# Evaluation of MR image artifacts of stent implants at 3 Tesla using a phantom filled with mineral oil compared to $CuSO_4$

**B. Koenig[1,2], F. Reintke[2], G. Schönwald[2,3], and G. Schaefers[2]**
[1]University of applied Science Gelsenkirchen, Gelsenkirchen, NRW, Germany, [2]MR Safety Testing Laboratory, MR:comp GmbH, Gelsenkirchen, Germany, [3]University Witten/Herdecke

**Purpose:** In MR examinations of patients with metallic implants like stents, various artifacts can occur in MR images, because of magnetic and electro-magnetic interactions of the implant with the MR environment [1]. The standard test method F2119-07 [3] of ASTM International is generally used for evaluation of susceptibility as well as radio frequency (RF) artifact appearance and size of implants. Measurements according to this standard use an in-vitro model filled with copper sulfate solution ($CuSO_4$). However, $CuSO_4$ is a conductive liquid, and it is observed that standing waves were increasingly detected in MRI with a high magnetic field strength (≥ 3 Tesla) and wavelength in dimension or smaller than the phantom used [2]. Standing waves inhibit precise artifact measurements due to strong inhomogeneities of the background signal. Different solutions are provided in literature for considering this problem for example changing the transmitter voltage [4], the phantom dimensions or using a multi-transmit coil. Our aim in this study was decreasing the electrical conductivity of the phantom liquid. Therefore it was investigated, if artifact analysis is providing the same dimensional results with a non-conductive mineral oil (ExxonMobile, Houston, USA) compared to the conductive standardized $CuSO_4$ at 3 Tesla.

**Subjects and Methods:** A commercially available 10 mm Nitinol stent (SMART, Cordis Langenfeld, Germany) and an arcyl tube with conductivity of an insulator as well magnetic susceptibility close to water have been fixed parallel within a cubic shaped phantom (30 x 30 x 30 cm). In the first test series the phantom was filled with $CuSO_4$. The measurement was carried out within the body coil of a 3 Tesla MR system (Magnetom Trio, Siemens Medical Solutions, Erlangen, Germany). The filled phantom was positioned at the isocenter. Furthermore the temperature of the fluid and the MR environment were recorded as well as the electrical conductivity of the liquid. The test devices are orientated perpendicular to the static magnetic field $B_0$. Spin echo (SE) and gradient echo (GRE) sequences were performed. Sequence parameters are: TR = 500 ms, TE = 15 (GRE)/ 20 (SE) ms, FoV = 300 mm, Matrix = $256^2$, slice thickness = 7.5 mm (sagittal slice)/ 2 mm (coronal slice), reference amplitude $CuSO_4$: 149.8 V/ oil: 264 V, read out: AP (sagittal)/ RL (coronal). Images were acquired with an automatic adjusted transmitter voltage. In the second test series the test setup was build up identically, but was filled with mineral oil instead of $CuSO_4$. For data analysis the artifact sizes (diameter/length) have been measured using Osiris DICOM viewer 4.19. After image analysis was done we used the statistic t-test with regard to the measured artifact size in the first and second test series. The significance level was fixed on $p < 0.05$.

**Results:** Tab. 1 shows the tested liquids in comparison concerning the occurred artifact of both test devices. No standing waves were detected during the measurements with oil. For the $CuSO_4$ solution the reference tube diameter (12.9 mm) and the length (99.6 mm) in the SE sequence are on par to those in the GRE sequence. The stent diameter shows a greater artifact in the SE sequence (65.5 mm), while the length shows less distortion in the GRE sequence. Regarding the mineral oil the dimensions of the reference tube is equal for the diameter and less different for the length, in both sequences. The same behavior of the artifact dimensions is essential for the stent. (Fig.1).

| | $CuSO_4$ | mineral oil | $CuSO_4$ | mineral oil |
|---|---|---|---|---|
| | reference tube diameter [mm] | | stent diameter [mm] | |
| SE | 12.90 | 12.90 | 65.50 | 11.70 |
| GRE | 12.90 | 12.90 | 16.40 | 11.70 |
| | reference tube length [mm] | | stent length [mm] | |
| SE | 99.60 | 98.40 | 105.50 | 104.30 |
| GRE | 99.60 | 99.60 | 106.60 | 107.80 |

TAB. 1 Results

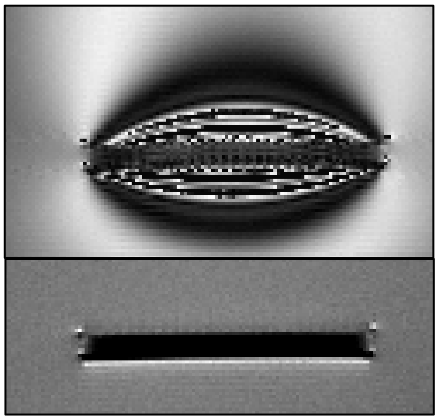

Fig. 1 SE sequence:
top: $CuSO_4$, stent length (105.5 mm)
bottom: mineral oil, stent length (104.3 mm)

**Discussion:** ASTM standard test method F2119-07 contains the requirement to use $CuSO_4$ or other adequate T1-reducing solution for testing. Even if RF artifacts and standing wave effects are possible to occur in MRI of humans, $CuSO_4$ leads to a strong standing waves characteristic in MR images when using a high magnetic field strength ≥ 3 Tesla. Our investigation was successful in this respect eliminating the effect of standing waves and allowing to use ASTM standard test method F2119-07 at all as well as providing artifact images according hereto. However, on the other hand side the solution found also includes a compromise for concentrating on susceptibility artifacts only, but leaves out RF artifacts which can still have a strong impact on artifact size in electrically conductive human tissue. The results of this study show, that the artifact size of the diameter and length of the test objects are comparable between $CuSO_4$ and mineral oil under certain boundary conditions described above. Also the statistically analysis confirmed, that the results are statistically not significant ($p=0.71$). Only one exception of the stent diameter in the SE sequence is a significant result due to the RF artifact.

**Conclusions**: The study shows that it can be possible to replace $CuSO_4$ by mineral oil for performing the ASTM standard test method F2119-07 with certain considerations. It is assumed that further research is necessary to prove these results for other test devices and different techniques of sequences. All in all, this study provides a metrological logistics for performing artifact testing at higher magnetic field strengths and also separating test results into RF and susceptibility artifacts.

References:

1. Bartels LW, Bakker CJG, Viergever MA (2002) Improved Lumen Visualization in Metallic Vascular Implants by Reducing RF Artifacts. Magn Reson Med 47:171-180
2. Beck BL, JenkinsKA, Fitzsimmons JR (2004) Wave Behaviour in Phantoms at 11.1 Tesla. Proc. Intl. Soc. Mag. Reson. Med. 11:1662
3. ASTM F2119-07, "Standard Test Method for Evaluation of MR Image Artifacts from Passive Implants"; 2007, www.astm.org
4. H. Wojtczyk et al, Behavior of rods and tubes made of carbon fiber reinforced plastic (cfrp) in a MR environment at 1.5 T and 3 T, ePoster 535, ESMRMB 2009