Iterative Reconstruction Technique for Reducing Body Radiation Dose at CT: Feasibility Study

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OBJECTIVE. The purpose of this study was to evaluate the image noise, low-contrast resolution, image quality, and spatial resolution of adaptive statistical iterative reconstruction in low-dose body CT.

MATERIALS AND METHODS. Adaptive statistical iterative reconstruction was used to scan the American College of Radiology phantom at the American College of Radiology reference value and at one-half that value (12.5 mGy). Test objects in low- and high-contrast and uniformity modules were evaluated. Low-dose CT with adaptive statistical iterative reconstruction was then tested on 12 patients (seven men, five women; average age, 67.5 years) who had previously undergone routine-dose CT. Two radiologists blinded to scanning technique evaluated images of the same patients obtained with routine-dose CT and low-dose CT with and without adaptive statistical iterative reconstruction. Image noise, low-contrast resolution, image quality, and spatial resolution were graded on a scale of 1 (best) to 4 (worst). Quantitative noise measurements were made on clinical images.

RESULTS. In the phantom, low- and high-contrast and uniformity assessments showed no significant difference between routine-dose imaging and low-dose CT with adaptive statistical iterative reconstruction. In patients, low-dose CT with adaptive statistical iterative reconstruction was associated with CT dose index reductions of 32–65% compared with routine imaging and had the least noise both quantitatively and qualitatively ($p < 0.05$). Low-dose CT with adaptive statistical iterative reconstruction and routine-dose CT had identical results for low-contrast resolution and nearly identical results for overall image quality (grade 2.1–2.2). Spatial resolution was better with routine-dose CT ($p = 0.004$).

CONCLUSION. These preliminary results support body CT dose index reductions of 32–65% when adaptive statistical iterative reconstruction is used. Studies with larger statistical samples are needed to confirm these findings.

Keywords: body CT, low-dose CT, radiation dose

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The explosive growth of CT can be attributed to its wide availability, speed, and diagnostic benefits. In a 2007 report [1] it was estimated that more than 68.7 million CT examinations are performed each year in the United States, a dramatic upsurge compared with the 3 million performed in 1980. Although it accounts for only 11–13% of radiologic examinations performed overall in the United States, CT is responsible for more than two thirds of the total radiation dose associated with medical imaging [2, 3]. Public concern with radiation exposure escalated when a widely publicized article [4] claimed that the estimated cancer risk in the United States attributable to CT radiation has grown from 0.4% to 1.5–2.0% owing to the substantial increase in use of CT.

Dose reduction with CT has been limited because the current CT reconstruction algorithm (filtered back projection [FBP]) does not produce consistently diagnostic images if tube current is substantially reduced. Iterative reconstruction is a reconstruction algorithm whereby image data are corrected with an assortment of models. Although new to CT, iterative reconstruction is widely used in PET and was used when CT was introduced [5]. A current limitation of iterative reconstruction, however, is the long computing time. Therefore, a modified and computationally faster iterative reconstruction technique, adaptive statistical iterative reconstruction, was developed in which only one corrective model is used to address image noise. This technique is used to solve one of the primary problems of dose reduction for CT with FBP: increased noise with decreased radiation dose. The purpose of this study was to determine the feasibility of adaptive statistical iterative reconstruction for low-dose body CT through an evaluation of image noise, low-contrast resolution, image quality, and spatial resolution both in a phantom and in patients.

Materials and Methods

Study Design

All examinations were performed on a 64-MDCT scanner (CT750 HD, GE Healthcare). This retrospective HIPAA-compliant study was approved by the institutional review board of our institution.

Adaptive Statistical Iterative Reconstruction

In computation with iterative reconstruction, the image has an initial condition of values, which are iteratively optimized according to the rules of the model. The FBP image is used for the initial condition in adaptive statistical iterative reconstruction (the initial value of each pixel) for the following reasons: it is presumably close to the final optimized solution (lessening the need for iterations); it is a valid indicator of specific-slice image noise; and it can be quickly obtained. For modeling and use of iterative reconstruction, minimum convergence is achievable with the adaptive statistical iterative reconstruction model (Fig. 1). A fully converged 100% adaptive statistical iterative reconstruction image, however, tends to have a noise-free appearance with unusually homogeneous attenuation. Because some noise is inherent in CT, use of 100% adaptive statistical iterative reconstruction may not be immediately appealing to most radiologists. However, a linear mixture of the original FBP and the full adaptive statistical iterative reconstruction images can result in a blended image with markedly decreased noise that retains a more typical CT appearance. This blended image can be adjusted from 1% to 100% in adaptive statistical iterative reconstruction. A mathematic description of adaptive statistical iterative reconstruction is shown in Appendix 1.

Phantom Study

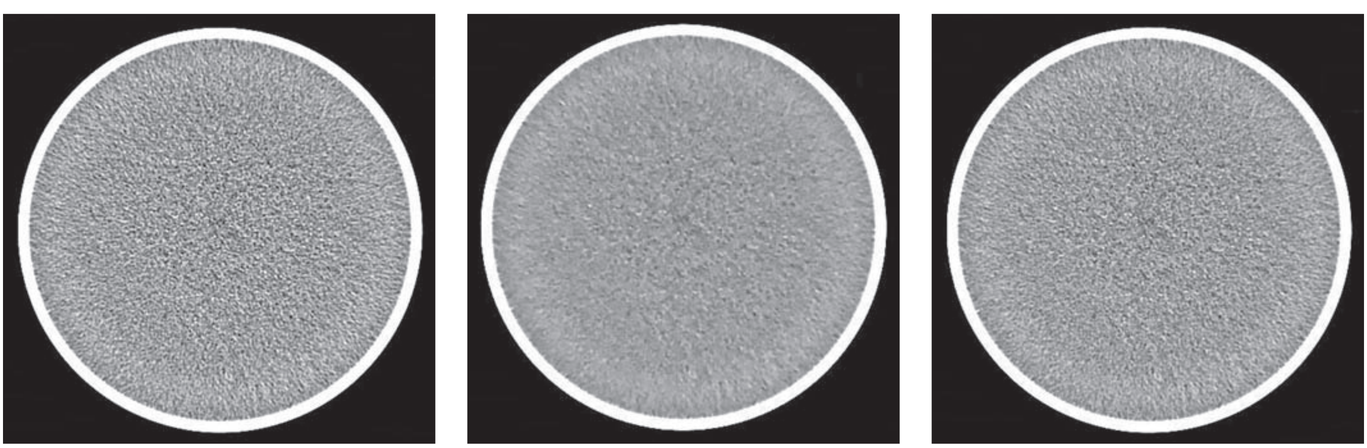
The American College of Radiology (ACR) CT phantom (Gammex 464, Gammex) was scanned twice, once with the ACR reference values (www.acr.org/accreditation/computed/ct_reqs.aspx) and then at one-half this value (12.5 mGy). Helical scanning was performed in the manner required for submission of images for scanner accreditation. Low-contrast resolution, high-contrast resolution, and uniformity modules were imaged, and these test objects were evaluated by CT physicists not blinded to scanning technique. Radiation dose and noise estimates were made in accordance with ACR protocol. Images were reconstructed with both FBP and multiple values of adaptive statistical iterative reconstruction ranging from 10% to 100%.

Patient Study

The study cohort consisted of 12 patients (seven men, five women; average age, 67.5 years; range, 53–86 years) who consecutively underwent low-dose CT and who had undergone routine-dose CT of the same region (abdomen or abdomen and pelvis) within an average of 10.1 months (range, 3 days–5 years) before low-dose CT. The comparisons were matched for IV contrast enhancement and imaging phase. In six comparisons, only the abdomen had been imaged, and in six, only the abdomen and pelvis. Ten of the 12 comparisons had been performed with IV contrast enhancement (nine venous phase, one arterial phase). In the other two examinations, CT was unenhanced. For routine-dose CT, the peak kilovoltage had been 140 kVp in eight examinations and 120 kVp in four. Seven of the CT examinations had been performed with dose modulation software with variable tube current at a slice thickness of 5 mm in two examinations, 3.75 mm in five, and 3 mm in five examinations. In most cases, 64-MDCT scanners had been used (three, VCT, GE Healthcare; six, Sensation 64, Siemens Healthcare). The other three examinations were performed with a 16-MDCT scanner (Sensation 16, Siemens Healthcare).

Technique of Low-Dose CT With Adaptive Statistical Iterative Reconstruction

Low-dose CT was performed with the following parameters: fixed noise index, 30.9; collimation, 0.625 mm; reconstruction slice thickness, 3.75 mm; tube potential, 120 kV; variable tube current determined by *x*, *y*, *z*-axis dose modulation; gantry rotation time, 0.5 second. The CT dose was reduced through an increase in accepted noise index for the study from 22.1 to 30.9. With the dose modulation software of the scanner, the tube current was automatically reduced to match the acceptable noise index. The dose varied with patient size; that is, larger patients needed a higher tube current for maintenance of the desired noise index than did thinner patients. All 12 low-dose CT examinations were reconstructed twice, once with FBP and once with 40% adaptive statistical iterative reconstruction. The 40% level was chosen on



A B C

Fig. 1—Production of adaptive statistical iterative reconstruction image.
A, Filtered back projection image obtained at 120 kVp and 300 mA at 12.5 mGy (half dose).
B, Image from 100% adaptive statistical iterative reconstruction generated through multiple iterations in accordance with rules of noise reduction model.
C, Linear combination of **A** and **B** produces blended image (50% adaptive statistical iterative reconstruction), which has less noise than filtered back projection image but without artifactual smoothing of 100% adaptive statistical iterative reconstruction image.

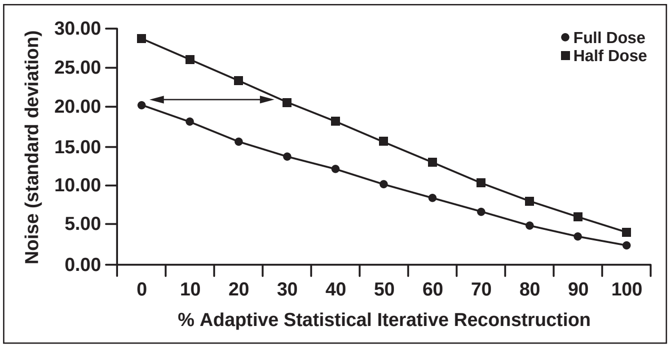


Fig. 2—Noise reduction in images reconstructed with adaptive statistical iterative reconstruction in phantom. Graph shows linear decrease in image noise (SD) as percentage adaptive statistical iterative reconstruction increases. Images acquired with 50% dose reduction (half dose) have 1.4 times SD value (28.57 compared with 20.39) without adaptive statistical iterative reconstruction. Reconstructing images with 30% adaptive statistical iterative reconstruction for half-dose acquisitions produces images with noise nearly equivalent to that of full-dose images without adaptive statistical iterative reconstruction (*double arrow*) (SD 20.52 compared with 20.39).

the basis of results of the phantom analysis, which indicated that 40% adaptive statistical iterative reconstruction should produce a diagnostically acceptable image with less noise than a full-dose FBP image.

Dose Comparison

Volume CT dose index (CTDI) and dose–length product (DLP) were compared for low-dose (n = 12) and routine-dose (n = 12) CT examinations. For comparison of radiation doses, the patients were divided into three groups based on body mass index (BMI) (weight in kilograms divided by height squared in meters): greater than 25 (n = 3), 20–24.9 (n = 6), and less than 20 (n = 3).

Quantitative Analysis

Two abdominal imaging fellows not involved in qualitative data analysis made quantitative noise measurements on a total of 36 data sets: 12 low-dose CT without adaptive statistical iterative reconstruction, 12 low-dose CT with adaptive statistical iterative reconstruction, and 12 routine-dose comparison CT. Noise measurements were made by recording the SD in an identically sized 2,500-mm^2 region of interest (ROI) placed 5 mm outside the anterior abdominal wall at the level of the umbilicus.

Qualitative Analysis

Qualitative image analysis was performed by two board-certified and fellowship-trained abdominal radiologists with 8 and 10 years of CT experience. The 36 data sets were randomized and deidentified so the readers were unaware of the postprocessing algorithm and dose. Only the axial images were displayed on a PACS (Centricity version 2.1, GE Healthcare). All data sets were displayed at soft-tissue settings (window, ~ 400 HU; level, ~ 40).

Image noise, image quality, low-contrast resolution, and spatial resolution were graded on a scale from 1 (best) to 4 (worst). A score of 1 meant that the image was better than expected at routine-dose CT, 2 meant the image was equivalent to that expected at routine-dose CT, 3 meant the image was worse than expected at routine-dose CT, and 4 meant the image was nondiagnostic. The readers independently assessed image noise, image quality, and low-contrast resolution. Readers were instructed to assess low-contrast resolution by evaluating the conspicuity of the hepatic veins within the liver or solid organ cysts. Spatial resolution was assessed through consensus evaluation by grading of the sharpness of the hepatic or renal edges.

Results

Phantom Study

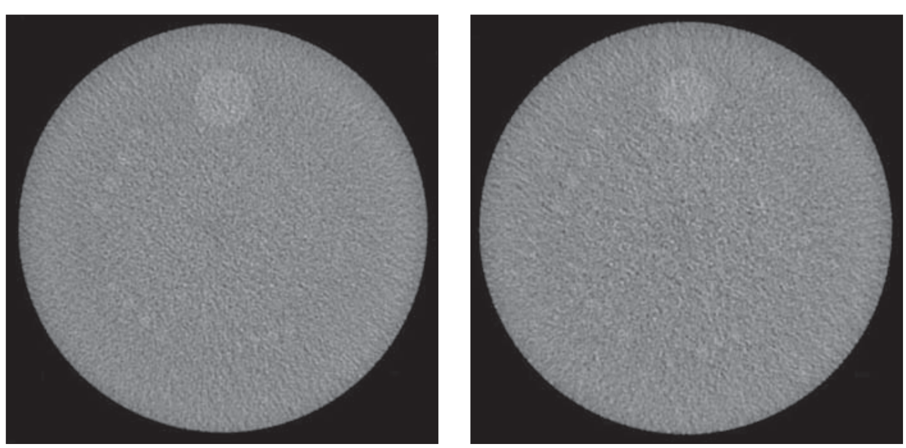
When adaptive statistical iterative reconstruction was applied to the FBP image in 10% increments, the result was a linear decrease in noise as measured with SD (Fig. 2). For full dose scanning, at 0% adaptive statistical iterative reconstruction, the SD (noise) was 20. At 100% adaptive statistical iterative reconstruction, the noise was minimum (SD 4), an approximately 75% reduction of noise from the original data. At approximately 50% adaptive statistical iterative reconstruction, the noise was approximately one-half that of a full-dose FBP image.

When the phantom was scanned at 50% lower dose, the noise as measured with SD was 1.4 times greater (28.6 vs 20.4) with 0% adaptive statistical iterative reconstruction. At 30% adaptive statistical iterative reconstruction, the noise was equivalent to that of a full-dose FBP image, and further reductions in noise occurred as percentage adaptive statistical iterative reconstruction was increased.

Comparison of low-contrast images showed comparable appearance of the ACR-required 6-mm objects at both routine-dose CT with FBP and low-dose CT with adaptive statistical iterative reconstruction (Fig. 3).

Comparison of the high-contrast object (12 line pairs/cm) showed that adaptive statistical iterative reconstruction was comparable with FBP in terms of spatial resolution and easily exceeded the spatial resolution requirement of 6 line pairs/cm required for accreditation (Fig. 4).

Uniformity was maintained at low-dose CT with adaptive statistical iterative reconstruction (the maximum deviation between the central ROI and peripheral ROIs was less than 5 HU) and was within ACR specifications [6]. Uniformity measurements on routine-



A B

Fig. 3—Low-contrast objects of comparable quality.
A, Filtered back projection image obtained with 25-mGy routine body image protocol.
B, Adaptive statistical iterative reconstruction image obtained at 50% reduced dose (12.5 mGy).

A B

Fig. 4—High-contrast objects.
A, Filtered back projection image obtained at routine dose of 25 mGy shows 12 line pairs/cm.
B, CT scan obtained with adaptive statistical iterative reconstruction at low dose of 12.5 mGy shows 12 line pairs/cm despite more image degradation than in **A.**

dose FBP images and low-dose CT images with adaptive statistical iterative reconstruction were nearly identical (Fig. 5).

Patient Study

Dose comparison—Overall, use of a low dose reduced the CTDI 47% and the DLP 44% (Table 1). For low-dose CT, the average CTDI was 12 compared with 22 for routine-dose CT. The average DLP was 470 mGy·cm for low-dose CT compared with 894 mGy·cm for routine-dose CT. Not surprisingly, when the 12 examinations were compared on the basis of BMI (Table 2), the percentage reductions in CTDI and DLP increased as BMI decreased. Therefore, patients with a BMI less than 20 had percentage reductions in CTDI and DLP of 65% compared with only 29–35% for patients with a BMI was greater than 25.

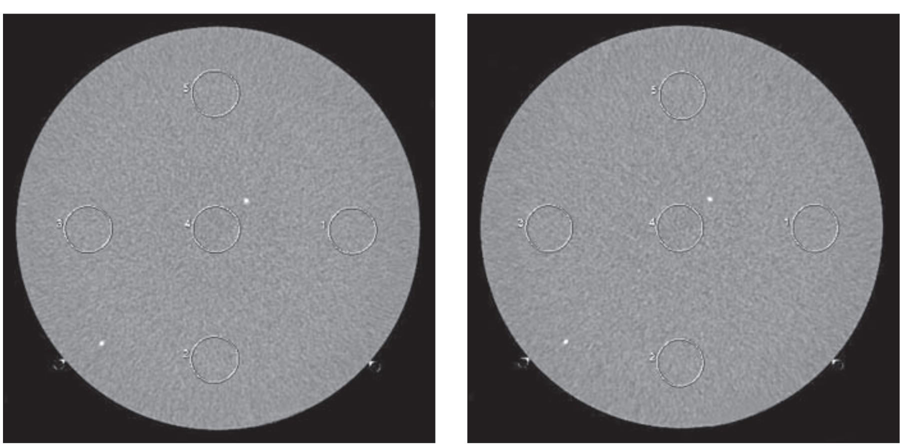
Quantitative comparisons—Quantitative ROI noise measurements were highest for low-dose CT without adaptive statistical iterative reconstruction (average, 35; range, 11–52). The noise indexes were nearly identical for low-dose CT with adaptive statistical iterative reconstruction (average, 31; range, 7–51) and routine-dose CT (average, 32; range, 10–45).

Qualitative comparisons—Low-dose CT without adaptive statistical iterative reconstruction had the worst scores for visually assessed image noise, image quality, spatial resolution, and low-contrast resolution. Low-dose CT with adaptive statistical iterative reconstruction had the least visually assessed image noise, and the average of the two readers was significantly better compared with those for low-dose CT without adaptive statistical iterative reconstruction ($p < 0.0001$) and routine-dose CT ($p = 0.01$) (Table 3). Averaged scores from both readers in the comparison of routine-dose CT and low-dose CT with adaptive statistical iterative reconstruction were equivalent or nearly equivalent for image quality and low-contrast resolution. Low-dose CT with adaptive statistical iterative reconstruction was significantly better than low-dose CT without it in low-contrast resolution ($p = 0.01$) and image quality ($p = 0.0002$). The consensus score for spatial resolution was significantly better for routine-dose CT compared with low-dose CT without ($p = 0.002$) and with ($p = 0.004$) adaptive statistical iterative reconstruction.

Three comparisons had identical scanning parameters (peak kilovoltage, slice thickness, scanner model), and the results were nearly identical to those in the overall group analysis. The only difference was that the averaged image quality grade was slightly higher for low-dose CT with adaptive statistical iterative reconstruction (2.0) than for routine-dose CT (2.2). In the overall analysis, routine-dose CT (2.1) had slightly better overall image quality (low-dose CT with adaptive statistical iterative reconstruction, 2.2).

Discussion

Several approaches have been used in the effort to minimize radiation dose at CT [7]. These include use of automated tube current modulation [8–12], noise reduction filters [13, 14], and low-dose protocols for specific clinical indications. With automated tube modulation techniques, CTDI reductions of 40–60% have been achieved without compromise of image quality and are now routinely used on most scanners [7, 12, 15]. Further dose reductions have been achieved mainly by implementation of specific low-dose protocols for indications such as renal stones and colonic polyps [16–19]. These protocols do not include IV contrast administration, and using them can reduce dose more than 50% if image quality outside the area of interest is sacrificed. The renal stone and CT colonography protocols are not widely implemented for routine body CT, however, because most routine body CT examinations are performed with IV contrast material. In addition, radiologists perform many of these examinations



A B

Fig. 5—Uniformity module in phantom.
A and **B,** Filtered back projection image obtained at routine dose of 25 mGy (**A**) has uniformity nearly identical to that of low-dose (12.5 mGy) CT scan obtained with adaptive statistical iterative reconstruction (**B**). Central region of interest (ROI) has attenuation between +3 and –3 HU. Maximum deviation between central ROI and peripheral ROIs must be less than 5 HU.

TABLE 1: Comparison of Low-Dose CT and Routine-Dose CT of Same Patients

Patient No.	Type of Examination	IV Contrast Enhancement	Body Mass Index	Dose–Length Product (mGy·cm) Routine Dose	Low Dose	Percentage Reduction	CT Dose Index Routine Dose	Low Dose	Percentage Reduction
1	Abdomen	Yes	34	707	441	38	27	17	37
2	Abdomen	No	30	1,008	773	23	31	20	37
3	Abdomen, pelvis	Yes	28	1,209	886	27	26	18	32
4	Abdomen	Yes	25	376	305	19	14	9	35
5	Abdomen	Yes	25	848	502	41	26	15	44
6	Abdomen, pelvis	No	22	921	549	40	20	11	43
7	Abdomen, pelvis	Yes	22	860	548	36	18	11	39
8	Abdomen	Yes	20	396	197	50	13	6	52
9	Abdomen, pelvis	Yes	20	1,128	451	60	21	8	62
10	Abdomen	Yes	19	353	114	68	14	5	65
11	Abdomen, pelvis	Yes	19	1,198	442	63	26	9	65
12	Abdomen, pelvis	Yes	18	1,073	430	60	22	8	62
Average			24	840	470	44	22	11	48

without a clear idea of the diagnosis and fear missing an important finding owing to poor image quality. A method of reducing dose at routine abdominal CT has been lacking.

In this preliminary study, we evaluated an alternative approach to reducing CT radiation dose for routine abdominal CT that has not been previously available for clinical use, to our knowledge. This approach, adaptive statistical iterative reconstruction, is a unique CT reconstruction algorithm compared with the only one previously available (FBP). Unlike with FBP, with adaptive statistical iterative reconstruction, it is not assumed that noise is evenly distributed across the entire image. Instead, matrix algebra is used to selectively identify and then subtract noise from the image with a mathematic model. The result is a less noisy image. The ability to selectively reduce image noise allows generation of a higher-quality image at a lower radiation dose with adaptive statistical iterative reconstruction than with FBP techniques.

For this study, we sought to determine the feasibility of using adaptive statistical iterative reconstruction for low-dose body CT of both a phantom and patients. An ACR phantom was used to validate the use of adaptive statistical iterative reconstruction. We found that use of a dose reduced by 50% (12.5 mGy) and adaptive statistical iterative reconstruction yielded low- and high-contrast resolution and image uniformity within ACR specifications. Images obtained with the technique easily exceeded the spatial resolution requirement for ACR accreditation. We are applying for ACR accreditation using this technique.

After the validation, low-dose CT with adaptive statistical iterative reconstruction was tested in a group of 12 patients who had undergone routine-dose imaging of the abdomen or abdomen and pelvis. This preliminary evaluation showed use of adaptive statistical iterative reconstruction reduces readers' perception of image noise in spite of a decrease in CTDI that was as high as 65% (Fig. 6). Actual measurements of image noise were nearly identical for low-dose CT with adaptive statistical iterative reconstruction and routine-dose CT. Not surprisingly, when CTDI was reduced without application of adaptive statistical iterative reconstruction, both readers found the images noisier than images from full-dose routine examinations, and quantitative noise measurements also were higher. These results support the ability of adaptive statistical iterative reconstruction to allow substantial reductions in radiation dose without the compromise in image quality due to noise that once was so troublesome. Furthermore, reader assessments of overall image quality and low-contrast resolution were nearly identical for low-dose CT scans with adaptive statistical iterative reconstruction and routine-dose images, further supporting the potential of this technique for routine imaging.

Spatial resolution was the only parameter that was worse with adaptive statistical iterative reconstruction than with routine-dose imaging in this pilot study (Fig. 7), although the actual score (2.5) meant the image had only slightly lower spatial resolution than was expected for routine-dose CT. In the review of adaptive statistical iterative reconstruction images with low scores, the main differences were slightly decreased sharpness of cyst edges and a mildly irregular or jagged margin of solid organs. These imperfections did not appear to affect the diagnostic value of the image itself. This factor was evaluated only on axial images. Coronal and sagittal multiplanar reformations were not available or included in the evaluation. This issue will be evaluated in a future study involving

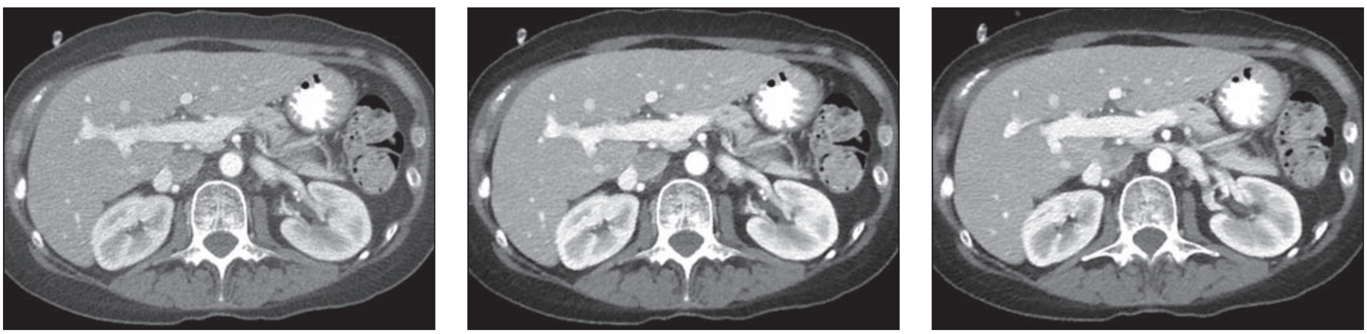
TABLE 2: Subset Comparison According to Body Mass Index

Body Mass Index	No. of Patients	Average Dose–Length Product (mGy·cm) Routine Dose	Low Dose	Percentage Reduction	Average Volume CT Dose Index Routine Dose	Low Dose	Percentage Reduction
> 25	3	975	700	29	28	18	35
20–24.9	6	755	425	41	19	10	46
< 20	3	875	328	64	21	7	64

TABLE 3: Visual Assessments by Two Readers

Reader	Image Noise			Low-Contrast Resolution			Overall Image Quality			Spatial Resolution		
	Low Dose			Low Dose			Low Dose			Low Dose		
	Non-ASIR	ASIR	Routine Dose	Non-ASIR	ASIR	Routine Dose	Non-ASIR	ASIR	Routine Dose	Non-ASIR	ASIR	Routine Dose
A	2.8	1.6	2.2	2.3	2.2	2.2	2.5	2.3	2.3	NA		
B	2.8	1.6	2.3	2.5	2.0	2.1	3.0	2.2	1.9	NA		
Average[a]	2.8	1.6	2.2	2.4	2.1	2.1	2.8	2.2	2.1	2.6	2.5	1.9

Note—Values are qualitative grading scale: 1, better than routine-dose CT; 2, similar to routine-dose CT; 3, worse than routine-dose CT; 4, nondiagnostic. ASIR = low-dose CT with adaptive statistical iterative reconstruction, NA = not applicable.
[a]Low-dose CT with adaptive statistical iterative reconstruction was significantly better than routine-dose CT for image noise ($p = 0.01$). Low-dose CT with ASIR was significantly better than low-dose CT without ASIR for image noise, low-contrast resolution, and overall image quality ($p < 0.01$). Routine-dose CT was significantly better than low-dose CT with or without ASIR for spatial resolution ($p \leq 0.004$).



A B C

Fig. 6—57-year-old woman with body mass index of 18.
A–C, Low-dose CT scan obtained at 120 kVp, 3.75-mm slice thickness, and CT dose index (CTDI) of 8 without adaptive statistical iterative reconstruction (**A**) has more image noise in liver than low-dose CT scan with adaptive statistical iterative reconstruction (**B**) and routine-dose CT scan (140 kVp; 3-mm slice thickness; CTDI, 22) (**C**). **B** and **C** have nearly identical image quality.

a group of patients with lesions to determine whether diagnostic confidence is affected. Future releases of adaptive statistical iterative reconstruction software also may help to resolve this issue.

The degree of dose reduction was greatest for patients with a lower BMI. In patients with a BMI less than 20, the average CTDI dose reduction was 64% compared with 35% for patients with a BMI greater than 25. That adaptive statistical iterative reconstruction allows dose reductions for smaller patients may help with pediatric imaging, which was not evaluated in this study. The idea of dose reduction in CT of even larger patients by use of adaptive statistical iterative reconstruction is encouraging because the number of obese patients in the United States continues to increase [20].

These preliminary results may help to encourage more widespread use of low-dose CT protocols. In our practice, we have instituted use of low-dose CT with adaptive statistical iterative reconstruction for all body CT performed on scanners with this reconstruction algorithm available. For our scanners that do not have adaptive statistical iterative reconstruction capability, we have used these results to investigate ways to reduce our standard-dose CT protocols, particularly in imaging of smaller patients. Studies in neurologic, musculoskeletal, chest, and cardiac CT are ongoing to determine whether low-dose protocols can be used in these areas.

Even more aggressive reductions in radiation dose may be possible in the future. In effect, scanning may be performed at doses low enough to render images nearly nondiagnostic but with advanced iterative reconstruction techniques to return image quality to an acceptable level. Currently, the use of iterative reconstruction at CT is limited by long reconstruction times. As hardware and software improve, more complex iterative reconstruction algorithms may be used clinically, resulting in even greater improvements in image quality. Iterative reconstruction also may allow routine image reconstruction at thinner slices. Currently, increased noise limits the evaluation of thin reconstructed images (< 2.5 mm) in abdominal imaging. With iterative reconstruction and adaptive statistical iterative reconstruction, whether or not radiation dose is reduced, thinner reconstructions may become diagnostic, improving detection and characterization of lesions.

This initial evaluation had limitations. First, because of the retrospective nature of the study, the low-dose and routine-dose CT examinations did not have identical scanning parameters. Changes in peak kilovoltage and slice thickness can affect noise and image quality. Results of prospective studies with similar imaging parameters will be helpful for confirming the initial results. Second, the small sample size had limited power, and prospective studies with larger samples are needed. In addition, for the purposes of this study, we chose an adaptive statistical iterative reconstruction level of 40% because it approximated the levels in the phantom study. It is possible that higher levels of adaptive statistical iterative reconstruction may improve results. Finally, we did not assess lesions specifically. It is possible that adaptive statistical iterative reconstruction may affect lesion conspicuity and detection, and this factor has to be assessed with future studies.

We conclude that low-dose body CT with adaptive statistical iterative reconstruction has quantitative and qualitative image noise

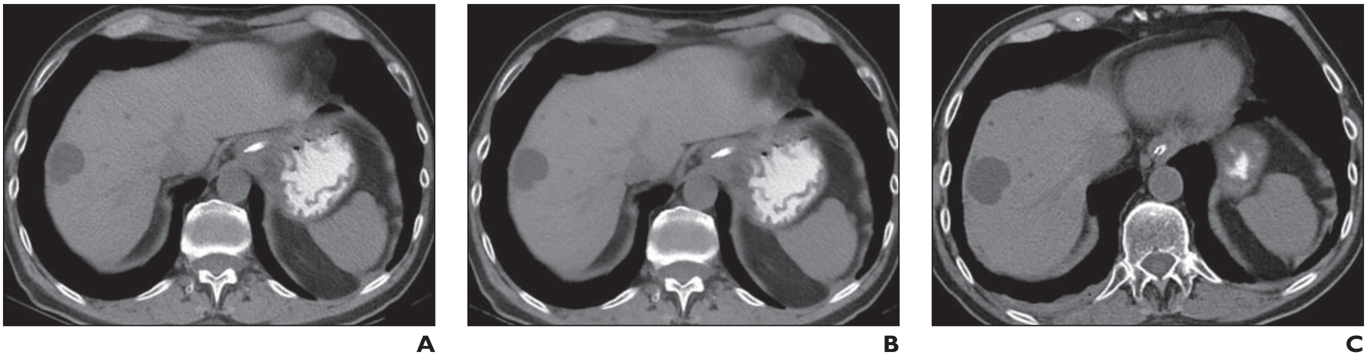


Fig. 7—75-year-old man with body mass index of 22.
A–C, Low-dose CT scans without (**A**) and with (**B**) adaptive statistical iterative reconstruction (120 kVp; 3.75-mm slice thickness; CT dose index [CTDI], 11) and routine-dose CT scan (**C**) (140 kVp; 3-mm slice thickness; CTDI, 20) all show hepatic cysts, but sharpness of cyst edges is best in **C. B** has least image noise.

and image quality similar to or better than those of routine-dose CT. Compared with those of conventional imaging, with adaptive statistical iterative reconstruction, CTDI and DLP both were reduced an average of nearly 50% and up to 65% in some patients using adaptive statistical iterative reconstruction when compared with routine dose imaging. The low-dose technique with adaptive statistical iterative reconstruction met ACR accreditation standards in a phantom analysis. On the basis of our results, we have implemented this low-dose technique for routine body CT in our practice. Future studies are needed to confirm these preliminary results and determine the effect of adaptive statistical iterative reconstruction on lesion detection and conspicuity.

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(Appendix appears on next page)

APPENDIX 1: Mathematical Description of Adaptive Statistical Iterative Reconstruction

Mathematically, the adaptive statistical iterative reconstruction model [21] is based on matrix algebra whereby the measured value of each pixel (y) is transformed to a new estimate of the pixel (y'). This pixel value is compared with the ideal answer predicted with the noise model (A). If needed, another iteration ensues.

$$\hat{x} = \underset{x}{\operatorname{argmin}}\{L(Ax, y) + \alpha G(x)\}$$

A final pixel value for the adaptive statistical iterative reconstruction image ($\hat{x}$) results when repeated y' values ultimately converge. G is the regularization term that enforces smoothing and edge preservation of the data [22].