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### Authors: W. Cai\(^1\), J. Gong\(^1\), W. Zhang\(^1\), J. Zhu\(^1\), K. Zhao\(^2\), S. Wang\(^2\), Y. Kang\(^2\); \(^1\)Suzhou/CN, \(^2\)Shenyang/CN
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Purpose

To compare the diagnostic performance of 3D and 2D bone subtraction CT angiography (BSCTA) with conventional CTA and digital subtraction angiography (DSA) for the detection of intracranial aneurysms.
Methods and Materials

1. Patient Population

This study was approved by the ethics committee of the second affiliated hospital of Soochow University. Informed consent was obtained from all patients. Between August 2009 and June 2010, 63 consecutive patients (35 men and 28 women; mean age 50.90±15.72 years) who underwent non-contrast-enhanced cranial computed tomography (NECT) followed by conventional CTA were retrospectively included in this study. The indication for all examinations was suspicion of intracranial aneurysms. Of 63 patients 50 presented with acute SAH. All patients also had to undergo either DSA examination or surgery for inclusion in our study.

2. Imaging Protocols

All CTA studies were performed with a 64-row multidetector CT system (LightSpeed VCT; GE Healthcare). All patients’ heads were fixed during CT imaging to prevent motion artifacts. For BSCTA, we added a NECT before the conventional CTA protocol that we regularly use in clinical settings. The CT parameters were as follows: 100 kV, 300 mAs; pitch 0.983; 0.6-mm section collimation; 0.625-mm reconstruction interval; matrix 512×512; 180- to 240-mm field of view. The CT examination extended from the first cervical vertebra to the cranial vault. A total of 70 mL of contrast agent (Ultravist, 370 mg iodine/mL; Schering, Germany) was injected through an 18-gauge needle into the antecubital vein by a power injector at a rate of 5 mL/s. The test bolus method was employed to determine the imaging delay for each patient.

Then the reconstructed axial images were respectively sent to the GE’s workstation (Advantage for Windows 4.3) and the Neusoft’s workstation for BS. Bone removal was performed by subtraction of the NECT data from the conventional CTA data using the dedicated software (3D BS of Neusoft's BSCTA tool and 2D BS of GE's Add/Sub). The principles of the Add/Sub software were that the two data sets (NECT and conventional CTA) were registered in a two-dimensional way by subtraction of the NECT data from the conventional CTA data slice by slice, and then the subtracted isotropic data sets were reformatted into 3D VR and MIP images for further review. The details of BSCTA tool software were that the two data sets were registered in a three-dimensional way; it selectively eliminated bones and soft tissues from the conventional CTA data sets while only contrast-enhanced vessels remained for further evaluation. But in our study, owing to the different ways of display of cervical and cerebral vasculature on GE and Neusoft’s workstation, the Neusoft's dedicated software must transform 3D subtracted isotropic data sets into 2D data sets, and then were transferred to the GE's workstation (Advantage for Windows 4.3) for 3D reconstruction including VR and MIP.
DSA was performed in all patients with femoral catheterisation by the Seldinger technique with a plane DSA unit (Allura Xper FD20, Philips Healthcare). DSA was performed with selective bilateral common carotid artery and vertebral artery injections. Anteroposterior, lateral and oblique DSA views were obtained and additional views were acquired at the discretion of the angiographer.

3. Image Interpretation

All CT angiograms were randomized before image interpretations. Two experienced radiologists who were blinded to the DSA results and the assessments of the other investigator, independently evaluated the CT angiograms. All aneurysms were assessed based on source images as well as 3D VR and MIP angiograms. In the interpretation of 3D, 2D BS and conventional CT angiograms, the readers had to evaluate the presence or absence of an aneurysm. The location, maximal sac diameter and neck size were also evaluated and recorded. The possibility of endovascular treatment or the surgical clipping of aneurysms was assessed based on the information provided by CT angiograms alone. The image quality of 3D, 2D BSCTA was rated as: 1, optimal image quality when only vascular structures were present; 2, suboptimal image quality when some bone remnants were visible but was adequate for diagnosis; 3, poor image quality when large bone remnants were present and caused problems in interpretation of aneurysms.
Results

All the 3D, 2D BSCTA were diagnostic. The image quality of 3D and 2D BSCTA was optimal respectively in 60 and 59 of 63 patients. For one patient, 3D BSCTA was rated optimal but 2D BSCTA was rated suboptimal due to artifacts of incomplete bone removal produced by mild head motion during the imaging process. For four patients, 3D, 2D BSCTA were rated suboptimal due to artifacts of incomplete bone removal produced by severe head motion during the imaging process.

1# Detection of aneurysms

According to the DSA and intraoperative findings, 66 aneurysms were present in 54 patients (Table 1). No aneurysms were detected in 9 patients. A single aneurysm was detected in 45 patients. Nine patients had multiple aneurysms: six patients had two aneurysms and three patients had three aneurysms. According to 3D BSCTA measurements, the average maximal aneurysm sac diameter was 4.2 mm (range 1.5-15.7 mm). The average neck size was 3.4 mm (range 1.0-9.3 mm).

For 3D BSCTA, both reader 1 and reader 2 identified all aneurysms in our patient cohort. For 2D BSCTA, reader 1 identified all aneurysms in our patient cohort, but reader 2 prospectively detected 65 aneurysms in 53 patients. One aneurysm located at the left communicating (C7) segment of the internal carotid artery was missed by reader 2 in a patient due to artifacts of incomplete bone removal produced by mild head motion during the imaging process. In a retrospective review of the 2D BSCTA images, both readers found that the left C7 segment of the internal carotid artery aneurysm was clearly present on VR and MIP angiograms, but was overlooked by reader 2 during the initial reading (Fig. 1). On a per-aneurysm and per-patient basis, the sensitivity and specificity of 3D BSCTA were both 100% for reader 1 and reader 2. However, the sensitivity of 2D BSCTA was 100% for reader 1, and 98.5% reader 2 on a per-aneurysm basis, and the sensitivity of 2D BSCTA was 100% for reader 1, and 98.1% reader 2 on a per-patient basis. There was excellent interobserver agreement (#=0.84 for 3D BSCTA, #=0.82 for 2D BSCTA) between two independent readers.

Conventional nonsubtracted CTA prospectively detected 62 out of 66 aneurysms in 52 patients. In a blinded review of conventional CT angiograms, reader 1 successfully detected 62 aneurysms and reader 2 correctly identified 61 aneurysms. Four aneurysms were missed by both readers. In one patient with SAH, one M1 segment of the left middle cerebral artery aneurysm was missed by reader 2 during the initial reading. Subsequent analysis of the images revealed that conventional CTA only allowed partial visualisation of the missed aneurysm (Fig. 2). However, the aneurysm was correctly identified on retrospective reading. Of the four aneurysms not detected by both readers, three were located at the clinoid (C5) segment of the internal carotid artery in a patient (Fig. 3) and the remaining one was located at the left ophthalmic (C6) segment of the internal carotid artery.
artery in a patient (Fig. 4). On a per-aneurysm basis, the sensitivity of conventional CTA was 93.9% for reader 1, and 92.4% for reader 2. However, the sensitivity of conventional CTA was 96.3% for reader 1, and 94.4% for reader 2 on a per-patient basis.

2# Pretreatment evaluation

For all patients, appropriate treatment decisions could be made based on 3D BSCTA images. For 53 of the 54 (98.1%) patients, appropriate treatment decisions could be made based on 2D BSCTA images. However, conventional CTA provided sufficient information to make this decision for 46 out of 51 (90.2%) patients. According to 3D BSCTA assessments, 34 patients were eligible for endovascular coiling, 18 patients were referred for surgical clipping, and 2 patients were suitable for conservative treatment. After DSA examination, surgical clipping or endovascular coiling was performed to treat 61 aneurysms in 52 patients. Five aneurysms were not treated because they were very small noncausative aneurysms in patients with multiple aneurysms. Of the 52 patients treated, successful coiling was achieved in 34 patients and the remaining 18 patients underwent surgical clipping.

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PCA posterior cerebral artery, ACA anterior cerebral artery, MCA middle cerebral artery, AcomA anterior communicating artery, PcomA posterior communicating artery, ICA internal carotid artery, VA vertebral artery, BA basilar artery
Images for this section:

Fig. 0: A 68-year-old man with left C7 segment of the internal carotid artery aneurysm. a-a’ 2D BSCTA VR and MIP angiograms illustrating the left C7 segment of the internal carotid artery aneurysm (arrow) despite a few bone remnants remaining at the internal carotid artery. Reader 2 missed the aneurysm during the initial reading. b-b’ 3D BSCTA VR and MIP images clearly showed the left C7 internal carotid artery aneurysm (arrow) due to optimal image quality when no bone remnant. c DSA images showing the left C7 segment of the internal carotid artery aneurysm (arrow)

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Fig. 0: Images in a patient with false-negative left middle cerebral artery aneurysm. a-a’ Conventional CTA VR and MIP angiograms allow partial visualisation of the bifurcation of
the M1 segment of the left middle cerebral artery aneurysm (arrow). The aneurysm was missed by reader 2 during the initial reading. b-b' Despite a few bone remnants remaining at the skull base which don't influence the diagnosis of the aneurysm, 2D BSCTA VR and MIP angiograms clearly delineate the shape and direction of the aneurysm (arrow). c-c' 3D BSCTA VR and MIP images also clearly show the relationship of three-dimensional space between the aneurysm (arrow) and the parent artery. The image quality is optimal because of no bone remnant. d DSA showing the bifurcation of the M1 segment of the left middle cerebral artery aneurysm (arrow)

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Fig. 0: A 77-year-old woman with SAH and three false-negative aneurysms on conventional CTA. The three aneurysms were surgically treated based on 2D and 3D BSCTA results. a-a' Conventional CTA VR and MIP images failed to detect the three C5 internal carotid artery aneurysms because of overlying bones. b-b' Despite some bone remnants remaining at the skull base, 2D BSCTA VR and MIP angiograms clearly depicted the three aneurysms (arrows). c-c' 3D BSCTA VR and MIP images clearly showed the three C5 internal carotid artery aneurysms (arrows) due to optimal image quality when no bone remnant and only arteries were present

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Fig. 0: A 73-year-old woman with SAH and one false-negative aneurysm on conventional CTA. a-a’ Conventional CTA VR and MIP angiograms failed to detect the C6 segment of the internal carotid artery aneurysm because of overlying bones. b-b’ 2D BSCTA VR and MIP images clearly depicted the aneurysm (arrow). c-c’ 3D BSCTA VR and MIP angiograms clearly showed the C6 segment of the internal carotid artery aneurysm (arrow). d The aneurysm was also clearly showed with DSA (arrow)

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Conclusion

Conventional CTA has limited sensitivity in detecting very small aneurysms as well as aneurysms adjacent to bone. BSCTA especially of Neusoft’s 3D BSCTA software performed on a 64-row multidetector CT is an accurate and promising diagnostic tool that seems to be equivalent to DSA for the detection and pretreatment planning of intracranial aneurysms.
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Personal Information

JianPing Gong, MD. PhD.
Department of Radiology, The Second Affiliated Hospital of Soochow University, Suzhou, China
E-mail#gongjianpingsz@126.com