Patient dose and image quality in low-dose abdominal CT: a comparison between iterative reconstruction and filtered back projection

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Abstract

Background: In Computed Tomography (CT), there is increasing concern for potential CT radiation hazards. Several raw-data-based iterative reconstruction techniques attempt to facilitate low-dose imaging without compromising image quality, which raises the question whether these techniques may allow further dose reduction.

Purpose: To compare image quality of iterative reconstruction and filtered back projection in low-dose abdominal Computed Tomography (CT) and study the potential for further dose reduction.

Material and Methods: Forty-five patients underwent CT of the abdomen twice: with standard low-dose technique and with 30 % reduced dose, using both iterative reconstruction and filtered back projection. Four radiologists made pair-wise image quality assessment using five visual criteria. Visual Grading Regression (VGR) and weighted kappa (κ_w) was used to analyze the data.

Results: There were significant effects of log (mAs) ($p<0.001$) and reconstruction algorithm ($p<0.01$) on all image quality criteria with an estimated potential dose reduction of 5–9%. Inter-observer agreement ranged from 70 to 91% and κ_w from –0.01 to 0.57.

Conclusion: An iterative reconstruction algorithm improved image quality in abdominal CT, but the estimated dose reduction was rather small. The full potential of the algorithm remains unclear.

Keywords: Computed Tomography, Iterative Reconstruction, Image Quality, Filtered Back Projection (FBP)

Advancements in Computed Tomography (CT) technique have led to its wide use in diagnostic radiology as a standard modality with improvements in treatment and diagnosis of numerous medical conditions. There is, however, a cost attached to this advancement, as there is increasing concern for potential CT radiation hazards, which may elevate a person's lifetime risk of developing cancer. Although there may be some difficulty in quantifying life-time risks for the individual person, this small risk, if applied to a large number of individuals, can result in a public health problem (1,2).

It has been projected that approximately 29,000 future cancers could be related to the 7 million CT scans performed in the United States in 2007 (3). Similarly, the risk of developing cancer from CT coronary angiography examinations has been estimated as being 1 in 270 for women, 1 in 600 for men at the age of 40 years. At 20 years of age, this risk escalates to twice as large and for 60 year-olds, it is half this amount (4). A recent retrospective cohort study on radiation exposure from CT scans in childhood, noted a positive association between radiation dose from CT scans to leukemia and brain tumors. The interpretation of the study results show that if use of CT scans in children delivers cumulative doses of about 50 mGy (milliGray) the risk for leukemia might be tripled and that doses of about 60 mGy might triple the risk of brain cancer (5).

Dose reduction can be achieved by judicious use of CT as an imaging modality (2,6). There are a multitude of dose-saving strategies available including examination-specific voltage settings, tube current modulation technique and the use of specific scan protocols for the **pediatric patients** (2). In compliance with the "as low as reasonably achievable" (ALARA) principle, the optimization of CT protocols is

necessary to meet the clinical need for accurate determination whilst maintaining sufficient image quality.

The standard image reconstruction algorithm is still Filtered Back Projection (FBP), but during the last decade new CT scanners have enabled the re-introduction of iterative reconstruction methods which were used in the infancy of CT history (7,8). Published studies indicate that this technique yields images with reduced image noise and artifacts (9-12).

Several raw-data-based iterative reconstruction techniques attempt to facilitate low-dose imaging without compromising image quality. It is thus of central clinical interest to study whether image quality with this reconstruction method is superior enough to allow further dose reduction.

This study focuses on efforts to reduce patient dose in abdominal CT by determining if the advantage of iterative reconstruction in terms of image quality is sufficient enough to facilitate dose reduction. We hypothesized that there is such a difference in image quality between iterative reconstruction and the FBP methods that there is room for further dose reduction with preserved image quality.

The aim of this study was to compare image quality with iterative reconstruction to filtered back projection in low-dose abdominal CT and to evaluate if further patient dose reduction is possible.

Material and Methods

This was a prospective study with a quantitative approach comprising a selection of patients presented to the radiology department at Vrinnevi Hospital, Norrköping for examination of a low-dose CT of the acute abdomen between October, 2011 and February, 2012.

Sample selection

A consecutive selection of 45 patients who underwent an acute abdominal CT presented to the radiology department. As radiation dose is cumulative for CT examinations, inclusion criterion was patients of at least 50 years of age and exclusion criterion was patients who had undergone **more than four CT examinations** over the past year. Non-Swedish speaking patients were excluded from this study as it was impossible to organize professional interpreter services for these examinations.

Procedure

Each patient was examined twice, using first a CT series of the abdomen with standard low-dose technique and then a second series with 30% less dose. Images were acquired in the clinical routine with a 128-slice Somatom Definition AS scanner (Siemens Medical Systems, Forchheim, Germany). The CT protocols employed the automatic exposure control technique for both the x-y (transverse) and z-(cranial-caudal) axis. Table 1 shows the parameters used for the two examinations.

For each examination, axial images were reconstructed from raw data both with the FBP algorithm and the iterative reconstruction algorithm SAFIRE strength 1 using B26f medium smooth ASA kernel, slice thickness 5 mm with a 2.5 mm reconstruction interval and window settings 400/40 HU. The results were stored in the Picture Archiving and Communication System (PACS) (IDS7; Sectra Imtec AB, Linköping, Sweden). Patient demographic data were obtained from the radiological information system (RIS) (Sectra Imtec AB, Linköping, Sweden). A dose report (including scanner and dose parameters) was recorded for each patient. Body Mass Index (BMI), which was expected to influence image quality, was calculated for each patient.

Four radiologists, with CT experience ranging from 1 to 3 years (less experienced) and from 20 to 22 years (experienced), independently performed visual image quality assessment comparing five pairs of image stacks from each patient (Fig.1) resulting in 900 observations.

The image stacks were shown in pair-wise random order with respect to dose level and image reconstruction, and all demographic and scanner data were removed at the PACS workstation so that the radiologists were blinded. Readings were performed according to European Guidelines on quality criteria for abdominal CT (13) on regular DICOM-calibrated PACS workstations. The image quality was evaluated at similar anatomic sites in the abdomen for each patient.

The criteria used were as follows:

1. Visually sharp reproduction of the intestine.
2. Visually sharp reproduction of the pancreatic contours
3. Visually sharp reproduction of the kidneys and proximal ureters.
4. Visually sharp reproduction of the aorta.
5. Critical reproduction of the gallbladder wall.

Image quality was graded on a 5-point Likert-type scale with the following scores:

- 2: image on left monitor is definitely better than image on right monitor
- 1: image on left monitor is probably better than image on right monitor
- 0: images on left and right monitors are equivalent
- +1: image on right monitor is probably better than image on left monitor
- +2: image on right monitor is definitely better than image on left monitor.

A sixth criterion was added to assess the visualization of pathology with the exclusion of diverticulosis and similar age related findings. This criterion was also assessed on a 5-point Likert-type scale as follows:

1. Normal examination
2. Probably normal examination
3. Inconclusive examination
4. Probably pathological examination
5. Pathological examination

Statistical Analysis

The scores were entered into a spreadsheet and statistically analyzed using visual grading regression (VGR), in which ordinal logistic regression is applied to scores from observer ratings whilst controlling for dependencies between observers, patients and methods (14) using STATA 10.1 (Stata Corporation LP, College Station, TX, USA). As standard statistical software does not allow for random effects in logistic regression, the STATA software module Generalized Linear and Latent Mixed Models (GLLAMM) was applied to take into consideration random effects due to individual patients and radiologists, who can both be seen as random samples from larger populations (15-17). The potential for dose reduction was quantified by relating the VGR coefficients for log (mAs) and SAFIRE reconstruction to each other, as described in (16). The principle underlying this calculation is to relate the differences in image quality score brought about by changing the reconstruction method to that brought about by changing the dose. Formally, if the regression coefficient of log(mAs) is a and that of iterative reconstruction is b , then the dose reduction is given by $1-\exp(-b/a)$. Weighted kappa (κ_w) was used to describe inter-observer agreement between the 4 readers. The significance limit was set at $p=0.05$.

Ethical aspects

Approval was obtained from the regional Ethics and Radiation Protection committees to carry out two CT examinations on each patient included in this study. Informed written consent was obtained from each patient before the examination

with information that participation in the study was voluntary and their right to withdraw from the study at any time. The images were displayed for the reading radiologists with all patient identification data removed thereby making it impossible to identify any individual patient.

Results

In the 45 patients (24 men and 21 women), age ranged from 50 to 95 years, mean age 65 years, standard deviation (SD) ± 9.6 with a Body Mass Index (BMI) range from 17.1 to 46.8, mean 28.21 and SD ± 5.6 . Patient scan data and dose parameters are presented in Table 2.

There were a total of 12 missing values, scores for criterion 5 (assessment of gall bladder wall), mostly due to the observer not being able to identify any gallbladder. These have not been included in the statistical analysis.

The distribution of the scores for the five evaluation criteria assessed is shown in (Figs. 2-6). The scores for SAFIRE versus FBP, when comparing pairs at the same dose level (left two stacked bars in each Figure), were mostly around 0, indicating that image quality was often judged as equivalent in the two images for all the assessed criteria. However, the scores in favor of SAFIRE (+1 and +2) were consistently slightly more common than those in favor of FBP (-1 and -2).

Comparisons between two dose levels with the same algorithm gave, not surprisingly, higher values to the higher dose level (many cases with -1 and -2 in the third and fourth stacked bar). There was deterioration of image quality when comparing images for SAFIRE at 35mAs with FBP at 50 mAs, with the scores more in favor of FBP 50 mAs (rightmost stacked bars).

Scores for the assessment of pathology in pair-wise comparison for all observations are shown in Fig. 7. Neither mAs nor type of reconstruction algorithm showed any effect on the distribution of the scores.

When analyzing all the data in one statistical model, the Visual Grading Regression coefficients (Table 3) reveal a strongly significant effect of log (mAs) ($p<0.001$) and a significant effect of SAFIRE reconstruction ($p<0.01$), on all image criteria. This is illustrated by higher coefficient values for log (mAs) and somewhat lower for SAFIRE reconstruction. The estimated dose reduction was rather small, ranging from 5% for sharp reproduction of the gallbladder wall to 9% for reproduction of the aorta, kidneys and proximal ureters.

Inter-observer reliability was calculated by using weighted pair-wise kappa (κ_w) for all four readers to see if there was any difference between experienced readers and readers with less experience. Table 4 illustrates the percentage of agreement (range 70-93%) and kappa values (range from -0.01 to 0.57) for comparison between pairs of experienced and inexperienced readers. Kappa values show a significant ($p<0.001$), fair to moderate agreement for experienced readers for all the criteria assessed. With the inexperienced readers, the results were more variable. **When agreement and kappa were calculated separately for images reconstructed with SAFIRE and FBP, no clear differences emerged (data not shown).**

To compare variations in estimation of dose reductions due to BMI the population was divided into two groups: BMI $< 30\text{kg/m}^2$ ($n= 30$) and BMI $\geq 30\text{kg/m}^2$ ($n=15$). The VGR analysis shows that dose reduction estimates were slightly higher for the group with BMI $< 30\text{kg/m}^2$ (Table 5) compared to the group with BMI $\geq 30\text{kg/m}^2$ (Table 6).

Discussion

CT technology continues to evolve, leading to an increase in its use as an imaging modality. Although the CT scans are medically beneficial, they have a higher radiation dose level compared to conventional X-rays. There is growing concern for potential cancer risks associated with irradiation making this a public health issue based on estimations from several studies which raise concerns regarding the continual increase in use of CT as an imaging modality (3-5). Emphasis should be placed on the benefit/risk ratio where benefit of CT scan outweighs the risk if the examination is medically justified (18,19). The reintroduction of iterative reconstruction technique is an important factor to be considered when optimizing clinical CT protocols. The processing time for iterative reconstruction has limited its use in clinical radiology, but with modern computer hardware and software, SAFIRE reconstruction times are today similar to those for FBP, thus facilitating wide use of this technique in both emergency and non-emergency CT examinations.

This study presents a clinical evaluation of subjective image quality of Sinogram Affirmed Iterative Reconstruction (SAFIRE) with repeat examinations of the same individual using low-dose and reduced-dose technique. This gives a realistic comparison of image quality between the two techniques in order to evaluate radiation dose reduction. Ethical issues involved were resolved by obtaining approval from the regional Ethics and Radiation Protection committees and by restricting population age selection to 50 years and over.

The inter-observer agreement ranged from poor to moderate with significant kappa values only when comparing the experienced readers. As the assessment is subjective, it is likely that variation does occur even when the same reader assesses the same pair of images on two different occasions. This is common practice in

radiology departments today, for quality assurance purposes of the examination reports, where a second interpretation either confirms or reviews the report from the first reading. In experimental studies like the present study, it is of importance to have several readers in order to achieve a good inter-observer reliability.

The blinding of the radiologists to all scanning and patient data reduces the risk for systematic errors occurring during assessment of image quality. Assessment of image quality was carried out on DICOM-calibrated PACS workstations with which the radiologists were familiar, thus reducing risk for random errors.

This study used test protocols with similar kV. The option to use a lower voltage such as 100 kV might have shown better results; however, the purpose in this first study was to isolate one factor (mAs) affecting image quality in order to avoid difficulties in interpretation of the results.

Subjective image quality is one of the corner-stones in the assessment of the diagnostic quality of an image. According to the ALARA principle, the amount of noise acceptable in an image is assessed to determine radiation dose necessary without compromising the diagnostic performance. The question that arises is “how low can one go?”, as methods for reducing CT dose have an impact on image quality as well. Balance between dose and image quality can be achieved by understanding the relation between newer CT applications and technology and CT dose (20). Of course, new reconstruction methods with improved balance between image quality and dose may permit either reduced dose at preserved image quality, or improved image quality at preserved dose. In this study, however, we have focused on the potential for dose reduction.

If iterative reconstruction allows for dose reduction by reducing image noise, this will facilitate optimization of dose protocols. Clinical trials similar to this study

could be carried out in order to optimize protocols, but the ethical issues involved with extra irradiation of the patient might limit the study population. However, VGR offers a method to quantify dose reduction and can be particularly useful in pilot studies where the actual testing and evaluation of dose reduction for certain measures can be estimated before designing the main study for testing its diagnostic value (16).

In the present study, an assumed dose reduction of 30% on a low-dose series was based on manufacturer recommendations suggesting up to 60 % dose reduction in full-dose examinations. With the results at hand, these figures were overly optimistic for low-dose abdominal examinations. To our knowledge, there are no comparative low-dose abdominal studies like the present study on the SAFIRE algorithm. A recent study of Kalra et al., (21) assessed the effect of SAFIRE and FBP on abdominal CT performed with standard dose 100% (Qref: 200mAs) compared to 50% (Qref: 100 mAs) and 75% (Q ref: 50 mAs) radiation dose reductions. They concluded that SAFIRE provides images with no loss in diagnostic value at 50% reduced dose and in some patients also at 75% reduced dose. There are two other studies, both utilizing CT angiography protocols, that show that SAFIRE image noise was significantly lower in half-dose data sets compared to full-dose data sets from FBP, indicating a potential for dose reductions by more than 50% (22, 23). One should bear in mind that the potential for dose reduction may be smaller in low-dose abdominal examinations, where strict optimization has already produced a protocol near the border of clinical acceptability. **It is possible that greater dose reduction could have been achieved if the same methodology had been applied to standard CT protocols.**

SAFIRE is available in 5 strengths from 1 to 5, where an increase in SAFIRE strength setting leads to a reduction in image noise. Still, the unfamiliar “plastic” appearance of these images may seem strange for unaccustomed readers, which in the beginning could lead to poorer diagnostic performance (24). In this study, clinical setting SAFIRE strength 1 was used, as it yields a somewhat comparable appearance to the standard FBP. The effect of SAFIRE strength 1 was rather small, and did not compensate for the increase in noise due to dose reduction when comparing series at 50 mAs and 35 mAs, as shown by the estimates of 5-9% in dose reduction.

With SAFIRE software upgrade of the scanner in September, 2011, the clinical routine dose was reduced by 30% for all CT protocols, and to date this dose reduction is still used for all other protocols except for the low-dose abdominal CT where the reduction from 50 mAs to 35 mAs yielded images of unacceptable quality. As there were concerns about the diagnostic accuracy of the examination, the routine dose was increased from 35 mAs to 45 mAs in October, 2011, immediately before the start of the present study. This is close to the dose reductions estimated from our study.

Possibly, a higher SAFIRE strength could have given higher dose reduction estimation values. A gradual increase in SAFIRE strength could enable radiologists to leave their comfort zone and adapt to the unfamiliar appearance of iteratively reconstructed images without having to compromise diagnostic accuracy. According to previous experience in iterative reconstruction imaging techniques, this adaptation should take place within a short period of time (25).

This study did not assess artifacts or image noise but ring artifacts were observed on CT low-dose images from the scanner during the course of this study. It is possible

that this could have affected the overall subjective assessment of the criteria on the 35mAs images as artifacts affect image quality.

For smaller patients, if automatic exposure control (AEC) is not employed, the noisy images due to photon starvation may affect the criteria for the anatomical sites in the abdomen by impairing visibility due to lack of fat around the abdominal organs (9). However, the use of dose reduction applications (Care Dose 4D) and the scanner setting for AEC by adjusting the adaptation strength (comparable to Noise index setting for other manufacturers), based on average patient weight, helps to maintain a desired quantum noise level on the image whilst improving dose efficiency. The quality reference mAs (Qref mAs) required by the AEC system to adjust the mA must be defined by the user. The adaptation strength setting adjusts this value for the bigger patients, where dose reduction leads to increase in image noise. The VGR analysis shows a better effect for SAFIRE compared to FBP for the present study population with a BMI < 30 compared to those with a BMI ≥ 30 .

Several studies show that low-dose protocols for imaged anatomy, such as CT of the paranasal sinuses and CT colon screening, can accommodate for possible further dose reductions, especially with iterative reconstruction without loss in diagnostic accuracy, due to the high contrast differences in the anatomy studied (26, 27). For these images with high contrast, there is a slightly increased tolerance for image noise compared to low-dose abdomen images where contrast differences between the solid organs are small, thus limiting the amount of acceptable image noise without impairing the diagnostic accuracy.

This study has several limitations, one of which is use of a low-dose protocol in comparison to a further 30% reduction in dose. Another limitation is use of SAFIRE strength 1 which restricted the evaluation of the full potential of the SAFIRE

algorithm. In future studies, it would be interesting to assess the effect of higher strength settings, i.e. reconstructions deviating more from standard FBP. Finally, the present study did not assess the appearance of artifacts, which is believed to affect image quality in CT examinations.

In conclusion, SAFIRE iterative reconstruction algorithm improved image quality in low-dose abdominal CT. With a SAFIRE strength setting of 1, the estimated dose reduction was rather small. The full potential of the algorithm remains unclear.

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Conflict of interest statement

The authors declare that there is no conflict of interest.

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Figure Legends

Fig. 1 Schematic diagram showing comparison of 5 pairs of image stacks for images acquired at 50mAs and 35mAs and reconstructed with SAFIRE and Filtered Back Projection (FBP)

Fig. 2 Criterion 1: Visually sharp reproduction of the intestine. Distribution of scores for pair-wise comparison of images acquired at 50 mAs and 35 mAs and reconstructed with SAFIRE and Filtered Back Projection (FBP). A positive score (+1 or +2) in the leftmost bar indicates that SAFIRE 50 mAs was rated better than FBP 50 mAs, whereas a negative score (−1 or −2) indicates that FBP 50 mAs was rated better than SAFIRE 50 mAs, and so forth.

Fig. 3 Criterion 2: Visually sharp reproduction of the pancreatic contours.

Distribution of scores for pair wise comparison of images acquired at 50 mAs and 35 mAs and reconstructed with SAFIRE and Filtered Back Projection (FBP). A positive score (+1 or +2) in the leftmost bar indicates that SAFIRE 50 mAs was rated better than FBP 50 mAs, whereas a negative score (−1 or −2) indicates that FBP 50 mAs was rated better than SAFIRE 50 mAs, and so forth.

Fig. 4 Criterion 3: Visually sharp reproduction of the kidneys and proximal ureters.

Distribution of scores for pair-wise comparison of images acquired at 50 mAs and 35 mAs and reconstructed with SAFIRE and Filtered Back Projection (FBP). A positive score (+1 or +2) in the leftmost bar indicates that SAFIRE 50 mAs was rated better than FBP 50 mAs, whereas a negative score (−1 or −2) indicates that FBP 50 mAs was rated better than SAFIRE 50 mAs, and so forth.

Fig. 5 Criterion 4: Visually sharp reproduction of the aorta Distribution of scores for pair-wise comparison of images acquired at 50 mAs and 35 mAs and reconstructed with SAFIRE and Filtered Back Projection (FBP). A positive score (+1 or +2) in the leftmost bar indicates that SAFIRE 50 mAs was rated better than FBP 50 mAs, whereas a negative score (−1 or −2) indicates that FBP 50 mAs was rated better than SAFIRE 50 mAs, and so forth.

Fig. 6 Criterion 5: Critical reproduction of the gallbladder wall. Distribution of scores for pair-wise comparison of images acquired at 50 mAs and 35 mAs and reconstructed with SAFIRE and Filtered Back Projection (FBP). A positive score (+1 or +2) in the leftmost bar indicates that SAFIRE 50 mAs was rated better than FBP 50 mAs, whereas a negative score (−1 or −2) indicates that FBP 50 mAs was rated better than SAFIRE 50 mAs, and so forth.

Fig. 7 Criterion 6: Presence of pathology excluding diverticulosis and other age related findings. Distribution of scores for pair-wise comparison of images acquired at 50 mAs and 35 mAs and reconstructed with SAFIRE and Filtered Back Projection (FBP).

Table 1 Scan parameters for standard low-dose abdominal CT and 30% reduced dose protocols for a 128 slice Siemens Somatom Definition AS Scanner.

Series description	Voltage (kV)	Quality Reference Tube current time product (mAs)	Acquisition mode	Dose modulation	CARE Dose 4D	Rotation Time	Pitch	Collimation (mm)	Slice Thickness (mm)
Standard low-dose protocol	120	50	Axial	on	CARE Dose4D	0.5	1.2	0.6	5
30% Reduced dose protocol	120	35	Axial	on	CARE Dose4D	0.5	1.2	0.6	5

Table 2 Patient scan and dose parameters presented as mean $\pm$ standard deviation (SD) for images acquired at 50mAs and 35mAs and reconstructed with SAFIRE and Filtered Back Projection (FBP)

Body Mass Index (BMI)	Parameters	Quality Reference (Q ref) Tube Current time product (mAs)	
		50mAs	35mAs
BMI<30 (n=30)	DLP (mGy cm ²)	125 $\pm$ 38	87 $\pm$ 26
	CTDI _{vol} (mGy)	2.9 $\pm$ 0.8	2 $\pm$ 0.6
	Effective mAs	42 $\pm$ 12	29 $\pm$ 8
BMI $\geq$ 30 (n=15)	DLP (mGy cm ²)	197 $\pm$ 43	137 $\pm$ 31
	CTDI _{vol} (mGy)	4.7 $\pm$ 0.8	3 $\pm$ 0.6
	Effective mAs	64 $\pm$ 12	44 $\pm$ 9
Dose Length Product(DLP), Computed Tomography Dose Index volume (CTDI _{vol})			

Table 3 Visual Grading Regression (VGR) Coefficient for all the criteria with estimated dose reduction values for pair-wise comparison of images acquired at 50 mAs and 35 mAs and reconstructed with SAFIRE and Filtered Back Projection (FBP)

Criterion	Regressions coefficients		Estimated % dose reduction (95% confidence intervals)
	log (mAs)	SAFIRE Reconstruction	
1. Visually sharp reproduction of the intestine	6.95 ^{***}	0.61 ^{***}	8% (6-11%)
2. Visually sharp reproduction of the pancreatic contours	7.80 ^{***}	0.55 ^{***}	7% (5-9%)
3. Visually sharp reproduction of the kidneys and proximal ureters	8.56 ^{***}	0.79 ^{***}	9% (7-11%)
4. Visually sharp reproduction of the aorta	9.49 ^{***}	0.94 ^{***}	9% (7-12%)
5. Critically sharp reproduction of the gallbladder wall	6.87 ^{***}	0.36 ^{**}	5% (2 -8%)

***) $p < 0.001$, **) $p < 0.01$

Table 4 Weighted pair-wise Kappa (κ_w) and agreement (%) scores for evaluation of criteria in pair-wise comparison between experienced and less experienced readers of images acquired at 50 mAs and 35 mAs and reconstructed with SAFIRE and Filtered Back Projection (FBP)

Criterion	Experienced vs Experienced		Less experienced vs Less experienced		Experienced vs Less experienced	
	Agreement	κ_w (95% CI)	Agreement	κ_w (95% CI)	Agreement	κ_w (95% CI)
1. Visually sharp reproduction of the intestine	87 %	0.21 ^{***} (0.15-0.27)	84 %	0.03 ^{**} (0.01-0.05)	84-91%	-0.01-0.39 ^o (-0.45-0.47)
2. Visually sharp reproduction of the pancreatic contours	91 %	0.57 ^{***} (0.49-0.65)	84 %	0.35 ^{***} (0.26-0.45)	84-87%	0.35-0.44 ^{***} (0.27-0.53)
3. Visually sharp re-production of the kidneys and proximal ureters	90 %	0.45 ^{***} (0.38-0.53)	85 %	0.42 ^{***} (0.33-0.50)	84-86%	0.33-0.45 ^{***} (0.25-0.53)
4. Visually sharp reproduction of the aorta	89 %	0.36 ^{***} (0.29-0.43)	81 %	0.05 ^{***} (0.02-0.08)	84-93%	0.12-0.44 ^{***} (0.05-0.52)
5. Critically sharp reproduction of the gallbladder wall	91 %	0.46 ^{***} (0.37-0.54)	84 %	0.04 ^o (-0.02-0.11)	85-91%	0.13-0.37 ^o (0.07-0.47)
6. Is there any pathology present?	84 %	0.53 ^{***} (0.41-0.65)	72 %	0.23 ^{***} (0.16-0.30)	70-86%	0.28-0.47 ^{***} (0.22-0.57)

***) $p < 0.001$, **) $p < 0.01$, °) not significant, (95% CI) =95% confidence interval

Table 5 Visual Grading Regression (VGR) Coefficient Body Mass Index (BMI) less than 30 for all the criteria with estimated dose reduction values for pair-wise comparison of images acquired at 50 mAs and 35 mAs and reconstructed with SAFIRE and Filtered Back Projection (FBP)

Criterion	Regression coefficients		Estimated % dose reduction (95% confidence intervals)
	log (mAs)	SAFIRE Reconstruction	
1. Visually sharp reproduction of the intestine	6.28 ^{***}	0.58 ^{***}	9% (5-13%)
2. Visually sharp reproduction of the pancreatic contours	7.37 ^{***}	0.55 ^{***}	7% (4-10%)
3. Visually sharp reproduction of the kidneys and proximal ureters	7.80 ^{***}	0.75 ^{***}	9% (7-12%)
4. Visually sharp reproduction of the aorta	9.05 ^{***}	1.00 ^{***}	10% (8-13%)
5. Critically sharp reproduction of the gallbladder wall	5.80 ^{***}	0.31 ^{**}	5% (1-10%)

***) $p=0.001$, **) $p < 0.05$

Table 6 Visual Grading Regression (VGR) Coefficient Body Mass Index (BMI) ≥ 30 for all the criteria with estimated dose reduction values for pair-wise comparison of images acquired at 50 mAs and 35 mAs and reconstructed with SAFIRE and Filtered Back Projection (FBP)

Criterion	Regression coefficients		Estimated % dose reduction (95% confidence intervals)
	log (mAs)	SAFIRE Reconstruction	
1. Visually sharp reproduction of the intestine	8.48 ^{***}	0.66 ^{**}	8% (3-12%)
2. Visually sharp reproduction of the pancreatic contours	9.68 ^{***}	0.57 ^{**}	6% (3-9%)
3. Visually sharp reproduction of the kidneys and proximal ureters	10.87 ^{***}	0.92 ^{***}	8% (5-11%)
4. Visually sharp reproduction of the aorta	10.51 ^{***}	0.84 ^{**}	8% (4-11%)
5. Critically sharp reproduction of the gallbladder wall	12.51 ^{***}	0.59 ^o	5% (0-9%)

***) $p < 0.001$, **) $p < 0.05$, °) not significant