# Feasibility of volume pulsation measurements of intracranial aneurysms using high-resolution 7T MRI images.

Bram Schermers, BSc[1,2], Rachel Kleinloog, MD[1], Bon H Verweij, MD, PhD[1], Ynte M Ruigrok, MD, PhD[1], Peter R Luijten, PhD[3], Fredy Visser[3,4], Luca Regli, MD, PhD[1,5], Gabriël JE Rinkel, MD[1], and Jaco J Zwanenburg, PhD[3]

*[1]Brain Center Rudolf Magnus, Department of Neurology and Neurosurgery, University Medical Center Utrecht, Utrecht, Utrecht, Netherlands, [2]Faculty of Science and Technology, Department of Technical Medicine, University of Twente, Enschede, Twente, Netherlands, [3]Department of Radiology, University Medical Center Utrecht, Utrecht, Netherlands, [4]Philips Healthcare, Best, Netherlands, [5]Department of Neurosurgery, University Hospital Zürich, Zürich, Switzerland*

**TARGET AUDIENCE:** Researchers working with high-field MRI and/or on the prediction of aneurysm rupture risk.

**Figure 1:** *QR-code containing a video of a dynamic aneurysm pulsation scan.*

**PURPOSE:** The purpose of this work is, first, to assess the feasibility of quantitative measurement of intracranial aneurysm volume pulsation at 7.0 tesla (7T) MRI, and, second, to quantify the inaccuracy of the measured volume pulsations. The inaccuracy is expected to depend on contrast-to-noise ratio (CNR), signal fluctuations in the aneurysm lumen due to inflow of blood, and aneurysm size. Intracranial aneurysms are sac-like widenings of the intracranial arteries and are prevalent in 3% of the general population[1]. Rupture of an aneurysm is associated with high mortality and morbidity. Treatment can prevent rupture, but carries a 4 to 8% risk of major complications including death, depending on age of the patient and size and site of the aneurysm.[2-4] Because of this risk, treatment should only be performed on aneurysms with high risk of rupture only. Current rupture risk assessment is difficult, due to the absence of good risk predictors. Aneurysm volume pulsation during the cardiac cycle has been postulated as a novel predictor of rupture risk[5].

**METHODS**: *Patient Study* Ten unruptured intracranial aneurysms in nine patients were imaged using a 7T MRI system (Philips Healthcare) using a 32 channel receive head coil (Nova Medical). Imaging parameters were: retrospectively gated 3D Turbo Field Echo (TFE) sequence, spatial resolution 0.6x0.6x0.6mm³, FOV 180x180x15mm$^3$ and a temporal resolution of 90ms (15 cardiac phases). Semi-automatic image analysis was performed in ANALYZE 11.0 (AnalyzeDirect) to segment the aneurysm for each cardiac phase using a fixed intensity threshold for the entire cardiac cycle. Volume pulsation was defined as the difference in volume between the phase with the largest volume and the smallest volume.

*Accuracy Study* The influence of image quality on the measured volume pulsations was investigated by implementing (in Matlab, MathWorks) a spherical non-pulsating digital phantom, and image analysis analogous to the method used in the patient study. The effects of *(1)* noise and *(2)* signal intensity fluctuations on the apparent volume pulsation were assessed as function of phantom (aneurysm) size. The noise had a Rician noise distribution, and resulted in CNRs between aneurysm lumen and background ranging from approximately 2 to 37. Sinusoidal intensity fluctuations throughout the cardiac cycle were simulated in conjunction with partial volume effects. The partial volume effect was introduced by rendering a high-resolution phantom (0.05 mm isotropic resolution) and cropping it back to the original resolution in the frequency domain. The absolute apparent volume pulsation (mm³) observed for this static digital phantom was used as a measure for the inaccuracy. Simulated phantom (aneurysm) sizes ranged from Ø 2.8 to 14 mm (12 to 1500 mm³). CNR and intensity fluctuation were also estimated for each aneurysm of the patient study. Given the aneurysm volume, this was used to estimate an aneurysm-specific total inaccuracy (mm³) due to noise and intensity fluctuations from the simulated data.

**Table 1**: *Overview of aneurysm data and inaccuracies.*

| Aneur. No. | Mean Volume (mm³) | CNR | Intensity Fluctuation (%) | Measured Pulsation (mm³) | Total Estimated inaccuracy (mm³) |
|---|---|---|---|---|---|
| **1** | 14 | 8 | 7 | 3 | 2 |
| **2** | 60 | 3 | 5 | 8 | 6 |
| **3** | 73 | 6 | 5 | 5 | 4 |
| **4** | 95 | 5 | 6 | 6 | 5 |
| **5** | 287 | 1 | 4 | 22 | 6* |
| **6** | 292 | 3 | 4 | 13 | 12 |
| **7** | 298 | 6 | 5 | 11 | 11 |
| **8** | 318 | 7 | 6 | 19 | 11 |
| **9** | 318 | 8 | 2 | 12 | 5 |
| **10** | 2103 | 3 | 3 | 51** | n/a** |

** Could not be estimated due to low CNR (outside simulated range)*
*** Aneurysm was larger than imaged FOV*

**RESULTS AND DISCUSSION:** *Patient Study* We found a mean aneurysm volume of 386 mm³ (SD 616 mm³) and a mean pulsation of 15 mm³ (SD 14 mm³), see Table 1.

*Accuracy Study* Inaccuracy, defined as the absolute observed volume pulsation in the static phantom, increased quickly below a CNR of approx. 6 (Fig. 2). A near-linear relationship was found for the intensity fluctuation versus observed volume pulsation (Fig. 3). As expected, both effects were found to be highly size dependent (Fig. 3). Normalized to the phantom volume, the inaccuracy due to both noise and intensity fluctuations increases with decreasing phantom volumes. As small aneurysms are most prevalent, further improvements in image quality and analysis are needed. Furthermore, the results suggest that inaccuracies should be estimated for the specific parameters of each aneurysm, due to the strong dependency on various parameters.

**CONCLUSION:** Volume pulsation in intracranial aneurysms can be observed with 7T MRI. Estimation of the inaccuracy in the measured volume pulsations depends on CNR, signal intensity fluctuations and aneurysm size. With the current protocol, the estimated inaccuracy is of similar size as the observed volume pulsations, indicating the need for further improvement of the image quality protocol and analysis.

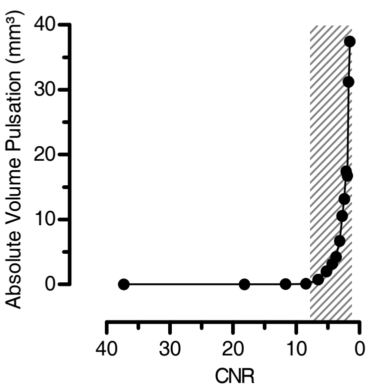


**Figure 2:** *Contrast-to-Noise versus apparent volume pulsation (mm³) in a static digital phantom (with a volume of 1500 mm³). The shaded area indicates the range of CNR's in the patient data.*

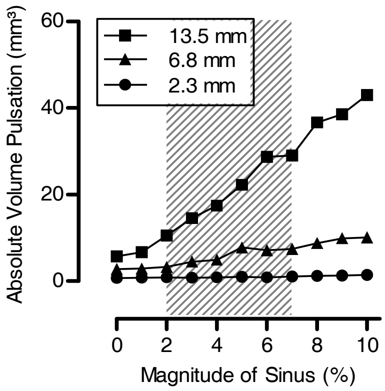


**Figure 3:** *Amplitude of sinusoidal intensity fluctuations versus apparent volume pulsation of a static phantom, simulated for three diameters. The shaded area indicates the intensity fluctuations observed in the patient data.*

**References**:

1. Vlak, M.H. et al. *Lancet Neurol.* 2011. 10(8):626–36
2. Alshekhlee, A. et al. *Stroke* 2010. 41(7):1471–6
3. Brinjikji, W. *et al. Am. J. Neuroradiol.* 2011. 32(6):1071-5
4. Naggara, O. et al. *Radiology* 2012. 263(3):828-35
5. Meyer, F. B. et al. *J. Neurosurg,* 1993. 78(6):879-83