2020-06-15 13:51:04

ESMRMB 2020 - 37th Annual Scientific Meeting

Topic: Special Focus Topics: MRI in Therapy
Type: Oral Presentation
Abstract no.: A-1035
Status: submitted
Young Investigator Award - Boost your Career! (and win € 1,000) No, I won’t apply for the Young Investigator Award
Moderator at ESMRMB 2020 Congress Yes, I would like to apply to become a moderator
If yes please indicate MRI-DV - Motion and Artefacts
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Guidewire Tracking Based on Passive MRI Markers for MR-Guided Endovascular Interventions

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Introduction
Percutaneous Transluminal Angioplasty (PTA) is commonly performed under X-ray guidance [1-2]. MR-guidance, however, would allow this widely distributed therapy to be performed without radiation. To support this, we present a guidewire tracking functionality that allows monitoring of the guidewire position during intervention.

Subjects/Methods
For monitoring, we use a fast gradient echo sequence acquiring three parallel slices at ~2 Hz frame rate (TE/TR 1.7ms/3.4ms). The guidewire is equipped with distinct markers (Nano4Imaging GmbH, Germany) that produce negative MR artefacts. Marker position and concentration (iron oxide nanoparticles) are shown in Fig. 1.

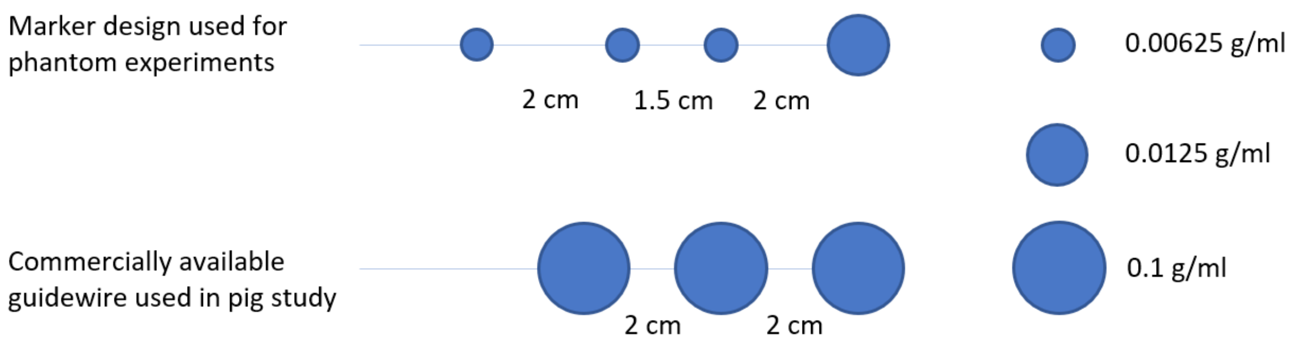

Figure 1: Guidewire design used for the performed experiments in MRI phantoms (top) and a pig study (bottom).

The tracking algorithm is shown in Fig. 2. A distinct front marker is used to locate the wire tip by utilizing Circle Hough Transforms with segmentation based on Connected Components. The search radius is then limited to represent the guidewire geometry before segmenting the smaller markers. Detected marker candidates are used to iteratively reconstruct the guidewire based on the angle between consecutive markers and the distances between markers (one-dimensional registration with a reference wire). Multimodal rigid image registration is used to align the images of the monitoring MRI sequence with a previously acquired volume scan.

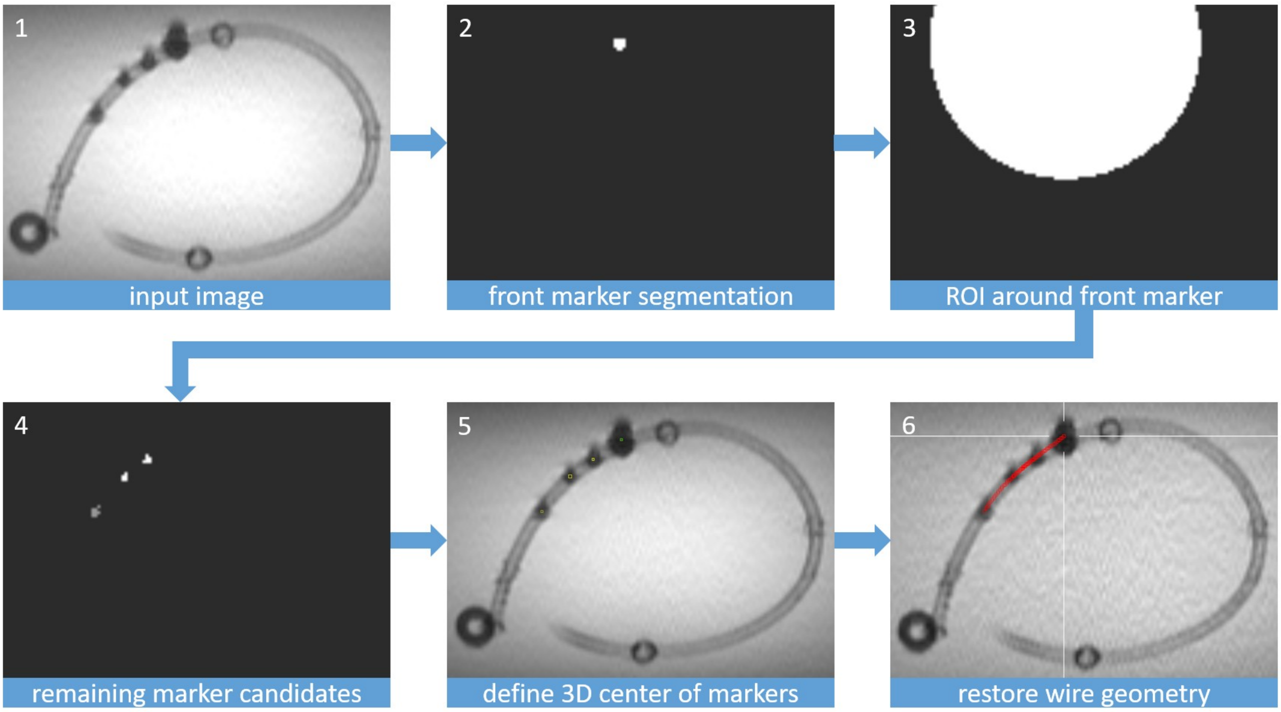

Figure 2: Overview of the wire reconstruction: (1) input image, (2) front marker segmentation, (3) limit search radius for subsequent algorithms, (4) segmentation of remaining markers, (5) define centers of gravity and (6) find best approximation.

Tracking performance was evaluated retrospectively using four different datasets; two phantom measurements mimicking vessels with different complexity (235 and 499 timepoints, three slices) and two time-series of a pig study, performed at the UT Southwestern Dallas (37 and 136 timepoints, single slice) using a commercially available guidewire with 3 equal markers at the tip (EmeryGlide, Nano4Imaging). Evaluation of image registration accuracy was conducted using in vivo datasets of the upper leg arteries with deliberate subject motion.

Results/Discussion

Fig. 3 shows the reconstructed guidewire in all four datasets, exemplary for a single slice and timepoint. Overall performance showed 98.1 % detection rate in phantom data with 0.4 % false positives; and 88.6 % detection rate with 1.1 % false positives in the animal datasets, only considering timepoints in which all markers were visible. The image registration decreased misalignments due to motion by 40 %, estimated by the Euclidean distances between manually annotated landmarks.

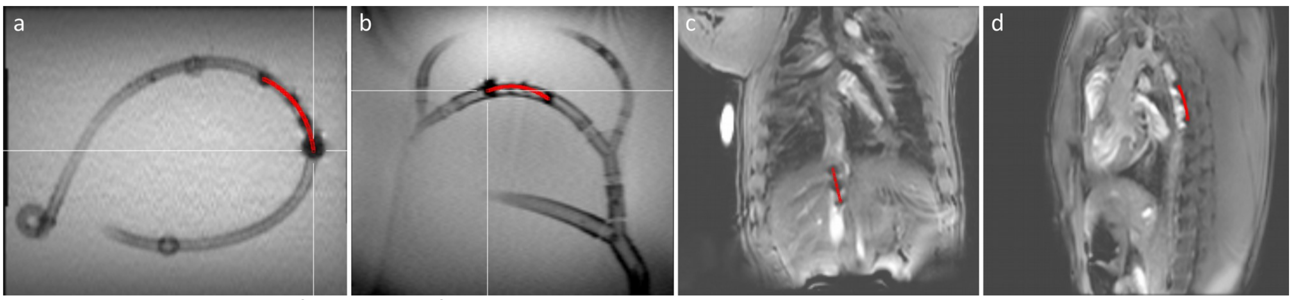

Figure 3: Image datasets used for validation of the wire tracking algorithms: (a, b) MRI phantoms mimicking vessel structures with different complexity and (c, d) animal (pig) data in two orientations.

We presented a tracking workflow able to detect passive MRI markers in a monitoring MRI sequence with high accuracy. It can ultimately be used to adjust the imaging slice during interventions to follow endovascular devices. This will enable more precise device positioning during MR-guided PTA, eliminating harmful ionizing radiation.

References
[1] Chambers et al. JACC; 2015;8:628–30.
[2] Picano et al. BioMed Central; 2011;9:35.

Acknowledgements: Funding from the Eurostars-2 joint programme with co-funding from the EU Horizon 2020 research and innovation programme (Eurostars E! 11263 - SPECTRE)

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