3D cine T1 mapping using a stack-of-spirals sampling scheme and a Look-Locker inversion recovery preparation at 7T : Application on small animal cardiac imaging.

Charles Robert Castets[1], William Lefrançois[1], Aurélien Julien Trotier[1], Emeline Julie Ribot[1], Jean-Michel Franconi[1], and Sylvain Miraux[1]
[1]*RMSB - UMR5536, CNRS - Université de Bordeaux, Bordeaux, Aquitaine, France*

TARGET AUDIENCE : This study is aimed at scientists and clinicians who need to simultaneously acquired in vivo 3D T_1 maps and, 3D cine imaging on a beating heart.

BACKGROUND : T_1 mapping and cardiac cine MRI are generally performed in 2D and, in separately experiments. However, to diagnose myocardial infarction it might be useful to obtain the T_1 maps in three dimensions (3D) which require a long acquisition time. In several studies [1,2], the T_1 maps are acquired in diastole state allowing to obtain a static image of the heart. However, obtaining both the T_1 quantification and the heart dynamic might be of a great interest for clinicians and researchers. In this project a new 3D T_1 cine mapping method based on Look-Locker protocol using continuous radio frequency (RF) excitation and spiral gradient shape has been developed. This method allows to obtain cine 3D T_1 maps with high spatial (200 x 200 x 300 μm^3) & temporal resolution (<12 min), five cine 3D images can be acquired allowing to visualize the entire cardiac motion.

METHODS : All the mice were imaged on a 7T horizontal magnet (Bruker Biospin) equipped with a gradient system capable of 660 mT/m maximum strength and 110 µs rise time. A volume resonator (75.4 mm inner diameter, active length.70 mm) operating in quadrature mode was used for excitation, and a four-element (2x2) phased array surface coil (outer dimensions of one coil element: 12 x 16mm^2; total outer dimensions: 26 x 21 mm^2) was used for signal reception.The acquisition sequence begins with an inversion pulse allowing to inverse the longitudinal magnetization. Then, a continuous RF pulse train synchronized with the mouse electrocardiogram was applied to acquires cine images at different inversion times. To reduce the acquisition time, two spiral interleaves were acquired per cine image for each RR interval. A total of five cine images were acquired per RR interval. For each experiments, the signal recovery was followed along twenty-three R-R intervals. A new fitting protocol has also been developed which takes into account the lower magnetization equilibrium induced by the continuous RF excitation during the cine acquisition. This protocol was tested on healthy mice injected with 60 µL of $MnCl_2$ (received dose = 100 $\mu mol.kg^{-1}$) with a calculated r_1 of 6.40 $mM.s^{-1}$. The following imaging parameters were used : matrix=96x96x48 ; field-of-view=20x20x15mm^3 ; TR/TE=6/1.5ms; bandwidth=300kHz; imaging pulse = Sinc with a 10° flip-angle; inversion pulse : Gauss 512 with 180° flip-angle; five cine images / R-R interval; R-R interval =140 ms.

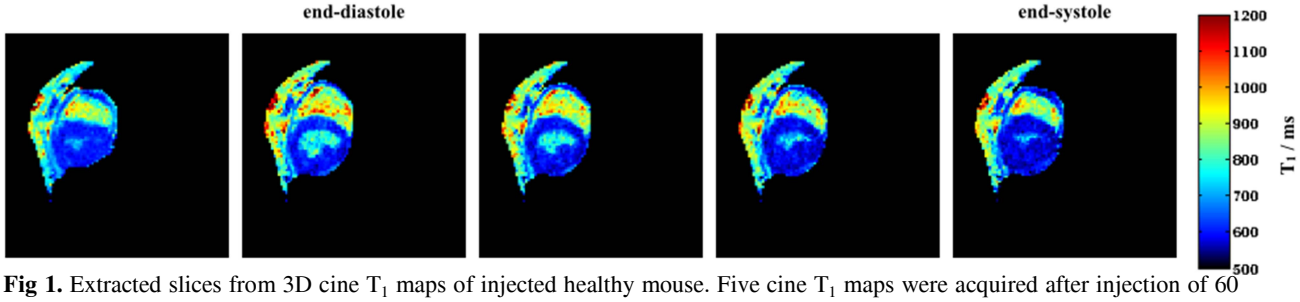

Fig 1. Extracted slices from 3D cine T_1 maps of injected healthy mouse. Five cine T_1 maps were acquired after injection of 60 µL of $MnCl_2$. The whole cardiac cinematic from systole to diastole can be followed.

RESULTS : Fig 1. shows five slices extracted from the 3D T_1 cine maps. Images allows to discriminate with a high contrast to noise ratio the blood from the myocardial tissue. The averaged T_1 measured for the five cine images were 634±24 , 610±26, 600±32, 603±33 and 616±60 ms respectively. The T_1 values were not influenced by the image position in the cardiac cycle. Moreover, the R^2 maps associated with the 3D T_1 maps demonstrated the good correlation between the acquired datas and, the theoretical new fitting approach.

CONCLUSION : In this study, a new 3D cine T_1 mapping imaging sequence has been developed. This method allows to visualize the whole cardiac cinematic during a cardiac beat. Moreover, we demonstrated that the calculated T_1 was not influenced by the cardiac motion opening the door to applications on pathological models. This protocol will be tested on ischemic mice to detect infarcted regions and, to determine the effect of myocardial infarction by quantifying the ejection fraction on the left-ventricle.

REFERENCES : [1] Coolen BF, Geelen T, Paulis LEM, Nauerth A, Nicolay K, Strijkers GJ. *Three-dimensional T_1 mapping of the mouse heart using variable flip angle steady-state MR imaging.* NMR Biomed. 2010; 24: 154–162.
[2] Coniglio A, Di Renzi P, Vilches Freixas G, et al. *Multiple 3D inversion recovery imaging for volume T_1 mapping of the heart.* Magn Reson Med 2012;69:163–170.