Development of intracardiac Radio Frequency coil for high resolution cardiac Magnetic Resonance Imaging -thermometry

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Summary of context, objectives and methods:

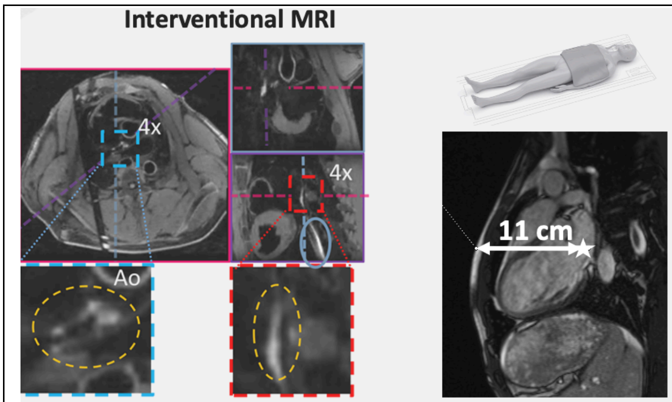

Figure 1 : Cardiac MRI acquisition with conventional Radio Frequency coils (left-volumic, right -urface coil). The position of the detector, relatively far from the field of view of interest (11 cm) contributed to the problems of low SNRs obtained.

MRI plays an important role in the diagnosis of cardiac pathologies such as atrial and ventricular cardiac arrhythmias, which are the leading cause of death worldwide [1]. Using ex vivo MRI and histological validation, it has been shown that the extent of fibrosis is strongly correlated with the onset, severity and duration of Areterial Fibrillation [2]. Despite the research efforts made by the international academic community and by MRI manufacturers in terms of reducing the data to be acquired (parallel imaging, compress sensing, multi-band,...) coupled with specific reconstruction algorithms (Sense/Grappa, Spirit, slice grappa,...), the current resolution of cardiac images remains limited to the mm at best on clinical magnets (1.5t and 3T). One of the intrinsic reasons is the relatively low signal-to-noise ratio (SNR) of the images produced, directly dependent on the quality of the instrumentation collecting the NMR signal (figure 1) [3-4].

The liryc HIU develops real-time MRI thermometry methods (5 slices/sec, with rapid acquisition, reconstruction, processing and online display) whose objective is to monitor tissue temperature variations during radiofrequency ablation of an arrhythmogenic zone, using an intracardiac catheter [5]. The coagulation necrosis induced is a few mm and ideally requires sub-mm spatial resolution, which is difficult to achieve with the instrumentation provided by the manufacturer. On the other hand, the characterisation of the cardiac substrate (fibrosis, fatty infiltrate) is an essential element to improve treatment. Here again, it would be beneficial to have an optimised instrumentation allowing the substrate to be probed with a much better resolution than the one obtained here.

Current RF coils are extracorporeal and placed around the patient's thorax, which limits the SNR and impose to choose a much larger field of view than the interested area to be imaged in order to avoid aliasing artifacts. To overcome this disadvantage, it seems appropriate to us to develop an intracardiac endoscopic RF coil that can be integrated into a catheter. This approach offers the double advantage of a substantial improvement in the SNR ratio of the region of interest and a reduction in the imaging field of view due to the spatial selectivity of the surface coil. Consequently, it should be possible with this approach to strongly improve the spatial resolution (isotropic 300 µm objective) of the images to allow a finer characterization of the arrhythmogenic cardiac substrate and/or to improve the thermometry (accuracy and spatial resolution) during treatment. It so happens that inserting a catheter into a patient is a procedure routinely performed by cardiologists.

The aim of this post doctoral internship is therefore to develop a **new minimally invasive instrumentation to develop cardiac MRI** with unequalled resolution, by associating two teams of complementary expertise (BIOMAPS - MRI instrumentation and LYRIC - diagnostic and interventional cardiac MRI).

The aim will be to develop a miniature radio RF coil or an intracardiac RF coils array to initially obtain high-resolution MRI images of a beating heart in order to monitor the temperature during the treatment of cardiac arrhythmias by radio frequency catheterisation in a second phase. For this purpose, flexible antennas will be built and interfaced with a clinical MRI (1.5T) (figure 2.a illustration of a rigid RF antenna and its conditioning at the acquisition chain of a clinical MRI [6]). They will have to be able to be deployed in the heart to improve the spatial selectivity and sensitivity of the images. For this, numerical simulation of original coil (electrical circuit fig 2-b and magnetic field map fig 2-c) will be necessary. The security aspects of the device will be analysed in detail. Several imaging methods will be developed to exploit these sensors in order to obtain real-time temperature images with a resolution of 150 µm or better in vivo during preclinical studies. The pre-clinical experiments will take place at the Bordeaux Cardio-Thoracic Research Centre.

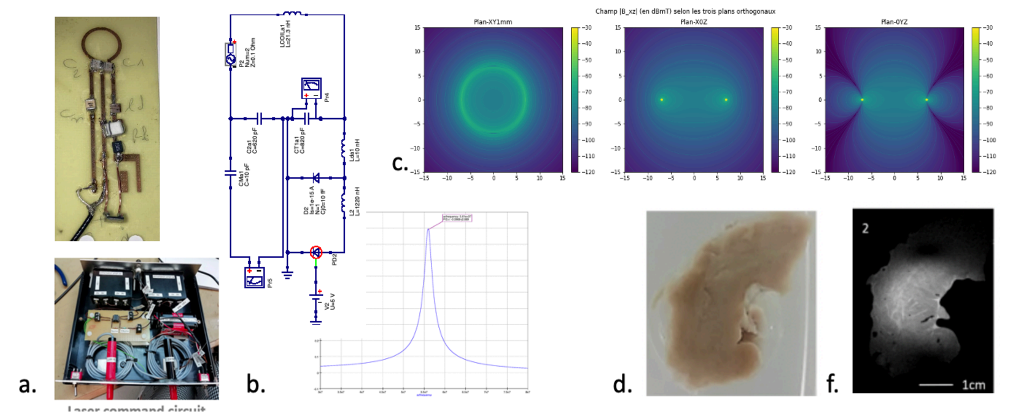

Figure 2 : Photographs of a 1 cm diameter optically decoupled receiving home made RF coil (ODC) and the dedicated interface box to connect the coils to the MR system (a). (b) numerical simulation of the electrical circuit and its response in frequency space, (c) simulation of the magnetic field maps of the RF coil in the 3 plans (parallel and perpendicular to the current loop) (d) ex vivo septum sample of a sheep (f) 3D gradient echo acquisition with isotropic resolution from 200µm3.

Références :

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