Evaluation of an integrated MR-EP suite and catheter-navigated local MR lesion monitoring after RF ablation

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Purpose: MR-guided electrophysiology (MR-EP) for the treatment of arrhythmias has the potential of improving catheter navigation and visualization of ablation-induced tissue changes. To realize this, actively tracked MR-conditional ablation catheters and an MR-EP suite with an appropriate image guidance platform are required. The objective of this work was to develop a clinical MR-EP platform and evaluate it for acute RF lesion monitoring in large animals using a catheter-navigated approach.

Methods: An MR-EP suite was developed that integrates a standard clinical 1.5T scanner (Achieva, Philips Healthcare, Best, Netherlands), a standard patient monitoring system for MR use (Expression, Invivo, Gainsville, FL), an EP recording system for MR use (Horizon, Imricor Medical Systems, Burnsville, MN), a standard EP RF generator (IBI 1500, St.Jude Medical, St. Paul, MN), and a real-time image guidance platform (Interventional MRI Suite, Philips Research, Hamburg, Germany)(Fig.1). In particular, a wireless ECG transmission was established between the patient monitor and both, the EP recorder and the MR. This allowed for patient monitoring, EP mapping, and MR-triggering with a single set of ECG electrodes applied. Secondly, an automatic transmission of EP activation time delays relative to the ECG was established from the EP recorder to the image guidance platform. Here, the activation delays were associated with catheter location information received from the MR scanner and stored as mapping points. Additionally, a color-coded activation time map based on a patient-specific cardiac 3D model was automatically calculated and updated on-the-fly. A deflectable MR-EP mapping and ablation catheter (Vision MRM, Imricor), equipped with two tracking coils and transformer cables [1] for safe tracking of tip position and direction, was used for pre-clinical evaluation. The image guidance platform allowed for automatic planning and acquisition of MR images relative to position and orientation of the catheter, i.e. the obtained images include the catheter tip section and the adjacent tissue. The mechanism was used to confirm the tracked catheter position by imaging before RF ablation (cardiac-gated SSFP cine with 40 phases, resolution 1.4x1.4x8mm, AQ=15sec) and to image the evolution of applied lesions after RF ablation (cardiac-triggered black-blood T2-weighted TSE with resolution 0.95x0.95x4mm, AQ=12sec). A similar method had been used earlier to generate pre-operative maps of the wall thickness [2]. The integrated MR-EP suite was evaluated during MR-guided mapping and ablation studies in vivo in 40kg pigs. EP-mapping of the right atrium was performed by recording voltages at up to 35 different locations. Several RF lesions were applied in the right atrium, and edema and wall thickness were monitored for each lesion over the first 5min and at 15, 30, and 45min.

Results: Right atrial mapping was time-efficient with 35 points acquired in 15 min in one of the sessions. Catheter tip position was confirmed before each ablation using catheter-navigated cine scans (Fig. 2a,b). Catheter-navigated T2-weighted TSE scans showed that the wall thickness and the signal enhancement increased to more than twice the original values during the first 30min (Fig. 2c,d).

Discussion: The integration of a patient monitoring unit into an MR-EP suite is essential for clinical use. Wireless transmission and re-use of the ECG acquired by the patient monitor for EP mapping and MR cardiac triggering simplifies patient handling and safety. The integration of the EP recorder and the image-guidance platform provides time-efficient mapping as performed in conventional EP procedures. Fast and semi-automatic planning of scans to confirm wall contact and to monitor lesion progression help to exploit the advantages that MR offers to EP procedures.

Conclusion: A close integration of commercial and prototype components resulted in an MR-EP suite that enables efficient mapping and ablation procedures including catheter-navigated monitoring of wall thickness, tissue contact and lesion formation. The preclinical results are the prerequisite for a first-in-man study planned for next year.

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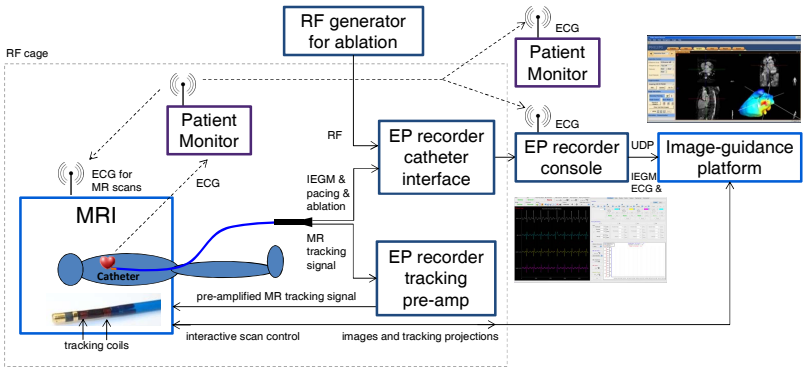

Fig. 1: MR-EP suite set-up with data exchange paths between components.

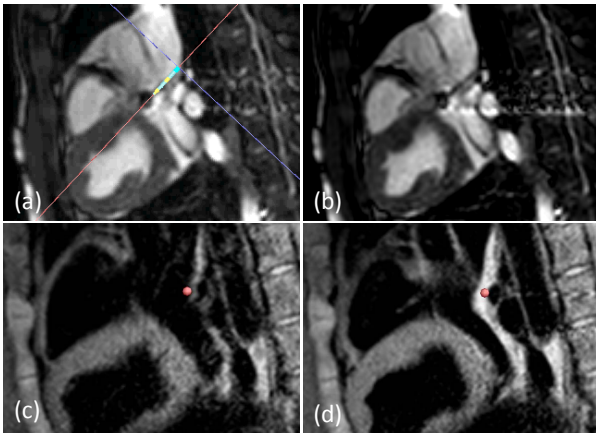

Fig. 2: The catheter position as obtained by tracking (a) is confirmed by a cine scan (b) before ablation, also confirming wall contact of the tip. Wall thickening observed between (c) 1min pre- and (d) 30min post-ablation at the position marked in red.