Tracking a 6F catheter under MRI using a controllable susceptibility device: a new tracking mechanism.

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Target Audience: Interventional radiologists and researchers.

Purpose: Due to the rich anatomic information available, MRI is an attractive tool for guiding catheters during interventional procedures. Susceptibility artifact–based tracking using paramagnetic markers[1] is a simple and economical approach, but has been used with limited enthusiasm partly because of the image degradation that results from such devices. More recently a novel susceptibility-based tracking device which can be mechanically turned ON and OFF was demonstrated *in vivo* with a 9F catheter tip and three layers of magnetic markers[2]. For this work, a new 2 layer tracking element was designed and integrated into a 6F catheter with a lumen. The catheter was demonstrated *in vivo* using a novel approach to find the device in projection images.

Theory: Signal that is modulated in k-space is replicated (ghosted) in image space. Here we exploit this effect to create a ghost of the catheter tip that is outside the anatomy, at precisely FOV/2 (in the phase-encode direction) from the true device location. This is done by turning the susceptibility effect ON and OFF every other TR (here we use a long TR and manual toggling for proof-of-concept). The utility of this is that the position of the device tip can then be quickly located in full projection images. The requirements are that the toggling of the ON/OFF states are synchronized with the TR and that the FOV is large enough that the ghost is outside of the anatomy.

Materials and Methods: The new tracking device design consisted of two concentric cylinders of titanium and graphite giving an outer diameter of 2mm and length of 3mm (Fig.1). The layer thicknesses were designed by numerical optimization to create a minimum susceptibility artifact in MRI when the cylinders are aligned (OFF position); and a large artifact when the cylinders are miss-aligned (ON position)[2]. The catheter was constructed by attaching the titanium cylinder to biocompatible Pebax-Polyimide tubing with heat-shrink. Polyimide tubing was glued and heat-shrunk to the graphite cylinder to push and pull this piece in and out relative to the titanium part (Fig.1.a). A guidewire of up to 0.022 inch diameter can be inserted through the inner lumen. Larger guidewires can be used and contrast agents can be administered by removing the inner graphite-polyimide tube during a procedure

A Yorkshire pig (36 kg) was anaesthetized and intubated under a protocol approved by the institutional animal care and use committee. A 6F sheath was placed in the femoral artery and the catheter was advanced to the carotid bifurcation using a guidewire under x-ray fluoroscopy. Once at the bifurcation, an angiogram was performed to advance the catheter into the carotid artery. The animal was repositioned in a 1.5T MR scanner (Signa, GE Healthcare, Waukesha, WI), with a 5 inch diameter receive-only surface coil. The novel tracking mechanism was demonstrated by acquiring gradient echo full-volume projection images and manually switching the device between ON and OFF configurations every TR, with TR=2s, TE=1.2ms, FOV=48cm, matrix=256/128. After locating the device, real-time tracking and visualization was performed by imaging every 0.64 sec around the device using a fast GRE pulse sequence[2]. High resolution fast gradient-recalled echo images were also taken with the tracking device in ON and OFF positions to quantify the susceptibility artifacts in both positions (TR/TE=300/2.3, FOV=20cm, matrix=256/128, slicethickness=3mm).

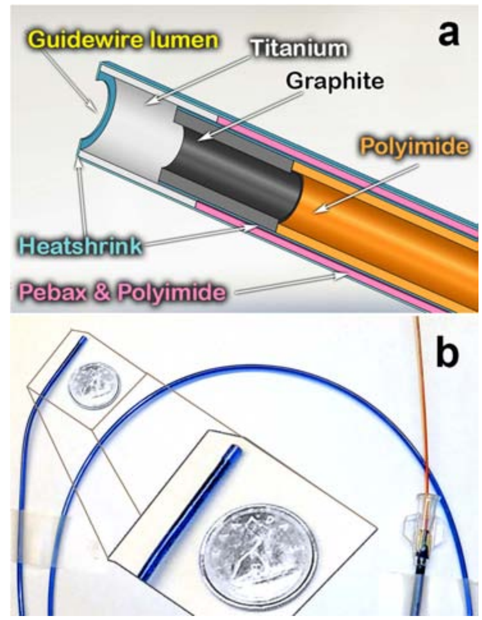

Figure 1. Catheter assembly with the susceptibility device. **a**: 3D model of the assembly. **b**: actual catheter picture.

Results and Discussion: Figure 1 b shows the picture of the 6F catheter built. The inner lumen of this design permitted the use of conventional guidewires and contrast under fluoroscopy to guide the catheter through the bifurcation in to the carotid. The maneuverability of this new design was significantly better comparing to the earlier 9F design with guidewire in monorail[2]. *In vivo* images acquired to find and track the catheter tip are shown in Fig. 2. By switching the device between ON and OFF positions every TR, the dephasing area around the device appears bright in the phase-encode direction displaced by half of the FOV (Fig. 2 a and b). This method can be more efficient comparing to the off resonance excitation used before[2] if an automatic actuator was used to switch the device between ON and OFF positions allowing much shorter TR. High resolution FGRE images of the neck area of a pig with the catheter in ON and OFF positions are shown in Fig.2 c and d respectively. Image distortions are smaller than those produced by the earlier 9F version of this device[2], but enough to facilitate tracking.

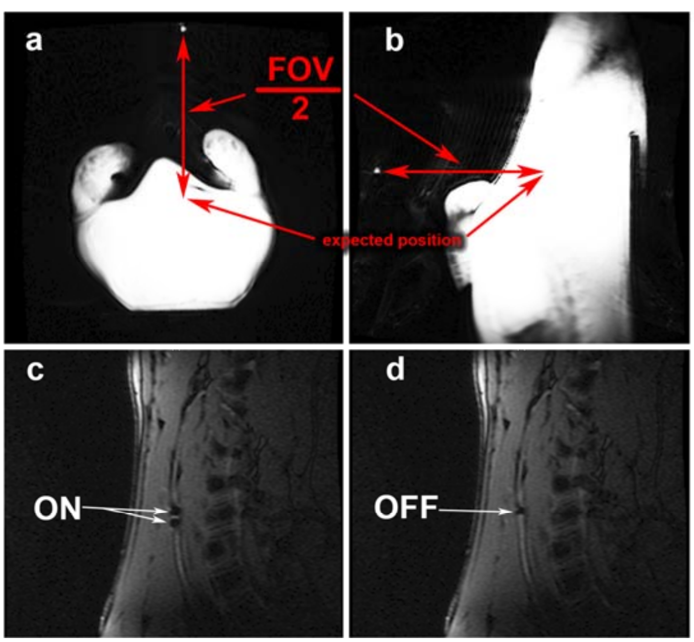

Figure 2: Images of the catheter *invivo* acquired at 1.5T. **a and b:** Axial and Sagittal Gradient Echo projection images of the neck area of a pig with the device alternating between ON and OFF position every TR, finding the device tip displaced FOV/2 of the phase encode direction. **c and d:** Fast GRE images of the area where the device was located in ON and OFF position respectively.

Conclusions

A new passive tracking catheter with a susceptibility effect that can be enabled and disabled by sliding one of the components was designed, fabricated and demonstrated *in vivo*. A novel tracking method was demonstrated in which the graphite layer was periodically moved every TR, creating a ghost of the catheter tip at precisely FOV/2 from the true location. The tracking tip demonstrated here can also be implemented on different tools or devices for interventional MR procedures. In future work, an automated actuator will be designed and constructed to permit toggling of the device during rapid, short-TR projection images, enabling quick snap-to-slice functionality.

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References:

1- Bakker CJ, et al. MR-guided endovascular interventions: susceptibility-based catheter and near-real-time imaging technique. *Radiology* 1997; 202:273–276.

2-Dominguez-Viqueira W, et al. A controllable susceptibility marker for passive device tracking. MRM, *DOI: 10.1002/mrm.24899,* 2013.