

Real Time MRI for Guidance of Electrophysiological Interventions Using Carbon Catheters

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Introduction: Today, electrophysiological (EP) examinations and ablation procedures in patients with rhythm disorders are usually performed under fluoroscopic guidance, sometimes complemented by additional imaging modalities like pre-procedural MRI or electroanatomical mapping. MRI guidance of these examinations has been suggested to be beneficial in many terms, but such an approach is accompanied with many difficulties, mainly due to electromagnetic interference of the electrophysiological equipment and the electromagnetic fields inherent to the MRI technology.

Methods: An interventional EP setup including steerable non-magnetic carbon catheters was envisioned aiming at minimizing safety concerns and imaging artifacts. This setup was tested for safety characteristics, image distortion, pacing and sensing properties, and feasibility of ablation at 1.5 T. MR imaging was performed in three different 1.5 T MR scanners using various receive coils and pulse sequences. A fluoroptic thermometry system was used to assess unintentional heating of the catheters by radio frequency pulses of the MR scanner in vitro. In vivo tests for catheter visualization, pacing and sensing properties, and ablation therapy were performed in eight mini pigs (45 to 55 kg).

Results: The carbon catheters showed no significant unintended heating using short, low-SAR pulse sequences, while at the same time allowing for adequate (passive) catheter visualization, thus meeting the requirements to be MR conditional. ECG interferences and imaging artifacts were minimized using custom RF-filters, thus enabling precise guidance to the target sites. Several RF-ablation procedures, including AV node modulation, were performed successfully. Lesions were then visualized with the catheter still in place using both contrast enhanced and non-contrast enhanced imaging techniques. Furthermore, potential EP intervention complications such as perforation of the RV myocardium were monitored in real time.



Representative series of MR images acquired during an ablation procedure. In this case, the coronary sinus was targeted. The left pictures show guidance of the catheter to the target, with the catheter body going from the jugular vein and the upper vena cava through the right atrium and the lower vena cava back to the coronary sinus (arrow=tip). After reaching final catheter placement RF-ablation was performed. The pictures on the right give an example of lesion visualization shortly after ablation using black blood T2 contrast and early gadolinium enhanced T1 contrast.

Conclusion: A new technology for interventional electrophysiology based on custom RF-filter-supplied carbon catheters in combination with low SAR pulse sequences was developed to perform electrophysiological examinations and interventions under real time MRI guidance. In vivo investigations in a porcine model demonstrated feasibility of MRI guidance for diagnostic and therapeutic EP procedures.