Semiautomatic Quantification of Left and Right Ventricular Functions in Magnetic Resonance Imaging

Lambert R Masip[1], Pablo G Tahoces[1], Miguel Souto[1,2], Amparo Martínez[2], Juan J Vidal[1,2]

[1]University of Santiago de Compostela, Santiago de Compostela, Spain
[2]University Hospital Complex of Santiago de Compostela (CHUS), Santiago de Compostela, Spain

Abstract

Twenty patients with cardiovascular diseases were examined using a 1.5-T magnetic resonance imaging (MRI) unit, and several parameters of both ventricles, such as ejection fraction (EF), end-diastolic and end-systolic volumes (EDV and ESV, respectively), were quantified by an experienced operator using two methods: 1) our semiautomatic segmentation method based on edge detection, iterative thresholding and region growing techniques, and 2) a commercially available software package based on manual contour tracing.

1. Introduction

Ventricular function is a primary indicator for the diagnosis and treatment monitoring of many cardiovascular diseases.

Cardiac cine MRI with steady state free precession (SSFP) sequences, which involves shorter scan time and higher image quality, is regarded to be the standard of reference for the assessment of ventricular function.

However, manual segmentation of MRI data is a time-consuming process and also suffers from inter/intra-observer variability.

This justifies the development of more automated segmentation methods to reduce the amount of time and effort that an experienced operator must spend on this process, and to make such methods practical.

2. Purpose of the study

The objective of this study was to develop and validate a semiautomatic segmentation method to quantify left and right ventricular (LV and RV, respectively) functions in cardiac MRI.

3. Materials and methods

3.1. Study population

The study population consisted of 20 consecutive patients, with several cardiovascular diseases: dilated myocardiopathy (4), hypertrophic myocardiopathy (3), non compacted myocardiopathy (3), ischemia (5), myocarditis (3), arrhythmogenic right ventricular dysplasia (2).

6 women (aged between 26 and 70; average age of 43) and 14 men (aged between 20 and 75; average age of 49) were studied.

The study was approved by the institutional ethics committee, and written informed consent was obtained from all the patients.

3.2. MRI protocol

Cardiac studies were performed in the department of Radiology of the University Hospital Complex of Santiago de Compostela (CHUS) on a 1.5-T MRI unit (Magnetom Symphony Maestro Class, syngo MR 2002B software; Siemens AG, Medical Solutions, Erlangen, Germany).

A stack of short-axis slices with a thickness of 6 mm (acquired with end-expiratory breath-hold cine SSFP sequences) was planned according to the vertical and horizontal long-axis views, to cover both ventricles from the base to the apex.

3.3. Image analysis

Segmentation of LV and RV volumes on both end-diastolic (ED) and end-systolic (ES) phases, including papillary muscles and trabeculae, was performed by an experienced operator using two segmentation methods:

3.3.1. Manual method

Ventricular function analysis was performed using a commercially available software package based on manual contour tracing (Argus, release syngo MR 2002B; Siemens AG, Medical Solutions, Erlangen, Germany) [1].

The ED phase was defined as the first cardiac phase of each slice location by default, and the ES phase as the

cardiac phase in which midventricular short-axis slices exhibited a minimum area by visual inspection.

After tracing ventricular contours in a midventricular ED frame by hand, the contours were propagated within ED phase. Every contour was checked and corrected manually if necessary. The contours were then propagated from the ED to the ES phase. Each ES contour was also checked and corrected if required.

3.3.2. Semiautomatic method

Ventricular function analysis was also performed using our semiautomatic segmentation method based on edge detection, iterative thresholding and region growing techniques (Figure 1).

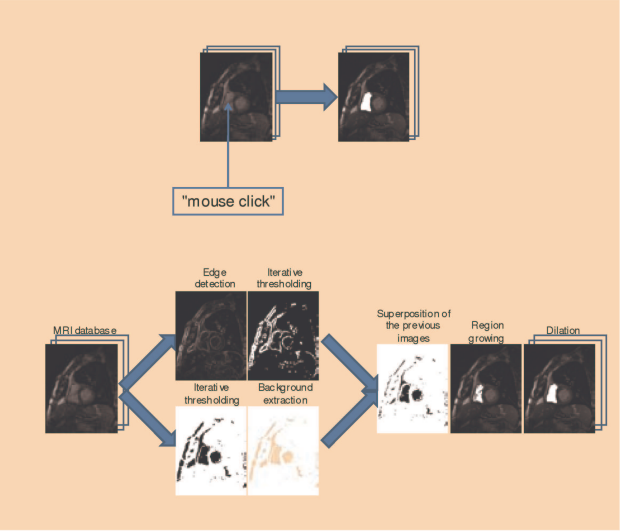


Figure 1. Semiautomatic segmentation scheme: User interaction was reduced to a "mouse click" on the analyzed ventricle, in a midventricular ED frame. Then, a square kernel was set up around the "mouse click" position and all the frames were automatically segmented.

3.4. Statistical Analysis

For each parameter, the Kolmogorov-Smirnov test rendered a normal distribution, and the mean ± SD of the results obtained using each method was presented.

Pearson test was used to analyze the correlation (r) between the two measurement results, and Student paired t-test was used to determine the statistical significance (p) of the differences found between them.

95% confidence interval was set and p-values ≤ 0.05 were considered statistically significant.

A 3% change in EF, and a 10 ml change in EDV and ESV, was considered of clinical relevance as proposed by Bellenger et al [2].

Bland-Altman plots [3] were used to assess the agreement between both methods.

4. Results

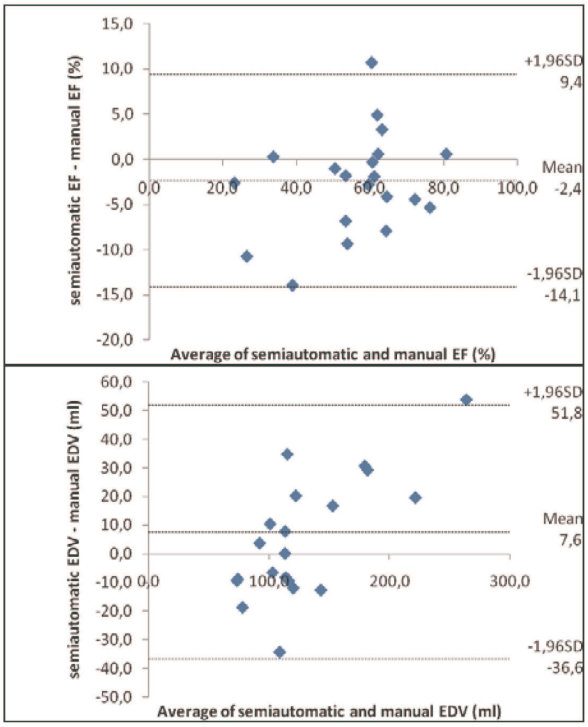
4.1. Quantification of LV parameters

Table 1. Quantification of LV parameters using semiautomatic and manual segmentation methods.

	Semiautomatic	Manual	Semiautomatic vs manual	
	Mean ±SD	Mean ±SD	r	p
EF(%)	54.4 ±17.3	56.8 ±15.3	0.939	0.124
EDV(ml)	139.2 ±59.2	131.6 ±43.7	0.948	0.183
ESV(ml)	71.4 ±58.9	61.8 ±44.1	0.974	0.051

As shown in Table 1, no statistically significant differences were found for EF and EDV ($p > 0.05$), and a high correlation value ($r > 0.9$) was obtained for each parameter. The difference in ESV was close to statistical significance ($p \leq 0.05$) but it was not considered clinically relevant (≥ 10 ml), according to the previously mentioned criteria.

The mean difference observed between the parameters using both methods was -2.4 ± 6% for EF, 7.6 ± 22.6 ml for EDV, and 9.6 ± 18.8 ml for ESV (Figure 2).



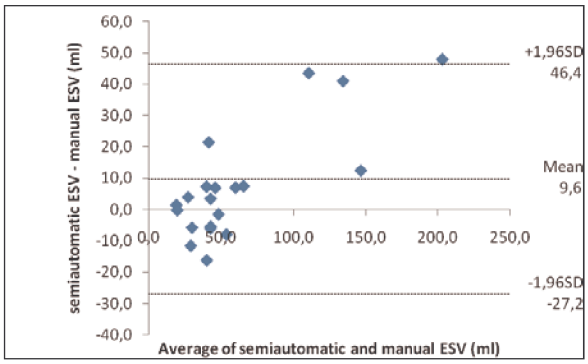


Figure 2. Bland-Altman plots for LV parameters.

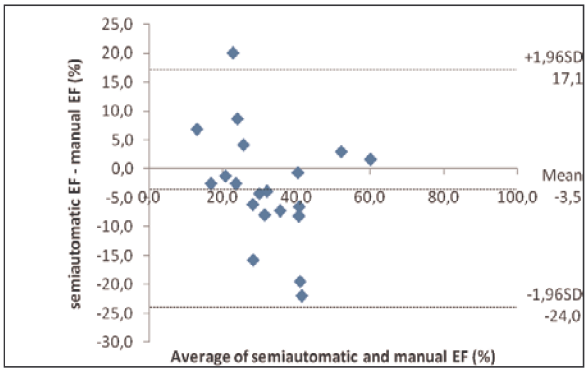
4.2. Quantification of RV parameters

Table 2. Quantification of RV parameters using semiautomatic and manual segmentation methods.

	Semiautomatic	Manual	Semiautomatic vs manual	
	Mean ±SD	Mean ±SD	r	p
EF(%)	30.9 ±11.8	34.3 ±14.8	0.711	0.190
EDV(ml)	103.3 ±40.4	118.0 ±33.3	0.712	0.050
ESV(ml)	72.9 ±34.7	78.0 ±29.9	0.807	0.318

As shown in Table 2, no statistically significant differences were found for EF and ESV ($p > 0.05$), and the correlation obtained for each parameter ($r > 0.7$) was slightly lower than that obtained for the left ventricle. Obtained results, in particular EDV quantification ($p \leq 0.05$), were affected by RV complex geometry and prominent trabeculae. Therefore, we must improve our semiautomatic segmentation performance in future work.

The mean difference observed between the parameters using both methods was -3.5 ± 10.5% for EF, -14.7 ± 28.7 ml for EDV, and -5.1 ± 20.6 ml for ESV (Figure 3).



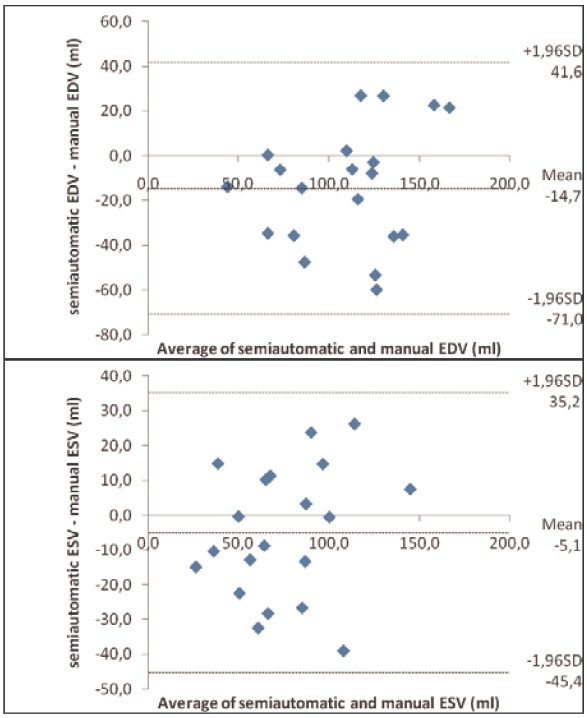


Figure 3. Bland-Altman plots for RV parameters.

5. Conclusions

In conclusion, our semiautomatic segmentation method: provides similar results to those achieved by manual contour tracing, reduces both the time employed and the inter/intra-observer variability to a "mouse click", and does not rely on a priori knowledge, providing a true segmentation of the anatomical features present in the image [4].

Acknowledgements

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Address for correspondence.

Name: Lambert-Raúl Masip Capdevila
Full postal address: Av. Portería 5 - 1º, Raxó-Poio (Pontevedra), CP: 36992, SPAIN
E-mail address (optional): lambertraul.masip@usc.es