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Detection of intracranial aneurysms using three-dimensional multidetector-row CT angiography: Is bone subtraction necessary?

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Purpose: The aim of this study was to evaluate the usefulness of three-dimensional CT angiography (3D CTA) with bone subtraction in a comparison with 3D CTA without bone subtraction for the detection of intracranial aneurysms.
Materials and methods: Among 337 consecutive patients who had intracranial aneurysms detected on 3D CTA, 170 patients who underwent digital subtraction angiography (DSA) were included in the study. CTA was performed with a 16-slice multidetector-row CT (MDCT) scanner. We created the 3D reconstruction images with and without bone subtraction by using the volume rendering technique. Three neuroradiologists in a blinded fashion interpreted both 3D CTA images with and without bone subtraction. The diagnostic accuracy of both techniques was evaluated using the alternative free-response receiver operating characteristic (ROC) analysis. The sensitivity and positive predictive value were also evaluated.
Results: A total of 200 aneurysms (size: 2–23 mm) were detected in 170 patients. The area under the receiver operating characteristic curve (Az) for 3D CTA with bone subtraction (mean, Az = 0.933) was significantly higher than that for 3D CTA without bone subtraction (mean, Az = 0.879) for all observers ($P < 0.05$). The sensitivity of 3D CTA with bone subtraction for three observers was 90.0, 92.0 and 92.5%, respectively, while the sensitivity of 3D CTA without bone subtraction was 83.5, 83.5 and 87.5%, respectively. No significant difference in positive predictive value was observed between the two modalities.
Conclusions: 3D CTA with bone subtraction showed significantly higher diagnostic accuracy for the detection of intracranial aneurysms as compared to 3D CTA without bone subtraction.

1. Introduction

Conventionally, digital subtraction angiography (DSA) has been considered the reference standard for the detection and evaluation of intracranial aneurysms. Recently, three-dimensional (3D) rotational angiography has provided an improved detection rate and characterization of intracranial aneurysms [1,2]. Nevertheless, DSA has still several disadvantages, such as invasiveness, time-consumption, a relatively high cost and some neurological complications [3,4]. Therefore, CT angiography (CTA) has been increasingly used and has become more important as a first diagnostic technique in patients with suspected intracranial aneurysms, especially for the evaluation of patients with subarachnoid hemorrhage in an emergency setting [5–10].

As CT technology has evolved and various subtraction and post-processing techniques have been developed, subtraction CTA with good image quality for the detection of intracranial aneurysms has become possible [6,11–16]. However, several problems, such as increased radiation dose due to a second scan, image degradation due to inevitable patient movement, venous contamination and bone artifacts still remain with the use of subtraction CTA [6,11,15]. There have been several reports on the potential usefulness of subtraction CTA, but most previously published studies have not included a large population and were concerned about evaluation of subtracted image quality or a comparison with DSA for the diagnosis of intracranial aneurysms [6,12–16]. The purpose of this retrospective study was to evaluate the usefulness of 3D CTA with bone subtraction in a comparison with 3D CTA without bone subtraction for the detection of intracranial aneurysms in a large patient population.

2. Materials and methods

2.1. Patient population

Between November 2004 and March 2008, 337 consecutive patients with intracranial aneurysms detected on CTA were retrospectively reviewed. Among the 337 patients, 170 (73 men and 79 women; median age, 54.6 years; age range, 28–76 years) patients

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who underwent DSA, which was considered as the standard of reference, were included in the study. Nontraumatic subarachnoid hemorrhage was detected in 138 (81%) of the patients. The remaining 32 patients had various indications of CTA, including headache suggestive of aneurysm ($n = 15$); evaluation of cerebral infarction or intracerebral hematoma ($n = 11$); evaluation of previously detected aneurysm on MR angiography ($n = 6$).

Institutional review board approval was obtained for this retrospective study. Informed consent was obtained from all patients or their legal representatives.

2.2. CTA examination

All CTA examinations were performed with a 16-slice multidetector-row CT (MDCT) scanner (Somatom Sensation 16, Siemens, Erlangen, Germany). After obtaining a lateral scanogram, the scanning range was planned in a caudocranial direction from the first cervical vertebra up to the vertex. The acquisition parameters for CTA were as follows: 120 kV and 100 mA s (effective); collimation, 0.75; 0.5-s gantry rotation time; table feed per rotation, 5 mm; reconstruction slice width, 1 mm; reconstruction increment, 1 mm; reconstruction kernel, H31f.

Contrast enhancement was provided by the intravenous administration of a 100 mL bolus of nonionic iodinated contrast material (Omnipaque 350, GE Healthcare, Cork, Ireland) at a rate of 4 mL/s via power injection. Synchronization between the scan and contrast enhancement was obtained using the bolus tracking technique. A region of interest was set in the lumen of the internal carotid artery with a threshold of +100 Hounsfield units and the scan was triggered automatically 4 s later.

2.3. 3D reconstruction

The obtained CTA data including pre-contrast and post-contrast images were transferred to a workstation that had incorporated 3D reconstruction software (RAPIDIA 3D; Infinitt, Seoul, Korea) for postprocessing. Volume-rendered images from the source image datasets were generated by the use of 3D reconstruction software (RAPIDIA 3D) installed on the workstation. For acquisition of subtracted images, both the nonenhanced and the contrast-enhanced data in the workstation memory were loaded and automatic segmentation that selectively eliminated any overlapping bone, surgical clip, calcification and soft tissue was performed.

2.4. Imaging analysis

Three neuroradiologists (G.H.C., H.S.K. and S.B.H.) evaluated independently and separately all of the CTA images. Each observer directly operated all 3D reconstructions and reviewed the CTA images in real time using the 3D reconstruction software (RAPIDIA 3D) for a comparative study. The observers knew that the patients were suspected of having intracranial aneurysms, but the observers were unaware of the presence and location of lesions and of the DSA findings. Each observer analyzed two sets of images, *i.e.*, 3D CTA with bone subtraction and 3D CTA without bone subtraction images. Two separate reading sessions were performed with at least a 4-week interval to minimize any learning bias. Each observer recorded the presence and location of one or more lesions, assigning each lesion a confidence level on a four-point scale: 1 = probably not present, 2 = possibly present, 3 = probably present, 4 = definitely present.

2.5. Statistical analysis

To assess the diagnostic accuracy of the two imaging modalities regarding the detection of intracranial aneurysms, an alternative free-response receiver operating characteristic (ROC) curve analysis was performed on a lesion-by-lesion basis, based on the reviews submitted by the three observers. The diagnostic accuracy of each imaging modality and for each observer was assessed by calculating the area under the alternative free-response ROC curve (A index, Az). The differences between the imaging modalities, with regard to the area under the ROC curves, were statistically analyzed using the two-tailed Student's *t*-test for the paired data. The sensitivities and positive predictive values for each observer and for each imaging modality were also calculated based on the number of lesions assigned a confidence level of 3 or 4 from among all of the lesions. The sensitivity and positive predictive value of each imaging modality were then compared using the McNemar test. A two-tailed *P*-value of less than 0.05 was considered to indicate a statistically significant difference.

To assess the interobserver agreement for the evaluation of the two imaging modalities, we calculated the kappa (κ) statistic for multiple observers. The degrees of agreement were categorized as follows: kappa values of less than 0.20 indicated positive but poor agreement, kappa values from 0.21 to 0.40 indicated fair agreement, kappa values from 0.41 to 0.60 indicated moderate agreement, kappa values from 0.61 to 0.80 indicated good agreement and kappa values greater than 0.81 indicated excellent agreement. All data were analyzed using the statistical software packages SPSS 12 and Medcalc version 10 for windows.

Table 1
Location and number of intracranial aneurysms.

Location	Number of aneurysms
Anterior communicating artery	63
Middle cerebral artery	57
Distal ICA	51
Anterior cerebral artery	10
Basilar tip	8
Vertebrobasilar artery	5
ICA bifurcation	5
Posterior cerebral artery	1
Total	200

Note: ICA indicates internal carotid artery.

3. Results

A total of 200 aneurysms were detected by the use of DSA in the 170 patients: 147 patients had 1 aneurysm, 19 patients had 2 aneurysms, 2 patients had 3 aneurysms, 1 patient had 4 aneurysms and 1 patient had 5 aneurysms. The location and number of aneurysms are summarized in Table 1. The size of the aneurysmal sac varied between 2 and 23 mm (mean size, 5.64 ± 3.14 mm).

For all 200 aneurysms, the calculated Az values for each observer for 3D CTA with bone subtraction and 3D CTA without bone subtraction are shown in Table 2. For the detection of intracranial aneurysms, all observers achieved significantly higher diagnostic accuracy for 3D CTA with bone subtraction (mean Az = 0.933 ± 0.010) than that for 3D CTA without bone subtraction (mean Az = 0.879 ± 0.015) ($P < 0.05$).

The sensitivities and positive predictive values determined for each observer for each imaging modality for the detection of intracranial aneurysms are shown in Table 3. The sensitivities of 3D CTA with bone subtraction for three observers were superior to those of 3D CTA without bone subtraction. However, no significant difference was achieved for all observers ($P = 0.077$ for observer 1, $P = 0.015$ for observer 2 and $P = 0.134$ for observer 3). All observers missed eight lesions on 3D CTA without bone subtraction, but the lesions were detected on 3D CTA with bone subtraction. Based on a retrospective analysis, seven of eight missed aneurysms on 3D CTA without bone subtraction were located on the distal segment of