Cerebral Aneurysms: Accuracy of 320–Detector Row Nonsubtracted and Subtracted Volumetric CT Angiography for Diagnosis

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Purpose:
To assess the accuracy of 320–detector row nonsubtracted and subtracted volumetric computed tomographic (CT) angiography for detection of cerebral aneurysms.

Materials and Methods:
After institutional review board approval and informed written consent were obtained, 282 consecutive patients suspected of having cerebral aneurysms underwent CT angiography with a 320–detector row volumetric CT scanner and three-dimensional (3D) rotational digital subtraction angiography (DSA). The sensitivity, specificity, and accuracy of nonsubtracted and subtracted volumetric CT angiography for depiction of aneurysms were analyzed, with 3D DSA as the reference standard. P values less than .05 were considered to indicate a significant difference.

Results:
Among the 282 patients, 198 (70.2%) had 239 cerebral aneurysms that were detected on the basis of 3D DSA. Nonsubtracted volumetric CT angiography showed 231 of the 239 (96.7%) aneurysms. The primary reason for missed aneurysms was close proximity to bone tissue. Sensitivity, specificity, and accuracy of nonsubtracted volumetric CT angiography for depicting aneurysms were 96.7%, 100%, and 97.5%, respectively, on a per-aneurysm basis. Subtracted volumetric CT angiography showed 237 of 239 (99.2%) aneurysms. Sensitivity, specificity, and accuracy of subtracted volumetric CT angiography for depicting aneurysms were 99.2%, 100%, and 99.4%, respectively, on a per-aneurysm basis. There was no statistically significant difference in accuracy between subtracted volumetric CT angiography and 3D DSA (P = .500). However, nonsubtracted volumetric CT angiography was significantly less sensitive than 3D DSA and subtracted volumetric CT angiography (P = .031 and .008, respectively).

Conclusion:
Subtracted 320–detector row volumetric CT angiography provides excellent sensitivity for detection of cerebral aneurysms and should be the first-line imaging technique for the noninvasive evaluation of aneurysms. The accuracy of nonsubtracted volumetric CT angiography was lower than that for subtracted volumetric CT angiography, especially for aneurysms adjacent to bone tissue.
Three-dimensional (3D) rotational digital subtraction angiography (DSA) currently is considered the “gold standard” for the detection of cerebral aneurysms (1,2). However, the technique is invasive, time consuming, technically demanding, relatively expensive, and has a 0.12% rate of permanent neurologic complication according to results of a previous prospective, randomized trial (3). Thus, developing an accurate, noninvasive diagnostic imaging modality for aneurysms is an important issue.

Multisection computed tomographic (CT) angiography is noninvasive and was proved accurate for the diagnosis of cerebral aneurysms (4–6). However, conventional CT angiography is not the best method for detecting aneurysms near the base of the skull because of overlying bone structures (7). Subtracted 320-detector row volumetric CT angiography, which allows bone-free visualization of aneurysms, has been developed and favorably compared with DSA for the detection of cerebral aneurysms (8–11). The aim of our study was to assess the accuracy of 320-detector row nonsubtracted and subtracted volumetric CT angiography in detecting cerebral aneurysms.

Materials and Methods

Patients

The authors of our study, all of whom were not employees of or supported or funded by Toshiba or Siemens Medical Solutions, controlled the inclusion of data in this study. The study was approved by the institutional review board, and informed written consent was obtained from patients or from a close family member. Between February 2011 and October 2012, 315 patients suspected of having cerebral aneurysms were enrolled in this retrospective study. Patients were scheduled to undergo DSA and were prospectively scheduled to undergo comparative CT angiography. Eighteen (5.7%) patients who had undergone prior surgical clipping or endovascular coiling for their cerebral aneurysms were excluded from the study. Another 15 (4.8%) patients who did not undergo DSA because of rapid clinical deterioration were also excluded. Thus, our study population consisted of 282 patients, including 138 (48.9%) men and 144 (51.1%) women (age range, 21–91 years; mean age, 58 years). Patients were selected by the referring physicians for volumetric CT angiography on the basis of a clinical history suggestive of cerebral aneurysm. Of the 282 patients, 179 (63.5%) patients had subarachnoid hemorrhage, 31 (11.0%) had subarachnoid and intraventricular hemorrhage, 15 (5.3%) had subarachnoid and intraparenchymal hemorrhage, 10 (3.6%) had intraparenchymal hemorrhage, 15 (5.3%) had subarachnoid, intraventricular, and intraparenchymal hemorrhage, and the remaining 32 (11.3%) patients had a variety of indications, including headache, oculomotor paralysis, tumor, and hydrocephalus.

Diagnostic Imaging

All 282 patients underwent volumetric CT angiography with a 320-detector row volumetric CT scanner (Aquilion ONE; Toshiba Medical Systems Corporation, Tochigi, Japan), and a standardized protocol was used. First, a nonenhanced CT protocol was used to obtain the mask image for subtraction. Then, a CT angiographic protocol was performed by using an intravenous injection of 50 mL of contrast material (Ultravist, 370 mg of iodine per milliliter; Bayer Schering Pharma, Berlin, Germany) with an 18-gauge catheter, followed by a 20-mL saline flush. The flow rate was kept constant at 5 mL per second throughout the procedure. CT scanning parameters were gantry rotation speed, 0.35 second per rotation; detector width, 320 × 0.5 mm; beam pitch, 0; matrix, 512 × 512; field of view, 180–240 mm; 120 kV, 310 mA for nonenhanced images; 80 kV, 300 mA for contrast material–enhanced images; and a scanning length of 16 cm of the entire neurocranium in a single rotation.

All subjects were positioned supine with the head maintained in a neutral position during CT scanning to prevent motion artifacts. Twelve

Advances in Knowledge

- The sensitivity of subtracted volumetric CT angiography for detecting cerebral aneurysms smaller than 3 mm, 3–8 mm, and larger than 8 mm was 95.6%, 100%, and 100%, respectively, on a per-aneurysm basis.
- There was no statistically significant difference in accuracy between subtracted volumetric CT angiography and three-dimensional rotational digital subtraction angiography (*P* = .500).
- The accuracy of nonsubtracted volumetric CT angiography was lower than that of subtracted volumetric CT angiography (*P* = .031), especially for cerebral aneurysms adjacent to bone tissue.

Implication for Patient Care

- Subtracted volumetric CT angiography could replace invasive digital subtraction angiography as the first-line imaging technique for noninvasive evaluation of suspected cerebral aneurysms because of its high diagnostic sensitivity.
(4.3%) patients with confusion and/or agitation were administered intravenous sedation; no patient required general anesthesia before CT angiography. A caudrocranial scanning direction was selected, and the volumetric coverage extended from the first cervical vertebra to the superior aspect of the frontal sinuses. The initial scan times of mask and volumetric CT angiography were 5 and 12.8 seconds after the start of intravenous infusion, respectively, with nine phases of volumetric CT angiographic image volumetric data obtained every 2 seconds. By using nine phases, we obtained optimal arterial phase images.

The subtracted CT angiographic volumetric data were obtained by subtracting the mask image volumetric data from the conventional nonsubtracted CT angiographic volumetric data. The subtraction process was started by loading both the nonenhanced and the contrast-enhanced imaging data in the console’s software. Bone tissue data were automatically removed, and these data were used for 3D visualization by means of direct volume-rendering techniques or maximum-intensity projections.

Invasive selective angiography was performed by means of the transfemoral approach with a biplane DSA unit with rotational capabilities (Artis Zee Biplane; Siemens Medical Solutions, Forchheim, Germany). Nonionic contrast material (Omnipaque, 300 mg of iodine per milliliter; Amersham Life Science, Clearbrook, III) was used in all patients and was injected with a power injector (Medrad, Stellant, Pa). We used 6-9 mL of nonionic contrast medium per acquisition, consisting of one anteroposterior, one lateral, and one to two oblique views, with the catheter in each of the three major arteries (both internal carotid arteries and one or more vertebral arteries). The scans were obtained with a 38-cm field of view (anteroposterior), a 30-cm field of view (lateral and oblique), and a 1024 × 1024 matrix. The spatial resolution was 0.32 × 0.32 mm. A single 3D DSA acquisition was performed before removal of the catheter from each vessel, even if no aneurysm was visible at conventional angiography.

Image Analysis

All 3D DSA and volumetric CT angiographic images were independently evaluated by five neuroradiologists who had 13 (W.X., W.H.C., Q.W.) and 10 (Z.M.H., C.Y.W.) years of experience in CT vascular imaging and angiography. Two readers (W.X., Z.M.H.) evaluated the subtracted volumetric CT angiographic images and two readers (W.H.C., C.Y.W.) evaluated the nonsubtracted volumetric CT angiographic images. All the readers were blinded to the assessments of the images obtained with the other technique and to the other investigators, who only knew that the patients were suspected of having cerebral aneurysms.

Subtracted and nonsubtracted CT angiographic volumetric data were exported to a workstation (VOXAR; Toshiba Medical Visualization Systems) with volume-rendering techniques or maximum-intensity projections. The total reading time for volumetric CT angiography was approximately 25 minutes per patient. The four readers assessed the presence of an aneurysm and its location, size, and morphology. The image quality of CT angiography was determined by using the following rating system: (a) excellent quality, with vascular structures clearly present without bones or artifacts; (b) moderate quality, with a few bone structure remnants or artifacts visible, but image quality adequate for diagnosis; (c) poor quality, with a large amount of bone remnants present on subtracted images, and/or obvious artifacts, which made identification of an aneurysm difficult.

On completion of the procedure, the 3D DSA images were immediately sent to an adjacent 3D workstation (Inspace; Siemens Medical Solutions). The time to transfer images was typically 1-2 minutes. After we reached consensus regarding the presence of an aneurysm in each patient, a neuroradiologist reviewer (Q.W., with 13 years of experience) measured the maximum size of each aneurysm on 3D DSA images. The largest diameter of each aneurysm was measured in millimeters to one decimal place, and aneurysms smaller than 2 mm were considered very small.

Statistical Analysis

In our study, we used 3D DSA as the reference standard. Two-by-two tables were constructed from true-positive, false-positive, false-negative, and true-negative results for subtracted and nonsubtracted volumetric CT angiography compared with those of 3D DSA. Sensitivity, specificity, positive and negative predictive values, and accuracy were compared on a per-aneurysm basis. One-sided 97.5% and two-sided 95% confidence intervals based on binomial probabilities were calculated for each independent reader for each statistical parameter (12). Stata 9.2 for Windows (Stata, College Station, Texas) was used for all statistical analyses. Comparisons between groups were made by using the McNemar test. P values of less than .05 were considered to indicate a significant difference.

Results

All of the CT images were diagnostic, and no obvious adverse effects or complications were observed after volumetric CT angiographic examination. Image quality was excellent in 276 (97.9%) patients and moderate in six (2.1%) patients. Moderate volumetric CT angiographic image quality was caused by incomplete bone removal due to head motion during CT scanning.

According to the 3D DSA reference standard results, no aneurysms were present in 84 (29.8%) patients. 61 (72.6%) patients had negative findings, 17 (20.2%) patients had arteriovenous malformation, and six (7.1%) patients had moyamoya disease. Of 282 patients, 198 (70.2%) had at least one cerebral aneurysm; 169 of the 198 (85.4%) patients had one aneurysm, including four patients with moyamoya disease; 20 (10.1%) patients had two aneurysms; and nine (4.5%) patients had three or more aneurysms. Of the 239 aneurysms, 183 (76.6%) had a saccular morphology, seven (2.9%)
Figure 1

**Figure 1:** Images in a 60-year-old woman with bilateral internal carotid artery aneurysms (2.9-mm diameter). (a) Volume-rendered image from nonsubtracted volumetric CT angiography clearly shows left internal carotid artery aneurysm (arrowhead) and does not show small right internal carotid artery aneurysm (arrow). Primary reason for missed aneurysm is close proximity to bone tissue and small size of aneurysm. (b) Volume-rendered image from subtracted volumetric CT angiography clearly shows bilateral internal carotid artery aneurysms (arrow and arrowhead). (c) Three-dimensional DSA image clearly shows small right internal carotid artery aneurysm (arrow). (d) Volume-rendered image shows bilateral internal carotid artery aneurysms (arrow and arrowhead) visible at retrospective review of nonsubtracted volumetric CT angiographic images.

<table>
<thead>
<tr>
<th>Aneurysm Location</th>
<th>Size (mm)</th>
<th>Nonsubtracted Reader 1</th>
<th>Nonsubtracted Reader 2</th>
<th>Subtracted Reader 3</th>
<th>Subtracted Reader 4</th>
<th>Subtracted Reader 5</th>
<th>3D DSA</th>
<th>Main Reason for Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right anterior cerebral artery</td>
<td>1.2</td>
<td>Negative</td>
<td>Negative</td>
<td>Negative</td>
<td>Negative</td>
<td>Positive</td>
<td>Positive</td>
<td>Very small</td>
</tr>
<tr>
<td>Left middle cerebral artery</td>
<td>1.5</td>
<td>Negative</td>
<td>Negative</td>
<td>Negative</td>
<td>Negative</td>
<td>Positive</td>
<td>Positive</td>
<td>Very small</td>
</tr>
<tr>
<td>Left internal carotid artery</td>
<td>2.7</td>
<td>Negative</td>
<td>Negative</td>
<td>Positive</td>
<td>Positive</td>
<td>Positive</td>
<td>Positive</td>
<td>Small, adjacent to bone</td>
</tr>
<tr>
<td>Right internal carotid artery</td>
<td>2.9</td>
<td>Negative</td>
<td>Negative</td>
<td>Positive</td>
<td>Positive</td>
<td>Positive</td>
<td>Positive</td>
<td>Small, adjacent to bone</td>
</tr>
<tr>
<td>Left internal carotid artery</td>
<td>3.0</td>
<td>Negative</td>
<td>Negative</td>
<td>Positive</td>
<td>Positive</td>
<td>Positive</td>
<td>Positive</td>
<td>Small, adjacent to bone</td>
</tr>
<tr>
<td>Right internal carotid artery</td>
<td>4.0</td>
<td>Negative</td>
<td>Negative</td>
<td>Positive</td>
<td>Positive</td>
<td>Positive</td>
<td>NA</td>
<td>Adjacent to bone</td>
</tr>
<tr>
<td>Right internal carotid artery</td>
<td>5.0</td>
<td>Negative</td>
<td>Negative</td>
<td>Positive</td>
<td>Positive</td>
<td>Positive</td>
<td>Positive</td>
<td>Adjacent to bone</td>
</tr>
<tr>
<td>Right vertebral artery</td>
<td>4.8</td>
<td>Negative</td>
<td>Negative</td>
<td>Positive</td>
<td>Positive</td>
<td>NA</td>
<td>Adjacent to bone</td>
<td></td>
</tr>
</tbody>
</table>

Note.—NA = not available.

were fusiform, and 49 (20.5%) were irregular. The two most common locations for all aneurysms were the anterior communicating artery (n = 62, 25.9%) and the posterior communicating artery (n = 57, 23.8%). Of the 239 aneurysms, 45 (18.8%) were smaller than 3 mm, 157 (65.7%) were 3–8 mm, and 37 (15.5%) were larger than 8 mm.

Among the 239 cerebral aneurysms, 231 (96.7%) were identified by the two independent readers in 192 patients by using nonsubtracted volumetric CT angiography. Eight aneurysms (3.3%) that were visible on 3D DSA images were not initially identified by the two readers of the nonsubtracted volumetric CT angiographic images and were considered to show false-negative results at nonsubtracted volumetric CT angiography. Data on missed aneurysms are listed in Table 1. On retrospective review, five aneurysms were displayed on the CT angiographic image (Fig 1), and the other three aneurysms were not detected. No aneurysms were considered to be false-positive at nonsubtracted volumetric CT angiography. Because readers 1 and 2 were in complete agreement regarding the results from nonsubtracted volumetric CT angiography, only the statistical results from nonsubtracted volumetric CT angiography for reader 1 are listed in Tables 2 and 3. There was a statistically significant difference in accuracy.
between nonsubtracted volumetric CT angiography and 3D DSA (McNemar test, \( P = .008 \)).

Among the 239 cerebral aneurysms, 237 (99.2%) were identified by the two independent readers in 197 patients by using subtracted volumetric CT angiography. Two (0.8%) aneurysms that were visible on 3D DSA images were not initially identified and were considered to be false-negative results with subtracted volumetric CT angiography. Data on missed aneurysms are listed in Table 1. At retrospective review, the two aneurysms were not detected (Figs 2, 3). No aneurysm was considered false-positive on the basis of subtracted volumetric CT angiography. Because readers 3 and 4 were in complete agreement regarding the results of subtracted volumetric CT angiographic images, only the statistical results of subtracted volumetric CT angiography for reader 3 are listed in Tables 2 and 3. There was no statistically significant difference in accuracy between subtracted volumetric CT angiographic and 3D DSA results (McNemar test, \( P = .500 \)). However, there was a statistically significant difference in accuracy between nonsubtracted and subtracted volumetric CT angiographic results (McNemar test, \( P = .031 \)). Twenty aneurysms were treated with surgery, 181 aneurysms were treated with embolization, and 38 aneurysms were not treated and were followed up.

### Table 2

<table>
<thead>
<tr>
<th>Aneurysm size</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>Accuracy (%)</th>
<th>Positive Predictive Value (%)</th>
<th>Negative Predictive Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;3 mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonsubtracted, reader 1</td>
<td>91.1 (78.8, 97.5)</td>
<td>100 (95.7, 100)*</td>
<td>96.9 (92.3, 99.1)</td>
<td>100 (91.4, 100)*</td>
<td>95.5 (88.8, 98.7)</td>
</tr>
<tr>
<td>Subtracted, reader 3</td>
<td>95.6 (84.6, 99.5)</td>
<td>100 (95.7, 100)*</td>
<td>98.4 (94.5, 98.8)</td>
<td>100 (91.8, 100)*</td>
<td>97.7 (91.9, 99.7)</td>
</tr>
<tr>
<td>3–8 mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonsubtracted, reader 1</td>
<td>97.5 (93.6, 99.3)</td>
<td>100 (95.7, 100)*</td>
<td>98.3 (95.8, 99.5)</td>
<td>100 (97.6, 100)*</td>
<td>95.5 (88.8, 98.7)</td>
</tr>
<tr>
<td>Subtracted, reader 3</td>
<td>100 (97.7, 100)*</td>
<td>100 (95.7, 100)*</td>
<td>100 (98.5, 100)*</td>
<td>100 (97.7, 100)*</td>
<td>100 (95.7, 100)*</td>
</tr>
<tr>
<td>&gt;8 mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonsubtracted, reader 1</td>
<td>100 (90.5, 100)*</td>
<td>100 (95.7, 100)*</td>
<td>100 (97.0, 100)*</td>
<td>100 (90.5, 100)*</td>
<td>100 (95.7, 100)*</td>
</tr>
<tr>
<td>Subtracted, reader 3</td>
<td>100 (90.5, 100)*</td>
<td>100 (95.7, 100)*</td>
<td>100 (97.0, 100)*</td>
<td>100 (90.5, 100)*</td>
<td>100 (95.7, 100)*</td>
</tr>
</tbody>
</table>

Note.—Unless otherwise indicated, data in parentheses are 95% confidence intervals.

* Data in parentheses are one-sided 97.5% confidence intervals.

### Table 3

<table>
<thead>
<tr>
<th>Approach</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>Accuracy (%)</th>
<th>Positive Predictive Value (%)</th>
<th>Negative Predictive Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per aneurysm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonsubtracted, reader 1</td>
<td>96.7 (93.5, 98.5)</td>
<td>100 (95.7, 100)</td>
<td>97.5 (95.2, 98.9)</td>
<td>100 (98.4, 100)</td>
<td>91.3 (83.6, 96.2)</td>
</tr>
<tr>
<td>Subtracted, reader 3</td>
<td>99.2 (97.0, 99.9)</td>
<td>100 (95.7, 100)</td>
<td>99.4 (97.8, 99.9)</td>
<td>100 (98.5, 100)</td>
<td>97.7 (91.9, 99.7)</td>
</tr>
<tr>
<td>Per patient</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonsubtracted, reader 1</td>
<td>96.0 (92.2, 98.2)</td>
<td>100 (95.7, 100)</td>
<td>97.2 (94.5, 98.8)</td>
<td>100 (98.1, 100)</td>
<td>91.3 (83.6, 96.2)</td>
</tr>
<tr>
<td>Subtracted, reader 3</td>
<td>99.0 (96.4, 99.9)</td>
<td>100 (95.7, 100)</td>
<td>99.3 (97.5, 99.9)</td>
<td>100 (98.1, 100)</td>
<td>97.7 (91.9, 99.7)</td>
</tr>
</tbody>
</table>

Note.—Unless otherwise indicated, data in parentheses are 95% confidence intervals.

* Data in parentheses are one-sided 97.5% confidence intervals.

### Discussion

This study demonstrated that, on a per-aneurysm basis, subtracted 320-detector row volumetric CT angiography achieved a high sensitivity and accuracy for depicting cerebral aneurysms. We observed that nonsubtracted volumetric CT angiography had a diagnostic ability comparable to that of subtracted volumetric CT angiography and 3D DSA for detecting aneurysms of the anterior communicating artery, the posterior communicating artery, the anterior cerebral artery, and the middle cerebral artery. The aneurysms missed at nonsubtracted volumetric CT angiography were generally located in the internal carotid artery. Detection of cerebral aneurysms adjacent to bone tissue was still challenging at nonsubtracted volumetric CT angiography because of the presence of overlying bone structures.

We observed that subtracted volumetric CT angiography had limitations.
First, microaneurysms were easily missed, and two microaneurysms were not diagnosed by using subtracted volumetric CT angiography. Comparatively, the sensitivity of subtracted volumetric CT angiography for detecting small aneurysms (<3 mm) was lower than that in the study by Luo et al (10); however, their patient population was relatively small (n = 56). Second, atherosclerotic plaque and aneurysmal calcification could not be displayed (Fig 4). Third, subtracted volumetric CT angiographic images could not show the relationship of aneurysms to bone structures, which is very important for aneurysm therapy.

Sensitivity and accuracy of CT angiography for detecting cerebral aneurysms has improved progressively during the evolution from four-section CT angiography to 16-section CT angiography, to the current routine use of 64-section CT angiography (4,13,14). By using four-section CT angiography, Dammert et al (13) reported that the sensitivity was 83.3% for small, 90.6% for medium, and 100% for large aneurysms. Yoon et al (14) studied 85 patients who underwent both 16-section CT angiography and DSA and reported that the overall sensitivity, specificity, and accuracy of 16-section CT angiography on a per-aneurysm basis were 92.5%, 93.3%, and 92.6%, respectively. Li et al (4) studied 96 patients with 107 aneurysms by using 64-section CT angiography and reported that, for aneurysms smaller than 3 mm, sensitivity was 93.7% for reader 1 and 96.8% for reader 2. Currently, 64-section CT angiography allows the detection of most cerebral aneurysms 3 mm or larger and allows the evaluation of the osseous anatomy and 3D rendering of vessels, which most neurosurgeons find helpful (15). Although previous studies showed that conventional CT angiography had a relatively high sensitivity and specificity in the diagnosis of cerebral aneurysms, one major disadvantage was in the detection of small aneurysms near the base of the skull. In addition, the helical scan mode used in these modalities has a major disadvantage of step artifact due to patient motion, which was commonly seen at CT angiography with a 64-section CT scanner (6,16,17). The recent introduction of the 320-detector row volumetric CT scanners significantly increased detector width (160 mm) and allowed whole-brain coverage in a single rotation, apparently resolving the shortcomings of the previous techniques (9–11). Compared with the results of previous studies in which four- to 64-section CT angiography was used, our data suggest that the use of 320-detector row volumetric CT angiography has better diagnostic performance for the detection of cerebral aneurysms.

At our hospital, 320-detector row volumetric CT angiography has been used as a first-line imaging modality to screen patients who present with subarachnoid hemorrhage possibly caused by a ruptured aneurysm. Compared with DSA, volumetric CT angiography is simpler and quicker to organize and perform. In the emergency setting, volumetric CT angiography can be performed immediately after a diagnosis of subarachnoid hemorrhage on the basis of a routine brain CT scan. Confused, agitated, or uncooperative patients need no more than a short-acting sedative for the performance of volumetric CT angiography, and general anesthesia, which is often required during an emergency DSA workup, can be avoided in most cases (18). In our study, all patients with confusion and agitation required general anesthesia before the DSA examinations, while no patient required general anesthesia before the CT angiographic examinations. If volumetric CT angiography showed an aneurysm, a diagnostic-only DSA examination was avoided, especially in patients with aneurysms who appeared to be good candidates for coil placement based on volumetric CT angiographic images. The interventional
neuroradiologists could, on the basis of volumetric CT angiographic results, explain to the patients’ families the purpose and importance of the aneurysm treatment, because most aneurysms were diagnosed definitively by using volumetric CT angiographic images before the endovascular therapy. Therefore, most of the coiled patients underwent DSA examination and endovascular therapy at the same time in our hospital.

We recognize that our study had some limitations. First, our study population included 240 (85%) patients with spontaneous subarachnoid hemorrhage, which may have been related to aneurysm. When there is a high suspicion of an aneurysm being present, expectation bias of the observer could result in high accuracy. Therefore, the relatively high prevalence of subarachnoid hemorrhage in our population may have influenced the sensitivity and specificity of aneurysm detection at 320–detector row volumetric CT angiography. Second, only one reader evaluated the 3D DSA examination, and hence, interobserver variability could not be calculated. This may be important for the reproducibility of our results. Third, in our study, no aneurysms were considered to be false-positive, and the specificity of nonsubtracted and subtracted volumetric CT angiography in detecting aneurysms were both 100% on a per-aneurysm basis. There were two main reasons for this 100% specificity. The primary reason was that volumetric CT angiography was performed by four experienced neuroradiologists with 10 or 13 years of postprocessing experience. Second, the accuracy of 3D DSA was higher than that for conventional DSA for detecting cerebral aneurysms, and 3D DSA could show more aneurysms than conventional DSA alone. In our study, all cerebral aneurysms detected by means of volumetric CT angiography were proved at 3D DSA. Moreover, we observed a patient with a false-positive result in our recent study. Fourth, Jayaraman and Kallmes (19,20) believe that CT angiography is redundant, adds costs, and exposes patients suspected of having aneurysmal subarachnoid hemorrhage to additional radiation and iodinated contrast material. We agree that patients considered suitable for endovascular coiling at CT angiography would eventually undergo DSA for endovascular therapy. However, that does not necessarily mean that CT angiography is a redundant examination. It is well established that emergency CT angiography could help in the choice of aneurysm therapy and the surgical and endovascular treatment of cerebral aneurysms (21–24). In a future study, we will assess the clinical usefulness of 320–detector row volumetric CT angiography in the surgical and endovascular treatment of cerebral aneurysms. Some ruptured aneurysms with mass intraparenchymal hemorrhage showed on 320–detector row volumetric CT angiographic images, and surgical therapy was chosen solely on the basis of volumetric CT angiographic findings.

In conclusion, subtracted 320–detector row volumetric CT angiography is excellent for the detection of cerebral aneurysms and might be considered as a first-line imaging technique for the noninvasive evaluation of cerebral aneurysms because of its high diagnostic accuracy in some circumstances; however, it may still result in some missed microaneurysms. The accuracy of nonsubtracted 320–detector row volumetric CT angiography is lower than that of subtracted

**Figure 3**

Images in a 64-year-old woman with right anterior cerebral artery microaneurysm (1.8-mm diameter) and posterior communicating artery aneurysm. (a) Volume-rendered image from subtracted volumetric CT angiography clearly shows right posterior communicating artery aneurysm (arrowhead) and does not show right anterior cerebral artery microaneurysm (arrow). (b) Three-dimensional DSA image clearly shows right anterior cerebral artery microaneurysm (arrow) and posterior communicating artery aneurysm (arrowheads). When volumetric CT angiography images were retrospectively reviewed, (c) volume-rendered and (d) maximum-intensity projection images from subtracted volumetric CT angiography show right posterior communicating artery aneurysm (arrowheads), and still do not show right anterior cerebral artery microaneurysm (arrow).
Disclosures of Conflicts of Interest: W.H.C.

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