A Reproducibility Comparison of Quantitative Left Ventricular Assessments in Healthy Volunteers Using Different MRI Scanners - Implications for Multicentre Cardiac MRI Studies

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Introduction and Aims Cardiac MRI has evolved into a potentially useful quantitative clinical tool for evaluating human left ventricular morphology and function [1, 2]. Quantitative assessments of ejection fraction (EF), end-diastolic blood volume (EDV), end-systolic blood volume (ESV), stroke volume (SV), cardiac output (CO) and left ventricular mass (LVM) all have the potential to provide useful clinical endpoints for longitudinal studies designed to monitor changes to morphology or function in response to therapy. The aim of this work was to evaluate the usefulness of these parameters for multicentre cardiac MRI investigations by imaging a cohort of ten normal volunteers on three separate occasions using two different MRI scanners. More specifically, the objective of the study was to obtain quantitative assessments of intraobserver and interobserver variation for EF, EDV, ESV, SV, CO and LVM data acquired from short-axis cardiac MRI images for (i) datasets acquired at a single timepoint, (ii) datasets acquired at two different timepoints on the same scanner, and (iii) datasets acquired at two different timepoints on different scanner models.

Methods Ten consenting healthy volunteers (age range 23-45 years, mean 33 years) were recruited for imaging. Each patient was imaged twice on a 1.5T Magnetom Avanto MRI scanner (Siemens, Erlangen, Germany), and once on a 1.5T Signa Excite MRI Scanner (General Electric, Milwaukee, USA) at the same time of day on separate occasions within a two-month period. A series of standard short-axis plane images of the left ventricle were acquired from the atrio-ventricular ring down to the apex on the Avanto scanner with a combination of body matrix and spine matrix RF coils using a 2D breath hold segmented TruFisp CINE sequence with prospective cardiac gating. The imaging parameters were TR 39.06ms, TE 1.2ms, and flip angle 60^o. 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 parallel imaging (GRAPPA x2). The resolution parameters were standardised to provide images with an in-plane pixel resolution of 256x256 over a field of view of 350mm, and a 6mm slice thickness with 4mm gap. The acquisitions were also repeated using an in-plane pixel resolution of 192x192 in order to compare the data resulting from two different resolutions. For the Signa Excite scanner, standard short-axis plane images of the left ventricle were acquired with an 8-channel torso pelvis array coil using a 2D breath hold FIESTA CINE sequence with retrospective gating. The imaging parameters were TR 3.4ms, TE 1.5ms and flip angle 45^o, with one slice per breath hold and identical resolution parameters. Five radiographic staff members participated in the study in order to simulate multicentre conditions where small slice positioning variations might be expected.

Image analysis was performed using ARGUS software (version VA60C) on a Leonardo Workstation for the Siemens data, and the process was repeated using MASS Analysis Plus software (version 5.1) on an Advantage Workstation for the GE data. Endocardial and epicardial myocardial borders were defined independently on all images corresponding to end-diastole (ED) and end-systole (ES) by two MRI Physicist segmenters (with assistance from a Consultant Radiologist as required) in order to obtain quantitative data for interobserver comparison. Additionally, one segmenter performed the segmentation task for all images on two separate occasions in order to obtain data for intraobserver comparison. 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 agreed between each segmenter prior to the analysis task in order to ensure as much consistency as possible. A total of 60 datasets were analysed (three imaging sessions and acquisition of 192x192 and 256x256 resolution short axis datasets for each of the ten patients), resulting in a total workload of 160 segmentations.

In addition to healthy volunteer scanning, a left ventricular anthropomorphic phantom model (Data Spectrum Co, North Carolina, USA) was filled with Gd-doped water and imaged on both scanners using identical parameters and analysis methods to those described above for the patient imaging.

Results and Discussion When the anthropomorphic phantom results were compared between the different scanners, measurement of simulated 'EDV' and 'LVM' on each scanner resulted in intraobserver coefficients of variation (CoV's) of 2.12% and 1.06% respectively.

For the 192x192 single timepoint patient data, mean test-retest intraobserver CoV's (e.g. 1.44% for EF, 2.58% for LVM – fig 1) were consistently smaller than those for mean interobserver CoV's (e.g. 1.51% for EF, 10.26% for LVM – fig 1). The same relationship was also obtained for the 256x256 data, although the reproducibility was slightly lower due to the inferior SNR on the higher resolution images.

Fig 1: Mean Intraobserver and Interobserver CoV's for Quantitative LV Assessments

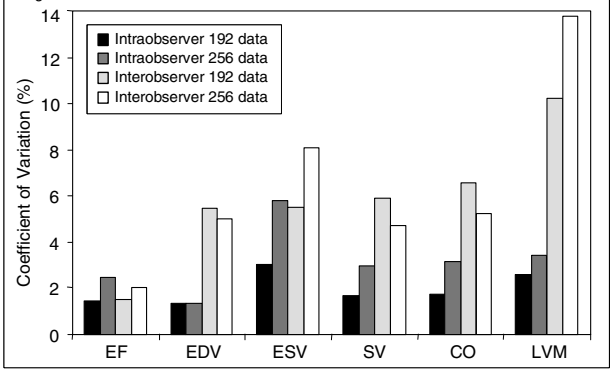
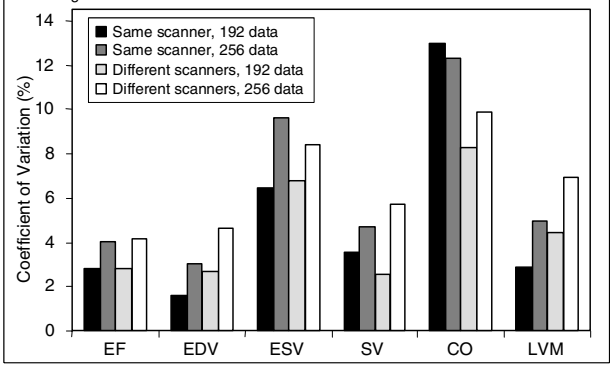


Fig 2: Intraobserver Scan-to-Scan CoV's for Quantitative LV Assessments



The mean intraobserver scan-to-scan CoV's for those parameters derived from 192x192 data acquired on the same scanner (e.g. 2.81% for EF, 2.91 for LVM – fig 2) were slightly larger than the mean intraobserver CoV's derived from data acquired at a single timepoint. These differences were thought to represent the small variations that occur in radiographic/technical slice positioning in addition to small biological fluctuations that may be present for each patient on a scan-to-scan basis. When intraobserver scan-to-scan CoV's were assessed for data acquired on different scanners, the mean intraobserver CoV's (e.g. 2.86% for EF, 4.45% for LVM) were higher than those for the single timepoint measurements, but comparable to the scan-to-scan measurements acquired on the same scanner (fig 2). Similar, but marginally less reproducible data were obtained for the 256x256 images.

Conclusion It is possible to obtain reproducible quantitative assessments of left ventricular structure and function at single or multiple timepoints, using either the same scanner or different scanner models. These MRI parameters have the potential to provide suitable endpoints for longitudinal monitoring and response to therapy as part of multicentre patient investigations. However, the reproducibility data for each parameter in healthy volunteers is dependent on whether single or multiple segmenters are involved in the analysis. This should be carefully considered in conjunction with the anticipated size of any clinical effect that one may wish to demonstrate.

References [1] Plein S et al. J. Magn Reson Imaging 14: 230-236 (2001), [2] Narayan G et al. J Magn Reson Imaging 22: 59-66 (2005)