

MRA at 7T: Unlocking the Potential of Small Vessel Imaging

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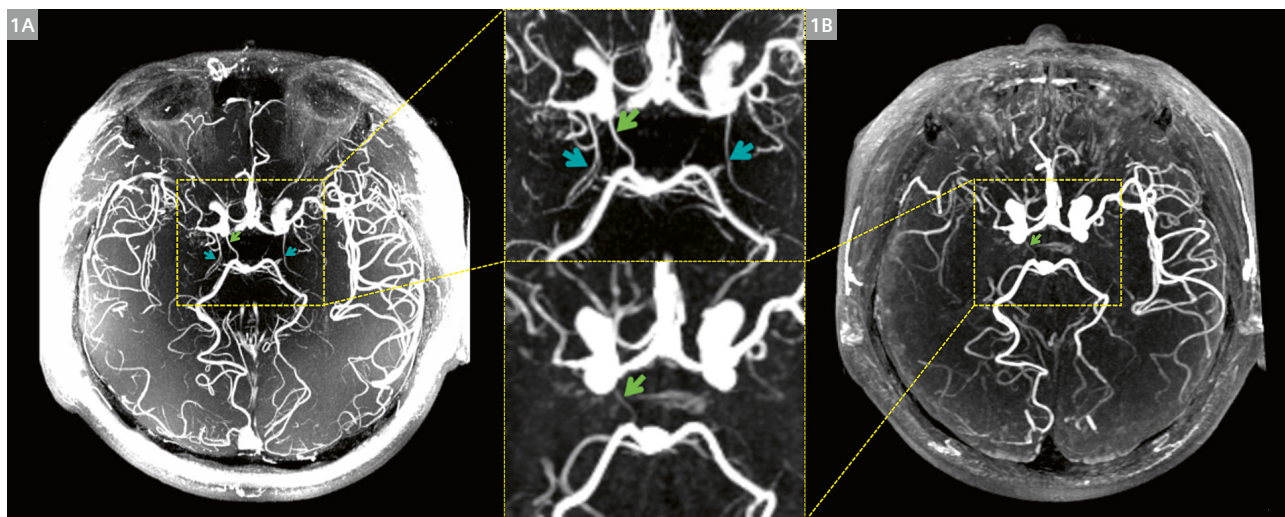
Introduction: The resolution revolution

Magnetic resonance angiography (MRA) is a mainstay of vascular imaging. Among its techniques, time-of-flight MRA (TOF-MRA) offers particular advantages: It needs no contrast agents, has no ionizing radiation, and uses the natural inflow of blood to map vessel architecture [1, 2]. It is a workhorse for screening, diagnosing, and monitoring cerebrovascular disease in MRI.

At 1.5T and 3T, the voxel size is typically capped at the hundred-nanoliter range (cubes of 0.5–0.8 mm) [3]. This leaves critical small vessels — perforating arteries, collateral networks, and distal branches — blurred or beyond reach. Their signal is diluted across volumes far larger than the structures themselves, and lesions or occlusions that could flag early stroke often risk going unseen.

The arrival of 7T MRI has changed the equation. The jump in signal-to-noise ratio (SNR) and the prolonged T1 relaxation time at 7T enable TOF-MRA to push the voxel size deeper into the 10-nanoliter range (down to 0.3 mm isotropic or even further). The vessel that once had to share its voxel with neighbors now gets one of its own [4].

At the PLA General Hospital (PLAGH), one of China's first centers to bring 7T MRI into clinical use, we have been continuously exploring and maximizing its clinical value since its deployment in 2021. Over the past several years, we have applied TOF-MRA across a spectrum of cerebrovascular conditions, including intracranial atherosclerotic stenosis, small vessel disease, and moyamoya disease, focusing on the brain's most vulnerable small vessels. Here, we present some of our findings.



1 Comparison between 7T TOF-MRA (1A) and 3T TOF-MRA (1B) in the visualization of the anterior choroidal artery and posterior communicating artery. The 7T TOF-MRA demonstrated superior performance to 3T and provided comparable visualization of both the anterior choroidal artery (blue arrows) and posterior communicating artery (green arrows). TOF-MRA = time-of-flight magnetic resonance angiography.

Imaging small vessels in moyamoya disease

Moyamoya disease (MMD) is a chronic, progressive cerebrovascular disorder characterized by steno-occlusion at the terminal internal carotid artery and by the sprouting of abnormal collateral networks. It is a leading cause of stroke in children and young adults. Digital subtraction angiography (DSA) is the gold standard, but its invasiveness and radiation burden make it impractical for repeated monitoring — especially for younger patients.

Two small vessels hold particular prognostic value in MMD: the anterior choroidal artery (AChA) and the posterior communicating artery (PComA) [5]. Dilation and branching of these arteries are strongly associated with hemorrhagic risk. Visualizing them with precision is essential for early risk stratification.

At the PLA General Hospital, we compared 7T TOF-MRA against 3T TOF-MRA in a head-to-head study of 180 patients. The finer spatial precision of 7T allowed more accurate identification of these hemorrhage-risk features. Notably, 42% of the AChA anomalies and 28% of the PComA anomalies detected on 7T were invisible on 3T. In a DSA-validated subset of 37 patients, 7T

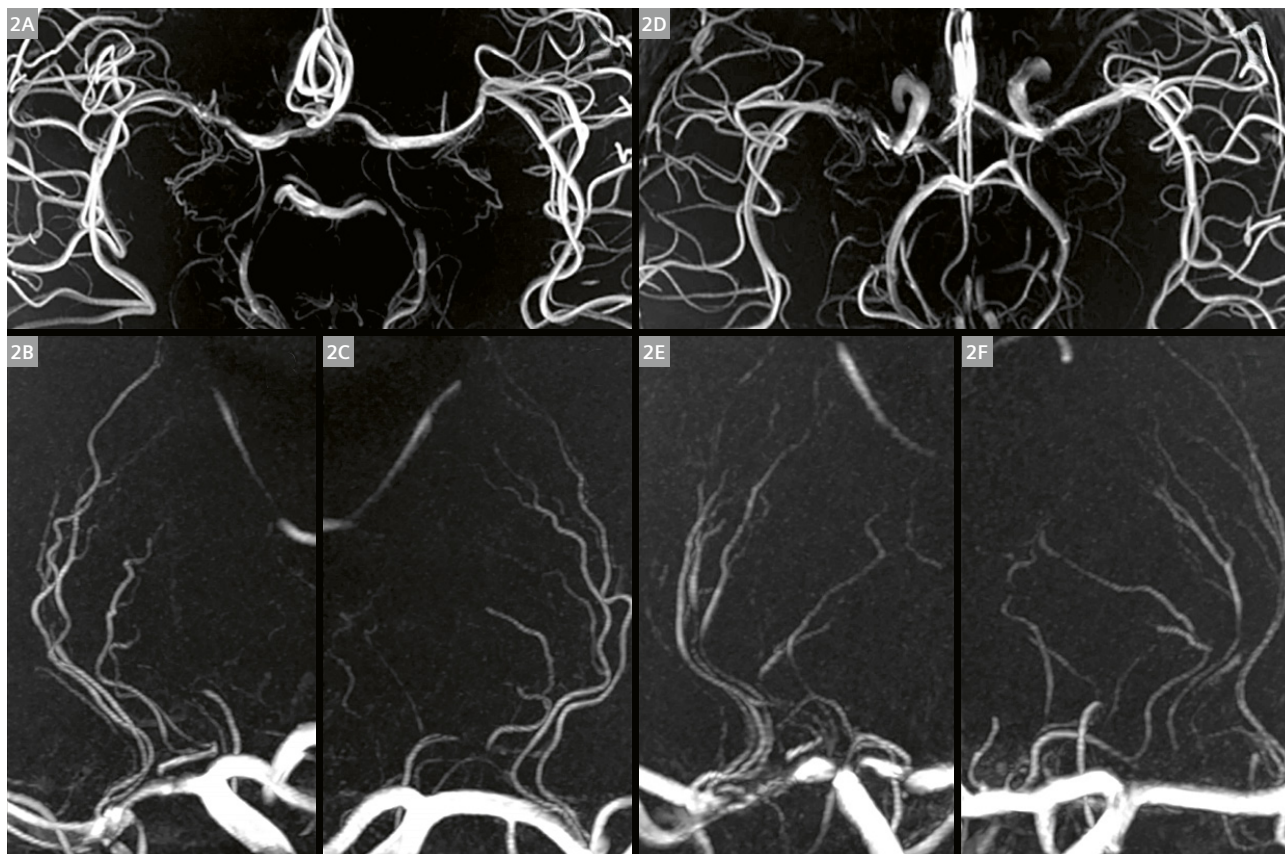
further demonstrated high concordance with the gold standard [6].

The practical meaning is clear: A completely non-invasive, radiation-free scan can now deliver reliable hemorrhage risk assessment for MMD patients, offering a safer pathway for long-term follow-up.

Imaging small vessels in middle cerebral artery stenosis

The lenticulostriate arteries (LSAs) are slender perforating arteries arising from the middle cerebral artery (MCA) and supplying the basal ganglia. This region lacks robust collateral circulation; when LSAs fail, basal ganglia infarction follows, often with severe neurological consequences. With diameters ranging from 0.08 to 1.5 mm, LSAs have long been among the most elusive targets in neuroimaging, reliably visible only through invasive DSA or in post-mortem anatomy. Even at 3T, their distal branches remain beyond reach.

In a large-sample quantitative study of 161 patients, we found that proximal location, rather than the stenosis



2 Representative images of a 46-year-old man with asymptomatic mild-to-moderate stenosis in the M1 segment of the right MCA (2A–2C) and a 30-year-old woman with asymptomatic severe right MCA M1-segment stenosis (2D–2F). Compared to those on the contralateral side, the number of LSA branches on the stenosis side and their length do not decrease (2B vs. 2C; 2E vs. 2F). MCA = middle cerebral artery; LSA = lenticulostriate artery.

severity, of the MCA M1-segment stenosis was the predominant determinant of LSA morphology — a finding established in asymptomatic subgroups and confirmed by multivariable regression [7]. Symptomatic patients showed significantly fewer LSA branches and shorter lengths on the affected side, while asymptomatic patients with proximal MCA M1-segment stenosis similarly exhibited diminished branching compared to those with distal stenosis.

This shifts the clinical approach to risk assessment for basal ganglia stroke. It means that a noninvasive scan, done at sufficient resolution, can now read the anatomical signature that predicts vulnerability — something previously only possible through catheter angiography or autopsy.

Conclusion

The transition from 3T to 7T is not just an improvement in image quality, but a shift in what clinicians can see and therefore in what they can act upon. At the PLA General Hospital, our work with TOF-MRA at 7T has demonstrated that hemorrhage risk stratification in moyamoya disease and morphological assessment of lenticulostriate arteries in MCA stenosis can now be performed noninvasively, reliably, and with high fidelity to the gold standard of DSA. For physicians, this means earlier and more precise risk stratification without exposing patients to radiation or invasive procedures. For patients, particularly children and young adults who face repeated follow-up, it means a safer diagnostic journey.

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