

POSTER PRESENTATION

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CMR trabecular fractal analysis - technical development of a measurement system

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Background

Cardiac trabeculae are complex and difficult to quantify but measuring their biological signal in many cardiac diseases (left ventricular [LV] non-compaction, hypertrophic cardiomyopathy [HCM]) has value. We have recently shown how trabeculae differ between ethnicities in health and between HCM mutation carriers without hypertrophy and healthy volunteers. Here we present a novel tool for measurement for LV trabecular complexity by cardiovascular magnetic resonance (CMR) using a fractal analysis. Theoretical fundamentals are discussed. They include the measurement procedure, mathematical modeling and performance evaluation through validation by digital phantoms and reproducibility analysis when applied to real-world cardiac data.

Methods

The measurement system consists of an in-house developed software written in MATLAB R2012b that parametrizes 2-dimensional LV cine end-diastolic short-axis frames in DICOM image format. Images are scaled, masked and segmented before undergoing fractal analysis. Endocardial contours serve as the basis for estimation of the fractal dimension (FD) -a unitless index of endocardial complexity, calculated using a box-counting algorithm which cycles through a series of grids of boxes overlying the region of interest. Validation was by digital phantoms consisting of planar targets of known FD (Figure 1) generated in MATLAB. The procedure was further evaluated in terms of intra- and inter-observer variability of calculated maximal apical FD in 45 randomly-selected scans from within a research CMR

database (all 1.5-T, Siemens and General Electric) and in terms of inter-study reproducibility (20 repeat scans, same 1.5T magnet; mixed healthy/diseased cohort). Impact of varying slice thickness (43 cine slices repeated at thicknesses: 8, 7, 6 mm) and magnetic field strength (134 cine slices repeated at 1.5 and 3T; mixed healthy/diseased cohort) on raw slice-by-slice FD was also evaluated.

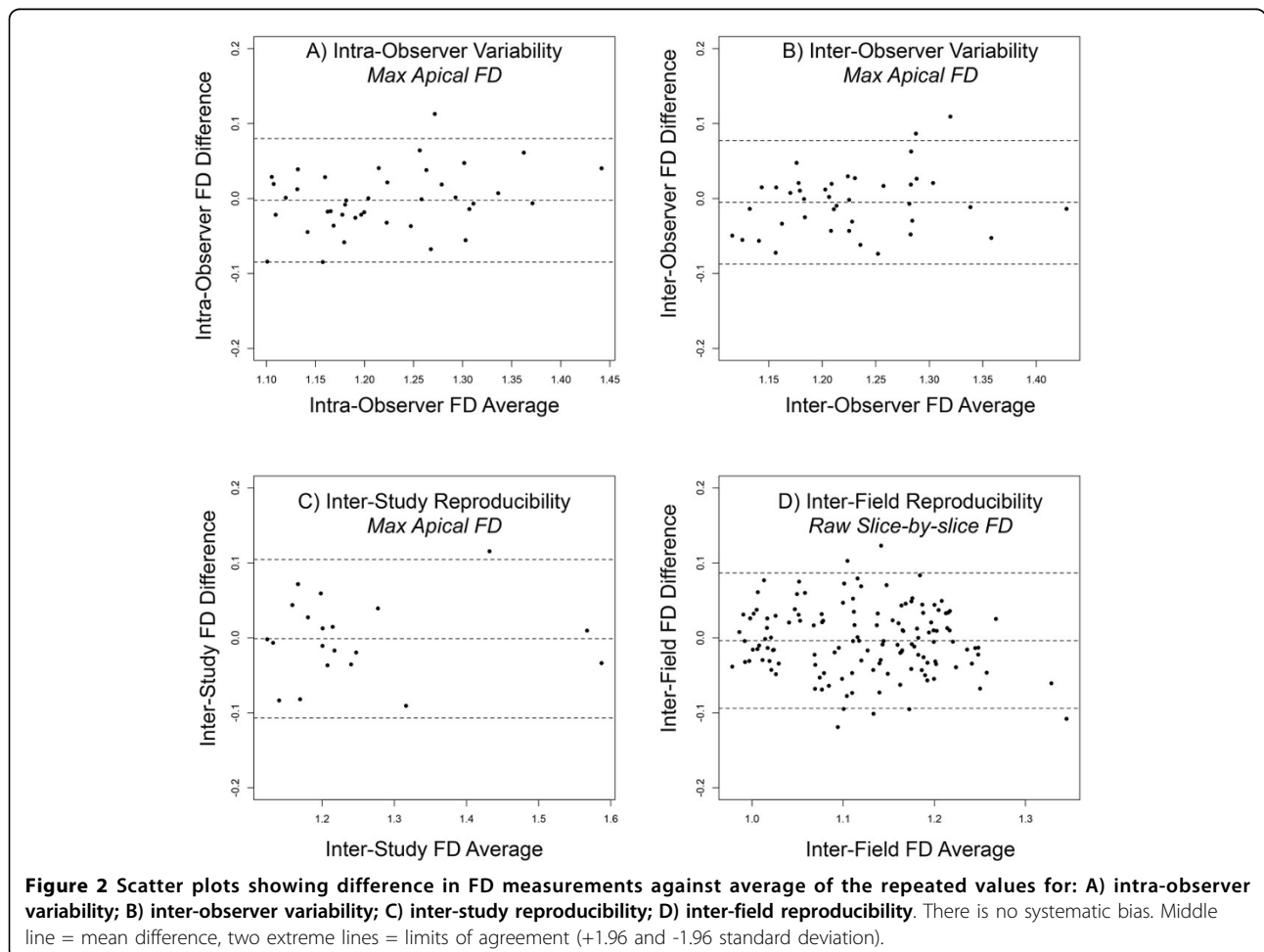
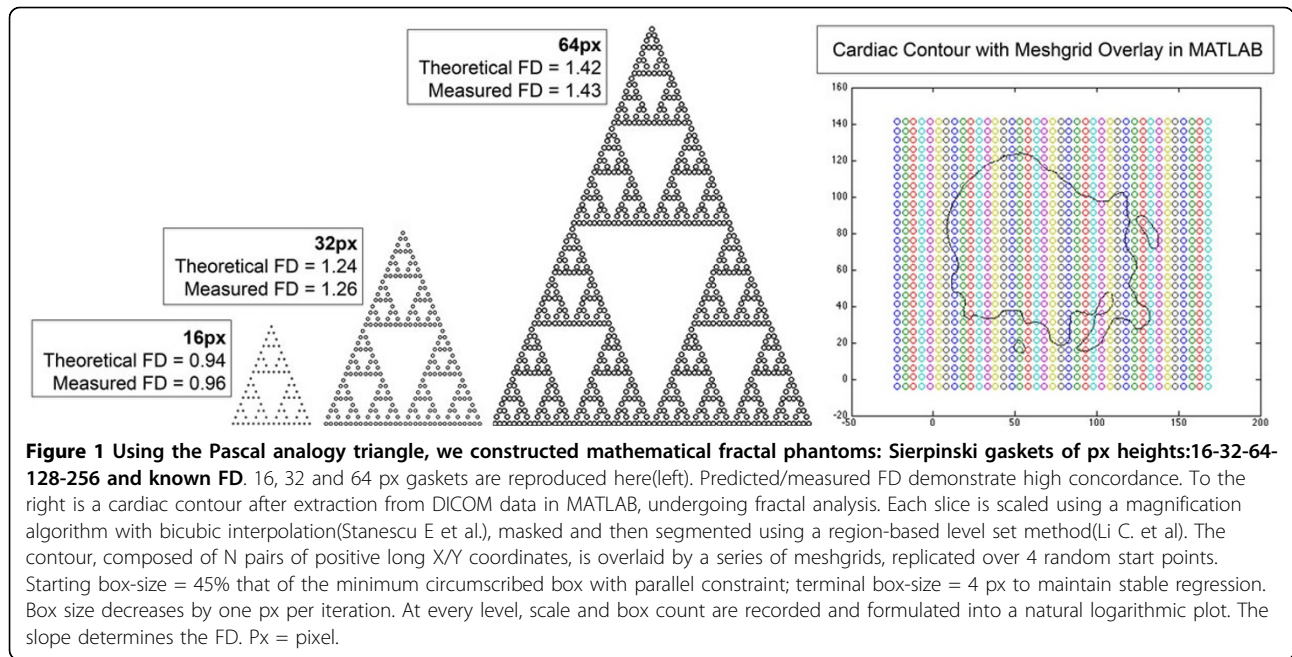
Results

Phantom validation of the box-counting algorithm produced measured FD which closely approximated expected values as proof of reliability. Intra- and inter-observer variability for maximal apical FD was high (ICCs: 0.94, 95%CI 0.90-0.97 and 0.92, 95%CI 0.86-0.95 respectively; Figure 2A, B) as was inter-study reproducibility (ICC 0.96, 95%CI 0.83-0.98; Figure 2C). ANOVA with repeated measures determined that mean FD did not differ significantly between the 3 slice thicknesses ($F(2, 84) = 2.259, p = 0.1$). Agreement between raw FD values was good irrespective of magnetic field strength (ICC 0.92, 95%CI 0.90-0.94; Figure 2D).

Conclusions

This is the first comprehensive implementation of a fractal procedure applied to the clinical CMR domain. Fractal analysis provides a way of collapsing the morphometric complexity of LV trabeculae into a single numerical value which can be compared between groups of subjects. Here we show how fractal analysis is a robust, reliable and reproducible method for capturing the richness of cardiac trabeculae imaged by CMR.

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