Effects of kernel and window setting combinations on assessments of small and complicated vasculature in computed tomography angiographic images of dogs with and without tumors

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OBJECTIVE

To evaluate the effect of kernel and window settings on the assessment of small and complicated vasculature in CT angiographic (CTA) images of kidneys, jejunum with mesentery, and tumors in dogs.

ANIMALS

20 healthy dogs and 20 dogs with tumors.

PROCEDURES

Images from CTA performed previously in dogs were reconstructed with 3 different combinations of kernel and window settings (soft kernel with soft tissue window, soft kernel with bone window, and sharp kernel with bone window), and reconstructed images of the left kidney and the jejunum with the mesentery in healthy dogs and tumors in affected dogs were evaluated by reviewers blinded to the settings.

RESULTS

For images of kidney and jejunum with mesentery, reviewers’ scores for the conspicuity of vascularity in the arterial phase and the differentiation of the organs from the adjacent structures were significantly higher when viewed in bone window (vs soft tissue window) regardless of kernel setting. For images of head and gastrointestinal tumors, reviewers’ scores for differentiation of intratumoral vasculature were higher when viewed in sharp kernel with bone window versus other setting combinations. However, the conspicuity of gastrointestinal, hepatic, or splenic tumoral vessels from the adjacent structures had higher reviewer scores for images in soft kernel with soft tissue window, compared with other setting combinations.

CONCLUSIONS AND CLINICAL RELEVANCE

Results indicated that reconstruction of CTA images with sharp kernel combined with bone window settings might have clinical utility in evaluating and planning treatments for dogs with various tumors; however, additional research is warranted to further identify effects of various kernel and window setting combinations on assessments of small and complicated vasculature in larger and more diverse populations of dogs with and without tumors. (Am J Vet Res 2020;81:940–949)

Computed tomography angiography enables visualization of blood vessels, with the tissue window and kernel algorithm used influencing CT visualization of the vascularity and conspicuity of lesions and other structures. For given ROIs, the reconstruction kernel is selectively used to optimize the trade-offs between spatial resolution (related to the number of pixels in an image and the ability to differentiate between structures of different densities) and pixel noise (image graininess related to the number of photons used to make the image). Soft kernel yields CT images with greater contrast resolution but lower spatial resolution, compared with sharp kernel; therefore, soft kernel images have smoother appearances and less noise and streak artifacts because of the greater contrast resolution; however, they have blurrier edges of fine structures because of the lower spatial resolution. Soft kernel is generally used for soft tissue ROIs. Sharp kernel provides the maximum spatial resolution, resulting in sharp edges of structures; however, it also generates noise and streak artifacts, resulting in grainy images. Sharp kernel is generally used for bony or pulmonary ROIs.

Settings for the CT window width (range of HU displayed in the image) and window level (midpoint of the window width) are used to manipulate the contrast and brightness, respectively, of an image’s gray scale to best visualize an ROI. Narrow window

ABBREVIATIONS

CTA  CT angiography  
ICC  Intraclass correlation coefficient  
MIP  Maximum intensity projection  
MPR  Multiplanar reconstruction  
ROI  Region of interest

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widths have smaller ranges of tissue densities represented in each gradation of the gray scale, compared with that of wide window widths. Clinically, soft tissues are usually evaluated with low window levels and narrow window widths, which enhance contrast resolution but also result in noise artifact, whereas high window levels and wide window widths show less contrast difference, which suppresses various soft tissue densities but displays bony structures well with better-delineated margins. Because narrow window widths result in noise artifact, narrow widths are not typically used with sharp kernel, which also generates noise artifact. However, in human medicine, investigators have used sharp kernel to reconstruct CTA images to measure the sizes of intracranial aneurysms, vertebral arteries, lower extremity arteries, and intravascular stents in coronary arteries with atherosclerotic plaques because sharp kernel intrinsically enhances edge definition and reduces or eliminates the partial volume artifact, point spread effect, and blooming artifact, which can be exaggerated with soft kernel.2–11 In addition, window settings can be manipulated according to the degree of intravascular contrast enhancement, presence of vascular wall calcifications, or contrast enhancement differences between vessels and surrounding tissues.12–21 For instance, in CTA images of blood vessels with insufficient contrast enhancement, the vessels differ minimally from the surrounding tissues; therefore, a narrow window width, which enhances contrast resolution, is required to visualize such vessels. However, for vessels with high contrast enhancement or mural calcifications, a wide window width can be used and results in less image noise.22

The purpose of the study reported here was to evaluate the effect of 3 combinations of kernel and window settings (soft kernel with soft tissue window, soft kernel with bone window, and sharp kernel with bone window) on the assessment of small and complicated vasculature in CTA images of kidneys, jejunum with mesentery, and tumors in dogs. We hypothesized that the combination of sharp kernel and bone window (wide window width) would more clearly differentiate small and complicated vessels from intensely enhanced regions or from bony structures than would the combination of soft kernel and soft tissue window (narrow window width).

Materials and Methods

Animals

Images from CTA performed at the Chonnam National University Veterinary Teaching Hospital between March 2013 and March 2018 on dogs with (n = 20) and without (20) tumors were retrospectively reviewed. A search of the medical records database was used to identify records of client-owned dogs with tumors that underwent CTA as part of their diagnostic evaluation. For inclusion, client-owned dogs had to have had dual-phasic CTA images of their tumors with an image acquisition slice thickness of 1 to 2 mm and good image quality without motion artifact as determined by 1 reviewer (SAY). Histologic diagnoses of tumors in affected dogs were not required for inclusion. Among the dogs matching the inclusion criteria, 5 dogs/tumor site location group (ie, those with tumors of the head, gastrointestinal tract, liver, or spleen) were randomly selected from similarly affected eligible dogs. For the 20 dogs without neoplasia, we used CTA images of healthy research Beagles that had been obtained as part of their initial examinations before being enrolled in an unrelated research project.

CTA acquisition

All CTA images had been acquired with a 16-row multidetector CT scanner.4 On the basis of standard protocols at the facility during the study period, the contrast medium was iohexol6 (600 mg of iodine/kg, IV), which was administered through cephalic vein catheters by use of a power injector.6 The scanning delay of the arterial and venous phases was determined with a test-bolus method or bolus-tracking method, where the ROIs were various anatomic locations depending on the purpose of the CTA. Settings for CT before and after administration of contrast medium were tube voltage of 130 kV, effective tube current of 120 mA, slice thickness of 1 to 2 mm, and helical pitch of 0.8 to 1. Dogs for which the medical records indicated exceptions to these standard protocols were excluded from the study.

CTA image reconstruction

The arterial and venous phases for each CTA series were reconstructed with soft kernel and sharp kernel algorithms (labeled settings of 40S medium and 70S sharp, respectively, on the CT scanner used). The transverse, sagittal, and dorsal plane images (ie, the MPR images) and the MIP image of the ROIs were reconstructed by 1 reviewer (SAY). For healthy dogs, the ROIs were the left kidney and the jejunum with the mesentery because of the typically small and complicated vasculature of these structures. For dogs with tumors, the ROIs were the tumors with adjacent structures. For each dog, 1 image of each ROI in each of the resulting reconstructed planes and the MIP were selected by a neutral observer (JHC). Each of these selected images was then adjusted by 1 reviewer (SAY) with each of the 3 separate setting combinations: soft kernel with soft tissue window, soft kernel with bone window, and sharp kernel with bone window. The soft tissue window setting was defined as a window level of 40 HU and a window width of 400 HU. The bone window setting was defined as a window level of 450 HU and a window width of 1,500 HU. For each ROI in each dog, there were 3 CTA series (1 for each kernel and window setting combination) of 1 MIP and 3 MPR (transverse, sagittal, and dorsal plane) images within the overall collection of images evaluated. The CTA series were randomized within

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subsets of images on the basis of ROI (left kidney, jejunum with mesentery, or tumors affecting the head, gastrointestinal tract, liver, or spleen) by a neutral observer (JHC).

CTA image evaluation

The reconstructed CTA images were evaluated independently by 2 reviewers (SAY and SJP) by use of the same picture-archiving and communication system; both reviewers were blinded to the kernel and window settings for all images. For the images of kidneys of healthy dogs, the differentiation between renal arteries and veins and the conspicuity of the intrarenal vessels (ie, the differentiation among the interlobar, arcuate, and interlobular vessels and the conspicuity of the intrarenal vessels vs the enhanced renal cortex) were assessed on the MPR and MIP images. For the images of jejunum with mesentery of healthy dogs, the differentiation between the mesenteric vessels (particularly the small branches) and the conspicuity of the mesenteric vessels versus the intestinal wall were assessed on the MIP images. For the images of tumors of affected dogs, differentiation of the intratumoral vessels from each other and the conspicuity of the tumor vessels versus adjacent bone or other hyperattenuated structures were evaluated on the MPR and MIP images. Each evaluation factor was scored on a 3-point scale (1 = poor, 2 = fair, and 3 = good).

Statistical analysis

Statistical analyses were performed with available software by 1 reviewer (SAY) under supervision of 1 statistician. Results were reported as mean ± SD. For each ROI, differences in scores on the basis of image setting (A, B, or C) were compared with the Kruskal-Wallis test and Tukey post hoc test. Interobserver agreement for qualitative evaluations of images was assessed by use of ICCs with 95% CIs. The ICCs were classified as poor (< 0.4), moderate (0.40 to 0.59), good (0.60 to 0.79), or excellent (≥ 0.80) agreement. Values of P < 0.05 were considered significant.

Results

Animals

A search of medical records identified 1,380 client-owned dogs with tumors that underwent CTA as part of tumor staging at the Chonnam National University Veterinary Teaching Hospital between March 2013 and March 2018. Of these, 807 met the inclusion criteria, and 5 dogs/tumor site location group (ie, those with tumors of the head, gastrointestinal tract, liver, or spleen) were randomly selected. The mean ± SD age and body weight at the time of CTA was 11.05 ± 4.02 years and 7.67 ± 6.49 kg for client-owned dogs. There were 4 Maltese, 3 Shih Tzus, 3 Toy Poodles, 2 West Highland White Terriers, 2 Miniature Schnauzers, 2 Yorkshire Terriers, 1 French Bulldog, 1 Chinese Shar-Pei, 1 Spitz-type dog, and 1 Labrador Retriever.

For the dogs without neoplasia, we used CTA images of healthy research Beagles that had been obtained as part of their initial examinations before being enrolled in an unrelated research project. These dogs were all 2 to 3 years old, and the mean ± SD body weight was 10.8 ± 0.8 kg.

CT images

Overall, reviewers evaluated 22,690 reconstructed CTA images (9,185 transverse, 5,023 sagittal, and 4,568 dorsal plane images and 3,914 MIP images).
constructed CTA images (4,600 transverse, 2,631 sagittal, and 2,382 dorsal plane images and 1,766 MIP images) of tumors with adjacent tissues evaluated. For healthy research dogs, there were 5,103 reconstructed CTA images (2,153 transverse, 1,022 sagittal, and 968 dorsal plane images and 960 MIP images) of the left kidney and 6,208 reconstructed CT images (2,432 transverse, 1,370 sagittal, and 1,218 dorsal plane images and 1,188 MIP images) of the jejunum with the mesentery evaluated.

**CTA image evaluation**

**Kidneys in healthy dogs**—Results for the qualitative evaluation of the effect of kernel and window setting combinations on CTA images of the left kidneys in 20 healthy dogs were compiled (Figure 1; Tables 1 and 2). For images of the arterial phase of CTA, the mean qualitative scores for the differentiation between renal arteries and veins and the conspicuity of the intrarenal vessels were significantly ($P < 0.05$) higher for the setting combinations with bone window (vs soft tissue window), regardless of kernel setting, in MPR and MIP images. For images of the venous phase, no significant differences were observed in scores for the differentiation between the renal arteries and veins and the conspicuity of the intrarenal vessels among the 3 setting combinations.

**Jejunum with mesentery in healthy dogs**—For MIP images of the mesentery in 20 healthy dogs during

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**Table 1**—Mean ± SD qualitative scores on a 3-point scale (1 = poor, 2 = fair, and 3 = good) for the differentiation between renal arteries and veins in MPR and MIP CTA images of the left kidneys in 20 healthy dogs when the images were reconstructed with 3 different combinations of kernel and window settings (soft kernel with soft tissue window, soft kernel with bone window, or sharp kernel with bone window) and evaluated by 2 reviewers blinded to the setting combination for all images.

<table>
<thead>
<tr>
<th>Image reconstruction combinations</th>
<th>Soft kernel with soft tissue window†</th>
<th>Soft kernel with bone window§</th>
<th>Sharp kernel with bone window§</th>
</tr>
</thead>
<tbody>
<tr>
<td>Art MPR</td>
<td>1.7 ± 0.73a</td>
<td>2.6 ± 0.75b</td>
<td>2.6 ± 0.74a</td>
</tr>
<tr>
<td>Ven MPR</td>
<td>1.9 ± 0.88</td>
<td>1.7 ± 0.73</td>
<td>1.8 ± 0.87</td>
</tr>
<tr>
<td>Art MIP</td>
<td>1.1 ± 0.30a</td>
<td>2.2 ± 0.83b</td>
<td>2.0 ± 0.97b</td>
</tr>
<tr>
<td>Ven MIP</td>
<td>1.4 ± 0.51</td>
<td>1.5 ± 0.51</td>
<td>1.1 ± 0.36</td>
</tr>
</tbody>
</table>

§Soft kernel (40S medium setting on the CT scanner used, with which the image sharpness is defined by the selected number [the higher the number, the sharper the image]). †Soft window (window level, 40 HU; window width, 400 HU). ‡ Sharp kernel (70S sharp setting on the CT scanner used, with which the image sharpness is defined by the selected number [the higher the number, the sharper the image]). §Bone window (window level, 450 HU; window width, 1,500 HU).

Art = Arterial phase. Ven = Venous phase.

a, b Within a row, values with different superscript letters differ significantly ($P < 0.05$).

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**Table 2**—Mean ± SD qualitative scores for the conspicuity of the intrarenal vessels in the CTA images described in Table 1.

<table>
<thead>
<tr>
<th>Image reconstruction combinations</th>
<th>Soft kernel with soft tissue window†</th>
<th>Soft kernel with bone window§</th>
<th>Sharp kernel with bone window§</th>
</tr>
</thead>
<tbody>
<tr>
<td>Art MPR</td>
<td>1.3 ± 0.48a</td>
<td>2.7 ± 0.44b</td>
<td>2.9 ± 0.30a</td>
</tr>
<tr>
<td>Ven MPR</td>
<td>1.2 ± 0.41</td>
<td>1.1 ± 0.30</td>
<td>1.2 ± 0.44</td>
</tr>
<tr>
<td>Art MIP</td>
<td>1.1 ± 0.36a</td>
<td>2.4 ± 0.31b</td>
<td>2.6 ± 0.39b</td>
</tr>
<tr>
<td>Ven MIP</td>
<td>1.1 ± 0.36</td>
<td>1.0 ± 0.22</td>
<td>1.4 ± 0.68</td>
</tr>
</tbody>
</table>

†Soft kernel (40S medium setting on the CT scanner used, with which the image sharpness is defined by the selected number [the higher the number, the sharper the image]). †Soft window (window level, 40 HU; window width, 400 HU). ‡ Sharp kernel (70S sharp setting on the CT scanner used, with which the image sharpness is defined by the selected number [the higher the number, the sharper the image]). §Bone window (window level, 450 HU; window width, 1,500 HU).

See Table 1 for key.

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**Figure 2**—Representative dorsal MIP reconstructed arterial phase CTA images of the mesenteric root in 1 of the 20 dogs described in Figure 1 qualitatively assessed for the differentiation between the mesenteric vessels (particularly the small branches) and the conspicuity of the mesenteric vessels from the intestinal wall when reconstructed with 3 different combinations of kernel and window settings: soft kernel with soft tissue window (window level, 40 HU; window width, 400 HU; A), soft kernel with bone window (window level, 450 HU; window width, 1,500 HU; B), and sharp kernel with bone window (window level, 450 HU; window width, 1,500 HU; C). A—The major mesenteric arteries are indistinguishable from each other, particularly in the furcation area of the major mesenteric vessels where numerous branched vessels are in close proximity. B and C—The major mesenteric arteries are clearly evident.
the arterial phase of CTA, the mean score for the differentiation between the mesenteric vascular branches was significantly \((P < 0.05)\) higher for setting combinations with bone window (vs soft tissue window), regardless of kernel setting (Figure 2; Table 3). For images of the venous phase, the mean scores for differentiation between the mesenteric vascular branches did not differ substantially on the basis of setting combinations. Similarly, the conspicuity of the mesenteric vessels from the intestinal wall did not differ between soft kernel with soft tissue window and sharp kernel with bone window, regardless of phase (arterial or venous; Table 4).

**Tumors in dogs**—Results for the qualitative evaluation of the effect of kernel and window setting combinations on the differentiation of intratumoral vessels and conspicuity of the tumor versus adjacent structures in CTA images of 20 dogs were compiled. When CTA images of tumors of the heads of dogs were evaluated, the mean scores for the differentiation of intratumoral vessels in arterial phase MPR and MIP images and venous MPR images were significantly \((P < 0.05)\) higher for those with the setting combination of sharp kernel with bone window, compared with the other setting combinations (Table 5). Also, for MRP images of tumors of the head, the mean scores

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**Table 3**—Mean ± SD qualitative scores for the differentiation between mesenteric vessels in CTA images of the dogs described in Table 1 when images were reconstructed and evaluated as described in Table 1.

<table>
<thead>
<tr>
<th>Image reconstruction combinations</th>
<th>Soft kernel(^a) with soft tissue window(^†)</th>
<th>Soft kernel(^a) with bone window(^§)</th>
<th>Sharp kernel(^†) with bone window(^§)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTA images</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Art MIP</td>
<td>(1.5 \pm 0.60^a)</td>
<td>(2.98 \pm 0.22^b)</td>
<td>(3.0^b)</td>
</tr>
<tr>
<td>Ven MIP</td>
<td>(1.8 \pm 0.58)</td>
<td>(2.1 \pm 0.58)</td>
<td>(1.6 \pm 0.50)</td>
</tr>
</tbody>
</table>

*See Table 1 for key.

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**Table 4**—Mean ± SD qualitative scores for the conspicuity of the mesenteric vessels, compared with the intestinal wall, in the CTA images described in Table 3 and evaluated as described in Table 1.

<table>
<thead>
<tr>
<th>Image reconstruction combinations</th>
<th>Soft kernel(^a) with soft tissue window(^†)</th>
<th>Soft kernel(^a) with bone window(^§)</th>
<th>Sharp kernel(^†) with bone window(^§)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTA images</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Art MIP</td>
<td>(2.6 \pm 0.48)</td>
<td>(2.6 \pm 0.59)</td>
<td>(2.9 \pm 0.22)</td>
</tr>
<tr>
<td>Ven MIP</td>
<td>(2.0 \pm 0.85^{ab})</td>
<td>(1.5 \pm 0.51^a)</td>
<td>(2.2 \pm 0.55^b)</td>
</tr>
</tbody>
</table>

*See Table 1 for key.

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**Table 5**—Mean ± SD qualitative scores for the differentiation of intratumoral vasculature in MPR and MIP CTA images of tumors of the head (\(n = 5\)), gastrointestinal tract (5), liver (5), or spleen (5) in 20 dogs that underwent CTA as part of tumor staging at the Chonnam National University Veterinary Teaching Hospital between March 2013 and March 2018 when reconstructed and evaluated as described in Table 1.

<table>
<thead>
<tr>
<th>Tumor location</th>
<th>CTA image</th>
<th>Soft kernel(^a) with soft tissue window(^†)</th>
<th>Soft kernel(^a) with bone window(^§)</th>
<th>Sharp kernel(^†) with bone window(^§)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>Art MPR</td>
<td>(1.7 \pm 0.67^a)</td>
<td>(2.2 \pm 0.42^a)</td>
<td>(2.9 \pm 0.31^b)</td>
</tr>
<tr>
<td></td>
<td>Ven MPR</td>
<td>(2.1 \pm 0.31)</td>
<td>(2.1 \pm 0.31)</td>
<td>(2.5 \pm 0.52)</td>
</tr>
<tr>
<td></td>
<td>Art MIP</td>
<td>(1.5 \pm 0.84^a)</td>
<td>(1.8 \pm 0.63^{ah})</td>
<td>(2.6 \pm 0.84^{ah})</td>
</tr>
<tr>
<td></td>
<td>Ven MIP</td>
<td>(1.5 \pm 0.71^a)</td>
<td>(2.0 \pm 0.47^{ah})</td>
<td>(2.3 \pm 0.67^{ah})</td>
</tr>
<tr>
<td>Gastrointestinal tract</td>
<td>Art MPR</td>
<td>(1.4 \pm 0.84^a)</td>
<td>(2.0^a)</td>
<td>(2.7 \pm 0.67^{ab})</td>
</tr>
<tr>
<td></td>
<td>Ven MPR</td>
<td>(2.3 \pm 0.67)</td>
<td>(1.6 \pm 0.51)</td>
<td>(2.4 \pm 0.84)</td>
</tr>
<tr>
<td></td>
<td>Art MIP</td>
<td>(1.5 \pm 0.84^a)</td>
<td>(2.3 \pm 0.48^{ah})</td>
<td>(2.5 \pm 0.70^{ah})</td>
</tr>
<tr>
<td></td>
<td>Ven MIP</td>
<td>(1.6 \pm 0.51)</td>
<td>(1.1 \pm 0.31)</td>
<td>(1.4 \pm 0.51)</td>
</tr>
<tr>
<td>Liver</td>
<td>Art MPR</td>
<td>(2.2 \pm 0.78)</td>
<td>(2.0 \pm 0.94)</td>
<td>(2.8 \pm 0.42)</td>
</tr>
<tr>
<td></td>
<td>Ven MPR</td>
<td>(2.2 \pm 0.81)</td>
<td>(1.6 \pm 0.51)</td>
<td>(2.1 \pm 0.87)</td>
</tr>
<tr>
<td></td>
<td>Art MIP</td>
<td>(2.0 \pm 0.66)</td>
<td>(2.1 \pm 0.73)</td>
<td>(2.5 \pm 0.70)</td>
</tr>
<tr>
<td></td>
<td>Ven MIP</td>
<td>(1.7 \pm 0.67)</td>
<td>(1.4 \pm 0.51)</td>
<td>(1.4 \pm 0.69)</td>
</tr>
<tr>
<td>Spleen</td>
<td>Art MPR</td>
<td>(2.7 \pm 0.48)</td>
<td>(2.4 \pm 0.51)</td>
<td>(2.8 \pm 0.63)</td>
</tr>
<tr>
<td></td>
<td>Ven MPR</td>
<td>(2.4 \pm 0.51^{a})</td>
<td>(1.5 \pm 0.52^{ah})</td>
<td>(2.1 \pm 0.87^{ah})</td>
</tr>
<tr>
<td></td>
<td>Art MIP</td>
<td>(2.4 \pm 0.51)</td>
<td>(2.4 \pm 0.84)</td>
<td>(2.8 \pm 0.42)</td>
</tr>
<tr>
<td></td>
<td>Ven MIP</td>
<td>(2.1 \pm 0.35)</td>
<td>(1.7 \pm 0.46)</td>
<td>(1.7 \pm 0.46)</td>
</tr>
</tbody>
</table>

*See Table 1 for key.
for the conspicuity of tumoral vessels versus adjacent structures were significantly higher for setting combinations with bone window (vs soft tissue window), regardless of kernel setting or phase.

In images of gastrointestinal tumors in dogs (Figure 3), the mean score for the differentiation among intratumoral vessels in arterial phase MPR images was significantly ($P < 0.05$) higher for images with the setting combination of sharp kernel with bone window, compared with the other setting combinations (Table 5). The mean score for the differentiation among intratumoral vessels in arterial phase MIP images was significantly higher for images with the setting combination of sharp kernel with bone window, compared with soft kernel with soft tissue window. However, the mean score for the conspicuity of the tumor vessels versus the adjacent structures in venous phase MPR images was significantly higher for the setting combination of soft kernel with soft tissue window versus soft kernel with bone window (Table 6).

When CTA images of hepatic tumors in dogs (Figure 4) were reviewed, the mean scores for the differentiation of the intratumoral vessels did not differ on the basis of kernel and window setting (Table 5). However, the mean scores for the conspicuity of the tumor vessels versus adjacent structures in arterial phase MPR and MIP images were significantly higher for images with the setting combination of soft kernel and soft tissue window, compared with the other setting combinations (Table 6).

In CTA images of splenic tumors in dogs, the mean scores for differentiation of intratumoral vessels in arterial phase images did not differ on the basis of setting combination; however, in the venous phase MPR images, the mean score was significantly higher

**Table 6**—Mean ± SD qualitative scores for the conspicuity of the tumoral vessels, compared with adjacent tumoral structures, in the CTA images described in Table 5 and evaluated as described in Table 1.

<table>
<thead>
<tr>
<th>Tumor location</th>
<th>CTA image</th>
<th>Soft kernel(^a) with soft tissue window(^\dagger)</th>
<th>Soft kernel(^b) with bone window(^\dagger)</th>
<th>Sharp kernel(^c) with bone window(^\dagger)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>Art MPR</td>
<td>1.7 ± 0.67(^a)</td>
<td>2.7 ± 0.48(^b)</td>
<td>3.0(^c)</td>
</tr>
<tr>
<td></td>
<td>Ven MPR</td>
<td>1.5 ± 0.52(^a)</td>
<td>2.5 ± 0.52(^b)</td>
<td>3.0(^c)</td>
</tr>
<tr>
<td></td>
<td>Art MIP</td>
<td>1.5 ± 0.84(^a)</td>
<td>2.0 ± 0.47(^b)</td>
<td>2.7 ± 0.48(^b)</td>
</tr>
<tr>
<td></td>
<td>Ven MIP</td>
<td>1.3 ± 0.48(^a)</td>
<td>1.9 ± 0.56(^b)</td>
<td>2.4 ± 0.84(^b)</td>
</tr>
<tr>
<td>Gastrointestinal tract</td>
<td>Art MPR</td>
<td>1.9 ± 0.56</td>
<td>1.9 ± 0.73</td>
<td>1.8 ± 0.91</td>
</tr>
<tr>
<td></td>
<td>Ven MPR</td>
<td>2.3 ± 0.82(^a)</td>
<td>1.3 ± 0.48(^b)</td>
<td>1.6 ± 0.51(^c)</td>
</tr>
<tr>
<td></td>
<td>Art MIP</td>
<td>1.3 ± 0.48</td>
<td>1.6 ± 0.51</td>
<td>1.4 ± 0.51</td>
</tr>
<tr>
<td></td>
<td>Ven MIP</td>
<td>1.3 ± 0.48</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Liver</td>
<td>Art MPR</td>
<td>1.9 ± 0.56(^a)</td>
<td>1.3 ± 0.48(^b)</td>
<td>1.3 ± 0.48(^b)</td>
</tr>
<tr>
<td></td>
<td>Ven MPR</td>
<td>2.6 ± 0.51</td>
<td>2.1 ± 0.99</td>
<td>2.1 ± 0.99</td>
</tr>
<tr>
<td></td>
<td>Art MIP</td>
<td>1.7 ± 0.48(^a)</td>
<td>1.0(^b)</td>
<td>1.2 ± 0.42(^c)</td>
</tr>
<tr>
<td></td>
<td>Ven MIP</td>
<td>2.1 ± 0.56</td>
<td>1.5 ± 0.52</td>
<td>1.6 ± 0.51</td>
</tr>
<tr>
<td>Spleen</td>
<td>Art MPR</td>
<td>2.4 ± 0.84(^a)</td>
<td>1.5 ± 0.52(^b)</td>
<td>1.7 ± 0.82(^b)</td>
</tr>
<tr>
<td></td>
<td>Ven MPR</td>
<td>2.6 ± 0.51</td>
<td>2.0 ± 0.66</td>
<td>2.2 ± 0.78</td>
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<tr>
<td></td>
<td>Art MIP</td>
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<td>1.5 ± 0.52</td>
<td>1.5 ± 0.70</td>
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<tr>
<td></td>
<td>Ven MIP</td>
<td>2.6 ± 0.74(^a)</td>
<td>1.8 ± 0.35(^b)</td>
<td>2.0(^c)</td>
</tr>
</tbody>
</table>

See Table 1 for key.
P < 0.05) higher for images with the setting combination of soft kernel with soft tissue window, compared with soft kernel with bone window (Table 5). In addition, the mean score for conspicuity of splenic tumor vessels versus adjacent structures in arterial phase MPR images was significantly higher for images with the setting combination of soft kernel with soft tissue window, compared with other setting combinations (Table 6).

Interobserver agreement

Results of ICC analysis were summarized (Table 7). Findings indicated strong interobserver agreement for all qualitative factors evaluated, with ICCs of > 0.8 for evaluation of images of kidneys and tumors and an ICC of 0.76 for evaluation of images of jejunum with mesentery.

Discussion

Tumor vascularity can be used to determine tumor characteristics, plan surgical treatment, and predict the prognosis in human patients with various tumors.25,26 In general, the setting of soft kernel combined with soft tissue window is used in evaluating images from CTA because the combination enables good visualization of contrast-enhancing soft tissues.27 However, the combination enables only limited demarcation of intricate vasculature and of intratumoral vessels in contrast-enhancing tumor parenchyma. Thus, in the present study, we evaluated the effects of 3 combinations of kernel and window settings on the qualitative assessment of the differentiation of small and complex vessels and the conspicuity of such vasculature versus adjacent contrast-enhancing or hyperattenuated structures in CTA images of dogs with and without tumors. The 3 setting combinations used were soft kernel with soft tissue window, soft kernel with bone window, and sharp kernel with bone window. For dogs without tumors, the ROIs were kidney and mesentery, which have complex internal vasculature. For dogs with tumors, we were interested in hepatic and splenic tumors because they generally contain soft tissues, gastrointestinal tumors because the gastrointestinal tract has many vascular branches, and tumors of the head because of the relatively close proximity of bone, soft tissues, vessels, and gas cavities (eg, nasal cavity and sinuses) in a small area. For CTA images with soft kernel combined with soft tissue window, we often encountered difficulties because the internal vascularity of the ROI was often masked by contrast-enhancing soft tissues and because vascular margins of interest were effaced by hyperattenuated adjacent structures. However, our findings indicated that CTA images with sharp kernel combined with bone window provided better visualization of small and complicated vasculature in tumors of the head and gastrointestinal tract and differentiation of these tumors from the surrounding bony or hyperattenuated structures. This finding supported our initial hypothesis that the combination of sharp kernel and bone window would more clearly differentiate small and complicated vessels from intensely enhanced regions or from bony structures than would the combination of soft kernel and soft tissue window.

The delineation of vascularity depended on several factors, including the size of the vessels, vascular...
complexity, and degree of contrast enhancement of the parenchyma and vessels. In a study of humans with intracranial artery aneurysms, large aneurysms were well visualized on CT images with sharp or soft kernel; however, with the sharp kernel, the shape of small aneurysms could be determined more accurately. In the present study, assessment of vascularity in large tumors, such as hepatic and splenic tumors, did not differ on the basis of kernel and window setting combination, except in the venous phase MPR images of splenic tumors, for which the soft tissue window (vs bone window) yielded better visualization when soft kernel was used. However, in tumors of the head and gastrointestinal tract, superior visualization of intratumoral vessels was achieved in images with sharp kernel combined with bone window. In addition, as vessels in ROIs became more complex or crowded, they could not be differentiated in images with the setting of soft kernel combined with soft tissue window because of the low spatial resolution and blooming artifact of the contrast-enhanced vessels, whereas the use of sharp kernel combined with bone window had greater spatial resolution and less blooming artifact.

Renal CT can provide a reliable and accurate depiction of the renal vasculature in terms of the number, size, course, and relationship of the renal arteries and veins. However, even with CTA, differentiating complex vasculature in the corticomedullary junction and at the renal pelvis may be difficult when small vascular lesions are suspected. In human medicine, applying various CT window settings has been attempted for use in evaluating renal vessels because the transverse and MIP CT images in soft tissue window are inadequate for evaluating renal vasculature and for differentiating such from adjacent calcifications. Our findings indicated that the differentiation between renal arteries and veins and the conspicuity of the intrarenal vessels in the arterial phase were significantly superior when viewed on CTA images with the bone window (vs soft tissue window) regardless of the kernel used, particularly near the hilum where the renal vessels were in close proximity to each other. When evaluating the mesenteric vasculature with dynamic CT, MIP images help in comprehensive interpretation of the mesenteric vascular system because in MIP images, complex vascular anatomy including peripheral vessel branches may be seen; however, mesenteric vessels close to each other and with high contrast enhancement are not seen as distinct vessels on MIP images. In the present study, the differentiation between the major mesenteric vessels or among their branches was significantly superior in arterial phase MIP images with the bone window setting (vs soft tissue window), particularly in the furcation area of the major mesenteric vessels where numerous branched vessels were in close proximity.

When ROIs with high degrees of contrast enhancement of parenchymal tissue, such as renal cortex and medulla or some highly perfused tumors, were viewed on CTA images in soft tissue window in the present study, intrarenal or intratumoral vessels essentially became invisible or indistinguishable because those vessels were masked by the contrast-enhanced parenchyma. However, our findings indicated that when these ROIs were viewed on CTA images in sharp kernel combined with bone window, those vessels could be distinguished from the parenchyma because of the wider window width. However, when ROIs with weak contrast enhancement of parenchymal tissue and sufficient contrast enhancement of vessels were evaluated, the reviewers’ scores for conspicuity of the vessels did not differ on the basis of the kernel and window setting combination used.

When there is little difference in the degree of contrast enhancement between the vasculature and adjacent structures of an ROI, CTA image settings with higher contrast resolution and less noise artifact are important for detecting subtle contrast differences among structures. For instance, narrower window widths, such as in the soft tissue window used in the present study, are more useful for detecting subtle density differences between tissues because they maximize differences in grayness in that narrowing the window width decreases the range of tissue densities represented in a given shade of gray and thereby allows subtle differences in tissue density to be displayed more conspicuously within the image’s available gray scale. In addition, the soft kernel yields images that have less noise and a more smooth appearance than does the sharp kernel. Thus, CTA images in soft kernel with soft tissue window are more favorable for evaluating vessels in the venous phase wherein the attenuation of vessels decreases and becomes similar to that of the tumor parenchyma. Our findings supported this in that the conspicuity of the intratumoral vessels of splenic and hepatic tumors viewed on venous phase CTA images in the present study was scored relatively higher for images in soft kernel combined with soft tissue window, compared with other setting combinations. However, we also found that the reviewers’ scores for the conspicuity of intratumoral vessels in head and gastrointestinal tumors, intrarenal vessels, and mesenteric vascular branches viewed in venous phase CTA images were similar across the 3 combinations of kernels and window settings, and these findings could have been attributable to other factors, including vascular complexity and size in the images used.

The conspicuity of tumor vessels versus adjacent bone or other hyperattenuated structures is highly dependent on the window setting. In humans, an appendicolith can easily be mistaken for intraluminal barium in the soft tissue window setting because of the high attenuation of both structures; moreover, the sensitivity of the bone window setting for differ-
entiating an appendicolith from intraluminal barium is almost double that of the soft tissue window setting. Because of the wide window width in the bone window used in the present study, the tumor vessels were more easily distinguishable from the adjacent bony structures, particularly in tumors of the head. There were limitations in the present study. First, all the healthy dogs were of similar size and age. Second, for CTA images of healthy dogs, only images of the left kidney and the jejunum with mesentery were reconstructed with the 3 setting combinations and evaluated; however, because the present study focused on the assessment of small and complicated vasculature, evaluating CTA images from these 2 anatomical locations was purposeful. Third, because of the retrospective study design, CTA protocols were not the same for all dogs with tumors.

The present study assessed the effect of kernel and window setting on vascular visualization on CTA images. Our findings indicated that the combined use of sharp kernel and bone window settings improved the conspicuity of internal vascularity in images of the kidney and jejunum with mesentery, improved the visualization of small and complicated vessels in tumors of the head and gastrointestinal tract, and improved the conspicuity of tumors from the surrounding bony or hyperattenuated structures.

Acknowledgments

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Footnotes

a. Emotion 16, Siemens AG, Forchheim, Germany.
b. Omnipaque 300, GE Healthcare, Oslo, Norway.
c. MEDRAD Vistron CT injection system, Medrad, Pa.
d. Infinit PACS, Infinit Healthcare Co Ltd, Seoul, South Korea.
e. SPSS Statistics for Windows, release 21.0, IBM Corp, Armonk, NY.

References


