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Reliability and reproducibility of quantitative assessment of left ventricular function and volumes with 3-slice segmentation of cine steady-state free precession short axis images

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ABSTRACT

Objectives: Quantitative assessment of left ventricular (LV) functional parameters in cardiac MR requires time-consuming contour tracing across multiple short axis images. This study assesses global LV functional parameters using 3-slice segmentation on steady state free precision (SSFP) cine short axis images and compares the results with conventional multi-slice segmentation of LV.

Methods: Data were collected from 61 patients who underwent cardiac MRI for various clinical indications. Semi-automated cardiac MR software was used to trace LV contours both at multiple slices from base to apex as well as just 3 slices (base, mid, and apical) by two readers. Left ventricular ejection fraction (LVEF), LV volumes, and LV mass were calculated using both methods.

Results: Bland–Altman plot revealed narrow limits of agreement (−4.4% to 5.1%) between LVEF obtained by the two methods. Bland–Altman analysis showed slightly wider limits of agreement between end-diastolic volumes (−5.0 to 12.0%; −3.9 to 8.5 ml/m^2), end-systolic volumes (−10.9 to 14.7%; −4.1 to 6.5 ml/m^2), and LV mass (−5.2 to 12.7%; −4.8 to 10.2 g/m^2) obtained by the two methods. There was a small mean difference between LV volumes and LV mass obtained using multi-slice and 3-slice segmentation. No statistically significant difference existed between the LV parameters obtained by the two readers using 3-slice segmentation ($p > 0.05$). Multi-slice assessment required approximately 15 min per study while 3-slice assessment required less than 5 min.

Conclusions: 3-slice segmentation of the left ventricle at basal, mid, and apical levels on cine SSFP short axis images can provide rapid and reliable assessment of LVEF with good reproducibility. The 3-slice method also provides a reasonable estimate of the LV volumes and LV mass.

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1. Introduction

The diagnosis and management of cardiovascular diseases require accurate assessment of cardiac function [1]. Cardiovascular magnetic resonance (CMR) imaging allows for highly accurate left ventricle (LV) quantification [2] and is considered the gold standard for non-invasive assessment of LV functional parameters [3,4]. Global cardiac contractile function can be quantified through LV volumes and left ventricular ejection fraction (LVEF) by segmenting the LV from cine MR images [5].

Manual segmentation across multiple short axis segments of LV is a time-consuming and tedious task [6–8]. Much research has been done about automated segmentation methods of the LV cavity to assess LV volumes, LV mass and LVEF [9–12]. Commercial software packages such as MASS and Argus are available for semi-automated contour tracing of the left and right ventricles to evaluate volumes, mass, and ejection fraction [13]. Even with the assistance of semi-automated software, reliable quantitative assessment of LV volumes and LVEF requires careful, time consuming segmentation and contour tracing of epicardial and endocardial borders of multiple steady state free precision (SSFP) cine short axis

Abbreviations: BSA, body surface area; CI, cardiac index; CMR, cardiovascular magnetic resonance; CO, cardiac output; ECG, electrocardiogram; EDV, end diastolic volume; ESV, end systolic volume; LV, left ventricle; LVEF, left ventricular ejection fraction; EDV index, end diastolic volume index (EDV/BSA); ESV index, end systolic volume index (ESV/BSA); LV mass index, left ventricular mass index (left ventricular mass/BSA); SV index, stroke volume index (SV/BSA); SA, short axis; SSFP, steady state free precession; SV, stroke volume.

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(SA) images of the LV, in both diastolic and systolic phases of the cardiac cycle. In this study, we hypothesize that analyzing only 3-slices (basal, mid, and apical slices) out of a full stack of SSFP short axis images may provide a more rapid, yet reliable quantitative assessment of global LV function.

Therefore, our aim is to assess LVEF, LV volumes, and LV mass using 3-slice segmentation of cine SSFP short axis images at the basal, mid, and apical levels of the LV and to compare the results with the conventional multi-slice segmentation method.

2. Materials and methods

2.1. Patient population

This retrospective study was approved by the Institutional Review Board. Informed consent was waived by the IRB. Datasets were collected from 61 consecutive patients who underwent cardiac MR for various clinical indications (31 men and 30 women, mean age: 52 years, age range: 18–85 years). Underlying diseases in these patients included ischemic cardiomyopathy ($n = 19$), non-ischemic cardiomyopathy ($n = 9$), valvular heart diseases ($n = 12$), congenital heart diseases ($n = 4$), and other cardiac pathologies (Table 1).

Table 1
Patient demographics.

Age[a]	52.3 ± 15.7 years
Age Range	18–85 years
Height[a]	173.0 ± 15.5 cm
Weight[a]	75.0 ± 16.7 kg
Sex	31 males: 30 females
Diagnoses	
Ischemic cardiomyopathy	19
Heart failure	14
Mitral regurgitation	5
Dilated cardiomyopathy	5
LV thrombus	4
Aortic regurgitation	4
Aortic stenosis	3
Tetralogy of Fallot	3
LV non-compaction	2
LV aneurysm	2
Hypertrophic cardiomyopathy	2
Arrhythmogenic right ventricular dysplasia	2
Truncus arteriosus	1
Tricuspid regurgitation	1
Pericardial cyst	1
Hemochromatosis	1
Atrial septal defect	1

[a] Values represent mean ± standard deviation.

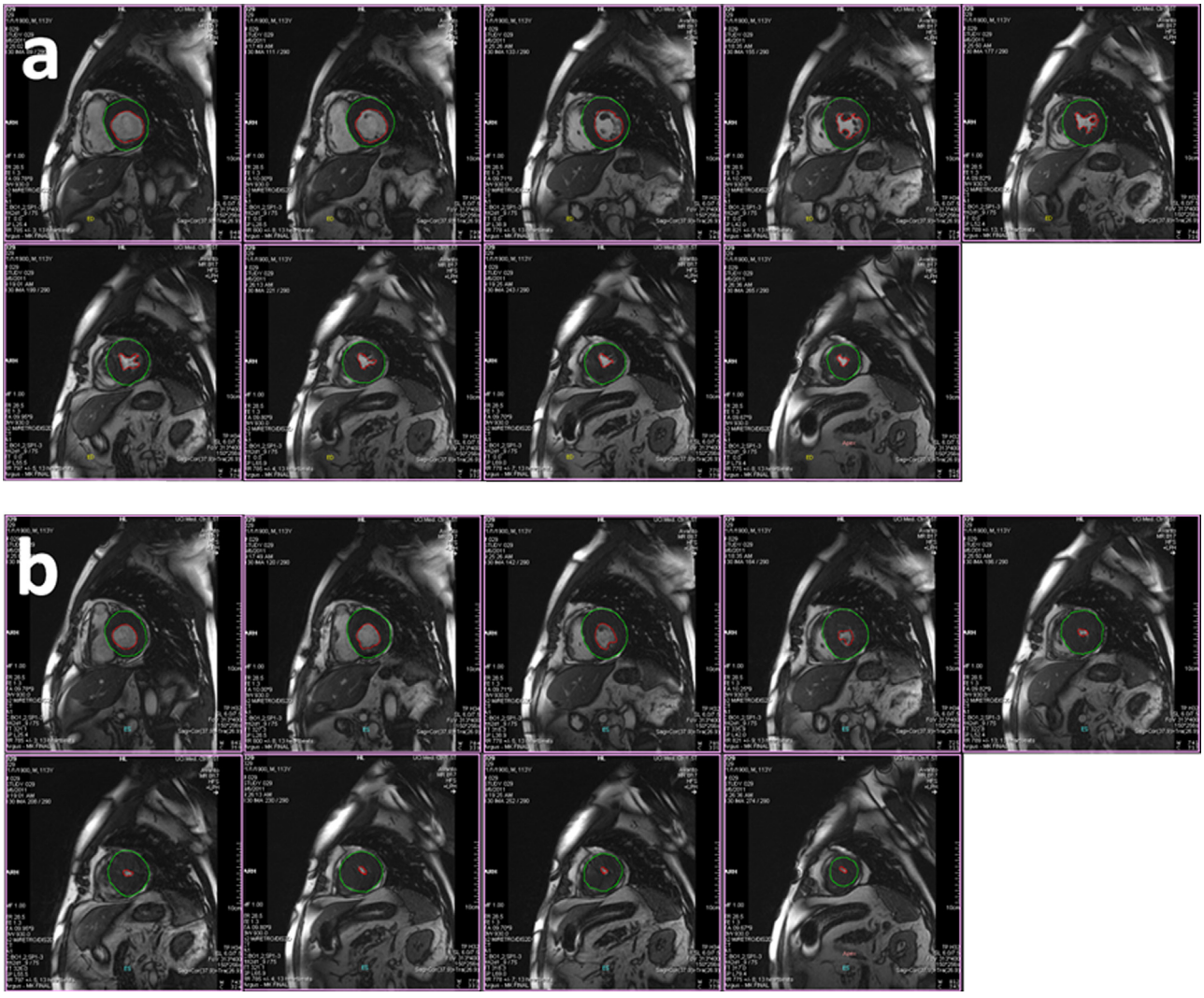

Fig. 1. Semi-automated segmentation and contour tracing using conventional multi-slice segmentation on a 57 year old male using Argus software. LV epicardial contours (red lines) and endocardial contours (green lines) of SSFP cine SA images were traced at multiple slices from base to apex in (a) end-diastole and (b) end-systole. The ejection fraction obtained using multi-slice segmentation for this patient was 54.4 and 55.1% for readers 1 and 2, respectively. Multi-slice segmentation took each reader 15 min to complete.