OPEN ACCESS

Journal of Clinical Advances and Research Reviews (JCARR)
Website: http://www.jcarr.in/
ISSN: 3048-6556
Vol. 3, Issue 3, Jul-Sept, 2026
Page No.: 06-11

Review

Advances in Radiation Dose Reduction Techniques in CT Imaging: Current Trends and Future Perspectives

Sapna Sahu*, Mandeep Kumar, Himanshu Mishra, Rashmi Singh, Sandeep Yadav

Radiology & Imaging Technology, Government Institute of Medical sciences, Greater Noida

Received: 01-05-2026 / **Revised:** 06-06-2026 / **Accepted:** 14-07-2026
Corresponding Author: Sapna Sahu
DOI: 10.62896/jcarr.3.3.02
Email: sapnasahu157@gmail.com
Conflict of interest: Nil

Abstract:
The ability of computed tomography (CT) to produce quick, high-resolution cross-sectional images for the assessment of a variety of medical illnesses, including as cancer, neurological disorders, cardiovascular diseases, and trauma, has made it a vital diagnostic imaging modality. Even though CT has several clinical advantages, it significantly increases the total amount of radiation that patients are exposed to. Radiation dose reduction techniques are becoming more popular as people become more conscious of the possible biological hazards connected to ionizing radiation, especially the danger of radiation-induced cancers. In order to reduce radiation exposure while preserving the quality of diagnostic images, CT dose optimization techniques are discussed in this study along with their present trends and perspectives for the future. Optimizing CT system components, such as detectors, collimators, and beam-shaping filters, as well as examination-specific strategy for dual-energy CT, pediatric CT, cardiac CT, and CT perfusion imaging, are important dose reduction measures. Modern CT practice has greatly increased dosage efficiency because of cutting-edge technology including automatic exposure control, low tube voltage procedures, iterative reconstruction, and patient-specific scanning techniques. Additionally, new developments such as deep learning algorithms, photon-counting detector CT, and artificial intelligence (AI)-based image reconstruction promise enormous potential for accomplishing ultra-low-dose imaging without impacting diagnostic accuracy. To ensure adherence to the ALARA principle, future advancements are predicted to concentrate on intelligent automated protocols, improved spectrum imaging, standardized worldwide dose optimization procedures, and cloud-based dose monitoring systems. Continuous collaboration among radiologists, medical physicists, radiologic technologists, and CT manufacturers will be essential for promoting safer and more efficient CT imaging practices. Overall, advancements in CT dose reduction techniques are expected to improve patient safety, optimize radiation protection, and maintain high-quality diagnostic performance in clinical imaging.

Keyword-Computed Tomography, Dose Reduction, CT Dose Optimization, Artificial Intelligence, Iterative Reconstruction, Deep Learning Reconstruction

INTRODUCTION

Modern diagnostic imaging has been transformed by computed tomography (CT), which produces rapid high-resolution cross-sectional images of the human body. Since its debut in the 1970s, CT has developed into an essential tool for diagnosis in clinical practice for an array of illnesses, such as neurological disorders, cancer, trauma, and cardiovascular diseases. Patient outcomes and clinical decision-making have been greatly enhanced by CT's ability to produce extensive anatomical information quickly. Multidetector CT (MDCT), spiral CT, dual-energy CT, and other developments in CT technology over the last few decades have considerably improved imaging capabilities, allowing for quicker acquisition times, more detailed image quality, and more accurate diagnoses [1].

CT scanners measure the body's x-ray attenuation characteristics from an array of angles to produce cross-sectional images. Nowadays, depending on where an individual lives, the radiation dose from a

Journal of Clinical Advances and Research Reviews (JCARR)
Website: http://www.jcarr.in/
ISSN: 3048-6556
Vol. 3, Issue 3, Jul-Sept, 2026
Page No.: 06-11

standard CT scan (1–14 mSv, depending on the exam) is similar to the annual exposure from natural radiation sources like radon and cosmic radiation (1–10 mSv) [2].

There are a number of reasons why CT is being used more frequently in diagnostic therapies. First, compared to MR scanners, CT scanners are the workhorse of diagnostic imaging in both emergent and non-emergent situations due to their constant availability in medical facilities, ranging from large academic to small regional hospitals, and their 24-hour availability, due to their ease of use for both staff and patients. Second, multi-row detector CT [3] has further improved this capability by enabling more axial coverage in a single rotation of the detector. Technological advancements in helical scanning [4] have increased the speed at which scans of the body at thinner slices can be performed, making three-dimensional imaging practical. Third, new CT applications such as virtual colonoscopy, perfusion examinations, and computed tomography angiography of the brain and heart have been made possible by high-speed imaging enabled available by helical scanning with multi-row detectors.

Although making for a smaller proportion of imaging procedures, CT imaging contributes significantly to medical radiation exposure, contributing to an excessive amount of the total radiation dose. The possible biological effects of ionizing radiation come out because to the higher radiation doses associated with CT compared to conventional radiography. Epidemiological research indicates that accumulating radiation exposure may raise the lifetime risk of cancer, especially in susceptible populations like children and those receiving frequent imaging [1].

STRATEGIES FOR GENERAL DOSE REDUCTION

OPTIMIZATION OF CT SYSTEMS

The detector, collimator, and beam-shaping filter are only a few of the many system components that are involved in the enormous amount of work that has been done to increase the dose efficiency of CT systems.

Detector

The most significant factor influencing a CT system's dose performance is most likely the x-ray detector. Quantum detection efficiency and geometrical efficiency are two dose-relevant parameters of a detector that combined define how well the detector converts incident x-ray energy into signals. Because of their better quantum detection efficiency, solid state detectors (such as Gd2O2S) are now frequently employed instead of xenon gas detectors, which were popular in the 1980s. To enable quick scanning times and excellent image quality, detectors with quick response times and minimal afterglow are also preferred [5].

Collimator

Prepatient collimators are placed between the patient and the x-ray source in order to specify the amount of protection of the x-ray beam and prevent patients from absorbing unnecessary radiation. The focal spot of the x-ray tube is not a point source, therefore some areas of the beam coverage are only partially exposed. Unlike the umbra region, which is completely exposed to the x-ray source, this area is called the penumbra region. The penumbra region in multislice CT is a useless dose to the patient and does not contribute to the development of the image. With the goal to filter out scattered radiation, postpatient collimators are placed between the patient and the detector, often just in front of it. This improves image quality at the cost of dose efficiency. Optimizing the design of scatter-rejection collimators requires careful consideration of the trade-off between dose and image quality [6].

Beam Shaping Filter

An essential factor in a CT system's dosage performance is X-ray beam-shaping. In order to make the x-ray beam hard enough to effectively penetrate the patient while still providing enough contrast information, the x-ray beam filter is a physical device that attenuates and "hardens" the beam spectrum. The attenuation in the peripheral region is lower than that through the center region because patients' cross-sections are usually circular in form. In order to decrease the radiation exposure to the patient, particularly the skin dose, some filters are made in a unique form (such as a bowtie) to lessen the incident x-ray intensity in the periphery region [7].

Scan Range

It is essential to maintain the scan range as small as reasonable and as extensive as necessary to prevent direct radiation exposure to any body parts that are not required for diagnosis, as the scan range is directly linked with the total radiation dose that is administered to the patient. This is potentially the simplest way to maintain the lowest possible dose.

Optimal tube potential

OPEN ACCESS

Journal of Clinical Advances and Research Reviews (JCARR)
Website: http://www.jcarr.in/
ISSN: 3048-6556
Vol. 3, Issue 3, Jul-Sept, 2026
Page No.: 06-11

Lower tube potentials (kV) in CT imaging have shown varying degrees of dose reduction or image quality enhancement in a number of recent physics and clinical research. According to Siegel et al., the improvement in image quality at lower kV rises as the phantom size decreases[8]. Funama et al .and Nakayama et al. have demonstrated that when the patient weight is less than 80 kg, it is feasible to lower the kV settings from 120 to 90 kV in abdominal CT without appreciably compromising the low-contrast detectability using both phantom and clinical tests. For the diagnosis of hypervascular liver cancers, Schindera et al. showed enhanced iodine CNR and decreased radiation dose at 80 kV.

TECHNIQUES FOR LOWER DOSES SPECIFIC FOR EXAMINATIONS-

Pediatric CT-

Due to its speed and diagnostic accuracy, CT has become more popular in pediatric imaging, with millions of tests performed each year. Children are more susceptible to radiation and have a longer lifespan, which enhances the risk of radiation-induced cancer,so reducing their radiation exposure is crucial. As a result, each CT scan must be carefully justified, and whenever feasible, alternative imaging techniques like ultrasound or MRI should be taken into account. Furthermore, if a single-phase scan provides adequate diagnostic data, needless multiphase scans should to be avoided [9].

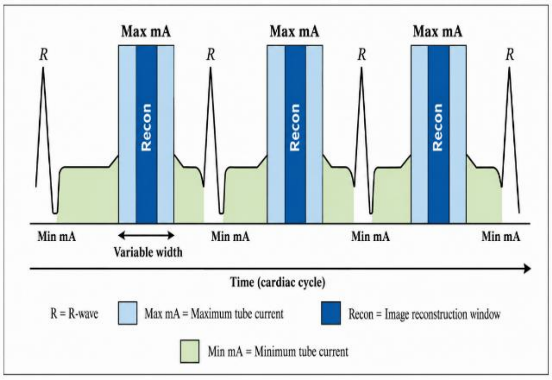
Pediatric-specific techniques must be used when CT is required, with a focus on dose optimization based on patient size. Radiation dose reduction methods include size-specific filters, weight-based tube current changes, and automatic exposure control (AEC). Specifically for iodine-enhanced studies, lower tube potential settings can further reduce exposure while preserving or enhancing image contrast. However, in order to prevent increasing noise and artifacts, these methods require careful adjustment of parameters like mAs, pitch, and rotation time. In general, safe and efficient CT imaging in children requires specific scanning techniques and following to pediatric guidelines [10].

Cardiac CT

Improvements in temporal and spatial resolution have made cardiac computed tomography (CT) far more advanced, enabling its use in a variety of clinical applications, including the evaluation of cardiac valves, myocardial perfusion, calcium scoring, and coronary artery disease [11]. Coronary artery imaging is still one of more difficult CT tasks, however, since it requires high spatial resolution to see small vascular structures and good temporal resolution to reduce motion distortions from cardiac activity. When compared to other CT exams, these limitations lead to higher radiation exposure. The use of half-scan reconstruction, low helical pitch in sequentially ECG-gated scanning, and continuous X-ray exposure are all contributing variables that result in unusually high radiation doses; median effective doses have been found to be around 12 mSv, with some cases reaching up to 30 mSv [12].

A number of techniques have been developed to lower the radiation dose in cardiac CT scans while maintaining the quality of the diagnostic images. An efficient technique that can reduce exposure by up to 64% without reducing image clarity is ECG tube-current modulation. Improved temporal resolution and dose reductions of up to 50% are made possible by technological innovations like dual-source CT scanners. In certain patients, prospective ECG-triggered (step-and-shoot) scanning can achieve effective doses as low as 1-2.6 mSv, making it a very dose-efficient method. Additionally, advancements like fast-pitch helical scanning and 320-slice CT scanners allows imaging of the entire heart in a single cardiac cycle, greatly increasing dose efficiency. Additionally, using a lower tube voltage helps reduce dose while preserving sufficient contrast and image quality, especially in patients of average body size.

In cardiac CT [13] ECG-based tube current regulation is a significant dose reduction technique. Figure 1: Illustration of the tube current regulation based on ECG. While the temporal width of the image reconstruction window (Recon) is fixed, the user can choose the width of the temporal window with the maximum tube current (Max mA). The reconstruction window (darker blue time interval) and maximum mA window (lighter blue time interval) will match for full quality images [14].



Journal of Clinical Advances and Research Reviews (JCARR)
Website: http://www.jcarr.in/
ISSN: 3048-6556
Vol. 3, Issue 3, Jul-Sept, 2026
Page No.: 06-11

Figure-1: Illustration of the tube current regulation based on ECG. While the temporal width of the image reconstruction window (Recon) is fixed, the user can choose the width of the temporal window with the maximum tube current (Max mA). The reconstruction window (darker blue time interval) and maximum mA window (lighter blue time interval) will match for full quality images.

Dual Energy CT

With the introduction of new CT technologies like DS, kV switching, and dual-layer detectors, dual-energy CT has recently drawn significant amounts of attention [15]. Numerous applications have been used clinically, including kidney stone characterisation, iodine quantification, and bone removal. Dual-energy CT uses a variety of dual-energy processing approaches to provide material-specific information by acquiring data at two tube potentials [16] .Since a dual-energy scan offers material-specific information in addition to images that resemble an conventional single-energy scan, one frequently asked question is if dual-energy CT requires a larger dose than single-energy CT. Virtual noncontrast imaging is another use of dual-energy CT for radiation dose reduction [17]. Repeated scans before and after contrast injection are a common part of CT exams. With dual-energy CT, "virtual" precontrast pictures can be created from a post-contrast dual-energy scan, potentially avoiding the precontrast scan and lowering the overall radiation dosage. However, the quality of the virtual noncontrast images produced in a dual-energy postcontrast scan has a significant impact on the amount of dose reduced. The virtual images frequently have a high noise level because of the noise amplification that occurs during dual-energy processing [18]. Increased distance between the low- and high-energy x-ray bands may enhance virtual image quality and enable more important radiation dose reduction.

CT Perfusion

Neurovascular, cardiovascular, and oncologic applications may benefit from computed tomography perfusion imaging. According to current methods, data must be collected for brain perfusion for at least 40 seconds, myocardial perfusion for 30 seconds, or renal perfusion for 3 minutes. Using different models of single-and multiple-compartment flow, the time-attenuation curve over the tissue/organ of interest is used to estimate characteristics such vascular permeability, absolute blood flow, and volume [19] .The radiation dose in a perfusion study is typically substantially higher than that of a standard CT scan due to the lengthy scanning period. Incorrect execution of the inspection may result in skin damage (deterministic risk).

For comparison, a single dose of 1000 mGy can be the threshold for deterministic effects. Skin reddening may start following a single dosage of 2000 mGy [20]. The technique factors (e.g., mAs, kV) are frequently set at a significantly lower level so that the cumulative examination skin dosage is below the threshold for skin injury in order to prevent such harm. However, this leads to higher levels of noise and distortion, which may harm the technique's quantitative accuracy. It is therefore very desired to find ways to reduce image noise at the same or lower dose levels.

FUTURE PERSPECTIVES

In order to increase diagnostic image quality while reducing radiation exposure, future developments in computed tomography (CT) dose reduction will likely focus on integrating artificial intelligence (AI), machine learning, and efficient detector technologies. In order to minimize images with noise and preserve diagnostic accuracy even at extremely low radiation doses, AI-based image reconstruction algorithms and deep learning reconstruction algorithms are being used more frequently. Without sacrificing image quality, these technologies might enable significant decreases in tube voltage and current. Additionally, compared to traditional energy-integrating detector systems, photon-counting detector CT offers better contrast differentiation, higher spatial resolution, and superior dosage efficiency, making it a possible advancement.

In order to promote specialized and safer imaging procedures, future CT systems are likely to have automated patient-specific scanning protocols that modify exposure parameters based on body physiology, clinical indication, and anatomical location. Additionally, it will be expected that continued advancements in spectrum imaging, low-dose cardiac and pediatric CT protocols, automatic exposure control systems, and iterative reconstruction will further maximize radiation safety while preserving diagnostic accuracy [21].

Journal of Clinical Advances and Research Reviews (JCARR)
Website: http://www.jcarr.in/
ISSN: 3048-6556
Vol. 3, Issue 3, Jul-Sept, 2026
Page No.: 06-11

Improving worldwide dose optimization standards and increasing awareness of radiation safety are two more crucial future perspectives. Developing standardized low-dose imaging methods and enhancing quality assurance systems will require increased cooperation between radiologists, medical physicists, radiologic technologists, and CT manufacturers [19]. Future studies are expected to concentrate on improving radiation risk assessment models and assessing the long-term biological impacts of low-dose radiation exposure. Additionally, national radiation dose registries and cloud-based dose monitoring systems may assist organizations in regularly comparing and auditing CT procedures to guarantee accordance with the ALARA (As Low As Reasonably Achievable) principle [21].

CONCLUSION

Computed tomography (CT) has become an indispensable imaging modality in modern medicine because of its rapid acquisition speed, excellent spatial resolution, and broad clinical applications. Radiation dose optimization has been a top objective in modern CT imaging procedures, but the growing use of CT has additionally caused concerns about patient exposure to ionizing radiation and its possible long-term biological consequences. As a result, radiation dose optimization is now an important issue in modern CT imaging procedures.

According to advancements in CT technology, software, and scanning procedures, significant progress has been made in lowering radiation exposure. Dose efficiency has been significantly increased while maintaining diagnostic image quality because to methods such automatic exposure control, low tube voltage imaging, iterative reconstruction, ECG-gated dose modulation, optimal collimation, and patient-specific scanning strategies. Furthermore, examination-specific methods in dual-energy CT, CT perfusion imaging, cardiac CT, and pediatric CT have improved radiation safety in certain clinical applications.

By enabling ultra-low-dose exams with better image quality and diagnostic accuracy, emerging technologies like photon-counting detector CT, deep learning algorithms, and artificial intelligence (AI)-based reconstruction are expected to change low-dose imaging. To ensure full compliance to the ALARA principle, future CT systems will probably include precise spectral imaging, cloud-based dose monitoring systems, intelligent automated algorithms, and globally standardized dose optimization guidelines. All things considered, increasing safer, more effective CT imaging procedures and enhancing patient safety will be significantly helped by ongoing technological innovation and productive cooperation between radiologists, medical physicists, radiologic technologists, and CT manufacturers. Finding the ideal balance between reducing radiation exposure and preserving high-quality diagnostic performance is vital for CT imaging's future.

REFERENCES

1. Kalender WA. X-ray computed tomography. Physics in medicine & Biology. 2006 Jul 7;51(13):R29-43.

2. McCollough CH, Primak AN, Braun N, Kofler J, Yu L, Christner J. Strategies for reducing radiation dose in CT. Radiologic Clinics of North America. 2009 Jan;47(1):27.

3. Hoffmann U, Bamberg F, Chae CU, Nichols JH, Rogers IS, Seneviratne SK, Truong QA, Cury RC, Abbara S, Shapiro MD, Moloo J. Coronary computed tomography angiography for early triage of patients with acute chest pain: the ROMICAT (Rule Out Myocardial Infarction using Computer Assisted Tomography) trial. Journal of the American College of Cardiology. 2009 May 5;53(18):1642-50.

4. Petersilka M, Bruder H, Krauss B, Stierstorfer K, Flohr TG. Technical principles of dual source CT. European journal of radiology. 2008 Dec 1;68(3):362-8.

5. Hsieh J. Computed Tomography: Principles, Design, Artifacts, and Recent Advances. Bellingham, WA, USA: SPIE Press; 2006. [Google Scholar]

6. Siewerdsen JH, Jaffray DA. Cone-beam computed tomography with a flat-panel imager: magnitude and effects of x-ray scatter. Med. Phys. 2001;28:220–231. doi: 10.1118/1.1339879. [DOI] [PubMed] [Google Scholar]

7. McCollough CH, Primak AN, Saba O, et al. Dose performance of a 64-channel dual-source CT scanner. Radiology. 2007;243:775–784. doi: 10.1148/radiol.2433061165. [DOI] [PubMed] [Google Scholar]

8. Siegel MJ, Schmidt B, Bradley D, Suess C, Hildebolt C. Radiation dose and image quality in pediatric CT: effect of technical factors and phantom size and shape. Radiology. 2004;233:515–522. doi: 10.1148/radiol.2332032107. [DOI] [PubMed] [Google Scholar]

9. Paterson A, Frush DP. Dose reduction in paediatric MDCT: general principles. Clin. Radiol. 2007;62:507–517. doi: 10.1016/j.crad.2006.12.004. ▪▪ Discusses dose-reduction strategies in pediatric CT.

10. Huda W,scalzetti EM,Levin G. Technique factor and image quality as functions of patients weight at abdominal CT Radiology.2000;217:430-435 doi:10.1148/radiology.217,200nv35430

11. Ruzsics B, Lee H, Zwerner PL, Gebregziabher M, Costello P, Schoepf UJ. Dual-energy CT of the heart for diagnosing coronary artery stenosis and myocardial ischemia-initial experience. Eur. Radiol. 2008;18:2414–2424. doi: 10.1007/s00330-008-1022-x. [DOI] [PubMed] [Google Scholar]

12. Hausleiter J, Meyer T, Hermann F, et al. Estimated radiation dose associated with cardiac CT angiography. JAMA. 2009;301:500–507. doi: 10.1001/jama.2009.54. [DOI] [PubMed] [Google Scholar]

13. McCollough CH, Bruesewitz MR, Kofler JM., Jr CT dose reduction and dose management tools: overview of available options. Radiographics. 2006 Mar-Apr;26(2):503–512. doi: 10.1148/rg.262055138. [DOI] [PubMed] [Google Scholar]

14. Jakobs TF, Becker CR, Ohnesorge B, et al. Multislice helical CT of the heart with retrospective ECG gating: reduction of radiation exposure by ECG-controlled tube current modulation. Eur Radiol. 2002;12(5):1081–1086. doi: 10.1007/s00330-001-1278-x. [DOI] [PubMed] [Google Scholar]

15. Johnson TR, Krauss B, Sedlmair M, et al. Material differentiation by dual energy CT: initial experience. Eur. Radiol. 2007;17:1510–1517. doi: 10.1007/s00330-006-0517-6. [DOI] [PubMed] [Google Scholar]

16. Lehmann LA, Alvarez RE, Macovski A, et al. Generalized image combinations in dual KVP digital radiography. Med. Phys. 1981;8:659–667. doi: 10.1118/1.595025. [DOI] [PubMed] [Google Scholar]

17. Kalra MK, Maher MM, Toth TL, Hamberg LM, Blake MA, Shepard JA, Saini S. Strategies for CT radiation dose optimization. Radiology. 2004 Mar;230(3):619-28.

18. Kelcz F, Joseph PM, Hilal SK. Noise considerations in dual energy CT scanning. Med. Phys. 1979;6:418–425. doi: 10.1118/1.594520. [DOI] [PubMed] [Google Scholar]

19. Dugdale PE, Miles KA, Bunce I, Kelley BB, Leggett DA. CT measurement of perfusion and permeability within lymphoma masses and its ability to assess grade, activity, and chemotherapeutic response. J. Comput. Assist. Tomogr. 1999;23:540–547. doi: 10.1097/00004728-199907000-00010. [DOI] [PubMed] [Google Scholar]

20. Wagner LK, Eifel PJ, Geise RA. Potential biological effects following high x-ray dose interventional procedures. J. Vasc. Interv. Radiol. 1994;5:71–84. doi: 10.1016/s1051-0443(94)71456-1. [DOI] [PubMed] [Google Scholar]

21. Brenner DJ, Hall EJ. Computed tomography—an increasing source of radiation exposure. New England journal of medicine. 2007 Nov 29;357(22):2277-84.

*****