Catheter Electrogram Signals in 3T MR Environment

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Introduction

During an RF ablation procedure for the treatment of atrial fibrillation, electrogram (EGM) signals are detected on the endocardial surface. These signals are displayed and recorded in real-time. A steerable ablation catheter is used to detect these EGM signals. The electronics of the system must allow for both ablating and signal detection. There is an increasing interest in performing ablation procedures in an MRI [1]. Electro-anatomical mapping and electrogram (EGM) recordings at 1.5 Tesla magnetic fields have been reported previously [2]. The goal of this study was to develop a system to acquire reliable EGM signals during an ablation procedure on a porcine subject in a 3T MRI scanner (Siemens Healthcare, Erlangen, Germany).

Methods

A novel, steerable 7F catheter system was developed for these procedures (MRI Interventions, Irvine, CA). An articulated tip allowed for catheter steering, with four embedded receiver coils allowing for the catheter's position to be tracked using a tip tracking sequence interleaved with real-time MRI imaging sequence. These sequences introduced noise in the EGM signals. The metal tip of the catheter was designed to deliver RF energy at a specific frequency for ablation. When not ablating, the tip was designed to either sense an EGM signal or deliver pacing current. The tip could be used to detect either a unipolar signal, or a bipolar signal utilizing a ring electrode spaced a few millimeters proximal from the tip.

Two catheters were used in a typical procedure: one for mapping/ablation, and the other as a reference. EGM signals were recorded by both catheters. The reference catheter was positioned at a landmark location inside the atrium. The mapping/ablation catheter was used to record EGM samples at different locations inside the left atrium. This catheter's signal was useful for determining the effectiveness of a previously-performed ablation (amplitude reduction). The location of the catheter tip was determined by the relative timing between the EGM signals of the two catheters.

The equipment setup of the catheters is shown in Figure 1. Both the MR-compatible data acquisition system (Biopac, Goleta, CA) and the RF ablation system (Stockert 70, Stockert GmbH, Freiburg, Germany) require a ground to be placed on the porcine subject. The data acquisition system measures multiple signals from the subject, but only one surface electrode ground reference is used. All electronic systems that share grounds on the subject were powered from the same power supply with an isolated ground.

The Data Acquisition (DAQ) system's cables passed through filters at the patch panel (waveguide in Figure 1). These filters protect against RF noise entering the MRI Suite. The data acquisition hardware was designed for EGM differential signals at the millivolt level. A 0.05Hz high-pass filter was used at the hardware input to the system. In addition, a software bandpass filter was used (3 - 150Hz is a typical setting). A notch filter was used to filter-out the 500kHz RF ablation signal, in order to prevent artifacts in the mapping catheter signal during ablation.

Results

A primary objective of this study was to understand and minimize the noise induced by the MR scanner in the EGM signals. It was experimentally verified that the presence of the static field (B_0) did not significantly affect the endocardial EGM signal, both in-vivo and with an external EGM signal generator. The real-time MR sequence used for catheter navigation did, however, introduce a level of noise into the EGM signal. The amount of noise injected into the catheter and cables was determined by running the RT scan with the catheter and cables inside the bore, and in a typical case was found to cause an increase in the noise floor from -86 dBV to -82 dBV. The effect of the RT scan was measured in-vivo. On average, the SNR of the catheter EGM signal decreased from 23 dB with the RT scan off vs. 18 dB during the scan.

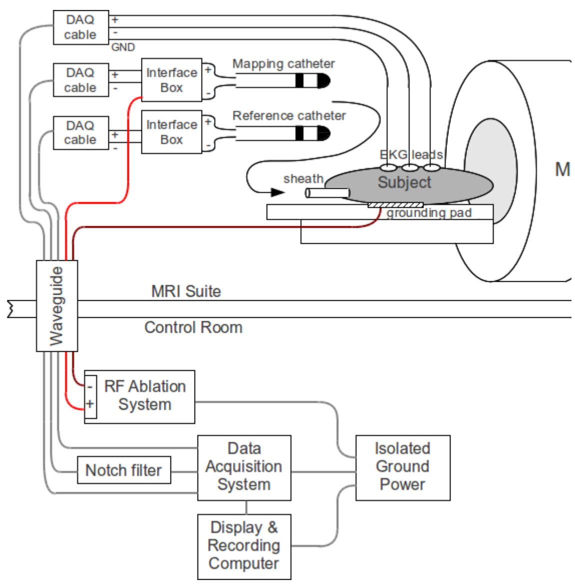

Figure 1. Experimental Setup.

Other factors contributing to noise in the EGM signal were also assessed. It appeared during multiple experiments that an unclean tip surface could cause excessive noise in the signal. Cleaning the tip either by dipping it in a slightly acidic solution or scrubbing it with emery paper helped reduce the noise level by a significant amount. The multiple use of these prototype catheter models, with a copper rather than platinum tip, may have contributed to the problem. This may be much less of an issue with one-time-use catheters in a typical clinical setting.

Ablations also had a significant effect on the quality of the EGM signal. Initially, it was not possible to obtain reliable EGM signals during—or even for a short time after—ablations. It is necessary to measure the amplitude of the EGM signal before and after an ablation in order to help determine its effectiveness. The addition of a notch filter, tuned to the 500 kHz frequency of the RF energy, was successful in allowing the EGM signal to be measured during an ablation. The reason for the inability to obtain these EGM signals during ablation was most likely due to the amplitude of the RF energy being far outside the allowable range of the millivolt-level DAQ preamp.

Conclusion

Assessing the different noise sources interfering with the recording of usable and reliable EGM signals during experimentation led to improvements in the MR-guided RF ablation system. The addition of extra filters in the circuit resolved the conflict between delivering RF energy and detecting EGMs.

Acknowledgments

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References

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