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Research Article

Contrast Media Effects and Radiation Dose Assessment in Contrast Enhanced Computed Tomography

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Abstract

Modern CT imaging walks a fine line between diagnostic precision and patient safety. Recent research highlights how smarter scanning techniques can protect patients—especially vulnerable groups like children—from unnecessary radiation exposure while maintaining high-quality results. A comprehensive review of literature was conducted to identify studies related to contrast media effects and radiation dose assessment in CECT. Relevant data including Location, Type of research, Objective, Method, Findings, Conclusion, authors and year of publications were extracted, analyzed and reported. For young patients undergoing abdominal scans, radiation doses can carry concerning long-term risks. This has led to calls for stricter dose guidelines tailored to pediatric cases. Meanwhile, new reconstruction software allows radiologists to slash radiation and contrast dye amounts in chest and kidney scans without losing critical diagnostic details. Some cardiac CT protocols now use dual-scan methods that cut exposure while delivering equally clear images of heart defects. Innovative approaches are proving that less can indeed be more. By pairing advanced imaging algorithms with reduced contrast doses, clinics can now lower organ radiation exposure significantly while still getting the answers they need. The research also reveals an often-overlooked factor: the contrast dye itself can boost radiation absorption in sensitive organs like kidneys by startling amounts sometimes over 70% depending on scan timing. These findings point to a new era of precision in CT scanning. By adopting smarter protocols, embracing new technologies, and carefully timing contrast delivery, healthcare providers can continue delivering life-saving diagnoses while minimizing risks. The future of medical imaging lies in doing more with less less radiation, less contrast, and less uncertainty about patient safety.

Keywords: computed tomography (CT); radiation dose optimization; contrast media; diagnostic reference levels; iterative reconstruction; patient safety

Introduction

In the realm of contemporary medicine, the utilization of contrast-enhanced computed tomography (CECT) has emerged as an indispensable and crucial diagnostic imaging technique, which is routinely employed in clinical practice. This method, which involves the administration of contrast agents, has revolutionized the field of radiology by providing a holistic and comprehensive understanding of both the anatomical and functional aspects of internal tissues and structures. The integration of contrast agents into the CECT procedure has heralded a paradigm shift in medical imaging, enabling healthcare professionals to glean invaluable insights into the pathophysiology of various diseases and conditions [37]. Particularly when compared to non-contrast scans, the utilization of contrast material in CT scans may lead to an escalation in radiation exposure. The objective of this systematic review of literature is to extensively examine the present body of research pertaining to the assessment of radiation dose in the context of CECT. Through the amalgamation of existing knowledge and evidence, this review endeavors to provide a nuanced comprehension of how CECT contributes to the cumulative radiation exposure of patients and the strategies employed to mitigate these hazards.

Radiation dose evaluation holds significant importance in the field of medical imaging, as it directly impacts the balance between benefits and risks associated with CECT examinations. This evaluation encompasses a comprehensive assessment, which involves the measurement of dose indices such as the computed tomography dose index (CTDI) and dose-length product (DLP), as well as the estimation of effective dose (ED). The latter estimation takes into consideration the varying sensitivity of different organs and tissues towards ionizing radiation, thereby providing a more comprehensive perspective on the risks associated with radiation [27,28]. Through a systematic and rigorous analysis of existing literature, this study aims to provide insights into various factors that influence radiation dose in CECT, including patient demographics, imaging protocols, and technological advancements. Furthermore, it will explore the evolving guidelines and strategies for dose optimization that have been implemented to ensure that CECT scans are conducted with the minimal radiation exposure possible while maintaining diagnostic efficacy.

This study aimed to review the previous works to assess the impacts of contrast media and radiation dose assessment. The outcome of this review will be a valuable resource for radiologists, medical physicists, and healthcare policymakers, as it synthesizes the latest evidence and best practices related to radiation dose assessment in CECT. By critically examining the current state of knowledge, this review seeks to contribute to the ongoing efforts to strike a balance between diagnostic accuracy and patient safety in the realm of contrast-enhanced computed tomography.

Materials and Method

Literature Search Strategy

A comprehensive literature search was conducted to identify relevant articles and studies related to contrast-enhanced computed tomography (CECT) with a specific emphasis on the effects of contrast media and the assessment of radiation doses. The following databases were utilized: PubMed/MEDLINE, Google Scholar, Scopus, Web of Science, science direct, research gate and academia. The search strategy employed a combination of keywords, including "contrast-enhanced computed tomography," "contrast media," "radiation dose," "radiation exposure," "CT scan," and related terms. The search was limited to articles published in English, with no restrictions on publication date up to the knowledge cutoff date in July, 2024 (Samaila *et al.*, 2022)

Search Flowchart

A flowchart detailing the search and selection process, including the number of articles retrieved, excluded, and included, was created to ensure transparency as shown below:

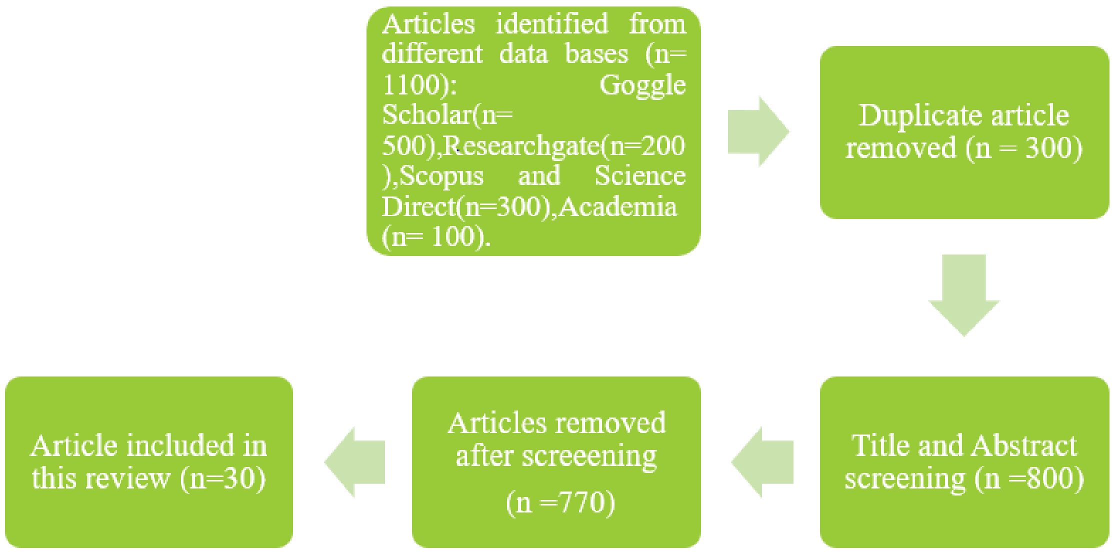

Figure 1: Flow chart diagram of the full literature screening process

Data Extraction and synthesis

Two independent reviewers conducted the initial screening of titles and abstracts to identify potentially relevant articles. In case of discrepancies, a third reviewer was consulted to reach a consensus. Full-text articles of the selected studies were then retrieved and assessed for eligibility. The extracted data were synthesized to provide an overview of the current knowledge regarding contrast media effects and radiation dose assessment in CECT. Findings were summarized in table 1 below (Samaila *et al.*, 2023; Samaila and Rilwanu, 2023)

Ethical Considerations

Ethical considerations were taken into account to ensure that the literature review adhered to ethical standards for research and publication. Proper citation and referencing were ensured to give credit to the original authors of the studies included in the review.

Results and Discussion

The use of contrast media in CECT can increase image quality and enhance the visualization of certain structures or abnormalities. However, the use of contrast media can also lead to an increase in radiation dose to the patient. Studies have shown that the radiation dose delivered during CECT can vary depending on factors such as the type of contrast media used, the scanning protocol, and the patient's age. It is important to optimize the scanning parameters and establish diagnostic reference levels to minimize radiation risks. Additionally, the use of alternative contrast agents, such as gold nanoparticles, has shown promise in optimizing CT imaging by reducing radiation dose while enhancing image contrast. The table below summarized the findings from the literature.

S/N	Location	Type of research	Objective	Method	Findings	Conclusion	References
1	Saudi Arabia	Infant and children radiation doses and cancer risks estimation during abdominal computed tomography (CT)	explores the infant and children radiation doses during computed tomography (CT) abdomen and estimates the cancer risk from the procedure using a total of 87 patients	-	The mean, standard deviation, and range of patients' age (years) are 13 ± 4.5 (2–17). The mean and range of the air kerma length product (PKL(mGy.cm)) and volume CT air kerma index (Cvol (mGy)) were 1740 (157.8–8440.3) (mGy.cm) and 9.8 (2.09–45.77) (mGy) per CT abdomen procedure, respectively.	The results of this study showed that child risk is high compared to other CT examinations. Therefore, patients' dose optimization and proper establishment of a diagnostic	**[37]**

					The mean and range of the effective dose (mSv) per procedure are 34 (3.14–176.8). The average radiogenic risk per CT procedure is one cancer incidence per 250 CT-enhanced abdomen procedures. The mean and range of total irradiation even are 4.0 (2.0–8.0) times per procedure.	reference level (DRL) are necessary to preventing avoidable radiation risks.	
2	China	Investigation of the clinical value of adaptive statistical iterative reconstruction in reducing the iodixanol content and radiation dose during contrast-enhanced chest CT scan for patients diagnosed with lung masses/nodules based on the analysis of image quality	To investigate the clinical value of adaptive statistical iterative reconstruction in reducing the iodixanol content and radiation dose during contrast-enhanced chest CT scan for patients diagnosed with lung masses/nodules based on the analysis of image quality	SPSS version 22.0 (IBM SPSS Statistics for Windows, released in 2013, IBM Corp., Armonk, NY, USA) was used for statistical analysis And mathematical equations	The two groups obtained non-significantly different subjective scores for five structures detected in the lung window and five structures detected in the mediastinal window, as well as the overall image ($P > 0.05$ for all). Both the two-group images obtained diagnosis-acceptable scores (≥ 3 points) on displays of 10 structures and overall image quality. The mean CT value of vessels (100 kVp vs. 120 kVp: 314.90 ± 23.42 vs. 308.93 ± 21.40; $P > 0.05$), standard deviation (13.03 ± 0.88 vs. 12.83 ± 0.90; $P > 0.05$), and contrast-to-noise ratio (20.77 ± 2.20 vs. 20.36 ± 1.94; $P > 0.05$) were not significantly different between two groups. However, the CT dose index, dose-length product, effective dose, and total iodine dose were reduced by 27.58%, 36.65%, 36.59%, and 22.86% in the 100-kVp group compared to the 120-kVp group	The ASIR showed great potential in reducing the radiation dose and iodine contrast dose, while maintaining good image quality and providing strong confidence for the diagnosis of lung cancer	**[16]**
3	Australia	Comparison of radiation dose, contrast enhancement, image noise and heart rate variability in electrocardiography (ECG)-gated computed tomography (CT) ventricular volumetry using a three-dimensional (3D) threshold-based segmentation between the conventional single scan and dual-focused scan methods in patients with congenital heart disease	To compare radiation dose, contrast enhancement, image noise and heart rate variability in electrocardiography (ECG)-gated computed tomography (CT) ventricular volumetry using a three-dimensional (3D) threshold-based segmentation between the conventional single scan and dual-focused scan methods in patients with congenital heart disease	Gafchromic films (XR-CT2)	The fndings indicatd that Volume CT dose index, dose-length product, and effective dose estimates, in group 1 were significantly higher than those in group 2 (28.4 ± 24.6 mGy vs. 9.7 ± 4.5 mGy, 636.5 ± 572.9 mGy cm vs. 379.5 ± 192.4 mGy cm, 8.9 ± 8.0 mSv vs. 5.3 ± 2.7 mSv, 8.2 ± 6.4 mSv vs. 5.0 ± 2.2 mSv, respectively; p values 0.05). Image noise measured in the air showed no significant differences between groups 1 and 2 (5.6 ± 1.9 HU vs. 5.5 ± 1.1 HU; $p > 0.05$). The proportion of heart rate variability ≥ 20 beats per minute in group 1 (15.6 %, 5/32) was significantly higher than that in group 2 (3.1 %).	Compared with the conventional single scan method, the dual focused scan method can provide a lower radiation dose with comparable contrast enhancement and image noise for ECG-gated CT ventricular volumetry using a 3D threshold-based segmentation in patients with congenital heart disease.	**(Geso *et al.*, 2020)**
4	**USA**	Radiation dose reduction while preserving observer performance and CT number at multi-phase dual energy (DE) renal CT	to determine if Prior iterative reconstruction (PIR) could reduce radiation dose while preserving observer performance and CT number at multi-phase dual energy (DE) renal CT	Validated noise insertion and PIR	Twenty-three patients had 49 renal lesions (11 solid renal neoplasms). CT number was nearly identical between techniques (mean CT number difference: unenhanced 2 ± 2 HU; enhanced 4 ± 4 HU). AUC for malignancy was similar between multi-phase routine dose DE and lower dose PIR images [per patient: 0.950 vs. 0.916 ($p = 0.356$); per lesion: 0.931 vs. 0.884 ($p = 0.304$)]. Per patient sensitivity was also similar (78% routine dose vs. 82% lower dose [$p \geq 0.99$]), as was specificity (91% routine dose vs. 93% lower dose PIR [$p > 0.99$]), with similar findings on a per lesion level. Subjective image quality was also similar ($p = 0.34$)	Prior iterative reconstruction is a new reconstruction method for multi-phase CT examinations that promises to facilitate radiation dose reduction by over 50% for multi-phase DE renal CT exams without compromising CT number or observer performance.	**(Navin *et al.*, 2019)**
5	**Japan**	Decreasing the radiation dose for contrast-enhanced	To compare the estimated radiation dose of 50%	Welch's *t*-test and	For the arterial phase, the mean organ doses normalized to CTDIvol	As compared with stdCM with the 120	(Sakabe *et al.*, 2020)

		abdominal spectral CT with a half contrast dose: a matched-pair comparison with a 120 kVp	reduced iodine contrast medium (halfCM) for virtual monochromatic images (VMIs) with that of standard CM (stdCM) with a 120 kVp imaging protocol for contrast-enhanced CT (CECT).	Monte-Carlo simulation tool (Impact MC; VAMP GmbH, Erlangen, Germany) was used to simulate the radiation dose delivered to each patient for NECT and CECT	for stdCM and halfCM were 1.22 and 1.29 for the liver, 1.50 and 1.35 for the spleen, 1.75 and 1.51 for the pancreas, and 1.89 and 1.53 for the kidneys. As compared with non-enhanced CT, the average increase in the organ dose was significantly lower for halfCM (13.8% ± 14.3 and 26.7% ± 16.7) than for stdCM (31.0% ± 14.3 and 38.5% ± 14.8) during the hepatic arterial and portal venous phases ($p < 0.01$).	kVp imaging protocol, a 50% reduction in CM with VMIs with the 55 keV protocol allowed for a substantial reduction of the average organ dose of iodine CM while maintaining the iodine CT number for CECT.	
6	China	Comparison of Application Value of Different Radiation Dose Evaluation Methods in Evaluating Radiation Dose of Adult Thoracic and Abdominal CT scan	To explore the differences among volumetric CT dose index (CTDIvol), body-specific dose assessment (SSDEED) based on effective diameter (ED), and SSDEWED based on water equivalent diameter (WED) in evaluating the radiation dose of adult thoracic and abdominal CT scanning.	workstation measurement software and SPSS22.0 software was used	The AP, LAT, ED, and WED of groups B, E, C, and F were higher than those of groups A and D, and those of groups C and F were higher than those of groups B and E ($P < 0.05$). The fsize,ED and fsize, WED of groups B, E, C, and F are lower than those of groups A and D, and those of groups C and F are lower than those of groups B and E ($P < 0.05$). CTDIvol, SSDEED, and SSDEWED in groups B, E, C, and F are higher than those in groups A and D, and those in groups C and F are higher than those in groups B and E ($p < 0.05$). In the same group, patients with chest- and abdomen-enhanced have higher SSDEWED and SSDEED than CTDIvol, patients with chest-enhanced CT scans have higher SSDEWED than SSDEED, and patients with abdomen-enhanced CT scans have higher SSDEED than SSDEWED ($P < 0.05$).	In Conclusion ,CTDIvol and ED-based SSDEED underestimated the radiation dose of the subject exposed, where the patient was actually exposed to a greater dose. However, SSDEWED based on WED considers better the difference in patient size and attenuation characteristics, and can more accurately evaluate the radiation dose received by patients of different sizes during the chest and abdomen CT scan.	(He *et al.*, 2022)
7	Iran	The effect of contrast material on radiation dose during computed tomography pulmonary angiography	To evaluate the impact of contrast material on radiation dose for adults undergoing computed tomography pulmonary angiography (CTPA)	Physiologically based pharmacokinetic (PBPK) model and Monte Carlo N-Particle extended code (MCNPX) version 2.6.0. were used	It was shown that the estimated radiation dose to the lungs could be 31–40% (27–34%) larger when considering the effect of iodinated contrast administration with injection rate of 5 (3) mL/s. Moreover, the effective dose for contrast-enhanced CT (CECT) would be utmost 10–13% larger than that for non-enhanced CT (NECT). The radiation doses to the other organs in-/outside the scanned region would be decreased if the scan performed on time. In case of late scanning, absorbed dose decreases slightly for lungs (~15–20%) whereas becomes (~10% or more) higher than its NECT value for some organs such as heart muscle, kidneys, and spleen.	To sum up, the late scanning ($\Delta t > 5$ s after the end of injection) is not recommended because of higher dose delivered to other organs than the lungs (particularly heart muscle).	**(Karami *et al.*, 2020)**
8	Durham	The Effect of Contrast Material on Radiation Dose at CT: Part I. Incorporation of Contrast Material	to develop a method to calculate the relative dose increase when a computerized tomography scan (CT) is	Pharmacokinetic Model	The data shown for the three patients exhibit an average relative dose increase between 22% for liver and 74% for kidneys; also, spleen (34%), pancreas (28%), and thyroid	The method developed allows a simple evaluation of the dose increase when iodinated	**(Sahbaee, Segars, *et al.*, 2017)**

		Dynamics in Anthropomorphic Phantoms	carried out after administration of iodinated contrast medium, with respect to the same CT scan in absence of contrast medium.		(48%) show a remarkable average increase	contrast medium is used in CT scans, basing on the increment in Hounsfield units observed on the patients' organs. Since many clinical protocols employ multiple scans at different circulatory phases after administration of contrast medium, such a method can be useful to evaluate the total dose to the patient, also in view of potential clinical protocol optimizations.	
9		Investigatio of the effect of iodine uptake on tissue/organ absorbed doses from CT exposure and its implications in CT dosimetry	To investigate the effect of iodine uptake on tissue/organ absorbed doses from CT exposure and its implications in CT dosimetry	Monte Carlo methods	The mean iodine uptake range during contrast-enhanced CT imaging was found to be 0.02-0.46% w/w for the investigated tissues, while the maximum value recorded was 0.82% w/w. For the same CT exposure, iodinated tissues were found to receive higher radiation dose than non-iodinated tissues, with dose increase exceeding 100% for tissues with high iodine uptake. Administration of iodinated contrast medium considerably increases radiation dose to tissues from CT exposure	Radiation absorption ability of organs/tissues is considerably affected by iodine uptake • Iodinated organ/tissues may absorb up to 100 % higher radiation dose • Compared to non-enhanced, contrast-enhanced CT may deliver higher dose to patient tissues • CT dosimetry of contrast-enhanced CT imaging should encounter tissue iodine uptake	**(Perisinakis *et al.*, 2018)**
10	Massachusetts	Reducing Radiation Dose and Contrast Medium Volume With Application of Dual-Energy CT in Children and Young Adults	to assess if dual-source dual-energy CT (DS-DECT) can be used with lower radiation doses and contrast material volumes than single-energy CT (SECT) in children and young adults	The descriptive statistical analysis was performed in Excel (version 2016, Microsoft) and CARE Dose 4D [Siemens Healthineers]	Mean patient ages and weights ± SD in DS-DECT (10 ± 6 years old, 38 ± 23 kg) and SECT (11 ± 7 years old, 43 ± 29 kg) groups were not significantly different ($p > 0.05$). Respective SSDEs for chest DS-DECT (4.0 ± 2.1 mGy), chest SECT (6.1 ± 4.4 mGy), abdomen-pelvis DS-DECT (5.0 ± 5.0 mGy), and abdomen-pelvis SECT (8.3 ± 4.0 mGy) were significantly different ($p = 0.003$-0.005). Contrast material volume for DS-DECT examinations was 19-22% lower compared with the weight- and body region-matched scans obtained with SECT. Image quality of DECT was acceptable in all patients	In children and young adults, chest and abdomen-pelvis DS-DECT enables substantial radiation dose and contrast volume reductions compared with weight- and region-matched SECT.	**(Tabari *et al.*, 2020)**
11		Comparison of radiation dose and image quality of DECT and SECT abdominopelvic examinations in children as a function of patient size	To compare radiation dose and image quality of DECT and SECT abdominopelvic examinations in children as a function of patient size		DECT SSDEs were lower across all effective patient diameters compared with SECT (mean: 8.5±1.8 mGv vs. 9.3±2.0 mGv, respectively, $P \leq 0.001$). DECT CTDIvol was lower compared to SECT (mean: 5.6±2.4 mGv vs. 6.1±2.7 mGv, respectively, $P \leq 0.001$) except in the smallest diameter group (0.05).	In children, regardless of effective diameter, contrast-enhanced abdominopelvic DECT can be performed with a similar or lower dose and similar image quality compared with SECT examinations.	**Marilyn et al (2021)**
12	US	Contribution of dose increase from iodine to biological effect	To establish the contribution of dose, increase from iodine to biological effect.	Phantom and simulated CT system	The presence of iodinated-contrast in CT increased the organ doses by 2% to 50% on average. Typical values were heart (50%±7%), kidney (19%±7%), and liver (2%±3%). The corresponding	Mean foci per cell and organ dose both increase in the presence of a contrast agent. The former, however, is at least	(Abadi *et al.*, 2016)

					increase in the average foci per cell was 107%±19%, indicating biological effect of iodine was greater than what would be anticipated from the iodine-initiated increase in radiation dose alone.	twice as large as the latter, indicating that iodine contributes to an increase in the probability of DNA damage not only as a consequence of increased x-ray energy deposition but also from other mechanisms. Hence iodine radiation dose, while relevant to be included in estimating the risk associated with contrast-enhanced CT, still can underestimate the biological effects.	
13	Norway	Impact of iodine concentration and scan parameters on image quality, contrast enhancement, and radiation dose in Thoracic CT	To investigate the impact of varying contrast medium (De Farias *et al.*) densities and x-ray tube potentials on contrast enhancement (CE), image quality, and radiation dose in thoracic computed tomography (CT) using two different scanning techniques	Analysis was performed using SPSS Version 26 (IBM Inc, Armonk, NY, USA)	A constant volume CT dose index (CTDIvol) depending on phantom size and automatic dose modulation was tested. CE (HU) and image quality (contrast-to-noise ratio, CNR) were measured for all combinations of CM density and tube potential. A reference threshold of CE and kVp was defined as ≥ 200 HU and 120 kVp. For the medium-sized phantom, with a specific CE of 100–600 HU, the diagnostic CE (200 HU) at 70 kVp was ~ 90% higher than at 120 kVp, for both scan techniques ($p < 0.001$). Changes in CM density/specific HU together with lower kVp resulted in significantly higher CE and CNR ($p < 0.001$). When changing only the kVp, no statistically significant differences were observed in CE or CNR ($p \geq 0.094$), using both dose modulation and constant CTDIvol.	For thoracic CT, diagnostic CE (≥ 200 HU) and maintained CNR was achieved by using lower CM density in combination with lower tube potential (< 120 kVp), independently of phantom size.	**(Solbak *et al.*, 2020)**
14	Thailand	Impact of iodinated contrast media concentration on image quality for dual-energy CT and single-energy CT with low tube voltage settings	To investigate the impact of low tube voltage settings on single-energy computed tomography (SECT) and rapid kV switching dual-energy CT (DECT) with reduced concentrations of iodinated CM	ATCM systems with different noise index (NI) settings were set, and the images were reconstructed using ASiR-V	Tube voltage settings of 70 kVp together with a 40% reduction in the iodinated CM are suitable for the small phantom size, while those of 80 kVp and 20% reduction are suitable for the medium and large sizes. This allows radiation doses to be reduced by 12%–30%. Values of CNR and contrast for DECT are better than those for SECT with the same NI setting.	Diagnostic reference of image quality can be maintained by using SECT with lower tube voltage and DECT with reductions of iodinated CM concentration and radiation dose. Therefore, the NI setting can be increased when DECT is used to achieve a similar image quality.	**(Sookpeng and Martin, 2023)**
15		Investigations of CT Dose with Contrast Agent and Its Effects on the CTDI	to utilize the effects of the contrast media "CM" used in computed tomography "CT" which is used to enhance subject contrast on the delivered CT via its inclusion into the CT dose index "CTDI", and to introduce a simple method to determine this effect via the available CT numbers at the imaged targets		Measured dose effects due to the inclusion of the CM varied depending on the concentration. The increase in dose is estimated to be about 17% for 20% contrast media in the target while that for 10% by volume is around 6.6%. These are estimated from the CT numbers. Patients' data also shows the influence of the CM on the CTDI values.	The dosimetric effects of the contrast media are included in the CTDI and can be estimated by using the CT numbers obtained.	**Geso et al (2020)**
16	Kingdom of Bahrain		to establish national diagnostic reference levels (NDRLs) for		The NDRLs were calculated for each clinical indication as the third quartile of the CT scanners' median	The NDRLs were established for the most common	**(Hasan *et al.*, 2022)**

			computed tomography (CT) examinations performed on adult patients based on clinical indications, patient gender, and size in the Kingdom of Bahrain		values of CTDIvol and DLP. They were also calculated based on the patient's gender (for the head) and their size (for the abdomen-pelvis and CAP clinical indications). From 1665 CT examinations, the NDRLs in terms of CTDIvol were 67, 66, 67, 13, 14, 17, 19, and 15 mGy for symptoms of headache, trauma, stroke, flank pain, renal colic, abdominal pain, diverticulitis/appendicitis and oncologic follow-up, respectively. Likewise, these were 1206, 1286, 1152, 690, 779, 972, 1061, and 1073 mGy cm in terms of DLP, respectively. For large-size patients, NDRLs in terms of CTDIvol were on average 1.7 times higher than those from medium size patients for all the clinical indications in the abdomen-pelvis and CAP regions.	clinical indications in the Kingdom of Bahrain. They are higher than those established in the literature, thus emphasizing the urgent need for an optimization strategy for better patient radiation protection.	
17	Germany	How low can we go in contrast-enhanced CT imaging of the chest? A dose-finding cadaver study using the model-based iterative image reconstruction approach	To study dose-finding cadavers using a model-based iterative image reconstruction approach	Statistical analysis, the intraclass correlation coefficient (ICC), and the Wilcoxon test were used.	Results Mean CT dose index values (mGy) were as follows: D0/FDBR = 10.1 ± 1.7, D1 = 6.2 ± 2.8, D2 = 5.7 ± 2.7, D3 = 3.5 ± 1.9, D4 = 1.8 ± 1.0, and D5 = 0.9 ± 0.5. Mean IQ ratings were as follows: D0 = +1.8 ± 0.2, D1 = +1.5 ± 0.3, D2 = +1.1 ± 0.3, D3 = +0.7 ± 0.5, D4 = +0.1 ± 0.5, and D5 = −1.2 ± 0.5. All values demonstrated a significant difference in baseline	Compared to ASIR, MBIR allowed for a significant dose reduction of 82% without impairment of IQ. This resulted in a calculated mean effective dose below 1 mSv.	(Mueck *et al.*, 2015)
18	Sudan	Survey of Patients Radiation Doses in Computed Tomography Chest Imaging: Proposal of Diagnostic Reference Level.	To evaluate patient doses during chest CT procedures in a certain radiological hospital to establish a local diagnostic reference level (DRL).	The data was analyzed using the Statistical Package for the Social Sciences (SPSS) version. 16.0 Chicago, Illinois, USA, SPSS Inc.). Descriptive statistics, Bivariate statistics (t-test, ANOVA). DLP (mGy.cm) and CTDIvol (mGy) were analyzed to obtain the third quartile value as a reference	A total of 78 CT chest procedures were performed during one year. The range of patient dose per CT procedure was 126.0 mGy.cm to 1104.0 mGy.cm per chest procedure. The CTDIvol ranged between 3.0 mGy to 20 mGy per procedure.	Patient dose variation attributed to CT modality and image acquisition protocol. Patients were exposed to a higher radiation dose in 64 slices compared to the other two modalities due to the use of sequential technique at the latter one. A diagnostic reference level was proposed for chest CT procedures.	**(Elnour *et al.*, 2015)**

				value for DRL for each hospital and the overall average			
19	Ghana	Radiation dose reduction without degrading image quality during computed tomography examinations: Dosimetry and quality control study	To reduce Radiation dose without degrading image quality during computed tomography	Computed Tomography Dose Index (CTDI) phantoms, RTI barracuda system with electrometer, and CT dose Profiler detector	Doses to patients using the default head sequence protocol had an average CTDI vol value of 65.45 mGy and a range of 7.10-16.80 mGy for thorax, abdomen, and pelvis examinations while the new protocol had an average CTDI vol of 58.32 mGy for the head and a range of 3.83-15.24 mGy for the truck region. The DLP value for default head scans decreased from an average of 2279.85 mGy.cm to 874.53 mGy.cm with the new protocol. Tube potentials (KV) and tube current-time (mAs) had an effect on spatial resolution and low contrast detectability as well as doses.	From the new protocols, lower values of KV and mAs together with other factors were enough to produce an acceptable level of image quality which leads to adequate diagnosis without unnecessary doses to patients.	**(Acquah *et al.*, 2014)**
20	Italy	Balancing Radiation and Contrast Media Dose in Single-Pass Abdominal Multidetector CT: Prospective Evaluation of Image Quality	To balance Radiation and Contrast Media Dose in Single-Pass Abdominal Multidetector CT: Prospective Evaluation of Image Quality	Workstation (OsiriX Imaging Software, Geneva, Switzerland) with standard window settings (Window Width = 400 Hounsfield units [HU]; Window Level = 50 HU) and Tukey honest significant difference test for multiple comparisons.	Although peak hepatic enhancement was 152 ± 16, 128 ± 12, and 101 ± 14 Hounsfield units ($P < .001$) for groups A, B, and C, respectively, no significant differences were observed in the corresponding SNRL with 9.2 ± 1.4, 9.1 ± 1.2, and 9.2 ± 3. Radiation (mGy × cm) and contrast media dose administered were 476 ± 147 and 155 ± 27 for group A, 926 ± 291 and 130 ± 16 for group B, and 1981 ± 451 and 106 ± 15 for group C, respectively ($P < .001$). None of the studies was graded as poor or inadequate by both readers, and the prevalence-adjusted bias-adjusted kappa ranged between 0.48 and 0.93 for all but one criteria.	A constant image quality in CE-MDCT can be obtained by balancing radiation and contrast media doses administered to patients of different age.	(Camera *et al.*, 2015)
21	North Carolina	The Effect of Contrast Material on Radiation Dose at CT: Part II. A Systematic Evaluation across 58 Patient Models	To estimate the radiation dose as a result of contrast medium administration in a typical abdominal computed tomographic (CT) examination across a library of contrast material–enhanced computational patient models.	Monte Carlo simulation software	The results from the patient models subjected to the injection protocol indicated up to a total of 53%, 30%, 35%, 54%, 27%, 18%, 17%, and 24% increase in radiation dose delivered to the heart, spleen, liver, kidneys, stomach, colon, small intestine, and pancreas, respectively. The biologically relevant dose increase concerning the dose at an unenhanced CT examination was in the range of 0%–18% increase for the liver and 27% for the kidney across 58 patient models.	The administration of contrast medium increases the total radiation dose. However, radiation dose, while relevant to be included in estimating the risk associated with contrast-enhanced CT, may still not fully characterize the total biological effects. Therefore, given the fact that many CT diagnostic decisions would be impossible without the use of iodine, this study suggests the need to	(Sahbaee, Abadi, *et al.*, 2017)

						consider the effect of iodinated contrast material on the organ doses of patients undergoing CT studies when designing CT protocols.	
22	Mexico	A prospective evaluation of the contrast, radiation dose, and image quality of contrast-enhanced CT scans of pediatric abdomens using a low-concentration iodinated contrast agent and low tube voltage combined with a 70% ASIR algorithm	To quantitatively and subjectively assess the image quality of and radiation dose for an abdominal enhanced computed tomography (CT) scan with a low tube voltage and a low concentration of iodinated contrast agent in children	5-point scale, paired t-tests, Mann-Whitney U tests, and mathematical modeling were used	There was no significant difference in age, weight, or body mass index (BMI) between the two groups (all P>.5). The iodine load in Group A (5517.3±3197.2 mg I) was 37% lower than that in Group B (8772.1±8474.6 mg I), although there was no significant difference between them (P=.111). The DLP and the CT dose index (CTDIvol) for Group A were also lower than for Group B, but were not statistically significantly different (DLP, 104 mGy-cm±45.81 vs 224.5 mGy-cm±45.83; CTDIvol, 1.44 mGy±0.50 vs 2.08 mGy±1.87, all P>.05). The mean arterial and portal venous enhancement (255.33 HU±83.42, 146.41 HU±23.45, respectively), noise (AP 14.96 HU±2.09, PVP 16.30 HU±3.21), CNRs (AO 14.54±7.12, PV 5.07±1.73) and SNRs (AO 20.76±6.76, PV 12.43±3.24) for Group A were similar to Group B (enhancement: 226.55 HU±77.71, 138.69 HU±33.22; noise: 14.92 HU±3.12, 15.36 HU±3.48; CNRs: 12.96±7.14, 5.16±2.28; SNRs: 19.13±7.30, 12.69±4.22; all P>.05). The mean scores of the quality of the AP and PVP images in Group B were 4.31±0.53 and 4.35±0.52, respectively, while the scores obtained in Group A were 4.29±0.51 and 4.25±0.51; there were no statistically significant differences between the two groups.	The scanning protocol using a low tube voltage (80 kV) together with 70% ASIR and a low-concentration iodinated contrast agent (270 mg I/mL) enables a 37% reduction in iodine load and a 30% reduction in radiation dose while maintaining compatible image quality.	**(Wang *et al.*, 2016)**
23	*India*	Effect of Iodinated Contrast Media on Serum Electrolyte Concentrations in Patients Undergoing Routine Contrast Computed Tomography Scan Procedure	To evaluate the changes in serum electrolyte concentrations with intravenous iodinated contrast media administration in the adult population and to correlate the changes in electrolyte concentrations, if any, with the demographic profile of the patients.	Eschweiler Combiline analyzer based on ion-selective electrode principle	The mean age of the study population in our study was 40.11 ± 20.51 years. We found that changes in serum sodium and chloride concentration after administration of contrast media are significant (sodium: 136.29 ± 3.53 vs. 132.49 ± 6.36 mmol/L and chloride: 100.03 ± 0.70 vs. 97.53 ± 0.70 mmol/L). Sodium concentration shows more decrease in females compared to males after administration of iodine contrast. The most probable reason for this decrease in serum electrolytes was secondary changes to hemodilution due to the high osmolality of the contrast.	Attending physicians must be alert for such possibilities of changes in electrolytes after contrast administration and be prepared to treat any adversity if one occurs.	**(Sankaran *et al.*, 2019)**
24	Russia	The role of atorvastatin in the frequency of contrast-induced acute kidney injury (CI-AKI) in patients with cardiovascular diseases (CVD) undergoing computed tomography (CT) with intravenous contrast media	To assess the role of atorvastatin in the frequency of contrast-induced acute kidney injury (CI-AKI) in patients with cardiovascular diseases (CVD) undergoing computed tomography (CT) with intravenous contrast media	Statistical analysis was used.	CI-AKI was diagnosed in 4 (3.96%) patients. At the same time, it was not possible to establish statistically significant relationships (p0.05) between risk factors and the development of CI-AKI. Statins can be a successful way to prevent this complication.	Cardiovascular diseases may increase the risk of CI-AKI after computed tomography with intravenous contrast media administration. Therefore, it is recommended to evaluate the serum creatinine	**(Vasin *et al.*, 2022)**

						concentration in such patients	
25	Khon Kaen	Adverse Reactions from Contrast Media in Patients Undergone Computed Tomography at the Department of Radiology, Srinagarind Hospital	To study the profile of adverse reactions to iodinated contrast media	Naranjo's algorithm and adverse reactions questionnaire	A total of 105 cases (9.5%) reported adverse reactions (57% male; 43% female); among whom 2% were iso-osmolar vs. 98% low-osmolar. Diagnoses included hepatoma and cholangiocarcinoma (24.8%), colorectal cancer (9.5%), breast cancer (5.7%), cervical cancer (3.8%), lung cancer (2.9%), bone cancer (1.9%), and others (51.5%). Underlying diseases included hypertension and diabetes mellitus type 2. Mild, moderate, and severe adverse reactions accounted for 92, 5 and 3%, respectively. The respective groups of escalating symptoms included (a) mild urticaria, itching, rash, nausea, vomiting, dizziness, and headache; (b) moderate hypertension, hypotension, dyspnea, tachycardia and bronchospasm; and (c) severe laryngeal edema, profound hypotension, and convulsions. All reactions could be anticipated per Naranjo's algorithm.	Mild to moderate adverse reactions to low-osmolar contrast media were most common and these occurred immediately after administration. For patient safety and better outcomes, improving the identification of patients likely to have an adverse reaction is essential	**(Suecharoen and Kanpittaya, 2017)**
26	Korea	Varied incidence of immediate adverse reactions to low-osmolar non-ionic iodide radiocontrast media used in computed tomography	To compare the incidence of immediate ADRs among different low-osmolar nonionic RCMs used in computed tomography (CT)	A logistic regression analysis was performed	Iopromide showed the highest incidence of immediate ADRs (1.03%) and was followed by iopamidol (0.67%), iohexol (0.64%), and iobitridol (0.34%). In cases of anaphylaxis, iopromide also showed the highest incidence (0.041%), followed by iopamidol (0.023%), iohexol (0.018%), and iobitridol (0.012%). Risk of immediate ADR due to multiple CT examinations (1.19%) was significantly higher than the risk due to a single CT examination (0.63%). Risk of anaphylaxis was also higher for multiple CT examinations (0.052%) than for a single CT examination (0.020%)	The incidence of immediate ADRs varied according to the low-osmolar nonionic RCM used. Iopromide-induced immediate ADRs were more frequent, while iobitridol was associated with fewer immediate ADRs than other RCMs. Multiple CT examinations per day resulted in a higher incidence of immediate ADRs and anaphylaxis than a single CT examination. Clinicians should consider these risk differences of immediate ADRs when prescribing contrasted CT examinations	**(Kim *et al.*, 2017)**
27	Mexico.	Immediate and nonimmediate reactions induced by contrast media: incidence, severity and risk factors	To estimate the incidence and the degree of severity of the adverse reactions to contrast media, administered for the first time, in hospitalized subjects	Manual on Contrast Media version 9 guides	The incidence of immediate and nonimmediate adverse reactions was of 26.3% and 10.1%, respectively. The mild immediate reactions were 18 (69.2%), the most common being the sensation of warmth, nausea and pruritus; among the more delayed reactions, nephrotoxicity stood out (5.1%). The serum creatinine median showed no difference either before or after the intravenous injection of contrast media ($p = 0.13$); in contrast, there was a significant difference in the total number of eosinophils ($p \leq 0.001$). The values of high baseline systolic blood pressure and the diminished baseline amounts in pulse oximetry	The incidence of the adverse reactions to contrast media was greater with respect to previous reports; the majority of these reactions were of the immediate type and of a mild nature. The risk factors that have mostly been implicated in the adverse reactions to contrast media could not be identified in our cohort.	**(Bedolla-Barajas *et al.*, 2013)**

					were significantly related with any type of the adverse reactions to contrast media		

Table 1: An overview literature finding

Contrast Media Injection Protocol in Computed tomography

Contrast media injection protocols in computed tomography (CT) have been evaluated in several studies. One study compared different injection durations and iodine concentrations for step-and-shoot coronary CT angiography (CCTA) and found that a bodyweight-adjusted iodinated contrast media (ICM) with a 13-second injection duration and a 350 mgI/mL iodine concentration yielded improved image quality. Another study evaluated low kV multiphase abdominal CT imaging and found that adapted injection protocols with reduced iodine load offer the potential for patient-individualized contrast media adaption. A study on contrast-enhanced 4D-CT scans for thoracic tumors found that varying the flow rate and delay time with minimal contrast agent usage can provide qualitatively acceptable enhancement. In terms of hepatic enhancement, a study compared fixed contrast media injection durations and rates and found that a fixed duration protocol yielded greater magnitude and inter-patient variability in hepatic enhancement compared to a fixed rate protocol. Lastly, a study compared a body-weight-based protocol to a semi-fixed protocol and found that the body-weight-based protocol increased interpatient uniformity of liver attenuation while maintaining good subjective image quality. **Costa and Peet (2021) assessed** whether a fixed contrast media injection duration improves the magnitude and inter-patient variability in hepatic enhancement over a fixed injection rate. Outpatients who underwent portovenous phase abdominal CT (fixed duration, February–November 2018; fixed rate, January–July 2020) with 1.22 mL/kg iohexol 350 were included. Subjects with liver, kidney or heart disease were excluded. The number of subjects and injection protocols were as follows: fixed duration arm, 56 women, 60 men, 35 s injection duration; fixed rate arm, 66 women, 62 men, 3 mL/s injection rate. Liver attenuation measurements were obtained from regions of interest on pre- and post-contrast images. Mean hepatic enhancement (MHE) and MHE normalized to iodine dose (MHE/I) were compared (unpaired t-tests and F-tests). There was no statistically significant difference in age, weight, body mass index or CM dosing ($p > 0.05$). Enhancement indices were significantly lower in the fixed rate group as compared to the fixed duration group, as follows: MHE, 50.0 ± 12 vs. 54.8 ± 11 HU ($p = 0.001$); and MHE/I, 1.53 ± 0.43 vs. 1.66 ± 0.51 HU/g, ($p = 0.04$). However, there was no significant difference in the variances of MHE ($p = 0.51$) and MHE/I ($p = 0.08$). A fixed CM injection duration yields a greater magnitude in hepatic enhancement indices than a fixed injection rate. Inter-patient variability in hepatic enhancement indices do not significantly differ between the two injection protocols. In a similar study conducted by Sakabe *et al.* (2020) regarding the standard Contrast Media (stdCM) protocol, 600 mgI/kg of CM (Omnipaque 300; Daiichi-Sankyo, Tokyo, Japan or Iomeron 300; Eisai Co., Ltd., Tokyo, Japan; or Iopamiron 370; Bayer Healthcare, Osaka, Japan) was delivered within 33.0 s followed by 30 ml of saline solution. CECTa and CECTp were started at 35 and 80 s after CM injection, respectively. We also delivered a 50% reduced iodinated CM dose of 300 mgI/kg in the halfCM protocol within 33.0 s followed by 30 ml of saline solution. CECTa and CE CTp were started at 37 and 80 s after CM injection, respectively. Regarding CECTa, the scan start time for the half CM protocol was 2.0 s later than that for the stdCM protocol due to the slower half injection rate.Matsumoto *et al.* (2019)compared enhancement of the aorta and liver on hepatic dynamic computed tomography scans acquired with contrast material doses based on the lean body weight (LBW) or the total body weight (TBW). The patients were randomly divided 529 patients (279 men, 250 women; median age, 66 years) scheduled for hepatic dynamic computed tomography into 2 groups. The LBW patients (n = 278) were injected with 679 mg iodine/kg (men) or 762 mg iodine/kg (women). The TBW group (n = 251) was injected with 600 mg iodine/kg TBW. Each group was subdivided into the 3 classes based on the body mass index (BMI; low, normal, high). Aortic enhancement during the hepatic arterial phase and hepatic enhancement during the portal venous phase was compared. The aortic and hepatic equivalence margins were 100 and 20 Hounsfield units, respectively. Comparison of the median iodine dose in patients with a normal or high BMI showed that it was significantly lower under the LBW protocol than the TBW protocol (558.2 and 507.0 mg iodine/kg, $P < 0.001$, respectively). However, in patients with a low BMI, the LBW protocol delivered a significantly higher dose than the TBW protocol (620.7 vs 600.0 mg iodine/kg, $P < 0.001$). The 95% confidence interval for the difference in aortic and hepatic enhancement between the 2 protocols was within the range of the predetermined equivalence margins in all BMI subgroups. Contrast enhancement was equivalent under both protocols. The LBW protocol can avoid iodine overdosing, especially in patients with a high BMI

Effects of contrast media in computed tomography procedures

Contrast media used in computed tomography (CT) can have various effects. Swelling of the salivary glands, known as iodide mumps, is a rare but benign adverse reaction to iodine-containing contrast media. Contrast-induced nephropathy (CIN) is a serious adverse effect, but it can be reduced by using low osmolality contrast media and ensuring good hydration before and after contrast administration (Yu *et al.*, 2021). The choice of iodide contrast media components can also affect the incidence of adverse reactions, with iopromide and iomeprol associated with higher incidences of severe reactions. Iodinated contrast media can cause changes in serum electrolyte concentrations, particularly sodium and chloride, due to fluid shifts and hemodilution. Atorvastatin may be effective in preventing contrast-induced acute kidney injury (CI-AKI) in patients with cardiovascular diseases undergoing CT with contrast media administration. The previous findings highlight the importance of careful consideration and monitoring of patients receiving contrast media during CT procedures (Kim *et al.*, 2017)**. Yu *et al.* (2021)** found that the use of iopromide and iomeprol in iodide contrast media resulted in a higher incidence of death and threat of life resulting from adverse reactions than other ingredients. Patients who are administered iodide contrast media containing iopromide and iomeprol during the computed tomography test should be carefully examined by the relevant medical professional, as the significance of gender and age varies from component to component. As multiple iodide contrast agents are available, the use of an appropriate iodide contrast media will reduce the incidence of iodide contrast media adverse reactions. In research of **Sankaran *et al.* (2019)** carried out with objectives of evaluating the changes in serum electrolyte concentrations with intravenous iodinated contrast media administration in adult population and to correlate the changes in electrolyte concentrations, if any, with the demographic profile of the patients. About 103 numbers of adult patient samples over a period of 2 months by collecting blood both before administration of contrast and after 24 h of the contrast-enhanced computed tomography scan procedure were analyzed. Serum concentrations of sodium, potassium, chloride, and ionized calcium were measured using Eschweiler Combiline analyzer based on ion-selective electrode principle. Results: The mean age of the study population in our study was 40.11 ± 20.51 years. They found that changes in serum sodium and chloride concentration after administration of contrast media are significant (sodium: 136.29 ± 3.53 vs. 132.49 ± 6.36 mmol/L and chloride: 100.03 ± 0.70 vs. 97.53 ± 0.70 mmol/L). Sodium concentration shows more decrease in females compared to males after administration of iodine contrast. The most probable reason for this decrease in serum electrolytes was secondary changes to hemodilution due to high osmolality of the contrast. Conclusions: Attending physicians must be alert for such possibilities of changes in electrolytes after contrast administration and be prepared to treat any adversity if one occurs.

Vasin *et al.* (2022) assessed the role of atorvastatin to the frequency of contrast-induced acute kidney injury (CI-AKI) in patients with cardiovascular diseases (CVD) undergoing computed tomography (CT) with intravenous contrast media. One hundred patients with CVD undergoing CT with intravenous contrast media administration were included in prospective observational study. Patients were divided into 3 groups 16 (15.8%) patients receiving atorvastatin at a dose of 80 mg 24 hours and 40 mg before the CT and 40 mg after; 33 (32.7%) patients 40 mg before the CT and 40 mg after; 52 (51.5%) people not receiving statin therapy. The primary endpoint was CI-AKI according to KDIGO criteria: the 25% rise (or 0.5 mg/dl) of serum creatinine from baseline assessed 4872 hours after administration of contrast media. There were 51% of men. The average age was 59.7714.4. The most frequent cardiovascular disease was hypertension 86%. RESULTS CI-AKI was diagnosed in 4 (3.96%) patients. At the same time, it was not possible to establish statistically significant relationships (p0.05) between risk factors and the development of CI-AKI. Statins can be a successful way to prevent this complication. CONCLUSION Cardiovascular diseases may increase the risk of CI-AKI after computed tomography with intravenous contrast media administration. Therefore, it is recommended to evaluate the serum creatinine concentration in such patients. Similarly, **Suecharoen and Kanpittaya (2017)** studied adverse reactions (causes and severity) to iodinated contrast media at Srinagarind Hospital between March and July, 2015, 1,101 patients from the Department of Radiology. The patients were classified per Naranjo's algorithm and through use of an adverse reactions' questionnaire. A total of 105 cases (9.5%) reported adverse reactions (57% male; 43% female); among whom 2% were iso-osmolar vs. 98% low-osmolar. Diagnoses included hepatoma and cholangiocarcinoma (24.8%), colorectal cancer (9.5%), breast cancer (5.7%), cervical cancer (3.8%), lung cancer (2.9%), bone cancer (1.9%), and others (51.5%). Underlying diseases included hypertension and diabetes mellitus type 2. Mild, moderate, and severe adverse reactions accounted for 92, 5 and 3%, respectively. The respective groups of escalating symptoms included (a) mild urticaria, itching, rash, nausea, vomiting, dizziness, and headache; (b) moderate hypertension, hypotension, dyspnea, tachycardia and bronchospasm; and (c) severe laryngeal edema, profound hypotension, and convulsions. All reactions could be anticipated per Naranjo's algorithm. Mild to moderate adverse reactions to low-osmolar contrast media were most common and these occurred immediately after administration. For patient safety and better outcomes, improving the identification of patients likely to have an adverse reaction is essential.

Kim *et al.* (2017) compared the incidence of immediate adverse drug reactions (ADRs) among different low-osmolar nonionic RCMs used in computed tomography (CT). The data was collected from several Hospitals for adverse reactions occurring using an internally developed system. About 1969 immediate ADRs from 286,087 RCM-contrasted CT examinations of 142,099 patients and compared the immediate ADRs of iobitridol, iohexol, iopamidol, and iopromide were reviewed. The incidence of immediate ADRs to different RCMs, as well as the effect of single or multiple CT examinations per day. Iopromide showed the highest incidence of immediate ADRs (1.03%) and was followed by iopamidol (0.67%), iohexol (0.64%), and iobitridol (0.34%). In cases of anaphylaxis, iopromide also showed the highest incidence (0.041%), followed by iopamidol (0.023%), iohexol (0.018%), and iobitridol (0.012%). Risk of immediate ADR due to multiple CT examinations (1.19%) was significantly higher than the risk due to a single CT examination (0.63%). Risk of anaphylaxis was also higher for multiple CT examinations (0.052%) than for a single CT examination (0.020%). The incidence of immediate ADRs varied according to the low-osmolar nonionic RCM used. Iopromide-induced immediate ADRs were more frequent, while iobitridol was associated with fewer immediate ADRs than other RCMs. Multiple CT examinations per day resulted in a higher incidence of immediate ADRs and anaphylaxis than a single CT examination. Clinicians should consider these risk differences of immediate ADRs when prescribing contrasted CT examinations. **Bedolla-Barajas *et al.* (2013)** estimated the incidence and the degree of severity of the adverse reactions to contrast media, administered for the first time, in hospitalized subjects. About 99 patients longitudinally on whom computed tomography with contrast media (iopamidol) was carried out were analyzed. The adverse reactions were identified by clinical examination; subsequently, they were classified as mild, moderate and severe, following the Manual on Contrast Media version 9 guides, and as immediate and nonimmediate. In addition, the vital functions, oxygen saturation, serum creatinine levels and the total number of eosinophils were measured before and after the procedure. The incidence of immediate and nonimmediate adverse reactions was of 26.3% and 10.1%, respectively. The mild immediate reactions were 18 (69.2%), the most common being the sensation of warmth, nausea and pruritus; among the more delayed reactions, nephrotoxicity stood out (5.1%). The serum creatinine median showed no difference either before or after the intravenous injection of contrast media ($p = 0.13$); in contrast, there was a significant difference in the total number of eosinophils ($p \leq 0.001$). The values of high baseline systolic blood pressure and the diminished baseline amounts in pulse oximetry were significantly related with any type of the adverse reactions to contrast media. The incidence of the adverse reactions to contrast media was greater with respect to previous reports; the majority of these reactions were of the immediate type and of a mild nature. The risk factors that have mostly been implicated in the adverse reactions to contrast media could not be identified in our cohort. **Sakabe *et al.* (2020)** developed a method to calculate the relative dose increase when a computerized tomography scan (CT) is carried out after administration of iodinated contrast medium, with respect to the same CT scan in absence of contrast medium. A Monte Carlo simulation in GEANT4 of anthropomorphic neck and abdomen phantoms exposed to a simplified model of CT scanner was set up in order to calculate the increase of dose to thyroid, liver, spleen, kidneys, and pancreas as a function of the quantity of iodine accumulated; a series of experimental measurements of Hounsfield unit (HU increment for known concentrations of iodinated contrast medium was carried out on a Siemens Sensation 16 CT scanner in order to obtain a relationship between the increment in HU and the relative dose increase in the organs studied. The authors applied such a method to calculate the average dose increase in three patients who underwent standard CT protocols consisting of one native scan in absence of contrast, followed by a contrast-enhanced scan in venous phase. The authors validated their GEANT4 Monte Carlo simulation by comparing the resulting dose increases for iodine solutions in water with the ones presented more » in literature and with their experimental data obtained through a Roentgen therapy unit. The relative dose increases as a function of the iodine mass fraction accumulated and as a function of the Hounsfield unit increment between the contrast-enhanced scan and the native scan are presented. The data shown for the three patients exhibit an average relative dose increase between 22% for liver and 74% for kidneys; also, spleen (34%), pancreas (28%), and thyroid (48%) show a remarkable average increase. The method developed allows a simple evaluation of the dose increase when iodinated contrast medium is used in CT scans, basing on the increment in Hounsfield units observed on the patients' organs. Since many clinical protocols employ multiple scans at different circulatory phases after administration of contrast medium, such a method can be useful to evaluate the total dose to the patient, also in view of potential clinical protocol optimizations. **Perisinakis *et al.* (2018)** investigated the effect of iodine uptake on tissue/organ absorbed doses from CT exposure and its implications in CT dosimetry. The contrast-induced CT number increase of several radiosensitive tissues was retrospectively determined in 120 CT examinations involving both non-enhanced and contrast-enhanced CT imaging. CT images of a phantom containing aqueous solutions of varying iodine concentration were obtained. The clinically occurring iodine tissue uptake was quantified by attributing recorded CT number increase to a certain concentration of aqueous iodine solution. Standard 120 kV CT exposures were simulated using Monte Carlo methods and resulting organ doses were derived for non-enhanced and iodine contrast-enhanced CT imaging. The mean iodine uptake range during contrast-enhanced CT imaging was found to be 0.02-0.46% w/w for the investigated tissues, while the maximum value recorded was 0.82% w/w. For the same CT exposure, iodinated tissues were found to receive higher radiation dose than non-iodinated tissues, with dose increase exceeding 100% for tissues with high iodine uptake. Administration of iodinated contrast medium considerably increases radiation dose to tissues from CT exposure. Radiation absorption ability of organs/tissues is considerably affected by iodine uptake. Iodinated organ/tissues may absorb up to 100 % higher radiation dose. Compared to non-enhanced, contrast-enhanced CT may deliver higher dose to patient tissues. CT dosimetry of contrast-enhanced CT imaging should encounter tissue iodine uptake.

Karami *et al.* (2020) evaluated the impact of contrast material on radiation dose for adults undergoing computed tomography pulmonary angiography (CTPA). A previously developed physiologically based pharmacokinetic (PBPK) model and phantoms representing the average (reference) adult male and female individual were used to evaluate the iodine concentration in tissues as a function of time elapsed since the initiation of iodinated contrast medium administration. In order to estimate the radiation dose more accurately, a detailed model of pulmonary vessels was added to the phantoms. Then, the material composition of phantoms was modified to include the iodine concentration in different organs and tissues at different acquisition times after CM injection. The calculations were performed using Monte Carlo N-Particle extended code (MCNPX) version 2.6.0. The radiation dose estimates during CTPA were provided as a function of scan acquisition time after injection considering the distribution of iodinated CM within ICRP reference phantoms. It was shown that the estimated radiation dose to the lungs could be 31–40% (27–34%) larger when considering the effect of iodinated contrast administration with injection rate of 5 (3) mL/s. Moreover, the effective dose for contrast-enhanced CT (CECT) would be utmost 10–13% larger than that for non-enhanced CT (NECT). The radiation doses to the other organs in-/outside the scanned region would be decreased if the scan performed on time. In case of late scanning, absorbed dose decreases slightly for lungs (~15–20%) whereas becomes (~10% or more) higher than its NECT value for some organs such as heart muscle, kidneys, and spleen. To sum up, the late scanning ($\Delta t > 5$ s after the end of injection) is not recommended because of higher dose delivered to other organs than the lungs (particularly heart muscle). **Abadi *et al.* (2016)** established the contribution of dose increase from iodine to biological effect. Radiation organ dose was estimated in 58 human (XCAT) phantoms "undergoing" chest CT examination (120 kVp, 9 mGy CTDI) on a simulated CT system (Definition Flash, Siemens) with and without iodinated-contrast agent (62.5 mL of iodine per subject). The dose without and with the presence of iodine was compared to the increase in foci per cell (a surrogate of DNA damage) measured before and after similar CT exams without and with contrast agent. The data were analyzed to ascertain how the enhancement in biological effect in contrast-enhanced CTs correlated with the increase in dose due to the presence of iodine. The presence of iodinated-contrast in CT increased the organ doses by 2% to 50% on average. Typical values were heart (50%±7%), kidney (19%±7%), and liver (2%±3%). The corresponding increase in the average foci per cell was 107%±19%, indicating biological effect of iodine was greater than what would be anticipated from the iodine-initiated increase in radiation dose alone. Mean foci per cell and organ dose both increase in the presence of contrast agent. The former, however, is at least twice as large as the latter, indicating that iodine contributes to an increase in the probability of DNA damage not only as a consequence of increased x-ray energy deposition but also from other mechanisms. Hence iodine radiation dose, while relevant to be included in estimating the risk associated with contrast-enhanced CT, still can underestimate the biological effects. **Solbak *et al.* (2020)** investigated the impact of varying contrast medium densities and x-ray tube potentials on contrast enhancement (CE), image quality and radiation dose in thoracic computed tomography (CT) using two different scanning techniques. Seven plastic tubes containing seven different CM densities ranging from of 0 to 600 HU were positioned inside a commercial chest phantom with padding, representing three different patient sizes. Helical scans of the phantom in single-source mode were obtained with varying tube potentials from 70 to 140 kVp. A constant volume CT dose index (CTDIvol) depending on phantom size and automatic dose modulation was tested. CE (HU) and image quality (contrast-to-noise ratio, CNR) were measured for all combinations of CM density and tube potential. A reference threshold of CE and kVp was defined as ≥ 200 HU and 120 kVp. For the medium-sized phantom, with a specific CE of 100–600 HU, the diagnostic CE (200 HU) at 70 kVp was ~ 90% higher than at 120 kVp, for both scan techniques ($p < 0.001$). Changes in CM density/specific HU together with lower kVp resulted in significantly higher CE and CNR ($p < 0.001$). When changing only the kVp, no statistically significant differences were observed in CE or CNR ($p \geq 0.094$), using both dose modulation and constant CTDIvol. For thoracic CT, diagnostic CE (≥ 200 HU) and maintained CNR were achieved by using lower CM density in combination with lower tube potential (< 120 kVp), independently of phantom size.

Radiation dose estimation and Reduction in CT

Radiation dose estimation and reduction in contrast-enhanced computed tomography (CT) is an important aspect of medical imaging. Various techniques have been proposed to minimize radiation dose and enhance image quality. Hardware methods involve adjusting parameters such as tube voltage, tube current, exposure time, focal distance, and filter type (Narayan and Mahabaleshwara, 2023). Software techniques, such as image processing algorithms, can also be used to reduce noise and improve image quality. Additionally, the use of generative adversarial networks (GANs) has shown promise in reducing the dose of intravenous iodine-based contrast media (ICM) in CT scans. Gold nanoparticles have also been investigated as potential contrast media for CT, as they can enhance image contrast while reducing radiation dose. Furthermore, the use of a 100-kVp protocol in coronary artery bypass graft (CABG) imaging has been shown to reduce radiation dose without compromising diagnostic ability (Canellas *et al.*, 2018). Dual-energy CT (DECT) of the chest can also be performed at a reduced radiation dose without loss of diagnostic information. Shamsuddin *et al.* (2022) compared the radiation dose between contrast-enhanced and non-contrast-enhanced CTAC acquisition in 18F-FDG-PET/CT examinations. CE-CTAC produced 250% higher radiation dose than NC-CTAC. Tube current and pitch value contributed to increased radiation dose. **Mazloumi *et al.* (2021)** investigated that the Presence of contrast agent increases organ radiation dose with 30%. **Taghavi et al. (2020)** compared the use of gold nanoparticles and iodinated contrast media in computed tomography on radiation dose reduction. Gold nanoparticles have higher contrast-to-noise ratio than iodinated contrast media. Gold nanoparticles can optimize CT imaging by reducing radiation dose., Geso et al. (2020) noted that Measured dose effects varied depending on concentration. Increase in dose estimated was 17% for 20% contrast media and 6.6% for 10% contrast media. **Sulieman *et al.* (2022)** performed abdominal CT scan with contrast was using a 128-slice multi slice CT (MSCT) scan for 87 patients. The mean, standard deviation, and range of patients' age (years) are 13 ± 4.5 (2–17). The mean and range of the air kerma length product (PKL(mGy.cm)) and volume CT air kerma index (Cvol (mGy)) were 1740 (157.8–8440.3) (mGy.cm) and 9.8 (2.09–45.77) (mGy) per CT abdomen procedure, respectively. The mean and range of the effective dose (mSv) per procedure are 34 (3.14–176.8). The average radiogenic risk per CT procedure is one cancer incidence per 250 CT enhanced abdomen procedures. The mean and range of total irradiation even are 4.0 (2.0–8.0) times per procedure. The results of this study showed that child risk is high compared to other CT examinations. Therefore, patients' dose optimization and proper establishment of a diagnostic reference level (DRL) are necessary to preventing avoidable radiation risks. In another investigation, **Goo (2021)** conducted comparative studies between radiation dose, contrast enhancement, image noise and heart rate variability in electrocardiography (ECG), and computed tomography (CT) ventricular volumetry using a three-dimensional (3D) threshold-based segmentation between the conventional single scan and dual focused scan methods in patients with congenital heart disease. After matching for age, sex, heart rate during the CT examination, and tube voltage, 96 patients (age range, 7 − 36 years; male: female = 63:33) who underwent ECG-gated CT volumetry using a 3D threshold-based segmentation, were divided into 32 patients who underwent a conventional single scan (group 1) and 64 who underwent dual focused scans (group 2). CT radiation dose, contrast enhancement, image noise, and heart rate variability were compared between the two groups. Volume CT dose index, dose-length product, and effective dose estimates, in group 1 were significantly higher than those in group 2 (28.4 ± 24.6 mGy vs. 9.7 ± 4.5 mGy, 636.5 ± 572.9 mGy cm vs. 379.5 ± 192.4 mGy cm, 8.9 ± 8.0 mSv vs. 5.3 ± 2.7 mSv, 8.2 ± 6.4 mSv vs. 5.0 ± 2.2 mSv, respectively; p values 0.05). Image noise measured in the air showed no significant differences between groups 1 and 2 (5.6 ± 1.9 HU vs. 5.5 ± 1.1 HU; p > 0.05). The proportion of heart rate variability ≥ 20 beats per minute in group 1 (15.6 %, 5/32) was significantly higher than that in group 2 (3.1 %). Compared with the conventional single scan method, the dual focused scan method can provide a lower radiation dose with comparable contrast enhancement and image noise for ECG-gated CT ventricular volumetry using a 3D threshold-based segmentation in patients with congenital heart disease. In a similar research, **Tabari *et al.* (2020) conducted** a retrospective study that included 85 consecutive children and young adults (age range, 1 month old to 19 years old; 81 male, 70 female) who underwent contrast-enhanced DS-DECT of the chest (n = 41) or the abdomen and pelvis (n = 44) on second- or third-generation dual-source CT scanners (Somatom Flash or Force, Siemens Healthineers) for clinically indicated reasons. 66 age-, sex-, body region-, and weight-matched patients who underwent SECT on the same scanner were included. Patients were scanned with either SECT (with automatic exposure control using both CARE kV [Siemens Healthineers] and CARE Dose 4D [Siemens Healthineers]) or DS-DECT (with CARE Dose 4D). Two pediatric radiologists assessed clinical indications, radiologic findings, image quality, and any study limitations (noise or artifacts). Patient demographics (age, sex, weight), scan parameters (tube voltage, tube current-time product, pitch, section thickness), CT dose descriptors (volume CT dose index, dose-length product, size-specific dose estimate [SSDE]), and contrast material volume were recorded. Descriptive statistics, paired t test, and Cohen kappa test were performed. Mean patient ages and weights ± SD in DS-DECT (10 ± 6 years old, 38 ± 23 kg) and SECT (11 ± 7 years old, 43 ± 29 kg) groups were not significantly different (p > 0.05). Respective SSDEs for chest DS-DECT (4.0 ± 2.1 mGy), chest SECT (6.1 ± 4.4 mGy), abdomen-pelvis DS-DECT (5.0 ± 5.0 mGy), and abdomen-pelvis SECT (8.3 ± 4.0 mGy) were significantly different (p = 0.003-0.005). Contrast material volume for DS-DECT examinations was 19-22% lower compared with the weight- and body region-matched scans obtained with SECT. Image quality of DECT was acceptable in all patients. CONCLUSION. In children and young adults, chest and abdomen-pelvis DS-DECT enables substantial radiation dose and contrast volume reductions compared with weight- and region-matched SECT.

Siegel *et al.* (2021) compared radiation dose and image quality of DECT and SECT abdominopelvic examinations in children as a function of patient size. This retrospective study included 860 children (age range: 12.3±5.3 years) who underwent contrast-enhanced abdominopelvic exams on second-generation dual-source CT in a five-year period. Two groups, SECT and DECT, consisting of 430 children each, were matched by 5 effective diameters. Volume CT dose index (CTDIvol) and size-specific dose estimate (SSDE) were analyzed as a function of effective diameter. Objective image quality was compared between the groups. DECT SSDEs were lower across all effective patient diameters compared with SECT (mean: 8.5±1.8 mGv vs. 9.3±2.0 mGv, respectively, P≤0.001). DECT CTDIvol was lower compared to SECT (mean: 5.6±2.4 mGv vs. 6.1±2.7 mGv, respectively, P≤0.001) except in the smallest diameter group (0.05). In children, regardless of effective diameter, contrast-enhanced abdominopelvic DECT can be performed with a similar or lower dose and similar image quality compared with SECT examinations.

(Hasan *et al.*, 2022)established national diagnostic reference levels (NDRLs) for computed tomography (CT) examinations performed on adult patients based on clinical indications, patient gender, and size in the Kingdom of Bahrain. The volume CT dose index (CTDIvol) and dose length product (DLP) were collected between September 2020 and September 2021 from 63% of the total number of CT scanners in the country (five out of eight CT scanners). The data were collected from at least ten patients for eight common clinical indications in the head, abdomen-pelvis and chest-abdomen-pelvis (CAP) regions. The NDRLs were calculated for each clinical indication as the third quartile of the CT scanners' median values of CTDIvol and DLP. They were also calculated based on the patient's gender (for the head) and their size (for the abdomen-pelvis and CAP clinical indications). From 1665 CT examinations, the NDRLs in term of CTDIvol were 67, 66, 67, 13, 14, 17, 19, and 15 mGy for symptoms of headache, trauma, stroke, flank pain, renal colic, abdominal pain, diverticulitis/appendicitis and oncologic follow-up, respectively. Likewise, these were 1206, 1286, 1152, 690, 779, 972, 1061, 1073 mGy cm in terms of DLP, respectively. For large size patients, NDRLs in terms of CTDIvol were on average 1.7 times higher than those from medium size patients for all the clinical indications in the abdomen-pelvis and CAP regions. The NDRLs were established for the most common clinical indications in the Kingdom of Bahrain. They are higher than those established in the literature, thus emphasizing the urgent need of an optimization strategy for better patient radiation protection. **Elnour *et al.* (2015)** evaluated patient doses during chest CT procedures in a certain radiological hospital in order to establish a local diagnostic reference level (DRL). A total of 78 CT chest procedures were performed during one year. The range of patient dose per CT procedure was 126.0 mGy.cm to 1104.0 mGy.cm per chest procedure. The CTDIvol ranged between 3.0 mGy to 20 mGy per procedure. Patient dose variation attributed to CT modality and image acquisition protocol. Patients exposed to a higher radiation dose in 64 slices compared to other two modalities due to the use of sequential technique at the later one. Diagnostic reference level was proposed for chest CT procedures

Li *et al.* (2022) investigated the clinical value of adaptive statistical iterative reconstruction in reducing the iodixanol content and radiation dose during contrast-enhanced chest CT scan for patients diagnosed with lung masses/nodules based on the analysis of image quality. This prospective study was conducted on 80 patients diagnosed with nodules or masses, who required contrast-enhanced chest CT scans. The experimental group (n = 40) was subjected to iohexol at a high concentration (350 mgI/L) with a tube voltage of 120 kVp and a filter back projection (FBP) reconstruction algorithm. The comparison group (n = 40) was subject to iodixanol at a lower concentration (270 mgI/L) with a tube voltage of 100 kVp and ASIR (blending ratio, 40%). The radiation dose and total iodixanol content, as well as subjective and objective evaluations of image quality, were analyzed and compared. Results: The two groups obtained non-significantly different subjective scores for five structures detected in the lung window and five structures detected in the mediastinal window, as well as the overall image (P > 0.05 for all). Both the two-group images obtained diagnosis-acceptable scores (≥ 3 points) on displays of 10 structures and overall image quality. The mean CT value of vessels (100 kVp vs. 120 kVp: 314.90 ± 23.42 vs. 308.93 ± 21.40; P > 0.05), standard deviation (13.03 ± 0.88 vs. 12.83 ± 0.90; P > 0.05), and contrast-to-noise ratio (20.77 ± 2.20 vs. 20.36 ± 1.94; P > 0.05) were not significantly different between two groups. However, the CT dose index, dose-length product, effective dose, and total iodine dose were reduced by 27.58%, 36.65%, 36.59%, and 22.86% in the 100-kVp group compared to the 120-kVp group. Conclusion: The ASIR showed great potential in reducing the radiation dose and iodine contrast dose, while maintaining good image quality and providing strong confidence for the diagnosis of lung cancer. **Navin *et al.* (2019) used Prior** iterative reconstruction (PIR) to reduce radiation dose while preserving observer performance and CT number at multi-phase dual energy (DE) renal CT. CT projection data from multi-phase DE renal CT examinations were collected. Images corresponding to 40% radiation dose were reconstructed using validated noise insertion and PIR. Three genitourinary radiologists examined routine and 40% dose PIR images. Probability of malignancy was assessed [from 0 to 100] with malignancy assumed at probability ≥ 75. Observer performance was compared on a per patient and per lesion level. CT number accuracy was measured. Twenty-three patients had 49 renal lesions (11 solid renal neoplasms). CT number was nearly identical between techniques (mean CT number difference: unenhanced 2 ± 2 HU; enhanced 4 ± 4 HU). AUC for malignancy was similar between multi-phase routine dose DE and lower dose PIR images [per patient: 0.950 vs. 0.916 ($p = 0.356$); per lesion: 0.931 vs. 0.884 ($p = 0.304$)]. Per patient sensitivity was also similar (78% routine dose vs. 82% lower dose [$p \geq 0.99$]), as was specificity (91% routine dose vs. 93% lower dose PIR [$p > 0.99$]), with similar findings on a per lesion level. Subjective image quality was also similar ($p = 0.34$). Prior iterative reconstruction is a new reconstruction method for multi-phase CT examinations that promises to facilitate radiation dose reduction by over 50% for multi-phase DE renal CT exams without compromising CT number or observer performance. **Sakabe *et al.* (2020)** compared the estimated radiation dose of 50% reduced iodine contrast medium (halfCM) for virtual monochromatic images (VMIs) with that of standard CM (stdCM) with a 120 kVp imaging protocol for contrast-enhanced CT (CECT). The 30 adults with renal dysfunction who underwent abdominal CT with halfCM for spectral CT was analyzed. As controls, 30 matched patients without renal dysfunction using stdCM were also enrolled. CT images were reconstructed with the VMIs at 55 keV with halfCM and 120 kVp images with stdCM and halfCM. The Monte-Carlo simulation tool was used to simulate the radiation dose. The organ doses were normalized to CTDIvol for the liver, pancreas, spleen, and kidneys and measured between halfCM and stdCM protocols. For the arterial phase, the mean organ doses normalized to CTDIvol for stdCM and halfCM were 1.22 and 1.29 for the liver, 1.50 and 1.35 for the spleen, 1.75 and 1.51 for the pancreas, and 1.89 and 1.53 for the kidneys. As compared with non-enhanced CT, the average increase in the organ dose was significantly lower for halfCM (13.8% ± 14.3 and 26.7% ± 16.7) than for stdCM (31.0% ± 14.3 and 38.5% ± 14.8) during the hepatic arterial and portal venous phases ($p < 0.01$). As compared with stdCM with the 120 kVp imaging protocol, a 50% reduction in CM with VMIs with the 55 keV protocol allowed for a substantial reduction of the average organ dose of iodine CM while maintaining the iodine CT number for CECT. **He *et al.* (2022)** explored the differences among volumetric CT dose index (CTDIvol), body-specific dose assessment (SSDEED) based on effective diameter (ED), and SSDEWED based on water equivalent diameter (WED) in evaluating the radiation dose of adult thoracic and abdominal CT scanning. From January 2021 to October 2021, enhanced chest CT scans of 100 patients and enhanced abdomen CT scans of another 100 patients were collected. According to the body mass index (BMI), they can be divided into groups A and D (BMI < 20 kg/m2), groups B and E (20 kg/m2 ≤ BMI ≤ 24.9 kg/m2), and groups C and F (BMI > 24.9 kg/m2). The CTDIvol, anteroposterior diameter (AP), and the left and rght diameter (LAT) of all the patients were recorded, and the ED, water equivalent diameter (WED), the conversion factor (fsize,ED), (fsize, WED), SSDEED, and SSDEWED were calculated. The differences were compared between the different groups. The AP, LAT, ED, and WED of groups B, E, C, and F were higher than those of groups A and D, and those of groups C and F were higher than those of groups B and E (Adedigba *et al.*). The field size, ED and WED of groups B, E, C, and F are lower than those of groups A and D, and those of groups C and F are lower than those of groups B and E ($P < 0.05$). CTDIvol, SSDEED, and SSDEWED in groups B, E, C, and F are higher than those in groups A and D, and those in groups C and F are higher than those in groups B and E ($p < 0.05$). In the same group, patients with chest- and abdomen-enhanced have higher SSDEWED and SSDEED than CTDIvol, patients with chest-enhanced CT scans have higher SSDEWED than SSDEED, and patients with abdomen-enhanced CT scans have higher SSDEED than SSDEWED ($P < 0.05$). CTDIvol and ED-based SSDEED underestimated the radiation dose of the subject exposed, where the patient was actually exposed to a greater dose. However, SSDEWED based on WED considers better the difference in patient size and attenuation characteristics, and can more accurately evaluate the radiation dose received by patients of different sizes during the chest and abdomen CT scan.

Sookpeng and Martin (2023) investigated the impact of low tube voltage settings on single-energy computed tomography (SECT) and rapid kV switching dual-energy CT (DECT) with reduced concentrations of iodinated CM. A phantom containing four different concentrations of CM (original concentration CM, 20%, 40%, and 60% reductions) was scanned using SECT mode with varying tube voltages (70, 80, 100, and 120 kVp) and DECT mode through reconstructing monoenergetic energy (50 keV and 70 keV) images. ATCM system with different noise index (NI) settings were set, and the images were reconstructed using ASiR-V. Image quality were measured for individual phantom sizes and protocols and compared to a reference protocol for SECT of 120 kVp, NI = 18, threshold contrast enhancement ≥280 HU, and CNR ≥17. Tube voltage settings of 70 kVp together with 40% reduction in the iodinated CM is suitable for small phantom size, those of 80 kVp and 20% reduction is suitable for the medium and large sizes. This allows radiation doses to be reduced by 12%–30%. Values of CNR and contrast for DECT are better than those for SECT with the same NI setting. Conclusion Diagnostic reference of image quality can be maintained by using SECT with lower tube voltage and DECT with reductions of iodinated CM concentration and radiation dose. Therefore, the NI setting can be increased when DECT is used to achieve a similar image quality.

Mueck *et al.* (2015) found that the Mean CT dose index values (mGy) were as follows: D0/FDBR = 10.1 ± 1.7, D1 = 6.2 ± 2.8, D2 = 5.7 ± 2.7, D3 = 3.5 ± 1.9, D4 = 1.8 ± 1.0, and D5 = 0.9 ± 0.5, while Mean IQ ratings were as follows: D0 = +1.8 ± 0.2, D1 = +1.5 ± 0.3, D2 = +1.1 ± 0.3, D3 = +0.7 ± 0.5, D4 = +0.1 ± 0.5, and D5 = −1.2 ± 0.5. All values demonstrated a significant difference to baseline. Compared to ASIR, MBIR allowed for a significant dose reduction of 82% without impairment of IQ. This resulted in a calculated mean effective dose below 1 mSv. **Acquah *et al.* (2014)** studied the doses and image qualities produced from the default primary scanning factors of a Siemens CT machine and afterwards came up with scanning protocols that allow radiologists to obtain the necessary diagnostic information while reducing radiation doses to as low as reasonably achievable. Approximately 1000 CT scans from mostly common examinations; head, thorax, abdomen and pelvis routines were selected and analyzed for their image quality and radiation doses over a two year interval. Dose measurements were performed for the same routines using Computed Tomography Dose Index (CTDI) phantoms, RTI barracuda system with electrometer, and CT dose Profiler detector to evaluate the doses delivered during these CT procedures. Subsequently, image quality checks were performed using the CT Catphan 600 and anthropomorphic phantoms. CTDI and Dose Length Product (DLP) values were calculated for each scan. From analyzing these measurements, the appropriate machine scanning parameters were adjusted to reduce radiation does while at the same time providing good image quality. Doses to patients using the default head sequence protocol had an average CTDI vol value of 65.45 mGy and a range of 7.10-16.80 mGy for thorax, abdomen and pelvis examinations whiles the new protocol had an average CTDI vol of 58.32 mGy for the head and a range of 3.83-15.24 mGy for the truck region. The DLP value for default head scans decreased from an average of 2279.85 mGy.cm to 874.53 mGy.cm with the new protocol. Tube potentials (KV) and tube current-time (mAs) had an effect on spatial resolution and low contrast detectability as well as doses. From the new protocols, lower values of KV and mAs together with other factors were enough to produce acceptable level of image quality which leads to adequate diagnosis without unnecessary doses to patients. **Camera *et al.* (2015)** balanced radiation and contrast media dose according to the age of the patients. Seventy-two (38 Men; 34 women; aged 20–83 years) patients underwent a single-pass abdominal CE-MDCT. Patients were divided into three different age groups: A (20–44 years); B (45–65 years); and C (>65 years). For each group, a different noise index (NI) and contrast media dose (370 mgI/mL) was selected as follows: A (NI, 15; 2.5 mL/kg), B (NI, 12.5; 2 mL/kg), and C (NI, 10; 1.5 mL/kg). Radiation exposure was reported as dose–length product (DLP) in mGy × cm. For quantitative analysis, signal-to-noise (SNR) and contrast-to-noise (CNR) ratios were calculated for both the liver (L) and the abdominal aorta (A). Statistical analysis was performed with a one-way analysis of variance. Standard imaging criteria were used for qualitative analysis. Results Although peak hepatic enhancement was 152 ± 16, 128 ± 12, and 101 ± 14 Hounsfield units (P < .001) for groups A, B, and C, respectively, no significant differences were observed in the corresponding SNRL with 9.2 ± 1.4, 9.1 ± 1.2, and 9.2 ± 3. Radiation (mGy × cm) and contrast media dose administered were 476 ± 147 and 155 ± 27 for group A, 926 ± 291 and 130 ± 16 for group B, and 1981 ± 451 and 106 ± 15 for group C, respectively (P < .001). None of the studies was graded as poor or inadequate by both readers, and the prevalence-adjusted bias-adjusted kappa ranged between 0.48 and 0.93 for all but one criterion. A constant image quality in CE-MDCT can be obtained balancing radiation and contrast media dose administered to patients of different age.

Wang *et al.* (2016) quantitatively and subjectively assessed the image quality and radiation dose for an abdominal enhanced computed tomography (CT) scan with a low tube voltage and a low concentration of iodinated contrast agent in children. Forty-eight patients were randomized to one of the two following protocols: Group A (n=24, mean age 46.96±44.65 months, mean weight 15.71±9.11 kg, BMI 16.48±2.40 kg/m2) and Group B (n=24, mean age 41.33±44.59 months, mean weight 18.15±17.67 kg, BMI 17.50±3.73 kg/m2). Group A: 80 kVp tube voltage, 270 mg iodine (I)/mL contrast agent (Visipaque, GE Healthcare) and images were reconstructed using 70% adaptive statistical iterative reconstruction. Group B: 100 kVp tube voltage, 370 mg I/mL contrast agent (Iopamiro, Bracco) and images were reconstructed using 50% ASIR. The volume of the contrast agent was 1.30 mL/kg in both Groups A and B. The degree of enhancement and noise in the abdominal aorta (AO) in the arterial phase (AP) and the portal vein (PV) in the portal venous phase (PVP) was measured; while the signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) for the AO and PV were calculated. A 5-point scale was used to subjectively evaluate the image quality and image noise by two radiologists with more than 10 years of experience. Dose-length product (DLP) (mGy-cm) and CTDIvol (mGy) were calculated. Objective measurements and subjective quality scores for the two groups were compared using paired t-tests and Mann-Whitney U tests, respectively. There was no significant difference in age, weight or body mass index (BMI) between the two groups (all P>.5). The iodine load in Group A (5517.3±3197.2 mg I) was 37% lower than that in Group B (8772.1±8474.6 mg I), although there was no significant difference between them (P=.111). The DLP and the CT dose index (CTDIvol) for Group A were also lower than for Group B, but were not statistically significantly different (DLP, 104 mGy-cm±45.81 vs 224.5 mGy-cm±45.83; CTDIvol, 1.44 mGy±0.50 vs 2.08 mGy±1.87, all P>.05). The mean arterial and portal venous enhancement (255.33 HU±83.42, 146.41 HU±23.45, respectively), noise (AP 14.96 HU±2.09, PVP 16.30 HU±3.21), CNRs (AO 14.54±7.12, PV 5.07±1.73) and SNRs (AO 20.76±6.76, PV 12.43±3.24) for Group A were similar to Group B (enhancement: 226.55 HU±77.71, 138.69 HU±33.22; noise: 14.92 HU±3.12, 15.36 HU±3.48; CNRs: 12.96±7.14, 5.16±2.28; SNRs: 19.13±7.30, 12.69±4.22; all P>.05). The mean scores of the quality of the AP and PVP images in Group B were 4.31±0.53 and 4.35±0.52, respectively, while the scores obtained in Group A were 4.29±0.51 and 4.25±0.51; there were no statistically significant differences between the two groups. The scanning protocol using a low tube voltage (80 kVp) together with 70% ASIR and a low-concentration iodinated contrast agent (270 mg I/mL) enables a 37% reduction in iodine load and a 30% reduction in radiation dose while maintaining compatible image quality.

Conclusion

Contrast-enhanced computed tomography (CECT) is a valuable imaging modality that provides detailed anatomical information for diagnosis and management of medical conditions [1]. However, it is important to recognize and mitigate the potential risks associated with contrast media administration and radiation exposure. Understanding the effects of contrast media on patients, including allergic reactions, renal impairment, and nephrogenic systemic fibrosis in at-risk populations, is crucial. Optimizing imaging protocols to minimize radiation dose while maintaining diagnostic accuracy is necessary. By carefully balancing the benefits and risks of CECT, healthcare providers can make informed decisions, ensuring patient safety and high-quality care. Continued research and advancements in imaging technology are essential for refining contrast administration protocols and reducing radiation exposure, ultimately improving patient outcomes in diagnostic radiology.

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