RESEARCH ARTICLE

Spatial and contrast resolution of ultralow dose dentomaxillofacial CT imaging using iterative reconstruction technology

¹Gerlig Widmann, ²Alexander Bischel, ³Andreas Stratis, ³Hilde Bosmans, ³Reinhilde Jacobs, ¹Eva-Maria Gassner, ²Wolfgang Puelacher and ^{3,4}Ruben Pauwels

¹Department of Radiology, Innsbruck Medical University, Innsbruck, Austria; ²Department of Craniomaxillofacial Surgery, Innsbruck Medical University, Innsbruck, Austria; ³Department of Imaging and Pathology, OMFS-IMPACT Research Group, KU Leuven—Group Biomedical Sciences Oral and Maxillofacial Surgery—UZ Leuven, Leuven, Belgium; ⁴Department of Radiology, Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand

Objectives: The objective of this study was to determine how iterative reconstruction technology (IRT) influences contrast and spatial resolution in ultralow-dose dentomaxillofacial CT imaging.

Methods: A polymethyl methacrylate phantom with various inserts was scanned using a reference protocol (RP) at CT dose index volume 36.56 mGy, a sinus protocol at 18.28 mGy and ultralow-dose protocols (LD) at 4.17 mGy, 2.36 mGy, 0.99 mGy and 0.53 mGy. All data sets were reconstructed using filtered back projection (FBP) and the following IRTs: adaptive statistical iterative reconstructions (ASIRs) (ASIR-50, ASIR-100) and model-based iterative reconstruction (MBIR). Inserts containing line-pair patterns and contrast detail patterns for three different materials were scored by three observers. Observer agreement was analyzed using Cohen's kappa and difference in performance between the protocols and reconstruction was analyzed with Dunn's test at $\alpha = 0.05$.

Results: Interobserver agreement was acceptable with a mean kappa value of 0.59. Compared with the RP using FBP, similar scores were achieved at 2.36 mGy using MBIR. MBIR reconstructions showed the highest noise suppression as well as good contrast even at the lowest doses. Overall, ASIR reconstructions did not outperform FBP.

Conclusions: LD and MBIR at a dose reduction of >90% may show no significant differences in spatial and contrast resolution compared with an RP and FBP. Ultralow-dose CT and IRT should be further explored in clinical studies.

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Keywords: CT; ultralow dose; iterative reconstruction technology; spatial resolution; contrast resolution

Introduction

CBCT is widely used in dentomaxillofacial imaging because CBCT scanners cost less and usually involve less radiation dose compared with multislice CT. Furthermore,

owing to their relatively small physical footprint, CBCT units can be installed in a dental office.

However, image quality in terms of contrast resolution and noise may be lower in CBCT than that in CT and varies considerably across different CBCT units.¹ Further, CBCT shows a wide range in doses, overlapping with

doses from CT, depending on field of view, imaging parameters and manufacturer.^{2,3} In fact, modern CT scanners enable high-resolution protocols at dose exposition equal or lower than CBCT levels (= ultralow dose).^{4,5} Published doses of a CT examination of the maxilla may be performed at an effective dose of 22 μSv , which is comparable with the values of a dental panoramic (26 μSv), while a CT scan of the mandible corresponds to an effective dose of 123 μSv , which is comparable with a full-mouth survey with intraoral films (150 μSv).⁶

A recent study demonstrated that the image quality of ultralow-dose CT protocols may be superior to several CBCT scanners.⁷ The introduction of iterative reconstruction technology (IRT) such as adaptive statistical iterative reconstruction (ASIR) and model-based iterative reconstruction (MBIR) allows for substantial noise reduction over the current standard of filtered back projection (FBP) and pushes on the goal of continuous reduction of medical exposure to ionizing radiation.^{8,9} However, IRT images reportedly demonstrate an “oversmoothing” effect which may interfere with the need for a high spatial accuracy in dentomaxillofacial imaging.^{8,10} Therefore, the aim of the study was to assess how IRT influences contrast and spatial resolution in ultralow-dose CT.

Methods and materials

Phantom and inserts

This study used the SedentexCT IQ phantom (Leeds Test Objects Ltd, Boroughbridge, UK), a customized polymethyl methacrylate (PMMA) phantom. The phantom is cylindrical and represents an adult head (diameter 16.0 cm, height 17.7 cm). It was initially invented for dental CBCT machines and contains one central and six peripheral holes, which allow for the placement of various inserts for image quality analysis (Figure 1).¹¹ The inserts were placed in the peripheral columns of the head-size phantom. Empty columns were filled with homogeneous PMMA inserts.

Two types of inserts (3.5 cm diameter, 2 cm height) were used for observer-based analysis of spatial and contrast resolution. The first insert contained a line-pair (lp) pattern using alternating aluminium and polymer sheets with different thicknesses, ranging from 1 lp mm⁻¹ to 10 lp mm⁻¹ (Figure 1). Two inserts of this type were used, allowing for an evaluation in the axial (xy) and transaxial (xz/yz) planes. The second type of insert contained five cylindrical rods of different sizes (1–5 mm) positioned at the vertices of a regular pentagon, using PMMA as a background material (Figure 2). For this type, five different inserts were produced, using air, aluminium and three different densities of hydroxyapatite (HA): 50 mg cm⁻³, 100 mg cm⁻³ and 200 mg cm⁻³. Finally, an insert containing a thin steel wire suspended in air was used to quantify the point spread function for each scan.

CT scanning

A 64-multislice CT scanner (Discovery CT 750 HD, GE Healthcare, Vienna, Austria) was used to execute the following high-resolution protocols: (a) a reference protocol (RP) for navigated surgery (120 kV, 100 mAs, rotation time 1 s), (b) a sinus protocol (SP) (120 kV, 50 mAs, rotation time 1 s) and (c) a series of four ultralow-dose protocols (LD I–IV) (100 kV, 35 mAs; 80 kV, 40 mAs; 80 kV, 15 mAs, rotation time 0.5 s; and 80 kV, 10 mAs, rotation time 0.4 s). All protocols used fixed kilovoltage and milliamperage levels, without dose modulation. In addition to standard image reconstruction based on FBP, the following iterative reconstructions were provided: ASIR-50 (50% FBP, 50% ASIR), ASIR-100 (0% FBP, 100% ASIR) and MBIR. All images were reconstructed using standard and bone kernels, except MBIR for which only a standard kernel was available.

The images were exported in digital imaging and communications in medicine format using IMPAX EE (Agfa HealthCare, Bonn, Germany) picture archiving and communication system.

CT dose index volume (CTDI_{vol}) and dose-length product were recorded from the digital imaging and communications in medicine tags.

Evaluation of spatial and contrast resolution

The evaluation followed a modified scoring system published by Pauwels *et al.*¹ One axial image and one coronal image were selected, with the latter showing the xz/yz lp insert and the former showing all other inserts. The slice position was identical for all scans. All images were blinded and prepared for analysis. ImageJ v. 1.49, public domain (National Institutes of Health, Bethesda, MD), was used by three readers. The images were viewed and evaluated in a dimly lit room. Observers were prepared for scoring by showing them sample images of high-, medium- and low-quality images and instructing them on the scoring criteria. A standardized scoring template was used by all readers.

The lp insert was evaluated using the following criteria: (i) visibility of individual lines for the first two groups of lps. For each of the two groups, a score of 0 or 1 corresponded to the lps being indistinguishable or distinguishable, respectively. A score of 0.5 was given when the individual lines could be partly distinguished. Score ranged between 0 and 2. (ii) Visibility of groups of lps. The total number of distinguishable groups (each consisting of three aluminium lines alternating with PMMA) was counted, with possible scores ranging between 0 (no groups can be distinguished) and 9 (all groups can be distinguished).

The contrast resolution inserts were evaluated by counting the number of visible rods for each insert, with possible scores ranging between 0 (no rods visible) and 5 (all rods visible). The air and aluminium inserts were excluded, seeing that all rods were easily visible on every image.

Sharpness and noise were evaluated using a three-point rating scale with a score of 2 corresponding to

Figure 1 Line-pair visibility. ASIR, adaptive statistical iterative reconstruction; FBP, filtered back projection; LD, ultralow-dose protocols; MBIR, model-based iterative reconstruction; RP, reference protocol; SP, sinus protocol; std, standard.

high sharpness or low noise, 1 for medium sharpness or medium noise and 0 for low sharpness or high noise.

The point spread function insert was evaluated by calculating the full width at half maximum (FWHM) of a large series of one-dimensional line profiles through the metal wire in the axial plane. The FWHM was calculated for 10 consecutive slices and the average value was calculated.

Statistical analysis

Three observers and three repeated observations with a 1-week interval between the readings were available for evaluation of intraobserver and interobserver agreements, which were assessed using weighted Cohen's kappa coefficients.

The difference in performance between the protocols and reconstructions was evaluated using Dunn's multiple comparison test at $\alpha = 0.05$.

Results

Radiation dose

CTDI_{vol} of the protocols was as follows: 36.58 mGy for RP, 18.28 mGy for SP, 4.14 mGy for LD-I, 2.63 mGy for LD-II, 0.99 mGy for LD-III and 0.53 mGy for LD-IV. Considering a scan length of 10 cm (*i.e.* a dentoalveolar scan of the mandible and maxilla), and a *k*-factor of 0.0021 for adult head examinations, the effective dose for these protocols applied to the dental region can be estimated at 768 μ Sv for RP, 384 μ Sv for

Figure 2 Contrast resolution showing insert hydroxyapatite 200 mg cm^{-3} . ASIR, adaptive statistical iterative reconstruction; FBP, filtered back projection; LD, ultralow-dose protocols; MBIR, model-based iterative reconstruction; RP, reference protocol; SP, sinus protocol; std, standard.

SP, $87 \mu\text{Sv}$ for LD-I, $55 \mu\text{Sv}$ for LD-II, $21 \mu\text{Sv}$ for LD-III and $11 \mu\text{Sv}$ for LD-IV.

Observer agreement

The intraobserver agreement was within all tests substantial to almost perfect. The interobserver agreement had a higher variation. For the contrast resolution section, the average interobserver agreement was 0.80. In the lp analysis, the average interobserver agreement was 0.61 for the visibility of groups and 0.64 for the visibility of individual lines. Sharpness showed an average interobserver agreement of 0.45 and noise 0.39. Overall, the mean interobserver agreement for the study was 0.59.

Effect of exposure

Spatial resolution—line-pair analysis: The lp images are shown in Figure 1. Scores for lp analysis are found in Tables 1 and 2. There was no statistically significant difference between RP and SP; also, there was no significant difference between SP, LD-I and LD-II, or between LD-I, II and III. For the visibility of individual lines, significantly lower scores were found for LD-IV than those for all others, except for LD-III.

Contrast resolution: Figure 2 shows sample images used for the contrast resolution analysis, and Table 3 shows the average score for the three contrast detail inserts. The contrast resolution was better at higher doses;

Table 1 The *xy* visibility of line pairs. Average score per exposure group (range 0–9)

<i>xy visibility groups</i>	<i>FBP standard</i>	<i>ASIR-50 standard</i>	<i>ASIR-100 standard</i>	<i>MBIR standard</i>	<i>FBP bone</i>	<i>ASIR-50 bone</i>	<i>ASIR-100 bone</i>	<i>Average score for each exposure protocol</i>
RP (36.56 mGy)	3.67	3.17	2.50	5.83	8.33	9.00	9.00	5.93
SP (18.28 mGy)	2.67	2.83	2.50	5.17	8.17	8.33	9.00	5.52
LD-I (4.17 mGy)	3.17	2.50	2.33	4.00	6.83	7.50	7.00	4.76
LD-II (2.36 mGy)	3.17	2.50	2.17	4.33	7.33	7.83	7.83	5.02
LD-III (0.99 mGy)	3.00	2.67	2.00	3.00	6.33	4.33	4.17	3.64
LD-IV (0.53 mGy)	2.83	2.17	2.00	2.50	3.00	3.50	3.17	2.74
Average score for each reconstruction	3.09	2.64	2.25	4.14	6.67	6.75	6.70	

ASIR, adaptive statistical iterative reconstruction; FBP, filtered back projection; LD, ultralow-dose protocols; MBIR, model-based iterative reconstruction; RP, reference protocol; SP, sinus protocol.

however, there was no significant difference between SP, LD-I and II. LD-III and IV had very similar results, with both protocols showing a significantly lower contrast resolution than other protocols.

Sharpness and noise: The effect of dose regarding observer scores for sharpness was very low and only significant at very low dose levels. Only when comparing RP vs LD-III or IV and SP vs LD-III or IV, the difference was statistically significant. Noise levels behaved similar to image sharpness. With higher dose levels, images had less noise (Figures 1 and 2). Statistically significant differences were found between RP and all LD protocols. Sharpness and noise scores can be found in Tables 4 and 5.

Point spread function: The overall average FWHM value was 1.004 mm for RP, 1.026 mm for SP, 1.070 mm for LD-I, 1.131 mm for LD-II, 1.165 mm for LD-III and 1.203 mm for LD-IV. FWHM values for each protocol and reconstruction technique are shown in Table 6. There was a statistically significant overall effect of exposure on FWHM, with lower doses corresponding to higher FWHM values (and therefore lower sharpness). RP did not statistically significantly differ from SP. All other pairwise comparisons were statistically significantly different except LD-III vs LD-IV.

Effect of reconstruction

Spatial resolution—line-pair analysis: Reconstructions using the standard convolution kernel showed a worse

spatial resolution than those using the bone kernel (Figure 1). MBIR standard was significantly better than ASIR-50 standard and ASIR-100 standard, yet still showed lower scores than bone kernel reconstructions. For differentiating individual lines in the lp groups, bone kernel reconstructions were also significantly better than all standard kernel reconstructions. MBIR standard kernel showed higher scores than FBP, ASIR-50 and ASIR-100 standard kernel, but the differences were not statistically significant. For standard kernel, FBP was better than ASIR-50 followed by ASIR-100; for bone kernel, however, ASIR-100 was better than ASIR-50 followed by FBP, but without statistical significance. Overall, the resolution scores in the axial plane were higher than those in the coronal plane (Tables 1 and 2).

Contrast resolution: MBIR reconstruction showed a significantly higher contrast resolution than all other reconstructions, especially for the HA 50 rods (Figure 2). ASIR-100 was better than ASIR-50 and FBP, but the results were not statistically significant. Scores for LD-I and II were as good as RP when using MBIR as the reconstruction algorithm (Table 3).

Sharpness and noise: Reconstructions using bone kernel were sharper than standard reconstructions (Figures 1 and 2). The differences within the bone group were small; the same applies to the standard reconstructions. Noise was significantly better in MBIR than in all other reconstructions. Standard

Table 2 The *z* visibility of line pairs. Average score per exposure group (range 0–9)

<i>z visibility groups</i>	<i>FBP standard</i>	<i>ASIR-50 standard</i>	<i>ASIR-100 standard</i>	<i>MBIR standard</i>	<i>FBP bone</i>	<i>ASIR-50 bone</i>	<i>ASIR-100 bone</i>	<i>Average score for each exposure protocol</i>
RP (36.56 mGy)	2.83	2.00	2.17	4.00	5.00	5.50	6.00	3.93
SP (18.28 mGy)	2.50	2.50	2.33	3.00	4.67	6.33	6.50	3.98
LD-I (4.17 mGy)	2.17	2.17	2.17	3.33	4.00	5.17	5.00	3.43
LD-II (2.36 mGy)	2.67	2.50	2.00	3.00	4.33	4.67	4.50	3.38
LD-III (0.99 mGy)	2.50	2.00	2.00	3.33	3.67	3.67	3.67	2.98
LD-IV (0.53 mGy)	2.50	2.00	2.17	2.00	1.67	1.67	1.83	1.98
Average score for each reconstruction	2.53	2.20	2.14	3.11	3.89	4.50	4.58	

ASIR, adaptive statistical iterative reconstruction; FBP, filtered back projection; LD, ultralow-dose protocols; MBIR, model-based iterative reconstruction; RP, reference protocol; SP, sinus protocol.

Table 3 Contrast resolution. Average score for the three hydroxyapatite (50 mg cm^{-3} , 100 mg cm^{-3} and 200 mg cm^{-3}) rod inserts per exposure group (range 0–5)

Average contrast	FBP standard	ASIR-50 standard	ASIR-100 standard	MBIR standard	FBP bone	ASIR-50 bone	ASIR-100 bone	Average score for each exposure protocol
RP (36.56 mGy)	3.72	3.17	3.28	3.50	3.50	3.50	3.50	3.45
SP (18.28 mGy)	2.94	2.94	3.00	3.33	3.22	3.00	3.06	3.07
LD-I (4.17 mGy)	2.67	2.94	2.94	3.44	2.89	2.67	3.00	2.94
LD-II (2.36 mGy)	2.83	2.83	2.61	3.83	2.78	2.89	2.94	2.96
LD-III (0.99 mGy)	1.50	1.50	1.44	3.22	1.44	1.50	1.83	1.78
LD-IV (0.53 mGy)	1.50	1.94	2.17	2.61	1.78	1.83	2.00	1.98
Average score for each reconstruction	2.53	2.55	2.57	3.32	2.60	2.57	2.72	

ASIR, adaptive statistical iterative reconstruction; FBP, filtered back projection; LD, ultralow-dose protocols; MBIR, model-based iterative reconstruction; RP, reference protocol; SP, sinus protocol.

kernels were slightly better than bone kernels in terms of noise, and FBP was better than ASIR but not significantly (Tables 4 and 5).

Point spread function: There was a significant overall effect of reconstruction. MBIR standard scored the best (FWHM: 0.879 mm); however, with no significant difference to ASIR-100 bone (0.935 mm). Both of the ASIR bone reconstructions scored better than the ASIR standard, which scored the worst (1.312–1.344 mm). There was no significant difference between ASIR-100 and ASIR-50 when comparing bone with bone and standard with standard kernel. ASIR standards scored significantly worse than FBP bone (1.150 mm) and FBP standard (1.108 mm).

Comparison of reference protocol filtered back projection vs test protocols and IRT

A statistical analysis was not possible owing to the limited sample if splitting up per exposure group. However, the following observation could be made: compared with the RP FBP images reconstructed using standard kernel, LD-II with MBIR showed similar scores for contrast resolution, xy and z visibility, sharpness and noise. Using bone kernel, scores from LD-I with ASIR-50 and ASIR-100 were very close to that of the RP FBP images.

Discussion

Following the as low as reasonable achievable principle, dose levels should be kept at a minimum and every technology reducing dose should be implemented in daily clinical practice as soon as possible.¹² Similar to CBCT, which may show very large exposure ranges based on low-dose and high-definition protocols and differences between CBCT units, CT radiation dose is substantially related to the selected protocol, available scanner generation and additional dose-saving technology.^{13,14} In this study, the LD provided images using only 11%, 7%, 3% and 1.5% of a high-resolution RP. In addition, all images were reconstructed using the IRTs ASIR and MBIR.¹⁵ ASIR integrates a comparison of the pixel values obtained from the FBP algorithm with an ideal value to selectively identify and then subtract noise from an image at adaptive blend levels freely selectable, typically from 10% to 100%.⁸ At a CTDI_{vol} of 2.19 mGy, ASIR-50 reduced noise by 22% and ASIR-100 by 35%.⁴ MBIR uses a more complex system of prediction models, including noise and the spatial and geometric features of the X-ray beam and detector technology.¹⁴ It requires a considerably long computational time and may not be used for acute imaging. However, MBIR is very powerful and could reduce noise by 67% (CTDI_{vol} of 2.19 mGy).⁴

Table 4 Overall sharpness. Average score per exposure group (range 0–2)

Overall sharpness	FBP standard	ASIR-50 standard	ASIR-100 standard	MBIR standard	FBP bone	ASIR-50 bone	ASIR-100 bone	Average score for each exposure protocol
RP (36.56 mGy)	1.17	1.00	0.83	1.67	1.67	2.00	2.00	1.48
SP (18.28 mGy)	1.00	0.83	0.67	1.33	1.67	2.00	2.00	1.36
LD-I (4.17 mGy)	1.17	0.83	0.33	1.00	1.67	2.00	2.00	1.29
LD-II (2.36 mGy)	0.83	0.67	0.00	1.50	1.67	1.67	1.67	1.14
LD-III (0.99 mGy)	0.50	0.50	0.00	0.33	1.67	1.67	1.50	0.88
LD-IV (0.53 mGy)	0.67	0.17	0.33	0.33	1.00	0.83	0.83	0.59
Average score for each reconstruction	0.89	0.67	0.36	1.03	1.56	1.70	1.67	

ASIR, adaptive statistical iterative reconstruction; FBP, filtered back projection; LD, ultralow-dose protocols; MBIR, model-based iterative reconstruction; RP, reference protocol; SP, sinus protocol.

Table 5 Overall noise. Average score per exposure group (range 0–2)

Overall noise	FBP standard	ASIR-50 standard	ASIR-100 standard	MBIR standard	FBP bone	ASIR-50 bone	ASIR-100 bone	Average score for each exposure protocol
RP (36.56 mGy)	1.67	1.67	1.33	2.00	2.00	1.67	1.67	1.72
SP (18.28 mGy)	0.67	1.50	1.67	2.00	1.67	1.50	1.50	1.50
LD-I (4.17 mGy)	1.00	1.00	1.00	1.67	1.00	1.00	1.00	1.10
LD-II (2.36 mGy)	1.33	1.00	1.00	1.67	1.33	1.00	0.67	1.14
LD-III (0.99 mGy)	0.83	0.33	0.50	1.50	0.50	0.50	1.00	0.74
LD-IV (0.53 mGy)	1.33	0.50	1.00	1.50	0.00	0.00	0.00	0.62
Average score for each reconstruction	1.14	1.00	1.08	1.72	1.08	0.95	0.97	

ASIR, adaptive statistical iterative reconstruction; FBP, filtered back projection; LD, ultralow-dose protocols; MBIR, model-based iterative reconstruction; RP, reference protocol; SP, sinus protocol.

The SedentexCT phantom was initially developed for the image quality analysis of CBCT scanners. The visibility of the lps and cylindrical rods are dependent on several contributing factors including the spatial resolution of the imaging system, contrast resolution, noise and geometric accuracy. In a previous study comparing CBCT devices with one CT scanner, CBCT performed better for the lp insert, but significantly worse for the rod insert.¹ Regarding image noise, CT was found to be superior to all CBCT systems.^{1,16,17} In the present study, the lp analysis showed no significant difference between RP and SP, and no statistically significant difference between SP, LD-I and LD-II or between LD-I, II and III. Contrast resolution showed no statistically significant difference between SP, LD-I and II. The overall effect of dose on sharpness was very low. Not surprisingly, reconstructions using the standard convolution kernel had a lower spatial resolution than those with the bone kernel, which is confirmed by other studies.^{1,18,19} MBIR standard was statistically significant better than ASIR-50 standard and ASIR-100 standard; however, the results were still not comparable with bone kernel. Among all protocols and reconstructions, coronal sharpness was lower than axial sharpness, which reflects the non-isotropic image acquisition of CT. For contrast resolution, MBIR was significantly better than all other reconstructions, especially when detecting the HA 50 and HA 100 rods where MBIR allowed visualizing one rod more, on an average, than FBP. ASIR-100 was better than ASIR-50 and FBP, but the results were not statistically

significant. The results are confirmed by a cadaver study, which showed that the detection rate of maxillofacial fractures could not be improved by use of IRT.¹⁰ When comparing the RP and FBP as the clinical reference with the other combinations, LD-I and II using MBIR were able to show comparable scores at a dose reduction of up to 93%.

As a limitation of this study, the scores were obtained from a geometrical phantom, which represents an average adult human head in terms of X-ray attenuation in scatter, but does not simulate the complexity of trabecular and cortical bone. Therefore, observer scores in this study as well as the FWHM do not directly represent diagnostic image quality. Furthermore, currently, no MBIR bone reconstruction is available; therefore, it was not possible to compare and interpret findings of the other bone reconstructions. If a bone kernel is available in MBIR, the quality of low-dose images regarding spatial resolution could improve radically. Although the contrast and lp analysis both showed substantial interobserver agreement, overall sharpness and noise had only moderate and fair agreements. Subjective grading of sharpness and noise remains difficult and may require more objective evaluations such as modulation transfer function and signal noise ratio. The present study completes the results of a previous publication of the variability of Hounsfield units for bone density estimation and contrast noise ratio using the same reference and low-dose protocols, iterative reconstructions and kernels.²⁰ The SedentexCT phantom with the described methods may be used for

Table 6 Point spread function. Full width at half maximum (FWHM) values for each protocol

FWHM	FBP standard	ASIR-50 standard	ASIR-100 standard	MBIR standard	FBP bone	ASIR-50 bone	ASIR-100 bone	Average score for each exposure protocol
RP (36.56 mGy)	0.871	1276	1254	0.780	1040	0.915	0890	1003
SP (18.28 mGy)	0.903	1306	1263	0.810	1088	0.913	0895	1025
LD-I (4.17 mGy)	0.962	1349	1286	0.859	1172	0.951	0907	1070
LD-II (2.36 mGy)	1257	1364	1340	0.871	1182	0.965	0937	1131
LD-III (0.99 mGy)	1305	1383	1360	0.911	1195	1020	0.979	1165
LD-IV (0.53 mGy)	1348	1385	1366	1044	1223	1055	1003	1203
Average score for each reconstruction	1108	1344	1311	0.879	1150	0.970	0935	

ASIR, adaptive statistical iterative reconstruction; FBP, filtered back projection; LD, ultralow-dose protocols; MBIR, model-based iterative reconstruction; RP, reference protocol; SP, sinus protocol.

a more objective comparison of image quality of various CT scanners, LD, IRTs and further dose reduction techniques such as 70 kV imaging and tin filtration.

Conclusions

Modern CT scanners may be able to reduce radiation exposure considerably compared with current RPs. The

present phantom study showed that dose reductions of >90% may be possible without compromising spatial and contrast resolutions, using the noise reduction and contrast improvement of MBIR.

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