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Extent determination of stent heating in MPI

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Abstract

MPI offers a huge potential for cardiovascular imaging and interventional guidance. Especially, stent lumen imaging is an advantageous feature of MPI. Due to the presence of oscillating magnetic fields some metallic objects show temperature increase during MPI scans. Regarding first available human size MPI scanners and thus, future clinical application, the extent of stent heating becomes an important safety issue which could limit the application of MPI for specific patient groups. In this work, the temperature increase of stents with large diameters was investigated to determine the extent of stent heating in MPI.

I. Introduction

Magnetic Particle Imaging (MPI) is a tomographic modality which offers a wide range of promising applications in the field of cardiovascular imaging and the guidance of endovascular interventions [1]–[3]. In the last decade, several proof of concept studies illustrated this potential and especially the visualization of endovascular stents emerged as a unique feature of MPI in comparison to established modalities like CT and MRI [4, 5].

Due to the use of oscillating magnetic fields in MPI scanners, heating of metallic objects is an important safety issue [6]. First in vitro studies showed a clinically mostly irrelevant heating behavior of stents, but identified the stent diameter as an influencing factor regarding stent heating in MPI [7, 8].

MPI is currently holding a preclinical status but first human scale scanners have become available recently [9, 10]. In addition to the perspective of direct stent lumen visualization, brain perfusion can be displayed using MPI. In this regard, the potential extent of stent heating becomes an important safety issue which might limit MPI's application for specific patient groups.

In this study, we investigated metallic stents with large diameters to determine the extent of stent heating in MPI.

II. Material and methods

Five different commercial endovascular stents made from stainless steel, nitinol or cobalt-chromium (Co-Cr) were investigated (Table 1). The stents had diameters between 12 mm and 31 mm, lengths of 38 mm to 100 mm and were implanted in polyvinyl-chloride tubes with corresponding diameters.

The temperature measurements during the 431 seconds MPI scans were performed in accordance to already published protocols [7, 8] by using a fiber-optic thermometer (FTX-300-LUX+, Osensa, Coquitlam, Canada). In accordance to initially performed thermographies, the

Table 1: Stent details

Stent type (Manufacturer/ name)	Length (mm)	Ø (mm)	Material
BARD/ Lifestream	38	12	Stainless steel
EV3/ Protege GPS	80	14	Nitinol
Boston Scientific/ Wallstent-Uni Endoprothesis	60	16	Nitinol
Bentley/BeGraft	48	20	Co-Cr
Gore/TAG	100	31	Nitinol

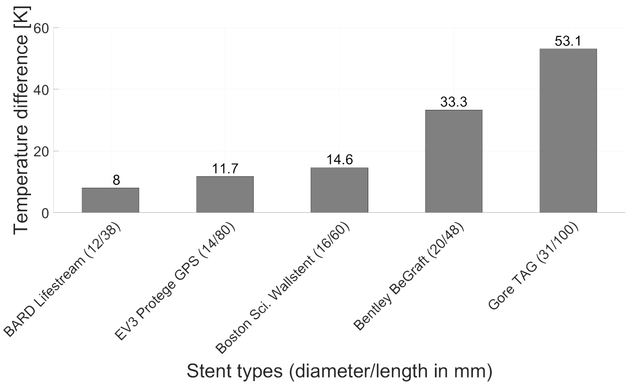

Figure 1: Temperature differences of the stents after 431s MPI scans. The results are sorted by the stent diameter (increasing from left to right).

temperature probes were fixed directly at the stent struts in the middle section of the stents (with exception of Gore/TAG) and as a reference at the bottom of a nonmagnetic phantom holder.

The experiments were performed in a preclinical MPI scanner (Bruker-Biospin, Ettlingen, Germany) with the following measurement parameters: selection field gradients: 1.25 T/m in x- and y-direction and 2.5 T/m in z-direction; drive field strength: 12 mT in each direction and drive field frequencies: 24.510 kHz, 26.042 kHz, and 25.252 kHz in x-, y-, and z-direction, respectively.

The temperature differences were computed by subtracting the temperatures after and before the MPI scans. The measured reference temperatures were subtracted from the stents' temperatures. A temperature increase of >0.1 K was defined as heating, based on the inaccuracy of the measurement setup.

III. Results and discussion

All tested stents revealed a temperature increase during the MPI sequences (Figure 1). The minimum was 8 K (BARD/Lifestream) and the maximum 53.1 K (Gore/TAG). The Gore/TAG stent graft only showed slight heating of 0.5 K, when measured at the center of the stent, but the highest increase of 53.1 K was observed at the stent's end. The measured temperature differences were increasing with growing diameter. Pearson's correlation coefficient (square root of temperature difference vs. stent diameter) depicted this relation with a value of R=0.97 (with exception of Gore/TAG in the middle section.).

This study shows that the amount of stent heating during MPI scans can reach more than 50 K. Furthermore, this work confirms the diameter of stents to be an important influencing factor regarding heating in MPI. Despite potential significant cooling effects of the blood flow [11], which were not addressed in this study, the detected temperature differences in this work remain potentially life threatening. Since a temperature increase of 6 K already has antiproliferative effects on the muscle cells of the vessel wall [12], the amount of heating observed in this study is expected to cause burn necroses with the danger of severe bleedings. Consequently, MPI examinations of patients carrying stents with such large diameters (aortic stents) should be avoided, at least when the field of view is covering the stent.

To guarantee MPI access for stent patients, it is necessary to take MPI compatibility into account during the development of future stents. Previous studies showed that the interruption of the stents' conductor loops in radial and longitudinal direction reduces the amount of heating drastically [7, 8]. Hence, such approaches might be a basis for the development of MPI compatible stent designs.

This study has several limitations: The heating behavior was investigated in vitro under static conditions. To estimate the cooling effect of the blood circulation, a flow study is needed. Furthermore, only a small number of stents was tested in this work. With the given perspective of human MPI, every medical implant should be tested for its safe usage in the respective MPI setup before the examination of patients.

IV. Conclusions

This study shows that metallic stents with large diameters may cause potentially harmful temperature increases during MPI.

Author's statement

The data presented in this abstract are part of a full paper which was recently accepted for a journal publication [13]. Conflict of interest: Authors state no conflict of interest. Informed consent: N/A Ethical approval: N/A

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