3,4,8]. However, radiation dose is not determined solely by the operator. Patient characteristics and procedural complexity may have a substantial impact; therefore, differences between operators should be interpreted within the appropriate clinical context.

The aim of this study was to analyse the association between operator experience and radiation dose during pPCI in patients with STEMI, with particular emphasis on CAK. Secondary objectives were to analyse the association between operator experience and fluoroscopy duration and contrast media volume in groups of patients with normal and elevated troponin levels, and to assess the variability of these parameters between operators.

Participants and Methods

Participants

A retrospective study was conducted at the Department of Cardiovascular Diseases of University Hospital Centre Zagreb, within the Division of Invasive and Interventional Cardiology.

A total of **1,140 patients with STEMI** treated between January 1, 2021, and December 31, 2025, were included in the study. Patients were divided into two groups according to their troponin levels at admission: the normal-troponin group consisted of 293 patients, while the elevated-troponin group consisted of 847 patients. All patients were hospitalised within 12 hours of symptom onset, and pPCI was indicated. Patients for whom complete data on radiation dose, fluoroscopy time, or contrast media use were unavailable were excluded from the analysis.

The study included 10 interventional cardiologists divided into three groups according to their experience working in the cardiac catheterisation laboratory: **senior operators** (10–15 years of experience), **mid-experienced operators** (5–10 years), and **junior operators** (1–5 years).

Analyzed Parameters

Patient age and sex, as well as three main procedural parameters, were analysed: cumulative air kerma (CAK), fluoroscopy time, and the volume of administered contrast media.

All procedures were performed using a Siemens Artis Zee angiographic system (Siemens Healthineers, Germany). Pulsed fluoroscopy and image acquisition at 15 frames per second were used. The primary outcome of the study was CAK, expressed in mGy, while the secondary outcomes were fluoroscopy time, expressed in minutes, and contrast media volume, expressed in mL.

Statistical Analysis

Continuous variables were described using the mean and standard deviation or the median and range, depending on the distribution of the data. Differences between operator experience groups were analyzed using one-way ANOVA, and Duncan's post-hoc test was used when statistically significant results were obtained.

The effects of demographic and operator-related factors on CAK, fluoroscopy time, and contrast media volume were assessed using multivariable linear regression. Standardized regression coefficients (β), p-values, R, and R^2 were reported. The level of statistical significance was set at $p < 0.05$.

Results

The analysis included 293 patients with normal troponin levels and 847 patients with elevated troponin levels. In the normal-troponin group, the highest number of procedures was performed by senior operators (n = 141), followed by junior operators (n = 88) and mid-experienced operators (n = 64).

Patients with Normal Troponin Levels

In this group (Table 1), no statistically significant differences were found between operator experience groups in CAK, fluoroscopy time, or contrast media volume.

The mean CAK was **1795.4 mGy** among senior operators, **1890.0 mGy** among mid-experienced operators, and **2168.2 mGy** among junior operators. Although there

Table 1. Basic procedural parameters according to operator experience in STEMI patients with normal troponin levels

Parameter	Senior (n=141)	Mid-experienced (n=64)	Junior (n=88)	F	p
CAK (mGy), $\bar{X}$ ± SD	1795,4 ± 1152,9	1890,0 ± 1498,8	2168,2 ± 1563,0	2,1	0,1273
Fluoroscopy time (min), $\bar{X}$ ± SD	28,3 ± 16,5	11,8 ± 9,6	13,1 ± 11,1	0,5	0,6261
Contrast media (mL), $\bar{X}$ ± SD	182,6 ± 88,5	185,3 ± 91,5	197,7 ± 102,4	0,8	0,4642
Age (years), $\bar{X}$ ± SD	61,6 ± 12,4	65,8 ± 12,6	64,0 ± 11,9	2,8	0,0631

Note: $\bar{X}$ – mean value; SD – standard deviation; CAK – cumulative air kerma.

Table 2. Basic procedural parameters according to operator experience in STEMI patients with elevated troponin levels

Parameter	Senior (n=412)	Mid-experienced (n=214)	Junior (n=221)	F	p
CAK (mGy), $\bar{X}$ ± SD	1879,9 ± 1294,8	1561,5 ± 1227,5	2254,2 ± 2023,6	11,6	<0,001
Fluoroscopy time (min), $\bar{X}$ ± SD	12,4 ± 8,1	10,2 ± 8,8	12,9 ± 14,2	4,2	0,0151
Contrast media (mL), $\bar{X}$ ± SD	207,9 ± 101,0	167,8 ± 71,9	207,7 ± 105,7	13,9	<0,001
Age (years), $\bar{X}$	63,0	63,0	64,0	0,2	0,8328

Note: $\bar{X}$ – mean value; SD – standard deviation; CAK – cumulative air kerma.

was a trend toward higher radiation doses among less experienced operators, the difference was not statistically significant ($F = 2.1$; $p = 0.1273$).

Fluoroscopy time also did not differ significantly between the groups ($F = 0.5$; $p = 0.6261$), nor did the volume of administered contrast media ($F = 0.8$; $p = 0.4642$).

Patients with Elevated Troponin Levels

In contrast to the previous group, statistically significant differences between operator experience groups were observed in patients with elevated troponin levels (Table 2).

The mean CAK was **1879.9 mGy** among senior operators, **1561.5 mGy** among mid-experienced operators, and **2254.2 mGy** among junior operators. The difference was statistically significant ($F = 11.6$; $p < 0.001$).

A statistically significant difference was also found in fluoroscopy time ($F = 4.2$; $p = 0.0151$). The shortest fluoroscopy time was recorded among mid-experienced operators.

The most pronounced difference was observed in contrast media volume ($F = 13.9$; $p < 0.001$). Mid-experienced operators used an average of **167.8 mL**, compared with **207.9 mL** among senior operators and **207.7 mL** among junior operators.

Patient age did not differ significantly between operator groups ($F = 0.2$; $p = 0.8328$).

Multivariable Analysis

The multivariable model for CAK was statistically significant ($R = 0.17$; $R^2 = 0.03$; $p < 0.001$), but explained only approximately 3% of the variability. Independent predictors of higher CAK were sex ($\beta = 0.17$; $p < 0.001$) and age ($\beta = 0.09$; $p = 0.003$), whereas operator experience was not an independent predictor.

The model for fluoroscopy time was not statistically significant ($R = 0.07$; $R^2 = 0.001$; $p = 0.287$).

The model for contrast media volume was statistically significant ($R = 0.18$; $R^2 = 0.03$; $p < 0.001$). Higher contrast media volume was associated with sex and age, whereas greater operator experience was associated with lower contrast media use ($\beta = -0.10$; $p < 0.001$) (Table 3).

Discussion

The main finding of this study was that the association between operator experience and procedural parameters was most clearly evident in patients with elevated troponin levels. In this group, operator experience was associated with CAK, fluoroscopy time, and contrast media volume, whereas such differences were not confirmed in patients with normal troponin levels.

In the normal-troponin group, there was a trend toward higher CAK among junior operators, but the difference was not statistically significant. This finding indicates that operator experience alone is insufficient to explain differences in radiation exposure. The substantial within-group variability, particularly in fluoroscopy time, may be attributable to differences in the complexity of individual procedures.

In the elevated-troponin group, the differences were more pronounced. Junior operators had the highest mean CAK, whereas mid-experienced operators had the lowest. A similar pattern was observed for fluoroscopy time and, particularly, contrast media volume. However, this finding does not imply that mid-experienced operators are generally more efficient than senior operators. Operator selection and case complexity may be influenced by numerous factors that were not captured in this retrospective analysis.

Table 3. Multivariable regression analysis of predictors of CAK, fluoroscopy time, and contrast media volume

Predictor	CAK β	p	Fluoroscopy β	p	Contrast β	p
Sex	0,17	<0,001*	0,02	0,515	0,11	<0,001*
Procedure year	0,02	0,493	−0,04	0,197	−0,05	0,076
Diagnosis	0,00	0,888	0,05	0,076	−0,05	0,108
Operator experience	−0,04	0,190	−0,03	0,385	−0,10	<0,001*
Age	0,09	0,003*	0,00	0,878	0,07	0,027*
Model R	0,17	<0,001*	0,07	0,287	0,18	<0,001*
Model R^2	0,03		0,001		0,03	

Note: β – standardizirani regresijski koeficijent; R – koeficijent multiple korelacije; R^2 – koeficijent determinacije; * $p < 0,05$.

The result of the multivariable analysis of CAK is particularly important. Although operator experience was associated with differences in CAK in the univariable analysis of patients with elevated troponin levels, it was not an independent predictor after adjustment. Patient sex and age were identified as independent predictors of higher CAK. The low R^2 value, approximately 3%, indicates that most of the variability in CAK remains unexplained by the variables included in the model.

This finding is expected given the complexity of pPCI procedures. Radiation dose may be influenced by the number and type of lesions, the number of treated vessels, calcifications, vessel tortuosity, the number of stents, vascular access, additional angiographic projections, and procedural complications. Future analyses should incorporate such indicators to enable a more precise assessment of the effect of operator experience.

Fluoroscopy time proved to be the least predictable parameter. Although a difference between operator groups was observed in patients with elevated troponin levels, the multivariable model was not significant. Therefore, fluoroscopy time should not be used as an isolated indicator of operator performance quality but should be interpreted in relation to procedural complexity.

In contrast to fluoroscopy time, contrast media volume showed a clearer association with operator experience. Greater experience remained independently associated with lower contrast media use. This represents an important practical finding, as rational use of contrast media can be improved through education, standardization, and supervision, particularly among less experienced operators.

The results are consistent with previous studies indicating an influence of operator and center experience on patient exposure during coronary interventions [3,4,8]. At the same time, a study by Balter et al. demonstrated that changes in procedural practices, optimisation of projections, and more rational use of image acquisitions can substantially reduce patient exposure [10].

From a practical perspective, the results support a multidimensional approach to pPCI optimisation. Application of the ALARA principle should include appropriate collimation, rational selection of projections, avoidance of unnecessary acquisitions, and optimal angiographic system settings. At the same time, unnecessary repeated contrast injections should be limited, and required projections should be planned before image acquisition.

Particular attention should be directed toward the education and supervision of junior operators in clinically demanding cases. In this group, junior operators had the highest CAK and greater contrast media use. Continuous monitoring of CAK, fluoroscopy time, and contrast media volume may enable the identification of extreme values and facilitate targeted improvement of procedural practices.

Study Limitations

The main limitations of the study arise from its retrospective design and the fact that it was conducted at a single center. Not all anatomical and procedural factors that may influence radiation exposure and procedure duration were included in the analysis. In particular, detailed indicators of lesion complexity, the number of treated vessels and stents, vascular access, and procedural complications were not available.

Furthermore, categorising operators according to years of experience may not fully reflect actual procedural competence. Differences may exist within individual groups in terms of the total number of procedures performed and experience with complex interventions.

Conclusion

In patients with STEMI, operator experience showed the strongest association with procedural parameters in the group with elevated troponin levels. In this group, significant differences were observed in CAK, fluoroscopy time, and contrast media volume, whereas such differences were not confirmed in patients with normal troponin levels.

Multivariable analysis showed that CAK was primarily dependent on patient characteristics, with sex and age identified as independent predictors, whereas operator experience was not significant after adjustment. In contrast, operator experience was independently associated with lower contrast media use.

The results confirm that optimisation of safety during pPCI cannot focus solely on operator experience. An individualised patient approach, assessment of procedural complexity, application of the ALARA principle, rational use of contrast media, and continuous education and supervision of less experienced operators are required.

All data presented in this paper are part of the results of the Master'thesis "Retrospective analysis of radiation doses in relation to operator experience during percutaneous coronary interventions in ST-elevation myocardial infarction" written at the Faculty of Health Sciences, University of Split (21).

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Retrospektivna analiza doze zračenja s obzirom na iskustvo operatera tijekom perkutanih koronarnih intervencija u akutnom infarktu miokarda sa ST-elevacijom

Sažetak

Uvod: Primarna perkutana koronarna intervencija (pPCI) standardni je oblik reperfuzijskog liječenja bolesnika sa STEMI-jem. Postupak uključuje izlaganje ionizirajućem zračenju i primjenu kontrastnog sredstva, pri čemu na razinu izloženosti mogu utjecati karakteristike bolesnika, složenost zahvata i iskustvo operatera.

Cilj: Analizirati povezanost iskustva operatera s dozom zračenja, uz poseban naglasak na kumulativnu zračnu kermu (CAK).

Ispitanici i metode: Provedena je retrospektivna analiza 1140 bolesnika sa STEMI-jem liječenih pPCI metodom od 1. siječnja 2021. do 31. prosinca 2025. Bolesnici su podijeljeni prema vrijednosti troponina pri prijemu na skupinu s urednim (n = 293) i povišenim troponinom (n = 847). Deset interventnih kardiologa podijeljeno je prema iskustvu na seniore, srednje iskusne operatere i juniore. Analizirani su CAK, fluoroskopsko vrijeme, količina kontrastnog sredstva, dob i spol. Razlike su analizirane ANOVA-om s Duncanovim post-hoc testom, a neovisni prediktori multivarijatnom linearnom regresijom.

Rezultati: U skupini s urednim troponinom nisu utvrđene značajne razlike između skupina operatera u CAK-u, fluoroskopskom vremenu ni količini kontrasta. U skupini s povišenim troponinom iskustvo operatera bilo je značajno povezano s CAK-om ($F = 11,6$; $p < 0,001$), fluoroskopskim vremenom ($F = 4,2$; $p = 0,0151$) i količinom kontrasta ($F = 13,9$; $p < 0,001$). Najviša srednja CAK zabilježena je kod juniora (2254,2 mGy), a najniža kod srednje iskusnih operatera (1561,5 mGy). Multivarijatnom analizom spol i dob utvrđeni su kao neovisni prediktori veće CAK, dok iskustvo operatera nije bilo neovisni prediktor. Veće iskustvo bilo je neovisno povezano s manjom potrošnjom kontrasta.

Zaključak: Povezanost iskustva operatera s proceduralnim parametrima bila je najizraženija u bolesnika s povišenim troponinom. Nakon prilagodbe, CAK je prvenstveno bila povezana s karakteristikama bolesnika, dok je potrošnja kontrasta ostala povezana s iskustvom operatera. Optimizacija pPCI-ja treba uključivati načelo ALARA, individualizaciju postupka, racionalnu primjenu kontrasta te kontinuiranu edukaciju i superviziju manje iskusnih operatera.

Ključne riječi: STEMI; primarna perkutana koronarna intervencija; kumulativna zračna kerma; fluoroskopija; kontrastno sredstvo; iskustvo operatera; radiološka zaštita

ORIGINAL SCIENTIFIC PAPER (IZVORNI ZNANSTVENI RAD)

Assessment of Intrafractional Displacements in Surface-Guided Inspiration Breath-Hold Stereotactic Body Radiation Therapy

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Abstract

Background: Stereotactic Body Radiation Therapy (SBRT) delivers high radiation doses to tumours with steep dose gradients, minimising exposure to surrounding healthy tissues. Surface-guided Inspiration Breath-Hold (IBH) is particularly useful for thoracic and upper abdominal tumours, where respiratory motion can affect target position.

Aim: This retrospective cohort study aimed to assess whether GTV or anatomical surrogate intrafractional displacement during surface-guided IBH remains ≤0.5 cm when surface guidance confirms reproducible breath-hold throughout treatment. The study also evaluated the accuracy and precision of an SBRT protocol using IBH monitored by Surface Guided Radiation Therapy (SGRT). Intrafractional displacement was compared between lung and liver cohorts.

Materials and Methods: Offline reviews were performed for 86 lung SBRT patients (182 fractions) and 124 liver SBRT patients (159 fractions).

Results: In the liver cohort, the greatest mean intrafractional displacement was observed in the vertical (VRT) direction (0.087 cm), while mean shifts in lateral (LAT) and longitudinal (LNG) directions were -0.031 cm and -0.042 cm, respectively. The highest SD was observed in LNG (±0.275 cm). Mean 3D displacement was 0.351 ± 0.181 cm.

In the lung cohort, the greatest mean displacement was observed in the LNG direction (-0.092 cm), followed by LAT (-0.025 cm) and VRT (0.036 cm). The highest SD was also observed in LNG (±0.251 cm). Mean 3D displacement was 0.298 ± 0.186 cm. Significant differences between liver and lung cohorts were observed for VRT, LNG, and 3D displacement (p=0.0140, p=0.0331, and p=0.0032, respectively).

Conclusion: The hypothesis that intrafractional displacement during surface-guided IBH is consistently ≤0.5 cm was not confirmed. Nevertheless, the protocol provided adequate geometric accuracy for most treatments, demonstrating high positional stability during SBRT. Significant differences between lung and liver cohorts suggest that region-specific considerations may be warranted when applying surface-guided IBH SBRT

Keywords: SBRT, inspiration breath-hold (IBH), surface-guided radiotherapy (SGRT), intrafraction motion, lung tumors, liver tumors, geometric accuracy

Background

According to the World Health Organisation (WHO) estimates in 2019, cancer ranks as the first or second leading cause of death before the age of 70 in most countries worldwide, with incidence and mortality rates rapidly increasing. The most commonly diagnosed cancer is female breast cancer, followed by lung, colorectal, prostate, and stomach cancers. However, lung cancer remains the leading cause of cancer death, followed by colorectal, liver, stomach, and female breast cancers [1]. Thanks to improvements in early detection and various treatment modalities such as radiation therapy, surgery, chemotherapy, immunotherapy, and hormonal therapy, many cancers have become curable. Here, radiation therapy plays a vital role since approximately half of all cancer patients will undergo radiation therapy during their illness, contributing to around 40% of curative treatment for cancer [2]. As a primary treatment option, patients at Specialty Hospital Radiochirurgia Zagreb receive SBRT, often in combination with other previously mentioned modalities.

Stereotactic Body Radiation Therapy

Stereotactic Radiosurgery (SRS) is a radiation therapy technique that safely delivers a high dose of radiation to the target volume for the treatment of malignant and benign tumours, blood vessel defects, or functional

disorders in the brain, using fewer fractions [3, 4]. The high dose per fraction and hypo-fractionated scheme have demonstrated satisfactory therapeutic effects with low toxicity in treating small-sized tumours, resulting in ablative effects and tumour control rates previously associated only with surgical resection [5, 6]. The successful outcomes and curative potential of SBRT in treating many primary tumours, along with long-term survival without disease symptoms related to the irradiation of oligometastatic disease, make SBRT a reasonable treatment option if surgery is unavailable or if the patient declines it [7].

Lung SBRT

Lung cancer is the leading cause of cancer deaths in most countries worldwide. The optimal treatment option for stage I non-small cell lung cancer (NSCLC) is surgery; however, a significant number of these patients are deemed inoperable. For inoperable cases, published evidence suggests that SBRT is a safe and feasible approach with results comparable to surgery [8]. Although there is a lack of randomised trials comparing SBRT and surgery in operable cases of early-stage NSCLC, existing evidence from case-control studies indicates equivalence between sublobar resection and SBRT [9]. An important aspect that needs to be considered when we talk about lung SBRT is that it is estimated that 20-54% of cancer patients have lung metastases during the course of their disease, and that lung metastases are the second most common malignant neoplasm of the lung. With that mentioned, it is essential to note that evidence exists supporting the clinical benefit and limited toxicity of SBRT in treating lung oligometastases [10]. In some studies, comparing surface-guided DIBH with the conventional free-breathing four-dimensional (FB-4D) technique in lung stereotactic body radiation therapy (SBRT), DIBH showed a significant reduction in planning target volume (PTV) and a dose reduction to organs at risk (OAR), as well as a higher dose gradient index (DGI) [11].

Liver SBRT

It is estimated that each year, 696,000 deaths occur from primary liver cancer, making it the third most common cancer death worldwide [12]. Similar to lung cancer, surgical resection is the standard treatment approach for solitary or metastatic liver tumours, but with a lot of cases being unresectable, the use of SBRT as a curative modality has increased [13]. The most common primary liver tumour is hepatocellular carcinoma (HCC), and according to Japanese data, only 38% of patients are suitable for surgery [14]. In cases when HCC is challenging to treat with other modalities, SBRT has shown potential to improve the prognosis with high LC and OS rates with acceptable toxicities [15, 16]. In the case of cholangiocarcinoma (CCC), the second most common liver tumour, there is a lack of robust evidence supporting the role of SBRT. Still, preliminary results have shown effectiveness in LC with acceptable treatment-related toxicities [14, 17].

SBRT is most commonly used in the treatment of liver metastases because only 20-30% of patients with liver-only metastases are potentially resectable [14]. Results from an extensive, multi-institutional study have shown that SBRT has reasonable local control (LC) and overall survival (OS) in patients with liver metastases [18]. Similar to the lung, liver SBRT in DIBH, utilising SGRT and IGRT, showed feasibility and a significant reduction in irradiated volume [19].

From indication to treatment at Radiochirurgia Zagreb

Every patient treated at the Specialty Hospital Radiochirurgia Zagreb is first presented to the institutional multidisciplinary tumour board (MTD), where imaging studies, pathology reports, and all available clinical data are presented and reviewed in detail to ensure an accurate diagnosis and identify the most suitable treatment options. If SBRT is indicated, the patient undergoes simulation Computed Tomography (CT) imaging for treatment planning. Usually, MTD does not indicate whether the patient should be treated in IBH or not; that decision is made by radiation oncologists (RO), medical physicists (MP), and radiation therapy technologists (RTT) during CT simulation, depending on the patient's overall condition. In some particular cases, when critical OARs are close to the treated target and dose escalation is necessary, SBRT in IBH is indicated by institutional MTD. The patient then undergoes IBH testing and breathing coaching, if needed, before CT simulation.

Inspiration Breath-Hold training

When institutional MTD indicates SBRT in IBH as a treatment option, the patient is scheduled for IBH testing on the LINAC, where the treatment will be delivered, ensuring consistency between the testing and the actual treatment environment. Before testing, patients receive counselling and detailed instructions regarding the breath-hold technique. They are advised to take a moderate, comfortable breath-hold rather than a deep one, because, in our experience, moderate and comfortable breath-holds are more sustainable and easier to reproduce. Before testing, patients are positioned on the treatment couch as they will be during treatment. An image of the patient's skin surface is captured using the surface-guided radiotherapy system, Optical Surface Management System (OSMS-AlignRT®).

This system generates a three-dimensional map of the patient's external surface geometry by projecting structured light with a speckle pattern.

The region of interest (ROI) for monitoring breath-hold reproducibility is placed on the upper abdomen, over the rib cage.

During IBH testing, patients are instructed to inhale and hold their breath multiple times moderately. The OSMS-AlignRT® system continuously monitors the ROI in real-time, providing feedback on patient motion in all six degrees of freedom.

The threshold for breath-hold reproducibility evaluation is set to ±0.3 cm for vertical (VRT), longitudinal (LNG), lateral (LAT), and rotational directions.

If patients demonstrate consistent and reproducible breath-holds within the defined tolerances during the initial training and testing, they proceed to the CT simulation. If they fail the testing, they are referred to a hospital's respiration therapist for further IBH coaching.

Treatment simulation

Before planning calculations and treatment, patients undergo CT simulation imaging. While CT images are used for treatment planning, magnetic resonance imaging (MRI) provides better soft-tissue evaluation, and positron emission tomography (PET) identifies the disease on the metabolic level. This additional imaging is helpful for image registration and transferring the information about the disease from MRI and PET to the CT scans [20]. At our institution, in addition to simulation CT imaging, patients undergoing liver SBRT also undergo further MRI imaging, which includes T1-weighted in- and opposed-phase and T2-weighted TSE images acquired in IBH, along with additional DWI. In some cases, both lung and liver SBRT patients also undergo PET-CT imaging.

As mentioned before, for some of the patients, institutional MTD indicates SBRT in IBH. Still, for others, RTTs play the major role in that decision during the CT simulation, depending on the patient's overall physical condition, and they are tested for breath-hold reproducibility on the CT machine immediately before the simulation.

Once the patient positioning and immobilisation are determined, patients are tested for breath-hold reproducibility and duration. When they show the ability for IBH, a CT scan is performed.

Patient positioning, immobilisation devices, and other relevant information for treatment are saved in the patient notes to ensure reproducibility and prevent setup errors and inaccuracies during treatment.

Treatment planning

Following CT and MRI simulation, the RO delineates the CTV and OARs. Once this contouring process is complete, the MP begins calculating the treatment plan. The RO prescribes the dose required for the CTV and, in collaboration with the MP, determines an appropriate fractionation scheme. To account for potential patient and setup variability, an isotropic margin of ±0.5 cm is added to the CTV to create the PTV.

All treatment plans for patients included in this study were created in the Varian Eclipse™ treatment planning system (TPS).

Once the plan is finalised, the patient's skin reference surface for setup is created from CT simulation data and sent to the OSMS-AlignRT® system.

Treatment

After the treatment plan is calculated, the patient undergoes the SBRT treatment itself. All patients included in this study were treated on the Varian Edge® LINAC, a radiosurgery system dedicated to intracranial and extracranial radiosurgery treatments [21].

During the treatment, the patient is immobilised and positioned on the treatment couch, according to the prewritten setup notes from the CT simulation. Patient positioning is determined according to the reference surface generated from CT simulation data with the OSMS-AlignRT®. Before the start of treatment, the patient is instructed to perform an IBH, and an image of the patient's skin surface is captured. The ROI for monitoring breath-hold reproducibility is then placed on the upper abdomen, over the rib cage.

A CBCT scan is then performed to correct setup inaccuracies and validate the GTV position against the reference simulation CT. Typically, a CBCT is performed with 2-4 breath-holds, monitored with a ±0.3 cm threshold on the OSMS-AlignRT®. When the GTV is not clearly visible on the CBCT and simulation CT, which often occurs in liver SBRT, the appropriate anatomical surrogates, such as the diaphragm and liver vessel position, can be assessed and used to correct for the setup inaccuracies [22]. When we are certain that our GTV or anatomical surrogate position is correct, the patient is instructed to take another breath-hold. If the breath-hold is the same as before, the treatment couch is shifted during that breath-hold, another image of the patient's skin surface is captured, and treatment can start. If the patient can maintain a reproducible breath-hold according to our surface-guided system, another CBCT is performed in the middle of the fraction to correct for intrafractional displacements. In the case of lung SBRT, the GTV is usually clearly visible on the CBCT and simulation CT, so the intrafractional displacement of that visible GTV is corrected, as shown in Figure 1.

In contrast, for liver SBRT, if the GTV is not visible, the diaphragm, liver vessels, or surgical clips in close prox-

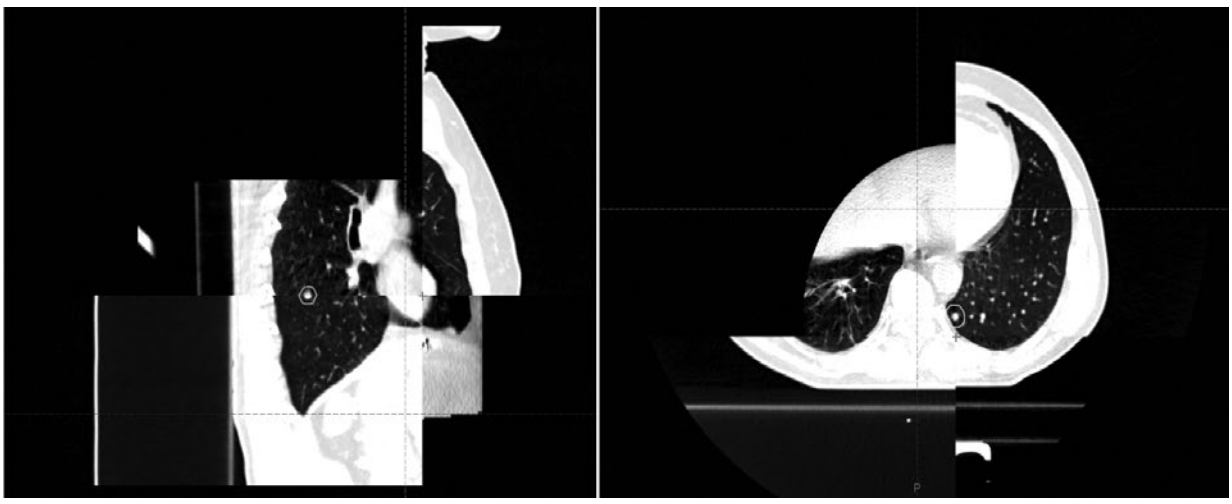


Figure 1: GTV position correction in lung SBRT done in IBH. (Source: Author)

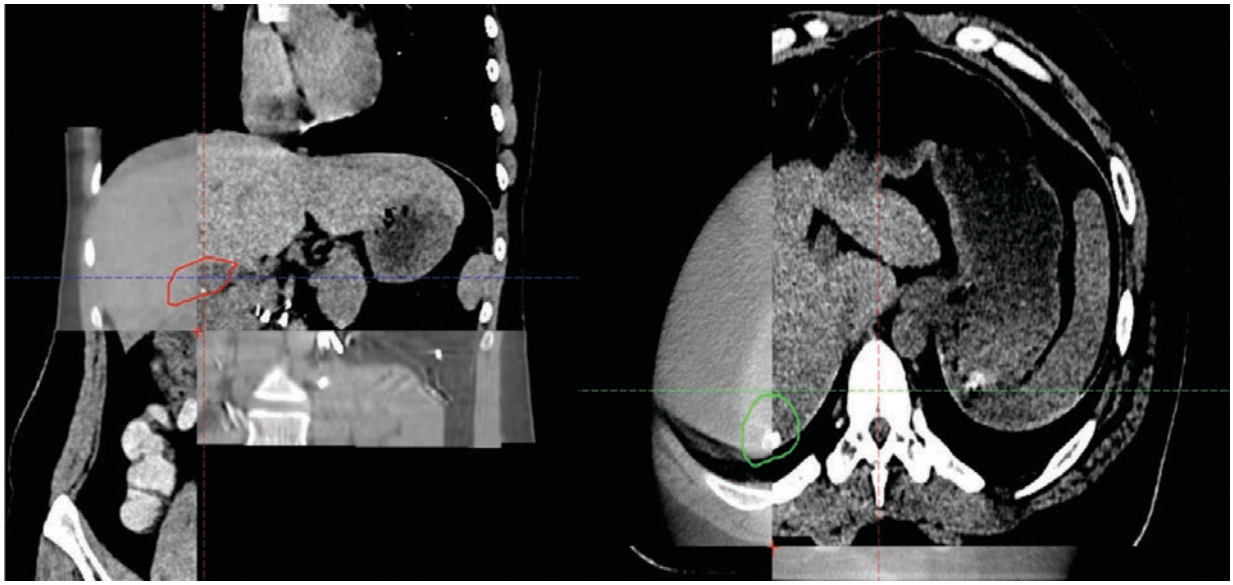


Figure 2: Diaphragm position correction in liver SBRT done in IBH. (Source: Author)

imity to the tumour position are corrected, as shown in Figure 2.

After the intrafractional displacement correction is completed, the couch shift is reapplied during the patient's breath-hold, an image of the patient's skin surface is captured, and the treatment continues.

If the patient moves or changes the amplitude of their breath-hold according to the surface-guidance system, CBCT is performed more frequently for additional correction.

After the treatment is conducted, the patient can go home with a referral for the first follow-up, typically scheduled 3 months post-treatment.

Preparatory work

As preparation for conducting this study, several studies have been reviewed that have evaluated intrafractional displacement in lung and liver SBRT during surface-guided DIBH in combination with IGRT.

As shown in Table 1, the number of studies analysing intrafractional displacement in surface-guided DIBH is limited. The number of patients included is usually lower, with differences in quantification metrics and displacement-direction information stated.

Considering the above, this study was designed to include more patients and fractions, with uniform metric quantification and displacement-direction information, for both lung and liver SBRT patients treated with IBH.

Objectives and Aims

The aim of this study was to confirm the hypothesis that, when OSMS-AlignRT® shows that patients maintain reproducible IBH during the whole treatment, GTV or anatomical surrogate intrafractional displacement during surface-guided IBH is ≤ 0.5 cm, which is used as the isotropic CTV-PTV margin in our institution.

The primary objective of this study was to assess the intrafractional accuracy and precision of our SBRT protocol using the IBH technique monitored by OSMS-AlignRT®. Specifically, we aimed to evaluate differences in couch position in the three main translational directions (VRT, LNG, LAT) from the start of treatment to the middle

Table 1: Publication review on intrafractional displacement for lung and liver SBRT in surface-guided DIBH

Study	Year	Tumour site	Sample size	Metric	Direction	Displacement (cm)
P. Naumann et al.	2020	Liver Lung	10 patients 41 fraction	Mean	3D	Lung: 0.16 (-0.39-0.05) Liver: 0.12 (-0.27-0.28)
E. Brown, E. Muscat, P. O'Connor, H. Liu, Y. Y. Lee, and D. Pryor	2020	Liver	8	Mean	LNG LAT VRT	0.2 (0-0.3) 0.15 (0-0.2) 0.18 (0-0.2)
D. Nguyen et al.	2023	Lung	13 patients 73 fractions 175 CBCTs	Median	LNG LAT VRT	0.12 (0.01-0.17) 0.1 (0.07-0.11) 0.08 (0.07-0.13)
L. B. Stick, I. R. Vogelius, S. Risum, and M. Josipovic	2020	Liver	10 patients	Median	LNG	0.3 (0.01-1.4)
C. Zeng et al.	2022	Liver	1 patient 2 metastases	Mean	3D	0.8 (0.6-1) 1.1 (1.1-1.2)

of the fraction, when a CBCT check is performed to verify and adjust positioning. Positional differences between the initial and middle fraction CBCT, which were analysed and quantified, are shown in Figure 3.

As an additional objective, a comparison of lung and liver cases for each of the translational directions was conducted to determine whether there is a significant difference in intrafractional displacement between lung and liver surface-guided SBRT in IBH.

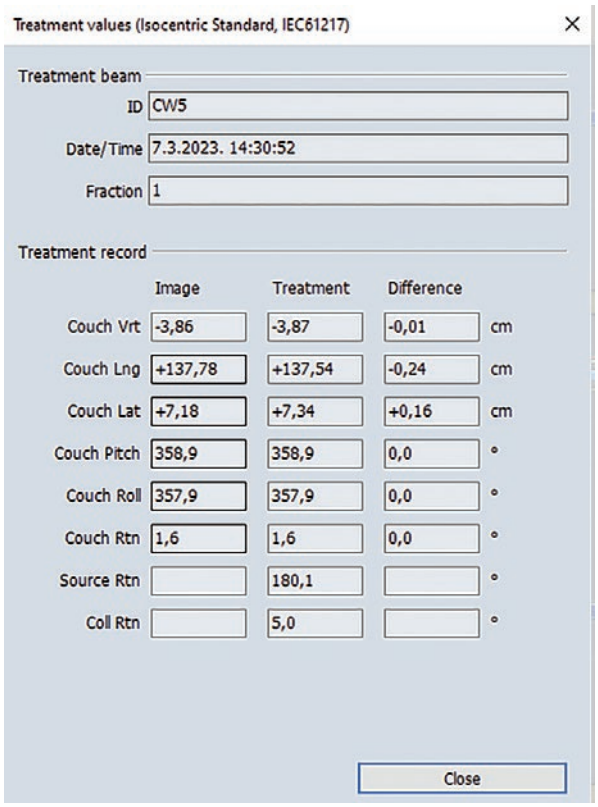


Figure 3: Positional differences between the initial and middle fraction CBCT. (Source: Author)

Materials and Methods

Data for this study were collected retrospectively by reviewing all offline review records found in the Aria® oncology information system of patients with lung and liver SBRT treated with surface-guided IBH from 2021 to 2024 at our institution. The analysis included only those patients who could maintain consistent and reproducible IBH, as per our institutional protocol. Examples of the offline reviews included in this study are shown in Figure 4, where it can be seen that after one or two initial CBCTs, done for patient setup, the next one is performed in the middle of the fraction for correction of intrafractional displacement, indicating that the patient could maintain stable and reproducible IBH through the entire treatment.

In Figure 5, examples of offline reviews excluded from this study are shown. More than one CBCT during the treatment, and a CBCT done in the middle of the same arch, are indicators that the patient moved or could not maintain reproducible IBH during the entire treatment.

Data collection

The initial data collection step was to identify all patients treated for lung and liver SBRT with surface-guided IBH from 2021 to 2024. The offline reviews of all those patients were checked, and based on the offline review, patients were included or excluded from this study.

If the patient met the inclusion criteria, the patient's age, sex, name of the PTV, treatment time, fraction, and positional difference between two CBCTs in VRT, LNG, and LAT directions in centimetres were manually extracted and stored in two separate Microsoft Excel files, one for lung SBRT and one for liver SBRT. In those files, the 3D Euclidean distance was calculated in a separate column.

As a second step, code for the software R [23] was created that utilises those Microsoft Excel files for statistical analysis and the creation of visual representations in the form of boxplot graphs, histograms for each translational direction, and 3D scatter plots.

Between 2021 and 2024, a total of 681 patients with liver and lung SBRT received surface-guided IBH treatment at our institution. Of those, the 210 patients' offline reviews met the criteria for indicating stable and reproducible IBH and were included in this study. The analysis included 86 lung SBRT and 124 liver SBRT patients, with 182 and 159 fractions, respectively. According to the offline review, the remaining 471 patients had multiple CBCTs done during the treatment, which indicated patient movement or changes in breath-hold, so they were excluded from this study.

Table 2 shows patients' demographics and treatment characteristics.



Figure 4: Example of offline reviews used in this study. (Source: Author)

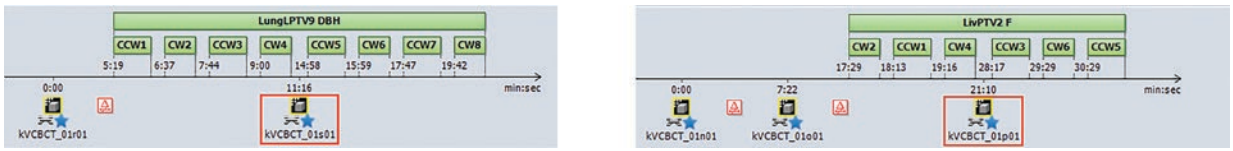


Figure 5: Example of offline review excluded from this study. (Source: Author)

Table 2: Patient demographics and treatment characteristics

Parameter	Lung SBRT	Liver SBRT
Number of patients	86	124
Sex (M/F)	38/48	74/50
Mean age (years)	60.2 ± 13.6	59.1 ± 10.8
Number of fractions	182	159
Average treatment time	24 min 23 sec	24 min 18 sec

Statistical Analysis

For statistical analysis, the software R was used. Microsoft Excel files were imported into R, and the mean, standard deviation (SD), median, and 95% confidence interval (95% CI) of positional differences for each of the three main translational directions (VRT, LNG, LAT) were calculated. 3D Euclidean distance for providing spatial displacement information was automatically calculated in a Microsoft Excel file, with visual representation done in R.

If, in some cases, intrafractional displacement exceeded a 0.5 cm margin, the number and percentage of those fractions were also determined.

Before comparing results between lung SBRT and liver SBRT data, the Shapiro-Wilk test was performed to check the data distribution.

Since the data were not normally distributed across all directions, as shown in Table 3, the non-parametric Mann-Whitney U test was used to compare the differences between the liver and lung SBRT data for each of the translational directions, including 3D displacement.

Table 3: Shapiro-Wilk test results for Region and Direction

Region	Direction	Shapiro-Wilk p-value	Distribution
Liver	VRT	0.00565	Not normal
Liver	LNG	0.0102	Not normal
Liver	LAT	0.0903	Normal
Liver	3D	0.0629	Normal
Lung	VRT	0.000522	Not normal
Lung	LNG	0.0743	Normal
Lung	LAT	0.0106	Not normal
Lung	3D	3.88×10^{-5}	Not normal

Additionally, boxplot graphs and histograms of intrafractional displacements in all directions, along with a 3D scatter plot of spatial distribution, were created to facilitate visual inspection and interpretation of the data.

Results

In liver SBRT patients, the most considerable intrafractional directional displacement has been observed in the mean VRT direction (0.087 cm), with lower mean values of -0.031 cm and -0.042 cm for the LAT and LNG directions, respectively, indicating intrafractional drift of the liver in the posterior–cranial–left lateral direction. The highest SD value has been observed in the LNG direction (±0.275 cm), indicating greater interpatient variability in the caudo-cranial direction. Low median values have indicated minimal displacement for 50% of the fractions in all directions. When looking into the 95% CI, all directions have excluded zero, indicating that the intrafractional displacements in all directions are not random, but rather systematic. The observed 3D mean displacement has been 0.351 ± 0.181 cm, suggesting that for some patients, spatial intrafractional displacement has exceeded a ±0.5 cm isotropic margin.

In lung SBRT patients, the highest mean intrafractional displacement has been observed in the LNG direction (-0.092 cm), with lower mean values of -0.025 cm and 0.036 cm for LAT and VRT directions, respectively, indicating intrafractional drift of the lung similar to the liver, in the posterior–cranial–left lateral direction, with predominantly cranial displacement. Also, identical to the liver, the highest SD value has been observed in the LNG direction. In lung cases, low median values have also been observed, and the 95% CI has excluded zero, indicating a minimal shift for 50% of the fractions, with a systematic trend in all directions. The 3D spatial displacement has been 0.298 ± 0.186 cm, indicating that there has been a possibility of exceeding the used margin in some cases.

Table 4 shows descriptive statistics for liver and lung SBRT patients treated with surface-guided IBH.

Table 4: Descriptive statistics of Intrafractional displacement by Region and Direction

Region	Direction	Mean ± SD (cm)	Median (cm)	95% CI low	95% CI high
Liver	VRT	0.087 ± 0.180	0.050	0.061	0.113
Liver	LNG	– 0.042 ± 0.275	– 0.030	– 0.082	– 0.002
Liver	LAT	– 0.031 ± 0.196	0.000	– 0.060	– 0.003
Liver	3D	0.351 ± 0.181	0.350	0.325	0.377
Lung	VRT	0.036 ± 0.161	0.030	0.014	0.059
Lung	LNG	– 0.092 ± 0.251	– 0.080	– 0.128	– 0.057
Lung	LAT	– 0.025 ± 0.157	0.000	– 0.047	– 0.003
Lung	3D	0.298 ± 0.186	0.281	0.272	0.325

Figure 6 shows a boxplot of intrafractional displacement across all translational directions, and we observed that most displacements in both liver and lung patients remained within ±0.5 cm in all directions. However, each direction has shown at least one outlier exceeding this margin, which indicates that, while intrafractional motion has been well controlled when using surface-guided IBH,

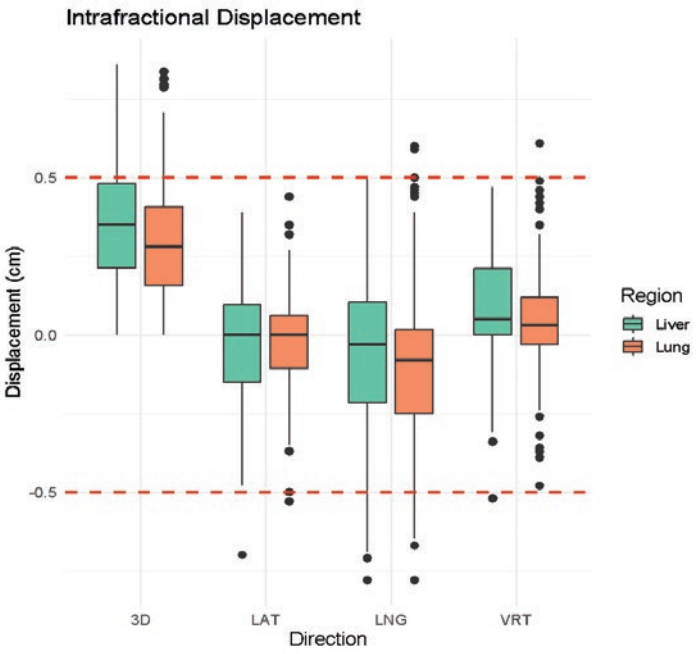


Figure 6: Boxplot graph of Intrafractional displacements in all directions. (Source: Author)

rare but significant excursions have occurred. In particular, both liver and lung patients have exhibited the most frequent margin exceedances in the longitudinal direction, consistent with the high SD values for both groups.

To further visualise the distribution of intrafractional displacements, histograms have been created for each translational direction (LAT, LNG, VRT) and the 3D vector magnitude separately for liver (Figure 7) and lung patients (Figure 8). In both the liver and lung groups, the LAT and LNG directions have been approximately centred around zero but have displayed some asymmetry, particularly in the LNG axis, with a skew toward negative values consistent with cranial displacement. The VRT direction also has shown a skew toward positive values in liver patients, indicating posterior drift. The 3D displacement has exhibited a distribution toward higher values in liver patients compared to lung patients, indicating greater spatial motion in the liver group.

The 3D scatter plot shown in Figure 9 has provided a comprehensive spatial overview of the intrafractional displacements, illustrating the simultaneous relationship between VRT, LNG, and LAT displacements, with each point representing a single treatment fraction. It is evident that although both groups are centred around the origin, the liver data have appeared more dispersed, indicating greater spatial motion in the liver group.

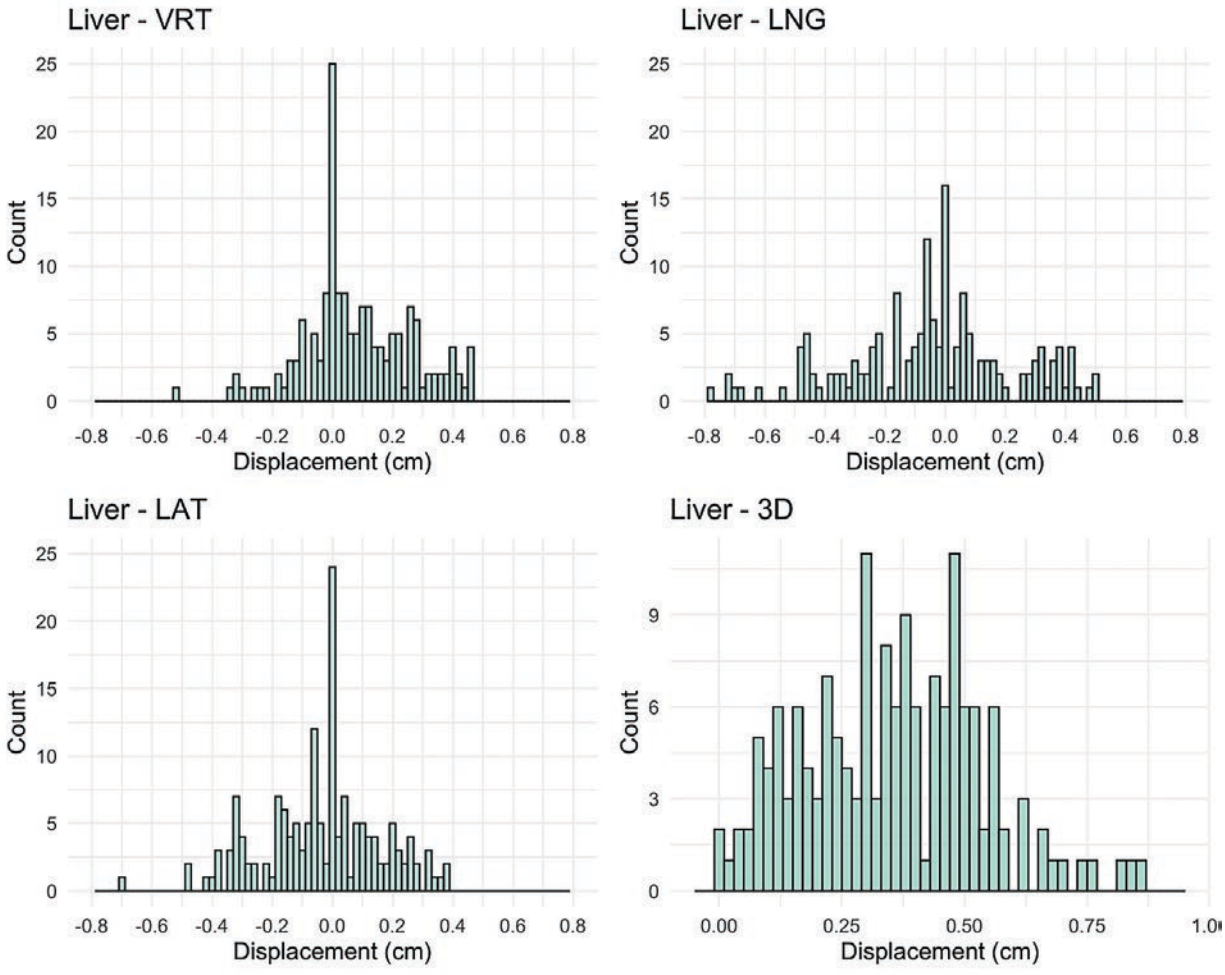


Figure 7: Histograms of liver Intrafractional displacements. (Source: Author)

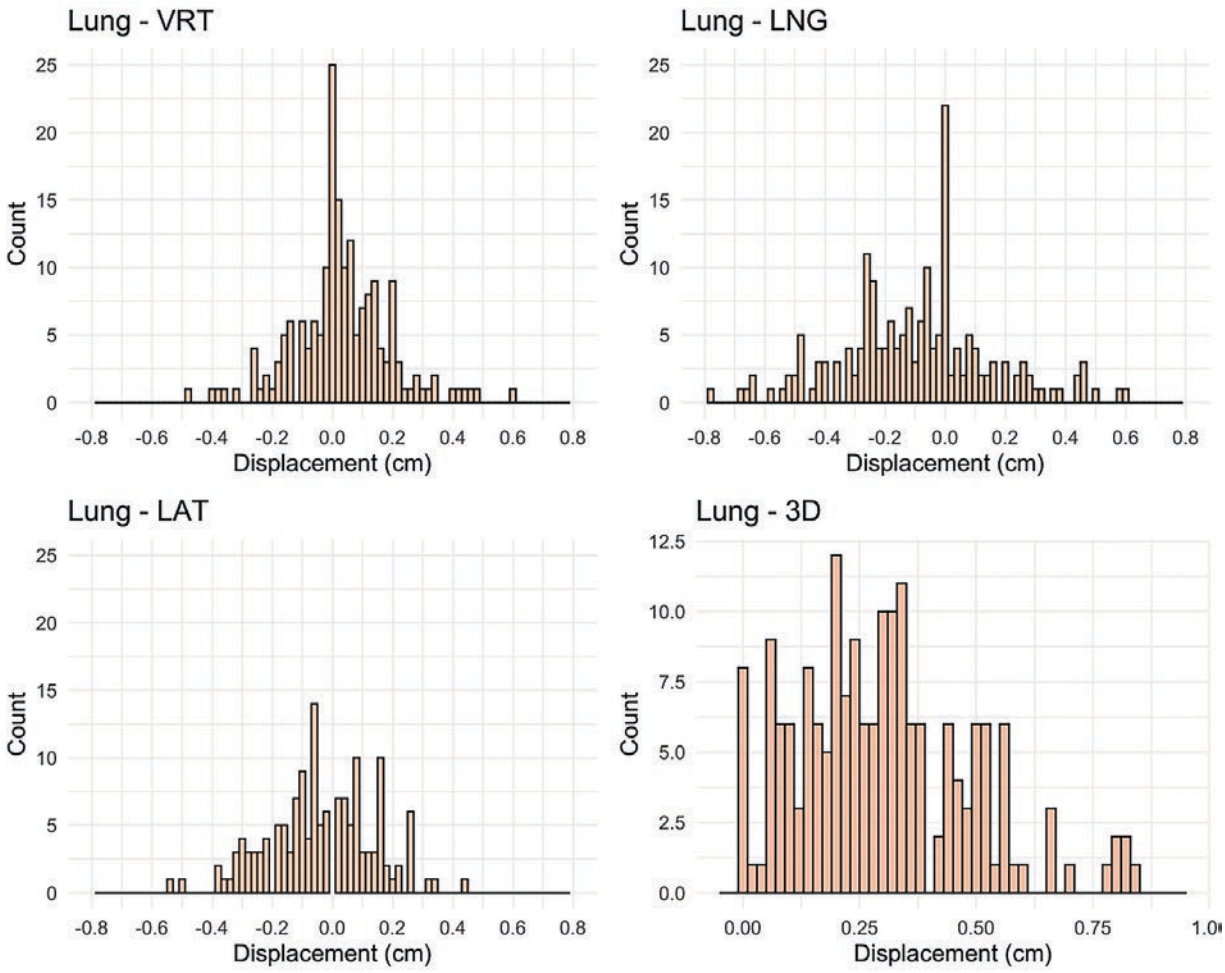


Figure 8: Histograms of lung Intrafractional displacements. (Source: Author)

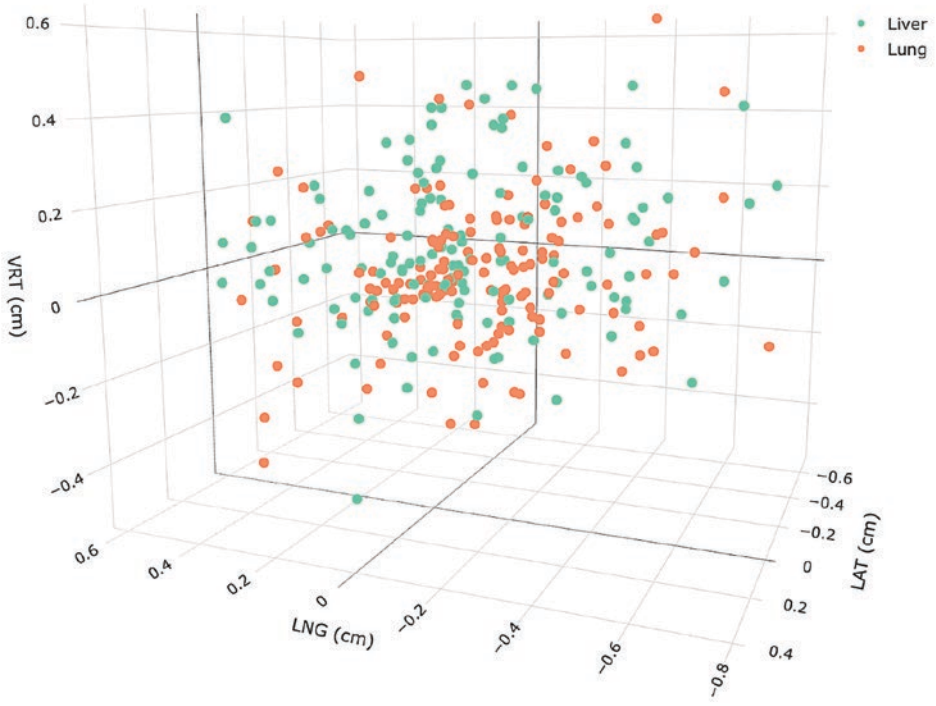


Figure 9: 3D scatter plot of Intrafractional displacements for liver and lung patients. (Source: Author)

Since the intrafractional displacement in all directions has exceeded the ±0.5 cm margin at least once, the number and percentage of those fractions have been determined. The highest number of exceedances has been observed in the 3D spatial direction, with 31 fractions (19.5%) for liver patients and 27 fractions (14.8%) for lung patients, respectively. When examining each translational direction separately, the highest number of exceedances has been, as mentioned above, in the LNG direction for both groups: 7 fractions (4.4%) for liver patients and 11 fractions (6.04%) for lung patients.

The summary of fractions with displacements exceeding ±0.5 cm can be seen in Table 5.

Table 5: Fractions with displacements exceeding ± 0.5 cm by direction and region

Region	Direction	Exceeding	Total	Percentage
Liver	3D	31	159	19.5%
Liver	LAT	1	159	0.63%
Liver	LNG	7	159	4.4%
Liver	VRT	1	159	0.63%
Lung	3D	27	182	14.8%
Lung	LAT	1	182	0.55%
Lung	LNG	11	182	6.04%
Lung	VRT	1	182	0.55%

As previously mentioned, the comparison of liver and lung data has been conducted using the Mann-Whitney U test. The results shown in Table 6 have revealed significant differences in VRT, LNG, and overall 3D spatial intrafractional displacement between liver and lung SBRT patients treated with surface-guided IBH (p-values = 0.0140, 0.0331, and 0.0032, respectively). These findings have aligned with prior results from descriptive analysis between these two groups, indicating that liver patients have experienced greater posterior intrafractional motion, while lung patients have exhibited more pronounced cranial intrafractional motion. In contrast, no significant difference has been found in LAT direction ($p = 0.786$), suggesting that lateral motion patterns have been similar for both anatomical regions when treated with surface-guided IBH. The results for 3D displacement have shown a significant difference between liver and lung patients ($p = 0.0032$), supporting the indication that the liver group has experienced higher spatial intrafractional motion during surface-guided IBH SBRT.

Table 6: Statistical comparison between lung and liver data

Direction	Mann-Whitney p-value
VRT	0.0140
LNG	0.0331
LAT	0.786
3D	0.0032

Discussion

In this large retrospective single-centre study, intrafractional displacement during surface-guided IBH SBRT was evaluated in liver and lung SBRT patients across a total of 341 treatment fractions. The cohort included 159 liver and 182 lung fractions.

The results demonstrated excellent positional stability, with mean directional displacements remaining well below the institutional isotropic CTV-PTV margin of ±0.5 cm.

The largest mean displacement was noted in the VRT direction for liver patients (0.087 cm) and in the LNG direction for lung patients (-0.092 cm). Both groups exhibited high variability in the LNG direction, with an SD of 0.275 cm for the liver and 0.251 cm for the lung, respectively.

Despite favourable average results, boxplot analysis showed that at least one outlier was identified in each direction that surpassed this margin.

The highest number of fractions surpassing a ±0.5 cm margin was observed in the 3D spatial direction, accounting for 19.5% of liver fractions and 14.8% of lung fractions. Additionally, in LNG directions, 4.4% of liver fractions and 6.04% of lung fractions exceeded this margin.

The histogram analysis conducted on both the liver and lung groups demonstrated a skew toward positive values in the VRT direction and negative values in the LNG direction, respectively, thereby visually confirming the findings derived from descriptive statistics. A 3D histogram revealed a broader distribution toward higher values in liver patients compared to lung patients, indicating that spatial displacement is not only greater in magnitude but also more variable in the liver group, which is further confirmed by the 3D scatter plot.

Shapiro-Wilk test p-values below 0.5 in five of eight region-direction combinations justified the use of the Mann-Whitney U test, which revealed significant differences in VRT, LNG, and 3D displacement between liver and lung patients ($p = 0.0140$, 0.0331, and 0.0032, respectively), while lateral shifts did not differ ($p = 0.786$).

These results support indications that during surface-guided IBH, intrafractional displacement of the liver is predominantly posterior, with higher spatial displacement, while in lung cases, intrafractional displacement is predominantly cranial.

When compared with previous publications, the mean 3D spatial displacements of 0.351 cm for liver patients and 0.298 cm for lung patients are somewhat higher than those previously reported, where mean 3D displacements were 0.12 cm and 0.16 cm for liver and lung patients, respectively [19].

Reported directional means of 0.2 cm (LNG), 0.15 cm (LAT), and 0.18 cm (VRT) for liver patients [24] are higher than those in this study, but have similar SD values.

Median displacements in the lung group were comparable to previously published values [25].

This study's results indicated the greatest variability in the LNG direction for both lung and liver patients, which is consistent with prior reports [26].

Some cases reported in the literature observed higher displacements with 3D values exceeding 0.8 cm in an individual patient [27], which supports this study's finding that rare but high excursions do occur.

Overall, when compared with the published literature, this study confirms the general magnitude and directionality of intrafractional displacements in patients treated with surface-guided IBH SBRT, with some differences in results that can potentially be attributed to variations in sample size.

One of the strengths of this study is its large sample size, uniform imaging with SGRT workflow, and standardised analysis methodology; however, its retrospective design and reliance on couch shift data for target displacement present a limitation, as this approach may not fully capture real-time target motion.

Despite these limitations, this study's findings provide valuable insight into intrafractional displacements in surface-guided IBH liver and lung SBRT, highlighting areas for future optimisation.

Conclusion

The results of this study demonstrated that the mean displacement along each axis was well below the ±0.5 cm margin; however, some fractions exceeded this threshold, most frequently in the 3D spatial direction and in the LNG direction. Consequently, the hypothesis cannot be accepted, as the current protocol provides adequate geometric accuracy for most treatments, but it is not universally applicable.

Differences in anatomical displacement were also noted. Liver targets showed larger posterior (VRT) and overall 3D shifts, while lung targets demonstrated greater superior/cranial (LNG) intrafractional motion. These findings suggest that a uniform isotropic margin may not adequately address axis-specific drift patterns, and that site-specific anisotropic margins tailored to individual anatomical sites could be more effective.

Despite its retrospective design and reliance on couch-shift data, this study derives significant advantages from a large cohort, a uniform SGRT workflow, and a standardised analytical framework.

Although intrafractional displacement excursions occurred and the main hypothesis wasn't confirmed, these results provided valuable insights and essential information for refining our protocol and approach to treating liver and lung targets with surface-guided IBH SBRT.

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Procjena intrafrakcijskog pomaka u stereotaktičkoj radioterapiji uz navođenje površinom i zadržavanje daha u inspiriju

Sažetak

Uvod: Stereotaktička radioterapija tijela (SBRT) omogućuje primjenu visokih doza zračenja na tumor uz strme gradijente doze i minimalno ozračenje okolnog zdravog tkiva. Površinski vođeni inspiracijski breath-hold (IBH) osobito je koristan kod tumora prsnog koša i gornjeg abdomena, gdje respiratorno gibanje može značajno utjecati na položaj cilja.

Cilj: Cilj ove retrospektivne kohortne studije bio je procijeniti intrafrakcijski pomak GTV-a ili anatomskog surogata tijekom površinski vođenog IBH-a u slučajevima u kojima je površinskim praćenjem potvrđeno održavanje reproducibilnog IBH-a tijekom cijelog tretmana. Također je procijenjena intrafrakcijska točnost i preciznost SBRT protokola primjenom IBH-a praćenog površinski vođenom radioterapijom (SGRT). Uspoređeni su intrafrakcijski pomaci između kohorti pacijenata s tumorima pluća i jetre.

Materijali i metode: Analizirane su frakcije 86 pacijenata liječenih SBRT-om zbog tumora pluća (182 frakcije) i 124 pacijenta s tumorima jetre (159 frakcija).

Rezultati: U kohorti tumora jetre najveći srednji intrafrakcijski pomak zabilježen je u vertikalnom (VRT) smjeru (0,087 cm), dok su srednji pomaci u lateralnom (LAT) i longitudinalnom (LNG) smjeru iznosili -0,031 cm i -0,042 cm. Najveća standardna devijacija zabilježena je u LNG smjeru (±0,275 cm). Srednji 3D pomak iznosio je 0,351 ± 0,181 cm.

U kohorti tumora pluća najveći srednji pomak zabilježen je u LNG smjeru (-0,092 cm), dok su pomaci u LAT i VRT smjeru iznosili -0,025 cm i 0,036 cm. Najveća standardna devijacija također je zabilježena u LNG smjeru (±0,251 cm). Srednji 3D pomak iznosio je 0,298 ± 0,186 cm.

Statistički značajne razlike između kohorti utvrđene su za VRT, LNG i 3D pomak ($p = 0,0140$, 0,0331 i 0,0032).

Zaključak: Studija nije potvrdila da je intrafrakcijski pomak tijekom površinski vođenog IBH-a uvijek ≤ 0,5 cm. Protokol osigurava odgovarajuću geometrijsku točnost u većini tretmana, uz značajne razlike između plućne i jetrene kohorte koje ukazuju na potrebu za regionalno prilagođenim pristupom.

Ključne riječi: SBRT, inspiracijski breath-hold (IBH), površinski vođena radioterapija (SGRT), intrafrakcijski pomak, tumori pluća, tumori jetre, geometrijska točnost

ORIGINAL SCIENTIFIC PAPER (IZVORNI ZNANSTVENI RAD)

Radiation Doses in Different Digital Radiography Systems: A Comparison of CR and DR

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Abstract

Introduction: This study evaluates radiation doses associated with computed radiography (CR) and digital radiography (DR) systems during radiographic examinations of the chest, shoulder, and pelvis with hips.

Objective: The aim of this study was to compare entrance surface doses (ESD) between CR and DR systems and to assess the potential of DR technology for radiation dose optimisation.

Methods: The study included 180 participants of both sexes and different ages. ESD was calculated based on data obtained during annual testing of the X-ray equipment performed in 2025. An independent-samples t-test was used to compare CR and DR systems, the Mann–Whitney U test was used to analyse differences between male and female participants, and linear regression analysis was used to assess the association between ESD values obtained with CR and DR systems. Statistical significance was set at $p < 0.05$.

Results: The DR system yielded lower mean ESD values in all analysed anatomical regions. Statistically significant differences were found for chest and shoulder examinations, whereas the difference for pelvic examinations was not statistically significant. Linear regression analysis showed no statistically significant linear association between ESD values obtained with CR and DR systems.

Conclusion: Under the conditions of this study, the DR system demonstrated lower ESD values than the CR system, particularly for chest and shoulder examinations. The results highlight the importance of proper use of the automatic exposure control (AEC) system and optimisation of exposure parameters to reduce patient exposure to ionising radiation.

Keywords: computed radiography, digital radiography, radiation dose, entrance surface dose (ESD), radiation protection

Introduction

Digital Radiography

Digital radiography is currently one of the fundamental imaging methods used in everyday radiological practice. The development of digital technologies has significantly changed the way radiographic images are acquired, processed, displayed, and stored, while also enabling their integration into modern information systems. The introduction of digital detectors has created new opportunities to optimise radiographic procedures, particularly regarding the relationship between image quality and patient exposure to ionising radiation (1,2).

Unlike conventional radiography, in which the image is formed using a film-screen system, digital radiographic systems enable electronic acquisition and computer-based processing of image data. Digital images can be processed, displayed, and stored without a physical medium. These capabilities increase the efficiency of the radiological workflow, but also require a systematic approach to controlling exposure parameters and protecting patients from unnecessary radiation exposure (1,2).

In contemporary digital radiography, two systems are commonly distinguished: computed radiography (CR) and digital radiography (DR). Although both systems ultimately produce a digital radiographic image, the mechanisms by which X-rays are converted into an image signal differ substantially. These differences are not only technological they may also affect acquisition efficiency, workflow, detector characteristics, and the relationship between required exposure and resulting image quality (3).

Computed Radiography (CR)

Computed radiography was one of the first widely implemented digital radiography technologies. CR systems use a photostimulable phosphor plate (PSP) housed within a radiographic cassette. During exposure, X-rays pass through the patient and reach the phosphor plate, where a portion of the X-ray photon energy is stored within its structure. In this way, a latent radiographic image is formed (4,5).

Unlike DR systems, CR technology does not make the digital image immediately available after exposure. Following the examination, the cassette must be transferred to a CR reader, where the phosphor plate is scanned with a laser beam. The energy stored during exposure is released in the form of light, and the resulting signal is converted into an electrical signal, which is subsequently digitised and processed. After reading, the plate is erased and prepared for reuse (5).

This workflow represents an important difference compared with DR technology, as CR involves an additional step between exposure and digital image acquisition. An advantage of CR systems is that they can be implemented with existing radiographic equipment with relatively minor infrastructure modifications, facilitating the gradual transition from conventional film-screen radiography to digital technology. However, cassette handling and the need for image readout prolong the workflow compared with direct digital image acquisition (4,5).

From the perspective of dose optimisation, the characteristics of CR detectors play an important role. The amount of radiation required to obtain an adequate radiographic image depends on the sensitivity of the phosphor plate, exposure parameters, and the method of image signal processing. At the same time, the wide dynamic range of digital systems allows an acceptable image to be obtained over a relatively broad range of exposure levels. Therefore, image quality alone cannot be used to determine whether an optimal amount of radiation was applied during the examination (5).

Digital Radiography (DR)

Digital radiography represents a technologically advanced approach to radiographic image acquisition. DR systems use flat-panel detectors that enable the near-immediate conversion of information obtained during X-ray exposure into a digital image. Unlike CR systems, there is no need to remove a cassette after exposure or to perform a separate phosphor plate readout procedure (6,7).

Flat-panel detectors can use different technologies for converting X-rays. In indirect conversion, a scintillator layer converts X-ray photons into light, after which photodiodes convert the light signal into an electrical signal. A thin-film transistor (TFT) array reads the electrical signal, then digitises and further processes it in a computer system. This enables rapid acquisition of the digital image and its near-immediate availability to the radiologic technologist and physician (7).

The immediate availability of images represents one of the major advantages of DR systems. It enables faster assessment of technical image quality, a more efficient workflow, and easier integration with digital systems for image storage and distribution. Digital image processing also allows adjustment of image display, including changes in contrast and visualisation of individual anatomical structures, without the need for repeated exposure (2,6).

However, the technological advantages of DR systems do not by themselves mean that every radiographic examination will be performed with a lower radiation dose. DR technology may provide a more favourable relationship between image quality and dose, but the actual dose also depends on the protocol, automatic exposure control, patient positioning, exposure parameters, and detector characteristics (6,7). Therefore, comparisons of CR and DR systems should be based on actual use conditions rather than solely on technological differences between detectors.

Detective Quantum Efficiency and the Relationship Between Image Quality and Dose

One important parameter used to describe digital detector efficiency is detective quantum efficiency (DQE). DQE describes the ability of a detector to convert incident X-ray radiation into useful image information while minimising signal loss and noise. A higher DQE value generally indicates more efficient use of incident radiation to produce a diagnostically useful image (8).

DQE therefore represents an important technological factor when considering the relationship between image quality and dose. However, DQE does not independently determine the patient's overall radiation exposure. The actual amount of radiation is also influenced by X-ray beam energy, exposure parameters, detector design, image processing, automatic exposure control, imaging geometry, and the patient's anatomical characteristics (7,8).

Therefore, when comparing CR and DR technologies, it is necessary to distinguish the detector's potential efficiency from the patient's actual radiation exposure in clinical practice. This distinction is one reason quantitative dose assessment is important in evaluating digital radiographic systems (8).

Optimisation of Radiographic Procedures and the *Dose Creep* Phenomenon

Patient protection from ionising radiation is based on the ALARA principle (As Low As Reasonably Achievable), according to which radiation exposure should be maintained at the lowest reasonably achievable level that allows a diagnostically acceptable image to be obtained. In radiography, the goal of optimisation is not simply to apply the lowest possible dose, but rather to achieve an appropriate balance between patient exposure and the image quality required for diagnosis (9).

Patient exposure is influenced by several interrelated factors. The most important include X-ray tube voltage (kV), tube current–time product (mAs), source-to-image distance (SID), filtration, collimation, detector characteristics, and the use of the automatic exposure control (AEC) system. Proper application of these factors enables standardisation of radiographic procedures and reduces unnecessary variations in patient exposure (4,9).

A particular challenge in digital radiography is the phenomenon known as *dose creep*. Digital detectors have a wide dynamic range, making it possible to obtain a diagnostically acceptable image at different exposure levels. Unlike

film-screen systems, in which excessive or insufficient exposure is relatively clearly manifested through changes in optical density, digital systems use image processing that can maintain an acceptable image appearance even when the amount of radiation applied increases (4,9).

Dose creep therefore refers to the gradual increase in exposure values over time, often intended to ensure sufficient image quality. Such increases may remain undetected if exposure is not systematically monitored. In the long term, this may lead to an unnecessary increase in patient dose without a corresponding diagnostic benefit (4,9).

Therefore, quality control of digital radiography systems should not focus exclusively on visual assessment of image quality. It is important to monitor exposure parameters and, whenever possible, use objective dosimetric indicators. Such an approach enables deviations from typical values to be identified and provides a basis for optimising radiographic protocols (4,9).

Assessment of Patient Exposure: DAP and ESD

Quantitative assessment of patient exposure is an important component of optimisation programs in radiology. Various dosimetric indicators can be used for this purpose, depending on the type of radiological procedure and the technical capabilities of the radiographic equipment (10,11).

One important dosimetric indicator is DAP (Dose Area Product). DAP represents the product of radiation dose and the irradiated field area. In this way, it combines information on radiation dose and the size of the irradiated area. Therefore, DAP can be useful for monitoring patient exposure, comparing different radiographic procedures, and evaluating protocol optimisation (10,11). An important property of DAP is that it is independent of the distance between the radiation source and the patient.

DAP can be determined using a DAP meter integrated into the radiographic system, allowing the value to be obtained for an individual exposure. However, its use depends on the equipment's technical capabilities and the availability of an appropriate measuring system. When DAP measurement is not available, patient exposure can be estimated by calculating the entrance surface dose (ESD) based on the X-ray tube output and the actual exposure parameters (11,12).

ESD represents the estimated radiation dose at the entrance surface of the patient's body. Its determination may take into account the X-ray tube output, tube voltage, mAs value, the distance from the focal spot to the patient's surface, and the contribution of backscattered radiation. This assessment method is particularly useful in retrospective studies because it estimates exposure from already available data without additional patient exposure to ionising radiation (2,11).

In this study, ESD was selected as the primary dosimetric indicator for comparing the CR and DR systems. Its use enables the estimated dose to be related to the specific exposure parameters used during clinical radiographic examinations. This provides a quantitative basis for comparing the two technologies under actual working conditions (2,12).

It is important to emphasise that ESD is not determined solely by the type of detector. The resulting value reflects the interaction of several factors, including the characteristics of the CR and DR systems, the selected exposure parameters, AEC, imaging geometry, and individual patient characteristics (9,12). Therefore, any difference between the CR and DR systems should be interpreted as a difference under the conditions of their specific clinical application rather than as an isolated effect of the detector technology itself.

Comparison of ESD values between different digital systems can therefore provide valuable insight into the potential for optimisation of radiographic procedures. Such comparisons are particularly relevant when combined with an analysis of exposure parameters and system characteristics, as this enables identification of areas where protocols could be further optimised without compromising diagnostic image quality (9,12).

Aim of the Study

The aim of this study was to compare entrance surface dose (ESD) values between CR and DR systems during standard radiographic examinations of the chest, shoulder, and pelvis with hips, and to determine whether statistically significant differences in ESD values exist between the two technologies. Additionally, differences in ESD values according to sex and the association between ESD values obtained with the CR and DR systems were analysed.

Participants and Methods

Participants

The study was a retrospective analysis of data collected at Health Centre Zagreb East. The study included data from patients who underwent standard radiographic examinations using CR and DR systems as part of routine clinical practice.

Three anatomical regions were analysed: the chest, shoulder, and pelvis with hip joints. For each anatomical region, 30 examinations using the CR system and 30 using the DR system were analysed, resulting in a total of 180 examinations. The CR group consisted of 90 participants, as did the DR group.

The distribution of participants according to sex was as follows: for chest examinations, the CR group included 16 male and 14 female subjects, while the DR group included 13 male and 17 female subjects. For shoulder examinations, both groups included 14 male and 16 female subjects. For pelvic examinations, the CR group included 13 male and 17 female subjects, while the DR group included 10 male and 20 female subjects (Table 1).

Table 1. Distribution of participants according to anatomical region, digital system, and sex

Anatomical region	System	n	Male	Female
Chest	CR	30	16	14
Chest	DR	30	13	17
Shoulder	CR	30	14	16
Shoulder	DR	30	14	16
Pelvis	CR	30	13	17
Pelvis	DR	30	10	20

The inclusion criterion was the availability of complete data required for analysis and ESD calculation. The analysis included data on X-ray tube voltage, mAs values, SID, anatomical region, and parameters required to determine the tube output.

The study was conducted as a retrospective analysis of existing data, without additional patient exposure to ionising radiation for research purposes. The data were processed while ensuring anonymity and confidentiality. The study was approved by the Ethics Committee of the Health Centre Zagreb East under reference number 01-1069-1/25.

Data Collection and Processing

The data used in this study were collected from the PACS of the Health Centre Zagreb East and entered into structured Excel spreadsheets. For each examination included in the analysis, the X-ray tube voltage (kV), tube current–time product (mAs), SID, type of radiographic examination, and data required for the calculation of ESD were recorded.

Prior to statistical analysis, the data were reviewed and organised according to anatomical region and the radiographic system used. The CR and DR systems were compared under routine clinical conditions using the same radiographic equipment.

X-ray Equipment and Digital Systems

Radiographic examinations were performed using a Siemens MULTIX Top radiographic system (Siemens Healthineers, Erlangen, Germany). The system was equipped with automatic exposure control (AEC).

For chest and pelvic examinations, the lateral AEC chambers were used, whereas the central AEC chamber was used for shoulder examinations. The AEC settings were 1 for CR chest examinations, 2.5 for CR shoulder and pelvic examinations, 0 for DR chest examinations, and 1 for DR shoulder and pelvic examinations.

For CR examinations, cassettes with photostimulable phosphor plates were used and read using the KODAK DirectView CR975 system. After exposure, the signal stored in the phosphor plate was read by laser stimulation, producing a signal that was converted into a digital record.

For DR examinations, an AGFA XD 17 flat-panel digital detector with the MUSICA image-processing system was used. The detector uses a scintillator layer to convert X-ray radiation into a light signal, photodiodes to convert light into an electrical signal, and a TFT array to read the signal. The resulting electrical signal is digitised and processed by the image-processing system.

Technical Imaging Conditions

For chest examinations, an X-ray tube voltage of 125 kV and an SID of 180 cm were used. For shoulder examinations, a tube voltage of 66 kV and an SID of 100 cm were used, whereas pelvic examinations were performed at 77 kV and an SID of 115 cm.

The mAs value was determined automatically using AEC. Thus, the analysis included the actual exposure parameters used during the clinical examinations.

Determination of Tube Output and Calculation of Entrance Surface Dose

Since the entire study is based on the assessment of entrance surface dose, the calculation procedure represents a central component of the methodology.

For the calculation of ESD, X-ray tube output data obtained during the routine annual testing of the equipment in 2025 were used. Measurements were performed at different X-ray tube voltage values in discrete increments of 10 kV. Tube output was measured at a tube loading of 20 mAs and a distance of 107 cm between the focal spot and the detector of the measuring device (13).

Since the tube voltage values used in the clinical examinations did not necessarily correspond to the directly measured values, interpolation was used for intermediate values. The relationship between tube output and X-ray tube voltage was described using a second-order polynomial:

where y represents air kerma expressed in mGy and x represents X-ray tube voltage expressed in kV.

$$y=0.0001x^2-0.0004x-0.1086$$

The following formula was used to calculate ESD (13):

$$ESD\ (\text{mGy}) = B \bullet (0{,}0001\text{KV}^2 - 0{,}0004\text{KV} - 0{,}1086) \bullet \left[\frac{107}{SID-30}\right]^2 \bullet \frac{\text{mAs}}{20}$$

In the formula, ESD represents the entrance surface dose expressed in mGy. B represents the backscatter factor for diagnostic X-ray beam qualities, and a value of B = 1.4 was used in this study. The backscatter factor (B) was set to 1.4 in accordance with the recommended values provided in the IAEA literature for diagnostic X-ray beams (2). The polynomial in parentheses represents the estimated tube output, i.e., air kerma, at the corresponding X-ray tube voltage. SID represents the distance from the X-ray tube focal spot to the detector, expressed in centimetres, while mAs represents the actual tube current–time product used during each examination.

The formula uses a reference distance of 107 cm, corresponding to the distance at which the tube output measurements were performed, and a reference tube loading of 20 mAs. The distance factor allows the tube output to be adjusted to the actual geometry of the clinical examination according to the inverse square law.

The term SID − 30 uses a value of 30 cm to represent the assumed average body thickness, which is subtracted from the SID to estimate the distance from the X-ray tube focal spot to the patient's surface. This way, the resulting value refers to the estimated dose at the patient's surface rather than the distance to the detector.

Multiplying the interpolated tube output by the backscatter factor provides an estimate of the dose at the patient's surface, including the contribution of backscattered radiation. Correcting for distance and the mAs value yields the final estimated ESD for each individual examination.

Application of the described formula enabled ESD to be calculated for each radiographic examination included in the analysis based on the actual exposure parameters. The obtained values represent estimates of ESD because a uniform approximation of body thickness of 30 cm was

used for all subjects, while tube output was determined based on previous measurements of the X-ray equipment.

Statistical Analysis

Descriptive and inferential statistical methods were used for data analysis. An independent-samples t-test was used to compare ESD values between the CR and DR systems, while the homogeneity of variances was assessed using the F-test.

The Mann–Whitney U test was used to compare ESD values between male and female subjects. The association between ESD values obtained with the CR and DR systems was analysed using linear regression analysis.

Results were presented as the mean, standard deviation, and 95% confidence interval. The level of statistical significance was set at $p < 0.05$. Statistical analyses were performed using MedCalc.

Results

A total of 180 radiographic examinations were analysed, with 30 examinations for each anatomical region performed using the CR system and 30 using the DR system. ESD values were analysed for chest, shoulder, and pelvic examinations. The technical imaging conditions were defined according to clinical protocols, with the mAs value automatically determined using AEC.

Chest

The mean ESD was 0.1273 mGy for the CR system and 0.07851 mGy for the DR system. The difference between the mean values was 0.04884 mGy, with a lower mean ESD observed for the DR system (Figure 1).

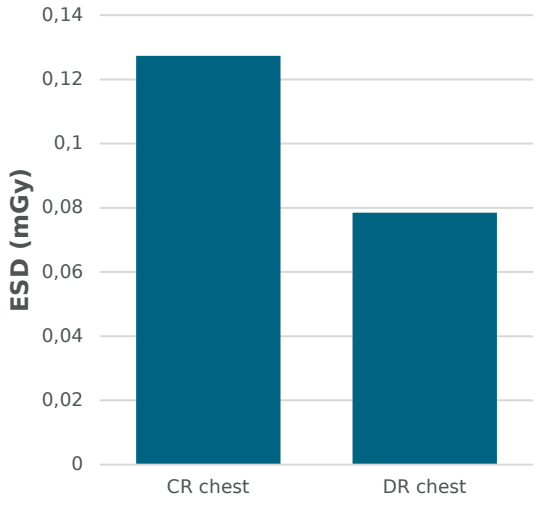


Figure 1. Graphical presentation of entrance surface dose (ESD, mGy) values for CR and DR chest radiography.

The **95% confidence interval** ranged from 0.1099 to 0.1448 mGy for CR and from 0.06801 to 0.08900 mGy for DR. The t-test showed a statistically significant difference ($t = 4.0908$; $df = 58$; $p < 0.0001$). The mean ESD value for the DR system was approximately **38.3% lower** than that for the CR system.

The F-test showed a statistically significant difference in variances between the groups ($p = 0.008$). Linear regression analysis showed a low association between ESD values ($R^2 = 0.06158$), and the regression model was not statistically significant ($p = 0.186$).

No statistically significant difference according to sex was found in the CR group. Among men ($n = 16$), the median ESD was 0.120 mGy, whereas among women ($n = 14$), it was 0.100 mGy ($U = 68.50$; $Z = 1.826$; $p = 0.0679$).

In the DR group, 13 men and 17 women were included in the analysis. The median ESD among men was 0.090 mGy, while among women it was 0.060 mGy. The Mann–Whitney U test showed a statistically significant difference ($U = 37.50$; $Z = 3.062$; $p = 0.0022$), with men having higher ESD values than women.

Shoulder

For shoulder examinations, the mean ESD was 0.8776 mGy for the CR system and 0.6752 mGy for the DR system (Figure 2). The difference between the mean values was 0.2024 mGy.

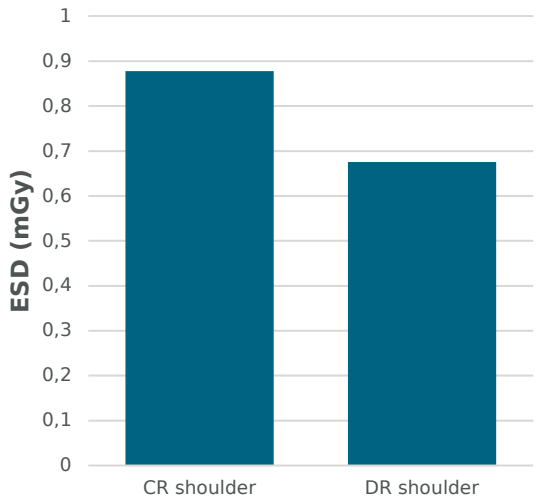


Figure 2. Graphical presentation of entrance surface dose (ESD, mGy) values for CR and DR shoulder radiography.

The **95% confidence interval** ranged from 0.7642 to 0.9910 mGy for CR and from 0.5550 to 0.7954 mGy for the DR system. The t-test showed a statistically significant difference ($t = -2.505$; $df = 58$; $p = 0.0151$).

The F-test showed no statistically significant difference in variances ($p = 0.753$). Linear regression analysis showed a very low association between ESD values ($R^2 = 0.01567$), and the regression model was not statistically significant ($p = 0.510$).

Analysis according to sex showed no statistically significant differences. In the CR group, the median ESD was 0.835 mGy in men and 0.774 mGy in women ($p = 0.5741$). In the DR group, the median ESD was 0.663 mGy in men and 0.516 mGy in women ($p = 0.2979$).

Pelvis

For pelvic examinations, the mean ESD was 2.0021 mGy for the CR system and 1.5578 mGy for the DR system (Figure 3). The difference between the mean values was 0.4444 mGy.

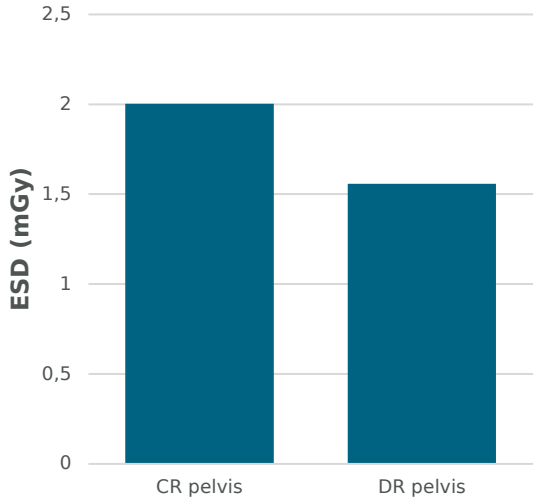


Figure 3. Graphical presentation of entrance surface dose (ESD, mGy) values for CR and DR pelvic radiography.

The 95% confidence interval ranged from 1.5871 to 2.4171 mGy for CR and from 1.3040 to 1.8115 mGy for DR. The difference was not statistically significant ($t = -1.868$; $df = 58$; $p = 0.0668$). The F-test showed a statistically significant difference in variances ($p = 0.010$).

Linear regression analysis showed a low association ($R^2 = 0.06053$), and the regression model was not statistically significant ($p = 0.190$).

In the CR group, no statistically significant difference by sex was found ($p = 0.3149$). The median ESD was 1.458 mGy in men and 1.911 mGy in women. In the DR group, a statistically significant difference was found ($U = 51.50$; $Z = 2.134$; $p = 0.0328$), with median ESD values of 1.710 mGy in men and 1.257 mGy in women.

Summary of the results

Across all three analysed anatomical regions, the mean ESD was lower with the DR system, as shown in Table 2 and Figure 4.

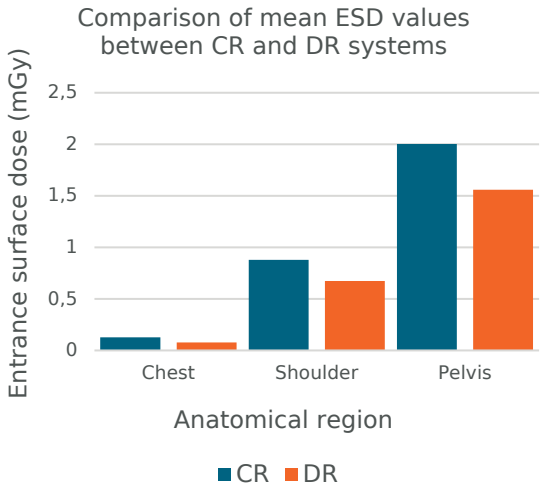


Figure 4. Comparison of mean entrance surface dose (ESD) values between CR and DR systems according to anatomical region.

Table 2. Comparison of mean ESD values between CR and DR systems

Anatomical region	CR ESD (mGy)	DR ESD (mGy)	Difference (mGy)	p
Chest	0.1273	0.07851	0.04884	<0.001
Shoulder	0.8776	0.6752	0.2024	0.0151
Pelvis	2.0021	1.5578	0.4444	0.0668

Statistically significant differences between the CR and DR systems were observed for chest and shoulder examinations, whereas the difference for pelvic examinations was not statistically significant.

Discussion

The results of this study showed that the DR system had lower mean ESD values than the CR system in all three analysed anatomical regions. Statistically significant differences were observed for chest and shoulder examinations, whereas the difference for pelvic examinations did not reach statistical significance. These findings indicate that, under the clinical conditions analysed, the DR system may be associated with a lower estimated entrance surface dose; however, the observed differences should be considered in the context of the radiographic procedure as a whole.

The largest relative difference was observed for chest examinations. The mean ESD was 0.1273 mGy for the CR system and 0.07851 mGy for the DR system, representing an approximately 38.3% lower value for the DR system. This difference was statistically significant. The examinations were performed at 125 kV and an SID of 180 cm, using the lateral AEC chambers.

The technological characteristics of DR detectors may contribute to more efficient utilisation of X-ray radiation for image formation. However, in this study, it was not possible to isolate the effect of detector technology from other factors. Particular attention should be given to the difference in AEC settings: for chest examinations, the CR system was used with setting 1, whereas the DR system was used with setting 0. Since mAs was determined by AEC, different settings may affect the amount of radiation required to terminate the exposure. Therefore, the observed difference reflects a combination of system characteristics and their specific clinical settings.

A statistically significant difference according to sex was also observed for chest examinations performed with the DR system. Men had a higher median ESD than women. This finding may be associated with differences in body characteristics; however, the exact cause cannot be determined from the retrospectively collected data.

For shoulder examinations, the mean ESD was also significantly lower with the DR system. The difference was 0.2024 mGy. Shoulder examinations were performed at 66 kV and an SID of 100 cm, using the central AEC chamber. The AEC setting was 2.5 for the CR system and 1 for the DR system.

Different AEC settings also represent an important factor in this context. Therefore, the lower ESD value observed with the DR system cannot be attributed solely to

detector type. The result reflects differences between the specific systems used in everyday clinical practice, including their technical and exposure settings.

No statistically significant differences according to sex were observed for shoulder examinations in either the CR or DR group. Although the median values differed, the observed differences were not statistically significant.

For pelvic examinations, the mean ESD was also lower with the DR system, but the difference was not statistically significant. The mean ESD was 2.0021 mGy for the CR system and 1.5578 mGy for the DR system. The p-value of 0.0668 was close to the significance threshold of 0.05; however, according to the predefined criterion, the result was not considered statistically significant.

In pelvic examinations, a statistically significant difference in variances was observed between the CR and DR groups. The greater variability may be associated with the anatomical characteristics of the region and differences between individual subjects. The pelvis is an anatomical region in which individual differences in body habitus and tissue thickness may have a substantial effect on the required exposure.

The AEC settings also differed between the systems for pelvic examinations. The CR system was used with setting 2.5, whereas the DR system was used with setting 1. Despite the lower mean ESD value observed with the DR system, the variability of the results prevented the difference from reaching statistical significance.

Sex-based analysis showed a statistically significant difference in the DR pelvic group, with men having a higher median ESD than women. No such difference was observed in the CR group. As with chest examinations, this finding may be associated with differences in body characteristics; however, based on the available data, it is not possible to determine their individual contribution.

Linear regression analysis did not show a statistically significant linear association between individual ESD values obtained with the CR and DR systems. The R^2 values were low for all three anatomical regions. This indicates that an individual ESD value obtained with one system cannot readily be used to predict the corresponding value obtained with the other system.

This relationship may be explained by the fact that CR and DR systems represent different image acquisition technologies, with different detector characteristics, signal processing methods, and exposure settings. In addition, differences in AEC settings affected the actual exposure conditions. Therefore, comparisons should focus on group-level measures and specific clinical protocols rather than on simple mathematical conversion of individual values.

A particularly important aspect of the study is the role of AEC. Since mAs was determined automatically, AEC settings were directly related to the amount of radiation delivered. Appropriate selection of the AEC chamber, patient positioning, and adequate collimation are therefore important elements of optimisation.

The results also show that DR technology alone does not automatically reduce dose in every clinical situation. If the DR system is improperly configured or unnecessarily high exposure settings are used, the potential advantages of the technology may be diminished. Conversely, a well-optimised CR system may achieve acceptable dose values while maintaining adequate image quality.

Due to the wide dynamic range of digital systems, diagnostically acceptable images can be obtained at different exposure levels. Therefore, an increase in dose is not always immediately apparent through deterioration in image quality. Continuous monitoring of exposure parameters and estimated ESD values may help identify unnecessarily high exposures.

In this study, ESD was calculated based on the X-ray tube output, mAs, and geometric conditions. The advantage of this approach is the possibility of retrospectively assessing radiation dose without additional exposure of patients. At the same time, the method has certain limitations. In particular, the use of an average body thickness of 30 cm should be emphasised, as this does not account for individual differences among patients.

Despite these limitations, the study enables comparison of ESD values under real-world clinical conditions. The results showed lower mean ESD values with the DR system in all analysed anatomical regions, with statistically significant differences observed for chest and shoulder examinations.

The practical significance of these findings lies in the need for continuous optimisation of radiographic protocols. Dose monitoring should be performed together with image quality assessment, as dose reduction itself should not be the goal if it results in a loss of diagnostic image quality. An optimal radiographic procedure requires a balance between the image quality required for diagnosis and the lowest reasonably achievable patient exposure.

Conclusion

This study compared entrance surface dose values between CR and DR systems during standard radiographic examinations of the chest, shoulder, and pelvis with hips. In all analysed anatomical regions, the mean ESD was lower with the DR system.

The most pronounced difference was observed for chest examinations, where the mean ESD with the DR system was 38.3% lower than that with the CR system, and the difference was statistically significant. A statistically significant difference was also observed for shoulder examinations, whereas the difference for pelvic examinations did not reach statistical significance.

The results show that differences in ESD between CR and DR systems cannot be attributed solely to detector technology. Patient exposure is also influenced by exposure parameters and automatic exposure control settings. In this study, AEC settings differed between the systems; therefore, the results should be interpreted as the combined effect of the technology and the specific clinical protocols used.

Linear regression analysis did not show a statistically significant linear association between individual ESD values obtained with the CR and DR systems. Sex-based analysis showed statistically significant differences in the DR group for chest and pelvic examinations, whereas no statistically significant differences were observed for shoulder examinations.

Based on these results, the DR system achieved lower mean ESD values than the CR system under the conditions of this study, with statistically significant differences observed for chest and shoulder examinations. The results

emphasise the importance of appropriate AEC settings, standardisation of radiographic protocols, and continuous dose monitoring to optimise patient protection from ionising radiation while maintaining adequate diagnostic image quality.

All data presented in this paper are part of the results of the Master's thesis "Radiation doses on different digital systems in radiology" written at the Faculty of Health Sciences, University of Split (13).

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Doze zračenja na različitim digitalnim sustavima u radiologiji: usporedba CR-a i DR-a

Sažetak

Uvod: Ovaj rad analizira doze zračenja na digitalnim radiografskim sustavima računalne radiografije (CR) i direktne digitalne radiografije (DR) pri snimanju pluća, ramena i zdjelice s kukovima.

Cilj: Cilj istraživanja bio je usporediti ulazne površinske doze zračenja (ESD) između CR i DR sustava te procijeniti mogućnosti DR tehnologije u optimizaciji doze zračenja.

Metode: Istraživanje je provedeno na 180 ispitanika različitog spola i životne dobi. ESD je izračunat na temelju podataka dobivenih godišnjim ispitivanjem rendgenskih uređaja iz 2025. godine. Za usporedbu CR i DR sustava primijenjen je t-test za nezavisne uzorke, za analizu razlika između muškaraca i žena Mann–Whitney U test, a linearna regresijska analiza korištena je za procjenu povezanosti vrijednosti dobivenih na CR i DR sustavima. Statistička značajnost postavljena je na $p < 0,05$.

Rezultati: DR sustav ostvario je niže srednje vrijednosti ESD-a u svim analiziranim anatomskim regijama. Statistički značajne razlike utvrđene su kod snimanja pluća i ramena, dok kod zdjelice razlika nije bila statistički značajna. Regresijska analiza nije pokazala značajnu linearnu povezanost između vrijednosti ESD-a dobivenih na CR i DR sustavima.

Zaključak: U uvjetima ovog istraživanja DR sustav pokazao je niže vrijednosti ESD-a u odnosu na CR sustav, osobito pri snimanju pluća i ramena. Dobiveni rezultati ističu važnost pravilne primjene AEC sustava i optimizacije ekspozicijskih parametara u cilju smanjenja izloženosti pacijenata ionizirajućem zračenju.

Ključne riječi: računalna radiografija, direktna digitalna radiografija, doza zračenja, ulazna površinska doza zračenja (ESD), radiološka zaštita

REVIEW PAPER, REVIEW ARTICLE (PREGLEDNI RAD)

Problems of HL7/DICOM Integration in Healthcare Systems

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Abstract

Modern healthcare information systems are based on the integration of HL7 and DICOM standards, which enable the exchange of administrative, clinical, and imaging data between HIS, RIS, and PACS systems. This thesis focuses on the analysis of the most significant integration problems that occur during communication and data exchange between these systems, including inconsistencies in patient identification data, errors related to orders and Accession Numbers, difficulties in mapping HL7 messages into DICOM metadata, radiology workflow issues, differences in vendor implementations, security and organizational challenges, as well as architectural differences between HL7 and DICOM standards. An analysis of the causes, consequences, and possible solutions to these problems was conducted, with emphasis on their impact on everyday clinical practice. Special attention was given to the Croatian national CEZIH system, its role in the exchange of administrative data, and the limitations related to the integration of imaging systems. The thesis also presents future directions of development through HL7 FHIR, DICOMweb, integration engines, and artificial intelligence, with the aim of creating a more connected, stable, and organizationally efficient healthcare information system that enables a higher quality approach to patient care.

Keywords: CEZIH; difficulties; DICOM; HL7; information system; integration

Abbreviations and acronyms: ADT (Admission, Discharge, and Transfer), AE (Application Entity), API (Application Programming Interface), CEZIH (Central Health Information System of the Republic of Croatia), DA (Date Value Representation), DICOM (Digital Imaging and Communications in Medicine), FHIR (Fast Healthcare Interoperability Resources), HIS (Hospital Information System), HL7 (Health Level Seven), HTTP (Hypertext Transfer Protocol), HTTPS (Hypertext Transfer Protocol Secure), IHE (Integrating the Healthcare Enterprise), MPPS (Modality Performed Procedure Step), MWL (Modality Worklist), ORM (Order Message), PACS (Picture Archiving and Communication System), PID (Patient Identification), PV1 (Patient Visit), REST (Representational State Transfer), RIS (Radiology Information System), TM (Time Value Representation), UID (Unique Identifier).

1. Introduction

The digital transformation of healthcare systems over recent decades has significantly increased the volume and complexity of health data exchanged daily among various information systems. In such an environment, interoperability represents one of the key prerequisites for efficient, safe, and high-quality healthcare delivery.

The exchange of administrative and clinical data between health information systems is largely based on the HL7 standard, whereas the DICOM standard is used for the management, storage, and exchange of medical imaging data. The implementation of these standards has enabled the standardization of communication between different information systems and medical devices and forms the foundation of modern healthcare and radiological workflows [1].

As health information systems continue to develop, the need for their integration is also increasing to ensure reliable and seamless data exchange throughout the entire clinical process. The successful integration of the HL7 and DICOM standards is an important prerequisite for functional interoperability and the efficient operation of information systems within healthcare organizations [2]. Continuous evaluation of integration mechanisms is essential for the timely identification of shortcomings and their optimization, thereby improving clinical and organizational processes and enhancing the reliability and efficiency of health data exchange.

2. Materials and Methods

This study was designed as a systematic literature review focusing on the challenges associated with the integration of the HL7 and DICOM standards in health information systems. A literature search was conducted in the PubMed and DABAR databases using the terms HL7, DICOM, PACS, HIS, RIS, interoperability, and IHE, combined using the Boolean operators AND, OR.

Because of the technical and interdisciplinary nature of the topic, the official websites of the relevant standards, technical documentation, and implementation frameworks were additionally reviewed. Studies addressing

interoperability, standards integration, and their impact on clinical and organisational processes were included. Studies that did not address integration-related aspects or for which the full text was unavailable were excluded.

The selected studies were recorded in a tabular database according to their bibliographic information, area of application, identified challenges, and proposed solutions. The studies were grouped according to shared thematic characteristics, followed by the categorisation and comparative analysis of integration challenges.

3. Results

3.1. Key Concepts

Health Level Seven (HL7)

Health Level Seven (HL7) comprises a set of standards intended for the exchange of clinical, administrative, and other health-related data between information systems. It is particularly widely used for communication between hospital and radiology information systems, where it enables the standardized transmission of patient, order, procedure, and report data [3].

HL7 v2 is based on the structured exchange of messages between systems, while subsequent developments have resulted in models such as HL7 v3 and the Clinical Document Architecture (CDA). A more contemporary approach is represented by FHIR, which uses web technologies, application programming interfaces (APIs), and structured resources to enable more flexible exchange and retrieval of health data, as well as simpler integration of different information systems [4].

Digital Imaging and Communications in Medicine (DICOM)

Digital Imaging and Communications in Medicine (DICOM) is an international standard for the storage, transmission, and management of medical imaging data and associated metadata. It enables interoperability among imaging modalities, workstations, and picture archiving and communication systems [5].

In addition to image data, DICOM contains metadata describing the patient, diagnostic procedure, and technical imaging characteristics. Identifiers such as the Patient ID, Study Instance UID, and Accession Number enable imaging data to be linked with administrative and clinical information exchanged among the HIS, RIS, and PACS. The correct exchange and alignment of these identifiers are important prerequisites for the integration of the HL7 and DICOM standards [6].

DICOM also defines network services for data storage, query, and transfer, as well as the Modality Worklist, which enables patient and procedure data to be transmitted to imaging modalities. Other elements of DICOM communication relevant to integration will be presented in the context of specific integration challenges.

3.2. Methodology for Categorising Integration Challenges

The analysis of integration challenges is primarily based on the HL7 v2 standard, as the most widely used data exchange model in existing health information systems, with HL7 v3 partially included as a reference conceptual framework. Through a qualitative analysis of the selected literature, specific interoperability challenges associated with the HL7, and DICOM standards were identified, together with their causes, mechanisms of occurrence, effects on information flow, and potential solutions.

The identified challenges were subsequently compared and grouped according to shared thematic characteristics, with particular attention given to challenges recurring across multiple analyzed sources. Based on this process, categories of integration challenges were established, enabling a systematic analysis of their causes, consequences, and potential resolution strategies across different health information environments.

3.3. Integration Challenges, Explanations, and Practical Solutions

3.3.1. Most Common HL7/DICOM Integration Challenges

(Table 1)

Table 1. Overview of the most common HL7/DICOM integration challenges

Category	Description	Cause	Impact	Solution
Patient identification	Inconsistent patient identity across systems	Different systems, manual entry, lack of an MPI	Incorrect image–patient association, duplicate records, security risks	Master Patient Index (MPI), validation
Order/ Accession Number	Failure to link orders with imaging data	Inconsistent number generation, incorrect ORM mapping	Inability to link orders with images	ORM standardization, uniqueness checks
Metadata and mapping	Differences between HL7 and DICOM data	Different data structures, incomplete mapping	Misinterpretation, poor interoperability	Definition of mappings, integration tools
Workflow synchronization	Inconsistent workflow across systems	Message delays, Modality Worklist (MWL) issues	Delays, incorrect examination status	IHE Scheduled Workflow (SWF), automation
Interoperability (vendor-related)	Differences in standards implementation	Vendor-specific differences, inconsistent conformance	Compatibility issues	Testing, standardization
Architectural differences	Different communication models	HL7 messages versus DICOM objects	Complex integration	Middleware, integration engine

3.3.2. Patient Identification

Reliable patient identification is essential for linking administrative, clinical, and imaging data within health information systems (Table 1). In HL7 communication, patient identification data are primarily transmitted through ADT messages, in which the PID segment contains key information such as the Patient ID, patient name, and date of birth [7]. Within the radiology information workflow, these data are linked to the procedure order and transmitted through the RIS and the DICOM Modality Worklist (MWL) service to imaging modalities, where the corresponding DICOM attributes become part of the metadata of the resulting imaging record [8].

Patient identification issues arise when identification data becomes inconsistent between the HL7 and DICOM layers. Potential causes include incorrect data mapping, a lack of synchronization between systems, manual data entry at the modality, or differences in identifier implementation. For example, a delay in updating data from an HL7 ADT message may result in outdated information in the MWL entry, while the manual entry of a Patient ID at the modality increases the likelihood of creating a DICOM object that is not correctly linked to the existing patient record (Figure 1). An additional challenge is the use of different identifier namespaces, which may result in the same patient having multiple identifiers across different systems without a clearly defined relationship among them [8].

Such inconsistencies may result in imaging records being incorrectly associated with a patient or order, the fragmentation of health data, and difficulties in searching for and retrieving medical images. These errors are not merely technical interoperability issues; they may also disrupt clinical workflows and increase the risk of data being incorrectly interpreted or used [8].

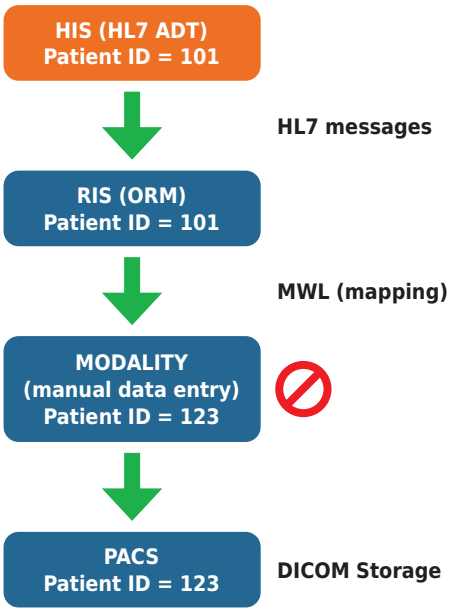


Figure 1. Schematic representation of the patient identification problem. The problem occurs at the modality level, where manual data entry or incorrect implementation of the Modality Worklist (MWL) results in the creation of a DICOM record that is inconsistent with the data transmitted via HL7. *Source: Author*

Risk reduction requires a combination of technical and organizational measures. The consistent use of DICOM MWL reduces the need for manual data entry, while a centralized Master Patient Index (MPI) enables patient identity management across multiple interconnected information systems. Additional support is provided by the IHE Patient Identifier Cross-referencing (PIX) and Patient Demographics Query (PDQ) profiles, which enable patient identities to be linked and verified across different systems [11]. When errors have already occurred, retrospective data reconciliation procedures may be performed within the PACS and integration layer. More contemporary approaches, including HL7 FHIR, also enable more flexible management of identification data and improve their availability across interconnected systems [9].

3.3.3. Order / Accession Number

A diagnostic procedure order represents an important link between the administrative and imaging components of a health information system (Table 1). Order information is transmitted through HL7 ORM messages, in which the OBR (Observation Request) segment contains data on the requested procedure. The Accession Number is one of the key order identifiers and, depending on the system architecture, is generated within the HIS or RIS. Its value is transmitted throughout the information workflow and links the order to the corresponding imaging data [10].

In the HL7–DICOM integration process, order data are used to create a DICOM Modality Worklist (MWL) entry, which is retrieved by the modality before the procedure is performed. The Accession Number is mapped to the corresponding DICOM attribute (0008,0050) and retained in the metadata of the resulting DICOM objects. It therefore provides a link among the order, the performed diagnostic procedure, and the study of imaging stored in the PACS [11].

Integration issues arise when inconsistencies occur in the generation, transmission, or mapping of the Accession Number. Differences in the interpretation of HL7 fields, incorrect MWL configuration, a lack of synchronization between the ORM message and the available MWL entry, or manual data entry at the modality may result in different identifier values across individual components of the system [11]. If the modality transmits DICOM objects containing an Accession Number that does not match the original order after the procedure has been performed, the PACS may store the study without an appropriate link to that order (Figure 2). This may make data linkage and retrieval more difficult and disrupt the continuity of the information workflow.

The prevention of such issues is based on consistent HL7–DICOM mapping, the correct configuration of MWL communication, and reducing the need for manual data entry. DICOM Modality Performed Procedure Step (MPPS) can additionally facilitate comparison between the scheduled and performed procedures, while validation mechanisms within the PACS and integration systems enable inconsistencies to be detected before they affect the clinical workflow [13]. Integration engines can provide continuous communication monitoring, while more contemporary approaches, such as HL7 FHIR and DICOMweb services, enable more flexible management of orders and their associated identifiers [9].

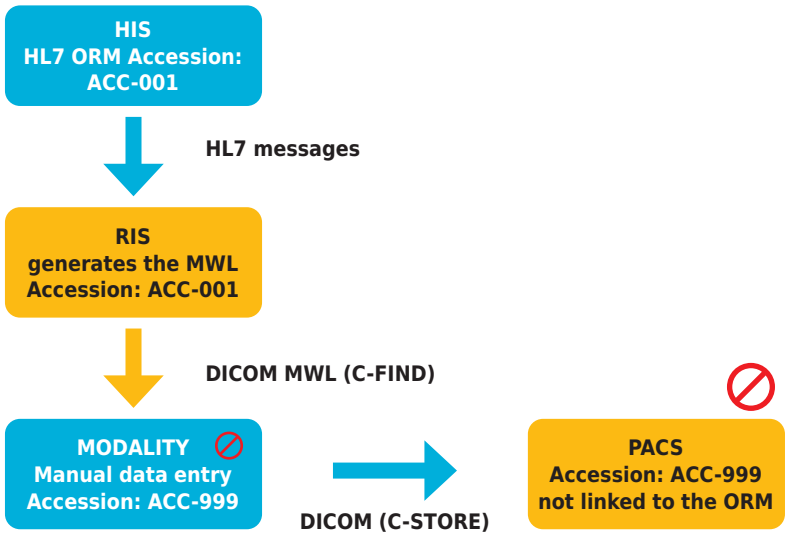


Figure 2. Schematic representation of an order transmission issue in HL7–DICOM integration. The issue occurs at the modality level, where the Accession Number is changed. This results in the loss of the link between the HL7 order and the DICOM imaging study within the PACS. *Source: Author*

3.3.4. Metadata and Mapping

Mapping represents one of the key aspects of HL7–DICOM integration because it enables data to be transferred and aligned between their different data structures (Table 1). Values contained in HL7 messages must be correctly extracted, transformed, and transferred to the corresponding DICOM attributes while preserving their semantic meaning and technical format. This process encompasses not only patient and order identification data but also information on the type and location of the procedure, as well as other elements required to describe the diagnostic procedure [8].

The alignment of different coding systems and local nomenclatures represents a particular challenge. Different names or codes for the same diagnostic procedure may result in semantic inconsistencies between systems; therefore, mapping tables and data normalization procedures are used in integration solutions. In addition, DICOM requirements regarding data formats and value types must be met, and the correct conversion of dates, times, textual values, and character encoding must be ensured [13].

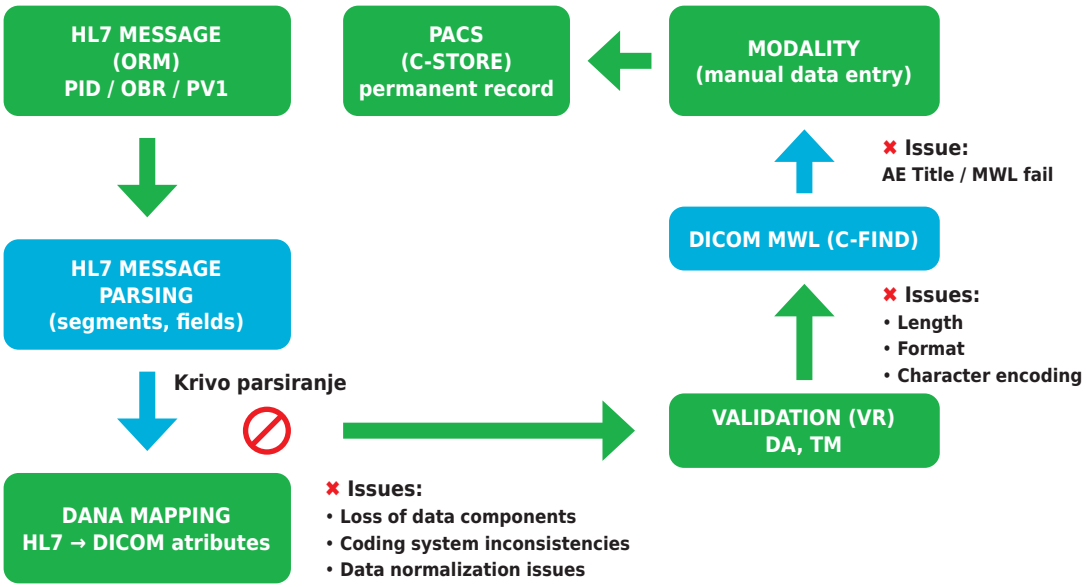


Figure 3. Schematic representation of errors occurring during the conversion of HL7 data into DICOM metadata. Numerous parameters may be incorrectly mapped, resulting in inaccurate metadata that affect the subsequent handling of imaging data. *Source: Author*

Integration issues arise when information is lost or values are incorrectly interpreted during data parsing, transformation, or validation. Incorrect mapping of multi-component HL7 fields, inconsistent local codes, inappropriate data formats, or incorrect character encoding may result in incomplete or inconsistent DICOM metadata (Figure 3). Because such data are not necessarily updated automatically after a DICOM object has been created and stored, an error introduced during mapping may persist throughout the subsequent stages of the information workflow [13].

These issues can be addressed through centralised integration systems that enable standardised parsing, the definition of mapping rules, and data validation before distribution. Code-mapping tables, terminology services, DICOM conformance checks, and the monitoring of HL7–DICOM communication enable the timely detection of inconsistencies and reduce the risk of incorrect metadata being propagated throughout the remainder of the system [14].

3.3.5. Workflow Synchronisation

The radiology workflow involves multiple interconnected components, including HIS, RIS, integration system, imaging modalities, and PACS (Table 1). In such a distributed environment, ensuring data transmission alone is insufficient; data must also be available in a timely manner, and their status must remain consistent across individual systems. Synchronisation issues arise when different components simultaneously hold conflicting information regarding the patient, order, or status of a diagnostic procedure.

HL7 messages represent events that change the state of an information system and are often processed through message queues within the integration system. Delays in message transmission or processing may result in a change being recorded in one system while another system still retains the previous state. Such temporal inconsistencies may disrupt automated workflows, make an order unavailable, or cause the status of a diagnostic procedure to be displayed incorrectly.

The DICOM Modality Worklist (MWL) represents a particularly important synchronisation point through which the modality retrieves current information regarding scheduled procedures. If the MWL does not reflect the current state of the system because of a delayed HL7 message, an unsuccessful update, or a lack of synchronization with the RIS, the modality may operate using outdated or incomplete data. Consequently, the need for manual data entry increases, further increasing the likelihood of errors and disrupting the continuity of the information workflow [15].

Preventing such issues requires controlled event processing, reliable synchronization between the RIS and MWL service, and continuous monitoring of communication status across interconnected systems. Integration systems can enable the monitoring of message queues, reprocessing of failed transactions, and timely detection of inconsistencies. The IHE Scheduled Workflow (SWF) profile provides an important reference framework by defining the roles of individual systems and the standardised sequence of their interactions. This approach reduces dependence on individual implementations and enables a more stable, predictable, and reliable radiology workflow [16].

3.3.6. Differences in Implementation (Vendor-Related Issues)

In addition to the previously described data- and synchronization-related issues, further integration challenges arise from how different vendors implement the HL7 and DICOM standards (Table 1). Although these standards define the fundamental rules for communication and data exchange, a certain degree of implementation flexibility allows technical differences to emerge among individual systems [15].

Different systems may support different versions or only specific parts of a standard. In HL7 communication, these differences may involve the use of optional fields, message structure, and the processing of individual values. In DICOM, they may be reflected in varying levels of support for services such as MWL and MPPS. Vendor-specific extensions, including private DICOM tags and customized HL7 fields, introduce further complexity. Consequently, two systems may formally support the same standard while interpreting or processing the same data differently.

Such differences may result in situations in which communication between systems is technically established, but its outcome is not functionally aligned with the expected clinical workflow. Conformance statements play an important role in this context because they describe how an individual system implements the standard and specify its supported communication capabilities. However, documented compatibility alone is insufficient, and interoperability must be confirmed through practical testing within the specific information environment.

Reducing vendor-specific issues requires standardised implementation practices and systematic interoperability testing. IHE integration profiles further define the roles of individual systems, their mutual transactions, and their expected behavior within the clinical workflow, thereby reducing the potential for different interpretations of the HL7 and DICOM standards. Continuous communication testing and validation are particularly important in heterogeneous, multivendor environments because they facilitate the early detection of inconsistencies and reduce the need for subsequent modifications to the integration layer [16].

3.3.7. Architectural Differences Between HL7 and DICOM

In addition to the previously described issues related to patient identification, orders, mapping, workflow synchronization, and differences in vendor implementation, a further integration challenge arises from the distinct architectural principles underlying the HL7 and DICOM standards (Table 1). HL7 v2 is based on structured messages representing events within a health information system, whereas DICOM organises data through information objects, metadata, and network services. Integration therefore requires the continuous alignment of two different models of information representation and exchange [17].

In an HL7 environment, data may be transmitted through multiple consecutive messages associated with events such as patient registration, order creation, or changes in procedure status. The final state of the information system results from the correct processing of

these events. Consequently, delayed, lost, or incorrectly ordered messages may lead to inconsistencies between interconnected systems. DICOM, by contrast, requires the creation of structured objects that contain the relevant identification, procedural, and imaging data required for their interpretation and subsequent storage.

This architectural difference is particularly important when information from multiple HL7 messages must be consolidated and transferred into the appropriate DICOM context. The integration system must ensure that the data is available in a timely manner, semantically aligned, and correctly mapped before being used in the DICOM workflow. An error occurring during this process may be transferred to the metadata of the imaging study and persist after storage in the PACS, thereby shifting the issue from the communication layer to the data layer of the system.

Overcoming these architectural differences requires an integration layer that mediates between the different communication models, manages events, performs data transformation and mapping, and ensures temporal and semantic consistency. Standardized integration profiles, such as IHE Scheduled Workflow, play an important role by defining the respective roles of systems and the sequence of transactions within the radiology workflow. Although such models do not eliminate the architectural differences between HL7 and DICOM, they enable their controlled and predictable integration within a health information system [16].

4. Discussion

4.1. Integration Challenges in Health Information System Practice

The analysis of the identified issues demonstrates that the integration of the HL7 and DICOM standards is a complex process extending beyond the technical exchange of data alone. Integration challenges arise from the interaction between data structures, temporal synchronization, differences in system implementation, and information management within the healthcare workflow (Table 1). Owing to their interconnected nature, an individual issue may affect multiple components of the information system and, consequently, the entire clinical process.

In everyday radiology practice, these issues may arise as early as the order creation stage. Incomplete or inconsistent identification data, an unavailable Modality Worklist entry, or a mismatch between the order and DICOM metadata may require manual data entry and additional verification. This reduces the level of automation and increases the likelihood of further errors. After the procedure has been performed, inconsistent identifiers or statuses may make it difficult to link the imaging study to the corresponding order, locate it in the PACS, and subsequently interpret and distribute the report.

Synchronisation issues and differences in standards implementation are of particular importance. Delayed or incomplete message processing may result in the same process being represented differently across individual systems, while vendor-specific implementations may require additional mapping rules and modifications to the integration layer. Consequently, interoperability depends not only on formal support for the HL7 and DICOM standards but also on their consistent implementation, configuration, and continuous evaluation.

The architectural differences between event-driven HL7 message exchange and DICOM's object- and service-oriented model further explain why these issues frequently occur simultaneously. The integration system must link data generated at different stages of the process, ensure their temporal and semantic consistency, and transfer them between different information models. Therefore, integration issues rarely occur in isolation but rather as interconnected inconsistencies that may result in data fragmentation, an increased workload for users, and reduced clinical workflow efficiency.

This interrelationship between technical and organizational factors allows the identified integration challenges to be further considered within the context of the broader health information infrastructure, including the Central Health Information System of the Republic of Croatia (CEZIH).

4.2. Comparison of the Identified Integration Challenges with CEZIH

The identified integration challenges can be further examined using the CEZIH as an example. CEZIH represents an important communication layer within the national health information infrastructure. Because publicly available literature on its detailed technical and architectural characteristics is limited, this analysis is based on the available system specifications and descriptions of its functionalities.

CEZIH enables the exchange of structured administrative and clinical data among different participants in the healthcare system. Its functionalities, such as eUputnice, eNalaza i eRecepta enable standardized data exchange among primary healthcare providers, hospital systems, pharmacies, and other participants, thereby facilitating interoperability at the national level [19]. The Health Portal additionally provides patients with access to some of the data available within the system, including medical reports, referrals, and treatment-related information [20].

Available specifications indicate a strong emphasis on the structured exchange of administrative and clinical information, whereas the centralized exchange of medical imaging data do not exist. Imaging data generated during radiological procedures are generally processed and stored within the local RIS and PACS environments of healthcare institutions. Consequently, the integration of the administrative and imaging layers is largely performed within individual healthcare organizations, where local HL7 and DICOM systems must be interconnected.

This organizational model may result in varying levels of interoperability among individual institutions because successful integration depends on the local architecture, implemented systems, and integration mechanisms used. Consequently, the availability of imaging data and associated clinical information across different healthcare organizations may be less consistent than the exchange of structured administrative data.

CEZIH therefore represents an important example of national standardization and centralized health information exchange. At the same time, it demonstrates that complete interoperability depends on more than merely connecting administrative and clinical data. The inclu-

sion of imaging information requires further integration of the national infrastructure with local DICOM environments, as well as the alignment of information models and integration mechanisms among individual healthcare organizations.

4.3. Future Development of Interoperability

The future development of health information systems is directed toward greater interoperability, flexibility, and data availability. HL7 FHIR plays an important role in this development by using web technologies, RESTful APIs, and structured resources to facilitate access to and exchange of health information among different systems. This approach reduces the need for complex transformations characteristic of traditional message exchange models and enables more flexible integration of clinical and administrative data [14]. The development of interoperability is also increasingly extending beyond the boundaries of individual healthcare organizations and national systems, as demonstrated by European initiatives such as the European Health Data Space, which aims to facilitate the secure and standardized cross-border exchange of health data [21].

In parallel, DICOMweb is being developed in the field of medical imaging, enabling DICOM data to be queried, retrieved, and stored using standard web protocols. Services such as QIDO-RS, WADO-RS, and STOW-RS facilitate the integration of imaging systems with web applications and other health information solutions [22]. The combination of FHIR and DICOMweb is particularly significant because it enables structured clinical data to be linked with imaging records within a more technologically harmonized environment [23].

The application of artificial intelligence represents an additional area of potential development. In addition to medical image analysis and clinical decision support, algorithmic approaches may be used to identify inconsistent metadata, link previously unassociated records, and monitor integration processes. The integration of such solutions with FHIR and DICOMweb technologies could further improve automation, data quality, and clinical workflow efficiency [23].

The increased availability and interconnectedness of health data simultaneously introduce greater requirements regarding security, access control, and the protection of patient privacy. The successful implementation of new integration models will therefore depend not only on technological development but also on the consistent implementation of security mechanisms, standardization, and the continuous education of healthcare and technical personnel. Future developments in interoperability may gradually reduce some of the limitations of existing HL7 and DICOM integration models; however, they will require the simultaneous alignment of technological, organisational, and security-related aspects.

5. Conclusion

The integration of the HL7 and DICOM standards represents an important prerequisite for the functional interoperability of modern health information systems. The analyzed challenges associated with patient identification, order management, data mapping, workflow synchronization, differences in vendor implementation, and architectural differences confirm that successful interoperability depends not only on the existence of standards but primarily on their consistent and coordinated implementation.

The practical significance of these issues is reflected in data fragmentation, the increased need for manual intervention, and difficulties in linking administrative, clinical, and imaging information. The analysis of CEZIH further highlights the importance of connecting the national exchange of structured health data with local radiology information environments to achieve a higher level of interoperability among healthcare organisations.

Further development of technologies such as HL7 FHIR and DICOMweb offers opportunities for more flexible integration of clinical and imaging data, while the application of artificial intelligence may contribute to automated monitoring, improved data quality, and optimized clinical workflows. Their successful implementation will require appropriate security infrastructure, standardisation, and the continuous education of healthcare and technical users.

In this process, radiologic technologists, as direct users of radiology information systems, can play an important role in identifying workflow issues, ensuring data quality, and aligning clinical requirements with the technical capabilities of the systems. Improving interoperability therefore requires interdisciplinary collaboration between clinical and information technology professionals, together with the continuous evaluation of existing integration mechanisms. The ultimate objective of these developments remains to ensure timely, reliable, and accessible health information that directly contributes to the quality and safety of patient care.

All data presented in this paper are part of the results of the master'thesis "Problems of HL7 and DICOM Integration in Healthcare Systems," written at the Faculty of Health Sciences, University of Split [24].

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Problemi HL7/DICOM integracije u zdravstvenim sustavima

Sažetak

Suvremeni zdravstveni informacijski sustavi temelje se na integraciji HL7 i DICOM standarda koji omogućuju razmjenu administrativnih, kliničkih i slikovnih podataka između HIS, RIS i PACS sustava. Rad za fokus ima analizu najvažnijih integracijskih problema koji nastaju tijekom komunikacije i razmjene podataka između navedenih sustava, uključujući neusklađenost identifikacijskih podataka pacijenta, pogreške povezane s narudžbom i accession number-om, poteškoće mapiranja HL7 poruka u DICOM metapodatke, probleme radiološkog workflowa, razlike u implementaciji između vendora, sigurnosne i organizacijske izazove te arhitekturne razlike između HL7 i DICOM standarda. Provedena je analiza uzroka, posljedica i mogućih rješenja navedenih problema, uz naglasak na njihov utjecaj u svakodnevnom kliničkom radu. Posebno je razmotren nacionalni sustav CEZIH, njegova uloga u razmjeni administrativnih podataka i ograničenja u povezivanju sa slikovnim sustavima. Rad također prikazuje buduće smjerove razvoja kroz HL7 FHIR, DICOMweb, integracijske softverske oblike i umjetnu inteligenciju, s ciljem stvaranja povezanijeg, stabilnijeg i organizacijski učinkovitijeg zdravstvenog informacijskog sustava koji omogućuje kvalitetniji pristup pacijentu.

Ključne riječi: CEZIH; DICOM; HL7; informatički sustav; integracija; poteškoće

REVIEW PAPER, REVIEW ARTICLE (PREGLEDNI RAD)

Between minimal dose and optimal image: Challenges of paediatric CT diagnostics

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Abstract

Computed tomography (CT) plays an important role in paediatric imaging due to its rapid acquisition, widespread availability, and high diagnostic value. At the same time, the increased sensitivity of children to ionising radiation requires particular attention to the justification of examinations and dose optimisation. The aim of this review was to summarise current evidence on the risks associated with exposure to ionising radiation during paediatric CT examinations and contemporary approaches to dose reduction. The literature indicates that advances in CT technology, the implementation of paediatric-specific protocols, automatic exposure control, iterative reconstruction techniques, and diagnostic reference levels enable reductions in radiation exposure while maintaining diagnostic image quality. Further risk reduction can be achieved through appropriate justification of each examination and adjustment of imaging protocols according to the child's age and body size. Standardisation of procedures, implementation of international recommendations, and the professional expertise of radiographers are important for further improving radiation protection and patient safety in paediatric imaging.

Keywords: dose optimisation; ionising radiation; paediatric computed tomography; radiation protection; radiation risks

Introduction

Ionising radiation has the ability to ionise matter and is classified as electromagnetic or particulate radiation (1, 2). Biological effects occur when electromagnetic radiation scatters or is absorbed in tissues, transferring energy (1). DNA damage may result from direct radiation action or from free-radical effects and may lead to malignant diseases and hereditary genetic damage (3). Deterministic effects occur after a threshold dose is exceeded, with their severity increasing with dose, whereas stochastic effects have no clearly defined threshold and their probability increases with dose, including the development of malignant tumours and leukaemia (4).

Paediatric patients are exposed to relatively high radiation doses during CT examinations, raising concerns about potential carcinogenic effects (5). Their increased radiosensitivity is associated with physiological, anatomical, developmental, and behavioural factors, particularly in younger children (6). Lower body mass, different body proportions, a thinner layer of visceral adipose tissue, and longer life expectancy further increase the significance of radiation exposure (6, 7). Children are more susceptible to developing certain cancers and leukaemia (6), while certain genetic conditions further increase radiosensitivity (6, 8). Radiation protection follows the ALARA principle, which aims to keep radiation doses as low as reasonably achievable (9).

CT is an important component of paediatric imaging, with head trauma being its most common indication (10). It is also used for other intracranial conditions (11) and in the evaluation of patients with multiple trauma (12). Its use has increased exponentially since its introduction (10), and CT accounts for almost half of the collective medical radiation dose in the USA (13) and up to 68% in the UK (14). In non-paediatric centres, children received twice the radiation doses observed in paediatric trauma centres (15), while inappropriate use is influenced by requests from consultants, patient expectations, and concerns about litigation (16).

At least four million paediatric CT examinations are performed annually in the USA (17), and between 2000 and 2006, head CT use increased by 23% and abdominal CT by 49% (18). Over the past decade, CT use has declined due to increased awareness of radiation risks (19–23), which had previously been insufficient (24), while subsequent studies demonstrated changes in clinical practice (25) and greater awareness of CT overuse (26).

CT is used more frequently in general than in paediatric emergency departments (27), as well as in non-paediatric trauma centres and non-academic emergency departments (28). Whole-body CT was performed in 3% of children at a paediatric centre compared with 9% at adult facilities (29), and differences have also been observed among physicians (30, 31). CT use has also increased

in cases of acute appendicitis (22, 32–34), particularly among children initially evaluated at general hospitals (35, 36), where CT is used more frequently and ultrasound less frequently (37), possibly due to its lower availability and a lack of trained personnel (38).

Most studies have reported more frequent CT use among older children (18, 27, 32, 39–43), White children (32, 42, 43), and boys (28, 32, 44). International comparisons have demonstrated differences among Japan, the USA, and Germany (45); unlike the USA, Japan did not experience an increase in CT use (46), and 1.22 million paediatric CT examinations were estimated to have been performed in Japan in 2003 (47). Japanese and German hospitals differed in terms of patient age and clinical indications (48). In Finland, an increase between 1996 and 2002 was followed by a decline through 2010 (49), with utilisation rates comparable to those in the UK and the Netherlands and lower than those in the USA (20, 50, 51). CT use may be influenced by financial incentives within healthcare systems (20, 52, 53), whereas universal healthcare systems place greater emphasis on the rational use of diagnostic procedures (54).

The aim of this review was to describe the potential risks associated with exposure to ionising radiation in paediatric CT imaging and to analyse approaches to radiation dose optimisation while maintaining diagnostic image quality.

Methods

This review was based on a search of the scientific literature on radiation doses, risks associated with exposure to ionising radiation, and approaches to dose optimisation in paediatric CT imaging. The literature was searched in the Scopus and PubMed databases during April 2026, while Google Scholar and ResearchGate were used for additional searches and access to full-text articles. Scopus was used as the starting point due to the larger number of available papers related to the research topic.

Two search strategies were applied in Scopus and PubMed. The first included the terms *paediatric CT, radiation dose, dose reduction,* and *dose optimisation, while the second included paediatric CT, radiation risk, cancer risk, and ionising radiation*. The inclusion criteria were articles published within the previous ten years, full-text availability (*Open Access* or *Free Full Text*), and publication in English. The time restriction was selected because of advances in CT technology, imaging protocols, dose optimisation, and updates to radiation protection guidelines.

Results

The first Scopus search strategy identified 460 articles, of which 53 were included after applying the inclusion criteria and assessing titles, abstracts, and full texts. The second strategy identified 165 articles, and 8 additional articles were included after applying the inclusion criteria, removing overlapping articles, and assessing relevance.

In PubMed, the first search strategy identified 165 articles, of which an additional 5 were included after applying the inclusion criteria, removing previously identified articles, and assessing relevance. The second strategy identified 58 articles, with an additional 4 included after applying the inclusion criteria, removing duplicates, and assessing relevance.

A total of 70 scientific articles were included in the final analysis, covering radiation doses, risks associated with ionising radiation exposure, dose optimisation methods, the role of radiographers, and alternative diagnostic imaging methods. Relevant guidelines and recommendations from professional societies were also used, together with articles identified by reviewing the reference lists of the included studies.

Discussion

Radiation Doses in Paediatric CT Imaging

Assessment of radiation dose during CT examinations is most commonly based on standardised dosimetric indicators: the volume computed tomography dose index (CTDIvol) and dose-length product (DLP). CTDIvol represents the radiation output of the CT scanner and depends on acquisition parameters such as mAs, kVp, pitch factor, and gantry rotation time (55-57). Although it enables comparison of radiation output between CT scanners, its ability to estimate the actual patient dose is limited because it does not account for body size, body shape, or tissue attenuation properties (55,58,59). A more accurate estimate is provided by the size-specific dose estimate (SSDE), which accounts for patient size by applying correction factors to CTDIvol (55), thereby providing a more realistic dose estimate in paediatric patients (60). Organ doses are also important when assessing biological effects because of differences in tissue radiosensitivity (61), although data on the actual doses received by individual organs during CT examinations have not yet been fully established (62–71). A summary of the most commonly used dosimetric indicators is presented in Table 1.

Table 1. Comparison of the most commonly used dosimetric indicators in paediatric CT imaging (55–71)

Indicator	Unit	Description
CTDIvol	mGy	Represents the radiation output of the CT scanner and depends on acquisition parameters
DLP	mGy·cm	Product of CTDIvol and scan length
SSDE	mGy	Patient size-specific dose estimate based on CTDIvol
Effective dose	mSv	Indicator of the patient's overall exposure to ionizing radiation during a CT examination
Organ (absorbed) dose	mGy	Dose absorbed by an individual organ or tissue

Chu et al. found that during routine head CT, the skin, brain, and eye lens received the highest absorbed doses, while the colon received the highest dose during high-dose abdominal and pelvic CT, and the thyroid during CT examinations of the neck, cervical spine, and chest. The youngest children, particularly those under one year of

age, received higher doses in most CT categories. Considerable variability among institutions was also observed: for abdominal and pelvic CT in children aged 6–10 years, the mean colon dose ranged from 5.6 to 116.6 mGy, while for head CT, the mean brain dose ranged from 29.6 to 59.1 mGy (72). Comparison with the European Epidemiological Study on Paediatric Computerised Tomography (EPI-CT) showed comparable brain doses during routine head CT in most age groups, whereas higher organ doses were reported in children under one year of age in the study by Chu et al. Higher thyroid and red bone marrow doses were also observed in the youngest children (70).

Poosiri et al. showed that DLP, brain dose, and eye lens dose increased with age. CTDIvol remained nearly constant within individual age groups despite differences in head size, whereas the size-specific dose estimate based on water-equivalent diameter (SSDEDw) varied according to patient size and more accurately reflected actual radiation exposure (73). Inoue et al. also reported an increase in DLP with age; however, the effective dose (ED) was highest in newborns and gradually decreased with age. Thus, despite higher DLP values in older children, younger children had a higher ED due to the age-dependent conversion factor and greater radiosensitivity (74).

Increased exposure in the youngest children is particularly important in the context of repeated CT examinations. Biegała et al. found the highest exposure in children under one year of age with hydrocephalus and concluded that age-adjusted paediatric protocols can significantly reduce radiation exposure (75).

Özsoykal et al. showed that CTDIvol remains nearly constant throughout the scan range, whereas SSDE varies according to patient size and anatomical region and was approximately twice as high as CTDIvol (76). Khan et al. also demonstrated that SSDE, by accounting for patient size, provides a more accurate estimate of actual radiation exposure than CTDIvol, with the highest SSDE values observed for head CT (77).

The importance of protocol adjustment was confirmed by Keshtkar et al. Compared with the routine chest CT protocol (RC-CT), the CT protocol for diagnosing COVID-19 (CD-CT) was associated with lower CTDIvol, DLP, SSDE, and ED values across all age groups. The lungs received the highest organ doses, while the estimated risk of malignancy was highest in the youngest age group, particularly for lung and breast cancer (78).

Risks of Exposure to Ionising Radiation in Paediatric CT Imaging

Brenner et al. were among the first to estimate the risk of cancer associated with paediatric CT, with the estimated risk of a fatal outcome ranging from 1 in 10,000 to 1 in 1,000 examined children, depending on age and the body region scanned (79). Subsequent epidemiological studies further indicated a possible association between CT examinations performed during childhood and early adulthood and an increased risk of malignancy (69, 80, 82).

The EPI-CT study demonstrated increased standardised mortality ratios (SMRs), particularly during the first five years after the first CT examination. After five years, the SMR decreased, and malignancy-associated mortality reached the level observed in the general population (83).

A meta-analysis by Huang et al. showed a 1.32-fold higher risk of malignancy in children exposed to CT radiation, with the risk increasing with dose. The risk of leukaemia was 1.23-fold higher and that of brain tumours 1.54-fold higher compared with unexposed children. The risk of malignancy was 1.24-fold higher within two years, 1.38-fold higher after five years, and 1.26-fold higher after ten years, with the highest risk observed in children who underwent their first CT examination between 0 and 5 years of age (84). De Gonzalez et al. found that predisposing conditions did not significantly affect the association between CT exposure and leukaemia or brain tumours. Previously unreported cancers may have partially influenced the estimates, particularly for brain tumours, but the association persisted after adjustment for potential sources of bias (85).

Bosch et al. found an association between cumulative dose and haematological malignancies. They observed an increased relative risk at doses ≥10 mGy, and at doses ≥50 mGy it was 2.66 times higher than at doses <5 mGy. The risk increased with dose, was more pronounced for non-Hodgkin lymphoma than for Hodgkin lymphoma, and exposure at a younger age was associated with a higher risk of leukaemia. The highest risk was observed 2 to <5 years after exposure. Each additional CT examination was associated with a 43% increase in the risk of haematological malignancies, a 42% increase in lymphoid malignancies, and a 48% increase in myeloid malignancies and acute leukaemias (86).

In the Dutch Paediatric CT Study, the risk of brain tumours increased with radiation dose to the brain, with the highest relative risk observed at doses >120 mGy (87). Wang et al. found no increased risk of intracranial tumours, leukaemia, Hodgkin lymphoma, or non-Hodgkin lymphoma after a single CT examination. After 2–3 examinations, the risk of intracranial tumours increased, while four or more examinations were associated with an increased risk of intracranial tumours, leukaemia, and non-Hodgkin lymphoma, but not Hodgkin lymphoma. The overall incidence of the malignancies investigated was 2.3 times higher after four or more examinations (88).

Kojimahara et al. found no association between head CT and an increased risk of brain tumours; however, due to the small sample size, the statistical power was insufficient to reliably detect a possible association (89). Journy et al. estimated that the excess lifetime cancer risk following a single CT examination decreased by 50–70% between 2000–2008 compared with 1990–1994. A single CT examination during childhood could result in approximately one additional cancer per 1,000 spontaneous cancers, and among 130,750 CT examinations performed in 2015, an estimated 64 additional lifetime cancer cases were projected, with brain tumours being the most common. The distribution of body regions examined by CT and the proportion of estimated future cancers associated with radiation exposure are shown in Figure 1 (90).

A meta-analysis by Al-Shangeeti et al. showed a 1.49-fold higher overall risk of cancer in children exposed to CT radiation. A single CT examination was not associated with a statistically significant increase in risk, whereas the risk was 2.51-fold higher after two or more examinations. The increase was particularly pronounced for brain tumours, while findings for leukaemia were less consistent (91).

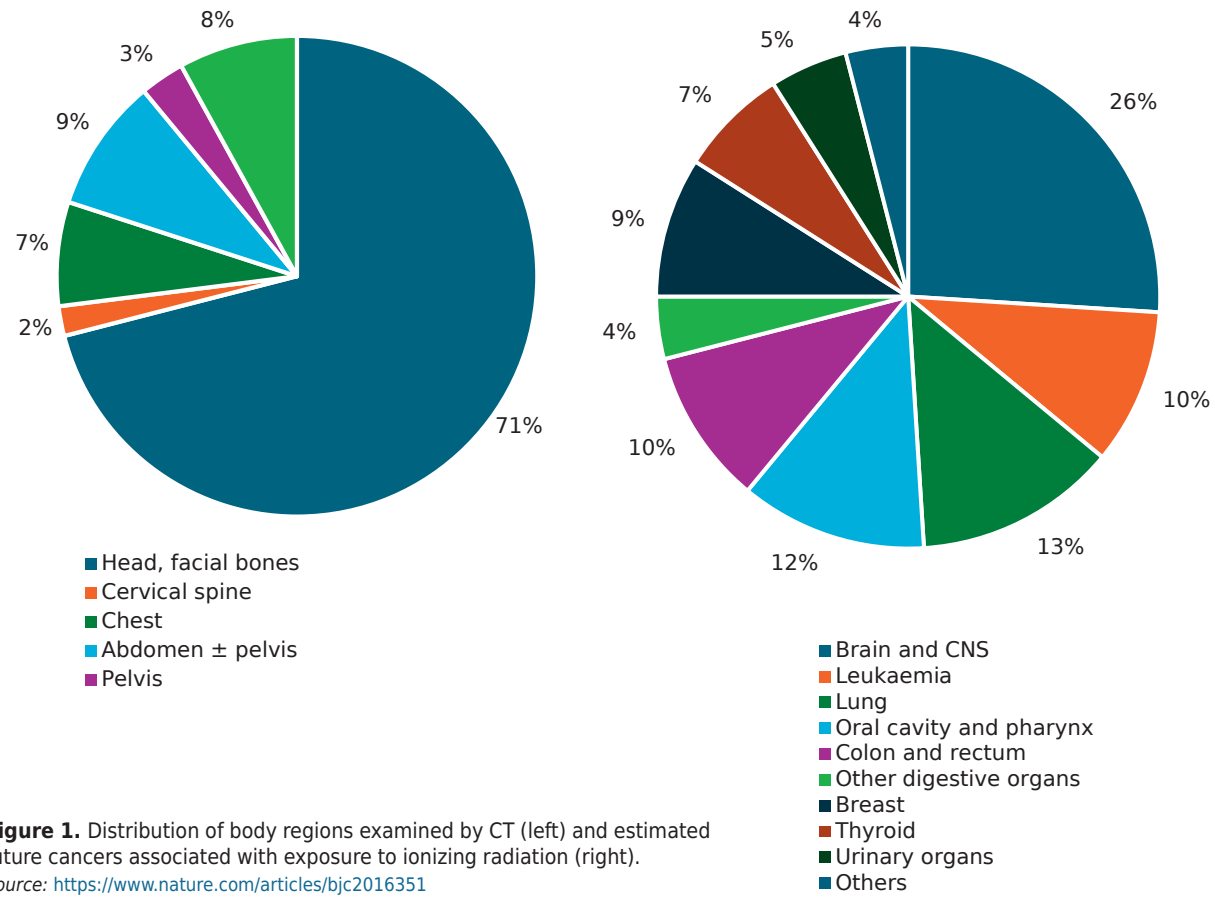


Figure 1. Distribution of body regions examined by CT (left) and estimated future cancers associated with exposure to ionizing radiation (right).
Source: https://www.nature.com/articles/bjc2016351

Dose Optimisation in Paediatric CT Imaging

Dose optimisation in paediatric CT imaging aims to achieve diagnostically acceptable image quality while keeping the ionising radiation dose as low as possible (92). Main strategies include adjusting kV, mAs, and pitch according to the child's age and size, limiting scan length to the region of interest, positioning the patient appropriately, and avoiding unnecessary multiphase examinations. Diagnostic reference levels (DRLs), achievable doses (ADs), automatic modulation of exposure parameters, iterative reconstruction techniques, and artificial intelligence-based methods also play an important role, together with protocol standardisation, staff education, and interdisciplinary collaboration (93).

The clinical application of the principles of justification and optimisation can directly reduce unnecessary radiation exposure in children, as demonstrated by Solomon et al., who reported that 11% of children were spared unnecessary exposure (94). Education of healthcare professionals and collaboration between specialised centres and local hospitals can also improve knowledge of radiation risks and the implementation of dose-reduction practices (95). Assessment of diagnostic image quality is additionally important for preventing the use of unnecessarily high radiation doses. Padole et al. developed Image Quality Scoring Criteria (IQSC), which may serve as a practical tool for protocol optimisation (96), while Samei et al. proposed a quantitative approach that enables individualisation of protocols according to patient size and the desired dose or image quality level (97).

Diagnostic Reference Levels and Radiation Dose Monitoring

Diagnostic reference levels (DRLs), proposed by the International Commission on Radiological Protection (ICRP) in 1990, represent an important tool for assessing dose levels during CT examinations (98). They are most commonly established as the 75th percentile of the CTDIvol and DLP distributions (99) and enable comparison of dose levels and identification of opportunities for further optimisation (100). Achievable doses (ADs) are defined as the median, or 50th percentile, of the dose distribution, and in paediatric CT imaging, DRL and AD values are often adjusted according to patient age, body weight, or size (101,102).

National and multicentre studies confirm the importance of regularly monitoring and updating DRLs. Based on a national audit, Worrall et al. proposed new DRLs for paediatric CT examinations in the United Kingdom (103), while Wagner et al. proposed values in Switzerland that were up to 20% lower than those previously used, indicating the potential for further optimisation (104). In Shanghai, Yang and Gao reported AD values approximately 60% lower than the corresponding DRLs, also indicating potential for reducing variability in radiation doses among institutions (105).

Studies from Japan demonstrated the need to establish national paediatric DRLs (106) and reported dose reductions following their introduction in 2015 (107). In Korea, CTDIvol and DLP increased with age, with substantial variability among hospitals despite the use of the same

protocols (108), while similar interhospital and regional differences were observed in China (109).

In addition to age, adjustment of DRLs according to patient size and body weight is increasingly being considered. Tonkopi et al. emphasised the importance of standardised data collection and the inclusion of SSDE in dose assessment (110), while Bos et al. demonstrated an increase in DRL values with age and differences among CT examination categories (111). A meta-analysis by Zakariaee et al. showed an increase in all dosimetric indicators with body size, with substantial heterogeneity among studies and a need to adjust protocols according to patient size (112). Significant differences according to hospital, age, protocol, and type of CT scanner were reported by Rawashdeh et al. (113), while Dastikas et al. demonstrated a strong positive association between body weight and CTDIvol and DLP, as well as the usefulness of body weight-based reference curves (114).

Dose levels may also be influenced by organisational factors. van der Merwe and Mahomed reported higher DLP values outside regular working hours, which may be related to staff experience and protocol selection (115). Aloufi et al. reported the highest doses during abdominal and head CT examinations, particularly in children under one year of age (116), while Bibbo et al. found higher DLP values with helical than with axial scanning (117).

Variability in exposure parameters and radiation doses within and between hospitals has also been confirmed in other studies (118). Differences were observed in radiation doses, image noise, and effective mAs, kVp, and pitch values among different CT examinations and age groups (119). Interhospital differences, particularly for chest CT and abdominal and pelvic CT, also indicate the need to review individual protocols (120). In Greece, CTDIvol values for head CT were comparable to European DRLs, whereas DLP values were higher (121), while in Cameroon, CTDIvol and DLP exceeded French DRLs in all age groups (122). In contrast, values in Ghana were generally lower than those reported in other studies, with the exception of head CT in children aged 11–15 years (123).

A systematic review by Priyanka et al. confirmed substantial international variability in CTDIvol and DLP, as well as differences in protocols and methods used to establish DRLs (124). Similar variability was observed in African countries, where the number of available studies remains limited (125). Table 2 provides a summary of the analysed studies, their key findings, and their contributions to dose optimisation associated with the use of DRLs in paediatric CT imaging.

The studies presented in this section confirm the importance of DRLs and systematic radiation dose monitoring in the optimisation of paediatric CT examinations. Despite the increasing implementation of national and local DRLs, substantial variability in protocols and dose levels persists among institutions and countries. Accordingly, continuous dose monitoring, protocol standardisation, and adjustment of CT examinations to individual patient

Table 2. Overview of key findings on diagnostic reference levels in paediatric CT imaging (103–125)

Research topic	Representative studies	Key findings	Key contribution to optimization
National DRLs and comparison with international values	Worrall et al.; Wagner et al.; Takei et al.; Matsunaga et al.; Kim et al.; Kang et al.	Substantial variability in radiation doses was observed among countries and institutions, while the introduction and regular updating of DRLs were associated with reductions in radiation dose.	Establishing and updating national DRLs enables comparison of radiation doses among institutions and identification of opportunities for further optimization.
Achievable doses (ADs) as an indicator of further optimization potential	Yang and Gao	Achievable doses were approximately 60% lower than the corresponding DRL values, indicating potential for further dose reduction.	They enable the identification of protocols in which radiation exposure can be further optimized.
Size-specific approach, SSDE, and adjustment according to patient size	Tonkopi et al.; Zakariaee et al.; Rawashdeh et al.; Dastikas et al.	CTDIvol, DLP, and SSDE values increase with increasing age, body weight, and patient size, while SSDE more accurately reflects actual radiation exposure.	Enables individualisation of dose assessment and adjustment of protocols according to patient characteristics.
DRLs according to clinical indications and CT examination categories	Bos et al.	Differences among individual CT categories were more pronounced than differences among individual indications within the same category.	Enables more precise standardization and optimization of protocols according to the clinical task.
Local DRLs, audits, and interinstitutional comparisons	van der Merwe and Mahomed; Aloufi et al.; Bibbo et al.; Alhailiy et al.; Muhammad et al.; Bouchareb et al.; Ploussi et al.; Eddy et al.; Amedzoame et al.	Substantial differences in radiation doses, acquisition parameters, and protocol quality were observed among institutions, with some variations associated with staff experience and protocol selection.	Enables the identification of areas for optimization, protocol standardization, and targeted staff education.
Systematic reviews of DRLs	Priyanka et al.; Gyan et al.	Considerable heterogeneity in DRL methodology, acquisition protocols, and reference values was confirmed among countries.	Highlights the need for harmonization of methodology and standardization of paediatric CT protocols.

characteristics represent important factors in the further optimisation of paediatric CT imaging.

Automatic Exposure Control and Optimisation of Acquisition Parameters

Adjustment of exposure parameters according to the child's age and size is a fundamental dose-reduction strategy. Kamdem et al. demonstrated that the introduction of age- and size-adjusted parameters, staff education, and optimised protocols can significantly reduce radiation dose even on CT scanners designed for adult patients (126). Age- and size-adjusted protocols and adjustment of mAs also enabled a significant reduction in effective dose during brain CT without a significant loss of diagnostic image quality (127).

Automated systems further enable exposure to be tailored to the individual patient. The CAREkV automatic tube voltage selection system can improve standardisation and reduce inter-operator variability but requires appropriate adjustment for paediatric patients to avoid the automatic selection of unnecessarily high kV values. For example, in patients with a pronounced difference between abdominal and pelvic width, automatic selection of a higher tube voltage was observed (Figure 2), further emphasising the importance of appropriate patient positioning and adjustment during paediatric CT examinations (128).

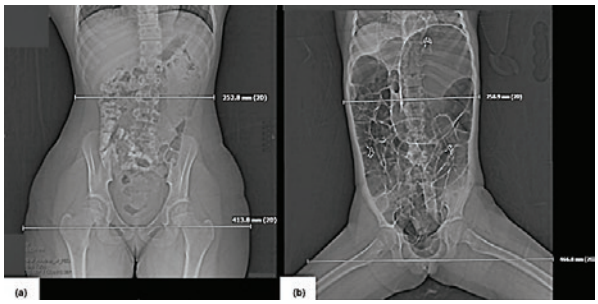


Figure 2. Example of automatic selection of a higher kV value due to differences in abdominal and pelvic width during a paediatric CT examination
Source: https://aapm.onlinelibrary.wiley.com/doi/epdf/10.1002/acm2.13098?getft_integrator=scopus&src=getftr&utm_source=scopus

Papadakis and Damilakis demonstrated that automatic tube current modulation (ATCM) can reduce CTDIvol by 8–24% for head CT, 16–39% for chest CT, and 25–41% for abdominal and pelvic CT. The additional use of automatic tube voltage selection (ATVS) enabled even greater dose reductions, reaching 70–79% for certain contrast-enhanced examinations, although it did not always result in dose reduction for non-contrast head CT (129).

Combining ATVS and ATCM during paediatric chest CT enabled better exposure adjustment to patient size and reduced high-dose outliers, with CTDIvol reductions observed in four of five age groups (130). Further optimisation can be achieved by using a lower tube voltage while monitoring the contrast-to-noise ratio (CNR), thereby reducing radiation dose while maintaining image quality (131). The main characteristics of the analysed studies are summarised in Table 3.

The studies presented confirm the importance of adjusting exposure parameters to reduce radiation dose while maintaining diagnostic image quality. The use of ATCM and ATVS, together with individualisation of parameters according to patient size and clinical indication, may further contribute to protocol standardisation, reduced inter-operator variability, and the safety of paediatric CT imaging.

Iterative Reconstruction and Artificial Intelligence

Iterative reconstruction methods and artificial intelligence-based systems enable reductions in image noise and artefacts while maintaining diagnostic image quality at lower radiation doses. The use of iDose iterative reconstruction during low-dose chest CT in neonates and young children can maintain diagnostic image quality at lower radiation doses (132).

In low-dose brain CT, iterative model reconstruction resulted in an approximately twofold improvement in the contrast-to-noise ratio and a more than twofold improvement in the signal-to-noise ratio of grey and white matter compared with filtered back projection (FBP) (133). Villanueva-Meyer et al. demonstrated that ultra-low-dose chest CT can be diagnostically acceptable for certain indications, particularly for excluding airway foreign bodies. Model-based iterative reconstruction (MBIR) reduced image noise compared with adaptive statistical iterative reconstruction (ASIR); however, ultra-low-dose CT did not

Table 3. Overview of studies on the optimisation of exposure parameters in paediatric CT imaging (126–131)

Optimization method	Studies	Key findings	Effect on dose
Age and size adjusted protocols	Kamdem et al.; Karappara et al.	Adjustment of kV, mAs, pitch, and other parameters according to the child's age and size enables dose reduction while maintaining diagnostic image quality.	CTDIvol reduced by up to 32% and effective dose by up to 71%.
Automatic tube voltage selection (CAREkV)	Browne et al.	Automated kV selection enables protocol standardization, reduces inter-operator variability, and decreases the risk of inappropriate parameter selection.	Image quality maintained while optimizing radiation dose.
Automatic tube current and voltage modulation (ATCM + ATVS)	Papadakis and Damilakis; Hojreh et al.	Automatic adjustment of kV and mAs according to patient size enables protocol individualization, reduces operator-related errors, and maintains diagnostic image quality.	Dose reduction of up to 79%, with CTDIvol reduced by up to approximately 46%.
Reduction of tube voltage using CNR	Masuda et al.	Maintaining an appropriate contrast-to-noise ratio (CNR) enables the use of lower kVp values while preserving diagnostic image quality and improving contrast.	Dose reduction of up to 56% at 80 kVp.

achieve the image quality of standard-dose CT for all indications (134).

Contemporary iterative reconstruction techniques such as ASIR and MBIR enable image quality to be maintained at lower radiation doses compared with FBP, with ASIR allowing dose reductions of approximately 40–50% and MBIR providing further dose reduction while maintaining diagnostic image quality (93). More recent methods include iterative model reconstruction (IMR), advanced modelled iterative reconstruction (ADMIRE), iDose4, and deep learning image reconstruction (DLIR). By applying artificial intelligence and deep learning, DLIR reduces image noise and artefacts while preserving anatomical detail and, in some studies, has enabled dose reductions of up to approximately 85% while maintaining diagnostically acceptable image quality. Compared with ASIR and FBP, improved lesion detection, a higher signal-to-noise ratio (SNR), better grey–white matter differentiation, and lower image noise have been reported (135). Table 4 summarises the reconstruction methods and their contribution to the optimisation of paediatric CT imaging.

Table 4. Reconstruction methods described in the systematic review by Patil et al. (2026) and their contribution to the optimization of paediatric CT imaging (135)

Reconstruction method	Brief description	Main findings of the systematic review
ASIR	Adaptive statistical iterative reconstruction.	Reduction in image noise and improvement in CNR, with radiation dose reductions of approximately 13–48%.
MBIR	Model-based iterative reconstruction.	Maintenance of high image quality with ultra-low-dose protocols, with radiation dose reductions of approximately 83–97%.
ADMIRE	Advanced modeled iterative reconstruction.	Average reductions in CTDIvol, DLP, and effective dose of approximately 30%.
IMR	Iterative model reconstruction.	Improved qualitative and quantitative image quality with lower CTDIvol values compared with FBP reconstruction.
DLIR	Deep learning image reconstruction.	Improved SNR, visualization of anatomical details, and lesion detection, with radiation dose reductions of up to approximately 85%.

Iterative reconstruction and deep learning technologies represent important contemporary approaches to the optimisation of paediatric CT imaging, as they enable substantial dose reductions while maintaining or improving diagnostic image quality. However, their implementation depends on the technical capabilities of the institution and the availability of modern CT scanners, which may limit the adoption of advanced optimisation strategies (135).

Radiographers in the Safety and Quality of Paediatric CT Examinations

Radiographers play an important role in the preparation and performance of paediatric CT examinations, the application of radiation protection principles, and communication with children, parents, and other members of the healthcare team. Working with children requires knowledge of paediatric protocols, adaptation of the approach to the patient, and the creation of appropriate conditions for the safe performance of diagnostically adequate examinations.

Aipanda et al. demonstrated that the active involvement of radiographers in communicating with parents about the risks and benefits of radiation contributes to professional satisfaction and confidence in practice, while the lack of formal communication training and disagreements regarding the justification of CT examinations were identified as important challenges (136). Insufficient knowledge of radiation doses and risks has also been identified among some healthcare professionals, including underestimation of radiation doses and limited awareness of the use of non-adapted adult protocols in paediatric patients (137).

The presence of a parent or caregiver may help reassure the child and reduce motion artefacts. During paediatric chest CT, Overhoff et al. found very low levels of radiation exposure to accompanying persons when contemporary protocols were used, while no measurable exposure was detected at the lateral side of the gantry (138).

Specific training and experience further influence the confidence of radiographers when working with children. Greenberg and Davis found lower levels of confidence when performing paediatric compared with adult CT examinations, particularly due to a lack of experience and specific training, while a significant increase in self-reported confidence was observed after training (139). The importance of continuing education, standardised protocols, and interdisciplinary collaboration has been particularly emphasised in smaller hospitals with limited experience in paediatric imaging (95). Education is also important for the appropriate adjustment of kV and mAs, the application of reconstruction methods, and limiting the number of acquisitions, as insufficient training may result in the use of automatically predefined parameters without appropriate adjustment for children (126).

In addition to technical competence, the psychological approach is also important. A child-friendly environment, distraction techniques, and effective communication with children and parents can reduce anxiety and improve cooperation, while clear explanations of the procedure and appropriate positioning can reduce motion artefacts and the need for repeat examinations (140).

European and International Recommendations for Dose Optimisation and Radiation Protection in Paediatric CT

The importance of dose optimisation and radiation protection in paediatric CT imaging is emphasised in international and European guidelines addressing the justification of examinations, adjustment of exposure parameters, implementation of diagnostic reference levels, and quality assurance of radiological procedures.

The guidelines of the British Institute of Radiology emphasise the increased radiosensitivity of children and the need to adapt CT protocols according to their age and body size. The use of protective shielding during CT is considered controversial because of the potential for artefacts, interference with automatic exposure control (AEC), and the need for repeat imaging. Protocol adjustment according to body weight, body mass index, and age, together with automatic exposure modulation, is recommended as a more effective approach. In a paediatric phantom, a lead apron reduced scattered radiation by only 0.2% at a distance of 10 cm and by 0.7% of the primary dose at 1 cm from the scanned region, which is very small relative to the total examination dose (141).

The International Atomic Energy Agency (IAEA) publication Radiation Protection in Paediatric Radiology emphasizes the strict justification of each CT examination based on the patient's age, clinical indication, and expected diagnostic benefit. Review of previous radiological records, avoidance of prematurely performed follow-up examinations, and reduction of multiphase, repeated, and unnecessary non-contrast acquisitions are recommended. Appropriate preparation of the child, reduction of anxiety, immobilization, and, when necessary, sedation or anaesthesia may reduce the need for repeat imaging. Interdisciplinary collaboration, clinical reviews, and audits of examination justification are also emphasized (7).

ICRP Publication 121 also emphasizes justification and optimization, including limiting the scan range according to the clinical indication, which can reduce radiation dose by up to 55% during follow-up examinations of patients with cystic fibrosis. A higher level of image noise is acceptable provided that diagnostic value is maintained, with the required image quality depending on the clinical indication. Lower tube voltages than those used in adults, often 80–100 kVp, are recommended in children, together with appropriate reconstruction and image post-processing methods (9).

ICRP Publication 135 highlights the complexity of establishing paediatric DRLs because of the substantial differences in body size among children and emphasizes the importance of precise collimation. Age alone is not a sufficiently reliable parameter for establishing DRLs; therefore, weight groups of <5 kg, 5–<15 kg, 15–<30 kg, 30–<50 kg, and 50–<80 kg are recommended for examinations of the trunk, whereas age groups are more appropriate for head CT. CTDIvol and DLP are recommended as dosimetric quantities, with SSDE providing an option for a more realistic assessment of radiation exposure. The document also highlights the limitations of AEC systems developed primarily for adults, which may require manual adjustment of exposure parameters in the smallest children (142).

The European Commission's European Guidelines on Diagnostic Reference Levels for Paediatric Imaging emphasize DRLs as one of the main tools for optimization. They highlight the lack of national paediatric DRLs in some European countries, as well as differences in the methods used to establish them and in the grouping of children according to age, weight, or body size. Accordingly, the guidelines emphasize the need to standardize dosimetric data collection and the establishment of DRLs. Comparison of local doses with DRL values is recommended at least annually, together with analyses and corrective measures when reference values are consistently exceeded (143).

International and European guidelines are consistent with the studies presented above and confirm the importance of individualizing paediatric CT protocols, monitoring dosimetric indicators, and standardizing procedures and DRL values to reduce variations in clinical practice and improve diagnostic quality.

Use of Alternative Diagnostic Imaging Methods to Reduce the Number of CT Examinations

Despite the development of dose optimisation strategies, the number of paediatric CT examinations continues to increase, and repeated examinations during long-term follow-up may result in substantial cumulative exposure to ionising radiation. Therefore, the justification of follow-up CT examinations should be carefully assessed, and alternative imaging methods should be considered whenever clinically appropriate (145). Minimising unnecessary CT examinations requires stricter justification, education of healthcare professionals, and restriction of their use to clinically justified cases (146).

ICRP and IAEA recommendations emphasise the use of imaging methods that do not involve ionising radiation whenever clinically appropriate. Ultrasound is particularly important in abdominal imaging and in cases of suspected acute appendicitis, while Magnetic Resonance Imaging (MRI) offers advantages in the evaluation of soft tissues, the nervous system, and bone marrow. CT retains an important role in emergency conditions, polytrauma, and the evaluation of cortical bone, whereas the use of MRI may be limited by its availability, particularly in emergency settings (7,9).

The World Health Organisation highlights that the development of new ultrasound techniques has expanded its use in paediatric radiology, while MRI, owing to its high soft-tissue contrast resolution and absence of ionising radiation, has gradually replaced CT and conventional radiography in certain areas. MRI is used in the diagnosis of diseases of the central nervous, urinary, musculoskeletal, and cardiovascular systems, as well as in the evaluation of malignant diseases. Despite the advantages of alternative imaging methods, the use of CT continues to increase because of its availability and rapid image acquisition (8).

A systematic review by Aziz et al. also emphasises the importance of ultrasound and MRI as non-ionising imaging methods. Ultrasound provides real-time imaging and plays an important role in emergency diagnostics and focused assessment with sonography for trauma (FAST), while MRI provides detailed visualisation of soft tissues and may represent an alternative to CT for certain clinical indications. However, ultrasound is operator-dependent, while MRI is more expensive and time-consuming and may require sedation in younger children. Additional limitations include risks associated with gadolinium-based contrast agents in patients with impaired renal function and the greater complexity of interpreting paediatric MRI findings (93). The higher cost, lower availability, and poorer tolerability of MRI in younger children have also been confirmed in other studies (10).

The increased use of ultrasound and MRI reflects the growing application of non-ionising imaging methods in paediatric diagnostics. However, the simultaneous

increase in the number of CT examinations emphasises the need for continuous assessment of their justification and the use of imaging methods without ionising radiation whenever possible (146).

Conclusion

CT imaging plays an important role in modern paediatric medicine; however, children's increased sensitivity to ionising radiation and the potential for long-term adverse effects require careful, justified use. The literature analysis showed differences in radiation exposure levels across healthcare institutions and countries, while modern optimisation approaches reduce dose while maintaining diagnostic image quality. Key measures include adapting protocols for paediatric patients, implementing diagnostic reference levels, automatic exposure control, and contemporary reconstruction methods. The safe use of CT requires justification of each examination, consistent radiation protection, and interdisciplinary collaboration, with radiographers playing an important role in protocol implementation, parameter optimisation, and continuing professional development. Rational use of CT, together with alternative imaging methods that do not involve ionising radiation whenever clinically appropriate, may further reduce unnecessary radiation exposure in paediatric patients.

All data in this paper are part of the results of the master's thesis "Potential risks of ionising radiation and dose optimisation in paediatric CT diagnostics", written at the Faculty of Health Sciences, University of Split (147).

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Između minimalne doze i optimalne slike: izazovi pedijatrijske CT dijagnostike

Sažetak

Kompjutorizirana tomografija (engl. *Computed Tomography*, CT) zbog brzine izvođenja, dostupnosti i visoke dijagnostičke vrijednosti ima značajno mjesto u pedijatrijskoj dijagnostici. Istodobno, povećana osjetljivost djece na ionizirajuće zračenje zahtijeva posebnu pozornost pri opravdanju pretraga i optimizaciji doze. Cilj ovog preglednog rada bio je prikazati spoznaje o rizicima izloženosti ionizirajućem zračenju tijekom pedijatrijskih CT pretraga te suvremenim mogućnostima smanjenja doze. Pregled literature pokazuje da tehnološki razvoj CT uređaja, primjena pedijatrijskih protokola, automatska kontrola ekspozicije, iterativne rekonstrukcije i dijagnostičke referentne razine omogućuju smanjenje izloženosti uz očuvanje dijagnostičke kvalitete slike. Dodatnom smanjenju rizika pridonose opravdanost svake pretrage te prilagodba protokola dobi i tjelesnoj građi djeteta. Standardizacija postupaka, primjena međunarodnih preporuka i stručne kompetencije radioloških tehnologa važni su za daljnje unapređenje radiološke zaštite i sigurnosti pedijatrijskih pacijenata.

Ključne riječi: optimizacija doze; ionizirajuće zračenje; pedijatrijska kompjutorizirana tomografija (CT); zaštita od zračenja; rizici zračenja.

REVIEW PAPER, REVIEW ARTICLE (PREGLEDNI RAD)

The Angiosome Concept in Endovascular Treatment of Peripheral Arterial Disease of the Lower Leg Arteries

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Abstract

Aim: The aim of this paper is to explain the angiosome concept and its role in planning endovascular treatment of infrapopliteal peripheral arterial disease, with particular emphasis on the appropriate selection of the target artery to restore foot perfusion and prevent adverse outcomes, including amputation and death. **Materials and Methods**: This paper is based on a narrative review of the available scientific and professional literature on peripheral arterial disease, endovascular treatment and the angiosome concept. The analysis included textbooks, original and review scientific articles and professional online resources retrieved from bibliographic databases (PubMed) and other relevant medical sources. **Results**: The reviewed literature indicates that endovascular revascularisation is one of the most effective treatment options for infrapopliteal peripheral arterial disease and plays a crucial role in patients with chronic limb-threatening ischemia. Application of the angiosome concept may improve wound healing and increase limb salvage by achieving direct revascularisation of the artery supplying the affected vascular territory. However, the angiosome concept has certain limitations, highlighting the importance of an individualised approach to each patient. **Conclusion**: The angiosome concept represents an effective strategy for restoring adequate arterial perfusion to ischemic tissue by directly linking the affected vascular territory with its corresponding source artery through endovascular revascularisation. This approach contributes to improved wound healing, limb preservation, reduced amputation rates, and lower mortality. Although numerous studies support the advantages of direct angiosome-targeted revascularisation, collateral circulation, anatomical variations, and technical feasibility should also be considered. Therefore, indirect revascularisation may represent an appropriate alternative in selected cases, emphasising the importance of an individualised treatment approach for each patient.

Keywords: angiosome; limb; endovascular revascularization; ischemia; peripheral arterial disease

1. Introduction

The angiosome concept plays an important role in planning endovascular treatment in patients with peripheral arterial disease affecting the arteries of the lower leg. This condition represents a significant risk factor for the development of ulcerations, ischemia, and gangrene. The angiosome concept links the localisation of the ischemic lesion to the selection of the target artery for intervention and its impact on clinical treatment outcomes. Furthermore, there is a distinction between direct and indirect revascularisation in achieving optimal perfusion, with the aim of promoting wound healing and achieving favourable outcomes, such as limb salvage and a reduction in the risk of mortality, ultimately contributing to an improved quality of life for the patient.

1.1. Peripheral arterial disease

Peripheral arterial disease (PAD), also referred to as peripheral vascular disease (PVD), is a condition characterised by systemic atherosclerotic involvement and affects more than 200 million people worldwide. It most commonly affects older adults, patients with diabetes, smokers, and individuals with chronic kidney disease. Atherosclerosis is a chronic progressive disease characterised by the accumulation of lipid plaque within the arterial walls, leading to narrowing (stenosis) or occlusion of the arteries. PAD results from this progressive arterial narrowing and most commonly affects the aortoiliac, femoropopliteal, and infrapopliteal segments. Consequently, perfusion of the lower extremities is impaired (1).

PAD manifests in various forms, ranging from asymptomatic disease to intermittent claudication (pain occurring

during movement) and chronic limb-threatening ischemia (CLTI), which carries a risk of limb loss. Coronary artery disease is present in approximately 70% of patients with PAD. Therefore, timely diagnosis and treatment are of great importance in order to prevent adverse outcomes and reduce mortality rates (1).

1.2. Classification of arterial insufficiency

To assess the severity of peripheral arterial disease (PAD), various classification systems are used. The most commonly used are the Rutherford and Fontaine classification systems (presented in Tables 1 and 2), which are used to determine the risk of limb ischemia that may occur in patients who are already at risk of amputation, particularly in the presence of infected wounds, such as those associated with diabetic foot disease (2).

Table 1. Rutherford Classification (2)

Grade	Clinical presentation
0	Asymptomatic
1	Mild claudication
2	Moderate claudication
3	Severe claudication
4	Ischemic rest pain
5	Tissue loss with ulceration
6	Severe ischemic ulcers and gangrene

Table 2. Fontaine Classification (2)

Stage	Clinical presentation
I	Asymptomatic
II	Intermittent claudication
IIa	Intermittent claudication after walking >200 m without pain
IIb	Intermittent claudication after walking <200 m
III	Rest pain
IV	Ischemic ulcers and gangrene

1.3. Infrapopliteal arterial disease

Infrapopliteal arterial disease refers to peripheral arterial disease (PAD) located in the arteries of the lower leg, i.e., below the popliteal bifurcation. It affects the anterior tibial artery, posterior tibial artery, and fibular (peroneal) artery. Chronic stable limb ischemia is generally asymptomatic, while approximately 20% of patients experience intermittent claudication. As a result of impaired blood flow, compensatory mechanisms and collateral circulation develop. When these mechanisms are no longer sufficient to meet the oxygen demands of the tissues, rest pain and tissue necrosis may occur. Pain usually develops in the distal parts of the foot, particularly in the toes or heel. Other characteristic symptoms include cold intolerance, joint stiffness, hyperesthesia (increased sensitivity to stimuli), and erythema accompanied by pallor upon elevation of the limb (Buerger's sign), among others (3).

1.4. Diagnosis of peripheral arterial disease

Since PAD is asymptomatic in most cases, timely recognition of any signs and symptoms, diagnosis, and treatment are of great importance. Early intervention reduces the likelihood of adverse outcomes, such as amputation or death (4).

One of the primary diagnostic methods is physical examination, during which limb pallor or abnormalities in the arterial pulse may be detected as part of the basic vascular assessment. Physical examination can also be used to rule out the presence of abdominal or popliteal artery aneurysms (4).

An objective and quantitative assessment of the disease can be obtained using non-invasive diagnostic methods, such as measurement of the ankle-brachial index (ABI), segmental resting pressure measurements and measurements following an exercise test, colour Doppler ultrasound (DUS), computed tomography angiography (CTA), or magnetic resonance angiography (MRA) (4).

In addition to the aforementioned non-invasive methods, digital subtraction angiography (DSA) is considered the gold standard for vascular imaging. DSA is an invasive diagnostic method that provides an accurate assessment of the severity and anatomical location of PAD. It provides a detailed visualisation of vascular anatomy and is used for planning endovascular interventions and surgical procedures. During the examination, both the patient and medical staff are continuously exposed to ionising radiation. In addition, the use of iodinated contrast media may result in adverse effects, including nephrotoxicity, particularly in patients with renal artery or renal parenchymal disease. DSA provides excellent visualisation of stenoses, occlusions, atherosclerotic plaques, filling defects, dilated arteries, and other vascular abnormalities (4).

1.5. Endovascular treatment

Endovascular treatment is a therapeutic approach aimed at preserving or restoring the patency of a diseased or damaged blood vessel in order to re-establish distal perfusion, promote wound healing, and preserve the affected limb. The procedure is performed using catheters, most commonly without the need for conventional surgical incision. Instead of open surgery, the physician introduces a catheter through an artery, most commonly via the groin or wrist, and under fluoroscopic or angiographic guidance advances it to the site of the vascular lesion, where the therapeutic intervention can then be performed (5).

The main methods of endovascular treatment include percutaneous transluminal angioplasty (PTA) and stent placement, the primary purpose of which is to dilate occluded or stenotic blood vessels, most commonly as a result of atherosclerosis, using a balloon catheter and a stent. These techniques are most commonly used in the treatment of coronary and peripheral arterial disease (Figure 1) (5).

Other endovascular techniques include embolisation, which involves intentional occlusion of a blood vessel and is used in the treatment of bleeding or tumours; treatment of aneurysms using coils (coiling) or stent grafts;

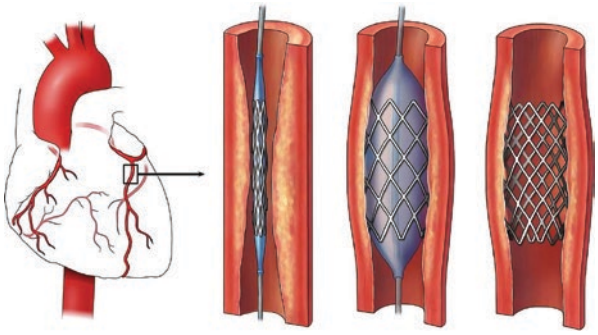


Figure 1. PTA and stent placement
Source: https://kardiocentar.com/wp-content/uploads/2019/04/stent-1-800.jpg

and thrombectomy, a procedure in which blood clots are mechanically removed, most commonly in the treatment of acute ischemic stroke (5).

Successful peripheral endovascular interventions require an angiography suite equipped with a C-arm with a large range of motion (Figure 2), as well as long guidewires. To obtain high-quality imaging, fluoroscopy, digital subtraction angiography (DSA), road mapping, and adequate image storage capacity are also used. In addition, continuous monitoring of the patient's vital signs is essential, as is careful selection of the vascular access site, arterial sheath, guidewire, catheter, stents, and any medications that may be required during the procedure (4).



Figure 2. C-arm for fluoroscopic imaging
Source: https://rgshealthcare.com/c-arm/

Endovascular procedures offer several advantages, including a lower risk of infection, shorter recovery time, avoidance of a large surgical incision, and the possibility of performing the procedure under local anaesthesia in many cases. However, certain complications may occur, although they are generally rare. These include bleeding at the catheter insertion site, vascular injury, allergic reactions to contrast media, embolisation, and vessel rupture (5).

1.6. Arteries of the lower leg

The main artery of the lower extremity is the femoral artery (*a. femoralis*), which continues directly as the popliteal artery (*a. poplitea*). The popliteal artery gives off branches supplying the knee joint and subsequently divides into two main branches: the anterior tibial artery (*a. tibialis anterior*) and the posterior tibial artery (*a. tibialis posterior*) (6).

The anterior tibial artery (*a. tibialis anterior*) passes through an opening in the superior part of the interosseous membrane and extends from the popliteal fossa between the muscles of the anterior compartment of the lower leg. After passing beneath the extensor retinaculum, it reaches the dorsum of the foot, where it continues as the dorsalis pedis artery (*a. dorsalis pedis*). This artery gives rise to two collateral branches: the arcuate artery (*a. arcuata*) and the deep plantar artery (*a. plantaris profunda*). The arcuate artery gives off branches to the intermetatarsal spaces and toes, while the deep plantar artery passes through the first intermetatarsal space and joins the plantar arterial circulation on the sole of the foot (6).

The posterior tibial artery (*a. tibialis posterior*) supplies the posterior and lateral muscle compartments of the lower leg. It passes between the muscles of the posterior compartment, travels posterior to the medial malleolus, and reaches the sole of the foot. It then divides into two branches that course along the plantar aspect of the foot. The proximal portion of the artery gives rise to the peroneal (fibular) artery (*a. peronea*, *a. fibularis*), which courses through the region of the muscles of the lateral compartment. The posterior tibial artery has two terminal branches: the medial plantar artery (*a. plantaris medialis*), which runs through the medial plantar groove, and the lateral plantar artery (*a. plantaris lateralis*), which gives off branches to the intermetatarsal spaces and toes (6).

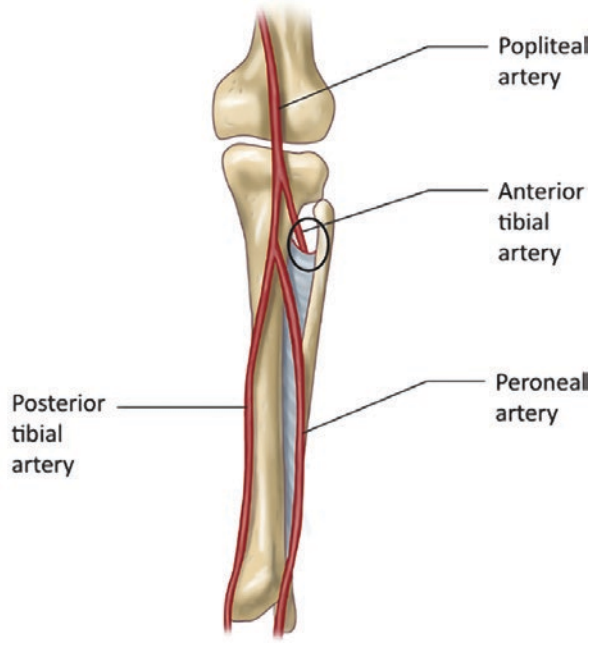


Figure 3. Main arteries of the lower leg
Source: https://www.cambridge.org/core/books/abs/atlas-of-surgical-techniques-in-trauma/lower-extremities/14A0823D78F69D00D097C7033253E678

Figure 3 illustrates the main arteries of the lower leg that are essential for supplying the angiosomes of the foot and ankle, namely the posterior tibial artery (*a. tibialis posterior*), anterior tibial artery (*a. tibialis anterior*), and peroneal (fibular) artery (*a. peronea* / *a. fibularis*).

1.7. Recanalization of the arteries of the lower leg

Adequate blood flow through the infrapopliteal arteries is essential for limb preservation. Although PTA has proven effective in the treatment of stenotic and occlusive disease of the iliac and femoral arteries, its application in atherosclerotic disease of the popliteal and tibial arteries is limited due to the technical complexity of the procedure and its limited effectiveness in patients classified as Rutherford stages III–VI, in whom surgical reconstruction or amputation has traditionally been considered the most common treatment option. In the presence of stenosis or occlusion, the primary objective is to restore vascular patency and re-establish blood flow in order to preserve the threatened limb. Figure 4 shows successful recanalisation of the anterior tibial artery. However, when multiple infrapopliteal lesions are present, the question is which artery to select as the target for intervention (4).

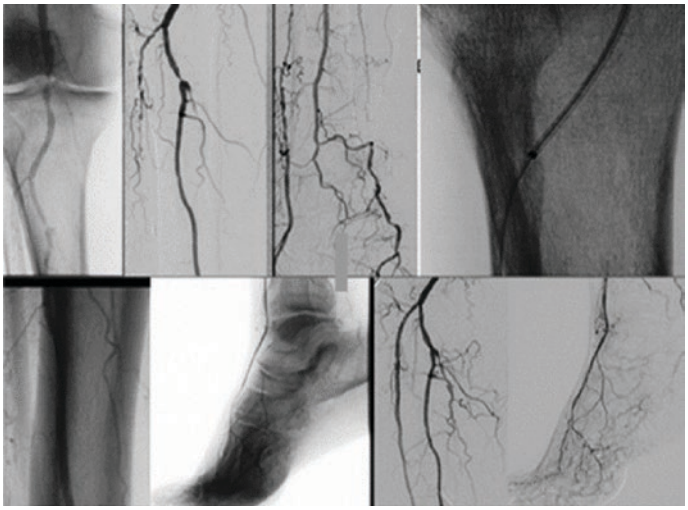


Figure 4. Recanalisation of the anterior tibial artery; stenosis before angioplasty, during the procedure, and the final result
Source: https://www.sciencedirect.com/science/article/pii/S2211568415000182

There are several approaches to arterial recanalisation, including:

- **angiosome-directed revascularisation**;
- ***easiest-first* strategy**;
- ***as many as possible* strategy**; and
- ***as far as possible* strategy** (7).

According to the angiosome concept, the foot and ankle are divided into six anatomical regions (angiosomes), each supplied by a source artery. Direct revascularisation targets the source artery supplying the angiosome in which the wound is located, with the aim of achieving improved and faster wound healing. If revascularisation through the source artery cannot be achieved, indirect revascularisation is performed through an alternative artery that can provide adequate perfusion of the foot via collateral vessels (7).

The ***easiest-first* strategy** involves recanalisation of the artery that is technically the most accessible, regardless of whether it is the artery that directly supplies the angiosome containing the wound. The aim of this approach is to restore adequate blood flow to the foot through the artery that can be crossed and treated most easily (7).

The ***as many as possible* strategy** involves recanalising as many infrapopliteal arteries as possible, regardless of lesion length or the angiosome to which the lesion corresponds, with the aim of maximising foot perfusion and increasing collateral circulation. Increasing the number of patent arteries may improve wound healing and increase the likelihood of limb salvage (7).

The ***as far as possible* strategy** aims to achieve recanalisation of the most distal areas of the foot, such as the dorsalis pedis artery, plantar arteries, or arteries of the pedal arch, in order to provide perfusion to distal wounds of the foot or toes (7).

Therefore, the goal of recanalisation is not merely to technically restore patency of the target artery, but to achieve effective distal perfusion. When selecting a recanalisation strategy, the anatomy and location of the lesion, wound location, status of distal blood flow and collateral circulation, as well as the patient's overall clinical condition, should be taken into consideration. The angiosome concept may assist in selecting the target artery, and direct revascularisation often results in better wound-healing outcomes; however, it may sometimes be technically challenging or not feasible (7).

1.8. Definition of the angiosome

The angiosome concept was introduced by Taylor and Palmer in their research in 1987. The concept is based on the idea that blood vessels form a continuous three-dimensional network that supplies the skin and underlying

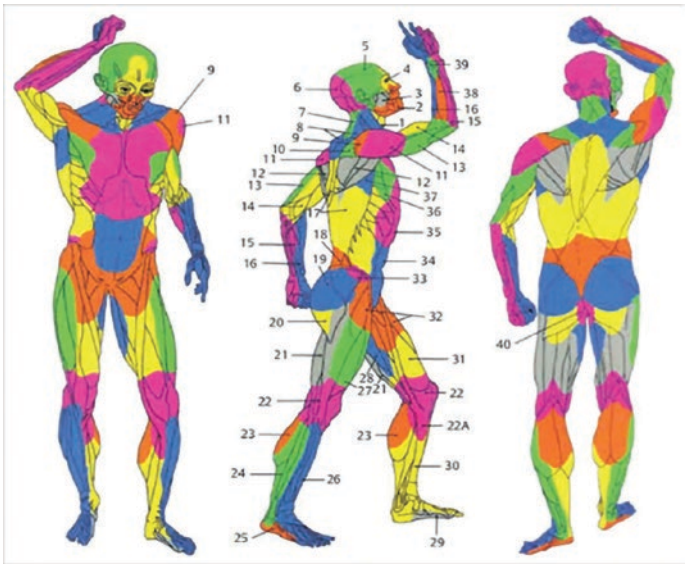


Figure 5. The 40 angiosomes of the human body
Source: https://www.researchgate.net/publication/366255248/figure/fig3/AS:11431281108032711@1671206870835/an-Taylors-vascular-territories-angiosomes-of-the-integument-of-the-skin-according-to.ppm

tissues. Each three-dimensional anatomical territory is supplied by a source artery that passes through the skin and subcutaneous tissue and extends into the deeper tissues. Based on this connection between the skin and deeper tissues through the source artery, the human body can be divided into 40 blocks, or vascular territories, i.e., segments known as angiosomes, which are illustrated in Figure 5 (8).

2. Aim of the study

The aim of this study is to explain the angiosome concept and to highlight its effectiveness in planning endovascular treatment of peripheral arterial disease affecting the arteries of the lower leg, with particular emphasis on the appropriate selection of the target artery through which foot perfusion can be restored and adverse outcomes prevented. This study is based on a narrative review of the available scientific and professional literature on peripheral arterial disease, endovascular treatment, and the angiosome concept. The analysis also includes relevant textbooks, scientific articles, and professional online sources identified through bibliographic databases, such as PubMed, as well as other medical sources.

3. Discussion

3.1. Organization of vascular territories

The human body is divided into 40 angiosomes. Each angiosome represents a three-dimensional anatomical territory or block consisting of several tissue layers, including the skin, subcutaneous tissue, fascia (the connective tissue layer surrounding muscles and internal organs), muscle, and bone. Each block is supplied by a source artery (8).

The internal vascular supply of an angiosome is provided by perforators, which are small blood vessels originating from deeper tissue layers, such as muscle or fascia, and extending toward the skin (8).

The vascular territories are not isolated from one another but are interconnected by so-called *choke vessels*, which may also be referred to as communicating vessels. Choke vessels are small blood vessels (arterioles) with a narrow lumen and limited blood flow that are constricted under normal physiological conditions but can dilate when required, such as in response to ischemia in a particular tissue territory. Their importance lies in providing collateral perfusion between adjacent territories, thereby enabling indirect tissue perfusion. Thus, these vessels allow blood flow between adjacent angiosomes when flow through the source artery is interrupted, for example, due to an obstruction. In addition to this indirect vascular supply, direct arterio-arterial connections also exist, allowing blood flow to bypass obstructions within the vascular network more immediately (8).

3.2. Application of the angiosome concept

The angiosome concept was initially introduced in the field of plastic and reconstructive surgery. The angiosome concept of reperfusion can be applied when planning surgical incisions and tissue dissection in a manner that preserves blood flow, thereby promoting wound healing and helping to predict which vascular territory can be successfully utilised and whether an amputation site is likely to heal. The angiosome concept may also assist in selecting the most appropriate revascularisation method, such as bypass grafting or endovascular therapy, that is more likely to result in successful healing of an existing ischemic ulcer (9).

3.3. Angiosomes of the foot and ankle

The foot and ankle region can be divided into six angiosomes, each of which is supplied by a specific artery of the lower leg. The foot and ankle represent the distal part of the lower extremity, where the major arteries have numerous additional arterial connections that provide alternative pathways for blood flow when flow through a major artery is compromised. Knowledge of the foot and ankle angiosomes and the interactions between their source arteries is clinically important in foot and ankle surgery, particularly in peripheral arterial disease (PAD) (10).

The six angiosomes of the foot and ankle originate from three major arteries: the posterior tibial artery (*a. tibialis posterior*), anterior tibial artery (*a. tibialis anterior*), and peroneal (fibular) artery (*a. peronea* / *a. fibularis*). Each of these arteries supplies a specific region of the foot and ankle. The posterior tibial artery supplies the medial ankle, plantar aspect of the foot, and medial aspect of the heel; the anterior tibial artery supplies the dorsal aspect of the foot; while the peroneal artery supplies the lateral ankle, the posterolateral aspect of the foot, and the lateral aspect of the heel (10).

Figure 6 illustrates the six angiosomes of the foot and ankle:

1. **Anterior communicating artery angiosome** (from the peroneal artery)
2. **Dorsalis pedis artery angiosome** (from the anterior tibial artery)



Figure 6. Angiosomes of the foot and ankle
Source: https://www.researchgate.net/figure/A-global-illustration-of-the-currently-described-foot-angiosomes-1-The-Anterior_fig1_331734135

3. **Lateral plantar artery angiosome** (from the posterior tibial artery)
4. **Lateral calcaneal artery angiosome** (from the peroneal artery)
5. **Medial calcaneal artery angiosome** (from the posterior tibial artery)
6. **Medial plantar artery angiosome** (from the posterior tibial artery) (11).

This division into vascular territories establishes a link between the location of a wound and the corresponding arterial blood supply to that region, which in turn forms the basis for planning revascularisation (10).

3.4. The angiosome concept in planning optimal revascularization

The primary goal of revascularisation is to achieve adequate distal perfusion rather than merely restoring patency of the target artery. The aim is therefore to restore arterial perfusion to the ischemic region, thereby ensuring sufficient blood flow to the distal parts of the limb and, consequently, improving tissue oxygenation and nutrient supply. Furthermore, optimal revascularisation promotes more effective healing of wounds and ulcers by facilitating faster tissue regeneration and, consequently, more rapid wound closure. The ultimate goal is to preserve the limb and its function in order to prevent adverse outcomes such as amputation or death. In addition to these favourable outcomes of successful revascularisation, alleviation of rest pain, sustained restoration of adequate distal perfusion, and improvement in the patient's quality of life are also important considerations (10).

To achieve these objectives, an appropriate target artery must be selected to provide optimal perfusion of the ischemic region, and the angiosome concept represents one approach that can be used for this purpose. Thus, restoring patency of any artery may not be sufficient, particularly in the presence of infrapopliteal lesions. The selection of the target artery may depend on the location of the wound, and the angiosome concept enables the anatomical region of the ischemic lesion to be linked to the artery that primarily supplies it (10). Figure 7 shows necrosis involving the right great toe, together with the corresponding angiosome and an angiogram of the foot circulation.

Although revascularisation techniques have advanced considerably, approximately 25% of patients with heel ulcers still undergo lower-limb amputation despite a palpable pulse in the foot (12). Such an adverse outcome may be associated with inadequate wound care or insufficient revascularisation of the local ischemic region, which may result from occlusion of vascular connections between the revascularised artery and the source artery supplying the ischemic area. This highlights the importance of successful revascularisation of an ischemic wound, which involves a more complex process than simply restoring blood flow through a particular artery (10).

Two main revascularisation strategies can be distinguished: surgical bypass grafting and endovascular therapy (EVT). Bypass surgery has been associated with greater risk due to a higher rate of mortality related to operative complications, such as wound infection, cardiovascular shock, early bypass graft occlusion, renal failure, and other complications. Approximately 15% of patients undergoing bypass surgery subsequently undergo amputation. The introduction of the angiosome concept has contributed to improved effectiveness of revascularisation procedures. Limb salvage rates following bypass surgery with direct revascularisation were reported to be 91%, compared with 62% following indirect revascularisation. On the other hand, EVT has proven to be an effective revascularisation method due to the development of various techniques, its low complication rate, and high limb salvage rate. Based on these findings, the effectiveness of applying the angiosome concept in the context of EVT has been investigated (9).

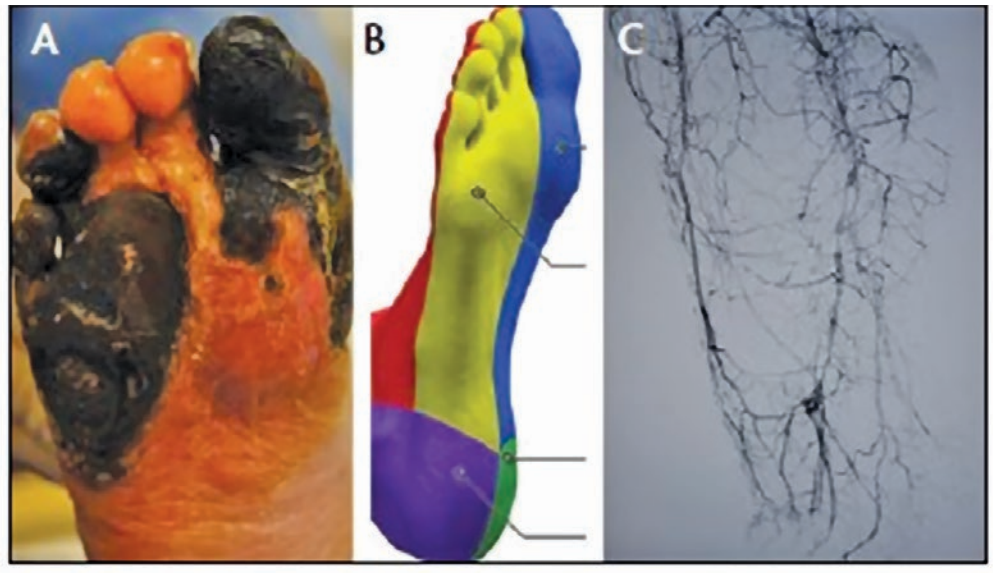


Figure 7. Necrosis of the great toe and visualization of the circulation of the corresponding angiosome. Tissue necrosis of the foot (A). Angiosome model of the foot (B). Arterial angiogram of the foot circulation (C).
Source: https://evtoday.com/articles/2014-may/angiosome-directed-therapy-for-the-cli-patient

3.4.1. Direct and indirect revascularization

Each wound corresponds to a specific angiosome supplied by a source artery (Figure 8). This artery is the primary target for revascularisation in order to achieve a favourable clinical outcome, namely healing of the corresponding wound and, ultimately, limb salvage. Therefore, the artery that directly supplies the angiosome affected by the wound should be revascularised endovascularly (direct revascularisation, DR). For heel wounds, the target arteries are the peroneal artery or the posterior tibial artery. For wounds involving the plantar aspect of the foot, the posterior tibial artery should be revascularised. In wounds located in the lateral ankle region, the peroneal artery should primarily be targeted. For wounds involving the dorsal aspect of the foot, the anterior tibial artery should be targeted. If revascularisation through the primary source artery cannot be achieved, revascularisation may instead be performed through another artery in order to establish perfusion via collateral connections (indirect revascularisation, IR) (10).

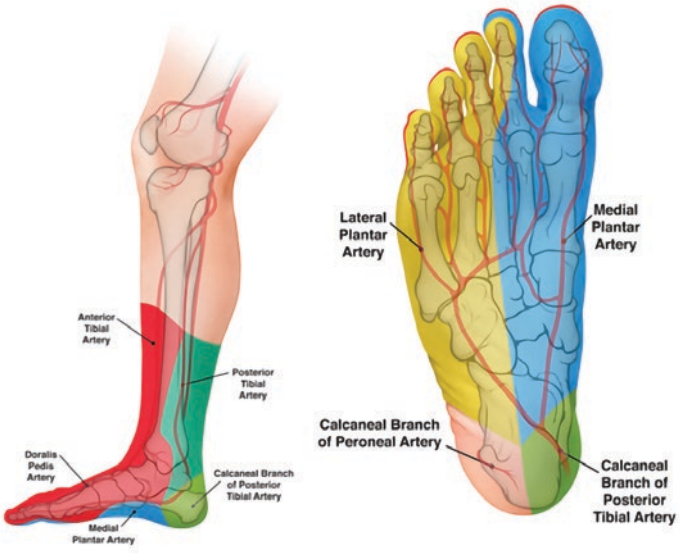


Figure 8. Angiosomes of the foot and ankle and their corresponding major source arteries
Source: https://diabeticfootonline.com/2013/08/26/does-direct-angiosome-revascularization-with-runoff-scoring-improve-outcomes/

EVT has proven useful in increasing blood volume and improving hemodynamics. During intervention, the angiosome-directed approach has demonstrated that DR can significantly improve perfusion of the ischemic region compared with perfusion achieved through collateral circulation alone. Compared with IR, angiosome-directed DR has been shown to be more effective in promoting wound healing and achieving adequate tissue perfusion (13). In particular, DR has been associated with a greater increase in tissue blood volume in the foot than IR, thereby improving local perfusion. Furthermore, TTP (*time to peak*), which represents the time required for the contrast agent to reach its peak concentration, has been shown to be significantly shorter following DR than IR. This indicates that blood reaches the distal parts of the limb, particularly the foot, more rapidly (14). Figure 9 demonstrates tissue

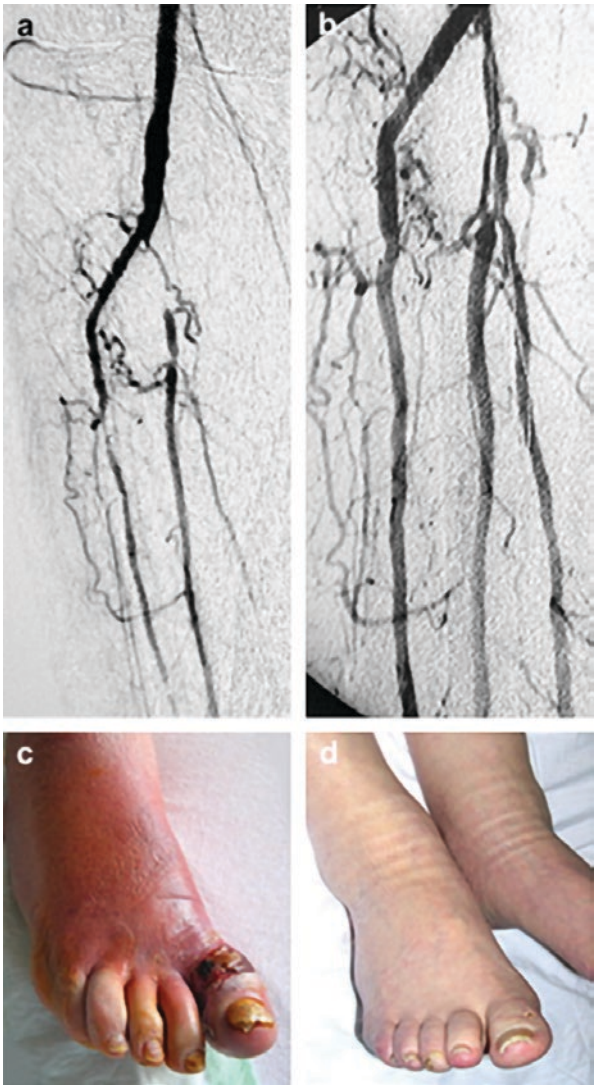


Figure 9. Clinical outcome of great toe revascularization after five months. Atherosclerotic arterial occlusion (A). Patent tibial arterial tree following revascularization (B). Right foot with great toe necrosis (C). Clinical outcome five months after revascularization (D).
Source: https://www.sciencedirect.com/science/article/pii/S1078588408006813

regeneration of the foot five months after revascularisation and the resulting limb salvage, while Figure 10 shows a healed heel ulcer five weeks after revascularisation.

3.5. Role of imaging in perfusion assessment during planning and after revascularization

Radiological imaging methods are used during the planning of revascularisation and endovascular procedures to assess tissue blood volume and blood flow velocity. Parenchymal blood volume (PBV) is a parameter determined following the administration of contrast media and subsequent CT imaging, which allows assessment of the amount of contrast agent present within the tissues of the foot. In this way, local tissue perfusion can be evaluated, providing information not only about arterial patency but also about the amount of blood reaching the foot. Another useful angiographic method is colour-coded quantitative digital subtraction angiography (CCQ-DSA), in which DSA

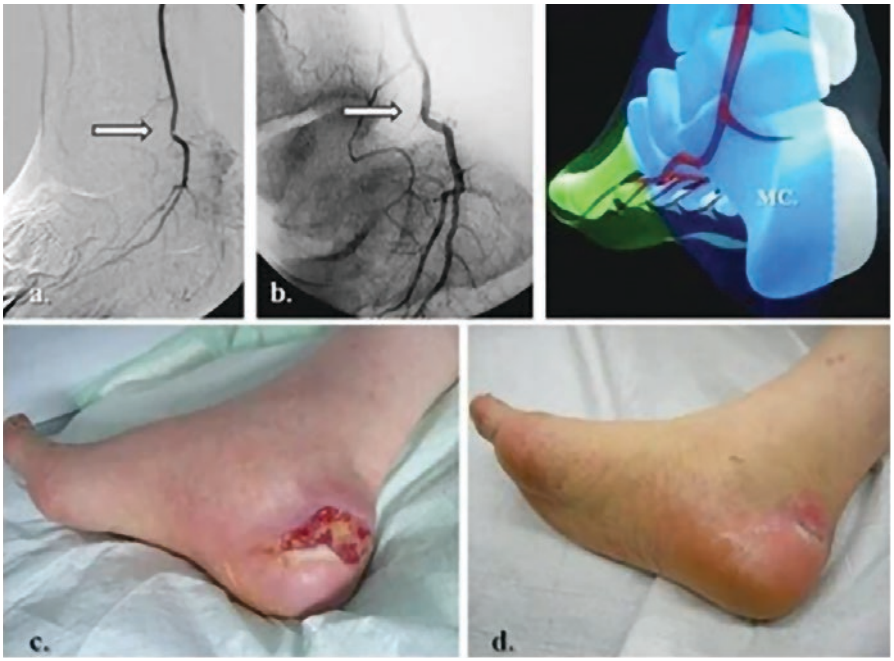


Figure 10. Revascularization of the posterior tibial and medial calcaneal artery angiosomes in a heel wound. Stenosis of the distal posterior tibial artery (A). Angiographic findings following selective angioplasty (B). Heel ulcer (C). Outcome five weeks after revascularization (D).
Source: https://www.researchgate.net/figure/Specific-posterior-tibial-and-adjacent-medial-calcaneal-artery-angiosome_fig8_51691463

is performed, and specialised software uses colour coding to visualise the passage of contrast through the blood vessels, thereby allowing assessment of flow dynamics. This method can be used to determine the time to peak (TTP) and assess how rapidly blood reaches the distal parts of the limb (14).

To demonstrate improvement in perfusion following revascularisation, various three-dimensional (3D) imaging methods have been used, including CT, MRI, and the hybrid imaging modality single-photon emission computed tomography/computed tomography (SPECT/CT). These methods enable assessment of blood volume within the foot and allow foot perfusion to be evaluated according to the angiosome concept. They have demonstrated greater effectiveness than two-dimensional (2D) assessment methods, such as Doppler flowmetry and tissue spectroscopy, which have not demonstrated substantial differences between direct and indirect revascularisation. The quantitative data obtained using these imaging methods may provide clinicians with an objective basis for developing more effective revascularisation strategies (14).

3.6. Limitations of the angiosome concept

Angiosomes vary among individual patients. In patients with PAD, blood vessels may be altered due to stenosis, occlusion, impaired blood flow, differences in the development of collateral circulation, and other vascular changes. Therefore, the main artery supplying an ischemic region is not necessarily the only or the optimal choice for revascularisation in every patient (9).

In a vascular-compromised foot, i.e., a foot with impaired circulation, the distribution of angiosomes may be altered, and blood flow may not necessarily follow the classical vascular pathways. The ischemic region may receive blood through alternative pathways and even from an adjacent angiosome via collateral arterial connections between the territories (9).

Given that the development of collateral circulation and the microcirculation may alter the actual blood supply to tissues, some researchers suggest that the classical angiosome concept may not be fully applicable in patients with PAD (14).

Therefore, in PAD, the normal pattern of perfusion may be altered due to the presence of vascular lesions or collateral circulation, resulting in changes to the angiosome map compared with that observed in normal anatomy (9).

4. Conclusion

Peripheral arterial disease affecting the arteries of the lower leg represents one of the major causes of chronic limb-threatening ischemia and may lead to serious adverse outcomes, such as ischemic ulceration, gangrene, and amputation. One of the fundamental treatment approaches is endovascular revascularisation, the success of which depends not only on technically successful performance of the procedure but also on achieving adequate perfusion of the ischemic region. The angiosome concept represents an approach to achieving adequate arterial perfusion of the ischemic region. By applying this concept, it is possible to identify the target artery supplying the angiosome affected by the wound. Endovascular revascularisation of the target artery may promote wound healing, increase the likelihood of limb preservation, and reduce the need for amputation. A substantial body of research indicates the potential benefits of direct revascularisation, which targets the main artery supplying the affected angiosome. However, collateral circulation, possible anatomical variations, and the technical complexity of the procedure must also be taken into consideration,

in which case indirect revascularisation may represent an alternative approach. Therefore, the angiosome concept represents an important approach to planning endovascular treatment of peripheral arterial disease affecting the arteries of the lower leg. By integrating clinical, anatomical, and radiological data, an individualised approach to each patient can be achieved, with the ultimate goals of limb preservation, prevention of adverse outcomes, and improvement of quality of life.

All data in this paper are part of the results of the undergraduate thesis „The Angiosome Concept in Endovascular Treatment of Peripheral Arterial Disease of the Lower Leg Arteries“ written at the University Department of Health Studies, University of Split (15).

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Koncept angiosoma u endovaskularnom liječenju periferne arterijske bolesti potkoljeničnih arterija

Sažetak

Cilj rada: Cilj ovoga rada je objasniti koncept angiosoma te ukazati na njegovu učinkovitost u planiranju endovaskularnog liječenja periferne arterijske bolesti potkoljeničnih arterija s naglaskom na pravilan odabir ciljne arterije uz pomoć koje će se obnoviti perfuzija stopala i time spriječiti neželjeni ishodi (amputacija, smrt). **Materijali i metode**: Rad se temelji na narativnom pregledu dostupne znanstvene i stručne literature o perifernoj arterijskoj bolesti, endovaskularnom liječenju i konceptu angiosoma. Također su u analizu uključeni i dostupni udžbenici, znanstveni radovi te stručni internetski izvori dostupni u bibliografskim bazama podataka (PubMed) i medicinskim izvorima. **Rezultati**: Analizom dostupne literature pokazalo se da je endovaskularna revaskularizacija jedno od učinkovitijih rješenja u liječenju periferne arterijske bolesti potkoljeničnih arterija te je izrazito značajna u primjeni kod bolesnika s kroničnom ishemijom ekstremiteta. Primjenom koncepta angiosoma može se poboljšati cijeljenje rana te time i očuvati ekstremitet ostvarenjem revaskularizacije arterije koja opskrbljuje određeni vaskularni segment. Angiosomski koncept ima i svoja ograničenja te se naglasak stavlja na individualnom pristupu svakom pacijentu. **Zaključak**: Angiosomski koncept jedno je od učinkovitijih rješenja za postizanje kvalitetne arterijske opskrbe ishemijskog područja kojim se rana određenog vaskularnog segmenta izravno povezuje s arterijom koja opskrbljuje navedeno područje te se primjenom endovaskularne revaskularizacije ostvaruju pozitivni ishodi poput cijeljenja rane, sprječavanja amputacija i smanjenja stope smrtnosti. Veliki broj istraživanja ukazuje na prednosti direktne revaskularizacije kojom se djeljuje na glavnu arteriju koja opskrbljuje angiosom, međutim, važno je uzeti u obzir i kolateralnu cirkulaciju, moguće anatomske varijacije i zahtjevnost tehničke izvedbe prilikom čega se kao drugo rješenje postavlja indirektna revaskularizacija uz naglasak na individualizirani pristup svakom pacijentu.

Ključne riječi: angiosom; ekstremitet; endovaskularna revaskularizacija; ishemija; periferna arterijska bolest

REVIEW PAPER, REVIEW ARTICLE (PREGLEDNI RAD)

The Role of Radiologic Technologist Empathy in Reducing Patient Anxiety Reactions and the Occurrence of Claustrophobia During MRI Examinations

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Abstract

Magnetic resonance imaging (MRI) is one of the most important diagnostic modalities in modern medicine, however for some patients it can be a psychologically demanding experience accompanied by anxiety and claustrophobic reactions. The aim of this study was to examine the association between an empathetic approach by radiologic technologists and the reduction of these reactions during MRI examinations, as well as to analyse the factors that shape patients' experience of the procedure. The study is based on a review and critical analysis of the available scientific and professional literature. The literature search was conducted in March 2026 using the PubMed and Scopus databases, while Google Scholar and ResearchGate were used to identify additional sources and access full-text articles. Of the 836 studies initially identified, 84 were included in the final analysis after removing duplicates and screening titles and abstracts, followed by full-text assessment. The reviewed studies indicate that anxiety during MRI examinations arises not only from the technical characteristics of the scanner but also from how patients understand and experience the procedure. A perceived loss of control, uncertainty, previous negative experiences, and limited communication during the examination were identified as particularly important factors. Clear communication, timely preparation, and an individualised, empathetic approach by radiologic technologists may enhance patients' sense of safety, improve cooperation, and alleviate anxiety. Such an approach does not replace technical expertise; rather, it complements it and contributes to a safer examination process and a more positive patient experience.

Keywords: anxiety; empathy; claustrophobia; magnetic resonance imaging; radiologic technologist

Introduction

In the radiologic technologist's daily practice, an MRI examination follows a precisely defined workflow, from safety screening and patient positioning to the acquisition of planned sequences and assessment of image quality. However, what is considered a routine and technically controlled procedure from a professional perspective may be an unfamiliar and psychologically demanding experience for the patient. Being inside the MRI scanner, exposure to intense noise, restricted movement, and the need to remain still for prolonged periods may contribute to feelings of insecurity and loss of control. In some patients, initial discomfort may develop into pronounced anxiety or a claustrophobic reaction, making it difficult or, in some cases, impossible to complete the examination. Furthermore, a patient's ability to tolerate the examination depends not only on the technical characteristics of the scanner but also on previous experiences, expectations, the reason for referral, and the patient's perception of their own ability to maintain control during the procedure (1 – 6). Anxiety does not necessarily arise only upon entering the MRI scanner. In some patients, it may already be present during the waiting or preparation period, particularly when they are concerned about the examination itself or its potential findings. Signs of anxiety are not always overt. Repeated questions, hesitant responses, tense posture, or sudden silence may indicate discomfort that can easily go unnoticed during a brief interaction. If such a reaction is not recognised in time, the patient may find it more difficult to maintain the required position, increasing the likelihood of artefacts, repeated sequences, or premature termination of the examination. An unpleasant experience may also affect the patient's willingness to undergo future imaging examinations (7 – 12). The role of the radiologic technologist therefore extends beyond

obtaining high-quality images to encompass how the patient experiences and tolerates the examination. A brief conversation before positioning provides an opportunity to assess what the patient knows about the examination, how they have tolerated previous imaging procedures, and whether there are any difficulties that may require adjustments to the preparation process (13 – 18). Clear and timely information can reduce uncertainty by helping patients understand what to expect during the examination, approximately how long it will take, and how they can communicate with the radiologic technologist. Effective communication therefore requires adapting the language, pace, and amount of information provided, particularly for patients with lower health literacy, language barriers, or specific communication needs (19 – 23). An empathetic approach in the MRI setting does not imply minimising the patient's fear or reassuring them that there is no reason to feel uncomfortable. Rather, its value lies in recognising how the patient experiences the procedure and adapting the approach to the patient's response while maintaining professional objectivity (24 – 27).

Aim of the study

The aim of this study was to examine the role of empathy, communication, and an individualised approach by radiologic technologists in alleviating anxiety and claustrophobic reactions during MRI examinations.

Participants and methods

This study was conducted as a review and critical analysis of scientific and professional literature on anxiety, claustrophobia, and patient experiences during MRI examinations, with particular emphasis on communication, empathy, and the professional approach of radiologic technologists. The literature search was conducted in March 2026 using the PubMed and Scopus electronic databases. PubMed was used as the primary database because it yielded a larger number of studies relevant to the topic, while Google Scholar and ResearchGate were used to identify additional literature and access full-text articles. Two predefined search strategies were applied in both databases. The first strategy included terms related to MRI examinations, anxiety, and patient support: MRI, Magnetic Resonance Imaging, claustrophobia, anxiety, communication, empathy, and patient support. The second strategy focused on radiologic technologists and their communication with patients: radiographer, radiologic technologist, communication, empathy, and patient interaction.

Studies published in English with full-text availability ("Open Access" or "Free Full Text") were included. No publication date restriction was applied in order to include all relevant studies related to the topic of this review.

Results

Using the "Open Access" filter and restricting the search to studies published in English, the first PubMed search strategy identified 434 studies. Following title screening, 289 studies were excluded, and a further 112 were excluded after abstract screening, resulting in 33 studies being included in the analysis. The second search strategy identified 221 studies. After removing 6 duplicates, 154 studies were excluded based on title screening and a further 31 following abstract screening, resulting in 30 studies being included in the analysis. The first Scopus search strategy identified 130 studies. After removing 16 duplicates, 93

Table 1. Factors Associated with Anxiety Levels During MRI Examinations

AUTHORS AND YEAR (REFERENCE NUMBER)	FACTOR	PSYCHOLOGICAL EFFECT	POTENTIAL CONSEQUENCE
Fakes, 2024. (7); Masalma et al., 2024. (8); Hudson et al., 2022. (11); Lawal et al., 2023. (12); Carlsson and Carlsson, 2013. (31); Evans et al., 2017. (42)	ENCLOSED SCANNER SPACE	DISCOMFORT AND A SENSE OF CONFINEMENT	CLAUSTROPHOBIC REACTIONS
Fakes, 2024. (7); Kang et al., 2024. (9); Lawal O. et al., 2023. (12); Glans et al., 2024. (51)	INTENSE NOISE	INCREASED TENSION	DIFFICULTY TOLERATING THE EXAMINATION
Masalma et al., 2024. (8); Kang et al., 2024. (9); Lawal et al., 2023. (12); Lei et al., 2025. (23); Carlsson and Carlsson, 2013. (31); Evans et al., 2017. (42)	PROLONGED IMMOBILITY	RESTLESSNESS AND FRUSTRATION	MOVEMENT DURING IMAGE ACQUISITION
Alghamdi, 2024. (3); Yakar and Pirinçci, 2020. (13); Hyde et al., 2018. (22); Lei et al., 2025. (23); Sosna, 2024. (55); Inhestern et al., 2024. (83)	INSUFFICIENT INFORMATION	UNCERTAINTY AND CONCERN	HIGHER LEVELS OF ANXIETY
Alamri, 2026. (4); Masalma et al., 2024. (8); Kamphuis et al., 2024. (24); Shah et al., 2025. (25); Carlsson and Carlsson, 2013. (31); Alsharif et al., 2026. (39)	UNCERTAINTY REGARDING THE RESULTS	PSYCHOLOGICAL DISTRESS	HEIGHTENED EMOTIONAL RESPONSE

Source: analysed studies.

Table 2. Methods for Reducing Anxiety During MRI Examinations

AUTHORS AND YEAR (REFERENCE NUMBER)	METHOD	MECHANISM OF ACTION	EFFECT
van Vuuren et al., 2021. (6); Hyde et al., 2018. (22); Santarém Semedo et al., 2020. (28); Carlsson and Carlsson, 2013. (31); Beardmore et al., 2024. (34); Newton-Hughes and Strudwick, 2023. (37)	CLEAR COMMUNICATION	EXPLANATION OF THE PROCEDURE	IMPROVED PATIENT COOPERATION
Alghamdi, 2024. (3); Yakar and Pirinçci, 2020. (13); Hyde et al., 2018. (22); Lei et al., 2025. (23); Sosna, 2024. (55); Inhestern et al., 2024. (83)	EDUCATIONAL PREPARATION	FAMILIARIZATION WITH THE EXAMINATION	REDUCED UNCERTAINTY
Oktay et al., 2025. (2); Castro et al., 2022. (16); Saron et al., 2023. (68); Festari et al., 2024. (70); Bonfitto et al., 2024. (80); Johnson et al., 2025. (82)	AUDIOVISUAL TECHNIQUES	DISTRACTION DURING IMAGE ACQUISITION	REDUCED STRESS
Oktay et al., 2025. (2); Stogiannos et al., 2022. (45); Stogiannos et al., 2023. (46); Festari et al., 2024. (70); Bonfitto et al., 2024. (80); Johnson et al., 2025. (82)	VIRTUAL REALITY	SIMULATION OF THE EXAMINATION	REDUCED FEAR
Castro et al., 2022. (16); Makanjee et al., 2021. (27); Carlsson and Carlsson, 2013. (31); Lawal et al., 2024. (32); Stogiannos et al., 2022. (45); Stogiannos et al., 2023. (46)	INDIVIDUALIZED APPROACH	ADAPTATION TO THE PATIENT	IMPROVED TOLERANCE OF THE EXAMINATION
Marshall et al., 2007. (15); Castro et al., 2022. (16); Stogiannos et al., 2022. (45); Stogiannos et al., 2023. (46); Oktay et al., 2025. (2); Johnson et al., 2025. (82)	SEDATION/ANESTHESIA	PHARMACOLOGICAL MANAGEMENT OF REACTIONS	FACILITATION OF EXAMINATION COMPLETION

Source: analysed studies.

studies were excluded based on title screening and a further 12 following abstract screening, resulting in 9 studies being included. The second search strategy identified 51 studies. After removing 9 duplicates, 24 studies were excluded based on title screening and a further 6 following abstract screening, resulting in 12 studies being included. Of the 836 studies identified overall, 31 duplicates were removed, 560 studies were excluded based on title screening, and a further 161 were excluded after abstract screening. A total of 84 scientific studies were included in the final analysis. Patient preparation and the manner of communication influenced how well patients tolerated the MRI examination. Clear information and a patient-centered approach were associated with lower levels of anxiety and better patient cooperation (Table 1).

Patients varied in their tolerance of the imaging conditions, ranging from mild discomfort to pronounced claustrophobic reactions and premature termination of the examination. Various preparation and support methods were used to alleviate these reactions, as shown in Table 2.

Discussion

The role of empathy during MRI examinations is difficult to separate from communication, patient preparation, and how radiologic technologists approach patients. In the available studies, these factors generally occur together, making it difficult to assess their individual effects on patient responses (28 – 36). The same applies to clinical practice, where patients experience the examination as a whole rather than as a series of individual procedures. Empathy is therefore more appropriately viewed as an integral part of the patient–technologist relationship than as a separate technique whose effects can be easily measured. Studies indicate that providing a greater amount of information does not, in itself, necessarily result in better patient preparation. What matters is when and how the information is provided, as well as how much a patient experiencing anxiety can understand and process (37 – 43). Standardized instructions provide essential information about the examination but cannot address the needs of every patient. Some patients may require additional explanation, whereas others may respond better to brief and clear instructions. These differences are even more pronounced among patients with sensory, cognitive, or communication-related needs (44 – 51). Comparison across studies is further complicated by differences in methods and timing of anxiety assessment, patient populations, and outcomes evaluated. The *STAI* and *MRI-DS* questionnaires do not measure exactly the same dimension of psychological distress (4, 9, 52 – 58), while the experience of MRI may also be influenced by uncertainty related to the expected diagnosis, a phenomenon described in the literature as *scanxiety* (24, 25). In addition to anxiety levels, studies commonly assess examination termination, patient cooperation, imaging artefacts, and image quality (59 – 64). Although these indicators

reflect the course and technical success of the examination, they do not necessarily capture how well the patient tolerated the experience. A patient may remain cooperative and complete the examination despite experiencing considerable distress, meaning that their psychological burden may go unrecognised (65 – 69). Consequently, a completed examination is not necessarily a well-tolerated examination. Non-pharmacological approaches may facilitate MRI examinations in such cases, but selection should depend on each patient's needs and responses. Studies describe various forms of patient preparation, audiovisual content, virtual reality, and other adaptations; however, their findings are not equally applicable across all clinical circumstances (70 – 75). In cases of severe claustrophobia, pain, or inability to maintain the required position, sedation or anaesthesia may still be appropriate options. Their use does not indicate that prior preparation or communication was unsuccessful; rather, it demonstrates the limitations of non-pharmacological approaches. Findings obtained under controlled conditions cannot always be directly translated into everyday clinical practice, where time constraints, staff availability, and opportunities for individualised patient preparation often determine what is realistically feasible (76 – 80). Simulation-based and communication training allow radiologic technologists to practice managing a range of situations, but cannot encompass every patient response they may encounter during MRI examinations (81 – 84). The technical and communicative aspects of the examination occur simultaneously; therefore, learned communication strategies cannot replace the assessment of each individual clinical situation. This review also has a limitation due to the broad scope of the included studies. Some studies directly address anxiety and claustrophobia during MRI examinations, whereas others examine the topic through communication, education, safety, artificial intelligence, and patient-centred care. Consequently, it is difficult to isolate the effects that can be specifically attributed to the empathetic approach of radiologic technologists. Future research should more precisely assess patient responses during individual stages of the MRI examination to better distinguish between factors that contribute to successful completion of the examination and those that help patients tolerate the experience more easily.

Conclusion

Patients experience MRI examinations differently, and therefore, anxiety and claustrophobic reactions cannot be attributed to a single cause or addressed with a single solution. Radiologic technologists should therefore be able to recognise when standard preparation is sufficient and when a patient requires a different approach. Technology may continue to advance, but the way patients experience the examination still depends on the person guiding them through it.

All data in this paper are part of the results of the master's thesis "The Role of Radiologic Technologist Empathy in Reducing Patient Anxiety Reactions and the Occurrence of Claustrophobia During MRI Examinations", written at the Faculty of Health Sciences, University of Split (85).

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Uloga empatije radiološkog tehnologa u ublažavanju pacijentovih anksioznih reakcija i pojave klaustrofobije tijekom MR pregleda

Sažetak

Magnetska rezonanca (MR) jedna je od najvažnijih dijagnostičkih metoda suvremene medicine, ali za dio pacijenata predstavlja psihološki zahtjevno iskustvo praćeno anksioznošću i klaustrofobičnim reakcijama. Cilj rada bio je prikazati povezanost empatijskog pristupa radiološkog tehnologa sa smanjenjem tih reakcija tijekom MR pregleda te analizirati čimbenike koji oblikuju pacijentov doživljaj postupka. Rad se temelji na preglednoj i kritičkoj analizi dostupne znanstvene i stručne literature. Pretraživanje je provedeno tijekom ožujka 2026. godine u bazama PubMed i Scopus, dok su Google Scholar i ResearchGate korišteni za pronalaženje dodatnih izvora i pristup cjelovitim tekstovima. Od ukupno 836 identificiranih radova, nakon uklanjanja duplikata, pregleda naslova i sažetaka te procjene cjelovitih tekstova, u konačnu su analizu uključena 84 rada. Studije pokazuju da anksioznost tijekom MR pregleda ne proizlazi samo iz tehničkih obilježja uređaja, nego i iz načina na koji pacijent razumije i doživljava postupak. Osjećaj gubitka kontrole, neizvjesnost, prethodna negativna iskustva i ograničena komunikacija tijekom snimanja izdvojeni su kao osobito važni čimbenici. Jasna komunikacija, pravodobna priprema i individualiziran empatijski pristup radiološkog tehnologa mogu povećati osjećaj sigurnosti, poboljšati suradljivost i ublažiti anksioznost. Takav pristup nikako ne zamjenjuje tehničku stručnost, nego je nadopunjuje i pridonosi sigurnijem provođenju pregleda i povoljnijem iskustvu pacijenta.

Ključne riječi: anksioznost; empatija; klaustrofobija; magnetska rezonanca; radiološki tehnolog

PREGLEDNI RAD (REVIEW PAPER, REVIEW ARTICLE)

130 godina od prvih rendgenskih eksperimenata na hrvatskom tlu: povijesno-analitička studija ranog razvoja radiologije u Hrvatskoj

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Sažetak

Uvod: Godine 1896. na hrvatskom je tlu zabilježena jedna od najranijih primjena novootkrivenih rendgenskih zraka, čime započinje 130-godišnji razvoj radiologije od eksperimentalne fizikalne metode prema samostalnoj kliničkoj, nastavnoj i znanstvenoj disciplini. Rani razvoj odvijao se policentrično, ponajprije u Rijeci, Zagrebu i Splitu.

Cilj: Prikazati ključne događaje ranog razvoja radiologije u Hrvatskoj, od prvih rendgenskih eksperimenata i medicinskih snimaka do razvoja stručne literature, edukacije i institucionalizacije profesije, uz analizu dosad nedovoljno korištene arhivske građe.

Materijali i metode: Provedeno je povijesno-analitičko istraživanje primarnih arhivskih izvora, suvremene medicinske i dnevne periodike, enciklopedijske i biografske građe, bolničkih monografija te relevantne historiografske literature. Istražena je građa Hrvatskog državnog arhiva i Državnog arhiva u Zagrebu te novopronađena građa Arhiva Jugoslavije u Beogradu. Pretraženi su fondovi Nacionalne i sveučilišne knjižnice, Središnje medicinske knjižnice i bolničkih knjižnica, publikacije Hrvatskog liječničkog zbora, *Liječnički vjesnik*, *Liječničke novine*, povijesna novinska građa te Hrvatska enciklopedija, Medicinska enciklopedija i Hrvatski biografski leksikon.

Rezultati: Recepcija Röntgenova otkrića u Hrvatskoj bila je vrlo brza: zagrebački *Obzor* o novim zrakama izvještava već 8. siječnja 1896. godine, a *Liječnički vjesnik* u veljači iste godine. Prof. Peter Salcher 20. veljače 1896. godine u Rijeci izvodi prve dokumentirane rendgenske pokuse na hrvatskom tlu, uključujući snimanje ruku barunice Josephine Vranyczany; izvorne snimke sačuvane su u fondu HR-HDA-782. Na njegov poticaj 1897. osnovan je Röntgen-komitet i nabavljen uređaj koji je 1899. predan Gradskoj bolnici sv. Duha, čime se nova tehnologija rano prenosi iz eksperimentalnog u bolničko okruženje. U Zagrebu prof. Vinko Dvořák 1897. godine pred Zborom liječnika Hrvatske demonstrira Röntgenove zrake i izrađuje među najranijim medicinskim rendgenskim snimkama, dok se rendgenska tehnologija početkom 20. stoljeća primjenjuje i u analizi krapinskih fosila te u radovima prof. Miroslava Čačkovića iz 1907. i 1913. godine.

Arhivska i historiografska građa dodatno dokumentira prijelaz od eksperimenta prema profesiji. Zorica Zec i Ela Vidić-Quinc školovane su u Holzknechtovu institutu kao prve hrvatske rendgenske asistentice, a dr. Srećko Hofman 1923. godine postaje prvi službeno zaposleni radiolog Bolnice sestara milosrdnica te 1924. preuzima novoosnovani Odjel za dijagnostičku i terapijsku radiologiju. Posebno vrijedna dokumentacija Hrvatskog državnog arhiva rekonstruira profesionalni put dr. Branka Bressana, prvog redovito educiranog hrvatskog radiologa, uključujući njegovo školovanje u Beču, profesionalno radijacijsko oštećenje s amputacijom ruke te izbor za pročelnika radiološke Sekcije Zbora liječnika 1936. godine.

Institucionalizacija se nastavlja osnutkom Katedre za rendgenologiju Medicinskog fakulteta u Zagrebu 1921. godine pod vodstvom Laze Popovića i Centralnog rentgenološkog instituta 1927. godine; Popović između 1923. i 1935. objavljuje četverosveščanu *Kliničku rentgenologiju*, a od 1937. uređuje *Radiološki glasnik*. Njegovi personalni spisi u Hrvatskom državnom arhivu dokumentiraju i profesionalnu bolest uzrokovanu rendgenskim zračenjem, zbog koje je 1939. zatražio umirovljenje. Novopronađena građa Arhiva Jugoslavije u Beogradu, osobito Popovićev *Prikaz postanka i razvitka Centralnog rentgenološkog instituta Medicinskog fakulteta u Zagrebu* i izvorni tlocrt Instituta, dodatno dokumentira plansko objedinjavanje dijagnostike, terapije, nastave i znanstvenog rada.

U Dalmaciji je rendgenski uređaj u sanatoriju dr. Jakše Račića u Splitu uveden već 1902.–1903. godine, a 1909. ondje djeluje zaseban „Rentgenov zavod“. Split je 1930. godine bio domaćin III. kongresa Sveslavenskog saveza za rendgenologiju i radiologiju i prvog sastanka Jugoslavenskog društva za rendgenologiju i radioterapiju, dok civilna bolnica vlastiti uređaj dobiva 1940. godine.

Zaključak: Rendgenska tehnologija u Hrvatskoj prihvaćena je vrlo brzo nakon Röntgenova otkrića, a njezin se razvoj odvijao policentrično, kroz međusobno povezane inicijative u Rijeci, Zagrebu i Dalmaciji. Prijelaz od fizikalnog eksperimenta prema samostalnoj medicinskoj disciplini ostvaren je povezivanjem kliničke primjene, sveučilišne nastave, specijalističke edukacije, profesionalnog organiziranja i javnozdravstvenih potreba. Nova arhivska građa dodatno nadopunjuje dosadašnju historiografiju, osobito dokumentiranjem profesionalnih sudbina ranih radiologa te prostornog i organizacijskog razvoja Centralnog rentgenološkog instituta u Zagrebu. Time se rani razvoj hrvatske radiologije pokazuje kao proces istodobne tehnološke, stručne i institucionalne modernizacije medicine.

Ključne riječi: radiologija; rendgenske zrake; povijest medicine; Hrvatska; arhivska građa; institucionalizacija radiologije

Uvod

Otkriće rendgenskih zraka Wilhelma Conrada Röntgena krajem 1895. godine iznimno se brzo iz fizikalnog eksperimenta pretvorilo u metodu s neposrednim medicinskim potencijalom. Već tijekom siječnja 1896. godine u srednjoeuropskim znanstvenim središtima izvođeni su pokusi usmjereni prema kliničkoj primjeni, među kojima se ističe rad Eduarda Hascheka i Otta Lindenthala u Beču (1–3). Vijest je gotovo istodobno stigla i u Hrvatsku: zagrebački *Obzor* o „senzacionalnom otkriću" izvještava 8. siječnja 1896. godine, a *Liječnički vjesnik* 15. veljače objavljuje članak „Röntgenovi traci", čime je hrvatska medicinska javnost o novoj metodi obaviještena svega nekoliko tjedana nakon njezina predstavljanja (4,5).

Prihvaćanje nove tehnologije u Hrvatskoj od početka nije bilo vezano uz samo jedno središte. U Rijeci je profesor fizike Peter Salcher 20. veljače 1896. godine javno demonstrirao rendgenske zrake i načinio prve dokumentirane rendgenske snimke na hrvatskom tlu, među kojima su sačuvane snimke ruku barunice Josephine Vranyczany. Već 1897. godine osnovan je odbor za nabavu rendgenskog uređaja, koji je 1899. godine premješten u riječku Gradsku bolnicu sv. Duha (6–8). U Zagrebu je Vinko Dvořák 1897. godine pred liječničkom i akademskom zajednicom predavao o „Röntgenovih zrakah" te izvodio rane medicinske rendgenske snimke, čime se nova tehnologija gotovo istodobno uključila u hrvatsku fizikalnu i medicinsku tradiciju (9,10).

Rani razvoj bio je izražen i u Dalmaciji. Prvi rendgenski uređaj u Splitu uveden je već 1902.–1903. godine u privatnom sanatoriju dr. Jakše Račića te je početkom 1904. bio u punom pogonu; 1909. godine Račić je u posebnom paviljonu otvorio „Rentgenov zavod" za rendgensku dijagnostiku, terapiju i elektroterapiju (11). Split je potom od 5. do 8. listopada 1930. godine bio domaćin III. kongresa Sveslavenskog saveza za rendgenologiju i radiologiju, uz prvi sastanak Jugoslavenskog društva za rendgenologiju i radioterapiju, što potvrđuje njegovu ranu ulogu ne samo u primjeni nego i u profesionalnom povezivanju radiološke profesije (11–13).

Prijelaz od pojedinačnih eksperimenata prema kliničkoj disciplini pratio je razvoj stručne literature. Miroslav pl. Čačković već 1907. godine objavljuje prikaze rijetkih rendgenskih nalaza, a 1913. sustavni rad o rendgenskoj pretrazi probavnih organa i lokalizaciji stranih tijela (18,19). Profesionalizacija se dodatno učvršćuje osnutkom Katedre za rendgenologiju Medicinskog fakulteta u Zagrebu 1921. godine, razvojem zasebnog Odjela za dijagnostičku i terapijsku radiologiju Bolnice sestara milosrdnica pod vodstvom Srećka Hofmana 1924., osnutkom Centralnog rendgenološkog instituta Medicinskog fakulteta 1927. pod vodstvom Laze Popovića te profesionalnim organiziranjem radiologa od 1928. godine (14–17).

Dosadašnji prikazi tih događaja raspršeni su među stručnim časopisima, enciklopedijama, bolničkim monografijama i pojedinačnim historiografskim radovima. Njihovo povezivanje s građom Hrvatskog državnog arhiva i Državnog arhiva u Zagrebu te novopronađenom građom Arhiva Jugoslavije u Beogradu omogućuje dopunu pojedinih biografskih i institucionalnih etapa ranog razvoja profesije.

Cilj ovog rada bio je, povodom 130 godina od prvih rendgenskih eksperimenata na hrvatskom tlu, rekonstruirati ključne etape razvoja radiologije u Hrvatskoj od prvih eksperimentalnih i medicinskih primjena do razvoja stručne literature, specijalističke edukacije i institucionalizacije u prvoj polovici 20. stoljeća, uz uključivanje dosad nedovoljno korištenih primarnih arhivskih izvora.

U skladu s ciljem rada postavljene su dvije radne hipoteze. Prva je da se rani razvoj radiologije u Hrvatskoj nije odvijao linearno iz jednoga središta, nego policentrično, kroz vremenski bliske inicijative u Rijeci, Zagrebu, Splitu i Osijeku te postupno povezivanje kliničke primjene, specijalističke edukacije, profesionalnog organiziranja i institucionalizacije radiologije. Druga hipoteza glasi da je prihvaćanje i rana primjena rendgenske tehnologije u Hrvatskoj vremenski slijedila vodeća europska središta

bez znatnijeg zaostajanja, dok je njezina bolnička i institucionalna primjena bila vremenski usporediva s drugim regionalnim središtima.

Materijali i metode

Provedeno je povijesno-analitičko istraživanje razvoja radiologije u Hrvatskoj, s težištem na razdoblju od Röntgenova otkrića 1895. godine do završetka Drugoga svjetskog rata i konsolidacije radiologije kao samostalne medicinske discipline. Kasniji izvori uključeni su kada su bili potrebni za praćenje kontinuiteta pojedinih ustanova, stručnih društava i razvojnih linija. Analiza je bila usmjerena na prve eksperimentalne i kliničke primjene rendgenskih zraka, razvoj radiološke literature i nastave, obrazovanje prvih stručnjaka, profesionalnu izloženost ionizirajućem zračenju te institucionalizaciju radiološke djelatnosti. Osnovni metodološki okvir preuzet je iz opsežnijeg povijesno-analitičkog istraživanja hrvatske radiologije, koje je povezivalo normativno-institucionalne izvore s nastavnom i kliničkom praksom.

Primarni izvori obuhvatili su građu Hrvatskog državnog arhiva u Zagrebu, Državnog arhiva u Zagrebu i Arhiva Jugoslavije u Beogradu. U Hrvatskom državnom arhivu analizirani su personalni i obiteljski fondovi povezani s ranim hrvatskim radiolozima i razvojem rendgenske dijagnostike, uključujući dokumentaciju dr. Branka Bressana, prof. Laze Popovića i obitelji Vranyczany-Dobrinović. Korištena je i građa Državnog arhiva u Zagrebu relevantna za razvoj zagrebačkih zdravstvenih ustanova. U Arhivu Jugoslavije pregledana je građa fonda Ministarstva prosvete Kraljevine Jugoslavije, AJ-66-417-676, koja se odnosi na Centralni rentgenološki institut Medicinskog fakulteta u Zagrebu, uključujući Popovićev *Prikaz postanka i razvitka Centralnog rentgenološkog instituta Medicinskog fakulteta u Zagrebu* te sačuvane planske nacrte Instituta.

Bibliografsko istraživanje obuhvatilo je fondove Nacionalne i sveučilišne knjižnice u Zagrebu, Središnje medicinske knjižnice Medicinskog fakulteta Sveučilišta u Zagrebu, knjižnica većih hrvatskih zdravstvenih ustanova, osobito Kliničkog bolničkog centra Split, te publikacije Hrvatskog liječničkog zbora i Hrvatske liječničke komore. Pretražena je digitalizirana i tiskana medicinska periodika, osobito *Liječnički vjesnik*, *Radiološki glasnik* i *Liječničke novine*, kao i povijesna dnevna periodika, uključujući *Obzor*, riječku *La Bilancia*, *Jadransku poštu*, *Slobodnu Dalmaciju*, *Večernji list* i *Jutarnji list*. Bibliografski i biografski podaci dodatno su provjeravani u Hrvatskoj enciklopediji, Hrvatskom biografskom leksikonu i Medicinskoj enciklopediji, kao i u bolničkim i sveučilišnim monografijama. Opsežnije istraživanje iz kojeg je izdvojen ovaj rad uključivalo je upravo ciljane pretrage nacionalnih i zdravstvenih knjižnica, novinskih arhiva, digitaliziranog *Liječničkog vjesnika* i bolničkih monografija.

Pretraživanje je provedeno kombinacijom pojmova „rendgen", „rentgen", „rendgenologija" i „radiologija", uz naknadne ciljane pretrage prema imenima liječnika, fizičara, ustanova i gradova identificiranih tijekom istraživanja. Za ključne kronološke tvrdnje prednost je dana suvremenim primarnim izvorima i arhivskoj dokumentaciji, dok su sekundarni historiografski i enciklopedijski izvori korišteni za kontekstualizaciju i provjeru podataka. Kada je bilo dostupno više izvora, podaci o datumima, osobama i institucionalnim promjenama međusobno su uspoređivani. Odabrani rani rendgenogrami i izvorni radiološki opisi analizirani su deskriptivno, a povijesna terminologija uspoređena je sa suvremenim radiološkim nazivljem.

Zbog provjere postavljenih hipoteza provedena je i komparativna kronološka analiza ranog razvoja radiologije. Uspoređeni su vrijeme i način prvih eksperimentalnih i kliničkih primjena rendgenskih zraka, uvođenje rendgenskih uređaja u zdravstvene ustanove te nastanak zasebnih radioloških službi i institucija u hrvatskim središtima, uz usporedbu s odabranim europskim i regionalnim centrima.

Rezultati

Rijeka 1896. – Peter Salcher i prvi dokumentirani rendgenski eksperimenti

Neposredno nakon Röntgenova otkrića nova je tehnologija stigla u Rijeku, tada snažno povezanu sa srednjoeuropskim znanstvenim prostorom. Profesor fizike Peter Salcher održao je 20. veljače 1896. godine u prostorijama riječkog Kluba za prirodne znanosti javno predavanje i demonstraciju rendgenskih zraka. O događaju je četiri dana poslije izvijestio riječki list *La Bilancia*, navodeći velik interes publike i prisutnost predstavnika gradske, liječničke i obrazovne zajednice **(Slika 1)**. U izvještaju se opisuje demonstracija prolaska zraka kroz različite predmete te prikaz kostiju i metalnih predmeta na fotografskim pločama, čime je riječkoj javnosti neposredno predstavljena medicinska vrijednost novootkrivene metode (6,7,20).

Tijekom Salcherovih pokusa načinjene su rendgenske snimke ruku barunice Josephine Vranyczany, rođene Mollinary von Monte Pastello. Snimke predstavljaju jedan od najranijih sačuvanih materijalnih dokaza primjene rendgenskih zraka na hrvatskom tlu, a izvorni primjerci sačuvani su u fondu obitelji Vranyczany-Dobrinović Hrvatskog državnog arhiva (6–8,21) (**Slika 2**). Salcherov je rad ubrzo



ANNO XXXIX. FIUME. Lunedì 24 Febbrajo 1896. N. 45.

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Club di scienze naturali. — Giorni fa il prof. Salcher tenne nella sala delle solennità della scuola com. maschile in via S. Andrea l'annunziata prelezione sui raggi di Röntgen.

La sala era piena zeppa di uditori. Notammo la presenza del signor podestà, di numerosi soci del Club colle rispettive famiglie, di allievi dell'i. e r. Accademia di marina, di professori regi e comunali, ecc.

Il prof. Dr P. Salcher incominciò la sua conferenza osservando, che l'importanza epocale dell'invenzione di Röntgen non sta già nel fotografare senza lente e senza luce, ma bensì nel fatto, che con essa si può fotografare l'interno dei corpi; e giacchè in questo caso la luce viene sostituita dall'elettricità, sarebbe più logico l'usare, invece della parola fotografia, le parole „elettrografia" oppure „röntgenografia".

Röntgen ha fatto in pari tempo una scoperta ed un'invenzione; poichè egli rinvenne elettricità ove finora non si sapeva che vi esistesse: egli scoperse i „raggi X". Avendo poi saputo approfittare in modo così importante della sua scoperta, fece una meravigliosa invenzione.

Dopo ciò il conferenziere passò agli esperimenti e precisamente in due maniere. Nella prima condusse la corrente di una batteria galvanica attraverso ad un rocchetto di Ruhmkorff e da questo ad un tubo di Hittorf (o Crookes).

Sotto a questo sul tavolo pose una cassetta fotografica contenente una piastra sensibile e pregò una delle signore di voler gentilmente prestarsi al già storico „esperimento della mano". La signora baronessa G. Vranyczany, vedendo che tutta indugiavano indecise, si dichiarò pronta a mettere la mano sulla cassetta. Nell'interno del tubo cominciò a risplendere una luce verde fosforescente, ed in tal modo ebbe principio l'elettrografia della mano. — Pel secondo esperimento l'elettricità venne presa da una macchina d'influenza e condotta ad un'egual tubo di Crookes; sotto a questo si trovavano delle monete ed accanto a queste una scatola di cartone il cui contenuto era ancora ignoto all'uditorio.

Mentre l'elettricità agiva sulle piastre nell'una e nell'altra maniera, il conferenziere prese a spiegare in modo più dettagliato l'oggetto della sua conferenza.

Dopo circa 15 min. il prof. Brattanich, dietro richiesta del conferenziere, prese le tre cassette onde sviluppare le piastre.

Riguardo all'importanza della Röntgenografia sulla scienza, il conferenziere osservò, che questa ha molto da sperare: progressi nella scoperta dell'„etere universale" soluzione di quel mistero che è la forza di gravità, del magnetismo terrestre ecc. (a ciò contribuiranno inoltre le osservazioni scientifiche al polo Nord e già in seguito a ciò il mondo scientifico attende con tensione il momento in cui questo verrà scoperto, il sogno di Nansen corre oggi di bocca in bocca).

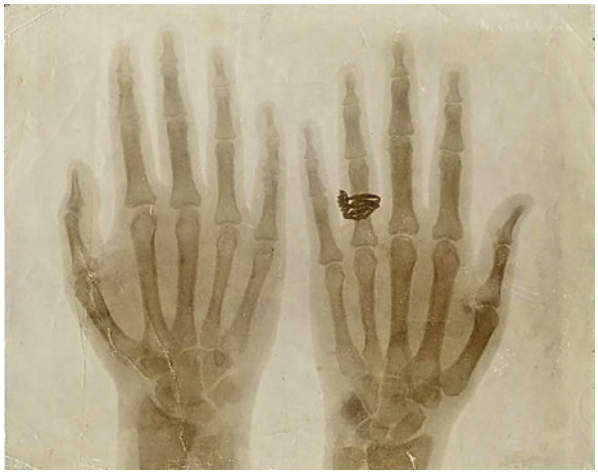
Verso la chiusa della conferenza comparve il prof. Brattanich colle piastre sviluppate. Su una di queste è visibile anche l'interno della mano coll'anello ad un dito. Sull'altra si vedevano le monete, quali cerchi bianchi, ed una striscia ovale nel mezzo della quale si leggeva „Röntgen" in inchiostro di bronzo.

Aperta la scatola, si scorse dentro una cornicietta di metallo ovale, colla scritta „Röntgen" in inchiostro di bronzo.

I raggi „X" avevano attraversato in tal modo il coperchio ed il fondo della scatola e la parete della cassetta fotografica coperta inoltre di tela.

Il distinto conferenziere, che tenne sempre viva l'attenzione del numeroso uditorio, fu applauditissimo e fatto segno ad ovazioni.

Slika 1. Naslovnica i izvještaj riječkog lista *La Bilancia* od 24. veljače 1896. godine o predavanju Petera Salchera i demonstraciji Röntgenovih zraka u Rijeci.
Izvor: La Bilancia, 24. veljače 1896., str. 2.



Slika 2. Rendgenske snimke ruku barunice Josephine Vranyczany nastale tijekom ranih riječkih rendgenskih eksperimenata 1896. godine.
Izvor: Hrvatski državni arhiv, fond HR-HDA-782, Obitelj Vranyczany-Dobrinović.

prerastao okvir javnog eksperimenta: 1897. godine osnovan je odbor za nabavu rendgenskog uređaja, a uređaj je 1899. godine predan riječkoj Gradskoj bolnici sv. Duha, čime se rendgenska tehnologija prenosi iz fizikalnog eksperimenta u organizirano bolničko okruženje (6,7).

Zagreb 1897. – prof. Vinko Dvořák i ulazak rendgenskih zraka u medicinsku praksu

Gotovo istodobno s riječkim pokusima nova se tehnologija pojavljuje i u Zagrebu. Profesor fizike Vinko Dvořák, tada jedna od središnjih osoba zagrebačke fizike, 1897. godine na izvanrednoj skupštini Zbora liječnika Hrvatske održao je predavanje „O Röntgenovih zrakah“ i javno demonstrirao njihovu primjenu (9,10,22). U historiografskim izvorima istom se razdoblju pripisuje i rendgensko snimanje ozlijeđene ruke nadvojvode Leopolda Salvatora, kao



Slika 3. RTG snimka šake prof. Dvořáka

jedna od najranijih dokumentiranih medicinskih primjena rendgenskih zraka u Zagrebu (10,22).

Sačuvana je i rendgenska snimka Dvořákove vlastite šake, reproducirana u ranom historiografskom prikazu razvoja hrvatske rendgenologije (**Slika 3**). Taj materijalni trag pokazuje da se rendgenska metoda u Zagrebu već tijekom prvih godina nakon Röntgenova otkrića nije zadržala samo na teorijskom interesu, nego je praktično primjenjivana u fizikalnom i medicinskom okruženju (9,10,22). Prema kasnijem sjećanju Stanka Hondla, jednostavan rendgenski uređaj postojao je i u zagrebačkoj Gornjogradskoj gimnaziji, gdje je prije 1900. godine profesor Stožir snimio deformirani palac vlastite šake, što dodatno potvrđuje rano širenje tehnologije izvan uskog bolničkog okvira (10,22).

Dalmacija – rana radiologija u Splitu i splitski sanatoriji

Radiološka tehnologija u Dalmaciji pojavila se vrlo rano i isprva izvan javnoga bolničkog sustava. U Splitu je prvi rendgenski uređaj nabavljen već 1902.–1903. godine za privatni sanatorij dr. Jakše Račića te je početkom 1904. godine bio u punom pogonu (11–13). Nakon proširenja djelatnosti Račić je 1909. godine u posebnom paviljonu otvorio „Rentgenov zavod prema najnovijim zahtjevima”, u kojem su se provodile rendgenske pretrage, rendgenska terapija i elektroterapija (11,12). U početku su snimani ekstremiteti i prsni koš, a poslije su uvedene i pretrage probavnog, hepatobilijarnog i uropoetskog sustava.

O tehničkoj razini Račićeva zavoda svjedoči i opis objavljen u dnevnom listu *Jug* 1911. godine, koji monografija splitske radiologije prenosi navodeći snažni induktor s iskrom duljine 60 cm te mogućnost „Röntgenografiranja cijelog prsnog koša u 1/10 sekunde” (11). Razvoj kliničke primjene potvrđuje i sačuvana rendgenska snimka žučnog mjehura na staklenoj ploči iz 1925. godine, koja dokumentira da je do sredine 1920-ih radiološka dijagnostika u Splitu već obuhvaćala i složenije pretrage hepatobilijarnog sustava (11) (Slika 4).

Račićev primjer ubrzo su slijedili i drugi privatni splitski sanatoriji. Godine 1929. u Kavanjinovoj ulici otvoren je sanatorij dr. Vladimira Roića, a 1933. godine na Poljani Grgura Ninskog sanatorij dr. Jakova Miličića; obje su ustanove raspolagale rendgenskim uređajima koji su služili za pregled hospitaliziranih i vanjskih bolesnika (11,12). Time je prije uvođenja rendgenskog uređaja u splitsku civilnu bolnicu 1940. godine već bila oblikovana razmjerno gusta mreža privatne radiološke djelatnosti u gradu (11,12).

Slavonija – rana primjena rendgenske dijagnostike u Osijeku

Razvoj radiologije u istočnoj Hrvatskoj nadovezao se na postojeću bolničku i liječničku infrastrukturu Osijeka, gdje je Zemaljska bolnica djelovala od 1874. godine, a Slavonsko liječničko društvo iste je godine uspostavilo jedan od najranijih organiziranih stručnih liječničkih okvira u Hrvatskoj. U dostupnoj literaturi početak rendgenske dijagnostike u osječkoj bolnici povezuje se s 1905. godinom i djelovanjem kirurga dr. Vatroslava Florschütza gdje je pouzdano je dokumentirano da je dr. Florschütz nakon zagrebačkog kirurškog usavršavanja kod glasovitog profesora Teodora Wickerhausera u Bolnici milosrdnih sestara od 1. travnja 1906. do 10. prosinca 1910. u Osijeku počet-



Slika 4. Rendgenska snimka žučnog mjehura na staklenoj ploči iz 1925.g.

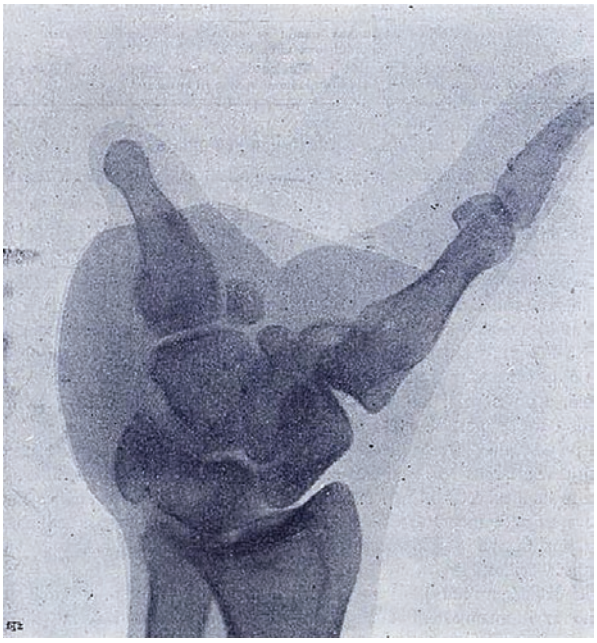
kom 1910-ih sustavno uključivao rendgensku dijagnostiku u svakodnevnu kirurško praksu te sudjelovao u nabavi i uporabi rendgenske opreme.

Rendgenske snimke koristio je u procjeni prijeloma i dokumentiranju traumatoloških i ortopedskih slučajeva, čime je nova metoda u Osijeku rano postala sastavnim dijelom kliničkog odlučivanja, a ne samo povremena tehnološka novost. Njegov rad iz 1911. o mehanici prijeloma pokazuje uporabu rendgenograma za usporedbu položaja koštanih ulomaka prije i nakon liječenja, dok je u kasnijim radovima naglašavao i vrijednost kontrastnih rendgenskih pretraga probavnog sustava. Nakon Prvoga svjetskog rata radiološka se djelatnost u Osijeku dodatno širila i izvan javne bolnice; privatni sanatorij Karla Weissmanna i Julija Batoryja raspolagao je vlastitim rendgenskim kabinetom.

Ovaj osječki primjer proširuje sliku ranoga razvoja hrvatske radiologije izvan Rijeke, Zagreba i Splita te dodatno pokazuje da se prihvaćanje rendgenske tehnologije odvijalo policentrično, uključujući i regionalna medicinska središta istočne Hrvatske.

Miroslav Čačković – od paleoradiologije do sustavne kliničke rendgenologije

Dr. Miroslav pl. Čačković pripada među prve hrvatske liječnike koji su rendgenske zrake sustavno uključivali u medicinsko istraživanje i kliničku dijagnostiku. Godine 1905. rendgenski je snimao skeletne ostatke krapinskih neandertalaca za Dragutina Gorjanovića-Krambergera, čime je rendgenska metoda u Hrvatskoj vrlo rano primijenjena i izvan neposredne kliničke medicine, u paleopatološkom i antropološkom istraživanju (22,23). Dvije godine poslije u *Liječničkom vjesniku* objavio je rad „Nekoliko rijedkih Röntgen-nalaza“, u kojem je prikazao tri klinička slučaja: kongenitalnu anomaliju šake, neobičan nalaz nakon prijeloma distalnog humerusa i višestruke prijelome metakarpalnih kostiju (18,22,23).



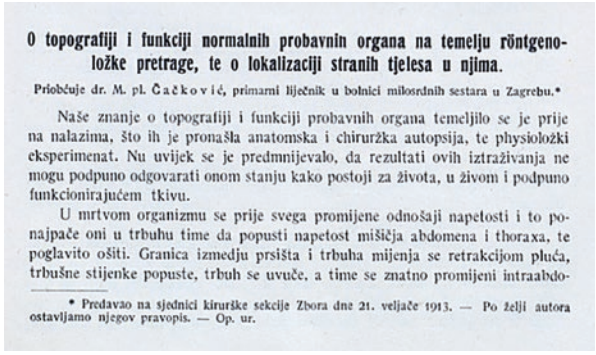
1. Anomalija desne ruke.

Jernej B., 62 god., primljen 10. listopada 1906. radi carcinoma želudca.

Nuzgredno se nalazi kod bolestnika anomalija desne ruke, na kojoj ima palac, koji je približno podpuno razvijen, jedino što ima samo jednu phalangu, a osim toga na ulnarnoj strani ruke jedan 3 cm. dugi prstoliki nastavak. Zapješće je manje nego na lijevoj ruci, te su mu svi promjeri smanjeni, ali najmanje dorsopalmarni.

Na Röntgen-slici (sl. 1.) vidimo, da palac ima samo jednu i to dugu phalangu, te vrlo dugi metacarpus (1 na sl. 2), koji na distalnom kraju ima samo jedan sesamoid, a proksimalni mu je kraj neobično formiran, imade oblik bisquita. Od drugog i trećeg prsta ne nalazimo ni traga, od četvrtog samo malu koščicu (4), koja po položaju odgovara četvrtom metacarpu, a od petoga samo metacarpus (5). Ovaj je metacarpus na svom dolnjem dijelu tako debeo, te bi se moglo pomišljati, da je to stopljeni četvrti i peti metacarpus, ali to nije, jer onda bi koščica 4 morala odgovarati trećem metacarpu, što nije moguće, jer treći metacarpus artikulira s os capitatum. Četvrti i peti metacarpus artikulira pako s os hamatum, kako to u našem slučaju i čine kosti 4 i 5.

U distalnom redu kosti zapješća nalazimo samo tri kosti, od kojih su normalno razviti i namješteni hamatum (8) i capitatum (7). Treća koščica (3) po svom položaju, artikulira bo s naviculare (6) i capitatumom (7), odgovara kosti multangulum minus. Prema tome nam u ovom redu manjka multangulum majus. Dolnji dio prve metacarpalne kosti bisquitu je naličar, uvučena sredina toga bisquita nalazi se u metacarpocarpalnoj crti, pa s toga imademo pravo uzeti, da je multangulum majus (2) stopljen s prvom metacarpalnom kosti (1). Ne može se uzeti, da bi bili stopljeni multangulum majus i naviculare (6), akoprem distalni dio naviculara siže daleko preko intercarpalne linije, jer taj distalni dio naviculara artikulira s multangulum minus (3) i proksimalnim dijelom prvoga metacarpa (2), za koji smo rekli, da je multangulum majus. Distalni dio naviculara artikulira pak normaliter s kostima multangulum majus i minus, dakle mora da je multangulum majus u našem slu-



O topografiji i funkciji normalnih probavnih organa na temelju röntgenološke pretrage, te o lokalizaciji stranih tjelesa u njima.

Priobćuje dr. M. pl. Čačković, primarni liječnik u bolnici milosrdnih sestara u Zagrebu.*

Naše znanje o topografiji i funkciji probavnih organa temeljilo se je prije na nalazima, što ih je pronašla anatomska i chirurška autopsija, te physiološki eksperimenat. Nu uvijek se je predmnijevalo, da rezultati ovih iztraživanja ne mogu podpuno odgovarati onom stanju kako postoji za života, u živom i podpuno funkcionirajućem tkivu.

U mrtvom organizmu se prije svega promijene odnošaji napetosti i to ponajpače oni u trbuhu time da popusti napetost mišićja abdomena i thoraxa, te poglavito ošiti. Granica izmedju prsišta i trbuha mijenja se retrakcijom pluća, trbušne stijenke popuste, trbuh se uvuče, a time se znatno promijeni intraabdo-

* Predavao na sjednici kirurške sekcije Zbora dne 21. veljače 1913. — Po želji autora ostavljamo njegov pravopis. — Op. ur.

Slika 5. Izvorni rendgenogram kongenitalne anomalije šake i pripadajući opis Miroslava Čačkovića iz rada *Nekoliko rijedkih Röntgen-nalaza*, objavljenog 1907. godine u *Liječničkom vjesniku*. Izvor: Čačković M. *Liječnički vjesnik*. 1907;29(10):269–275.

Posebno je vrijedan izvorni rendgenogram kongenitalno malformirane desne šake 62-godišnjeg bolesnika (**Slika 5**). Čačković opisuje odsutnost drugog i trećeg prsta, rudimentarni razvoj četvrtog i petog prsta te kompleksna srastanja karpalnih i metakarpalnih kostiju (18,22). Ponovnom interpretacijom sačuvanog rendgenograma suvremenom radiološkom terminologijom uočavaju se elongirana falanga i metakarpalna kost palca, ageneza drugog i trećeg prsta, hipoplazija pojedinih kostiju distalnog karpalnog reda te koštane fuzije, uključujući vjerojatno srastanje lunatuma i triquetruma. Takva ponovna analiza pokazuje da je anatomska preciznost Čačkovićeva izvornog opisa iz 1907. godine bila iznimna s obzirom na tadašnju tehničku razinu rendgenske dijagnostike (18).

Čačković je 1913. godine objavio i opsežniji rad „O topografiji i funkciji normalnih probavnih organa na temelju röntgenološke pretrage, te o lokalizaciji stranih tjelesa u njima“, u kojem se rendgenska metoda više ne pojavljuje samo kao prikaz pojedinačnih zanimljivih slučajeva, nego kao sustavan dijagnostički postupak za proučavanje anatomije, funkcije i lokalizacije patoloških ili stranih sadržaja (19,22). Niz njegovih radova između 1905. i 1913. godine stoga dokumentira prijelaz od eksperimentalne uporabe rendgenskih zraka prema njihovoj strukturiranoj primjeni u hrvatskoj kliničkoj medicini.

Branko Bressan – profesionalizacija radiologije i posljedice izloženosti zračenju

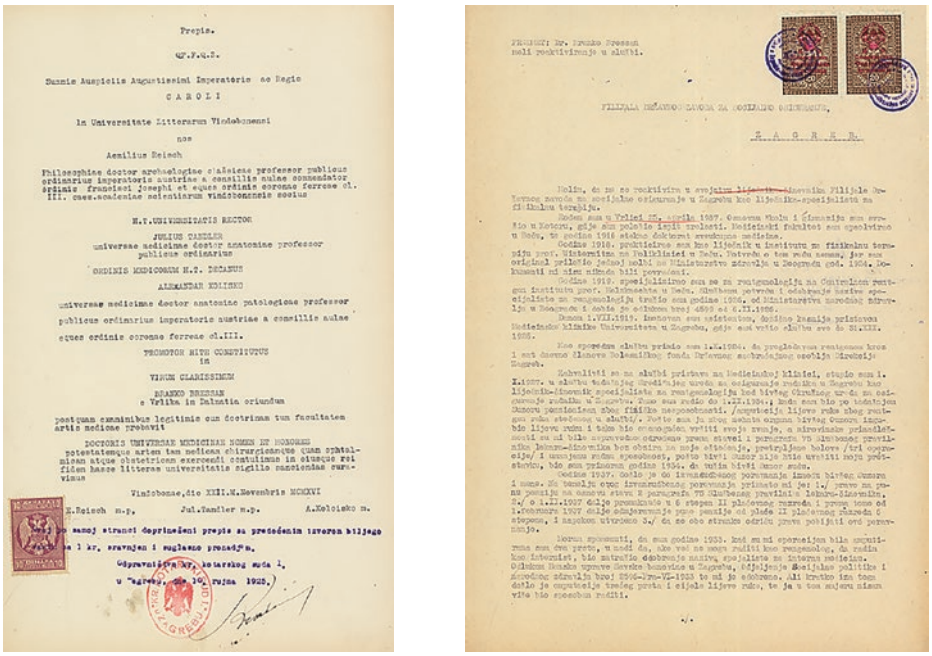
Profesionalni put Branka Bressana dokumentira prijelaz od radiologije kojom su se bavili liječnici drugih specijalnosti prema zasebno educiranom radiološkom kadru. Bressan je medicinu završio u Beču, a nakon dvogodišnjeg usavršavanja iz rendgenologije, povezanog s bečkom školom Guida Holzknechta, vratio se u Zagreb kao jedan od prvih sustavno educiranih hrvatskih radiologa (22,24). Vodio je rendgenski laboratorij Interne klinike Medicinskog fakulteta u Zagrebu dr. Karla Radoničića do 1926. godine, a potom djelovao na rendgenskom odjelu radničkog osiguranja – OUZOR-a (22,24).

Posebno vrijedan rezultat arhivskog istraživanja čini Bressanova osobna dokumentacija **(Slika 6 a i b)**. U sačuvanoj molbi Zavodu za socijalno osiguranje opisao je svoje medicinsko obrazovanje, specijalizaciju iz rendgenologije i profesionalno oštećenje nastalo nakon dugotrajne izloženosti rendgenskim zrakama. Posljedice su bile izrazito teške te mu je zbog radijacijskog oštećenja amputirana ruka i priznata invalidnost (24). Godine 1935. pokrenuo je i sudski spor protiv OUZOR-a zbog trajnih posljedica profesionalne izloženosti, čime njegov slučaj predstavlja rijedak dokumentirani spoj rane radiologije, profesionalne bolesti i pitanja institucionalne odgovornosti (24).

Unatoč trajnom invaliditetu, Bressan je ostao aktivan u organiziranju radiološke profesije. Na osnivačkoj skupštini Sekcije Zbora liječnika za radiologiju, fizikalnu terapiju i klimatobalneologiju 13. listopada 1936. godine jednoglasno je izabran za pročelnika Sekcije, a iste je godine izradio izvješće o stanju rendgenologije pri Okružnom uredu u Zagrebu (15,24). Njegov profesionalni put tako istodobno dokumentira dvije temeljne značajke ranog razdoblja hrvatske radiologije: razvoj specijalističkog identiteta i visoku cijenu rada u razdoblju prije standardizirane zaštite od ionizirajućeg zračenja.

Srećko Hofman – institucionalizacija bolničke radiologije

Srećko Hofman radiološko je obrazovanje stekao u Holzknechtovu institutu u Beču, jednom od vodećih europskih radioloških središta toga vremena. U Bolnici sestara milosrdnica zaposlen je 1923. godine kao prvi službeno zaposleni radiolog, a već 1924. preuzeo je vodstvo novoosnovanog Odjela za dijagnostičku i terapijsku radiologiju (13,25).



Slika 6. Dokumenti iz profesionalnog života Branka Bressana. a) preslika diplome stečena u Beču; b) osobna molba u kojoj iznosi specijalističko obrazovanje i okolnosti profesionalnog oštećenja povezanog s dugotrajnom izloženošću rendgenskom zračenju (HR-HDA 890, personalije dr. Branka Bressana)

Hofmanov dolazak nije predstavljao početak uporabe rendgenskih zraka u toj bolnici: prvi je uređaj nabavljen još 1901. godine, a njime su se služili kirurzi i drugi liječnici, među njima Kurt Hühn i Miroslav Čačković. Promjena iz 1923.–1924. godine bila je prije svega organizacijska i specijalistička – rendgenska dijagnostika i terapija dobile su vlastiti odjel i liječnika čije je primarno stručno područje bila radiologija (13,25). Dr. Hofman je u početku radio s jednom asistenticom, dr. Katarinom Divić, a poslije mu se pridružuju i drugi liječnici, među njima i prof. Ferdo Petrovčić (13).

Upravo se u toj transformaciji vidi prijelaz od ranog razdoblja, u kojem je rendgenski uređaj bio instrument kirurga ili internista, prema radiologiji kao zasebno organiziranoj bolničkoj djelatnosti. Arhivski personalni spisi dr. Srećka Hofmana u Hrvatskom državnom arhivu dodatno dokumentiraju njegov profesionalni položaj u tom razdoblju (25).

Laza Popović i institucionalizacija akademske radiologije

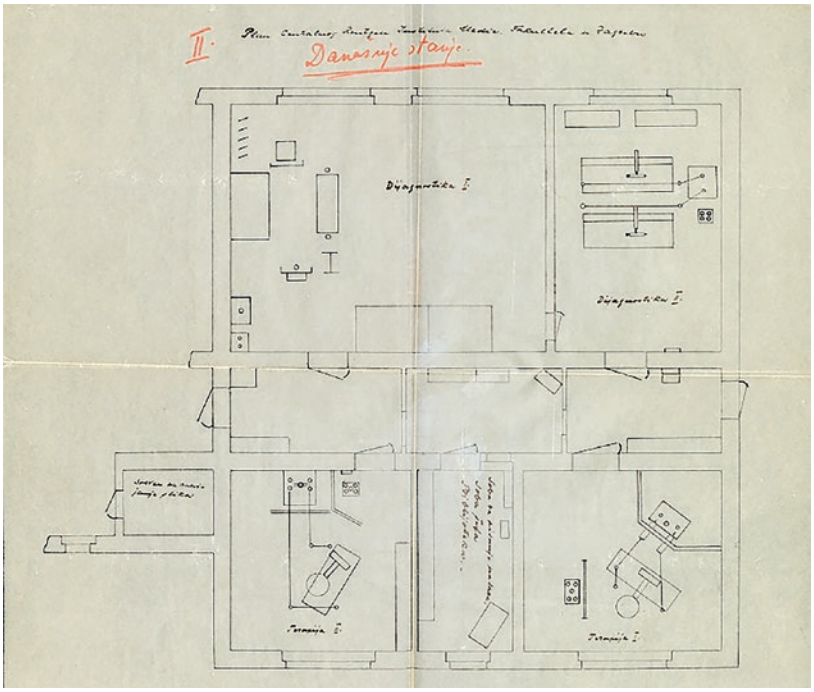
Razvoj akademske radiologije u Zagrebu početkom 1920-ih godina snažno je povezan s Lazom Popovićem koji je stasao kao asistent neurologa dr. Ivana Herzoga u Bolnici milosrdne braće na Jelačićevom trgu u Zagrebu. ondje je rendgenski uređaj nabavljen 1907. godine, a dr. Ivan Herzog je od 1909. radio na internom odjelu, a od 1912. vodio rendgenski laboratorij. S njim je od 1917. radio i prof. Lazar Popović.

Analizirajući povijesne izvore osnutak Katedre za rendgenologiju veže se za 1921. godinu, dok novopregledana personalna građa Hrvatskog državnog arhiva sadrži dekret od 11. kolovoza 1922. godine kojim je Popović imenovan izvanrednim profesorom radiologije i rendgenologije Medicinskog fakulteta Sveučilišta u Zagrebu (16,26). Ta razlika pokazuje da se proces akademskog utemeljenja radiologije odvijao tijekom 1921.–1922. godine, a Popović je 1931. izabran za redovitog profesora rendgenologije (17,26).

Ključni institucionalni korak uslijedio je 1927. godine osnutkom Centralnog rentgenološkog instituta Medicinskog fakulteta u Zagrebu u Draškovićevoj ulici. Institut je bio zamišljen za praktičnu nastavu radiologije te kliničku i znanstveno-istraživačku djelatnost za potrebe fakultetskih klinika, drugih zdravstvenih ustanova i vanjskih bolesnika. Imao je dvije dijagnostičke jedinice, od kojih je jedna bila opremljena i za dijaskopiju (16,17).

Nova građa pronađena u Arhivu Jugoslavije u Beogradu, u fondu Ministarstva prosvete Kraljevine Jugoslavije AJ-66-417-676, znatno proširuje dosadašnji prikaz Instituta. Građa sadrži Popovićev „Prikaz postanka i razvitka Centralnog rentgenološkog instituta Medicinskog fakulteta u Zagrebu“, četiri planska nacrta, fotografsku dokumentaciju i negative, korespondenciju Instituta s Medicinskim fakultetom, Rektoratom i drugim ustanovama te specifikaciju opreme (27). Sačuvani tlocrt, koji je izradio Popović, prikazuje prostorno odvajanje dijagnostičkih i terapijskih prostorija i potvrđuje da je Institut od početka koncipiran kao višefunkcionalna radiološka ustanova **(**Slika 7**)**.

Ista arhivska građa omogućuje i kvantitativan uvid u rast rada Instituta: dokumentirano je 4466 rendgenskih snimki tijekom 1927. godine, dok ih je 1934. godine učinjeno 9826 (27). Taj porast, zajedno s planskim razdvajanjem dijagnostičke i terapijske djelatnosti, pokazuje brzo povećavanje opsega radiološkog rada tijekom prvoga desetljeća djelovanja Instituta. Popovićev doprinos nije bio ograničen na organizaciju ustanove. Između 1923. i 1935. godine objavio je četverosveščanu Kliničku rentgenologiju, prvi hrvatski rendgenološki udžbenik, a od 1937. godine pokrenuo je i uređivao *Radiološki glasnik*, prvi južnoslavenski rendgenološki časopis, koji je u Zagrebu izlazio do broja 2 iz lipnja 1940. godine. Dvobroj 3–4 objav-



Slika 7. Tlocrt Centralnog rentgenološkog instituta Medicinskog fakulteta u Zagrebu koji je izradio prof. Laza Popović. Prikazane su odvojene prostorije za rendgensku dijagnostiku i terapiju.
Izvor: Arhiv Jugoslavije, Beograd, Ministarstvo prosvete Kraljevine Jugoslavije, AJ-66-417-676.

ljen je u Beogradu u prosincu 1940. godine pod nazivom „Jugoslavenski radiološki glasnik". U ožujku 1941. godine u Beogradu je pod istim nazivom objavljen broj 1. Arhivski izvori istodobno dokumentiraju i profesionalnu cijenu njegova rada. U molbi za umirovljenje od 27. studenoga 1939. godine Popović navodi profesionalnu bolest povezanu s dugotrajnom izloženošću rendgenskim zrakama. Priložena liječnička dokumentacija opisuje kronične promjene kože obiju ruku, osobito dorzalnih strana prstiju, te prethodno liječenje ulcerativnih promjena u praškom Radium institutu (26). Taj nalaz, zajedno s prethodno prikazanim slučajem dr. Branka Bressana, kao i dr. Katarine Divić, dokumentira profesionalni rizik kojemu je bila izložena prva generacija hrvatskih rendgenologa.

Od pojedinačnih pionira prema organiziranoj struci i javnozdravstvenoj radiologiji

Profesionalizacija rendgenologije nije obuhvaćala samo liječnike. Na Holzknechtovu institutu u Beču školovale su se Zorica Zec i Ela Vidić-Quinc, koje se u dostupnoj historiografiji navode kao prve hrvatske rendgenske asistentice, aktivne od 1920. godine (10). Time se već u početnoj fazi razvoja može pratiti nastanak stručnog tima u kojem su uz liječnika-rendgenologa djelovali posebno educirani suradnici, što je predstavljalo preduvjet za organizaciju sve složenijih dijagnostičkih i terapijskih postupaka.

Paralelno se razvijala i profesionalna organizacija radiologa. Godine 1928. osnovano je Društvo za rentgenologiju, čime su radiolozi prvi put dobili zaseban profesionalni organizacijski okvir. Tijekom sredine 1930-ih društvena se organizacija mijenjala i povezivala sa sekcijskim djelovanjem liječničkog zbora, a hrvatski su radiolozi sudjelovali i u širem jugoslavenskom i srednjoeuropskom stručnom povezivanju (15). Split je 1930. godine bio domaćin prvoga jugoslavenskog radiološkog sastanka u sklopu III. kongresa Sveslavenskog saveza, a drugi radiološki sastanak održan je 1935. godine u Beogradu uz sudjelovanje Laze Popovića, Milana Smokvine i drugih zagrebačkih radiologa (15).

Krajem promatranog razdoblja radiologija prelazi i granice individualne dijagnostike te postaje sredstvo masovnog javnozdravstvenog probira. Nakon što je rad na fluorografskom probiru započet prije Drugoga svjetskog rata, u akademskoj godini 1945./1946. provedena su 7163 fluorografska pregleda, ponajprije usmjerena prema ranom otkrivanju plućne tuberkuloze (30). Tehnički je postupak omogućavao serijsko snimanje velikog broja ispitanika na filmu maloga formata, uz organizaciju prilagođenu brzom protoku pregledavanih osoba. U analiziranoj populaciji neki stadij tuberkuloznog procesa pronađen je u približno jednog od deset pregledanih studenata, što pokazuje javnozdravstveni značaj rendgenske tehnologije neposredno nakon Drugoga svjetskog rata (30).

Na taj se način u približno pola stoljeća može pratiti jasan razvojni slijed: od pojedinačnih fizikalnih pokusa i prvih rendgenograma, preko specijalističke edukacije i osnivanja bolničkih i sveučilišnih radioloških jedinica, do organizirane profesije, stručnog radiološkog tima i populacijske primjene rendgenske dijagnostike.

Komparativna analiza i provjera radnih hipoteza

Analizirani izvori potvrdili su policentričan obrazac ranoga razvoja radiologije u Hrvatskoj. Rani eksperimenti i kliničke primjene dokumentirani su u Rijeci i Zagrebu već tijekom prvih godina nakon Röntgenova otkrića, dok su se početkom 20. stoljeća neovisne razvojne linije oblikovale i u Splitu te Osijeku. Usporedna kronologija pokazuje i da je prihvaćanje rendgenske tehnologije u Hrvatskoj vremenski slijedilo vodeća europska središta, dok je njezina bolnička i institucionalna primjena bila vremenski usporediva s drugim regionalnim centrima: Sarajevo je prvi aparat imalo 1899., Ljubljana 1900., a u Zagrebu je bolnički rendgenski uređaj dokumentiran 1901. godine. Tijekom 1920-ih slijedi i usporediv proces institucionalizacije, s osnivanjem zasebnih radioloških ustanova u Ljubljani 1923., Sarajevu 1925./1926. i Zagrebu 1927. godine. Time su nalazi poduprli obje postavljene radne hipoteze.

Rasprava

Rezultati ovog istraživanja podupiru obje postavljene radne hipoteze. Prvo, radiologija se u Hrvatskoj nije razvijala linearno iz jednoga središta, nego policentrično i gotovo istodobno kroz fiziku, kliničku medicinu i privatnu liječničku inicijativu. Riječki pokusi prof. Petera Salchera 1896. godine predstavljaju neposredan prijenos Röntgenova otkrića u lokalnu znanstvenu sredinu, dok zagrebački rad prof. Vinka Dvořáka već sljedeće godine pokazuje ulazak nove metode u akademski i liječnički prostor (6–10,22). U Splitu se razvoj odvijao izrazito rano kroz privatni sanatorij dr. Jakše Račića, a osječki primjer početkom 20. stoljeća dodatno pokazuje da se prihvaćanje rendgenske tehnologije širilo i prema regionalnim medicinskim središtima izvan Zagreba i jadranskoga prostora. Takav razvoj potvrđuje da širenje rendgenske tehnologije nije ovisilo isključivo o institucionalnoj snazi velikih bolnica, nego i o pojedincima sposobnima brzo prenijeti novu tehnologiju u lokalnu praksu.

Druga radna hipoteza također je poduprta komparativnom kronologijom. Brzina prihvaćanja rendgenskih zraka bila je usporediva s tadašnjim srednjoeuropskim znanstvenim prostorom, dok se bolnička i institucionalna primjena u Hrvatskoj razvijala u vremenski bliskom okviru s drugim regionalnim središtima. Takva vremenska podudarnost pokazuje da hrvatski prostor u ranom prihvaćanju nove tehnologije nije bio izdvojen iz šire srednjoeuropske i regionalne mreže prijenosa znanja i medicinske tehnologije. Rani hrvatski primjeri nastaju u neposrednom intelektualnom krugu Beča, Graza i drugih središta, u kojima su djelovali profesori Haschek, Lindenthal i poslije Holzknecht (1–3). Upravo je bečka radiološka škola imala posebno snažan utjecaj na profesionalizaciju hrvatske radiologije: ondje su se obrazovali dr. Branko Bressan i dr. Srećko Hofman, a s Holzknechtovim institutom bio je povezan i prof. Laza Popović. Time se razvoj profesije može pratiti kao prijenos znanja iz srednjoeuropskih centara prema hrvatskim bolnicama i Medicinskom fakultetu, nakon čega se postupno formira domaći sustav edukacije i stručnog napredovanja. Edukacijska uloga bečkog radiološkog kruga potvrđena je i u širem povijesnom prikazu razvoja hrvatske radiologije.

Posebnu vrijednost imaju rani radovi dr. Miroslava Čačkovića jer pokazuju da rendgenska metoda vrlo brzo prestaje biti samo tehnološka zanimljivost. Njegovi radovi iz 1907. i 1913. godine dokumentiraju prijelaz od prikaza pojedinačnih rijetkih nalaza prema sustavnoj primjeni rendgenske dijagnostike u kliničkoj medicini (18,19). Ponovna analiza izvornog rendgenograma kongenitalne anomalije

šake pokazuje da je anatomski opis bio iznimno precizan i prema današnjim kriterijima, premda je nastao u razdoblju ograničene tehničke kvalitete slike. Time povijesni rendgenogrami nisu samo ilustracija razvoja tehnologije, nego i izvor koji omogućuje usporedbu ranoga i suvremenog radiološkog mišljenja.

Drugu razvojnu liniju predstavlja profesionalizacija radiologa kao zasebnoga liječničkog zanimanja. Bressanova specijalistička edukacija, Hofmanovo preuzimanje zasebnoga bolničkog radiološkog odjela te osnutak akademske katedre i Centralnog rentgenološkog instituta pokazuju da se tijekom 1920-ih godina rendgenologija odvaja od kirurgije i interne medicine i dobiva vlastitu organizacijsku strukturu (14–17,25–27). Formalno organiziranje radiologa od 1928. godine dodatno potvrđuje taj proces (14). Šimunić i suradnici pokazuju kontinuitet profesionalnog organiziranja od Društva za rentgenologiju prema kasnijim radiološkim sekcijama i društvima, čime se hrvatska radiologija uključila i u šire jugoslavenske profesionalne strukture (14).

Najvažniji novi historiografski doprinos ovog istraživanja proizlazi iz povezivanja dosad razdvojene građe Hrvatskog državnog arhiva s dokumentacijom Arhiva Jugoslavije u Beogradu. Popovićev *Prikaz postanka i razvitka Centralnog rentgenološkog instituta Medicinskog fakulteta u Zagrebu*, planski nacrti Instituta, korespondencija i podatci o opsegu rada omogućuju precizniju rekonstrukciju ranoga institucionalnog razvoja nego što je bilo moguće samo na temelju kasnijih monografija i enciklopedijskih prikaza (26,27). Posebno je značajan porast broja snimanja s 4466 u 1927. na 9826 u 1934. godini, jer pokazuje da Centralni institut nije predstavljao samo nastavnu instituciju, nego ustanovu s brzo rastućim kliničkim opsegom rada. Sačuvani tlocrt dodatno dokumentira plansko odvajanje dijagnostičkih i terapijskih funkcija, što svjedoči o relativno visokom stupnju organizacije radiološke djelatnosti već u međuratnom razdoblju.

Profesionalni razvoj bio je praćen i ozbiljnim zdravstvenim posljedicama za prve generacije radiologa. Bressanova amputacija nakon dugotrajne profesionalne izloženosti i Popovićeve kronične ulcerativne promjene kože dokumentirane u liječničkoj svjedodžbi iz 1939. godine pokazuju da su se granice sigurnoga rada uspostavljale tek nakon stvarnih profesionalnih oštećenja (24,26). Popovićev suvremenik i učitelj Guido Holzknecht također je pretrpio teška radijacijska oštećenja, što potvrđuje da hrvatski slučajevi nisu bili izolirani, nego dio širega problema rane europske radiologije. U tom kontekstu razvoj radiologije predstavlja istodobno povijest tehnološkog napretka i postupnog razumijevanja bioloških posljedica ionizirajućeg zračenja.

Do sredine 20. stoljeća rendgenska se tehnologija proširila i izvan individualne kliničke dijagnostike. Fluorografski pregledi provedeni 1945./1946. godine, kada su pregledane 7163 osobe, pokazuju primjenu radiologije kao javnozdravstvenog instrumenta u borbi protiv tuberkuloze (30). Time se razvojni luk od Salcherova pojedinačnog eksperimenta iz 1896. godine do masovnog probira neposredno nakon Drugoga svjetskog rata zatvara u svega približno pola stoljeća.

Promatrani zajedno, nalazi upućuju na to da se rana hrvatska radiologija razvijala kroz tri međusobno povezana procesa: brzi prijenos nove tehnologije iz srednjoeuropskog znanstvenog prostora, profesionalizaciju radiološkog kadra i postupnu institucionalizaciju radiologije unutar bolnica, sveučilišne nastave i stručnih društava.

Ograničenja istraživanja

Sačuvanost arhivske građe nije jednaka za sve ustanove i pojedince, zbog čega se intenzitet radiološke djelatnosti pojedinih centara ne može izravno uspoređivati. Dio kronoloških podataka u sekundarnim izvorima međusobno se razlikuje, kao što pokazuje primjer akademskog imenovanja prof. Laze Popovića i početka rada pojedinih ustanova. U takvim je slučajevima prednost dana suvremenim primarnim dokumentima, dok su nesuglasja sa sekundarnom literaturom posebno naznačena. Nadalje, rad nije zamišljen kao iscrpan popis svih rendgenskih uređaja, liječnika i bolničkih odjela u Hrvatskoj, nego kao rekonstrukcija ključnih razvojnih procesa i institucija na temelju dostupnih primarnih i reprezentativnih sekundarnih izvora sa naglaskom na početke hrvatske radiologije.

Zaključak

Razvoj radiologije u Hrvatskoj započeo je gotovo neposredno nakon Röntgenova otkrića i tijekom prve polovice 20. stoljeća prerastao iz pojedinačnih fizikalnih eksperimenata u organiziranu medicinsku disciplinu. Rani pokusi Petera Salchera u Rijeci, djelovanje Vinka Dvořáka u Zagrebu i rana primjena rendgenske tehnologije u sanatoriju Jakše Račića u Splitu pokazuju da su počeci bili policentrični i snažno povezani sa srednjoeuropskim znanstvenim prostorom. Klinički radovi Miroslava Čačkovića, specijalističko obrazovanje Branka Bressana i Srećka Hofmana te akademsko i institucionalno djelovanje Laze Popovića dokumentiraju postupni prijelaz od uporabe rendgenskih zraka kao pomoćne metode prema radiologiji kao zasebnoj liječničkoj struci.

Analiza primarne arhivske građe dodatno je omogućila precizniju rekonstrukciju tog procesa. Osobni dokumenti ranih radiologa svjedoče o profesionalnim rizicima vremena u kojem zaštita od ionizirajućeg zračenja još nije bila standardizirana, dok novopregledana dokumentacija Centralnog rentgenološkog instituta Medicinskog fakulteta u Zagrebu pokazuje rast kliničkog opsega rada i plansku organizaciju akademske radiologije već tijekom međuratnog razdoblja. Do završetka promatranog razdoblja radiologija je u Hrvatskoj imala vlastite stručnjake, bolničke i sveučilišne jedinice, stručnu literaturu, profesionalne udruge i mogućnost populacijske primjene rendgenskih metoda.

Sto trideset godina nakon prvih rendgenskih eksperimenata na hrvatskom tlu, sačuvani rendgenogrami, stručne publikacije i arhivski dokumenti ne predstavljaju samo svjedočanstva tehnološke prošlosti, nego omogućuju rekonstrukciju procesa kojim je nova fizikalna pojava postala samostalna medicinska disciplina.

Zahvale

Autori posebno zahvaljuju prof. dr. sc. Nadi Bešenski, umirovljenoj profesorici radiologije, mr. sc. Franki Jelavić Kojić, specijalistici kliničke radiologije Kliničke bolnice Sveti Duh, i mr. sc. Ivici Vučaku, umirovljenom specijalistu pneumoftizeologije, na stručnim savjetima, dragocjenim informacijama i nesebičnom dijeljenju profesionalnog iskustva koje je pridonijelo potpunijoj rekonstrukciji pojedinih događaja i osoba iz povijesti hrvatske radiologije.

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130 Years Since the First X-ray Experiments on Croatian Soil: A Historical-Analytical Study of the Early Development of Radiology in Croatia

Abstract

Background: In 1896, one of the earliest applications of the newly discovered X-rays was documented on Croatian territory, marking the beginning of a 130-year development of radiology from an experimental physical method into an independent clinical, academic, and scientific discipline. Its early development was polycentric, primarily involving Rijeka, Zagreb, and Split.

Objective: To present the key events in the early development of radiology in Croatia, from the first X-ray experiments and medical radiographs to the emergence of professional literature, education, and institutionalisation of the discipline, with particular emphasis on previously underused archival material.

Materials and Methods: A historical-analytical study was conducted using primary archival sources, contemporary medical and daily periodicals, encyclopaedic and biographical sources, hospital monographs, and relevant historiographical literature. Materials from the Croatian State Archives and the State Archives in Zagreb were examined, together with newly identified records from the Archives of Yugoslavia in Belgrade. The collections of the National and

University Library, the Central Medical Library, and hospital libraries were searched, as were publications of the Croatian Medical Association, *Liječnički vjesnik*, *Liječničke novine*, historical newspapers, and the Croatian Encyclopedia, Medical Encyclopedia, and Croatian Biographical Lexicon.

Results: The reception of Röntgen's discovery in Croatia was remarkably rapid: the Zagreb newspaper *Obzor* reported on the new rays as early as 8 January 1896, while *Liječnički vjesnik* published a report in February of the same year. On 20 February 1896, Prof. Peter Salcher performed the first documented X-ray experiments on Croatian territory in Rijeka, including radiographs of the hands of Baroness Josephine Vranyczany; the original images are preserved in archival collection HR-HDA-782. At his initiative, a Röntgen Committee was established in 1897 and an X-ray apparatus was acquired; in 1899, the device was transferred to the Municipal Hospital of the Holy Spirit, representing an early transition of the new technology from the experimental to the hospital setting. In Zagreb, Prof. Vinko Dvořák demonstrated Röntgen rays before the Croatian Medical Association in 1897 and produced some of the earliest medical radiographs, while in the early twentieth century X-ray technology was also applied to the study of the Krapina fossils and in the work of Prof. Miroslav Čačković, published in 1907 and 1913.

Archival and historiographical sources further document the transition from experimentation to professional practice. Zorica Zec and Ela Vidić-Quinc were trained at Holzknecht's institute as the first Croatian X-ray assistants, while Dr Srećko Hofman became the first formally employed radiologist at the Sisters of Charity Hospital in 1923 and, in 1924, assumed leadership of the newly established Department of Diagnostic and Therapeutic Radiology. Particularly valuable documentation from the Croatian State Archives enables reconstruction of the professional career of Dr Branko Bressan, the first Croatian radiologist to receive systematic specialist training, including his education in Vienna, occupational radiation injury resulting in amputation of an arm, and his election as head of the Radiology Section of the Croatian Medical Association in 1936.

Institutionalisation continued with the establishment of the Chair of Roentgenology at the University of Zagreb School of Medicine in 1921 under Laza Popović and the Central Institute of Roentgenology in 1927. Between 1923 and 1935, Popović published the four-volume *Clinical Roentgenology* (*Klinička rentgenologija*), and from 1937 he edited *Radiološki glasnik*. His personnel files in the Croatian State Archives also document an occupational disease caused by prolonged exposure to X-rays, which led him to request retirement in 1939. Newly identified material from the Archives of Yugoslavia in Belgrade, particularly Popović's *Account of the Establishment and Development of the Central Institute of Roentgenology of the University of Zagreb School of Medicine* and the original floor plan of the Institute, further documents the deliberate integration of diagnostics, therapy, teaching, and scientific research.

In Dalmatia, an X-ray apparatus was introduced at Dr Jakša Račić's sanatorium in Split as early as 1902–1903, and by 1909 a separate "Röntgen Institute" was operating there. In 1930, Split hosted the Third Congress of the Pan-Slavic Association for Roentgenology and Radiology and the first meeting of the Yugoslav Society of Roentgenology and Radiotherapy, while the municipal hospital acquired its own X-ray apparatus in 1940.

Conclusion: X-ray technology was adopted in Croatia very shortly after Röntgen's discovery, and its development followed a polycentric pattern through interconnected initiatives in Rijeka, Zagreb, and Dalmatia. The transition from physical experimentation to an independent medical discipline was achieved through the integration of clinical practice, university teaching, specialist education, professional organisation, and public health needs. Newly identified archival material further expands the existing historiography, particularly by documenting the professional trajectories of early radiologists and the spatial and organisational development of the Central Institute of Roentgenology in Zagreb. The early development of Croatian radiology can therefore be understood as a process of simultaneous technological, professional, and institutional modernisation of medicine.

Keywords: radiology; X-rays; history of medicine; Croatia; archival records; institutionalization of radiology

PREGLEDNI RAD (REVIEW PAPER, REVIEW ARTICLE)

Škola mamografskog pozicioniranja i interpretacije nalaza kao model unaprjeđenja kvalitete mamografske dijagnostike u Republici Hrvatskoj

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Sažetak

Uvod: Kvaliteta mamografske dijagnostike u organiziranom probiru raka dojke uvelike ovisi o standardizaciji postupaka, kompetencijama zdravstvenih djelatnika i sustavnoj kontroli kvalitete. Škola „Pravila mamografskog pozicioniranja i interpretacije nalaza“ Kliničkog bolničkog centra (KBC) Rijeka razvijena je kao model strukturiranog stručnog usavršavanja u području mamografskog pozicioniranja, interpretacije nalaza i multidisciplinarne suradnje.

Cilj: Prikazati organizacijski model, sadržaj i rezultate višegodišnje provedbe Škole te njezin doprinos unaprjeđenju kvalitete mamografske dijagnostike.

Metode: Retrospektivno je analizirana kontinuirana provedba tečaja 1. kategorije kroz osam godina (2018.–2026.). Svaka škola trajala je dva dana i uključivala teorijska predavanja te praktične radionice iz mamografskog pozicioniranja, ultrazvuka dojke, kontrole kvalitete uređaja, analize mamograma različite kvalitete i simulacije standardnih i nestandardnih projekcija.

Rezultati: Edukaciju je završilo više od 220 zdravstvenih djelatnika (radiološki tehnolozi, radiolozi, medicinski fizičari i drugi članovi tima). Svi polaznici uspješno su završili program i stekli dodatne kompetencije iz pozicioniranja, primjene dijagnostičkih metoda i provedbi procedura kontrole kvalitete. Zabilježena je visoka motiviranost i kontinuiran porast interesa za sudjelovanje.

Zaključak: Strukturirana, teorijsko-praktična edukacija predstavlja ključan preduvjet za standardizirano izvođenje mamografije, poboljšanje kvalitete mamograma i jačanje multidisciplinarne suradnje, uz potencijalno povećanje dijagnostičke točnosti i sigurnosti pacijentica u probiru raka dojke.

Ključne riječi: edukacija; mamografija; multidisciplinarna suradnja; kontrola kvalitete; pozicioniranje dojke; probir raka dojke; radiološki tehnolozi;

Uvod

Kvaliteta mamografske dijagnostike u organiziranom probiru raka dojke ne ovisi isključivo o tehnološkoj opremljenosti centra, nego ponajprije o razini standardizacije postupaka, kompetencijama zdravstvenih djelatnika i sustavnoj kontroli kvalitete. U tom kontekstu, Škola „Pravila mamografskog pozicioniranja i interpretacije nalaza“ Kliničkog zavoda za dijagnostičku i intervencijsku radiologiju KBC-a Rijeka predstavlja važan i stručno utemeljen model profesionalnog usavršavanja, usmjeren na optimizaciju mamografskog pozicioniranja, interpretacije nalaza i multidisciplinarne suradnje u probiru raka dojke. Poseban značaj ovakvog programa proizlazi iz činjenice da objedinjuje teorijsko-praktične sadržaje, samoprocjenu, auditni pristup i kontinuiranu edukaciju, što je u skladu s temeljnim načelima europskih smjernica za osiguranje kvalitete u probiru raka dojke [1-3].

Pozicioniranje dojke u mamografiji jedan je od najosjetljivijih i najsloženijih koraka cjelokupnog dijagnostičkog procesa, jer izravno određuje dijagnostičku valjanost dobivenih slikovnih podataka. Neadekvatno pozicioniranje može rezultirati nepotpunim prikazom žljezdanog i retroglandularnog tkiva, izostavljanjem perifernih dijelova dojke, slabijom vizualizacijom potencijalno suspektnih lezija te povećanom potrebom za ponavljanjem snimanja. Takve





tehničke pogreške ne utječu samo na osjetljivost pretrage nego i na ukupnu sigurnost probira, budući da ponavljanje mamografije povećava izloženost zračenju i opterećenje sustava, a kod žena može smanjiti povjerenje u pregled i buduću suradljivost u probirnim ciklusima [4,5]. Stoga je unaprjeđenje tehnike pozicioniranja istodobno stručno, organizacijsko i javnozdravstveno pitanje.

Standardne mamografske projekcije, kraniokaudalna (CC) i mediolateralna kosa (MLO), moraju osigurati prikaz maksimalnog parenhima dojke, uključujući potkožno i retroglandularno tkivo, uz tehnički adekvatnu kompresiju i minimalan broj artefakata. Kvaliteta ovih projekcija ne procjenjuje se samo vizualnim dojmom, nego nizom kriterija koji uključuju pokrivenost tkiva, položaj bradavice, prikaz inframamarnog sulkusa (osobito na MLO projekciji), prikaz pektoralnog mišića kada je očekivan te geometrijske pokazatelje poput posterior nipple line (PNL) [4,6,7]. Međutim, literatura pokazuje da u međunarodnoj praksi i dalje postoji heterogenost u procjeni kvalitete slike, osobito za CC projekciju. Pregledni rad Sweeney i sur. ukazuje na varijabilnost kriterija kvalitete za CC projekciju i potrebu za dosljednijim, objektivnijim pristupom procjeni [4]. Slično tomu, multicentrična međunarodna evaluacija Taylor i sur. pokazala je odstupanja među centrima i među sustavima procjene kvalitete mamografskih snimaka, čime je dodatno naglašena potreba za standardizacijom i validacijom jedinstvene metodologije ocjene pozicioniranja dojke [7].

Upravo u tom području Škola mamografskog pozicioniranja ima posebno važnu ulogu, jer omogućuje sustavno uvježbavanje i evaluaciju tehničkih postupaka na razini svakodnevne kliničke prakse. Važnost takvog pristupa potvrđena je i hrvatskim iskustvom. Valković Zujić i sur. pokazali su da formalizirana edukacija i samoevaluacija radioloških tehnologa uključenih u program probira raka dojke u KBC-u Rijeka dovode do statistički značajnog poboljšanja kvalitete mamograma, što predstavlja izravni dokaz da strukturirane edukacijske intervencije mogu mjerljivo unaprijediti tehničku kvalitetu pretrage [1]. Ovaj nalaz ima posebnu težinu jer dolazi iz hrvatskog zdravstvenog sustava i pokazuje da se načela europskih smjernica mogu uspješno implementirati u hrvatskom kontekstu kroz ciljano organiziranu edukaciju.

Osim pozicioniranja, kompresija dojke predstavlja ključnu tehničku komponentu mamografskog postupka. Fizička kompresija smanjuje debljinu dojke, smanjuje raspršeno zračenje, poboljšava kontrastnu rezoluciju, smanjuje superpoziciju anatomskih struktura i posredno doprinosi smanjenju srednje glandularne doze [5,8]. Unatoč tomu, optimalna kompresijska sila nije jednoznačno standardizirana i u praksi se razlikuje među centrima, uređajima i radom radioloških tehnologa. Waade i sur. u Norveškom programu probira pokazali su značajnu varijabilnost primijenjenih kompresijskih sila, što upućuje na potrebu dodatne standardizacije i edukacije osoblja [5]. Istodobno, suvremeni pristup naglašava važnost individualizacije kompresije, odnosno prilagodbe sile kompresije anatomskim i subjektivnim karakteristikama žene, kako bi se održala dijagnostička kvaliteta slikovnih podataka uz što bolje iskustvo pregleda [9]. U tom smislu, edukacija radioloških tehnologa mora uključivati ne samo tehničke kriterije adekvatne kompresije, nego i kompetencije profesionalne komunikacije, procjene tolerancije na bol te pacijent-centrični pristup koji može doprinijeti većoj prihvatljivosti probira [2,3,8,9].

Dodatni izazov kvaliteti mamografije predstavljaju artefakti i tehnička ograničenja koja mogu nastati zbog pokreta tijekom snimanja, tjelesne konstitucije žene, prisutnosti implantata, nepravilnog položaja tijela ili drugih smetnji [10,11]. U klasičnoj radiološkoj interpretaciji artefakti mogu prikriti lezije ili simulirati patološke promjene, dok u kontekstu razvoja automatiziranih sustava i umjetne inteligencije postaju još značajniji problem jer mogu smanjiti točnost algoritama i narušiti pouzdanost automatske interpretacije [11,12]. Noviji radovi iz područja računalne analize mamografskih slikovnih podataka pokazuju da automatska detekcija artefakata i procjena njihova utjecaja na daljnju analitiku predstavljaju važan smjer razvoja digitalne kontrole kvalitete slike [12]. To jasno potvrđuje da visoka kvaliteta akvizicije i pravilno pozicioniranje dojke ostaju temeljni preduvjeti čak i u eri naprednih algoritama: automatizacija može nadopuniti klasične procese kontrole kvalitete, ali ne može nadoknaditi sustavne tehničke pogreške nastale tijekom snimanja.

Suvremena praksa osiguranja kvalitete u mamografiji stoga se sve više oslanja na kombinaciju klasičnih kriterija procjene slikovnih podataka i kvantitativnih pristupa. Sustavi procjene poput PGMI (engl. *Quality grading system for mammographic image positioning/technical image quality: Perfect, Good, Moderate, Inadequat)* modela, „Pravila 1-cm rule“ i PNL (*engl. Posterior Nipple Line*, *a measurement used in mammography quality assessment to evaluate how much posterior breast tissue is included on the image*)) – mjerenje koje se koristi u procjeni

kvalitete mamograma kao pokazatelj obuhvaćenosti stražnjeg dijela tkiva dojke na snimci, mogu doprinijeti objektivizaciji ocjene kvalitete, osobito ako se koriste u sklopu standardiziranih edukacijskih i auditnih protokola [4,7]. Međutim, sama implementacija kriterija nije dovoljna ako nije praćena ujednačenim tumačenjem, treningom procjenitelja i periodičnom provjerom međusobnog slaganja. Zbog toga bi u nacionalnim protokolima osiguranja kvalitete trebalo jasno definirati minimalne kriterije prihvatljivosti za CC i MLO projekcije, način dokumentiranja tehničkih odstupanja, metodologiju samoprocjene i vanjske procjene te mehanizme povratne informacije prema radiološkim tehnolozima i radiolozima [2,3,13]. Takav pristup pretvara kontrolu kvalitete iz administrativne obveze u stvarni alat stručnog razvoja i poboljšanja ishoda.

Europske smjernice i dokumenti Europske komisije sustavno naglašavaju važnost auditiranja, periodične edukacije, implementacije protokola kontrole kvalitete i kontinuirane profesionalne evaluacije osoblja uključenog u probir raka dojke [3,13]. Pritom se posebno ističe potreba jasno definiranih kompetencija radioloških tehnologa i radiologa u digitalnoj mamografiji, uključujući tehničke vještine, razumijevanje kriterija kvalitete slikovnih podataka, pravilnu komunikaciju sa ženama te interdisciplinarnu suradnju unutar probirnog lanca [13]. Hrvatski nacionalni dokumenti o osiguranju kvalitete u provođenju Nacionalnog programa probira raka dojke također prepoznaju važnost standardizacije postupaka i edukacije osoblja kao ključnih elemenata održavanja kvalitete programa [2]. U tom okviru Škola KBC-a Rijeka može se promatrati kao konkretna provedbena platforma europskih i nacionalnih zahtjeva, odnosno kao model kojim se načela smjernica prevode u kliničku praksu.

Važna snaga opisanog programa jest i njegova multidisciplinarna dimenzija. Iako je primarni fokus škole usmjeren na mamografsko pozicioniranje i interpretaciju nalaza, uključivanje radiologa, medicinskih fizičara i radioloških tehnologa te drugih zdravstvenih djelatnika relevantnih za probir i liječenje raka dojke omogućuje šire razumijevanje dijagnostičkog procesa i jača profesionalnu koordinaciju [14,15]. U praksi, kvaliteta skrbi za žene s promjenama dojke ne ovisi samo o tehničkoj ispravnosti mamograma, nego i o sposobnosti tima da poveže mamografski nalaz s ultrazvučnim prikazom, kliničkim pregledom, patohistološkom potvrdom i daljnjim terapijskim planiranjem [14-16]. Interaktivne radionice koje omogućuju bolju korelaciju između mamografskog i ultrazvučnog prikaza mogu unaprijediti dijagnostičku konzistentnost i komunikaciju između članova tima, što je osobito važno u probirnim programima gdje je pravovremena i točna odluka ključna za ishod liječenja [15,16].

Dodatnu vrijednost ovakvog edukacijskog modela daje činjenica da on može djelovati i kao platforma za kontinuirano praćenje učinaka edukacije. Umjesto jednokratne nastave, dugoročno učinkoviti programi kvalitete u mamografiji zahtijevaju ciklički model: inicijalnu edukaciju, evaluaciju prakse, audit tehničke kvalitete, ciljanu povratnu informaciju, ponovnu edukaciju i ponovnu procjenu rezultata [1,3,13,17]. Takav pristup u skladu je s recentnim međunarodnim inicijativama usmjerenima na poboljšanje mamografskog pozicioniranja kroz mrežne modele učenja i razmjenu standardiziranih kriterija [18]. Na taj se način kvaliteta mamograma ne promatra kao statična osobina pojedinog centra, nego kao dinamičan



proces koji se može mjeriti, uspoređivati i kontinuirano unapređivati.

Iz perspektive javnog zdravstva, visoka tehnička kvaliteta mamografije ima šire implikacije. Lošija kvaliteta slikovnih podataka može biti povezana s nižom stopom detekcije raka i potencijalno nepovoljnijim stadijem bolesti pri dijagnozi, osobito u populacijskim programima probira [17,19]. Stoga ulaganje u edukaciju radioloških tehnologa i radiologa nije samo profesionalni standard, nego i mjera koja može imati izravan utjecaj na učinkovitost probira i ishode liječenja. U tom smislu, Škola mamografskog pozicioniranja i interpretacije nalaza predstavlja važan primjer kako se lokalna stručna inicijativa može pozicionirati kao strateški element unaprjeđenja nacionalnog probirnog programa.

Zaključno, Škola „Pravila mamografskog pozicioniranja i interpretacije mamografskog nalaza“ KBC-a Rijeka predstavlja znanstveno i stručno opravdan model unaprjeđenja kvalitete mamografske dijagnostike u Hrvatskoj. Njezina vrijednost očituje se u povezivanju strukturirane edukacije, objektivnijih kriterija procjene kvalitete slike, razvoja tehničkih i komunikacijskih kompetencija, multidisciplinarne suradnje te kontinuiranog audita i samoprocjene. Usklađivanje ovakvih edukacijskih modela s nacionalnim protokolima i europskim smjernicama, uz postupnu integraciju digitalnih alata i umjetne inteligencije za kontrolu kvalitete slike, može dodatno osnažiti sigurnost, pouzdanost i učinkovitost probira raka dojke u Hrvatskoj [2,3,12,13]. Time se stvara održiva platforma za ranije otkrivanje karcinoma dojke i unaprjeđenje kvalitete skrbi za žene u svim fazama dijagnostičkog i terapijskog procesa.

Metode

Škole tečaja 1. kategorije mamografskog pozicioniranja i interpretacije nalaza provodile su se kontinuirano, u razdoblju od 2018. do 2026. godine. Svaka je škola bila strukturirana kao dvodnevni edukacijski program koji je kombinirao teorijska znanja i praktične radionice. Prvi je dan bio posvećen prvenstveno predavanjima, tijekom kojih su domaći i inozemni stručnjaci iz područja radiologije dojke, radiološke tehnologije i medicinske fizike obrađivali tematske cjeline iz anatomije i patologije dojke, tehnika pravilnog pozicioniranja, dijagnostičkih metoda oslikavanja dojke i patoloških promjena u dojci, konstrukcije i rada mamografskih i ultrazvučnih uređaja te postupaka



kontrole kvalitete, s naglaskom na čimbenike koji utječu na ukupnu kvalitetu mamografske dijagnostike. Drugi dan kombinirao je nekoliko predavanja sa sveobuhvatnim praktičnim radom. Sudionici su bili podijeljeni u manje radne skupine i sudjelovali u interaktivnim vježbama koje su uključivale:

- praktično vježbanje mamografskog pozicioniranja na dobrovoljnim ispitanicama kojima je bila indicirana mamografska pretraga,
- izvođenje ultrazvučnog pregleda dojki,
- teorijsko objašnjavanje i praktična demonstracija procedura kontrole kvalitete mamografskih uređaja,
- analizu 100 primjera mamograma različite kvalitete, s posebnim prikazima patoloških nalaza,
- simulaciju standardnih i nestandardnih projekcija dojke,
- usvajanje i demonstraciju tehnika ultrazvučne vizualizacije.

Sve ispitanice uključene u praktični dio nastave nisu bile izložene prekomjernom ionizirajućem zračenju, budući da su pregledi bili provedeni u skladu s kliničkom indikacijom i dopunjeni ultrazvučnim snimanjem. Nazočnost na svim predavanjima i vježbama bila je obavezna za sve sudionike. Edukacijske radionice radiološke tehnologije vodili su iskusni radiološki tehnolozi koji su položili certifikat za edukatore mamografskog pozicioniranja, završili prvu Školu mamografskog pozicioniranja i u daljnjoj kliničkoj praksi ostvarili izvrsne rezultate. Ovakva strukturirana edukacija omogućila je polaznicima integraciju teorijskog znanja s praktičnim vještinama, a fokus je bio na unaprjeđenju kompetencija potrebnih za standardizirano izvođenje mamografije, podizanju kvalitete mamograma i usvajanju procedura kontrole kvalitete.

Rezultati

Kroz razdoblje, od 2018. do 2026. godine, edukaciju u okviru Škole mamografskog pozicioniranja i interpretacije nalaza prošlo je više od 220 zdravstvenih djelatnika, među kojima su radiološki tehnolozi, radiolozi, medicinski fizičari, ostali specijalisti i medicinske sestre koji su uključeni u mamografski probir i liječenje raka dojke. Svi polaznici uspješno su završili program i položili tečaj, čime su stekli dodatne kompetencije iz područja pravilnog pozicioniranja dojke, primjene dijagnostičkih metoda, uporabe mamografskih uređaja te procedura kontrole kvalitete. Ovakav rezultat potvrđuje visoku razinu zainteresiranosti i motiviranosti zdravstvenih djelatnika za kontinuiranim stručnim usavršavanjem u cilju postizanja što veće kvalitete mamografske dijagnostike**.** Rastući broj sudionika kroz godine svjedoči o tome da zdravstvena zajednica prepoznaje nužnost stalnog razvoja kompetencija, kao i važnost standardizacije postupaka u svrhu postizanja vrhunske kvalitete mamografskih snimaka i veće sigurnosti pacijentica.

Zaključak

Dodatna edukacija koja uključuje ne samo teorijsko znanje nego i praktične vještine ključna je za postizanje mamograma vrhunske kvalitete koji zadovoljavaju preporuke struke i međunarodne kriterije. Sustavno usavršavanje u mamografskom pozicioniranju i interpretaciji nalaza značajno doprinosi smanjenju broja tehnički neadekvatnih snimaka, povećanju dijagnostičke točnosti te smanjenju potrebe za ponavljanjem snimke, čime se dodatno smanjuje izloženost pacijentica ionizirajućem zračenju. Škola mamografskog pozicioniranja i interpretacije nalaza u KBC Rijeka nije samo regionalni program za edukaciju, već predstavlja nacionalni i međunarodno relevantan model koji integrira najmodernije principe svjetske znanstvene prakse, europske smjernice i nacionalne propise. Ovakav edukacijski okvir osigurava prijenos znanja i vještina među radiološkim tehnolozima, radiolozima i drugim zdravstvenim djelatnicima uključenima u mamografsku dijagnostiku i liječenje raka dojke, čime se jača multidisciplinarna suradnja i kvaliteta cijelog dijagnostičko-terapijskog lanca. Permanentna edukacija, evaluacija postupaka, auditiranje i implementacija novih tehnologija predstavljaju temelj održivosti mamografske dijagnostike raka dojke [20]. Sve veća zainteresiranost zdravstvenih djelatnika za sudjelovanjem u ovakvim edukacijama potvrđuje potrebu i važnost kontinuiranog razvoja stručnih kompetencija. Time se ne osigurava samo unaprjeđenje profesionalne prakse, već i stvarna korist za žene – kroz raniju i točniju detekciju malignih bolesti, smanjenje mortaliteta i podizanje opće kvalitete zdravstvene skrbi. Kontinuirano usavršavanje vještina, stručna validacija postupaka i znanstvena evaluacija rezultata jamče dugoročnu održivost sustava probira, optimalnu dijagnostičku vrijednost mamografije te najveću moguću sigurnost i povjerenje žena uključenih u nacionalni program probira raka dojke.

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The School of Mammographic Positioning and Image Interpretation as a Model for Improving the Quality of Mammographic Diagnostics in Croatia

Abstract

Introduction: The quality of mammographic diagnostics within organised breast cancer screening programmes largely depends on the standardisation of procedures, the competencies of healthcare professionals, and a systematic quality assurance programme. The School of Mammographic Positioning and Image Interpretation at Clinical Hospital Centre Rijeka was developed as a model of structured professional education in mammographic positioning, image interpretation, and multidisciplinary collaboration.

Aim: To present the organisational model, educational content, and outcomes of the School over an eight-year period, and to assess its contribution to improving the quality of mammographic diagnostics.

Methods: A retrospective analysis was conducted of the continuous implementation of a Category 1 accredited educational course over an eight-year period (2018–2026). Each School lasted two days and included theoretical lectures and practical workshops covering mammographic positioning, breast ultrasound, quality control, analysis of mammograms of varying quality, and simulation of standard and non-standard mammographic projections.

Results: More than 220 healthcare professionals, including radiographers, radiologists, medical physicists, and other members of the multidisciplinary team, completed the educational program. All participants successfully completed the course and acquired additional competencies in mammographic positioning, the application of diagnostic methods, and quality control procedures. High participant motivation was observed, along with a continuous increase in interest in participation.

Conclusion: Structured theoretical and practical education represents an essential prerequisite for standardised mammographic imaging, improved mammographic image quality, and strengthened multidisciplinary collaboration, with the potential to improve diagnostic accuracy and patient safety in breast cancer screening.

Keywords: education; mammography; multidisciplinary collaboration; quality control; breast positioning; breast cancer screening; radiographers

STRUČNI RAD (PROFESSIONAL PAPER)

Specifičnosti rada radiološkog tehnologa s pacijentima s mentalnim poremećajima u klasičnoj radiografiji

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Sažetak

Radiološki tehnolozi imaju ključnu ulogu u postupku nastanka radiološke slike. Kvaliteta izvedene pretrage ovisi o pravilnoj pripremi pacijenta, tehničkoj izvedbi i uspješnoj komunikaciji.

Klasična radiografija predstavlja jednu od najčešćih korištenih dijagnostičkih metoda u svakodnevnoj kliničkoj praksi, a njezina učinkovitost ovisi i o suradnji pacijenta tijekom snimanja. Rad s pacijentima koji boluju od mentalnih poremećaja predstavlja poseban izazov. Takvi pacijenti mogu pokazivati različite oblike ponašanja, što može uključivati anksioznost, dezorijentiranost, smanjenu mogućnost razumijevanja uputa ili agresivnost, što može utjecati na provedbu dijagnostičkih postupaka te kvalitetu radiografskih snimaka. U takvim situacijama važne su komunikacijske vještine, strpljenje te sposobnost procjene situacije. Specifičnosti rada s pacijentima s mentalnim poremećajima zahtijeva individualizirani pristup, prilagodbu standardnih protokola te često suradnju s drugim zdravstvenim djelatnicima. U ovakvim situacijama nužno je osigurati sigurnost pacijenta te zdravstvenog osoblja, uz istovremeno poštivanje etičkih načela i dostojanstva pacijenta.

Cilj ovog rada je prikazati specifičnosti rada radiološkog tehnologa s pacijentima s mentalnim poremećajima u klasičnoj radiografiji koje se temelji na vlastitom profesionalnom iskustvu u svakodnevnom radu.

Ključne riječi: radiološki tehnolog, psihijatrija, radiografija, komunikacija, profesionalnost

Uvod

Psihijatrija kao grana medicine bavi se dijagnostikom, liječenjem i prevencijom mentalnih poremećaja, koji predstavljaju značajan javnozdravstveni problem na globalnoj nacionalnoj razini. Mentalni poremećaji obuhvaćaju širok spektar stanja- od anksioznih i depresivnih poremećaja do psihotičkih poremećaja te poremećaja uzrokovanih psihoaktivnim tvarima (1). Suvremeni trendovi pokazuju porast broja oboljelih. Prema podatcima Hrvatskog zavoda za javno zdravstvo iz 2025. godine procjenjuje se da je više od 800 000 osoba u Hrvatskoj imalo neku dijagnozu iz skupine mentalnih poremećaja (2). Iako radiologija primarno nije usmjerena na mentalne poremećaje, pacijenti s tim dijagnozama često zahtijevaju radiološku dijagnostiku zbog komorbiditeta, ozljeda ili drugih somatskih stanja. Ključnu ulogu ovdje imaju radiološki tehnolozi koji svojim pristupom prema pacijentu, komunikacijskim vještinama, procjenom situacije te modificiranom izvedbom dolaze do radiografske snimke kod pacijenata s kojima je suradnja vrlo specifična i u većini slučajeva otežana.

Pacijenti s mentalnim poremećajima u radiografiji

Najčešća skupina mentalnih poremećaja s kojima se susreću radiološki tehnolozi su anksiozni poremećaji. Kod ovih pacijenata prisutan je izraženi osjećaj straha, napetost i nelagoda, koji se mogu dodatno pojačati u nepoznatom bolničkom okruženju. Zatvoreni prostor, uređaji u prostoriji te sama procedura mogu izazvati panične reakcije (3). Posljedično, može doći do povećanog rizika od pokreta tijekom ekspozicije što negativno utječe na kvalitetu radiografske slike te ponavljanja ekspozicije.

Depresivni poremećaji karakterizirani su sniženim raspoloženjem, gubitkom interesa i psihomotornom usporenošću. To dovodi do smanjene motivacije za suradnjom tijekom snimanja i sporijom reakcijom na upute. Pacijenti često djeluju nezainteresirano i iscrpljeno. Takvo stanje može produžiti trajanje postupka, zahtijevati dodatno strpljenje te jasne i kratke upute od strane radiološkog tehnologa (4).

Psihotički poremećaji, poput shizofrenije predstavljaju poseban izazov zbog prisutnosti halucinacija, deluzija i dezorganiziranog mišljenja. Pacijenti pokazuju nepovjerenje prema medicinskom osoblju, odbijaju suradnju te mogu imati nepredvidivo ponašanje tijekom snimanja (5). U radiološkoj praksi potrebna je visoka razina profesionalnosti, smirenost i dodatan oprez u radu.

Demencije i drugi kognitivni poremećaji, posebno kod starije populacije, okarakterizirani gubitkom pamćenja, dezorijentiranošću i smanjenom sposobnošću razumijevanja često utječu na nemogućnost razumijevanja najjednostavnijih uputa. Potrebno je konstantno ponavljanje

uputa, demonstracija postupaka i prisutnost pratnje koja može pomoći u komunikaciji (3). Postoji povećan rizik od nepravilnog pozicioniranja i pokreta tijekom ekspozicije.

Pacijenti s intelektualnim teškoćama imaju ograničene kognitivne sposobnosti. Razumijevanje složenih uputa najčešće je otežano, nužno je koristiti pojednostavljenu komunikaciju, vizualne demonstracije te individualizirani pristup. Radiološki tehnolog u ovakvim situacijama pravilnom komunikacijom izravno utječe na kvalitetu radiološkog postupka (4).

Poremećaji iz spektra autizma specifični su zbog osjetljivosti na podražaje svjetla, zvukova i dodira. Nepoznato okruženje radiološkog odjela može izazvati stres, anksioznost ili obrambene reakcije. Važno je osigurati što mirnije okruženje, uz jasnu strukturu postupka i minimalne distrakcije (6).

Uloga radiološkoh tehnologa u radu s psihijatrijskim pacijentima

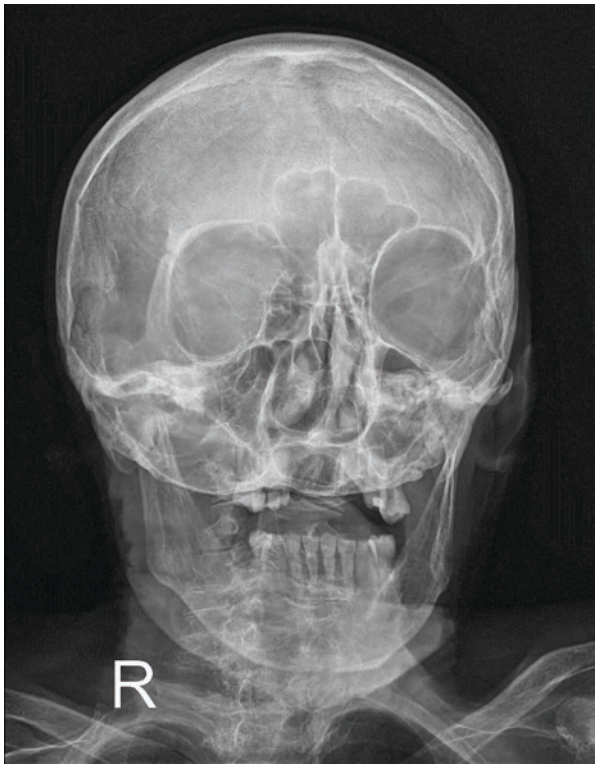
Profesionalni pristup i učinkovita komunikacija predstavljaju temelj kvalitetne zdravstvene skrbi, osobito u području radiologije gdje uspješnost dijagnostičkog postupka ovisi o suradnji pacijenta. Radiološki tehnolozi imaju odgovornost uspostavljanja odnosa povjerenja s pacijentom, razumijevanje postupka te ovisno o stanju pacijenta potrebno je prilagoditi komunikaciju (4). U radu s pacijentima koji imaju mentalne poremećaje komunikacija zahtijeva dodatnu složenost. Pacijenti mogu imati poteškoće u razumijevanju uputa, izražavanju ili održavanju pažnje. Takve situacije zahtijevaju jasan, smiren i strukturiran način komunikacije. Preporučuje se korištenje jednostavnih riječi te kratkih i preciznih uputa uz ponavljanje informacija koliko god je puta potrebno. Neverbalna komunikacija, poput tona glasa, izrazi lica te govor tijela imaju značajnu ulogu u smanjenju anksioznosti i uspostavljanja osjećaja sigurnosti kod pacijenta. Poželjno je izbjegavati nagle pokrete te održavati siguran razmak, koliko je to u pojedinim radiografskim postupcima moguće (7). Razvijene komunikacijske vještine ne doprinose samo postupku nastanka kvalitetne radiološke slike, već i cjelokupnom iskustvu pacijenta u zdravstvenom sustavu. Empatija, strpljenje i profesionalnost omogućuju bolje razumijevanje potreba svakog pacijenta te smanjuju mogućnost nastanka komplikacija i nesporazuma tijekom postupka (8). Profesionalni pristup uključuje očuvanje dostojanstva pacijenta, poštivanje privatnosti te primjenu etičkih načela u svakodnevnom radu. Kada pacijent pokazuje uznemirenost ili agresivnost tijekom dijagnostičkog postupka važno je ostati smiren, izbjegavati konfrontaciju te ukoliko je potrebno, uključiti i drugo zdravstveno osoblje. Interdisciplinarna suradnja ključna je u osiguranju sigurnosti i učinkovitosti izvedbe dijagnostičkog postupka (9).

Izazovi i prilagodba radiografskih postupaka u praksi

Radiološki tehnolozi u svom radu svakodnevno se susreću s izazovima pri izvođenju radiografskih postupaka kod pacijenata s mentalnim poremećajima. Standardne protokole snimanja većinom nije moguće primijeniti u potpunosti zbog specifičnih oblika ponašanja, smanjene suradnje ili nemogućnosti razumijevanja uputa. To dovodi do produženog trajanja dijagnostike te povećava mogućnost ponavljanja radioloških snimaka iz čega proizlazi povećana



Slika 1.: RTG zdjelice s kukovima kod pacijenta s dijagnozom F10.7 (Izvor: autor)



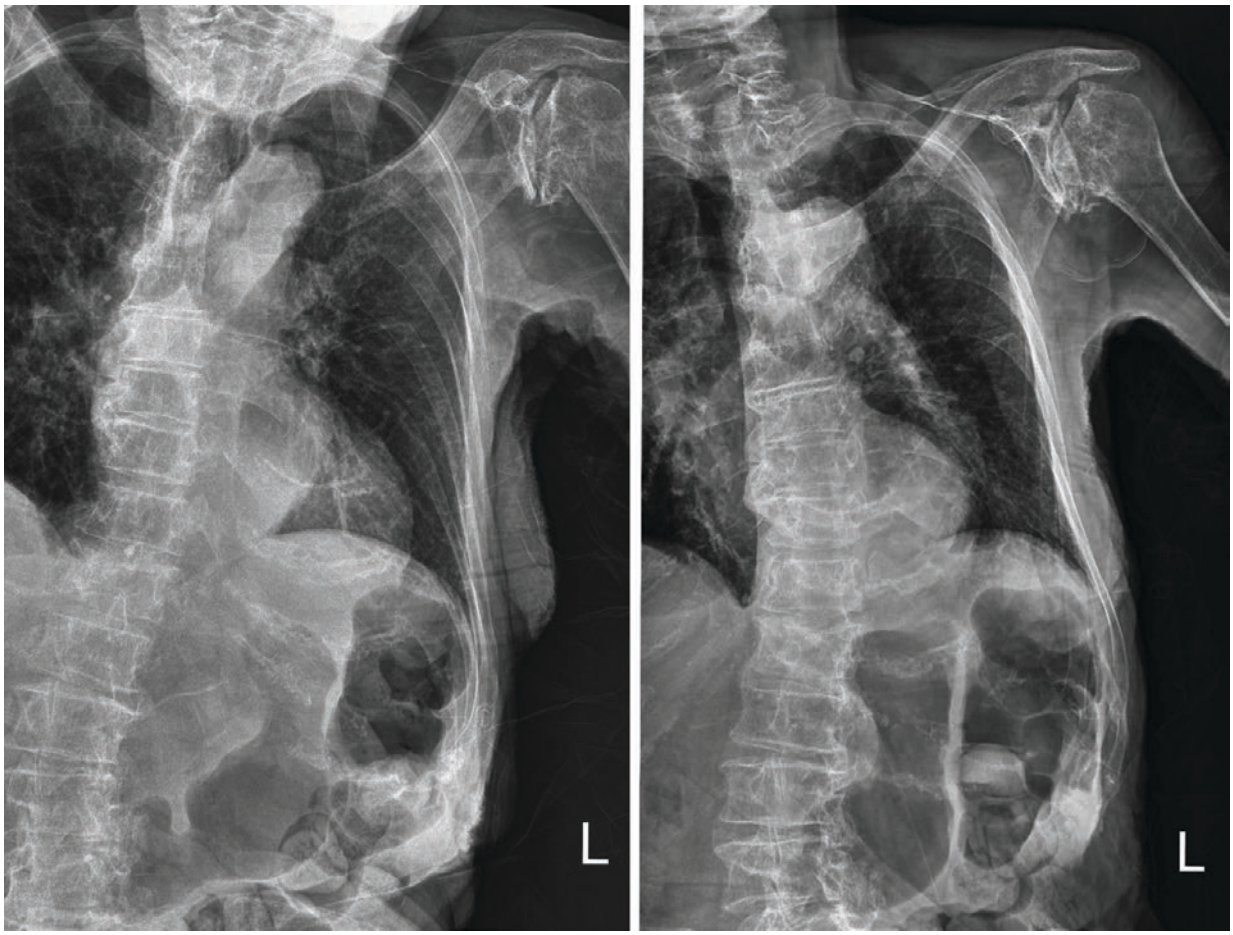
Slika 2.: Kraniogram pacijentice s dijagnozom F07.9 (Izvor: autor)

doza zračenja. U takvim situacijama nužna je prilagodba postupaka kako bi se osigurala kvaliteta dijagnostičke slike. Na slici 1. prikazan je primjer pacijenta s dijagnozom F10.7- duševni poremećaji i poremećaji ponašanja uzrokovani alkoholom, koji je došao na RTG zdjelice s kukovima. Jedan od najšešćih izazova je nesuradnja, pacijent odbija zauzeti potreban položaj te ne miruje tijekom snimanja što je rezultiralo nesimetričnom slikom.

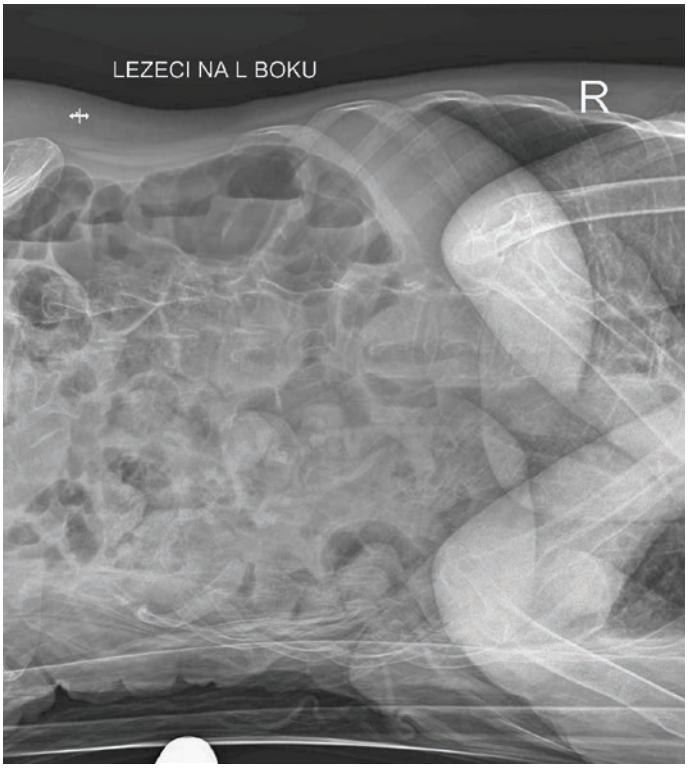
Izazov je i razumijevanje uputa te nemogućnost zadržavanja položaja koji se traži od pacijenta. Slika 2. prikazuje kraniogram pacijentice s dijagnozom F07.9- nespecificiran organski poremećaj ličnosti i poremećaj ponašanja uzrokovani bolešću, oštećenjem indisfunkcijom mozga. Slika je nezadovoljavajuća dijagnostičke kvalitete za analizu.

Standardne protokole snimanja nije uvijek moguće primijeniti u potpunosti zbog specifičnih oblika ponašanja pacijenta. Pacijent je nemiran te ima nekontrolirane pokrete. U takvim situacijama nužna je prilagodba postupaka kako bi se osigurala kvaliteta dijagnostičke slike i sigurnost pacijenta. Na slici 3. prikazuje se RTG hemitoraksa u ležećem položaju zbog nemogućnosti zauzimanja standardnog stojećeg položaja. Pacijent ima dijagnozu F07- poremećaji ličnosti i poremećaji ponašanja zbog bolesti, oštećenja i disfunkcije mozga.

Anksioznost i strah od medicinskog okruženja te radioloških aparata mogu negativno utjecati na izvedbu snimanja. Radiografski postupci često se moraju prilagoditi i imobilizacijom određenih dijelova tijela. Na slici 4. prika-



Slika 3.: RTG L hemitoraksa u ležećem položaju kod pacijenta s dijagnozom F07 (Izvor: autor)



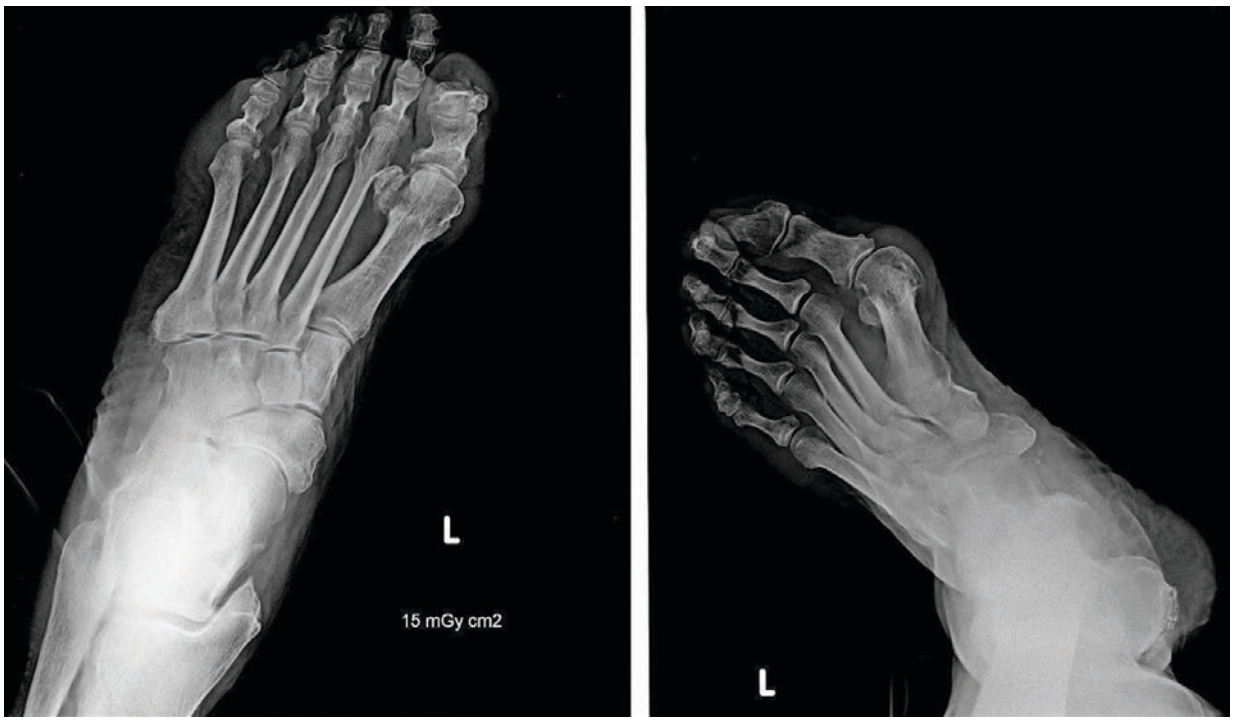
Slika 4.: RTG abdomena kod pacijentice s dijagnozom F20 (Izvor: autor)

zuje se RTG abdomena ležeći na L boku kod pacijentice s dijagnozom F20- shizofrenija. Pacijentica odbija suradnju, dolazi do agresivnog ponašanja te se na snimci prikazuju i gornji ekstremiteti.

Za pojedine pacijente potrebna je i suradnja s drugim zdravstvenim osoblje, kao na primjer zdravstveno osoblje u pratnji koje može pomoći u smirivanju pacijenta. Na slici 5. prikazuju se plantarna i kosa snimka stopala pacijenta s dijagnozom F06.3- organiski afektivni poremećaji. Uz pojednostavljene i ponovljene upute, smiren pristup i korištenje neverbalne komunikacije, pacijent ne razumije upute, ne surađuje te ograničava pokretljivost ekstremiteta prilikom namještaja za snimanje.

Sigurnost radiološkog tehnologa

Sigurnost u radiologiji nije isključiva odgovornost pojedinca, već zajednička odgovornost svih članova zdravstvenog tima. Prema smjernicama međunarodnih organizacija, uključujući Međunarodnu agenciju za atomsku energiju (IAEA), odgovornosti su raspoređene na više razina (10). Radiolog je odgovoran za opravdanost i optimizaciju pretrage te donošenje kliničkih odluka. Radiološki tehnolog je odgovoran za pravilno izvođenje postupka, sigurnu manipulaciju pacijentom i primjenu mjera zaštite. Medicinski fizičar sudjeluje u kontroli doze zračenja te tehničkoj sigurnosti. Ustanova je odgovorna za organizaciju rada, edukaciju osoblja, osiguranje sigurnosti protokola te adekvatni resurs (6). Sigurnosni protokoli u radiologiji temelje se na načelima prevencije rizika, edukaciji osoblja i organizacijskim mjerama. Radiološko okruženje ima kompleksan tijek rada, što zahtijeva standardizirane procedure kako bi se smanjila mogućnost incidenata (11). Jedna od komponenti protokola zaštite je procjena rizika prije pregleda, što uključuje identifikaciju pacijenta s potencijalnim agresivnim ponašanjem kroz njegovu medicinsku dokumentaciju. Potrebno je osigurati dovoljan broj radioloških tehnologa na radnoj stanici, prisutnost sigurnosne službe te uspostavljeni jasni komunikacijski kanali. Raspored prostorije treba biti takav da omogućuje brzi izlaz te da postoji mogućnost održavanja sigurne distance između pacijenta i tehnologa. (11) Radiološki tehnolog ima izravnu i neposrednu od-



Slika 5.: Plantarna i kosa snimka stopala pacijenta s dijagnozom F06.3 (Izvor: autor)

govornost za sigurnost tijekom izvođenja dijagnostičkog postupka, budući da je najčešće prvi zdravstveni djelatnik koji dolazi u kontakt s pacijentom na odjelu radiologije. Njegova odgovornost je procijeniti ponašanje pacijenta, prepoznati znakove agresije ili agitacije te primijeniti odgovarajuće mjere zaštite i deeskalacije (12). Posebno je naglašena edukacija u tehnikama verbalne deeskalacije te pravovremenog pozivanja pomoći. Osoblje mora biti upoznato s procedurom prijave incidenta i potencijalnog nasilja. Radiološki tehnolog dužan je prekinuti postupak ukoliko procijeni da postoji opasnost za sigurnost osoblja ili pacijenta (13).

Zaključak

Rad s pacijentima koji boluju od mentalnih poremećaja predstavlja značajan izazov u području klasične radiografije te zahtijeva dodatne profesionalne kompetencije radioloških tehnologa. Osim tehničkih znanja i vještina, ključnu ulogu imaju komunikacijske sposobnosti, strpljenje, empatija i sposobnost prilagodbe različitim situacijama u svakodnevnoj praksi. Kvaliteta radiografskih slika ovisi o suradnji pacijenta koja je kod pacijenata s mentalnim poremećajima u većini slučajeva otežana. U takvim situacijama nužno je primijeniti individualizirani pristup svakom pacijentu i prilagoditi standardne postupke kako bi se osigurala uspješna izvedba pretrage uz minimalno ponavljanje radioloških snimaka i smanjenje izloženosti zračenju. Važna je i interdisciplinarna suradnja s drugim zdravstvenim djelatnicima, ali i sigurnost svih koji su uključeni u postupak. Potrebno je kontinuirano poštivanje etičkih načela i dostojanstva pacijenta. Radiološke tehnologe potrebno je više educirati o radu s pacijentima s mentalnim poremećajima, jer unapređenje znanja i vještina rezultira kvalitetnijom dijagnostikom, većom sigurnosti te humanijem pristupu prema pacijentu.

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Specificities of work of a radiological technologist with patients with mental disorders in classic radiography

Abstract

Radiology technologists play a key role in producing radiographic images. The quality of the performed examination depends on proper patient preparation, technical execution and effective communication.

Conventional radiography is one of the most commonly used diagnostic methods in everyday clinical practice, and its effectiveness also depends on patients suffering from psychiatric disorders, who present a particular challenge. Such patients may exhibit various forms of behavior, including anxiety, disorientation, reduced ability to understand instructions or agression, which can affect the performance of diagnostic procedures as well as the quality of radiographic images. In such situations, communication skills, patience, and the ability to assess the situation are essential. The specific nature of working with psychiatric patients requires an individualised approach, adaptation of standard protocols and often collaboration with other healthcare professionals. In these situations, it is necessary to ensure the safety of both the patient and healthcare staff, while respecting ethical principles and the patient's dignity.

The main goal of this paper is to present specific aspects of radiologic technologists' work with psychiatric patients in conventional radiography, based on personal professional experience in everyday practice.

Keywords: radiologic technologist, psychiatry, radiography, communication, professionalism

Agresivna perineuralna i intrakranijalna progresija lezije baze lubanje s naknadno otkrivenim sarkomatoidnim karcinomom: prikaz slučaja

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Sažetak

Cilj: Prikaz slučaja 52-godišnjeg bolesnika kod kojeg se liječila kronična upala i gljivična infekcija (Aspergillus), izvedene su višestruke operacije bez poboljšanja i u konačnici otkriven sarkomatoidni karcinom orbite i sinusa. Prikazana je uloga radioterapijskog liječenja kao primarne terapije sarkomatoidnog karcinoma.

Prikaz slučaja: Kod bolesnika kod kojeg se u početku liječila kronična upala i gljivična infekcija, također je izvedeno više operativnih zahvata koje nisu dovele do poboljšana. Nakon što je 2026. napravljena nova biopsija otkrivena je dijagnoza sarkomatoidnog karcinoma orbite i sinusa. Tumor se brzo širio duž živaca prema orbiti, sluhovodu i moždanom stablu, uzrokujući teška neurološka oštećenja (gubitak vida, sluha i osjeta u licu) Sarkomatoidni karcinom je rijedak i vrlo agresivan tumor s obilježjima karcinoma i sarkoma. Ovaj tumor vrlo brzo razara koštano tkivo i vrlo brzo metastazira. Zbog specifične građe i simptoma koji nalikuju upalnim procesima vrlo teško se dijagnosticira te je biopsija zlatni standard dijagnostike ovog tumora. Kao terapija ovog opsežnog i agresivnog procesa provedena je primarna radioterapija područja tumora fotonskim zrakama energije 6 MeV, VMAT tehnikom uz svakodnevnu kontrolu pozicioniranja kV CBCT-om. Na područje tumora koji infiltrira početno moždano deblo je aplicirano TD 54 Gy/27 frakcija, a na ostalo područje TD 68 Gy u 34 frakcije.

Zaključak: Kombinacija agresivnog tumora i invazivne gljivične infekcije s prodorom u mozak je izrazito rijedak dijagnostičko terapijski izazov. Primarna terapija zračenjem VMAT tehnikom je provedena uspješno.

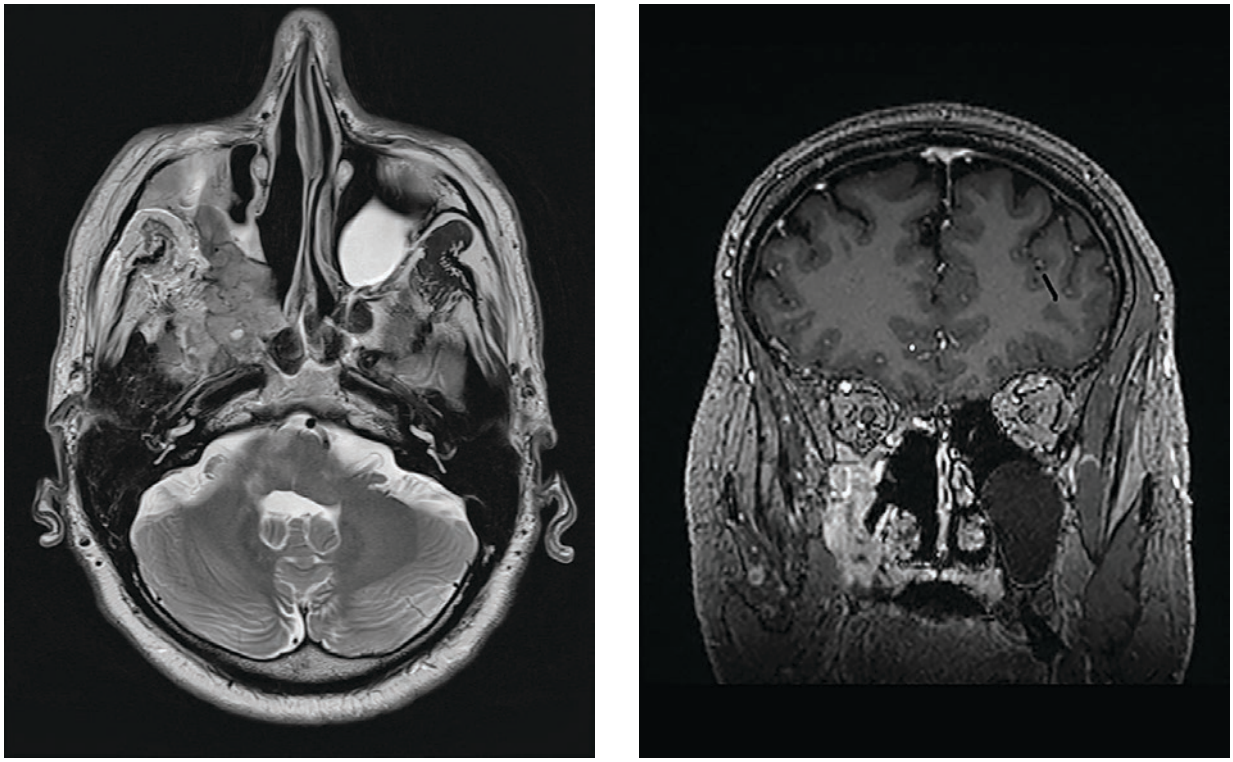
Ključne riječi: gljivična infekcija, sarkomatoidni karcinom, rijetki tumori, planiranje radioterapije

Uvod

Prvi simptomi bolesti baze lubanje mogu biti nespecifični poput blage boli, osjećaja pritiska u licu ili sinusnih tegoba, te se u početku najčešće razmatraju upalni ili infektivni uzroci. S druge strane, sarkomatoidni karcinom vrlo je agresivna vrsta tumora koja ima značajke i epitelnog podrijetla (karcinom) i mezenhimalnog podrijetla (sarkom) [1].

Sarkomatoidni karcinomi mogu biti morfološki monofazni ili bifazni, pri čemu bifazni oblici sadrže i epitelnu i mezenhimalnu komponentu. U većini slučajeva moguće je razlikovati dominantni i sporedni histološki uzorak, iako se oni često međusobno isprepliću. Ovi tumori u literaturi se opisuju pod različitim nazivima, uključujući karcinosarkom, pseudosarkom, vretenastostanični skvamozni karcinom, pleomorfni karcinom te karcinom s pseudosarkomatoznom stromom. Klinički se najčešće prezentiraju u uznapredovalom stadiju bolesti, pri čemu je većina tumora u trenutku dijagnoze klasificirana kao T3 ili T4. Karakterizira ih agresivan tijek, a često je prisutna i zahvaćenost vratnih limfnih čvorova [2].

Ovaj hibridni tumor može se pojaviti u različitim organima, najčešće u plućima, bubrezima, prostati i mekim tkivima. Sarkomatoidni karcinomi brzo napreduju i imaju izraženu sklonost ranom metastaziranju. Sarkomatoidni izgled tumorskih stanica pod mikroskopom može dodatno otežati dijagnostiku i liječenje. Zbog toga biopsija i patohistološka analiza predstavljaju zlatni standard u potvrdi dijagnoze malignih bolesti, budući da se slikovnim metodama ovaj tumor često ne može jasno razlikovati od drugih malignih lezija [3].



Slika 1. Magnetska rezonancija (MR) baze lubanje; *Prikaz tumorske mase na MR-u*
Izvor: KBC Zagreb, PACS/Sectra sustav, Klinički zavod za dijagnostičku i intervencijsku radiologiju (privatna arhivska snimka).

Pojava sarkomatoidnog karcinoma orbitalne regije glave i vrata izuzetno je rijetka. Ostale regije glave i vrata u kojima je opisana pojavnost uključuju grkljan, ždrijelo, usnu šupljinu i nosno područje. Klinička prezentacija najčešće je uznapredovala i obilježena agresivnim tijekom bolesti [2].

Liječenje sarkomatoidnog karcinoma najčešće je kombinacija operativnog liječenja, kemoterapije i radioterapije, što varira od pacijenta do pacijenta. U novije vrijeme napredak u imunoterapiji otvara nove mogućnosti liječenja pacijenata s ovom vrstom tumora [4].

Prikaz slučaja

Prikazuje se kompleksan klinički slučaj 52-godišnjeg bolesnika kod kojeg je bolest započela kao lokalizirana promjena u području paranazalnih sinusa, inicijalno interpretirana kao kronična upalna promjena te invazivna gljivična infekcija baze lubanje. Dijagnostika takvih lezija baze lubanje često je otežana zbog kliničkog i radiološkog preklapanja infektivnih i neoplastičnih procesa u tom području [5,6,7].

Unatoč višestrukim kirurškim zahvatima područja maksilarnog sinusa i baze lubanje te antifungalnoj terapiji, dolazi do progresivnog neurološkog pogoršanja kliničke slike (slika 1). Patohistološki nalaz (PHD) upućuje na kroničnu upalu i aktivni osteomijelitis. Osteomijelitis baze lubanje je također rijedak i predstavlja dijagnostički i terapijski izazov. Tek nakon biopsije orbitalnog područja postavlja se dijagnoza agresivnog sarkomatoidnog tumora, rijetkog tumora visokog maligniteta sinonazalne regije, koji karakterizira agresivno lokalno ponašanje s lošim prognostičkim tijekom.

Anamneza i tijek bolesti

Bolesnik se u našoj ustanovi prati od listopada 2025. zbog progresivnog osteomijelitisa baze lubanje i višestrukih kranijalnih neuropatija. Dijagnostički je potvrđena kronična invazivna aspergiloza s perineuralnim širenjem. Ova ozbiljna i po život opasna gljivična infekcija uzrokovana je vrstama *Aspergillus flavus* i *Aspergillus fumigatus*, koje su najčešći uzročnici invazivne aspirgeloze. Liječenje se provodi antimikoticima širokog spektra [8].

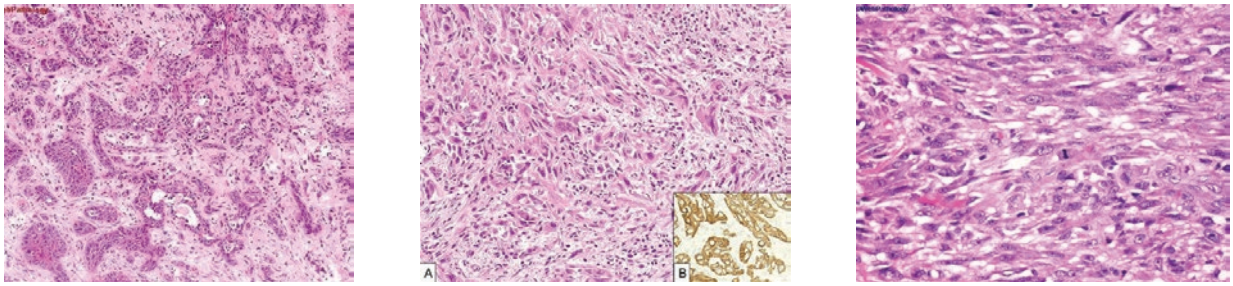
Liječenje je uključivalo više endoskopskih endonazalnih zahvata pod dijagnozom kronične upale i osteomijelitisa. Biopsijom medijalnog zida orbite u veljači 2026. godine PHD je potvrdio da se radi o sarkomatoidnom karcinomu.

Klinički status

Bolesnik je dobrog općeg stanja, ali ima izražene neurološke deficite: ptoza desnog kapka, oslabljen vid lijevo i gubitak sluha desno sa smanjenim osjetom cijele desne strane. Također pareza n. facialis i n. abducens desno te senzitivna neuropatija n. trigeminusa desno.

Dijagnoza

Nakon PHD nalaza 2026. postavljena je dijagnoza sarkomatoidnog karcinoma desne orbite s kroničnom invazivnom aspergilozom baze lubanje i perineuralnim širenjem te infiltracijom kranijalnih živaca (V1–V3, VII, VI) desno (slika 2).



Slika 2. Patohistološki prikaz sarkomatoidnog karcinoma (H&E bojenje); *Na ovim slikama se vide tipične značajke: vretenaste tumorske stanice, izražen stanični pleomorfizam, područja nekroze i agresivnog rasta, kombinacija karcinomske i sarkomatoidne komponente*
Izvor: WebPathology – Visual Pathology Digest (sarcomatoid carcinoma, H&E micrograph). Pristupljeno: srpanj 2026.

Kombinacija invazivne gljivične infekcije i agresivnog malignog procesa predstavlja dijagnostički i terapijski izazov zbog preklapanja simptoma, perineuralnog širenja te brze progresije bolesti s intrakranijalnim i orbitalnim zahvaćanjem. Otkrivanje perineuralnog širenja zahtijeva poznavanje uobičajenih vrsta tumora i lokacija koje mogu uzrokovati njegov nastanak, razumijevanje anatomije relevantnih kranijalnih živaca i poznavanje radiološkog izgleda i tehnika koje su najprikladnije za snimanje ove važne i često zanemarene komplikacije raka glave i vrata [9]. Na MR 3T dokazano je perineuralno širenje tumora što je bilo važno za definiranje terapijskih metoda liječenja [10].

MR mozga (2026.) pokazuje značajnu progresiju bolesti: novonastali patološki nodus u području ponsa desno (12 mm) uz edem, infiltracija srednjeg cerebelarnog pedunkla, progresija perineuralnog širenja duž trigeminalnog živca, izraženija infiltracija desne orbite i ovojnice optičkog živca, zahvaćanje facijalnog i abducensnog živca, potpuna infiltracija desnog sluhovoda tumorskom masom, ekspanzivna tvorba u području nosne šupljine s propagacijom u epifarinks, sfenoidni sinus i pterigopalatinu jamu (33 × 23 × 25 mm), širenje prema infratemporalnoj regiji, denervacijska atrofija mastikatorne muskulature desno.

Odlukom multidisciplinarnog tima indicirana je radikalna radioterapija kao plan liječenja.

Planiranje radioterapije i konturiranje

S obzirom na to da u našoj ustanovi još nije dostupan MR simulator, planiranje radioterapije provedeno je na CT simulatoru uz suradnju radioterapijskog i radiološkog tima. Kako bi se osigurala što bolja anatomska korelacija i točnost fuzije slikovnih metoda, položaj bolesnika na CT simulaciji maksimalno je usklađen s položajem u kojem je učinjen dijagnostički MR pregled na uređaju 3T (MAGNETOM Prisma) uz upotrebu gadolinijskog kontrastnog sredstva.

Precizna i reproducibilna imobilizacija glave i vrata ključna je za točnost visoko precizne radioterapije u području baze lubanje i sinonazalne regije. Naglašena je i preciznost određivanja ukupnog volumena tumora (eng. *Gross Tumor Volume* – GTV) i organa od rizika (eng. *Organs at Risk* – OAR) (slika 3), korištenjem najsuvremenijih tehnika snimanja [11,12].

U tu svrhu korištena je individualizirana dvostruka termoplastična maska radi minimalizacije inter i intrafrakcijskih pomaka. Za snimanje je korišten klasični protokol za glavu i vrat s dva topograma AP i LL na kojima se odredila regija snimanja uz korištenje jodnog kontrastnog sredstva.

Fuzija slikovnih prikaza i izrada plana

CT simulacijski podaci su fuzionirani s MR slikama dobivenim na 3T MR uređaju u svrhu preciznije evaluacije: intrakranijalnog i orbitalnog širenja tumora; perineuralnog širenja duž kranijalnih živaca; odnosa prema kritičnim organskim strukturama (optički živci, optička hijazma, moždano stablo).

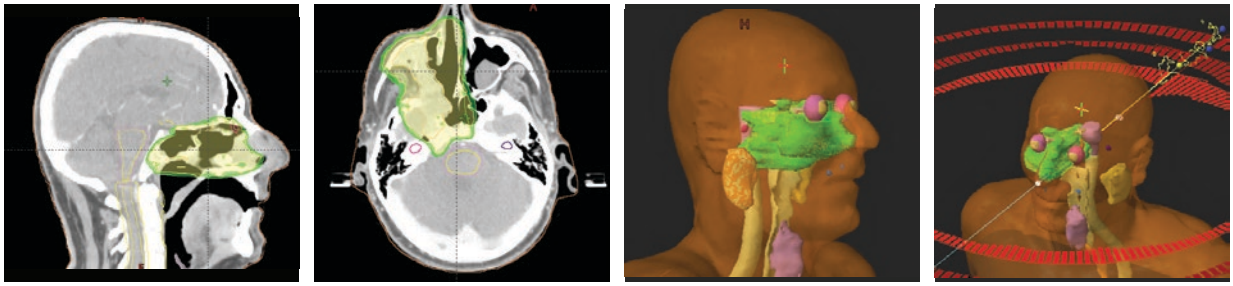
MR ima ključnu ulogu i predstavlja zlatni standard u detekciji mekotkivne i perineuralne infiltracije, zbog izvrsnog prikaza mekih tkiva i živaca, dok i PET/CT postaje sve važniji jer može pokazati intenzitet potrošnje glukoze (pojačano nakupljanje FDG-a) duž živca, metabolički aktivno širenje tumora, promjene mišića zbog denervacije [10].

Snimanje na CT-u omogućuje nam točno dozimetrijsko planiranje [13].

Konturiranje je provedeno u skladu s međunarodnim smjernicama za radioterapijsko ciljanje u području glave i vrata. Plan je izrađen s ciljem postizanja optimalne pokrivenosti PTV-a uz maksimalno poštivanje tolerancijskih doza za organe od rizika (OAR) (slika 3).

Primijenjena je konformalna tehnika visoko preciznog zračenja, odnosno lučna terapija promjenjivog intenziteta (eng. *Volumetric Modulated Arc Therapy* – VMAT), uz svakodnevnu kontrolu pozicioniranja kV CBCT-om. Na područje tumora koji infiltrira početno moždano deblo je aplicirano TD 54 Gy/27 frakcija, a na ostalo područje TD 68 Gy u 34 frakcije s obzirom na kompleksnu anatomiju i blizinu kritičnih struktura [14].

- **GTV (Gross Tumor Volume):** makroskopski vidljiva tumorska masa u orbitalnoj regiji, sinusima i bazi lubanje
- **CTV (Clinical Target Volume):** GTV + potencijalno mikroskopsko širenje uključujući perineuralne putove
- **PTV (Planning Target Volume):** sigurnosni rub za geometrijske nesigurnosti (ICRU)
- **OAR** Organi od rizika (optički živci i optička hijazma, očna jabučica i retina, moždano stablo, temporalni režnjevi, hipofiza (ovisno o zahvaćenosti područja).



Slika 3. Prikaz kontura tumorske mase GTV; CTV; PTV i organa od rizika OAR u sustavu za planiranje temeljem čega je izrađen individualni plan zračenja..
Izvor: autor – sustav za planiranje radioterapije (TPS), KBC Zagreb

Rasprava

Sarkomatoidni karcinomi predstavljaju iznimno rijetke i agresivne malignitete s lošom prognozom i velikim izazovom za dijagnostiku i liječenje bolesti. Zbog rijetkosti ovih karcinoma, u literaturi nema opsežnih studija. U potrazi za boljim razumijevanjem ove patologije, Harris i suradnici (2022.) proveli su studiju na uzorku od 30 pacijenata iz velike američke baze podataka (National Cancer Database) kako bi se bolje objasnili obolijevanje i načini liječenja, s obzirom na blizinu baze lubanje i put širenja prema mozgu [15]. Prognoza ove rijetke bolesti je izrazito loša, sa stopom ukupnog preživljenja od 79,2 % nakon prve godine, te nakon pet godina pada na svega 43,3 %. Univarijantne analize u ovoj kohorti pokazale određene razlike u preživljenju ovisno o dobi, spolu i terapijskom pristupu, međutim multivarijantnom analizom utvrdilo se da nijedan od čimbenika nije neovisni prediktor preživljenja. To jasno ukazuje na agresivnost samog tumora i potrebu detaljnim istraživanjima radi optimizacije liječenja.

Zbog invazivnog rasta ovih tumora i brzom prodiranju i uništavanju okolnog koštanog tkiva otežana je pravovremena intervencija. Ovu agresivnu prirodu detaljno opisuju de Souza Cruz i suradnici (2020.) u prikazu slučaja pacijentice kod koje je CT-om verificirana opsežna ekspanzivna hipodenzna lezija s destrukcijom tvrdog nepca te etmoidnog i sfenoidnog sinusa [16]. Unatoč provedenom kirurškom zahvatu i adjuvantnoj kemoradioterapiji, pacijentica je preminula zbog nagle progresije tumora. Takvu nepovoljnu prognozu dodatno potkrepljuju i Zhu i suradnici (2022.) u svojoj retrospektivnoj studiji sedam pacijenata sa sarkomatoidnim karcinomom sinonazalne regije [17]. U njihovoj studiji prezentirana su četiri pacijenta u uznapredovalom stadiju, s orbitalnom invazijom i zahvaćenošću baze lubanje, a svi su preminuli unutar prve godine od postavljanja dijagnoze.

Konsenzus oko optimalnog terapijskog protokola kod ovakvih lokalno uznapredovalih tumora još uvijek ne postoji, no dosadašnja praksa snažno podupire agresivni multimodalni pristup. Tako je u studiji Harrisa i suradnika (2022.) najčešći oblik liječenja bio kirurški zahvat nakon kojeg je uslijedila radioterapija (kod 76,7 % pacijenata), dok je trećina bolesnika primala i adjuvantnu kemoterapiju [15]. Slično tome, Zhu i suradnici navode da je upravo kombinacija kirurgije i radioterapije pokazala najbolje dostupne ishode u lokalnoj kontroli bolesti kod preostalih preživjelih pacijenata.

Kod bolesnika, poput onog opisanog u našem prikazu, koji pokazuje brzu progresiju bolesti i intrakranijalno širenje tumora u moždani parenhim (dodatno otežano prisutnošću gljivične infekcije), precizno planiranje adjuvantne radioterapije postaje od ključne važnosti. U tom kontekstu, Lin i suradnici (2025.) donose najnovije međunarodne konsenzusne smjernice za ocrtavanje kliničkih ciljnih volumena (CTV) kod različitih razina doza zračenja [11]. Ove smjernice, proizašle iz suradnje vodećih svjetskih stručnjaka, preciziraju anatomske granice za definiranje volumena visokog, srednjeg i niskog rizika, čime se standardizira radioterapijsko planiranje i smanjuje varijabilnost između institucija. Pravilno ocrtavanje CTV-a prema ovim preporukama omogućuje postizanje optimalne letalne doze zračenja na samo tumorsko tkivo uz maksimalnu moguću zaštitu okolnih zdravih tkiva i vitalnih neurovaskularnih struktura, što je pri zahvaćenosti baze lubanje presudno za smanjenje rizika od ozljeda, komplikacija i neželjenih morbiditeta uzrokovanih liječenjem.

Zaključak

Radi se o izrazito kompleksnom i rijetkom kliničkom slučaju obilježenom istodobnim postojanjem agresivnog malignog tumora i kronične invazivne gljivične infekcije. Bolest pokazuje brzu progresiju s intrakranijalnim širenjem i zahvaćanjem moždanog parenhima, što značajno pogoršava prognozu i terapijske mogućnosti. Sljedeći preporuke Lin i suradnika u ovom slučaju je uspješno provedena iradijacija VMAT tehnikom kao primarna metoda liječenja.

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Aggressive perineural and intracranial progression of a skull base lesion with subsequently detected sarcomatoid carcinoma: a case report

Abstract

Objective: A case report of a 52-year-old patient who was treated for chronic inflammation and fungal infection (Aspergillus), underwent multiple surgeries without improvement, and was ultimately diagnosed with sarcomatoid carcinoma of the orbit and sinuses. The role of radiotherapy as the primary therapy for sarcomatoid carcinoma is presented.

Case report: A patient who was initially treated for chronic inflammation and fungal infection also underwent multiple surgeries that did not lead to improvement. After a new biopsy was performed in 2026, the diagnosis of sarcomatoid carcinoma of the orbit and sinuses was revealed. The tumour rapidly spread along the nerves to the orbit, auditory canal, and brainstem, causing severe neurological damage (loss of vision, hearing, and facial sensation). Sarcomatoid carcinoma is a rare and very aggressive tumour with features of both carcinoma and sarcoma. This tumour rapidly destroys bone tissue and metastasises very quickly. Because of its specific structure and symptoms that resemble inflammatory processes, it is very difficult to diagnose, so biopsy is the gold standard for diagnosing this tumour. To treat this extensive and aggressive process, we delivered primary radiotherapy to the tumour area with 6 MeV photon beams using the VMAT technique, with daily positioning control via kV CBCT. TD 54 Gy/27 fractions was applied to the tumour area that infiltrates the initial brainstem, and TD 68 Gy in 34 fractions was applied to the remaining area.

Conclusion: The combination of an aggressive tumour and invasive fungal infection with brain penetration is an extremely rare diagnostic and therapeutic challenge. Primary radiation therapy using the VMAT technique was performed successfully.

Keywords: fungal infection, sarcomatoid carcinoma, rare tumours, radiotherapy planning

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CILJ ZNANSTVENOG SKUPA / AIM OF THE CONGRESS:

Istraživanje opsega djelatnosti zdravstvene radiološko-tehnološke profesije u Republici Hrvatskoj; definiranje položaja i djelokruga rada zdravstvenih radnika – radioloških tehnologa u sustavu zdravstva s fokusom na specifična područja aplikacije kontrastnog sredstva i kliničke edukacije / stažiranja radioloških tehnologa u sustavu zdravstvene zaštite i sustavu visokog obrazovanja.

Motivacija i integracija studenata Radiološke tehnologije kao i aktivnosti u stručnom i profesionalnom razvoju profesije radioloških tehnologa.

Research into the scope of practice of the Medical Radiation Technology profession in the Republic of Croatia; defining the role and work domain of health workers – radiologic technologists in the health system, with a focus on specific areas of contrast medium application and clinical training/ internship of radiologic technologists in the health care system and the higher education system.

Motivation and integration of Medical Radiation Technology students into the activities and professional and vocational development of the Radiologic technologist profession.

Organizator / Organiser:

Hrvatsko društvo radiološke tehnologije
Croatian Association of Radiation Technology
Mlinarska cesta 38, 10000 Zagreb, Hrvatska / Croatia
info@hdtr.hr, www.hdrt.hr

Tehnički organizator / Technical organiser:

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PROGRAM

Četvrtak, 05. studeni 2026. / Thursday, 5th of November 2026

13:00 – 15:00 Registracija / Registration

Dani radiološke tehnologije – pozvana predavanja / Radiation Technology days – invited lectures

moderatori / Chairs: Andrija Čop, Velimir Karadža

16:00 – 16:30 Otvaranje Kongresa / Congress Opening

16:30 – 16:50 Formal Education: Bachelor-level radiographer education and internship requirements across Europe, *Mark F. McEntee (IE)*

16:50 – 17:10 Radiologija kao temelj 3D printanja u personaliziranoj medicini / Radiology as the foundation of 3D printing in personalized medicine, *Merim Jusufbegovic (BA)*

17:10 – 17:30 130 godina od prvog rendgena na hrvatskom tlu / 130 years since the first X-ray on Croatian soil, *Vinko Bubić (HR), Helga Sertić Milić, Ivica Vučak, Krunoslav Marinčević, Frane Mihanović, Mihaela Justić, Željana Bašić, Ivan Jerković, Krešimir Dolić, Velimir Karadža, Vinko Vidjak*

17:30 – 17:50 Building Radiology Safety Culture: An overview of the framework for safety culture in radiology, *Vladimir Bahun (QA)*

17:50 – 18:05 Sponzorsko predavanje – Sponsored Presentation: Budućnost terapije zračenjem: Siemens Healthineers Varian Accela *NeoArc – DMAT* / The Future of Radiation Therapy: Siemens Healthineers Varian Accela *NeoArc – DMAT*

18:30 Riječ dobrodošlice / Welcome reception

Petak, 06. studeni 2026. / Friday, 6th November 2026

Dani Radiološke tehnologije – 2. Simpozij studenata radiološke tehnologije / 2nd Radiation Technology Students Symposium

08:00 – 09:00 Registracija / Registration

09:30 – 10:30 **I dio / Session 1**

voditelji / Chairs: Tatjana Matijaš, Frane Mihanović, Ivan Skejić

09:30 – 09:45 Potencijalni rizici ionizirajućeg zračenja i optimizacija doze u pedijatrijskoj CT dijagnostici / Potential risks of ionizing radiation and dose optimization in paediatric CT diagnostics, *Ira Gabela, Tatjana Matijaš*

09:45 – 09:55 Važnost primjene umjetne inteligencije u dijagnostici multiple skleroze na MR-u / The importance of applying artificial intelligence in the diagnosis of multiple sclerosis on MRI, *Ana Jonjić, Frane Mihanović*

09:55 – 10:05 Od prvostupnika do doktora znanosti: razvoj obrazovanja radioloških tehnologa u RH / From bachelor's degree to doctor of science: the development of radiographer education in Croatia, P*etra Obradović, Lara Zeko, Tatjana Matijaš*

10:05 – 10:20 Vizija razvoja radiološke tehnologije očima studenata / Students vision of the future development of Radiologic technology, *Katarina Parilo, Ivana Rajčić, Nina Zečić*

10:30 - 11:00 Pauza za kavu / Coffee break

11:00 - 12:00 **II dio / Session 2**

voditelji / Chairs: Melita Kukuljan, Maja Karić, Damir Ciprić

11:00 - 11:10 Procjena težine SARS-Cov-2 pneumonije na torakalnim radiogramima modificiranim Brixia sustavom bodovanja / Assessment of the severity of SARS-CoV-2 pneumonia on thoracic radiographs using the modified Brixia scoring system, *Lucija Furjan, Klaudija Višković*

11:10 - 11:20 Primjena kompjutorizirane tomografije u detekciji i procjeni bolesti urotrakta / Application of computed tomography in the detection and assessment of urinary tract diseases, L*orena Kovčić, Karla Špoljar, Maja Karić*

11:20 - 11:30 Usporedba prikaza pektoralnog mišića na MLO mamografskim projekcijama između radioloških tehnologa / Comparison of pectoral muscle representation on MLO mammographic projections between radiological technologists, *Ana Kaluđerović, Maja Karić, Doris Šegota Ritoša*

11:30 - 11:40 Optimizacija kvalitete CT pregleda toraksa: prepoznavanje tehničkih pogrešaka i pravilna primjena dodatnih akvizicija / Optimizing the quality of chest CT examinations: identifying technical errors and correctly applying additional acquisitions, *Valnea Šporer, Melita Kukuljan*

11:40 – 11:50 Optimizacija CT aortografija u pacijenata s aneurizmom abdominalne aorte / Optimization of CT aortography in patients with abdominal aortic aneurysm, *Ivana Grubišić, Lovro Tkalčić*

11:50 – 12:00 Pauza / Break

12:00 – 13:10 **III dio / Session 3**

voditelji / Chairs: Klaudija Višković, Andrija Čop, Dražen Horvatinec

12:00 – 12:15 Što o preporukama za (ne)korištenje kontaktnih zaštitnih sredstava za pacijente znaju i misle studenti treće godine studija radiološke tehnologije? / What do third-year radiological technology students know and think about the recommendations on the (non-)use of patient contact shielding?, *Ian Hriberski, Ivana Kralik*

12:15 – 12:25 Teleradiologija u Hrvatskoj / Teleradiology in Croatia, *Nika Čehulić, Željko Blažić, Đurđa Vincelj Szabo*

12:25 – 12:40 Zračenje protonima u onkološkoj skrbi djece / Proton radiation in paediatric oncology care, *Lana Majetić, Velimir Karadža*

12:40 – 12:50 Vizualna priprema pacijenata / Visual preparation of patients, *Klaudija Dražina, Antonija Serdarević, Ivan Božić, Damir Ciprić*

12:50 – 13:00 Development of a 3D-printed anatomically accurate cardiac phantom with coronary arteries, *Laura Jurša, Nejc Mekiš*

Okrugli stol / Roundtable

moderatori / Chairs: Ana Tripalo Batoš, Velimir Karadža, Tatjana Matijaš

13:00 – 14:00 Okrugli stol – Studiji radiološke tehnologije i kliničke vježbe/praksa / Roundtable – Radiological Technology Studies and Clinical Practice/Placement

14:00 – 15:00 Pauza za ručak / Lunch Break

Dani Radiološke tehnologije – plenarna predavanja / Radiation Technology Days – Plenary session

moderatori / Chairs: Ivanka Herman, Nenad Vodopija

15:00-15:15 Integrirani angio-CT sustavi u intervencijskoj radiologiji – od dijagnostike do liječenja / Integrated angio-CT systems in interventional radiology – from diagnostics to treatment, *Lucija Bratinčević, Bruna Goleš*

15:15-15:30 Koncept angiosoma u endovaskularnom liječenju periferne arterijske bolesti potkoljeničnih arterija / The angiosoma concept in endovascular treatment of peripheral arterial disease of the lower leg arteries, *Josipa Šaškor, Tonći Batinić*

15:30-15:45 MR sigurnost: jesmo li mislili na sve? / MRI Safety: Have We Thought of Everything?, *Krunoslav Marinčević, Mihaela Justić, Lovro Kavur*

15:45-16:00 Škola mamografskog pozicioniranja i interpretacije nalaza kao model unaprjeđenja kvalitete mamografske dijagnostike u Republici Hrvatskoj / School of mammographic positioning and interpretation of findings as a model for improving the quality of mammographic diagnostics in the Republic of Croatia, *Maja Karić, Doris Šegota Ritoša, Petra Valković Zujić*

Radionica / Workshop

moderatori / Chairs: Efthimios Tim Agadakos, Velimir Karadža, Adnan Šehić

16:00 – 17:15 Radionica / Workshop: CT Quality and Safety

Subota, 7. studeni 2026. / Saturday, 7th of November

08:00 Registracija / Registration

Dani Radiološke tehnologije – plenarna predavanja / Radiation Technology Days – Plenary session

Predavanja I / Part 1

moderatori / Chairs: Matija Hranić, Aleksandar Kostovski

10:00 – 10:15 Vidjeti nevidljivo: uloga kontrastom pojačane mamografije u suvremenoj dijagnostici dojke / Seeing the invisible: the role of contrast-enhanced mammography in modern breast diagnostics, *Simona Peremin, Jana Bebek, Gordana Ivanac*

10:15 – 10:30 Ishodi mehaničke trombektomije u izravno primljenih i transferiranih pacijenata u KBC Split tijekom 2025. godine / Outcomes of mechanical thrombectomy in directly admitted and transferred patients at University hospital centre Split during 2025, *Nera Tomić*

10:30 – 10:45 Procjena intrafrakcijskih pomaka tijekom površinski navođene stereotaksijske radioterapije tijela uz zadržavanje daha / Assessment of Intrafractional Displacements in Surface-Guided Inspiration Breath-Hold Stereotactic Body Radiation Therapy, *Domagoj Brkić, Renata Delić Galović, Jelena Trajković, Hrvoje Kaučić*

10:45 – 10:55 Medicinski dijagnostički monitori u radiologiji: tehnički zahtjevi i kontrola kvalitete / Medical diagnostic monitors in radiology: technical requirements and quality control, *Branko Kovalisko, Matija Hranić*

10:55 – 11:05 Učiti na tuđim greškama: ROSEIS sustav kao alat za jačanje sigurnosti pacijenata u radioterapiji / Learning from others' mistakes: ROSEIS as a tool for strengthening patient safety in radiotherapy, *Aleksandar Kostovski*

11:05 – 11:30 Pauza za kavu / Coffee Break

Predavanja II / Part 2

moderatori / Chairs: Dubravko Bobinec, Josip Mamić

11:30 – 11:45 Kontaktna zaštitna sredstva za pacijente: praksa i stavovi radioloških tehnologa i radiologa / Patient contact shielding: practice and attitudes of radiologic technologists and radiologists, *Ivana Kralik, Dario Faj, Matija Hranić, Tomislav Jovanić, Velimir Karadža, Tajana Turk*

11:45 – 12:00 Usporedba pristupa određivanju aktivnosti ^{18}F-FDG-a u onkološkom PET/CT-u / Comparison of approaches to determining ^{18}F-FDG activity in oncological PET/CT, *Josip Grgat, Goran Miličević*

12:00 – 12:15 Optimizacija CT protokola neurokranija u SKB Mostar / Optimization of CT protocol of neurocrania at UCH Mostar, *Bruno Rajič, Marko Krpan*

12:15 – 12:30 Doze zračenja na različitim digitalnim sustavima u radiologiji / Radiation doses on different digital systems in radiology, *Goran Bajs, Dario Posedel, Frane Mihanović*

12:30 – 14:00 Pauza za ručak / Lunch Break

Predavanja III / Part 3

moderatori / Chairs: Branko Kovalisko, Tomislav Jovanić

14:00 – 14:10 MR DOJKE: kada kvaliteta počinje prije prve sekvence / Breast MRI: When quality begins before the first sequence, *Bernarda Malnar Cazin*

14:10 – 14:20 Vrijednost probirne mamografije u detekciji karcinoma dojke / The value of screening mammography in detecting breast cancer, *Ana Matić, Krešimir Dolić*

14:20 – 14:30 MR skrotuma i penisa – indikacije, izvođenje pretrage i prikaz slučaja / MRI of the scrotum and penis – indications, examination performance and case report, *Sara Gabrić*

14:30 – 14:40 MR artrografija ramena / MR arthrography of the shoulder, *Monika Likić, Eugen Divjak*

14:40 – 14:50 Analiza učestalosti fraktura gornjih i donjih ekstremiteta kod pedijatrijskih hitnih prijema / Analysis of the frequency of upper and lower extremity fractures in paediatric emergency departments, *Ana Tibljaš, Maja Karić*

14:50 – 15:00 Brzina aplikacije kontrastnog sredstva kao jedan od čimbenika postkontrastnog obojenja / Contrast injection rate as a factor in post-contrast opacification, *Tomislav Jovanić*

15:00 – 15:10 Pauza / Break

Predavanja IV / Part 4

moderatori / Chairs: Vedran Manestar, Krunoslav Marinčević

15:10 – 15:20 Denzitometrija kao tabu u dječjoj dobi – važnost pravodobne procjene koštanog zdravlja u pedijatrijskoj populaciji / Densitometry as a taboo in childhood – the importance of timely assessment of bone health in the paediatric population, *Ana Marija Medenjak, Kristina Puklin, Ana Tripalo Batoš*

15:20 – 15:30 Utjecaj kratke edukacije na razumijevanje medicinskog zračenja u privatnoj radiološkoj praksi / The impact of a short training course on the understanding of medical radiation in private radiology practice, *Rudolf Rogić, Toni Knežević, Maja Crnogorac, Mališa Vasić, Martin Drinković*

15:30 – 15:40 Stres pod kontrolom: perfuzijska magnetska rezonancija srca u kliničkoj praksi / Stress under control: cardiac perfusion Magnetic Resonance Imaging in clinical practice, *Morana Madžo, Tomislav Delić*

15:40 – 15:50 Uloga empatije radiološkog tehnologa u ublažavanju anksioznosti i klaustrofobije tijekom MR pregleda / The role of radiologic technologist empathy in alleviating anxiety and claustrophobia during MR examinations, *Nikolina Gracić, Tatjana Matijaš*

15:50 – 16:00 Uloga „traffic light" sustava u prepoznavanju potrebe za resimulacijom tijekom radioterapije bolesnika s tumorima glave i vrata / The role of the „traffic light" system in identifying the need for re-simulation during radiotherapy of patients with head and neck tumours, *Mirta Barbir, Marta Topić*

DVORANA FORUM – RADIONICA / FORUM HALL – WORKSHOP

moderatori /Chairs: Ema Muše, Sara Morović, Enis Tinjak, Valerija Žager Marciuš

14:00 – 16:00 Radionica / Workshop: "Train the RTT Trainers" – Uključivanje novih sadržaja iz područja radioterapije u postojeći obrazovni program / Building New Radiotherapy Content into the Existing Educational Programme

16:00 – 16:30 Pauza za kavu / Coffee Break

16:30 – 16:45 IV Contrast: International practice, education, and variation in contrast administration, *Mark F. McEntee*

Okrugli stol / Roundtable

moderatori / Chairs: Vladimir Bahun, Mark F. McEntee

16:45 – 18:00 Okrugli stol / Roundtable: Aplikacija kontrastnog sredstva – preporuke i klinička praksa / Contrast agents – administration, recommendations and clinical practice

18:00 Završna riječ drugog dana Kongresa / Final word of the Congress Second Day

Nedjelja, 8. studenog 2026. / Sunday, 8th of November

Predavanja V / Part 5

moderatori / Chairs: Ivan Božić, Jozo Prcela

10:00 – 10:10 MSCT koronarografija i CT srca u svakodnevnoj kliničkoj praksi / MSCT coronary angiography and cardiac CT in everyday clinical practice, *Ivo Kalčić, Damir Pranjić*

10:10 – 10:20 CT angiografija donjih ekstremiteta naprednom „double time bolus" metodom snimanja / CT angiography of the lower extremities using the advanced „double time bolus" imaging method, *Toni Lovnički*

10:20 – 10:30 vFFR metoda u procjeni stenoze koronarnih arterija / vFFR method in the assessment of coronary artery stenosis, *Dora Sladaković, Marijo Kujundžić-Lujan*

10:30 – 10:40 Implementacija ABUS metode u KBC-u Rijeka: Iskustva u kliničkoj praksi / Implementation of Automated Breast Ultrasound (ABUS) at Rijeka Clinical Hospital Center: Clinical Practice Experience, *Ema Komadina*

10:40 – 10:50	Uloga radiološkog tehnologa u CT dijagnostici akutnog ishemijskog moždanog udara i pripremi za neurointervencijske postupke / The role of the radiological technologist in CT diagnostics of acute ischemic stroke and preparation for neurointerventional procedures, *Lorena Fugošić, Ariana Vidmar, Lara Kragulj*
10:50 – 11:00	Krioablacija osteoid osteoma pod kontrolom CT-a / CT-guided cryoablation of osteoid osteoma, *Ivana Mrmić Bašić, Marta Serdarušić, Martina Gregurović*
11:00 – 11:3	Pauza za kavu / Coffee Break
11:30 – 11:45	Obilježavanje Svjetskog dana radiologije / Celebrating World Radiology Day

Okrugli stol / Roundtable

moderatori / Chairs: Tatjana Matijaš, Frane Mihanović

11:45 – 12:15	Okrugli stol / Roundtable: Suradnja, zajedništvo i udruživanje snaga – „Viribus Unitis" u radiološkoj tehnologiji / Cooperation, togetherness and joining forces – „Viribus Unitis" in radiological technology
12:15	Zatvaranje Kongresa / Closing Ceremony

Poster prezentacije / Poster presentations

1. Suvremeni pristup TBI terapiji na Klinici za onkologiju KBC-a Zagreb / Contemporary approach to TBI therapy at the Oncology Clinic of UHC Zagreb, *Arijana Petković, Helena Režić, Marina Puntarec*
2. Utjecaj različitih čimbenika na kvalitetu slikovnih podataka kod MR-a i radioterapije prostate / The influence of various factors on the quality of imaging data in MRI and prostate radiotherapy, *Sara Jurilj, Ivana Vukašinović, Tomislav Jovanić*
3. Pristup pacijentu uz empatiju i razumijevanje tijekom radioloških pretraga / Approaching the patient with empathy and understanding during radiological examinations, *Vladimir Tolić, Mate Marasović*
4. Embolizacija aneurizme lijenalne arterije / Embolization of splenic artery aneurysm, *Marko Milićević, Andrej Požgaj*
5. Optimizacija dnevne provjere kvalitete na linearnom akceleratoru Elekta Harmony KZT integracijom sustava IBA myQA Daily / Optimization of Daily Quality Assurance on the Elekta Harmony Linear Accelerator by Integrating the IBA myQA Daily System, *Ana Udovičić, Edina Meštrović, Vladimira Ugarković*
6. MSCT Polytrauma Dual Energy, *Alen Udovičić, Mateo Mance*
7. Shielding doors in radiology and radiotherapy, *Milan Radojević, Luka Lazarević, Mirjana Milinčić, Jovan Stevanović*
8. Umjetna inteligencija kao podrška radiološkom tehnologu u suvremenoj radiološkoj praksi / Artificial intelligence as support for radiological technologists in modern radiological practice, *Bruna Goleš, Lucija Bratinčević*
9. The role of the radiologic technologist (RTT) in VMAT treatment of primary CNS tumours, *Daniela Pavlovska, Igor Stojkovski*
10. Modularne intervencije temeljene na igri u pedijatrijskoj radiologiji i radioterapiji: perspektiva radiološkog tehnologa / Modular Play-Based Interventions in Paediatric Imaging and Radiotherapy: A Technologist's Perspective, *Ema Matoš, Mia Šimić, Damir Ciprić*
11. Tetovaže kao dijagnostički izazov u mamografiji / Tattoos as a diagnostic challenge in mammography, *Matea Bolčić*, *Marina Krmek*
12. Usporedba udaljenosti mandibularnog kanala od ruba alveolarnog grebena u ozubljenih i bezubih ispitanika analizom CBCT snimki / Comparison of the distance between the alveolar ridge crest and the mandibular canal in dentate and edentulous subjects using CBCT imaging analysis, *Lucija Kraljević*, *Tatjana Matijaš*, *Tea Galić*
13. PET CT u dijagnostici srčanih infekcija / PET/CT in the diagnosis of cardiac infections, *Helena Medvedec, Martina Ivandić*
14. Perfuzijska scintigrafija mozga s Tc-99m-HMPAO u postupku dokazivanja moždane smrti / Brain perfusion scintigraphy with Tc-99m-HMPAO in the procedure of confirming brain death, *Domagoj Štefanić, Lucija Čičak*
15. Uloga tehnologa kod izvođenja jednofotonske emisijske tomografije mozga sa I-123 ioflupanom (DaTscan) / The role of the technologist in performing brain single-photon emission computed tomography (SPECT) with I-123 ioflupane (DaTscan), *Matija Mlinar, Marija Kos Rožman*

KNJIGA SAŽETAKA

USMENA IZLAGANJA / ORAL PRESENTATIONS

* Prezentatori su označeni zvjezdicom / Presenters are marked with an asterisk

Formal Education: Bachelor-level radiographer education and internship requirements across Europe

Mark F. McEntee*
College of Medicine and Health, Brookfield Health Sciences

Abstract

Rapid technological transformation, including artificial intelligence, hybrid imaging, and complex radiation oncology, demands elevated clinical autonomy and scientific rigour from radiographers. To safeguard patient safety and optimize clinical outcomes, initial pre-registration training must decisively transcend historical vocational frameworks. The European Federation of Radiographers' Societies firmly establishes that standard pre-registration radiography education must be positioned at European Qualifications Framework Level 6, comprising a comprehensive 180 to 240 ECTS Bachelor curriculum within the European Higher Education Area. Crucially, international empirical research demonstrates that robust, structured clinical internships representing a minimum of twenty-five percent of overall programme duration are indispensable for bridging theoretical knowledge, ensuring radiation protection competencies under Council Directive 2013/59/Euratom, and fostering critical reflexive practice. Aligning national standards with these educational benchmarks directly reinforces European Union strategic healthcare workforce priorities, elevates service quality, and facilitates seamless cross-border professional mobility pursuant to Directive 2005/36/EC. However, substantial variations in academic entry requirements and practical internship hours across European states continue to generate unwarranted disparities in clinical capability and recognition. The EFRS aims to unify European academic standards, guarantee harmonised clinical internships, and empower radiographers as autonomous leaders shaping future healthcare.

Keywords: *Formal Education, Bachelor, radiographer, internship*

Radiology as the foundation of 3D printing in personalised medicine

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Abstract

Radiological diagnostics represent the foundation of contemporary medical 3D printing, as they enable precise visualisation of anatomical structures, digital segmentation, and the creation of personalised models based on real patient data. The development of advanced radiological technologies, particularly CT and MRI imaging, has made it possible to transform medical images into three-dimensional digital and physical models that play an increasingly important role in education, planning of complex surgical procedures, communication within multidisciplinary teams, and the development of individualised therapeutic solutions.

Keywords: *Radiology, Medical 3D printing, Personalised medicine*

130 godina od prvog rendgena na hrvatskom tlu

Vinko Bubić*[1], Helga Sertić Milić[2], Ivica Vučak[2], Krunoslav Marinčević[1], Frane Mihanović[3], Mihaela Justić[1], Željana Bašić[4], Ivan Jerković[4], Krešimir Dolić[5], Velimir Karadža[6], Vinko Vidjak[1,7]

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Sažetak

Cilj: Prikazati razvoj radiologije u Hrvatskoj u kontekstu europskih i svjetskih zbivanja, s naglaskom na dinamiku prijenosa znanja, ranu primjenu rendgenskih zraka, institucionalizaciju struke te uvođenje ključnih slikovnih metoda tijekom 20. stoljeća. **Materijali i metode:** Provedeno je povijesno-analitičko istraživanje primarnih i sekundarnih izvora. Analizirani su arhivski dokumenti, stručni i znanstveni časopisi, bolničke monografije, novinski izvori, osobne ostavštine i digitalizirane zbirke. Pretraživani su hrvatski i inozemni izvori prema pojmovima vezanim uz rendgenologiju, radiologiju, računalnu tomografiju, magnetsku rezonanciju i intervencijsku radiologiju, uz usporedbu hrvatskih vremenskih točaka s vodećim europskim i svjetskim centrima. **Rezultati:** Hrvatska je vrlo rano prihvatila Röntgenovo otkriće. Već 1896. pojavljuju se prvi stručni prikazi i pokusi, a krajem 19. i početkom 20. stoljeća rendgenski uređaji uvode se u više hrvatskih gradova. Razvoj struke obilježili su prijenos znanja iz Beča i drugih europskih središta, osnivanje radioloških odjela i sveučilišne nastave te profesionalizacija radiologa. Arhivska građa dodatno rasvjetljava uloge ranih hrvatskih radiologa, uključujući Branka Bressana i Milana Neumanna. Prvi CT uređaj instaliran je na KBC-u Zagreb 1975., čime je Hrvatska pratila rani europski razvoj računalne tomografije. Prvi MR uređaj u Hrvatskoj uveden je 7. srpnja 1989. u tadašnjoj Bolnici Josip Kajfež u Zagrebu. Od kraja 1970-ih i tijekom 1980-ih intenzivno se razvija i intervencijska radiologija. **Zaključak:** Razvoj hrvatske radiologije pokazuje da je Hrvatska u ranoj implementaciji rendgenske tehnologije i CT-a pratila europski razvojni tijek, dok je uvođenje MR-a ostvareno s većim vremenskim odmakom. Povijest radiologije pritom nije samo povijest uređaja, nego i institucionalizacije, prijenosa znanja i profesionalizacije medicinske struke.

Ključne riječi: *Hrvatska; povijest medicine; medicinsko oslikavanje; radiologija; rendgenske zrake.*

130 years since the first X-ray on Croatian soil

Abstract

Objective: To present the development of radiology in Croatia within the context of European and global developments, with emphasis on the transfer of knowledge, early adoption of X-rays, institutionalization of the profession, and introduction of key imaging modalities during the twentieth century. **Materials and Methods:** A historical-analytical study of primary and secondary sources was performed. Archival documents, professional and scientific journals, hospital monographs, newspaper sources, personal collections, and digitized archives were analyzed. Croatian and international sources were searched using terms related to roentgenology, radiology, computed tomography, magnetic resonance imaging, and interventional radiology, and major Croatian milestones were compared with developments in leading European and international centers. **Results:** Croatia adopted Röntgen's discovery at an early stage. The first professional reports and experiments appeared as early as 1896, while X-ray equipment was introduced in several Croatian cities by the end of the nineteenth and beginning of the twentieth century. The development of the discipline was shaped by the transfer of knowledge from Vienna and other European centers, the establishment of radiology departments and university teaching, and the professionalization of

radiologists. Archival material further clarifies the roles of early Croatian radiologists, including Branko Bressan and Milan Neumann. The first CT scanner was installed at Zagreb University Hospital Centre in 1975, placing Croatia within the early European development of computed tomography. The first MRI system in Croatia entered clinical use on 7 July 1989 at the then Josip Kajfež Hospital in Zagreb. Interventional radiology developed rapidly from the late 1970s and throughout the 1980s. **Conclusion:** The development of Croatian radiology shows that Croatia closely followed leading European trends in the early implementation of X-ray technology and CT, whereas MRI was introduced with a greater time lag. The history of radiology should therefore be understood not only as a history of technology, but also as a process of institutionalization, knowledge transfer, and professional development.

Keywords: *Croatia; history of medicine; medical imaging; radiology; X-rays*

Building radiology safety culture: Prikaz okvira za sigurnosnu kulturu u radiologiji

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Sažetak

Cilj: Uvesti pojam sigurnosne kulture u radiološku praksu i predstaviti Building Radiology Safety Culture (BRSC) – strukturirani okvir za uloge, obveze i ponašanja koja podržavaju sigurnost pacijenata i osoblja u radiologiji, konceptualno i operativno razgraničen od radijacijske sigurnosti i osiguranja kvalitete. **Materijali i metode:** BRSC je razvijen kao okvir usmjeren na kliničku praksu, utemeljen na literaturi o sigurnosnoj kulturi, kulturi pravednosti (just culture), psihološkoj sigurnosti i ljudskim faktorima, te na kliničkom iskustvu autora u radiološkoj praksi. Okvir je strukturiran u dvanaest međusobno povezanih područja koja pokrivaju individualnu, lidersku i sustavnu dimenziju sigurnosti. Nakon razvoja, eksplicitno je usklađen s međunarodnim standardima i regulatornim dokumentima primjenjivim u zdravstvu i radiologiji, uključujući JCI, IAEA (GSR Part 1/3, SSG-46, Safety Culture Traits), WHO GPSAP, Euratom 2013/59, IR(ME)R 2017 te norme ISO 9001/45001/31000, uz usklađenost s dodatnim nacionalnim okvirima u više jurisdikcija, kako bi bio izravno primjenjiv u akreditacijskim procesima. Prva prezentacija okvira evaluirana je putem pre/post upitnika (N=25). **Rezultati:** Okvir razlikuje tri konceptualno zasebna sloja – tehničku sigurnost, osiguranje kvalitete i sigurnosnu kulturu – koji se u praksi često pogrešno izjednačavaju. Model podijeljene odgovornosti (pojedinac – vodstvo – organizacija) rješava paradoks da je "gdje su svi odgovorni, zapravo nitko nije" pružanjem eksplicitne mape primarne i dijeljene odgovornosti, te odgovornosti na razini obaviještenosti, po ulogama u radiološkom timu (radiolog, radiološki tehnolog, medicinska sestra, medicinski fizičar, prateće osoblje). U prvoj provedbi edukacije, razumijevanje sigurnosne kulture poraslo je sa srednje vrijednosti 2,6 na 4,6 na petostupanjskoj Likertovoj ljestvici (+68 %); prihvaćanje okvira bilo je 4,8/5. Najveći pomak u razumijevanju zabilježen je među najiskusnijim kliničarima (16+ godina iskustva): +2,50 – veći od ispitanika sa 6-15 godina iskustva. **Zaključak:** BRSC pruža operativnu strukturu koju radijacijska sigurnost i osiguranje kvalitete po svom opsegu ne mogu strukturalno pokriti. Namijenjen je svim zdravstvenim profesionalcima u radiologiji, bez obzira na ulogu, kao i voditeljima odjela, izvršnom menadžmentu i regulatornim tijelima. Primjena okvira zahtijeva multidisciplinarni pristup na odjelnoj i organizacijskoj razini.

Ključne riječi: *BRSC; kultura pravednosti; psihološka sigurnost; radiologija; sigurnosna kultura*

Building Radiology Safety Culture: An overview of the framework for safety culture in radiology

Abstract

Objective: To introduce the concept of safety culture to radiology practice and present Building Radiology Safety Culture (BRSC) – a structured framework for roles, obligations, and behaviours that support patient and staff safety in radiology, conceptually and operationally distinguished from radiation safety and quality assurance. **Materials and Methods:** BRSC was developed as a practitioner-facing framework, grounded in the literature on safety culture, just culture, psychological safety, and human factors, and drawing on the author's clinical experience in radiology practice. The framework is structured into twelve interrelated domains covering individual, leadership, and systemic dimensions of safety. Following development, it was explicitly mapped to international standards and regulatory documents applicable in healthcare and radiology, including JCI, IAEA (GSR Part 1/3, SSG-46, Safety Culture Traits), WHO GPSAP, Euratom 2013/59, IR(ME)R 2017, and ISO 9001/45001/31000 standards, alongside alignment with further national frameworks across multiple jurisdictions, to make it directly applicable within accreditation processes. The initial presentation of the framework was evaluated by a pre/post questionnaire (N=25). **Results:** The framework distinguishes three conceptually distinct layers – technical safety, quality assurance, and safety culture – that are frequently conflated in practice. A shared responsibility model (individual – leadership – organisation) resolves the paradox that "where everyone is responsible, no one really is" by providing an explicit map of primary, shared, and awareness-level responsibilities across roles in the radiology team (radiologist, radiographer, nurse, medical physicist, support staff). In the initial delivery, understanding of safety culture increased from a mean of 2.6 to 4.6 on a five- point Likert scale (+68 %); framework acceptance was 4.8/5. The largest shift in understanding was recorded among the most experienced clinicians (16+ years of experience): +2.50 – greater than respondents with 6-15 years of experience. **Conclusion:** BRSC provides an operational structure that radiation safety and quality assurance cannot, by their scope, structurally cover. It is intended for all healthcare professionals in radiology, regardless of role, as well as for department leaders, executive management, and regulatory bodies. The application of the framework requires a multidisciplinary approach at the departmental and organisational levels.

Keywords: *BRSC; just culture; psychological safety; radiology; safety culture*

Potencijalni rizici ionizirajućeg zračenja i optimizacija doze u pedijatrijskoj CT dijagnostici

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Sažetak

Kompjutorizirana tomografija (CT) ima važnu ulogu u dijagnostici brojnih pedijatrijskih bolesti i ozljeda zbog svoje brzine, dostupnosti i visoke dijagnostičke točnosti. Međutim, zbog veće osjetljivosti djece na ionizirajuće zračenje, optimizacija doze predstavlja važan izazov pedijatrijske radiologije. Ovaj pregledni rad analizira potencijalne rizike izloženosti ionizirajućem zračenju tijekom pedijatrijskih CT pretraga te mogućnosti smanjenja i optimizacije doze. Pretraživanje literature provedeno je tijekom ožujka i travnja 2026. u bazama PubMed i Scopus, dok su Google Scholar i ResearchGate korišteni za dodatno pretraživanje relevantne literature i pristup cjelovitim tekstovima radova. Sustavnim pretraživanjem identificirano je ukupno 848 radova. Nakon uklanjanja duplikata te pregleda naslova, sažetaka i procjene cjelovitih tekstova, u konačnu analizu uključeno je 70 znanstvenih radova. Dostupna literatura pokazuje trend smanjenja doza zahvaljujući tehnološkom napretku CT uređaja, primjeni prilagođenih pedijatrijskih protokola, automatskoj kontroli ekspozicije, iterativnim rekonstrukcijama i dijagnostičkim referentnim razinama. Rizik povezan s CT dijagnostikom moguće je značajno smanjiti pravilnom opravdanošću pretrage, prilagodbom protokola dobi i tjelesnoj građi djeteta te primjenom suvremenih tehnologija za redukciju doze. Posebno se ističe uloga radioloških tehnologa i međunarodnih smjernica u standardizaciji postupaka i unapređenju radiološke zaštite djece.

Ključne riječi: *ionizirajuće zračenje; optimizacija doze; pedijatrijska CT dijagnostika; radiološka zaštita; radiološki tehnolog; rizici zračenja*

Potential risks of ionizing radiation and dose optimization in paediatric CT diagnostics

Abstract

Computed tomography (CT) plays an important role in the diagnosis of numerous paediatric diseases and injuries due to its speed, availability, and high diagnostic accuracy. However, because children are more sensitive to ionizing radiation, dose optimization represents a significant challenge in paediatric radiology. This review paper analyzes the potential risks associated with exposure to ionizing radiation during paediatric CT examinations, as well as the possibilities for dose reduction and optimization. A literature search was conducted during March and April 2026 using the PubMed and Scopus databases, while Google Scholar and ResearchGate were used for additional searches of relevant literature and access to full-text articles. A total of 848 studies were identified through the systematic search. After the removal of duplicates and the screening of titles, abstracts, and full-text articles, 70 scientific papers were included in the final analysis. The available literature indicates a trend toward dose reduction due to technological advancements in CT systems, the implementation of adapted paediatric protocols, automatic exposure control, iterative reconstruction techniques, and diagnostic reference levels. The risks associated with CT imaging can be significantly reduced through appropriate justification of examinations, adaptation of protocols to the child's age and body habitus, and the application of modern dose-reduction technologies. Particular emphasis is placed on the role of radiologic technologists and international guidelines in the standardization of procedures and the enhancement of radiation protection for children.

Keywords: *dose optimization; ionizing radiation; paediatric computed tomography; radiation protection; radiation risks; radiologic technologist*

Važnost primjene umjetne inteligencije u dijagnostici multiple skleroze na MR-u

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Sažetak

Multipla skleroza kronična je autoimuna bolest središnjeg živčanog sustava koja zahvaća mozak i leđnu moždinu te može uzrokovati različite neurološke simptome i oštećenja. Najvažnija metoda dijagnostike i praćenja bolesti je magnetska rezonancija zbog mogućnosti detaljnog prikaza promjena u mekim tkivima. Ovaj rad prikazuje važnost primjene umjetne inteligencije u analizi MR snimki k od bolesnika s multiplom sklerozom. Opisane su mogućnosti njezine primjene u automatskom prepoznavanju i segmentaciji lezija te u praćenju progresije bolesti. Poseban naglasak stavljen je na važnost korištenja odgovarajućih MR sekvenci i pravilnog izvođenja protokola kako bi se dobile kvalitetne i pouzdane snimke za analizu. Također je istaknuta važna uloga radiološkog tehologa u izvođenju MR pretrage, odabiru protokola i osiguravanju kvalitete snimki potrebnih za točnu dijagnostiku i daljnje praćenje bolesnika.

Ključne riječi: *Multipla skleroza, magnetska rezonancija, umjetna inteligencija, radiološki tehnolog, MR dijagnostika*

The importance of applying artificial intelligence in the diagnosis of multiple sclerosis on MRI

Abstract

Multiple sclerosis is a chronic autoimmune disease of the central nervous system that affects the brain and spinal cord and may cause various neurological symptoms and impairments. Magnetic resonance imaging is the most important diagnostic method for monitoring the disease due to its ability to provide a detailed view of soft tissue structures. This paper presents the importance of artificial intelligence in the analysis of MR images in patients with multiple sclerosis. The possibilities of its application in the automatic detection and segmentation of lesions, as well as in monitoring disease progression, are described. Special emphasis is placed on the importance of using appropriate MR sequences and properly performed protocols in order to obtain high-quality and reliable images for analysis. The important role of the radiological technologist in performing MR examinations, selecting protocols, and ensuring image quality necessary for accurate diagnosis and further patient monitoring is also highlighted.

Keywords: *Multiple sclerosis, magnetic resonance imaging, artificial intelligence, radiological technologist, MR diagnostics*

Od prvostupnika do doktora znanosti: razvoj obrazovanja radioloških tehnologa u RH

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Sažetak

Razvoj suvremene radiološke tehnologije i sve složeniji zahtjevi zdravstvenog sustava stvaraju potrebu za kontinuiranim obrazovanjem radioloških tehnologa. Cilj rada je prikazati moguænosti obrazovanja i profesionalnog razvoja radioloških tehnologa u RH, od prijediplomske i diplomske do doktorske razine obrazovanja. Poseban naglasak stavljen je na važnost nastavka obrazovanja za razvoj struènih, istraživaèkih i akademskih kompetencija. Obrazovanje radioloških tehnologa provodi se na sveuèilišnoj prijediplomskoj i diplomskoj razini, dok se daljnji znanstveni razvoj može nastaviti kroz doktorske studije u području Biomedicine i zdravstva. Doktorski studiji u RH omoguæuju stjecanje kompetencija potrebnih za samostalan znanstveno-istraživaèki rad te razvoj akademske i znanstveno-nastavne karijere. Obrazovanje na višim razinama omoguæuje radiološkim tehnolozima uključèivanje u znanstveno-istraživaèki rad, razvoj novih znanja i sudjelovanje u unapređenju zdravstvene skrbi. Stoga kontinuirano obrazovanje ne treba promatrati samo kao stjecanje višeg akademskog stupnja, veæ kao moguænost razvoja profesije i njezine veæe prepoznatljivosti u zdravstvenom sustavu.

Zaključno, povezivanje prijediplomskog, diplomskog i doktorskog obrazovanja predstavlja važan korak u daljnjem razvoju radiološke tehnologije kao suvremene zdravstvene profesije.

Ključne riječi: *radiološka tehnologija, obrazovanje, profesionalni razvoj, doktorski studij, Biomedicina i zdravstvo.*

From bachelor's degree to doctor of science: the development of radiographer education in Croatia

Abstract

The development of modern radiologic technology and the increasingly complex demands of the healthcare system create a need for continuous education of radiographers. The aim of this paper is to present the opportunities for education and professional development of radiographers in Croatia, from undergraduate and graduate to doctoral levels of education. Particular emphasis is placed on the importance of continuing education for the development of professional, research, and academic competencies. Radiographer education is provided at the university undergraduate and graduate levels, while further scientific development can be pursued through doctoral studies in the field of Biomedicine and Health. Doctoral studies in Croatia enable the acquisition of competencies required for independent scientific research and the development of academic and scientific-teaching careers. Education at higher levels enables radiographers to become involved in scientific research, contribute to the development of new knowledge, and participate in the improvement of healthcare. Therefore, continuous education should not be viewed solely as obtaining a higher academic degree, but rather as an opportunity for the development of the profession and its greater recognition within the healthcare system.

In conclusion, connecting undergraduate, graduate, and doctoral education represents an important step in the further development of radiography as a modern healthcare profession.

Keywords: *radiography, education, professional development, doctoral studies, Biomedicine and Health.*

Vizija razvoja radiološke tehnologije očima studenata

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Sažetak

Radiološka tehnologija jedno je od najdinamičnijih područja suvremene zdravstvene skrbi, a njezin razvoj usko je povezan s napretkom medicinske tehnologije, digitalizacijom zdravstvenog sustava i sve većom primjenom umjetne inteligencije. Razvoj radiografije, računalne tomografije, magnetske rezonancije, nuklearne medicine i radioterapije omogućuje precizniju dijagnostiku i liječenje te istodobno nadopunjuje znanja, vještine i odgovornosti radiološkog tehnologa. Cilj rada je prikazati viziju budućeg razvoja radiološke tehnologije iz perspektive studenata te istaknuti tehnološke, stručne i obrazovne promjene važne za budućnost profesije. Posebno važan smjer razvoja predstavlja primjena umjetne inteligencije i automatiziranih sustava u obradi medicinskih slika, optimizaciji protokola snimanja i podršci zdravstvenim stručnjacima pri donošenju odluka. Očekuje se daljnje unaprjeđenje slikovnih dijagnostičkih metoda, povećanje kvalitete prikaza i skraćivanje vremena izvođenja postupaka. Pritom ključni cilj ostaje optimizacija izloženosti ionizirajućem zračenju uz očuvanje dijagnostičke kvalitete slike i sigurnosti pacijenta. Uloga radiološkog tehnologa neće se temeljiti samo na tehničkom znanju i rukovanju medicinskom opremom. Sve važnije bit će digitalne kompetencije, razumijevanje umjetne inteligencije, procjena kvalitete radioloških postupaka, interdisciplinarna suradnja i kontinuirano stručno usavršavanje. Zbog brzih tehnoloških promjena obrazovanje budućih radioloških tehnologa potrebno je stalno prilagođavati suvremenoj kliničkoj praksi. Takav razvoj zahtijeva veću prilagodljivost, kvalitetnije povezivanje teorijskog obrazovanja s praktičnim radom te spremnost studenata na cjeloživotno učenje, praćenje novih tehnologija i aktivno sudjelovanje u unapređenju radiološke profesije i zdravstvene skrbi.

Iz studentske perspektive, tehnološki napredak ne smije umanjiti važnost ljudskog čimbenika. Komunikacija s pacijentom, empatija, etičnost, profesionalna odgovornost, zaštita privatnosti i sigurnost pacijenta ostaju temelj kvalitetne zdravstvene skrbi. Tehnologiju stoga treba promatrati kao nadopunu stručnosti, a ne njezinu zamjenu. Studenti, kao budući nositelji razvoja profesije, imaju važnu ulogu u odgovornom prihvaćanju i kritičkoj primjeni inovacija. Budućnost radiološke tehnologije predstavlja spoj tehnološkog napretka, stručnog znanja i pristupa usmjerenog na pacijenta.

Ključne riječi: *radiološka tehnologija, studenti, umjetna inteligencija, digitalizacija, radiološki tehnolog, budućnost struke*

Students vision of the future development of Radiologic technology

Abstract

Radiological technology is one of the most dynamic fields of modern healthcare, and its development is closely linked to advances in medical technology, the digitalization of the healthcare system, and the increasing application of artificial intelligence. The development of radiography, computed tomography, magnetic resonance imaging, nuclear medicine, and radiotherapy enables more precise diagnosis and treatment while simultaneously expanding knowledge, skills, and responsibilities of radiologic technologists. The aim of this paper is to present a vision of the future development of radiological technology from the perspective of students and to highlight technological, professional, and educational changes important for the future of the profession.

A particularly important direction of development is the application of artificial intelligence and automated systems in medical image processing, optimization of imaging protocols, and support for healthcare professionals in decision-making. Further improvement of diagnostic imaging methods, higher image quality, and shorter procedure times are expected. At the same time, a key objective remains the optimization of exposure to ionizing radiation while preserving diagnostic image quality and patient safety.

The role of radiologic technologists will not be based solely on technical knowledge and the operation of medical equipment. Digital competencies, understanding of artificial intelligence, assessment of the quality of radiological procedures, interdisciplinary collaboration, and continuous professional development will become increasingly important. Due to rapid technological changes, the education of future radiologic technologists must be continuously adapted to contemporary clinical practice. Such development requires greater adaptability, better integration of theoretical education with practical work, and students' readiness for lifelong learning, keeping up with new technologies, and actively contributing to the advancement of the radiological profession and healthcare.

From the students' perspective, technological progress must not diminish the importance of the human factor. Communication with patients, empathy, ethics, professional responsibility, privacy protection, and patient safety remain the foundations of high-quality healthcare. Technology should therefore be viewed as a complement to professional expertise rather than its replacement. As future drivers of professional development, students have an important role in the responsible adoption and critical application of innovations. The future of radiological technology represents a combination of technological progress, professional knowledge, and a patient-centered approach.

Keywords: *radiological technology, students, artificial intelligence, digitalization, radiologic technologist, future of the profession*

Procjena težine SARS-CoV-2 pneumonije na torakalnim radiogramima modificiranim Brixia sustavom bodovanja

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Sažetak

Uvod i cilj: COVID-19, uzrokovan virusom SARS-CoV-2, obilježava širok spektar kliničkih manifestacija, od asimptomatske infekcije do teške pneumonije. Digitalna torakalna radiografija omogućuje procjenu zahvaćenosti plućnog parenhima i težine bolesti. Cilj istraživanja bio je analizirati inicijalne digitalne torakalne radiograme hospitaliziranih bolesnika s PCR-dokazanom COVID-19 pneumonijom, odrediti težinu pneumonije prema modificiranom Brixia sustavu bodovanja (MBSB) te ispitati povezanost MBSB-a s ishodom bolesti i komplikacijama. **Ispitanici i metode:** Retrospektivnim istraživanjem obuhvaćeno je 150 bolesnika hospitaliziranih u Klinici za infektivne bolesti „Dr. Fran Mihaljević"u Zagrebu, od kojih je 75 izliječeno, a 75 preminulo. Bolesnici su odabrani jednostavnim slučajnim uzorkovanjem prema definiranim kriterijima uključivanja. Analizirani su inicijalni digitalni torakalni radiogrami, uz određivanje MBSB-a i procjenu njegove povezanosti s težinom bolesti, ishodom i komplikacijama. **Rezultati:** Više vrijednosti MBSB-a bile su povezane s težim kliničkim oblicima COVID-19 pneumonije. Bolesnici s blagim i umjerenim oblikom bolesti imali su niže vrijednosti bodovanja, dok su bolesnici s teškim i kritičnim oblikom imali značajno više vrijednosti MBSB-a. **Zaključak:** Modificirani Brixia sustav bodovanja pokazao se korisnim za radiografsku procjenu težine COVID-19 pneumonije. Više vrijednosti MBSB-a povezane su s težim kliničkim tijekom bolesti te mogu pridonijeti ranoj procjeni rizika, kliničkom odlučivanju i pravodobnom usmjeravanju liječenja.

Ključne riječi: *COVID-19, SARS-CoV-2, pneumonija, Brixia*

Assessment of SARS-CoV-2 pneumonia severity on thoracic radiograms using modified brixia scoring system

Abstract

Introduction and Aim: COVID-19, caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), is characterized by a broad spectrum of clinical manifestations, ranging from asymptomatic infection to severe pneumonia. Digital chest radiography enables assessment of pulmonary parenchymal involvement and disease severity. The aim of this study was to analyze initial digital chest radiographs of hospitalized pa-

tients with PCR-confirmed COVID-19 pneumonia, determine pneumonia severity using the modified Brixia scoring system (MBSS), and investigate the association between MBSS and clinical outcomes and complications. **Subjects and Methods:** This retrospective study included 150 patients hospitalized at the University Hospital for Infectious Diseases "Dr. Fran Mihaljević," in Zagreb, of whom 75 recovered and 75 died. Patients were selected by simple random sampling according to predefined inclusion criteria. Initial digital chest radiographs were analyzed, and the MBSS was determined. Its association with disease severity, clinical outcome, and complications was subsequently assessed. **Results:** Higher MBSS values were associated with more severe clinical forms of COVID-19 pneumonia. Patients with mild and moderate disease had lower scores, whereas patients with severe and critical disease had significantly higher MBSS values. **Conclusion:** The modified Brixia scoring system proved to be a useful tool for radiographic assessment of COVID-19 pneumonia severity. Higher MBSS values were associated with a more severe clinical course and may contribute to early risk stratification, clinical decision-making, and timely treatment planning.

Keywords: *COVID-19, SARS-CoV-2, pneumonia, Brixia*

Primjena kompjutorizirane tomografije u detekciji i procjeni bolesti urotrakta

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Sažetak

Kompjuterizirana tomografija (CT) predstavlja važnu neinvazivnu radiološku metodu u dijagnostici bolesti urotrakta. Zbog visoke prostorne rezolucije, brzine izvođenja i mogućnosti detaljne procjene anatomskih i patoloških struktura, CT ima značajnu ulogu u otkrivanju patoloških promjena mokraćnog sustava. CT urografija posebno je važna u prikazu bubrega, mokraćovoda i mokraćnog mjehura te se koristi kod sumnje na urolitijazu, opstrukciju, hematuriju, tumore i druge bolesti urotrakta. Cilj ovog rada bio je utvrditi učestalost patoloških nalaza urotrakta na CT pretragama te ispitati njihovu povezanost s dobi i spolom ispitanika. Istraživanje je provedeno retrospektivno na Kliničkom zavodu za dijagnostičku i intervencijsku radiologiju, Kliničkog bolničkog centra (KBC) Rijeka. Podaci su prikupljeni iz medicinske dokumentacije i radioloških nalaza bolničkog arhivskog sustava. U istraživanje je uključeno 155 ispitanika koji su bili podvrgnuti CT pretrazi urotrakta. Analizirani su dob, spol te prisutnost ili odsutnost patološkog nalaza. Patološki nalaz urotrakta utvrđen je kod 131 ispitanika, odnosno 84,5 % uzorka, dok kod 24 ispitanika, odnosno 15,5 %, nalaz je bio uredan. Udio patoloških nalaza bio je statistički značajno veći od 50 % ($p < 0,001$). Patološki nalazi bili su češći kod ispitanika starijih od 65 godina i kod muškaraca, no povezanost dobi i spola s prisutnošću patološkog nalaza nije bila statistički značajna. Rezultati potvrđuju važnu ulogu CT-a u detekciji i procjeni bolesti urotrakta te upućuju na njegovu opravdanu primjenu kod bolesnika s kliničkom sumnjom na patologiju mokraćnog sustava.

Ključne riječi: *CT urografija; kompjuterizirana tomografija; patološki nalaz; urotrakt*

Application of computed tomography in the detection and assessment of urinary tract diseases

Abstract

Computed tomography (CT) is an important non-invasive radiological method in the diagnosis of urinary tract diseases. Due to its high spatial resolution, rapid acquisition, and ability to provide detailed evaluation of anatomical and pathological structures, CT plays a significant role in the detection of pathological changes in the urinary system. CT urography is particularly important for visualizing the kidneys, ureters, and urinary bladder, and is used in cases of suspected urolithiasis, obstruction, hematuria, tumors, and other urinary tract diseases. The aim of this study was to determine the frequency of pathological urinary tract findings on CT examinations and to examine their association with the age and sex of the participants. The study was conducted retrospectively at the Clinical Department of Diagnostic and Interventional Radiology of the Clinical Hospital Centre Rijeka. Data were collected from medical documentation and radiological reports stored in the hospital archive system. The study included 155 participants who underwent CT examination of the urinary tract. Age, sex, and the presence or absence of a pathological finding were analyzed. A pathological urinary tract finding was identified in 131 participants, representing 84.5% of the sample, while no pathological finding was present in 24 participants, representing 15.5%. The proportion of pathological findings was statistically significantly higher than 50% ($p < 0.001$). Pathological findings were more frequent in participants older than 65 years and in male participants; however, the association between age and sex and the presence of a pathological finding was not statistically significant. The results confirm the important role of CT in the detection and assessment of urinary tract diseases and indicate its justified use in patients with clinical suspicion of urinary tract pathology.

Keywords: *computed tomography; CT urography; pathological finding; urinary tract*

Usporedba prikaza pektoralnog mišića na MLO mamografskim projekcijama između radioloških tehnologa

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Sažetak

Uvod i cilj: Pravilno pozicioniranje dojke jedan je od ključnih preduvjeta za dobivanje kvalitetne mamografske snimke. Kod mediolateralne kose (MLO) projekcije prikaz pektoralnog mišića koristi se kao jedan od pokazatelja odgovarajućeg pozicioniranja i uključenosti posteriornog tkiva dojke. Kvantitativno mjerenje duljine i širine pektoralnog mišića može omogućiti objektivniju procjenu i usporedbu kvalitete pozicioniranja. Cilj istraživanja bio je usporediti duljinu i širinu prikazanog pektoralnog mišića na MLO projekcijama između devet radioloških tehnologa. **Materijali i metode:** Provedena je retrospektivna analiza MLO mamografskih snimki. Za svakog od devet radioloških tehnologa nasumično je odabrano 15 pacijentica, pri čemu su analizirane MLO projekcije obje dojke. Analizirano je 30 projekcija po tehnologu, odnosno ukupno 270 MLO projekcija. Na svakoj projekciji izmjerene su duljina i širina prikazanog pektoralnog mišića. Dobivene vrijednosti statistički su uspoređene između devet radioloških tehnologa, uz razinu statističke značajnosti $p < 0,05$. **Rezultati:** Prosječna duljina pektoralnog mišića iznosila je 134,19 ± 20,16 mm. Srednje vrijednosti pojedinih tehnologa kretale su se od 127,28 do 145,11 mm, uz statistički značajnu razliku između tehnologa ($p = 0,001$). Prosječna širina pektoralnog mišića iznosila je 45,99 ± 10,99 mm, a srednje vrijednosti pojedinih tehnologa kretale su se od 36,06 do 56,23 mm. I za širinu je utvrđena statistički značajna razlika između radioloških tehnologa ($p < 0,001$). Tehnolog s najvećom prosječnom duljinom pektoralnog mišića istodobno je imao najmanju prosječnu širinu, što upućuje na to da ova dva parametra mogu opisivati različite aspekte prikaza pektoralnog mišića. Dobivene prosječne vrijednosti usporedive su s prethodno objavljenim rezultatima. Bentley i sur. navode prosječnu širinu od 48 mm i duljinu od 139 mm, dok Spuur i sur. navode širinu od 46,5 mm i duljinu od 140,2 mm. Prethodna istraživanja također upućuju na potrebu zasebne procjene duljine i širine pektoralnog mišića. **Zaključak:** Utvrđene su statistički značajne razlike u duljini i širini prikazanog pektoralnog mišića između devet radioloških tehnologa. Rezultati su usporedivi s vrijednostima objavljenima u literaturi te pokazuju da duljina i širina mogu pružati komplementarne informacije o MLO pozicioniranju. Kvantitativno praćenje oba parametra može biti koristan alat u edukaciji radioloških tehnologa, praćenju kvalitete te standardizaciji i optimizaciji tehnike mamografskog pozicioniranja.

Ključne riječi: *mamografija, MLO projekcija, pektoralni mišić, pozicioniranje, radiološki tehnolozi*

Comparison of pectoral muscle representation on MLO mammographic projections between radiological technologists

Abstract

Abstract Introduction and Objective: Proper breast positioning is a key prerequisite for obtaining high-quality mammographic images. In the mediolateral oblique (MLO) projection, visualization of the pectoral muscle is used as an indicator of appropriate positioning and inclusion of posterior breast tissue. Quantitative measurement of pectoral muscle length and width may enable a more objective assessment and comparison of positioning quality. This study aimed to compare these parameters on MLO projections obtained by 9 radiologic technologists. **Materials and Methods:** A retrospective analysis of MLO mammographic images was conducted. The dataset comprised 15 randomly selected patients and 30 bilateral MLO projections per technologist, resulting in a total of 270 projections. The length and width of the visualized pectoral muscle were measured on each projection. Measurements were statistically compared across technologists, with statistical significance set at $p < 0.05$. **Results:** The mean pectoral muscle length was 134.19 ± 20.16 mm. Individual mean values ranged from 127.28 to 145.11 mm, with a statistically significant difference among technologists ($p = 0.001$). The mean pectoral muscle width was 45.99 ± 10.99 mm, with individual mean values ranging from 36.06 to 56.23 mm. Significant variation between technologists was also found in muscle width ($p < 0.001$). The technologist with the greatest mean pectoral muscle length also had the smallest mean width, suggesting that these parameters may describe different aspects of pectoral muscle visualization. The overall mean values were comparable to previously published findings. Bentley et al. reported a mean width of 48 mm and a mean length of 139 mm, while Spuur et al. reported a width of 46.5 mm and a length of 140.2 mm. Previous studies have also indicated that pectoral muscle length and width should be assessed separately. **Conclusion:** Significant differences between technologists were found in the length and width of the visualized pectoral muscle. The results are comparable to values reported in the literature and demonstrate that these parameters may provide complementary information about MLO positioning. Quantitative monitoring of both measurements may be useful in technologist education, quality monitoring, and the standardization and optimization of mammographic positioning techniques.

Keywords: *mammography, MLO projection, pectoral muscle, positioning, radiologic technologists, Department of Medical Physics and Radiation Protection, Clinical Hospital Center Rijeka*

Optimizacija kvalitete CT pregleda toraksa: prepoznavanje tehničkih pogrešaka i pravilna primjena dodatnih akvizicija

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Sažetak

Uvod: kvaliteta CT pregleda toraksa ovisi o pravilnoj pripremi i pozicioniranju bolesnika, adekvatnom inspiriju, izostanku artefakata te pravilnom odabiru područja snimanja. Radiološki tehnolog ima ključnu ulogu u osiguravanju dijagnostičke kvalitete pregleda, ali i u prepoznavanju situacija u kojima je osnovnu akviziciju potrebno ponoviti ili nadopuniti dodatnim akvizicijama. **Cilj:** prikazati najčešće tehničke čimbenike koji utječu na kvalitetu CT pregleda toraksa te istaknuti ulogu radiološkog tehnologa u njihovu prepoznavanju i pravilnoj primjeni dodatnih akvizicija. **Razrada teme:** prije početka pregleda bolesniku je potrebno objasniti važnost maksimalnog inspirija te, prema potrebi, s njim uvježbati pravilno izvođenje udaha i zadržavanje daha. Bolesnik se standardno pozicionira u supinaciji, s rukama iznad glave, a područje snimanja mora obuhvatiti cijeli toraks. Kod sumnje na karcinom pluća ili poznate maligne bolesti pregledom je potrebno obuhvatiti i područje nadbubrežnih žlijezda. Neadekvatan inspirij može se prepoznati prema povećanoj atenuaciji plućnog parenhima, koja može poprimiti izgled ground-glass opacifikacija, te prema promjeni oblika traheje, čija stražnja membranozna stijenka u ekspiriju postaje ravna ili konkavna prema naprijed. Promjene ograničene na posterobazalne dijelove pluća, osobito kod bolesnika upućenih zbog sumnje na intersticijsku bolest pluća, zahtijevaju dodatnu akviziciju u pronaciji i maksimalnom inspiriju radi razlikovanja gravitacijski uvjetovanih promjena od stvarne patologije. Radiološki tehnolog također mora prepoznati artefakte pokreta te, kada oni značajno narušavaju dijagnostičku kvalitetu pregleda, u dogovoru s radiologom procijeniti potrebu za ponavljanjem akvizicije. Kod znakova mozaične perfuzije, koja se očituje razlikama u atenuaciji plućnog parenhima te broju i kalibru krvnih žila, pregled je potrebno nadopuniti ekspiratornom akvizicijom radi procjene prisutnosti zadržavanja zraka (air trappinga). **Zaključak:** optimalna kvaliteta CT pregleda toraksa ne ovisi samo o tehničkim parametrima snimanja, već i o pravilnoj pripremi bolesnika te sposobnosti radiološkog tehnologa da pravodobno prepozna nedostatke osnovne akvizicije i indikacije za dodatno snimanje. Poznavanje znakova neadekvatnog inspirija, artefakata pokreta, gravitacijski uvjetovanih promjena i mozaične perfuzije omogućuje ciljanu primjenu ponovljenih, pronacijskih i ekspiratornih akvizicija te smanjuje mogućnost pogrešne interpretacije CT nalaza.

Ključne riječi: *CT toraksa, radiološki tehnolog, kvaliteta slike, akvizicije, artefakti*

Optimizing the quality of chest CT examinations: identifying technical errors and correctly applying additional acquisitions

Abstract

Introduction: The diagnostic quality of chest CT examinations depends on appropriate patient preparation and positioning, adequate inspiration, the absence of artifacts, and appropriate scan coverage. Radiologic technologists play a key role in ensuring diagnostic image quality and recognizing situations in which the initial acquisition should be repeated or supplemented with additional acquisitions. **Objective:** To present the most common technical factors affecting the quality of chest CT examinations and to emphasize the role of the radiologic technologist in recognizing these factors and appropriately applying additional acquisitions. **Topic overview:** Before the examination, the patient should be informed about the importance of maximal inspiration. When necessary, proper inspiration and breath-holding should be practiced with the patient before scanning. Patients are routinely positioned supine with their arms above the head, while the scan range should include the entire thorax. In patients with suspected or known lung cancer, the scan should also include the adrenal glands. Inadequate inspiration may be recognized by increased attenuation of the lung parenchyma, which may mimic ground-glass opacity, as well as by changes in tracheal morphology. During expiration, the posterior membranous wall of the trachea may become flattened or anteriorly concave. When abnormalities are confined to the posterobasal lung regions, particularly in patients referred for suspected interstitial lung disease, an additional acquisition in the prone position during maximal inspiration may be necessary. This helps differentiate gravity-dependent changes from true pulmonary abnormalities. Radiologic technologists should recognize motion artifacts and, when these significantly compromise diagnostic image quality, assess the need for repeat acquisition in consultation with the radiologist. In examinations demonstrating signs of mosaic perfusion, characterized by differences in lung attenuation and variations in the number and caliber of pulmonary vessels, an additional expiratory acquisition should be performed to assess for air trapping. **Conclusion:** Optimal chest CT quality depends not only on acquisition parameters but also on adequate patient preparation and the radiologic technologist's ability to identify technical limitations and indications for additional imaging. Recognizing inadequate inspiration, motion artifacts, gravity-dependent changes, and mosaic perfusion enables targeted use of repeat, prone, and expiratory acquisitions, reducing the risk of misinterpretation and improving diagnostic confidence.

Keywords: *chest CT, radiologic technologist, image quality, acquisitions, motion artifacts*

Optimizacija CT aortografija u pacijenata s aneurizmom abdominalne aorte

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Sažetak

Aneurizma abdominalne aorte (AAA) predstavlja fokalno proširenje abdominalne aorte čiji je promjer 50% veći u odnosu na proksimalni normalni segment aorte ili maksimalni promjer iznosi više od 3 cm. CT aortografija (CTA) smatra se referentnom slikovnom metodom u dijagnostičkoj obradi aneurizmi abdominalne aorte (AAA), posebno u kontekstu preoperativnog planiranja. Omogućuje detaljnu procjenu morfologije, dimenzija i anatomskog odnosa aneurizme prema ograncima aorte i njezinoj bifurkaciji. S obzirom na primjenu ionizirajućeg zračenja i jodnog kontrastnog sredstva, važna sastavnica suvremene radiološke prakse je optimizacija CTA protokola uz očuvanje zadovoljavajuće dijagnostičke kvalitete. Optimizacija se temelji na individualnom prilagođavanju parametara akvizicije i primjene kontrastnog sredstva karakteristikama bolesnika. Primjenom odgovarajućeg napona cijevi, automatske modulacije struje, optimiziranog protoka i volumena kontrasta te preciznog određivanja vremena akvizicije moguće je smanjiti dozu zračenja i količinu primijenjenog kontrastnog sredstva. Cilj optimizacije CTA protokola je postići ravnotežu između dijagnostičke kvalitete slike, izloženosti ionizirajućem zračenju i količine kontrastnog sredstva, uz individualni pristup svakom bolesniku.

Ključne riječi: *aneurizma abdominalne aorte; artefakti pokreta; CT aortografija; kvaliteta slike; radiološki tehnolog*

Optimization of CT aortography in patients with abdominal aortic aneurysm

Abstract

Abdominal aortic aneurysm (AAA) is a focal dilation of the abdominal aorta in which the diameter is 50% greater than that of the proximal normal aortic segment, or the maximum diameter exceeds 3 cm. CT aortography (CTA) is considered the reference imaging method in the diagnostic workup of abdominal aortic aneurysms (AAA), especially in the context of preoperative planning. It allows for a detailed assessment of the morphology, dimensions, and anatomical relationship of the aneurysm to the branches of the aorta and its bifurcation. Given the use of ionizing radiation and iodinated contrast media, an important component of modern radiological practice is the optimization of the CTA protocol while maintaining satisfactory diagnostic quality. Optimization is based on individual adjustment of acquisition parameters and contrast media application to patient characteristics. By using appropriate tube voltage, automatic current modulation, optimized contrast flow and volume, and precise determination of acquisition time, it is possible to reduce the radiation dose and the amount of contrast media applied. The goal of optimizing CTA protocols is to achieve a balance between diagnostic image quality, exposure to ionizing radiation, and the amount of contrast agent, with an individual approach to each patient.

Keywords: *aneurysm of the abdominal aorta; motion artifacts; CT aortography; image quality; radiologic technologist*

Što o preporukama za (ne)korištenje kontaktnih zaštitnih sredstava za pacijente znaju i misle studenti treće godine studija radiološke tehnologije?

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Sažetak

Cilj: Utvrditi razinu poznavanja novih europskih preporuka o korištenju kontaktnih zaštitnih sredstava za pacijente te stavove studenata treće godine studija radiološke tehnologije. **Materijali i metode:** Provedeno je anonimno anketno istraživanje među 47 studenata. Upitnik je uključivao sedam pitanja o poznavanju preporuka te pitanja o mišljenjima i stavovima. **Rezultati:** Studenti su prosječno točno odgovorili na 4,5 od 7 pitanja, a svih sedam točno je odgovorilo 13%. Najviše točnih odgovora odnosilo se na utjecaj zaštitnih sredstava na AEC (83%), a najmanje na korist zaštite dijelova tijela izvan primarnog snopa (30%) i zaštitu gonada (45%). Kontaktna zaštitna sredstva ne bi koristilo ni za jedan modalitet 30% studenata. Za vlastito dijete zaštitu bi tražilo 60%, a 51% smatra da trudnicu treba štititi radi zaštite fetusa. Dodatno informiranje pacijenata potrebnim smatra 92%, a 72% radiološkog tehnologa vidi kao osobu koja bi trebala pružiti te informacije. **Zaključak:** Poznavanje preporuka je neujednačeno, a stavovi odražavaju zadržano povjerenje u zaštitna sredstva, osobito za djecu i trudnice. Rezultati ukazuju na potrebu za daljnjim jačanjem razumijevanja važnosti novih preporuka i razloga za njihovu implementaciju, uz odgovarajuću pripremu studenata za buduće informiranje pacijenata o promjenama u praksi.

Ključne riječi: *edukacija, europske preporuke, kontaktna zaštitna sredstva, studenti radiološke tehnologije, zaštita od zračenja*

What do third-year radiological technology students know and think about the recommendations on the (non-) use of patient contact shielding?

Abstract

AIM: To determine the level of knowledge of the new European recommendations on patient contact shielding and the attitudes of third-year radiography students. **Materials and Methods:** An anonymous survey was conducted among 47 students. The questionnaire included seven questions assessing knowledge of the recommendations, as well as questions on opinions and attitudes. **Main Results:** Students answered a mean of 4.5 of 7 questions correctly, while 13% answered all seven correctly. The highest proportion of correct responses related to the effect of shielding on automatic exposure control (AEC) (83%), and the lowest to the benefit of shielding body parts outside the primary X-ray beam (30%) and gonadal shielding (45%). 30% of students would not use patient contact shielding for any imaging modality. 60% would request shielding for their own child, while 51% considered that pregnant patients should be shielded for fetal protection. Additional patient information was considered necessary by 92%, and 72% identified radiographers as the professionals who should provide this information. **Conclusion:** Knowledge of the recommendations was inconsistent, while attitudes reflected persistent confidence in shielding, particularly for children and pregnant patients. The results indicate a need for further efforts to strengthen understanding of the importance of the new recommendations and the reasons for their implementation, together with appropriate preparation of students to provide patients with information about changes in practice in the future.

Keywords: *education, European consensus, patient contact shielding, radiography students, radiation protection*

Teleradiologija u Hrvatskoj

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Sažetak

Cilj ovog rada bio je ispitati ulogu teleradiologije u unaprjeđenju dostupnosti radioloških usluga u ruralnim područjima Hrvatske te usporediti njezinu primjenu u Hrvatskoj s primjenom u razvijenijim državama svijeta. Rad predstavlja pregled suvremene stručne i znanstvene literature iz područja teleradiologije. Teleradiologija je grana telemedicine koja omogućuje prijenos radioloških slika na udaljenu lokaciju radi očitanja i stručnog tumačenja. Omogućuje specijalistima iz većih zdravstvenih ustanova analizu slika dobivenih u manjim ustanovama, čime se ubrzava dijagnostički postupak i poboljšava dostupnost stručnog mišljenja. U ruralnim područjima Hrvatske teleradiologija je pridonijela bržem pristupu radiološkoj dijagnostici, smanjenju potrebe za putovanjem u veće zdravstvene centre te učinkovitijem korištenju dostupnog stručnog kadra. Analiza literature pokazuje da se u Hrvatskoj teleradiologija prvenstveno koristi za premošćivanje nedostatka radiologa i osiguravanje dostupno-

sti radioloških usluga izvan većih bolničkih ustanova, dok u razvijenijim državama predstavlja standardizirani dio zdravstvene infrastrukture. Iako se PACS sustavi za pohranu i distribuciju radioloških slika koriste diljem svijeta, u razvijenijim zemljama često su dio opsežnih teleradioloških mreža koje omogućuju međunarodnu suradnju i razmjenu stručnih mišljenja, dok je u Hrvatskoj teleradiologija uglavnom organizirana unutar nacionalnog zdravstvenog sustava. U radu su korištene metode pretraživanja, odabira i analize literature, a kao izvori podataka korišteni su znanstveni članci, diplomski radovi, službene mrežne stranice zdravstvenih institucija i drugi javno dostupni izvori. Teleradiologija predstavlja važan alat za povećanje dostupnosti i učinkovitosti radioloških usluga u Hrvatskoj, a njezin daljnji razvoj zahtijeva kontinuirano unaprjeđenje organizacijskih i tehničkih uvjeta te prilagodbu zakonskog okvira suvremenim potrebama zdravstvenog sustava.

Ključne riječi: *Hrvatska; PACS; radiološka dijagnostika; telemedicina; teleradiologija*

Teleradiology in Croatia

Abstract

The aim of this paper was to examine the role of teleradiology in improving the availability of radiological services in rural areas of Croatia and to compare its implementation in Croatia with its application in more developed countries. The paper presents a review of contemporary professional and scientific literature in the field of teleradiology. Teleradiology is a branch of telemedicine that enables the transmission of radiological images to a remote location for interpretation and professional reporting. It enables specialists from larger healthcare institutions to analyse images obtained in smaller institutions, thereby accelerating the diagnostic process and improving access to expert opinion. In rural areas of Croatia, teleradiology has contributed to faster access to radiological diagnostics, reduced the need for travel to larger healthcare centres, and enabled more efficient use of available professional staff. Literature analysis indicates that in Croatia, teleradiology is primarily used to address the shortage of radiologists and to ensure the availability of radiological services outside major hospital institutions, while in more developed countries it represents a standardised component of healthcare infrastructure. Although PACS systems for the storage and distribution of radiological images are used worldwide, in more developed countries they are often part of extensive teleradiology networks that enable international collaboration and the exchange of expert opinions, whereas in Croatia teleradiology is mainly organised within the national healthcare system. The methods used in this paper included literature search, selection, and analysis, while the sources consisted of scientific articles, graduate theses, official websites of healthcare institutions, and other publicly available resources. Teleradiology represents an important tool for increasing the availability and efficiency of radiological services in Croatia, and its further development requires continuous improvement of organisational and technical conditions, as well as adaptation of the legal framework to the contemporary needs of the healthcare system.

Keywords: *Croatia; PACS systems; radiological diagnostics; telemedicine; teleradiology*

Zračenje protonima u onkološkoj skrbi djece

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Sažetak

Uvod: Protonska radioterapija zauzima sve važnije mjesto u pedijatrijskoj onkologiji zbog mogućnosti preciznog ozračivanja tumora uz bolje očuvanje okolnih zdravih tkiva. U radu se opisuju posebnosti i prednosti primjene protona u liječenju djece s malignim bolestima, s naglaskom na zaštitu zdravih okolnih struktura i smanjenje mogućih kasnih posljedica zračenja. **Materijali i metode:** Analizom stručne i znanstvene literature obuhvaćena su fizikalna svojstva protonskog snopa, planiranje i provođenje terapije, imobilizacija te posebnosti skrbi za pedijatrijske bolesnike. **Rezultati:** Zahvaljujući Braggovu vrhu, protoni najveći dio energije predaju na određenoj dubini, nakon čega doza naglo opada što omogućuje smanjenje izloženosti organa od rizika i ukupne doze zdravim tkivima. Takva raspodjela doze je posebno značajna u djece čiji su organi i tkiva još u razvoju, a posljedice zračenja mogu se očitovati godinama nakon završetka liječenja. Sigurna i precizna primjena protona zahtijeva kvalitetno planiranje, reproducibilnu imobilizaciju, slikovno navođenje i kontrolu nesigurnosti raspona, dok kod mlađe djece može biti potrebna sedacija ili anestezija. Važnu ulogu u cijelom postupku ima multidisciplinarni tim, uključujući radiološkog tehnologa koji sudjeluje u pripremi, pozicioniranju i provođenju terapije. **Zaključak:** Protonska radioterapija predstavlja vrijednu mogućnost suvremene onkološke skrbi djece jer omogućuje učinkovito ozračivanje ciljnog volumena uz maksimalno moguće poštedivanje zdravih tkiva i potencijalno smanjenje dugoročne toksičnosti.

Ključne riječi: *djeca, protoni, radioterapija, zračenje*

Proton radiation in paediatric oncology care

Abstract

Introduction: Proton radiotherapy is becoming increasingly important in paediatric oncology because it can precisely irradiate tumours while better sparing surrounding healthy tissues. This paper describes the features and advantages of proton therapy in treating children with malignant diseases, with particular emphasis on protecting surrounding healthy structures and reducing potential late radiation effects. **Methods:** The analysis of professional and scientific literature includes the physical properties of proton beams, treatment planning and delivery, immobilisation, and specific aspects of paediatric care. **Results:** Because of the Bragg peak, protons deliver most of their energy at a specific depth, after which the dose decreases rapidly, reducing radiation exposure to organs at risk and the overall dose delivered to healthy tissues. This dose distribution is particularly important in children, whose organs and tissues are still developing and in whom radiation-related effects may become apparent years after treatment is completed. Safe and precise proton therapy requires high-quality treatment planning, reproducible immobilisation, image guidance, and management of range uncertainties, while sedation or anaesthesia may be required in younger children. A multidisciplinary team plays an important role throughout the entire process, including the radiologic technologist, who participates in patient preparation, positioning, and treatment delivery. **Conclusion:** Proton radiotherapy is a valuable option in modern paediatric oncology care because it enables effective irradiation of the target volume while sparing healthy tissues and potentially reducing long-term toxicity.

Keywords: *children, protons, radiotherapy, radiation*

Vizualna priprema pacijenata

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Sažetak

Priprema pacijenata prije dijagnostičkih i terapijskih postupaka važan je dio zdravstvene skrbi jer može utjecati na njihovu suradljivost i cjelokupno iskustvo tijekom pregleda. U radiologiji, radioterapiji i nuklearnoj medicini pacijenti često osjećaju strah zbog nepoznatog okruženja, zatvorenog prostora, glasnih zvukova uređaja ili postupaka koji uključuju zračenje i imobilizaciju. Zbog toga mogu biti nemirni, teže surađivati i češće dolazi do artefakata na snimkama, ponavljanja snimanja ili potrebe za sedacijom, osobito kod djece. Jedan od načina poboljšanja pripreme pacijenata jest korištenje vizualnih materijala poput slika, edukativnih slikovnica, kratkih videozapisa. Vizualna priprema pomaže tako što pacijenta unaprijed upoznaje s izgledom uređaja, prostorom u kojem će se pregled provoditi te mu tijekom samog postupka prikazuje što se od njega očekuje. Na taj način postupak postaje jasniji i manje zastrašujući. Kratki filmovi mogu prikazati uređaje, zvukove i ponašanje koje se očekuje od pacijenta, dok slikovni materijali dodatno objašnjavaju važnost mirovanja i suradnje. U radiologiji se tako mogu koristiti pri pripremi za MR i CT, u radioterapiji pri upoznavanju s linearnim akceleratorom i imobilizacijskom opremom, dok se u nuklearnoj medicini pacijentima objašnjava primjena radiofarmaka i dugotrajnog čekanja prije snimanja. Prema dostupnim istraživanjima, primjena vizualnih materijala doprinosi smanjenju anksioznosti, boljoj suradljivosti pacijenata i kvalitetnijim

snimkama uz manji broj artefakata. U dječjoj populaciji može smanjiti potrebu za općom anestezijom, a zdravstvenim djelatnicima olakšati komunikaciju i pripremu pacijenta. Posebno je vrijedna jer se može primijeniti jednostavno, brzo i uz male troškove, a pacijentu daje osjećaj sigurnosti, kontrole i bolje pripremljenosti za pregled. Cilj ovog rada je prikazati kako vizualni materijali mogu pomoći u pripremi pacijenata za postupke u radiologiji, radioterapiji i nuklearnoj medicini te istaknuti njihov značaj u svakodnevnoj kliničkoj praksi. Kao praktični dio rada izradit će se dva edukativna videozapisa. Prvi će prikazivati pripremu i tijek rendgenskog snimanja pluća, a drugi postupak planiranja radioterapije dojke.

Ključne riječi: *Dijagnostička radiologija, neverbalna komunikacija, priprema pacijenata, radioterapija, vizualni materijali*

Visual preparation of patients

Abstract

Patient preparation prior to diagnostic and therapeutic procedures is an important aspect of healthcare, as it can influence patient compliance and their overall experience during examination. In radiology, radiotherapy, and nuclear medicine, patients frequently experience fear due to unfamiliar surroundings, enclosed spaces, loud device noises, or procedures involving radiation and immobilization. Consequently, patients may become anxious, find it more difficult to cooperate, and increase the likelihood of image artifacts, repeat scans, or the need for sedation, particularly in children. One approach to improving patient preparation is the use of visual materials such as images, educational picture books, and short videos. Visual preparation helps by familiarizing patients in advance with the appearance of the equipment and the surrounding environment, as well as by demonstrating what is expected of them during the procedure itself. In this way, the process becomes clearer and less intimidating. Short films can illustrate devices, sounds, and expected patient behavior, while visual aids further explain the importance of remaining still and cooperative. In radiology, these tools can be utilized in preparation for MRI and CT scans; in radiotherapy, for introducing patients to the linear accelerator and immobilization equipment; and in nuclear medicine, for explaining the administration of radiopharmaceuticals and the prolonged waiting period prior to imaging. According to available research, the application of visual materials contributes to reduced anxiety, better patient compliance, and higher-quality images with fewer artifacts. In pediatric populations, it can reduce the need for general anesthesia, while facilitating communication and preparation for healthcare professionals. It is particularly valuable because it can be implemented easily, quickly, and cost-effectively, providing patients with a sense of security, control, and better preparedness for their examination. The aim of this paper is to demonstrate how visual materials can assist in preparing patients for procedures in radiology, radiotherapy, and nuclear medicine, and to highlight their importance in daily clinical practice. As a practical component of this work, two educational videos will be produced. The first will show the preparation and procedure for a chest X-ray, and the second will depict the treatment planning process for breast radiotherapy.

Keywords: *Diagnostic radiology, Non-verbal communication, Patient preparation, Radiotherapy, Visual materials*

Development of a 3D-printed anatomically accurate cardiac phantom with coronary arteries

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Abstract

Introduction: In radiography, anthropomorphic phantoms are particularly important in education, as they allow practitioners to perform repeated exposures without involving real patients. They are therefore valuable for developing a three-dimensional understanding of anatomy, which is crucial in medical imaging. However, despite the extensive range of commercially available phantoms, many anatomical systems remain under-represented, and their relatively high cost often limits accessibility. Three-dimensional printing offers a promising alternative for producing phantoms when they are not commercially available or are otherwise inaccessible. One example is invasive coronary angiography, in which the quality of the imaging procedure depends on a thorough understanding of vascular anatomy. **Purpose:** The study aimed to produce an anatomically accurate cardiac phantom with coronary arteries using three-dimensional printing. **Methodology:** The study comprised two phases. In the first phase, a prototype phantom was designed using computed tomography (CT) image segmentation and three-dimensional printing with polylactic acid to create a heart model. The left and right coronary arteries were then outlined on separate models using a radiopaque material. In the second phase, the final phantoms were designed using multimaterial three-dimensional printing, with polylactic acid used for the heart model and a radiopaque material used for the coronary arteries. Fluoroscopic imaging and comparison with reference angiograms were performed to verify all phantoms. The prototype was imaged using the hospital protocol, whereas the final phantoms were assessed using projections derived from the literature. **Results:** Four phantoms were produced, two for the right and two for the left coronary artery. The prototype depicted the main branches of both coronary arteries but few, if any, smaller ones. Compared with the prototype, the final phantoms showed more clearly delineated vascular details and closer correspondence with the reference angiograms. **Discussion and conclusion:** The superior anatomical accuracy of the final phantoms likely resulted from the combination of segmentation and three-dimensional printing techniques used in their production, which were more precise than the manual application of radiopaque material. Improved anatomical accuracy, combined with imaging projections corresponding to those of the reference angiograms, led to closer agreement with the reference angiograms compared with the prototype phantoms.

Keywords: *Three-dimensional printing, X-ray phantom, invasive coronary angiography, flouroscopy, coronary arteries*

Integrirani angio-CT sustavi u intervencijskoj radiologiji – od dijagnostike do liječenja

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Sažetak

Uvod: Integrirani Angio-CT sustavi objedinjuju kompjutoriziranu tomografiju (CT) i angiografiju u jedinstvenom intervencijskom okruženju, omogućujući izvođenje dijagnostičkog i terapijskog dijela zahvata bez premještanja bolesnika. **Cilj:** Prikazati mogućnosti, područja primjene i prednosti integriranih Angio-CT sustava u suvremenoj intervencijskoj radiologiji. **Materijali i metode:** Rad se temelji na pregledu literature dostupne u bazi PubMed. **Rezultati:** Integracija CT-a i angiografije omogućuje precizniju lokalizaciju ciljnih lezija, bolje planiranje intervencijskog pristupa, sigurnije izvođenje zahvata i neposrednu procjenu uspješnosti liječenja. Najveća korist opisana je kod složenih vaskularnih, neurointervencijskih i onkoloških zahvata. Primjer ovakvog koncepta predstavlja Nexaris Hybrid OR, koji objedinjuje CT i angiografiju u jedinstvenom radnom prostoru. Primjena ovih sustava proširuje ulogu radiološkog tehnologa, koji uz rad na angiografskom sustavu mora biti osposobljen i za rad s CT-om, zbog čega su kontinuirana edukacija i dodatne kompetencije od ključne važnosti. **Zaključak:** Širu primjenu ovih sustava ograničavaju visoki troškovi, prilagodba postojećih intervencijskih sala i složenija organizacija rada. Daljnji razvoj, uz primjenu umjetne inteligencije, napredne fuzije slikovnih podataka i automatizirane navigacije, mogao bi dodatno unaprijediti preciznost i sigurnost zahvata te pridonijeti boljim ishodima liječenja na dobrobit pacijenata.

Ključne riječi: *Angiografija; Angio-CT; CT, intervencijska radiologija,radiološki tehnolog*

Integrated angio-CT systems in interventional radiology – from diagnostics to treatment

Abstract

Introduction: Integrated Angio-CT systems combine computed tomography (CT) and angiography within a single interventional environment, enabling both diagnostic and therapeutic procedures to be performed without patient transfer. **Objective:** To present the capabilities, clinical applications, and advantages of integrated Angio-CT systems in contemporary interventional radiology. **Materials and Methods:** This paper is based on a review of the literature available in the PubMed database. **Results:** The integration of CT and angiography enables more accurate

lesion localization, improved procedural planning, safer intervention guidance, and immediate assessment of procedural success. The greatest clinical benefit has been reported in complex vascular, neurointerventional, and oncological procedures. An example of this concept is Nexaris Hybrid OR, which integrates CT and angiography into a single interventional workspace. The implementation of these systems also expands the role of the radiologic technologist, who must be proficient in both angiographic and CT procedures, highlighting the importance of continuous education and advanced professional competencies. **Conclusion:** The wider implementation of integrated Angio-CT systems is limited by high acquisition and maintenance costs, the need to adapt existing interventional suites, and complex workflow organization. Future developments, including artificial intelligence, advanced image fusion, and automated navigation, are expected to further improve the precision, safety, and efficiency of image-guided interventions, ultimately contributing to better patient outcomes.

Keywords: *Angio-CT; angiography; computed tomography; interventional radiology; radiologic technologist.*

Koncept angiosoma u endovaskularnom liječenju periferne arterijske bolesti potkoljeničnih arterija

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Sažetak

Cilj rada: Cilj ovoga rada je objasniti koncept angiosoma te ukazati na njegovu učinkovitost u planiranju endovaskularnog liječenja periferne arterijske bolesti potkoljeničnih arterija s naglaskom na pravilan odabir ciljne arterije uz pomoć koje će se obnoviti perfuzija stopala i time spriječiti neželjeni ishodi (amputacija, smrt). **Materijali i metode:** Rad se temelji na narativnom pregledu dostupne znanstvene i stručne literature o perifernoj arterijskoj bolesti, endovaskularnom liječenju i konceptu angiosoma. Također su u analizu uključeni i dostupni udžbenici, znanstveni radovi te stručni internetski izvori dostupni u bibliografskim bazama podataka (PubMed) i medicinskim izvorima. **Rezultati:** Analizom dostupne literature pokazalo se da je endovaskularna revaskularizacija jedno od učinkovitijih rješenja u liječenju periferne arterijske bolesti potkoljeničnih arterija te je izrazito značajna u primjeni kod bolesnika s kroničnom ishemijom ekstremiteta. Primjenom koncepta angiosoma može se poboljšati cijeljenje rana te time i očuvati ekstremitet ostvarenjem revaskularizacije arterije koja opskrbljuje određeni vaskularni segment. Angiosomski koncept ima i svoja ograničenja te se naglasak stavlja na individualnom pristupu svakom pacijentu. **Zaključak:** Angiosomski koncept jedno je od učinkovitijih rješenja za postizanje kvalitetne arterijske opskrbe ishemijskog područja kojim se rana određenog vaskularnog segmenta izravno povezuje s arterijom koja opskrbljuje navedeno područje te se primjenom endovaskularne revaskularizacije ostvaruju pozitivni ishodi poput cijeljenja rane, sprječavanja amputacija i smanjenja stope smrtnosti. Veliki broj istraživanja ukazuje na prednosti direktne revaskularizacije kojom se djeljuje na glavnu arteriju koja opskrbljuje angiosom, međutim, važno je uzeti u obzir i kolateralnu cirkulaciju, moguće anatomske varijacije i zahtjevnost tehničke izvedbe prilikom čega se kao drugo rješenje postavlja indirektna revaskularizacija uz naglasak na individualizirani pristup svakom pacijentu.

Ključne riječi: *angiosom, ekstremitet, endovaskularna revaskularizacija, ishemija, periferna arterijska bolest*

The angiosoma concept in endovascular treatment of peripheral arterial disease of the lower leg arteries

Abstract

Aim: Thea im of this paper is to explain the angiosome concept and its role in planning endovascular treatment of infrapopliteal peripheral arterial disease, with particular emphasis on the appropriate selection of the target artery to restore foot perfusion and prevent adverse outcomes, including amputation and death. **Materials and Methods:** This paper is based on narrative review of the available scientific and professional literature of peripheral arterial disease, endovascular treatment and the angisome concept. The analysis included textbooks, original and riview scientific articles and professional online resources retrieved from bibliographic databases (PubMed) and other relevant medical sources. **Results:** The reviewed literature indicates that endovascular revascularization is one of the most effective treatment options for infrapopliteal peripheral arterial disease and plays a crucial role in patients with chronic limb-threatening ischemia. Application of the angiosome concept may improve wound healing and increase limb salvage by achieving direct revascularization of the artery supplying the affected vascular territory. However, the angiosome concept has certain limitations, highlighting the importance of an individualized approach to each patient. **Conclusion:** The angiosome concept represents an effective strategy for restoring adequate arterial perfusion to ischemic tissue by directly linking the affected vascular territory with its corresponding source artery through endovascular revascularization. This approach contributes to improved wound healing, limb preservation, reduced amputation rates, and lower mortality. Although numerous studies support the advantages of direct angiosome-targeted revascularization, collateral circulation, anatomical variations, and technical feasibility should also be considered. Therefore, indirect revascularization may represent an appropriate alternative in selected cases, emphasizing the importance of an individualized treatment approach for each patient.

Keywords: *angiosome, limb, endovascular revascularization, ischemia, peripheral arterial disease*

MR sigurnost: jesmo li mislili na sve?

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Sažetak

Uvod: Brzi tehnološki napredak i porast broja pretraga mogu povećati broj neželjenih događaja u MR dijagnostici. Unatoč postojanju smjernica, incidenti se i dalje događaju, najčešće zbog previda u svakodnevnoj praksi ili nedostatka trajne edukacije. **Cilj:** Analizirati ključne elemente sveobuhvatnog sustava MR sigurnosti te identificirati najčešće slabe točke i propuste u pristupu i protokolima postupanja vezanim uz pacijente i osoblje. **Metode:** Provedena je analiza postojećih sigurnosnih protokola i postojeće opreme, revizija radnih uputa u našoj ustanovi kroz proteklo vrijeme uz osvrt na relevantne međunarodne smjernice. Poseban naglasak stavljen je na upravljanje rizikom kod kontrole pristupa zonama opasnosti te razinu educiranosti osoblja. **Rezultati:** Analiza pokazuje da uvođenje standardiziranih protokola postupanja, sigurnosnih obrazaca te konstantna edukacija na nivou odjela i ustanove smanjuje rizik od neželjenih događaja. **Zaključak:** Odgovor na pitanje "jesmo li na sve mislili?" zahtijeva stalnu reviziju protokola ne samo u smislu pisanog dokumenta u sustavu kvalitete. Sigurnost nije statičan dokument, već dinamičan proces koji spaja strogu kontrolu pristupa, stalnu edukaciju svih profila djelatnika i jasne algoritme za rješavanje svih neželjenih događaja i hitnih situacija.

Ključne riječi: *MR sigurnost, protokoli, upravljanje rizikom, edukacija osoblja*

MRI Safety: Have We Thought of Everything?

Abstract

Introduction: Rapid technological advancements and an increasing number of examinations can lead to a higher incidence of adverse events in MRI diagnostics. Despite the existence of guidelines, incidents still occur, most commonly due to oversights in daily practice or a lack of continuous education. **Objective:** To analyze the key elements of a comprehensive MRI safety system and to identify the most common weak points and flaws in approaches and operating protocols related to patients and staff. **Methods:** An analysis of existing safety protocols and current equipment was conducted, along with a review of work instructions in our institution over time, with reference to relevant international guidelines. Special emphasis was placed on risk management in access control to safety zones and the level of staff education. **Results:** The analysis shows that the introduction of standardized operating protocols, safety checklists, and continuous education at the department and institutional levels reduces the risk of adverse events. **Conclusion:** Answering the

question “have we thought of everything?” requires constant revision of protocols, not just as a written document within the quality system. Safety is not a static document, but a dynamic process that combines strict access control, continuous education for all staff profiles, and clear algorithms for managing all adverse events and emergencies.

Keywords: *MR safety, protocols, risk management, staff training*

Škola mamografskog pozicioniranja i interpretacije nalaza kao model unaprjeđenja kvalitete mamografske dijagnostike u Republici Hrvatskoj

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Sažetak

Škola „Pravila mamografskog pozicioniranja i interpretacije mamografskog nalaza“, koja se provodi pri Kliničkom zavodu za dijagnostičku i intervencijsku radiologiju Kliničkog bolničkog centra Rijeka, predstavlja strukturirani program trajne medicinske izobrazbe usmjeren na unaprjeđenje kvalitete mamografske dijagnostike u Hrvatskoj. Program je namijenjen radiološkim tehnolozima, radiolozima i drugim zdravstvenim djelatnicima uključenima u probir, dijagnostiku i liječenje raka dojke te objedinjuje teorijska predavanja, praktične radionice i analizu mamografskih snimaka različite kvalitete. Temeljni cilj Škole jest osnažiti stručne kompetencije sudionika u području pravilnog mamografskog pozicioniranja, interpretacije nalaza, optimizacije kompresije, prepoznavanja tehničkih nedostataka i provedbe postupaka kontrole kvalitete. Pravilno pozicioniranje dojke ključno je za postizanje dijagnostički vrijedne slike jer omogućuje optimalan prikaz žljezdanog, potkožnog i retroglandularnog tkiva, smanjuje mogućnost izostavljanja lezija, pojave artefakata i ponavljanja pregleda te doprinosi sigurnosti pacijentica smanjenjem nepotrebne izloženosti zračenju. Program se provodi u skladu s europskim smjernicama i nacionalnim preporukama koje naglašavaju važnost standardizacije postupaka, kontinuirane edukacije, auditnih mehanizama, sustavne povratne informacije i profesionalne komunikacije s pacijenticama. U razdoblju od 2018. do 2026. godine edukaciju je uspješno završilo više od 220 stručnjaka, što potvrđuje prepoznatu potrebu za trajnim usavršavanjem u ovom području. Škola KBC-a Rijeka pridonosi standardizaciji mamografske prakse, povećanju dijagnostičke pouzdanosti, razvoju multidisciplinarne suradnje i unaprjeđenju kvalitete skrbi za žene u programu probira i dijagnostike raka dojke.

Ključne riječi: *interpretacija nalaza, kontrola kvalitete, mamografija, pozicioniranje dojke, trajna medicinska izobrazba*

School of mammographic positioning and interpretation of findings as a model for improving the quality of mammographic diagnostics in the Republic of Croatia

Abstract

The School “Rules of Mammographic Positioning and Interpretation of Mammographic Findings”, which is conducted at theDepartment of Diagnostic and Interventional Radiology of the Rijeka University Hospital Center, is a structured program of continuing medical education aimed at improving the quality of mammographic diagnostics in Croatia. The program is intended for radiological technologists, radiologists and other healthcare professionals involved in the screening, diagnosis and treatment of breast cancer and combines theoretical lectures, practical workshops and analysis of mammographic images of varying quality. The main goal of the School is to strengthen the professional competencies of participants in the field of correct mammographic positioning, interpretation of findings, optimization of compression, recognition of technical deficiencies and implementation of quality control procedures. Correct positioning of the breast is crucial for achieving a diagnostically valuable image because it allows for optimal visualization of glandular, subcutaneous and retroglandular tissue, reduces the possibility of missing lesions, the appearance of artifacts and repeat examinations, and contributes to patient safety by reducing unnecessary radiation exposure. The program is implemented in accordance with European guidelines and national recommendations that emphasize the importance of standardization of procedures, continuous education, audit mechanisms, systematic feedback and professional communication with patients. In the period from 2018 to 2026, more than 220 experts successfully completed the training, which confirms the recognized need for continuous training in this area. The School contributes to the standardization of mammography practice, enhances diagnostic reliability, fosters multidisciplinary collaboration, and improves the quality of care for women participating in the breast cancer screening program.

Keywords: *breast positioning, continuing medical education, interpretation of findings, mammography, quality control*

Vidjeti nevidljivo: uloga kontrastom pojačane mamografije u suvremenoj dijagnostici dojke

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Sažetak

Kontrastom pojačana mamografija (engl. Contrast-Enhanced Mammography, CEM) suvremena je slikovna metoda dojke koja kombinira digitalnu mamografiju i intravensku primjenu jodnog kontrastnog sredstva radi procjene morfoloških i funkcionalnih obilježja lezija. Temelji se na dual-energy tehnici koja omogućava prikaz niskoenergetskih i rekombiniranih slika s prikazom raspodjele kontrastnog sredstva u tkivu. Zbog pojačane angiogeneze, maligne lezije pokazuju izraženije nakupljanje kontrastnog sredstva, što omogućava bolju detekciju i karakterizaciju promjena u odnosu na konvencionalnu mamografiju. Metoda se primjenjuje u obradi suspektnih nalaza, procjeni proširenosti karcinoma dojke, praćenju odgovora na neoadjuvantnu terapiju te u pacijentica s gustim žljezdanim tkivom dojke. Cilj rada je prikazati dijagnostičku vrijednost CEM-a s naglaskom na tehničke principe, indikacije i usporedbu s magnetskom rezonancijom dojki. Pregledom literature i odabranih kliničkih primjera istaknute su prednosti, ograničenja i dijagnostička vrijednost metode. Dostupni podaci ukazuju na to da CEM povećava dijagnostičku točnost i olakšava odabir optimalnog terapijskog pristupa. Zaključno, CEM predstavlja vrijednu slikovnu metodu koja može unaprijediti dijagnostiku bolesti dojke i pridonijeti učinkovitijem zbrinjavanju pacijentica.

Ključne riječi: *angiogeneza, CEM, dijagnostika dojke, jodno kontrastno sredstvo, karcinom dojke*

Seeing the invisible: the role of contrast-enhanced mammography in modern breast diagnostics

Abstract

Contrast-enhanced mammography (CEM) is a modern breast imaging technique that combines digital mammography with intravenous administration of iodinated contrast media to assess the morphological and functional characteristics of lesions. It is based on a dual-energy technique that provides low-energy and recombined images showing contrast distribution within the tissue. Due to increased angiogenesis, malignant lesions demonstrate greater contrast enhancement, enabling improved detection and characterization compared with conventional mammography. CEM is used in the evaluation of suspicious findings, assessment of the extent of breast cancer, monitoring of response to neoadjuvant therapy, and imaging of patients with dense breast tissue. The aim of this study is to present the diagnostic value of CEM, focusing on its technical principles, indications, and a comparison with breast magnetic resonance imaging. A review of the literature and selected clinical cases highlights the advantages, limitations, and diagnostic performance of the method. Current evidence indicates that CEM improves diagnostic accuracy and may facilitate the selection of optimal treatment strategies. CEM represents a valuable imaging modality that may improve breast disease diagnosis and contribute to more effective patient management.

Keywords: *angiogenesis, breast cancer, breast imaging, CEM, iodinated contrast media*

Ishodi mehaničke trombektomije u izravno primljenih i transferiranih pacijenata u KBC Split tijekom 2025. godine

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Sažetak

Ishodi mehaničke trombektomije u izravno primljenih i transferiranih pacijenata u KBC Split tijekom 2025. Godine Nera Tomić KBC SPLIT Spinčićeva 1, Split, Hrvatska e-mail: nera.tomic78@gmail.com Sažetak Mehanička trombektomija predstavlja standardnu metodu liječenja akutnog ishemijskog moždanog udara uzrokovanog okluzijom velikih moždanih arterija. U KBC-u Split bolesnici se zbrinjavaju izravnim prijemom prema modelu mother-ship ili nakon transfera iz regionalnih bolnica prema modelu drip-and-ship. Cilj ovog rada bio je analizirati organizaciju regionalne mreže za liječenje akutnog ishemijskog moždanog udara te usporediti kliničke ishode bolesnika liječenih navedenim modelima tijekom 2025. godine. Provedena je retrospektivna analiza svih bolesnika liječenih mehaničkom trombektomijom u KBC-u Split od siječnja do prosinca 2025. godine. Analizirani su način prijema, ustanova iz koje je bolesnik upućen, prethodno provedena terapija, uspješnost reperfuzije prema TICI klasifikaciji te klinički ishod tijekom hospitalizacije. Tijekom promatranog razdoblja zaprimljena su 153 bolesnika s akutnim ishemijskim moždanim udarom, od kojih je 127 liječeno mehaničkom trombektomijom. Pedeset i pet bolesnika transferirano je iz regionalnih bolnica, najčešće iz Zadra, Šibenika, Dubrovnika, Sinja, Makarske, Hvara, Korčule i Knina. U većine bolesnika postignuta je uspješna reperfuzija (pretežno TICI 2b–3), a najveći broj otpušten je na daljnje liječenje ili rehabilitaciju, dok je manji broj bolesnika preminuo tijekom hospitalizacije. Dobiveni rezultati potvrđuju da regionalna organizacija skrbi omogućuje pravodobnu dostupnost endovaskularnog liječenja bolesnicima s akutnim ishemijskim moždanim udarom, neovisno o mjestu prvog zbrinjavanja. Pravodobno prepoznavanje i organizirani transfer ključni su čimbenici uspješnog liječenja mehaničkom trombektomijom.

Ključne riječi: *akutni ishemijski moždani udar, mehanička trombektomija, mother-ship, drip-and-ship, regionalna mreža*

Outcomes of mechanical thrombectomy in directly admitted and transferred patients at University hospital centre Split during 2025

Abstract

Mechanical thrombectomy is the standard treatment for acute ischemic stroke caused by large vessel occlusion. At the University Hospital Centre Split, patients are managed either through direct admission according to the mother-ship model or after transfer from regional hospitals following the drip-and-ship model. The aim of this study was to evaluate the organization of the regional stroke network and compare the clinical outcomes of patients treated using these two models during 2025. A retrospective analysis was conducted on all patients who underwent mechanical thrombectomy at the University Hospital Centre Split between January and December 2025. The mode of admission, referring institution, previous therapy, reperfusion success according to the Thrombolysis in Cerebral Infarction (TICI) classification, and clinical outcomes during hospitalization were analyzed. During the study period, 153 patients with acute ischemic stroke were admitted, of whom 127 underwent mechanical thrombectomy. Fifty-five patients were transferred from regional hospitals, most commonly from Zadar, Šibenik, Dubrovnik, Sinj, Makarska, Hvar, Korčula, and Knin. Successful reperfusion was achieved in the majority of patients (predominantly TICI 2b–3). Most patients were discharged for further treatment or rehabilitation, while a smaller proportion died during hospitalization. The results confirm that the regional organization of stroke care provides timely access to endovascular treatment for patients with acute ischemic stroke regardless of the location of their initial medical care. Early recognition, rapid transfer, and coordinated organization of care remain key factors for successful treatment with mechanical thrombectomy.

Keywords: *acute ischemic stroke; mechanical thrombectomy, mother-ship, drip-and-ship, regional stroke network.*

Procjena intrafrakcijskih pomaka tijekom površinski navođene stereotaksijske radioterapije tijela uz zadržavanje daha

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Sažetak

Cilj: Procijeniti točnost i preciznost površinski navođene stereotaksijske radioterapije tijela (SBRT) u zadržavanju udaha (IBH) te usporediti intrafrakcijske pomake između bolesnika s tumorima pluća i jetre. **Materijali i metode:** Retrospektivna analiza obuhvatila je bolesnike liječene SBRT-om uz IBH u razdoblju od 2021. do 2024. godine. Intrafrakcijski pomaci procijenjeni su na temelju korekcija učinjenih u sredini frakcije u vertikalnom (VRT), longitudinalnom (LNG) i lateralnom (LAT) smjeru. U istraživanje je uključeno 86 bolesnika s tumorima pluća (182 frakcije) i 124 bolesnika s tumorima jetre (159 frakcija). Izračunate su srednje vrijednosti, standardne devijacije, 95 %-tni intervali pouzdanosti i 3D vektori pomaka. Skupine su uspoređene Mann–Whitneyjevim U testom. **Rezultati:** Kod bolesnika s tumorima jetre najveći prosječni pomak zabilježen je u VRT smjeru (0,087 cm), uz prosječni 3D pomak od 0,351 ± 0,181 cm. Kod bolesnika s tumorima pluća najveći prosječni pomak zabilježen je u LNG smjeru (-0,092 cm), uz prosječni 3D pomak od 0,298 ± 0,186 cm. Statistički značajne razlike između skupina utvrđene su za VRT, LNG i 3D pomak (p = 0,0140; 0,0331; 0,0032). **Zaključak:** Površinski navođena SBRT uz IBH pokazala je visoku točnost i preciznost. Uočene razlike između skupina bolesnika s tumorima pluća i jetre upućuju na potrebu za regijski specifičnim pristupom planiranju i provedbi liječenja.

Ključne riječi: *IBH, jetra, pluća, SBRT, SGRT*

Assessment of Intrafractional Displacements in Surface-Guided Inspiration Breath-Hold Stereotactic Body Radiation Therapy

Abstract

Purpose: To evaluate the accuracy and precision of surface-guided inspiration breath-hold (IBH) in stereotactic body radiation therapy (SBRT) and compare intrafractional displacements between lung and liver patients. **Material and Methods:** A retrospective analysis included lung and liver SBRT patients treated with IBH from 2021–2024. Intrafractional displacements were assessed from midpoint corrections in vertical (VRT), longitudinal (LNG), and lateral (LAT) directions. The study included 86 lung patients (182 fractions) and 124 liver patients (159 fractions). Mean values, standard deviations, 95% confidence intervals, and 3D displacement vectors were calculated. Cohorts were compared using the Mann–Whitney U test. **Results:** Liver patients showed the largest mean displacement in VRT (0.087 cm) and a mean 3D displacement of 0.351 ± 0.181 cm. Lung patients showed the largest mean displacement in LNG (-0.092 cm) and a mean 3D displacement of 0.298 ± 0.186 cm. Significant differences were found for VRT, LNG, and 3D displacement (p = 0.0140, 0.0331, and 0.0032). **Conclusion:** Surface-guided IBH SBRT demonstrated high positional accuracy and precision. Differences between lung and liver cohorts suggest the need for region-specific treatment approaches.

Keywords: *IBH, Liver, Lung, SBRT, SGRT*

Medicinski dijagnostički monitori u radiologiji: tehnički zahtjevi i kontrola kvalitete

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Sažetak

Cilj rada je prikazati ulogu medicinskih dijagnostičkih monitora u radiološkom dijagnostičkom lancu te istaknuti važnost odgovarajućih tehničkih svojstava, kalibracije i kontrole kvalitete. Kao materijali korišteni su stručna literatura, međunarodne norme i smjernice, uključujući DICOM PS3.14, AAPM TG18, IEC 62563-1 i DIN 6868-157, kao i relevantni europski i hrvatski propisi. Metodom deskriptivnog pregleda analizi-

rane su vrste monitora prema namjeni, rezoluciji, luminanciji, prikazu sivih tonova, internoj LUT obradi, ugrađenim senzorima, ergonomiji te postupcima prihvatnog i periodičnog testiranja. Analiza pokazuje da primarna dijagnostika zahtijeva certificirane monitore odgovarajuće rezolucije i luminancije, kalibrirane prema funkciji DICOM GSDF uz dokumentirani program osiguranja kvalitete. Posebno strogi zahtjevi primjenjuju se na mamografske monitore zbog potrebe za pouzdanim prikazom mikrokalcifikacija i drugih suptilnih promjena. Zaključno, medicinske dijagnostičke monitore treba promatrati kao regulirani dio dijagnostičkog sustava, a ne samo kao računalni izlazni uređaj. Sustavna kontrola kvalitete, pravilno okruženje i osposobljenost osoblja važni su za održavanje pouzdanosti prikaza i sigurnosti pacijenta.

Ključne riječi: *dijagnostički monitori; DICOM GSDF; kontrola kvalitete; radiologija; zaštita pacijenta*

Medical diagnostic monitors in radiology: technical requirements and quality control

Abstract

The aim is to describe the role of medical diagnostic displays in the radiological imaging chain and to highlight the importance of appropriate technical characteristics, calibration and quality assurance. The materials consisted of professional literature, international standards and guidelines, including DICOM PS3.14, AAPM TG18, IEC 62563-1 and DIN 6868-157, as well as relevant European and Croatian regulations. A descriptive review was used to analyse display types according to their intended use, resolution, luminance, grayscale reproduction, internal look-up-table processing, built-in sensors, ergonomics and acceptance and constancy testing procedures. The analysis shows that primary diagnosis requires certified displays with appropriate resolution and luminance, calibrated according to the DICOM GSDF, together with a documented quality assurance programme. Particularly strict requirements apply to mammography displays because reliable visualization of microcalcifications and other subtle findings is essential. In conclusion, a medical diagnostic display should be considered a regulated component of the diagnostic system rather than merely a computer output device. Systematic quality assurance, an appropriate reading-room environment and adequately trained personnel are essential for maintaining reliable image display and patient safety.

Keywords: *DICOM GSDF; diagnostic displays; patient safety; quality assurance; radiology*

Učiti na tuđim greškama: ROSEIS sustav kao alat za jačanje sigurnosti pacijenata u radioterapiji

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Sažetak

Uvod: Sigurnost pacijenata jedan je od najvažnijih aspekata radioterapije. Iako se u svakodnevnom radu primjenjuju brojni postupci kontrole i provjere, pogreške i događaji koji su na vrijeme prepoznati i spriječeni (near-miss) ipak se događaju. Upravo analiza i sustavno prijavljivanje takvih događaja može pomoći u prepoznavanju slabosti u procesu i spriječiti da se ista pogreška ponovi. **Cilj rada:** Cilj ovog rada je predstaviti ROSEIS (Radiation Oncology Safety Education and Information System) kao sustav za prijavu radioterapijskih događaja i razmjenu iskustava vezanih uz sigurnosne događaje u radioterapiji. Posebno se želi ukazati na važnost njegove primjene u svakodnevnom radu radioloških tehnologa i na važnost dijeljenja iskustava između radioterapijskih centara. **Prikaz sustava:** ROSEIS je razvijen na temelju iskustava stečenih kroz ROSIS, međunarodni sustav za prijavljivanje i učenje iz incidenata u radioterapiji, te predstavlja njegovu daljnju evoluciju. Sustav omogućuje prijavljivanje različitih incidenata i odstupanja koji se mogu pojaviti tijekom radioterapijskog procesa. Prijavljeni podaci mogu se koristiti za lokalnu analizu i poboljšanje vlastitih postupaka, ali se, u anonimnom obliku, mogu podijeliti i s drugim korisnicima. Na taj način iskustvo jednog radioterapijskog centra može pomoći drugome u prepoznavanju sličnih rizika i sprječavanju ponavljanja istih ili sličnih događaja. Upravo mogućnost učenja iz iskustava drugih centara i razmjene informacija predstavlja jednu od glavnih vrijednosti ROSEIS-a. **Uloga radioloških tehnologa:** Radiološki tehnolozi sudjeluju u gotovo svim fazama radioterapijskog procesa i često su posljednja kontrola prije same isporuke zračenja. Zbog toga njihova sposobnost prepoznavanja i prijavljivanja odstupanja ima važnu ulogu u sigurnosti pacijenata. Za učinkovito prijavljivanje potrebno je razvijati kulturu u kojoj se pogreške ne promatraju prvenstveno kroz traženje krivca, nego kao mogućnost da se unaprijedi proces i spriječi njihovo ponavljanje. **Zaključak:** ROSEIS može biti koristan alat za učenje iz iskustava drugih radioterapijskih centara. Prijavljivanje i analiza događaja omogućuju da se problemi prepoznaju prije nego što dovedu do ozbiljnijih posljedica. Veće uključivanje radioloških tehnologa i hrvatskih radioterapijskih centara u ovakav način razmjene iskustava može biti jedan od koraka prema daljnjem razvoju kulture sigurnosti u radioterapiji.

Ključne riječi: *ROSEIS, ESTRO, sigurnost pacijenata, radioterapija, incidenti, radiološki tehnolozi*

Learning from others' mistakes: ROSEIS as a tool for strengthening patient safety in radiotherapy

Abstract

Introduction: Patient safety is one of the most important aspects of radiotherapy. Despite numerous quality control and verification procedures, errors and „near-miss" events still occur. Systematic reporting and analysis of such events can help identify weaknesses in the radiotherapy process and prevent recurrence. **Aim:** The aim of this paper is to present ROSEIS (Radiation Oncology Safety Education and Information System) as a system for reporting radiotherapy-related incidents and sharing safety experiences. Particular attention is given to its relevance to the daily work of radiation technologists and to the importance of sharing experiences between radiotherapy centres. **System Overview:** ROSEIS was developed based on the experience gained through ROSIS, an international system for reporting and learning from incidents in radiotherapy, and represents its further evolution. It enables the reporting of incidents and deviations occurring during the radiotherapy process. Reported data can be used for local analysis and improvement of clinical procedures and can also be shared anonymously with other users. In this way, the experience of one radiotherapy centre can help others identify similar risks and prevent recurrence. Learning from the experiences of other centres and sharing information represents one of the main strengths of ROSEIS. **Role of Radiation Technologists:** Radiation technologists are involved in almost every stage of the radiotherapy process and often represent the final safety check before radiation delivery. Their ability to recognise and report deviations therefore plays an important role in patient safety. Effective reporting requires a culture in which errors are viewed not primarily as a reason to assign blame, but as an opportunity to improve processes and prevent recurrence. **Conclusion:** ROSEIS can be a valuable tool for learning from the experiences of other radiotherapy centres. Reporting and analysing events can help identify problems before they lead to more serious consequences. Greater involvement of radiation technologists and Croatian radiotherapy centres in this type of experience-sharing network could contribute to further development of a strong safety culture in radiotherapy.

Keywords*: ROSEIS, ESTRO, patient safety, radiotherapy, incidents, near-misses, radiation technologists*

Kontaktna zaštitna sredstva za pacijente: praksa i stavovi radioloških tehnologa i radiologa

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Sažetak

Cilj: Usporediti kliničku praksu i stavove radioloških tehnologa i radiologa o uporabi kontaktnih zaštitnih sredstava u dijagnostičkoj i intervencijskoj radiologiji u Republici Hrvatskoj. **Materijali i metode:** Provedeno je anonimno anketno istraživanje među radiološkim tehnolozima i radiolozima u Republici Hrvatskoj. Za svaku skupinu izrađen je zaseban upitnik kojim je ispitana klinička praksa, stavovi o uporabi kontaktnih zaštitnih sredstava, poznavanje novih europskih preporuka te prepreke njihovoj provedbi. **Glavni rezultati:** Analizirani su odgovori 229 radioloških tehnologa i 47 radiologa. Obje skupine navode da se kontaktna zaštitna sredstva i dalje koriste u svakodnevnoj kliničkoj praksi. Dio ispitanika smatra da ona znatno doprinose smanjenju ozračenja pacijenata. U obje skupine zabilježene su različite razine upoznatosti s novim europskim preporukama. Najčešće prepoznate prepreke provedbi novih preporuka bila su očekivanja pacijenata i psihološki aspekti, dok su otvoreni odgovori dodatno ukazali na potrebu za edukacijom i usklađivanjem zakonodavnog okvira. **Zaključak:** Implementacija novih europskih preporuka o prestanku rutinske uporabe kontaktnih zaštitnih sredstava predstavlja izazov u svakodnevnoj kliničkoj praksi. Potrebni su edukacija zdravstvenih djelatnika, informiranje pacijenata i usklađivanje nacionalnog zakonodavnog okvira s aktualnim međunarodnim preporukama.

Ključne riječi: *kontaktna zaštitna sredstva, europske preporuke, stavovi*

Patient contact shielding: practice and attitudes of radiologic technologists and radiologists

Abstract

AIM: To compare the clinical practice and attitudes of radiographers and radiologists regarding the use of patient contact shielding in diagnostic and interventional radiology in Croatia. **Materials and Methods:** An anonymous survey was conducted among radiographers and radiologists in Croatia. Separate questionnaires were developed for each group to assess clinical practice, attitudes towards the use of patient contact shielding, awareness of the new European recommendations and barriers to their implementation. Main **Results:** Responses from 229 radiographers and 47 radiologists were analysed. Both groups reported that patient contact shielding continues to be used in everyday clinical practice. Some respondents believed that it substantially reduces patient radiation exposure. Different levels of awareness of the new European recommendations were observed in both groups. The most frequently identified barriers to implementation were patient expectations and psychological factors, while open-ended responses additionally highlighted the need for education and alignment of the legislative framework. **Conclusion:** Implementing the new European recommendations on discontinuing the routine use of patient contact shielding remains challenging in everyday clinical practice. Education of healthcare professionals, patient information and alignment of the national legislative framework with current international recommendations are needed.

Keywords: *patient contact shielding, European recommendations, attitudes*

Usporedba pristupa određivanju aktivnosti ^{18}F-FDG-a u onkološkom PET/CT-u

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Sažetak

Cilj: Usporediti različite načine određivanja aktivnosti ^{18}F-FDG-a u onkološkom PET/CT-u i prikazati kako oni utječu na kvalitetu slike i izloženost pacijenta zračenju. **Materijali i metode:** Proveden je pregled relevantne literature, te su izdvojena četiri znanstvena rada, uključujući tri klinička istraživanja i jedno istraživanje na fantomu, koja su analizirala fiksnu aktivnost, doziranje prema tjelesnoj masi i prilagodbu vremena snimanja. **Rezultati:** Istraživanja pokazuju da jednaka aktivnost za sve pacijente ne daje jednaku kvalitetu slike jer ona opada s porastom tjelesne mase. U istraživanju na 1231 pacijentu doziranje prema tjelesnoj masi smanjilo je efektivnu dozu za 11 % i poboljšalo pokazatelj kvalitete slike za 10 %, ponajviše u pacijenata mase od 50 do 69 kg. U pacijenata težih od 70 kg povećanje aktivnosti nije dovelo do značajnog poboljšanja slike. U drugom istraživanju ni povećanje aktivnosti do 2,5 puta nije poboljšalo omjer signala i šuma u jetri, dok je dulje snimanje bilo učinkovitije. Istraživanje na fantomu pokazalo je da aktivnost i vrijeme snimanja treba promatrati zajedno i prilagoditi ih tjelesnoj masi. U našoj ustanovi odraslim se pacijentima, ovisno o tjelesnoj masi, primjenjuje približno 5–6 mCi ^{18}F-FDG-a, uz standardizirani protokol snimanja. **Zaključak:** Ne postoji jedan način doziranja radiofarmaka koji je najbolji za sve pacijente. Za postizanje dobre kvalitete slike uz što manje zračenje potrebno je uskladiti tjelesnu masu, primijenjenu aktivnost, trajanje snimanja i mogućnosti PET/CT uređaja.

Ključne riječi: *doziranje, kvaliteta slike, PET*

Comparison of approaches to determining ^{18}F-FDG activity in oncological PET/CT

Abstract

Objective: To compare different approaches to determining ^{18}F-FDG activity in oncologic PET/CT and describe how they affect image quality and patient radiation exposure. **Materials and Methods:** A review of relevant literature was conducted, and four scientific papers were included in the study, including three clinical studies and one study on phantom, which analyzed fixed activity, body weight-based dosing, and adjustment of imaging time. **Results:** The studies showed that giving the same activity to every patient does not provide the same image quality, because image quality decreases as body weight increases. In a study of 1,231 patients, body-weight-based dosing reduced the effective dose by 11% and improved an image-quality measure by 10%, with the greatest benefit in patients weighing 50–69 kg. In patients weighing more than 70 kg, increasing the activity did not significantly improve image quality. In another study, even increasing activity up to 2.5-fold did not improve the liver signal-to-noise ratio, whereas longer acquisition was more effective. A study on phantom showed that administered activity and acquisition time should be considered together and adjusted to body weight. At our institution, adult patients are administered approximately 5–6 mCi of ^{18}F-FDG, depending on body weight, using a standardized imaging protocol. **Conclusion:** No single method of dosing radiopharmaceuticals is optimal for every patient. To achieve good image quality with the lowest reasonable radiation exposure, body weight, administered activity, acquisition time, and PET/CT system performance should be considered together.

Keywords: *CT, tjelesna masa, vrijeme snimanja*

Optimizacija CT protokola neurokranija u SKB Mostar

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Sveučilišna klinička bolnica Mostar

Sažetak

CT glave jedno je od najčešće izvođenih CT pregleda u kliničkoj praksi i značajno doprinosi kolektivnoj dozi zračenja populacije. Bosna i Hercegovina još nije uspostavila nacionalne dijagnostičke referentne razine (DRL) za CT, pa se ustanove oslanjaju na europske smjernice. Ova retrospektivna jednoinstitucijska studija analizirala je parametre doze CT pregleda neurokranija izvedenih u SKB-u Mostar. Podaci iz 315 pregleda neurokranija bez kontrasta iz 2019. godine, prije optimizacije protokola, uspoređeni su s podacima 244 pregleda izvedenih od svibnja 2025. do svibnja 2026. godine, nakon optimizacije. Parametri doze – volumni CT indeks doze (CTDIvol) i produkt doze i duljine (DLP) – izvučeni su iz bolničkog informacijskog sustava i softvera OpenREM. Rezultati su pokazali statistički značajno smanjenje i CTDIvol-a i DLP-a ($p < 0,001$). Medijan CTDIvol-a smanjio se s 72,7 mGy na 54,2 mGy (25,4%), a medijan DLP-a s 1275,1 na 987,0 mGy·cm (22,6%). Percentil 75 CTDIvol-a snizio se na 58,4 mGy (ispod europskog DRL-a od 60 mGy), a percentil 75 DLP-a od 1027,6 mGy·cm bio je neznatno ispod DRL-a od 1050 mGy·cm. Ovi nalazi potvrđuju vrijednost sustavne optimizacije protokola i pružaju važne polazišne podatke za buduće uspostavljanje nacionalnih DRL-ova u Bosni i Hercegovini.

Ključne riječi: *CTDIvol; dijagnostičke referentne razine; DLP; neurokranij; kompjutorizirana tomografija*

Optimisation of CT protocol of neurocrania at UCH Mostar

Abstract

CT of the head is among the most frequently performed CT examinations and contributes substantially to the collective radiation dose received by the population. Bosnia and Herzegovina has not yet established national diagnostic reference levels (DRLs) for CT, and institutions rely on European guidelines. This retrospective single-centre study analysed CT dose parameters for neurocranium examinations at University Clinical Hospital Mostar. Data from 315 unenhanced examinations acquired in 2019, prior to protocol optimisation, were compared with 244 examinations acquired between May 2025 and May 2026, following optimisation. Dose parameters (CTDIvol and DLP) were extracted from the hospital information system and OpenREM. Results showed a statistically significant reduction in both parameters ($p < 0.001$). The median CTDIvol decreased from 72.7 mGy to 54.2 mGy (25.4%), and median DLP from 1275.1 to 987.0 mGy·cm (22.6%). The 75th percentile CTDIvol (58.4 mGy) fell below the European DRL of 60 mGy, and the 75th percentile DLP (1027.6 mGy·cm) was marginally below the DRL of 1050 mGy·cm. These findings demonstrate the value of systematic optimisation and provide baseline data for future national DRLs in Bosnia and Herzegovina.

Keywords: *computed tomography; CTDIvol; diagnostic reference levels; DLP; neurocranium*

Doze zračenja na različitim digitalnim sustavima u radiologiji

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Sažetak

Ovaj rad analizira doze zračenja na digitalnim radiografskim sustavima. Računalna radiografija (eng. Computed Radiography) i direktna digitalna radiografija (eng. Direct Radiography), pri snimanju anatomskih regija pluća, ramena i zdjelice s kukovima. Cilj istraživanja bio je usporediti ulazne površinske doze zračenja (ESD), te procijeniti prednosti direktne digitalne (DR) tehnologije u optimizaciji doze zračenja uz očuvanje dijagnostičke kvalitete slike u odnosu na računalnu digitalnu tehnologiju (CR). Istraživanje provedeno na 180 ispitanika različitog spola i životne dobi, postavljena je formula za izračun ulazne površinske doze (ESD) na osnovu godišnjeg ispitivanja rendgenskih uređaja iz 2025 godine. Podaci su najprije opisani deskriptivnom statistikom, a zatim su za usporedbu CR i DR sustava primijenjeni t-test za nezavisne uzorke. Razlike između muškaraca i žena analizirane su Mann–Whitney U testom, dok je linearna regresijska analiza korištena za procjenu povezanosti između vrijednosti dobivenih na CR i DR sustavima. Statistička značajnost postavljena je na razinu p manju od 0,05. Rezultati su pokazali da Direktna digitalna radiografija u većini slučajeva omogućuje niže doze zračenja, osobito kod snimanja pluća i ramena, dok su razlike kod zdjelice manje izražene zbog veće debljine tkiva i potrebe za višom energijom zračenja. Na temelju provedenog istraživanja može se zaključiti da je digitalna radiografija ostvarila niže vrijednosti ulazne površinske doze u odnosu na računalnu radiografiju u svim analiziranim anatomskim regijama. Statistički značajne razlike potvrđene su za snimanje pluća i ramena, dok je kod zdjelice zabilježen trend nižih doza bez statističke značajnosti. Regresijska analiza pokazala je da između CR i DR sustava ne postoji značajna linearna povezanost, što potvrđuje njihovu tehnološku različitost. Dobiveni rezultati također ističu važnost pravilne primjene AEC sustava i optimizacije ekspozicijskih parametara. Zaključno, može se istaknuti da DR sustavi, uz optimizaciju ekspozicijskih parametara i AEC sustava, omogućuju smanjenje doze zračenja uz očuvanje dijagnostičke kvalitete slike, čime se dodatno povećava sigurnost pacijenata u svakodnevnoj radiološkoj praksi.

Ključne riječi: *Digitalni radiografski sustavi, ulazna površinska doza (ESD), optimizacija ekspozicijskih parametara*

Radiation doses on different digital systems in radiology

Abstract

This study analyzes radiation doses in the digital radiographic systems Computed Radiography (CR) and Direct Radiography (DR) during imaging of the chest, shoulder, and pelvis with hips. The aim of this study was to compare entrance surface doses (ESD) and to evaluate the advantages of direct radiography (DR) in optimizing radiation dose while preserving diagnostic image quality compared with computed radiography (CR). The study was conducted on 180 participants of different sexes and ages. A formula for calculating the entrance surface dose (ESD) was established based on the annual quality control testing of X-ray equipment performed in 2025. The data were first analyzed using descriptive statistics. An independent-samples t-test was then applied to compare the CR and DR systems. Differences between male and female participants were analyzed using the Mann–Whitney U test, while linear regression analysis was used to assess the relationship between the values obtained from the CR and DR systems. Statistical significance was set at $p < 0.05$. The results showed that direct radiography (DR) generally enables lower radiation doses, particularly during chest and shoulder imaging, whereas the differences were less pronounced for the pelvis due to greater tissue thickness and the need for higher X-ray beam energy. Based on the findings of this study, it can be concluded that direct radiography (DR) achieved lower entrance surface dose (ESD) values than computed radiography (CR) across all analyzed anatomical regions. Statistically significant differences were confirmed for chest and shoulder imaging, whereas pelvic imaging showed a trend toward lower doses without reaching statistical significance. Linear regression analysis demonstrated no significant linear relationship between the CR and DR systems, confirming their technological differences. The results also highlight the importance of the proper use of the automatic exposure control (AEC) system and the optimization of exposure parameters. In conclusion, when combined with optimized exposure parameters and appropriate use of the AEC system, DR systems can reduce radiation dose while preserving diagnostic image quality, thereby further enhancing patient safety in routine radiological practice.

Keywords: *Digital radiographic systems, Entrance surface dose (ESD), Optimization of exposure parameters*

MR dojke: kada kvaliteta počinje prije prve sekvence

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Sažetak

Magnetska rezonancija dojki predstavlja jednu od najsloženijih dijagnostičkih pretraga u radiologiji, pri čemu kvaliteta dobivenih slika ne ovisi isključivo o odabiru protokola i tehničkim parametrima snimanja. Ključ uspješne pretrage započinje mnogo prije prve sekvence – kroz kvalitetnu komunikaciju s pacijenticom, pravilnu pripremu, stvaranje osjećaja sigurnosti te precizno pozicioniranje. Ovo predavanje prikazat će cjelovit pristup radiološkog tehnologa tijekom izvođenja MR dojki, naglašavajući njegovu ulogu u svakom koraku pretrage. Bit će obrađeni postupci pripreme pacijentice, način objašnjavanja tijeka pregleda, prepoznavanje najčešćih izvora nelagode i anksioznosti te važnost individualiziranog pristupa u ostvarivanju suradnje tijekom snimanja. Poseban naglasak stavit će se na pravilno pozicioniranje dojki u zavojnici, osiguravanje stabilnosti položaja i udobnosti pacijentice, kao preduvjeta za smanjenje artefakata i postizanje dijagnostički kvalitetnih slika. Uz prikaz osnovnih elemenata MR protokola dojki, predavanje će istaknuti kako tehnička izvrsnost proizlazi iz uspješnog povezivanja stručnog znanja, komunikacijskih vještina i iskustva radiološkog tehnologa. Kroz primjere iz svakodnevne kliničke prakse bit će prikazani izazovi s kojima se tehnolozi susreću te praktična rješenja koja mogu unaprijediti kvalitetu pretrage i iskustvo pacijentice. Cilj predavanja jest naglasiti da radiološki tehnolog nije samo izvršitelj tehničkog dijela pretrage, već ključan član multidisciplinarnog tima koji svojim znanjem, empatijom i profesionalnim pristupom izravno utječe na uspješnost MR dojki. Kvalitetna komunikacija, pažljiva priprema i pravilno pozicioniranje jednako su važni kao i odabir optimalnog protokola,

jer upravo oni stvaraju preduvjete za pouzdanu dijagnostiku i sigurnije iskustvo pacijentice.

Ključne riječi: *magnetska rezonanca, dojke, povjerenje, komunikacija, izvrsnost*

Breast MRI: When quality begins before the first sequence

Abstract

BREAST MRI: When Quality Begins Before the First Sequence Breast magnetic resonance imaging (MRI) is one of the most demanding diagnostic imaging examinations, where image quality depends not only on the imaging protocol and technical parameters but also on the preparation and management of the patient. The foundation of a successful examination is established long before the first sequence is acquired through effective communication, thorough patient preparation, reassurance, and accurate positioning. This presentation will demonstrate a comprehensive approach to breast MRI from the perspective of the radiographer, emphasizing their role throughout every stage of the examination. Topics will include patient preparation, explaining the examination process, identifying common causes of anxiety and discomfort, and the importance of an individualized approach in achieving patient cooperation during image acquisition. Particular attention will be given to correct breast positioning within the dedicated coil, ensuring patient comfort and stability, and their impact on minimizing motion artefacts and obtaining diagnostically reliable images. In addition to reviewing the essential elements of the breast MRI protocol, the presentation will highlight how technical excellence results from the integration of professional expertise, communication skills, and the radiographer's clinical experience. Practical examples from everyday clinical practice will illustrate common challenges encountered during breast MRI examinations, together with strategies for improving both image quality and the overall patient experience. The aim of this presentation is to emphasize that radiographers are not merely responsible for the technical execution of breast MRI but are key members of the multidisciplinary team whose knowledge, empathy, and professional approach directly influence the success of the examination. Effective communication, careful preparation, and optimal patient positioning are as important as selecting the appropriate imaging protocol, as they provide the basis for high-quality diagnostic imaging and a positive patient experience.

Keywords: *magnetic resonance imaging, breast, trust, communication, excellence*

Vrijednost probirne mamografije u detekciji karcinoma dojke

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Sažetak

Probirna mamografija i dalje predstavlja temelj ranog otkrivanja raka dojke, s dobro dokumentiranim dokazima o smanjenju smrtnosti. Kao zlatni standard probira, mamografija se temelji na fizikalnim principima koji omogućuju razlikovanje normalnog i malignog tkiva. Iako je integracija DBT u populacijske programe još uvijek u tijeku, pilot-studije i implementacijska istraživanja potvrđuju njezinu izvedivost i učinkovitost. Područje probira kontinuirano se razvija, a smjernice se prilagođavaju sve složenijem razumijevanju ravnoteže između koristi i šteta probira, koja ovisi o dobi, čimbenicima rizika i individualnim okolnostima. Dodatni probirni modaliteti, poput ultrazvuka, MR-a, termografije i gama-snimanja specifičnog za dojku, imaju važnu ulogu u odabranim populacijama, osobito kod žena s gustim dojkama i povećanim rizikom. Integracija različitih tehnologija time proširuje dijagnostičke mogućnosti probira. UI i CAD predstavljaju važan razvoj u oslikavanju dojke, s potencijalom za poboljšanje točnosti detekcije, učinkovitosti radnih procesa i modela procjene rizika. Iako algoritmi pokazuju obećavajuće rezultate u otkrivanju karcinoma i predviđanju rizika, njihova primjena zahtijeva rigoroznu validaciju, prevladavanje organizacijskih izazova i rješavanje etičkih pitanja. Novi modeli, poput 3D-GMIC za klasifikaciju 3D medicinskih slika i NSBR-Net mreže za segmentaciju tumora u ultrazvučnim slikama, dodatno proširuju mogućnosti automatizirane analize medicinskih slika. Probir stratificiran prema riziku predstavlja novu paradigmu koja omogućuje prilagodbu preporuka individualnim profilima rizika. Prema preporukama EUSOBI-ja, takav pristup može poboljšati omjer koristi i šteta te povećati isplativost probira. Budućnost oslikavanja dojke usmjerena je prema integraciji više slikovnih modaliteta, interpretaciji potpomognutoj sa UI i personaliziranim strategijama probira prilagođenima individualnim profilima rizika. Dijagnostika i liječenje raka dojke sve više ide prema personaliziranoj medicini koja uključuje naprednu dijagnostiku, molekularno oslikavanje i genomsku analizu u kombinaciji s UI. Takav razvoj ima potencijal poboljšati ishode liječenja uz istodobno smanjenje šteta povezanih s probirom i terapijom. Krajnji cilj ostaje smanjenje smrtnosti od raka dojke putem ranog otkrivanja i učinkovite terapije, uz poštovanje autonomije, preferencija i vrijednosti pacijentica u procesu donošenja odluka o probiru.

Ključne riječi: *mamografija; probirna mamografija; rak dojke; umjetna inteligencija*

The value of screening mammography in breast cancer detection

Abstract

Screening mammography remains the cornerstone of early breast cancer detection, with well-documented evidence demonstrating its ability to reduce breast cancer mortality. As the gold standard for breast cancer screening, mammography is based on physical principles that allow differentiation between normal and malignant breast tissue. Although the integration of digital breast tomosynthesis (DBT) into population-based screening programmes is still ongoing, pilot studies and implementation research have confirmed its feasibility and effectiveness. The field of breast cancer screening continues to evolve, and screening guidelines are being refined in response to an increasingly sophisticated understanding of the balance between the benefits and harms of screening, which depends on age, risk factors, and individual circumstances. Additional screening modalities, including ultrasound, magnetic resonance imaging (MRI), thermography, and breast-specific gamma imaging (BSGI), play an important role in selected populations, particularly among women with dense breasts and those at increased risk. The integration of multiple imaging technologies therefore expands the diagnostic capabilities of breast cancer screening. Artificial intelligence (AI) and computer-aided detection (CAD) represent important advances in breast imaging, with the potential to improve cancer detection accuracy, workflow efficiency, and risk assessment models. Although AI algorithms have shown promising results in cancer detection and risk prediction, their implementation requires rigorous validation, the resolution of organisational challenges, and careful consideration of ethical issues. Emerging models, such as 3D-GMIC for the classification of three-dimensional medical images and the NSBR-Net architecture for tumour segmentation in ultrasound images, further expand the capabilities of automated medical image analysis. Risk-stratified screening represents a new paradigm that enables screening recommendations to be tailored to individual risk profiles. According to the recommendations of the European Society of Breast Imaging (EUSOBI), this approach has the potential to improve the balance between the benefits and harms of screening while also enhancing its cost-effectiveness. The future of breast imaging is directed towards the integration of multiple imaging modalities, AI-assisted image interpretation, and personalised screening strategies tailored to individual risk profiles. Breast cancer diagnosis and treatment are increasingly moving towards personalised medicine, incorporating advanced diagnostic techniques, molecular imaging, genomic analysis, and AI. These developments have the potential to improve clinical outcomes while simultaneously reducing the harms associated with screening and treatment. The ultimate goal remains to reduce breast cancer mortality through early detection and effective treatment while respecting patients' autonomy, preferences, and values in the shared decision-making process regarding breast cancer screening..

Keywords: *mammography; screening mammography; breast cancer; artificial intelligence*

MR skrotuma i penisa – indikacije, izvođenje pretrage i prikaz slučaja

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Sažetak

Uvod: Magnetska rezonancija (MR) postala je važna komplementarna slikovna metoda u obradi bolesti skrotuma i penisa kada ultrazvučni nalaz nije dovoljno jasan ili kada je potrebna detaljna anatomska procjena. Zahvaljujući izvrsnom prikazu mekih tkiva, mogućnosti multiplanarnog prikaza i naprednim funkcionalnim sekvencama, MR omogućuje preciznu karakterizaciju širokog spektra benignih i malignih patologija te pruža vrijedne informacije za planiranje liječenja. **Cilj:** Prikazati aktualne indikacije za MR skrotuma i penisa, predstaviti standardizirani protokol pretrage koji se koristi u Kliničkom bolničkom centru Rijeka te demonstrirati njegovu kliničku vrijednost kroz odabrane prikaze slučajeva iz prakse. **Materijali i metode:** U Kliničkom bolničkom centru Rijeka MR penisa i skrotuma izvodi se prema standardiziranom protokolu kako bi postigli optimalnu anatomsku vizualizaciju i kvalitetu slike. U ovom radu prikazali smo pripremu i pozicioniranje pacijenta te protokol koji se rutinski koristi za standardne pretrage. Protokol uključuje visokorezolucijske multiplanarne sekvence uz dodatne difuzijske sekvence. Također su prikazani slučajevi iz naše kliničke prakse koji ilustriraju dijagnostički doprinos MR-a u različitim patološkim stanjima. **Rezultati i rasprava:** MR ima osobitu vrijednost u određivanju stadija karcinoma penisa procjenom zahvaćenosti kavernoznih tijela, spongioznog tijela i uretre, čime pridonosi planiranju kirurškog liječenja i strategijama očuvanja organa. Dodatne indikacije uključuju benigne i maligne tumore penisa i uretre, traumu i frakturu penisa, postradijacijske ozljede, upalne bolesti, priapizam, patologiju uretre te odabrane bolesti skrotuma poput neoplazmi, infekcija, torzije i traume. Kod sumnje na frakturu penisa MR pokazuje visoku točnost u potvrđivanju rupture tunice albuginee i procjeni opsega ozljede. **Zaključak:** MR predstavlja vrijednu metodu za rješavanje dijagnostičkih dvojbi u obradi bolesti skrotuma i penisa te poboljšava dijagnostičku sigurnost, točnost procjene stadija tumora i donošenje terapijskih odluka. Standardizirani protokoli osiguravaju reproducibilnost pretrage i doprinose optimalnom zbrinjavanju bolesnika.

Ključne riječi: *Fraktura penisa; Karcinom penisa; Magnetska rezonancija (MR); Skrotum; Urogenitalno oslikavanje*

MRI of the scrotum and penis – indications, examination performance and case report

Abstract

Background: Magnetic resonance imaging (MRI) has become an important complementary imaging modality in the evaluation of scrotal and penile disorders when ultrasonography is inconclusive or when detailed anatomical assessment is required. Owing to its superior soft-tissue contrast, multiplanar capability, and advanced functional sequences, MRI enables accurate characterization of a broad spectrum of benign and malignant pathologies and provides valuable information for treatment planning. **Purpose:** To review the current indications for scrotal and penile MRI, present the standardized examination protocol used at Clinical Hospital Center Rijeka, and demonstrate its clinical value through selected case presentations from routine practice. **Methods and Materials:** At Clinical Hospital Center Rijeka, MRI of the penis and scrotum is performed according to a standardized protocol designed to ensure optimal anatomical visualization and reproducible image quality. In this work, we present patient preparation, positioning, and the imaging protocol routinely used for standard examinations. The protocol includes high-resolution multiplanar sequences with additional diffusion-weighted imaging. Representative clinical cases from our institution are included to illustrate the diagnostic contribution of MRI in various pathological conditions. **Results and Discussion:** MRI is particularly valuable in the local staging of penile carcinoma by assessing infiltration of the corpora cavernosa, corpus spongiosum, and urethra, thereby supporting surgical planning and organ-preserving treatment strategies. Additional indications include benign and malignant penile and urethral tumours, penile trauma and fracture, post-radiation injury, inflammatory conditions, priapism, urethral pathology, and selected scrotal disorders such as neoplasms, infection, torsion, and trauma. In cases of suspected penile fracture, MRI has demonstrated superior accuracy in confirming tunica albuginea rupture and defining the extent of injury. **Conclusion:** MRI represents a valuable problem-solving tool in the evaluation of scrotal and penile diseases, improving diagnostic confidence, staging accuracy, and therapeutic decision-making. Standardized imaging protocols facilitate reproducible examinations and contribute to optimal patient management.

Keywords: *Magnetic Resonance Imaging (MRI); Penile Carcinoma; Penile Fracture; Scrotum; Urogenital Imaging*

MR artrografija ramena

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Sažetak

Uvod: MR artrografija ramena minimalno je invazivna dijagnostička metoda koja kombinira intraartikularnu primjenu kontrastnog sredstva pod kontrolom ultrazvuka i magnetsku rezonanciju radi detaljnijeg prikaza unutarnjih struktura ramenog zgloba u odnosu na standardni MR pregled. Omogućuje precizniji prikaz glenoidnog labruma, zglobne čahure, ligamenata i parcijalnih ruptura rotatorne manšete. Primjenjuje se u bolesnika s dugotrajnim bolovima, osjećajem nestabilnosti ili ograničenom funkcijom ramenog zgloba kada postoji sumnja na intraartikularnu patologiju koja se ne može pouzdano procijeniti standardnim MR pregledom. Cilj rada je prikazati dijagnostički put bolesnika od postavljanja indikacije do konačne radiološke dijagnoze. **Materijali i metode:** prikaz bolesnika s dugotrajnim bolovima i smetnjama ramena kod kojega je nakon ortopedskog pregleda postavljena indikacija za MR artrografiju. Prikazan je dijagnostički postupak koji uključuje nativno MR snimanje, intraartikularnu primjenu kontrastnog sredstva pod kontrolom ultrazvuka te postkontrastno MR snimanje. **Rezultati:** usporedbom nativnih i postkontrastnih snimaka prikazat će se dodatne informacije dobivene MR artrografijom koje omogućuju preciznije određivanje intraartikularne patologije. **Zaključak:** MR artrografija ramena vrijedna je nadopuna standardnom MR pregledu u jasno definiranim kliničkim indikacijama. Omogućuje detaljniji prikaz intraartikularnih struktura i patoloških promjena te povećava dijagnostičku pouzdanost nalaza.

Ključne riječi: *artrografija, kontrastno sredstvo, magnetska rezonancija, rameni zglob*

MR arthrography of the shoulder

Abstract

MR arthrography of the shoulder is a minimally invasive diagnostic method that combines intra-articular administration of contrast medium under ultrasound guidance with magnetic resonance imaging for a detailed assessment of shoulder joint structures compared with standard MRI. It enables an accurate evaluation of the glenoid labrum, joint capsule, ligaments, and partial ruptures of the rotator cuff. The examination is indicated in patients with chronic shoulder pain, a sensation of instability, or limited function when intra-articular pathology cannot be reliably assessed by standard MRI. The aim of this study is to present the diagnostic pathway from indication for MR arthrography to final radiological diagnosis. **Materials and Methods:** a case report of a patient with chronic shoulder pain and dysfunction in whom the indication for MR arthrography was established following an orthopedic examination. The procedure included native MRI, intra-articular administration of contrast medium under ultrasound guidance, and post-contrast MRI. **Results:** comparison of native and post-contrast images will demonstrate the additional information provided by MR arthrography, enabling a more precise assessment of intra-articular pathology. **Conclusion:** MR arthrography of the shoulder is a valuable adjunct to standard MRI in clearly defined clinical indications. It provides a more detailed depiction of intra-articular structures and pathological changes, thereby increasing diagnostic confidence.

Keywords: *arthrography, contrast medium, magnetic resonance imaging, shoulder joint*

Analiza učestalosti fraktura gornjih i donjih ekstremiteta kod pedijatrijskih hitnih prijema

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Sveučilište u Rijeci

Sažetak

Frakture u dječjoj dobi predstavljaju česte traumatske ozljede i važan javnozdravstveni problem. Cilj istraživanja bio je utvrditi učestalost fraktura gornjih i donjih ekstremiteta u pedijatrijskih pacijenata zaprimljenih putem hitnog prijema u KBC-u Rijeka te usporediti njihovu zastupljenost. Retrospektivnim istraživanjem obuhvaćeno je 837 pacijenata zaprimljenih u Hitnu ambulantu za dječju kirurgiju od 1. svibnja do 30. lipnja 2024. godine zbog sumnje na frakturu. Podaci su prikupljeni iz radiološkog informacijskog sustava ISSA te su uključivali dob, spol i vrstu radiografskog snimanja. Fraktura je potvrđena u 278 (33,21%) pacijenata, dok je 559 nalaza bilo negativno. Frakture gornjih ekstremiteta bile su statistički značajno učestalije od fraktura donjih ekstremiteta; pozitivan nalaz utvrđen je u 219 od 511 pregleda gornjih te u 68 od 375 pregleda donjih ekstremiteta. Među djecom s potvrđenom frakturom prevladavali su dječaci (70,14%). Najveća učestalost fraktura u djevojčica zabilježena je u dobi od 7 do 10 godina, najčešće u području prsta šake, dok je u dječaka najveća incidencija utvrđena u dobi od 11 do 13 godina, najčešće u području podlaktice. Rezultati potvrđuju veću zastupljenost fraktura gornjih ekstremiteta te važnost radiološke tehnologije u dijagnostici i usmjeravanju liječenja djece s traumatskim ozljedama.

Ključne riječi: *dijete; frakture; hitni prijem; radiološka tehnologija; traumatologija*

Analysis of the frequency of upper and lower extremity fractures in paediatric emergency departments

Abstract

Fractures in childhood represent common traumatic injuries and an important public health issue. The aim of this study was to determine the frequency of upper and lower extremity fractures in pediatric patients admitted through the emergency department at University Hospital Centre Rijeka and to compare their distribution. This retrospective study included 837 pediatric patients admitted to the Pediatric Surgery Emergency Department from May 1 to June 30, 2024, due to suspected fracture. Data were collected from the radiological information system ISSA and included age, sex, and the type of radiographic examination performed. Fracture was confirmed in 278 patients (33.21%), while 559 findings were negative. Upper extremity fractures were statistically significantly more frequent than lower extremity fractures; a positive finding was confirmed in 219 of 511 upper extremity examinations and in 68 of 375 lower extremity examinations. Among children with confirmed fractures, boys predominated (70.14%). The highest frequency of fractures in girls was recorded between 7 and 10 years of age, most commonly in the fingers, whereas in boys the highest incidence was found between 11 and 13 years of age, most commonly in the forearm. The results confirm a higher prevalence of upper extremity fractures and emphasize the importance of radiologic technology in the diagnosis and management of children with traumatic extremity injuries.

Keywords: *child; emergency department; fractures; radiologic technology; traumatology*

Brzina aplikacije kontrastnog sredstva kao jedan od čimbenika postkontrastnog obojenja

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Sažetak

Cilj rada je procijeniti utjecaj različitih brzina intravenske aplikacije kontrastnog sredstva na vrijeme dolaska kontrasta do definirane razine arterijske opacifikacije u silaznoj aorti te utvrditi u kojoj mjeri brzina aplikacije određuje kvalitetu opacifikacije. Naglasak je na procjeni opravdanosti oslanjanja isključivo na brzinu protoka kontrasta kao ključnog parametra. **Materijali i metode:** U istraživanje su uključeni pacijenti podvrgnuti CT pretragama uz intravensku primjenu jodnog kontrastnog sredstva. Pacijenti su podijeljeni u tri skupine prema brzini aplikacije kontrasta. Svim pacijentima se kontrastno sredstvo aplciralo kroz IV kanilu promjera 20G postavljenoj u desnoj lakatnoj jami. Kod svih pacijenata primjenjuje standardizirani protokol s jednakim načinom praćenja dolaska kontrasta (Care Bolus). Vrijeme dolaska kontrasta do postizanja unaprijed definirane vrijednosti od 120 HU u silaznoj aorti je zabilježeno i analizirano. Uspoređene su razlike u vremenu postizanja ciljne opacifikacije između skupina s različitim brzinama aplikacije kontrastnog sredstva. Rezultati pokazuju da osim brzine aplikacije, na dinamiku kontrastnog bolusa utječu i drugi čimbenici povezani s individualnim cirkulacijskim karakteristikama bolesnika. **Zaključak:** Brzina aplikacije kontrastnog sredstva predstavlja važan parametar ali ne određuje u potpunosti kvalitetu opacifikacije. Analizom vremena dolaska kontrasta do definirane razine obojenja moguće je procijeniti stvarni utjecaj brzine protoka i identificirati ograničenja standardiziranih protokola.

Ključne riječi: *Kontrastno sredstvo; Postkontrastna opacifikacija; Protok;*

Contrast injection rate as a factor in post-contrast opacification

Abstract

Objective is to assess the impact of different intravenous contrast media injection rates on the time required to reach a predefined level of arterial opacification in the descending aorta and to determine to what extent injection rate influences contrast enhancement quality. The study focuses on evaluating whether relying solely on contrast injection rate as a key optimization parameter is justified. **Materials and Methods:** The study included patients undergoing CT examinations with intravenous administration of iodinated contrast media. Patients were divided into three groups according to the contrast injection rate. A standardized protocol with the same contrast arrival monitoring method (Care Bolus) was applied in all patients. The time required to reach a predefined attenuation value of 120 HU in the descending aorta was recorded and analyzed. Differences in the time needed to achieve the target opacification level were compared between groups with different contrast injection rates. **Results:** The results indicate that, in addition to the injection rate, other factors related to individual circulatory characteristics influence contrast bolus dynamics and the achieved arterial enhancement. **Conclusion:** Contrast injection rate represents an important technical parameter; however, it does not fully determine the quality of arterial opacification. By analyzing the time required to reach a predefined enhancement threshold, it is possible to evaluate the actual impact of injection rate and identify limitations of standardized contrast administration protocols.

Keywords: *Contrast agent; Injection rate; Postcontrast opacification;*

Denzitometrija kao tabu u dječjoj dobi – važnost pravodobne procjene koštanog zdravlja u pedijatrijskoj populaciji

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Sažetak

Uvod: Razvoj koštanog sustava tijekom djetinjstva i adolescencije ključan je za postizanje optimalne vršne koštane mase u odrasloj dobi. Poremećaji mineralizacije kostiju u djece mogu dovesti do povećanog rizika od prijeloma, smanjene kvalitete života i razvoja osteoporoze u kasnijem životu. Dvoenergetska apsorcimetrija rendgenskih zraka (DXA) predstavlja zlatni standard za procjenu mineralne gustoće kostiju, no u pedijatrijskoj populaciji i dalje nedovoljno zastupljeno. **Cilj rada:** Prikazati specifičnosti DXA u dječjoj dobi te naglasiti njezinu dijagnostičku vrijednost u ranom otkrivanju poremećaja koštanog zdravlja. **Rasprava:** Za razliku od odraslih u djece se rezultati DXA pretrage inerpretiraju pomoću Z-vrijednosti uzimajući u obzir dob, spol, visinu i pubertetski status. Denzitometrija je osobito važna kod djece s kroničnim bolestima, malasorpcijskim sindromima, endokrinološkim poremećajima i kroničnim bubrežnim bolestima. Pravodobno prepoznavanje smanjene mineralne gustoće kostiju omogućuje rano uvođenje preventivnih i terapijskih mjera, uključujući nutritivne intervenicije, suplementaciju vitaminom D i kalcijem i liječenjem osnovne bolesti. Unatoč jasnim indikacijama,

pretraga se često provodi tek nakon pojave ponavljanih prijeloma. **Zaključak:** Denzitometrija predstavlja vrijednu, sigurnu i preciznu metodu za procjenu koštanog zdravlja. Veća osviještenost zdravstvenih djelatnika, standardizacija interpretacije nalaza i pravodobno upućivanje na DXA pretragu ključni su za rano otkrivanje poremećaja koštane mineralizacije i očuvanja zdravlja djece.

Ključne riječi: *DXA, koštani metabolizam, mineralna gustoća kostiju, pedijatrijska denzitometrija, pedijatrijska radiologija*

Densitometry as a taboo in childhood – the importance of timely assessment of bone health in the paediatric population

Abstract

Introduction: Skeletal development during childhood and adolescence is crucial for achieving optimal peak bone mass in adulthood. Bone mineralization disorders in children can lead to an increased risk of fractures, reduced quality of life, and the development of osteoporosis in later life. Dual-energy X-ray absorptiometry (DXA) is the gold standard for assessing bone mineral density, but it is still under-represented in the pediatric population. **Objective:** To present the specificities of DXE in childhood and emphasize its diagnostic value in the early detection of bone health disorders. **Discussion:** Unlike adults, in children, DXA results are interpreted using Z-scores, taking into account age, gender, height, and pubertal status. Densitometry is particularly important in children with chronic diseases, malabsorption syndromes, endocrine disorders, and chronic kidney disease. Timely recognition of reduced bone mineral density allows for early implementation of preventive and therapeutic measures, including nutritional interventions, vitamin D and calcium supplementation, and treatment of the underlying disease. Despite clear indications, the test is often performed only after the occurrence of recurrent fractures. **Conclusion:** Densitometry is a valuable, safe, and accurate method for assessing bone health. Increased awareness among healthcare professionals, standardization of interpretation of findings, and timely referral for DXA testing are key to early detection of bone mineralization disorders and preservation of children's health.

Keywords: *DXA, bone metabolism, bone mineral density, pediatric densitometry, pediatric radiology*

Utjecaj kratke edukacije na razumijevanje medicinskog zračenja u privatnoj radiološkoj praksi

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Sažetak

Pacijenti često nemaju dovoljno znanja o medicinskom zračenju i razlikama između radioloških dijagnostičkih metoda koje koriste ionizirajuće zračenje i onih koje se temelje na drugim fizikalnim principima. Cilj ovog istraživanja je procijeniti znanje pacijenata o medicinskom zračenju prije i nakon kratke edukacije te ispitati poznavanje pojedinih radioloških pretraga. U istraživanje će biti uključeno 100 odraslih pacijenata privatne radiološke poliklinike Drinković. Kriteriji za uključivanje su dob od 18 godina ili više, dolazak na radiološku pretragu na uputu specijalista, nezdravstvena struka te pristanak na anonimno sudjelovanje. Prije obavljanja pregleda ispitanici anonimno odgovaraju na pitanja o znanju vezanom uz medicinsko zračenje. Nakon ispunjavanja upitnika dobivaju kratki edukativni materijal koji objašnjava razlike između RTG-a, CT-a, MR-a i ultrazvuka. Materijal uključuje i usporedbe doza zračenja s prirodnim pozadinskim zračenjem kojem je stanovništvo svakodnevno izloženo. Iako su informacije o dozama zračenja dostupne na mrežnim stranicama poliklinike, nije poznato koliko ih pacijenti čitaju i razumiju. Zato je važno ispitati njihovu razinu znanja te procijeniti može li jednostavan edukativni materijal poboljšati razumijevanje medicinskog zračenja. Istraživanjem se ispituje znaju li pacijenti koje dijagnostičke metode koriste ionizirajuće zračenje, prepoznaju li da MR i ultrazvuk ne koriste ionizirajuće zračenje te razumiju li razlike u dozama zračenja između pojedinih pretraga. Preliminarni rezultati na prvih 20 ispitanika pokazuju značajno poboljšanje znanja nakon edukacije. Ukupni udio točnih odgovora porastao je s 37,7% prije edukacije na 82,2% nakon edukacije. U području poznavanja dijagnostičkih metoda udio točnih odgovora porastao je s 38,9% na 82,2%. Rezultati posebno upućuju na bolje razumijevanje činjenice da MR ne koristi ionizirajuće zračenje te da je doza zračenja pri CT-u abdomena i zdjelice veća nego pri RTG snimci pluća. Zaključno, kratka edukacija pokazala se kao jednostavan i praktičan način povećanja zdravstvene pismenosti pacijenata. Rezultati upućuju na potrebu za jasnim i standardiziranim edukativnim materijalima o zračenju na svim radiološkim radilištima kako bi se smanjila nesigurnost i pogrešne predodžbe povezane s medicinskim zračenjem

Ključne riječi: *dijagnostičke metode, edukacija pacijenata, medicinsko zračenje, radiologija*

The impact of a short training course on the understanding of medical radiation in private radiology practice

Abstract

Patients generally have insufficient knowledge about medical radiation and differences between radiological diagnostic methods that use ionizing radiation and those based on other physical principles. This study included 100 adult patients of a private radiology clinic. Before imaging examinations, participants anonymously completed a questionnaire assessing knowledge of medical radiation. After the questionnaire, patients received short educational material explaining differences between X-ray (RTG), computed tomography (CT), magnetic resonance imaging (MRI), and ultrasound (US). The material also included comparisons with natural background radiation exposure. Although this information is available on the clinic website, it is unclear whether patients read and understand it. Therefore, it is important to assess baseline knowledge and evaluate the effect of a short educational intervention. The aim of the study was to assess patients' knowledge before and after a short educational intervention, as well as their understanding of which radiological methods use ionizing radiation, whether they know that MRI and ultrasound do not use ionizing radiation, and which examinations involve higher radiation doses. The study was conducted at the Drinković Polyclinic. Inclusion criteria were age 18 years or older, referral for a radiological examination by a specialist, and voluntary informed consent for anonymous participation. Preliminary results from the analyzed sample show that the percentage of correct answers before education was 37.65%, while after education it increased to 82.2%, indicating a substantial improvement in patients' knowledge. Regarding specific diagnostic methods, correct answers increased from 38.9% before education to 82.2% after education. The first 20 patients analyzed so far demonstrated a clear improvement in understanding that MRI does not use ionizing radiation and that CT of the abdomen and pelvis carries a higher radiation dose compared to a chest X-ray. The findings suggest that even a short educational intervention can significantly improve patients' health literacy regarding medical radiation. This approach may reduce misconceptions and improve understanding of radiological procedures. The results support implementing clear and standardized educational materials in radiology departments, which could systematically enhance patient knowledge and reduce uncertainty related to medical radiation exposure and improve overall patient safety and communication in clinical practice today significantly across settings also.

Keywords: *ct, mr, x-ray, medical radiation, patient education*

Stres pod kontrolom: perfuzijska magnetska rezonancija srca u kliničkoj praksi

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Sažetak

Perfuzijska magnetska rezonancija srca uz farmakološko opterećenje neinvazivna je metoda za procjenu ishemije miokarda te se smatra zlatnim standardom među radiološkim metodama za procjenu srčane funkcije i tkivnu karakterizaciju.Cilj rada je prikazati standardizirani protokol izvođenja stres perfuzijske MR na 1,5 T uređaju te istaknuti ulogu radiološkog tehnologa u pripremi bolesnika, provedbi protokola i osiguravanju kvalitete snimanja.Prikazani protokol temelji se na kliničkoj primjeni

i iskustvu stečenom tijekom izvođenja više od 80 stres perfuzijskih MR pretraga srca. Priprema bolesnika uključuje provjeru unosa kofeina, procjenu kontraindikacija, mjerenje vitalnih parametara i uspostavu venskog puta visokog protoka.Nakon lokalizacijskih i cine sekvenci planiraju se perfuzijske sekvence uz EKG sinkronizaciju.Kao farmakološki stresor primjenjuje se regadenozon (Rapiscan), uz kontinuirano praćenje bolesnika i mogućih nuspojava.Stres perfuzijsko snimanje izvodi se tijekom prvog prolaska gadolinijskog kontrastnog sredstva kroz miokard.Nakon antagonizacije učinka regadenozona aminofilinom izvodi se rest perfuzija, a završni dio pretrage uključuje snimanje odgođenog nakupljanja kontrasta (LGE) i T1 mapping.Primjena standardiziranog protokola omogućuje visoku reproducibilnost pretrage, optimalnu kvalitetu slike i pouzdanu procjenu perfuzije miokarda.Radiološki tehnolog ima ključnu ulogu u koordinaciji postupaka, nadzoru bolesnika i osiguravanju tehničke kvalitete snimanja.

Ključne riječi: *ishemija miokarda,MR srca,radiološki tehnolog,regadenozon,stres perfuzija miokarda*

Stress under control: cardiac perfusion Magnetic Resonance Imaging in clinical practice

Abstract

Stress perfusion cardiac magnetic resonance imaging (CMR) is a non-invasive method for assessing myocardial ischemia and is considered the gold standard among radiological imaging modalities for cardiac function assessment and tissue characterization. The aim of this paper is to present a standardized protocol for stress perfusion CMR on a 1.5 T scanner and to highlight the role of the radiologic technologist in patient preparation, protocol implementation, and image quality assurance. The protocol is based on routine clinical practice and experience from more than 80 examinations. Patient preparation includes verification of caffeine abstinence, assessment of contraindications, measurement of vital signs, and establishment of a high-flow intravenous line. Following localization and cine sequences, perfusion sequences are planned using ECG synchronization. Regadenoson (Rapiscan) is administered as the stress agent with continuous patient monitoring. Stress perfusion imaging is performed during the first pass of gadolinium contrast through the myocardium. After reversal with aminophylline, rest perfusion imaging is performed. The examination concludes with late gadolinium enhancement (LGE) imaging and T1 mapping. A standardized protocol ensures reproducibility, optimal image quality, and reliable assessment of myocardial perfusion. The radiologic technologist plays a key role in procedure coordination, patient monitoring, and technical image quality.

Keywords: *cardiac MRI,myocardial ischemia,radiologic technologist,regadenoson,stress perfusion MRI*

Uloga empatije radiološkog tehnologa u ublažavanju anksioznosti i klaustrofobije tijekom MR pregleda

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Sažetak

Razvoj suvremene medicine doveo je do toga da MR postane jedan od ključnih dijagnostičkih alata u kliničkoj praksi. Iako se ubraja među najznačajnije dijagnostičke metode izbora, za dio pacijenata MR pregled predstavlja psihološki zahtjevan postupak praćen pojavom anksioznosti i klaustrofobičnih reakcija. Cilj ovog rada bio je prikazati povezanost empatijskog pristupa radiološkog tehnologa sa smanjenjem anksioznih reakcija i pojave klaustrofobije tijekom MR pregleda te analizirati čimbenike koji utječu na psihološko iskustvo pacijenata tijekom dijagnostičkog postupka. Rad je izrađen metodom pregledne i kritičke analize dostupnih znanstvenih i stručnih studija. Pretraživanje literature provedeno je tijekom ožujka u bazama PubMed i Scopus, dok su Google Scholar i ResearchGate korišteni za dodatno pretraživanje relevantne literature i pristup cjelovitim tekstovima radova. Sustavnim pretraživanjem identificirano je ukupno 836 radova. Nakon uklanjanja duplikata te pregleda naslova, sažetaka i procjene cjelovitih tekstova, u konačnu analizu uključena su 84 znanstvena rada. Analizirane studije pokazuju da psihološke reakcije tijekom MR pregleda ne ovise isključivo o tehničkim obilježjima uređaja, nego i o načinu na koji pacijent doživljava sam postupak. Kao važni čimbenici izdvojeni su osjećaj gubitka kontrole, neizvjesnost, prethodna negativna iskustva i ograničena mogućnost komunikacije tijekom snimanja. Jasna komunikacija i prilagođen pristup povezani su s boljom suradljivosti pacijenata i manjom razinom anksioznosti tijekom pregleda.

Ključne riječi: *anksioznost; empatija; klaustrofobija; magnetska rezonanca; radiološki tehnolog*

The role of radiologic technologist empathy in alleviating anxiety and claustrophobia during MR examinations

Abstract

The development of modern medicine has established MRI as one of the key diagnostic tools in clinical practice. Although MRI is considered one of the most important diagnostic imaging modalities, for some patients it represents a psychologically demanding procedure accompanied by anxiety and claustrophobic reactions. The aim of this study was to examine the association between the empathetic approach of radiologic technologists and the reduction of anxiety and claustrophobic reactions during MRI examinations, as well as to analyse the factors influencing patients' psychological experience throughout the diagnostic procedure. This study was conducted using a review and critical analysis of the available scientific and professional literature. The literature search was performed during March using the PubMed and Scopus databases, while Google Scholar and ResearchGate were used to identify additional relevant literature and access full-text articles. A total of 836 records were identified through the systematic literature search. After the removal of duplicates, screening of titles and abstracts, and full-text eligibility assessment, 84 scientific studies were included in the final analysis. The analysed studies indicate that psychological reactions during MRI examinations are influenced not only by the technical characteristics of the scanner but also by the patient's perception of the examination itself. Key contributing factors included loss of control, uncertainty, previous negative experiences, and limited communication during image acquisition. Clear communication and an individualised approach were associated with better patient cooperation and lower levels of anxiety during MRI examinations.

Keywords: *anxiety; claustrophobia; empathy; magnetic resonance imaging; radiologic technologist*

Uloga "traffic light" sustava u prepoznavanju potrebe za resimulacijom tijekom radioterapije bolesnika s tumorima glave i vrata

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Sažetak

Cilj rada: Prikazati ulogu "traffic light" sustava kao alata za pravovremeno prepoznavanje anatomskih promjena tijekom radioterapije bolesnika s tumorima glave i vrata te procijeniti njegovu korisnost u donošenju odluka o potrebi za resimulacijom i prilagodbom plana liječenja. **Materijali i metode:**"Traffic light" sustav predstavlja standardizirani model procjene temeljen na semaforskoj klasifikaciji, pri čemu se bolesnici svrstavaju u tri kategorije: zelenu, koja označava odsutnost značajnih promjena i nastavak liječenja prema postojećem planu; žutu, koja upućuje na umjerene promjene koje zahtijevaju pojačano praćenje; te crvenu, koja označava značajne anatomske promjene. **Glavni rezultati:** Primjena "traffic light" sustava omogućila je sustavno praćenje anatomskih promjena tijekom liječenja i standardizirano donošenje odluka o potrebi za resimulacijom. **Kratak zaključak:** "Traffic light" sustav predstavlja učinkovit alat za rano prepoznavanje bolesnika kojima je tijekom radioterapije tumora glave i vrata potrebna resimulacija. Njegova primjena povećava sigurnost liječenja i omogućuje pravovremenu prilagodbu radioterapijskog plana.

Ključne riječi: *adaptivna radioterapija, glava i vrat, resimulacija, traffic light sustav*

The role of the "traffic light" system in identifying the need for re-simulation during radiotherapy of patients with head and neck tumours

Abstract

Aim: To present the role of the "traffic light" system as a tool for the timely identification of anatomical changes during radiotherapy in patients with head and neck tumors, and to evaluate its usefulness in decision-making regarding the need for re-simulation and adaptation of the treatment plan. **Materials and Methods:** The "traffic light" system is a standardized assessment model based on a traffic light classification, in which patients are categorized into three groups: green, indicating the absence of significant changes and continuation of treatment according to the existing plan; yellow, indicating moderate changes that require closer monitoring; and red, indicating significant anatomical changes. **Main results:** The application of the "traffic light" system enabled systematic monitoring of anatomical changes during treatment and standardized decision-making regarding the need for re-simulation. **Brief conclusion:** The "traffic light" system is an effective tool for the early identification of patients requiring re-simulation during radiotherapy for head and neck tumors. Its implementation enhances treatment safety and enables timely adaptation of the radiotherapy plan.

Keywords: *adaptive radiotherapy, head and neck, re-simulation, traffic light system*

IV Contrast: International practice, education, and variation in contrast administration

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Abstract

Intravenous contrast administration is central to modern medical imaging, demanding high-level clinical decision-making, patient screening, and acute adverse reaction management. While autonomous, radiographer-led contrast administration streamlines clinical workflows, reduces diagnostic turnaround times, and maintains impeccable safety profiles, stark international variations persist. Across Europe, disparate national legislation, conflicting institutional policies, and fragmented educational curricula generate substantial inequities in clinical autonomy and scope of practice. Under Council Directive 2013/59/Euratom, patient safety and protocol optimisation require rigorous pharmacovigilance and verified clinical competence. To eliminate cross-border disparities, the European Federation of Radiographers' Societies champions harmonised curricula aligned with the European Qualifications Framework and Directive 2005/36/EC on mutual recognition of qualifications. Advancements in automated power injectors, personalised weight-adapted dosing, and artificial intelligence necessitate advanced venipuncture training, pre-screening competency, and acute management of hypersensitivity reactions and extravasation. By bridging peer-reviewed science with unified European policy, the EFRS empower radiographers to safely navigate expanded clinical responsibilities, eliminate operational variability, and guarantee equitable, high-standard patient care throughout European healthcare systems.

Keywords: *contrast administration, radiography, international practice, education*

MSCT koronarografija i CT srca u svakodnevnoj kliničkoj praksi

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KBC RIJEKA

Sažetak

Cilj rada je prikazati mogućnosti i kliničku primjenu MSCT koronarografije i CT srca u svakodnevnom radu KBC Rijeka. MSCT koronarografija danas predstavlja vodeću neinvazivnu metodu za prikaz koronarnih arterija i isključenje značajne koronarne bolesti zahvaljujući visokoj dijagnostičkoj točnosti i negativnoj prediktivnoj vrijednosti. Materijali i metode uključuju prikaz organizacije rada, pripreme bolesnika, premedikacije, kontrole srčane frekvencije te važnosti pravilne komunikacije s bolesnikom radi postizanja optimalne kvalitete snimki. Prikazane su tehnike snimanja korištene u svakodnevnoj praksi, uključujući retrospektivni i prospektivni EKG-gating te Flash tehniku, kao i njihova primjena ovisno o kliničkoj indikaciji. Rezultati pokazuju široku primjenu metode kroz standardnu MSCT koronarografiju, prikaz aortokoronarnih premosnica, planiranje TAVI zahvata, prikaz trikuspidalne valvule te primjenu Bordeaux protokola u pripremi invazivnih kardioloških zahvata kod bolesnika s poremećajima provođenja srca. Kroz prikaz odabranih slučajeva istaknuta je važnost pravilnog odabira protokola i individualnog pristupa bolesniku. Zaključno, MSCT koronarografija i CT srca predstavljaju nezaobilazne dijagnostičke metode suvremene kardiologije koje omogućuju preciznu procjenu anatomije srca i koronarnih arterija te značajno doprinose planiranju daljnjeg liječenja i intervencijskih zahvata.

Ključne riječi: *MSCT, koronarografija, CT, srca*

MSCT coronary angiography and cardiac CT in everyday clinical practice

Abstract

The aim of this study is to present the capabilities and clinical applications of MSCT coronary angiography and cardiac CT in the daily practice of the University Hospital Centre Rijeka. Today, MSCT coronary angiography represents the leading non-invasive imaging modality for the visualization of coronary arteries and the exclusion of significant coronary artery disease due to its high diagnostic accuracy and negative predictive value. Materials and methods include an overview of workflow organization, patient preparation, premedication, heart rate control, and the importance of effective patient communication to achieve optimal image quality. Imaging techniques routinely used in clinical practice are presented, including retrospective ECG-gating, prospective ECG-triggering, and Flash acquisition, together with their specific indications and applications. The results demonstrate the broad clinical utility of these methods through standard MSCT coronary angiography, coronary artery bypass graft assessment, cardiac CT for TAVI planning, tricuspid valve imaging, and the implementation of the Bordeaux protocol in the preparation of invasive cardiac procedures in patients with cardiac conduction disorders. Selected clinical cases highlight the importance of appropriate protocol selection and an individualized approach to each patient. In conclusion, MSCT coronary angiography and cardiac CT have become indispensable diagnostic tools in modern cardiology, enabling precise assessment of cardiac and coronary anatomy while significantly contributing to treatment planning and the guidance of interventional procedures.

Keywords: *MSCT, coronary, angiography, cardiac, CT*

CT angiografija donjih ekstremiteta naprednom „double time bolus" metodom snimanja

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Specijalna bolnica Sveta Katarina

Sažetak

CT angiografija donjih ekstremiteta dijagnostička je radiološka metoda koju izvodi radiološki tehnolog. Radi se o metodi kojom se prikazuju i analiziraju krvne žile (arterije) u području zdjelice i nogu. Na pretragu dolaze pacijenti koji imaju preporuku liječnika specijalista vaskularne kirurgije ili radiologije. Svakom pacijentu angiografijom se nastoji pronaći uzrok problema i potvrditi postavljena dijagnoza. Pretraga se izvodi pomoću uređaja za kompjutoriziranu tomografiju (CT) koji koristi ionizirajuće zračenje uz aplikaciju jodnog kontrastnog sredstva. Pacijent na dan pretrage mora imati nalaze ureje i kreatinina, ali moramo znati i to koristi li pacijent lijekove za šećernu bolest. Kod nekih pacijenata postoje određene kontraindikacije za izvođenje ove pretrage. Prije početka izvođenja pretrage pacijentu je potrebno postaviti odgovarajuću kanilu u venu kako bi mogao primiti kontrastno sredstvo. Kod navedene pretrage cilj nam je postići približno jednake vrijednosti intenziteta kontrasta u svim prikazanim arterijama, od srca do stopala, kako bi se optimalnom opacifikacijom dokazalo prisustvo određene bolesti koja uzrokuje poteškoće kod pacijenta. Razlog poremećaja punjenja krvnih žila nogu mogu biti primjerice postojanje aneurizmi i kolateralnih arterija uzrokovanih aterosklerozom, venskom trombozom, arterijskom okluzijom ili sma-

njenom fizičkom aktivnošću. Zbog optimalne raspodjele kontrasta u navedenoj pretrazi, a na temelju vlastitih iskustava u radiološkoj praksi, u Specijalnoj bolnici Sveta Katarina koristimo optimalnu metodu „double time bolusa" uz pomoć koje jasno i precizno definiramo vrijeme najvišeg intenziteta kontrasta na početku abdominalne aorte i u poplitealnim arterijama. Uz pomoć dobivena dva različita vremena s najvišim HU vrijednostima, radimo optimizaciju brzine pomaka stola i rotacije cijevi, točnije PITCH faktora, a sve u svrhu precizne dijagnoze, optimiziranja količine kontrasta, kvalitete slike, vremena skeniranja i smanjenje količine ionizirajućeg zračenja. Cilj ovog predavanje je prikazati kako individualnim pristupom kod pacijenata s različitom dinamikom i problematikom cirkulacije u donjim ekstremitetima možemo pouzdano dobiti optimalne dijagnostičke rezultate uz minimalne izmjene parametara CT skenera, a sve uz poštedu izlaganja pacijenta od nepotrebno velike količine jodnog kontrastnog sredstva kod periferne CT angiografije donjih ekstremiteta.

Ključne riječi: *1. CT angiografija donjih ekstremiteta; 2. PITCH faktor; 3. jodno kontrastno sredstvo; 4. double time bolus metoda; 5. personalizirana medicina*

CT angiography of the lower extremities using the advanced "double time bolus" imaging method

Abstract

CT angiography of the lower extremities is a diagnostic radiological method performed by a radiological technologist. It is a method that shows and analyzes blood vessels (arteries) in the area of the pelvis and legs. The search is performed using a computerized tomography (CT) device that uses ionizing radiation with the application of an iodine contrast agent. On the day of the test, the patient must have urea and creatinine results, but we also need to know if the patient is taking medication for diabetes. With the mentioned examination, our goal is to achieve approximately equal contrast intensity values in all shown arteries, from the heart to the feet, in order to prove the presence of a certain disease that causes difficulties for the patient through optimal opacification. The reason for the filling disorder of the blood vessels of the legs can be, for example, the existence of aneurysms and collateral arteries caused by atherosclerosis, venous thrombosis, arterial occlusion or reduced physical activity. Due to the optimal distribution of contrast in the above examination, and based on our own experiences in radiological practice, at the St. Catherines Special Hospital we use the optimal "double time bolus" method, with the help of which we clearly and precisely define the time of highest contrast intensity at the beginning of the abdominal aorta and in the popliteal arteries. With the help of the two different times with the highest HU values, we optimize the table displacement speed and tube rotation, more precisely the PITCH factor, all for the purpose of precise diagnosis, optimizing the amount of contrast, image quality, scanning time and reducing the amount of ionizing radiation. The aim of this lecture is to show how, with an individual approach in patients with different dynamics and circulatory problems in the lower extremities, we can reliably obtain optimal diagnostic results with minimal changes to the CT scanner parameters, all while sparing the patient from unnecessarily large amounts of iodine contrast agent in peripheral CT angiography of the lower extremities.

Keywords: *1. CT angiography oh the lower extremities; 2. PITCH factor; 3. ionide contrast agent; 4. double time bolus method; 5. personalized medicine*

vFFR metoda u procjeni stenoze koronarnih arterija

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Sažetak

FFR (eng. Fractional Flow Reserve) je metoda kojom se, tijekom izvođenja koronarografije, pomoću tlakovne žice, procjenjuje funkcionalni značaj stenoze na koronarnim arterijama. Ovom se metodom mjeri stvarni pad tlaka preko suženja, što pomaže u procjeni potrebe ugradnje stenta. vFFR (Vessel Fractional Flow Reserve) je nova, softverska metoda kojom se procjenjuje funkcionalna značajnost stenoze koronarnih arterija pomoću snimki dobivenih koronarografijom, a bez potrebe korištenja tlakovne žice. Ova metoda predstavlja neinvazivnu, brzu i preciznu procjenu funkcionalne značajnosti stenoze, uz smanjenje postintervencijskih komplikacija. Podaci su prikupljeni pretraživanjem dostupne literature u elektroničkim bazama podataka. Prema dostupnim znanstvenim člancima, vFFR pokazuje visoku točnost i dobru korelaciju s invazivnom FFR metodom, zbog čega može biti korisna alternativa u procjeni funkcionalne značajnosti stenoze koronarnih arterija.

Ključne riječi: *FFR, koronarografija, stenoza koronarnih arterija, vFFR*

vFFR method in the assessment of coronary artery stenosis

Abstract

FFR (Fractional Flow Reserve) is a method used during coronary angiography to assess the functional significance of stenosis in the coronary arteries by means of a pressure wire. This method measures the actual pressure drop across the narrowing, which helps in assessing the need for stent implantation. vFFR (Vessel Fractional Flow Reserve) is a new software-based method used to assess the functional significance of coronary artery stenosis using images obtained by coronary angiography, without the need for a pressure wire. This method provides a non-invasive, rapid, and precise assessment of the functional significance of stenosis, while reducing post-interventional complications. The data were collected by searching the available literature in electronic databases. According to the available scientific articles, vFFR demonstrates high accuracy and good correlation with the invasive FFR method, which is why it may be a useful alternative in assessing the functional significance of coronary artery stenosis.

Keywords: *coronary angiography, coronary artery stenosis, FFR, vFFR*

Implementacija ABUS metode u KBC-u Rijeka: Iskustva u kliničkoj praksi

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Sažetak

Uvod: Automatski ultrazvuk dojke (ABUS) je standardizirana ultrazvučna metoda razvijena za detekciju karcinoma dojki s gustom žljezdanom strukturom. Omogućuje volumetrijsko snimanje dojki, pohranu cjelokupnog volumena te naknadnu analizu nalaza. **Cilj:** Prikazati organizaciju rada, indikacije za primjenu i dosadašnja iskustva korištenja automatskog ultrazvuka dojki (ABUS) u KBC-u Rijeka, s naglaskom na ulogu radiološkog tehnologa. **Materijali i metode:** U KBC-u Rijeka ABUS se provodi na uređaju Invenia ABUS (GE HealthCare) prema standardiziranom protokolu od strane educiranih radioloških tehnologa. U tijeku je retrospektivna analiza pregleda učinjenih od 1. listopada 2025. do 1. listopada 2026. godine. Analiza obuhvaća broj pregleda, indikacije, dob pacijentica i potrebu za dodatnom obradom. **Rezultati i rasprava:** Dosadašnja iskustva pokazuju da ABUS omogućuje reproducibilno snimanje dojki. Ključni čimbenici kvalitete su pravilno pozicioniranje, prepoznavanje artefakata i dokumentiranje površinskih struktura. **Zaključak:** ABUS predstavlja vrijednu dopunsku metodu u obradi žena s denznim dojkama te doprinosi standardizaciji dijagnostičkog procesa.

Ključne riječi: *ABUS, automatski ultrazvuk dojki, denzne dojke, radiološki tehnolog, dijagnostika dojke*

Implementation of Automated Breast Ultrasound (ABUS) at Rijeka Clinical Hospital Center

Abstract

Implementation of Automated Breast Ultrasound (ABUS) at Rijeka Clinical Hospital Center: Clinical Practice Experience Ema, Komadina Clinical Hospital Center Rijeka, Krešimirova 42, Rijeka, Croatia (ema.komadina@gmail.com) **Background:** Automated Breast Ultrasound (ABUS) is a standardized ultrasound method developed for the detection of breast cancer in women with dense glandular breast tissue. It enables volumetric breast imaging, full-volume data storage and subsequent image analysis. **Purpose:** To present the workflow organization, indications for use,

and current experience with ABUS at the Rijeka Clinical Hospital Center, with emphasis on the role of the radiologic technologist. **Materials and Methods:** At the Rijeka Clinical Hospital Center, ABUS is performed using the Invenia ABUS system (GE HealthCare) according to a standardized protocol by trained radiologic technologists. A retrospective analysis of examinations performed between October 1, 2025, and October 1, 2026, is currently underway. The analysis includes the number of examinations, indications, patient age, and the need for additional diagnostic work-up. **Results and Discussion:** Current experience shows that ABUS enables reproducible breast imaging. Key quality factors include proper patient positioning, artifact recognition, and documentation of superficial structures. **Conclusion:** ABUS represents a valuable complementary imaging method in the management of women with dense breasts and contributes to the standardization of the diagnostic process.

Keywords: *ABUS, automated breast ultrasound, dense breasts, radiologic technologist, breast imaging*

Uloga radiološkog tehnologa u CT dijagnostici akutnog ishemijskog moždanog udara i pripremi za neurointervencijske postupke

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Sažetak

Akutni ishemijski moždani udar zahtijeva brzu dijagnostiku i pravovremeno liječenje kako bi se smanjilo neurološko oštećenje. Cilj rada je prikazati dijagnostički CT protokol koji se koristi u KBC-u Rijeka kod pacijenata sa sumnjom na akutni moždani udar te istaknuti ulogu radiološkog tehnologa u cjelokupnom procesu zbrinjavanja. Pravovremena provedba standardiziranog CT protokola omogućuje bržu dijagnostiku, kraće vrijeme obrade i bolje ishode pacijenata. Radiološki tehnolog ima ključnu ulogu u optimizaciji i provedbi hitne neuroradiološke obrade. U radu su opisane: indikacije za izvođenje pojedinih pretraga, priprema pacijenta, tijek snimanja te obrada slikovnih podataka potrebnih za donošenje odluke o daljnjem liječenju. Poseban naglasak stavljen je na važnost slikovne dijagnostike u probiru pacijenata za intravensku trombolizu i mehaničku trombektomiju. Obrada se provodi na CT uređaju Siemens Somatom Definition Flash s 256-slojnom tehnologijom i Siemens Somatom AS+ s 128-slojevnom tehnologijom te uključuje nativni CT mozga, CT angiografiju karotidnih i intrakranijskih arterija te CT perfuziju mozga. Prikazani su statistički podaci o broju izvedenih pregleda i neurointervencijskih postupaka u Kliničkom bolničkom centru Rijeka u promatranom razdoblju od 1. siječnja 2021. do 1. siječnja 2026. godine.

Ključne riječi: *akutni ishemijski moždani udar, CT angiografija, CT perfuzija, neurointervencija, trombektomija*

The role of the radiological technologist in CT diagnostics of acute ischemic stroke and preparation for neurointerventional procedures

Abstract

Acute ischemic stroke requires rapid diagnosis and timely treatment to reduce neurological damage. The aim of this paper is to present the CT diagnostic protocol used at the Clinical hospital center Rijeka in patients with suspected acute stroke and to highlight the role of the radiologic technologist in the care process. Timely implementation of the standardized CT protocol enables faster diagnosis, shorter workup time and better patient outcomes. The radiologic technologist plays a key role in optimizing and implementing emergency neuroradiological workup. This paper describes: indications for performing specific diagnostic procedures, patient preparation, imaging protocol and processing of image data necessary for making a decision on further treatment. Special emphasis is placed on the importance of imaging diagnostics in selecting patients for intravenous thrombolysis and mechanical thrombectomy. The diagnostic process is performed on a Siemens Somatom Definiton Flash CT device with 256 slices and a Siemens Somatom AS+ CT device with 128 slices and includes a native brain CT scan, CT angiography of the carotid and intracranial arteries, and CT perfusion of the brain. Statistical data on the number of examinations and neurointerventional procedures performed in Clinical hospital center Rijeka between 1st of January 2021 and 1st of January 2026 is included.

Keywords: *acute ischemic stroke, CT angiography, CT perfusion, neurointervention, thrombectomy*

Krioablacija osteoid osteoma pod kontrolom CT-a

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Sažetak

Krioablacija je perkutana tehnika toplinske ablacije razvijena za uništavanje žarišnih skupina stanica primjenom ekstremne hladnoće (od -20 do -40 °C uz tekući argon ili dušik). Riječ je o slikovno vođenom postupku koji se izvodi u lokalnoj anesteziji, uz kratko vrijeme oporavka i dobre ishode. Temelji se na dovođenju plina kroz dvokomornu iglu do njezina vrha, gdje ekspanzija plina hladi okolno tkivo i stvara ledenu kuglu. Omogućuje obradu velikih i nepravilnih volumena patološkog tkiva te procjenu područja ablacije u stvarnom vremenu, a manje je bolno od tehnika temeljenih na toplini, poput radiofrekvencije i mikrovalova. Za ciljanje lezije može se koristiti ultrazvuk, kompjutorizirana tomografija (CT) ili magnetska rezonancija (MR). CT ima prednosti pred ultrazvukom: manje ovisi o operateru, nema artefakata zbog crijevnih plinova i jasno prikazuje okolne strukture. Osteoidni osteom je dobroćudni koštani tumor građen od osteoida i pletene kosti, okružen oreolom reaktivne sklerotične kosti. Najčešće se javlja u apendikularnom skeletu i kralježnici, obično u kortikalnom dijelu ili blizu njega. Lezija uzrokuje bol, osobito noću, a ovisno o smještaju može izazvati i zglobnu bol, sinovitis i izljev ili bolnu skoliozu. Tijek bolesti je nepredvidiv te može zahtijevati liječenje ili spontano nestati. Krioablacija je preferirana metoda liječenja jer nudi manji morbiditet i brži oporavak od operacije te smanjuje uporabu analgetika, uključujući opioide, i pripadajuće nuspojave.

Ključne riječi: *krioablacija, osteoidni osteom, perkutana toplinska ablacija*

CT-guided cryoablation of osteoid osteoma

Abstract

Cryoablation is a percutaneous thermal ablation technique developed to destroy focal groups of cells using extreme cold (from -20 to -40 °C using liquid argon or nitrogen). It is an image-guided procedure performed under local anaesthesia, with short recovery times and good outcomes. Gas is brought through a two-chamber needle probe to its tip, where gas expansion cools the surrounding tissue and forms an ice ball. It allows treatment of large and irregular volumes of pathological tissue, real-time evaluation of the ablation area and is less painful than heat-based techniques like radiofrequency and microwaves. Ultrasound, computed tomography (CT) or magnetic resonance (MR) imaging can target a lesion and monitor the ablation. CT has advantages over ultrasound: it is less operator dependent, has no artefact from bowel gas and gives a clear image of surrounding vital structures. Osteoid osteoma is a benign bone tumour consisting of osteoid and woven bone, surrounded by a halo of reactive sclerotic bone. It usually occurs in the appendicular skeleton and the spine, generally in or near the cortex. The lesion causes pain, especially at night, but may cause joint pain with synovitis and effusion near chondral structures, or painful scoliosis in the spine. Cryoablation is the preferred treatment because it offers lower morbidity and faster recovery than surgery, and reduces use of pain medication, including opioids, and associated side effects.

Keywords: *Cryoablation, Osteoid osteoma, Percutaneous thermal ablation*

POSTER PREZENTACIJA / POSTER PRESENTATIONS

Suvremeni pristup TBI terapiji na Klinici za onkologiju KBC-a Zagreb

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Sažetak

Uvod: TBI (engl. Total Body Irradiation – zračenje cijelog tijela) radioterapijska metoda koja se primjenjuje u liječenju hematoloških malignih bolesti, najčešće leukemija, kao dio pripreme bolesnika za transplantaciju koštane srži. **Cilj:** Prikazati suvremeni pristup planiranju i provođenju TBI terapije na Klinici za onkologiju KBC-a Zagreb te naglasiti važnost individualiziranog pristupa i modernizacije radioterapijske opreme. **Metode:** TBI terapija provodi se uz sudjelovanje multidisciplinarnog tima koji čine liječnik specijalist, medicinski fizičari i radiološki tehnolozi. Za svakog bolesnika izrađuje se individualni plan zračenja radi postizanja homogene raspodjele doze uz zaštitu plućnog parenhima. U tu svrhu izrađuju se olovni blokovi za pluća, dok se nadoknada doze u području rebara provodi elektronskim snopom. Priprema i planiranje terapije provode se nekoliko dana prije početka liječenja. **Rezultati i zaključak**: Primjena suvremene radioterapijske opreme omogućuje veću preciznost i sigurnost pri isporuci visokih doza zračenja. Kontinuirani nadzor bolesnika tijekom terapije dodatno pridonosi kvaliteti i sigurnosti liječenja. Individualizirano planiranje, multidisciplinarna suradnja i napredna tehnologija ključni su čimbenici uspješne provedbe TBI terapije u bolesnika koji se pripremaju za transplantaciju hematopoetskih matičnih stanica.

Ključne riječi: *TBI, radioterapija, zračenje cijelog tijela, transplantacija hematopoetskih matičnih stanica, hematološki maligniteti*

Contemporary approach to TBI therapy at the Oncology Clinic of UHC Zagreb

Abstract

Introduction: Total Body Irradiation (TBI) is a radiotherapy technique used in the treatment of hematological malignancies, most commonly leukemia, as part of preparing patients for bone marrow transplantation **Aim:** To present a modern approach to planning and implementing TBI therapy at the Oncology Clinic of KBC Zagreb and to emphasize the importance of an individualized approach and modernization of radiotherapy equipment. **Methods:** TBI therapy is performed with the participation of a multidisciplinary team consisting of a specialist physician, medical physicists and radiological technologists. An individual radiation plan is created for each patient to achieve a homogeneous dose distribution while protecting the lung parenchyma. For this purpose, lead blocks are made for the lungs, while dose compensation in the rib area is performed with an electron beam. Preparation and planning of therapy are carried out several days before the start of treatment. **Results and conclusion:** Modern radiotherapy equipment enables precise and safe delivery of high radiation doses. Continuous patient monitoring further improves treatment quality and safety. Individualized planning, multidisciplinary collaboration, and advanced technology are essential for the successful implementation of TBI therapy in patients undergoing hematopoietic stem cell transplantation.

Keywords: *TBI, radiotherapy, whole body irradiation, hematopoietic stem cell transplantation, hematological malignancies*

Utjecaj različitih čimbenika na kvalitetu slikovnih podataka kod MR-a i radioterapije prostate

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Sažetak

Uvod: Kvaliteta slikovnih podataka predstavlja jedan od ključnih preduvjeta za dijagnostičku procjenu i verifikaciju položaja pacijenta tijekom cijelog radioterapijskog procesa. Kod bolesnika koji prolaze obradu i liječenje karcinoma prostate, određeni anatomski i fiziološki čimbenici mogu utjecati na kvalitetu dobivenih slika. **Cilj:** Prikazati najčešće čimbenike s kojima se radiološki tehnolozi susreću, a negativno utječu na kvalitetu slikovnih prikaza tijekom MR-a, CT simulacije i IGRT-a. Naglasak je na rektalnoj distenziji, varijabilnom punjenju mokraćnog mjehura, prisutnosti endoproteze kuka i pojačanoj peristaltici. **Materijali i metode:** Prikazom odabranih primjera iz svakodnevne prakse analiziran je utjecaj navedenih čimbenika na kvalitetu MR, CT i CBCT prikaza. **Rezultati:** Promjene u ispunjenosti mokraćnog mjehura i rektuma pokazali su značajan utjecaj na promjenu položaja anatomskih struktura sto je otežalo njihovo precizno prikazivanje i usporedbu. Metalni implantati uzrokovali su artefakte različitog intenizeta na MR i CT slikama, dok je povećana peristaltika predstavljala dodatni izvor degradacije kvalitete prikaza. **Zaključak:** Anatomske i fiziološke promjene kod pacijenta značajno utječu na kvalitetu slikovnih prikaza kod MR-a i radioterapije prostate. Radiološki tehnolozi imaju važnu ulogu u pripremi pacijenta, optimizaciji protokola i prepoznavanju problema kako bi se povećala pouzdanost i reproducibilnost oslikavanja tijekom dijagostičko-terapijskog postupka.

Ključne riječi: *prostata, magnetska rezonanca, slikovno vođena radioterapija (IGRT), kvaliteta slikovnih podataka, artefakti*

The influence of various factors on the quality of imaging data in MRI and prostate radiotherapy

Abstract

Introduction: Image quality is one of the key postulates for diagnostic assessment and verification of patient position throughout the radiotherapy process. In patients undergoing prostate cancer treatment, certain anatomical and physiological factors can affect the quality of the images obtained. **Objective:** To present the most common factors encountered by radiologic technologists that negatively affect the quality of image images during MRI, CT simulation, and IGRT. Emphasis is placed on rectal distension, variable bladder filling, presence of hip endoprosthesis, and increased peristalsis. **Materials and Methods:** Selected examples from everyday practice were used to analyse the impact of the listed factors on the quality of MR, CT, and CBCT images. **Results:** Changes in bladder and rectal filling significantly affected the position of anatomical structures, which made their precise presentation and comparison difficult. Metallic implants caused artifacts of varying intensity on MR and CT images, while increased peristalsis represented an additional source of image quality degradation. **Conclusion:** Anatomical and physiological changes in the patient significantly affect the quality of images in MR and prostate radiotherapy. Radiologic technologists play an important role in patient preparation, protocol optimization, and problem recognition to increase the reliability and reproducibility of imaging during the diagnostic and therapeutic procedure.

Keywords: *prostate, magnetic resonance imaging, image-guided radiotherapy (IGRT), image data quality, artifacts*

Pristup pacijentu uz empatiju i razumijevanje tijekom radioloških pretraga

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Sažetak

Uvod: Radiološke pretrage poput radiografije (RTG), kompjutorizirane tomografije (CT) i magnetske rezonancije (MR) predstavljaju ključne dijagnostičke metode u suvremenoj medicini. U suvremenom zdravstvenom sustavu naglasak je često na tehničkoj kvaliteti i učinkovitosti dijagnostičkih postupaka, no pritom ne smiju biti zanemarene fizičke i emocionalne potrebe pacijenata. Empatija, razumijevanje i kvalitetna komunikacija omogućuju stvaranje odnosa povjerenja, smanjuju anksioznost te doprinose uspješnijem izvođenju pretraga i kvalitetnijim dijagnostičkim rezultatima. **Cilj:** Istaknuti važnost empatije, razumijevanja i kvalitetne

komunikacije u radu radioloških tehnologa tijekom izvođenja RTG, CT i MR pretraga te prikazati njihov utjecaj na uspješnost dijagnostičkog postupka i iskustvo pacijenta. **Rasprava:** Pacijenti koji dolaze na radiološke pretrage često su suočeni s boli, strahom, nelagodom ili neizvjesnošću vezanom uz svoje zdravstveno stanje. Stoga je važno uspostaviti odnos povjerenja kroz profesionalnu i jasnu komunikaciju. Objašnjavanje svrhe, tijeka i trajanja pretrage na razumljiv način može smanjiti anksioznost te povećati suradljivost pacijenta tijekom pregleda. Pacijent koji razumije što se od njega očekuje lakše će slijediti upute, što doprinosi kvaliteti snimaka i smanjuje potrebu za ponavljanjem pretrage. Posebnu pozornost potrebno je posvetiti pacijentima s boli, ozljedama ili ograničenom pokretljivošću koji nisu u mogućnosti zauzeti idealan položaj za snimanje. U takvim situacijama radiološki tehnolog treba prilagoditi pristup individualnim potrebama pacijenta te, kada je moguće, pronaći alternativne načine pozicioniranja uz očuvanje dijagnostičke vrijednosti snimke. **Zaključak:** Empatija, razumijevanje i učinkovita komunikacija važan su dio svakodnevnog rada radioloških tehnologa. Uz stručnost i tehničko znanje, individualiziran pristup pacijentu omogućuje kvalitetnije izvođenje radioloških pretraga, veću suradljivost pacijenata i postizanje optimalnih dijagnostičkih rezultata. Stoga empatijski pristup treba biti sastavni dio profesionalne radiološke prakse i kvalitetne zdravstvene skrbi.

Ključne riječi: *empatija, komunikacija, pacijent, radiološke pretrage, radiološki tehnolog*

Approaching the patient with empathy and understanding during radiological examinations

Abstract

Introduction: Radiological examinations such as radiography (X-ray), computed tomography (CT), and magnetic resonance imaging (MRI) represent key diagnostic methods in modern medicine. Although the healthcare system often emphasizes technical quality and efficiency of diagnostic procedures, the physical and emotional needs of patients must not be overlooked. Empathy, understanding, and effective communication enable the development of a trusting relationship, reduce patient anxiety, and contribute to more successful examinations and higher-quality diagnostic results. **Aim:** To emphasize the importance of empathy, understanding, and effective communication in the work of radiologic technologists during RTG, CT, and MRI examinations, and to demonstrate their impact on the success of the diagnostic procedure and the patient experience. **Discussion:** Patients undergoing radiological examinations are often faced with pain, fear, discomfort, or uncertainty related to their health condition. Therefore, it is important to establish a relationship of trust through professional, clear, and understandable communication. Providing timely explanations about the purpose, procedure, and duration of the examination can reduce anxiety and improve patient cooperation during the examination. Patients who understand the procedure and receive clear instructions are more likely to cooperate, which contributes to the quality of obtained images and reduces the need for repeat examinations. Special attention should be given to patients experiencing pain, injuries, or limited mobility who are unable to achieve the ideal position for imaging. In such situations, the radiologic technologist should adapt the approach to the individual needs of the patient and, whenever possible, find alternative positioning methods while preserving the diagnostic value of the image. **Conclusion:** Empathy, understanding, and effective communication are an important part of the daily work of radiologic technologists. Along with professional expertise and technical knowledge, an individualized approach to the patient enables higher-quality radiological examinations, better patient cooperation, and optimal diagnostic outcomes. Therefore, an empathetic approach should be an integral part of professional radiological practice and an important element of quality healthcare.

Keywords: *empathy, communication, patient, radiological examinations, radiologic technologist.*

Embolizacija aneurizme lijenalne arterije

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Sažetak

Endovaskularna embolizacija, definirana kao kontrolirana okluzija krvnih žila, ima ključnu ulogu u zbrinjavanju traumatskih i netraumatskih krvarenja. Embolizacija je minimalno invazivan postupak koji može spasiti život. Omogućuje kontrolu krvarenja uz manje oštećenje normalnog tkiva u usporedbi sa standardnim kirurškim zahvatima, što rezultira manjim morbiditetom i boljim preživljenjem [1]. Embolizacija aneurizme lijenalne arterije je izvedena u našem kliničkom bolničkom centru u Rijeci, na zavodu za dijagnostičku i intervencijsku radiologiju, kod pacijentkinje kojoj je na prvom CT pregledu abdomena i zdjelice ustanovljena široka vaskularna struktura od 25mm, koja nije bila odvojiva od lijenalne arterije i zatraženo je učiniti CT aortografiju kako bi se struktura jasnije opisala. Nakon učinjene CT aortografije dokazana je aneurizma lijenalne arterije veličine 25mm ali bez znakova o rupturi. Aneurizma lijenalne arterije je selektivno kateterizirana, DSA serijama je najprije utvrđen položaj aneurizme. U samu aneurizmu plasirane su mikrozavojnice do adekvatne "gustoće". DSA serijama i fluoroskopijom nije se prikazalo da nema punjenja aneurizme, dok je ostao samo protok rubno u distalne grane. Pacijentici je preporučen kontrolni UZV za mjesec dana i CT aortografija za 6 mjeseci.

Ključne riječi: *aneurizme lijenalne arterije, embolizacija; intervencijski postupak, uloga inženjera medicinske radiologije*

Embolization of splenic artery aneurysm

Abstract

Endovascular embolization, defined as the controlled occlusion of vessels, has a pivotal role in the management of both traumatic and non-traumatic bleeding. Embolization is a minimally invasive procedure that can be lifesaving. It can provide hemorrhage control with less disruption of normal tissue compared with standard surgical interventions, resulting in decreased morbidity and improved survival [1]. Splenic artery aneurysm embolization was performed at the Clinical Hospital Center Rijeka, Department of Diagnostic and Interventional Radiology, in a female patient. Initial CT imaging of the abdomen and pelvis revealed a 25 mm vascular structure that could not be clearly differentiated from the splenic artery. Consequently, CT aortography was performed, confirming a 25 mm splenic artery aneurysm without evidence of rupture. The aneurysm was selectively catheterized, and its location was verified using digital subtraction angiography (DSA). Microcoils were deployed within the aneurysm sac until satisfactory packing density was achieved. Subsequent DSA and fluoroscopic imaging demonstrated complete occlusion of the aneurysm with no residual filling, while preserving blood flow to the distal splenic artery branches. The patient was advised to undergo ultrasound follow-up after one month and CT aortography after six months.

Keywords: *embolization, interventional procedure; role of medical radiology engineer, splenic artery aneurysm*

Optimizacija dnevne provjere kvalitete na linearnom akceleratoru Elekta Harmony KZT integracijom sustava IBA myQA Daily

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Sažetak

Uvod: Svakodnevna provjera kvalitete (QA) medicinskih linearnih akceleratora temelj je sigurnosti i preciznosti u radioterapiji. Uvođenjem modernih platformi, poput akceleratora Elekta Harmony, te naprednih eksternih detektora, otvaraju se mogućnosti za značajnu optimizaciju jutarnjeg radnog tijeka uz striktno poštivanje međunarodnih preporuka (npr. TG-142). **Cilj:** Evaluirati učinkovitost, točnost i brzinu provođenja dnevnog QA protokola na uređaju Elekta Harmony koristeći napredni detektorski sustav IBA myQA Daily. **Materijali i metode:** Dnevni QA protokol podijeljen je na dozimetrijske, mehaničke, slikovne i sigurnosne provjere. Za dozimetrijsku evaluaciju fotonskog snopa korišten je uređaj IBA myQA Daily koji kroz matricu od 125 ionizacijskih komora raspoređenih duž glavnih osi istovremeno analizira izlaznu dozu, simetriju, homogenost i energiju snopa. Geometrijska točnost lasera, optičkog indikatora udaljenosti (ODI) i kolimatora (MLC) provjerena je ugrađenim

vizualnim markerima polja (10 × 10 cm i 20 × 20 cm) na gornjoj ploči detektora. Slikovni IGRT sustavi validirani su analizom kV/MV izocentra, dok su interlockovi provjereni manualno. Podaci su automatski analizirani kroz web-orijentirani softver myQA. **Rezultati:** Implementacija IBA myQA Daily sustava na platformi Elekta Harmony omogućila je završetak svih ključnih dozimetrijskih i profilnih mjerenja u samo jednom ispaljivanju snopa po energiji. Cjelokupni proces dnevnog testiranja reduciran je na manje od 10 minuta. Sva izmjerena dozimetrijska odstupanja bila su stabilna i unutar propisanih granica od ±3%, dok su prostorna i mehanička odstupanja uspješno zadržana unutar kritične tolerancije od ≤2 mm. Trend-analiza softvera omogućila je rano prepoznavanje minimalnih pomaka u radu akceleratora prije aktivacije hardverskih blokada. **Zaključak:** Kombinacija linearnog akceleratora Elekta Harmony i detektora IBA myQA Daily osigurava iznimno brz, pouzdan i ergonomski optimiziran dnevni QA. Visoka gustoća ionizacijskih komora minimiziraju rizik od ljudske pogreške, skraćuju vrijeme pripreme uređaja te jamče najvišu razinu sigurnosti pacijenata prije isporuke terapijske doze.

Ključne riječi: *dnevna kontrola kvalitete (Daily QA), radioterapija, dozimetrija, verifikacija snopa*

Optimisation of Daily Quality Assurance on the Elekta Harmony Linear Accelerator by Integrating the IBA myQA Daily System

Abstract

Introduction: Daily quality assurance (QA) of medical linear accelerators is the foundation of safety and precision in radiotherapy. The introduction of modern platforms, such as the Elekta Harmony accelerator, alongside advanced external detectors, opens opportunities for significant optimization of the morning workflow while strictly adhering to international recommendations (e.g., TG-142). **Objective:** To evaluate the efficiency, accuracy, and speed of conducting the daily QA protocol on the Elekta Harmony device using the advanced IBA myQA Daily detector system. **Materials and Methods:** The daily QA protocol is divided into dosimetric, mechanical, imaging, and safety checks. For the dosimetric evaluation of the photon beam, the IBA myQA Daily device was used, which simultaneously analyzes output dose, symmetry, flatness, and beam energy through a matrix of 125 ionization chambers arranged along the main axes. The geometric accuracy of lasers, the optical distance indicator (ODI), and the multi-leaf collimator (MLC) was verified using built-in visual field markers (10 × 10 cm and 20 × 20 cm) on the detector's top plate. Imaging IGRT systems were validated through kV/MV isocenter analysis, while interlocks were checked manually. Data were automatically analyzed using the web-based myQA software. **Results:** The implementation of the IBA myQA Daily system on the Elekta Harmony platform enabled the completion of all key dosimetric and profile measurements in just a single beam delivery per energy. The entire daily testing process was reduced to less than 10 minutes. All measured dosimetric deviations were stable and within the prescribed limits of ±3%, while spatial and mechanical deviations were successfully kept within the critical tolerance of ≤2 mm. The software's trend analysis enabled the early detection of minimal shifts in accelerator performance before the activation of hardware interlocks. **Conclusion:** The combination of the Elekta Harmony linear accelerator and the IBA myQA Daily detector ensures an exceptionally fast, reliable, and ergonomically optimized daily QA. The high density of ionization chambers minimizes the risk of human error, shortens device preparation time, and guarantees the highest level of patient safety prior to therapeutic dose delivery.

Keywords: *Daily Quality Assurance (Daily QA), Radiotherapy, Dosimetry, Beam Verification*

MSCT Politrauma Dual Energy

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Sažetak

Politrauma predstavlja jedan od najvećih izazova u hitnoj medicini, pri čemu je brza i precizna dijagnostika ključna za pravovremeno zbrinjavanje bolesnika. Računalna tomografija već je dugo zlatni standard u obradi politraumatiziranih pacijenata jer omogućuje brzu procjenu više organskih sustava u jednoj pretrazi. Ipak, konvencionalni CT ima određena ograničenja u diferencijaciji tkiva, detekciji suptilnih ozljeda i razlikovanju kontrastnog sredstva od krvarenja. Dual Energy CT predstavlja tehnološki napredak koji omogućuje akviziciju podataka na dvije različite energetske razine X-zraka. Na temelju različite apsorpcije zračenja pojedinih materijala, DECT omogućuje bolju karakterizaciju tkiva i stvaranje dodatnih rekonstrukcija, poput virtualno nekontrastnih slika, jodnih mapa i virtualnih monokromatskih slika. Time se povećava dijagnostička sigurnost u hitnim stanjima. Cilj rada je prikazati primjenu MSCT DE Politrauma protokola u obradi hemodinamski stabilnih i nestabilnih politraumatiziranih bolesnika te usporediti njegove mogućnosti sa standardnim MSCT politrauma protokolom. U radu se opisuju tehnički principi DECT-a, dostupne vrste sustava, uključujući dual-source, rapid kVp switching, dual-layer detector i split-filter tehnologiju, te njihova klinička primjena. Poseban naglasak stavljen je na detekciju aktivnog krvarenja, procjenu perfuzije organa, smanjenje metalnih artefakata te prepoznavanje kontuzija, fraktura i drugih suptilnih ozljeda. Prednosti DECT-a uključuju bolju diferencijaciju materijala, smanjenje potrebe za dodatnim dijagnostičkim postupcima, brže donošenje kliničkih odluka te mogućnost smanjenja doze zračenja u odnosu na standardni MSCT politrauma protokol. Glavni izazovi ostaju visoki troškovi opreme i potreba za dodatnom edukacijom radioloških tehnologa i radiologa.

Ključne riječi: *Politrauma; Dual Energy CT; virtualne nekontrastne slike; jodne mape*

MSCT Polytrauma Dual Energy

Abstract

Polytrauma represents one of the most demanding challenges in emergency medicine, where rapid and accurate diagnosis is essential for timely patient management. Computed tomography has long been considered the gold standard in the evaluation of polytraumatized patients due to its speed, availability and ability to assess multiple organ systems within a single examination. However, conventional CT has certain limitations in tissue differentiation, detection of subtle injuries and distinction between contrast material and hemorrhage. Dual Energy CT represents an important technological advancement, allowing data acquisition at two different X-ray energy levels. Based on the different absorption characteristics of various materials, DECT enables improved tissue characterization and the creation of additional image reconstructions, including virtual non-contrast images, iodine maps and virtual monoenergetic images. These tools increase diagnostic confidence, particularly in emergency settings. The aim of this paper is to present the application of the MSCT DE Polytrauma protocol in the evaluation of hemodynamically stable and unstable polytraumatized patients, and to compare its diagnostic potential with the standard MSCT polytrauma protocol. The paper describes the technical principles of DECT, available system types, including dual-source, rapid kVp switching, dual-layer detector and split-filter technology, as well as their clinical applications. Special emphasis is placed on the detection of active bleeding, assessment of organ perfusion, reduction of metal artifacts and identification of contusions, fractures and other subtle traumatic injuries. The advantages of DECT include improved material differentiation, reduced need for additional diagnostic procedures, faster clinical decision-making and the potential for radiation dose reduction compared with the standard MSCT polytrauma protocol. The main limitations remain the high cost of equipment and the need for additional education of radiologic technologists and radiologists.

Keywords: *Polytrauma; Dual Energy CT; virtual non-contrast images; iodine maps*

Shielding doors in radiology and radiotherapy

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Abstract

Ionizing radiation is widely used in diagnostics, nuclear medicine and radiotherapy. Although it brings significant benefits, its application requires the implementation of strict radiation protection measures in order to minimize the exposure of employees and patients in accordance

with the ALARA principle. One of the basic elements of protection is the protective door, which prevents the spread of ionizing radiation from the controlled zones to the surrounding rooms. They are installed at the entrances to X-ray rooms, CT and angiography rooms, nuclear medicine, bunkers of linear accelerators, and brachytherapy. The type of door is chosen depending on the type of device, radiation energy, workload and purpose of the room. Doors in diagnostic radiology are made of wood or steel structure in which a lead sheet of appropriate thickness is embedded. If necessary, they also contain leaded glass that enables visual contact with the room; Doors in nuclear medicine in rooms where open radioactive sources are used, the protection is adapted to the type of radionuclide and the energy of the emitted radiation. They can contain lead or steel protective layers, while in rooms with PET devices and radionuclides that emit high-energy gamma photons, thicker protective materials are used than in classic diagnostic radiology; In radiotherapy, linear accelerator bunkers represent the most complex type of protective door. Due to the high energies of photon and electron beams, they are made of several protective layers, which may include steel, lead, concrete and materials rich in hydrogen (eg polyethylene with added boron) for the absorption of neutrons produced during the operation of accelerators with energies greater than approximately 10 MV. These doors have a large mass, often several tons, so they are opened using electromechanical or hydraulic systems and it is necessary to have an integrated security system. Properly designed protective doors are one of the most important components of the radiation protection system and enable safe work in all areas of application of ionizing radiation. They play a key role in the radiation protection system, because they prevent the spread of primary and scattered ionizing radiation from rooms where it is used.

Keywords: *bunker, ionising radiation, linear accelerator, shielding door*

Umjetna inteligencija kao podrška radiološkom tehnologu u suvremenoj radiološkoj praksi

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Sažetak

Uvod i cilj: Umjetna inteligencija (AI) sve se više primjenjuje u radiologiji te mijenja način rada radioloških tehnologa. Cilj rada je prikazati mogućnosti njezine primjene te utjecaj na kvalitetu radioloških postupaka, sigurnost pacijenata i rad radioloških tehnologa. **Metode:** Proveden je pregled znanstvene literature o primjeni AI u radiologiji, s naglaskom na pozicioniranje pacijenata, optimizaciju parametara snimanja, poboljšanje kvalitete slike, smanjenje doze zračenja i automatizaciju radnih procesa. **Rezultati:** Istraživanja pokazuju da su AI alati dostupni u približno 70 % radnog tijeka magnetske rezonancije i 64 % kompjutorizirane tomografije. Umjetna inteligencija skraćuje vrijeme snimanja i obrade podataka te omogućuje pretrage uz niže doze zračenja bez gubitka dijagnostičke kvalitete slike. Time se povećava sigurnost pacijenata, smanjuje broj ponovljenih snimanja, a radiološkim tehnolozima ostaje više vremena za stručni rad i komunikaciju s pacijentima. **Zaključak:** Umjetna inteligencija značajno pridonosi učinkovitijem radu radioloških tehnologa, a njezina uspješna primjena zahtijeva kontinuiranu edukaciju i razvoj digitalnih kompetencija. Time se stvaraju preduvjeti za sigurnije i kvalitetnije radiološke postupke te bolju skrb za pacijente.

Ključne riječi: *kvaliteta slike; medicinsko oslikavanje; optimizacija radnog procesa; radiološki tehnolog; umjetna inteligencija*

Artificial intelligence as support for radiological technologists in modern radiological practice

Abstract

Introduction and Objective: Artificial intelligence (AI) is increasingly being integrated into radiological practice, transforming the role of radiologic technologists. The aim of this study was to present the applications of AI in radiology and its impact on the quality of radiological procedures, patient safety, and the daily work of radiologic technologists. **Methods:** A review of the scientific literature on the application of AI in radiology was conducted, focusing on patient positioning, optimization of imaging parameters, image quality enhancement, radiation dose reduction, and workflow automation. **Results:** Studies indicate that AI tools are currently available for approximately 70% of the magnetic resonance imaging (MRI) workflow and 64% of the computed tomography (CT) workflow. AI shortens image acquisition and data processing times while enabling examinations to be performed with lower radiation doses without compromising diagnostic image quality. This improves patient safety, reduces the need for repeat examinations, and allows radiologic technologists to dedicate more time to professional tasks and patient communication. **Conclusion:** Artificial intelligence significantly improves the efficiency of radiologic technologists' work; however, its successful implementation depends on continuous education and the development of digital competencies. These advances create the conditions for safer, higher-quality radiological procedures and ultimately contribute to improved patient care.

Keywords: *artificial intelligence; image quality; medical imaging; radiologic technologist; workflow optimization*

The role of the radiologic technologist (RTT) in VMAT treatment of primary CNS tumours

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Abstract

Primary tumors of the central nervous system (CNS) are complex conditions that require accuratediagnosis, individualized treatment planning, and precise delivery of radiotherapy. VolumetricModulated Arc Therapy (VMAT) is an advanced radiation therapy technique that enables highlyconformal dose distribution to the tumor while helping to minimize radiation exposure to surroundinghealthy brain tissue and critical structures. The radiologic technologist (RTT) plays an important role inthe safe and effective implementation of VMAT for patients with primary CNS tumors. This role includespatient preparation, immobilization, accurate positioning, acquisition of planning computedtomography (CT) images, and verification of treatment setup. RTTs are also responsible for maintainingimage quality, following established treatment protocols, applying radiation protection principles, andensuring patient safety throughout the treatment process. Accurate patient positioning andreproducibility are particularly important in CNS radiotherapy because of the close proximity of tumorsto sensitive organs at risk. Effective communication with the patient and collaboration with radiationoncologists, medical physicists, and other members of the multidisciplinary team are essential forachieving accurate treatment delivery. The radiologic technologist therefore contributes significantly tothe quality, precision, and safety of VMAT treatment in patients with primary CNS tumors.

Keywords: *Central Nervous System, VMAT, radiologic technologist, RTT, radiotherapy, radiation protection*

Modularne intervencije temeljene na igri u pedijatrijskoj radiologiji i radioterapiji: perspektiva radiološkog tehnologa

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Zdravstveno veleučilište

Sažetak

Uvod: Izvođenje složenih radioloških dijagnostičkih postupaka (npr. MR) ili radioterapije često izaziva izrazit strah i tjeskobu kod pedijatrijskih bolesnika zbog dugotrajne imobilizacije, nepoznatog okruženja i buke uređaja. Iako farmakološka sedacija nosi kliničke rizike i zahtijeva dodatne logističke resurse, nefarmakološke se intervencije još uvijek nedovoljno primjenjuju. Uloga radiološkog tehnologa: Djelujući na spoju tehničke preciznosti i skrbi za bolesnika, radiološki tehnolog ima ključnu ulogu u psihosocijalnoj pripremi djeteta prije samog zahvata. Koristeći modularne građevne kocke (poput LEGO®-kompatibilnih medicinskih setova), tehnolog može vjerno rekonstruirati kliničko okruženje — uključujući MR uređaje, CT simulatore, linearne akceleratore, imobilizacijska pomagala i komandnu sobu, uz pripadajuće figurice pacijenata i medicinskog

osoblja. **Primjena i procjena:** Kroz interaktivnu desenzibilizaciju temeljenu na igri, tehnolozi djeci na primjeren i razumljiv način prikazuju tijek postupka, objašnjavaju zvukove uređaja te postavljaju jasna očekivanja u pogledu suradnje. Ovakva neposredna komunikacija omogućuje tehnologu procjenu razine djetetova straha, kognitivne spremnosti i sposobnosti za suradnju, što otvara prostor za individualizirani pristup i aktivno uključivanje roditelja. **Klinički značaj:** Upoznavanje s postupkom kroz igru pretvara zastrašujuće kliničko okruženje u djetetu razumljivo iskustvo. Primjena ove metode temeljene na dokazima povećava suradljivost pedijatrijskih bolesnika, optimizira radni tijek i protok pacijenata te značajno smanjuje potrebu za primjenom sedacije i opće anestezije.

Ključne riječi: *pedijatrijska radiologija, radioterapija, terapija igrom, radiološki tehnolog, priprema bolesnika, nefarmakološke intervencije*

Modular Play-Based Interventions in paediatric imaging and radiotherapy: A technologist's perspective

Abstract

Background: Undergoing complex diagnostic imaging (e.g., MRI) or radiotherapy often induces severe anxiety in paediatric patients due to prolonged immobilisation, unfamiliar physical environments, and acoustic noise. While pharmacological sedation carries clinical risks and logistical demands, non-pharmacological interventions remain underutilised. **The Radiologic Technologist's Role:** Positioned at the intersection of technical precision and patient care, the radiologic technologist plays a pivotal role in psychosocial pre-procedural preparation. Utilising modular building blocks (such as LEGO®-compatible medical sets), technologists can reconstruct clinical settings—including MRI scanners, CT simulators, linear accelerators, immobilisation devices, and operator consoles, alongside patient and staff figurines. **Application & Assessment:** Through interactive, play-based desensitisation, technologists demonstrate procedural workflows, demystify acoustic signatures, and set clear behavioural expectations in an age-appropriate format. This hands-on dialogue allows technologists to gauge the patient's anxiety level, cognitive readiness, and capacity for compliance, enabling personalised coaching and parental engagement. **Clinical Impact:** Play-based familiarisation transforms an intimidating clinical setting into a comprehensible experience. Evidence-informed application of this method enhances paediatric cooperation, optimises procedural throughput, and substantially lowers reliance on general anaesthesia and sedation.

Keywords: *Paediatric Radiology, Radiotherapy, Play Therapy, Radiologic Technologist, Patient Preparation*

Tetovaže kao dijagnostički izazov u mamografiji

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Sažetak

Cilj ovoga rada je analizirati utjecaj tetovaža na interpretaciju mamografskih nalaza, s posebnim naglaskom na pseudokalcifikacije uzrokovane pigmentima tetovaža te istaknuti ulogu radiološkog tehnologa u njihovom prepoznavanju. Pretraga relevantne stručne i znanstvene literature provedena je u bazi podataka PubMed od 27. travnja do 16. svibnja 2026. godine, pri čemu su korištene ključne kombinacije pojmova „mammography AND tattoo" i „mammography AND pseudocalcifications". Uključeni su radovi koji opisuju pojavu pigmenta tetovaža kao uzroka pseudokalcifikacija na mamografiji i u aksilarnim limfnim čvorovima. Sve veća prisutnost tetovaža predstavlja izazov u mamografskoj dijagnostici, osobito zbog važnosti pravilne interpretacije mikrokalcifikacija u ranom otkrivanju karcinoma dojke. Pigmenti tetovaža mogu sadržavati metalne čestice poput željeza, titana, bakra i aluminija, zbog čega na mamografskim snimkama mogu izgledati poput mikrokalcifikacija. Pigment se može zadržavati u koži, ali i limfnim putem migrirati u regionalne, najčešće aksilarne, limfne čvorove te oponašati patološke kalcifikacije ili metastatske promjene. Takvi nalazi mogu zahtijevati dodatnu dijagnostičku obradu, uključujući ciljane projekcije, tomosintezu, ultrazvuk, magnetsku rezonanciju ili biopsiju. Pacijentice često ne navode prisutnost tetovaža tijekom anamneze jer ih ne povezuju s mogućim utjecajem na radiološki nalaz, što može povećati mogućnost pogrešne interpretacije i psihološkog opterećenja. Radiološki tehnolog, kao jedan od prvih zdravstvenih djelatnika u kontaktu s pacijenticom, ima važnu ulogu u prikupljanju anamneze, dokumentiranju tetovaža i njihovoj lokalizaciji te, prema potrebi, označavanju površinskih promjena tijekom snimanja. Digitalna tomosinteza može dodatno pomoći u razlikovanju kožnih artefakata od stvarnih lezija. Kontinuirana edukacija tehnologa i radiologa o artefaktima povezanima s tetovažama važna je zbog njihova sve većeg broja u populaciji. Zaključno, pigmenti tetovaža mogu uzrokovati pseudokalcifikacije koje oponašaju mikrokalcifikacije dojke ili kalcifikacije aksilarnih limfnih čvorova. Pravodobnim prepoznavanjem tetovaža, pravilnim dokumentiranjem i suradnjom radiološkog tehnologa s radiologom može se smanjiti mogućnost pogrešne interpretacije, nepotrebnih pretraga i biopsija te povećati kvaliteta mamografske dijagnostike.

Ključne riječi: *artefakti; mamografija; pseudokalcifikacije; radiološki tehnolog; tetovaže*

Tattoos as a diagnostic challenge in mammography

Abstract

The aim of this study is to analyse the impact of tattoos on the interpretation of mammographic findings, with particular emphasis on pseudocalcifications caused by tattoo pigments, and to highlight the role of the radiologic technologist in their recognition. A search of relevant professional and scientific literature was conducted in the PubMed database from April 27 to May 16, 2026, using the key search terms "mammography AND tattoo" and "mammography AND pseudocalcifications." Studies describing cases in which tattoo pigments caused pseudocalcifications on mammography and in axillary lymph nodes were included. The increasing prevalence of tattoos represents a challenge in mammographic diagnosis, particularly due to the importance of accurate interpretation of microcalcifications for the early detection of breast cancer. Tattoo pigments may contain metal particles such as iron, titanium, copper, and aluminium, which may cause them to appear as microcalcifications on mammographic images. Pigment may remain in the skin but can also migrate through the lymphatic system to regional, most commonly axillary, lymph nodes, where it may mimic pathological calcifications or metastatic changes. Such findings may require additional diagnostic evaluation, including additional mammographic views, tomosynthesis, ultrasound, magnetic resonance imaging, or biopsy. Patients often do not report the presence of tattoos during the medical history assessment because they do not associate them with a possible effect on the radiological findings, which may increase the risk of misinterpretation and psychological distress. As one of the first healthcare professionals to interact with the patient, the radiologic technologist plays an important role in obtaining the medical history, documenting tattoos and their location, and, when necessary, marking superficial changes during imaging. Digital breast tomosynthesis can further assist in distinguishing skin artefacts from actual lesions. Continuous education of radiologic technologists and radiologists regarding tattoo-related artefacts is important due to the increasing prevalence of tattoos in the population. In conclusion, tattoo pigments can cause pseudocalcifications that mimic breast microcalcifications or calcifications in axillary lymph nodes. Timely recognition of tattoos, proper documentation, and collaboration between the radiologic technologist and radiologist can reduce the risk of misinterpretation, unnecessary examinations, and biopsies, while improving the quality of mammographic diagnosis.

Keywords*: artifacts; mammography; pseudocalcifications; radiologic technologist; tattoos*

Usporedba udaljenosti mandibularnog kanala od ruba alveolarnog grebena u ozubljenih i bezubih ispitanika analizom CBCT snimki

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Sažetak

Ciljevi: Izmjeriti i usporediti vertikalnu udaljenost od vrha alveolarnoga grebena do gornjeg ruba mandibularnoga kanala na CBCT snimkama između ozubljenih i bezubih ispitanika u donjem lateralnom kvadrantu te utvrditi postoji li statistički značajna razlika između tih dviju skupina.

Materijali i metode: Provedeno je retrospektivno presječno istraživanje na 60 CBCT snimki punoljetnih ispitanika iz baze Centra za dentalnu radiologiju X-Dent u Splitu, podijeljenih u dvije jednake skupine od po 30 ispitanika (ozubljeni i bezubi u analiziranom kvadrantu). Visina kosti iznad mandibularnoga kanala mjerena je na poprečnim presjecima od razine foramena mentale do 30 mm distalno, u koracima od 5 mm, u programu Ez3D-i (Vatech, Južna Koreja). Za usporedbu dviju skupina korišten je Mann-Whitney U test, a za usporedbu četiriju skupina prema spolu i dentalnom statusu jednosmjerna analiza varijance (ANOVA) sa Scheffé post-hoc testom. Statistička značajnost postavljena je na P<0,05. **Rezultati:** U skupini ozubljenih ispitanika prosječna dob bila je 37,50±10,68 godina (19 muškaraca, 11 žena), a u skupini bezubih 59,13±13,68 godina (15 muškaraca, 15 žena). Bezubi ispitanici imali su statistički značajno manju udaljenost od vrha alveolarnoga grebena do gornjeg ruba mandibularnoga kanala na svim presjecima, s razlikom već na razini foramena mentale (18,74±3,02 mm vs. 14,21±4,01 mm, P<0,001) sve do presjeka na + 30 mm; razlika je iznosila do približno 5 mm i bila najveća u srednjem segmentu. Isti je obrazac potvrđen i pri analizi ograničenoj na presjeke unutar područja bezubosti. Bezubost je bila najčešća na presjeku + 10 mm (93 %), gdje su izmjerene i najmanje visine kosti. Muškarci su, neovisno o dentalnom statusu, imali veće izmjerene udaljenosti od žena. **Zaključci:** Bezubi ispitanici imaju statistički značajno manju udaljenost od vrha alveolarnoga grebena do gornjeg ruba mandibularnoga kanala od ozubljenih, na svim analiziranim presjecima.

Ključne riječi*: CBCT, mandibularni kanal, alveolarni greben, bezubost, resorpcija alveolarne kosti*

Comparison of the distance between the alveolar ridge crest and the mandibular canal in dentate and edentulous subjects using CBCT imaging analysis

Abstract

Objectives: To measure and compare the vertical distance from the crest of the alveolar ridge to the superior edge of the mandibular canal on CBCT scans between dentate and edentulous subjects in the lower lateral quadrant, and to determine whether a statistically significant difference exists between the two groups. **Materials and Methods:** A retrospective cross-sectional study was conducted on 60 CBCT scans of adult subjects from the database of the Centre for Dental Radiology X-Dent in Split, Croatia divided into two equal groups of 30 subjects each (dentate and edentulous in the analysed quadrant). Bone height above the mandibular canal was measured on cross-sectional images from the level of the mental foramen to 30 mm distally, in 5-mm increments, using Ez3D-i software (Vatech, South Korea). The Mann-Whitney U test and one-way analysis of variance (ANOVA) with the Scheffé post-hoc test were used for statistical analyses. **Results:** The mean age was 37.50±10.68 years in the dentate group (19 men, 11 women) and 59.13±13.68 years in the edentulous group (15 men, 15 women). Edentulous subjects had a statistically significantly smaller distance from the alveolar ridge crest to the superior edge of the mandibular canal at all cross-sections, with the difference present already at the level of the mental foramen (18.74±3.02 mm vs. 14.21±4.01 mm, P<0.001) up to the most distal cross-section at +30 mm (16.88±3.32 mm vs. 13.90±2.73 mm, P<0.001); the difference reached approximately 5 mm and was largest in the middle segment. The same pattern was confirmed in the analysis restricted to cross-sections within each edentulous region. Edentulism was most frequent at the + 10 mm cross-section (93%), where the smallest bone heights were also measured. Men, regardless of dental status, generally had a greater distance than women. **Conclusions:** Edentulous subjects have a statistically significantly smaller distance from the alveolar ridge crest to the superior edge of the mandibular canal than dentate subjects at all analysed cross-sections.

Keywords*: CBCT, mandibular canal, alveolar ridge, edentulism, alveolar bone resorption*

PET CT u dijagnostici srčanih infekcija

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Sažetak

Uvod: Srčane infekcije (endokarditis, miokarditis, perikarditis i postoperativna stanja) u stalnom su porastu zbog sve veće ugradnje srčanih implantata poput umjetnih zalistaka, elektrostimulatora i LVAD-a. Iako je ehokardiografija primarna metoda izbora, klasični dijagnostički postupci ponekad daju nedorečene rezultate, ostavljajući dio infekcija nedijagnosticiranim. **Cilj**: Prikazati ulogu, prednosti, klinička ograničenja i značaj standardizacije protokola slikovne metode ^{18}F-FDG PET/CT u ranoj dijagnostici infektivnog endokarditisa i popratnih srčanih infekcija. **Metode (Prikaz)**: Analizom kliničke primjene utvrđeno je da ^{18}F-FDG PET/CT u kombinaciji s modificiranim Duke kriterijima ima visoku osjetljivost kod infekcija umjetnih zalistaka i elektrostimulatora, dok mu je osjetljivost kod prirodnih zalistaka niska. Metoda uspješno otkriva udaljena izvansrčana sijela infekcije i sprječava nepotrebna kirurška uklanjanja uređaja. Glavna ograničenja obuhvaćaju lažno pozitivne nalaze na mjestima ranijih kirurških zahvata, lažno negativne nalaze kod upala slabog intenziteta te artefakte zbog micanja srca. U svakodnevnoj praksi primjenjuje se specifičan pripremni protokol: prehrana bogata proteinima i masnoćama dan prije pretrage, gladovanje od 12 sati te aplikacija heparina neposredno prije injiciranja radiofarmaka, s ciljem suzbijanja fiziološkog nakupljanja glukoze u miokardu. **Zaključak**: ^{18}F-FDG PET/CT je moćna dodatna dijagnostička metoda koja omogućuje rano otkrivanje srčanih infekcija prije nastanka morfoloških oštećenja, osobito pri negativnom nalazu ehokardiografije. Za maksimalno iskorištavanje potencijala ove metode nužna je hitna uspostava međunarodno standardiziranih protokola pripreme pacijenata, doziranja i samog snimanja.

Ključne riječi*: PET/CT; srčane infekcije; endokarditis; ^{18}F-FDG*

PET/CT in the diagnosis of cardiac infections

Abstract

Introduction: Cardiac infections (endocarditis, myocarditis, pericarditis, and postoperative states) are steadily increasing due to the rising implantation of cardiac devices such as prosthetic valves, pacemakers, and LVADs. Although echocardiography remains the primary method of choice, standard diagnostic procedures can sometimes yield inconclusive results, leaving a portion of infections undiagnosed. **Objective**: To present the role, advantages, clinical limitations, and importance of protocol standardisation for the ^{18}F-FDG PET/CT imaging method in the early diagnosis of infective endocarditis and associated cardiac infections. **Methods**: Clinical application analysis indicates that ^{18}F-FDG PET/CT, combined with modified Duke criteria, possesses high sensitivity in detecting infections of prosthetic valves and cardiac devices, whereas its sensitivity for native valve endocarditis remains low. The method successfully detects distant extracardiac infectious foci and prevents unnecessary surgical removal of devices. Main limitations include false-positive findings at prior surgical sites, false-negative findings in low-intensity inflammations, and cardiac motion artefacts. In daily practice, a specific preparation protocol is implemented: a high-protein, high-fat diet the day before the scan, 12-hour fasting, and heparin administration immediately prior to radiopharmaceutical injection to suppress physiological myocardial glucose uptake. **Conclusion**: ^{18}F-FDG PET/CT is a powerful complementary diagnostic tool that enables early detection of cardiac infections before morphological damage occurs, particularly in cases with negative echocardiographic findings. To fully maximise the potential of this method, the urgent establishment of internationally standardised protocols for patient preparation, dosing, and imaging acquisition is essential.

Keywords*: PET/CT; cardiac infections; endocarditis; ^{18}F-FDG*

Perfuzijska scintigrafija mozga s Tc-99m-HMPAO u postupku dokazivanja moždane smrti

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Sažetak

Cilj: Cilj rada je prikazati nuklearnomedicinske metode koje se koriste za procjenu moždane smrti. Scintigrafija mozga slikovna je dijagnostička metoda kojom se pomoću intravenske aplikacije radiofarmaka (Tc-99m-HMPAO) i snimanja gama-kamerom dobivaju podaci o vaskularnim, žarišnim i difuznim oboljenjima mozga. **Metode**: Snimanje započinje

injiciranjem Tc-99m-HMPAO. Razlikujemo dinamičku scintigrafiju, ranu i kasnu statičku scintigrafiju mozga te jednofotonsku emsijsku tomografiju mozga. SPECT snimanje ima veliku prednost boljeg prikaza stražnje lubanjske jame i moždanog debla, a dodatne vrijedne informacije dobivaju se dodatnim snimanjem kompjutorizirane tomografije u niskodoznom načinu rada (SPECT/CT). **Zaključak**: Scintigrafija se prikazala kao metoda koja je manje invazivna od drugih dijagnostičkih postupaka za utvrđivanje moždane smrti odnosno procjenu cerebralnog protoka, omogućava nam brzu interpretaciju, a radiofarmak nema nepovoljan utjecaj na bubrežnu funkciju što je značajno kod eventualne transplantacije organa.

Ključne riječi: *Perfuzijska scintigrafija; mozak; Tc-99m-HMPAO; moždana smrt*

Brain perfusion scintigraphy with Tc-99m-HMPAO in the procedure of confirming brain death

Abstract

Objective: The aim of this paper is to present nuclear medicine methods used for the assessment of brain death. Brain scintigraphy is an imaging diagnostic method that provides data on vascular, focal, and diffuse brain diseases using intravenous administration of a radiopharmaceutical (Tc-99m-HMPAO) and gamma camera imaging. **Methods**: Imaging begins with the injection of Tc-99m-HMPAO. We distinguish between dynamic scintigraphy, early and late static brain scintigraphy, and single-photon emission computed tomography (SPECT) of the brain. SPECT imaging offers a major advantage of better visualising the posterior cranial fossa and the brainstem, while additional valuable information is obtained through low-dose computed tomography imaging (SPECT/CT). **Conclusion**: Scintigraphy has proven to be less invasive than other diagnostic procedures for confirming brain death or assessing cerebral blood flow. It allows for rapid interpretation, and the radiopharmaceutical has no adverse effect on renal function, which is significant in the event of potential organ transplantation.

Keywords: *Perfusion scintigraphy; brain; Tc-99m-HMPAO; brain death*

Uloga tehnologa kod izvođenja jednofotonske emisijske tomografije mozga sa I-123 ioflupanom (DaTscan)

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Sažetak

Cilj rada: Prikazati ulogu radiološkog tehnologa u izvođenju DaT SCAN pretrage kroz poznavanje protokola snimanja, aplikacije radiofarmaka i rada s nuklearno-medicinskom opremom. **Uvod**: SPECT mozga s I-123 ioflupanom je funkcijska nuklearno-medicinska pretraga za prikaz dopaminergijskog sustava, indicirana kod specifičnih poremećaja pokreta. Koristi se radiofarmak 123 I-ioflupan. **Priprema bolesnika**: Tehnolog prikuplja podatke, educira bolesnika te isključuje kontraindikacije (trudnoća, dojenje).Ključno je prepoznati i tjedan dana prije pretrage obustaviti lijekove koji interferiraju s vezivanjem farmaka (npr. amfetamin, metilfenidat). Za zaštitu štitnjače bolesnik prima Lugolovu otopinu (2x5 kapi) dan prije, na dan pretrage i dan poslije. **Izvođenje i akvizicija**: Doza od 111-185 MBq injicira se sporo intravenski (minimalno 15-20 sekundi). Tomografsko snimanje na gama kameri započinje 3-6 sati nakon aplikacije. Zadatak tehnologa je unos podataka, odabir protokola, fiksacija glave bolesnika radi smanjenja pokreta te postavljanje parametara akvizicije (HR kolimator, matrica 128x128). **Zaključak**: Stručnost radiološkog tehnologa u pripremi pacijenta i preciznoj tehničkoj izvedbi protokola presudna je za izbjegavanje artefakata pomaka i dobivanje dijagnostički validnog nalaza.

Ključne riječi: *SPECT; mozak; I-123 ioflupan; DaTscan*

The role of the technologist in performing brain single-photon emission computed tomography (SPECT) with I-123 ioflupane (DaTscan)

Abstract

Objective: To present the role of the radiologic technologist in performing the DaT SCAN procedure through knowledge of imaging protocols, radiopharmaceutical administration, and operation of nuclear medicine equipment. **Introduction:** Brain SPECT with I-123 ioflupane is a functional nuclear medicine imaging technique used to visualise the dopaminergic system, indicated in specific movement disorders. The radiopharmaceutical I-123 ioflupane is used. **Patient Preparation**: The technologist collects relevant data, educates the patient, and rules out contraindications (pregnancy, lactation). It is crucial to identify and discontinue medications that interfere with pharmaceutical binding (e.g., amphetamine, methylphenidate) one week prior to the scan. To protect the thyroid gland, the patient receives Lugol's solution (2x5 drops daily) the day before, on the day of, and the day after the procedure. **Procedure and Acquisition**: A dose of 111–185 MBq is administered via slow intravenous injection (minimum 15–20 seconds). Tomographic imaging on the gamma camera begins 3–6 hours post-injection. The technologist's tasks include data entry, protocol selection, head fixation to minimise motion artefacts, and setting acquisition parameters (HR collimator, 128x128 matrix). **Conclusion**: The expertise of the radiologic technologist in patient preparation and precise technical execution of the protocol is critical for avoiding motion artefacts and obtaining a diagnostically valid finding.

Keywords: *SPECT; brain; I-123 ioflupane; DaTscan*

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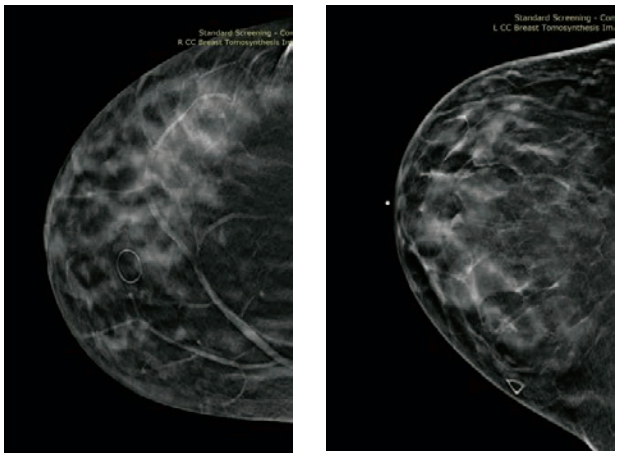


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Svako zadržavanje daha je važno. Zato Accela, pokretana tehnologijom NeoArc, omogućuje isporuku SBRT-a tijekom jednog zadržavanja daha. Ono što je nekoć zahtijevalo višestruka zadržavanja daha sada se može isporučiti u jednom. Accela pomaže da svaki udah bude iskorišten.

Najzahtjevniji slučajevi upravo su postali jednostavniji za liječenje.

Složenost slučaja oduvijek je utjecala na kvalitetu ishoda. Ne zbog kliničke prosudbe, nego zbog ograničenja dostupne tehnologije. NeoArc (DMAT) na sustavu Accela to mijenja. Omogućavanje SBRT-a na više lokalizacija u samo jednoj minuti znači da svaki pacijent dobiva pristup istom standardu skrbi, bez obzira na složenost njegova stanja.

Adaptacija prema vašim uvjetima.

Adaptivna terapija dosad je značila rad na način koji rješenje dopušta. Eclipse Neo i Accela to mijenjaju: fleksibilna adaptacija podržava i online i offline prilagodbu, pa vi odlučujete kako i kada prilagoditi terapiju — od slučaja do slučaja, iz dana u dan. Plan se prilagođava trenutku, a ne obrnuto.

Manje vremena za pomicanje. Manje prostora za sumnju.

U radioterapiji je svaka sekunda između snimanja i završetka zračenja prilika da se cilj pomakne. Accela skraćuje to razdoblje od snimanja do završetka zračenja na samo 90 sekundi kako bi pomogla osigurati da liječite upravo ono što vidite.

Cjelovita slika u jednom zadržavanju daha.

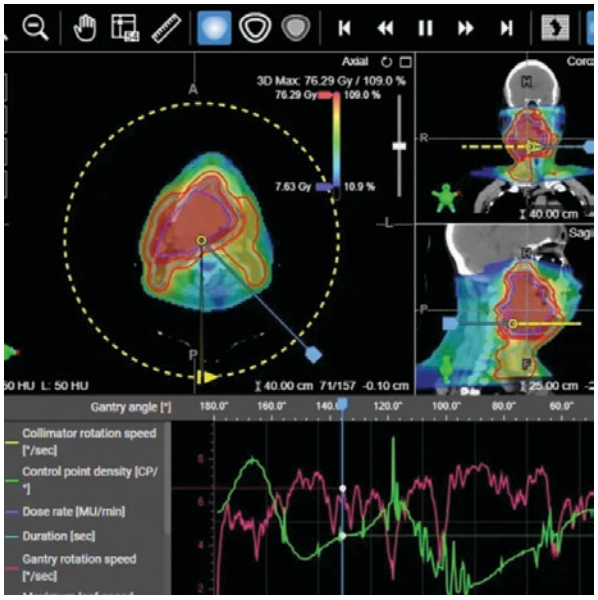
Snimanje je oduvijek bilo ključno za preciznost. Sada ide ukorak s terapijom. Uz CBCT tijekom jednog zadržavanja daha za samo 15 sekundi, Accela može obuhvatiti ključnu anatomiju u jednom neprekinutom zadržavanju daha, čime pomaže pojednostavniti postupak koji je nekoć zahtijevao više vremena i od pacijenata i od kliničkog osoblja. Jer put prema liječenju započinje uvidom u ono što je moguće.

Ne biste trebali birati između složenosti slučaja i vremena.

Accela, pokretana tehnologijom NeoArc, osmišljena je tako da onkolog i medicinski fizičar sami određuju ravnotežu između složenosti, vremena isporuke i kvalitete. Radioterapija se može oblikovati prema potrebama pacijenta, a ne obrnuto.

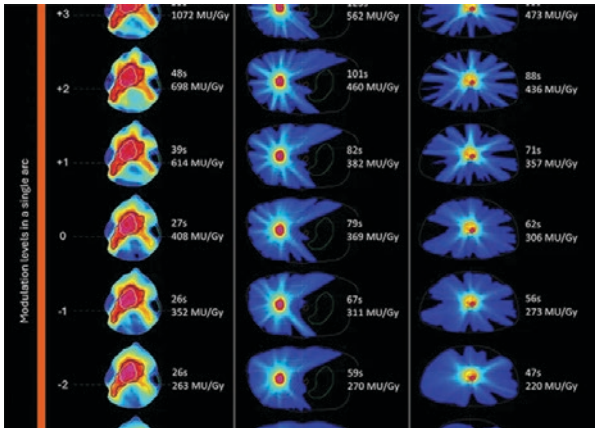
- **Radioterapijsko rješenje Accela[1] projektirano je oko dinamičke modulirane lučne terapije NeoArc (DMAT)[2], revolucionarne tehnike koja objedinjuje brzinu i preciznost**
- **NeoArc omogućuje stereotaktičko liječenje tijekom jednog zadržavanja daha te SBRT liječenje na više lokalizacija u samo 60 sekundi**
- **Brzom isporukom i planiranjem terapije Accela čini složeno liječenje praktičnijim i skalabilnijim za centre za liječenje raka**

Siemens Healthineers je predstavio Accelu, prvo radioterapijsko rješenje projektirano oko tehnologije NeoArc, koje objedinjuje brzinu i preciznost za širok raspon slučajeva, istodobno poboljšavajući skalabilnost složenih terapija i skraćujući vrijeme koje pacijenti provode na radioterapijskom tretmanu.



Rješenje Accela omogućuje stereotaktičke tretmane tijekom jednog zadržavanja daha i SBRT tretman na više lokalizacija u samo 60 sekundi, čime se skraćuje vrijeme koje pacijent provodi na stolu za terapiju. Napredna umjetna inteligencija i algoritmi softvera za planiranje omogućuju kliničkom osoblju uravnoteženje optimizacije kvalitete plana i brzine isporuke.

Uz to, Accela donosi nenadmašnu funkcionalnost linearnog akceleratora, s velikim HyperSight panelom za konusno-slojno CT snimanje, novodizajniranim višelamelarnim kolimatorom, velikom brzinom rotacije gantryja od 2,5 okretaja u minuti, brzinama doze do 40 Gy/min i novom energetskom postavkom od osam megavolta bez filtra za izravnavanje snopa.



„Accela predstavlja iskorak kakav se u našem području rijetko viđa", rekao je dr. med. Dee Khuntia, glavni medicinski direktor društva Varian, poslovne jedinice za skrb o oboljelima od raka unutar Siemens Healthineersa. „Brža je od prethodnih sustava, izgrađena je na temeljito modernoj arhitekturi i uvodi generacijski pomak u planiranju terapije. No najviše me oduševljava njezin potencijal da promijeni biološki odgovor na radioterapiju. To nije postupan napredak; to je novo poglavlje."

Za zdravstvene sustave koji se suočavaju s rastućim opterećenjem rakom, sve većom složenošću liječenja i ograničenjima u pogledu osoblja, Accela proširuje mogućnosti radioterapijskog liječenja, omogućuje brže i preciznije radne procese te poboljšano iskustvo za pacijente i kliničko osoblje.

„Današnja objava pokazuje razinu inovacije u radioterapiji kakvu može pružiti samo Siemens Healthineers", rekao je Arthur Kaindl, voditelj Variana. „Počiva na temeljima koji su se gradili desetljećima: globalnom poslovanju u području snimanja, našoj instaliranoj bazi u radijacijskoj onkologiji, zreloj umjetnoj inteligenciji i softveru te dugoročnim kliničkim odnosima. Neizmjerno smo zahvalni tisućama kolega čiji su rad i domišljatost tijekom proteklih osam godina doveli do ovoga."

Razvoj sustava Accela i tehnologije NeoArc oblikovan je kroz višegodišnju suradnju Siemens Healthineersa i savjetodavne skupine vodećih ustanova za istraživanje raka: Mayo Clinic, Washington University School of Medicine Siteman Cancer Center, University Hospital Zurich, Seidman Cancer Center pri University Hospitals Cleveland Medical Center, Maastro – Maastricht Radiation Oncology Institute, Mass General Brigham Cancer Center i Memorial Sloan Kettering Cancer Center (MSK). Njihovi klinički doprinosi, istraživačka suradnja i evaluacija proizvoda pomogli su usmjeriti ovu inovaciju.

*510(k) pending. Not available for sale in any market.

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