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Optimization and Assessment of CT Dose Indices (CTDIvol and DLP) in Contrast-Enhanced Chest and Abdomen CT: Integrating Diagnostic Reference Levels for Patient Safety

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Abstract: ***Computed Tomography (CT) has become an essential diagnostic tool for evaluating thoracic and abdominal diseases, particularly through contrast-enhanced examinations. However, the growing frequency of CT usage has heightened concerns about radiation exposure, necessitating optimization of dose parameters and adherence to Diagnostic Reference Levels (DRLs). This study reviews the optimization and assessment of CT dose indices-Computed Tomography Dose Index (CTDIvol) and Dose-Length Product (DLP)-in contrast-enhanced chest and abdomen CT. It integrates global DRL data and explores advanced dose-reduction strategies, including automatic exposure control, iterative and deep-learning reconstruction, and artificial intelligence (AI)-based optimization. Findings indicate that typical CTDIvol values range between 8–12 mGy for chest and 10–15 mGy for abdomen scans, with AI and reconstruction algorithms achieving up to 60% dose reduction while maintaining diagnostic image quality. The integration of adaptive DRLs, AI-driven exposure control, and emerging technologies such as photon-counting CT ensures a balanced approach to image quality and patient safety, paving the way for intelligent, patient- centered radiation dose management.***

Keywords: CT Dose Index (CTDIvol); Dose-Length Product (DLP); Diagnostic Reference Levels (DRLs); Contrast-Enhanced CT (CECT); Radiation Dose Optimization; Iterative Reconstruction; Deep Learning Reconstruction (DLR); Artificial Intelligence (AI); Photon-Counting CT; Patient Safety.

1. Introduction

1.1 Background and Rationale

Computed tomography (CT) has transformed diagnostic medicine since its introduction in the 1970s, offering unparalleled cross-sectional visualization of internal anatomy. Today, contrast-enhanced CT (CECT) of the chest and abdomen represents one of the most frequently performed examinations worldwide, essential for evaluating pulmonary embolism, aortic pathology, hepatic lesions, renal obstruction, and oncologic staging.

However, this rapid expansion of CT utilization has increased the collective medical radiation dose, prompting heightened awareness of potential long-term risks. Epidemiologic studies (Brenner & Hall, 2020) estimate that CT contributes over 60 % of all diagnostic imaging radiation exposure in developed nations. Consequently, radiation-dose optimization has become a cornerstone of radiological protection and quality assurance.

1.2 Principles of Dose Optimization

Radiological protection follows the ALARA principle-***as low as reasonably achievable***-which emphasizes minimizing patient exposure while maintaining sufficient image quality for accurate diagnosis. In practice, optimization requires a delicate balance between dose reduction and diagnostic adequacy. Over-reduction of dose may compromise image quality and diagnostic confidence, whereas excessive dose increases stochastic risk. The objective is therefore ***dose justification*** **and** ***optimization*** rather than absolute minimization.

1.3 Role of Dose Indices in Optimization

To quantify scanner output and compare radiation levels among institutions, standardized dose metrics were introduced. The **Computed Tomography Dose Index (CTDI)** and **Dose-Length Product (DLP)** have become the cornerstones of CT dose assessment. They provide reproducible indicators of scanner performance and form the basis for the establishment of **Diagnostic Reference Levels (DRLs)**. Together, these indices facilitate cross-platform comparisons, protocol auditing, and patient-safety benchmarking.

1.4 Diagnostic Reference Levels and Global Harmonization

Introduced by the International Commission on Radiological Protection (ICRP Publication 135, 2017), DRLs represent the 75th percentile of typical dose distributions for standard-sized patients. They are not limits but investigative thresholds designed to highlight cases where optimization review is warranted. Over the past decade, organizations such as the IAEA, European Commission, and AERB (India) have conducted nationwide DRL surveys, leading to improved dose harmonization.

1.5 Aim and Scope of This Review

This paper provides a comprehensive analysis of CT dose indices (CTDIvol and DLP) in contrast-enhanced thoraco-abdominal imaging. It synthesizes current literature, compares international DRLs, examines factors influencing dose variability, and explores advanced optimization technologies including artificial intelligence (AI). The ultimate goal is to integrate technological innovation with radiation-safety governance for improved patient outcomes.

2. Fundamentals of Radiation Dose and CT Dose Indices

2.1 Radiation Quantities and Units

Radiation exposure in CT can be described by several interrelated quantities:

- **Absorbed Dose (D):** Energy deposited per unit mass (Gray, Gy).
- **Equivalent Dose (H):** Absorbed dose × radiation weighting factor.
- **Effective Dose (E):** Equivalent dose × tissue weighting factors (mSv).

CT-specific indices-CTDI, DLP, and SSDE-translate scanner output into quantifiable dose surrogates. These parameters enable physicists and radiologists to standardize measurements and compare performance across equipment vendors.

2.2 Evolution and Derivation of CTDI

The **CT Dose Index (CTDI)** was first defined by Shope et al. (1981) to quantify dose output for a single axial scan. $CTDI_{100}$ is determined using a 100 mm pencil ionization chamber inserted into a polymethyl-methacrylate (PMMA) phantom of 16 cm (head) or 32 cm (body) diameter.

Because dose distribution varies radially, a **Weighted CTDI (CTDIw)** is derived as:

$$CTDI_w = \frac{1}{3} CTDI_{center} + \frac{2}{3} CTDI_{periphery}$$

For helical scans, **CTDIvol** corrects CTDIw by dividing by the pitch factor (p):

$$CTDI_{vol} = \frac{CTDI_w}{pitch}$$

This volumetric index represents the average scanner output across the entire helical rotation.

2.3 Relationship Between CTDI, DLP, and Effective Dose

While CTDIvol reflects scanner output per slice, **DLP = CTDIvol × scan length** represents the integrated dose over the scanned region. Effective dose (E) can then be approximated using region-specific conversion factors (k):

$$E = DLP \times k$$

Typical k-factors are 0.014 mSv/(mGy·cm) for chest and 0.015 mSv/(mGy·cm) for abdomen (ICRP 103, 2007). However, this conversion provides only a population-averaged risk estimate rather than an individual absorbed dose.

2.4 Size-Specific Dose Estimate (SSDE)

The **AAPM Report 204 (2011)** introduced **SSDE**, which applies size-dependent conversion factors to CTDIvol based on patient effective diameter. The later **AAPM Report 220 (2014)** refined this by using water-equivalent diameter (Dw), yielding improved accuracy for both adults and pediatrics. SSDE thus bridges the gap between machine output and patient-specific absorbed dose.

2.5 Measurement Protocols and Quality Assurance

Routine quality assurance (QA) of CTDI measurement involves annual calibration using standard PMMA phantoms and cross-validation with dosimetry software. Each scanner's CTDI output must remain within ±15 % of manufacturer specifications. QA ensures consistency for DRL comparison and regulatory compliance.

Table 1: Common CT Dose Indices and Applications

Parameter	Definition	Unit	Purpose
$CTDI_{100}$	Dose along 100 mm ion chamber	mGy	Baseline scanner output measurement
CTDIw	Weighted average of center and periphery	mGy	Represents mean cross-sectional dose
CTDIvol	CTDIw ÷ Pitch	mGy	Standardized output for helical CT
DLP	CTDIvol × Scan length	mGy·cm	Total exposure for exam
SSDE	CTDIvol × Conversion factor	mGy	Patient-size-corrected dose

Table 1: Overview of key CT dose indices used for optimization and DRL comparison

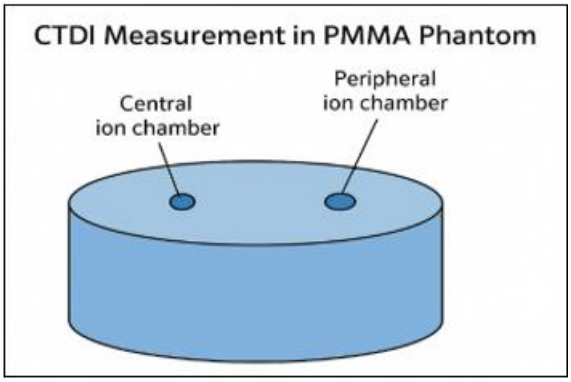

Figure 1: Schematic representation of CTDI measurement in a PMMA phantom showing ion-chamber placement and calculation of CTDIw and CTDIvol

2.6 Limitations of CTDI

CTDIvol does not account for patient anatomy, scanner calibration differences, or variable scan ranges. It assumes uniform dose distribution within the phantom, which may underestimate surface or organ doses in larger patients. Despite these limitations, CTDI remains the global reference because of its reproducibility and simplicity.

3. Contrast Enhancement and Dose Optimization

3.1 Importance of Contrast-Enhanced CT

Intravenous contrast enhances tissue differentiation, enabling accurate evaluation of vascular structures, parenchymal organs, and pathological lesions. CECT is particularly valuable for liver, pancreas, and renal imaging, and for thoracic assessment of pulmonary vasculature. However, the requirement for multiple phases-arterial, portal, and delayed-can significantly elevate radiation dose if not optimized.

3.2 Phasic Imaging and Dose Implications

A typical multiphase abdominal CT includes pre-contrast, arterial, portal, and delayed phases. Each additional phase roughly doubles the cumulative dose. Selective phase acquisition, guided by clinical indication, can substantially lower dose. For example, in routine oncologic follow-up, a single portal-venous phase often suffices.

3.3 Low-kVp and Adaptive kVp Techniques

Lowering tube voltage (e.g., from 120 to 100 or 80 kVp) increases iodine contrast because of proximity to the K-edge of iodine (33.2 keV). This permits reduction in contrast volume while maintaining enhancement, thereby lowering both radiation and nephrotoxic risk (Awai et al., 2023). Automatic kVp selection algorithms now adjust voltage according to patient size and scan region.

3.4 Iterative Reconstruction and Dose Reduction in Contrast Studies

Iterative reconstruction (IR) techniques -such as ASIR-V, ADMIRE, and Veo- reduce image noise and enable scanning at lower mA values. Studies have demonstrated up to 50 % CTDIvol reduction with no loss of diagnostic accuracy (McCollough et al., 2020). IR is particularly beneficial in contrast imaging, where contrast-to-noise ratio (CNR) is critical for vascular and organ assessment.

3.5 Protocol Optimization and Clinical Decision Making

Optimization extends beyond scanner settings to protocol design and clinical workflow:

- Restricting phases to indications (e.g., single phase for metastatic screening).
- Implementing bolus tracking and test-bolus methods for timing accuracy.
- Reducing scan length to the region of interest.
- Avoiding repeat imaging through adequate communication between radiology and referrers.

3.6 Emerging Technologies for Contrast Optimization

Dual-energy and spectral CT provide energy-dependent information, enabling virtual non-contrast images and iodine maps that reduce the need for multiple acquisitions. Photon-counting detectors (PCT) further improve dose efficiency by eliminating electronic noise and enhancing low-energy photon detection. These technologies promise up to 40 % dose savings in contrast studies (McNitt-Gray et al., 2022).

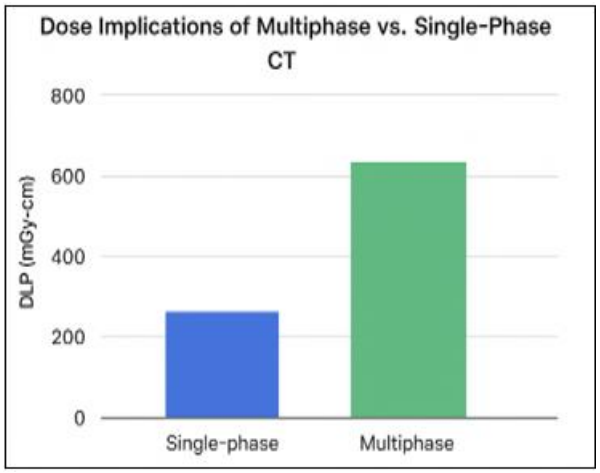

Figure 2: Diagram illustrating dose implications of single- versus multi-phase contrast protocols and the impact of iterative reconstruction on image noise and CNR.

4. Diagnostic Reference Levels (DRLs)

4.1 Concept and Historical Evolution

The concept of Diagnostic Reference Levels emerged from the need to establish practical radiation-dose benchmarks that could be universally applied for quality assurance. First introduced by the International Commission on Radiological Protection (ICRP Publication 60, 1990) and later refined in Publication 135 (2017), DRLs represent dose values that should not normally be exceeded for standard-sized patients when good practice is applied.

Unlike regulatory limits, DRLs are **investigative tools**. Exceeding a DRL does not imply malpractice but signals the need to evaluate the protocol, scanner calibration, or operator performance. Early DRL surveys in Europe during the 1990s focused primarily on adult head and body CT. Over time, national health authorities-including the European Commission, the American College of Radiology (ACR), and India's Atomic Energy Regulatory Board (AERB)-have developed region-specific DRLs, reflecting differences in equipment, population size, and clinical practice.

4.2 Methodology for Establishing DRLs

A DRL is typically set at the **75th percentile** of the distribution of median CTDIvol or DLP values collected from multiple institutions. The process involves:

1) Collecting anonymized dose data from representative facilities.
2) Computing median values for each procedure type and patient group.
3) Determining the 75th percentile of these medians as the national DRL.

To maintain relevance, DRLs should be re-evaluated every 3–5 years, as technological advancements (e.g., iterative and deep-learning reconstruction) tend to lower achievable doses.

4.3 Types of DRLs

- **National DRLs (NDRLs):** Published by health authorities (e.g., AERB, EC).
- **Local DRLs (LDRLs):** Institution-specific benchmarks based on in-house audits.
- **Achievable Doses (ADs):** Represent the 50th percentile of national distributions and serve as aspirational targets.

4.4 Global DRL Comparison

Table 2: International DRL comparison for contrast-enhanced thoraco-abdominal CT

Region	Examination	CTDIvol (mGy)	DLP (mGy·cm)	Reference
Europe	Chest	10–12	350–450	EC DRL Guidelines (2023)
Europe	Abdomen	12–15	450–650	EC DRL Guidelines (2023)
USA	Chest	12	400	ACR (2022)
India	Chest	8–11	300–420	AERB (2024)
India	Abdomen	10–14	400–650	AERB (2024)

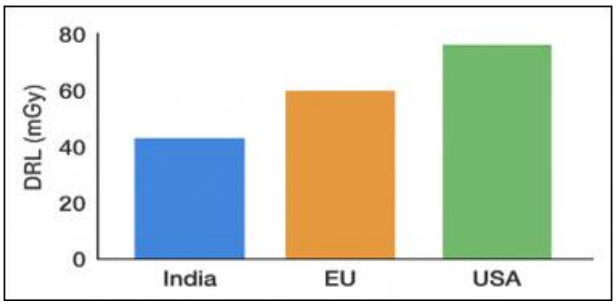

Figure 3: Illustrative bar chart comparing CTDIvol and DLP benchmarks across global regions

4.5 Trends in DRL Harmonization

Recent initiatives such as **EUCLID (European Study on Clinical Diagnostic Reference Levels, 2023)** and the **IAEA SmartDRL Project (2023)** have emphasized global harmonization by integrating dose data from multiple continents. These databases allow real-time comparison and identification of outliers, thereby promoting dose optimization internationally.

4.6 DRLs in the Indian Context

In India, the AERB's 2024 report established updated DRLs for common CT examinations based on a nationwide survey of 85 centers. The results showed median CTDIvol of 9.6 mGy for chest and 12.3 mGy for abdomen, comparable with European benchmarks. However, variability among states highlighted the need for continued training and regular audits.

5. Factors Influencing CT Dose

5.1 Patient-Related Factors

Body habitus significantly influences CTDIvol. For a constant protocol, a 5 cm increase in patient diameter can raise CTDIvol by nearly 30 %. Pediatric and small-stature adults require reduced tube current and voltage to prevent unnecessary exposure.

Age and gender also affect dose sensitivity-children and females exhibit higher radiosensitivity in tissues such as breast and thyroid, demanding special low-dose strategies.

5.2 Technical Parameters

5.2.1 Tube Current and Exposure Time

mA-s (milliampere-seconds) controls photon flux; doubling mA or exposure time approximately doubles patient dose. Automatic exposure control (AEC) dynamically adjusts mA in real time to maintain uniform image noise.

5.2.2 Tube Voltage (kVp)

Lowering kVp enhances iodine contrast but may increase noise. Optimal balance depends on patient size and diagnostic task.

5.2.3 Pitch and Collimation

Higher pitch reduces dose but can affect image resolution. Modern scanners employ helical pitch > 1.0 for thoraco-abdominal studies to balance coverage and dose efficiency.

5.2.4 Reconstruction Algorithms

Iterative reconstruction (IR) and deep-learning reconstruction (DLR) techniques reduce image noise, enabling scans at lower mA and kVp settings.

5.3 Equipment and Manufacturer Variability

Different vendors implement dose-modulation algorithms differently. **Boos et al. (2022)** found up to 25 % variation in CTDIvol between scanners performing identical protocols. Hence, cross-vendor calibration and periodic phantom testing are essential.

5.4 Operator and Workflow Factors

Technologist experience, protocol adherence, and patient centering strongly influence dose outcomes. Poor positioning can increase CTDIvol by 15–20 %. Structured training programs and standardized workflow checklists significantly reduce such errors.

5.5 Institutional Dose Culture

A culture of safety-regular audits, feedback sessions, and dose-management meetings-correlates with lower mean CTDI vol. Institutions adopting a "learning health-system" model often achieve 20–30 % dose reduction compared with those lacking formal oversight.

6. Clinical Optimization Strategies

6.1 Automatic Exposure Control (AEC)

AEC systems modulate mA based on patient attenuation. There are two major approaches:

- **Angular modulation:** Adjusts current during rotation to match lateral thickness.

- **Longitudinal modulation:** Varies current along the z-axis for regions with different densities.

Modern AEC systems combine both modes, achieving 15–40 % dose savings while preserving image quality (McCollough et al., 2020).

6.2 Iterative and Deep-Learning Reconstruction

IR methods replace filtered back projection with iterative refinements that model system noise and photon statistics. DLR goes further by using neural networks trained on high- and low-dose image pairs. These techniques maintain diagnostic image quality at up to 60 % lower CTDIvol.

6.3 Protocol Customization and Phase Optimization

Clinical justification is the first step toward optimization. Protocols should be tailored to indication:

- **Lung nodule follow-up:** Low-dose chest CT (≤ 1 mSv).
- **Hepatocellular carcinoma:** Triphasic but limited to target region.
- **Trauma:** Split-bolus dual-phase technique to combine arterial and venous information.

6.4 Organ-Based Dose Modulation

Organ-based AEC shields radiosensitive regions such as breasts and thyroid by selectively lowering tube current during specific gantry angles. Studies show 20–30 % reduction in localized organ dose without diagnostic compromise.

6.5 Scan-Range Limitation and Scout Optimization

Reducing scan length to the essential anatomy directly lowers DLP. Automated scout-view planning now employs AI to predict optimal z-coverage, minimizing unnecessary exposure.

6.6 Use of Dual-Energy and Spectral CT

Dual-energy CT (DECT) acquires two energy spectra simultaneously, enabling material decomposition and virtual non-contrast imaging. Eliminating the true non-contrast phase can save 25–35 % of total dose.

6.7 Quality Assurance and Continuous Feedback

Dose-tracking dashboards display real-time CTDIvol and DLP values, alerting technologists to potential over-exposures. Regular multidisciplinary meetings involving physicists and radiologists foster ongoing optimization.

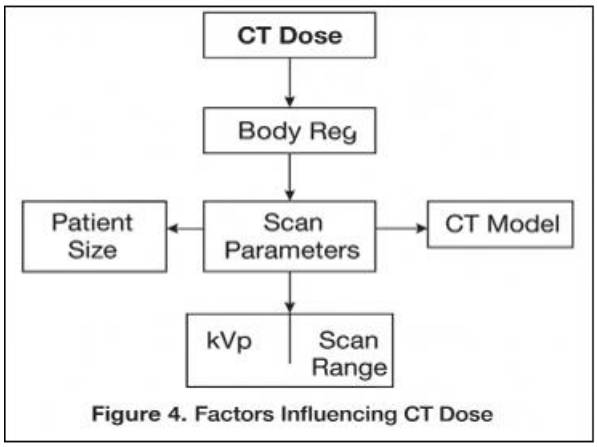

Figure 4: Schematic overview of technical and human factors influencing CT radiation dose and optimization strategies

7. Institutional DRLs and Benchmarking

Institutions are increasingly establishing **Local Diagnostic Reference Levels (LDRLs)** based on internal audits. These serve as practical tools for routine monitoring, allowing comparison across scanners and technologists. Hospitals conducting semi-annual dose audits often achieve 20–30 % dose reduction compared with facilities lacking such programs (Huda et al., 2022).

LDRLs also aid in identifying outdated protocols or equipment anomalies. When linked to dose-tracking software, they enable continuous performance improvement and facilitate benchmarking against national DRLs.

7.1 Regional Variability and Harmonization

Despite global progress, significant **regional variability** persists. Differences in scanner technology, patient demographics, and protocol preferences contribute to discrepancies between regions. In India, AERB's 2024 survey reported CTDIvol ranges from 7.8–14.2 mGy for chest and 9.6–18.5 mGy for abdomen across states, revealing up to a two-fold variation.

Harmonization requires periodic inter-center workshops, consistent calibration protocols, and unified reporting formats. Collaborative networks such as **IAEA SmartDRL** and **EUCLID** now facilitate multinational comparisons, accelerating standardization.

7.2 Institutional Dose Audits and Continuous Quality Improvement

Institutions adopting **Dose Management Systems (DMS)** integrated into RIS-PACS architecture can automatically collect CTDIvol, DLP, and SSDE data. Continuous data review helps identify outliers and guide corrective measures. A 2023 multi-center European study demonstrated that DMS-equipped hospitals reduced mean DLP by 18 % within six months of implementation.

7.3 Role of Accreditation and Regulatory Compliance

Organizations such as the **American College of Radiology (ACR)** and **NABH (India)** require dose monitoring as part of accreditation. Compliance promotes safety culture and aligns local practice with international standards.

8. Correlation of CTDI with Clinical and Technical Factors

8.1 Influence of Patient Size and BMI

Patient body habitus directly impacts attenuation and scatter, influencing automatic exposure control response. Overweight patients receive higher CTDIvol to maintain image quality, whereas underweight or pediatric patients require reduced mA.

AAPM Report 220 (2014) provides **conversion factors (size)** linking CTDIvol to SSDE across patient diameters. Clinical application of SSDE enables fairer comparison among patients of varying sizes.

8.2 Age- and Gender-Based Variations

Children and young adults have greater tissue radiosensitivity. The ICRP assigns tissue weighting factors of 0.12 to breast and bone marrow, emphasizing the importance of tailored pediatric protocols. Gender-specific optimization-especially breast shielding in women during thoracic imaging-can reduce effective dose by 30 %.

8.3 Correlation Between CTDI, DLP, and Effective Dose

CTDIvol and DLP are closely correlated but do not always reflect organ-specific absorbed dose. Incorporating SSDE and patient anatomical modeling enhances estimation accuracy.

A regression model proposed by **Leng et al. (2021)** demonstrated strong correlation ($R^2 = 0.92$) between DLP and effective dose across 500 abdominal studies.

8.4 Technical Influences: Scanner Design and Reconstruction Algorithms

Scanner generation influences radiation efficiency. 256-slice and 320-slice CT systems achieve faster acquisition and superior dose economy compared with older 64-slice models. Dual-source scanners enable lower kVp imaging with iterative or deep-learning reconstruction, further enhancing contrast-to-noise ratio at reduced CTDIvol.

8.5 Workflow and Operator Skill

Human factors remain vital. Mis-centering or improper use of AEC can raise dose by up to 40 %. Education, protocol standardization, and cross-disciplinary collaboration among technologists, radiologists, and physicists ensure optimal outcomes.

9. Artificial Intelligence and Machine Learning in Dose Optimization

9.1 Introduction to AI-Based Dose Management

Artificial Intelligence (AI) now represents a transformative force in CT dose optimization. Through large-scale data analysis and pattern recognition, AI can predict ideal exposure settings, reconstruct high-quality images at lower dose, and continuously audit scanner performance.

Machine learning (ML) models trained on extensive patient databases can identify dose outliers, learn optimal scanner behaviour, and provide feedback to operators-functions that far exceed manual capability.

9.2 Predictive Modeling for Personalized Exposure

AI dose-prediction models analyze patient BMI, effective diameter, and region of interest to estimate optimal tube current and voltage prior to scanning. **Zhang et al. (2024)** demonstrated that AI-driven parameter prediction achieved a 35 % reduction in CTDIvol while maintaining equivalent diagnostic confidence. These models evolve continuously, adjusting to local DRLs and institutional dose histories. Eventually, this may lead to **personalized DRLs** unique to each patient's body composition and clinical indication

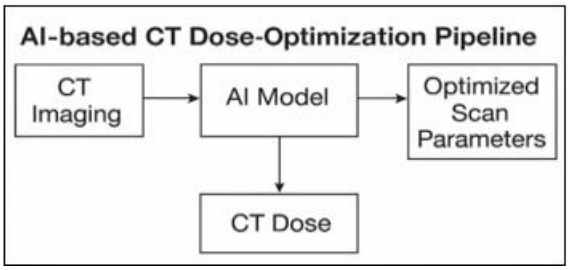

Figure 5: AI-based CT dose optimization pipeline: Workflow showing patient and scan data processed through an AI model to generate optimized CT parameters and reduced radiation dose

9.3 Intelligent Protocol Standardization

AI-based systems now provide protocol consistency across scanners by automatically adapting parameters according to patient type, body region, and indication. Centralized cloud-based software can update multiple scanners simultaneously, ensuring harmonized dose performance.

9.4 Real-Time Dose Control and Anomaly Detection

Real-time monitoring tools embedded in scanners analyze exposure parameters during acquisition, automatically intervening when CTDIvol exceeds target thresholds. Machine learning classifiers detect abnormal patterns-such as repeated scans or excessive scan range-and notify technologists instantly.

9.5 Deep-Learning Image Reconstruction

Deep Learning Reconstruction (DLR) algorithms such as Canon's AiCE and GE's True Fidelity utilize convolutional

neural networks trained on paired low- and high-dose datasets. These systems can reconstruct diagnostic-quality images at 40–60 % lower dose levels.

McCollough et al. (2020) found that DLR images exhibited higher edge preservation and lower noise variance compared to traditional iterative methods.

9.6 AI Ethics and Data Privacy

The integration of AI raises ethical challenges regarding patient-data security and algorithm transparency. Models must comply with privacy laws (GDPR, HIPAA) and undergo validation against independent datasets to avoid bias.

Future frameworks should incorporate explainable AI (XAI) to ensure interpretability of dose-reduction decisions. Ethical AI integration will be central to radiology's technological evolution.

10. Recommendations and Policy Implications

10.1 Institutional Recommendations

- **Establish Dose-Tracking Infrastructure:** Integrate automated dose-monitoring software into PACS/RIS systems.
- **Routine DRL Evaluation:** Conduct audits every 6–12 months to ensure compliance and identify outliers.
- **Staff Training and Credentialing:** Regular workshops on AEC, reconstruction algorithms, and DRL methodology.
- **Multidisciplinary Committees:** Form institutional radiation-safety boards to oversee optimization strategies.
- **Data Transparency:** Report anonymized dose data to national DRL databases for benchmarking.

10.2 National and International Policy Recommendations

- **DRL Standardization:** Global alignment under IAEA's SmartDRL and WHO's Dose Wise initiatives.
- **Mandatory Dose Reporting:** National health authorities should require reporting of CTDIvol and DLP for all CT studies.
- **Periodic Technology Assessment:** Regulatory updates to reflect emerging low-dose technologies such as photon-counting CT.
- **AI Governance Frameworks:** Mandate algorithm validation, ethical review, and bias assessment before clinical deployment.
- **Education and Accreditation:** Include radiation-dose management and AI literacy in medical curricula and technologist certification.

10.3 Ethical and Patient-Centered Approaches

Radiation safety must remain patient-focused. Providing **personalized dose reports** and risk comparisons (e.g., background radiation equivalents) promotes transparency and patient empowerment. Informed consent for high-dose procedures ensures ethical compliance and shared responsibility.

11. Future Outlook

11.1 Photon-Counting CT and Spectral Optimization

Photon-Counting CT (PCCT) technology represents the next frontier in dose efficiency. Its detectors directly convert photons into electrical signals, minimizing noise and enhancing energy discrimination. Studies predict up to 40 % reduction in dose compared with energy-integrating detectors while improving soft-tissue contrast.

11.2 Adaptive and Personalized DRLs

Traditional DRLs are static; future DRLs will be **adaptive**, recalculated continuously from large-scale population data. AI integration will enable DRLs tailored to patient-specific parameters such as age, sex, and BMI.

11.3 Integration of Radiobiological Risk Models

Emerging research aims to merge radiobiological data-such as DNA damage biomarkers and radiosensitivity indices-with dosimetric metrics. These "biologically weighted DRLs" could personalize dose optimization beyond physical parameters alone.

11.4 Global Collaboration and Cloud-Based Registries

Cloud-based dose registries (e.g., IAEA SmartDRL) will facilitate real-time comparison among thousands of institutions worldwide. Such global synergy ensures equitable access to optimized protocols, particularly in developing countries.

11.5 Educational Evolution

Future radiology curricula will integrate radiation physics, AI ethics, and dose analytics. Developing a generation of radiologists fluent in data-driven decision-making will be critical for sustainable dose governance.

12. Discussion

CTDI-based evaluation remains the gold standard for quantifying scanner output and ensuring radiation safety. Despite its limitations, CTDIvol provides a reliable framework for comparison and optimization.

The incorporation of SSDE, DLP, and effective dose has refined the understanding of radiation exposure, bridging the gap between machine output and biological relevance. Studies across multiple regions demonstrate convergence toward optimized protocols-typically yielding CTDIvol between 8–12 mGy for chest and 10–15 mGy for abdomen in adult CECT scans.

Artificial intelligence is redefining dose optimization, transforming reactive monitoring into proactive control. AI-assisted dose prediction and DLR allow radiologists to deliver diagnostic-quality images at historically low

exposures. However, challenges persist: algorithm validation, patient privacy, and overreliance on automation must be addressed through robust governance.

Harmonization of DRLs remains a global challenge. Differences in phantom standards, reporting units, and patient demographics complicate cross-border comparisons. International collaboration and consistent methodologies are essential for a unified global dose culture.

Future research should focus on integrating radiobiological risk assessment with physical dosimetry, establishing **biological DRLs** that more accurately reflect individual susceptibility.

13. Conclusion

Optimization and assessment of CT dose indices in contrast-enhanced thoraco-abdominal imaging represent a continuous process driven by technological innovation and clinical responsibility.

CTDIvol and DLP remain fundamental tools for quantifying radiation output, while DRLs provide a global framework for comparison and safety evaluation.

The synergy between advanced reconstruction algorithms, AI-guided exposure control, and adaptive DRLs ensures that image quality and patient safety coexist in balance.

The future of CT dose optimization lies in intelligent, patient-centered systems capable of learning from every scan. By harmonizing international efforts, promoting AI transparency, and embedding ethics into innovation, radiology can uphold its core mission-**to diagnose accurately while protecting every patient from unnecessary radiation exposure**.

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