Comparison of the Transverse Relaxation Time of the Left Ventricle during the Mid-diastolic Rest and the End-systolic Rest Periods

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INTRODUCTION:
T2 assessment of the Left Ventricle (LV) is widely used for different cardiac pathologies such as to detect myocardial edema [1] or heart transplant rejection [2]. T2 is generally estimated by repeating a Double Inversion Recovery Fast Spin Echo (DIR-FSE) sequence at different TE [3]. Due to the long inversion time required to nullify the blood signal, T2 measurements are usually perfomed using images acquired in the mid-diastolic rest period. However, it has been shown that in patients whose heart rate is high (above 85 bpm) end-systolic rest period is longer than the mid-diastolic one [4], which makes standard DIR-FSE acquisitions difficult [5]. Consequently, it could be interesting to perform T2 measurements during the end-systolic rest period in such cases. This is made possible thanks to a recently published adaptive method [6], which enables to acquire black-blood images during the end-systolic rest by taking heart rate variations into account. In this preliminary study, T2 value differences between the end-systolic and the mid-diastolic rest periods are investigated in fourteen healthy volunteers.

METHODS:
MR Experiment: To compare the T2 values of LV myocardium during end-systolic and mid-diastolic rest, fourteen healthy volunteers (28.7 ± 11 years, weight 70.9 ± 14.3 kg, height 1.72 ± 0.1m; 7 males) underwent a cardiac examination on a 1.5T scanner (HDx, General Electric, Waukesha, WI) using a standard eight-element cardiac coil. This study was approved by the local ethics committee and conducted in compliance with laws on clinical research. Informed consent was obtained for all volunteers. Each acquisition was performed in the same mid-ventricular short axis plane. For each volunteer, two series of seven black-blood images were acquired with TE ranging from 10 to 70 ms. The first series was acquired in mid-diastolic rest with the standard DIR-FSE [3] and the second one in end-systolic rest with the adaptive DIR-FSE sequence [5]. Other acquisition parameters are presented in table 1.

TE	*10 to 70ms*
TR	*1 or 2RR**
TI	*500ms*
Matrix size	*256x256*
FOV	*36cm*
BW	*125kHz*
Slice thickness	*6mm*
ETL	*16*

Table 1: Acquisition parameters.
**depending on heart rate*

Image analysis: First, the images were manually registered to correct motion which may occur between successive breath holds. Then, the myocardium was manually segmented. The left ventricle was segmented using the normalized segmentation in six segments for the mid-ventricular plane [6] (see figure 1). A region-of-interest (ROI) encompassing the entire left ventricular myocardium was also considered. Finally, the T2 value was computed using a mono-exponential model (Eq. (1)) with the Levenberg-Marquardt fitting algorithm provided by Matlab (The MathWorks Inc, Natick, MA).

$$S(TE) = S_0 e^{-TE/T2} \quad (1)$$

S(TE) represents the ROI mean signal intensity. All these manual operations were achieved by an expert.

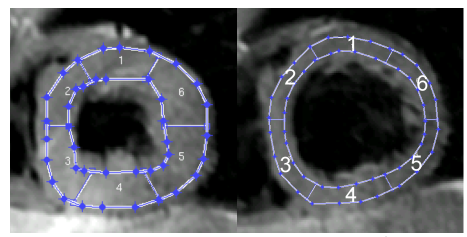

Figure 1: the normalized segmentation of the LV in end-systolic rest (left) and in mid-diastolic rest (right).

Statistical analysis: For each segment, a Kolmogorov-Smirnoff test was performed to confirm that estimated T2s are consistent with a normal distribution. Statistical differences between T2 measured on images in end-systolic rest and those in mid-diastolic rest were assessed using a two-sided paired student t-test for each segment and for the whole LV. The numbers of pixels in the ROI on the whole LV in the different cardiac rest periods were also compared.

RESULTS:
A volunteer was rejected from the image analysis due to poor image quality caused by a bad cardiac synchronization. The Kolmogorov-Smirnoff test demonstrated that all dataset could be considered as Gaussian distributed (p>0.3). The T2 estimates on the whole LV for all volunteers was 53.56±4.12 ms in end-systolic rest and was 53.85±2.9 ms in mid-diastolic rest. No significant difference was found (p>0.8). Fitting regression coefficients R^2, representing the fitting quality, were 0.96±0.04 in both cases. T2 measured in each LV segment for all volunteers is given on the figure 2 and in table 2. According to the t-test, no significant difference was found (p>0.1) for each segment. The number of pixels on the LV in end-systolic rest was 4181±1122 pixels and in mid-diastolic rest was 2875±846 pixels with a significant difference ($p<10^5$).

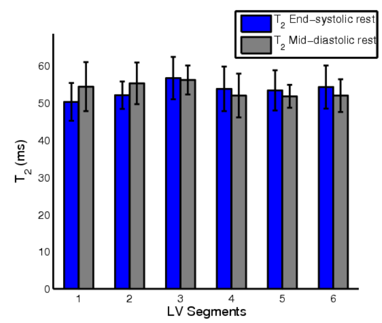

Figure 2: mean and standard deviation of T2 for each LV segment for all volunteers.

LV segment	*T2 End-systole*	*R^2 End-systole*	*T2 Mid-diastole*	*R^2 Mid-diastole*
1	50.28±5.14	0.96±0.06	54.44±*6.55*	0.96±0.04
2	52.09±3.73	0.97±0.04	55.26±*5.59*	0.97±0.05
3	56.63±5.71	0.96±0.04	56.20±*3.95*	0.97±0.03
4	53.81±6.02	0.96±0.03	51.96±*5.89*	0.94±0.05
5	53.38±5.37	0.96±0.03	51.76±*3.14*	0.94±0.06
6	54.28±5.82	0.96±0.05	51.98±*4.39*	0.96±0.03

Table 2: T2 and R^2 (fitting regression coefficients) for all volunteers for each segment in end-systolic rest and in mid-diastolic rest.

DISCUSSION AND CONCLUSION:
This study demonstrates the feasibility of estimating T2 during the end-systolic rest thanks to an adaptive DIR-FSE sequence [5]. T2 measurements performed in this study are in good agreement with previous studies [2,8,9]. Since no difference was found between T2 estimates in end-systolic rest and in mid-diastolic rest, results of this study suggest that the T2 can be measured in any of the two cardiac rest periods. Consequently the longest cardiac rest period could be chosen to perform this examination, depending on patient heart rate. In cases of patient with high heart rate it could be preferable to use the adaptive method in end-systolic rest; otherwise both the standard method and the adaptive method can be used. Moreover, as a larger ROI can be obtained on end-systolic images, image analysis (segmentation) is made easier with such images; especially in diseases were the myocardium is getting thinner.

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