

Deep Learning Reconstruction Combined with Ultra-Low Pitch Scanning: A Synergistic Strategy for Helical Artifact Suppression in Low-Dose Abdominal CT

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Deep Learning Reconstruction Combined with Ultra-Low Pitch Scanning: A Synergistic Strategy for Helical Artifact Suppression in Low-Dose Abdominal CT

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Ethical Statement:

Informed consent was obtained from all individual participants included in the study.All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national

research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This study was approved by the Ethics Committee/Institutional Review Board of Guiqian International General Hospital. This study was approved by the Ethics Committee/Institutional Review Board of Guiqian International General Hospital (IRB Approval No.: 20260002).

Clinical Trial Registration:

This study is a non-interventional diagnostic accuracy study evaluating a synergistic optimization protocol combining ultra-low pitch scanning and deep learning reconstruction for abdominal CT examinations. No clinical trial registration is required as it does not involve patient interventions, treatment allocation, or alterations to clinical care. As requested.

Clinical trial number: not applicable.

Funding Declaration:

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Abstract

Background:

Deep learning reconstruction (DLR) and low-pitch scanning individually improve abdominal CT image quality but cannot concurrently reduce radiation dose, suppress helical artifacts, and maintain diagnostic adequacy. The synergistic effect of ultra-low pitch combined with DLR in hollow-viscus CT has not been rigorously validated.

Purpose: To compare the clinical performance of an ultra-low-pitch protocol with DLR-M (deep learning reconstruction-model) versus conventional-pitch and moderate-low-pitch iterative reconstruction protocols in abdominal CT, with respect to radiation exposure, scan efficiency, objective image quality, artifact suppression, and diagnostic confidence.

Materials and Methods: In this prospective controlled study, 90 patients underwent abdominal CT on a 256-detector scanner and were randomly assigned to three protocols

(n=30 each): conventional pitch with ASIR-V (group C), moderate-low pitch with ASIR-V (group B), and ultra-low pitch (0.516:1) with either ASIR-V (subgroup A1) or DLR-M (subgroup A2). Radiation dose, scan time, bowel attenuation, standard deviation (SD), Signal-to-Noise Ratio (SNR), Contrast-to-Noise Ratio (CNR), and artifact indices were quantified. Two radiologists independently scored helical artifacts and image noise on a 5-point Likert scale. Intergroup comparisons used ANOVA with post-hoc LSD-t tests; interobserver agreement was assessed by Kappa statistics.

Results: Subgroup A2 yielded the lowest radiation dose (CTDIvol 9.88 ± 0.60 vs $10.93 \pm 0.93 - 14.12 \pm 1.76$ mGy, all $P < 0.001$) and the lowest bowel SD, a 56.66% reduction relative to group C and 60.64% relative to subgroup A1 (both $P < 0.001$). Subgroup A2 also achieved the highest SNR and CNR (all $P < 0.001$). Artifact incidence was 16.7% in group A (both subgroups) versus 63% in group B and 83% in group C ($P < 0.001$). Beam-hardening and multi-planar artifact lengths were longest in group C and shortest in group A. Subjective scores were best for subgroup A2 (artifacts 4.82 ± 0.38 , noise 4.78 ± 0.39) and worst for group C (3.92 ± 0.66 and 3.52 ± 0.48), with good inter-observer agreement (Kappa=0.702 - 0.943).

Conclusion: Ultra-low pitch combined with DLR-M enables dual-domain artifact suppression (acquisition and reconstruction), substantially lowers radiation dose, and improves image contrast and diagnostic confidence. This strategy is readily standardizable for routine abdominal CT practice.

Keywords: Deep learning reconstruction; Low pitch; Helical artifact; Adaptive statistical iterative reconstruction

Introduction

Abdominal helical computed tomography (CT) serves as a fundamental tool for the assessment of solid organ pathology and acute abdominal conditions. Nonetheless, achieving accurate imaging of hollow viscera, particularly the gastrointestinal tract, presents significant challenges. This is due to the dual concerns of cancer risk from excessive radiation exposure and the necessity for clear visualization of the intricate bowel wall and its surrounding

anatomical structures—areas where image quality is particularly vulnerable to noise and helical artifacts¹. Conventional scanning protocols often encounter a trade-off: while a high pitch can reduce scan time and radiation dose, it also results in projection data gaps that generate helical artifacts, thereby blurring the margins of continuous structures such as the bowel wall and small vessels, which severely compromises the visualization of fine anatomical details^{2,3}. Conversely, reducing the pitch enhances data sampling density and mitigates helical artifacts, but it also prolongs scan duration and increases radiation exposure. Thus, the primary challenge in the advancement of contemporary abdominal CT technology lies in balancing the reduction of radiation dose with the suppression of noise and helical artifacts⁴.

In recent years, iterative reconstruction techniques, such as Adaptive Statistical Iterative Reconstruction V (ASIR-V), have successfully achieved a balance between noise suppression and dose reduction through the statistical optimization of projection data, leading to their widespread adoption in clinical practice^{5,6}. However, ASIR-V's noise suppression capability is limited; at higher strengths or levels, it tends to produce waxy or plastic-like artifacts and excessive smoothing, which can compromise diagnostic interpretation and thus restrict the potential for further dose reduction^{7,8}. With the increasing integration of artificial intelligence in medical imaging, deep learning reconstruction (DLR) has demonstrated superior capabilities in noise suppression and artifact correction in abdominal CT. This is attributed to its advanced feature learning and image restoration capabilities^{9,10}. By being trained on large-scale clinical datasets, DLR can more effectively differentiate between noise, artifacts, and true anatomical information, achieving significant radiation dose reduction while preserving lesion details and tissue contrast^{11,12}. Previous studies have demonstrated that deep learning reconstruction (DLR) can improve image quality and boost diagnostic confidence for low-dose abdominal CT examinations^{13,14}. Consequently, integrating low pitch with DLR may concurrently mitigate helical artifacts and diminish image noise in low-dose abdominal CT, while preserving image quality. Nonetheless, this synergistic effect has not yet been empirically validated.

To address this research gap, the current study devised three comparative groups—conventional pitch, moderate-low pitch, and ultra-low pitch (each with dual reconstruction

subgroups)—and proposed a synergistic approach combining ultra-low pitch scanning with DLR. This study systematically assessed the approach's efficacy in reducing radiation dose, enhancing image quality, and ensuring diagnostic reliability, thereby providing empirical support for a standardized abdominal CT protocol that achieves low dose, minimal artifacts, and high image quality^{15,16}.

Materials and Methods

Study Design and Participants

this prospective, single-center study involved the enrollment of 90 patients who required CT scans due to clinically suspected abdominal pathology. Participants were randomly assigned into three groups in a 1:1:1 ratio, with each group comprising 30 patients. The inclusion criteria were as follows: (1) age of 18 years or older; (2) clinical indication for an abdominal CT scan; and (3) the ability to comply with breath-hold instructions.

The exclusion criteria included: (1) inability to perform breath-holding or maintain proper positioning; (2) presence of extensive calcifications or metallic implants in the abdominopelvic region that could significantly interfere with image evaluation; (3) pregnancy or lactation; and (4) undergoing a gastrointestinal barium contrast study within 7 days prior to the examination, resulting in residual high-density barium in the intestinal tract.

The recruitment process is shown in Figure 1.

Data Acquisition

All examinations were conducted using a GE Revolution Apex Expert 256-slice CT scanner, adhering to the following fixed parameters: a tube voltage of 120 kV, automatic tube current modulation, a reconstruction slice thickness and interval of 1.25 mm, and a detector width of 40 mm. The study established three groups based on pitch, noise index (NI), and reconstruction algorithm:

the Conventional-pitch control group (Group C) with a pitch of 1.375:1, 50% ASIR-V reconstruction, and NI=8;

the Moderate-low-pitch control group (Group B) with a pitch of 0.984:1, 50% ASIR-V reconstruction, and NI=8;

the Ultra-low-pitch experimental group (Group A) with a pitch of 0.516:1, further divided into two reconstruction subgroups:

- Subgroup A1, utilizing 50% ASIR-V reconstruction with NI=10
- Subgroup A2, employing deep learning reconstruction (DLR-M) with NI=10.

Detailed acquisition and reconstruction parameters for each group are delineated in Table 1.

Throughout the scanning procedure, radiation dose metrics, including volume CT dose index (CTDIvol) and dose-length product (DLP), as well as scan duration, over-scan length, and actual versus target scan lengths, were meticulously recorded for subsequent quantitative analysis.

Image Analysis

The image analysis encompassed both objective quantitative assessments and subjective qualitative blinded evaluations. All images were systematically reviewed and analyzed using a dedicated post-processing workstation.

Objective Quantitative Image Assessment

Regions of interest (ROIs) were strategically placed at the margins of the ascending colon, transverse colon, descending colon, and rectum. For each segment of the bowel, ROIs were independently delineated on axial images by two experienced radiologists (Radiologist 1 with 5 years of experience and Radiologist 2 with 7 years of experience) and measured artifact lengths on axial, coronal and sagittal reformatted images (Figure 2). A standardized ROI area of 2.5 mm², with meticulous care taken to avoid bowel wall lesions, calcifications, gas, and various beam-hardening artifact regions. Measurements of bowel CT attenuation and image standard deviation (SD)—which quantify noise and helical artifact intensity—were conducted. Furthermore, signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) were calculated to objectively characterize image noise, tissue contrast, and artifact levels across different groups. The formulas used for computing SNR and CNR were as follows:

$$\text{SNR} = \frac{\text{HU}_{\text{bowel}}}{\text{SD}_{\text{muscle}}}$$

$$\text{CNR} = \frac{\text{HU}_{\text{mucle}} - \text{HU}_{\text{bowel}}}{\sqrt{\text{SD}_{\text{bowel}}^2 + \text{SD}_{\text{mucle}}^2}}$$

Subjective Scoring

Two radiologists, each possessing a decade of experience in abdominal imaging, independently and blindly evaluated all images without access to information regarding scan grouping. The evaluation criteria encompassed the severity of helical artifacts and the overall image noise, both assessed using a 5-point Likert scale.

The criteria for scoring helical artifacts were as follows: 1=poor, with extensive artifacts that preclude anatomical identification; 2=fair, with locally severe artifacts that severely limit structural evaluation; 3=moderate, with multiple artifacts that mildly affect diagnosis; 4=good, with only minimal artifacts that do not affect diagnosis; 5=excellent, with virtually no helical artifacts and clear anatomical structures.

The criteria for scoring image noise were: 1=severe noise, rendering the image nondiagnostic; 2=substantial noise, with diagnosis barely achievable; 3=moderate noise, with diagnosis feasible; 4=mild noise, with diagnosis unaffected; 5=no appreciable noise, resulting in excellent image quality.

Statistical Analysis

Statistical analyses were conducted utilizing SPSS (version 26.0, IBM, Armonk, NY, USA) and GraphPad Prism (version 10.6, GraphPad Software, San Diego, CA, USA). Continuous variables were presented as mean $\pm$ standard deviation or median (interquartile range), contingent upon the outcomes of normality tests. Overall comparisons across multiple groups were executed using one-way ANOVA, followed by post-hoc pairwise comparisons employing the LSD-t test. Categorical variables were assessed using the chi-square test. Statistical significance was established at $P < 0.05$. Inter-observer agreement for subjective scores was assessed via Kappa coefficients.

Results

Baseline Characteristics

No significant differences were detected among the three groups with respect to age, sex, height, weight, or body mass index (all $P > 0.05$). The data pertaining to radiation dose and scan duration for each group are presented in Table 2.

Radiation Dose and Scan Parameters

Notably, scan duration increased progressively from Group C (3.40 ± 0.54 s) to Group B (4.51 ± 0.28 s) and further to Group A (8.94 ± 0.70 s). Significant inter-group differences were identified for CTDIvol and DLP (both $P < 0.001$). Pairwise comparisons revealed that subgroup A2 (ultra-low pitch + DLR-M) exhibited a significantly lower radiation dose compared to subgroup A1, Group B, and Group C. Group B demonstrated the highest radiation dose among the four groups, and the difference between subgroup A1 and Group C was also statistically significant ($P < 0.05$).

Objective Quantitative Image Metrics

No significant intergroup differences were identified for mean bowel HU attenuation (all $P > 0.05$), demonstrating consistent baseline intestinal tissue density across all four study arms and eliminating tissue heterogeneity as a confounding factor for noise and contrast metrics. Statistically significant overall intergroup differences were detected for bowel SD (image noise), SNR, and CNR (all $P < 0.001$) by one-way ANOVA, with post hoc LSD pairwise comparisons revealing distinct intergroup gradients in image quality indices (Figure 3).

For bowel SD, a marker of image noise, subgroup A2 (ultra-low pitch + DLR-M) yielded the lowest mean value, corresponding to a 56.66% noise reduction relative to Group C (conventional pitch + ASIR-V) and a 60.64% reduction relative to subgroup A1 (ultra-low pitch + ASIR-V), both pairwise comparisons $P < 0.001$. Consistently, subgroup A2 achieved the highest SNR and CNR values among all four cohorts, with statistically superior contrast and noise performance versus A1, B, and C (all $P < 0.001$). Pairwise testing showed no statistically meaningful differences in either SNR or CNR between subgroup A1 and Group C ($P > 0.05$). Among all reconstruction protocols using ASIR-V, Group A1 (1.375 ultra-low pitch) displayed the highest bowel SD, lowest SNR, and lowest CNR, representing the poorest objective image quality across all study groups. Quantitative measurements of

ascending, transverse, descending colon and rectal segments across all pitch and reconstruction combinations are visualized in Figure 3 for direct intergroup comparison.

Helical Artifact Quantification

The incidence of artifacts varied significantly among the groups ($P<0.001$), with both subgroup A1 and subgroup A2 exhibiting an incidence rate of 16.7% (5/30), compared to Group B at 63% (19/30) and Group C at 83% (25/30). Detailed measurements of multi-planar artifact lengths and beam-hardening artifact indices are provided in Table 3.

Notable inter-group differences were identified in the axial, coronal, and sagittal artifact lengths, as well as in the beam-hardening artifact index ($P<0.05$ and $P=0.005$, respectively). Group A displayed significantly shorter artifact lengths across all planes compared to Groups B and C. Conversely, Group C exhibited the longest multi-planar artifact lengths and the highest beam-hardening index. Group A's beam-hardening index was the lowest, suggesting superior artifact suppression (As shown in Figure 4).

Subjective Image Quality Scores

Regarding the severity of helical artifacts, significant differences were noted among the groups ($P<0.001$). The scores, ranked from highest to lowest, were as follows: subgroup A1 (4.85 ± 0.33), subgroup A2 (4.82 ± 0.38), Group B (4.38 ± 0.67), and Group C (3.92 ± 0.66). Subgroups A1 and A2 demonstrated comparable scores, both of which were significantly higher than those of Groups B and C.

In terms of image noise scores, significant inter-group differences were also observed ($P<0.001$), with subgroup A2 (4.78 ± 0.39) achieving significantly higher scores than subgroup A1, Group B, and Group C. Group A1 recorded the lowest noise scores (3.38 ± 0.58 ; all $P<0.001$). A summary of the mean scores for all groups is provided in Table 4.

Two radiologists, each possessing a decade of experience in abdominal imaging, independently conducted blinded assessments using a 5-point Likert scale. The inter-observer agreement was robust, as evidenced by Kappa coefficients ranging from 0.609 to 0.943 for helical artifact scores and from 0.706 to 0.800 for image noise scores (refer to Table 5 for detailed results).

Discussion

The ultra-low-pitch reconstruction cohort exhibited a significantly reduced radiation dose compared to all other cohorts. The ultra-low-pitch protocol markedly decreased the incidence of helical artifacts, and when integrated with DLR-M reconstruction, it further diminished image noise. These results suggest that the combined application of ultra-low pitch and deep learning reconstruction concurrently achieves reduced radiation exposure, artifact suppression, and enhanced image quality, thereby effectively overcoming the inherent limitations of conventional abdominal CT protocols.

The synergistic mechanism in question functions at two distinct levels: firstly, the utilization of ultra-low pitch enhances the density of projection sampling and addresses gaps in raw projection data, thereby fundamentally mitigating the generation of helical artifacts during the acquisition phase. This serves as the foundational basis for the enhancement of image quality in this study. Secondly, the DLR-M, which is trained on extensive clinical image features, accurately distinguishes between residual noise, minor helical artifacts, and the true intestinal anatomy, thereby executing a secondary correction during the post-processing phase. Our quantitative findings substantiate the reliability of this algorithmic correction: in comparison to subgroup A1 (which employed ultra-low pitch with ASIR-V alone), subgroup A2 exhibited a substantial reduction in bowel SD and significant improvements in SNR and CNR, alongside optimal subjective scores for artifacts and noise. This evidence confirms that DLR-M effectively compensates for residual image degradation following ultra-low-pitch acquisition, ultimately establishing a dual-optimization framework of "acquisition-level pre-suppression combined with reconstruction-level refined correction." This approach overcomes the limitations of prior studies that examined low pitch or deep learning reconstruction in isolation.

To mitigate radiation exposure, our ultra-low-pitch cohort increased the NI to 10, resulting in reduced photon counts and potentially leading to photon starvation and increased noise levels—a phenomenon previously documented⁴. While ASIR-V alone exhibits limited capacity for noise reduction and may introduce waxy artifacts due to excessive smoothing, DLR-M effectively distinguishes random noise from fine bowel wall textures in a hierarchical

manner. Subgroup A2 achieved a 66.1% reduction in bowel SD compared to the conventional group, with SNR and CNR significantly surpassing those of all other groups, aligning with findings from previous intestinal CT studies^{11,13}. This effectively counteracts the image degradation typically associated with low-dose scanning. Evaluating all metrics, the 0.516 ultra-low-pitch protocol combined with DLR-M for low-dose imaging requires no additional hardware, employs easily standardized parameters, reduces radiation exposure, and is well-suited for health screenings, elderly patients, and individuals requiring frequent follow-up examinations. For the long-term monitoring of Crohn's disease, which necessitates repeated CT evaluations of bowel wall ulcers, fistulas, and strictures, traditional protocols pose a significant risk due to cumulative radiation exposure, and helical artifacts can obscure subtle inflammatory lesions. Our protocol effectively combines low radiation exposure with high-definition bowel imaging, allowing for the clear visualization of subtle lesions while significantly minimizing cumulative ionizing radiation damage. This makes it a preferred standardized abdominal CT protocol for the comprehensive follow-up of Crohn's disease.

In the context of subjective qualitative assessment by radiologists, our study utilized a 5-point Likert scale for blinded evaluation of helical artifacts and image noise. The inter-observer Kappa coefficients ranged from 0.702 to 0.943, reflecting good agreement and high reliability. Notably, Subgroup A2 achieved near-perfect scores in artifact and noise assessment, indicating that this protocol effectively and comprehensively delineates bowel margins and fine anatomical details, significantly mitigating structural blurring caused by artifact interference. For conditions reliant on nuanced interpretation of the bowel wall—such as intestinal obstruction, gastrointestinal tumors, and inflammatory bowel diseases—the reduction of artifacts and enhancement of contrast aid in the detection of subtle lesions that are frequently obscured by noise in conventional CT imaging, thereby enhancing diagnostic confidence²⁰.

From a clinical translation standpoint, the ultra-low-pitch combined DLR-M protocol presents several practical advantages. Firstly, it enables higher noise index scanning, which effectively diminishes the overall radiation dose and cumulative ionizing radiation exposure. This is particularly advantageous for populations undergoing health screenings, patients with chronic abdominal conditions necessitating long-term follow-up, and elderly patients with

limited tolerance. Secondly, the protocol's comprehensive enhancement of image quality reduces the rates of missed diagnoses and misdiagnoses due to artifacts, thereby optimizing diagnostic efficiency in radiology. Thirdly, the standardization and reproducibility of the scanning and reconstruction parameters, which require only adjustments to the pitch and reconstruction algorithm without necessitating additional specialized hardware, facilitate the protocol's integration into routine departmental abdominal CT protocols, thereby supporting its widespread clinical adoption.

While our findings hold significant clinical promise, it is important to recognize several limitations inherent in this study. Firstly, the research was conducted as a single-center prospective study with samples sourced from a single location, which restricts the generalizability of the results across diverse populations and equipment. To substantiate the imaging efficacy of this protocol, future research should involve multicenter, large-sample controlled trials encompassing various CT platforms and age groups. Secondly, the use of an ultra-low pitch setting notably extends the total scan duration (mean scan time of 8.94 seconds, which is more than twice that of the conventional protocol), thereby increasing the breath-holding demands on patients. This protocol is not advisable for patients with severe chronic obstructive pulmonary disease, agitation, consciousness disorders, critically ill patients in emergency situations, or those experiencing severe abdominal pain who are unable to maintain a stationary position for prolonged periods, as respiratory motion artifacts may negate the advantages of helical artifact suppression. Future advancements in hardware technology, such as high-speed gantries and ultra-wide detectors, could potentially reduce acquisition time and broaden the applicability of this protocol. Third, this study exclusively concentrated on the assessment of image quality pertaining to hollow viscus structures within the gastrointestinal tract. The optimization effects on solid abdominal organs, such as the liver, pancreas, and kidneys, were not stratified. Future research should undertake subgroup analyses for various organs and disease subtypes to refine the clinical indications of this protocol and further validate its applicability across a comprehensive range of abdominal pathologies. Fourth, this study limited its comparisons to image noise, artifacts, and subjective image quality, without a systematic evaluation of diagnostic performance. Measures related to lesion detection were not incorporated, and data on ROC curves,

diagnostic sensitivity, specificity, and accuracy are absent. The suggested advantages in detecting subtle lesions, such as Crohn's disease ulcers, tumors, and strictures, remain speculative, grounded in image quality assessments rather than corroborated by clinical follow-up or endoscopic gold standards. Future investigations should include populations with confirmed intestinal diseases to conduct focused evaluations of diagnostic performance.

Conclusion

The implementation of an ultra-low pitch (0.516) is highly effective in mitigating helical artifacts in abdominal CT. When integrated with DLR-M, this approach substantially decreases radiation exposure while enhancing the SNR, the clarity of anatomical details, and diagnostic confidence. This method constitutes a safe, efficient, and potentially standardizable protocol for abdominal CT imaging.

Abbreviations

CT Computed Tomography

DLR Deep-learning reconstruction

DLR-M Deep-learning reconstruction-Model

ASIR-V Adaptive statistical iterative reconstruction-V

CTDIvol Volume computed tomography dose index

DLP Dose length product

SD Standard deviation

SNR Signal-to-noise ratio

CNR Contrast-to-noise-ratio

ROI Region of interest

ICC Intraclass correlation coefficient

NI Noise index

mA Milliampere

kV Kilovolt

BMI Body mass index

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Not applicable.

Author contributions

Author A: Conceptualized and designed the study; performed data curation, measurement, and formal analysis; wrote the original manuscript draft; reviewed and edited the manuscript; created figures and tables.

Author B: Contributed to study design; performed data curation and measurement; reviewed and edited the manuscript; optimized figures and tables.

Author C: Provided scientific oversight for study feasibility; critically reviewed the manuscript for intellectual content and provided revision suggestions; provided technical support.

Author D: Critically reviewed the manuscript for intellectual content and provided revision suggestions; provided technical support.

Author E: Performed data collection and measurement.

Author F: Performed data collection and measurement.

Author G: Performed data collection and measurement.

Author H: Performed data collection and measurement.

Author I: Performed data collection and measurement.

Author J: Performed data collection and measurement.

All authors reviewed and approved the final manuscript. All authors contributed significantly to this work.

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Data availability

The data is available from the authors upon reasonable request.

Declarations

Ethical approval and consent to participate

Informed consent and consent for publication was obtained from all participants. This study was approved by the Ethics Committee/Institutional Review Board of Guiqian International General Hospital (IRB Approval No.: 20260002). This study was conducted in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its' later amendments.

Consent for publication

Consent for publication was given by the local ethic's review board. All patients included in this study consented in the publication of the data.

Competing interests

The authors declare no competing interests.

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Figures

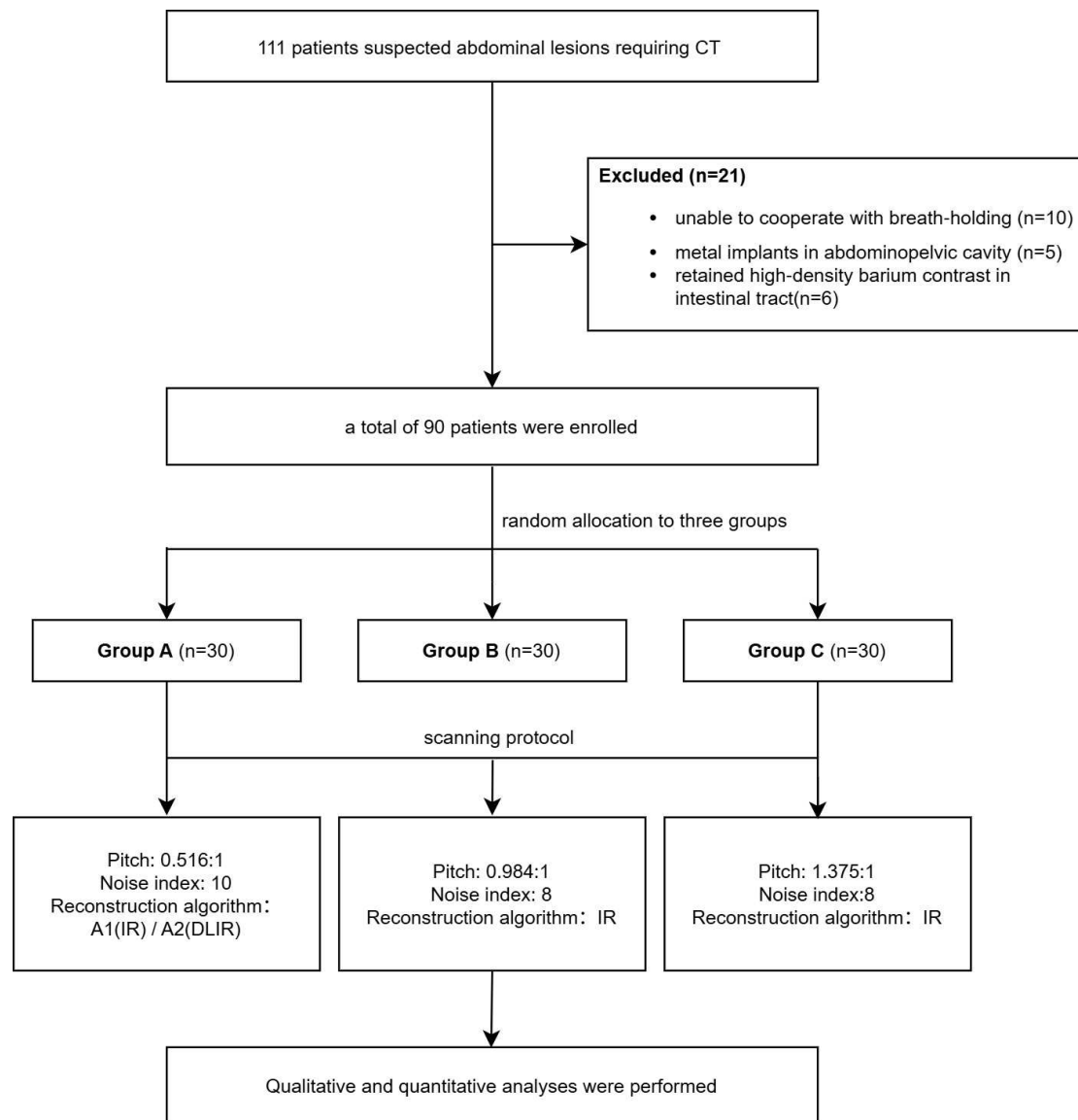


Figure 1. Flowchart of participant inclusions and exclusions.

Table 1. Abdominal CT acquisition and reconstruction parameters for the four groups

Image acquisition	Group A		Group B	Group C
	A1	A2		
Scan mode	Helical		Helical	Helical
Pitch	0.516:1		0.984:1	1.375:1
Detector width	40mm		40mm	40mm
Rotation speed	0.35s/rot		0.35s/rot	0.35s/rot
Tube voltage	120KVP		120KVP	120KVP
mA Mode	SmartmA 200ms-650ms		SmartmA 200ms-650ms	SmartmA 200ms-650ms
Noise Index	10		8	8
Thickness and spacing	1.25mm		1.25mm	1.25mm

Reconstruction algorithm	IR(ASiR-V50%)	DLIR-M	IR(ASiR-V50%)	IR(ASiR-V50%)
A1 = ultra-low-pitch ASIR-V reconstruction subgroup; A2 = ultra-low-pitch DLR-M deep learning reconstruction subgroup; B = moderate-low-pitch ASIR-V control group; C = conventional-pitch ASIR-V control group; SmartmA denotes automatic tube current modulation technology;; NI = noise index; slice thickness and interval were uniform at 1.25 mm across all groups.				

Figure 2.Schematic diagram for helical artifact length measurement



Table 2.Baseline characteristics, scan length, and radiation dose parameters across the three groups

Basic information	Group A	Group B	Group C
Female (%)	33.33% (10/30)	63.33% (19/30)	60% (18/30)
Age (years)	59.10 ± 13.99	58.63 ± 15.92	5.67 ± 13.22
Height (cm)	163.10 ± 7.81	159.37 ± 5.86	161.68 ± 9.11
Weight (kg)	61.39 ± 8.66	60.35 ± 9.53	59.03 ± 11.18
BMI (kg/m ²)	23.11 ± 3.17	23.74 ± 3.48	22.50 ± 3.02
CTDIvol (mGy)	9.88 ± 0.60	14.12 ± 1.76	10.93 ± 0.93
DLP (mGy • cm)	518.26 ± 54.42	717.11 ± 108.84	567.29 ± 77.21
Effective dose (mSv)	7.77 ± 0.82	10.76 ± 1.63	8.51 ± 1.16
Actual Scanning Length	52.40 ± 3.57	50.67 ± 3.01	51.77 ± 4.19
target length	48.30 ± 3.56	47.82 ± 3.01	47.46 ± 4.18
Double sweep length	4.10 ± 0.18	2.85 ± 0.14	4.30 ± 0.19
scan time	8.94 ± 0.70	4.51 ± 0.28	3.40 ± 0.54

Group A represents the unified 0.516 ultra-low-pitch group (including subgroups A1 and A2).

Continuous data are expressed as mean ± standard deviation. CTDIvol = volume CT dose

index; DLP = dose-length product; effective dose was calculated using the standard abdominal CT conversion coefficient. $P > 0.05$ indicates no statistically significant differences in baseline characteristics among the three groups.

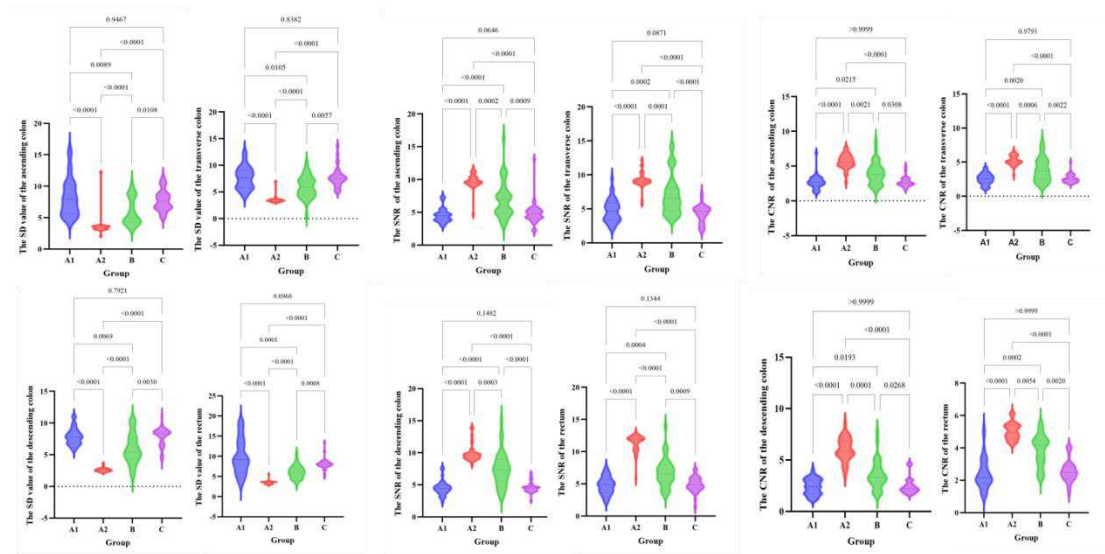


Figure 3. Quantitative objective metrics of the four colonic segments across different pitch and reconstruction algorithm combinations. Four imaging groups were established: conventional-pitch iterative reconstruction (Group C), moderate-low-pitch iterative reconstruction (Group B), ultra-low-pitch ASIR-V iterative reconstruction (Subgroup A1), and ultra-low-pitch DLR-M deep learning reconstruction (Subgroup A2). Measured parameters included SD, SNR and CNR, reflecting image noise and artifact intensity. Statistical analysis revealed significant differences in SD, SNR, and CNR between Subgroup A2 and Group C compared with the other three groups ($P < 0.001$). The ultra-low-pitch combined with deep learning reconstruction (Subgroup A2) demonstrated optimal noise suppression and tissue contrast.

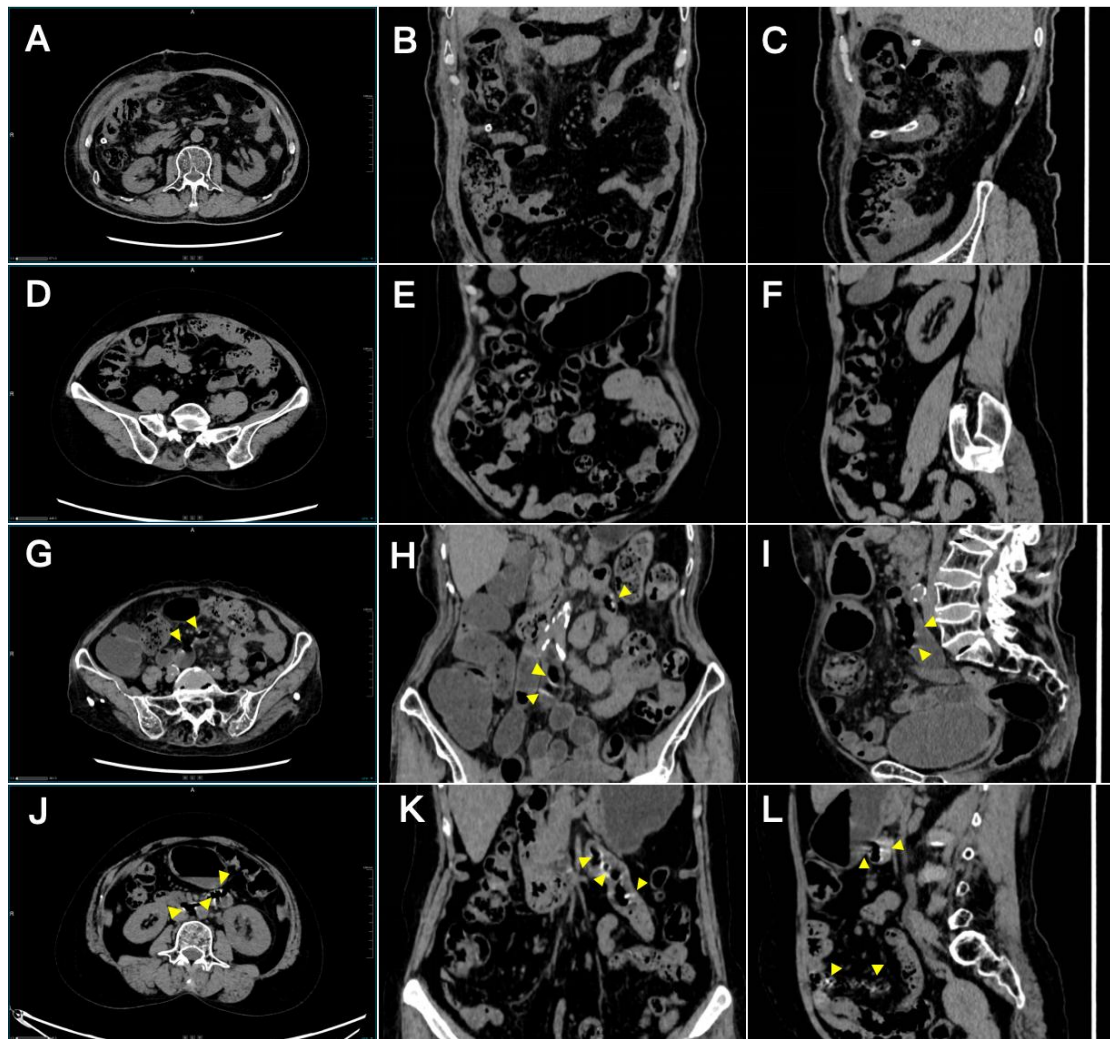


Figure 4. Panels A – C: representative cases of ultra-low pitch ASIR-V iterative reconstruction (Subgroup A1); Panels D – F: ultra-low pitch DLR-M deep learning reconstruction (Subgroup A2); Panels G – I: mid-low pitch iterative reconstruction (Group B); Panels J – L: standard helical pitch iterative reconstruction (Group C). Group A demonstrated optimal suppression of intestinal helical artifacts compared with Groups B and C. Note: Small yellow triangles in Panels G – L point to intestinal helical artifacts.

Table 3. Helical artifact incidence, multi-planar artifact length, and beam-hardening artifact index

	Group A (0.5)	Group B (0.9)	Group C (1.3)
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Artifact incidence	16.7% (5/30)	63% (19/30)	83% (25/30)
Artifact length (slices)	24.48 ± 16.63	38.61 ± 26.65	34.81 ± 29.02
Axial artifact length	6.36 ± 1.66	8.38 ± 4.19	13.05 ± 6.66
Coronal artifact length	6.58 ± 2.95	8.07 ± 4.19	12.62 ± 6.85
Sagittal artifact length	6.24 ± 2.51	8.07 ± 4.17	12.54 ± 7.88
Beam-hardening artifact index	17.14 ± 10.42	27.43 ± 8.15	40.24 ± 21.92

OAX = axial; Cor = coronal; Sag = sagittal. Artifact incidence indicates the proportion of patients in each group exhibiting helical artifacts. Group A represents the unified 0.516 ultra-low-pitch group (including subgroups A1 and A2).

Table 4. Summary of blinded subjective image quality scores by two radiologists

Parameters	reader 1		reader 2		Average	
	Artifacts	Noise	Artifacts	Noise	Artifacts	Noise
Group A1	4.83 ± 0.38 _{B,C}	3.4 ± 0.62 _{A2,C}	4.87 ± 0.35 _{B,C}	3.37 ± 0.61 _{A2,C}	4.85 ± 0.33 _{B,C}	3.38 ± 0.58 _{A2,C}
Group A2	4.80 ± 0.41 _{B,C}	4.77 ± 0.43 _{A1,B,C}	4.83 ± 0.38 _{B,C}	4.8 ± 0.41 _{A1,B,C}	4.82 ± 0.38 _{B,C}	4.78 ± 0.39 _{A1,B,C}
Group B	4.4 ± 0.68 _{A1,A2,C}	4.27 ± 0.74 _{A2,C}	4.37 ± 0.67 _{A1,A2,C}	4.43 ± 0.63 _{A2,C}	4.38 ± 0.67 _{A1,A2,C}	4.35 ± 0.63 _{A2,C}
Group C	3.93 ± 0.69 _{A1,A2,B}	3.53 ± 0.51 _{A1,A2,B}	3.9 ± 0.66 _{A1,A2,B}	3.50 ± 0.51 _{A1,A2,B}	3.92 ± 0.66 _{A1,A2,B}	3.52 ± 0.48 _{A1,A2,B}

Artifacts = helical artifact severity score; Noise = image noise score. Scores range from 1 to 5, with higher scores indicating better image quality. Data are expressed as mean ± standard deviation.

Table 5. Inter-observer agreement Kappa coefficients for subjective scores by two readers

	Artifacts			Noise		
	kappa	95%CI	P	kappa	95%CI	P
Group A1	0.609	0.20916~1.00884	< 0.001	0.775	0.47368~0.94624	< 0.001
Group A2	0.889	0.67536~1.10264	< 0.001	0.706	0.39632~1.01568	< 0.001
Group B	0.943	0.82424~1.04376	< 0.001	0.722	0.51032~0.93368	< 0.001

Group C	0.831	0.64872~1.01328	$\begin{matrix} < \\ 0.001 \end{matrix}$	0.8	0.58636~1.01364	$\begin{matrix} < \\ 0.001 \end{matrix}$
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95% CI = 95% confidence interval. Kappa coefficients of 0.7 - 0.95 indicate good inter-observer agreement. All groups $P < 0.001$, indicating statistically significant agreement.