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Comparison of cardiovascular magnetic resonance feature tracking and tagging for the assessment of left ventricular systolic strain in acute myocardial infarction

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ABSTRACT

Aims: To assess the feasibility of feature tracking (FT)-measured systolic strain post acute ST-segment elevation myocardial infarction (STEMI) and compare strain values to those obtained with tagging.
Methods: Cardiovascular MRI at 1.5 T was performed in 24 patients, 2.2 days post STEMI. Global and segmental circumferential (Ecc) and longitudinal (Ell) strain were assessed using FT and tagging, and correlated with total and segmental infarct size, area at risk and myocardial salvage.
Results: All segments tracked satisfactorily with FT ($p < 0.001$ vs. tagging). Total analysis time per patient was shorter with FT (38.2 ± 3.8 min vs. 63.7 ± 10.3 min, $p < 0.001$ vs. tagging). Global Ecc and Ell were higher with FT than with tagging, apart from FT Ecc using the average of endocardial and epicardial contours (-13.45 ± 4.1 [FT] vs. -13.85 ± 3.9 [tagging], $p = 0.66$). Intraobserver and interobserver agreement for global strain were excellent for FT (ICC 0.906–0.990) but interobserver agreement for tagging was lower (ICC < 0.765). Interobserver and intraobserver agreement for segmental strain was good for both techniques (ICC > 0.7) apart from tagging Ell, which was poor (ICC = 0.15). FT-derived Ecc significantly correlated with total infarct size ($r = 0.44$, $p = 0.03$) and segmental infarct extent ($r = 0.44$, $p < 0.01$), and best distinguished transmurally infarcted segments (AUC 0.77) and infarcted from adjacent and remote segments. FT-derived Ecc correlated strongest with segmental myocardial salvage ($r_s = -0.406$).
Conclusions: FT global Ecc and Ell measurement in acute STEMI is feasible and robust. FT-derived strain is quicker to analyse, tracks myocardium better, has better interobserver variability and correlated more strongly with infarct, area at risk (oedema), myocardial salvage and infarct transmurality.

1. Introduction

Contractile dysfunction following acute ST-segment elevation myocardial infarction (STEMI) predicts prognosis [1]. Cardiovascular MRI measured myocardial strain is the gold standard measure of myocardial function [2]. It offers greater accuracy in detecting dysfunctional myocardium compared with global (ejection fraction) and regional (wall-motion scoring, wall thickening) measures of function [3]. Global strain is also an independent predictor of medium-term prognosis post STEMI [4].

Myocardial tissue tagging creates saturated lines perpendicular to the slice plane and act as tissue markers in a grid, tracking myocardial motion. Various tagging analysis techniques are available, including local sine-wave modelling (SinMod) and harmonic phase analysis (HARP), which have demonstrated close agreement [5,6]. Tagging requires the acquisition of additional sequences and time-consuming post-processing. Feature tracking (FT) tracks features of interest (tissue-cavity interfaces, tissue dishomogeneities, anatomic landmarks) along contour lines on routinely acquired steady-state free-precession (SSFP) cine images, analogous to echocardiographic speckle tracking [7,8]. FT-derived strain has been compared to tagging in muscular dystrophy patients [7] and normal volunteers [9] showing reasonable agreement although we have recently shown that FT overestimates systolic strain compared to tagging [10]. There are no published strain data using FT in acute STEMI.

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This study aimed to assess the feasibility of FT measured global and segmental peak circumferential (Ecc) and longitudinal (Ell) strain assessment post acute STEMI and compare strain values to those obtained with tagging.

2. Materials and methods

2.1. Study population

Twenty-four acute STEMI patients were recruited. STEMI was diagnosed according to European Society of Cardiology definitions [11] and patients underwent primary percutaneous coronary intervention within 12 h of symptoms. The study was approved by the local research ethics committee, conducted according to the Declaration of Helsinki and patients provided written informed consent.

2.2. Cardiovascular MRI

MRI was performed at a median of 2.2 days following STEMI presentation on a 1.5 T scanner (Siemens Avanto, Erlangen, Germany) with dedicated cardiac receiver coils. SSFP cine, T2-weighted short-tau inversion recovery (T2w-STIR) and Late Gadolinium Enhancement (LGE) imaging were performed in long-axis (2/3/4-chamber) views and contiguous short-axis slices covering the left ventricle (LV). LGE images were acquired 10 min after 0.2 mmol/kg gadolinium-DTPA (Magnevist, Bayer, Germany) using a segmented inversion-recovery gradient-echo sequence. The inversion time was progressively adjusted to null unaffected myocardium. Three pre-contrast short-axis (base, mid, apical) and long-axis tagged images were acquired using a prospectively-gated spatial modulation of magnetization (SPAMM) gradient-echo sequence. The imaging protocol is detailed in Fig. 1.

2.3. MRI analysis

2.3.1. Volumetric and LGE analysis

Analysis was performed using *cmr42* (Circle Cardiovascular Imaging, Calgary, Canada). LV volumes and function were calculated as previously described [12]. Oedema (area-at-risk, AAR) and infarct size (IS) were quantified on T2w-STIR and LGE imaging using Otsu's Automated Method [13] and Full-Width Half-Maximum technique, respectively [14]. Myocardial salvage index (MSI) defines the proportion of the AAR that does not progress to infarction and was calculated as $[(\text{AAR} - \text{infarct size})/\text{AAR}] \times 100$. Total oedema and infarct size were expressed as a percentage of LV end-diastolic mass. Segmental oedema, infarct and MSI were calculated as a percentage area for each of the 16 segments in the American Heart Association model [15,16]. Transmural enhancement was defined as >50% segmental enhanced area. Segments with <1% area of oedema or LGE were classed as having no oedema or infarct, respectively. 'Infarct' segments had LGE and oedema, 'adjacent' ('at risk') segments had oedema but no LGE, and 'remote' segments had no oedema or LGE [17].

2.3.2. Circumferential and longitudinal strain analysis

Global peak Ecc and Ell strain were calculated as the average of values obtained in the three short-axis slices and long-axis views, respectively. We recorded the time taken to: (a) analyse images, (b) post-process numerical data (generate and extract strain data on a segmental, slice and long-axis basis and paste them into a spreadsheet where segmental data are illustrated for the 16 segments in numerical order as per American Heart Association nomenclature) [15] and (c) total analysis time (sum of a and b).

2.3.2.1. Tagging analysis. Strain was measured using dedicated software (*inTag*, CREATIS, Lyon, France run as a plug-in for OsiriX v3.8, Pixmeo, Switzerland) as described previously [5] and illustrated in Fig. 2. OsiriX functions only on Apple Mac (Cupertino, California, USA) computers. Intag uses the SinMod technique. Endocardial and epicardial contours were manually drawn onto the end-systolic image and automatically propagated through the cardiac cycle. Numerical data was outputted for further post-processing.

2.3.2.2. FT analysis. Strain was measured using dedicated software (*Diogenes Image Arena*, Tomtec, Munich, Germany). The FT algorithm has been described previously [18]. Short-axis cine slices were cross-referenced with the corresponding tagged image. Endocardial and epicardial contours were manually drawn onto the end-diastolic image and propagated. The software automatically places 8–12 points of interest along contours for optimal tracking (Fig. 3). Strain values were examined using three methods: (a) endocardial contours only, (b) epicardial contours only and (c) an average of both endocardial and epicardial values.

Suboptimally tracking segments using both techniques were manually adjusted and excluded from analysis if the movement of contoured borders deviated from true myocardial motion by >50% [9]. Interobserver and intraobserver variability of global and segmental strain analysis for both techniques was performed by two observers (JNK, AS) on a subset of 10 patients and repeated by a single observer (JNK) after 4 weeks, respectively.

2.4. Statistical analysis

Normality was assessed using the Shapiro–Wilk test, histograms and Q–Q plots. Normally distributed data were expressed as mean ± standard deviation. Non-parametric data were expressed as median (25–75% interquartile range). Global and segmental Ecc and Ell using the FT and tagging methods were compared using paired *t*-testing, two-way mixed-effect intraclass correlation coefficient for absolute agreement (ICC) [19] and Bland–Altman analysis [20]. Interobserver and intraobserver variabilities were expressed using ICC, coefficient of variation (COV) and Bland–Altman analysis. On ICC, agreement was defined as excellent (ICC ≥ 0.75), good (ICC 0.6–0.74), fair (ICC 0.4–0.59), or poor (ICC < 0.40) [21]. Strain was correlated with infarct and MSI using Spearman's Ranked Correlation Coefficient (r_s) and with oedema using Pearson's Correlation Coefficient (r). The sample size was chosen according to the table of Critical Values of the Spearman's Ranked Correlation Coefficient for $r_s \sim 0.40$ with $p < 0.05$, based on an initial pilot of 10 patients [22]. The correlation between global strain and number of transmurally-enhanced segments after correction for total IS was assessed using multiple regression. Independent *t*-testing compared segmental strain according to the presence of infarct, transmural infarction and oedema. Receiver Operating Curve (ROC) Area Under the Curve (AUC) analysis assessed the accuracy of each method in predicting transmural infarction. Statistical tests were performed using SPSS V20. $p < 0.05$ was considered significant.

3. Results

3.1. Baseline characteristics

MRI data for the 24 patients studied are summarized in Table 1. All segments tracked satisfactorily with FT despite hypoenhancement (microvascular obstruction) or hyperenhancement (contrast enhancement) in the infarct territory on cine imaging (Fig. 4). The number of segments excluded from analysis was significantly higher for tagging than FT. The time taken to contour, post-process