Real-Time MR-Guided Transarterial Aortic Valve Implantation (TAVI): In vivo Evaluation in Swine

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Objective: Transcatheter, transarterial aortic valve implantation (TAVI) is rapidly emerging as a promising new treatment option for patients with severe symptomatic aortic valve stenosis who are considered at high or prohibitive surgical risk [1,2]. Envisioning real-time MR guidance of the TAVI procedure, the objective of this study was the systematical *in vitro* evaluation of the MR imaging characteristics of a currently commercially available TAVI prosthesis and its delivery device and subsequent modification of the delivery device towards MR-compatibility [3]. Featuring the modified MR compatible stent valve delivery device, real-time MR guided TAVI has been performed *in vivo* in eight swine.

Methods: The self-expandable Medtronic CoreValve® aortic bioprosthesis (Medtronic, Inc., Minneapolis, MN, USA) is composed of a nitinol stent frame with an integrated trileaflet porcine pericardial tissue valve and is either implanted via the femoral or subclavian artery. Its delivery catheter has a 12 Fr shaft with 18 Fr distal end comprising the crimped prosthesis which can be released stepwise with continuous transaortic blood flow. The original catheter shaft revealed ferromagnetic attraction thus potentially compromizing MR imaging and safety **(Fig. 1)**. The delivery device consequently was re-designed obviating any metal braiding which resulted in full MR compatibility of the delivery device **(Fig. 2)**. MR-guided TAVI was performed on 8 farm pigs (75-85 kg) via transfemoral (2/8) and via subclavian (6/8) access on a 1.5 T MRI system (Avanto, Siemens Healthcare, Germany) equipped with an interventional in-room monitor. Catheter placement and stent release was performed under real-time MR guidance with a rt-TrueFISP sequence providing 5 fps.

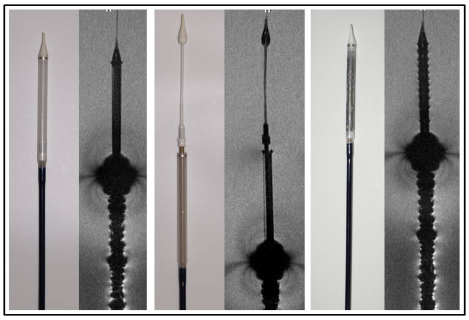

Fig. 1: Photos vs. high-res 3D FLASH MRI of the commercially available delivery catheter to screen for ferromagnetic artifacts. Left: delivery catheter without stent; middle: release position without stent; right: delivery catheter loaded with crimped nitinol stent.

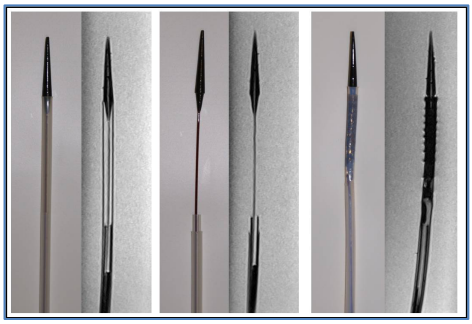

Fig. 2: Photos vs. high-res 3D FLASH MRI of the modified delivery catheter demonstrating excellent MR image quality without metal artifacts. All ferromagnetic components and metal braidings have been omitted rendering the device MR-compatible.

Results: The nitinol-based self-expandable stent-valve was excellently visualized with delineation even of small details. The commercial delivery catheter shaft of this device revealed strong ferromagnetic artifacts **(Fig. 1)**, thus also raising concerns regarding RF-related device heating and ferromagnetic attraction. Replacement of the commercial delivery device by the re-designed delivery device resulted in artifact elimination **(Fig. 2)** and excellent real-time visualization of catheter movement and valve deployment. MR-guided TAVI was successful in 6/8 swine **(Fig. 3)**. Post-interventional therapeutic success could be confirmed using ECG-triggered cine-TrueFISP sequences and flow-sensitive phase contrast sequences. Final stent valve position was confirmed by ex vivo histology **(Fig. 3)**.

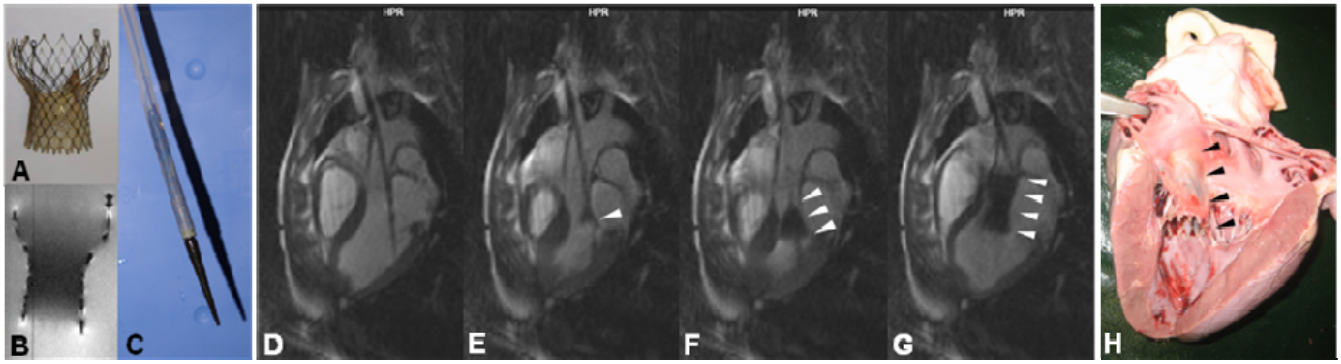

Fig. 3: Nitinol CoreValve **(A)** featuring an aortic valve formed from porcine pericardial tissue; MR image **(B);** modified MR compatible delivery catheter **(C)**. **(D-G)** Real-time TrueFISP images of MR-guided CoreValve deployment in vivo. Arrowheads in **(E-G)** show successive stent release and final stent position in histologic correlation **(H)**.

Conclusions: The self-expandable CoreValve aortic stent-valve is potentially suited for real-time MRI-guided placement after suggested design modifications of the delivery-system. MR imaging in this interventional setup provided excellent pre-interventional anatomic and functional evaluation of the native aortic valve, precise real-time instrument guidance allowing accurate placement of the stent-valve within the native aortic annulus, and finally detailed post-interventional evaluation of therapeutic success.

References

[1] Webb JG, et al. Transcatheter aortic valve implantation: impact on clinical and valve-related outcomes. *Circulation* 2009;119(23):3009.
[2] Grube E, et al. Progress and current status of percutaneous aortic valve replacement. *Circ Cardiovasc Intervent* 2008;1(1):167.
[3] Kahlert P, Quick HH, et al. Towards real-time cardiovascular magnetic resonance-guided transarterial aortic valve implantation: In vitro evaluation and modification of existing devices. J Cardiovasc Magn Reson. 2010 Oct 13;12(1):58.