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Evaluation of Abdominal CT Image Quality Using a New Version of Vendor-Specific Model-Based Iterative Reconstruction

Corey T. Jensen, MD¹, Morgan E. Telesmanich, MD⁴, Nicolaus A. Wagner-Bartak, MD¹, Xinming Liu, PhD³, John Rong, PhD³, Janio Szklaruk, MD, PhD¹, Aliya Qayyum, MBBS¹, Wei Wei, MS², Adam G. Chandler, PhD^{3,5}, and Eric P. Tamm, MD¹

¹ Department of Diagnostic Radiology, The University of Texas MD Anderson Cancer Center, 1400 Pressler Street, Unit 1473, Houston, TX 77030-4009

² Departments of Biostatistics, The University of Texas MD Anderson Cancer Center, Houston, TX

³ Imaging Physics, The University of Texas MD Anderson Cancer Center, Houston, TX

⁴ Department of Diagnostic Radiology, Baylor College of Medicine, Houston, TX

⁵ Molecular Imaging and Computed Tomography Research, GE Healthcare, Waukesha, WI

Abstract

Purpose—To qualitatively and quantitatively compare abdominal CT images reconstructed with a new version of model-based iterative reconstruction (Vevo 3.0; GE Healthcare) to those created with Vevo 2.0.

Materials & Methods—This retrospective study was approved by our IRB and was HIPAA compliant. The raw data from 29 consecutive patients who had undergone CT abdomen scanning was used to reconstruct 4 sets of 3.75mm axial images: Vevo 2.0, Vevo 3.0 standard, Vevo 3.0 5% resolution preference and Vevo 3.0 20% resolution preference. A slice thickness optimization of 3.75 mm and texture feature was selected for Vevo 3.0 reconstructions.

The images were reviewed by three independent readers in a blinded, randomized fashion using a 5-point Likert scale and 5-point comparative scale.

Multiple 2D circular regions of interest were defined for noise and contrast-to-noise ratio (CNR) measurements. Line profiles were drawn across the 7 lp/cm bar pattern of the CatPhan 600 phantom for spatial resolution evaluation.

Results—The Vevo 3.0 standard image set was scored better than Vevo 2.0 in terms of artifacts (mean difference 0.43, 95% CI 0.25–0.6, $P < 0.0001$), overall image quality (mean difference 0.87, 95% CI 0.62–1.13, $P < 0.0001$) and qualitative resolution (mean difference 0.9, 95% CI 0.69–1.1, $P < 0.0001$). While the Vevo 3.0 standard and RP05 presets were preferred across most categories, the Vevo 3.0 RP20 series ranked best for bone detail. Image noise and spatial resolution increased along a spectrum with Vevo 2.0 the lowest and RP20 the highest.

Conclusion—Vevo 3.0 enhances imaging evaluation relative to Vevo 2.0; readers preferred Vevo 3.0 image appearance despite the associated mild increases in image noise. These results provide suggested parameters to be used clinically and as a basis for future evaluations such as focal lesion detection in the oncology setting.

Introduction

Iterative reconstruction (IR) is a robust tool to optimize imaging performance in Computed Tomography (CT)(1). IR techniques provide significant image noise reduction, which can be especially useful when scanning large patients, performing small field-of-view scans (e.g., cardiac CT studies) or implementing low radiation dose protocols (2). Adaptive statistical iterative reconstruction (ASIR) (GE Healthcare, Waukesha, WI, USA) involves iterative reconstructions using multiple back projections that compare to an ideal noise model blended with filtered back projection (FBP) (2-4). Model-based iterative reconstruction (MBIR), in contradistinction, is a purely iterative reconstruction technique, without FBP blending, using both back and forward projections (3). MBIR models system optics and the geometry of the CT machine, including the response of the x-ray tube and detectors, and incorporates the physics of scatter and crosstalk (5). This modeling decreases image noise, reduces artifacts and improves spatial resolution (6-8). These benefits can be used to either improve image quality at a given CT radiation dose or maintain image quality while reducing radiation dose (3, 4, 7, 9).

Although significant improvements in CT imaging have been realized with the use of MBIR, there are opportunities for further improvement. Images created with current algorithms of MBIR have been criticized as having a waxy or blotchy appearance (3, 9, 10). The degree to which this appearance may affect diagnostic accuracy is still under investigation, although most reports indicate improved image quality compared to ASIR and maintained or improved diagnostic quality compared to FBP (3, 9, 11-13). Since those reports, a new, third-version of MBIR, Vevo 3.0 (GE Healthcare, Waukesha, WI, USA), has become available, with new user options and workflow.

Similar to reconstruction kernels, one of the new options termed “presets” allows selection of trade-off between image noise and resolution (Fig 1). At the middle of this spectrum is a baseline Vevo 3.0 standard reconstruction, whereas noise reduction (NR) and resolution preference (RP) presets can be selected to preferentially reduce noise or increase resolution, respectively, relative to the standard. For example, RP20 represents a 20% increase in resolution from the standard preset. Each selected preset is reconstructed separately; thus, choosing more than one preset per body section is currently not practical given the average post-processing time of 20-30 minutes per anatomic section. While the reconstruction time for Vevo 3.0 is similar to Vevo 2.0, the new automation of multiplanar reformations (sagittal, coronal, etc.) should improve image processing workflow and lessen the impact of the overall reconstruction time.

Vevo 3.0 also incorporates a new ‘texture’ function. This function, as reported by the vendor, rebalances the noise model in order to achieve isotropic noise in three dimensions, especially at low radiation doses, and maintains consistent image quality across all viewing planes

(e.g., axial, sagittal, and coronal). Further enhancements reportedly improve low-signal artifact reduction and quantitative accuracy in ultra-low-dose cases and in the presence of strongly attenuating materials. A new selection is also present for image optimization based on desired slice thickness; this function attempts to reduce excessive smoothness that can result from a mismatch between the algorithm-targeted quality and the slice thickness used for clinical review.

To our knowledge, this is the first study of Veo 3.0; prior studies have demonstrated the improved image quality and radiation dose reduction potential of MBIR compared to blended IR methods and FBP, therefore, herein, we qualitatively and quantitatively compared abdominal CT images created with Veo 3.0 to those created with Veo 2.0.

Materials and Methods

This retrospective study was approved by our institutional review board (IRB) as Health Insurance Portability and Accountability Act compliant and the need for informed consent was waived.

Patient Selection

On the basis of a power analysis performed prior to the study, we acquired imaging data from 29 patients, who had undergone routine CT scanning with our MBIR (Veo 2.0) protocol between February and September 2014, and had raw imaging data saved. Routine, short-term saving of raw image data had been implemented for such patients at our institution to facilitate clinical implementation of future post-processing techniques.

The patients' primary cancer diagnosis, height, weight and body mass index (BMI) were recorded.

Radiation Dose Estimation

The volume CT dose index (CTDI_{vol}) for a 32-cm phantom was used for each scan to calculate size-specific dose estimates (SSDE) by using the effective diameter based on anterior posterior (AP) and lateral (LAT) scout measurements of the abdomen ($\text{effective diameter} = (\text{AP} \cdot \text{LAT})^{1/2}$), as recommended by the American Association of Physicists in Medicine Report No. 204 (14, 15) (Table 1).

Imaging Technique

All patients underwent CT of the chest, abdomen and pelvis with an identical imaging protocol performed on Discovery CT750 HD scanners (GE Healthcare, Waukesha, WI) with the following parameters: gantry speed of 0.6 seconds, pitch of 0.984:1, table speed of 39.375 mm/rotation, beam collimation of 40 mm with detector configuration of 64×0.625 mm, 120 kVp and tube current modulation using a noise index adjusted for patient circumference. One hundred milliliters of Omnipaque 350 (GE Healthcare) was injected at 2.5-3 mL/sec with bolus tracking using a 100-Hounsfield-unit (HU) trigger value in the abdominal aorta at the level of the celiac artery and a scan delay of 45 seconds.

Image Reconstruction

Veo 3.0 employs several parameters, or presets, that affect the appearance of the resultant images: presets described by the manufacturer as being optimized for imaging of the head and neck, thorax, and abdomen/pelvis. These options can each be applied with or without a new texture (TX) option. Unlike Veo 2.0, which was optimized for 0.625-mm slice thickness, Veo 3.0 includes an option to optimize image reconstruction to a specific target slice thickness (2.5 mm, 3.75 mm, etc.) chosen by the user.

For each patient, only the abdomen portion of the raw CT data was reconstructed into the following four separate sets of 3.75-mm axial images for review: Veo 2.0 which is inherently without TX, Veo 3.0 standard with TX, Veo 3.0 RP05 with TX and Veo 3.0 RP20 with TX. The Veo 3.0 images were reconstructed with optimization to the target slice thickness of 3.75mm. The image sets were then transferred to an Advantage Workstation thin-client server, version 2.0 (GE Healthcare, Waukesha, WI), to be reviewed on a standard high-resolution diagnostic workstation under standard diagnostic conditions.

Qualitative Image Assessment

The four image sets were reviewed in a two up-two down method on a picture archiving and communication system reading station by three independent readers in a blinded, randomized fashion over three sessions after reviewing an initial orientation case that was not part of the final data set. Each reader was fellowship-trained in abdominal imaging with 5 (N.W.-B.), 17 (J.S.), and 19 (E.P.T.) years of experience reading abdominal CT. No time limit was set for review.

The qualitative rating system for the images was explained in detail to each reader and a written copy of the system was given for reference.

A five-point Likert scale was used by the readers to qualitatively grade overall image quality, noise, and resolution/detail as follows: 1, excellent; 2, good; 3, acceptable; 4, suboptimal; 5, very poor. The four image sets were then ranked against one another on a comparative scale with regard to overall image quality, image noise, and resolution. A score of 0 was given for the best series, -1 for slightly inferior (no influence on diagnosis), -2 for mildly inferior (possible influence on diagnosis), -3 for moderately inferior (probable influence on diagnosis), and -4 for markedly inferior (impairing diagnosis).

The comparative scale was also used for relative ranking of image sets with regard to the imaging of specific structures, which included bone, bowel wall, vessels, and liver (contour and parenchyma). Readers were asked to focus on perceived sharpness/detail of the organ/structure in question.

Lastly, the presence of artifacts was judged on a five-point Likert scale. A score of 1 was given for no artifacts, 2 for minor artifacts not interfering with diagnostic decision making, 3 for minor artifacts possibly interfering with diagnostic decision making, 4 for major artifacts affecting visualization of major structures (diagnosis still possible) and 5 for artifacts clearly affecting diagnosis.

Quantitative Image Assessment

Two-dimensional circular regions of interest (ROIs) were defined on the liver, aorta, paraspinal musculature, and subcutaneous fat for the purpose of noise and contrast-to-noise ratio (CNR) measurements. Three ROIs were placed in the right lobe of the liver (15-mm diameter), one within the aorta (10-12 mm), one within each side of the paraspinal musculature (12-15 mm), and one within both the anterior and the posterior subcutaneous fat (5-15 mm). The ROI sizes were chosen to gather representative sampling of the region while remaining small enough to avoid undesired structures. Each of the measurements was performed on three contiguous slices. Care was taken to avoid any possible confounding structures, such as atheromatous plaques, hepatic cysts, or bile ducts within the ROIs. ROI sizes varied slightly between patients because of differences in patient size/anatomy but were identical within each patient between series.

For each Veo reconstruction, the CNR relative to muscle was calculated for the aorta and liver as $(ROI_i - ROI_m)/SD$, where ROI_i is the mean HU for the anatomy of interest, ROI_m is the mean HU of paraspinal muscles, and SD is the mean image noise based on subcutaneous fat, using the average standard deviation in HU (16).

Catphan 600 phantom (The Phantom Laboratory, Inc., Salem, NY) images were acquired with module CTP528 high-contrast module for spatial resolution evaluation with the following scan parameters: 120 kVp, 40 mA, 0.8 s rotation time, 40-mm beam width, and a pitch factor of 0.984. Phantom images were reconstructed into four separate sets of 3.75-mm axial images: Veo 2.0 without TX, Veo 3.0 standard with TX, Veo 3.0 RP05 with TX and Veo 3.0 RP20 with TX. The display field-of-view (DFOV) was set to 15 cm for the reconstructed images of Catphan phantom. Upon the completion of Veo reconstruction, the image sets were then transferred to a desktop computer and analyzed by line profiles drawn across the 7 lp/cm bar pattern (Fig 2) using Matlab software (The MathWorks, Inc., Natick, MA).

Statistical Analysis

Summary statistics for image quality scores, side-by-side comparison rankings, and CNRs were calculated as means, standard deviations, and ranges for each image quality item, series, and reader. Analysis of variance was used to compare CNRs between series. A linear mixed model was used to estimate and compare scores and rankings between series by item, with reader modeled as a random effect. The mixed model takes into account correlations between scores and rankings from the same image and reader. Tukey-Kramer adjustment was used for pairwise comparisons between series to control the overall type I error rate at 5%. All tests were two-sided, and p-values of 0.05 or less were considered statistically significant. Statistical analysis was performed by a biostatistician using SAS version 9 (SAS Institute, Cary, NC).

Results

Subjects

The studied group consisted of 29 patients (14 males, 15 females) with a mean age of 32.6 years (range, 19-44). Patient weights ranged from 43.4 to 125.5 kg, and effective diameter ranged from 22.7 to 39.2 cm (Table 1). Twenty-six patients had a primary diagnosis of lymphoma; the remaining three patient primary cancer diagnoses were melanoma, testicular germ cell tumor, and vaginal endodermal sinus tumor.

Patient Radiation Dose

The mean CTDI_{vol} was 7.26 ± 3.85 (range, 3.31-24.36), and the mean SSDE was 8.38 ± 3.33 (range, 4.73-23.14).

Qualitative Assessments of Image Quality

On the five-point Likert scale evaluation, the Veo 3.0 standard image set was scored as significantly better than the Veo 2.0 set in terms of artifacts (mean difference 0.43, 95% CI 0.25-0.6, $P < 0.0001$), overall image quality (mean difference 0.87, 95% CI 0.62-1.13, $P < 0.0001$), and qualitative resolution (mean difference 0.9, 95% CI 0.69-1.1, $P < 0.0001$). There was no significant difference between the three Veo 3.0 image sets with regard to artifacts and resolution. However, with regard to overall image quality, Veo 3.0 standard and RP05 images were rated as significantly better than Veo 3.0 RP20 images; Veo 3.0 RP20 images were often rated better than Veo 2.0 for overall image quality but this was not statistically significant ($p = 0.72$). In agreement with quantitative measurements, readers identified Veo 2.0 images as having less noise than was observed for each of the three Veo 3.0 presets ($p < 0.05$). The image preset with the highest perceived noise was Veo 3.0 RP20 (Fig 3 and Table 2).

On the five-point comparative scale, the three Veo 3.0 presets were all ranked significantly better than Veo 2.0 except for the Veo 3.0 RP20 image set with regard to detail of liver parenchyma ($p = 0.16$) and overall image quality ($p = 0.41$). In contrast, the Veo 3.0 RP20 series were ranked significantly better than all other series on perceived bone detail. Veo 3.0 standard and Veo 3.0 RP05 were scored as significantly better than Veo 3.0 RP20 and Veo 2.0 for bowel, hepatic contour, hepatic parenchyma, overall image quality, qualitative resolution and vessel assessments; Veo 3.0 standard was slightly favored for hepatic parenchyma and vessels ($p = 0.56$ and $p = 0.88$, respectively) whereas Veo 3.0 RP05 was rated to be slightly better for bowel and hepatic contour evaluation ($p = 0.68$ and $p = 0.87$, respectively).

No significant correlation was identified between reader evaluations and CTDI_{vol}, SSDE or BMI.

Quantitative Assessments of Image Quality

The CNRs per series for the liver and aorta are listed in Table 3. The CNRs were significantly higher for Veo 2.0 than for each Veo 3.0 preset. Veo 3.0 RP05 and RP20 images had progressively lower CNRs than Veo 3.0 standard images. The mean HU and noise for

the liver, aorta, subcutaneous fat, and paraspinal muscles are also listed in Table 3. Veo 2.0 images had consistently higher HU measurements than images obtained with each Veo 3.0 preset, but the differences were not statistically significant and were less than 1 HU on average.

The spatial resolution was compared by plotting the line profiles drawn across the 7 lp/cm bar pattern on the CTP528 high-contrast resolution module of the CatPhan 600 phantom for the Veo reconstructions (Fig 2). Veo 3.0 standard with TX and Veo 3.0 RP05 with TX had approximately the same spatial resolution. Veo 3.0 RP20 demonstrated the highest spatial resolution while Veo 2.0 without TX had the lowest spatial resolution.

Discussion

MBIR is a robust tool for CT image noise reduction that has been shown to effectively maintain CT image quality despite marked reductions in radiation dose (6, 17). Our study evaluated the new, third version of vendor-specific software available at our institution, Veo 3.0, indicating improved image quality relative to Veo 2.0. We evaluated qualitative and quantitative image quality for three Veo 3.0 clinical presets in comparison to Veo 2.0: standard, RP05 and RP20 with processing chosen to be optimized for a standard slice thickness of 3.75 mm.

The three readers favored Veo 3.0 standard over Veo 2.0 on overall image quality and qualitative resolution. Furthermore, each specific anatomic region of interest was also rated to be significantly better by all three readers in Veo 3.0 standard images in terms of perceived detail/sharpness, which paralleled improved spatial resolution noted during phantom bar pattern assessment. Readers reported a mild but noticeable improvement in image appearance, the specifics of which varied for each case and between readers (Fig 4).

Interestingly, readers rated the three Veo 3.0 presets to be significantly better than Veo 2.0 on almost every category, despite quantitatively and qualitatively increased noise on the Veo 3.0 images. Veo 3.0 standard and RP05 were generally preferred over RP20 with the exception of the bone evaluation, for which RP20 was rated the highest ($p < 0.05$) (Fig 5). From Veo 2.0 to Veo 3.0 standard, RP05, and RP20, there was a predictable and significant increase in image noise, which correlated with progressively lower CNRs. This perceived and measured noise apparently reached a threshold for reader evaluations as evidenced by relatively lower subjective rating for Veo 3.0 RP20 on many categories, with some of the ratings being lower than those for Veo 2.0. These findings are in-agreement with the current vendor recommendation for use of RP05 for contrast-enhanced evaluation of the abdomen. The differences in reader ratings support the concept of presets that can be tailored to specific clinical needs and preferences.

Artifacts were also shown to be less apparent for Veo 3.0 than for Veo 2.0. One case was of particular interest because it involved the use of a breast shield, which is generally not recommended in our protocol due to known artifacts and the new availability of organ-based dose modulation. The effects of this and a few other artifacts along high-contrast interfaces

in our patient group were reduced with Veo 3.0, which, as we discovered during preparation of this study, appears to be a function of the new texture setting (Fig 6 and 7).

The evaluated patients were a relatively homogeneous group, consisting predominantly of patients with treated lymphoma. This homogeneity facilitated comparison of normal anatomic structures between techniques and patients. However, future studies are needed to assess Veo 3.0 performance related to specific organs and disease processes. Assessment of lesion detection accuracy is also necessary as a few studies have raised concerns regarding small-lesion detection on ultralow-dose CT examinations (9, 17).

Our study had a few limitations. First, we assessed only the RP presets and standard Veo 3.0 in comparison to Veo 2.0. To obtain a full scope of Veo 3.0 assessment, another study will need to evaluate the NR presets; these presets were not chosen for this initial evaluation since the vendor currently recommends Veo 3.0 standard and RP presets for evaluation of the abdomen. Second, a detailed phantom evaluation is required to further characterize the effects of Veo 2.0 and the various settings of Veo 3.0 on the modulation transfer function and noise power spectrum. Third, we only evaluated a single slice thickness of 3.75 mm at a pitch of 0.984:1; evaluation of Veo 3.0 behavior across variations of slice thickness and pitch would be of interest. Fourth, we did not compare to FBP or ASIR directly given prior works which have already carried out this evaluation using Veo 2.0. Fifth, our study was vendor-specific, as this is the only MBIR system available at our institution. Sixth, these results can be used to guide the next step in evaluation, which should likely include assessment of effect upon lesion detection accuracy in various organs. Lastly, our dose reductions were modest due to the high pretest probability of disease in our oncology practice. Future work will need to assess Veo 3.0 at lower radiation dose levels.

The third version of a vendor-specific variant of MBIR, Veo 3.0, represents an improvement over Veo 2.0 with enhanced overall image quality, spatial resolution and artifact reduction. Readers preferred the Veo 3.0 image appearance despite the associated mild increased degree of image noise. The standard and RP05 presets were generally preferred in this study of contrast enhanced CT of the abdomen. These results provide suggested parameters to be used clinically as well as for future studies on lesion detection, particularly for comparing Veo 3.0 to filtered back projection with and without ASIR.

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Figure 1. Increasing noise and qualitative resolution is noted from a Veo 2.0 image (**a**) to Veo 3.0 with texture (**b**), Veo 3.0 RP05 with texture (**c**) and Veo 3.0 RP20 with texture (**d**). The Veo 3.0 RP20 series had the highest level of noise quantitatively and qualitatively, which may explain why readers typically rated Veo 3.0 standard and Veo 3.0 RP05 to be of higher quality.

Figure 2.

(a-b) Line profiles were drawn across the 7 lp/cm bar pattern in the CTP528 high-contrast resolution module of the CatPhan 600 phantom for spatial resolution evaluation between Veo reconstructions.

Figure 3.

Mean qualitative scores for the three readers by series based on a Likert scale. For noise, resolution, and overall image quality, the scale was as follows: 1, excellent; 2, good; 3, acceptable; 4, suboptimal; 5, very poor. For artifacts, the scale was as follows: 1, no artifacts; 2, minor artifacts not interfering with diagnostic decision making; 3, minor artifacts possibly interfering with diagnostic decision making; 4, major artifacts affecting visualization of major structures (diagnosis still possible); 5, artifacts clearly affecting diagnosis.

Note.—RP=resolution preference.

Figure 4.

An example of decreased mild ‘whirling’ within the liver in Veo 2.0 CT imaging **(a)** compared to Veo 3.0 standard **(b)**, RP05 **(c)**, and RP20 **(d)**.

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Figure 5.

Magnified CT images of the spine in bone window provide an in vivo example of resolution differences between series: **(a)** Veo 2.0 and **(b)** Veo 3.0 RP20 with texture.

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Figure 6. CT images with a breast shield artifact demonstrate the reduction of streaking with the application of the new texture function available with Veo 3.0. For reference, Veo 3.0 standard images are shown without **(a)** and with **(b)** the texture function applied.

Figure 7.

An artifact within anterior subcutaneous soft tissues in a Veo 3.0 standard image without texture **(a)** is reduced upon application of the texture function **(b)** but is accentuated when the higher-resolution RP20 preset with texture **(c)** is used.

Table 1**Patient Characteristics**

Characteristic	Mean $\pm$ SD (range)
No. of patients	29
No. of males	14
No. of females	15
Age (y)	32.6 (19-44)
Weight (kg)	82.1 (43.4-125.5)
Body mass index (kg/m ²)	28.2 $\pm$ 5.8 (18.2-40.3)
Effective diameter (cm)	30.7 $\pm$ 4.5 (22.7-39.2)
CTDI _{vol} (mGy)	7.26 $\pm$ 3.85 (3.31-24.36)
DLP (mGy $\cdot$ cm)	225.75 $\pm$ 113.59 (97.69-633.34)
SSDE (mGy $\cdot$ cm)	8.38 $\pm$ 3.33 (4.73-23.14)

Note.—SD = standard deviation, CTDI_{vol} = volume computed tomography dose index, DLP = dose length product, SSDE = size-specific dose estimate.

Table 2

Qualitative Assessment of Image Quality

Reader Scores																
Veo 2.0				Veo 3.0				Veo 3.0 RP05				Veo 3.0 RP20				
Median		Mean ± SD		Median		Mean ± SD		Median		Mean ± SD		Median				
R1	R2	R3		R1	R2	R3		R1	R2	R3		R1	R2	R3		
Likert score *																
Overall image quality	1	3	3	2.63 ± 0.99	1	2	2	1.76 ± 0.61	1	2	2	1.66 ± 0.59	2	1	4	2.53 ± 1.14
Resolution	1	2	4	2.41 ± 1.08	1	1	2	1.52 ± 0.66	1	1	2	1.45 ± 0.52	2	1	2	1.6 ± 0.56
Noise	1	1	1	1.09 ± 0.29	1	2	2	1.71 ± 0.5	1	2	2	1.92 ± 0.69	2	2	4	2.93 ± 0.87
Artifacts	2	1	3	1.99 ± 0.83	1	1	2	1.56 ± 0.64	1	1	2	1.48 ± 0.63	1	1	2	1.37 ± 0.61
Comparative series †																
Overall image quality	-1	-2	-3	-1.78 ± 0.89	0	-1	-1	-0.56 ± 0.58	-1	-1	0	-0.54 ± 0.5	-2	0	-3	-1.6 ± 1.07
Resolution	-1	-1	-2	-1.48 ± 0.91	0	0	-1	-0.41 ± 0.58	0	0	-1	-0.36 ± 0.48	-1	0	0	-0.53 ± 0.66
Noise	0	0	0	0	-1	-1	-1	-0.99 ± 0.11	-1	-1	-1	-1.17 ± 0.44	-2	-1	-3	-2.16 ± 0.81
Bone	-1	-1	-3	-1.66 ± 1.13	-1	0	-2	-0.99 ± 0.77	-1	0	-1	-0.77 ± 0.56	0	0	0	-0.03 ± 0.32
Bowel	-1	-1	-3	-1.49 ± 1.03	0	0	-1	-0.32 ± 0.56	0	0	0	-0.21 ± 0.41	-1	0	-1	-0.9 ± 0.94
Hepatic parenchyma	0	-2	-2	-1.48 ± 1.02	0	-1	0	-0.47 ± 0.61	-1	-1	0	-0.64 ± 0.63	-3	0	-3	-1.76 ± 1.22
Hepatic contour	0	0	-2	-0.7 ± 1.06	0	0	-1	-0.23 ± 0.47	0	0	0	-0.16 ± 0.37	0	0	0	-0.4 ± 0.69
Vessels	0	-1	-3	-1.22 ± 1.08	0	0	-1	-0.34 ± 0.59	-1	0	0	-0.44 ± 0.54	-2	0	0	-0.84 ± 0.96

Note.—SD = standard deviation, R = reader.

* 1 = excellent, 2 = good, 3 = acceptable, 4 = suboptimal, 5 = very poor.

[†] 0 = best series, -1 = slightly inferior (no influence on diagnosis), -2 = mildly inferior (possible influence on diagnosis), -3 = moderately inferior (probable influence on diagnosis), -4 = markedly inferior (impairing diagnosis).

Table 3

Attenuation, Image Noise, and Contrast-to-Noise Ratios for Four Veo Reconstructions

		Mean ± SD		
		Veo 3.0		
		Standard	RP05	RP20
Veo 2.0				
Attenuation (HU) *				
Liver	119.77 ± 21.5	117.64 ± 22.52	118.79 ± 21.11	118.75 ± 21.16
Aorta	154.56 ± 36.14	152.45 ± 35.6	152.36 ± 35.64	152.17 ± 35.66
Paraspinal muscle	65.48 ± 7.25	65.76 ± 7.74	65.77 ± 7.75	65.77 ± 7.77
Noise (HU SD)				
Liver	8.95 ± 1.04	12.2 ± 1.35	14.37 ± 1.8	21.45 ± 2.88
Aorta	10.64 ± 1.44	14.26 ± 1.73	16.65 ± 2.2	24.44 ± 3.51
Paraspinal muscle	9.24 ± 1.113	12.58 ± 1.77	14.83 ± 2.24	21.8 ± 3.75
Subcutaneous fat	10.12 ± 1.69	12.87 ± 1.37	14.34 ± 1.44	19.07 ± 2.23
CNR †				
Liver	5.44 ± 1.78	4.08 ± 1.49	3.76 ± 1.28	2.84 ± 1.04
Aorta	8.94 ± 3.35	6.81 ± 2.54	6.15 ± 2.39	4.65 ± 1.87

Note.—SD = standard deviation, HU = Hounsfield units.

* No significant differences were identified between image sets

[†] CNRs were higher for Veo 2.0 than for to each Veo 3.0 preset ($p < 0.05$). Veo 3.0 RP05 and RP20 images had slightly lower CNRs than Veo 3.0 standard images, with p values of 0.83 and 0.76, respectively, for the liver and 0.01 for each comparison for the aorta.