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Radiation Dose Optimization in Computed Tomography: A Narrative Review

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Abstract

Computed tomography (CT) is a critical diagnostic imaging tool that plays a vital role in the early diagnosis and proper management of diseases. However, the increasing reliance on CT scans has led to concerns regarding the associated radiation dose. CT scans are a major contributor to medical imaging dose. This review aims to address the current trends and techniques of optimizing the dose of radiation used in CT scans while maintaining the quality of images obtained. The dose of radiation is reduced by the use of hardware technologies such as automatic exposure control, tube current modulation, and beam filters. Software technologies such as iterative reconstruction and deep learning algorithms are also being used. The optimization of CT scans is carried out through techniques such as patient size adaptation and reduction of multiphase scanning. The advancement of CT scans includes technologies such as dual-energy scanning, photon counting, and intelligent workflow.

Keywords: *Computed Tomography; Radiation Dose Optimization; Iterative Reconstruction; Deep Learning Reconstruction; Low-Dose CT.*

1. Introduction

Computed Tomography (CT), an imaging modality, has emerged as one of the most effective imaging tools in the present day clinical practice since its clinical introduction by Hounsfield in 1972 (Hounsfield, 1973). CT imaging is crucial for the diagnosis and management of emergency medicine cases, cancer diagnosis, cardiovascular imaging, and surgery planning as it can scan the body's anatomy in cross-sections without invading the body at an unmatched speed (Mettler FA, et al.,2024).Compared with conventional radiography, CT scans involve a higher amount of ionizing radiation, which is attributed to the multi-angle acquisition method used in CT scanning. For example, a conventional chest X-ray has an exposure rate of 0.1 mSv, whereas a CT scan has an exposure rate of 1 to 20 mSv, depending on the type of scan. Though the risks involved in a CT scan are low, repeated exposure may increase the possibility of adverse health effects, such as cancer, which is caused by radiation (Brenne, et. Al.,2007)The association between the amount of radiation and cancer risk is usually explained through the linear no threshold model, which states that even a low amount of radiation has some level of risk. Research, including the cohort study by Pearce et al., has shown a small but statistically significant increase in cancer risk, particularly for children exposed to CT scan radiation (Pearce MS et al., 2012).This has led to the development of various strategies to reduce the dose while maintaining the quality of the images obtained. The ALARA principle, which stands for "As Low As Reasonably Achievable," is the basis of radiation protection. The ALADA principle, which stands for "As Low As Diagnostically Acceptable," is a related term. Optimization of the dose in CT scans is a complex process, and a number of factors are included in the process, which are related to the technology used, image reconstruction, and clinical decision-making. This article offers a comprehensive overview of these different aspects, with a focus on the current trends and future developments in dose reduction in CT scans.

2. Dose Optimization Techniques

2.1.CT Radiation Dose Metrics

It can be useful to understand what exactly is being decreased and how it is measured before entering any serious discussion about dose reduction. In clinical practice, CT dosimetry uses a variety of related but separate parameters, which, in a sense, answer a given[1 – 5] question in a somewhat different way (McCollough CH, et al., 2015)The number most visible at the point of scanning is the volume CT dose index, universally abbreviated as CTDIvol and expressed in milligrays. It represents the average absorbed radiation over a standardized cylindrical phantom during the acquisition, and it appears on the scanner console at the end of each examination. Its companion metric, the dose-length product (DLP), extends this by factoring in how far along the patient the scan ran — longer scans accumulate more total dose even when the per-centimetre output is constant. DLP is the figure from which effective dose is most often estimated, using published body-region conversion coefficients (Boone JM, et al., 2011)Effective dose, measured in millisieverts, is the metric most familiar to patients and the one most commonly cited in radiation risk discussions. It converts absorbed dose into a single risk-weighted number by accounting for the fact that organs differ in their vulnerability to radiation-induced harm. The thyroid, bone marrow, breast tissue, and gonads, for instance, are considerably more sensitive than muscle or bone. Effective dose is useful for comparing radiation levels across different scan types or modalities, but it should be understood as a statistical description of population risk rather than a precise measure of what any individual patient has received. All of these metrics are connected at the departmental level through a tool called the diagnostic reference levels (DRL). Created by the International Commission on Radiological Protection as the dose values at the 75th percentile of the observed distribution for a standard procedure for a given department, DRLs are not limits to be kept below; rather, they are a benchmark by which a department's performance can be realistically evaluated. A consistent ranking near the DRL for a standard procedure should prompt investigation (ICRP, 2017).Table 1

2.2.Hardware Strategies for Dose Reduction

2.2.1. Tube Current Modulation

For much of CT’s history, the X-ray tube delivered a fixed output throughout the entire scan, irrespective of what was being imaged at any given moment. The shoulders and pelvis received the same beam as the thinner waist and neck, even though the thicker regions needed more penetration and the thinner ones far less. Tube current modulation ended that inefficiency. By reading the patient’s attenuating profile from the preliminary scout radiograph and then adjusting the milliamperage in real time as the scan progresses, modern automatic exposure control systems can tailor output to the anatomy moment by moment — higher through dense structures, lower through thinner ones, and dynamically balanced between the anteroposterior and lateral orientations, which attenuate very differently through the pelvis and chest (Gies, et al., 1999).Shown as Table 1 Radiation dose metrics used in CT dosimetry[6].

Table 1 Radiation dose metrics used in CT dosimetry

Dosimetric Metric	Unit	What It Captures	Where It Is Most Useful
CTDIvol	mGy	Mean phantom absorbed dose for the acquisition volume	Protocol bench-marking; DRL comparison at the console

DLP	mGy·cm	Total radiation along the full scan length	Effective dose estimation; cross-examination dose comparison
Effective Dose	mSv	Organ-weighted dose index reflecting stochastic cancer risk	Patient risk communication; comparison across imaging modalities
SSDE	mGy	CTDIvol corrected for actual body dimensions	Accurate individual dose estimation, especially in children
Organ Dose	mGy	Absorbed dose to a specific radiosensitive structure	Risk assessment for repeat images and radiosensitive patients

CTDIvol = volume CT dose index; DLP = dose-length product; SSDE = size-specific dose estimate; DRL = diagnostic reference level.

All major scanner manufacturers have developed their own implementations of this principle — among them CARE Dose4D from Siemens, Auto mA and Smart mA from GE, DoseRight from Philips, and Sure Exposure from Canon. Despite varying in their underlying algorithms, these systems share a consistent and well-documented outcome: dose reductions in the range of 20 to 40 percent compared to fixed-tube-current protocols, without meaningful compromise to the images that result. For a technology that requires no additional infrastructure and is already installed in most modern scanners, its impact-to-effort ratio is difficult to match[9].

2.2.2. Kilovoltage Selection

The kilovoltage setting on a CT scanner represents one of the most important, though least understood, dose management parameters. The relationship between voltage and dose output is not linear, as might be expected, but rather quadratic, so that small changes in voltage result in large changes in dose outputWhat makes voltage selection particularly interesting from a clinical standpoint is that lower kilovoltage settings do not simply reduce dose — they simultaneously enhance iodine visibility. Iodine, the basis of most CT contrast agents, absorbs low-energy X-rays more avidly[7], meaning that contrast-enhanced studies performed at lower kVp often appear sharper and more conspicuous, particularly in vessels and parenchymal organs. Automated tube voltage selection platforms — such as CARE kV and kV Assist — exploit this by sizing the kVp to each patient's body habitus and the expected clinical task, routinely achieving dose reductions of 30 to 50 percent[8] in appropriately selected patients undergoing contrast-enhanced examinations (May MS, et al., 2011).

2.2.3. Beam Filtration and Organ-Based Modulation

The bow-tie filter, which has been included in CT systems from the first generation, constricts the X-ray beam from the sides towards the center, thereby reducing the X-ray intensity in the peripheral regions of the beam where the path length through the body is a minimum, and where full beam intensity would result in an unnecessarily high skin dose. Advanced adaptive versions of this type of filter can alter the rate of constricting the beam in accordance with the individual patient on the table.Organ-based tube current modulation advances this by stepping down the tube output for those angular positions where the beam passes through the radiosensitive anterior structures: the thyroid, the breast tissue, the lenses of the eyes. At the same time, full tube output is maintained for all other posterior projections. This is because the sensitive structures are not in the x-ray beam's path from the rear. In fact, a study on the specific dose to the breast has shown a reduction of 30 to 40 percent by this method without impairing the quality of the posterior images (Rayner NJ, et al., 2019).

2.2.4. Photon-Counting Detector CT

A new technology appears that does not merely improve upon the previous one but rather fundamentally changes the nature of the question being posed. Photon-counting detector CT is one such innovation. To understand the significance of this point, it is necessary to understand the function of the detector array in a standard CT system. Shown as Table 2 compaeision of conventional energy integrating and photon couting detector.

Table 2 Comparison of Conventional Energy-Integrating and Photon-Counting Detector

Characteristic	Conventional Energy-Integrating Detector	Photon-Counting Detector
Detection architecture	Scintillator + photodiode; X-rays converted to light and integrated into a continuous signal	Direct semiconductor conversion; each photon counted individually above an energy threshold
Electronic noise behaviour	Noise enters the image signal indiscriminately; worsens substantially at low doses	Noise below the threshold is rejected; image signal remains clean at low mAs
Spectral imaging capability	Requires dual-source hardware or tube voltage switching; incurs dose or time penalties	Inherent in every acquisition; multiple energy bins captured simultaneously without added dose
Spatial resolution	Constrained by element size and the septa that electrically isolate adjacent elements	Improved by smaller elements and the absence of inter-element septa
Dose efficiency	Substantially improved by AEC and TCM; further gains approach diminishing returns	50–65% dose reductions reported vs. conventional systems in initial clinical studies
Current clinical availability	Standard equipment in imaging departments globally	First system approved 2021; limited to specialist and academic centres as of 2024

When X-rays travel through the body and hit the detector array, a scintillator material changes them to a form of light, which is then converted to a continuous electrical current by a photodiode. This current is a measure of the total energy absorbed by the sum total of the incident photons, but the specific characteristics of each photon are lost in the integration. In addition, random noise from the photodiode circuit contributes to the total current (Rajagopal JR, et al., 2022). Table 2

2.3.Image Reconstruction Advances

2.3.1. Filtered Back-Projection: The Historical Baseline

Every CT image begins as raw data — a vast array of X-ray attenuation measurements collected from hundreds of angular positions around the patient. Turning that dataset into a picture requires a mathematical reconstruction process, and for the first four decades of CT, that process was filtered back-projection. The method is computationally elegant and fast, and it produces images whose characteristics are well-understood. Its core limitation, however, is rigid: as the number of photons in the dataset falls — which is precisely what happens when dose is reduced — image noise rises in direct proportion. There is no[10] flexibility in this relationship. You could reduce dose or you could have acceptable image quality, but pushing hard on both simultaneously was not an option filtered back-projection could accommodate

(Kachelrieß M, et al., 2007)

2.3.2. Iterative Reconstruction

Iterative reconstruction reframed the problem. Rather than deriving the image in a single mathematical step, iterative algorithms approach reconstruction as an optimization challenge: they generate a candidate image, simulate what the scanner measurements would look like if that image were correct, compare those simulated measurements against what was actually recorded[11], and update the image to close the gap. This cycle is repeated many times, each pass bringing the image closer to an internally consistent solution. Because the algorithm incorporates explicit statistical models of photon noise behaviour — and in its more advanced forms, detailed physical models of the scanner hardware itself — it can identify and suppress noise that filtered back-projection would simply reproduce (Saiprasad et al., 2015)Three distinct generations of iterative reconstruction have been introduced into clinical CT practice. First-generation hybrid systems, such as GE ASIR and Siemens iDose4, blend the iterative output with a filtered back-projection component in the image domain, producing modest dose reductions of roughly 10 to 30 percent while keeping image texture close enough to the familiar FBP appearance that radiologists accept them readily. Second-generation adaptive statistical methods — including GE ASIR-V, Siemens SAFIRE, and Canon AIDR 3D — apply the iterative optimization across both the raw projection data and the image domain, delivering reductions in the 30 to 60 percent range with better preservation of low-contrast detectability. Third-generation model-based algorithm technologies from GE VEO, Siemens ADMIRE, and Canon FIRST incorporate comprehensive modeling of the focal spot geometry, the beam profile, and the detector response, reducing doses by as much as 80 percent for selected clinical applications. Their practical limitation has been a smooth, unnaturally processed image texture that appears at high reconstruction strengths and that radiologists have found uncomfortable, particularly for detecting subtle parenchymal or mucosal abnormalities.

2.3.3. Deep Learning Image Reconstruction

The arrival of deep learning image reconstruction at the clinical CT workstation in 2019 introduced a fundamentally different approach to the dose-quality trade-off. Where iterative algorithms encode explicit mathematical[12] rules about noise and scanner physics, deep learning systems encode nothing explicitly — they learn. Training involves exposing a convolutional neural network to thousands of matched image pairs: noisy low-dose acquisitions alongside corresponding standard-dose or ground-truth reference images. Through repeated exposure to these pairs, the network learns to recognize what true anatomical structure looks like against a background of noise, and to reconstruct it reliably even from reduced photon counts. Applied to clinical acquisitions, the trained network processes each new dataset through what it has learned, producing images that have been denoise and detail-enhanced by the accumulated pattern recognition of its training (Lell MM, et al., 2020).Table 3

2.4.Protocol - Level Optimization

2.4.1. Clinical Justification

No hardware upgrade or algorithmic refinement can reduce the radiation burden of a CT examination that should not have taken place. An unjustified scan is not a scan performed at too high a dose — it is a scan performed at infinite cost-to-benefit ratio, because there is no benefit against which to weigh the cost. Clinical decision support tools built into electronic ordering systems, anchored to evidence-based imaging guidelines, have been shown to reduce inappropriate[13] CT orders by 10 to 30 percent in prospective implementation studies (Berrington de González A, et al., 2004). That is a population-level dose saving achievable immediately, at no capital cost, through attention to the appropriateness of each referral before it becomes a scan. Table 3 CT image reconstruction method: Dose reduction, strengths and limitation[14]

Table 3 CT image reconstruction method: Dose reduction, strengths and limitation

Reconstruction Approach	Representative Commercial Systems	Reported Dose Reduction Vs FBP	Primary Strength	Practical Limitation
Filtered Back-Projection (FBP)	Standard across all vendors – historical baseline	Reference (0%)	Speed; predictability; well-characterised image noise behaviour	Noise rises in direct proportion as dose falls — no flexibility
Hybrid Iterative (1st gen)	GE ASIR; Siemens iDose4; Philips iDose	10–30%	Familiar image appearance; straightforward to introduce clinically	Modest ceiling on achievable reduction
Adaptive Statistical Iterative (2nd gen)	GE ASIR-V; Siemens SAFIRE; Canon AIDR 3D	30–60%	Strong noise suppression while preserving spatial resolution	Texture begins to change at higher reconstruction strengths
Model-Based Iterative (3rd gen)	GE VEO; Siemens ADMIRE; Canon FIRST	Up to 80%	Greatest noise reduction achievable with iterative methods	Unnatural 'processed' texture; longer reconstruction times
Deep Learning Reconstruction (DLIR)	GE TrueFidelity; Canon AiCE; Siemens Deep Resolve; Philips SmartSpeed	50–82%	Natural texture; superior noise reduction; sharpness preserved; high radiologist acceptance	Hallucination artifact risk; vendor-specific training; needs validation per application

2.4.2. Body Size Adaptation

A protocol calibrated for a standard adult will overdose a small patient and may underdose a large one. The range of body sizes presenting for CT in any busy department is enormous, yet many protocols still operate from a single default configuration. Size-adapted protocols — whether through noise-index-based automatic exposure control targeting or through manually curated weight- and size-bracket protocol tables — address one of the most prevalent and most remediable sources of excess radiation in clinical CT. The logic is unambiguous; the implementation requires institutional discipline and radiographer education, not new equipment (Henner A, et al., 2021).

2.4.3. Scan Length and Phase Reduction

Two protocol behaviours that routinely add to patient dose without adding proportionate diagnostic return are excessive scan length and unreflective multiphase acquisition. Scan ranges that extend beyond the anatomical region of clinical interest — shown in observational studies to exceed the minimum necessary extent by five to fifteen centimetres in routine practice — accumulate dose linearly with every extra centimetre (McCollough CH, et al., 2012). Multiphase protocols, which image the same anatomical region at multiple time points after contrast administration, carry a proportional multiplication of dose for each additional phase. Many examinations currently performed in three or four phases can be managed adequately in one or two, with the remaining phases made available on request rather than supplied by default. Systematic protocol review — carried out by radiologists who understand both the clinical question and the dosimetric consequences — is the vehicle for achieving this.

2.4.4. Special Population Protocols

Children, cardiac patients, and individuals enrolled in lung cancer screening programmes represent three clinical populations whose dose management warrants specific, dedicated attention — and where the evidence supporting meaningful reduction is clearest.In pediatric CT, the main problem is that it is not possible to simply reduce adult standards. This is because, for children, their radiosensitivity is greater, their life expectancy is longer, and their body volume is smaller, so even when acquisition parameters are the same, tissue doses per kilogram are greater. The Image Gently campaign, coordinated by the Alliance for Radiation Safety in Pediatric Imaging since 2008, has embedded a simple but powerful message into paediatric imaging culture: the dose should be sized to the child, not the scanner's default.[19] Departments participating in the campaign have documented measurable, sustained reductions in paediatric CT dosing — evidence that professional culture and practical guidance, not only technology, drive improvement.Cardiac CT has undergone its own dose reduction revolution. The traditional approach of retrospective ECG gating — in which radiation is delivered continuously across the full cardiac cycle and only a subset of the acquired data is used for image reconstruction — has been largely superseded in routine practice by prospective ECG triggering, in which the beam is activated only during the brief diastolic window that yields motion-free images. The dose saving is substantial: 40 to 80 percent in head-to-head comparisons. On systems equipped with dual X-ray sources, high-pitch acquisition modes can capture the entire heart in a fraction of a second at effective doses comparable to a conventional radiograph series. These are not incremental refinements; they represent a fundamental change in the radiation economics of cardiac CT.Low-dose CT for lung cancer screening has become one of the field's most compelling clinical applications of dose optimization. Screening is, by definition, applied to people who do not yet know they are sick. The radiation burden of a programme that will be offered to millions of people over many years must therefore be kept as low as the detection task allows. Optimized low-dose lung CT protocols now routinely achieve effective doses of 0.5 to 1.5 millisieverts — a fraction of what standard diagnostic chest CT delivers — while maintaining sufficient sensitivity to reduce lung cancer mortality by a fifth or more in eligible high-risk populations, as demonstrated in the major randomised trials (National Lung Screening Trial Research Team, 2011).

2.5.Emerging Technologies

2.5.1. Dual -Energy and Spectral CT

Acquiring CT data at two different X-ray energies simultaneously unlocks capabilities not available from single-energy scanning: the ability to distinguish materials by their elemental composition, to generate images simulating any desired photon energy, and to map the distribution of specific substances such as iodine within tissues. From a dose standpoint, the most directly useful application is the generation of virtual unenhanced images —

mathematically derived representations of how tissue would appear without contrast — from a post-contrast dual-energy dataset. Where a conventional protocol would require a separate unenhanced acquisition, a well-designed dual-energy study can provide equivalent information from a single pass, eliminating a phase and its associated dose. The feasibility of this substitution varies by clinical indication, but its evidence base is growing for adrenal and renal lesion characterization, among other applications (Siegel MJ, et al., 2016).

2.5.2. Artificial Intelligence in Dose Optimization Workflows

Artificial intelligence is entering the CT optimization workflow at several pressure points. Automated protocol recommendation systems can match acquisition parameters to the clinical indication and patient characteristics more consistently than protocols[15 – 20] selected from a static menu, reducing the inter-operator and inter-shift variability that generates much of the avoidable dose variation in busy departments. Dose management platforms powered by AI can continuously harvest radiation dose records from every scanner and examination, cross-reference them against reference benchmarks, and alert the team to outliers before they accumulate into a pattern. These systems do not supplant clinical judgment; they give clinical judgment the data it needs to function reliably at scale (Doda Khera R, et al., 2022).

2.5.3. Compressed Sensing Reconstruction

Compressed sensing is a mathematical framework built on a counterintuitive observation: if an image has an underlying structure that is sparse in some mathematical transform domain, it can often be reconstructed accurately from far fewer measurements than classical sampling theory would suggest necessary. Applied to CT acquisition, this opens the theoretical possibility of obtaining diagnostically useful images from reduced numbers of X-ray projections or from lower-dose projections, effectively decoupling dose from sampling completeness within certain limits.[23] Clinical applications are still in early phases, with the most promising results reported in contexts where data sparsity is already inherent — CT fluoroscopy guidance, dynamic organ imaging, and time-resolved cardiac studies[21 – 25]. As the computational infrastructure to support it becomes more accessible, compressed sensing is expected to expand its role in the optimization toolkit (Candès EJ, et al., 2006).

2.6.Quality Assurance and Institutional Governance

The technologies and strategies described above create the conditions for dose optimization; quality assurance systems and professional culture are what determine whether those conditions are consistently realized.The basis of this is structured dose monitoring. Automated systems that monitor radiation dose and compare them against a set of established benchmarks and then statistically analyze those results to find outliers in near real time turn dose monitoring into a real-time process rather than simply an after-the-fact exercise. Departments that do not monitor dose on a regular basis cannot react to changes in their dose profile before they become problematic. Departments with real-time monitoring capabilities can react to individual and collective dose concerns before they become systemically problematic.Behind the monitoring systems lies the need for written, reviewed, and approved protocols — not as bureaucratic documents but as the institutional memory of best practice. CT protocols that have not been formally reviewed since the last scanner software update are likely to contain parameters that no longer reflect what is achievable. Multidisciplinary review committees that bring radiologists, physicists, and radiographers into the same room are positioned to identify both the unnecessary doses and the compromised image quality that no single professional group is placed to see alone (Malone, et al., 2012)And behind the protocols lies the people who implement them. A radiographer who understands what tube current modulation does — and recognizes the circumstances in which it may underperform — is better placed to protect a patient than one who treats it as a checkbox.

A radiologist who appreciates the dose implications of adding a phase or extending a scan range is better placed to design clinically lean protocols. Dose literacy, distributed across the whole clinical team, is not a luxury in a high-volume CT department. It is the mechanism through which every other optimization strategy actually reaches the patient.

3. Discussion

The results presented in this review also emphasize the progress that has been made in reducing the dose in CT scans over the past few years. With advancements in technology, significant progress has been made in making low-dose CT scans possible in routine clinical practice.Although significant progress has been made in making dose reduction possible in routine clinical practice, a significant difference still exists between the technical possibilities and actual practice in clinical routine practice. In routine practice, significant opportunities exist for dose reduction with the help of technologies currently available, which are not being utilized in practice due to a lack of awareness or knowledge about the benefits of dose reduction in CT scans.A significant point that can be emphasized from the literature is that not all dose reduction methods require the use of advanced technology, which can be very costly for routine practice. Simple methods, such as ensuring the justification of the scans, keeping the length of the scans as short as possible, and avoiding multiphase scans, can also be very useful in reducing the dose in CT scans, especially in countries where advanced technologies are not readily available.Paediatric imaging is still a key area for concern because of the sensitivity of children to ionizing radiation and their life expectancy. Research has continued to stress the significance of size-based protocols and dose management in paediatric imaging. Such interventions as awareness campaigns and the implementation of guidelines have proven that continuous progress is achievable if there is a combined effort among healthcare staff.New technologies such as photon counting CT scanners and artificial intelligence-based imaging methods are also believed to help improve dose optimization in the future. Though the initial outcomes appear to be positive, their practical use depends on many factors, such as their cost and availability for different patients.However, some drawbacks should also be considered. First off, most information is based on data obtained from observational research, technical assessments, or small-scale research rather than large-scale clinical trials. Moreover, some data on dose reduction have been published without adequate assessment of diagnostic performance, making it hard to determine their practical utility. In addition, there is a lack of information obtained from settings with poor healthcare resources.Thus, it can be concluded that although much has been achieved, further work needs to be done to implement this achievement in practice. Emphasis should be given to education and standardization of the protocols and the doses.

Conclusion

Radiation dose optimization in CT is not a solved problem, but it is a well-mapped one. The tools available today — adaptive scanner hardware, deep learning reconstruction, carefully governed clinical protocols, and an emerging generation of photon-counting detector systems — make it possible to deliver the diagnostic information that CT provides at radiation levels substantially lower than those accepted as standard even a decade ago. That progress is real, and its clinical implications are significant, especially in paediatric patients and in patient groups who will require CT scans many times in a lifetime.What the evidence does show, however, is that technology alone does not solve the optimization problem. The machine that can adjust its dose in real-time still needs a protocol that sets a reasonable starting point, the deep learning technique that can recover image quality from a lower photon count still needs a set of acquisition parameters appropriate for the patient on the table, and the dose monitoring system that can track performance against peers still needs radiologists and radiographers who react to the information that it presents. Optimization is a system property, not a hardware feature, and its long-term success depends on a culture in which everyone in the clinical team takes responsibility for radiation use.Achieving these advances and extending them will necessitate concerted effort across the radiology landscape with standardized dose reporting and monitoring, periodic multidisciplinary governance of protocols, education for professionals, and commitment to performance characterization by scanner vendors. As global use of CT scanning increases, so too does our collective duty to ensure optimization of each and every examination to ensure that the diagnostic benefit is commensurate with the radiation dose required and to do so with the least dose possible.From being only an area of study, radiology-driven 3D printing technology has developed into a crucial component of modern patient care. Better surgical planning, training, and patient-specific care are all made possible by it. We can produce precise anatomical reproductions if we adhere to established procedures from data intake in DICOM format to the finished product made utilizing additive manufacturing. This leads to shorter operations, less blood loss, and better surgical outcomes, according to studies.The technique is also utilized in many areas of medicine, and by adding new dimensions to tissue engineering and drug administration through stimulus-responsive devices, 4D printing is creating new opportunities in this field. However, the lack of standards, material problems, legal concerns, and financial limitations are preventing this technology from gaining widespread use. In the near future, it is anticipated that advancements in technology, legislation, and interdisciplinary cooperation will make 3D and 4D printing technologies an essential component of patient care.

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