High resolution, first pass 3D gadolinium-enhanced venography of the jugular veins: application to multiple sclerosis

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Purpose: First pass, 3D gadolinium-enhanced venography of the jugular veins is difficult to perform when seeking both large spatial coverage and high spatial resolution. Particularly when considering routine clinical 1.5 T systems that may not be equipped with dense phased arrays for parallel imaging, capturing the venous phase without overwhelming arterial enhancement becomes difficult. We take advantage of existing methods of fluoroscopically-triggered arterial angiography, to test first pass Gd-enhanced venography encompassing a large 3D coronal field-of-view at 0.64 mm^3 voxel dimensions using a single 36 sec acquisition. High resolution enables proper assessment of venous narrowing. We report on the feasibility of this method and apply it to 60 subjects, 30 with multiple sclerosis (MS) and 30 healthy controls to examine cerebral venous drainage.

Methods: *MRI sequence* A contrast-enhanced exam was performed using a three-dimensional volume that extended from the superior vena cava takeoffs of the jugular veins to the transverse sinuses. Twenty mL of Magnevist^{TM} was injected at a rate of 3 mL/sec followed by a 20 mL saline flush. To capture the venous contrast phase with reduced arterial enhancement, real-time imaging was used to trigger a 36 sec centric 3D acquisition, similar to methods currently used for fluoroscopically-triggered carotid artery imaging (1,2). Detailed 3D parameters included: TE/TR of 1.4/3.8 ms, flip angle 25˚, field-of-view 30.0 cm x 22.5 cm x7.2 cm depth; voxel dimensions (before interpolation) 0.59mm x 0.84mm x 1.3 mm yielding 0.64 mm^3 voxel volumes. The 3D scan was triggered fluoroscopically from an oblique sagittal 2D image displayed once every second encompassing the pulmonary vessels, the aortic arch and the carotid artery. Contrast agent was observed to enter and fill the common carotid artery before triggering 12 seconds after the carotid artery filled. A 1.5T MR imaging system (Siemens Sonata) was used. Although this system has 8 receiver channels, the coil combination of spine, chest and neck arrays included a single element circumscribing head coil which precludes parallel imaging.

Patient study Thirty healthy controls and 30 subjects with MS were enrolled. Both groups were matched with 20 female/10 male and mean age of 49 years. MS subjects had a mean disease duration of 18.6 ± 7.2 years with half having progressive disease and half relapsing-remitting MS. All subjects gave informed consent in line with the institutional ethics requirements.

Analysis: Both qualitative and quantitative analysis was performed. An experienced neuroradiologist examined the degree of venous narrowing or occlusion throughout the internal jugular veins using 3D reformats. Narrowing was classified as patent, severe stenosis or occlusion. Statistical tests were performed to check for difference between groups (Pearson Chi-squared). In addition contrast measurements determined the degree of venous-to-arterial contrast.

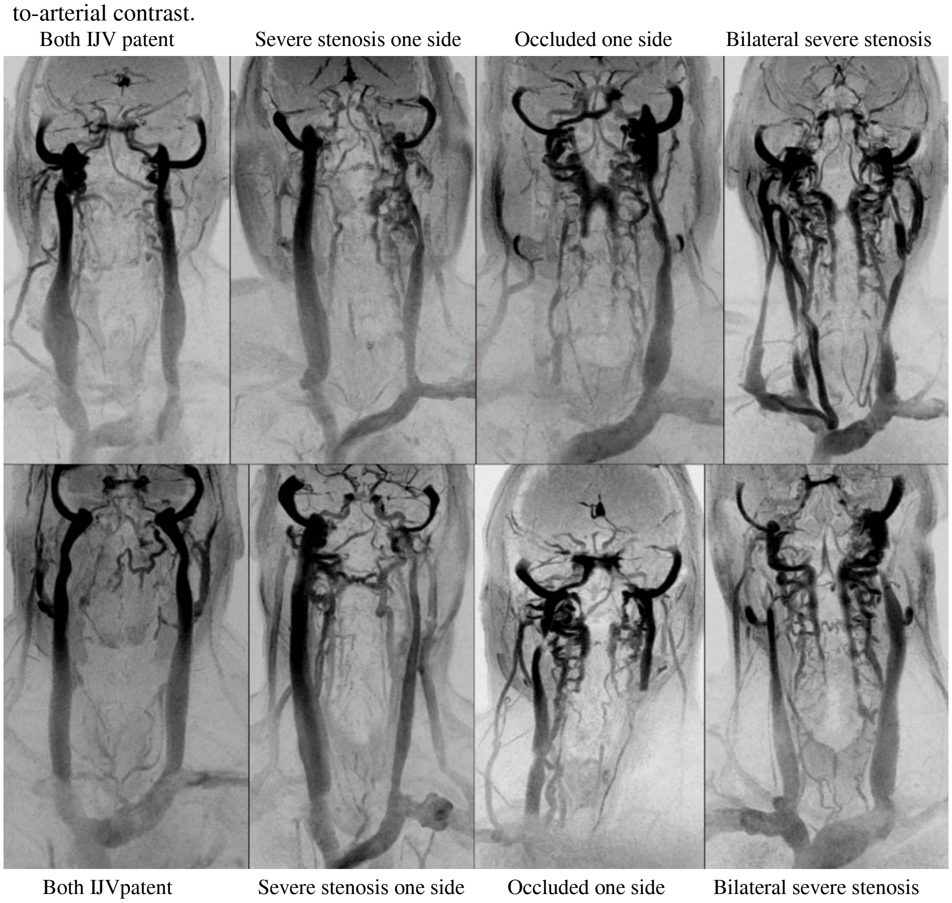

Figure 1: Maximum intensity projections (inverted scale) from 3D contrast-enhanced venograms. Top row: Healthy volunteers. Bottom row: MS subjects. Note similar characteristics of both rows. Prominent vertebral veins are evident when there is a jugular occlusion or stenosis. The venous system has multiple pathways of drainage.

Results: Contrast-enhanced venography was performed successfully on all subjects. Internal jugular vein (IJV) contrast exceeded carotid artery contrast making for easy visibility of jugular patency, enabling accurate neuroradiological assessment. A range of anomalies were found in both patients and control subjects. Severe stenosis of the internal jugular vein was found in 9/30 patients and 8/30 controls ($p<0.82$). Occluded IJVs occurred in 8/30 MS subjects and 2/30 controls ($p<0.04$). Overall 43% of patients had an occluded or severe stenosed vessel, compared to 33% of controls ($p<0.43$). Figure 1 illustrates the range of venous anomalies found in both patients (bottom row) and controls (top row). The presence of significant IJV stenosis or occlusion leads to increased vertebral vein drainage. Multiple pathways of drainage are available so venous outflow is not restricted.

Discussion: Typically one would trigger directly off the vessel of interest; however, separation of jugular vein from enhancing carotid artery was difficult, therefore triggering was performed after the carotid filled with a 12 sec delay for transit and filling of the venous system. We have examined IJV patency and determined that healthy subjects and MS patients have similar degrees of anomalies. However, a higher number of occlusions in the patient group were found, although the sample size was small. IJV studies can be enhanced by using higher resolution imaging as used here, with new coil systems enabling further resolution improvements.

References: 1. Hnatiuk B, JMRI 27:71-77 (2008).
2. Huston J, Radiology **211** 265-273 (1999).