A safe and practical guide wire for use during passive tracking in endovascular interventional procedures

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Introduction

For successful and safe endovascular catheterizations, a guide wire is absolutely essential. For MR guided catheterizations, MR visibility and RF safety of guide wires are currently the main issues of concern. On MR, guide wires can be visualized by using them as antennas (the active approach), or by mounting susceptibility markers (the passive approach) onto them. Mixed techniques using fiducial markers cannot be used because fiducials are too bulky for mounting onto guide wires. Concerning the RF safety, one should avoid long conducting structures by using non-metallic guide wire material, limiting the length of conducting material, or applying transformers to transmit the detected MR signal [1]. This latter approach is active and safe, but cannot be applied for thin guide wires. Moreover, a practical clinical use of guide wires severely limits the physical design of MR safe guide wires. For example, a coax connection at the end of the guide wire complicates the exchange of catheters over the guide wire, and may hamper subtle or multiple rotations of the wire during interventions. Taking all of the above into account, a non-metallic, connection-free guide wire with susceptibility markers is thought to be the best candidate for clinical use of an MR safe guide wire. In this study, we used a prototype synthetic material-based guide wire with a conventional guide-wire tip equipped with stainless steel 410 markers. We will demonstrate the use of the prototype guide wire in *in vitro* and *in vivo* pig experiments and show that the guide wire is depicted with very good quality, can be tracked easily and allows for safe and smooth catheterization of the renal and hepatic arteries

Materials and Methods

A prototype guide wire was constructed with a Nitinol tip segment of 12 cm (< λ/4 at 1.5 T in water) and a non-conducting plastic base. Onto the Nitinol tip segment six markers were mounted. The first marker contained $4.2 \cdot 10^{-3}$ mm^3 stainless steel 410 to accentuate the tip, the others $2.1 \cdot 10^{-3}$ mm^3. The guide wire was tested in an abdominal aorta phantom (Elastrat, Shelley, North York, Ontario, Canada) in which the renal arteries were catheterized and *in vivo* in two pig experiments in which the renal and hepatic arteries were catheterized. Next to the guide wire, a Cobra 5-Fr catheter (Terumo, Haasrode, Belgium) was used for the procedures. Four $1.5 \cdot 10^{-3}$ mm^3 stainless steel 410 markers were mounted at the tip of the catheter. Passive tracking was performed on a 1.5T MR scanner (Achieva, Philips, Best, The Netherlands) with T_2^*-weighted gradient echo sequences with parameters: MTX 224x145, FOV 350x262.5 mm^2, TH 30 mm, α 10°, T_R/T_E 6.7/4.6 ms/ms, SENSE 2. Baseline subtraction with motion correction with 10 seconds of training data [2] and overlay with a previously acquired phase contrast angiogram was performed on an external workstation. Lower matrix sizes and EPI acceleration factors of 3 and 5 were used to test the depiction at various tracking speeds [3], in this study up to 20 frames per second.

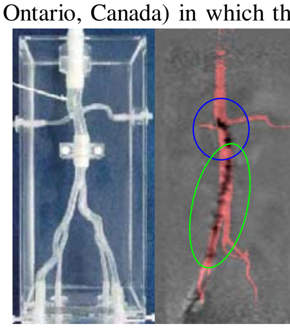

Figure 1: *a) Picture of the abdominal aorta phantom. b) subtraction image of the tracking procedure with angiogram overlay in red, the markers of the catheter encircled in blue and the guide wire in green.*

Results

In both the *in vitro* and *in vivo* experiments, the guide wire and catheter were clearly visible (Figures 1 and 2). The magnetic moments of the markers, respectively 7.0 and 3.5 Amm^2 for the guide wire and 2.5 Amm^2 for the catheter, were strong enough to create satisfactory artifacts with only very little material at all tracking speeds. Because of the different magnetic moments of the markers, the tip of the guide wire was always detected and the catheter could be distinguished as well. With the use of the guide wire, branches could easily be entered and the catheter did not kink.

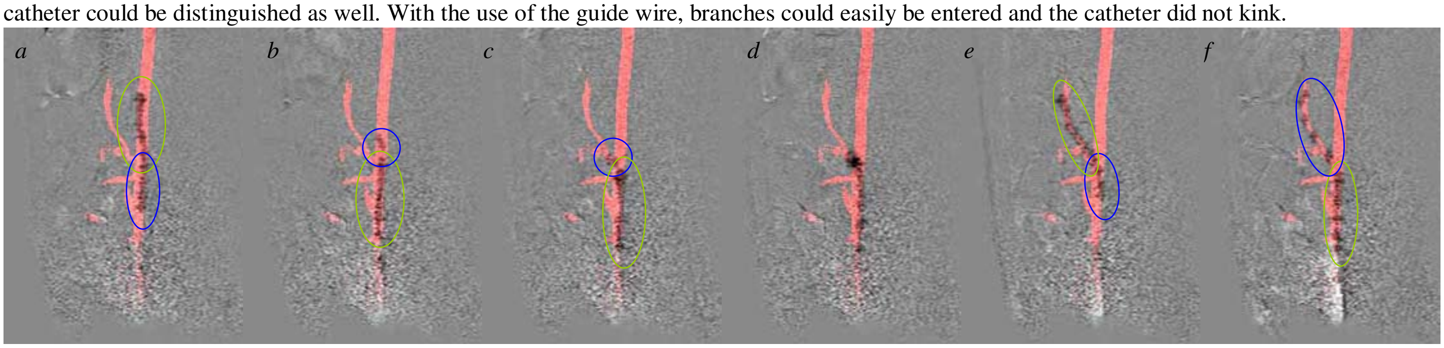

Figure 2: *Different stages of the catheterization of the hepatic artery of the pig showing subtraction images of the tracking procedure with angiogram overlay (in red), the markers of the catheter (encircled in blue) and the guide wire (encircled in green). a) Guide wire and catheter in the aorta. b) Retraction of the guide wire. c) Entering the truncus with the catheter. d) Advancing the guide wire into the hepatic artery. e) The guide wire is completely inside the hepatic artery, the catheter is joining. f) After guidance of the catheter over the guide wire into the hepatic artery, the guide wire is taken out.*

Discussion

The use of the guide wire allowed for safe and easy MR-guided catheterization of the renal and hepatic arteries. The guide wire was robustly depicted with susceptibility-based device tracking at different tracking speeds. The stainless steel 410 powder invoked satisfactory magnetic moments with only very little material. The Nitinol tip segment was short enough to avoid heating due to resonance of long conducting elements, but long enough to maintain the mechanical properties of the tip. Only the distal synthetic part was slightly stiffer than that of a conventional guide wire, which makes it not yet fully optimized for clinical operation. By way of passive device tracking, the procedure of guide wire manipulation is safe and allows easy exchange of catheters over the wire without the interference of long transmission lines and connections for signal transmission. The results encourage us to develop new prototypes with the same markers, but with a better distal part or a completely non-conducting synthetic structure with equal mechanical properties.

References

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