Real-Time MR-Guided Endovascular Stent-Graft Placement in An Animal Model of Aortic Dissection

H. H. Quick[1], H. Eggebrecht[2], H. Kuehl[1], G. M. Kaiser[3], S. Aker[4], M. O. Zenge[1], F. Breukmann[2], F. Stock[1], M. E. Ladd[1]

[1]Department of Diagnostic and Interventional Radiology and Neuroradiology, University Hospital Essen, Essen, Germany, [2]Department of Cardiology, University Hospital Essen, Essen, Germany, [3]Department of General and Transplantation Surgery, University Hospital Essen, Essen, Germany, [4]Institute of Pathophysiology, University Hospital Essen, Essen, Germany

Introduction:

Endovascular stent-graft placement is emerging as a promising alternative to medical and surgical therapy in the treatment of patients with descending aortic dissection (1). The aim of endovascular repair in aortic dissection is to obliterate the false lumen by implantation of a membrane-covered stent-graft into the true lumen across the proximal entry tear (2). Precise placement of the stent-graft, which is currently performed under x-ray, remains challenging, however, as there are several shortcomings to fluoroscopic guidance: radiation exposure, administration of nephrotoxic contrast media that can not be repeated as needed, and, x-ray angiography does not visualize the false lumen. MR-guidance of vascular interventional procedures offers several potential advantages over fluoroscopy-guided techniques and can, furthermore, provide all relevant information for pre-interventional planning of such procedures (3) as well as post-interventional evaluation of procedure success (4). The purpose of this study was to evaluate the feasibility of real-time MRI- guided stent-graft placement in an animal model of thoracic aortic dissection, using commercially available stent-graft devices.

Methods

In vivo experiments were performed on fully anesthetized domestic pigs (*n*= 8) weighing 63-98 kg. Creation of descending aortic dissection was performed under x-ray by modifying a previously described catheter-based technique (5). A self-expandable, nitinol-based tubular stent-graft device (GoreTAG, W.L. Gore Inc., Flagstaff, AZ) was chosen for the in vivo experiments (6) (Fig. 1). Stent-grafts with lengths of 10 cm and diameters of 2.6 and 2.8 cm were available on 18-F polyurethane delivery catheters. Middle-to-end deployment was initiated by retraction of a GoreTex filament, which rapidly released the stent-graft from the ePTFE sleeve. Scanning was performed on a 1.5 T scanner (Avanto, Siemens Medical Solutions, Erlangen, Germany). The animals were placed head first supine inside the scanner on a spine phased-array RF coil. Two body flex phased-array RF coils were placed anteriorly on the pig. The imaging protocol subsequent to creation of descending aortic dissection encompassed I) pre and post-interventional TrueFISP retro imaging with ECG gating and retrospective image reconstruction within one breath-hold in parasagittal and in axial orientation, and II) pre and post-interventional 3D contrast enhanced MRA in coronal orientation covering the ascending and descending aorta as well as the aortic arch. For implantation, the delivery system with mounted stent-graft was advanced from the iliac artery to the thoracic aorta under real-time MRI fluoroscopy without use of guide wires. III) MRI fluoroscopy was based on interactive real-time TrueFISP with radial k-space filling (TR 3.0 ms, TE 1.5 ms, flip 80°, FOV 360x360 mm^2, matrix 192x192, BW 1530 Hz/pixel, slice thickness 6 mm, 49 projections/image) providing 7 fps. The deployment system was visualized purely passively based on signal dropout due to blood displacement and minor susceptibility artifacts. Images were projected with an RF-shielded video projector onto an in-room 60" high-contrast projection screen (MRIscreen, MR-Innovation GmbH, Essen, Germany). All resulting post-interventional images were compared with macroscopic examination of the ex vivo aorta.

Fig. 1: Stent-graft mounted (A) and deployed (B).

Results:

Descending aortic dissections were successfully created under x-ray in all 8 pigs. Real-time MRI allowed for simultaneous visualization of vessel lumen and delivery system and stent-graft, with image quality sufficient for successful intervention. In one pig, the delivery system was inadvertently advanced within the false lumen. This was immediately detected by MRI and corrected. After repositioning the device into the true lumen, however, the pig developed severe arrhythmias with hemodynamic instability, and was euthanized before stent-graft placement could be attempted. In the remaining 7 pigs, real-time MRI allowed for successful navigation of the stent-graft delivery system to the thoracic aorta and provided real-time monitoring of stent-graft deployment. The susceptibility artifacts of the loaded stent-graft in combination with the simultaneously visible dissection flap allowed for precise positioning over the proximal dissection tear (Figs. 2, 3a). MRI times for navigation, positioning, and stent-graft deployment ranged from 1 to 4 minutes (mean 2 min.). Post-interventional MRI evaluation (Figs. 3b, 4b) demonstrated correct position of the stent-graft in all 7 cases. All stent-grafts were well expanded. MRI showed complete coverage of the proximal dissection tear, and thrombosis of the false lumen, as confirmed by macroscopic examination of the ex vivo aorta.

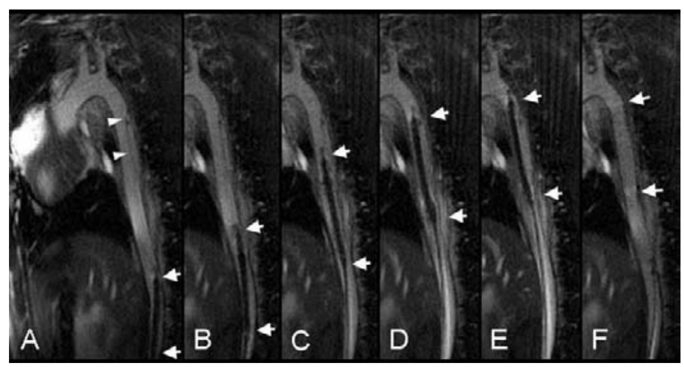

Fig. 2: Advancement of the stent-graft delivery system (arrows) up to the level of the dissection (arrowheads) under real-time MRI guidance. Real-time PR TrueFISP imaging provided 7 fps.

Discussion:

The present study demonstrates the feasibility of real-time MRI-guided endo-vascular stent-graft placement for aortic dissection in a porcine animal model. Commercially available catheter devices without any modifications were used. Beyond detailed pre-interventional evaluation and treatment planning, real-time MRI permitted 1) verification of delivery system position within the true lumen, 2) successful and safe device navigation to the thoracic aorta, 3) precise stent-graft positioning and 4) deployment, and 5) safe catheter withdrawal. Following stent-graft placement, functional imaging with dynamic contrast MRA complemented anatomic imaging for immediate confirmation of treatment success. MRI for this interventional procedure has shown to provide additional diagnostic information not available with x-ray fluoroscopy.

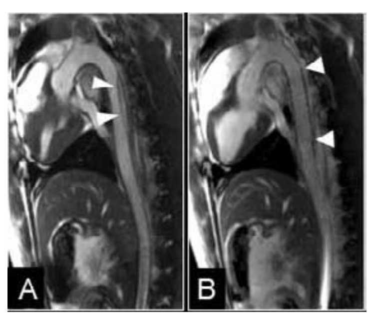

Fig. 3: Pre (A) and post-interventional (B) MRI evaluation with TrueFISP retro in parasagittal orientation. (A): Arrowheads show the dissection flap in the proximal descending thoracic aorta. (B): Arrows show the correct position of the stent-graft with complete coverage of the dissection.

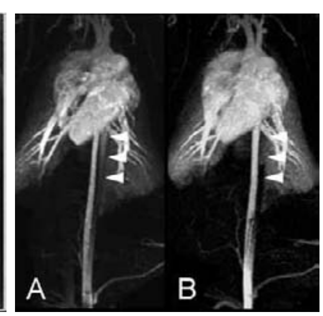

Fig. 4: (A): Pre-interventional contrast-enhanced 3D MR angiography showing true and false lumen (arrowheads). (B): Following stent-graft placement, the false lumen (arrowheads) is completely obli-terated.

References:

1. Eggebrecht H, et al. *Eur Heart J*. 2005;26:489-497.
2. Nienaber CA, et al. *N Engl J Med*. 1999;340:1539-1545.
3. Engellau L, et al. *Acta Radiol*. 2003;44:177-184.
4. Ayuso JR, et al. *J Magn Reson Imaging*. 2004;20:803-810.
5. Razavi MK, et al. *J Vasc Interv Radiol*. 1998;9:626-632.
6. Eggebrecht H, et al. *Proc ISMRM 2005, p.2143*2143.