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SAR in Magnetic Resonance Imaging

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Riječ urednika

Suvremena radiologija i radiološka tehnologija nalaze se u središtu tehnološkog procvata koji kontinuirano redefinira kliničke standarde i sigurnosne protokole. U ovom proljetnom izdanju Radiološkog vjesnika za 2026. godinu, fokus stavljamo na inovativna rješenja koja izravno pridonose optimizaciji dijagnostičkih procesa i zaštiti bolesnika. Paralelno s dijagnostičkim napretkom, bavimo se i ključnim pitanjima sigurnosti u MR okruženju kroz analizu znanja radioloških tehnologa o specifičnoj stopi apsorpcije (SAR). Od implementacije dvoenergijskog CT-a (DECT) u zbrinjavanju politrauma, koji omogućuje značajno smanjenje doze zračenja bez kompromitiranja kvalitete slike, do istraživanja utjecaja preciznog pozicioniranja stola na dozu bolesnika, naši autori demonstriraju važnost tehnološke izvrsnosti u svakodnevnoj praksi. Ovaj broj također istražuje prednosti manje zastupljenih, ali visokovrijednih metoda poput MR-histerosalpingografije (MR-HSG), koja nudi sigurnu i sveobuhvatnu alternativu u obradi neplodnosti. Upravo ta sinergija napredne tehnologije, stručnog znanja i etičke odgovornosti, koju dodatno učvršćujemo uvođenjem nove platforme Radiološkog vjesnika, čini temelj našeg daljnjeg razvoja. Bogata stručna aktivnost naše zajednice zabilježena je kroz izvještaje s ključnih skupova, uključujući 6. Kongres radiološke tehnologije u Vodicama, SEETRO 2025, Europski kongres radiologije (ECR 2026), te međunarodna iskustva kroz program Erasmus+. Ovi prilozi potvrđuju da je kontinuirana razmjena znanja na globalnoj razini neophodna za napredak struke. Pozivamo vas da istražite ove stranice kao izvor novih spoznaja i motivaciju za daljnje istraživačke napore koji će oblikovati budućnost radiološko-tehnološke znanosti i prakse.

Glavni urednik:
Frane Mihanović

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Tatjana Matijaš i Velimir Karadža

A word from the Editor

Modern radiology and radiological technology are at the centre of a technological boom that continuously redefines clinical standards and safety protocols. In this Spring 2026 issue of the Radiological Journal, we focus on innovative solutions that directly contribute to the optimisation of diagnostic processes and patient protection. In parallel with diagnostic advancements, we address key safety issues in the MR environment by analysing radiologic technologists' knowledge of Specific Absorption Rate (SAR). From the implementation of dual-energy CT (DECT) in polytrauma management, which enables a significant reduction in radiation dose without compromising image quality, to investigations into the impact of precise table positioning on patient dose, our authors demonstrate the importance of technological excellence in daily practice. This issue also explores the advantages of less common but highly valuable methods, such as MR-hysterosalpingography (MR-HSG), which offers a safe and comprehensive alternative in infertility workups. It is this synergy of advanced technology, professional expertise, and ethical responsibility, which we are further strengthening by introducing the new Radiological Journal platform, that forms the foundation of our continued development. The rich professional activity of our community is captured in reports from key meetings, including the 6th Congress of Radiological Technology in Vodice, SEETRO 2025, the European Congress of Radiology (ECR 2026), and international experiences through the Erasmus+ program. These contributions confirm that the continuous exchange of knowledge on a global level is essential for the advancement of the profession. We invite you to explore these pages as a source of new insights and motivation for further research efforts that will shape the future of radiological science and practice.

Editor in Chief:
Frane Mihanović

Deputy Editors-in-Chief:
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SADRŽAJ

18 **SAR in Magnetic Resonance Imaging: A Study on the Education, Knowledge, and Practice of Radiologic Technologists in the Republic of Croatia**

Matija Hranić, Branko Kovalisko, Frane Mihanović

Original scientific paper
(Izvorni znanstveni članak)

6 **MR-HSG as a safe, reliable, and underused method**

Barbara Škrabal, Tihana Šitum, Daniel Čorak, Domagoj Dokozić, Krešimir Musić, Nikola Gotovac

Original scientific paper
(Izvorni znanstveni članak)

2 **Dual-energy CT in polytrauma: protocol implementation and radiation dose reduction at University Hospital Centre Zagreb**

Alen Udovičić, Bepo Vasić, Marijana Pervan

Original scientific paper
(Izvorni znanstveni članak)

11 **Utjecaj vertikalnog odstupanja od izocentra na dozu zračenja u CT dijagnostici**

Marko Krpan, Bruno Rajič, Marin Brajković, Vedran Markotić, Ivan Lasić, Ante Bošnjak

Izvorni znanstveni članak
(Original scientific paper)

24 **Izvještaj sa 7. kongresa SEETRO 2025: Tehnološki iskoraci i redefiniranje uloge radiološkog tehnologa u suvremenoj radioterapiji**

E. Muše, M. Sofilić Ušković, V. Ugarković

Sažetak sa skupa (Meeting abstract)

29 **Izvješće sa 6. Kongresa radiološke tehnologije**

Sažetak sa skupa (Meeting abstract)

26 **Izvještaj s ESTRO edukacijskog programa**

Ivan Balentović, Miran Gašparović

Pregled stručnog događaja
(Review of professional event)

32 **HDRT na Europskom kongresu radiologije, ECR 2026, Beč, 04. – 08. ožujka 2026.**

Vladimir Bahun, tajnik za međunarodnu suradnju HDRT-a

Sažetak sa skupa (Meeting abstract)

30 **Iskustva sa ERASMUS+ programa na Zdravstvenom Fakultetu u Ljubljani**

Domagoj Babić[1,2]

Pregled stručnog događaja
(Review of professional event)

35 **Medicinski dijagnostički monitori LG**

Marko Stošić

Promotivni članak (Promotional article)

38 **AI in lung screening and beyond**

Promotional article (Promotivni članak)

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 ČLANAK)

SAR in Magnetic Resonance Imaging: A Study on the Education, Knowledge, and Practice of Radiologic Technologists in the Republic of Croatia

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Abstract

Introduction: Magnetic resonance imaging (MRI), as a modern diagnostic method, presents specific safety challenges due to patients' exposure to strong electromagnetic fields. From this perspective, the Specific Absorption Rate (SAR) is a key safety parameter. Managing SAR in clinical practice is crucial for preventing excessive tissue heating and ensuring patient safety, prevalence of metallic implants, tattoos, and cosmetics containing metallic pigments, as well as the diverse age profile of patients, which necessitates special consideration for thermoregulation in paediatric and geriatric populations. Radiologic technologists play a central role in this process. Still, it remains unclear to what extent they possess formal education and knowledge about SAR, and how these aspects are applied in practice.

Aim: To analyse the current state of education, theoretical knowledge, and clinical practice of radiologic technologists in the Republic of Croatia in the context of SAR management and optimisation during MRI examinations.

Methods: A survey was conducted among radiologic technologists with MRI work experience in the Republic of Croatia. The questionnaire included questions regarding their formal training in MRI safety, understanding of the SAR concept, and implementation of safety protocols in practice.

Results: Neither level of education nor work experience significantly correlated with knowledge scores. No statistically significant difference was found in the number of correct answers between master's degree holders and bachelor's degree holders ($p = 0.382$), nor with total work experience ($p = 0.618$) or MRI-specific experience ($p = 0.409$). In contrast, one-way ANOVA revealed statistically significant regional differences in knowledge levels ($p = 0.049$). A pronounced discrepancy between theoretical knowledge and its practical application was identified. This finding is further supported by the fact that 96.2% of participants expressed a need for additional education.

Conclusion: The findings indicate the necessity of establishing systematic education for radiologic technologists on MRI safety, with a particular focus on SAR management. It is also recommended to implement unified, clearly defined safety protocols and to appoint responsible personnel for MR safety within healthcare institutions.

Keywords: education; magnetic resonance imaging; radiologic technologists; safety protocols; SAR

Introduction

Magnetic resonance imaging (MRI) is one of the most important diagnostic imaging methods in modern medicine due to its ability to generate high-contrast images of soft tissues without ionizing radiation [1]. Despite its great advantages, MRI carries certain safety challenges, particularly due to the exposure of patients to electromagnetic fields, which requires special attention given the increasing number of performed examinations and the growing number of implants in patients [2].

A key safety parameter in MRI is the Specific Absorption Rate (SAR), which defines the amount of radiofre-

quency (RF) energy absorbed in the body per unit mass over time, expressed in W/kg [3]. SAR directly correlates with thermal effects on tissues. Excessive levels of SAR can cause significant local tissue heating, discomfort, or even serious thermal injuries, such as burns, especially if not carefully controlled in clinical practice [4].

Radiologic technologists play a crucial role in adjusting imaging protocols because technical characteristics and parameters, such as TR, sequence duration, flip angle (FA), fat suppression techniques, and coil selection, significantly affect SAR levels [5]. European and international recommendations highlight the importance of a clear division of roles. The MR Medical Director (MRMD) is responsible for MR safety, while the MR Safety Officer (MRSO) implements and supervises safety protocols, educates staff, and analyses incidents [6, 7]. A lack of formal education and the absence of appointed MRSOs directly increase the risk of incidents [7]. In the Republic of Croatia, however, systematic data on radiologic technologists' knowledge and clinical practice regarding SAR are currently unavailable, further justifying the need for this research.

The primary aim of this study was to provide a comprehensive analysis of the current state of education, theoretical knowledge, and clinical practice among radiologic technologists in the Republic of Croatia in relation to SAR management and optimization during MRI examinations. An additional objective was to identify critical gaps in the implementation of safety protocols, with the intention of informing future improvements and supporting the development of targeted continuing education initiatives.

Within this framework, particular emphasis was placed on examining factors that may influence both the understanding and practical application of SAR-related concepts. These included the role of formal education and professional experience, potential regional variability in knowledge levels and clinical approaches, and the extent to which theoretical knowledge is effectively translated into routine clinical practice.

Materials and Methods

Study Design and Participants

A cross-sectional study was conducted using a structured survey questionnaire. The participants were radiologic technologists employed in public and private healthcare institutions in the Republic of Croatia with experience in performing MRI examinations. A total of 52 validly completed questionnaires were collected.

Data Collection Instrument

The structured questionnaire, created specifically for this research, contained 25 questions divided into three sections: demographic and professional data; self-assessment of knowledge and perception of educational needs; and objective assessment of knowledge and clinical practice. The content of the questionnaire was based on current international guidelines (IEC 60601-2-33, ACR Manual on MR Safety, FDA) [8, 9, 10]. The survey questionnaire was distributed electronically via Microsoft Forms.

Statistical Analysis

All responses were exported in .xlsx format and analysed using Microsoft Excel and PSPP. Descriptive analysis and correlation analysis were performed.

Results

Demographic and Professional Characteristics

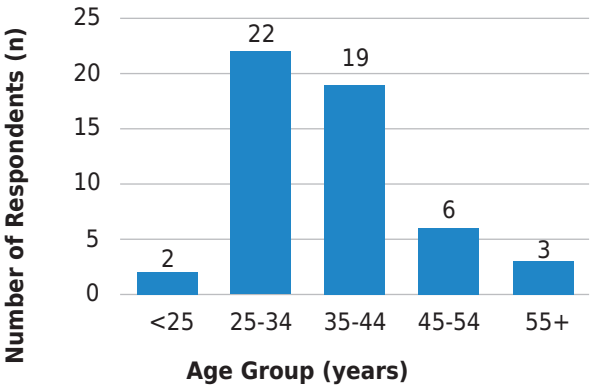


Figure 1. Distribution of respondents by age group

A total of 52 radiologic technologists participated. A slightly larger portion of participants were male (n = 27; 52%) compared to female (n = 25; 48%). The most represented age group was 25–34 years (n = 22; 42.3%), followed by 35–44 years (n = 19; 36.5%). Smaller proportions were observed in the 45–54 (n = 6; 11.5%), 55+ (n = 3; 5.8%), and <25 years (n = 2; 3.8%) age groups (Figure 1).

Regarding their formal education, 40 participants (77%) held bachelor's degrees, while 12 (23%) held master's degrees. The majority of respondents were employed in general hospitals (n = 26; 50%), followed by clinical hospital centres (n = 14; 27%). Smaller proportions worked in the private sector (n = 9; 17%) and clinical hospitals (n = 3; 6%), as shown in Figure 2.

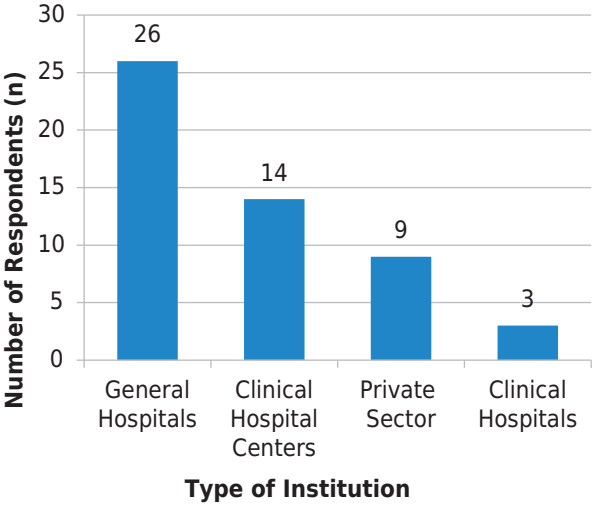


Figure 2. Distribution of respondents by type of healthcare institution

Regarding specific experience in MRI diagnostics, the largest proportion of participants had less than 5 years of experience (n = 22; 42%), followed by those with 5–14 years (n = 20; 38%). A smaller group reported 15–24 years of experience (n = 9; 17%), while only one participant had more than 25 years of MRI experience (n = 1; 2%) (Figure 3).

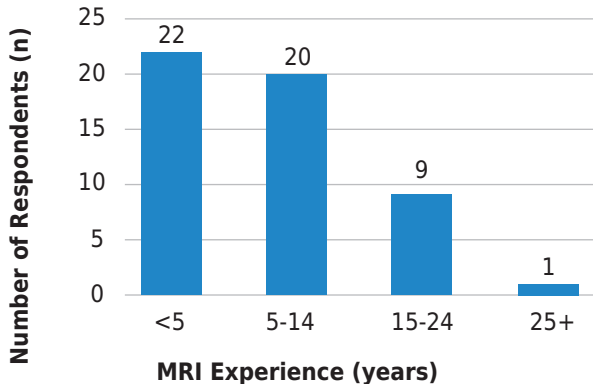


Figure 3. Distribution of respondents according to years of professional experience in MRI diagnostics

From a geographical perspective, the distribution of respondents across Regional Councils indicates that the largest cohort originated from the 4th Regional Council (n = 21; 40%), followed by the 2nd (n = 17; 33%) and the 1st (n = 10; 19%). The smallest representation was observed in the 3rd Regional Council (n = 4; 8%), as shown in Figure 4.

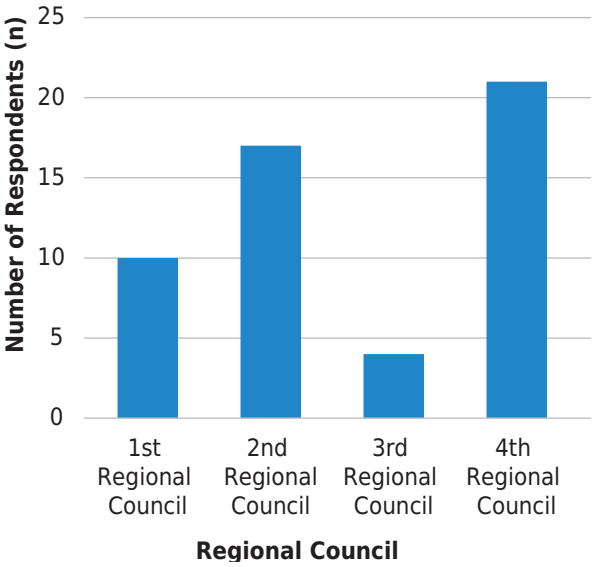


Figure 4. Geographical distribution of respondents by Regional Council

Objective Knowledge on SAR

Participants' objective knowledge of SAR was assessed using 9 questions. The average number of correctly answered questions was 5.08 (56.4%). The concept of SAR was correctly defined by the majority of participants (n = 47; 90%). Furthermore, 88.5% of respondents (n = 46) correctly indicated that SAR is not negligible even during short examinations. The maximum allowed whole-body SAR value in normal operating mode (2 W/kg) was correctly identified by less than half of the participants (n = 25; 48%). A lower level of accuracy was observed in assessing the impact of parallel acquisition techniques on SAR, with only 31% of participants (n = 16) correctly recognizing that these techniques reduce SAR by decreasing acquisition time and the number of RF pulses (Figure 5).

Optimization Practices and Educational Gaps

The most frequently mentioned recommended methods for SAR reduction that technologists recognized were reducing FA (60% of participants) and using sequences with fewer consecutive RF pulses (50%). A substantial majority of respondents (86.5%) perceived a significant discrepancy between the theoretical knowledge of Specific Absorption Rate (SAR) acquired during their academic studies and its practical application in clinical settings (Table 1).

Table 1: Perceived gap between academic education and clinical practice

Perception of Difference	Frequency (n)	Percentage (%)
Significant difference exists	45	86.5%
No significant difference	7	13.5%

Furthermore, the findings underscore a near-universal demand for professional development, with 96.2% of participants expressing a clear need for additional education on SAR management (Table 2). Notably, despite this high level of interest, only 17% of respondents had participated in specific SAR-related training.

Table 2: Participant self-assessment on the need for further education

Need for Additional Education	Frequency (n)	Percentage (%)
Expressed need for education	50	96.2%
No need for further education	2	3.8%

Correlations

Comparing the knowledge test results between master's and bachelor's degree holders in radiologic technology showed no statistically significant difference ($p = 0.382$). Examining the correlation between total work experience and the test result showed a very low, non-significant correlation ($p = 0.618$). However, the knowledge test results showed statistically significant differences among regions

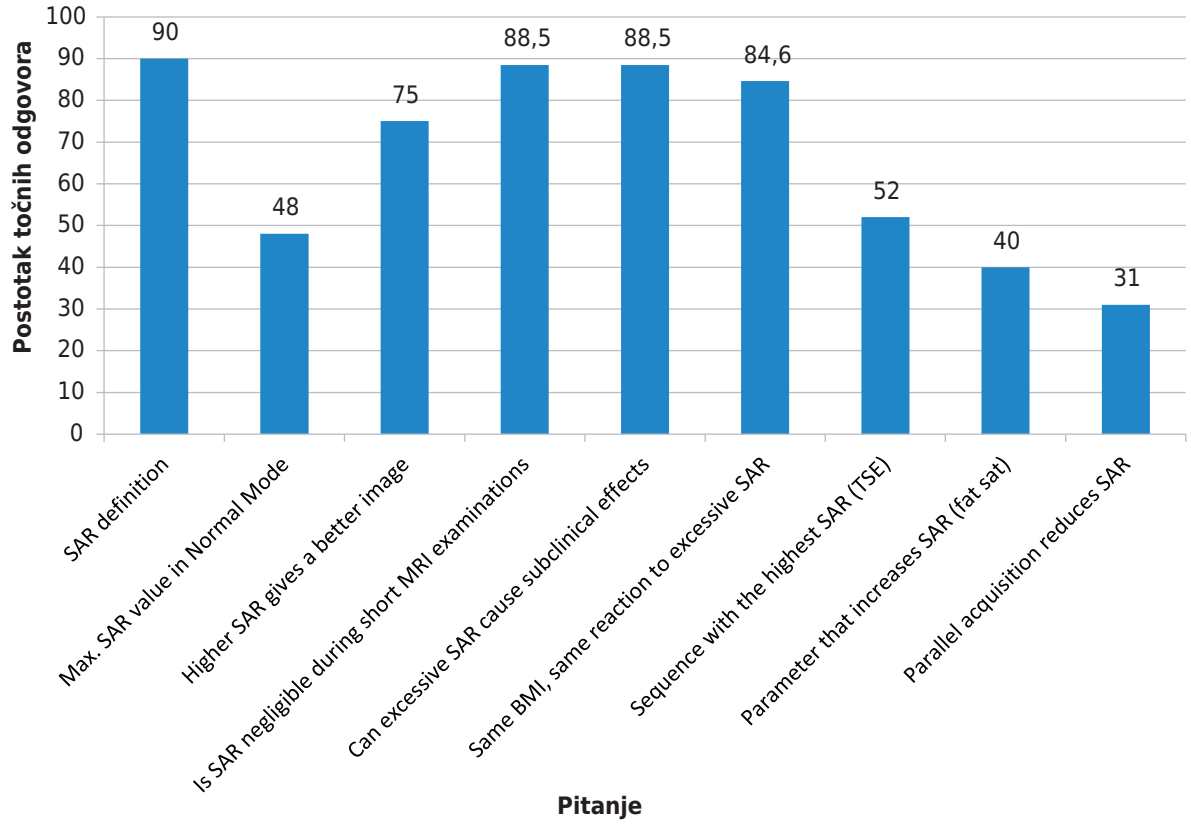


Figure 5. Distribution of correct answers on the objective knowledge test regarding SAR

(p = 0.049), with the highest average score recorded in the 1st Regional Council and the lowest in the 4th Council (Table 3).

Table 3: Comparative Analysis of Knowledge Test Scores by Education and Region

Variable	Group	Mean Score (± SD)	Statistical Significance (p)
Education Level	Master's Degree	6.6±1.4	**0.382**
	Bachelor's Degree	6.2±1.3	
Regional Council	1st Council	7.20±1.76	**0.049**
	4th Council	5.76±1.38	

Experience working on an MRI scanner also did not show a significant correlation with acquired knowledge (p = 0.409) (Table 4).

Table 4: Correlation Between Experience and Knowledge Test Scores

Variable	Correlation Coefficient (r)	Statistical Significance (p)
Specific MRI Experience	Low/Negligible	0.409

Discussion

The results of this research indicate that while radiologic technologists in the Republic of Croatia possess a solid foundational understanding of the Specific Absorption Rate (SAR) concept, significant gaps exist regarding advanced technical parameters and practical optimization strategies. The average score on the objective knowledge test was 56.4%, which represents a moderate level of competency. However, this average masks a sharp decline in performance as questions transitioned from theoretical definitions to clinical application.

The Theory-Practice Gap

While a vast majority of respondents (90%) correctly identified the basic definition of SAR, accuracy plummeted when addressing regulatory limits and technical variables. For instance, only 48% of participants were aware of the maximum allowed SAR value for the whole body in normal operating mode. This discrepancy suggests that while technologists "know of" SAR, they may not be fully equipped to manage SAR within safe regulatory boundaries.

The most critical deficit was observed in practical optimization scenarios. The finding that only 31% of participants understood the impact of parallel acquisition on SAR is particularly concerning, as it directly relates to the technologist's ability to adjust scan parameters to ensure patient safety. This result highlights a substantial disconnect between academic preparation and the complexities of modern clinical practice.

Educational Deficits and Professional Needs

The near-unanimous demand for further education (96.2%), coupled with the perceived discrepancy between academic curricula and clinical reality (86.5%), underscores a systemic gap in professional training. Current educational frameworks appear to provide only a foundational understanding of SAR, and they struggle to keep pace with rapid technological advancements. This is particularly critical as the industry shifts toward higher field strengths, such as 3T and 7T, where precise SAR management becomes a fundamental safety requirement rather than a theoretical consideration. Furthermore, the lack of a statistically significant correlation between work experience and test scores ($p = 0.409$) suggests that "learning on the job" is an insufficient substitute for formal, targeted training. This implies that even seasoned technologists may be operating based on inherited workplace habits rather than evidence-based safety protocols.

Comparison with International Standards

The international radiological community has already recognized these challenges by moving toward standardizing MR safety roles. The American College of Radiology (ACR) emphasizes the necessity of the MR Safety Officer (MRSO) role to bridge the gap between technical knowledge and clinical safety [9]. Similarly, the European Federation of Radiographer Societies (EFRS) is actively developing the European Curriculum for Safety Officers in MRI (ECSO-MRI) to ensure a unified level of competence across Europe [11, 12].

In Croatia, the absence of a formal "MR Safety Officer" certification or a standardized national curriculum for SAR management leaves individual departments to establish their own, often informal, safety benchmarks. Implementing a structured certification process, aligned with EFRS and ACR guidelines, would not only elevate the professional status of radiologic technologists but, more importantly, enhance patient safety by ensuring that SAR optimization is a deliberate, data-driven process rather than a trial-and-error approach.

Study Limitations and Implications

When interpreting these findings, several research limitations should be considered. The sample size of 52 radiologic technologists, although not negligible, may be too small for robust generalizations. Geographical representation was not fully balanced, partly due to the data collection method. Additionally, the objective knowledge test was conducted online without supervision, so it cannot be ruled out that some respondents consulted literature.

Despite these limitations, the findings provide a valuable initial overview of the situation. Based on the results, recommendations include introducing systematic additional education, formalizing the role of the MRSO, developing national guidelines and protocols, improving educational programs, and establishing a system of continuous monitoring in practice.

Conclusion

The research demonstrated that radiologic technologists' understanding of SAR in the Republic of Croatia is primarily grounded in a solid grasp of basic concepts, whereas practical and technical aspects remain insufficiently applied. Neither a higher academic degree nor a longer work tenure statistically influenced knowledge test results, and self-assessment proved to be an unreliable measure of actual competence. Significant differences in the points achieved between the 1st and 4th Regional Councils confirm that the local context can substantially affect the level of expertise.

The strongest message comes from the profession itself: almost all participants expressed the need for additional, practically oriented education, which clearly speaks of awareness, but also of a gap that needs to be filled. Furthermore, it is necessary to enable targeted, evidence-based interventions in terms of MRSO certification, which would create a unified national framework for MR safety.

All data in this paper are part of the results of the master's thesis "SAR in Magnetic Resonance Imaging: A Study on the Education, Knowledge, and Practice of Radiologic Technologists in the Republic of Croatia", written at the Faculty of Health Sciences, University of Split. ■

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SAR u magnetskoj rezonanci: Istraživanje o edukaciji, znanju i praksi radioloških tehnologa u Republici Hrvatskoj

Sažetak

Uvod: Magnetska rezonancija (MR), kao suvremena dijagnostička metoda, predstavlja specifične sigurnosne izazove zbog izlaganja pacijenata snažnim elektromagnetskim poljima. Iz te perspektive, specifična apsorbirana snaga (*engl. Specific Absorption Rate – SAR*) ključni je sigurnosni parametar. Upravljanje SAR-om u kliničkoj praksi presudno je za sprječavanje prekomjernog zagrijavanja tkiva i osiguravanje sigurnosti pacijenata, posebice s obzirom na sve veći broj pregleda, učestalost metalnih implantata, tetovaža i kozmetike koja sadrži metalne pigmente, kao i na različitu dobnu strukturu pacijenata, što zahtijeva poseban obzir prema termoregulaciji kod pedijatrijske i gerijatrijske populacije. Radiološki tehnolozi imaju središnju ulogu u tom procesu, no ostaje nejasno u kojoj mjeri posjeduju formalnu edukaciju i znanje o SAR-u te kako se ti aspekti primjenjuju u praksi.

Cilj: Analizirati trenutačno stanje edukacije, teorijskog znanja i kliničke prakse radioloških tehnologa u Republici Hrvatskoj u kontekstu upravljanja i optimizacije SAR-a tijekom MR pregleda.

Metode: Provedeno je istraživanje među radiološkim tehnolozima s radnim iskustvom na MR-u u Republici Hrvatskoj. Upitnik je obuhvaćao pitanja o njihovoj formalnoj izobrazbi o sigurnosti na MR-u, razumijevanju koncepta SAR-a i provedbi sigurnosnih protokola u praksi.

Rezultati: Rezultati su pokazali da ni razina obrazovanja niti radno iskustvo nisu značajno korelirali s rezultatima na testu znanja. Nije pronađena statistički značajna razlika u broju točnih odgovora između magistara i prvostupnika ($p = 0,382$), kao ni s ukupnim radnim stažom ($p = 0,618$) ili specifičnim iskustvom na MR-u ($p = 0,409$). Jednosmjerna ANOVA otkrila je statistički značajne regionalne razlike u znanju ($p = 0,049$). Rezultati ukazuju na izražen raskorak između teorijskog znanja i njegove praktične primjene, što je dodatno potkrijepljeno činjenicom da je 96,2% ispitanika izrazilo potrebu za dodatnom edukacijom.

Zaključak: Dobiveni nalazi upućuju na nužnost uspostave sustavne edukacije radioloških tehnologa o sigurnosti na MR-u, s posebnim naglaskom na upravljanje SAR-om. Također se preporučuje uvođenje jedinstvenih, jasno definiranih sigurnosnih protokola te imenovanje osoba zaduženih za MR sigurnost unutar zdravstvenih ustanova.

Ključne riječi: edukacija; magnetska rezonanca; radiološki tehnolozi; SAR; sigurnosni protokoli

ORIGINAL SCIENTIFIC PAPER (IZVORNI ZNANSTVENI ČLANAK)

MR-HSG as a safe, reliable, and underused method

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Abstract

Introduction: Hysterosalpingography (HSG) is the gold standard for assessing fallopian tube patency, but it involves ionizing radiation and iodinated contrast medium. Magnetic resonance hysterosalpingography (MR-HSG) allows assessment of tubal patency without ionizing radiation, while offering superior visualization of pelvic soft tissues.

Aim: To evaluate the diagnostic value of MR-HSG in assessing fallopian tube patency, with particular emphasis on the MRI protocol, and to compare the findings with those obtained using conventional HSG.

Materials and methods: Fifty patients were included. All underwent MR-HSG followed immediately by HSG. During MR-HSG, a diluted gadolinium contrast solution was administered in the uterine cavity. The protocol consisted of T2-weighted sequences and dynamic T1-weighted imaging. The presence of contrast solution adjacent to the ovaries and in the pouch of Douglas was recorded as an indicator of tubal patency. Agreement between the methods was assessed using Cronbach's alpha coefficient.

Results: Bilateral tubal occlusion was confirmed in 6 cases (12%). Cronbach's alpha demonstrated excellent agreement between the methods (0.97 for the left ovary; 0.84 for the right ovary; 0.80 for the pouch of Douglas). No adverse effects were observed.

Conclusion: MR-HSG is an effective, well-tolerated method with high agreement with HSG. Its advantages include the absence of ionizing radiation and superior visualization of pelvic soft tissues. MR-HSG may be considered a reliable alternative to HSG.

Keywords: MR-HSG, HSG, tubal patency, MRI, gadolinium contrast, infertility, pelvic imaging

Introduction

Hysterosalpingography (HSG) is a radiological diagnostic procedure used to evaluate fallopian tube patency and uterine morphology in the clinical assessment of women with primary or secondary infertility [1,2]. Unlike HSG, which uses ionizing radiation, and sonohysterosalpingography (US HSG), which uses ultrasound, magnetic resonance imaging can also be used to visualize tubal patency and uterine morphology (MR-HSG) [2–9]. MR-HSG is performed without ionizing radiation following intrauterine administration of a gadolinium-based contrast agent. MR-HSG enables detailed evaluation of the uterus, fallopian tubes, ovaries, and surrounding structures [3,10]. This study aimed to demonstrate how the dynamic nature of MR-HSG enables assessment of tubal patency comparable to that obtained with conventional HSG.

Materials and methods

The study included 50 patients referred for MR-HSG (Airis II, Hitachi, Japan; Aera, Siemens Healthineers, Germany) as part of an infertility evaluation, followed immediately by conventional HSG. HSG was performed on a digital radiography/fluoroscopy (DRF) system (Axiom Luminos dRF, Siemens Healthineers, Germany) using an iodinated contrast agent (iobitridol; Xenetix 350 mg I/mL; Guerbet, France). To facilitate direct comparison, MR-HSG and HSG were performed within 10 minutes of each other.

The study was conducted at Požega County General Hospital, Croatia, between 2012 and 2015. Initial data collection began in 2012, and the cohort was subsequently expanded through additional patient enrolment during the study period. Written informed consent was obtained from all participants. Ethics committee approval was granted in 2012, prior to study initiation, and covered

both the preliminary dataset presented at ECR 2014 and the expanded dataset analysed in the present study.

All images were obtained at the Department of Radiology, Požega County General Hospital, Croatia.

Patients

The primary indication for HSG is the evaluation of female infertility. Infertility, according to the World Health Organization, is defined as the inability to achieve a pregnancy after 12 months of regular unprotected sexual intercourse [11]. MRI is also used when uterine or tubal anatomical/pathological abnormalities are suspected, including fibroids, polyps, adenomyosis, and congenital malformations [2,3,8,10]. Only women with primary infertility were included in this study.

Preparation of the contrast solution

For MR-HSG, a diluted gadolinium contrast solution was prepared by adding 1 mL of gadolinium contrast agent (gadoteric acid; Dotarem, 0.5 mmol/mL; Guerbet, France) to 100 mL of normal saline. During imaging, 10–40 mL of the prepared solution was administered into the uterine cavity using a 50-mL syringe in three separate aliquots, allowing real-time assessment of contrast passage through the fallopian tubes and reducing discomfort during injection. Although automated pump injection is possible, for safety and practical reasons, we did not use this approach. The solution was warmed to 37 °C to improve patient comfort.

Patient preparation

The examination is scheduled during the follicular phase of the menstrual cycle, most commonly between days 7 and 10 to minimize artifacts related to endometrial thickening and to exclude pregnancy [12].

The procedure is preceded by gynaecologic preparation, including placement of an intrauterine balloon catheter and inflation of the balloon with saline. Correct catheter placement is confirmed by ultrasound. Patients should be instructed to empty the urinary bladder before MR imaging. Rectal gas typically does not produce significant artifacts at 1.5T; however, bowel preparation is recommended at 3T and higher field strengths.

The patient is positioned supine on the scanner table. A syringe filled with 50 mL of the prepared contrast solution is connected to the intrauterine catheter. Imaging is performed using a multichannel flexible body coil, as in standard pelvic MRI examinations.

MRI acquisition protocol

T2-weighted sequences

T2-weighted sequences are acquired first for anatomical orientation and assessment of the uterus and ovaries, including the endometrium and myometrium, as well as the fallopian tubes and surrounding pelvic structures. They are particularly useful for detecting fibroids, adenomyosis, hydrosalpinx, and congenital or other uterine malformations. Due to their high sensitivity to fluid, they are also helpful in identifying free pelvic fluid that may be present prior to contrast administration. Imaging is initially performed in the sagittal plane (Figure 1). Subsequent acquisitions are then planned in an oblique transverse (axial) or coronal plane to optimize visualization of the uterus and ovaries, ideally including all three structures within a single imaging block.

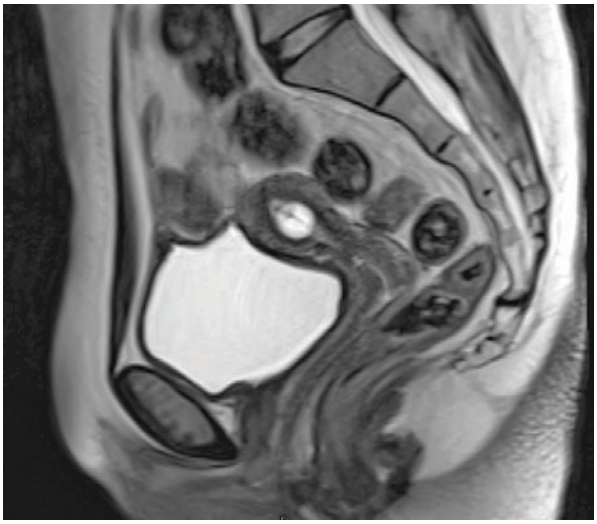


Figure 1. Sagittal T2-weighted image of the uterus demonstrating the catheter balloon within the uterine cavity.

Dynamic T1-weighted sequences

MR-HSG uses serial imaging during contrast administration. Imaging is performed in an oblique plane as described above. Repeated acquisitions with contrast injection during short pauses provide better insight into tubal patency, i.e., spillage of contrast into the pelvic cavity. Heavily T1-weighted sequences (Figure 2), similar to angiographic sequences, are typically used.

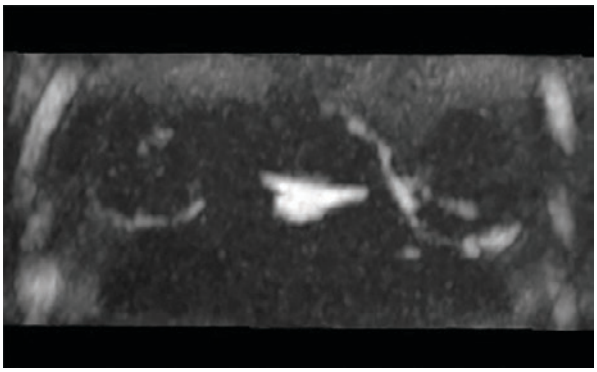


Figure 2. 3D T1-weighted image showing the contrast solution within the uterine cavity and around the ovaries after intrauterine administration through the catheter.

T1 sequences after contrast administration

After completion of contrast administration, an additional 3D T1 gradient-echo sequence (with Dixon or other fat-suppression technique) is acquired in the coronal plane

(Figure 3). This sequence uses a larger field of view (FOV) than the dynamic acquisition. It does not need to be obtained in oblique planes, given its high spatial resolution and suitability for multiplanar reconstructions. Since the contrast solution is administered intrauterinely rather than intravenously, imaging can be repeated if necessary (in the presence of artifacts).

This sequence is useful for depicting contrast retained within the fallopian tubes; the presence of contrast within the lumen or the tubal wall may suggest pathological changes such as hydrosalpinx, chronic inflammation, or obstruction.

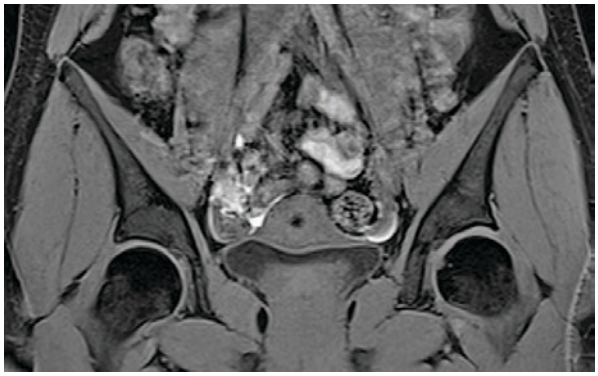


Figure 3. Visualization of the uterus (with the catheter balloon visible), the ovaries, and the contrast solution surrounding them using a 3D T1 technique in the coronal plane.

Additional sequences in MR-HSG

In addition to the standard protocol, MR-HSG may also include 2D T1 SE FS sequences, STIR, or T2 SE sequences with motion-artifact suppression techniques (BLADE, PROPELLER, etc.), depending on artifacts from bowel motion or arterial pulsation, clinical findings, or suspicion of associated pathology. Their use is not routine; rather, they are applied selectively when there is concern for additional pathology beyond the basic assessment of tubal patency.

The decision to include these sequences depends on the individual clinical scenario and is intended to increase diagnostic yield. MRI provides very good to excellent visualization of uterine and ovarian structures in many pathological conditions, and in such cases, these additional sequences should be utilized. If there is no indication, they are avoided to prevent unnecessary prolongation of the examination.

Completion of the examination

After imaging, the catheter balloon is deflated using a syringe (filled with 1–2 mL of saline), and the catheter is gently removed. Although catheter removal is not mandatory, we recommend it to reduce the risk of discomfort. The patient is then observed for about 10 minutes (usually in the outpatient gynaecology clinic) and discharged home.

Outcome measures

The primary outcome measure was assessment of tubal patency on MR-HSG and HSG by recording the presence of contrast solution adjacent to the ovaries and in the pouch of Douglas, and analysis of agreement between the methods using Cronbach's alpha coefficient.

Data collection and analysis

Each patient underwent MR-HSG followed by conventional HSG, allowing direct comparison of tubal patency. Data on contrast presence in the pouch of Douglas and around the left and right ovaries were recorded during both procedures. Measurements were performed by a radiologist with more than 15 years of experience. Results were entered into a table for further analysis. Statistical analysis was performed using MedCalc (MedCalc Software Ltd., Ostend, Belgium); for each parameter, Cronbach's alpha was calculated as a measure of internal consistency.

Results

In total, 52 women with primary infertility consented to MR-HSG followed by HSG. In one patient, the catheter was mistakenly placed in the vagina, and one patient withdrew during the procedure; both were excluded (4%). Bilateral tubal occlusion was recorded in 6 patients (12%). Among these, five reported more intense pain during contrast administration, as expected in cases of tubal obstruction. All other patients reported discomfort, but none experienced pain severe enough to prevent completion of the examination. The study was completed after 50 patients had successfully undergone both examinations.

Patients were 21–37 years old (mean 28.6 ± 4 years).

Table 1. Presence of gadolinium/iodinated contrast as an indicator of tubal patency recorded on MR-HSG (Figure 5) and HSG (Figure 4). A total of 50 patients were analysed. Numbers (n) indicate the number of patients in whom contrast was present adjacent to the left or right ovary or in the pouch of Douglas on MR-HSG and HSG images.

MR-HSG			HSG		
Left	**Right**	**Douglas**	**Left**	**Right**	**Douglas**
37	37	41	38	33	37

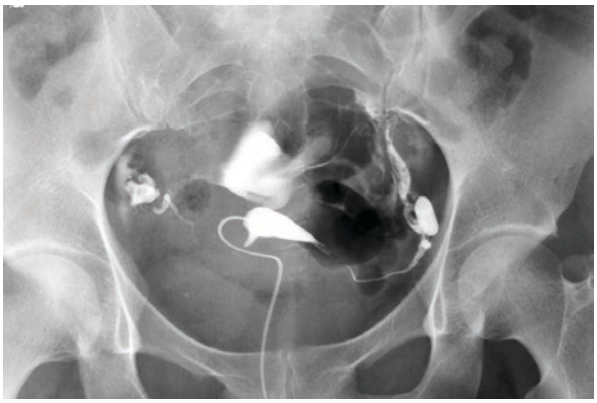


Figure 4. HSG demonstrating the uterus and fallopian tubes, with contrast seen around the ovaries and in the pouch of Douglas.

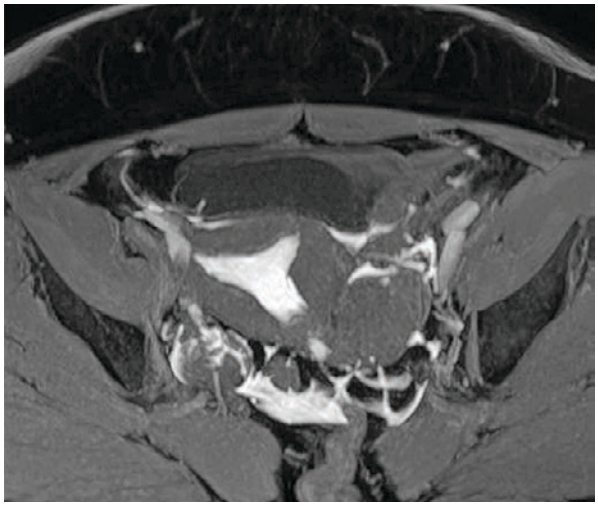


Figure 5. Multi-planar reconstruction from 3D T1-weighted images acquired after MR-HSG. The contrast solution is visible within the uterine cavity, around the ovaries, and in the pouch of Douglas.

After assessing the presence of gadolinium contrast solution (in all patients in whom both HSG and MR-HSG were successfully performed), adjacent to the left and right ovary and in the pouch of Douglas, Cronbach's alpha coefficient was calculated as a measure of congruence (Table 2).

Table 2. Congruence between HSG and MR-HSG measurements assessed using Cronbach's alpha coefficient. Higher values indicate better agreement. Values in parentheses represent the 95% lower confidence limit.

MR-HSG vs. HSG	Cronbach's Alpha
Left ovary	0.97 (0.96)
Right ovary	0.84 (0.75)
Pouch of Douglas	0.80 (0.68)

No adverse effects (such as infection, bleeding, or ectopic pregnancy) were observed after MR-HSG or conventional HSG. The examination was completed within 10 minutes in all cases.

Discussion

Among the 6 patients with bilateral tubal occlusion (12%), five reported pain during contrast administration, while the others experienced discomfort that was not severe enough to interrupt the procedure. Cronbach's alpha results indicate excellent agreement between conventional HSG and MR-HSG when the presence of contrast adjacent to the ovary is used as an indicator of tubal patency. Agreement is slightly lower when contrast in the pouch of Douglas is used as the patency indicator. These findings also warrant consideration of ultrasound-guided HSG, where fluid in the pouch of Douglas is commonly interpreted as evidence of tubal patency. There are also studies using Doppler imaging as well as 3D and 4D techniques, although it is not entirely clear which method is predominantly used in routine practice [4–7].

Fewer patients showed reduced patency on conventional HSG than on MR-HSG. This difference may be explained by the higher viscosity of iodinated contrast medium, which may not flow as readily through the fallopian tubes as the gadolinium solution used for MR-HSG.

Advantages of MR-HSG

Compared with traditional methods, MR-HSG offers several advantages: complete absence of ionizing radiation, detailed visualization of the uterus and ovaries, the ability to detect other pelvic pathology independent of tubal patency, and better tolerability in most cases [2,3,10].

Contribution of the radiologic technologist

The radiologic technologist is actively involved in patient preparation, examination performance, and optimization of the MR protocol. This includes confirming patient identity and obtaining informed consent, ensuring correct positioning and clear communication to minimize discomfort, preparing and administering contrast solution, planning imaging planes, as well as optimizing image quality. The technologist monitors the patient throughout the examination, recognizes discomfort, and responds to potential complications.

Practical guidance for radiologic technologists:

- Communication: explain each step to reduce anxiety and ensure cooperation. Clear communication and reassurance improve cooperation and may reduce patient anxiety during positioning and contrast administration.
- Comfort: ensure the patient remains still and breathes normally to minimize motion artifacts and avoid the need for additional medication.
- Safety: review MR contraindications (e.g., metallic implants) and potential contrast-related issues.
- Image quality: adjust the protocol as needed to obtain diagnostically adequate images.

Managing discomfort and pain

Mild discomfort during contrast administration is expected. However, severe or sharp pain requires immediate action: the injection should be stopped immediately and, in critical cases, the radiologist or gynaecologist should be consulted. The patient should be asked to localize the discomfort or pain, and this information should be documented and reported to the radiologist. Even minimal contrast administration can have diagnostic value, but the injection should never be forced. Patient safety is always the priority.

Conclusion

MR-HSG is a safe and accurate diagnostic method for assessing fallopian tube patency and the morphology of the female reproductive system. In addition to the absence of ionizing radiation, it provides high-quality imaging and improved patient comfort.

Successful implementation relies on appropriate patient preparation and strict protocol compliance by the radiologic technologist. Our study demonstrates high diagnostic accuracy, and the procedure was well tolerated by most patients.

Although our results support the effectiveness of MR-HSG, it should be emphasized that similar studies conducted across multiple institutions have reported comparable findings. Wider implementation of MR-HSG in clinical practice is essential to improve its availability and facilitate its integration into routine care, ultimately benefiting our patients.

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MR-HSG kao sigurna, pouzdana i nedovoljno korištena metoda

Sažetak

Uvod: Histerosalpingografija (HSG) predstavlja zlatni standard za procjenu prohodnosti jajovoda, no uključuje izlaganje ionizirajućem zračenju i primjenu jodnog kontrastnog sredstva. Magnetska rezonancijska histerosalpingografija (MR-HSG) omogućuje procjenu prohodnosti jajovoda bez ionizirajućeg zračenja, uz superiornu vizualizaciju mekih tkiva zdjelice.

Cilj: Procijeniti dijagnostičku vrijednost MR-HSG u procjeni prohodnosti jajovoda, s posebnim naglaskom na MRI protokol, te usporediti nalaze s onima dobivenima konvencionalnom HSG metodom.

Materijali i metode: U istraživanje je uključeno pedeset pacijentica. Sve su podvrgnute MR-HSG pretrazi, nakon čega je odmah slijedila HSG. Tijekom MR-HSG-a u šupljinu maternice aplicirana je razrijeđena otopina gadolinijskog kontrasta. Protokol se sastojao od T2-vagnih sekvenci i dinamičkog T1-vaganog snimanja. Prisutnost kontrastne otopine uz jajnike i u Douglasu bilježena je kao pokazatelj prohodnosti jajovoda. Podudarnost metoda procijenjena je Cronbachovim alfa koeficijentom.

Rezultati: Bilateralna opstrukcija jajovoda potvrđena je u 6 slučajeva (12%). Cronbachova alfa pokazala je izvrsnu podudarnost između metoda (0,97 za lijevi jajnik; 0,84 za desni jajnik; 0,80 za Douglasov prostor). Nisu zabilježene nuspojave.

Zaključak: MR-HSG je učinkovita i dobro podnošljiva metoda s visokom podudarnošću u odnosu na HSG. Prednosti uključuju izostanak ionizirajućeg zračenja i superiornu vizualizaciju mekih tkiva zdjelice. MR-HSG može se smatrati pouzdanom alternativom HSG-u.

Ključne riječi: MR-HSG, HSG, prohodnost jajovoda, magnetska rezonancija, gadolinij, tubarna opstrukcija, neplodnost, zdjelica

ORIGINAL SCIENTIFIC PAPER (IZVORNI ZNANSTVENI ČLANAK)

Dual-energy CT in polytrauma: protocol implementation and radiation dose reduction at University Hospital Centre Zagreb

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Abstract

Aim: To evaluate dual-energy CT (DECT) whole-body polytrauma protocols and quantify radiation dose reduction compared with a standard multiphase CT protocol.

Materials and Methods: This retrospective single-centre study included polytrauma patients, stratified into three groups: standard CT (n = 255), DECT-stable (n = 164), and DECT-unstable (n = 19). Radiation dose was assessed using the dose-length product (DLP).

Results: Median DLP was 5940 mGy·cm (standard), 2671 mGy·cm (DECT stable), and 3247.5 mGy·cm (DECT unstable), corresponding to dose reductions of 55.0% and 45.3%, respectively.

Conclusion: DECT protocols enable substantial radiation dose reduction while maintaining clinical workflow efficiency.

Keywords: polytrauma; computed tomography; dual-energy CT; split-bolus; virtual non-contrast; radiation dose; dose-length product (DLP)

Abbreviations and acronyms: DECT = dual-energy CT; VNC = virtual non-contrast; VMI = virtual monoenergetic images; DLP = dose-length product; CTDIvol = volume CT dose index.

Introduction

Whole-body CT has become the standard imaging modality in the initial assessment of polytrauma patients due to its speed, availability, and high diagnostic accuracy. However, multiphase protocols are associated with substantial radiation exposure [1,2].

Recent advances in dual-energy CT (DECT) technology have made it possible to reduce radiation dose without compromising diagnostic performance. By acquiring data at two different energy spectra, DECT enables advanced post-processing techniques such as virtual non-contrast (VNC), iodine mapping, and virtual monoenergetic imaging (VMI) [3–5].

These capabilities are particularly relevant in trauma imaging, where rapid diagnosis must be balanced against radiation safety. While previous studies have demonstrated the utility of DECT in specific anatomical regions, there is limited literature addressing its integration into a comprehensive whole-body trauma workflow.

Dual-energy CT is based on the acquisition of two datasets at different X-ray energy spectra, enabling differentiation of materials based on their attenuation properties. Several hardware implementations exist, including dual-source systems, rapid kVp switching, dual-layer detectors, and split-filter (TwinBeam) technology [3].

The TwinBeam approach utilises a split-filter design to simultaneously generate high- and low-energy spectra from a single X-ray tube, allowing spectral imaging without temporal misregistration.

Post-processing techniques relevant to trauma imaging include: *Virtual non-contrast* (VNC), which enables subtraction of iodine signal, potentially replacing true non-contrast scans; *Iodine maps*, enabling visualisation of contrast distribution and detection of active bleeding; *and Virtual monoenergetic imaging (VMI),* which optimises the contrast-to-noise ratio and reduces beam-hardening artefacts.

These techniques simplify protocols by reducing the number of required acquisition phases while preserving diagnostic information.

The aim of this study was to implement and evaluate DECT-based whole-body polytrauma protocols tailored to haemodynamic status and to assess their impact on radiation dose in a real-world clinical setting.

Materials and Methods

Protocol design at University Hospital Centre Zagreb

Protocols were developed at University Hospital Centre Zagreb (KBC Zagreb) in accordance with contemporary emergency radiology guidelines. All examinations were performed using a dual-energy capable CT system (Siemens SOMATOM X.Ceed).

Patient categorisation into haemodynamically stable and unstable groups followed the standard clinical trauma workflow, based on vital parameters and resuscitation status. Protocol optimisation focused on reducing redundant acquisition phases and utilising DECT-derived virtual non-contrast (VNC) reconstructions where appropriate.

Standard polytrauma CT protocol (reference)

The reference protocol includes a non-contrast CT of the head and neck, followed by non-contrast imaging of the chest, abdomen, and pelvis. Contrast-enhanced acquisitions of the chest, abdomen, and pelvis are subsequently performed in separate arterial and portal venous phases.

DECT protocol for haemodynamically stable patients (split-bolus)

The protocol includes a non-contrast CT of the head and neck. A split-bolus injection technique is used to achieve combined arterial and venous enhancement within a single acquisition of the chest, abdomen, and pelvis.

An example injection protocol consists of 60 mL of contrast medium followed by 20 mL of saline at 5 mL/s, a delay of approximately 78 seconds, followed by a second bolus of 50 mL of contrast medium and 30 mL of saline at 5 mL/s. Image acquisition is triggered at approximately 95 seconds to capture both arterial and venous enhancement.

Virtual non-contrast (VNC) reconstructions are used to replace true non-contrast imaging of the chest, abdomen, and pelvis, where clinically appropriate (Figure 1).

DECT protocol for haemodynamically unstable patients

For haemodynamically unstable patients, the protocol includes a non-contrast CT of the head, followed by rapid angiographic acquisition of the neck, chest, abdomen,

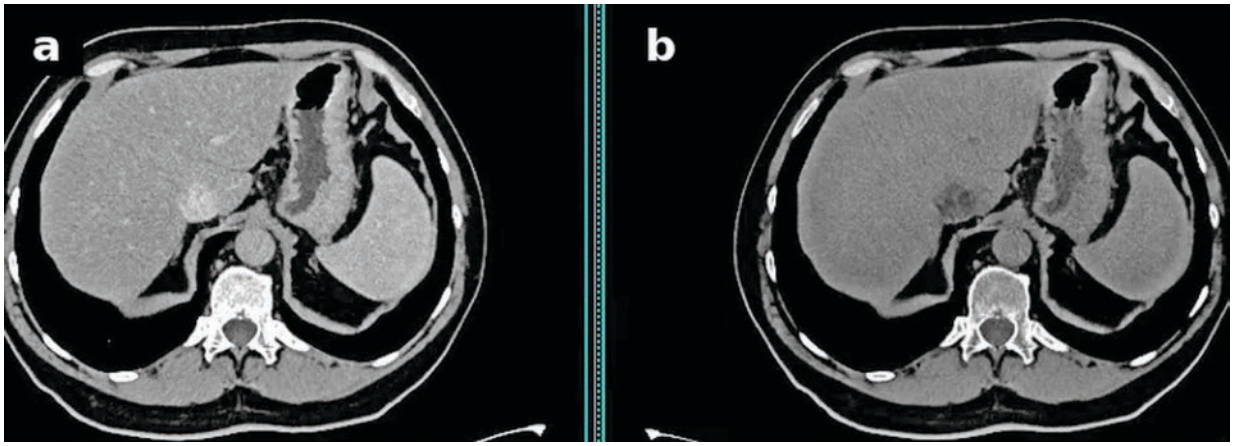


Figure 1. Example of VNC comparison in a haemodynamically stable patient: (a) conventional contrast-enhanced image, (b) virtual non-contrast reconstruction.

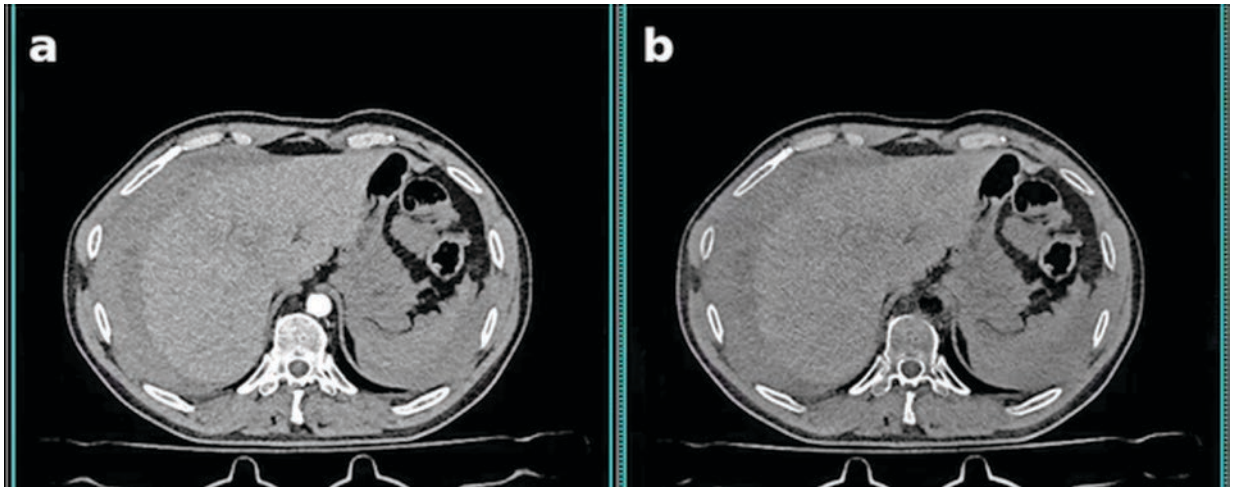


Figure 2. Example of VNC comparison in a haemodynamically unstable patient: (a) conventional contrast-enhanced image, (b) virtual non-contrast reconstruction.

and pelvis, and a subsequent portal venous phase of the abdomen and pelvis.

An example injection protocol consists of 90 mL of contrast medium followed by 30 mL of saline at 5 mL/s.

The protocol prioritises rapid detection of active bleeding and life-threatening injuries while maintaining the benefits of DECT post-processing (Figure 2).

Optional add-on: lower-extremity CTA in unstable patients

In selected haemodynamically unstable patients, an additional CT angiography (CTA) acquisition of the lower extremities may be performed when there is clinical suspicion of active bleeding or vascular injury in the peripheral arterial system. This add-on is performed at the clinician's discretion and is not part of the standard protocol. In such cases, the examination consists of a DECT acquisition of the neck, chest, abdomen, and pelvis, followed by a standard spiral CT angiography of the lower extremities.

This retrospective single-centre study included polytrauma patients examined at University Hospital Centre Zagreb between July 2024 and October 2025.

Patients were stratified into three groups: standard multiphase CT (n=255); DECT protocol for haemodynamically stable patients (n=164); DECT protocol for haemodynamically unstable patients (n=19).

Radiation dose was evaluated using dose-length product (DLP, mGy•cm), extracted from CT dose reports. Median values were used because the dose data were non-normally distributed.

Relative dose reduction (%) was calculated as: Reduction (%) = (DLP_standard − DLP_DECT) / DLP_standard × 100.

No formal statistical hypothesis testing was performed due to the retrospective design and unequal group sizes. All data were anonymised prior to analysis.

Results

Radiation dose results are summarised in Table 1 (standard protocol n = 255; DECT stable n = 164; DECT unstable n = 19).

Median DLP for the standard protocol was 5940 mGy·cm. The DECT stable protocol achieved a median DLP of 2671 mGy·cm, corresponding to a relative reduction of 55.0%, while the DECT unstable protocol showed a median DLP of 3247.5 mGy·cm, corresponding to a reduction of 45.3%.

Discussion

The observed reduction in median DLP reflects the core strategy of the implemented protocols, namely the reduction of acquisition phases in the chest, abdomen, and pelvis through the use of split-bolus techniques and DECT-derived reconstructions.

In haemodynamically stable patients, a single-pass combined enhancement acquisition can replace separate arterial and portal venous phases, while virtual non-contrast (VNC) images can substitute true non-contrast imaging. In haemodynamically unstable patients, the protocol prioritises rapid identification of life-threatening injuries, while still benefiting from DECT post-processing capabilities.

The magnitude of dose reduction observed in this study (45–55%) is consistent with previously reported reductions using DECT in trauma imaging [4,7], supporting the validity of this approach in a real-world clinical setting. Importantly, this reduction was achieved without compromising workflow efficiency, which is critical in emergency radiology.

The optional lower-extremity CTA add-on should be applied selectively, as it increases scan length and therefore radiation exposure. Its clinical value lies in the rapid identification of peripheral vascular injury when clinically indicated.

Several limitations should be acknowledged. First, radiation dose assessment was based on DLP, which does not directly correspond to effective dose and is influenced by scan length and patient habitus. Second, the smaller sample size in the haemodynamically unstable group limits generalisability. Third, image quality and diagnostic performance were not formally evaluated.

Conclusion

DECT-based whole-body trauma protocols tailored to haemodynamic status achieved a substantial reduction in radiation dose (≈45–55%) compared with a conventional multiphase protocol, while providing additional spectral information (VNC, iodine maps, VMI).

This approach represents a practical and clinically applicable strategy for radiation dose optimisation in high-throughput trauma imaging.

Wider implementation of such protocols may contribute to meaningful reductions in cumulative radiation exposure at the population level.

Protocol	n	Median DLP (mGy·cm)	Dose reduction vs standard	Key phase strategy
Standard protocol	255	5940	–	Multi-phase chest/abdomen/pelvis as indicated
DECT stable (split-bolus)	164	2671	55%	Single-pass combined enhancement + VNC
DECT unstable	19	3247.5	45%	Streamlined angiographic DECT ± add-ons

Ethics approval and consent to participate

No patient-identifiable information is presented in the manuscript. Images and videos used for internal review were fully anonymized prior to export.

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Dvoenergetska CT dijagnostika u politraumi: implementacija protokola i smanjenje doze zračenja u Kliničkom bolničkom centru Zagreb

Sažetak

Cilj: Procijeniti protokole dvoenergetskog CT-a (DECT) za politraumu cijelog tijela i kvantificirati smanjenje doze zračenja u usporedbi sa standardnim višefaznim CT protokolom.

Materijali i metode: Ova retrospektivna studija u jednom centru uključivala je pacijente s politraumom stratificirane u tri skupine: standardni CT (n = 255), stabilni DECT (n = 164) i nestabilni DECT (n = 19). Doza zračenja procijenjena je pomoću produkta doze i duljine (DLP).

Rezultati: Medijan DLP-a bio je 5940 mGy•cm (standardni), 2671 mGy•cm (stabilan DECT) i 3247,5 mGy•cm (nestabilan DECT), što odgovara smanjenju doze od 55,0% odnosno 45,3%.

Zaključak: DECT protokoli omogućuju značajno smanjenje doze zračenja uz održavanje učinkovitosti kliničkog tijeka rada.

Ključne riječi: politrauma; kompjutorska tomografija; dvoenergetski CT; split-bolus; virtualni bez kontrasta; doza zračenja; produkt doze i duljine (DLP)

IZVORNI ZNANSTVENI ČLANAK (ORIGINAL SCIENTIFIC PAPER)

Utjecaj vertikalnog odstupanja od izocentra na dozu zračenja u CT dijagnostici

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Sažetak

Uvod: Precizno pozicioniranje pacijenta u izocentar CT uređaja jedan je od ključnih čimbenika za postizanje optimalne kvalitete slike i optimizaciju doze zračenja. Odstupanja stola od izocentra mogu uzrokovati geometrijske promjene na topogramu koje utječu na rad sustava automatske regulacije ekspozicije (AEC) i posljedično na primijenjenu dozu zračenja. Unatoč tome, nepravilno centriranje pacijenta i dalje je česta pojava u kliničkoj praksi.

Cilj: Kvantificirati utjecaj vertikalnog odstupanja visine stola u odnosu na izocentar na vrijednosti CTDIvol i DLP tijekom CT snimanja torakalnog i zdjeličnog fantoma na dva CT uređaja.

Ispitanici i metode: Istraživanje je provedeno na CT uređajima GE Revolution Maxima 128 i GE Revolution ES 256. Visina stola mijenjala se od –10 cm do +10 cm u koracima od 2 cm u odnosu na izocentar. Snimanja su provedena na torakalnom fantomu Multipurpose Chest Phantom N1 Lungman (Kyoto Kagaku, Japan) i zdjeličnom antropomorfnom fantomu CIRS Virtual Human Male Pelvis Phantom 801P (CIRS Inc., Norfolk, VA, USA) uz standardizirane i optimizirane protokole snimanja za svaki CT uređaj. Za svaki položaj visine stola izvedena su dva skeniranja radi pouzdanosti mjerenja. Vrijednosti CTDIvol i DLP prikupljene su iz CT izvješća o dozi svakog skeniranja.

Rezultati: Na uređaju GE Maxima podizanje stola za +10 cm rezultiralo je povećanjem doze za 71 % kod torakalnog protokola i 106 % kod zdjeličnog protokola, dok je spuštanje stola za –10 cm dovelo do smanjenja doze u rasponu od 3 % do 30 %. Na uređaju GE Revolution ES maksimalno povećanje doze iznosilo je 53 %, dok je spuštanje stola rezultiralo smanjenjem doze od 8 % do 20 %. Promjene su bile izraženije u zdjeličnim protokolima, što se može objasniti većom debljinom fantoma i većom osjetljivošću AEC algoritma na promjene projekcijske geometrije. Također su uočene veće varijacije doze na uređaju GE Maxima.

Zaključak: Vertikalno odstupanje od izocentra ima značajan i klinički relevantan utjecaj na dozu zračenja tijekom CT pretraga. Podizanje stola iznad izocentra sustavno dovodi do povećane kompenzacije sustava automatske regulacije ekspozicije i značajnog porasta CT doze. Precizno pozicioniranje pacijenta u izocentar predstavlja jednostavnu, ali ključnu mjeru optimizacije u CT dijagnostici.

Ključne riječi: CT, izocentar, CTDIvol, automatska kontrola ekspozicije, optimizacija doze

Uvod

Kompjutorizirana tomografija (CT) čini iznimno važan dio suvremene radiološke dijagnostike i odgovorna je za značajan udio ukupne medicinske izloženosti ionizirajućem zračenju. Međunarodne organizacije poput International Commission on Radiological Protection (ICRP) i International Atomic Energy Agency (IAEA) naglašavaju da CT pregledi doprinose i do 50% ukupne kolektivne medicinske doze, unatoč tome što čine relativno manji udio ukupnog broja radioloških postupaka, ali s trendom stalnog porasta (1).

Stoga optimizacija CT protokola predstavlja ključnu komponentu radiološke zaštite. Posebnu ulogu imaju tehnike koje osiguravaju pravilan rad sustava automatske regulacije ekspozicije (Automatic Exposure Control – AEC), optimizaciju tehničkih parametara snimanja te održavanje vrijednosti doze unutar dijagnostičkih referentnih razina (Diagnostic Reference Levels – DRL) (2,3).

Jedan od najvažnijih, ali često podcijenjenih čimbenika optimizacije jest precizno pozicioniranje pacijenta u izocentar CT uređaja. Izocentar predstavlja središnju točku rotacije rendgenske cijevi i detektorskog sustava. Ako je

pacijent pozicioniran izvan te točke, dolazi do geometrijskih distorzija na topogramu, odnosno povećanja ili smanjenja projicirane širine tijela, ovisno o smjeru pomaka.

AEC algoritam procjenjuje potrebnu struju cijevi na temelju analize topograma. Pogrešna geometrijska projekcija može dovesti do značajne pogreške u procjeni potrebne struje cijevi (mA) za postizanje željene razine šuma slike, što rezultira povećanjem ili smanjenjem primijenjene doze zračenja (4,5).

U kliničkoj praksi nepravilno pozicioniranje pacijenta relativno je često. Toth i suradnici pokazali su da 46 % pacijenata nije pravilno centrirano u izocentar tijekom CT snimanja. Habibzadeh i suradnici izvijestili su da 67–85 % radioloških tehnologa odstupa više od 1 cm od točnog izocentra tijekom pozicioniranja pacijenta. Takva odstupanja mogu imati mjerljiv utjecaj na dozu zračenja i kvalitetu slike. Pojedine studije navode da vertikalni pomaci od ±4 do ±6 cm mogu povećati vrijednosti CTDIvol i više od 40 %, ovisno o protokolu snimanja i konfiguraciji CT uređaja (5,6).

S obzirom na relativno visoku učestalost nepravilnog centriranja pacijenata i njihov potencijalni utjecaj na izlaganje zračenju, cilj ovog istraživanja bio je sustavno izmjeriti promjene vrijednosti CTDIvol i DLP pri pomicanju visine stola od –10 cm do +10 cm u odnosu na izocentar na dva CT uređaja različitih tehničkih karakteristika te kvantificirati razlike u dozi.

Cilj istraživanja

Cilj istraživanja bio je kvantificirati utjecaj vertikalnog odstupanja položaja stola u odnosu na izocentar CT uređaja na dozu zračenja (CTDIvol i DLP) tijekom CT snimanja torakalnog i abdominalnog fantoma te usporediti dobivene promjene između dva CT uređaja različitih tehničkih karakteristika.

Materijal i metode

Istraživanje je provedeno u tercijarnoj zdravstvenoj ustanovi.

Snimanja su provedena na dva CT uređaja proizvođača General Electric. Protokoli snimanja prethodno su optimizirani i standardizirani u suradnji s odjelom za medicinsku fiziku ustanove, sukladno međunarodnim smjernicama (IAEA, ICRP) te u skladu s dijagnostičkim referentnim razinama (DRL) .

Statistička analiza provedena je deskriptivnim pristupom. Vrijednosti CTDIvol i DLP prikazane su kao apsolutne vrijednosti te kao relativne promjene u postocima u odnosu na referentni položaj izocentra (0 cm). Trendovi promjena doze analizirani su u odnosu na vertikalno odstupanje od izocentra.

CT uređaji

U istraživanju su korištena dva CT uređaja, GE Revolution Maxima 128 i GE Revolution ES 256.

Fantomi

Za potrebe istraživanja korištena su dva antropomorfna fantoma. Torakalni fantom: Multipurpose Chest Phantom N1 Lungman (Kyoto Kagaku, Kyoto, Japan) i zdjelični fantom: CIRS Virtual Human Male Pelvis Phantom 801P (CIRS Inc., Norfolk, VA, USA) (slika 1.). Oba fantoma snimana su u neutralnom položaju bez dodatnih modifikacija konfiguracije fantoma.

Pomicanje visine stola

Visina stola mijenjala se u rasponu od –10 cm do +10 cm u odnosu na izocentar, u koracima od 2 cm.

Za svaki položaj visine stola izvedena su dva skeniranja radi povećanja pouzdanosti mjerenja.

Za sve protokole snimanja izrađeni su anteroposteriorni (AP) i laterolateralni (LL) topogrami. Markeri izraženi u centimetrima bili su označeni na fantomima kako bi se osigurala precizna reprodukcija položaja tijekom pomicanja visine stola (slika 2.).

Parametri snimanja, uključujući duljinu topograma, FOV, početnu i završnu lokaciju snimanja te tehničke postavke skeniranja, bili su identični za svaki slikovni isječak (tablica 1.).

Prikupljanje podataka

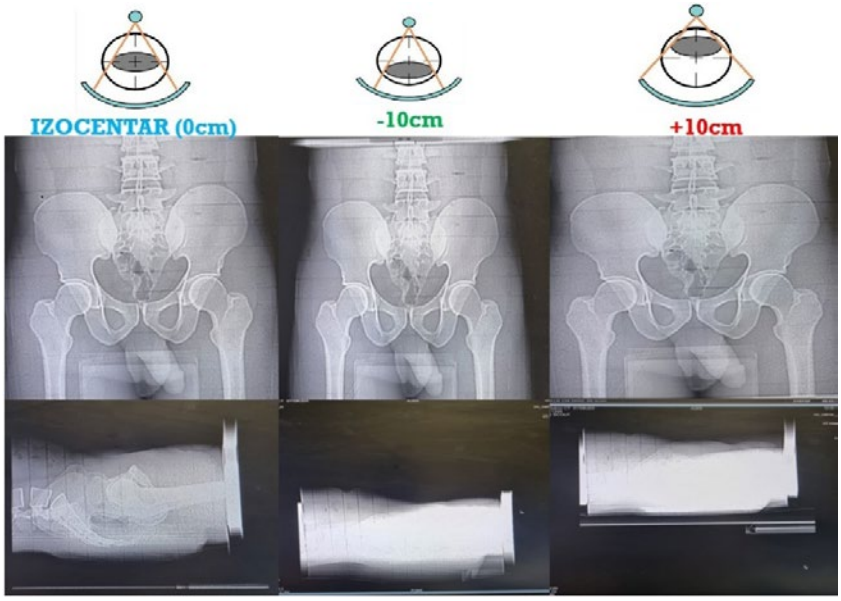
Vrijednosti **CTDIvol** i **DLP** prikupljene su iz CT izvješća o dozi svakog pojedinog skeniranja te su korištene za analizu promjena doze pri različitim visinama stola u odnosu na izocentar (slika 3.).

Tablica 1. Tehnički parametri protokola snimanja

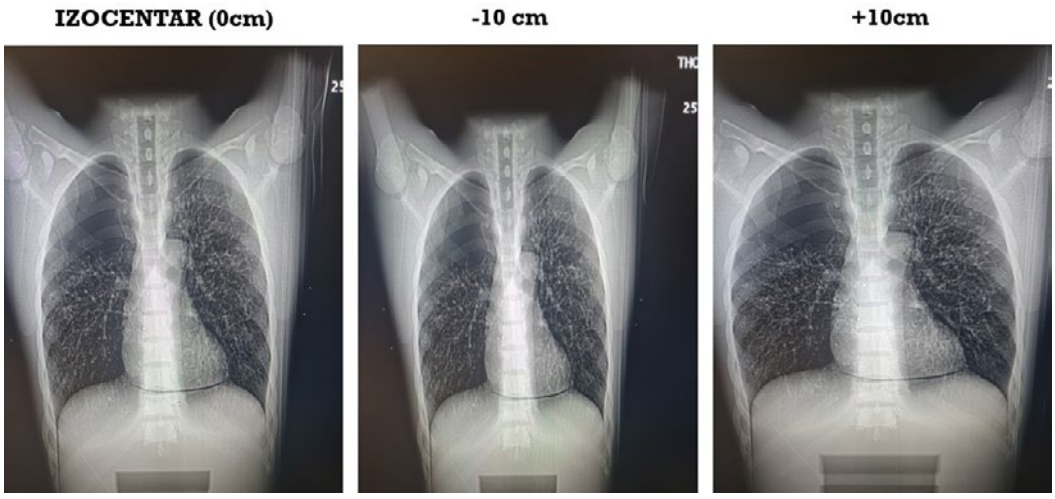
	GE Revolution ES 256 – toraks	GE Revolution Maxima 128 – toraks	GE Revolution ES 256 – zdjelica	GE Revolution Maxima 128 – zdjelica
kV	100	100	120	120
AEC	uključen (80–560 mA)	uključen (50–680 mA)	uključen (80–700 mA)	uključen (80–700 mA)
Detector coverage (mm)	80	40	80	40
Mode / debljina sloja	spiralno; 2,5	spiralno; 2,5	spiralno; 3,75	spiralno; 3,75
Pitch	0,992	0,984	0,984:1	0,984:1
Vrijeme rotacije (s)	0,5	0,6	0,5	0,8
Noise index (šum)	16	18	16	12
Redukcija doze	–	40%	–	50%



Slika 1. Torakalni i zdjelični fantomi



Slika 2. Topogrami zdjeličnog fantoma u različitim visinama stola



Slika 3. Topogrami torakalnog fantoma u različitim visinama stola

Za analizu promjena doze korištene su apsolutne vrijednosti CTDIvol i DLP te relativne promjene izražene u postocima u odnosu na referentni položaj izocentra. Trend promjene doze analiziran je linearnom procjenom odnosa između visine stola i CTDIvol/DLP.

Rezultati

Provedena je deskriptivna statistička analiza. Vrijednosti CTDIvol i DLP analizirane su kao apsolutne vrijednosti te kao relativne promjene izražene u postocima u odnosu na referentni položaj izocentra.

Rezultati pokazuju dosljedan trend promjene vrijednosti doze zračenja u ovisnosti o vertikalnom odstupanju od izocentra. S povećanjem pozitivnog odstupanja (podizanje stola iznad izocentra) dolazi do progresivnog porasta vrijednosti CTDIvol i DLP, dok negativno odstupanje (spuštanje stola ispod izocentra) rezultira smanjenjem ili manjim promjenama doze.

Kod zdjeličnog fantoma na uređaju GE Revolution Maxima 128 vrijednost DLP-a povećala se s 331 mGy·cm u izocentru na 678 mGy·cm pri visini stola od +10 cm, što predstavlja povećanje od 106 %. Smanjenjem visine stola na –10 cm zabilježeno je smanjenje doze u rasponu od 11 % do 30 %, ovisno o stupnju odstupanja. Promjene su bile izražene i već pri manjim pozitivnim odstupanjima, pri čemu je već na +2 cm zabilježen porast doze od 16 % (tablica 2.).

Na uređaju GE Revolution ES 256 zabilježen je sličan obrazac promjene doze, ali s manjim amplitudama. Vrijednost DLP-a povećala se s 139 mGy·cm u izocentru na 212 mGy·cm pri +10 cm, što odgovara povećanju od 53 %. Negativno odstupanje rezultiralo je smanjenjem doze u rasponu od 8 % do 14 % (tablica 3.).

Kod torakalnog fantoma promjene doze bile su manje izražene u odnosu na zdjelični protokol, no zadržan je isti trend. Na uređaju GE Revolution Maxima 128 povećanje doze pri +10 cm iznosilo je 71 %, dok su negativna odstupanja rezultirala minimalnim promjenama doze (do –6 %) (tablica 4.). Na uređaju GE Revolution ES 256 maksimalno povećanje doze iznosilo je 53 %, dok je spuštanje stola do –10 cm rezultiralo smanjenjem doze do 20 % (tablica 5.).

Usporedno promatranje oba uređaja pokazuje veću osjetljivost na odstupanje od izocentra kod uređaja GE Revolution Maxima 128, osobito u zdjeličnom protokolu, gdje su zabilježene najveće relativne promjene doze (slika 4.). Navedeni rezultati ukazuju na izraženu ovisnost doze o geometrijskom položaju objekta u odnosu na izocentar, uz vidljive razlike u ponašanju sustava automatske regulacije ekspozicije između analiziranih CT uređaja.

Tablica 2. Utjecaj vertikalnog odstupanja od izocentra na DLP tijekom snimanja zdjeličnog fantoma na CT uređaju GE Maxima 128

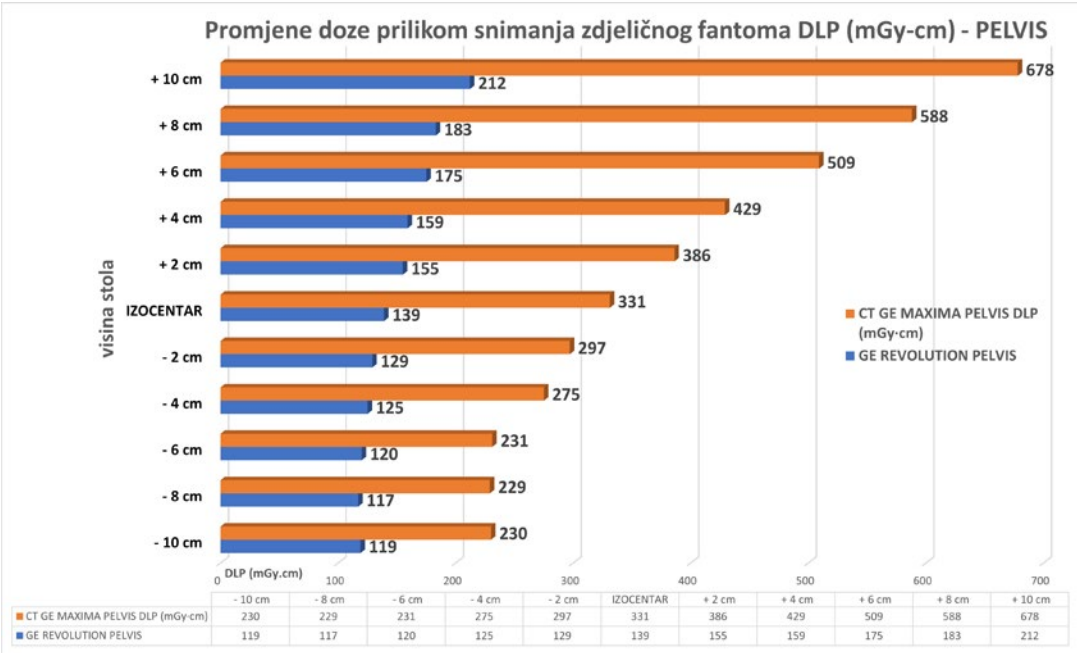
	CT GE MAXIMA 128	ZDJELICA	
VISINA STOLA	**CTDIvol (mGy)**	**DLP (mGy·cm)**	**Promjena doze**
+ 10 cm	18	678	**↑ 106%**
+ 8 cm	16	588	**↑ 78%**
+ 6 cm	13	509	**↑ 54%**
+ 4 cm	11,2	429	**↑ 29%**
+ 2 cm	10,1	386	**↑ 16%**
IZOCENTAR	8,7	331	
– 2 cm	7,7	297	**↓ -11%**
– 4 cm	7,4	275	**↓ -15%**
– 6 cm	6	231	**↓ -30%**
– 8 cm	6,2	229	**↓ -28%**
– 10 cm	6	230	**↓ -30%**

Tablica 3. Promjena DLP vrijednosti pri različitim visinama stola u odnosu na izocentar tijekom CT snimanja zdjeličnog fantoma na uređaju GE Revolution ES 256.

CT GE REVOLUTION ES 256 ZDJELICA			
VISINA STOLA	**CTDIvol (mGy)**	**DLP (mGy·cm)**	**Promjena doze**
+ 10 cm	5,2	212	**↑ 53%**
+ 8 cm	4,3	183	**↑ 32%**
+ 6 cm	4,3	175	**↑ 26%**
+ 4 cm	3,9	159	**↑ 15%**
+ 2 cm	3,8	155	**↑ 12%**
IZOCENTAR	3,4	139	
- 2 cm	3,1	129	**↓ -8%**
- 4 cm	3	125	**↓ -10%**
- 6 cm	3	120	**↓ -14%**
- 8 cm	2,9	117	**↓ -14%**
- 10 cm	2,9	119	**↓ -14%**

Tablica 4. Utjecaj vertikalnog odstupanja od izocentra na DLP tijekom snimanja torakalnog fantoma na CT uređaju GE Maxima 128.

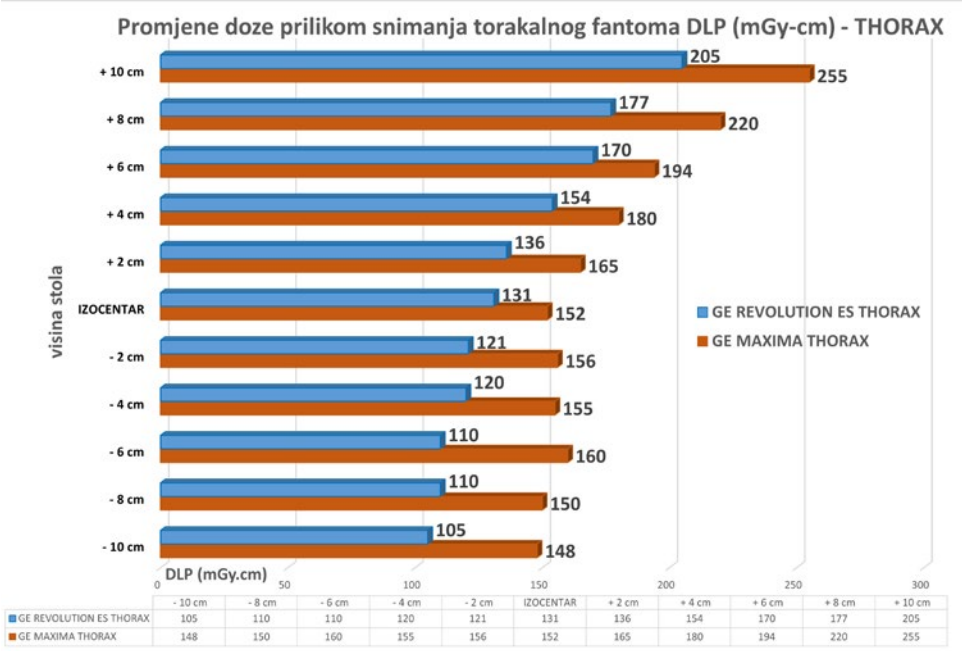
CT GE MAXIMA 128 TORAKS			
VISINA STOLA	**CTDIvol (mGy)**	**DLP (mGy·cm)**	**Promjena doze**
+ 10 cm	7,4	255	**↑ 71%**
+ 8 cm	6,4	220	**↑ 48%**
+ 6 cm	5,6	194	**↑ 29%**
+ 4 cm	5,2	180	**↑ 20%**
+ 2 cm	4,7	165	**↑ 9%**
IZOCENTAR	4,3	152	
- 2 cm	4,3	156	**↓ -3%**
- 4 cm	4,3	155	**↓ -3%**
- 6 cm	4,3	160	**↓ -6%**
- 8 cm	4,3	150	**↓ -5%**
- 10 cm	4,3	148	**↓ -3%**



Slika 4. Grafički prikaz usporedbe promjene doze prilikom snimanja zdjeličnog fantoma.

Tablica 5. Promjena DLP vrijednosti pri različitim visinama stola u odnosu na izocentar tijekom CT snimanja torakalnog fantoma na uređaju GE Revolution ES 256.

	CT GE REVOLUTION ES 256 TORAKS		
VISINA STOLA	**CTDIvol (mGy)**	**DLP (mGy·cm)**	**Promjena doze**
+ 10 cm	5,5	205	**↑ 53%**
+ 8 cm	4,9	177	**↑ 36%**
+ 6 cm	4,7	170	**↑ 31%**
+ 4 cm	4,2	154	**↑ 16%**
+ 2 cm	3,7	136	**↑ 4%**
IZOCENTAR	3,6	131	
- 2 cm	3,3	121	**↓ -8%**
- 4 cm	3,3	120	**↓ -8%**
- 6 cm	3	110	**↓ -16%**
- 8 cm	3	110	**↓ -16%**
- 10 cm	2,9	105	**↓ -20%**



Slika 5. Grafički prikaz usporedbe promjene doze prilikom snimanja torakalnog fantoma.

Rasprava

Rezultati ovog istraživanja jasno pokazuju da vertikalno odstupanje fantoma od izocentra CT uređaja ima značajan utjecaj na vrijednosti CTDIvol i DLP. U svim analiziranim protokolima zabilježen je trend povećanja doze pri podizanju stola iznad izocentra, dok je spuštanje stola rezultiralo manjim povećanjem ili smanjenjem doze (slika 5.). Najizraženije promjene zabilježene su kod zdjeličnih protokola, gdje je na uređaju GE Maxima povećanje doze pri pomaku od +10 cm iznosilo čak 106 % u odnosu na referentni položaj u izocentru.

Glavni razlog ovakvog fenomena leži u geometriji CT sustava i načinu rada automatske regulacije ekspozicije (AEC). Tijekom izrade topograma CT sustav procjenjuje veličinu i atenuaciju pacijenta na temelju projekcijske slike. Kada je pacijent ili fantom pozicioniran iznad izocentra, dolazi do smanjenja projicirane širine tijela na topogramu zbog geometrijskog efekta projekcije. Sustav to interpretira kao manju projekcijsku širinu tijela, što rezultira povećanjem struje rendgenske cijevi (mA) kako bi se postigla zadana razina šuma slike. Posljedica toga je povećanje primijenjene doze zračenja.

Suprotno tome, kada je pacijent pozicioniran ispod izocentra, projekcijska širina tijela na topogramu povećava se, što može dovesti do drugačije procjene atenuacije i smanjene potrebe za kompenzacijom struje rendgenske cijevi. Ovakav mehanizam objašnjava zašto su u ovom istraživanju povećanja doze bila znatno izraženija pri podizanju stola nego pri njegovom spuštanju.

Dobiveni rezultati u skladu su s ranijim istraživanjima koja su istraživala utjecaj centriranja pacijenta na dozu zračenja u CT dijagnostici (6). Toth i suradnici pokazali su kako nepravilno centriranje pacijenata može uzrokovati značajne promjene u vrijednostima CTDIvol zbog promjena u radu AEC sustava (7). Habibzadeh i suradnici također su pokazali da vertikalna odstupanja od izocentra mogu rezultirati povećanjem doze i pogoršanjem kvalitete slike, osobito kod većih anatomskih regija.

Slične rezultate navode i druga istraživanja koja pokazuju da nepravilno centriranje pacijenata može značajno povećati organ dozu i razinu šuma slike (8,9).

U ovom istraživanju promjene doze bile su izraženije kod zdjeličnog fantoma u odnosu na torakalni fantom. Moguće objašnjenje leži u većoj masi, konstituciji, debljini i većoj ukupnoj atenuaciji zdjeličnog fantoma, što čini AEC algoritam osjetljivijim na promjene projekcijske geometrije. Također je uočeno da su promjene doze bile izraženije na uređaju GE Maxima u usporedbi s uređajem GE Revolution ES. Ova razlika može biti povezana s razlikama u konfiguraciji detektora, širini kolimacije, algoritmima AEC sustava, karakteristikama same rendgenske cijevi kao i konstrukciji bow-tie filtra.

Klinički značaj ovih rezultata je iznimno važan. U svakodnevnoj praksi radiološki tehnolozi često se oslanjaju na laserske markere ili vizualnu procjenu prilikom pozicioniranja pacijenta. Brojna istraživanja pokazuju da značajan udio pacijenata nije optimalno centriran u izocentar. Čak i relativno mala odstupanja mogu dovesti do značajnog povećanja doze zračenja, kao što je pokazano u ovom istraživanju.

S obzirom na to da je pravilno pozicioniranje pacijenta jednostavna i brzo primjenjiva mjera, edukacija radioloških tehnologa i standardizacija postupaka pozicioniranja mogu imati značajan učinak na optimizaciju CT doze. Precizno i točno centriranje pacijenta predstavlja jednu od najjednostavnijih i najučinkovitijih strategija za smanjenje nepotrebnog izlaganja zračenju, bez negativnog utjecaja na dijagnostičku kvalitetu slike. Ovi rezultati dodatno potvrđuju da optimizacija CT doze ne ovisi isključivo o tehničkim parametrima skeniranja, već i o pravilnom izvođenju osnovnih postupaka pozicioniranja pacijenta, kao osnovnog preduvjeta za optimalan rad sustava automatske regulacije ekspozicije (10).

Ograničenja istraživanja

Ovo istraživanje ima nekoliko ograničenja koja je potrebno uzeti u obzir prilikom interpretacije rezultata. Prije svega, istraživanje je provedeno na fantomima koji, iako omogućuju standardizirane i reproducibilne uvjete snimanja, ne mogu u potpunosti odražavati anatomsku varijabilnost i heterogenost stvarnih pacijenata. Razlike u tjelesnoj konstituciji, raspodjeli tkiva i respiratornim pokretima u kliničkoj praksi mogu dodatno utjecati na rad sustava automatske regulacije ekspozicije.

Drugo ograničenje odnosi se na činjenicu da su mjerenja provedena na CT uređajima istog proizvođača. Budući da različiti proizvođači koriste različite algoritme automatske regulacije ekspozicije (npr. samo jedan startni topogram za izračun AEC, umjesto dva kao u našem slučaju), konstrukciju bow-tie filtra i rekonstrukcijske algoritme, rezultati se ne mogu u potpunosti generalizirati na sve CT sustave.

Također, u ovom istraživanju analizirane su samo vrijednosti CTDIvol i DLP, dok drugi parametri kvalitete slike, poput razine šuma ili kontrastne rezolucije, nisu kvantitativno analizirani. Buduća istraživanja trebala bi uključiti i objektivnu procjenu kvalitete slike te kliničku validaciju rezultata na pacijentima.

Zaključak

Rezultati ovog istraživanja pokazuju da vertikalno odstupanje od izocentra CT uređaja ima značajan utjecaj na primijenjenu dozu zračenja tijekom CT snimanja. Podizanje stola iznad izocentra dovodi do sustavnog povećanja vrijednosti CTDIvol i DLP, dok spuštanje stola rezultira manjim promjenama ili blagim smanjenjem doze.

Dobiveni rezultati potvrđuju da čak i relativno mala odstupanja u pozicioniranju mogu rezultirati značajnim povećanjem doze zračenja, osobito kod protokola koji uključuju anatomsku regiju veće debljine, poput abdomena i zdjelice. Ovakav učinak povezan je s načinom rada sustava automatske regulacije ekspozicije koji procjenjuje debljinu pacijenta na temelju topograma.

Precizno pozicioniranje pacijenta u izocentar CT uređaja predstavlja jednostavnu, ali izuzetno važnu mjeru optimizacije CT pretraga. Standardizacija postupaka pozicioniranja i kontinuirana edukacija radioloških tehnologa mogu značajno doprinijeti smanjenju varijabilnosti doze te poboljšanju radiološke zaštite pacijenata.

Ovi rezultati naglašavaju važnost pravilnog centriranja pacijenta kao jednog od najjednostavnijih i najučinkovitijih koraka optimizacije doze u CT dijagnostici, bez potrebe za dodatnim tehničkim intervencijama ili promjenom protokola snimanja.

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Influence of vertical position of the table from the isocenter on radiation dose in CT imaging

Abstract

Introduction: Precise positioning of the patient at the CT scanner isocenter is a key factor in achieving optimal image quality and optimizing radiation dose. Deviations from the isocenter can cause geometric changes in the topogram that affect the operation of the automatic exposure control (AEC) system and consequently the applied radiation dose. Despite this, incorrect patient centering remains common in clinical practice.

Objective: The objective of this study was to quantify the influence of vertical deviation of the table height relative to the isocenter on the CTDIvol and DLP values during CT imaging of the thoracic and pelvic phantoms on two CT scanners.

Subjects and methods: The research was conducted on CT devices GE Revolution Maxima 128 and GE Revolution ES 256. The table height was changed from -10 cm to +10 cm in 2 cm increments relative to the isocenter. Imaging was performed on the Multipurpose Chest Phantom N1 Lungman (Kyoto Kagaku, Japan) and the CIRS Virtual Human Male Pelvis Phantom 801P (CIRS Inc., Norfolk, VA, USA) using standardized and optimized imaging protocols for each CT device. For each table height position, two scans were performed for measurement reliability. CTDIvol and DLP values were obtained from the dose report for each scan.

Results: On the GE Maxima, raising the table by +10 cm increased the dose by 71% in the thoracic protocol and 106% in the pelvic protocol, whereas lowering the table by -10 cm reduced the dose by 3% to 30%. On the GE Revolution ES, the maximum dose increase was 53%, while lowering the table resulted in a 8% to 20% dose reduction. The changes were more pronounced in pelvic protocols, which can be explained by the greater thickness of the phantom and the AEC algorithm's greater sensitivity to changes in projection geometry. Larger dose variations were also observed on the GE Maxima.

Conclusion: Vertical deviation from the isocenter has a significant and clinically relevant impact on radiation dose during CT examinations. Raising the table above the isocenter systematically increases the automatic exposure control system's compensation and significantly increases the CT dose. Precise positioning of the patient at the isocenter is a simple yet key optimization measure in CT diagnostics.

Key words: computed tomography (CT), isocenter, CTDIvol, automatic exposure control (AEC), dose optimization

Izvještaj sa 7. kongresa SEETRO 2025: Tehnološki iskoraci i redefiniranje uloge radiološkog tehnologa u suvremenoj radioterapiji

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Uvod i značaj skupa

Sedmi kongres SEETRO 2025 (*South and East Europe Technology in Radiation Oncology*), održan od 19. do 21. rujna 2025. godine u Istanbulu, potvrdio je status jednog od najvažnijih regionalnih događaja u području radijacijske onkologije. Pod krovnom temom **„***Advanced Practice in Radiation Therapy and the Role of RTTs***“**, skup je stavio fokus na sinergiju napredne tehnologije i stručnog doprinosa radioloških tehnologa (RTT) u multidisciplinarnim timovima. Sudjelovanje na ovom kongresu omogućilo je uvid u najnovije trendove koji izravno oblikuju budućnost kliničke prakse.



Harmonizacija edukacije i standardi kvalitete

Prvi radni dan bio je posvećen strateškom pregledu stanja radioterapije u zemljama jugoistočne Europe. Kroz prizmu smjernica *Međunarodne agencije za atomsku energiju* (IAEA), analizirani su modeli edukacije i profesionalnog



razvoja RTT-a. Poseban naglasak stavljen je na nužnost standardizacije obrazovanja i kontinuiranog usavršavanja kao preduvjeta za osiguranje kvalitete. Istaknuto je kako je uloga RTT-a kritična točka u osiguravanju sigurnosti pacijenata i preciznosti provedbe složenih terapijskih protokola.

Sve je izraženiji trend tranzicije RTT-a iz isključivo tehničkog osoblja u aktivne partnere unutar onkoloških timova, što predstavlja ključan korak u evoluciji struke.

Tehnološke inovacije: AI i personalizirani pristup

Središnji dio znanstvenog programa bio je usmjeren na tehnologije koje redefiniraju granice preciznosti u radioterapiji:

Umjetna inteligencija (AI): Detaljno je obrađena primjena AI algoritama u procesima automatskog konturiranja organa i planiranja terapije, što značajno optimizira radni proces.

*Napredna vizualizacija***:** Predstavljene su mogućnosti *photon-counting CT* tehnologije te primjena *MR-vođene radioterapije* (MRgRT).

Adaptivni i stereotaktički pristupi: Razmatrane su metode individualizacije terapije u stvarnom vremenu, poput površinski vođene radioterapije (SGRT) i stereotaktičke radioterapije, koje omogućuju maksimalnu poštedu zdravog tkiva.

Inovacije u brahiterapiji: Poseban interes izazvala je prezentacija korištenja *3D printanih aplikatora,* koji omogućuju personalizirani pristup svakom pacijentu.

Izazovi struke i praktična primjena

Završni dio kongresa adresirao je praktične izazove u regiji, poput zapošljavanja, profesionalnog priznanja i potrebe za jačanjem međunarodne suradnje. Teoretska saznanja zaokružena su stručnom radionicom u lokalnoj bolnici u Istanbulu. Ovaj oblik praktične edukacije omogućio je izravnu interakciju s kolegama iz kliničkog okruženja i uvid u konkretnu implementaciju najmodernijih tehnologija o kojima se raspravljalo tijekom sesija.

Socijalna dimenzija i kulturna razmjena

Uz bogat stručni program, kongres je ponudio platformu za neformalno umrežavanje kroz društvene aktivnosti. Vožnja brodom po Bosporu omogućila je razmjenu iskustava s kolegama iz drugih zemalja u opuštenoj atmosferi. Zajednička večera uz tradicionalne turske plesove dodatno je doprinijela jačanju kolegijalnih veza unutar regionalne zajednice. Boravak u Istanbulu, gradu bogate povijesti i arhitekture, pružio je i vrijednu kulturnu dimenziju cijelom putovanju.

Zaključak

Sudjelovanje na SEETRO 2025 kongresu bilo je izuzetno poticajno iskustvo koje je potvrdilo važnost stalnog praćenja tehnološkog razvoja. Stečena znanja o umjetnoj inteligenciji, adaptivnim sustavima i novim modalitetima zračenja zasigurno će naći primjenu u našoj svakodnevnoj kliničkoj praksi, pridonoseći daljnjem unapređenju kvalitete skrbi za pacijente. ■





Izvješće sa 6. Kongresa radiološke tehnologije



6. Kongres radiološke tehnologije (6. KRT) s međunarodnim sudjelovanjem u organizaciji Strukovnog razreda za zdravstvenu radiološko-tehnološku djelatnost Hrvatske komore zdravstvenih radnika održan je od 07. do 09. studenog 2025. godine u hotelu Olympia u Vodicama.

Prilikom odabira mjesta za održavanja 6. KRT vodilo se računa o zastupljenosti u cijeloj Hrvatskoj, kako bi se na taj način sudjelovanje na kongresima učinilo podjednako dostupnim svim članovima, a sudionicima iz okolnih zemalja i svijeta približilo kulturna bogatstva i raznolikost naše zemlje. Tako je 2025. godine odabir pao na predivne Vodice.



Nastavljajući tradiciju održavanja Kongresa diljem Hrvatske, s ciljem osiguravanja jednake dostupnosti stručnih skupova svim članovima te približavanja naše struke i kulture sudionicima iz regije i svijeta, 6. KRT je donio još bogatiji i svestraniji program. U tri dana trajanja Kongresa održano je ukupno 30 predavanja, od kojih je 8 bilo pozvanih predavanja, 3 okrugla stola, jedan satelitski simpozij i prezentirano je 19 postera. Teme izuzetno dobro posjećenih okruglih stolova bile su: Stručni nadzor u zdravstvenoj radiološko-tehnološkoj djelatnosti, Uloga sindikata u zdravstvenoj radiološko-tehnološkoj djelatnosti i Sustavi komora i profesionalnih udruženja u regiji.



Predavanja i poster prezentacije pokrili su sva područja radiologije i radiološke tehnologije te prikazali najnovija dostignuća u radiološko-tehnološkoj djelatnosti.

Organizatori 6. KRT se ovom prilikom još jednom žele zahvaliti svim pozvanim predavačima, uvaženim gostima i svim kolegicama i kolegama koji su svoji prisustvom uveličali ovaj stručni događaj. Smatramo da su susreti ovog tipa od velikog značaja u razmjeni iskustava te usvajanju novih spoznaja, ali i učvršćivanju položaja profesije u zdravstvenom sustavu.



Ovom Kongresu je prisustvovalo ukupno 408 sudionika, čineći ga do sada najvećim i najposjećenijim kongresom radiološke tehnologije u povijesti RH.

Povratne informacije sa 6. KRT su vrlo pozitivne što nas posebno veseli te se radujemo i daljnjoj dobroj suradnji sa svim dionicima naše profesije i susretima na budućim kongresima radiološke tehnologije! ■

Organizacijski odbor:
Miroslav Bašić, Dario Celjak,
Nina Jakobčić i Igor Mulković.

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HDRT na Europskom kongresu radiologije, ECR 2026, Beč, 04. – 08. ožujka 2026.

Vladimir Bahun, tajnik za međunarodnu suradnju HDRT-a

Europski kongres radiologije (ECR 2026), pod temom "Rays of Knowledge", i ove je godine potvrdio zašto je najveći i najvažniji europski skup u našem području: 22,418 sudionika u Beču. Buka, gužva i stotine paralelnih predavanja. Lako se izgubiti na ECR-u ako ne znate točno po što ste došli. Hrvatsko društvo radiološke tehnologije ove godine nije došlo samo slušati. Došli smo raditi.

Hrvatsko društvo radiološke tehnologije predstavljali su Velimir Karadža, dopredsjednik HDRT-a, Branko Kovalisko, glavni tajnik HDRT-a i Vladimir Bahun, tajnik za međunarodnu suradnju HDRT-a.

Tri člana vodstva, tri perspektive, jedan zajednički mandat: zastupati interese naših članova i naše profesije na europskoj i svjetskoj razini.

Što smo radili – konkretno

Aktivno sudjelovanje u programu kongresa

Članovi delegacije HDRT-a aktivno su sudjelovali u znanstvenom i stručnom programu kongresa – kroz prezentacije i otvorene diskusije, u sesijama koje su se izravno ticale radiološke tehnologije, sigurnosti pacijenata i razvoja profesije.

Sudjelovali smo u sesijama posvećenim specifičnim modalitetima snimanja, zaštiti od zračenja, osiguranju kvalitete i ulozi radiološkog tehnologa u multidisciplinarnom timu. Ovo nije bilo pasivno sjedenje u publici. Ovo je bilo aktivno zastupanje naše profesije – prezentiranje, postavljanje pitanja, dijeljenje iskustava iz hrvatske prak-





se, i sudjelovanje u raspravama koje oblikuju budućnost struke.

Za naše članove to znači jedno – HDRT ne čeka da se standardi definiraju negdje drugdje i da ih mi onda samo prihvatimo. Mi smo za stolom dok se ti standardi kreiraju.

Suradnja s Hrvatskim Društvom Radiologa

Delegacija HDRT-a održala je i sastanak s predstavnicima Hrvatskog društva radiologa (HDR).

Ovo je važno iz jednostavnog razloga: radiološka profesija u Hrvatskoj ne može napredovati u silosima. Radiolozi i radiološki tehnolozi rade svaki dan zajedno – isti odjeli, isti pacijenti, iste dijagnostičke i terapijske procedure. Logično je da i profesionalna društva koja ih zastupaju djeluju usklađeno.

Na sastanku smo potvrdili zajedničko opredjeljenje za koordinirano djelovanje na razini radiološke profesije u Hrvatskoj.

Ovo nije formalnost. Ovo je partnerstvo dviju strukovnih organizacija koje razumiju da je zajednički nastup najbolji način da se glas radiološke profesije u Hrvatskoj čuje.

Rad s EFRS-om – europska razina

Europska federacija društava radiografera (EFRS) okuplja 41 nacionalno društvo i zastupa preko 100 000 radiografera diljem Europe. HDRT je punopravni član ove organizacije, i to članstvo za naše članove znači pristup europskim projektima, smjernicama i profesionalnom umrežavanju koje bi nam inače bilo nedostupno.

Na ECR-u 2026, delegacija HDRT-a aktivno je surađivala s vodstvom i tijelima EFRS-a. ECR je ujedno i službeni godišnji skup EFRS-a, što znači da se tu donose ključne odluke za profesiju na europskoj razini.

Razgovarali smo o nekoliko ključnih tema koje izravno utječu na naše članove:

- Harmonizacija edukacije te standardizacije rada radioloških tehnologa u Europi.
  EFRS kroz projekt EU-REST (European Union Radiation, Education, Staffing and Training) radi na usklađivanju standarda za radiološke tehnologe u cijeloj Europskoj uniji.
- Sigurnost pacijenata i zaštita od zračenja.
  Ovo je jedna od temeljnih misija EFRS-a i HDRT-a.



Razgovarali smo o implementaciji najnovijih smjernica za zaštitu od zračenja, o ulozi radiološkog tehnologa u osiguranju kvalitete i sigurnosti pacijenata, kao i o potrebi za stalnim stručnim usavršavanjem u ovom području. Za naše članove koji svakodnevno rade s ionizirajućim zračenjem, ovo nije birokratska tema – ovo je pitanje profesionalnog integriteta i odgovornosti prema pacijentima.

- Proširenje uloge radiološkog tehnologa.
  EFRS aktivno zagovara proširenje profesionalnih kompetencija radioloških tehnologa, uključujući formalnu ulogu u MR sigurnosti (MRSO – Magnetic Resonance Safety Officer) i veću autonomiju u kliničkom radu. Projekt ECSO-MRI (European Curriculum for Safety Officers in MRI) razvija harmonizirani europski kurikulum za ovu ulogu. HDRT prati ove inicijative i radi na tome da naši članovi budu u poziciji iskoristiti ove prilike za profesionalni razvoj.
- Istraživanje i znanstveni rad u radiološkoj tehnologiji.
  EFRS potiče razvoj istraživačke kulture među radiološkim tehnolozima. Za HDRT, to znači podrška našim članovima koji žele objavljivati radove, sudjelovati u istraživanjima i doprinositi bazi znanja naše profesije – ne samo kroz Radiološki Vjesnik, nego i na međunarodnoj razini.

Poruka je jasna: HDRT i Hrvatska nisu izolirani. Povezani smo s europskom zajednicom radioloških tehnologa, imamo pristup relevantnim projektima i inicijativama, i aktivno zastupamo interese naših članova na razini na kojoj se donose odluke koje oblikuju budućnost profesije u Europi.

Sastanak s glavnim odborom ISRRT-a – svjetska razina

Ovo je možda najvažniji dio izvještaja za naše članove.

ISRRT, Međunarodno društvo radiografera i radioloških tehnologa, globalna je krovna organizacija naše profesije. Osnovana 1959. godine, danas okuplja nacionalna društva sa svih kontinenata i predstavlja glas radiološke tehnologije na svjetskoj razini, uključujući suradnju sa Svjetskom zdravstvenom organizacijom (WHO).

Na ECR-u 2026, delegacija HDRT-a održala je radni sastanak s glavnim odborom ISRRT-a.

Na tom sastanku raspravljali smo o:

- Globalnim standardima za profesiju.
  ISRRT radi na uspostavljanju i promicanju standarda koji osiguravaju da radiološki tehnolozi diljem svijeta rade prema usporedivim profesionalnim i etičkim normama. Za naše članove to znači da HDRT, kroz članstvo i aktivnu suradnju s ISRRT-om, doprinosi oblikovanju tih standarda – a ne da ih samo preuzima.
- Razvoju obrazovnih kurikuluma. ISRRT pomaže nacionalnim društvima u razvoju i unapređenju obrazovnih programa za radiološke tehnologe. Ovo je posebno važno za Hrvatsku, gdje se obrazovni sustav za našu profesiju kontinuirano razvija.
- Programima osiguranja kvalitete. ISRRT zagovara implementaciju programa osiguranja kvalitete u radiološkim odjelima diljem svijeta. Za naše članove koji svakodnevno teže izvrsnosti u svom radu, ovo je potvrda da je kvaliteta, ne samo kvantiteta, ono čemu profesija mora težiti.
- Razmjeni znanja i iskustava. ISRRT potiče međunarodnu razmjenu znanja između profesionalaca, i HDRT je aktivno uključen u ovu mrežu. To za naše članove znači pristup globalnim stručnim resursima, mogućnost sudjelovanja u međunarodnim projektima, te umrežavanje s kolegama koji rade u različitim zdravstvenim sustavima i s različitom tehnologijom.
- Pozicioniranju na Svjetskom kongresu ISRRT-a u Dubaiju. 24. Svjetski kongres ISRRT-a planiran je za 2026. godinu u Dubaiju, i HDRT namjerava biti aktivno prisutan. Ovaj sastanak s glavnim odborom ISRRT-a bio je, između ostalog, i priprema za naš nastup na toj globalnoj pozornici.

Ono što je ovaj sastanak potvrdio: HDRT ima mjesto za stolom na kojem se donose odluke o budućnosti profesije na svjetskoj razini. Ne kao statist. Kao partner.

Što ovo znači za vas, naše članove

Svaki sastanak, svaka prezentacija, svaka rasprava u kojoj smo sudjelovali na ECR-u 2026 imala je jedan cilj – osigurati da radiološki tehnolozi u Hrvatskoj imaju glas, imaju pristup i imaju budućnost.

Konkretno:

- Na nacionalnoj razini potvrdili smo i osnažili partnerstvo s Hrvatskim društvom radiologa. Zajedno smo jači. Zajedničkim djelovanjem možemo učinkovitije zagovarati poboljšanje uvjeta rada, standarda obrazovanja i statusa profesije u hrvatskom zdravstvenom sustavu.
- Na europskoj razini aktivno smo uključeni u rad EFRS-a i ključne europske projekte koji definiraju budućnost naše profesije. Od harmonizacije edukacije, preko zaštite od zračenja, do proširenja profesionalnih kompetencija – HDRT je prisutan i HDRT zagovara interese svojih članova.
- Na svjetskoj razini kroz rad s ISRRT-om, HDRT osigurava da Hrvatska nije samo primatelj međunarodnih standarda, već aktivan sudionik u njihovom kreiranju.

Zaključak

ECR 2026 u Beču bio je jedan od najproduktivnijih kongresa za Hrvatsko društvo radiološke tehnologije.

U pet dana intenzivnog rada, učvrstili smo poziciju HDRT-a na tri razine – hrvatskoj, europskoj i međunarodnoj. Aktivno smo sudjelovali u znanstvenom programu, prezentirali rad naše zajednice, vodili strateške razgovore s ključnim partnerima, i potvrdili da HDRT nije društvo koje čeka. HDRT je društvo koje je prisutno i koje djeluje.

Za naše članove ovo znači da vaše društvo radi na terenu. Na kongresima, u radnim skupinama, za pregovaračkim stolovima. Tamo gdje se oblikuje budućnost profesije.

Više od 50 godina postojanja HDRT-a nije samo brojka za monografiju. To je alat. U Beču smo taj alat iskoristili. Na europskoj i svjetskoj razini pravila za našu struku se konstantno mijenjaju. Ako nismo za stolom dok se ta pravila pišu, usvajati ćemo ih kada budu gotova.

Biti u mogućnosti sjesti i sudjelovati u ovim diskusijama čast je i priznanje našem radu. Ali čast ne piše pravila. Ljudi za tim stolovima ih pišu. ■

Napredne vještine u modernoj radioterapiji:

Izvještaj s ESTRO edukacijskog programa

Ivan Balentović[1], **Miran Gašparović**[1]

[1] KBC Rijeka, Klinika za tumore



European Society for Radiotherapy and Oncology (ESTRO) od svog utemeljenja 1980. godine djeluje kao središnji autoritet za onkološku radioterapiju u Europi. Njegova uloga nadilazi puku organizaciju kongresa; ESTRO definira standarde kvalitete, koordinira multicentrična istraživanja i postavlja temelje za harmonizaciju edukacije radioloških tehnologa (RTT), medicinskih fizičara i radijacijskih onkologa. Kroz inicijative poput *Global Impact of Radiotherapy*, društvo aktivno radi na dostupnosti modernih tehnologija svim pacijentima, bez obzira na zemljopisnu lokaciju.

U listopadu 2025. godine imali smo priliku sudjelovati na tečaju Advanced Skills in Modern Radiotherapy, koji je organiziran pod okriljem ESTRO-a. Tečaj je bio usmjeren na produbljivanje znanja i razvoj naprednih kompetencija u području suvremenih radioterapijskih tehnika, trajao je 5 dana te je program obuhvatio aktualne teme poput: naprednih tehnika planiranja (IMRT, VMAT), adaptivne radioterapije, stereotaksijske radioterapije (SBRT/SRS), integracije slikovnih metoda u planiranju i verifikaciji terapije, optimizacije doze i zaštite rizičnih organa i procjene ishoda liječenja.

Poseban naglasak stavljen je na kliničko donošenje odluka, analizu kompleksnih slučajeva te multidisciplinarni pristup liječenju onkoloških bolesnika. Interaktivni format rada, uključujući diskusije i prikaze kliničkih scenarija, omogućio je aktivno sudjelovanje polaznika (Onkologa, Radioloških tehnologa te Medicinskih fizičara) i razmjenu iskustava među stručnjacima iz različitih europskih centara.

Preciznost u pripremi i definicija volumena (ICRU Standardi)

U suvremenoj radioterapiji, faza planiranja kritičnija je od same isporuke zračenja. Svaki milimetar odstupanja u ovoj fazi multiplicira se kroz frakcionirani proces liječenja.

Geometrijska nesigurnost: Naglašena je razlika između sustavnih pogrešaka (nastalih tijekom simulacije) i slučajnih pogrešaka (dnevne varijacije položaja). Adekvatna imobilizacija (individualni fiksatori, termoplastične maske, *vacuum-bags*) smanjuje ove varijacije na minimum.

Standardizacija prema ICRU 50/62/83:

GTV (Gross Tumor Volume): Primarna tumorska masa identificirana palpacijom ili vizualizacijom (CT, MR, PET).

CTV (Clinical Target Volume): Uključuje subkliničku mikroskopsku proširenost tumora. Definiranje CTV-a zahtijeva duboko poznavanje biologije tumora i puteva limfne drenaže.

PTV (Planning Target Volume): Geometrijski konstrukt koji osigurava da propisana doza doista bude isporučena u CTV, uzimajući u obzir pomičnost organa i nesigurnosti u postavljanju pacijenta.

*Multimodalna fuzija***:** CT pruža informacije o elektronskoj gustoći tkiva nužne za izračun doze, ali MR nudi superiornu mekotkivnu kontrastnost (osobito kod tumora mozga, prostate i rektuma). PET/CT integracija omogućuje biološko konturiranje, gdje se volumen može modificirati ovisno o metaboličkoj aktivnosti (standardizirana vrijednost nakupljanja – SUV).

Planiranje radioterapije: Konfiguraciju snopova zračenja, oblikovanje snopa pomoću MLC-a (*multileaf collimator*), izračun raspodjele doze, optimizaciju plana, postavljanje ograničenja za OAR (organe od rizika), evaluaciju plana (analiza DVH-a i pokrivenosti ciljnog volumena). Cilj je postići optimalanu ravnotežu adekvatne doze tumoru i zaštite okolnih zdravih struktura.

Dinamički menadžment i slikovno vođena radioterapija (IGRT)

Napredak u tehnologiji linearnih akceleratora omogućio je razvoj tehnika poput VMAT (*Volumetric Modulated Arc Therapy*), gdje se zračenje isporučuje u punom krugu (360°) uz kontinuiranu promjenu brzine rotacije, oblika snopa (MLC) i brzine doze (*dose rate*).

Uloga IGRT-a: Svakodnevna primjena CBCT-a (*Cone Beam CT*) omogućuje uvid u unutrašnju anatomiju neposredno prije zračenja. To je ključno za adaptaciju plana, kada je to moguće/potrebno, kod pacijenata kod kojih dolazi do brzog gubitka tjelesne mase ili promjene punjenja šupljih organa.

Kontrola respiratornih kretnji: Kod tumora u prsnom košu i gornjem abdomenu, tumor se može pomicati više od 2 cm tijekom disanja.

4D CT simulacija: Snima se cijeli respiratorni ciklus i dijeli u faze (0–100%).

DIBH (Deep Inspiration Breath Hold): Pacijent zadržava dah u dubokom inspiriju, što stabilizira položaj tumora i maksimalno udaljava srce od prednje prsne stijenke kod zračenja lijeve dojke, smanjujući kardiotoksičnost.

Čestična terapija: Prednosti protonskog zračenja

Protonska terapija predstavlja iskorak u odnosu na konvencionalne fotone zbog specifičnog načina interakcije s materijom.

Fizika zračenja: Dok fotoni gube energiju duž cijelog puta kroz tijelo, protoni najveći dio energije oslobađaju na točno određenoj dubini – u vrhu Braggove krivulje. Iza te točke doza zračenja praktički pada na nulu.

Kliničke indikacije: * Pedijatrija: Drastično smanjenje integralne doze (ukupna energija apsorbirana u cijelom tijelu), čime se minimizira rizik od sekundarnih karcinoma i razvojnih poremećaja.

Re-iradiacija: Mogućnost ponovnog zračenja područja koja su već primila maksimalnu tolerantnu dozu fotona.

Baza lubanje (hordomi, hondrosarkomi): Mogućnost isporuke ekstremno visokih doza u neposrednoj blizini moždanog debla i optičkih živaca.

Adaptivna radioterapija u realnom vremenu (MR-linac)

Najnoviji trend u struci je *MR-linac*, sustav koji integrira MR uređaj (najčešće 0.35T ili 1.5T) s linearnim akceleratorom.

Cine-MR: Omogućuje kontinuirano snimanje ("film") dok je zračenje uključeno. Ako se tumor pomakne izvan zadanih granica (npr. zbog peristaltike ili kašlja), sustav automatski prekida snop zračenja (*gating*).

On-line adaptacija: Umjesto jednog plana koji se koristi kroz cijeli ciklus od 30 frakcija, MR-linac omogućuje izradu novog plana zračenja svakoga dana, dok pacijent leži na stolu, prilagođavajući se trenutačnom obliku i položaju tumora i zdravih organa.

PRoMs (Patient-Reported Outcomes): Naglašena je važnost integracije digitalnih alata za prijavu nuspojava. Pravovremena detekcija (npr. preko mobilnih aplikacija) omogućuje onkolozima i RTT-ima da interveniraju prije nego što toksičnost postane klinički limitirajuća.

Specifični protokoli za ginekologiju i karcinom dojke

Ginekološki tumori: Fokus je na *inter-frakcijskim varijacijama*. Analizirani su protokoli pripreme pacijentica (prazan rektum, specifičan volumen u mjehuru) kako bi se osigurala fiksna pozicija uterusa i smanjila doza na tanko crijevo. Kod brahiterapije, preporuča se prelazak s CT na MR planiranje radi bolje vizualizacije parametarija.

Karcinom dojke: Razmatrana je primjena *hipofrakcioniranih režima* (npr. 15 ili 5 frakcija umjesto 25), koji su se pokazali jednako učinkovitima uz bolju logističku podnošljivost za pacijentice i zdravstveni sustav. IGRT verifikacija položaja ležišta tumora (*boost*) pomoću kirurških klipova postala je standard za postizanje lokalne kontrole.

Zaključno razmatranje: Suvremena radioterapija više nije samo primjena ionizirajućeg zračenja, već visokotehnološki proces koji spaja napredno računalno planiranje, precizno oslikavanje i biološku prilagodbu. Suvremeni onkološki pristup obuhvaća, osim tehnološkog procesa, praćenje i pravovremeno zbrinjavanje nuspojava, psihološku podršku pacijentu, jasnu i empatičnu komunikaciju. Pacijente treba potaknuti da pravovremeno prijave bol, umor, kožne reakcije, poteškoće s gutanjem, mokrenjem ili disanjem, emocionalne tegobe jer rano prepoznavanje simptoma omogućuje bržu intervenciju, bolju kvalitetu života i manji rizik od prekida terapije.

Kontinuirana edukacija ključna je za sigurnu implementaciju ovih tehnologija u svakodnevni rad.

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Abstract

Modern radiotherapy is no longer just the application of ionizing radiation, but a high-tech process that combines advanced computer planning, precise imaging and biological adaptation. A modern oncological approach includes, in addition to the technological process, monitoring and timely management of side effects, psychological support for the patient, and clear and empathetic communication. Patients should be encouraged to promptly report pain, fatigue, skin reactions, difficulties with swallowing, urination or breathing, and emotional distress, as early recognition of symptoms allows for faster intervention, better quality of life and a lower risk of therapy interruption.

Continuous education is essential for the safe implementation of these technologies in everyday work. ■

Iskustva sa ERASMUS+ programa na Zdravstvenom Fakultetu u Ljubljani

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Sažetak

U prosincu 2025. godine realiziran je Erasmus+ program mobilnosti sa Zdravstvenog Veleučilišta Zagreb na Zdravstvenom fakultetu Sveučilišta u Ljubljani. Fokus boravka bio je na analizi organizacije kurikuluma, razmjeni pedagoških iskustava, te uvid u suvremenu infrastrukturu namijenjenu obrazovanju radioloških tehnologa. Ljubljana predstavlja strateški važnu destinaciju zbog sličnosti nastavnih planova i visoke razine tehnološke opremljenosti, što omogućuje izravnu primjenu stečenih saznanja u matičnoj ustanovi.



Simulacijska učionica Siemens View&Go

Prostorija je opremljena s 19 radnih stanica s licenciranim softverima za simulaciju rada na uređajima za magnetsku rezonanciju (MR). Ovakav sustav omogućuje studentima usvajanje kompleksnih protokola u kontroliranim uvjetima.



Radiografski kabinet

Fakultet posjeduje potpuno funkcionalnu radiografsku dvoranu s uređajem Siemens Multix Pro. Praktična nastava u ovom prostoru omogućuje simulaciju realnih kliničkih scenarija.

Analiza edukacijske infrastrukture

Zdravstveni fakultet u Ljubljani odlikuje se visokom razinom integracije tehnologije u nastavni proces. Poseban naglasak stavljen je na simulacijsku nastavu koja prethodi kliničkoj praksi.

Usporedba studijskih programa i kurikuluma

Tijekom stručnih razgovora s Odjelom za radiološku tehnologiju, identificirane su ključne razlike i sličnosti u obrazovnim sustavima Hrvatske i Slovenije:

Struktura nastave: Slovenski kurikulum karakterizira manji broj predmeta uz veću usmjerenost na praktični rad.

Klinička praksa: Poseban naglasak stavljen je na ljetnu praksu koja se provodi po modelu individualnog mentorstva („jedan na jedan“) u trajanju od nekoliko tjedana.

Diplomski studij: Program nudi specijalizaciju kroz četiri modula: dijagnostička radiologija, radioterapija, nuklearna medicina i ultrazvuk srca.

Realizacija nastavnih aktivnosti

Program mobilnosti obuhvatio je sudjelovanje u teorijskoj nastavi, uključujući predavanja o radiološkom oslikavanju mozga magnetskom rezonancijom, te uvid u praktičnu edukaciju koja se provodi u suradnim kliničkim ustanovama fakulteta.

Zaključak

Zdravstveni fakultet u Ljubljani pruža visok standard obrazovanja zahvaljujući stručnom kadru i naprednim infrastrukturnim uvjetima. Postignuti uvid u slovenski sustav obrazovanja radioloških tehnologa ukazuje na značajan potencijal za daljnju prekograničnu međuinstitucionalnu suradnju. Razmjena metodologija podučavanja i zajednički razvoj modula na diplomskoj razini mogli bi doprinijeti kvaliteti struke u obje države. ■



Fantom-lutke i trenažeri

U procesu edukacije koriste se anatomski vjerni modeli (poput „Newborn Whole Body Phantom“) za optimizaciju ekspozicijskih parametara i dozimetrije. Također, dostupna je oprema za dentalnu radiografiju, mobilni C-luk te trenažeri za invazivne postupke poput postavljanja intravenskih kanila.

Medicinski dijagnostički monitori LG: tehnički opis, benchmark komparacija i cost–benefit analiza

Marko Stošić

Sažetak

U radu se daje sustavni stručni prikaz medicinskih dijagnostičkih monitora LG (3 MP, 5 MP, 8 MP i 12 MP klase) namijenjenih općoj radiologiji i mamografiji. Analiza uključuje verificirane tehničke parametre (rezolucija, luminancija, kontrast), integrirane kalibracijske funkcije te komparativni benchmark s referentnim proizvođačima medicinskih monitora. Posebna pažnja posvećena je cost–benefit analizi implementacije jedinstvenih visoko- rezolucijskih monitora u odnosu na klasične dual-monitor konfiguracije.

Uvod

Digitalna radiologija zahtijeva monitore visoke rezolucije, stabilne luminancije i DICOM GSDF kalibracije. Jedinstveni visoko-rezolucijski monitori (8 MP i 12 MP) omogućuju kontinuirani prikaz slike bez fizičkog razmaka između zaslona, čime se poboljšava ergonomija rada, smanjuje vizualni zamor radiologa te olakšava usporedna analiza serija i prethodnih studija.

Tehnički pregled analiziranih LG modela

Model	Rezolucija	Svjetlina	Kontrast	Primjena
LG 32HL512D	8 MP (3840×2160)	450 cd/m²	1300:1	Opća radiologija
LG 32HQ713D	8 MP (3840×2160)	1000 cd/m²	2000:1	Napredna radiologija
LG 31HN713D	12 MP (4200×2800)	1200 cd/m²	1500:1	Mamografija
LG 21HK512D	3 MP (2048×1536)	1000 cd/m²	1400:1	Vertikalni radiološki
LG 21HQ613D	5 MP (2048×2560)	1100 cd/m²	1800:1	Mamografija

Benchmark komparacija s drugim proizvođačima

Komparacija je temeljena na javno dostupnim tehničkim specifikacijama proizvođača (rezolucija, luminancija, kontrast, kalibracijski sustavi i mamografska namjena). Usporedba uključuje tipične modele ostalih proizvođača, koji predstavljaju referentni standard u dijagnostičkim medicinskim monitorima.

Parametar	LG (8–12 MP)	Proizvođač A (referentno)*	Proizvođač B (referentno)*
Rezolucija	8–12 MP	5–12 MP	5–12 MP
Svjetlina	450–1200 cd/m²	≈800–1000 cd/m²	≈700–900 cd/m²
Kontrast	1300–2000:1	≈1500–1700:1	≈1400–1600:1
Kalibracija	Integrirani senzori (odabrani modeli)	Integrirani senzori + QA ekosustav	Integrirani senzori + QA alati

* Podaci o proizvođaču dostupni na upit autoru.

Cost–benefit analiza implementacije

Implementacija jedinstvenih visoko-rezolucijskih monitora može donijeti organizacijske i ekonomske prednosti u odnosu na klasične dual-monitor konfiguracije. Smanjuje se potreba za dvostrukom kalibracijom, održavanjem i potrošnjom energije, dok integrirani kalibracijski senzori pojednostavljuju QA postupke.

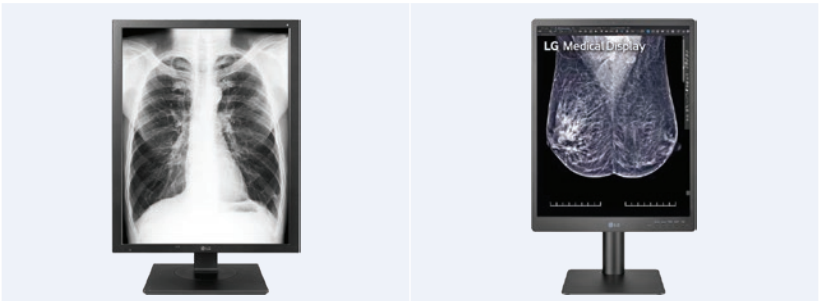
S kliničkog aspekta, kontinuirani prikaz bez fizičkog razmaka između zaslona poboljšava preglednost serija i može skratiti vrijeme očitanja nalaza. Ergonomija radnog mjesta je poboljšana smanjenjem pokreta glave i očiju tijekom interpretacije slika.

Iako je inicijalna cijena velikog medicinskog monitora viša od pojedinačnog manjeg monitora, ukupni trošak vlasništva (TCO) tijekom životnog ciklusa može biti usporediv ili povoljniji zbog smanjenih troškova održavanja, kalibracije i povećane produktivnosti radiološkog odjela.

Ilustrativni prikaz monitora (jednake veličine)



LG 32HL512D | LG 32HQ713D | LG 31HN713D



LG 21HK512D | LG 21HQ613D

Zaključak

Analizirani LG medicinski monitori visoke rezolucije predstavljaju konkurentno rješenje u suvremenoj radiološkoj dijagnostici. Tehničke karakteristike, integrirana kalibracija i mogućnost implementacije jedinstvenog visoko- rezolucijskog zaslona omogućuju usporedivu funkcionalnost s referentnim proizvođačima, uz potencijalne organizacijske i ekonomske prednosti tijekom životnog ciklusa uređaja. ■

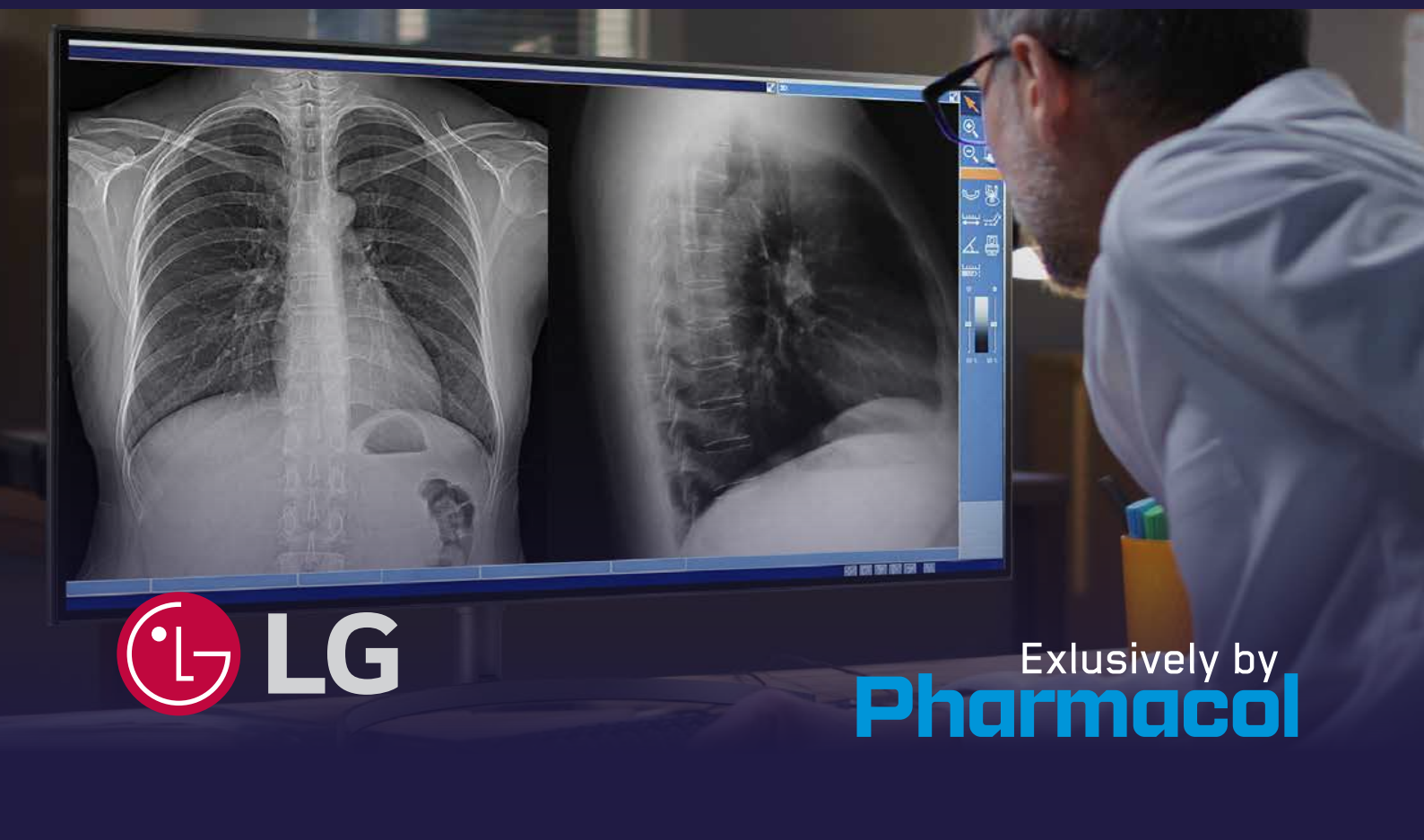
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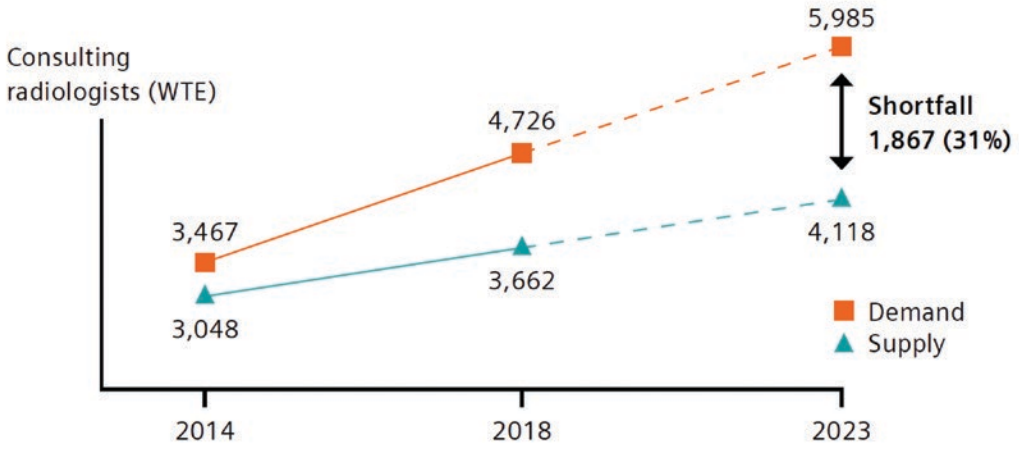


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AI in lung screening and beyond



Artificial intelligence – a second pair of eyes for the radiologist

Lung screening using low-dose CT has been shown to reduce lung cancer-specific mortality. Various countries have already implemented or are currently considering the implementation of lung screening programs.

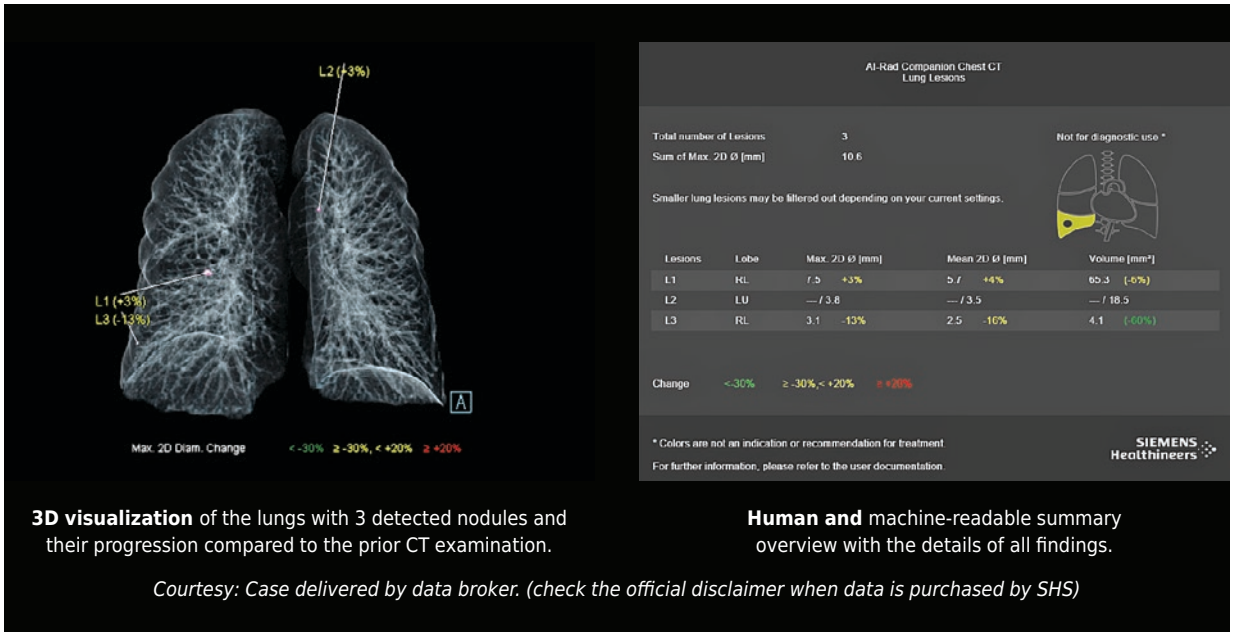
These programs often result in additional workload for medical experts1 in a world where this already a shortfall of radiologists. Artificial intelligence (AI) can potential- ly increase the efficiency of lung screening.[2]

The most recent algorithms have similar performance or are close to double reading by radiologists. AI algorithms that provide a second reading for lung nodule detec- tion and simultaneous assessment of smoking-related comorbidities could increase radiologist confidence, shorten turnaround time, provide better patient outcomes, and eventually reduce costs by improving disease prevention in this high-risk population.1

AI-Rad Companion Chest CT in screening for lung cancer ...

The AI-Rad Companion Chest CT3 is a decision support tool for the radiological assessment of (low-dose) CT images of the chest. It offers an assessment of the lung, to support the radiologist in the main tasks of screening for lung cancer, including:

- Detection of lung nodules (Lung CAD)
- Segmentation and measurements of solid and sub-solid lung nodules
- Correlation of segmented lung nodules of current scan with known priors and quantitative assessment of changes of the correlated data e.g. volume doubling time



3D visualization of the lungs with 3 detected nodules and their progression compared to the prior CT examination.

Human and machine-readable summary overview with the details of all findings.

Courtesy: Case delivered by data broker. (check the official disclaimer when data is purchased by SHS)

... and beyond

At the same time, algorithms have been developed to detect and quantify on chest CT scans other smoking related diseases, including coronary artery calcifications, emphysema, and osteoporosis, that have an impact on morbidity and mortality.1

Therefore, the assessment of the lung includes also:

- Identification of areas with lower Hounsfield units in comparison to a predefined threshold for complete lung and lung lobes.

For the assessment of the function of the heart and the vascular system around the heart, the AI-Rad Companion Chest CT includes:

- Segmentation and measurement of the volume of the heart
- Quantification of the total calcium volume in the coronary arteries
- Segmentation of the Aorta and measurement of maximum diameters at 9 landmarks according AHA guidelines andat the location of maximum diameter of the ascending and descending aorta.This even works on native scans.

And the AI-Rad Companion Chest CT offers also an assessment of the thoracic spine health.



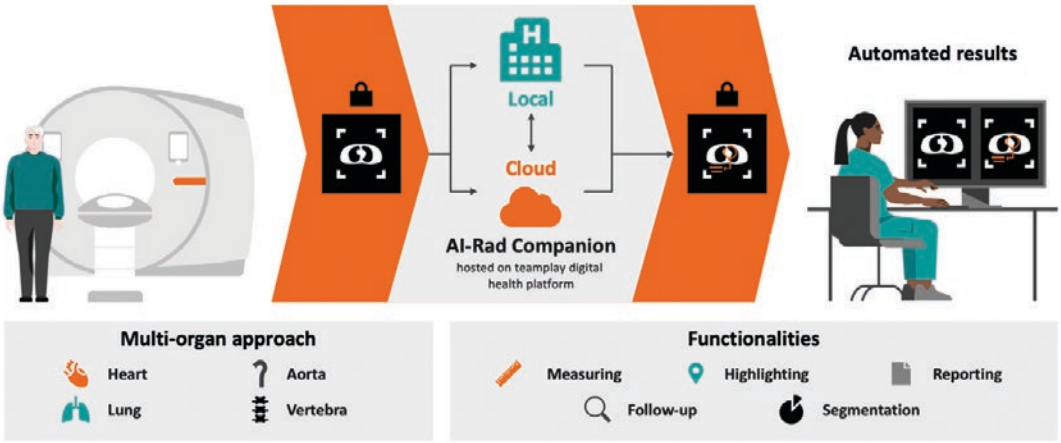
3D visualization of aorta including the calculation of the diameter at different anatomical landmarks

Courtesy: Klinikum Nürnberg, Nuremberg, Germany

Smooth integration of artificial intelligence into the radiology environment

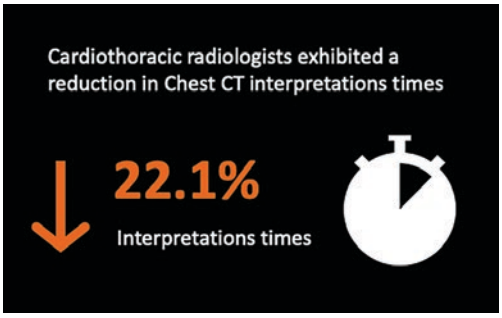
AI-Rad Companion Chest CT can be fully integrated into the image interpretation workflow and the results will be delivered at the radiologist's workplace.

Seamless integration in the reading and reporting workflow including automated measurements and DICOM structured reports may help to drive productivity.



Impact on interpretation times

A scientific study shows that cardiothoracic radiologists exhibited a reduction in Chest CT interpretation times of 22.1% when using the AI-Rad Companion Chest CT. 3,4,5



Next steps

For more info, download the Whitepaper or contact your local sales represen- tative from Siemens Healthineers.

1. The Royal College of Radiologists. Clinical radiology, UK workforce census 2018 report. London: The Royal College of Radiologists, 2019.
2. P.A. Grenier, A.L. Brun & F.Mellot (2022), The potential role of artificial intelligence in lung cancer screening using low-dose computed tomography. Diagnostics, 2022, 12(20), 2435.
3. AI-Rad Companion Chest CT consists of several medical devices and is not commercially available in all countries. Its future availability cannot be ensured.
4. B.Yacoub, A. Varga-Szemes, et.al. (2022). Impact of Artificial Intelligence Assistance on Chest CT Interpretation Times: A Prospective Randomized Study. American Journal of Roentgenology, 2022, 219(5), 743-751.
5. The statements by Siemens Healthineers' customers described herein are based on results that were achieved in the customer's unique setting. Because there is no "typical" hospital or laboratory and many variables exist (e.g., hospital size, samples mix, case mix, level of IT and/or automation adoption) there can be no guarantee that other customers will achieve the same results.

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DRT 2026.

DANI RADIOLOŠKE TEHNOLOGIJE

KONGRES S MEĐUNARODNIM SUDJELOVANJEM

U sklopu Kongresa održati će se:

2. SIMPOZIJ STUDENATA RADIOLOŠKE TEHNOLOGIJE

5–8. studenoga 2026.

Pozivamo sve zainteresirane na sudjelovanje na kongresu *Dani radiološke tehnologije* s međunarodnim sudjelovanjem, koji će se održati od 5. do 8. studenoga 2026. u Hotelu Pinija, Petrčane.

U sklopu kongresa održat će se i *2. Simpozij studenata radiološke tehnologije*.

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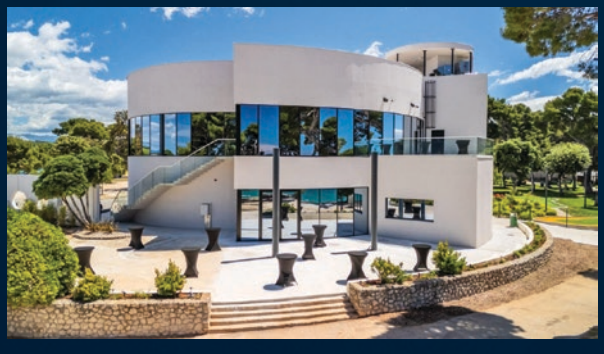
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