Direct Visualization of Susceptibility-Based Devices in Relation to the Vasculature

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Introduction
Addition of intravascular T1-shortening contrast agent to the blood is potentially advantageous for passive visualization of devices used in MR-guided endovascular therapy. Throughout the intervention, contrast-enhanced strategies can be employed for MR angiography, which are less susceptible to flow-related artifacts than time-of-flight or phase contrast techniques. Passive tracking of devices equipped with paramagnetic markers [1] will benefit form the high signal in the blood vessels. Thus, imaging strategies are conceivable that provide bright blood angiograms, which directly show the devices in correct relation to the vasculature by means of the small signal voids caused by the paramagnetic rings.

In this in vitro study, we will investigate the advantages of shortening the T1 of blood for susceptibility-based tracking for the purpose of an MR-guided percutaneous balloon angioplasty procedure.

Materials and Methods
A bifurcation phantom consisting of tubes with an internal diameter of 6 mm was mounted in a basin filled with chunks of bovine cardiac muscle and vegetable oil (T1 = 170 msec), to provide an inhomogeneous background. A dilatable stenosis was created in one of the branches. Diluted Gd-DTPA (Magnevist, Schering, Berlin), 6.5 mM resulting in T1 ~ 30 msec, was used to mimic blood containing an intravascular contrast agent. The fluid circulated at 8 ml/sec.

A balloon catheter and glass fiber guidewire were prepared for susceptibility-based tracking with dysprosium oxide markers delimiting the balloon and catheter tip, respectively. (Cordis Europa, Roden) The balloon was inflated with demineralized water. Imaging was performed on a 1.5-T scanner (Gyroscan ACS-NT, Philips, Best) with a quadrature neck coil. All vessels were contained in a thick slice of 50 mm. For device tracking, we used a 2D segmented spoiled gradient-echo sequence, TR/TE/τ/α 5.3 msec/1.8 msec/40°, with asymmetric echo and flow compensation. To suppress background signal, every group of ten echoes was preceded by a non-selective 110° prepulse and a 15 msec delay; data was acquired with a low-high profile order. In addition, a slice-dephasing gradient of 2τ/20 mm was applied. Acquisition time was 0.9 sec per image. Balloon inflation was imaged using a strongly T2-weighted single-shot turbo spin-echo acquisition, TR/TE 5000 msec/1200 msec. Images were available in the MR-suite after a delay of about 0.5 sec.

Pre- and postoperative angiograms were acquired with a 3D spoiled gradient-echo sequence.

Results
All steps involved in balloon angioplasty could be monitored effectively. The preoperative angiogram clearly delineated the stenosis, without flow-related artifacts, fig. 1a. The measures taken to suppress the inhomogeneous background were adequate to allow positioning of the guidewire and balloon catheter based on the source images without the need for postprocessing, fig. 2a-c. After dilation of the stenosis, fig. 2d,e, the instruments were withdrawn, fig. 2f. A postoperative 3D angiogram, fig. 1b, confirmed the morphological improvement already apparent from the images used for device tracking.

Discussion
For MR guidance of endovascular interventional procedures, simultaneous visualization of devices and vasculature is desirable as it obviates subtraction and overlay techniques to extract the position of the devices and their relation to the vasculature. In this way, the sensitivity of susceptibility-based tracking to gross subject motion is eliminated.

A requirement to be fulfilled is the availability of a suitable intravascular contrast agent, with a retention time of the order of the duration of the intervention and which provides a sufficiently short T1, at tolerable doses. High transversal relaxivity makes the class of ultrasmall superparamagnetic particles of iron oxide unsuitable for this purpose. Macromolecular or Gadolinium-based polymers have a small difference between longitudinal and transversal relaxivities, and are thus, in this respect, more promising [2].

In conclusion, susceptibility-based tracking may be facilitated considerably by adding a T1-shortening agent to the blood.

References

Figure 1: Coronal maximum intensity projections of preoperative (a) and postoperative (b) 3D contrast-enhanced MR angiograms.

Figure 2: Frames from the thick slab acquisition monitoring the insertion of the guidewire (arrows), and the balloon catheter (arrowheads) (a-c). Subsequent inflation of the balloon: initially the stenosis is visible as an indentation of the balloon (d), but eventually gives way (e). Withdrawal of the devices (f). The absence of the stenosis can be appreciated already.