Time-resolved MR Angiography in Evaluation and Mapping of Central Thoracic Veno-occlusive Disease

K. Nael[1], S. G. Ruehm[1], M. Krishnam[1], G. Laub[2], and J. Finn[1]

[1]Radiological Sciences, David Geffen School of Medicine at UCLA, Los Angeles, CA, United States, [2]Siemens, Los Angeles, CA, United States

Introduction: Advances in fast imaging tools such as parallel acquisition **(1)** and sparse k-space sampling methods such as time-resolved angiography with interleaved stochastic trajectories (TWIST) **(2, 3)**, have the potential to improve the performance of time-resolved MR angiography (TR-MRA). Another potential advantage of TR-MRA is the requirement for substantially less gadolinium in comparison to conventional MRA. In light of recent reports regarding the implication of gadolinium-based contrast agents as a causative factor in the development of nephrogenic systemic fibrosis **(4)**, it seems logical to minimize the amount of gadolinium administered, particularly in high risk population of patient with central venous disease many of whom with underlying renal disease.
Purpose: The purpose of our study was to evaluate the feasibility and diagnostic performance of a 3D TR-MRA protocol in evaluation of central thoracic venous occlusive disease and comparison with conventional MRA and catheter angiography.
Materials and Methods: Twenty patients (8F, age range: 19-74 y/o) with suspected central venous disease were examined by a CE-MRA protocol including both time-resolved and conventional MRA acquisitions on a 32-channel 1.5T whole-body MR scanner (Magnetom Avanto, Siemens Medical Solutions). A combination of 24 coil elements was used to cover a maximum field of view of 500 mm over the entire thorax and upper extremities. After intravenous injection of 6ml gadolinium at 2ml/s, TR-MRA was implemented in the coronal plane, using a 3D fast GRE sequence (TR/TE: 2/0.9 ms, FA: 20°, BW: 1000 Hz/pixels, FOV: 500 x 458 mm, matrix: 384 x 342, slice thickness: 7mm; slab thickness: 140 mm). Generalized autocalibrating partially parallel acquisitions (GRAPPA) **(1)** with an acceleration factor of 2 in phase encoding direction was employed, as was TWIST, a recent view-sharing technique, which undersamples the periphery of k-space depending on the radial distance of the center of k-space **(2)**. By combination of GRAPPA and TWIST, the resulting 3D datasets were acquired with a temporal resolution of 1.5 seconds per frame for a total of 20 sequential measurements. Subsequently after IV injection of 0.2 mmol/kg of contrast, conventional CE-MRA was performed during a 20s breath-hold with acquired voxel dimension of 1 x 1 x 1.1 mm^3 using a GRE sequence (TR/TE: 2.8/1.1ms, FA: 25°, BW: 610 Hz/pixels, FOV: 500 x 375mm; matrix: 512 x 330, 124 slices with 1.1 mm thickness, and GRAPPA x 3). Time-resolved and conventional MRA images were evaluated in separate reading sessions by two independent radiologists for image quality/level of confidence and degree of veno-occlusive disease. The interobserver/intermodality agreements were evaluated and sensitivity and specificity were calculated using catheter angiography as standard of reference.
Results: TR-MRA were resulted in diagnostic image quality without significant difference in comparison with conventional MRA. Thirty one segmental disease were identified including 5 segments with <70% stenosis, 12 segments with 70-99% stenosis, and 14 segmental occlusions. Interobserver agreement was good for TR-MRA ($\kappa = 0.62$; 95% CI: 0.42, 0.83) and excellent for conventional CE-MRA ($\kappa = 0.84$; 95% CI: 0.67, 0.98). Kappa coefficient revealed good intermodality agreement ($\kappa = 0.68$; 95% CI: 0.42, 0.76) between TR-MRA and conventional CE-MRA. When compared to catheter angiography, the sensitivity and specificity for diagnosis of significant stenosis (>70%) were 87.5% and 68% for TR-MRA and 90% and 90% for conventional CE-MRA respectively. In five patients both TR-MRA and conventional CE-MRA were negative. In 4 patients with occlusion of superior venacava, TR-MRA mapped the sequential filling of the collateral circulation, a sequence not apparent on conventional MRA images.
Conclusion: Described 3D TR-MRA protocol over a large field of view provides comprehensive assessment of central venous occlusive disease anatomy, collateralization and hemodynamics. Having a high comparable sensitivity, and need for only a small gadolinium dose, TR-MRA has the potential to be used as an initial and screening diagnostic tool, obviating the need for conventional MRA and higher contrast dose in normal or near-normal examination. However, due to its relatively lower specificity, adjunct use of conventional CE-MRA is still required for accurate grading of venous occlusive disease.

References:

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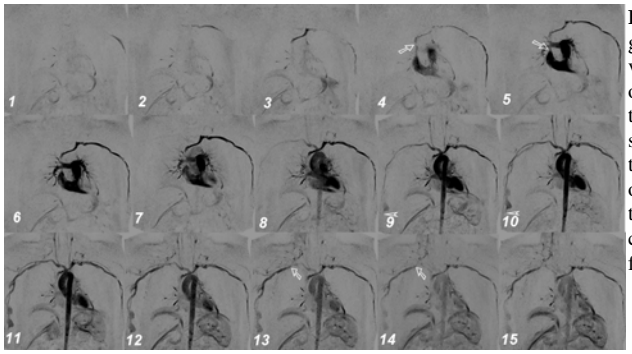

Figure. Coronal MIP images from TR-MRA (6ml gadolinium) show sequential filling of the central thoracic veins with temporal resolution of 1.5s. Using a 500 mm filed of view allows for comprehensive evaluation of the entire thoracic and upper extremity arterial and venous system in a single station acquisition. Note high-grade focal stenosis of the superior vena cava (arrows in frame 4 & 5), the presence of arterio-venous fistula with aneurysmal venous dilatation in the right upper arm (arrowheads in frame 9 & 10), and complete occlusion of the right subclavian vein (arrows in frame 13 & 14).