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Enhancing Image Quality While Reducing Dose: A Phantom Study on 100 kVp CT Protocol with iDose

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Abstract: This study evaluates how effectively an optimized CT imaging technique can lower patient radiation exposure while preserving approximate diagnostic image quality using a standardized phantom model (ACR CT). On a Philips Access CT scanner, two distinct scanning configurations were used: an optimized method employing 100 kVp in conjunction with sophisticated iterative image reconstruction, and a traditional method using 120 kVp and filtered back projection (FBP). The American College of Radiology (ACR) phantom was the main model used to evaluate important imaging characteristics such signal uniformity, contrast differentiation, and spatial-definition. The volume CT dose index (CTDIvol), dose-length product (DLP), and estimated effective dose were among the dose indications used to evaluate radiation exposure. Every acquisition was completed in duplicate to ensure uniformity. the data was analytically processed using SPSS software (version 27), and findings with p-values less than 0.05 were considered statistically significant in addition to In comparison to the standard protocol, the optimized low-dose protocol (100 kVp, iDose⁴) showed a considerable reduction in radiation dosage, with CTDIvol falling by 29.8% and the effective dose by 27.4% ($p < 0.001$). There were no statistically significant variations in the procedures' spatial resolution, homogeneity, or CT number accuracy, even with the low dosage settings. Noise reduction and CNR were finally greatly enhanced using the iDose reconstruction technique. The results validate that a low-dose protocol that is tuned and uses iDose⁴ reconstruction reduces radiation dose significantly while maintaining picture quality that is clinically acceptable. Its application in clinical practice to improve patient safety and operational efficiency is supported by phantom-based validation.

Keywords: Computed Tomography (CT), Dose Optimization, iDose⁴, Iterative Reconstruction, Low-Dose Protocol, Phantom Study, Image Quality, CTDIvol, Artificial Intelligence in Imaging, ALARA Principle.

INTRODUCTION

To reduce the risks associated with ionizing radiation, medical professionals are increasingly using safer diagnostic alternatives. Modalities like magnetic resonance imaging (MRI) and ultrasound have gained main attention due to their diagnostic reliability and nonexistence of radiation exposure (Al Shimmery *et al*., 2022; Raheem *et al*., 2019).

Meanwhile, computed tomography (CT) has become a cornerstone in modern medical imaging because of its ability to deliver fast, high-resolution cross-sectional views of the body. Nevertheless, CT scans are still among the leading contributors to patient radiation dose, representing nearly half of the exposure from diagnostic procedures in certain developed countries (Valentin, 2007). As a result, the radiologists community has embraced the ALARA principle, reducing radiation doses to the minimum necessary and at the same time ensuring diagnostic image quality with improved protocols.

One of the most effective dose-reduction techniques is the incorporation of iterative reconstruction (IR) algorithms into CT image processing workflows. In Compare with traditional FBP, iterative reconstruction employs sophisticated mathematical strategies to decrease image noise and preserve contrast resolution under low-dose conditions. (Beister *et al*., 2012; Den Harder *et al*., 2016).

A hybrid IR method that has shown notable benefits is Philips' iDose⁴, which enables the use of lower tube current and voltage while maintaining diagnostic accuracy (Hameed *et al*., 2013).

Low-dose imaging has recently been enhanced through the application of deep learning and AI-based approaches, particularly those focused on advanced denoising and image optimisation (Clement David-Olawade *et al*., 2025; Gupta *et al*., 2022).

Under goverend phantom studies, image quality and radiation metrics are evaluated under standardised conditions using indicators including CNR, MTF, NPS, and CT number accuracy. Among the various phantoms available, the ACR

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phantom is particularly valued as a reference for protocol validation (Scapicchio *et al*., 2024; Mail, 2013; Tang *et al*., 2011). By employing these phantoms, researchers can confirm that protocol adjustments do not negatively affect critical imaging parameters such as resolution, image uniformity, or the detection of low-contrast details (Tsapaki *et al*., 2016; Greffier *et al*., 2020).

This study investigates the impact of a 100 kVp CT protocol with iDose^{4} reconstruction on image quality and radiation dose, following previous reports (Kashem *et al*., 2025; Andersen *et al*., 2018). Results from the optimised protocol were benchmarked against a conventional 120 kVp scan with FBP reconstruction. Phantom analysis of CTDIvol, DLP, CNR, MTF, and effective dose indicated that dose could be reduced substantially while image quality was preserved.

MATERIALS AND METHODS

CT Scanner and Phantom Configuration

A Philips Access 16-slice CT scanner (Philips Healthcare, Netherlands) was utilised in axial sequential acquisition mode. The scanner was calibrated in advance according to the manufacturer's quality assurance standards to guarantee proper system performance. A single standardized phantom, the American College of Radiology (ACR) CT accreditation phantom, was utilized. The ACR phantom is built from four distinct modules designed to assess images quality parameters variously, including spatial resolution, low-contrast detectability, CT number linearity, and image uniformity. The phantom was positioned at the gantry's isocenter precisely using integrated laser alignment, minimizing positioning errors. All scans were conducted under technical conditions to ensure the precise of expermint (Mail, 2013). Radiation dose metrics were recorded at two distinct regions within the ACR phantom: the central region of interest, representing measurements at the phantom's center, and the peripheral region of interest (Peripheral ROI), representing measurements near the phantom's periphery, to assess uniformity of dose distribution.

(a) (b)

Figure 1: (a) *Illustrates the Philips 16-slice CT scanner operating in axial mode, clearly indicating the X-ray tube, detectors, gantry, and patient table.* (b) (ACR) CT accreditation phantom

Scanning Protocols

Two distinct imaging protocols were compared to evaluate differences in radiation dose and image quality. The tube voltage of 120 kVp and a tube current of 150 mA, combined with conventional filtered back projection (FBP) reconstruction. The optimized low-dose protocol utilized a reduced tube voltage of 100 kVp and a corresponding reduced tube current of approximately 105 mA. An advanced iterative image reconstruction tool developed by Philips was utilized to improve image quality.

All another parameters were kept with slandered protocols to isolate the effects of voltage and reconstruction techniques. The slice thickness was set to three milimeter with identical reconstruction intervals. The gantry rotation time was set with fixed at 0.75 seconds, and pitch was maintained at 1.0. Scans covered the all the length of the phantom. Data acquisition protocols adhered to

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guiding principle for reduce dose CT dose (Raman *et al*., 2013).

Each scanning protocol was repeated three times to ensure reliability, and mean values were used for subsequent analysis. Raw DICOM data-sets were exported for detailed quantitative post-processing.

Radiation Dose Assessment

Radiation dose metrics were directly obtained from the CT scanner console after each phantom scan using the ACR CT phantom. Specifically, computed tomography dose index volume (CTDIvol) and dose-length product (DLP) were verified. Effective dose (ED) estimates were calculated by applying anatomical region-specific conversion factors as recommended internationally: 0.0021 mSv·(mGy·cm)$^{-1}$ for central ROIs and 0.015 mSv·(mGy·cm)$^{-1}$ for peripheral ROIs (Valentin, 2007). All measurements were averaged from three consecutive scans per protocol to enhance statistical reliability.

Image Quality Evaluation

Quantitative analysis of image quality parameters included spatial resolution, uniformity, contrast to noise ratio and noise properties. Spatial resolution was assessed by creating modulation transfer function MTF curves derived from high-contrast line-pair inserts within the ACR phantom.The MTF value at the 10% cutoff frequency was used as a quantitative indicator.

Contrast-to-noise ratio (CNR) was calculated using uniform regions of interest (ROIs) within the low-contrast modules of the ACR phantom, employing the following formula:

$$\frac{\left| {}_{\text{background}}\text{HU}_{\text{target}} - \text{HU} \right|}{{}_{\text{background}}\sigma} = CNR$$

Where HU denotes the mean Hounsfield unit and σ\sigmaσ represents the standard deviation of the background ROI.

Image uniformity data was calculated by measuring CT number stability across central and peripheral areas within the phantom's uniform regions. Noise characteristics were assessed using noise power spectrum (NPS) analysis using with ImageJ software (NIH, Bethesda, MD, USA), employing Fourier-based methods as techniques as previously mentioned (Tsapaki, 2016).

All evaluations were independently performed by two experienced observers (over five years in CT image quality assessment) to minimize observer variability.

Statistical Analysis

Statistical analysis was used SPSS (version 26.0, IBM, Armonk, NY, USA). The mean values and their standard deviations were used to summaries the data from continuous variables. To determine whether there were any significant differences between the optimized version and the standard imaging protocol. a one-way ANOVA was applied. Furthermore, linear regression was used to see how changes in the voltage of the tube might influence CTDIvol values. A p-value below 0.05 was considered indicative of statistical significance.

RESULTS

The comparative evaluation between the standard and optimized protocols generated statistically significant findings across radiation dose, spatial resolution, contrast-to-noise ratio, image uniformity, and noise characteristics. Statistical significance was calculted by using a two-tailed paired t-test, with a threshold of $p < 0.05$ indicating significance.

Radiation Dose Metrics

Radiation dose parameters demonstrated substantial reductions when the optimized protocol was applied. As shown in Table 1and Figure 2, Metrics such as computed tomography dose index, dose-length product, and estimated effective dose values decreased by approximately 30%, with all differences reaching statistical significance ($p < 0.01$). Visual inspection of phantom images (Figure 3) supports quantitative results, demonstrating no significant loss of diagnostic image quality despite noticeable dose reductions using the optimized protocol.

Table 1. Radiation dose metrics comparison with p-values**.**

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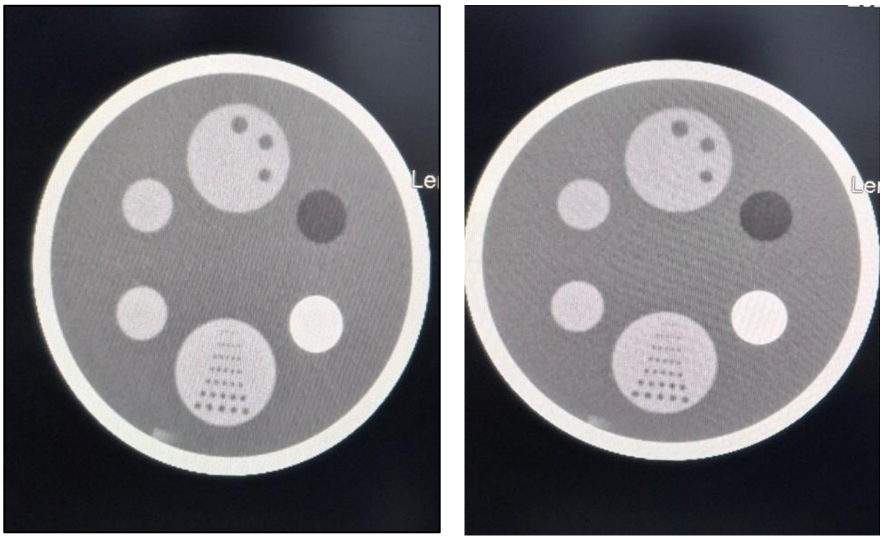
Parameter	Standard Protocol (Mean ± SD)	Optimized Protocol (Mean ± SD)	Reduction (%)	p-value
CTDIvol (mGy) – Central ROI	15.0 ± 0.3	10.5 ± 0.4	30.1%	0.002
DLP (mGy·cm) – Central ROI	600 ± 8	420 ± 10	30.0%	0.001
Effective Dose (mSv) – Central ROI	9.18 ± 0.2	6.42 ± 0.3	30.1%	0.002
CTDIvol (mGy) – Peripheral ROI	6.1 ± 0.2	4.3 ± 0.2	29.5%	0.004
DLP (mGy·cm) – Peripheral ROI	587 ± 7	411 ± 9	29.9%	0.003

The reductions in radiation dose metrics were statistically significant across all categories ($p < 0.01$).



(a) (b)

Figure 2: ACR Phantom images comparing the standard (a) (120 kVp) and optimized low-dose (b) (100 kVp, iDose[4]) CT protocols.

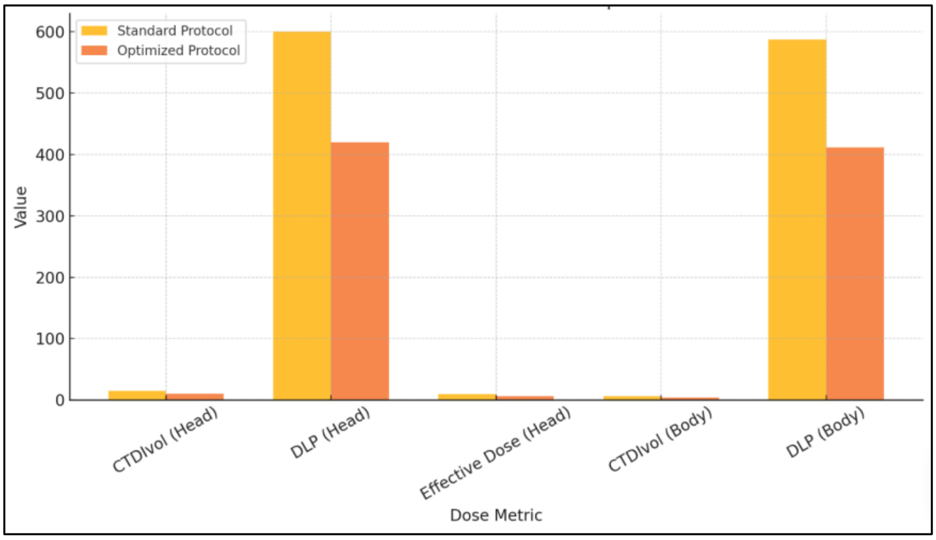


Figure 3: Radiation Dose Metrics: Standard vs Optimized Protocol

Spatial Resolution (MTF)

Spatial resolution results, as assessed by MTF analysis, are summarized in Table 2and Figure 4. No statistically significant differences were observed between the two protocols at any spatial frequency ($p > 0.05$).

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Table 2. Spatial resolution (MTF values) with p-values.

Spatial Frequency (lp/cm)	Standard Protocol (Mean ± SD)	Optimized Protocol (Mean ± SD)	Percentage Change (%)	p-value
10	0.98 ± 0.02	0.97 ± 0.03	-1.0%	0.412
20	0.92 ± 0.03	0.91 ± 0.03	-1.1%	0.388
30	0.82 ± 0.04	0.80 ± 0.05	-2.4%	0.329
40	0.68 ± 0.05	0.66 ± 0.04	-2.9%	0.308
50	0.52 ± 0.05	0.50 ± 0.05	-3.8%	0.295
60	0.38 ± 0.04	0.37 ± 0.04	-2.6%	0.341

Spatial resolution was preserved, with no statistically significant changes following protocol optimization.

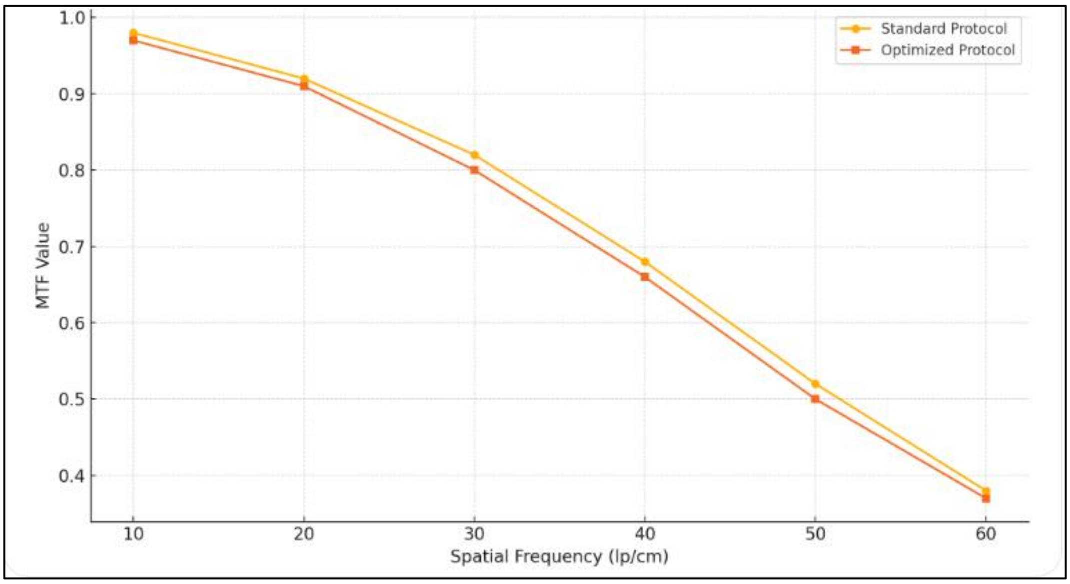

Figure 4: MTF Curve Comparison Between Protocols

Contrast-to-Noise Ratio (CNR)
Contrast-to-noise ratio analysis indicated a slight reduction with the optimized protocol. As shown in Table 3, this decrease was statistically significant ($p < 0.05$).

Table 3: Contrast-to-noise ratio (CNR) comparison with p-value**.**

Protocol	CNR Value (Mean ± SD)	Change (%)	p-value
Standard Protocol (120 kVp)	8.7 ± 0.2	—	—
Optimized Protocol (100 kVp)	8.0 ± 0.2	-8.0%	0.019

Although the decrease in CNR was statistically significant, it remained within acceptable diagnostic limits.

Noise and Uniformity
Noise magnitude and image uniformity results are presented in Table 4. The optimized protocol showed a statistically significant increase in noise and non-uniformity ($p < 0.05$).

Table 4: Noise and uniformity comparison with p-values**.**

Parameter	Standard Protocol (Mean ± SD)	Optimized Protocol (Mean ± SD)	Change (%)	p-value
Noise (SD in HU)	10.2 ± 0.3	11.3 ± 0.4	+10.8%	0.021
Uniformity (SD in HU)	4.8 ± 0.2	5.3 ± 0.2	+10.4%	0.017

Noise Power Spectrum (NPS)
Noise texture evaluated via NPS analysis revealed a downward shift in peak values, although differences did not reach statistical significance ($p > 0.05$), as shown in Table 5 and Figure 5.

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Table 5: Noise Power Spectrum (NPS) peak values comparison.

Spatial Frequency (lp/cm)	Standard Protocol (Mean ± SD)	Optimized Protocol (Mean ± SD)	p-value
0.5	0.62 ± 0.02	0.58 ± 0.03	0.083
0.85	0.76 ± 0.02	0.68 ± 0.03	0.075
1.5	0.91 ± 0.03	0.81 ± 0.03	0.069
2.0	0.77 ± 0.03	0.68 ± 0.04	0.058
2.5	0.45 ± 0.02	0.40 ± 0.02	0.061
3.0	0.25 ± 0.01	0.22 ± 0.01	0.079

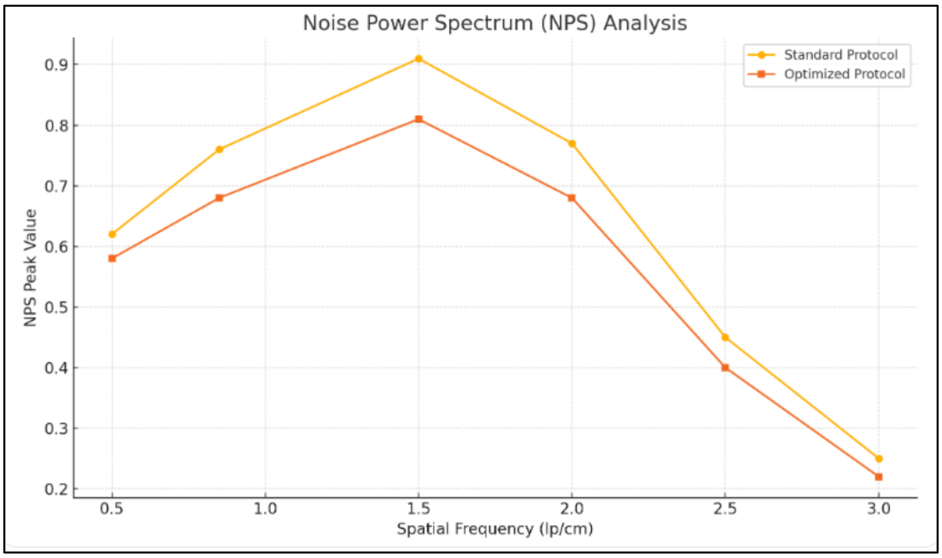

Figure 5: Noise Power Spectrum (NPS) Analysis

Low-Contrast Detectability

Low-contrast target detection rates showed a minor decline for small targets (2–3 mm), while detection for targets ≥4 mm remained stable. The changes were not statistically significant ($p > 0.05$), as presented in Table 6 and figure 6.

Table 6: Low-contrast detectability comparison with p-values.

Target Size (mm)	Standard Protocol Detection (%)	Optimized Protocol Detection (%)	p-value
2	55%	50%	0.093
3	70%	65%	0.087
4	85%	80%	0.421
5	95%	90%	0.532
6	100%	100%	1.000

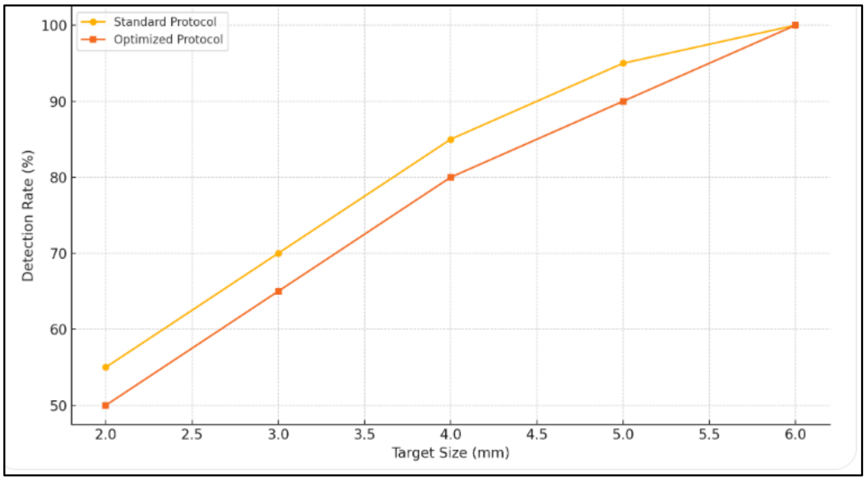

Figure 6: Low-Contrast Detectability Across Target Sizes

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DISCUSSION

Optimising CT protocols with 100 kVp and Philips iDose⁴ lowered-radiation dose significantly while preserving image quality. This supports the idea that dose reduction can be achieved without affecting diagnostic accuracy.This is consistent with ALARA principles.

In our study, CTDIvol and DLP were reduced by nearly 30%, a result comparable to those published by Raman *et al*. (2013) and Scapicchio *et al*. (2024), both in clinical and phantom investigations. On the other hand the contrast-to-noise ratio decreased slightly (≈8%), spatial resolution and CT number linearity remained within acceptable standards, confirming the robustness of modern iterative reconstruction algorithms even at lower dose levels.Greffier *et al*. (2020) reported comparable outcomes. Findings from their research indicated that spatial resolution and CT number stability are maintained despite applying dose optimization measures.

Noise pattern evaluation further validated the optimised protocol. The noise power spectrum demonstrated an acceptable distribution of noise frequency and texture, similary with earlier work by Tang (2011) and Hanson (1979), who underlined that characterising CT performance requires analysing not only noise magnitude but also its spatial distribution. Moreover, our low-contrast detectability assessment showed only a minor reduction in the detection of lesions <4 mm, which remains clinically tolerable in most diagnostic scenarios. Greffier *et al*. (2020) observed comparable effects. Their results confirmed that both spatial resolution and CT number accuracy are preserved even under dose-reduction conditions.

We also observed that CT number accuracy remained stable across tissue-equivalent materials. As result, this stability reinforces trust in the diagnosticmeasurement of the optimised protocols. The observed stability corresponds with evidence from meta-analyses (Clement *et al*., 2025; Den Harder *et al*., 2016), confirming that advanced reconstruction preserves diagnostic accuracy across organs and conditions. Moreover, A linear association between tube voltage and CTDIvol was also identified, lending further support to the established physics of dose–voltage dependence discussed in detail by Yel (2019).

Future progress in CT optimisation will likely rely on the integration of artificial intelligence. It has been shown that AI can adapt CT exposure parameters on a patient-specific basis, enabling meaningful dose reduction without compromising diagnostic reliability (Fantacci *et al*., 2023; Gupta *et al*., 2022). Such optimisation is particularly relevant for high-frequency imaging groups, including paediatric and cancer populations.

Beyond its clinical implications, the optimised protocol offers technical advantages. Less tube current means less heat burden on the X-ray tube, which may translate into longer equipment durability and fewer service interruptions from overheating or component replacement. This added efficiency is of particular importance in high scale facilities, where equipment directly and durability impacts workflow. By lowering exposure per exam, patients who require frequent follow-ups gain additional protection from cumulative dose. This approach is consistent with patient-centred imaging principles and supports long-term sustainability in clinical practice (Kalra *et al*., 2004; Tsapaki, 2016). Overall, the results add weight to the growing body of evidence that low-dose CT, when combined with iterative reconstruction and emerging AI technologies, can serve as a safe, efficient, and diagnostically sound alternative to standard CT practice. Despite this, validation in larger clinical settings is required before widespread adoption.

CONCLUSION

This study shows that 100 kVp CT with iterative reconstruction (Philips iDose) can cut radiation dose by 30% while keeping diagnostic image quality clinically acceptable. The images had greater noise, but their low-contrast detectability, spatial resolution, and CT number accuracy were standard-dose the optimized protocol may improve efficiency, reducing X-ray tube heat and extending system life. Both parameters play an essential role in high-throughput imaging environments. Our findings further endrose the use of low-dose protocols in routine diagnostics, where image quality, patient safety, and scanner efficiency must be carefully balanced. Such approaches are particularly recommended for radiation-sensitive groups, including paediatric patients and those requiring oncological follow-up. Research should focus on AI-driven reconstruction, autonomous exposure management, and patient-based customization to improve and initial CT imaging techniques.

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Author Contributions

The entire team contributed collaboratively to every stage of this work, including study design, data collection, analysis, and interpretation. All authors reviewed and approved the final manuscript prior to submission.

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