

# Automatic Assessment of Left Ventricular Contraction Synchronicity in Cine MRI Studies

S. Ordas<sup>1</sup>, C. Tobon-Gomez<sup>1</sup>, C. Moure<sup>2</sup>, M. Huguet<sup>2</sup>, A. F. Frangi<sup>1</sup>

<sup>1</sup>Computational Imaging Laboratory, Pompeu Fabra University, Barcelona, Spain, <sup>2</sup>CETIR-Sant Jordi Cardiovascular Centre, Barcelona, Barcelona, Spain

## Introduction

Cardiac Resynchronization Therapy (CRT) is an emerging technique that attempts to restore contractile coordination in dyssynchronous hearts. As nearly one-third of recipients who fulfill current recommendations do not improve, recent clinical studies aim to modify the recruiting criteria for this therapy [1]. Cardiac MRI (CMRI) is continuously gaining new applications in clinical practice. However, its use in CRT planning has been limited to the visual inspection of a portion of the available data, principally owing to the lack of automatic analysis tools that can efficiently deal with the tremendous amount of produced information. By providing precise information of both, endocardial wall motion (WM) and myocardial wall thickening (WT), dynamic CMRI studies are specially suitable for the quantitative analysis of left ventricular (LV) contraction patterns and the assessment of segmental dyssynchrony. In this work we present a processing pipeline for automatic global and regional function analysis employing all available images of a routinely acquired cine CMRI study. The study was tailored to seek for new parameters that could enhance current targeting of CRT to those patients most likely to benefit from it.

## Materials and Methods

A group of 24 cine CMRI scans were recruited for this study: 12 correspond to healthy volunteers and 12 are patients with LV dyssynchrony with diverse etiologies. Studies were acquired using a GE Signa CV/i, 1.5T scanner (General Electric, Milwaukee, USA) with the FIESTA protocol. All dynamic data sets contained short-axis (SA) and long-axis (LA) image stacks, at 20 temporal phases (slice thickness: 8-10 mm, in-plane resolution: 1.56 x 1.56 mm<sup>2</sup>).

The processing pipeline comprises three main steps: 1) LV segmentation, 2) WT and WM calculation, and 3) assessment of LV regional delays. Computing time for the whole process takes approximately 20 minutes in modern CPUs, depending on the number of image stacks and slices.

1) LV segmentation was achieved using a 3D Active Shape Model (3D-ASM) algorithm, adapted from [2]. All temporal phases of the study were automatically segmented simultaneously employing SA and LA image stacks. Segmentation was successful in all studies achieving clinically accepted accuracy. Only a semi-automatic initial positioning (by four points) in the first temporal phase of the study was necessary to initialize the whole procedure. The segmentation of the other phases was launched automatically using the result of the previous temporal phase.

2) From the set of segmented surfaces (20 in our case), WT was assessed employing a myocardial center surface, i.e. equidistant to the epicardial (*Epi*) and endocardial (*Endo*) surfaces. Chords were drawn perpendicular to *Endo*, towards their intersection with *Epi*. The length of each chord gives an estimate of the local wall thickness, and WT was locally defined using a fixed time frame as reference (ED phase). Regional endocardial WM was assessed by calculating the shortest (signed) distance from each *Endo* point to the *Endo* reference at ED.

3) In recent research, LV dyssynchrony has been evaluated in several ways, although none of them has yet been proved to be optimal. By measuring the time for each *Endo* point to reach its maximal WT or WM ( $T_s$ ), the level of intraventricular dyssynchrony can be suggested with the standard deviation (SD) of all  $T_s$  measurements ( $T_s$ -SD), or by measuring the relative delay with respect to the earliest ( $T_s$ -Diff). This can be simplified over 6, 12, and 16 LV segments.

## Discussion

Although the temporal resolution in CMRI is inferior in comparison to other 2D techniques like i.e. strain or tissue Doppler, the possibility of directly analyzing  $T_s$ -SD and  $T_s$ -Diff in all LV wall segments automatically, constitutes a more efficient and reproducible way to interpret and quantify myocardial contraction abnormalities, without simplified geometrical assumptions or limiting the analysis to two temporal instants.

Both,  $T_s$ -SD and  $T_s$ -Diff were strongly linearly correlated in normal patients, but rarely in hearts with dyssynchronous rhythm. Furthermore,  $T_s$ -SD measurements were similar with both approaches (WT and WM) only in normal patients, while  $T_s$ -Diff always differed.

Other new indexes that could help discriminate groups among CRT candidates may be originated from LV contraction patterns, which means the local assessment of WT in all regions of the LV at all temporal phases of the dynamic study. WT is known to be less subject to translational artifacts than WM, and thus more appropriate for assessing regional LV function and measuring contraction delays. Figures 1 and 2 suggest the potential discriminative power of contraction patterns, not only between healthy and dyssynchronous LVs, but also among CRT candidates. All normal patients exhibited highly homogeneous contraction patterns, whereas the behavior of CRT candidates was variable. This information may be related to different responses to CRT.

## Conclusions

Cine CMRI studies combined with automatic 3D regional myocardial functional analysis, allows to calculate currently assessed dyssynchrony indexes, in an accurate and reproducible way, within the time of a routine examination. Moreover, together with the haemodynamic evaluation of the whole cardiac cycle and contraction patterns, all within the same automatic analysis, the presented methodology provides a compact framework for fast and accurate information providing, aiming to improve CRT planning and candidate recruiting. The extraction of new parameters from such analysis will be the subject of future research.

## References

[1] CM. Yu, WH. Fung, H. Lin, Q. Zhang, J.E. Sanderson, and C.P. Lau, "Predictors of left ventricular reverse remodeling after cardiac resynchronization therapy for heart failure secondary to idiopathic dilated or ischemic cardiomyopathy," *Am J Cardiol*, vol. 91, 2002.

[2] H.C. van Assen, M.G. Danilouchkine, A.F. Frangi, S. Ordas, J.J.M. Westenberg, J.H.C. Reiber, and B.P.F. Lelieveldt, "Spasm: a 3D-ASM for segmentation of sparse and arbitrarily oriented cardiac MRI data," Accepted for publication in *Med Image Anal*, 2005.

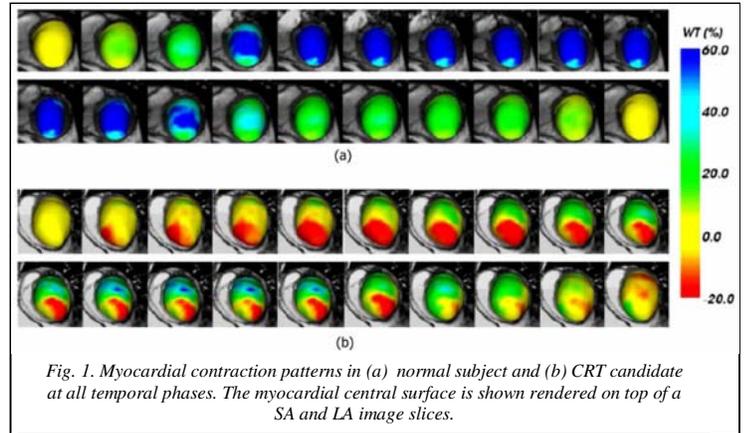


Fig. 1. Myocardial contraction patterns in (a) normal subject and (b) CRT candidate at all temporal phases. The myocardial central surface is shown rendered on top of a SA and LA image slices.

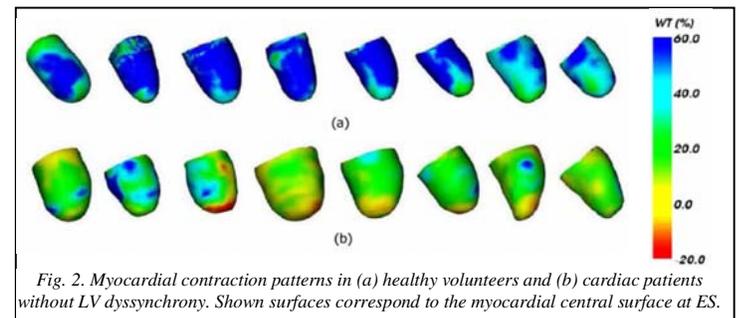


Fig. 2. Myocardial contraction patterns in (a) healthy volunteers and (b) cardiac patients without LV dyssynchrony. Shown surfaces correspond to the myocardial central surface at ES.