# Multisequence Whole-Brain Intracranial Vessel Wall Imaging at 7.0 Tesla MRI

Anja G. van der Kolk[1], Jeroen Hendrikse[1], Manon Brundel[2], Geert Jan Biessels[2], Ewoud J. Smit[1], Fredy Visser[1,3], Peter R. Luijten[1], and Jaco J.M. Zwanenburg[1,4]
[1]*Department of Radiology, University Medical Center Utrecht, Utrecht, Netherlands,* [2]*Department of Neurology, University Medical Center Utrecht, Utrecht, Netherlands,* [3]*Philips Healthcare, Best, Netherlands,* [4]*Image Sciences Institute, University Medical Center Utrecht, Utrecht, Netherlands*

## Introduction

For imaging of intracranial arterial pathology, visualization of the lumen is not enough due to arterial remodeling[1]. Therefore, an imaging method directly depicting the arterial vessel wall is of great value. It was previously shown that imaging of healthy and diseased intracranial vessel wall at 7.0 Tesla (7T) MRI is possible with the 3D $T_1$-weighted MPIR-TSE sequence, with high resolution and sufficient contrast[2]. However, due to its limited coverage (13mm), more extensive assessment of the whole cerebral arterial tree is not possible. Furthermore, a multisequence MRI protocol, including – besides $T_1$-weighting – proton density(PD)- and $T_2$-weighting, may better characterize vessel wall pathology. The aim of this study was to develop a multisequence high-resolution intracranial vessel wall protocol with whole-brain coverage.

## Methods

This study was approved by the institutional review board of our institution; all subjects gave written informed consent. Imaging was performed on a 7T whole body system (Philips Healthcare, Cleveland, OH, USA) with a 32-channel receive coil and volume transmit/receive coil for transmission (Nova Medical, Wilmington, MA, USA). A modified MPIR-TSE sequence with non-selective short RF pulses and SENSE in two directions was used to obtain a sequence with whole-brain coverage (Figure 1). The parameters were adapted to obtain the three different contrast weightings (Table 1). All sequences had the same variable refocusing flip angle scheme[3], with low refocusing angles ranging between 12° and 40°, optimized to yield a constant signal response for tissue with a $T_1/T_2$ of 2000/55ms for at least half the train length. This allows a long readout with limited blurring. Five healthy volunteers (mean age 26 years, range 22-34 years) were scanned with both the limited-coverage MPIR-TSE sequence, and the three whole-brain sequences. For two patients who were scanned for clinical purposes, individually relevant vessel wall sequences were performed. Three observers independently compared[4] conspicuity and image contrast of all four vessel wall sequences in the healthy volunteers. Furthermore, in all scans, multiple signal profiles of a predefined area including vessel wall and background were used to calculate mean highest (vessel wall) and lowest (background signal) signals calculated. The ratio of vessel wall and background signal was used as a measure of image contrast / vessel wall conspicuousness.

***Table 1*** *Scan parameters*

| **Scan parameter** | **PD** | **$T_1$** | **$T_2$** |
|---|---|---|---|
| FOV (mm) | 250x250x190 | 250x250x190 | 250x250x190 |
| Acquired resolution (mm) | 0.8x0.8x0.8 | 0.8x0.8x0.8 | 0.8x0.8x0.8 |
| Orientation | Sagittal | Sagittal | Sagittal |
| TR/TI (ms) | 6000/1900 | 3952/1375 | 8000/2200 |
| TE/equivalent TE (ms) | 37/19 | 37/19 | 287/126 |
| Flip angle (degrees) | 150[1] | 150[1] | 150[1] |
| Refocusing angles (degrees)[3] | 12-40 | 12-40 | 12-40 |
| TSE-factor | 158 | 158 | 158 |
| NSA | 2 | 2 | 1 |
| SENSE factor | 2x4 (APxRL) | 2x3 (APxRL) | 2x3 (APxRL) |
| Duration (min:sec) | 12:12 | 10:40 | 10:56 |

[1]*Overtipping was used to compensate low $B_1$ values at the periphery of the brain.*

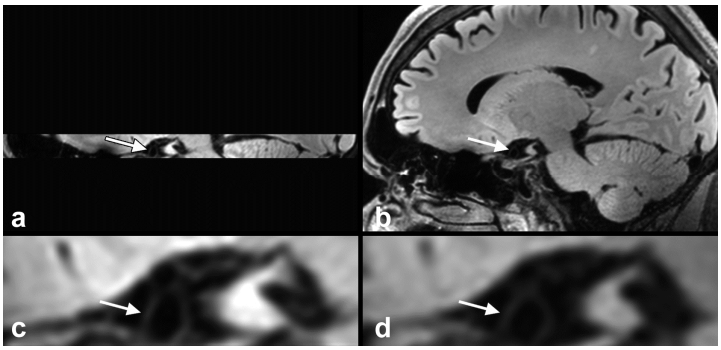


***Figure 1.*** *Comparison of coverage between the limited-coverage MPIR-TSE sequence (**a**) and the whole-brain MPIR-TSE sequence (**b**). On both sequences, vessel wall of the distal internal carotid artery (ICA) can be observed (arrows in **a** and **b**), more clearly illustrated on the zoomed-in images (arrows in **c** and **d**. Note that the vessel lies at the inferior border of the field of view (FOV) of the limited-coverage sequence (**a**), which illustrates the sensitivity of this sequence to malpositioning of the FOV or patient motion between the scan at which FOV planning is performed and the actual vessel wall sequence.*

## Conclusion

With our whole-brain multisequence vessel wall protocol, we have shown the possibility of whole-brain assessment of the intracranial arterial vessel wall with multiple different image contrast weightings. In future, vessel wall imaging using multisequence MRI at 7T may be able to distinguish between several types of intracranial vessel wall pathology similar to assessment of carotid artery plaques.

## Acknowledgements

This research was supported by the Center for Translational Molecular Medicine and the Dutch Heart Foundation (PARISk).

## References

[1]*Glagov S, et al. N Engl J Med 1987;* [2]*van der Kolk AG, et al. Stroke 2011;* [3]*Busse RF, et al. Magn Reson Med 2006;* [4]*Smit EJ, et al. Radiology 2012*

## Results

Whole-brain coverage for the PD-, $T_1$- and $T_2$-weighted vessel wall sequences was successfully obtained in all subjects. Vessel walls of the large vessels of the Circle of Willis, as well as their smaller branches were clearly visible in all whole-brain scans. All three whole-brain sequences had similar ratings regarding visibility of the vessel wall, artifacts and overall image quality, though slightly less than the limited-coverage MPIR-TSE sequence, which was judged to give the best conspicuity of the vessel walls in most cases. The signal ratios for all three whole-brain sequences were similar, with approximately a factor of two more signal in the vessel walls compared to their surroundings. For the limited-coverage scan, this signal ratio between vessel wall and surroundings was 2.6. For the two patients both the whole-brain-coverage MPIR-TSE sequences and the limited-coverage sequence gave similar diagnostic information. In the vasculitis patient (Figure 2), enhancing small arterial branches were found, that could not be appreciated on the limited-coverage MPIR-TSE sequence.

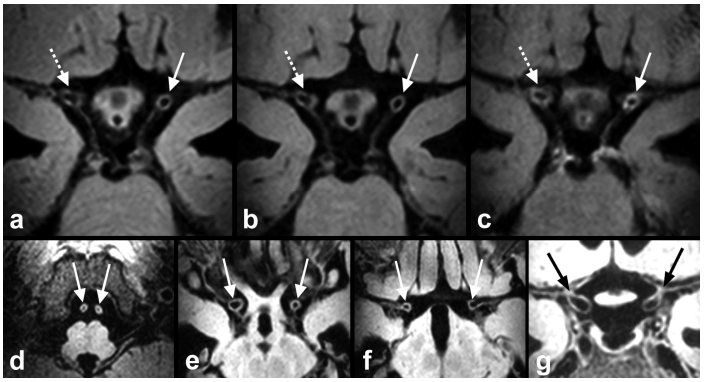


***Figure 2*** *7.0 Tesla limited-coverage 3D MPIR-TSE (**a**), and whole-brain $T_1$-weighted MPIR-TSE images before (**b**) and after (**c-h**) contrast administration of patient with vasculitis. Diffuse thickening of all intracranial vessel walls, like the MCA (dashed white arrow in **a-c**), can be seen. After contrast administration, there is diffuse enhancement of most of the intracranial arteries (white and black arrows in **c-g**).*