

Non contrast MRA of the extracranial carotid arteries utilizing a 3D ECG-triggered balanced steady state free precession technique with spatial saturation

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Purpose:

Time-of-flight (TOF) and gadolinium enhanced MRA (CE-MRA) are the two most widely utilized MRA techniques used to image the extracranial carotid vessels¹. The association of gadolinium and Nephrogenic Systemic Fibrosis has led to a renewed interest in non-contrast MRA techniques². Conventional TOF is a high spatial resolution technique, however it suffers from in-flow effects and requires long imaging time which limits anatomic coverage. Recently, 2D balanced steady state free precession (b-SSFP) MRA has been proposed to improve the contrast-to-noise ratio (CNR) for carotid vessel imaging³. An ECG-gated 3D b-SSFP MRA sequence, utilizing an inversion pulse to null out background tissue and a spatial saturation pulse to null out slow-flowing venous blood, has been described as a means to visualize "fresh" arterial blood flowing into the image⁴. The purpose of our study was to assess the feasibility, diagnostic quality and accuracy of 3D b-SSFP MRA, as compared with conventional TOF MRA for evaluation of the extracranial carotid arteries with reference to CE MRA.

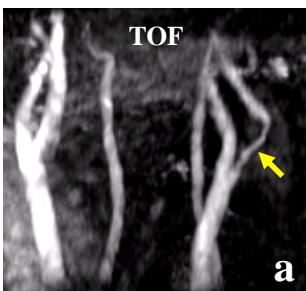
Methods:

3D ECG-gated b-SSFP, TOF and CE MRA of the extracranial carotid arteries was performed on 15 consecutive patients (12 male, 3 female, mean age 67.1 ± 17.2 years) imaged on a whole-body 1.5 T MR system (Siemens; Avanto). The ECG-gated b-SSFP MRA was acquired in a coronal plane with the inversion time (1000-1400 ms) adjusted for each patient based on heart rate. Preliminary data showed that flow artifact was minimal in late diastole. Additional b-SSFP parameters were: TR = 2 R-R intervals, TE = 1.6 ms, voxel size = $1.1 \times 1.0 \times 0.9$ mm, FA = 50° , TA = 2.5 minutes (range 2-4 minutes), GRAPPA⁵ with acceleration factor = 3. Axial 3D TOF parameters were: TR = 25 ms, TE = 7.2 ms, voxel size = $0.7 \times 0.5 \times 0.9$ mm, FA = 25° , TA = 2.75 minutes, GRAPPA with acceleration factor = 3. Oblique sagittal CE MRA parameters were: TR = 3.6 ms, TE = 1.4 ms, voxel size = $0.9 \times 0.7 \times 1.0$ mm, FA = 25° , 3 measures (total acquisition time, 1.0 minute), GRAPPA with acceleration factor = 2, 15 cc Gd-DTPA at 2 ml/s, with the first post contrast scan timed to peak arterial enhancement based on a test bolus. b-SSFP and TOF were independently evaluated by two radiologists in random order on a 3D workstation for vessel segment (internal carotid, common carotid and vertebral artery segments) image quality and diagnostic confidence with an ordinal rating scale (1 = poor, 2 = satisfactory, 3 = excellent). Internal carotid arteries were assessed for percentage stenosis, with CE MRA as the reference standard. Additional vascular pathology was also noted and compared. Due to the use of GRAPPA parallel imaging, signal-to-noise (SNR) was estimated as $\text{blood}_{SI}/\text{SD}_{\text{muscle}}$, and CNR as $(\text{blood}_{SI}-\text{muscle})/\text{SD}_{\text{muscle}}$, with region of interest analysis of the internal carotid artery and the ipsilateral homogeneous sternocleidomastoid muscle as reference⁶.

Results:

A total of 90 segments were evaluated. There were 3 significant ICA stenoses as judged by the reference standard (Fig 1). Mean image quality score for b-SSFP and TOF was 2.58 ± 0.62 and 2.34 ± 0.69 ($p < 0.001$), respectively, and diagnostic confidence for b-SSFP and TOF was 2.53 ± 0.69 and 2.30 ± 0.68 ($p < 0.001$) respectively. There was agreement with the reference standard in 115 (97%) segments for TOF and in 114 (95%) segments for b-SSFP MRA. b-SSFP had significantly higher SNR (38.0 ± 9.6 versus 27.1 ± 7.3 , $p = 0.003$), CNR (25.4 ± 7.3 versus 19.0 ± 6.6 , $p = 0.02$), image quality ($p < 0.001$) and diagnostic confidence ($p < 0.001$). The sensitivity, specificity, positive predictive value and negative predictive value for stenosis for SSFP was 75.0%, 98.1%, 86.7%, 96.2%, and for TOF was 87.5%, 95.2%, 73.7%, 98.0% respectively. A carotid dissection with pseudoaneurysm was detected on b-SSFP, outside the imaging range of TOF MRA, and poorly seen at CE MRA, confirmed at conventional angiography (Fig 2).

Fig 1. a) TOF, b) SSFP, c) CEMRA, demonstrate moderate (60%) stenosis of the left proximal internal carotid artery in a 75yo male with right parasthesias (arrow). Note larger anatomic coverage of SSFP compared to TOF MRA.



Conclusion:

ECG-gated b-SSFP MRA is feasible at 1.5T, with significantly higher SNR, CNR, image quality and diagnostic confidence as compared with TOF, the established noncontrast carotid MRA technique, in comparable imaging time. Note that reported SNR and CNR measures are estimates due to the use of GRAPPA parallel imaging. b-SSFP MRA has promising accuracy for stenosis detection. Potential developments could include pulse sequence optimization for better background suppression and evaluation at 3T for improved vessel visualization.

References:

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Fig 2. a)TOF, b) b-SSFP, c) CEMRA and d) digital subtraction angiography of a 41 year old male with left neck and facial pain. A focal dissection with pseudoaneurysm is present in the pre-petrous ICA (arrow), outside the routine field of view of TOF MRA. Mural irregularity of the anterior wall is barely perceptible at CE-MRA (arrowhead).

