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Impact of Advanced Reconstruction Algorithms on CT Image Quality

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ABSTRACT

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Background: Computed tomography (CT) is a cornerstone of modern diagnostic imaging; however, concerns regarding radiation exposure and image noise persist. Conventional filtered back projection (FBP) reconstruction is limited by increased noise at reduced radiation doses. Advanced reconstruction techniques, including iterative reconstruction (IR) and deep learning reconstruction (DLR), have been developed to enhance image quality while enabling radiation dose optimization.
Objective: To evaluate the impact of advanced reconstruction algorithms on CT image quality and to assess their potential role in radiation dose reduction compared with conventional FBP.
Materials and Methods: This prospective observational study included 150 adult patients undergoing routine CT chest or CT abdomen examinations. All datasets were reconstructed using FBP, IR, and DLR techniques. Radiation dose parameters, including CT dose index volume (CTDIvol) and dose-length product (DLP), were recorded. Objective image quality was assessed using signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR). Subjective image quality evaluation was independently performed by two experienced radiologists using a five-point Likert scale. Statistical analysis was conducted to compare reconstruction techniques, with $p < 0.05$ considered significant.
Results: Advanced reconstruction algorithms demonstrated significant improvements in image quality compared with FBP. Both IR and DLR showed higher SNR and CNR values ($p < 0.001$), with DLR achieving the greatest noise reduction and contrast preservation. Radiation dose reductions of approximately 20–30% were achievable without compromising diagnostic image quality. Subjective assessments revealed superior image noise characteristics, anatomical detail, and diagnostic confidence with DLR, while all IR- and DLR-reconstructed images were deemed diagnostically acceptable.
Conclusion: Advanced CT reconstruction algorithms significantly enhance image quality and enable meaningful radiation dose reduction. Deep learning reconstruction, in particular, offers superior performance over conventional and iterative methods, supporting its integration into routine clinical CT imaging to improve diagnostic accuracy and patient safety.

Keywords: Computed Tomography; Iterative Reconstruction; Deep Learning Reconstruction; Image Quality

INTRODUCTION

Computed tomography (CT) has become indispensable in clinical diagnostics due to its rapid acquisition and high spatial resolution, providing detailed cross-sectional images for a broad spectrum of diseases. [1] However, CT image quality can be negatively impacted by noise and artifacts, especially at lower radiation doses. Balancing radiation safety with diagnostic image quality has driven the development of advanced image reconstruction methods. Historically, filtered back projection (FBP) was the standard CT reconstruction technique owing to its computational efficiency and reliable performance. However, FBP is susceptible to increased image noise, particularly at low dose levels, limiting its potential for significant dose reduction. [2] To address these limitations, iterative reconstruction (IR) algorithms were introduced. IR techniques improve image quality by modeling the imaging system and noise statistics through repeated refinement of the reconstructed image. Multiple clinical studies have shown that IR reduces noise and improves contrast compared with FBP, enabling radiation dose reduction while preserving diagnostic quality. [3,4] More recently, deep learning reconstruction (DLR) algorithms have emerged, leveraging neural networks trained on large datasets to learn noise patterns and reconstruct images with enhanced detail and lower noise. DLR has demonstrated superior performance in noise suppression and contrast resolution compared with both FBP and IR in multiple anatomical regions. [5–7] These advanced reconstruction tools hold promise for further radiation dose reduction without compromise to diagnostic confidence. Despite widespread adoption, there remains a need to systematically evaluate differences in image quality between these reconstruction methods using both quantitative and qualitative metrics. Objective measures such as signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) provide critical insight into image performance, while subjective radiologist assessments evaluate clinical acceptability. This study aims to investigate the impact of advanced reconstruction methods on CT image quality and to determine potential implications for radiation dose optimization.

AIM AND OBJECTIVES

Aim: To assess the impact of advanced CT reconstruction algorithms, specifically iterative reconstruction and deep learning reconstruction on image quality and the potential for radiation dose reduction compared with conventional filtered back projection.

Objectives

1. To compare objective image quality metrics (SNR and CNR) among FBP, IR, and DLR techniques.
2. To evaluate subjective image quality attributes (noise, contrast, anatomical detail, diagnostic acceptability) for each reconstruction method.
3. To analyze the relationship between reconstruction algorithms and achievable radiation dose reduction.
4. To provide recommendations for clinical implementation of advanced reconstruction in routine CT practice.

MATERIALS AND METHODS

Study Design and Population: This prospective observational study was conducted in the Department of Radiology of a tertiary care hospital over eight months. A total of 150 adult patients referred for routine CT chest or abdomen imaging were enrolled after institutional ethical approval and informed consent.

CT Protocol: CT examinations were performed on a multi-detector CT scanner with standard acquisition parameters. For each patient, projection data were reconstructed using three algorithms:

- Filtered Back Projection (FBP) – conventional method
- Iterative Reconstruction (IR) – vendor-specific iterative technique
- Deep Learning Reconstruction (DLR) – neural network–based reconstruction

Radiation Dose Recording: Radiation dose metrics including CT dose index volume (CTDIvol) and dose-length product (DLP) were recorded from the scanner console.

Image Quality Assessment: Objective Metrics

- Signal-to-Noise Ratio (SNR): Mean signal in ROI / standard deviation of noise
- Contrast-to-Noise Ratio (CNR): Difference between tissue and background signal / noise

Subjective Evaluation: Two experienced radiologists, blinded to reconstruction technique, independently scored images on a five-point scale for noise, contrast resolution, anatomical detail, and overall diagnostic acceptability.

Statistical Analysis: Continuous variables were expressed as mean ± SD. Comparisons were made using ANOVA with post-hoc Tukey tests. $P < 0.05$ was considered statistically significant.

RESULTS

A total of 150 adult patients undergoing routine CT chest and CT abdomen examinations were included in the study. All examinations were successfully reconstructed using filtered back projection (FBP), iterative reconstruction (IR), and deep learning reconstruction (DLR) techniques. Patient demographics and scan parameters were comparable across all reconstruction methods, ensuring uniformity in analysis.

Radiation Dose Assessment: Radiation dose metrics, including CT dose index volume (CTDIvol) and dose-length product (DLP), were recorded for all examinations. The use of advanced reconstruction algorithms enabled the acceptance of lower noise levels, allowing protocol optimization and subsequent dose reduction. Compared with FBP-based protocols, examinations reconstructed using IR and DLR demonstrated a dose reduction of approximately 20–30%, while maintaining diagnostic image quality. The reduction in radiation dose was statistically significant ($p < 0.05$).

Objective Image Quality Analysis: Objective image quality was assessed using signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) measurements obtained from standardized regions of interest. Images reconstructed with IR showed a significant improvement in both SNR and CNR compared with FBP ($p < 0.001$). DLR demonstrated the highest improvement among all techniques, with significantly superior SNR and CNR values compared with both FBP and IR ($p < 0.001$). The progressive improvement in objective image quality followed the order: FBP < IR < DLR. Noise levels were markedly reduced in IR and DLR images, with DLR providing the most effective noise suppression while preserving fine anatomical details. These improvements were consistent across both CT chest and CT abdomen examinations.

Subjective Image Quality Evaluation: Subjective image quality was independently assessed by two experienced radiologists using a five-point Likert scale. Inter-observer agreement was good, with no significant disagreement affecting overall scoring trends. FBP-reconstructed images received lower scores for image noise and contrast resolution, particularly in low-attenuation regions. IR images demonstrated improved noise texture and contrast clarity, resulting in higher diagnostic confidence. DLR images achieved the highest subjective scores across all evaluated parameters, including image noise, contrast resolution, anatomical detail, and overall diagnostic acceptability. Importantly, all images reconstructed with IR and DLR were considered diagnostically acceptable, and no repeat examinations were required due to inadequate image quality. Radiologists reported increased confidence in lesion detection and anatomical visualization, particularly in low-contrast regions, with DLR-reconstructed images.

Comparative Performance of Reconstruction Techniques: When compared across reconstruction techniques, DLR consistently outperformed both FBP and IR in terms of noise reduction, contrast preservation, and overall image appearance. IR provided substantial improvements over FBP but did not achieve the same level of image smoothness and detail preservation observed with DLR. These findings highlight the added value of deep learning–based reconstruction in routine clinical CT imaging.

DISCUSSION

The current study demonstrates that advanced reconstruction algorithms, particularly deep learning–based techniques, significantly improve CT image quality compared with conventional FBP. Higher SNR and CNR values with IR and DLR indicate superior noise suppression and contrast enhancement, which can facilitate reliable diagnosis even at reduced radiation doses. Improved subjective ratings align with quantitative metrics, suggesting clinical confidence in interpreting images reconstructed with advanced methods. Previous studies have corroborated these findings, reporting that IR enables meaningful dose reduction while preserving image clarity. [3,4] DLR expands on these advantages by leveraging data-driven models to further suppress noise and enhance detail, demonstrating potential for even greater radiation savings without quality compromise. [5–7] This is critically important in clinical settings where minimizing radiation exposure is essential, such as in repeat imaging or pediatric patients. The results suggest that routine implementation of advanced reconstruction should be encouraged as part of CT protocol optimization strategies. Technologists and radiologists should collaborate to adjust acquisition parameters in tandem with reconstruction techniques to balance dose and image quality appropriately.

CONCLUSION AND LIMITATION

Advanced reconstruction algorithms, particularly deep learning–based methods, have a significant positive impact on CT image quality. These techniques enable improved objective and subjective image quality metrics while permitting radiation dose reduction, supporting enhanced diagnostic performance and patient safety in routine clinical CT imaging. This study was single-center and did not stratify results by body habitus or specific pathology. Larger multi-center studies are recommended.

DECLARATION

Ethics Approval and Consent to Participate: Institutional ethical approval was obtained, and all participants provided informed consent.
Availability of Data and Materials: Available on request from the corresponding author.
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