High Temporal Resolution Monitoring of Contact Between Catheter Tip and Target Tissue During a Real-Time-MRI-Guided Ablation using a 2D RF Navigator

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Introduction: We present a novel method to monitor the contact made between the catheter tip and the target tissue during real-time-MRI-guided radiofrequency (RF) ablation. The monitoring of tip-tissue contact is a known shortcoming of current real-time MRI technology [1]. During RF ablation, commonly used to treat cardiac arrhythmias such as atrial fibrillation, scars are intentionally created in the atrial wall to isolate the sources/triggers of abnormal electrical activity. The success rate of RF ablation is limited by the poor imaging, namely X-ray projection imaging and intracardiac echo (ICE), that is currently clinically available. Poor imaging guidance results in the inaccurate deposition of RF energy and, consequently, results in errors in the intended locations of the scars. This results in the incomplete electrical isolation of the AF triggers and, in turn, the recurrence of symptoms. Real-time MRI guidance is expected to provide improved imaging guidance and, consequently, better outcomes.

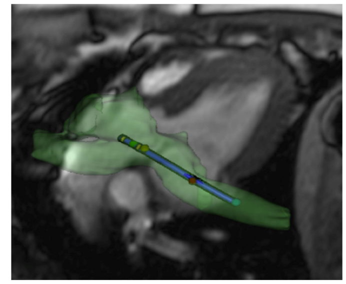

Figure 1: Real-time MRI display

It is necessary to accurately monitor contact made between the tip of the ablation catheter and target tissue in order to (a) effectively deliver RF energy by ensuring contact between the heat source and the target, and (b) better evaluate the quality of an ablation from the electrogram. The quality of the ablation is judged by estimating the post-ablation reduction of the signal measured by the electrodes at the catheter tip but poor imaging makes it hard to determine if the reason for a reduced signal is a successful ablation or the lack of contact between the catheter tip and the target tissue. We propose using a pencil beam (2D RF) navigator [2], positioned at the catheter-tip and perpendicular to the atrial wall, in order to automatically detect wall location at a high resolution. Combining this with real-time catheter tracking, which is currently available, allows for real-time monitoring of tip-tissue contact.

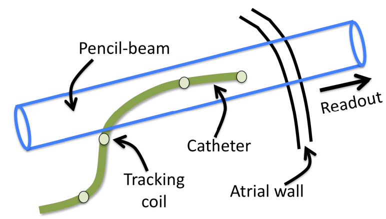

Figure 2: Geometry of our method

Under the current real-time MRI paradigm, as shown in Fig 1, a single slice, whose location and orientation are modified interactively by the operator, is imaged continuously with a spatial resolution of about 2 mm and a frame rate of 3 to 4 frames a second. In addition a 3D static shell of the atrium, extracted from an MR angiography scan acquired at the start of the procedure, and a cartoon of the catheter, tracked in real-time using four tracking coils located on the catheter shaft, are displayed. The temporal and spatial resolution provided by this display is sufficient while the operator navigates the device towards the target but during the actual ablation of a target it would be beneficial for the operator to switch to an imaging mode in which visualization is provided solely by a static shell, the cartoon of the moving catheter, and the real-time pencil beam navigator display.

Methods: The positioning of the pencil-beam, through the catheter tip and perpendicular to the atrial wall as shown in Fig 2, is possible due to the real-time tracking of the catheter and the acquisition of a 3D MR angiography scan at the start of the procedure. The pencil-beam navigator is implemented using a 2D RF excitation, in which a spiral gradient is played concurrently with an RF pulse to produce a circular excitation profile, followed by a readout and a spoiler gradient.

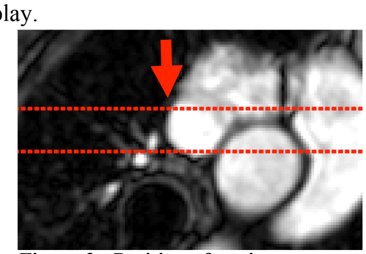

Figure 3 : Position of navigator (dotted lines) and RA wall (arrow)

Results: Figs 3 and 4 demonstrate the use of the pencil-beam navigator (TE/TR=3.5/25 ms, 8° flip angle, 1.5 mm readout resolution) to detect the location of the right atrial wall in a pig in a 3T scanner. Fig 3 shows the position of the pencil-beam by overlaying it on a slice of the MR angiography image. The 5-mm radius pencil-beam is located within the dotted red lines and intersects the wall of the right atrium as indicated by the arrow. Fig 4 shows the signal from the navigator in an M-mode display that plots distance along the pencil-beam versus time. The navigator is acquired continuously over more than three heartbeats at about 40 frames a second. The automatic detection of the wall, denoted by the horizontal wavy line, is performed by finding the center of the edge in the known neighborhood of the atrial wall. The vertical dashed lines denote the R-wave detected from the concurrently acquired ECG signal and are seen to match the periodicity of motion of the wall.

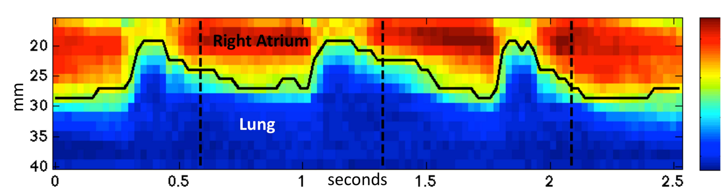

Figure 4: M-mode display of navigator over several cardiac cycles with automatic wall detection of RA wall (black wavy line)

Discussion: We have demonstrated the feasibility of detecting atrial wall motion, in vivo, using a pencil-beam navigator in order to monitor tip-tissue contact during real-time-MRI-guided RF ablation. We will incorporate this method into a real-time, interactive sequence and combine it with the existing catheter tracking in order to monitor the tip-tissue contact in real-time. Further optimizations, such as of the length and profile of the RF pulse, the automatic positioning of the pencil-beam, the relative timing of the acquisition of catheter tracking data, and the most effective visualization of the information, will be performed. Other potential improvements include the use of a 2D echoplanar projection readout of the excited pencil-beam volume instead of the 1D projection currently acquired, and the use of bSSFP-like, instead of GRE-like, blood-tissue contrast by adjusting the gradient moments accordingly.

References: [1] *Vergara* et al., Heart Rhythm 8:295-303 (2011), [2] *Börnert*, MAGMA,7:166-178 (1998)