Magnetic Resonance Imaging of Bioresorbable Vascular Scaffolds

Potential Approach for Noninvasive Evaluation of Coronary Patency

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Bioresorbable vascular scaffolds (BVSs) are a rapidly evolving technique in interventional cardiology. Bioresorption of the scaffolds polylactate backbone takes ≈2 years, leaving behind only the distal and proximal platinum markers used for scaffold localization in fluoroscopy. Recent studies comparing BVS with standard drug eluting stents have suggested potential benefits for the patients including a significant reduction in postprocedural angina, or a trend toward the reduction of revascularization rates.\(^1\)\(^2\) Multiple large-scale studies are currently ongoing to further clarify the future role of BVS compared with drug eluting stents.

Because of the nonmetallic polylactate backbone, BVS therapy might also allow for noninvasive evaluation of coronary arteries by magnetic resonance imaging (MRI), simultaneously yielding information about anatomy and atherosclerotic plaque dynamics. Conventional metallic stents are known to shield off the radio frequency fields during MRI signal excitation and data acquisition, which leads to a severely reduced MRI sensitivity inside the stent. In addition, the closed metallic ring structures can create unwanted field distortions from susceptibility differences and gradient-induced eddy currents.\(^3\)

Thus, direct MRI of the lumen of a conventional stent is difficult, and an in-stent restenosis or neatherosclerosis can hardly be detected. In contrast, BVS might allow for an artifact-free imaging of the scaffold lumen, so that the patency of the vessel can be directly assessed in a noninvasive manner. Compared with conventional stents that can be easily identified by their imaging artifacts, BVS could only be detected by their proximal and distal platinum markers. The artifacts of these markers are small so that dedicated techniques for their identification in the MRI are needed to localize the treated vessel segment.

We, here, describe first proof-of-principle MRI concepts for BVS. In vitro, we show that the scaffold markers of a BVS can be identified. We further demonstrate that MRI within the close proximity of the BVS can be done without any substantial artifacts as would be seen with conventional stents. In 2 patient cases of mixed clinical scenarios, these concepts are further transferred into clinical findings.

For in vitro experiments, a 3.0/18 mm ABSORB-BVS (ABBOTT Vascular, Santa Clara, CA) was placed in a plastic cylinder filled with saline solution. Imaging was performed at 1.5T (Siemens Symphony) using 2 basic sequence types (FLASH and turbo spin echo) with high spatial resolution (200 μm isotropic). The scaffold architecture is hypointense compared with the surrounding solution (Figure 1) because the polylactate material does not yield a detectable MRI signal. The distal and proximal platinum markers are visible as clearly circumscribed artifacts with a diameter of ≈1 mm (Figure 1B, blue arrows), whereas the luminal vessel area can be imaged without artifacts (Figure 1B, red arrows). A three-dimensional (3D) reconstruction of the scaffold is demonstrated in Figure 1C (blue arrows: platinum marker artifacts; green arrow: thread used to fix the scaffold; full 3D view available as Movie in the Data Supplement). The image shown in Figure 1D was acquired using a turbo spin echo sequence with a spatial resolution similar to the clinical application. Here, the scaffold is faintly visible indicated by yellow arrows without causing artifacts in its vicinity.

We transferred this knowledge into 2 patient cases of mixed clinical scenarios. Patient 1 is a 76-year-old woman presenting to our hospital with an non-ST–elevation acute coronary syndromes and a subtotal occlusion of the proximal left anterior descending (LAD) artery after plaque rupture. A 3.0/18 mm ABSORB was placed with a good angiographic result (Figure 2, top left). Contrast agent–free 1.5T coronary–free breathing MRI (ECG triggered and navigator gated) showed a patent LAD and allowed artifact-free evaluation of the scaffolded area in dark-blood 3D turbo spin echo acquisition (Figure 2, top middle). Bright-blood T1-weighted 3D FLASH imaging (Figure 2, top right) demonstrates that artifact-free images can also be obtained from the lumen of the scaffolded vessel without any shielding effects, which would be visible with conventional stents. Furthermore, a 73-year-old woman with stable coronary artery disease and multiple significant stenoses of a diffusely diseased right coronary artery was treated with 2 overlapping BVS (distal, 3.0/18 mm; proximal,
3.5/28 mm) with a good angiographic result (Figure 2, bottom left). BVS-MRI with a dark-blood turbo spin echo sequence also showed a patent right coronary artery (Figure 2, bottom middle/right) without any artifacts.

In summary, this proof-of-concept study demonstrates the potential for artifact-free MRI of the BVS and the intraluminal area. The MRI sequences presented here are of low burden for the patients because they do not involve the use of any contrast agent, require no breathhold, and, of course, no radiation. As a perspective, they could therefore be used in a majority of clinical populations. However, as already described in a previous first experience of BVS in MRI, application of such MRI strategies is currently limited to proximal and mid sections of the coronary vessels because image quality in these segments is higher. Future improvements of MRI sequences will also aim for optimized identification of the platinum markers, which could serve in the long-term for an exact identification and localization of the scaffolded area.

Sources of Funding
This work was supported by grants of the Deutsche Forschungsgemeinschaft (Dr Bock: BO 3025/2-2; Dr von zur Muhlen: MU2727/6-1).

Disclosures
T. Pfannebecker is an employee of ABBOTT vascular. The other authors report no conflicts.

References

Key Words: coronary artery disease ■ magnetic resonance imaging
Figure 2. Magnetic resonance imaging of bioresorbable vascular scaffold (BVS) in patient cases. Top, Patient 1 with non-ST–elevation acute coronary syndromes and a soft plaque in the proximal left anterior descending was implanted with a BVS (3.0/18 mm). Left, Coronary angiographic result. Middle/Right, 1.5T dark-blood prepared three-dimensional (3D) turbo spin echo (TSE)/bright-blood 3D FLASH imaging shows the patent vessel lumen without any artifacts within the lumen or the vessel wall. Arrows indicate scaffolded area. Bottom, Patient 2 with stable CAD was implanted with 2 BVS overlapping scaffolds (3.0/18 mm and 3.5/28 mm). Left, Coronary angiographic result. Middle/Right, 1.5T dark-blood TSE images of the right coronary artery and a cross-section of the scaffolded area indicated by the arrow. Compared with patient 1, image quality especially in the proximal part slightly degraded because of incomplete dark-blood preparation and motion.
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_Circ Cardiovasc Interv._ 2015;8:
doi: 10.1161/CIRCINTERVENTIONS.115.002388

_Circulation: Cardiovascular Interventions_ is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 1941-7640. Online ISSN: 1941-7632

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http://circinterventions.ahajournals.org/content/8/4/e002388

Data Supplement (unedited) at:
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