MR-guided RF Ablation

Tobias Schaeffter
Division of Imaging Sciences, King’s College London

Background:
Cardiac arrhythmias are common, affecting 3-5% of the over 40s. Population growth and ageing will lead to a large increase in new arrhythmia cases [1]. Cardiac arrhythmias cause considerable morbidity and significant mortality as well as considerable anxiety in patients and their relatives. Early and accurate diagnosis is essential for the selection of an appropriate treatment, which can be drug or ablation treatment. Once the arrhythmogenic substrate is fully elucidated then it is often possible to complete cure the condition by either burning the endocardial surface where the abnormal electrical activity is originating to block the propagation of the abnormal electrical activity. This procedure is called radio-frequency (RF) ablation as the most common technique used is deposition of heat using RF energy via specially adapted catheters. Currently, X-ray fluoroscopy is the standard technique used for image guidance. Since this imaging modality offers no 3D information and no soft tissue contrast, the procedure normally takes several hours, with fluoroscopy and thus radiation exposure taking up a large fraction of this time. Electro-anatomical mapping systems (Biosense Webster Carto, California, USA, and St Jude Medical ESI, Minnesota USA) generate static anatomical maps by tracking the electrical catheters or recently by importing a static 3D image dataset (CT or MRI). However, there is a degree of inaccuracy in the registration of the MR or CT derived and mapping catheter-derived surfaces.

MR-guided RF-ablation
Real-time MRI for guidance of cardiovascular interventions [2] is increasing due to its superior soft-tissue contrast combined with the lack of radiation [3], which is especially important for pediatric and long cardiovascular interventions (e.g. arrhythmia treatment). Recently a number of groups have demonstrated the MR-guided EP procedures [4-6] and assessment of rf-ablation lesions [7-10]. For these procedures a number of technical challenges have to be addressed:

1. **Safe catheter tracking and visualization.** The key is to provide the cardiologist with images showing the myocardial tissue and the position and shape of the catheter devices. However, device localization in MRI is complicated by the fact MRI is a tomographic imaging modality. Therefore fast catheter-tracking techniques are highly desirable, i.e. to track the MR-safe catheter devices within the MR-scanner. A variety of techniques have been proposed for these purposes, many of which incorporate a receive coil in the catheter and localizing this coil by obtaining projections [11]. In addition, visualization of the catheter shape is important to determine the direction and orientation of the device with respect to the anatomy. For this, a loop-less antenna is often integrated into the catheter allowing visualization of a long portion of the catheter. However, both approaches (tracking and visualization) are not safe, since they involve the introduction of a conductive wire into the body, which can cause severe heating problems. Therefore, most of all research programs in the world on interventional MRI have been restricted to animal experiments only. Recently, safe transmission line technology has been introduced allowing safe catheter tracking [12] as well as safe sensing of EP-signals and pacing [13].

2. **Roadmap Visualization.** Another requirement is to visualize the catheter device on a 3D roadmap. However, the cardiac anatomy is dynamically changing due to cardiac and respiratory motion. Therefore, either real-time MRI [14] or a motion compensated roadmap is used. For the latter a motion model is determined from dynamic MR-data and this information is used to deform the pre-acquired high-resolution MR-data [15,16].

3. **MR lesion imaging.** Recently non-invasive MR-techniques have been proposed to quantify the size and shape of the ablation lesion. These techniques are either based on delayed enhancement of lesions using a contrast agent [7-10] or using T2-weighted imaging for imaging of edema [17]. Furthermore, the three-dimensional visualization of the lesions and edema pattern [18] is of great importance to provide the interventionalist with location of potential gaps.

**Conclusion**

It is possible to use MR-guidance to navigate catheters in heart, to measure electrogram activity, and to perform rf-Ablations. These procedures can either be performed in a combined X-ray/MRI systems or completely in the MRI environment. The latter, however, requires the development and availability of safe catheter devices, which requires strong involvement of the device industry.

**References**

17. Yokokawa M et al The change in the tissue characterization detected by magnetic resonance imaging after radiofrequency ablation of isthmus-dependent atrial flutter. Int J Cardiol. 2009 [Epub]
18. Knowles B. et al. Three-dimensional visualization of acute radiofrequency ablation lesions using MRI for the simultaneous determination of the patterns of necrosis and edema. IEEE TBME in press