4D flow measurements in the superior cerebellar artery at 7 Tesla: feasibility and potential for applications in patients with trigeminal neuralgia

Sebastian Schmitter[1], Bharathi D Jagadeesan[2], Andrew W Grande[3], Julien Sein[1], Kamil Ugurbil[1], and Pierre-Francois Van de Moortele[1]

[1]*Center for Magnetic Resonance Research, University of Minnesota, Minneapolis, MN, United States,* [2]*Departments of Radiology and Neurosurgery, University of Minnesota, Minneapolis, MN, United States,* [3]*Departments of Radiology, Neurosurgery and Neurology, University of Minnesota, Minneapolis, MN, United States*

INTRODUCTION. Trigeminal Neuralgia (TN) is one of the most painful medical conditions, and it is characterized by episodes of severe, lancinating facial pain triggered by otherwise non-painful stimuli [1]. The most common cause for TN is thought to be compression of the Trigeminal Nerve Root Entry Zone (REZ) just ventral to its entry into the Pons by a loop of the adjacent superior cerebellar artery (SCA), a phenomenon otherwise known as "Neurovascular conflict" (NVC) [2]. However, similar degrees of physical contact between the REZ and SCA may be found in both patients and asymptomatic individuals [3]. Some have suggested that "pulsatile" compression wherein compression of the REZ from transmitted pulsations of the SCA loops in contact with the REZ rather than the mere presence or extent of physical contact between the two structures is likely the underlying etiology in TN. This suggestion can only be proven if there is a means to non-invasively measure the pulsatility of loops of the SCA adjacent to the REZ in patients with TN and normal individuals [4]. Therefore, we explored the feasibility of measuring the Pulsatility Index (PI) of loops of the SCA adjacent to the REZ, as well as loops of the nearby posterior cerebral artery (PCA) by performing time resolved 4D Flow acquisition [5,6] in normal subjects. Given the small size of the SCA (~1.5mm ∅), we used a 7 Tesla scanner to benefit from higher Signal to Noise Ratio (SNR).

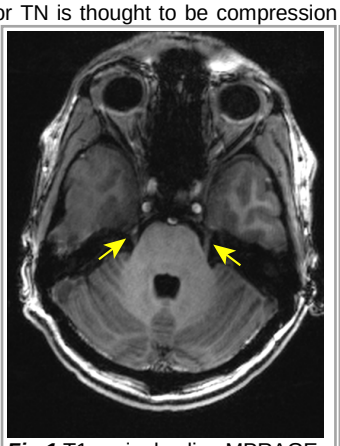

Fig.1 T1w, single slice MPRAGE image, showing the Trigeminal nerve (see arrows).

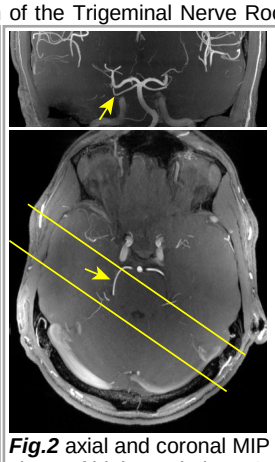

Fig.2 axial and coronal MIP views of high resolution TOF images used for positioning and identifying the SCA (arrow). Yellow bars show the acquired volume for 4D flow

METHODS. The data shown here was collected in a healthy 27 year old male subject after signing IRB-approved consent on a human 7T magnet (Siemens, Germany) using a 32 channel receiver head coil (Nova Medical, USA). After B0 shimming and flip angle adjustments using acquired flip angle maps, a T1 weighted 3D MPRAGE dataset was acquired to identify the location of the Trigeminal nerve (see Fig.1) with 0.8x0.8x1.5 mm^3 resolution. For localization of the SCA/PCA and planning of the 4D flow acquisition, a high resolution TOF dataset was acquired (see Fig.2); parameters: TR/TE = 25/2.4ms, FA=22°, $(0.4mm)^3$ resolution, 3 slabs of 25cm thickness. 3 different 4D flow acquisitions were performed with the imaging planes perpendicular to the loops of the SCA adjacent to the REZ of the Trigeminal Nerve (see Fig.2) with different in-plane resolutions: 1mm, 0.75mm and 0.5mm, and a constant slice thickness of 1mm. 8 temporal phases (or 9 for 1mm resolution) were acquired, distributed over the cardiac cycle. Further parameters:VENC=60cm/s, FA=12°, TR= 105/95/93 ms (for 0.5/0.75/1mm resolution) and TE = 4.5/4.0/4.0ms. All further post-processing was performed in Matlab (The Mathworks, USA). The reconstructed phase datasets were corrected for linear phase shifts (resulting e.g. from eddy currents) determined within the static tissue. No spatial filtering was applied in this work. Time resolved velocity maps where computed based on the 3 phase-difference datasets. To quantify the averaged velocity within PCA and SCA in the center of each vessel, over 15 contiguous slices the center voxel for each artery in each slice was identified in the magnitude image and the 2x15 positions were then stored in two vector arrays. The time resolved velocity was then extracted from the phase data in the voxels defined by each array, and finally the mean velocity and standard deviation for each artery were calculated. The analysis was performed independently at each of the 3 resolutions. PIs were computed from the temporal curves using (max systolic velocity - min diastolic velocity)/mean velocity.

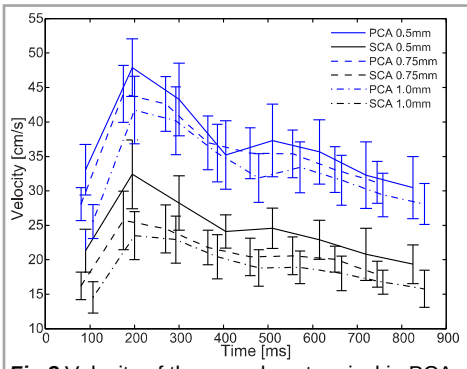

Fig.3 Velocity of the vessel center pixel in PCA and SCA averaged over 15 slices as a function of the cardiac phase

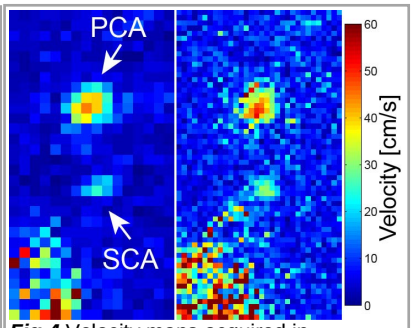

Fig.4 Velocity maps acquired in perpendicular orientation to SCA and PCA with 1mm slice thickness and 1mm (left) and 0.5mm (right) inplane resolution

RESULTS. Fig. 1 shows the MPRAGE images which clearly outlines the Trigeminal Nerve nerve, located inferior to the SCA. A 5mm axial MIP and 20mm coronal MIP shown in Fig.2 highlight the strong TOF contrast obtained at 7T with signal ratios of ~4 between SCA and background tissue. Fig.3 shows mean velocity (+/- std) curves within the center of SCA (black) and PCA (blue) for different resolutions as a function of the cardiac cycle phase. A significant difference in blood velocity between PCA and SCA is visible for all 3 resolutions with systolic peak values of 47.9 cm/s and 32.4 cm/s for 0.5 mm in-plane resolution. The PIs amount to 0.54/0.45/0.47 (SCA) and 0.47/0.45/0.49 (PCA) for 0.5/0.75/1 mm inplane resolutions. Comparing the curves for different resolution shows a consistent trend towards lower velocities with increasing voxel size for both arteries, which can be explained by increased partial volume effects with increased voxel size. Consistent with this observation, 2D velocity maps perpendicular to the arteries (Fig.4) clearly reflect the loss of details at 1mm resolution (partial volume effect), especially for the smaller vessel with only 2-3 voxels covering the SCA radially at 1mm resolution and approx. 5-6 voxels at 0.5mm resolution.

DISCUSSION :

Herein, we have demonstrated that it is possible to measure the PIs of the SCA and the PCA using time resolved 4D Flow acquisitions 7 Tesla. We have also demonstrated that the measured values of velocity and PIs may directly depend upon in-plane resolution. Comparison of the PI values of SCA loops adjacent to the REZ obtained using this technique in patients with TN and in normal people may help us to understand the role of "pulsatile" compression in the etiology of this poorly understood disorder. Extending this approach to other small vessels at the skull base may also help understand the etiology of other NVC disorders such as Occipital neuralgia, hemi-facial spasm and pulsatile tinnitus which are also thought to be due to "pulsatile" compression of the respective cranial nerves by adjacent arterial loops.

ACKNOWLEDGMENTS: P41 EB015894, S10 RR026783, R21-EB009138, KECK Foundation. Dinxing Wang, Siemens **REFERENCES**

[1] Merskey et al, Classification of chronic pain. 2nd ed. Seattle: IASP Press;1994 [2] Gardner et al, J Neurosurg 1962; 19:947 [3] Ouaknine et al. Surg Neurol 1980; 13:147 [4] Jannetta et al Arch neurol .1985;42: 800 [5] Markl et al. JMRI 2003, 17:499 [6] Bammer et al. MRM 2007, 57:127