

Electronic Supplementary Material 1

ESM 1.1 Interventional instrumentation for in vitro and in vivo testing

Interventional instrumentation used for the MRI-guided experiments included a CE-marked 0.035" (0.89 mm), 260 cm hydrophilic-coated guidewire labelled MR Conditional (REF 39012526, EPflex Feinwerktechnik GmbH, Dettingen an der Erms, Germany). According to the manufacturer, the guidewire is MR Conditional at static magnetic field strengths of 1.5 T and 3.0 T, with a maximum spatial field gradient of 128 T/m, a maximum force product of 231 T²/m, and a maximum whole-body-averaged specific absorption rate of 2 W/kg in Normal Operating Mode or 4 W/kg in First Level Controlled Operating Mode. Additional instruments comprised an 18 G MR cannula (EPflex Feinwerktechnik GmbH), a short guidewire (REF 46012082, EPflex Feinwerktechnik GmbH), and a screw syringe with a pressure gauge for balloon dilatation (In-Ka®, Coloplast, Hamburg, Germany). Standard angiographic sheaths without metal braiding (Performer Check-Flo® Introducer, 8 Fr; Cook Medical, Bloomington, IN, USA) were used to minimize MR image artifacts.

For MRI visualization during balloon inflation, the balloon catheter was filled with gadobutrol (Gadovist, Bayer AG, Leverkusen, Germany) diluted 1:100 (v/v) in 0.9% saline solution.

ESM 1.2 Additional information on MRI acquisition setup

At 1.5 T, Stage 1 imaging was performed using one BioMatrix Body 18 surface coil. At 3.0 T, one Body 6 surface coil was used during Stage 1 and Stage 2, whereas two Body 6 surface coils were used during Stage 3 (all Siemens Healthineers, Erlangen, Germany). The coils were positioned over the respective test box, vascular phantom, or thoracoabdominal interventional region. No physiological triggering was used.

Table ESM-1.2. MRI acquisition setup: receive coil configurations

Stage	Field strength	Receive coil configuration*	Coil positioning
Stage 1	1.5 T	One BioMatrix Body 18 surface coil	Positioned over the test box
	3.0 T	One Body 6 surface coil	Positioned over the test box
Stage 2		One Body 6 surface coil	Positioned over the vascular phantom
Stage 3		Two Body 6 surface coils	Positioned over the thoracoabdominal interventional region

*All receive coils: Siemens Healthineers, Erlangen, Germany;

ESM 1.3 In vitro CoA phantom setup

The utilized phantom was produced according to the previously published manufacturing protocol (1). The phantom geometry was derived from a contrast-enhanced MRI dataset of a 10-year-old boy with CoA. The dataset had been anonymized prior to its use for phantom construction. According to the local institutional assessment, additional informed consent or ethics approval was not required for this secondary use of anonymized imaging data. The source imaging parameters were as follows:

Siemens SymphonyTim 1.5 T (Syngo MR B17), ST = 1.2 mm, TR = 3.47 ms, TE = 1.28 ms, FA = 40°, matrix = 384×288, pixel size = 0.52×0.52 mm². The source MRI dataset used for phantom construction was acquired following intravenous gadolinium administration.

The vascular structure was housed in an acrylic glass case (45 × 15 × 16 cm) embedded in a tissue-mimicking gel of water-binding superabsorbent multipurpose polymer (HVDE 235, Schauch Granulate, Lauffen am Neckar, Germany). Blood flow (5 L min⁻¹) was simulated using a physiological saline solution mixed with 30% glycerol (WHC GmbH, Hilgertshausen-Tandern, Germany) and a pulsatile flow pump (MultiFlow centrifugal pump, GAMPT mbH, Merseburg, Germany).

Femoral access for interventional devices such as guidewires and catheters were realized by puncturing silicone tubes (Deutsch & Neumann GmbH, Hennigsdorf, Germany) at the proximal femoral section of the polymer-based vascular phantom (outside the housing) with lumen diameters of 9 mm (wall thickness: 2 mm). 3D-printed connectors enabled the fixation and exchange of vessel segments of the descending aorta using zip ties. The vessel segments can be customized to mimic various consistencies and resistances (2).

References

1. Gholami Bajestani D, Reich CM, Mulik C, Mokosch M, Melzer A. Hybrid polymer vessel phantoms for feasibility studies and clinical training of MRI-guided interventions. *Current Directions in Biomedical Engineering*. 2022 Sep 2;8(2):656–9. doi:10.1515/cdbme-2022-1167
2. Gholami Bajestani D, Mulik C, Mokosch M, Melzer A. Design and Validation of Silicone-Based Stenosis Vessel Segments for MRI Vascular Phantoms. Preprint. 2025 Aug 11. doi:10.21203/rs.3.rs-7298192/v1

ESM 1.4 Silicone-based stenosis simulation mechanism for MRI-compatible vascular phantoms

For simulation of catheter-based stent implantation and balloon dilatation, we developed a mechanism (Figure S1) which allows placement and latter removal of stents inside of our vessel phantom at the location of the descending aorta. The connectors are 3D-printed and allow fixation of fitted vessel segments using zip ties. These vessel segments can be tailored to mimic different consistencies and resistances.

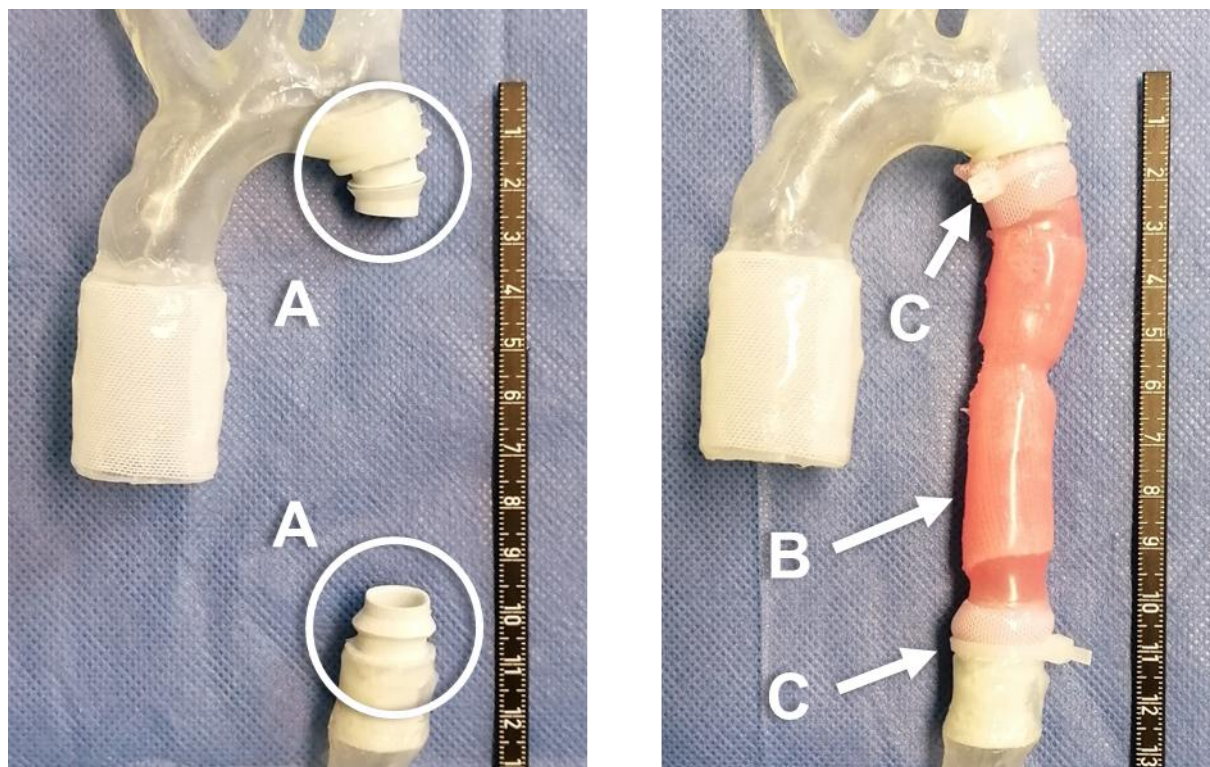


Figure S1: 3-D printed connectors (A) for attachment of manufactured stenosed vessel segment (B) for simulation of aortic Coarctation. The vessel segment is mounted using zip ties (C).

ESM 1.5 Animal study design details (ARRIVE Statements)

The in vivo experiments were conducted within a larger exploratory preclinical study investigating the feasibility of multiple MRI-guided cardiovascular interventions. The study was approved by the competent animal welfare authority, the Landesdirektion Sachsen, and was performed in accordance with the German Animal Welfare Act and applicable European regulations, including Directive 2010/63/EU. The experimental unit was a single animal. Sample size was determined based on feasibility considerations within the exploratory study design, and no a priori sample size calculation was performed. Ten healthy female pigs (*Sus scrofa domestica*), aged 12–16 weeks and weighing 34–58 kg, were enrolled in the larger exploratory preclinical study. Of these, five animals underwent MRI-guided stent implantation. The allocation of animals to stent implantation was determined by procedural workflow requirements and the sequence of technical test procedures within the exploratory study. No animals assigned to MRI-guided stent implantation were excluded from the analysis. Inclusion criteria were female sex, health status suitable for general anesthesia and catheter intervention. Animals not fulfilling these criteria would have been excluded. Randomization and blinding were not performed due to the procedural feasibility study design. Outcome measures included procedural feasibility, device visibility during MRI guidance, successful stent deployment, and intervention duration. Animals were euthanized at the end of the procedure according to the approved protocol. Humane endpoints and monitoring criteria were defined in the approved animal welfare score sheet.