Despite the promising results of time-of-flight MR angiography (TOF-MRA) for evaluation of intracranial aneurysms, disadvantages include spin saturation and phase dispersion due to slow or turbulent flow and long acquisition times, typically lasting several minutes.

Contrast-enhanced MRA can address these limitations and has already shown promise for evaluation of intracranial aneurysms. However, the competing requirements for coverage and acquisition speed generally force a compromise in spatial resolution relative to TOF-MRA.

The broad availability of 3T MR imaging systems with higher available signal-to-noise ratios (SNRs) and the introduction of parallel imaging have significantly enhanced the performance of MRA techniques in evaluation of cerebrovascular disease.

If its potential is realized, contrast-enhanced MRA at 3T might achieve a spatial resolution and image quality that rivals TOF-MRA, without the known drawbacks. The purpose of this study was to evaluate a high-spatial-resolution contrast-enhanced MRA protocol, integrated with highly accelerated parallel acquisition for visualization and characterization of intracranial aneurysms, and to compare the results with a more standard clinical routine (TOF-MRA) at 3T, in a population of patients with known intracranial aneurysms.

**Methods**

Fifteen patients (2 men, 13 women; age range, 46–83 years) with known intracranial aneurysms were prospectively scanned by using 3T TOF and contrast-enhanced MR imaging techniques. All MRA studies were performed on a 3T whole-body MR imaging system (Magnetom Trio, Siemens Medical Solutions, Erlangen, Germany) by using an 8-channel Neurovascular Array Coil (Invivo, Orlando, Fla) for signal cross partitioning due to slow or turbulent flow and long acquisition times, typically lasting several minutes.

For evaluation of aneurysms, the observers were asked to grade the quality of aneurysm depiction and their diagnostic confidence for perception of aneurysm and its relation to parent vessels, by using a 1–3 scoring scale (1, poor image quality and arterial enhancement and/or presence of significant artifact, and/or noise; 2, good image quality and arterial enhancement and/or mild-to-moderate amount of artifacts/noise not interfering with diagnosis; and 3, excellent image quality for highly confident diagnosis with none-to-minimal amount of artifacts/noise).

For evaluation of aneurysms, the observers were asked to grade the quality of aneurysm depiction and their diagnostic confidence for perception of aneurysm and its relation to parent vessels, by using a 3-point scale: grade 3, excellent depiction of an aneurysm, full confidence for perception of aneurysm border, and clear relationship between the aneurysm and the parent vessel; grade 2, good depiction of an aneurysm, not completely confident for the perception of aneurysm border, and/or no clear relationship with parent vessel; and grade 1, lesion scarcely visible. Maximal spheric diameters of the aneurysm sac were measured on both TOF-MRA and contrast-enhanced MRA, separately.
Results

All studies were determined to be of diagnostic image quality by both observers. The overall image quality scores for contrast-enhanced MRA and TOF-MRA were in the diagnostic range (median, 3; range, 2–3) for both observers. There was no significant difference for image quality scores between the 2 readers or between the 2 techniques. No parallel acquisition reconstruction artifact was noted, and image noise was not found to interfere with diagnostic image quality.

Sixteen aneurysms were detected. Aneurysm locations included the supraclinoid internal carotid artery (n = 5), intracranial internal carotid artery (n = 8), anterior communicating (AcomA) (n = 2) (Fig 1), and the basilar artery (n = 1).

In qualitative analysis for aneurysm visualization by using contrast-enhanced MRA, both observers identified 14 aneurysms (87%) with excellent confidence (score 3) and 2 (13%) with good confidence (score 2). In a qualitative analysis for the aneurysm visualization by using TOF-MRA, both observers identified 10 aneurysms (63%) with excellent confidence (score 3) and 5 aneurysms (31%) with good confidence (score 2), whereas 1 aneurysm (6%) was scarcely visible (score 1). This was a 21-mm basilar tip aneurysm (Fig 2).
There was excellent interobserver agreement for qualitative analysis of the aneurysm depiction and perception for both contrast-enhanced MRA (κ = 1) and TOF-MRA (κ = 0.9). However, there was a relatively high intertechnique variability (κ = 0.43) for qualitative evaluation of aneurysms. This was due to lower scores in 6/16 (37%) aneurysms on TOF-MRA, which was thought be due to the presence of intra-aneurysmal signal intensity loss (Figs 2 and 3).

For dimensional measurements, the average maximal spheric aneurysm sac diameter was 6.26 mm (range, 2.6–22.1 mm) on contrast-enhanced MRA and 5.91 mm (range, 2.4–20 mm) on TOF-MRA, with no statistically significant difference (P = .3). There was significant correlation for the dimensional measurements of the sac between TOF and contrast-enhanced MRA (r = 0.91, 95% confidence interval [CI] = 0.87 to 0.96) (Fig 4). Six aneurysms (38%) were <4 mm in maximal diameter, 6 (38%) aneurysms were between 4–10 mm in maximal diameter, and 4 (24%) were larger than 10 mm.

Discussion

The results of our study indicate that contrast-enhanced MR angiography at 3T performs at least as well as 3D TOF-MRA for detection and evaluation of intracranial aneurysms. The requirement to image the cranial arteries quickly on first pass, before major venous enhancement, has previously forced a substantial compromise in spatial resolution relative to TOF-MRA.

Parallel imaging7-9 offers the ability to greatly increase the speed, coverage, and spatial resolution of first-pass contrast-enhanced MRA. The increased scanning efficiency can be used flexibly to increase spatial and temporal resolution and to increase coverage. However, the SNR penalty associated with parallel acquisition is ultimately limiting as acceleration factors increase, mainly on the basis of the degree of k-space undersampling and the coil-array geometry.7 The higher baseline SNR at 3T can be used to offset the SNR penalty and to support highly accelerated parallel acquisition in the evaluation of cerebrovascular disease.10,11
The combination of 3T and highly accelerated parallel acquisition (GRAPPA × 4) enabled us to achieve a high spatial resolution (0.7 × 0.6 × 0.8 mm³) over the entire carotid and vertebro-basilar circulation during a short acquisition time. The intracranial aneurysms in our study population were identified and characterized with diagnostic performance equal or superior (in one third of patients) to TOF-MRA. However, our study population was relatively small, and the results must, therefore, be regarded as preliminary. Larger studies will be necessary before our interim conclusions can be generalized.

In conclusion, TOF and contrast-enhanced MRA perform comparably at 3T for evaluation of intracranial aneurysms. The more aggressive parallel acquisition can be used to improve the spatial resolution and coverage of contrast-enhanced MRA, generating submillimeter voxels (0.33 mm³) in a 20-second acquisition, without the sensitivity to saturation or flow effects characteristic of TOF techniques.

References