In vivo evaluation of simultaneous MR-Electrophysiology in large animal model.

Delphine Elbes[1], Julie Magat[1], Assaf Govari[2], Yaron Ephrath[2], Delphine Vieillot[3], Christopher Beeckler[2], Pierre Jais[1], and Bruno Quesson[1]
[1]*CRCTB/IHU LIRYC, University of Bordeaux, Pessac, Gironde, France,* [2]*Biosense Webster, Israel,* [3]*PTIB, University of Bordeaux, Pessac, Gironde, France*

Target audience: MR Scientist in the field of interventional cardiology, cardiac electrophysiologists

Purpose:

Cardiac electrical dysfunction can be assessed by electrophysiological (EP) mapping, using diagnostic catheters equipped with a number of sensors (temperature, position, electrodes…) located near the tip. The electrical information derived from these local measurements can be correlated with anatomical (cardiac structure, fibre orientation, presence of scars…) and functional (ejection fraction, strain, flow…) data that can be non invasively measured with MRI (1). In current clinical practice, electrical recording and imaging data are collected separately and merged afterward using 3D registration techniques. Being able to collect electrical data simultaneously to MR acquisition (2) would simplify the procedure, allow for reduction of examination duration for the patients and clinicians, reduce registration errors and more importantly allow for ablation under MR guidance and monitoring. However, such capability requires MR compatible catheters, including minimal artefact generation on the MR images and absence of significant catheter heating (~2°C temperature increase) during MR scanning, while ensuring sufficient attenuation of the RF signal generated by B1 emission (kW)/gradient switching to allow for collection of exploitable (~1 mV amplitude) cardiac electrical recordings. This work presents Ep studies under MR using a 10 poles, circular, EP catheter. Evaluation of the MR-compatibility is presented, together with simultaneous MR-EP measurements obtained *in vivo* on a large animal model. The electrograms recorded in the MR scanner operating at 1.5 T were compared those recorded under identical conditions in the same animal at the same catheter position in the adjacent catheter lab under X-Ray fluoroscopy.

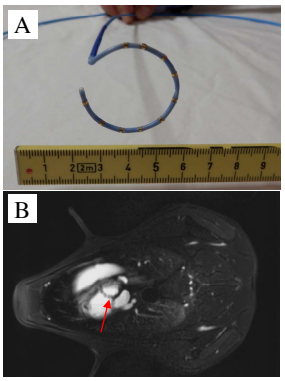

Figure 1: photograph of the catheter (a) and transverse MR image (b) of the thorax of the animal showing catheter in the right Atrium (red arrow).

Methods:

Animal preparation: five sheeps (~50 kg body weight) were sedated (ketamine IV 1 g/h, Pentobarbital 0.5 g/h), intubated and maintained under general anaesthesia/analgesia during the complete experiment (protocol approved by ethic committee). The animal was positioned in supine position on a plastic stretcher (Ferno, SMSp, France) installed in a conventional catheter lab equipped with X-Ray fluoroscopy (Infinix,Toshiba). Each leg of the animal was securely attached to the stretcher to minimize motion of the animal during transfer. The thorax surrounding the heart was shaved and residual hairs were removed with depilatory cream (Veet, Reckitt Benckise, France) to position 3 ECG electrodes. A 11 Fr introducer (St Jude medical, France) was inserted in the right femoral vein to allow percutaneous positioning of the catheter into the right atrium. Then, a 10 pole circular (2 cm diameter, see Fig. 1) MR-compatible diagnostic catheter (Biosense-Webster, Israel) was inserted through the introducer to the right atrium under intermittent X-Ray fluoroscopy. The catheter was connected to the recording device of the manufacturer (Carto3, Biosense-Webster) and its analysis console (through optical fibre) to visualize and record the 9 bipolar EP signals online. Software processing included an adjustable low pass filter with cut-off values of 120, 240 and 500 Hz, respectively. After collection of reference EP data, the animal was transferred to the adjacent MRI bed (Siemens Avanto 1.5 T) without displacement of the catheter using the stretcher and a trolley. Two 16 elements cardiac coils were positioned laterally to the thorax and the ECG device of the MR system was connected to the surface electrodes for synchronizing the MRI acquisition sequences. The recording device was installed inside the faraday cage and connected to the catheter using attenuation filters tuned to the MR frequency (64 MHz) on each electrical line. Except insertion of the filters, the acquisition chain remained unchanged.

MR-EP acquisition protocol: because induced signals in the EP measurements may vary with the acquisition sequence, an exhaustive list of acquisitions were tested with conventional clinical parameters, including multiplanar localizer, balanced SSFP for selection of conventional cardiac orientations (short axis, 4 chambers and 2 chambers), radial transverse cine, flow assessment, late enhancement and 3D coronary artery imaging.

Data processing: image quality was compared to measurements performed in similar conditions but in absence of catheter. EP recordings were displayed at high sensibility (1mV/cm) to estimate maximal signal and noise amplitudes in order to calculate Signal to Noise Ratio (SNR).

Ex vivo testing: additional data were collected on gel samples (3% Agar in saline solution to reproduce tissue conductivity) to estimate potential temperature increase during a 4 min balanced-SSFP sequence with high energy deposition (4 W/kg). Local temperature readings were collected at the contact of the electrodes with optical thermometers (Luxtron) under different catheter orientations (from 0° to 90°) with respect to the static magnetic field.

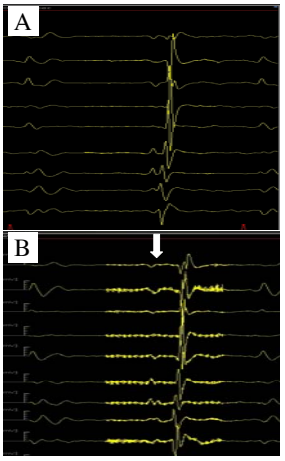

Figure 2: examples of two EP signals (1 cardiac cycle) collected during T1w delay enhanced (A) and balanced–SSFP (B) sequences. The white arrow in (B) shows the artefact on EP signal due to gradient switching. The callipers on the left side of (B) correspond to 1 mV amplitude.

Results:

No loss in image quality (see Fig 1B) could be observed on all the tested sequences, except a hyposignal corresponding to the catheter. EP signals acquired during MR acquisition (Fog. 2) were of sufficient quality to be interpreted (Fig. 2). No loss of EP signal quality could be observed for most of the sequences (Fig 2A), with similar noise levels (<0.1 mV) to those measured prior to MR acquisition. Typical SNR values in the catheter lab ranged from 30 to 75 and were similar to those measured inside the MRI scanner (ranging from 27 to more than 100). However, for balanced-SSFP sequences (Figure 2B), the noise level increased up to 0.25 mV, which was attributed to rapid gradient switching. However, the quality of each bipolar EP signals remained acceptable, allowing interpretation of each electrogram. No technical failure was observed on all animals and no unwanted cardiac stimuli induced by potential interaction between the MR system and the catheter could be identified. Measurements of catheter heating in gel samples showed a maximal temperature increase below 3°C (at 90° orientation with B_0).

Discussion:

This study shows that simultaneous MR-EP data can be acquired with minimal modification of the EP recording system providing adequate technology. The recorded EP signals from the multipolar MR-compatible catheter were of sufficient quality to provide quantitative analysis of the local cardiac electrical activity. Image quality was not altered by the presence of the catheter. Local catheter heating was found acceptable and are expected to be lower *in vivo* due to blood flow cooling and lower SAR values.

Conclusions:

We demonstrate that MR-EP can be performed simultaneously *in vivo* under safe experimental conditions using a multipolar catheter. These results are encouraging in the perspective of clinical application.

References: (1) AS Jadidi, H Cochet, AJ Shah, *et al*., « Inverse relationship between fractionated electrograms and atrial fibrosis in persistent atrial fibrillation: combined magnetic resonance imaging and high-density mapping ». J Am Coll Cardiol. 2013;62(9):802-12, (2) AN Ganesan, JB Selvanayagam, R Mahanan, *et al*., "Mapping and ablation of the pulmonary veins and cavo-tricuspid isthmus with a Magnetic resonance imaging-compatible externally irrigated ablation catheter and integrated electrophysiology system", Circ Arrythm Electrophysiol 2012;5;1136-1142.