REVIEW PAPER (PREGLEDNI RAD)

The overview of imaging protocols for chest CT

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Abstract

Computed Tomography (CT) is a common method of choice in the diagnosis of thoracic diseases. Since CT operates on the principle of ionizing radiation and frequently involves the use of contrast agents, it is crucial to standardize CT protocols to reduce the need for repeat imaging and, consequently, minimize patient exposure to radiation. The selection of a CT protocol primarily depends on the patient's clinical indications and needs. The main classification of CT protocols distinguishes between the use of contrast agents (CECT) and non-contrast protocols (NCCT). The LDCT protocol is characterized by a low radiation dose and high sensitivity for detecting pulmonary nodules, making it suitable for lung cancer screening. Ultra-LDCT yields satisfactory results in diagnosing pneumonia and pneumothorax. Cine CT enables the assessment of cardiac function throughout the entire cardiac cycle, though it involves a high radiation dose and low temporal resolution.
The use of contrast agents is particularly beneficial for differentiating adjacent non-vascular structures, more accurately identifying vascular anatomy, and improving the detection and characterization of pathological lesions. For diagnosing vascular pathologies, CTA is used, while CTPA is essential for diagnosing pulmonary embolism (PE) with high sensitivity and specificity. TRO CT is useful in cases of acute chest pain to rule out emergencies. Dynamic changes in tissue perfusion are monitored with DCE-CT, which is also valuable in tumor diagnostics. In pediatric applications of CT for the chest, it is essential to emphasize the use of the lowest possible radiation dose and contrast agent to minimize risks.

Keywords: contrast enhanced chest CT; CT; CT angiography; low dose CT; non-contrast chest CT

Abbreviations and acronyms:

ALARA (As Low As Reasonably Achievable), BMI (Body Mass Indeks), CECT (Contrast-Enhanced Computed Tomography), Cine CT (Cinematic Computed Tomography), CPR (Curved-Planar Reformation), COPD (Chronic Obstructive Pulmonary Disease), CT (Computed Tomography), CTA (Computed Tomography Angiography), CTPA (Computed Tomography Pulmonary Angiography), DCE-CT (Dynamic Contrast-Enhanced Computed Tomography), DSCT (Dual-Source Computed Tomography), ECG (Electrocardiogram), HU (Hounsfield Units), i.m. (intramuscular), i.v. (intravenous), ILD (Interstinal Lung Disease), kV (kilovolt), LDCT (Low Dose Computed Tomography), MinIP (Minimum Intensity Projection), MIP (Maximum Intensity Projection), MPR (Multiplanar Reconstruction), MS (Multi Segment), MSCT (Multi Slice Computed Tomography), mAs (milliampere-second), mSv (millisievert), PE (Pulmonary Embolism), PUO (Pyrexia of Unkown Origin), TRO (Triple Rule Out), VRT (Volume Rendering Technique)

Introduction

Computed Tomography (CT) is a fundamental imaging technique in the diagnosis of chest diseases. Due to the increasing range of clinical chest disorders, the frequency of CT examinations is rising. When ordering a CT scan, it is important to consider the risk of increased radiation exposure and the use of intravenous (i.v.) iodinated contrast agents, particularly in young patients and those requiring repeat imaging. Therefore, it is crucial to evaluate the benefits of obtaining diagnostic information against the risks to patient safety. CT protocols should, among other considerations, be standardised in case a patient needs to transfer to another institution for treatment. This would prevent repeat imaging and avoid additional radiation exposure and contrast administration [1]

CT protocols and clinical indications

There are various CT protocols, and it is the clinician's responsibility to select the one that provides the most relevant information for a given clinical indication. CT protocols can be categorised into two main groups: non-contrast computed tomography (NCCT) and contrast-enhanced computed tomography (CECT), which are further divided into smaller, more specific protocol subgroups (Table 1).

Table 1. Types of imaging protocols [1]

CT protocols	
Non-contrast CT protocols	Routine NCCT LDCT Ultra-LDCT Cine CT
Contrast-enhanced CT protocols	Routine CECT
CT angiography protocols	CTA CTPA TRO
Functional imaging	DCE-CT

Contrast agents are chemical substances introduced into the body to enhance the contrast between adjacent structures that naturally exhibit low contrast due to similar attenuation values. They achieve their effect by altering the absorption of X-rays. Based on the method of administration, contrast agents can be applied parenterally (i.v., i.m.), enterally (orally, rectally, via catheters), or locally (injection into body cavities and organs). For CT applications, iodine-based and barium sulphate contrast agents are used. Due to the potential for side effects and allergic reactions, patients are required to sign informed consent prior to contrast-enhanced imaging [2-4].

Chest CT provides significant information about the condition of the lung parenchyma, hila, mediastinum, as well as the pleura, bones, and soft tissue organs of the chest. Consequently, there are numerous indications for CT (Table 2). CT may be chosen as the preferred method in further diagnostic evaluation when abnormalities are detected on other imaging modalities, such as conventional X-ray or ultrasound, or when further investigation is required for symptoms such as persistent cough, hemoptysis, chest pain, and similar conditions. It is commonly used for the assessment and screening of lung cancer, as well as for evaluating emphysema, infections, chronic pulmonary diseases, bronchiectasis, and traumatic injuries [5].

Table 2. Overview of clinical indications and corresponding CT protocols [1]

Klinical indications	CT protocol
Screening – pulmonary metastasis	NCCT
Screening – lung cancer	LDCT
Unexplained dyspnoea – suspected ILD	NCCT
Bronchiectasis	NCCT/LDCT
PUO	CECT (chest and abdomen)
Non-resolving pneumonia	CECT
Malignant pleural effusion, empyema	CECT
Staging and follow-up of lung cancer	CECT
Staging and follow-up of lymphoma	CECT (neck, chest and abdomen)
Unexplained vocal cord palsy	CECT
Evaluation of solitary pulmonary nodules	CECT, DCE-CT
Bunt or penetrating chest trauma	CECT, CTA
Recurrent/significant haemoptysis	CTA
Atypical chest pain (e.g. Pulmonary embolism, aortic dissection)	CTA
Suspected pulmonary thromboembolism	CTPA

Aim of the paper

The aim of this paper is to describe specific imaging protocols for chest CT and explain how to achieve the highest possible image quality with the lowest dose of ionising radiation for the patient. CT protocols with and without the use of contrast agents are compared. A literature search was conducted using key terms on PubMed for the period 2000–2024, yielding 306 studies, of which 33 were relevant to the topic of this paper. In addition to the PubMed database, 13 relevant websites and 2 undergraduate and graduate theses were utilised.

Discussion

NCCT protocols

The purpose of NCCT protocols is to avoid administering contrast agents to patients when it is not necessary. This reduces the risk of adverse side effects, such as hypersensitivity reactions and contrast-induced nephropathy [6].

Routine NCCT

During a routine NCCT of the chest, the patient lies with their arms raised above the head, and the scan direction is craniocaudal. The scan field covers an area from 1 cm

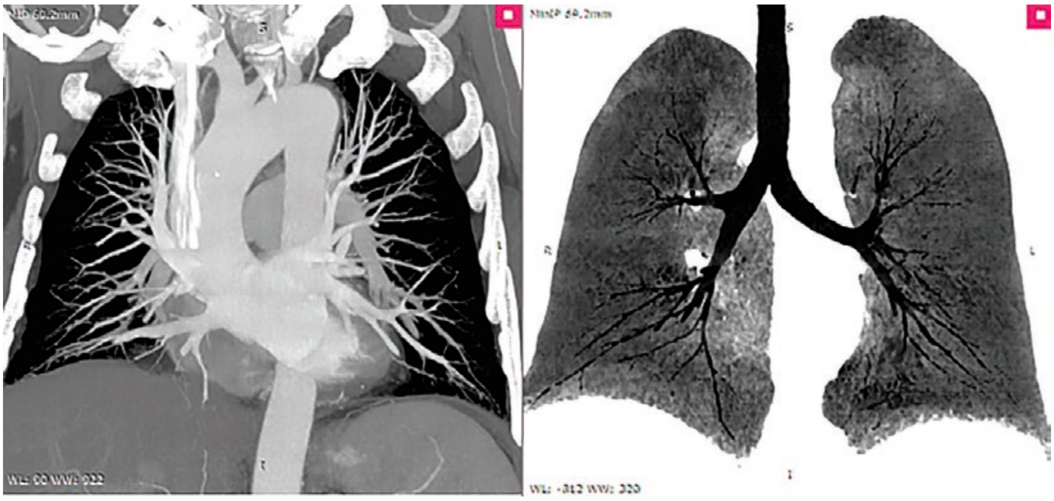

Figure 1. Comparison of images from conventional CT dose (6.7 mSv; left image) and ultra-low CT dose (0.2 mSv; right image)
Source: https://www.radiantviewer.com/dicom-viewer-manual/3dmpr-thickness.html

above the lung apex to below the lung base. Imaging is performed during inspiration. The tube voltage is 120 kV (~ 80-113 kg), and the tube current is 130-200 mAs. Slice thickness ranges from 1.2 to 15 mm, and the image matrix consists of 512x512 pixels. The obtained CT images are reconstructed using a soft tissue window (soft algorithm: 20-30 kernels) and a lung window (sharp algorithm: 60-80 kernels). Volumetric data can be further processed using various techniques, such as multiplanar reconstruction (MPR), maximum intensity projection (MIP), minimum intensity projection (MinIP), and virtual bronchoscopy. MIP is recommended for assessing lung nodules, while MinIP is recommended for airway evaluation (Figure 1). The expected radiation dose for NCCT protocols is 3-8 mSv [1, 6, 7].

Low dose CT (LDCT)

Low dose computed tomography (LDCT) significantly contributes to reducing mortality from lung cancer, which is currently one of the leading causes of death [8]. It is particularly beneficial for patients requiring repeated imaging, as it significantly reduces the cumulative radiation dose, aligning with the ALARA (As Low As Reasonably Achievable) principle [1]. LDCT has become the standard for lung cancer screening by increasing the rate of early detection while maintaining a low radiation dose (Figure 2) [9]. During the procedure, the patient lies supine on the table in a craniocaudal orientation. The scanning field covers an area from 1 cm above the lung apex to below the lung base. The scan is performed during inspiration, and the patient must hold their breath briefly during the imaging. The tube voltage ranges from 80-120 kV, and the tube current is 20-40 mAs [1, 10, 11]. However, some studies suggest that a tube current of 10 mAs does not significantly affect the sensitivity for detecting lung nodules, indicating that this value should be considered the diagnostic threshold [12]. For LDCT, the slice thickness is between 1.2-1.5 mm, and the image matrix is a standard size of 512x512 pixels [1]. Thanks to advanced techniques like iterative reconstructions, LDCT provides satisfactory image quality, with sensitivity and specificity in detecting lung nodules comparable to standard CT [13]. The advantage of iterative algorithms is the reduction of noise while preserving spatial resolution, CT number accuracy, and linearity. In addition to lung information, LDCT can also provide diagnostic data for cardiovascular diseases and

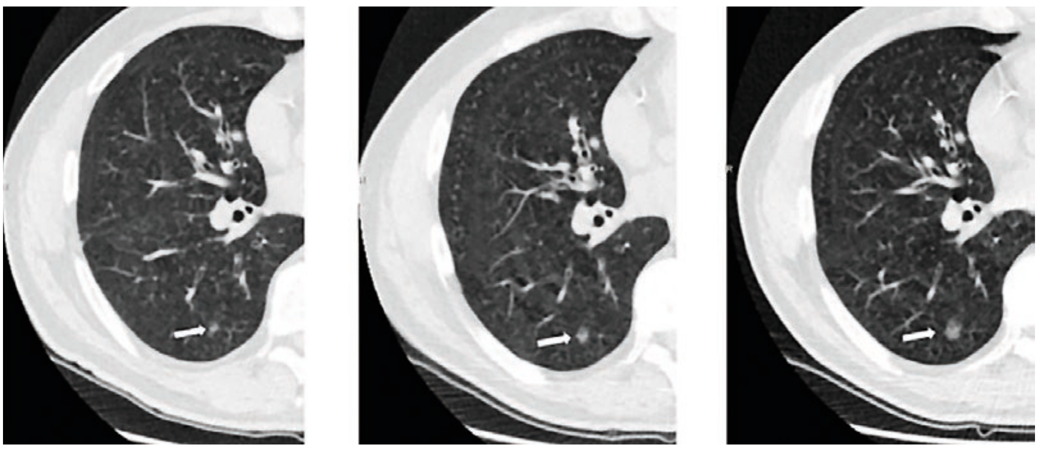

Figure 2. Monitoring of a pulmonary nodule using the LDCT protocol First image (2007) shows a nodule measuring 5.5 mm; second image (2009) shows a nodule measuring 8.5 mm; third image (2012) shows a nodule measuring 11 mm
Source: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3569671/

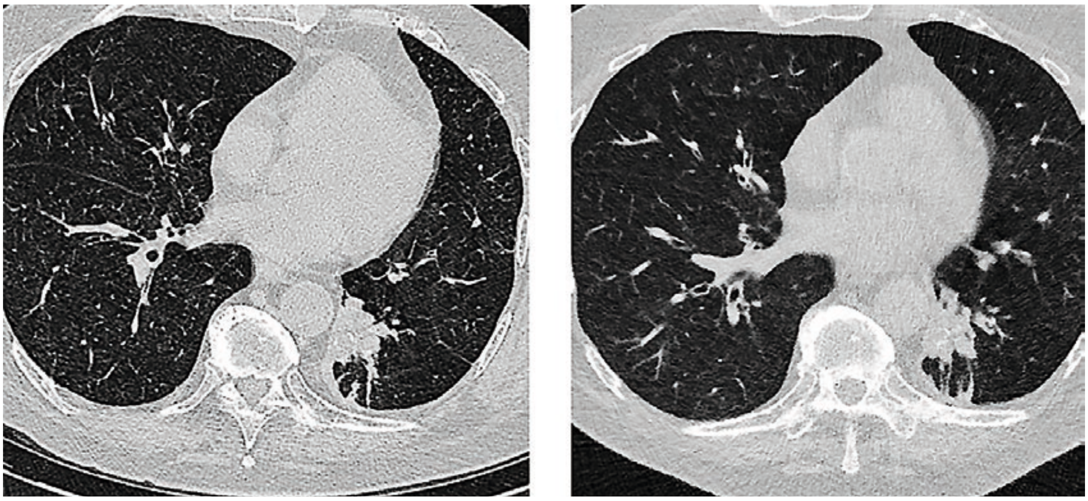

Figure 3. Depiction of chest CT in MIP (left image) and MinIP projection (right image)
Source: https://radiologysa.com.au/subspecialty-services/ultra-low-dose-ct-chest

COPD (Chronic Obstructive Pulmonary Disease) [14]. The expected radiation dose for LDCT protocols is 1-3 mSv [1].

Ultra-LDCT

Low-dose diagnostic methods, including ultra-LDCT, have garnered increasing interest in recent years. It is an excellent choice for lung cancer screening, detecting pneumonia and pneumothorax, as well as for patients requiring repeated imaging or when further clarification of conventional X-ray findings is needed [15, 16]. The tube voltage used in this CT protocol is 120 kV, with a current of 10-20 mAs and a slice thickness of 1 mm. A key feature of ultra-LDCT is the dose of < 1.5 mSv [1, 17]. Although lower doses increase image noise, this can be significantly reduced using iterative reconstruction techniques, thereby improving image quality [18]. There is an ongoing debate about the potential use of ultra-LDCT instead of conventional X-rays for selected indications, even in emergency cases. In images obtained by ultra-LDCT, mucosal airway filling and partial collapse of the left lower lung lobe remain clearly visible (Figure 3). However, the availability and cost of this diagnostic method pose challenges, so it is anticipated that it will not enter routine use in the near future [17, 19].

Cine CT

The assessment of the heart throughout the entire cardiac cycle became possible with the introduction of the multiphase acquisition technique, cine CT (*Cinematic Computed Tomography*). Cine CT, or 4D CT, provides dynamic imaging for functional analysis during systole and diastole. The reconstructed cine images allow the visualisation of contraction and relaxation during the cardiac cycle, offering insights into heart wall motion [20]. The primary drawback of this CT protocol is the high radiation dose, which can range from 6 to 15 mSv, along with low temporal resolution. The use of Multi-Segment (MS) reconstructions can help reduce the dose [20, 21]. In addition to heart imaging, cine CT enables continuous recording of other body movements, such as breathing. It can therefore be used to reliably assess dynamic airway collapse. Once the region of collapse is localised, cine CT with a slice thickness of 2 mm, an X-ray tube voltage of 120 kV, and a current of 53-145 mAs continuously collects data while the patient breathes deeply and slowly. Cine CT has been shown to have comparable diagnostic efficacy to flexible bronchoscopy [1, 22].

CECT PROTOCOLS

The use of contrast agents in CT protocols enables reliable identification of blood vessel anatomy, facilitates the differentiation of adjacent non-vascular structures, and improves the detection and characterization of pathological lesions. Contrast agents are employed in the assessment of mediastinal structures, vascular structures, chronic pleural diseases, and other conditions [23].

Routine CECT

The routine CECT protocol generally retains the same parameters as NCCT, with the addition of contrast administration. CECT of the chest is often extended to include the upper abdomen (liver and adrenal glands) for the initial staging and follow-up of lung cancer, and to the neck and abdomen for assessing Pyrexia of Unknown Origin (PUO) or other malignancies, such as lymphoma (Figure 4) [1]. The patient is positioned supine on the table in a craniocaudal direction, with scanning starting, as before, from 1 cm above the lung apex to the lung base, while breath is held during inspiration. Tube voltage settings of 120 kV and tube current of 150 mAs are typically selected [24]. The scan delay, or the time interval between contrast administration and the start of scanning, depends on the body region being imaged, diagnostic needs, and the patient's physiological factors. To minimise patient dose, factors such as age, sex, height, weight, and underlying pathology should be considered. The use of iterative reconstruction improves image quality by reducing noise [25]. Current CT devices allow the use of 1-1.5 ml/kg of contrast agent for a routine CECT protocol [1]. The expected radiation dose for CECT protocols is approximately 6.1 mSv [26].

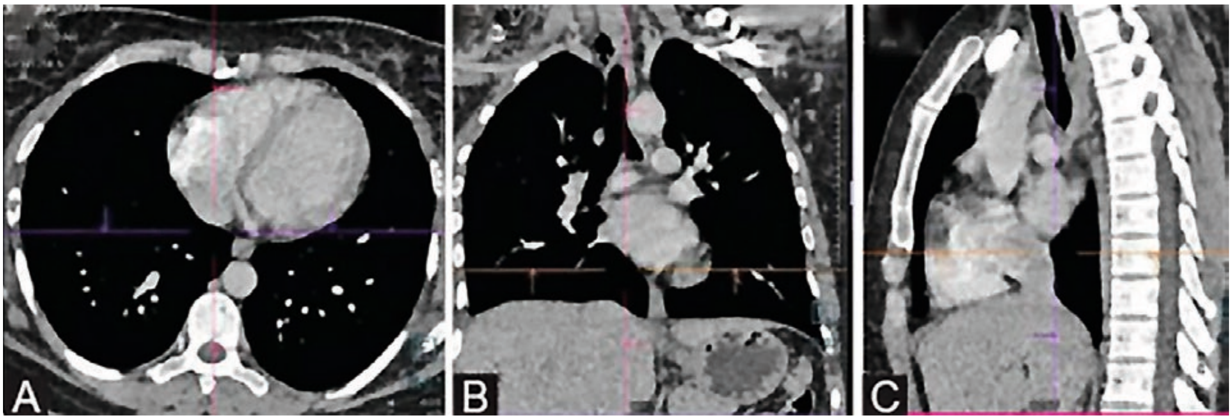

Figure 4. Illustration of routine CECT protocol in axial, coronal, and sagittal planes
Source: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6857267/#ref18

CT an giography (CTA)

The computed tomography angiography (CTA) protocol is used for diagnosing and evaluating various vascular pathologies, such as aneurysms, blood clots, vascular malformations, and vessel dissections (Figure 5) [27]. It is particularly important for diagnosing acute aortic syndrome, which is associated with high morbidity and mortality [28]. The patient is positioned supine on the table in a craniocaudal direction, with scanning conducted from 1 cm above the lung apex to the lower boundary of the L2 vertebra. Imaging is performed during inspiration, with an X-ray tube voltage of 100-120 kV, a tube current of 150 mAs, and a contrast injection rate of 3-5 ml/s. In CTA, bolus tracking is employed to determine the optimal timing for imaging as the contrast passes through the vessels. A region of interest (ROI) is placed on a selected vessel, and a threshold of Hounsfield units (e.g., 130 HU) is used to trigger the scan. The aorta is opacified with contrast for 15-20 seconds, depending on cardiac output. The reconstruction slice thickness is < 2 mm. Reconstruction settings are adjusted with a mediastinal window width of 400 HU and a centre of 40 HU (soft tissue algorithm: 30 kernel). Sagittal plane image reconstruction at a 45° angle displays the aorta from proximal to distal, aiding in aortic pathology assessment [1, 28, 29]. Image quality can be affected by pulsation artefacts, but these can be minimised by synchronising with ECG [28].

CT pulmonary angiography (CTPA)

The primary role of Computed Tomography Pulmonary Angiography (CTPA) is the diagnosis and assessment of pulmonary embolism (PE), the third most common cause of cardiovascular death, following stroke and myocardial infarction. CTPA offers high sensitivity (96-100%) and specificity (89-98%) in detecting PE (Figure 6) [30]. The patient is positioned supine, but in a caudocranial direction to avoid streak artefacts from contrast media in the superior vena cava or subclavian vein. Scanning extends from the lung apex to just below the lung base, except in pregnant women and young patients with minimal suspicion of PE, where it is limited to just above the aortic arch to just below the heart. The scan should be performed during shallow inspiratory breath-hold. The tube voltage is 80-120 kV, depending on the patient's body mass index (BMI), and the tube current is 150-200 mAs. The contrast injection rate is 3-4 ml/s if the patient has a normal resting heart rate [1, 31]. Images are displayed in the pulmonary

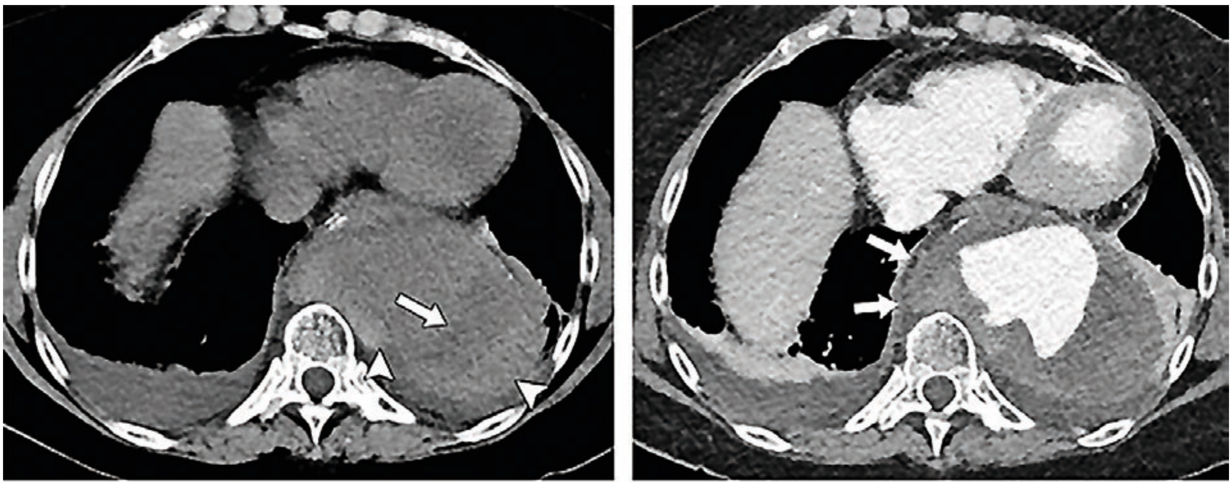

Figure 5. Aneurysm rupture; axial non-contrast image (left) and axial post-contrast image (right)
Source: file:///C:/Users/miaml/Downloads/ko-et-al-2021-chest-ct-angiography-for-acute-aortic-pathologic-conditions-pearls-and-pitfalls.pdf

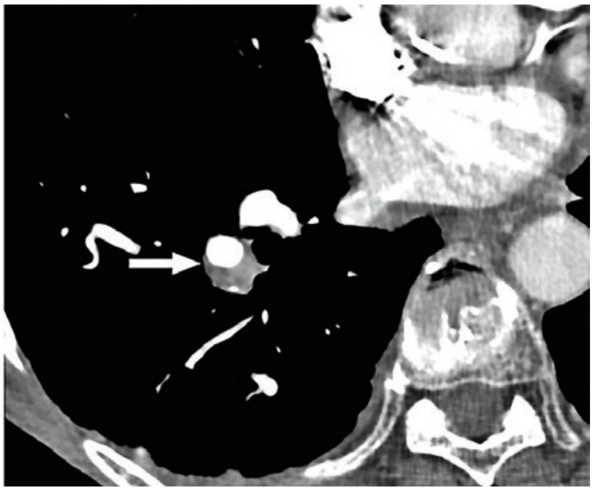

Figure 6. FIGO stage IIA2 cervical cancer (>4 cm) in the sagittal plane on T2-weighted imaging
Source: https://zir.nsk.hr/islandora/object/mef:3661/datastream/PDF/view

window (window width, 1500 HU; window centre, -600 HU), the mediastinal window (window width, 350 HU; window centre, 40 HU), and the PE-specific window (window width, 700 HU; window centre, 100 HU), which is critical as PE may be missed if only viewed in the mediastinal window due to strong contrast [32]. In addition to iterative reconstructions that reduce image noise, MIP reconstruction is also applied [1].

CTA for hemoptysis

Hemoptysis is the expectoration of blood from the tracheobronchial tree, most commonly caused by bronchiectasis, chronic bronchitis, and lung cancer, and represents a life-threatening condition. The expectorated blood typically originates from the bronchial arteries. Computed Tomography Angiography (CTA) is a non-invasive method that can identify the presence, origin, number, and course of systemic thoracic and pulmonary arterial sources of bleeding. After confirming the suspicion of hemoptysis, it is essential to determine its severity, locate the site of bleeding, and identify the underlying cause. The image shows a coronal maximum intensity projection (MIP) of a CT scan with consolidation in the upper lobe and bronchiectasis. Enlarged right-sided orthotopic bronchial arteries (arrow) are visible in the mediastinum (Figure 7). CTA successfully identifies the bleeding site in 70-88% of cases [33]. In a CT protocol for hemoptysis, the patient is positioned supine in a craniocaudal orientation, and the scanning area extends from the base of the neck to the level of the renal arteries, corresponding to the L2 vertebra. The scan is performed during maximal inspiratory breath-hold. The tube voltage is set at 120 kV, with a tube current of 180 mAs, and the slice thickness is 1.25 mm [1, 34]. High-resolution reconstructions of the pulmonary parenchyma are suitable for assessing the cause of bleeding and its impact on the parenchyma, while multiplanar and volumetric reconstructions are used for airway evaluation [33].

TRO CT

Triple Rule Out Computed Tomography (TRO CT) is an angiographic protocol designed to evaluate the aorta, coronary artery, pulmonary artery, and lower half of the thorax in a single scan. It is a valuable tool for assessing patients with acute chest pain in emergency situations, aiding in the exclusion of acute coronary syndrome, pulmonary embolism (PE), or acute aortic syndrome (Figure 8) [1, 35, 36]. The scanning area extends from the upper arch of the aorta to below the heart. The tube voltage is set at 120 kV, and the tube current at 600 mAs. In the absence of tube modulation, the radiation dose for the patient is 18 mSv, while with tube modulation, the dose is reduced to 8.75 mSv. To complete the scan in a single breath-hold, the device must be capable of scanning the required volume using ECG monitoring within a maximum of 15 seconds, necessitating a CT scanner with at least 64 detector rows. ECG synchronisation eliminates motion artefacts related to heartbeats [1, 35]. For image reconstruction, techniques such as multiplanar reconstruction (MPR), maximum intensity projection (MIP), volume rendering technique (VRT), and curved-planar reformation (CPR) can be utilised [37].

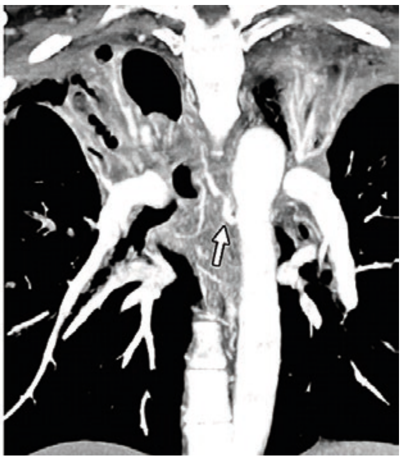

Figure 7. Hemoptysis in a 28-year-old male with cystic fibrosis
Source: https://pubs.rsna.org/doi/10.1148/rg.2021200150

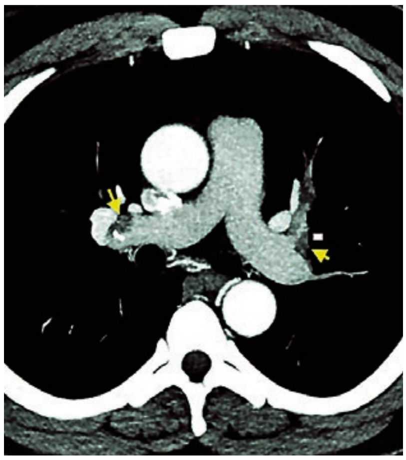

Figure 8. TRO CT image of a 38-year-old male with chest pain: extensive bilateral PE detected
Source: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10028717/

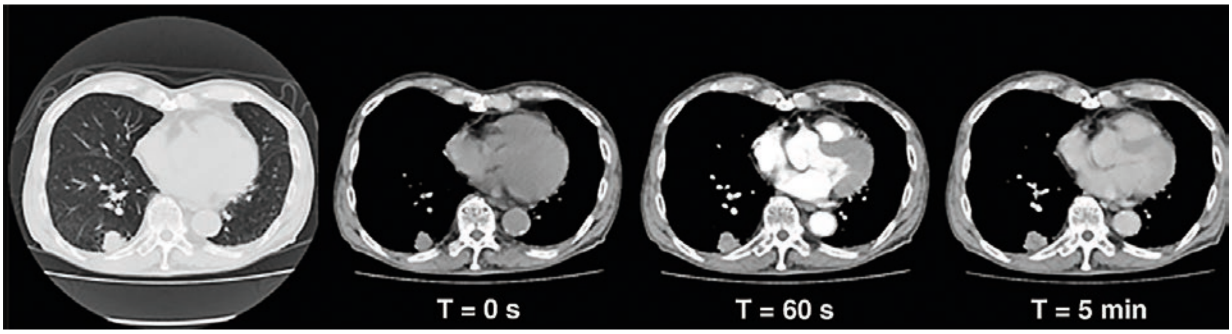

Figure 9. 79-year-old male with lung adenocarcinoma
Source: https://www.ajronline.org/doi/10.2214/AJR.13.11888

DCE-CT

Dynamic Contrast Enhanced Computed Tomography (DCE-CT) is a functional imaging technique that involves capturing a dynamic series of images over time following the administration of contrast agents. It allows for the monitoring of changes in tissue vascularization and perfusion, making it useful in diagnosing various pathological conditions, including tumours. However, DCE-CT has certain limitations, such as when nodules are smaller than 8 mm or in patients with panic attacks or difficulty holding their breath [38]. There are two approaches for conducting DCE-CT protocols. The first is the „first pass" method, which tracks dynamic changes in the distribution of the contrast agent during its initial passage through the target area, usually a tumour or lesion. This approach involves rapid and continuous image acquisition after the contrast injection, followed by the assessment of various perfusion-related parameters. The first image on the left shows a non-contrast scan, while the images on the right display DCE-CT images. „T" denotes the time after the bolus administration of the contrast agent, and the images show a 25 mm nodule in the right lower lobe (Figure 9). This technique is primarily used in research settings [39]. The second method, currently used in clinical practice, involves the analysis of dynamic image series of the nodule before and after contrast administration. This technique allows for the measurement of the nodule's maximum average enhancement in Hounsfield units (HU), with malignant nodules typically demonstrating higher contrast enhancement (an increase of >20 HU at 100 kV) [40, 41]. The recommended tube voltage is 100 kV, while the tube current is determined by the patient's weight: 200 mAs for patients weighing <60 kg, 350 mAs for those between 60-90 kg, and 500 mAs for patients weighing >90 kg. The slice thickness is 3 mm, with reconstructions performed at 2 mm thickness. The nodule should be analysed in the mediastinal window (window width 400 HU, window centre 40 HU) in the axial plane [38].

Paediatric application of CT chest protocols

The use of ionising radiation in paediatrics is always a concern, which is why it is crucial to carefully analyse the benefits and risks and strictly adhere to the ALARA principle [42]. Radiation doses in children are significantly more carcinogenic than equivalent doses in adults for several reasons, including their longer life expectancy, which increases the risk of radiation-induced tumour development [43]. Due to the higher heart rate in children, it is preferable to use faster CT scanners. LDCT protocols are recommended, requiring 34-50 mAs for quality imaging, instead of the standard 100-200 mAs [44, 45]. The optimization of CT protocols aims to achieve diagnostic image quality with minimal radiation exposure [46]. During chest CT imaging in paediatrics, patients lie in the supine position in a craniocaudal direction, with the scan area covering from the lung apex to the lung base. For all patients, including paediatric ones, it is desirable to raise their arms above their heads for chest imaging. Tube voltage is adjusted based on the child's weight; for children weighing less than 9 kg, 80 kV is required, while for those weighing 10-25 kg, 100 kV is used. The X-ray tube current should be reduced to the extent that the resulting image noise does not interfere with the radiologist's interpretation of the CT image. In some cases, the use of contrast agents is necessary, with a dosage of 1.5-2 ml/kg [42, 46, 47]. Improved temporal resolution reduces the need for sedation in the paediatric population. In addition to sedation, ECG synchronisation is also commonly used [44]. The expected dose for children is 2.5 mSv (ages 1-5) and 3 mSv (ages 6-10), compared to the adult dose of 5.9 mSv for chest CT examinations [48].

Conclusion

CT significantly enhances the quality and accuracy of diagnosing various thoracic diseases. Detailed imaging protocols for chest CT and their execution procedures have been thoroughly described. The selection of an appropriate CT protocol is critical for accurate diagnosis and monitoring of various pathological conditions, with protocol choice based on clinical indications and the patient's condition. The primary classification of protocols distinguishes between those using contrast agents and those without. Contraindications for contrast agent use may include poor renal function or the presence of allergies. When determining technical settings, individual patient characteristics, such as body weight and height, must be taken into consideration. Reconstruction methods greatly improve the quality of diagnostic images while reducing the radiation dose. It is important to carefully assess the benefits and risks of using ionising radiation, adhering to the ALARA principle during procedures. Special emphasis is placed on paediatric patients regarding the use of ionising radiation. Through protocol optimization and the application of advanced techniques, such as LDCT and ECG synchronisation, diagnostic image quality is ensured while minimising radiation exposure. In conclusion, continuous protocol optimization and technological advancements contribute to increasing reliability and safety in diagnosing various thoracic pathologies, paving the way for early detection and precise disease monitoring.

All data in this paper are part of the results of the undergraduate thesis „Imaging protocols for chest CT" written at the University Department of Health Studies, University of Split [49].

Pregled slikovnih protokola za CT prsnog koša

Sažetak

Kompjutorizirana tomografija (CT) je česta metoda izbora kada je u pitanju dijagnostika bolesti prsnog koša. Budući da CT radi na principu ionizirajućeg zračenja, a uz to je i česta primjena kontrastnog sredstva, nužno je standardizirati CT protokole ne bi li se smanjila potreba za ponovnim snimanjem, a samim time i izloženost pacijenta zračenju. Odabir CT protokola prvenstveno ovisi o kliničkim indikacijama i potrebama pacijenta. Glavna podjela CT protokola je ona na primjenu kontrastnog sredstva (CECT) i bez primjene (NCCT) istog. LDCT protokol odlikuje se niskom dozom zračenja te visokom osjetljivošću otkrivanja plućnih čvorova, zbog čega se primjenjuje za probir raka pluća. Ultra-LDCT daje zadovoljavajuće rezultate prilikom dijagnosticiranja upale pluća i pneumotoraksa. Procjenu srčane funkcije tijekom cijelog srčanog ciklusa, omogućuje pak cine CT, ali uz visoku dozu zračenja i nisku vremensku rezoluciju. Primjena kontrastnih sredstava prednjači prilikom razlikovanja susjednih nevaskularnih struktura, preciznijeg identificiranja anatomije krvnih žila te bolje detekcije i karakterizacije patoloških lezija. Za dijagnosticiranje vaskularnih patologija, primjenjuje se CTA, dok je CTPA ključna u dijagnosticiranju PE s visokom osjetljivošću i specifičnošću. TRO CT je koristan kod akutne boli u prsima, ne bi li se isključila hitna stanja. Dinamičke promjene u perfuziji tkiva prati DCE-CT, a koristan je i u dijagnostici tumora. Pedijatrijska primjena CT protokola za prsni koš naglašava važnost primjene najniže moguće doze zračenja i kontrastnog sredstva kako bi se rizici sveli na minimum.

Ključne riječi: bezkontrastni CT prsnog koša; CT; CT angiografija; kontrastni CT prsnog koša; niskodozni CT

Literature

1. Bhalla AS, Das A, Naranje P, Irodi A, Raj V, Goyal A. Imaging protocols for CT chest: A recommendation. Indian J Radiol Imaging. 2019 Jul-Sep;29(3):236-246. doi: 10.4103/ijri.IJRI_34_19.
2. Kovačić, MV. Upotreba kontrastnih sredstava u radiologiji [Završni rad]. Split: Sveučilište u Splitu, 2014 (pristupljeno 20.04.2024.). Available at: https://urn.nsk.hr/urn:nbn:hr:176:347628 (22)
3. Ilhana Mujala (2021.): Kontrastna radiografija, ABC DOC, Edukativna medicinska platforma za studente i zdravstvene radnike (pristupljeno 28.04.2024.). Available at: https://www.abc-doctors.com/kontrastna-radiografija
4. RadiologyInfo.org (2022.): Contrast Materials (pristupljeno 29.04.2024.). Available at: https://www.radiologyinfo.org/en/info/safety-contrast
5. Guilford Radiology (2024.): CT Chest Cat Scan Quick Reference Guide for Patients (pristupljeno 29.04.2024.). Available at: https://guilfordradiology.com/patient-portal/ct-chest-quick-reference-guide
6. Murphy A, Feger J, Bickle I, CT chest non-contrast (protocol). Reference article, Radiopaedia.org (pristupljeno 1.05.2024.). Available at: https://doi.org/10.53347/rID-75149
7. Oregon Health & Science University (2024.): CT Protocols, Diagnostic Radiology (pristupljeno 01.05.2024.). Available at: https://www.ohsu.edu/school-of-medicine/diagnostic-radiology/ct-protocols
8. Aberle DR, Adams AM, Berg CD, Black WC, Clapp JD, Fagerstrom RM, et al. Reduced lung-cancer mortality with low-dose computed tomographic screening. N Engl J Med. 2011 Aug 4;365(5):395-409. doi: 10.1056/NEJMoa1102873.
9. Siegel RL, Miller KD, Wagle NS, Jemal A. Cancer statistics, 2023. CA Cancer J Clin. 2023 Jan;73(1):17-48. doi: 10.3322/caac.21763. PMID: 36633525.
10. American Association of Physicists (2015.): Lung Cancer Screening CT (pristupljeno 05.05.2024.). Available at: https://www.aapm.org/pubs/CTProtocols/documents/LungCancerScreeningCT.pdf
11. Lifespan (2022.): CT Scan (Computed Tomography/CT Scan) – RIH – LUNG SCREENING SIEMENS DEFINITION AS+ PROTOCOL (pristupljeno 05.05.2024.). Available at: https://www.lifespan.org/sites/default/files/lifespan-files/documents/centers/ct-scan/protocols/chest/plus/as-plus-lung-screening.pdf
12. Christe A, Torrente JC, Lin M, Yen A, Hallett R, Roychoudhury K, et al. CT screening and follow-up of lung nodules: effects of tube current-time setting and nodule size and density on detectability and of tube current-time setting on apparent size. AJR Am J Roentgenol. 2011 Sep;197(3):623-30. doi: 10.2214/AJR.10.5288. PMID: 21862804.
13. Hu QJ, Liu YW, Chen C, Kang SC, Sun ZY, Wang YJ, et al. Prospective Study of Low- and Standard-dose Chest CT for Pulmonary Nodule Detection: A Comparison of Image Quality, Size Measurements and Radiation Exposure. Curr Med Sci. 2021 Oct;41(5):966-973. doi: 10.1007/s11596-021-2433-z.
14. Rampinelli C, Origgi D, Bellomi M. Low-dose CT: technique, reading methods and image interpretation. Cancer Imaging. 2013 Feb 8;12(3):548-56. doi: 10.1102/1470-7330.2012.0049. PMID: 23400217; PMCID: PMC3569671.
15. Radiology SA (2024.): Ultra-low dose CT chest (pristupljeno 06.05.2024.). Available at: https://radiologysa.com.au/subspecialty-services/ultra-low-dose-ct-chest

16. Kristjánsdóttir B, Taekker M, Andersen MB, Bentsen LP, Berntsen MH, Dahlin J, et al. Ultra-low dose computed tomography of the chest in an emergency setting: A prospective agreement study. Medicine (Baltimore). 2022 Aug 5;101(31):e29553. doi: 10.1097/MD.0000000000029553. PMID: 35945776; PMCID: PMC9351905.
17. Macri F, Greffier J, Pereira FR, Mandoul C, Khasanova E, Gualdi G, Beregi JP. Ultra-low-dose chest CT with iterative reconstruction does not alter anatomical image quality. Diagn Interv Imaging. 2016 Nov;97(11):1131-1140. doi: 10.1016/j.diii.2016.06.009.
18. Jiang B, Li N, Shi X, Zhang S, Li J, de Bock GH, et al. Deep Learning Reconstruction Shows Better Lung Nodule Detection for Ultra-Low-Dose Chest CT. Radiology. 2022 Apr;303(1):202-212. doi: 10.1148/radiol.210551.
19. van den Berk, Inge A H et al. „Ultra-low-dose CT versus chest X-ray for patients suspected of pulmonary disease at the emergency department: a multicentre randomised clinical trial." *Thorax* vol. 78,5 (2023): 515-522. doi:10.1136/thoraxjnl-2021-218337
20. Peper J, Suchá D, Swaans M, Leiner T. Functional cardiac CT-Going beyond Anatomical Evaluation of Coronary Artery Disease with Cine CT, CT-FFR, CT Perfusion and Machine Learning. Br J Radiol. 2020 Sep 1;93(1113):20200349. doi: 10.1259/bjr.20200349.
21. Choi YJ, Ahlman MA, Mallek M, Cork TE, Chen MY, Bluemke DA, Sandfort V. Cardiac cine CT approaching 1 mSv: implementation and assessment of a 58-ms temporal resolution protocol. Int J Cardiovasc Imaging. 2020 Aug;36(8):1583-1591. doi: 10.1007/s10554-020-01863-z.
22. Heussel CP, Hafner B, Lill J, Schreiber W, Thelen M, Kauczor HU. Paired inspiratory/expiratory spiral CT and continuous respiration cine CT in the diagnosis of tracheal instability. Eur Radiol. 2001;11(6):982-9. doi: 10.1007/s003300100818. PMID: 11419175.
23. P Whiting, N Singatullina, JH Rosser, Computed tomography of the chest: I. Basic principles, *BJA Education*, Volume 15, Issue 6, December 2015, Pages 299–304 (pristupljeno 02.05.2024.). Available at: https://doi.org/10.1093/bjaceaccp/mku063
24. Lifespan (2022.): CT Scan (Computed Tomography/CT Scan) – RIH – CHEST SIEMENS DEFINITION AS+ PROTOCOL (pristupljeno 03.05.2024.). Available at: https://www.lifespan.org/sites/default/files/lifespan-files/documents/centers/ct-scan/protocols/chest/plus/as-plus-chest.pdf
25. Iezzi R, Larici AR, Franchi P, Marano R, Magarelli N, Posa A, et al. Tailoring protocols for chest CT applications: when and how? Diagn Interv Radiol. 2017 Nov-Dec;23(6):420-427. doi: 10.5152/dir.2017.16615. PMID: 29097345; PMCID: PMC5669541.
26. RadiologyInfo.org (2022.): Radiation dose (pristupljeno 06.05.2024.). Available at: https://www.radiologyinfo.org/en/info/safety-xray
27. RadiologyInfo.org (2022.): CT Angiography (CTA) (pristupljeno 06.05.2024.). Available at: https://www.radiologyinfo.org/en/info/angioct
28. Ko JP, Goldstein JM, Latson LA Jr, Azour L, Gozansky EK, Moore W, et al. Chest CT Angiography for Acute Aortic Pathologic Conditions: Pearls and Pitfalls. Radiographics. 2021 Mar-Apr;41(2):399-424. doi: 10.1148/rg.2021200055. PMID: 33646903.
29. Lifespan (2022.): CT Scan (Computed Tomography/CT Scan) – RIH – CHEST ANGIOGRAM SIEMENS DEFINITION AS+ PROTOCOL (pristupljeno 07.05.2024.). Available at: https://www.lifespan.org/sites/default/files/lifespan-files/documents/centers/ct-scan/protocols/chest/plus/as-plus-chest-cta.pdf
30. Zantonelli G, Cozzi D, Bindi A, Cavigli E, Moroni C, Luvarà S, et al. Acute Pulmonary Embolism: Prognostic Role of Computed Tomography Pulmonary Angiography (CTPA). Tomography. 2022 Feb 14;8(1):529-539. doi: 10.3390/tomography8010042. PMID: 35202207; PMCID: PMC8880178.
31. Albrecht MH, Bickford MW, Nance JW Jr, Zhang L, De Cecco CN, Wichmann JL, et al. State-of-the-Art Pulmonary CT Angiography for Acute Pulmonary Embolism. AJR Am J Roentgenol. 2017 Mar;208(3):495-504. doi: 10.2214/AJR.16.17202.
32. Wittram C. How I do it: CT pulmonary angiography. AJR Am J Roentgenol. 2007 May;188(5):1255-61. doi: 10.2214/AJR.06.1104. PMID: 17449768.
33. Cordovilla R, Bollo de Miguel E, Nuñez Ares A, Cosano Povedano FJ, Herráez Ortega I, Jiménez Merchán R. Diagnosis and Treatment of Hemoptysis. Arch Bronconeumol. 2016 Jul;52(7):368-77. English, Spanish. doi: 10.1016/j.arbres.2015.12.002.
34. Fukamatsu F, Yamada A, Yamada K, Nonaka T, Aonuma T, Tsukahara Y, et al. Serial assessment of computed tomography angiography for pulmonary and systemic arteries using a reduced contrast agent dose for the diagnosis of systemic artery-to-pulmonary artery shunts. Jpn J Radiol. 2024 May;42(5):460-467. doi: 10.1007/s11604-023-01520-0.
35. Halpern EJ. Triple-rule-out CT angiography for evaluation of acute chest pain and possible acute coronary syndrome. Radiology. 2009 Aug;252(2):332-45. doi: 10.1148/radiol.2522082335. PMID: 19703877.
36. Russo V, Sportoletti C, Scalas G, Attinà D, Buia F, Niro F, et al. The triple rule out CT in acute chest pain: a challenge for emergency radiologists? Emerg Radiol. 2021 Aug;28(4):735-742. doi: 10.1007/s10140-021-01911-8.
37. Eltabbakh, A.R., Dawoud, M.A., Langer, M. *et al.* 'Triple-rule-out' CT angiography for clinical decision making and early triage of acute chest pain patients: use of 320-multislice CT angiography. *Egypt J Radiol Nucl Med* **50**, 3 (2019) (pristupljeno 03.05.2024.). Available at: https://doi.org/10.1186/s43055-019-0003-1
38. Qureshi NR, Shah A, Eaton RJ, Miles K, Gilbert FJ; Sputnik investigators. Dynamic contrast enhanced CT in nodule characterization: How we review and report. Cancer Imaging. 2016 Jul 18;16(1):16. doi: 10.1186/s40644-016-0074-4. PMID: 27430260; PMCID: PMC4948091.
39. Jeong YJ, Lee KS, Jeong SY, Chung MJ, Shim SS, Kim H, et al. Solitary pulmonary nodule: characterization with combined wash-in and washout features at dynamic multi-detector row CT. Radiology. 2005 Nov;237(2):675-83. doi: 10.1148/radiol.2372041549. PMID: 16244276.
40. O'Connor JP, Tofts PS, Miles KA, Parkes LM, Thompson G, Jackson A. Dynamic contrast-enhanced imaging techniques: CT and MRI. Br J Radiol. 2011 Dec;84 Spec No 2(Spec Iss 2):S112-20. doi: 10.1259/bjr/55166688. PMID: 22433822; PMCID: PMC3473907.
41. Miles KA, Lee TY, Goh V, Klotz E, Cuenod C, Bisdas S, et al. Experimental Cancer Medicine Centre Imaging Network Group. Current status and guidelines for the assessment of tumour vascular support with dynamic contrast-enhanced computed tomography. Eur Radiol. 2012 Jul;22(7):1430-41. doi: 10.1007/s00330-012-2379-4.
42. Young C, Xie C, Owens CM. Paediatric multi-detector row chest CT: what you really need to know. Insights Imaging. 2012 Jun;3(3):229-46. doi: 10.1007/s13244-012-0152-5.
43. National Cancer Institute: Radiation Risks and Pediatric Computed Tomography (CT): A Guide for Health Care Providers (pristupljeno 07.05.2024.). Available at: https://www.cancer.gov/about-cancer/causes-prevention/risk/radiation/pediatric-ct-scans
44. Matoš, A. Napredne CT metode za redukciju doze zračenja i optimizaciju kvalitete slike u pedijatrijskoj radiologiji [Diplomski rad]. Split: Sveučilište u Splitu, 2023 (pristupljeno 09.05.2024.). Available at: https://urn.nsk.hr/urn:nbn:hr:176:122178
45. Rapp JB, Ho-Fung VM, Ramirez KI, White AM, Otero HJ, Biko DM. Dual-source computed tomography protocols for the pediatric chest – scan optimization techniques. Pediatr Radiol. 2023 Jun;53(7):1248-1259. doi: 10.1007/s00247-022-05468-7.
46. Nagy E, Tschauner S, Schramek C, Sorantin E. Paediatric CT made easy. Pediatr Radiol. 2023 Apr;53(4):581-588. doi: 10.1007/s00247-022-05526-0.
47. North Star Radiology (2022.): Pediatric CT Protocols (18 years old or less) (pristupljeno 08.05.2024.). Available at: https://northstarradiology.com/wp-content/uploads/2017/07/Protocols-Pediatric-CT-12-2015.pdf
48. Chodick G, Kim KP, Shwarz M, Horev G, Shalev V, Ron E. Radiation risks from pediatric computed tomography scanning. Pediatr Endocrinol Rev. 2009 Dec;7(2):29-36. PMID: 20118891; PMCID: PMC6298033.
49. Milanović Litre M. Imaging protocols for chest CT (Završni rad). Split: Sveučilište u Splitu, Sveučilišni odjel zdravstvenih studija; 2024 (pristupljeno 12.9.2024.) Available at: https://repo.ozs.unist.hr/islandora/object/ozs%3A1672/datastream/PDF/view