High Resolution Thoracic and Neurovascular 3T MRI for the Comprehensive Assessment of Inflammatory Disease

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Introduction: Detailed visualization of vascular geometry and morphology is of high interest for the assessment of inflammatory disease such as giant cell arteritis (GCA) in order to detect small changes in superficial cranial arteries as well as extra-cranial involvement [1, 2]. Here, we present a novel imaging protocol which utilizes an advanced neurovascular coil and parallel imaging with high acceleration factors to considerably improve spatial resolution and anatomical coverage. The MR imaging protocol included high-resolution 3D contrast enhanced MR angiography (CE-MRA, [3]) from head to thorax and the simultaneous assessment of inflammatory changes in the small arteries of the head with ultra-high in-plane resolution (195µm x 260µm) [4]. Results of a patient study demonstrate the feasibility for a comprehensive assessment of inflammatory disease with optimal use of contrast agent for both CE-MRA and post contrast imaging of mural inflammation.

Methods: Seven patients with suspected GCA (5m, 2f, 46-78 years, mean age = 65 years) were investigated using a 3T system (TRIO, Siemens, Germany) and a phased array neurovascular coil with two choices of 8-channel configurations. The first 8-channel setup permitted full coverage of the thoracic aortic arch, supra-aortic vessels, neck and the entire head and was used for CE-MRA (Gd-BOPTA, ALTANA Pharma, Germany, dose = 0.1 mmol/kg, injection rate = 3ml/s). Parallel imaging was used to accelerate data acquisition (GRAPPA, acceleration factor = 3, 32 reference lines) [5] and data were acquired in a coronal 3D volume with a spatial resolution of (0.63 x 0.83 x 1.25)mm^3. For morphological analysis of the cranial arteries, the second 8-channel configuration of the neurovascular coil was used which corresponded to an 8-channel phased array head coil. Pre- and post-contrast arterial wall imaging with high in-plane sub-millimeter spatial resolution (195µm x 260µm) was performed using a T_1-weighted 2D multi-slice Turbo Spin Echo sequence with an echo train length of 3 (TSE-3) and the following imaging parameters: TE = 16ms, TR = 573ms, FOV = (200 x 181)mm^2, matrix = 1024 x 696, 30 slices, slice thickness =3 mm, total scan time = 5.56min.

Results: MR exams could be completed in less than 45 minutes in all patients. The aortic arch, supra-aortic vessels including parts of the left and right subclavian arteries, and cervical arteries were well visualized for all patients. Consensus reading revealed that the common superficial temporal arteries, the proximal 5 cm of the temporal branch and the proximal 5 cm of the occipital arteries were clearly depicted in all cases. Due to incomplete volumetric coverage the parietal branch of the superficial temporal arteries could only be successfully visualized in 4 patients. Figure 1 shows representative CE-MRA results and illustrates the large anatomical coverage and excellent delineation of the small superficial temporal arteries.

Characteristic signs of inflammatory changes related to GCA could be identified in post-contrast TSE-3 head images for a 64 years old male patient. Localized cranial arterial inflammation could be detected due to the accumulation of contrast agent and circumferential luminal thickening in the superficial left occipital artery (figure 2, post contrast, solid white arrows). No or only minor signs of inflammation were seen for the right occipital artery (figure 2, feathered white arrow). MR images of a 66 year old female patient one day after a biopsy of the left superficial temporal artery are depicted in figure 3. Location and extent (19 mm) of the removed arterial segment as well as the enhancing inflammatory tissue along the vessel track can be readily revealed (open white arrows). In all cases, inflammatory changes such as mural wall enhancement could clearly be identified even without the information available in the pre contrast images.

Discussion: The results of this study demonstrate the feasibility to assess morphological inflammatory changes in superficial cranial arteries and simultaneous angiographic assessment in thorax and neck for the evaluation of cranial and extra-cranial manifestations of rheumatologic disease. Even with single dose (0.1 mmol/kg) contrast agent administration, excellent CE-MRA image quality could be achieved and vascular geometry of small superficial cranial arteries could be successfully visualized. Additional head imaging with in-plane spatial resolution in the order of 200µm provides high detail information about vascular morphology of the small superficial cranial arteries.

However, higher and especially isotropic spatial resolution in the order of 0.3-0.4 mm^3 is desirable for reliable angiography of the distal segments of the superficial arteries. Further trials with respect an optimal trade-off between MR and contrast agent parameters are needed to systematically test and optimize such imaging protocols and determine their clinical utility. Preliminary results (figure 4) display a 3D CE-MRA with an acceleration factor of 4 resulting in higher spatial resolution of (0.54 x 0.68 x 1.0)mm^3 and increased volumetric coverage. High detail representation of even distal segments of the superficial temporal arteries could be achieved (arrows). Non-subtracted pre and post contrast images revealed enhanced parallel imaging reconstruction artifacts and increased background noise but background subtraction and the strong contrast agent effect at 3T seemed to compensate for such drawbacks.

References: 1. Salvarani C, et al. N Engl J Med 2002;347(4):261-71. **2.** Stanson AW, et al. AJR Am J Roentgenol. 1976;127:957–963. **3.** Prince MR. Radiology 1994;191(1):155-164. **4.** Bley TA, et al. Am J Roentgenol. 2005 Jan;184(1):283-7 **5.** Griswold MA, et al. Magn Reson Med 2002;47(6):1202-1210.

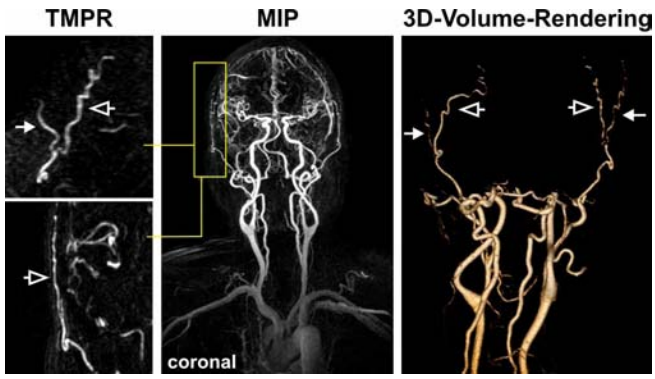

Fig. 1: CE-MRA from head to thorax: Frontal (open arrows) and parietal branches (solid arrows) of the temporal arteries can be clearly visualized using thick multi-planar reformat (TMPR) or 3D volume rendering.

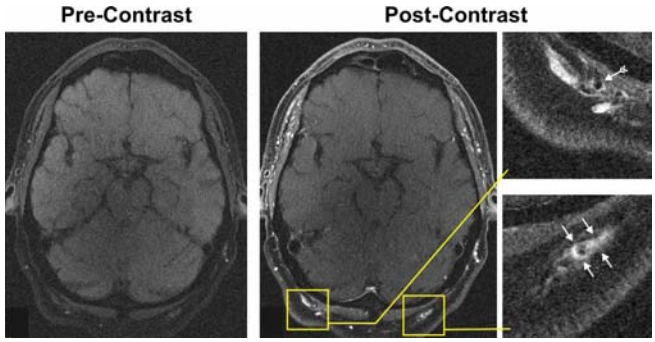

Fig. 2: Pre- and post contrast T_1-TSE-3 for inflammatory changes in the left (arrows) and no changes in the right (feathered arrow) occipital arteries.

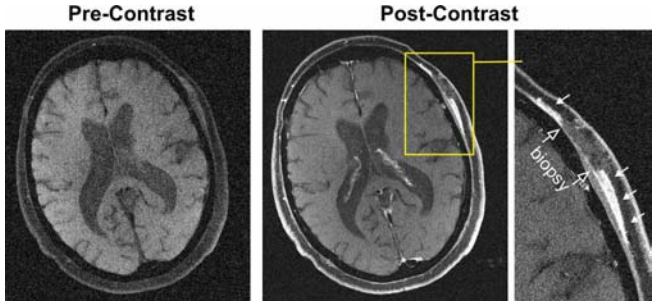

Fig. 3: Pre- and post contrast T_1-TSE-3 images for substantial inflammation of the left temporal artery with previously performed biopsy (open arrows).

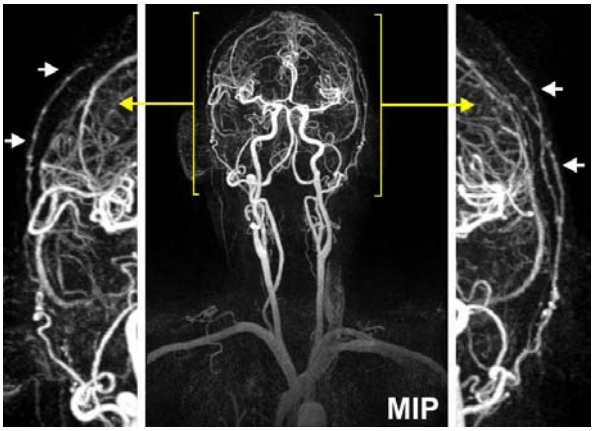

Fig. 5: Preliminary results for CE-MRA with an acceleration factor of 4 and increased spatial resolution and volumetric coverage as compared to fig. 1. Note the high detail visualization of large section of both superficial temporal arteries (solid white arrows).