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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DOI: 10.55378/rv.50.1.3

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,

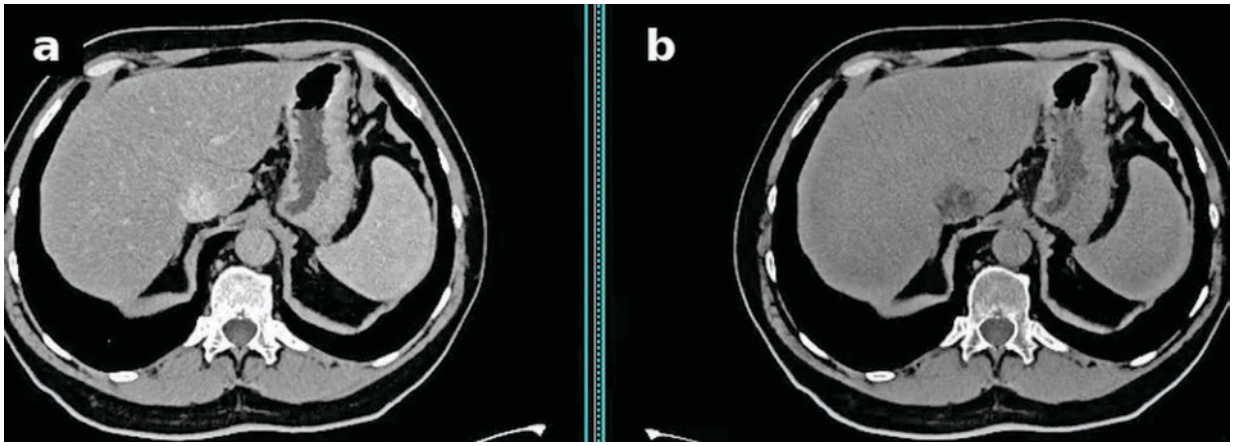


Figure 1. Example of VNC comparison in a haemodynamically stable patient: (a) conventional contrast-enhanced image, (b) virtual non-contrast reconstruction.

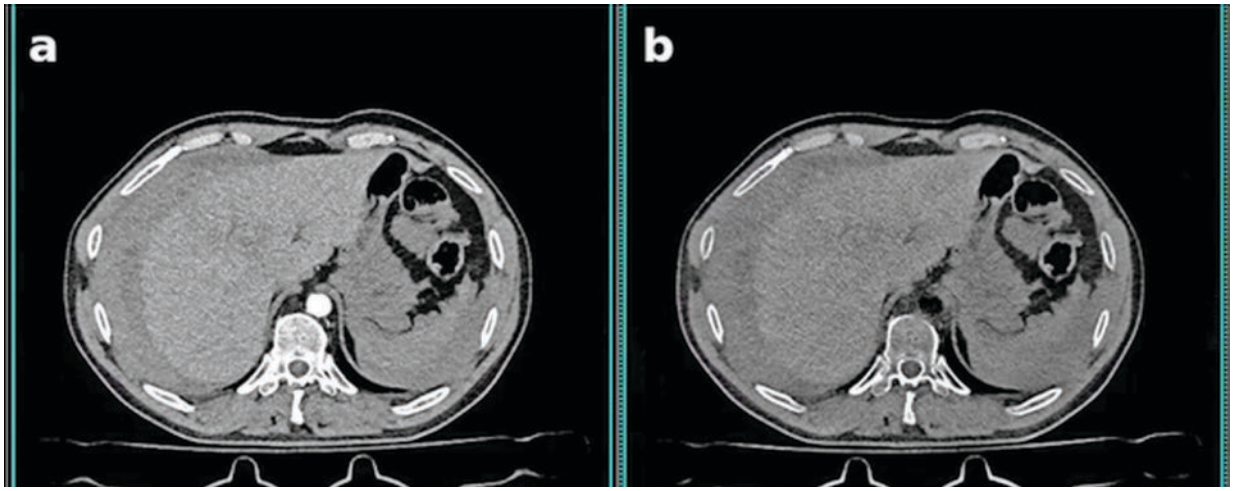


Figure 2. Example of VNC comparison in a haemodynamically unstable patient: (a) conventional contrast-enhanced image, (b) virtual non-contrast reconstruction.

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)