Hybrid STAR MR Angiography of the Intracranial Circulation

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Introduction: There are several methods available for MRA of the intracranial circulation. Widely used 3D time-of-flight (TOF) techniques have changed little over the last decade. Despite recent advances in time-resolved contrast-enhanced 3D MRA, it is not yet competitive with 3D TOF in this region. Alternatively, pulsed arterial spin labeling (STAR) was first applied to the intracranial circulation 13 years ago (1). However, image quality never approached that of 3D TOF and the method has had little clinical utility. Moreover, ECG gating was required. We propose a new approach to imaging of the intracranial circulation called *hybrid STAR MRA* that overcomes previous limitations of STAR. It demonstrates far greater arterial detail than is possible using 3D TOF or CE MRA.

Methods: Two types of STAR acquisitions are combined for the hybrid technique. Regions in which the local magnetic field homogeneity falls beneath a predetermined threshold (e.g. near the skull base) are designated for acquisition (A), whereas regions in which the local magnetic field homogeneity is above the threshold level are designated for acquisition (B). For acquisition (A), a segmented 3D spoiled gradient-recalled-echo (GRE) read-out is used. For acquisition (B), a segmented 3D trueFISP read-out is used. Multiple overlapping 3D slabs are acquired with acquisitions (A) and (B) as appropriate to the threshold. After data acquisition is complete, a scaling factor is applied to the data so that acquisitions (A) and (B) have comparable levels of arterial signal intensity and the data are merged into a single data set. The merged data set is then processed using a maximum intensity projection algorithm.

Three healthy volunteers were imaged on a 32-channel 1.5 T Siemens Avanto system equipped with a 6-channel head and neck coil. Imaging parameters for hybrid STAR MRA were: FOV = 210 mm x 184 mm, matrix = 256 x 224, GRE (trueFISP) flip angle = 15° (90°), TR = 2.5 sec, labeling time = 0.9 s, GRE (trueFISP) TR/TE = 11.3/6.9 (1.9/3.8) ms, Grappa acceleration = 2, 32 0.8 mm slices per slab, slice partial Fourier = 6/8, slice oversampling = 25%, overlapping slabs = 5, slab overlap = 9.6 mm. A standard 3D TOF MRA was performed with comparable through-plane and in-plane spatial resolution. Maximum vessel lengths for the anterior cerebral (ACA), middle cerebral (MCA), and posterior cerebral arteries (PCA) and basilar artery (as measured from the origin to the end of the longest branch vessel) were measured from images acquired using both techniques. The number of vessels branching from the middle cerebral artery, as seen on a transverse maximum intensity projection image, was counted.

Results: Figure 1 shows a comparison of intracranial MR angiography using 3D TOF and hybrid STAR. It is apparent that far more vascular detail, including more extensive vessel lengths and improved conspicuity of small arterial branches, is seen with hybrid STAR. The improved vessel depiction likely relates to the complete background suppression afforded by hybrid STAR. The maximum lengths (in mm) for the ACA, MCA, PCA, and basilar artery (hybrid STAR vs. 3D TOF) were 113 ± 10 vs. 84 ± 17 ($p < 0.01$), 164 ± 10 vs. 126 ± 27 ($p < 0.01$), and 119 ± 11 vs. 89 ± 19 ($p < 0.05$), respectively. Hybrid STAR and 3D TOF respectively depicted 16 and 9 ± 1 branching vessels of the middle cerebral artery ($p < 0.001$).

Conclusion: The hybrid STAR technique provides significantly improved depiction of the intracranial circulation than has previously been feasible using 3D TOF or contrast-enhanced approaches. The benefit derives from the complete background suppression and consequently large vessel-to-background contrast. The hybrid technique avoids the severe disruption of intravascular signal that would otherwise occur with trueFISP for the portions of the intracranial circulation within and near the skull base. Moreover, no cardiac gating is required. Potential improvements will involve 2D parallel imaging techniques to further reduce scan time, phased array coils with larger numbers of elements to improve SNR, along with use of higher field systems.

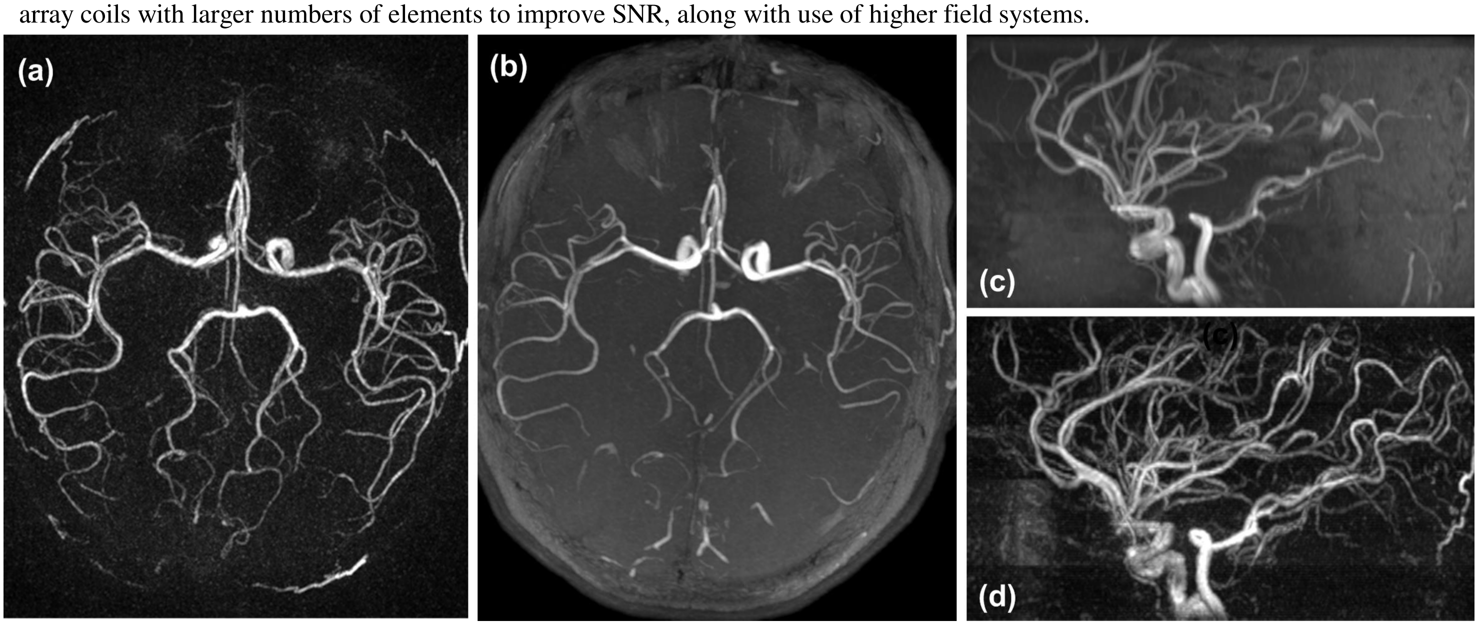

Figure 1. Comparison of standard 3D TOF and hybrid STAR. (a) Axial MIP, hybrid STAR. (b) Axial MIP, 3D TOF. (c) Sagittal MIP, 3D TOF. (d) Sagittal MIP, hybrid STAR. Note far greater vessel conspicuity and improved depiction of small branches with the hybrid technique.

(1) Edelman, RR et al. Magn Reson Med 1994; 31(22): 233-38