

This course is primarily intended for physicists and engineers interested in entering the exciting field of Cardiac Electrophysiology (EP) using MRI guidance. It will introduce them to some of the achievements which several groups have made collectively since 2001 in bringing interventional EP closer to a clinical reality, as well as the substantial challenges we still have. The focus of this talk is on practical issues, which is especially relevant today, when there is a need for solutions that will make MRI-guided EP affordable, efficient in utilization of time and staffing, as well as safe for the patient. It is prime time to do that now, since the EP community is already convinced in the advantages that MRI imaging could provide, especially in reducing the high incidence of repeat procedures and the rate of complications, but is mostly unable to benefit from it. There is an enormous need for contributions in software (acquisition and post-processing methods) as well as in hardware (catheters, coils, peripheral devices), so as to make MRI-guided EP affordable and safe for the millions of EP patients.

We will start by presenting our own experience with human MRI-guided EP procedures. We currently perform repeat (“touch-up”) EP atrial fibrillation (AF) radio-frequency ablation (RFA) procedures in our AMIGO suite, which is a two-room suite with a magnet that can move into (and out of) the standard EP interventional suite without moving the patient. We currently perform MRI imaging before the treatment, determining where the previous procedure left incomplete ablation lesions (“gaps”), correct this by performing RFA in the standard EP lab, and then follow the therapy with a post-ablation imaging session. We use MRA for vascular roadmaps, T2 for visualizing edema and MDE for visualizing scar. The success of this method is astounding (0 recurrences of AF to-date), although these methods are not applicable in most EP centers and there are numerous EP patients and diseases we need to exclude from treatment.

The main issues we encounter are: (1) there are very few MRI-compatible EP interventional devices so that we need to remove most of the devices from within the patient before the MRI arrives, and then reintroduce and re-register them once the MRI leaves. As a result, each transfer takes 30-45 minutes, and the accuracy of the treatment is reduced due to the re-registration. (2) The lack of adequate fidelity MRI-compatible physiological monitoring excludes most patients with ischemic histories from AF treatment. It also excludes most interventions in the left ventricle. (3) Understanding the MRI signatures of acute lesions is lacking. While we observe T2-elevation and regions of MDE enhancement in the immediate post-RFA images, we are unsure which lesion will become permanent (i.e. convert to scar), versus those which will recover, possibly leading to AF recurrence. The spatial resolution we obtain in the atrial wall using surface MRI coil with lengthy scan times (10-15 minutes) is also border line, due to the thin left-atrial wall, coupled with sizeable physiological motion. This reduces our ability to provide the clinicians with a response to one of the greatest questions in EP; how permanent are the lesions created and do they need to burn more? (4) Integration of MRI with other imaging modalities, such as Intra-cardiac echo (ICE) and x-ray, and with the Electro-anatomic mapping (EAM) workstations that integrate much of the EP suite’s devices and workflow is lacking. This leads to lengthy registrations, to a need to utilize MRI where it is sub-optimal (or not really needed) or to the reduction in use of MRI.

We provide examples of solutions to some issues. (A) We detail a prototype MRI-compatible 12-lead ECG system, which could allow treating more severe patients, and would provide more confidence during MRI-guided procedures. (B) We detail two types of MRI-compatible EP ablation catheters, which can be left inside the patient inside the MRI and thereby shorten transfer times and reduce re-registration issues. One form is an MRI-tracked EP catheter, which is tracked using MRI projections. The second form is a voltage-tracked EP catheter, which uses a

tracking method commonly used in the conventional EP suite, and allows continuous tracking inside and outside the MRI scanner. (C) We detail a prototype Intra-Cardiac MR Imaging catheter that provides much higher signal-to-noise than surface MRI coils, so that scan times are shortened, and which can be used during RFA delivery to monitor the ablation process.

We expect to provide attendees with a better understanding of the challenges to human MRI-guided interventional EP. As a result of dissemination of this information, novel or innovative approaches may be tried, which may bring us closer to resolving the remaining hurdles.