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Influence of observer experience on cardiac magnetic resonance strain measurements using feature tracking and conventional tagging

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ABSTRACT

Aim: CMR quantitative myocardial strain analysis is increasingly being utilized in clinical routine. CMR feature tracking (FT) is now considered an alternative to the reference standard for strain assessment -CMR tagging. The impact of observer experience on the validity of FT results has not yet been investigated. The aim of this study was therefore to evaluate the observer experience-dependency of CMR FT and to compare results with the reference standard.

Methods: CSPAMM and SSFP-Cine sequences were acquired in 38 individuals (19 patients with HFpEF,19 controls) in identical midventricular short-axis locations. Global peak systolic circumferential strain (PSCS) together with LV ejection fraction (EF) and volumes were assessed by three observers (5,3 and 0 years of CMR-strain experience). Intermodality, intra- as well inter-observer variability were assessed.

Results: Correlation between tagging and FT derived PSCS depended on observer experience ($r = 0.69$, $r = 0.58$ and $r = 0.53$). For the inexperienced observer tagging and FT derived PSCS differed significantly ($p = 0.0061$). Intra-observer reproducibility of tagging derived PSCS were similar for all observers (coefficient of variation (CV): 6%, 6.8% and 4.9%) while reproducibility of FT derived PSCS (CV: 7.4%, 9.4% and 15.8%) varied depending on observer experience. Inter-observer reproducibility of tagging derived PSCS for observer 1 and 2 as well as 1 and 3 for tagging (CV: 6.17%, 9.18%) was superior in comparison to FT (CV: 11.8%, 16.4%).

Conclusions: Reliability and accuracy of FT based strain analysis, more than tagging based strain analysis, is dependent on reader experience. CMR strain experience or dedicated training in strain evaluation is necessary for FT to deliver accurate strain data, comparable to that of CMR tagging.

1. Introduction

Cardiac magnetic resonance (CMR) is considered the gold-standard for cardiac functional analysis [1], as unlike other modalities, CMR allows for comprehensive and precise appraisal of the entire left- and right ventricle (LV&RV) [2]. Although qualitative assessment of LV wall motion in CMR cine-images (i.e. visual assessment) has been shown to be reader dependent [3], it is currently the standard clinical practice. In contrast, quantitative wall motion (i.e. strain assessment) assessment methods, such as CMR tagging, have been shown to deliver robust, reproducible results [4]. However, to date clinically strain assessment has not been widely adopted due the necessity of additional scan acquisition as well as off-line post-processing. CMR myocardial feature tracking (FT) enables rapid and therefore clinically feasible quantitative wall motion analysis using standard balanced steady state free precession (bSSFP) cine scans. Although FT offers several advantages, one of the main identified drawbacks is the increased inter-observer variability [5,6]. In this regard the impact of observer experience on validity and variability of FT derived strain has not yet been investigated. The aim of this study was therefore first, to evaluate the observer experience-dependency of CMR FT and second, to compare results with the current reference standard for quantitative wall motion analysis - CMR tagging.

2. Methods

2.1. Study population

Controls (Group A) and patients with heart failure but preserved ejection fraction (HFpEF) (Group B) were prospectively enrolled into the study. HFpEF was diagnosed using standard criteria [7] according

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to the current European Society of Cardiology guidelines [8]: 1. signs of heart failure (HF); 2. preserved systolic LV function (ejection fraction ≥50%); 3. evidence of echocardiographically diagnosed diastolic LV dysfunction (DD) and/or surrogate markers (e.g. hypertrophy, elevated plasma levels of BNP) of diastolic LV dysfunction. DD was evaluated and graded by means of echocardiography as previously described [9]. All subjects gave their written informed consent before being included in this study, which received approval by the local institutional review board.

2.2. MR Imaging

Examinations were performed using a 1.5 T clinical MR scanner (Ingenia, Philips Medical Systems, Best, the Netherlands). For functional analysis retrospectively gated SSFP sequences were acquired in the standard cardiac axes [10]. Ejection fraction was assessed in short axis bSSFP sequences with a minimum of 12 short axis slices and 30 phases reconstructed per slice. For the evaluation of FT strain additional prospectively gated bSSFP cine images with 25 cardiac frames per RR-cycle were acquired in the short axis orientation at the midventricular level.

To ensure the highest possible congruency of scanning parameters between tagged images and bSSFP cine images prospective ECG gating was employed. Further scan parameters were: FOV 370 mm, TE/TR of 1.4/3.0 ms, flip angle 50°, slice thickness 8 mm, and in plane resolution of 1.4 mm. Tagged images were acquired in identical positions using the same number of cardiac frames [25] and an identical trigger delay. For tagged images the following parameters were used: complementary spatial modulation of magnetization in a grid pattern with a grid-gap space of 8 mm; FOV 320 mm, typical TE/TR 6/33 ms, flip angle 25°.

All images were analysed by an experienced reader (reader 1: 5 years of CMR experience, 5 years of experience in strain analysis), a second reader with 2 years of CMR experience (reader 2: 1.5 years of experience in strain analysis), and one reader with 1 year of CMR experience and no experience in strain analysis (reader 3). The third reader received a 30 min tutorial in both FT and tagging derived strain analysis. FT and tagging derived global peak systolic circumferential strain (PSCS) were calculated. To investigate the intra- and inter-observer reproducibility FT and tagging analysis was performed twice by all readers with an interval of two weeks between the first and second analysis. All readers were blinded to their own intermodality results as well as to each other's inter-observer results.

2.3. TAG analysis

Dedicated harmonic phase-analysis software (Tag Track, GyroTools Ltd., Zurich, Switzerland) was used to calculate midmyocardial strain. As previously reported, short axis circumferential strain values were derived from mid-left-ventricular short axis slices [6,11]. Tracking is commenced after manually drawing a midmyocardial track-line in a diastolic phase with optimal myocardium-blood contrast. Automatic propagation of track-lines (endocardial, midmyocardial or epicardial) throughout the entire RR cycle is achieved by using the grid crossing points as points of orientation. In case of faulty propagation track lines were manually corrected.

2.4. FT analysis

Dedicated software (Diogenes; TomTec; Germany) was employed to perform FT strain analysis. Short axis circumferential strain was calculated from the same midventricular short-axis slice as used for tagging analysis. Based on an initial manually drawn endocardial contour in an end-diastolic image the LV endocardial borders are identified over the entire RR cycle. The Feature Tracking method has been previously described elsewhere in detail [6]. In brief, strain evaluation in bSSFP sequences is achieved by assigning each voxel of the endocardial/epicardial border a number of characteristics (e.g. brightness and dishomogeneities of the tissue) in a defined phase which are then tracked in the following phases. Strain information can then be deducted from the endocardial/epicardial motion. In case of faulty propagation the track line can be re-adapted to the endocardial border in a selected phase, the software then propagates a new track line based on the manually made corrections.

2.5. Statistical analyses

Statistical analyses were performed with MedCalc (Medcalc Software, Mariakerke, Belgium). Results are expressed as mean ± standard deviation (SD). Comparison between tagging and FT derived peak systolic circumferential strain (PSCS) were performed with the Wilcoxon signed rank test. P-values of <0.05 were considered statistically significant. Intra- as well as inter-observer comparisons along with reproducibility were assessed with Bland–Altman plots [12], the Wilcoxon signed rank test and the coefficient of variation (CV) [13]. Correlation between FT and tagging derived PSCS was evaluated with the Spearman correlation coefficient. Correlation coefficients were graded depending on their value ($r \leq 0.35$- weak correlation; $r = 0.36$ to 0.69 - moderate correlation; $r = 0.70$–1.0- strong correlation).

3. Results

A total of 19 healthy controls (7 female) (Group A) (32 ± 11 years, mean ejection fraction 63 ± 3%) and 19 patients (12 female) with HFpEF (Group B) (67 ± 18 years, mean ejection fraction 60 ± 8%) were included in the study. The study protocol could be completed in all participants. Fig. 1 demonstrates strain curves of a healthy volunteer computed by each of the three readers employing both, FT and TAG analysis. Table 1 summarizes subgroup results for Tagging and FT.

3.1. Reader 1

Using tagging analysis mean midventricular PSCS was −21.04 ± 3.5%, while FT derived mean midventricular PSCS was −20.89 ± 3.8%. Correlation was moderate ($r = 0.65$) and results did not significantly differ from each other ($p = 0.74$). Intra-observer variability of PSCS yielded identical mean differences yet an increased deviation for FT (0.4 ± 2.4 (95% CI: −1.1 to 0.4) (FT) vs. 0.4 ± 1.7 (95% CI: −0.95 to 0.18) (tagging)). The intra-observer coefficients of variation were 6% for tagging and 7.4% for FT derived PSCS. Results of subgroup intra-observer reproducibility are given in Table 2.

3.2. Reader 2

Tagging derived mean midventricular PSCS was −20.91 ± 3.5%, while FT derived midventricular PSCS was −19.57 ± 4.9%. Correlation was moderate ($r = 0.54$), results did not differ significantly ($p = 0.09$). Intra-observer variability of PSCS yielded higher mean differences but similar deviation for FT (0.8 ± 1.8 (95% CI: −4.4 to −2.4) (FT) vs. 0.06 ± 2 (95% CI: −0.72 to 0.6) (tagging)). The intra-observer coefficients of variation were 6.8% for tagging and 9.4% for FT derived PSCS. Results of subgroup intra-observer reproducibility are given in Table 2.

3.3. Reader 3

Tagging derived mean midventricular PSCS was −21.32 ± 4.2%, while FT derived midventricular PSCS was −19.31 ± 4.8%. Correlation was only moderate ($r = 0.48$) and results differed significantly ($p = 0.0061$). Intra-observer variability of PSCS yielded slightly higher mean differences and an increased deviation for FT (1.17 ± 4.3 (95% CI: −2.6 to 0.2) (FT) vs. 0.32 ± 1.3 (95% CI: −0.74 to 0.09) (tagging)). The intra-observer coefficients of variation were 4.9% for tagging and 15.4% for FT derived PSCS. Results of subgroup intra-observer reproducibility are given in Table 2.