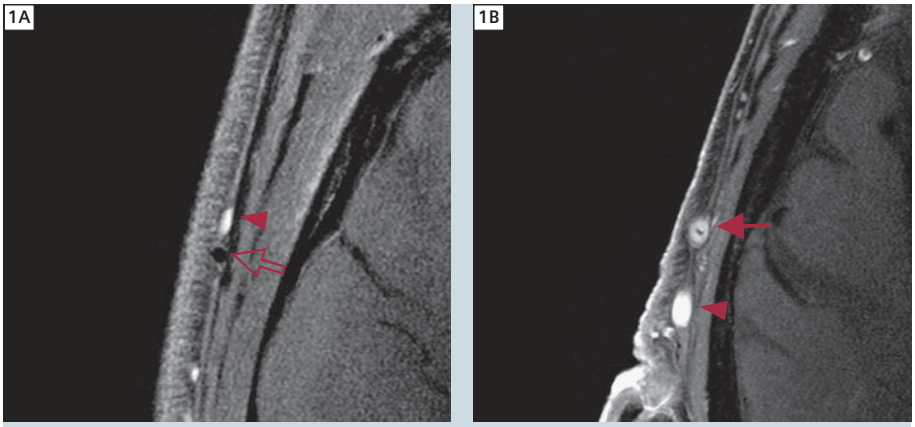
MRI of Giant Cell (Temporal) Arteritis, GCA

Thorsten Alexander Bley[1], Julia Geiger[2], Oliver Wieben[3], Michael Markl[4]

[1]Department of Diagnostic and Interventional Radiology, University Medical Center Hamburg-Eppendorf, Hamburg, Germany
[2]Department of Radiology, University Hospital Freiburg, Freiburg, Germany
[3]Departments of Radiology and Medical Physics, University of Wisconsin-Madison, Madison, USA
[4]Departments of Radiology and Biomedical Engineering, Northwestern University, Chicago, IL, USA



1 High-resolution MRI of the superficial temporal arteries: enlargement of contrast enhanced T1 weighted Spin Echo imaging with 197 x 260 µm² in plane resolution. The vessel wall of unaffected segments of the superficial temporal artery is very thin (open arrow in **1A**). Due to high arterial flow no intraluminal signal is visible ('flow void'). Slower flow in the concomittant vein renders homogeneous intraluminal signal (arrowhead in **1A** and **1B**). Mural inflammatory changes of the affected superficial temporal artery include mural thickening and contrast enhancement (arrow in **1B**).

Introduction

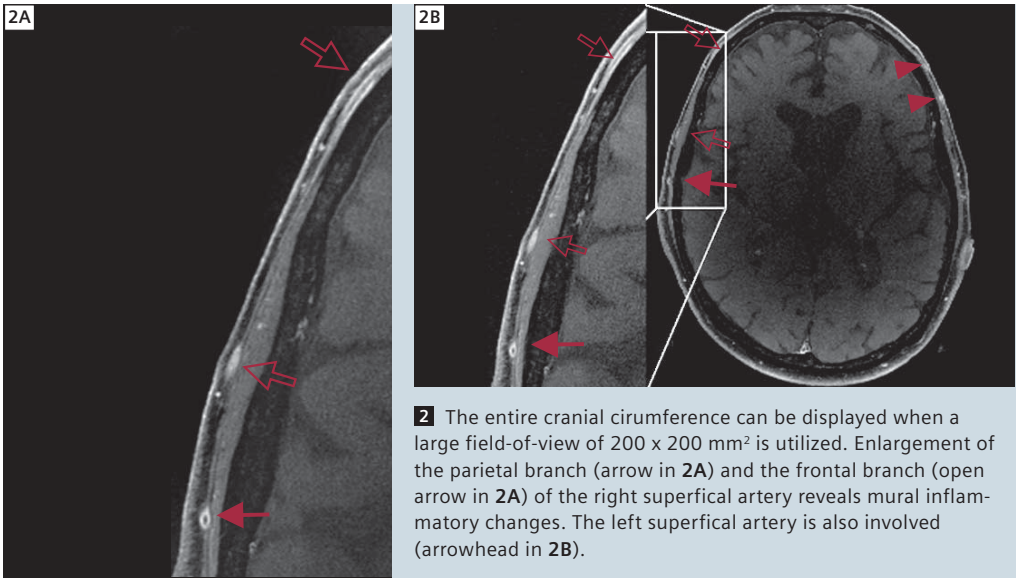
Giant cell (temporal) arteritis (GCA), is a chronic, granulomatous vasculitis, which primarily affects large-to-medium size arteries and is often associated with polymyalgia rheumatica [1]. It occurs more frequently in women than in men with a gender ratio of up to 2-4:1. The maximum incidence occurs in those aged between 70 and 80. The annual rate of new cases is rising and ranges between 15 and 25 per 100.000 for those aged 50 and older [2]. Interestingly, the rate of occurrence is 2.25 times higher in urban compared to rural regions [3].

The classic leading symptom of GCA is new onset of headaches with tender temporal arteries. In addition, the masticatory muscles and scalp may demonstrate enhanced sensitivity associated with pain. Visual symptoms include amaurosis fugax and diplopia. Loss of sight is a severe complication as a consequence of inflammatory involvement of the posterior ciliar arteries (anterior ischaemic optic neuropathy, AION) [4]. The American College of Rheumatology (ACR) has drafted classification criteria to facilitate the difficult clinical diagnosis of GCA [5]. To date, a biopsy of the superficial temporal artery is considered the diagnostic gold standard. However, a segmental affliction pattern is typical for GCA. As a result, even negative biopsy results may erroneously indicate the absence of the disease if the biopsy was taken from a non-affected segment of the superficial temporal artery [1, 6]. In addition to or instead of the superficial temporal artery, other superficial cranial arteries may be affected. Modern imaging techniques such as CT, MRI, and FDG PET have recently demonstrated that extracranial manifestation of GCA was present in up to 70% of cases [7]. In this context, the following vessels may be affected in decreasing order of occurrence: Aorta, subclavian and axillary arteries, vertebral arteries, visceral branches of the aorta including renal and mesenterial arteries, coronary and pulmonary arteries, and the arteries of the extremities.

At least 1 mg prednisone equivalent per kg bodyweight per day is recommended for initial treatment of GCA. In most cases, clinical and serological remission occurs within the very first week of treatment, which permits tapering of the corticoid dosage. However, the period of illness is likely to vary from one individual to another and often spans several years. Disease may recur in phases over a period of up to ten years.

Imaging

Signs of vascular inflammatory involvement such as a dark halo that may be caused by an edema of the arterial wall can be identified with the help of color-coded duplex sonography (CCDS) of the



2 The entire cranial circumference can be displayed when a large field-of-view of 200 x 200 mm² is utilized. Enlargement of the parietal branch (arrow in **2A**) and the frontal branch (open arrow in **2A**) of the right superfical artery reveals mural inflammatory changes. The left superfical artery is also involved (arrowhead in **2B**).

superficial temporal artery. Sensitivities of 73–93% and specifities of 89–93% can be achieved with this method [8]. In the hands of an experienced observer CCDS is considered the non-invasive imaging modality of first choice. However, the clinical significance of CCDS is still debated and its operator dependency may limit its diagnostic accuracy. As alternative imaging modalites, CT and MRI/angiography are suitable for non-invasive assessment of extracranial manifestation, particularly to rule out aortitis and inflammation of the supra-aortic branches. FDG-PET represents a valuable and highly sensitive tool for assessment the extracranial manifestation pattern.

High-resolution MRI

Recently, high-resolution post-contrast MRI has been developed as an alternative diagnostic imaging technique for the detailed assessment of segmental inflammation patterns associated with GCA [9]. For the successful evaluation of the small extra-cranial arteries high spatial resolution in the sub-millimeter range is needed. In addition, sufficiently high signal-to-noise (SNR) is necessary to detect contrast agent accumulation (i.e. T1 shortening and bright signal) as a sign of mural inflammatory changes in the very small superficial temporal arteries.

We have developed an imaging protocol for the complete assessment of all superficial cranial arteries based on high-resolution, fat-saturated, contrast enhanced multi-slice T1-weighted spin echo imaging with a spatial resolution of 195 µm x 260 µm [9].

The sequence parameters for data acquisition at 1.5 and at 3 Tesla (T) are listed below.

Sequence parameters at 1.5T

- TR/TE 500/22 ms
- Acquisition matrix of 1024 x 768 voxels
- Field-of-view (FOV) = 200 x 200 mm²
- Spatial resolution: 195 x 260 µm²
- Slice thickness = 3 mm
- Number of excitations = 1
- Bandwidth 65 Hz/pixel
- Acquisition time 6:55 min
- Fat saturation

Sequence parameters at 3T

- TR/TE 500/22 ms
- Acquisition matrix of 1024 x 768 voxels
- FOV 200 x 200 mm²
- Spatial resolution 195 x 260 µm²
- Slice thickness = 3 mm
- Number of excitations = 1
- Bandwidth 76 Hz/pixel
- Partial Fourier acquisition along the phase encoding direction
- (Half Fourier factor) = 6/8
- Acquisition time 4:52 min
- Fat saturation

Ten slices of 3 mm thickness spaced at 3 mm intervals cover a total distance of 63 mm of the temporal artery. Data acquisition using 3 slice packages allows assessment of the complete course of the temporal arteries as needed for GCA. The complete coverage makes it possible to assess the frontal and the parietal branches of the superficial temporal arteries as well as the occipital arteries bilaterally. Increased SNR at 3 Tesla can successfully be used to reduce the measurement time (partial Fourier acquisition along the phase encoding direction). In addition, the contrast agent effect (T1 shortening) is increased at higher field strength and an enhanced blood background contrast can be achieved. We have shown in a number of studies that this protocol allows displaying the arterial wall and lumen of the superficial temporal arteries accurately [9–15]. Mural inflammation is graded on a four-point scale according to mural thickening and contrast enhancement

of the arterial wall and perivascular tissue:

– = No wall thickening (< 0.6 mm), no mural contrast enhancement.
\+ = No wall thickening (< 0.6 mm), barely detectable mural contrast enhancement.
++ = Wall thickening (≥ 0.6 mm) and clearly visible mural contrast enhancement.
+++ = Substantial wall thickening (≥ 0.6 mm) and pronounced mural contrast enhancement.

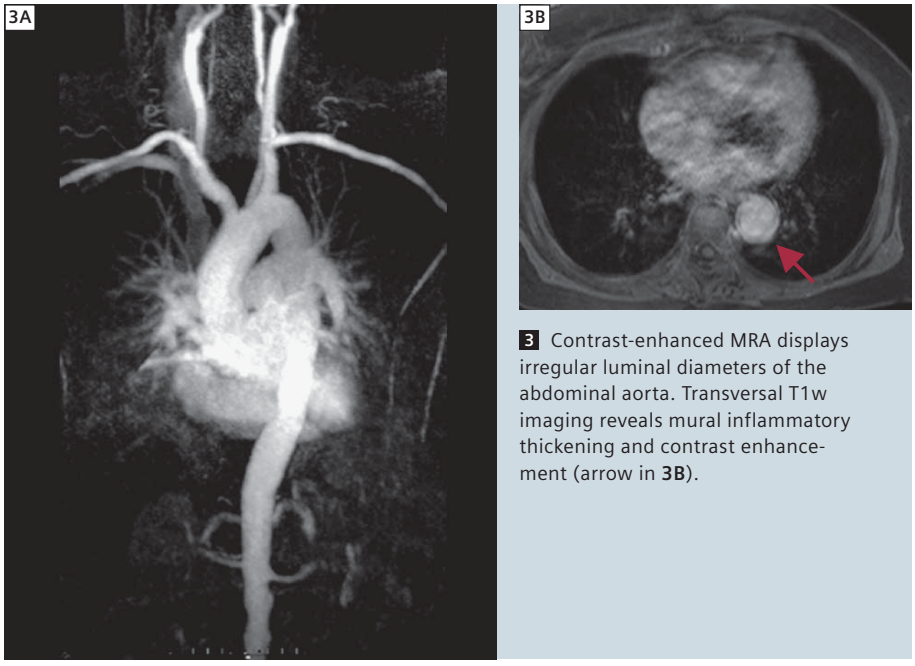
Arteries can be differentiated from the accompanying veins by their flow characteristics: Blood flows considerably faster in arteries than in veins. In spin echo imaging, fast arterial flow results in the flow of blood prior to spin echo generation and signal reception and thus dark signal in the vessel lumen or 'flow void'. In contrast, slower venous flow contributes to a bright intraluminal venous signal. Furthermore, as a result of the high spatial resolution, the thicker arterial walls can be distinguished from the thin venous walls in most cases.

MR angiography

For assessment of the extracranial involvement in GCA the MR protocol can be extended to include an examination of the thoracic, cervical, and cranial arteries. The contrast agent administration used for post-contrast analysis of the temporal arteries can be used for large FOV time-resolved MR angiography (MRA) prior to high-resolution cranial MRI. As a result, a single dose contrast agent administration can efficiently be used to provide both high-resolution images of the inflamed vessel wall and information on additional stenosis or wall inflammation in the neck and thorax.

Sample protocol for time-resolved MRA

- TE 1.11 ms
- TR 3.15 ms
- FOV 400-500 x 320 mm²
- 3D volume thickness (slab thickness) 120 mm
- Acquisition matrix 640 x 384
- Parallel imaging with up to 3 times the acceleration factor
- 96 slices
- Partial Fourier acquisition along the phase encoded direction (partial Fourier factor 6/8)
- Spatial resolution = 0.63 x 0.83 x 1.25 mm



3 Contrast-enhanced MRA displays irregular luminal diameters of the abdominal aorta. Transversal T1w imaging reveals mural inflammatory thickening and contrast enhancement (arrow in **3B**).

The MRA volume should cover the thoracic aorta, the subclavian and axillary arteries and the carotid and vertebral arteries. Ideally, a whole-body MRA covering the entire vasculature from head to toe is performed prior to high-resolution vessel wall imaging of the superficial cranial arteries. It is known that mural inflammatory contrast enhancement persists for several minutes. Sufficient time for repositioning of the patient and planning of the high-resolution images is therefore available.
Of note, axial images of the aortic wall should also be acquired to detect aortitis. An axial gradient echo sequence may be used, for example, to assess mural thickening and contrast enhancement of the aortic wall. The inflammatory edema can also be displayed with a TIRM sequence. High contrast between the intra-luminal and mural signal is favored so that mural thickness and inflammatory changes such as edema and contrast agent enhancement can be revealed.
The non-invasive high-resolution MRI protocol was evaluated in a number of studies in patients with proven GCA and inflammation of the superficial cranial arteries. The sensitivity and specificity of this method was 80.6% and 97.0%. In a subgroup of patients who received their MRI within the first 10 days of treatment, the sensitivity was 85.5% [14]. In a retrospective, intra-individual comparison high-resolution MRI and CCDS revealed similar results. Sensitivity of the MRI was slightly higher but did not reach the level of significance [12].

Discussion

In GCA, steroid treatment has high priority due to severe complications such as blindness. Patients suffering from GCA typically show rapid improvement under steroid treatment. However, temporal artery biopsy may still show signs of GCA even after two weeks of treatment. Our experience has shown that mural contrast enhancement and wall thickening is reduced considerably under treatment. Hence, patients should be scanned prior to or soon after onset of treatment. After a few weeks

of successful treatment, the signs of inflammation recede considerably and can no longer be detected after long term treatment.
High-resolution post-contrast T1-weigted spin echo MRI can be employed to precisely assess the cranial distribution pattern of this inflammatory disease, which is known to occur in a segmental manner. This is particularly important, since negative biopsy results may occur erroneously if, for example, a non-affected segment has been chosen for biopsy. Imaging guided biopsy may have the potential to reduce the rate of false negative biopsy results.
The highest achievable spatial resolution and contrast-to-noise ratio should be selected for imaging small structures such as the wall of the superficial cranial arteries. Hence, imaging at 3T is preferred. To permit imaging with high spatial resolution and SNR, parallel imaging techniques, which could be used to reduce total scan time but are associated with SNR loss, have not been applied. In a comparison of image quality for both 1.5T and 3T, imaging at high field was clearly superior. Nonetheless, examinations at 1.5T demonstrated good image quality and were found to be highly suitable for diagnostic purposes.

Summary

GCA is a diagnostic challenge. Early high-dose steroid treatment is needed to reduce the risk of blindness. The proposed MRI protocol represents a valid and non-invasive method for diagnosing giant cell arteritis. With a high spatial resolution of 195 x 260 µm, the superficial cranial arteries and their inflammatory mural enhancement pattern can be visualized. In a single, non-invasive examination, the cranial inflammation pattern associated with GCA can be displayed.
The high-resolution MRI examination of the superficial cranial arteries should be combined with an MRA of the aorta and the supra-aortic branches. This is particularly useful, since GCA affects also the extracranial arteries in up to 70% of patients. Inflammatory changes of the aorta, the carotid, vertebral, subclavian and axillary arteries can be displayed in a single examination of 30 to 40 minutes.

Conclusions

1. The superficial cranial arteries along with the mural and luminal properties can be displayed in detail using high-resolution MRI.
2. Inflamed arterial segments can be differentiated from non-affected segments.
3. Steroid treatment leads to a rapid reduction in inflammatory mural contrast enhancement. After successful long term steroid treatment mural inflammatory changes vanish entirely.
4. 3T image quality is superior to 1.5T. Nonetheless, imaging at 1.5T provides sufficient diagnostic image quality.
5. High-resolution MRI should be combined with thoracic and cervical MRA to assess the aortic and supraaortic arteries' involvement pattern within one integrated MRI/MRA study.

Thorsten A. Bley, M.D.

Contact
Thorsten Alexander Bley, M.D.
Assistant Professor of
Radiology
University Medical Center
Hamburg-Eppendorf
Department of Diagnostic
and Interventional Radiology
Martinistrasse 52
20246 Hamburg
Germany
Phone.: +49 1522 2816990
Fax: +49 40 7410 53802
t.bley@uke.de

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