Large-Cohort Comparison Between Three-Dimensional Time-of-Flight Magnetic Resonance and Rotational Digital Subtraction Angiographies in Intracranial Aneurysm Detection

Ming-Hua Li, MD, PhD; Ying-Sheng Cheng, MD, PhD; Yong-Dong Li, MD, PhD; Chun Fang, MD; Shi-Wen Chen, MD, PhD; Wu Wang, MD; Ding-Jun Hu, MD; Hao-Wen Xu, MD

Background and Purpose—The value of MR angiography varies in diagnosis of intracranial aneurysms due to the difference of equipment and imaging technique. This study was to compare the effectiveness of 3-dimensional time-of-flight MR angiography at 3 T and rotational digital subtraction angiography, both with volume rendering (VR), in detecting intracranial aneurysms.

Methods—One hundred thirty-eight patients with suspected or known aneurysms and other cerebral vascular diseases detected by MR angiography underwent digital subtraction angiography examinations. Postprocessing techniques, including VR and the single artery highlighting method, were performed by a 3-dimensional specialist. The VR-digital subtraction angiography was obtained as the gold standard.

Results—The rotational digital subtraction angiography and VR-digital subtraction angiography revealed 146 aneurysms in 122 patients and no aneurysms in 16 patients. Of the 276 vessels examined, 136 vessels had 146 aneurysms and 140 vessels had none. Per vessel and per aneurysm sensitivities were 100%, whereas the per vessel accuracy ranged from 97.5% to 98.6% and the per aneurysm accuracy ranged from 95.1% to 97.0%.

Conclusions—VR 3-dimensional time-of-flight MR angiography at 3 T has excellent sensitivity, accuracy, and correlation with VR-digital subtraction angiography and is comparable to catheter cerebral angiography for the evaluation of patients with intracranial aneurysms who tolerate MR angiography well. (Stroke. 2009;40:00-00.)

Key Words: digital subtraction angiography ■ intracranial aneurysm ■ magnetic resonance angiography ■ volume rendering

The reference standard for identifying intracranial aneurysms, digital subtraction angiography (DSA), carries a 1% complication risk with a 0.5% rate of neurological deficit.1 Recently, MR angiography (MRA) has played an increasing role in patient evaluation for aneurysms.2-4 Rotational DSA (RDSA) has become a useful technique to evaluate aneurysm morphology and to detect aneurysms.5,6 The purpose of our study was to prospectively evaluate the effectiveness of volume rendering (VR) 3-dimensional time-of-flight MRA (3D-TOF-MRA) at 3 T in the detection of intracranial aneurysms and to compare our results with those of RDSA and VR-DSA.

Subjects and Methods

Patients
From June 2007 to October 2008, 138 patients (54 men, 84 women; median age, 55 years; range, 18 to 83 years) with suspected or known intracranial aneurysms and other cerebral vascular diseases, including 25 patients with both subarachnoid hemorrhage and a Glasgow Coma Scale of 15 points, detected by MRA, underwent DSA examinations. The Institutional Review Board approved the study protocol, and the patients or qualifying family members provided informed consent.

Image Acquisition
We performed MRA examinations using a 3.0-T system (Achieva X-Series). The TOF-MRA was obtained using 3D-T1-fast field echo sequences with TR/TE, 35/7; flip angle, 20°; 250×108 field of view; matrix, 732×1024; and acquisition time, 8 minutes 56 seconds. VR was performed by a 3D specialist with a workstation (EWS 2.5.3.0; Philips). To reduce artery overlay, the single artery highlighting method was applied (Figures 1A and 2A). For the left or right internal carotid artery (ICA), we removed the right or left ICA system, respectively, and the posterior circulation from the middle of the 2 posterior communicating arteries. For posterior circulation, we removed the anterior circulation system from the middle of the 2 posterior communicating arteries.

Conventional 2-dimensional DSA was performed on a monoplanar unit (Axion Artis) with a 1024×1024 matrix and 17 to 20 cm field of view. Rotational DSA was performed with an 8-second, 200° rotational run. A complete DSA consisted of a 3-vessel 2-dimensional DSA and 2-vessel RDSA with VR for each patient.
All VR 3D-TOF-MRA images were interpreted by 3 readers using any projection on screen and the single artery highlighting method. Diagnostic confidence in aneurysm presence was assessed using a 5-point scale. Aneurysms identified as probably or definitely present were considered positive; all others were negative. Sites were divided into anterior or middle cerebral artery, ICA, and vertebrobasilar artery groups. Size was recorded as <3 mm, 3 to 5 mm, or >5 mm.

Statistical Analyses
The unweighted $\chi$ statistic was used to assess intermodality and interobserver agreement.

Results
The RDSA and VR-DSA revealed 146 aneurysms in 122 patients and no aneurysms in 16 patients. Of the 276 vessels examined by RDSA and VR-DSA, 136 vessels had a total of 146 aneurysms, and 140 vessels had no aneurysms. Aneurysms were located in the ICA ($n=99$), middle cerebral artery ($n=13$), anterior cerebral artery ($n=28$), and vertebrobasilar artery ($n=6$). Fifty-two aneurysms were <3 mm, 83 were 3 to 10 mm, and 11 were >10 mm in maximum diameter (Figure 1).

For DSA Reader 2, the DSA had a sensitivity of 98.5% or 98.6% and accuracy of 99.3% or 98.8% per vessel or aneurysm, respectively (Table). The per vessel and per aneurysm accuracies were 100%. The per vessel accuracy ranged from 97.5% to 98.6%, and the per aneurysm accuracy ranged from 95.1% to 97.0% for each reader (Table). Interobserver agreement was excellent with a $\chi$ statistic of 0.93 for per vessel and 0.86 for per aneurysm with VR 3D-TOF-MRA at 3.0 T.

All readers correctly detected aneurysms located in the ICA, anterior cerebral artery, middle cerebral artery, or vertebrobasilar artery with a sensitivity of 100%, whereas the accuracy was lower in aneurysms located in the ICA (92.5% to 95.3%) than in the anterior cerebral artery (100%), middle cerebral artery (100%), or vertebrobasilar artery (100%). The sensitivity of detecting aneurysms of <3 mm (100%) or >3 mm (100%) in maximum diameter was the same, whereas the accuracy of detecting small aneurysms (88.1% to 93.2%) was lower than that for large aneurysms (98.9%).

Discussion
We found that the sensitivity of VR 3D-TOF-MRA in detecting aneurysms for all readers was 100%, and the accuracy was 97.5% to 98.6% per vessel and 95.1% to 97% per aneurysm. This >95% rate of sensitivity and accuracy indicate the effectiveness of VR 3D-TOF-MRA at 3 T as an alternative approach to DSA in the diagnosis and treatment planning of patients with intracranial aneurysms.

There were 3 reasons for the high sensitivity and accuracy obtained in this study. The increased signal-to-noise ratio and background suppression at 3.0 T enable better delineation of vessels. Second, the 3D specialist postprocessing techniques used augmented diagnostic confidence and improved the perception of aneurysm morphology. Third, the single artery highlighting method helped reduce artery overlay.

Although aneurysm size is one of the most important factors affecting sensitivity and accuracy, especially for small aneurysms (<3 mm), our 100% sensitivity in detecting small aneurysms (Figure 2) with an accuracy of 88.1% to 93.2% does not support a 3-mm cutoff level for aneurysm detection with 3D-TOF-MRA.

There are some limitations to our study. The aneurysm size was overestimated, and the distal aneurysms might be missed by VR 3D-TOF-MRA. For patients with acute subarachnoid hemorrhage and a Glasgow Coma Scale of 15 points, A, VR 3D-TOF-MRA at 3 T with left ICA highlighting method shows an aneurysm (arrowhead) on the left anterior cerebral artery. B–C, DSA (B) and VR-DSA (C) demonstrate the aneurysm (arrowhead).
hemorrhage who do not tolerate MRI very well, CTA is the preferred noninvasive investigation due to a short scan time and high spatial resolution. The signal intensity might be inhomogeneous due to turbulent flow. Finally, MRA studies were incomplete sometimes due to patient noncompliance, metal, or pacemakers. In addition, RDSA versus DSA involves higher contrast load per acquisitioned run, longer acquisition time, and increased patient radiation dose.

In conclusion, the effectiveness of VR 3D-TOF-MRA at 3 T was validated by its excellent sensitivity, accuracy, and correlation with VR-DSA. The VR 3D-TOF-MRA method at 3 T could be comparable to catheter cerebral angiography for the evaluation of patients with intracranial aneurysms who tolerate MRA well.

Acknowledgments
We thank Yu-Lan Qiu, from the Faculty of Public Health, The Medical College of Shanghai Jiao Tong University, for his kindness in checking the statistical data and analysis during preparation of the manuscript.

Sources of Funding
This study has been supported by the National Natural Scientific Fund of China (Contract number 30570540), the Shanghai Important Subject Fund of Medicine (Contract number 05 III 023), and the Program for Shanghai Outstanding Medical Academic Leader (Contract number LJ 06016).

Disclosures
None.

References
Large-Cohort Comparison Between Three-Dimensional Time-of-Flight Magnetic Resonance and Rotational Digital Subtraction Angiographies in Intracranial Aneurysm Detection

Ming-Hua Li, Ying-Sheng Cheng, Yong-Dong Li, Chun Fang, Shi-Wen Chen, Wu Wang, Ding-Jun Hu and Hao-Wen Xu

Stroke. published online June 25, 2009;
Stroke is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2009 American Heart Association, Inc. All rights reserved.
Print ISSN: 0039-2499. Online ISSN: 1524-4628

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://stroke.ahajournals.org/content/early/2009/06/25/STROKEAHA.109.553800.citation

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Stroke can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Stroke is online at:
http://stroke.ahajournals.org//subscriptions/