

An MRI Comparison of Quantitative Left Ventricular Structure, Function and Measurement Reproducibility in Patient Cohorts with A Range of Clinically Distinct Cardiac Conditions

S. J. Gandy¹, R. S. Nicholas¹, S. A. Waugh¹, H. J. Simpson², P. Martin³, and J. G. Houston³

¹NHS Tayside Medical Physics, Ninewells Hospital, Dundee, Angus, United Kingdom, ²University of Dundee School of Medicine, Ninewells Hospital, Dundee, Angus, United Kingdom, ³NHS Tayside Clinical Radiology, Ninewells Hospital, Dundee, Angus, United Kingdom

Introduction and Aims

Recent MR and image post-processing advances have identified quantitative left ventricular (LV) assessments as potentially suitable endpoints for evaluating images of patients with cardiac abnormalities [1,2]. The aim of this MRI investigation was to examine how LV assessments of ejection fraction (EF) and left ventricular mass (LVM) together with the measurement reproducibility of each varied across cohorts of individuals with carefully defined and clinically distinct cardiac conditions. The longer-term objective of the work was to examine the effect of the clinical condition on the LV parameters and measurement reproducibility, in order to establish the suitability of the technique for longitudinal investigations on similar clinical cohorts. In this pilot investigation the clinical cohorts were defined as follows: (i) patients with chronic heart failure (CHF), (ii) patients with left ventricular hypertrophy (LVH), (iii) patients post-myocardial infarct <7 days (PMI), and (iv) healthy normal volunteers (HNV).

Methods

Four cohorts of consenting patient volunteers (each consisting of nine males and one female) were recruited. The age ranges in years were 60-84, mean 73 (CHF patients), 52-78, mean 66 (LVH patients), 36-67, mean 54 (PMI patients) and 25-42, mean 33 (HNV patients). The inclusion criteria for each patient cohort were carefully defined as follows: (i) CHF cohort – only those individuals undergoing stable and optimally tolerated therapy for clinically diagnosed chronic heart failure, together with an echocardiography report confirming an EF of 40 percent or lower; (ii) LVH cohort - only those individuals with a normal blood pressure according to current recommendations [3], and clinically diagnosed LVH from echocardiography; (iii) PMI cohort – only those individuals who had experienced a recent MI and were able to tolerate MR imaging within seven days of the event (with the acknowledgment that this cohort would be clinically more diverse than the others); and (iv) HNV cohort – only those individuals with no medical history of cardiovascular disease of any sort.

Each individual was imaged on a 1.5T Magnetom Avanto MRI scanner (Siemens, Erlangen, Germany). A series of standard short axis plane images of the left ventricle were acquired from the atrio-ventricular ring down to the apex using a combination of body matrix and spine matrix RF coils and a 2D cardiac-gated breath hold segmented TruFisp CINE sequence. The imaging parameters were TR 38.25ms, TE 1.08ms, and flip angle 60-70°. One or two slices per breath hold were acquired (dependent upon the ability of the volunteer to sustain breath holding at end expiration) and the scan time for each acquisition was minimised by use of a parallel imaging acceleration factor of two. A series of 6mm thick images covering the entire left ventricle was acquired for each patient with an in-plane resolution of 192 pixels over an optimal (patient size-dependent) field of view ranging from 340-450mm.

Image analysis was performed using ARGUS software (version VA60C) on a Leonardo Workstation. Endocardial and epicardial borders were defined independently on all images corresponding to end-diastole (ED) and end-systole (ES) by an MRI Physicist segmenter, with assistance from a Consultant Radiologist as required. Segmentation rules relating to the appropriate identification of ED and ES phases, along with inclusion or exclusion of appropriate basal slices and papillary muscles were standardised prior to the analysis in order to ensure as much consistency as possible. A total of 40 datasets (four patient cohorts each consisting of ten volunteers) were analysed twice by the segmenter, resulting in a total workload of 80 segmentations. A single segmenter was responsible for undertaking the work, since the use of multiple segmenters in such investigations is subject to larger inter-observer measurement variability.

Ejection Fraction (EF) and Left Ventricular Mass at ED (LVM) data were evaluated, and reproducibility was assessed both graphically and statistically. A test-retest coefficient of repeatability (CoR) was calculated for each cohort, given by $CoR = 1.96 * [\sum(m_2 - m_1)^2 / (n-1)]^{0.5}$, with m_1 and m_2 representing each repeated measurement (either EF or LVM), and n being the size of the individual patient cohort.

Results and Discussion

Qualitative inspection of the resulting MRI scans revealed that the CHF cohort images consisted predominantly of enlarged left ventricles with very fragmented myocardium and inefficient myocardial function. Conversely, the LVM cohort images consisted predominantly of very thick and clearly delineated myocardial structures, together with very pronounced myocardial function. The PMI and HNV images demonstrated less obvious myocardial thickening, but the PMI cohort LV structures were generally less easy to interpret than those of the HNV cohort.

The mean EF and LVM values for each cohort are identified in TABLE 1. As expected, the mean EF for the CHF patients was significantly lower than the mean EF for each of the other cohorts ($p < 0.0002$), and the mean EF was greatest for the LVH cohort. The range of EF values present was greatest in the PMI cohort, reflecting the relative functional heterogeneity of the clinical cases contained within this group. The mean LVM for the CHF patients was larger than for the rest of the cohorts, although statistical significance was only reached when comparing this mean with that from the healthy volunteers ($p = 0.004$). The mean LVM was very similar for each of the other two (LVH and PMI) cohorts.

The intra-observer CoR (FIGURE 1) for EF ranged from a low of 1.5% for the LVH cohort to a high of 5.5% for the CHF cohort, whilst the intra-observer CoR for LVM ranged from a low of 4.6g for the HNV cohort to a high of 9.8g for the LVH cohort. In the case of the CHF cohort, it is likely that the elevated EF CoR may have resulted from difficulties in delineating the endocardial borders of the often highly fragmented myocardium at each cardiac phase. The reason for the elevated LVM CoR in the LVH cohort is less obvious, although may have been in part due to poor differentiation of hypertrophic myocardial borders and errors associated with identifying the enlarged papillary muscles and trabeculae often associated with the endocardial border.

Conclusion

This study has demonstrated that the reproducibility of EF and LVM is quite variable and dependent upon the clinical cardiac condition under investigation. The relationship between reproducibility data within the same cohort is not straightforward, and a low CoR for one parameter does not necessarily correspond to a low CoR for the other. Clinical Cardiac MRI studies should ensure that appropriate reproducibility data for EF and LVM are acquired individually and specifically on a per-cohort basis if the parameters are to form reliable quantitative endpoints for longitudinal investigations. These data may also assist with correct sample size or power calculation assessments as part of future cardiac MRI study designs.

References

- [1] Lyne JC, Pennell DJ. Cardiovascular MR in the Quantitative Assessment of LV Mass, Volumes and Contractile Function. *Coron Artery Dis* 2005; 16:337-343
- [2] Alfakih K, Reid S, Jones T, Sivananthan M. Assessment of Ventricular Function and Mass by Cardiac MR Imaging. *Eur Radiol* 2004; 14: 1813-1822
- [3] JBS2: Joint British Societies' guidelines on prevention of cardiovascular disease in clinical practice. *Heart* 2005; 91: 1-52

TABLE 1

Parameter	CHF	LVH	PMI	HNV
LV Ejection Fraction, EF (%)	30.4 +/- 6.4	72.7 +/- 7.5	53.0 +/- 13.9	67.0 +/- 5.2
LVM at End Diastole (g)	143 +/- 29	122 +/- 22	124 +/- 27	107 +/- 19

FIGURE 1

