Diagnosis of Subclavian Steal Syndrome using a Novel Time-Resolved Magnetic Resonance Angiographic Technique

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Introduction: The term "Subclavian steal" refers to reversal of normal direction of flow in the vertebral artery ipsilateral to severe stenosis/occlusion occurring between aortic arch and vertebral artery origin. The diagnosis of subclavian steal syndrome can be suggested by many techniques which include invasive angiography, noninvasive continuous wave Doppler ultrasonography of neck, multi-slice CT angiography, phase-contrast MR imaging and conventional contrast enhanced MRA. Since its introduction in the early 1990s contrast-enhanced MR angiography (CE-MRA), has revolutionized the diagnosis of vascular disease and has become the first-line tool for evaluating vascular disease in many centers. The advantages of CE-MRA over DSA and CTA include, no exposure to ionizing radiation and no risk of nephrotoxic iodinated contrast, as CE-MRA uses Gadolinium. The most common implementation of CE-MRA produces a detailed static image of vascular structures, similar to CTA with no temporal information about vascular dynamics. In recent years, a number of imaging techniques that increase the frame rate of MRA have been developed such as: SMASH, SENSE and TRICKS (2). All these acceleration strategies intentionally undersample MRI imaging data and synthesize missing data to create high frame rate 3D MR angiograms. When used in combination, they can produce up to a six fold increase in imaging speed and significantly improve temporal resolution while maintaining spatial resolution. With these advances 3D MRA images can now provide the dynamic information that is inherent in DSA exams, It allows vasculature to be visualized over time, capturing various phases of circulation while providing snapshots of vessels in a manner similar to that of DSA, but with more informative images that can be manipulated in three dimensions. In addition, time-resolved MR angiography permits specific vessel flow quantification.

Purpose: Our objective was to diagnose subclavian steal syndrome by use of a novel time resolved high-resolution 3D contrast-enhanced MR angiography(3D CEMRA)using combination of two complimentary undersampling techniques and data synthesis algorithm: Time-Resolved Echo sharing Angiographic Technique (TREAT)(2) and a SENSE-based parallel imaging acquisition using GRAPPA(1) for synthesis of missing image data.

Materials and Methods: We studied 15 patients with clinical suspicion of subclavian steal syndrome, aged 55 to 70 years, using time-resolved contrast enhanced MR angiographic techniques. Flow dynamics were confirmed at a single level using standard phase contrast MRI scan. All imaging was performed on 1.5 T Siemens Avanto scanner. A 3D gradient echo FLASH pulse sequence (TR/TE: 2.8/1.2; flip angle 20°; 512 readout; 40-44 partitions; 1.2 x 0.7 x 1.3 mm^3 voxels, slice thickness 1.6 -2.5 mm depending on the temporal resolution) was used for imaging. This was combined with GRAPPA (acceleration factor 2) and TREAT. The frame time of this sequence was 1-3 seconds. An injection of 15 ml of a gadolinium based contrast agent was injected using a power injector at a rate of 5.0 ml/sec at the initiation of the image acquisition and concurrent with the breath hold. Data sets were subtracted inline and maximum intensity projection(MIP) processing were run to produce a time series of images throughout the passage of the bolus of contrast agent through the pulmonary vasculature ,aorta and major neck vessels. In addition to the time-resolved series, a high spatial resolution static MRA was acquired using a bolus timing technique.

Results: We found that 8 patients had normal study and in 7 patients subclavian steal was seen. The findings included segmental occlusion of proximal part of left subclavian artery with delayed filling and retrograde flow in left vertebral artery in 3 patients; focal stenosis of proximal part of right subclavian artery with right sided subclavian steal in 3 patients; 1 patient showed segmental occlusion of innominate artery at its origin with focal stenosis of proximal left subclavian artery with retrograde flow in vertebral artery of right side only. The diagnosis of subclavian steal was made primarily using time-resolved CE MRA, which was quite reliable and accurate technique as similar findings were correlated with DSA or Doppler USG, in almost all patients. This technique was also used to plan intervention at the same time in 4 out of 7 patients.

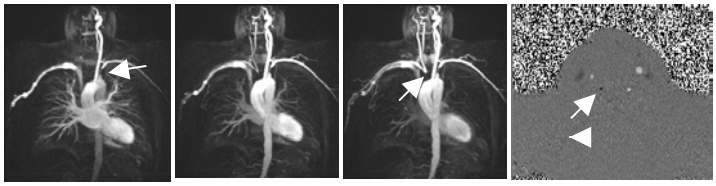

Figure 1a Figure 1b Figure 1c Figure 1d

Figure 1: Right sided subclavian steal in 65 year old male

3D contrast enhanced Time resolved MRA study of aortic arch and great vessels in early time frame (fig 1a) shows focal high grade stenosis (arrow) involving the proximal left subclavian artery with nonvisualisation of right common carotid and subclavian artery. Segmental occlusion of the innominate artery (arrow) at its origin with delayed filling of right vertebral artery seen in late time frame images (fig 1b, 1c). Phase contrast angiogram over lower neck (fig 1d) shows cephalad flow in bilateral common carotid arteries and left vertebral artery (bright area) and caudal flow in right vertebral artery (dark area, arrow) suggesting right sided subclavian steal.

Discussion: TREAT, which is a slight variation of the original TRICKS (2) approach, is based on a T1 weighted spoiled, 3D gradient echo pulse sequence (3D FLASH) which employs temporal undersampling and echo sharing (2), in order to improve acquisition speed, reduce artifact and improve overall image quality. In this study, we have implemented a novel approach to time-resolved MR angiography by combining parallel imaging (GRAPPA) (1) and TREAT (2) for the diagnosis of subclavian steal syndrome. Compared to DSA, it provides more informative images that can be acquired during short, non-invasive procedures in an outpatient setting. It also drastically reduces the complexity of image acquisition compared to traditional CE-MRA exams that require coordination of image acquisition, arrival of the contrast agent in the targeted vessels and initiation of the breath hold. The ease of use afforded by time-resolved CE-MRA makes it a more reliable and by extension, a more practical approach than timed CE-MRA exams. The combination of TREAT and GRAPPA demonstrates the anatomy of the cervicothoracic vessels in a fast and noninvasive way; also quantify clearly the amount and direction of flow-through vessels of small caliber. Acquiring a temporal series of images offers advantages over other current contrast enhanced 3D MRA techniques in that it 1) increases the likelihood that an arterial –only 3D image set will be obtained 2) permits the passage of the contrast to be observed, and 3) allows temporal processing techniques to be applied to yield additional information regarding both anatomy and flow dynamics (2).

Conclusion: In conclusion, this study confirms the use of Time-resolved CEMRA technique to diagnose subclavian steal syndrome, however we do acknowledge the limitation of the present study as it comprised of small number of patients. So this technique can be considered as a valuable substitute for invasive techniques such as conventional angiography and may also be used to plan interventions at the same time.

References:

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