Sixty-Four-Row Multislice Computed Tomographic Angiography in the Diagnosis and Characterization of Intracranial Aneurysms: Comparison with 3D Rotational Angiography

Wei Xing¹, Wenhua Chen², Jing Sheng¹, Ya Peng³, Jianping Lu⁴, Xiaowu Wu⁴, Jianming Tian¹

BACKGROUND: Sixty-four-row multislice computed tomographic angiography (CTA) has great potential for use in vascular studies. The aim of our study was to compare 64-slice CTA with three-dimensional rotational angiography (3DRA) in the detection and characterization of intracranial aneurysms with special attention to smaller (<3-mm) aneurysms.

METHODS: In a prospective study, a total of 133 patients were included who successively underwent 64-slice CTA and digital subtraction angiography (DSA) examinations for suspected intracranial aneurysms. The 64-slice CTA, conventional DSA, and 3DRA images were independently reviewed by five readers who performed the presence, shape, dimension, and location of aneurysms. The 3DRA results were considered as the ultimate reference standard.

RESULTS: The reference standard revealed 111 aneurysms in 93 patients: 27 aneurysms were read as <3 mm, 66 were read as being between 3 and 8 mm, and 18 were read as >8 mm. The sensitivities of 64-slice CTA for aneurysms <3 mm, between 3 and 8 mm, and >8 mm were 96.3%, 98.5%, and 100%, respectively, on a per-aneurysm basis. The sensitivities of conventional DSA for aneurysms <3 mm, between 3 and 8 mm, and >8 mm were 85.2%, 100%, and 100%, respectively, on a per-aneurysm basis. The 64-slice CT angiographic images could clearly show the aneurysmal characteristics and the relationship between aneurysms and adjacent branch vessels.

CONCLUSION: Sixty-four-slice CTA is a highly accurate imaging examination of the first-line imaging technique for detecting and characterizing intracranial aneurysms including <3-mm aneurysms.

INTRODUCTION

The main cause of nontraumatic subarachnoid hemorrhage (SAH) (80% of cases) is rupture of an intracranial aneurysm, an event accompanied by high morbidity and mortality rates (17). The severe SAH rebleeding and death rates may be minimized by means of adequate neurosurgical or endovascular treatment (9). Therefore, prompt diagnosis and therapy of the aneurysms are critical for the patients with nontraumatic SAH. For aneurysm detection, digital subtraction angiography (DSA) has traditionally been considered the gold standard (20). However, DSA has a permanent neurologic complication rate of 0.07%–0.5% in patients examined for suspected intracranial aneurysm and it is invasive, time-consuming, and relatively expensive (10, 24). Hence, an accurate noninvasive imaging method will be invaluable in aneurysm detection.

Computed tomographic angiography (CTA) is a new noninvasive volumetric imaging technique. Imaging acquisition of CTA requires only 1 minute or less, and CTA is well tolerated by the majority of high-risk patients with acute SAH. CTA can be performed after plain computed tomography (CT), and a positive CTA result will not only improve the diagnosis of the patient but also guide the treating procedure, which can be either neurosurgical treatment of the aneurysm or endovascular therapy (2, 3, 5-7).

In previous reports, the diagnostic performance of CTA for aneurysm detection has been compared favorably with that of DSA. However, previous studies with 4- to 16-row CTA have reported limited sensitivity for detecting smaller (<3-mm) aneurysms (8, 19, 21, 26). The recent introduction of 64-row spiral CT scanners has greatly advanced the role of CTA in neurovascular imaging. A 64-slice CT scanner provides thinner collimation, improved z-axis resolution, and shortened acquisition time, which, in turn, may potentially lead to improved detection of the smaller aneurysms (1, 11, 13, 14, 16). Moreover, three-dimensional rotational angiography...
phy (3DRA) may offer increased aneurysm detection, with improved visualization of an aneurysm’s configuration and contour compared with conventional DSA alone (18). The purpose of this prospective study was to assess the accuracy of 64-slice CTA in comparison with 3DRA, in detection and characterization of intracranial aneurysms with special attention to smaller (<3-mm) aneurysms.

PATIENTS AND METHODS

Between July 2008 and October 2009, a total of 157 consecutive patients with suspected intracranial aneurysms were referred to our institution. The patients were scheduled to undergo DSA and prospectively scheduled to undergo comparative CTA. Of them, 13 patients who had undergone prior surgical clipping or endovascular coiling for their intracranial aneurysm were excluded from the study because we believed that postoperative follow-up with CTA is a different issue. Another 11 patients who did not undergo DSA because of rapid clinical deterioration were also excluded from our study. There was no patient with contraindication to intravenously administered iodinated contrast material in this series. Thus, our study population consisted of 133 patients; this group included 63 men and 70 women (age range, 9–87 years; mean age, 52 years). Patients were selected by the referring physicians for CTA on the basis of clinical history, including symptoms and signs suggestive of intracranial aneurysm. Eighty-seven of these 133 patients had SAH, 16 patients had SAH and intraventricular hemorrhage, 7 patients had SAH and IPH, 6 patients had IPH, 2 patients had SAH, intraventricular hemorrhage, and IPH, and the remaining 15 patients had a variety of indications, including headache, oculomotor paralysis, tumor, trauma, and hydrocephalus.

64-Slice CTA Acquisition

The CTA study was performed with a 64-row multislice CT machine (Somaton Sensation 64; Siemens Medical Systems, Forchheim, Germany) with the following acquisition and reconstruction parameters: rotation time of 0.5 seconds, pitch of 1, 100 kVp, 200 effective milliamps, slice thickness 0.75 mm, and reconstruction interval of 0.40 mm. Contrast enhancement was provided by the intravenous antecubital administration of an 85-100 mL bolus of nonionic iodinated contrast material (Xenetix 350 mg I/mL; Guerbet, Aulnay-sous-Bois, France) at a 3.5 mL/s flow rate and with an

<table>
<thead>
<tr>
<th>Table 1. Data of the False-Negative Aneurysms for 64-Slice Computed Tomographic Angiography and 2D Digital Subtraction Angiography</th>
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<tbody>
<tr>
<td>Aneurysm Location</td>
</tr>
<tr>
<td>Right PCoA</td>
</tr>
<tr>
<td>Right SCA</td>
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<tr>
<td>ACoA</td>
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<tr>
<td>ACoA</td>
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<td>ACoA</td>
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<td>ACoA</td>
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ACoA, anterior communicating artery; CTA, computed tomographic angiography; DSA, digital subtraction angiography; PCoA, posterior communicating artery; SCA, superior cerebellar artery; 3DRA, three-dimensional rotational angiography.
imaging start delay determined by a bolus
tracking facility and a threshold fixed at 100
Hounsfield units. The CTA was initiated
16–28 seconds (mean time, 18.3 seconds)
after the start of an IV infusion. A caudocran-
ial scanning direction was selected, cover-
ing the volume extending from the first cer-
vascular vertebra to the superior aspect of the
frontal sinuses. In six patients with confu-
sion or agitation or both, intravenous seda-
tion was administered before the CTA ex-
aminations.

Protocol for DSA
All of the DSA examinations were per-
formed within 3 days after CTA. Intra-arte-
rificial was performed with femoral cath-
eterization by the Seldinger technique with
a DSA unit (AXIOM Artis dTA; Siemens
Medical Systems) that has rotational capa-
ibilities. Nonionic contrast material (Om-
nipaque 350 mg I/mL; Amersham Life Sci-
ence, Clearbrook, Illinois, USA) was used in
all cases. All injections in the angiography
suite were performed with a power injector
(Medrad, Stellant, Pennsylvania, USA). Se-
lective carotid angiograms usually con-
sisted of one anteroposterior, one lateral,
and one to two oblique views. The runs con-
sisted of a 38-cm field of view (anteroposte-
rior), 30-cm field of view (lateral and
oblique), and a 1024 × 1024 matrix. The
spatial resolution was 0.32 × 0.32 mm.
While the catheter was within each of the
three major arteries (bilateral internal ca-
rotid and ≥1 vertebral artery), standard an-
teroposterior, lateral, and oblique DSA runs
were obtained; a single rotational 3DRA ac-
quision was typically obtained before re-
moving the catheter from each vessel. The
DSA examinations required 50–70 minutes
to perform (mean 60 minutes).

Review Process
All CTA and DSA images were indepen-
dently evaluated on the workstations by five
neuroradiologists who had 10 (W.X., W.C.)
and 5 (J.S., J.T., Z.H.) years of experience in
CT vascular imaging and angiography. The
five readers were blinded to the assess-
ments of the other technique or of the other
investigator only knew that the patients
were suspected of having intracranial aneu-
rysms. Two neuroradiologists (W.X., W.C.)
independently interpreted CTA images to
detect and evaluate intracranial aneurysms.
Reconstructed CT images were read on a
clinical workstation (Leonardo; Siemens
Medical Systems) with maximum-intensity
projection and volume-rendering tech-
nique. The total examination time for CTA
was approximately 12 minutes per case. If
an aneurysm was detected, several morpho-
logic characteristics were evaluated: aneu-
rysmal location, size and morphology, its
parent and feeding vessels and finally rela-
tionship to other structures such as bone.
The aneurysm maximal diameter, dome (D)
and neck (N) dimensions were measured. All
of the measures were performed on the max-
imum-intensity projection images by the
workstation; the aneurysm diameter, dome
and neck dimensions were measured at a se-
lected projection, which allowed the optimal
demonstration of the neck of the aneurysm.
Each CTA reader performed an indepen-
dent measurement of the aneurysm, and results were averaged. In discordant cases, a definite unique result was reached by consensus. We have classified aneurysm diameter into three grades: large (8 mm), medium (3–8 mm), and small (<3 mm). The N/D ratio was calculated: narrow (N/D ratio <0.50), intermediate (N/D ratio, 0.50–0.80), and broad (N/D ratio >0.80). When CTA failed to clearly demonstrate an aneurysm, 3DRA images were used to measure the size of the missed aneurysm. The image quality of CTA was rated given the following criteria: (a) excellent quality, in which all intracranial vascular structures are clearly visualized; (b) moderate quality, in which some vascular structures are obscured by artifacts; and (c) poor quality, in which vascular structures are poorly visualized. The DSA studies were reviewed by the three experienced interventional neuroradiologists (J.S., J.T., Z.H.) blinded to CTA results. The conventional DSA images were evaluated on monitors by one interventional neuroradiologist (J.S.). The 3DRA images were evaluated on an adjacent 3D workstation (Syngo Inspace; Siemens Medical Systems) by two interventional neuroradiologists (J.T., Z.H.). The three readers also assessed the presence of an aneurysm, its location, its size and morphology.

### Table 2. Diagnostic Performance of 64-Slice Computed Tomographic Angiography and 2D Digital Subtraction Angiography According to Lesion Size

<table>
<thead>
<tr>
<th>Aneurysm Size (Reader)</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>Accuracy (%)</th>
<th>PPV (%)</th>
<th>NPV (%)</th>
</tr>
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<tbody>
<tr>
<td>&lt;3 mm</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>CTA reader 1</td>
<td>96.3 (26/27)</td>
<td>100 (40/40)</td>
<td>98.5 (66/67)</td>
<td>100 (26/26)</td>
<td>97.6 (40/41)</td>
</tr>
<tr>
<td>(81.0–99.9)</td>
<td>(91.2–100*)</td>
<td>(92.0–100)</td>
<td>(86.8–100*)</td>
<td>(87.1–99.9)</td>
<td></td>
</tr>
<tr>
<td>2D-DSA reader</td>
<td>85.2 (23/27)</td>
<td>100 (40/40)</td>
<td>94.0 (63/67)</td>
<td>100 (23/23)</td>
<td>90.9 (40/44)</td>
</tr>
<tr>
<td>(66.3–95.8)</td>
<td>(91.2–100*)</td>
<td>(85.4–98.3)</td>
<td>(85.2–100*)</td>
<td>(78.3–97.5)</td>
<td></td>
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<tr>
<td>3–8 mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CTA reader 1</td>
<td>98.5 (65/66)</td>
<td>100 (40/40)</td>
<td>99.1 (105/106)</td>
<td>100 (65/65)</td>
<td>97.6 (40/41)</td>
</tr>
<tr>
<td>(91.8–100)</td>
<td>(91.2–100*)</td>
<td>(94.9–100)</td>
<td>(94.5–100*)</td>
<td>(87.1–99.9)</td>
<td></td>
</tr>
<tr>
<td>2D-DSA reader</td>
<td>100 (66/66)</td>
<td>100 (40/40)</td>
<td>100 (106/106)</td>
<td>100 (66/66)</td>
<td>100 (40/40)</td>
</tr>
<tr>
<td>(94.6–100*)</td>
<td>(91.2–100*)</td>
<td>(95.6–100*)</td>
<td>(94.6–100*)</td>
<td>(91.2–100*)</td>
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<td>&gt;8 mm</td>
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<tr>
<td>CTA reader 1</td>
<td>100 (18/18)</td>
<td>100 (40/40)</td>
<td>100 (58/58)</td>
<td>100 (18/18)</td>
<td>100 (40/40)</td>
</tr>
<tr>
<td>(81.5–100*)</td>
<td>(91.2–100*)</td>
<td>(93.8–100*)</td>
<td>(81.5–100*)</td>
<td>(91.2–100*)</td>
<td></td>
</tr>
<tr>
<td>2D-DSA reader</td>
<td>100 (18/18)</td>
<td>100 (40/40)</td>
<td>100 (58/58)</td>
<td>100 (18/18)</td>
<td>100 (40/40)</td>
</tr>
<tr>
<td>(81.5–100*)</td>
<td>(91.2–100*)</td>
<td>(93.8–100*)</td>
<td>(81.5–100*)</td>
<td>(91.2–100*)</td>
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</table>

The numbers in the first parentheses are the numbers of aneurysms, and the numbers in the second parentheses are the 95% CIs.

CTA, computed tomographic angiography; DSA, digital subtraction angiography; NPV, negative predictive value; PPV, positive predictive value; 3DRA, three-dimensional rotational angiography; 2D, two-dimensional.

*One-sided 97.5% CIs.

RESULTS

All of the CTA images were diagnostic, and there were no technical failures or complications during scanning. The quality of the images was excellent in 130 patients (98%) and moderate in three patients (2%). Moderate CTA image quality was the result of the following: a late acquisition time with venous-phase imaging in one patient and the presence of motion artifacts in two patients.

The 3DR angiographic readers identified 111 aneurysms in 91 patients for each of the two independent readers, and the assessment of both readers was the same. The interobserver agreement was very good (K = 1.0). According to the 3DRA reference standard, no aneurysm was present in 40 patients: 32 had negative findings, 6 had arteriovenous malformation, and 2 had moyamoya disease. In addition, 93 patients had at least one intracranial aneurysm: 77 patients had one aneurysm; 14 patients, two aneurysms; and 2 patients, three aneurysms. Ninety-six aneurysms were saccular in morphology, 10 irregular, and 5 fusiform. The most common location for all the aneurysms was PCoA (27%), and the second location was ACoA (25%). The CTA interobserver agreement of average measurements was very good (K = 1.0). Twenty-seven (24%) of 111 aneurysms were read as <3 mm, 66 (60%) were read as being between 3 and 8 mm, and 18 (16%) were read as >8 mm. The aneurysm maximal diameter ranged from 1.2 to 32.0 mm (mean size = 6.0 mm), the aneurysm neck size ranged from 1.0 to 9.0 mm (mean size = 3.3 mm), the aneurysm dome size ranged from 1.0 to 26.8 mm (mean size = 4.7 mm), and the mean N/D ratio was 0.80 ranging from 0.19 to 1.36.

The CTA readers identified 109 aneurysms in 91 patients for each of the two independent readers, and the assessment of
Figure 3. Images from a 33-year-old woman with a small anterior communicating artery aneurysm (2.2 mm diameter). Volume-rendering technique and maximum-intensity projection images (A, B) from computed tomographic angiography definitely depict the small aneurysm (arrow). Conventional digital subtraction angiographic (DSA) images (C, D) fail to clearly detect the small aneurysm initially, which is proved by the three-dimensional rotational angiographic image (E) (arrow). When conventional DSA images were viewed retrospectively, the anterior communicating artery aneurysm could be diagnosed by the conventional DSA reader (arrow). Volume-rendering technique image (F) from computed tomographic angiography displays the aneurysm occluded by one titanium clip (arrow).

Table 3. Diagnostic Performance of 64-Slice Computed Tomographic Angiography and 2D Digital Subtraction Angiography in Detecting Aneurysms on Per-Aneurysm and Per-Patient Bases

<table>
<thead>
<tr>
<th>Aneurysm Size (Reader)</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>Accuracy (%)</th>
<th>PPV (%)</th>
<th>NPV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per-aneurysm</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>CTA reader 1</td>
<td>98.2 (109/111)</td>
<td>100 (40/40)</td>
<td>98.7 (149/151)</td>
<td>100 (109/109)</td>
<td>95.2 (40/42)</td>
</tr>
<tr>
<td>(93.6–99.1)</td>
<td>(91.2–100*)</td>
<td>(95.3–99.8)</td>
<td>(96.7–100*)</td>
<td>(83.8–99.4)</td>
<td></td>
</tr>
<tr>
<td>2D-DSA reader</td>
<td>96.4 (107/111)</td>
<td>100 (40/40)</td>
<td>97.4 (147/151)</td>
<td>100 (107/107)</td>
<td>90.9 (40/44)</td>
</tr>
<tr>
<td>(91.0–99.0)</td>
<td>(91.2–100*)</td>
<td>(93.4–99.3)</td>
<td>(96.6–100*)</td>
<td>(78.3–97.5)</td>
<td></td>
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<tr>
<td>Per-patient</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>CTA reader 1</td>
<td>97.8 (91/93)</td>
<td>100 (40/40)</td>
<td>98.5 (131/133)</td>
<td>100 (91/91)</td>
<td>95.2 (40/42)</td>
</tr>
<tr>
<td>(92.4–99.7)</td>
<td>(91.2–100*)</td>
<td>(94.7–99.8)</td>
<td>(96.0–100*)</td>
<td>(83.8–99.4)</td>
<td></td>
</tr>
<tr>
<td>2D-DSA reader</td>
<td>95.7 (89/93)</td>
<td>100 (40/40)</td>
<td>97.0 (129/133)</td>
<td>100 (89/89)</td>
<td>90.9 (40/44)</td>
</tr>
<tr>
<td>(89.4–98.8)</td>
<td>(91.2–100*)</td>
<td>(92.5–99.2)</td>
<td>(95.9–100*)</td>
<td>(78.3–97.5)</td>
<td></td>
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</tbody>
</table>

The numbers in the first parentheses are the numbers of aneurysms, and the numbers in the second parentheses are the 95% CIs. CTA, computed tomographic angiography; DSA, digital subtraction angiography; NPV, negative predictive value; PPV, positive predictive value; 3DRA, three-dimensional rotational angiography; 2D, two-dimensional.

*One-sided 97.5% CIs.
both observers was the same. The interobserver agreement was very good ($K = 1.0$).

Two aneurysms identified by 3DRA images were not depicted by the two CTA readers initially, and the two aneurysms were considered as false-negative interpretations with 64-slice CTA. Data on missed aneurysms are listed in Table 1. When CTA images were viewed retrospectively, the missed PCoA aneurysm (1.5-mm-diameter) was displayed on the CTA image (Figure 1), and the missed SCA aneurysm (3.9-mm-diameter) still failed to be detected by the two CTA readers (Figure 2). No aneurysm was considered as false-positive interpretation with 64-slice CTA. Because the CTA reader 1 and reader 2 results are consistent, only the statistical results of CTA reader 1 are listed here. The statistical results of conventional DSA were provided in Figures 3 and 5D. No aneurysm was considered as false-positive interpretation with conventional DSA. Data on missed aneurysms were not depicted by the two CTA readers initially, and the two aneurysms were considered as false-negative interpretations with conventional DSA. Data on missed aneurysms are listed in Tables 2 and 3. There was no statistically significant difference in accuracy among the three imaging techniques (Fisher’s exact test, between 64-slice CTA and 3DRA, $P = 0.50 > 0.05$, between conventional DSA and 3DRA, $P = 0.13 > 0.05$, between conventional DSA and 64-slice CTA, $P = 0.69 > 0.05$).

Seventeen aneurysms underwent surgery, and surgical findings were well correlated with surgical views generated with the CTA data (Figures 3 and 5). The titanium clips used to treat these 17 aneurysms did not appear to cause significant scatter artifacts on CTA images (Figures 3F and 5D). Sixty-nine aneurysms were treated by embolization, and the CTA data provided information for making a decision to perform coil embolization (Figure 6). Twenty-five aneurysms were not treated and followed.

**DISCUSSION**

There have been numerous studies regarding the diagnostic accuracy of CTA in helping detect intracranial aneurysms. Numerous reports have been published that describe a relatively low sensitivity of CTA in detecting small aneurysms. Dammert et al. (8) studied 39 patients with 48 aneurysms using four-slice CTA, and reported that the sensitivity was 83.3% for small (<4 mm), 90.6% for medium-size (5–12 mm), and 100% for large (>12 mm) aneurysms. Tekasam et al. (19) investigated 103 patients admitted for four-slice CTA; they detected 49 small intracranial aneurysms (<5 mm) in 37 (36%) of 103 patients, with overall sensitivity, specificity, and accuracy for detecting aneurysms <5 mm of 85%, 65%, and 79%, respectively. Yoon et al. (26) studied 85 patients with suspected intracranial aneurysm who underwent both 16-slice CTA and DSA, and reported that the overall sensitivity, specificity, and accuracy of 16-slice CTA on a per-aneurysm basis were 92.5%, 93.3%, and 92.6%, respectively, for both independent readers. For aneurysms of <3 mm, however, 16-slice CTA had a sensitivity of 74.1% for reader 1 and 77.8% for reader 2. In another study, investigators reported that 16-slice CTA demonstrated sensitivity and specificity of CTA were 96.2% and 100%, respectively; however, for aneurysms of <3 mm, 16-slice CTA had a sensitivity of 91.7% for each reader (21).
Three studies on 64-slice CTA have shown slightly improved results for the detection of small aneurysms (11, 13, 14). In a study of 28 patients with 41 aneurysms, the authors found that sensitivity of 64-slice CTA was 92.3% for <4-mm aneurysms (14). In another study of 48 patients, the sensitivity of 64-slice CTA was 81.8% for <3-mm aneurysms (13). Li et al. (11) studied 96 patients with 107 aneurysms using 64-slice CTA and reported that for <3-mm aneurysms sensitivity was 93.7% for reader 1 and 96.8% for reader 2.

Compared with previous studies of 64-slice CTA, we reported high sensitivity for <3-mm aneurysms (11, 13, 14). In our study, we found that the sensitivity of 64-slice CTA in detecting small aneurysms (<3 mm) was all 96.3% for both CTA readers. The result was attributable to the 64-slice CT technology, which could provide better postprocessing software, thinner collimation, and shortened acquisition time. In addition, the CTA readers had 10 years of experience in CT vascular imaging. To our knowledge, our comprehensive study of 64-slice CTA and 3D-DSA is the largest study to date. From our experience, we can observe that the accuracy of 64-slice CTA in detecting small (<3 mm) and medium-size (3–8 mm) aneurysms was 98.5% and 99.1%, respectively (Table 2). For the interpretation of 64-slice CTA images, only two aneurysms failed to be detected by both CTA readers during the initial reading in our study. The two missed aneurysms were located at the PCoA and distal SCA, respectively (Table 1). When CTA images were viewed retrospectively, the missed PCoA aneurysm was displayed on the CTA image (Figure 1), and the missed SCA aneurysm still failed to be detected. Moreover, the SCA aneurysm also could not be clearly visible on early arterial-phase DSA image (Figure 1). The primary reason for the missed PCoA aneurysm seemed to be the small size (1.5 mm diameter) of the aneurysm in addition to its proximity to bone and looking like a widened infundibulum (Figure 1). In addition, when conventional DSA and 3D-DSA images were viewed retrospectively, the conventional DSA readers also considered that the PCoA “aneurysm” might be a prominent infundibulum. In the previous reports (13, 26), some PCoA aneurysms were considered as prominent infundibulum, and the prominent infundibulum could be also mistaken for PCoA aneurysms by CTA images. The reason for the missed SCA aneurysm (3.9-mm-diameter) should seem to the distal location and minor parent artery, and early arterial phase failed to display the missed aneurysm (Figure 2), which was the cause that the sensitivity and accuracy of 64-slice CTA in detecting medium aneurysms in our study were slightly lower than that of previous study (11). The 64-slice CTA had 100% sensitivity for >3-mm-sized aneurysms in the previous studies (13, 14, 15).

In our study, all aneurysms detected by 64-slice CTA could be clearly depicted at 3DRA images, which was the cause that the specificity and positive predictive value of 64-slice CTA in aneurysm detection were all 100%. In our previous study (7), an aneurysm without 3DRA or surgical confirmation was considered to be a false-positive interpretation with CTA, and the specificity of 16-slice CTA in the detection of all aneurysms was 90.1% on a per-aneurysm basis. The increased speed of 64-slice scanners facilitates the coupling of image acquisition with peak vascular enhancement, which may provide isotropic data with spatial resolution comparable to those of DSA. Therefore, the improved diagnostic accuracy and specificity of our study depend on the technical advancements of 64-slice CT scanner and 3D-DSA unit.

Traditionally, conventional DSA has been considered the gold standard in aneurysm detection (19, 20, 25). In some previous reports, when intracranial aneurysms identified by CTA were not found by conventional DSA, the result was considered false positive for CTA (19, 20, 25). However, in fact, the result was not necessarily false positive, for conventional DSA might have missed some extremely small aneurysms. In our previous study of 192 patients (4), we found that three small aneurysms identified by CTA were not clearly depicted in the conventional DSA images. These patients were treated on the basis of CTA information alone and were confirmed to have aneurysms. False-negative aneurysms were also reported in another study.
of 94 patients in which conventional DSA was used (15). Consistent with previous reports, 3DRA was also found to be able to depict more aneurysms than conventional DSA alone in our study, and four aneurysms missed by conventional DSA were clearly visible on 3DRA images and were all located at the ACoA (Figures 3 and 4). When conventional DSA images were viewed retrospectively, three missed ACoA aneurysms were detected on the conventional DSA images (Figure 3), and the other missed ACoA aneurysm still failed to be displayed (Figure 4). The primary reason for this seemed to be the 2D method as well as the location and small size of the aneurysms (Table 1). Moreover, the conventional DSA reader had only 5 years of experience in cerebral angiography. With the increase of observers’ experience, the probability of missed aneurysms would decrease. If the aneurysms missed by conventional DSA were not confirmed by 3DRA, the aneurysms would be considered as false-positive interpretations for CTA (Figures 3 and 4). 3DRA images could more clearly show the characterization of intracranial aneurysms (Figures 5 and 6). Therefore, our study indicated 3DRA rather than conventional DSA should be considered the gold standard in aneurysm detection. In addition, there are previous studies, even using 64-slice CTA, that also demonstrate an increased accuracy and point toward 3DRA being the gold standard (13, 14).

Compared with DSA, CTA is simpler and quicker to organize and perform. In the emergency setting, CTA can be performed immediately after a diagnosis of SAH has been given based on a routine plain CT scan of the brain. Confused, irritable, or uncooperative patients need no more than a short-acting sedative to complete CTA and a complete diagnostic workup can be performed without general anesthesia in most cases, which is often required during an emergency angiographic workup (25). In the present study, only six patients with confusion or agitation or both had been administered intravenous sedation before the CTA examinations, and there were no technical failures or complications during scanning. Presurgical knowledge of adjacent nonvascular anatomy and relationship to other structures such as bone are some benefits of CTA relative to DSA. In addition, CTA may be able to better characterize giant aneurysms and their adjacent vital structures, although these aneurysms may not entirely fill even with a larger bolus during catheter angiography. Hence, in our hospital, 64-slice CTA has been employed as a first-line imaging modality in screening patients with SAH possibly caused by ruptured aneurysms. In addition, the 64-slice CTA is also an accurate noninvasive tool used for assessment of clipped aneurysms, the titanium clips do not appear to cause significant scatter artifacts on CTA images (Figures 3F and 5D), and it may be a valuable tool for the screening and management of aneurysm clip placement in patients after surgical clipping.

There have been important technical advances including smaller catheters, hydrophilic guide wires, and digital imaging systems (12, 23). However, the technical advances in cerebral angiography have not overcome the patient-related risk factors associated with neurologic complications. The risk of neurologic complications increases with age. Cardiovascular disease and fluoroscopic times longer than 10 minutes were independent predictors of risk. These findings substantiate the argument that patients at a higher risk should undergo minimally invasive imaging of the craniovascular vessels and that catheter angiography should be avoided. In patients without these risk factors, neurologic complications still occur and, therefore, the indications for catheter angiography should be limited (24). In our study, most (98%) aneurysms have been definitely diagnosed by 64-slice CTA images (Figures 3-6), most of the coiled patients underwent DSA examination and endovascular therapy simultaneously, and a purely diagnostic DSA examination could be avoided during the endovascular therapy. Therefore, we believe that most aneurysms could be directly treated with endovascular coiling or surgical clipping, and a purely diagnostic DSA examination should be limited for reducing neurologic complications.

We recognize that our study has some limitations. First, our study population included patients with a variety of symptoms (which may have been related to aneurysm), although most (84%) had SAH. When there is high suspicion of an aneurysm being present, a high estimate of accuracy could result owing to observer expectation bias. Therefore, the relatively high prevalence of SAH in our population may have influenced the sensitivity and specificity of aneurysm detection by 64-slice CTA. Second, this trial has only one reader evaluated in the conventional DSA study, and hence interobserver variability could not be calculated. This may be important in the reproducibility of the results of our study. Third, noninvasive 64-slice CTA is only an accu-
rate imaging method for the detection of intracranial aneurysms and has no role in intraoperative cerebral angiography, which is the ideal study in the setting of clipping, or in the detailed control angiograms done in the setting of coiling. Therefore, there is less of an advantage of noninvasive imaging such as CTA in the setting of planned clipping or coiling. Fourthly, 64-slice CTA could not offer the hemodynamic evaluation of the aneurysms, especially in the giant aneurysms, which is very useful for the surgical treatment of aneurysms.

**CONCLUSION**

This study suggests that 64-slice CTA is excellent in the detection and delineation of intracranial aneurysms including smaller (<3 mm) aneurysms, and, in comparison with the available literature, is probably better than 4- or 16-slice CTA; the 64-slice CTA is a highly accurate imaging examination of the first-line imaging technique in aneurysm detection. The 3DRA should be considered the gold standard in detection of intracranial aneurysms, because 64-slice CTA and conventional DSA may still miss some aneurysms in particular locations.

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