ORIGINAL ARTICLE

Comparison of 2D Echocardiography Speckle Tracking and Cardiac Magnetic Resonance Feature Tracking for Prediction of LV Remodeling in Patients with ST-Elevation Acute Myocardial Infarction

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Abstract

Background: ***LV global longitudinal strain (GLS) by 2-dimensional speckle tracking echocardiography (2DSTE) is the most widely used strain parameter in clinical practice. CMR feature tracking (CMRFT) is a strain modality that is quite new and is being prepared for clinical implementation. One of the clinical applications of strain we worked on is LV remodeling prediction in post-STEMI patients. We compare both techniques and study the connection between LV remodeling and strain values determined by both methods.***

Aim: ***To compare LV GLS by 2D STE versus CMRFT in patients with acute ST-elevation myocardial infarction (STEMI), and to validate the assumption linking GLS to LV remodeling following STEMI.***

Methods: ***This prospective, non-randomized cohort study was conducted on 53 patients (51 ± 12 years old, 85% males) with STEMI who underwent primary PCI or pharmaco-invasive strategy between December 2022 and December 2024. Strain analysis was done before discharge using 2D STE and CMRFT. 2nd visit CMR was done after 3 months to detect the occurrence of LV remodeling.***

Results: ***CMRFT measurements are well correlated with 2D STE in deformation quantification (r = 0.66). Impaired GLS in 2D STE or CMRFT after STEMI shows a good correlation with the occurrence of LV remodeling.***

Conclusion: ***CMRFT is comparable to 2D STE in myocardial strain analysis measurements. GLS measured by STE or CMRFT during acute STEMI patients can be a valuable tool for predicting future LV remodeling. CMRFT was more reliable than STE in predicting the occurrence of LV remodeling.***

Keywords: Myocardial strain; GLS; CMRF; LV remodeling

1. Introduction

Left ventricular (LV) remodeling is a dynamic phenomenon that commences during the acute phase of myocardial infarction (MI) despite the introduction of modern reperfusion therapy.[1] It is a significant process because its progression can result in life-threatening arrhythmias and heart failure, raising the mortality rate.[2] Tools for predicting LV remodeling have evolved with time. The LV ejection fraction (EF) and the wall motion score index (WMSI) were used traditionally as remodeling predictors. However, both parameters possess many limitations, as the phenomenon of compensatory regional hyperkinesis in non-infarcted regions is likely to have played a significant role in sustaining left ventricular ejection fraction (LV EF).[3] Additionally, WMSI constitutes a semi-quantitative metric for evaluating motion that is characterized by intrinsic inter-observer variability.[4]

So, studying LV mechanics, such as strain, has been developed for practical use.[5] Myocardial strain assessment has undergone significant advancements, from cardiac magnetic resonance (CMR) tissue tagging to tissue Doppler echocardiography to the current STE and CMRFT approaches.[6] STE and CMRFT are analogous to each other, where speckles manifest as reflections of the tissue that are meticulously monitored on a frame-by-frame basis to assess myocardial displacement, velocity, and strain.[7]

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Despite the two techniques demonstrating utility in diverse clinical contexts, comparative analysis of cardiac magnetic resonance functional testing and STE aimed at assessing LV strain is scarce. We intend to examine the viability of quantifying myocardial strain using the two techniques to compare the data collected from each. Additionally, we have been investigating the possible correlation between GLS and LV remodeling in post-STEMI patients.

2. Patients and methods

This prospective, non-randomized cohort study was conducted on 53 participants with STEMI who received initial percutaneous coronary intervention (PCI) treatment for their condition or a pharmaco-invasive strategy and agreed to undergo 2D echo and CMR before hospital discharge. Patients from 2 tertiary hospitals (Aswan Heart Centre and Al-Hussien University Hospital) were included between December 2022 and December 2024. Informed consent was obtained.

All those with previous MI, CABG, significant valvular abnormalities, rhythm other than sinus rhythm, renal impairment, poor echocardiographic window obscured the ability to analyze the obtained images, having any MR-incompatible implants, weighing more standard MR-table tolerated weight, having a very wide waist circumference, having claustrophobia, or with altered loading conditions either physiological as pregnant women or pathological as pulmonary edema were excluded.

History was taken from all patients, including age, sex, weight, height, HTN, DM, ischemic heart disease, previous cardiac surgery, or any implants that had been done before. The focused examination included vital data, as well as general and local cardiac examinations to assess gallop, audible murmur, or basal crepitus. A standard resting 12-lead ECG was recorded to identify the heart rate, rhythm, and STEMI infarct territory.

Transthoracic echocardiography (TTE) images were generated by an ultrasound machine made available to healthcare professionals by a commercial enterprise (EPIQ CVx, Philips Healthcare, Andover, MA, USA). The apical 4ch, 2ch, and 3ch views during three uninterrupted cardiac cycles were obtained with the patients lying on their left side. The compression of the gain was modified to clarify LV myocardial borders. To optimize visual clarity and enable a higher frame rate for the entire left ventricle (LV), the depth, sector size, and sector angle settings were calibrated. Measurements included EF, LV end-diastolic volume (LVEDV), and end-systolic volume (LVESV). All measurements were done according to the recommendations of the American Society of Echocardiography.[8]

Using vendor-independent speckle-tracking software, a two-dimensional STE analysis was carried out (QLAB 15.3, Philips Healthcare, Andover, MA, USA). After a manual procedure to outline the inner and outer walls of the heart (endocardium and epicardium, respectively), the software automatically partitioned the LV into a modified 16-segment model, adhering to the American Heart Association's 17-segment standard, but excluding the apical cap. The sum of absolute difference algorithm was used to track specific appropriate myocardial speckles frame by frame. Lastly, the software automatically generated each segment's peak strain. The average of each segment's peak strain readings was used to calculate GLS.

Cardiac magnetic resonance imaging was carried out using a 1.5 Tesla MR scanner (Area, Siemens Medical Systems, Erlangen, Germany). Imaging was conducted using a specialized cardiac phased-array receiver coil. All patients were placed in the supine position during the procedure. Vector electrocardiac activity was utilized to trigger the R-wave. The volume and function of the left ventricle were evaluated through SSFP images, which were gathered in a short-axis orientation and encompassed the LV from the base to the apex. Long-axis images (4ch, 2ch, and 3ch views) were employed in the strain analysis that followed.

Software for feature tracking was used to evaluate cardiac magnetic resonance pictures (Segment version 3.3, Medviso AB, Lund, Sweden). This instrument utilizes a feature-tracking-based analysis, employing an algorithm that has been validated through numerous experimental and clinical studies in the past.[9] For all three short-axis and long-axis plane cine films, the LV endocardial and epicardial borders at the end-diastolic frame were manually created. After that, the program automatically spreads the contour and tracks its characteristics across all tracked segments' strain values.

CMR 2nd visit was performed 3 months after STEMI follow-up to determine the occurrence of LV remodeling. Remodeling definition based on an increase in both LVEDV & LVESV equal to or more than 12% of the first visit CMR volumes.[10]

The acquired data were compiled and analyzed using statistical software (SPSS 27, IBM Inc., Armonk, NY, USA). Numbers and percentages were used to describe the qualitative data. The mean and standard deviation were used to describe quantitative data. The correlation coefficient was calculated using Pearson's correlation for parametric data and Spearman's Rho for non-parametric data. The significance of the obtained results was judged at the 5% level. Correlation is interpreted as r = 0-0.2: probably a meaningless correlation, r = 0.2-0.4: a low correlation, r = 0.4–

0.6: a reasonable correlation, r = 0.6–0.8: a high correlation, r = 0.8–1.0: a very high correlation.

3. Results

Patients' demographics and relevant clinical data are shown in Table 1. 84.9% of the population were male gender, while 71.7% had AWMI. 45.3 % of patients were considered to have LV remodeling, and subsequently, the diagnostic performance of strain measurements was statistically applied. Tables (2), (3), and (4) show the parameters measured by echocardiography and CMR.

Table 1. Patients' demographics and clinical data

VARIABLES		N=53	
AGE		51.7	+/- 11.9 yrs
MALE GENDER		45	84.9 %
WEIGHT		79.4	+/- 13.3 Kgm
HEIGHT		170	+/- 8.2 cm
BMI		27.5	+/- 4.5 kgm/m^2
HYPERTENSION		28	52.8 %
DM		21	39.6 %
STEMI	AWMI	38	71.7 %
	IWMI	13	24.5 %
	LWMI	1	1.9 %
	Inferolateral	1	1.9 %
ADVERSE LV REMODELLING		24	45.3 %

Table 2. Echocardiographic data

	EF (M)	LVEDD	LVESD	EF(2D)	LVEDV	LVESV	LVEDVI	LVESVI	GLS
MEAN	50.8%	4.9	3.6	45.2%	103.6	57.0	54	29	-11.7
MEDIAN	52.0%	5.1	3.7	48.0%	103.0	58.2	53	30	-11.0
MODE	47.0%[a]	4.7	3.9	48.0%	84.1	57.6	46	30	-11.0
SD	8.6%	0.59	0.58	8.49%	29.5	18.1	15	9	4.32
MINIMUM	28.0%	3.0	2.3	27.0%	39.5	17.8	23	11	-22.2
MAXIMUM	73.0%	5.9	5.0	65.0%	174	91.0	94	48	-5.0

Table 3. CMR 1st visit data

	EF	LVEDV	LVESV	LVEDVI	LVESVI	GLS	CS	RS
MEAN	44.4%	148.3	82.1	78.5	43.8	-10.6	-12.1	26.8
MEDIAN	43.0%	147.0	82.0	78.0	41.0	-10.0	-12.0	23.5
MODE	37.0%[a]	144.0	81.0	90.0	31.0	-8.0	-12.0	22.0
SD	9.5%	32.8	27.5	19.1	16.6	4.1	3.3	8.6
MINIMUM	29.0%	93.0	28.0	46.0	14.0	-20.0	-21.0	13.0
MAXIMUM	70.0%	213.0	134.0	142.0	104.0	-2.0	-7.0	52.0

Table 4. CMR 2nd visit data

	EF	LVEDV	LVESV	LVEDVI	LVESVI
MEAN	47.2	178.8	97.0	91.7	50.8
MEDIAN	47.5	180.5	92.0	89.5	46.5
MODE	50.0	156.0	80.0	89.0	37.0
SD	11.4	45.8	41.9	24.0	21.7
MINIMUM	20.0	95.0	27.0	46.0	13.0
MAXIMUM	74.0	294.0	214.0	142.0	104.0

Comparison between data obtained from echocardiography and CMR 1st visit has shown significant statistical differences in LV volumes and GLS measured by 2D echocardiography and CMR, while no statistical difference is noted in EF estimation, See Figure 1.

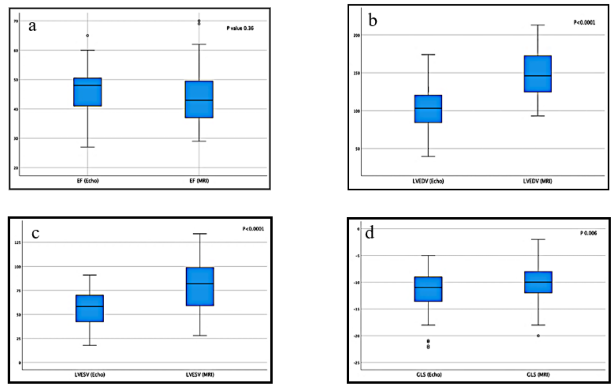

Figure 1. Box & Whisker plot shows the comparison between data obtained from echocardiography and CMR 1st visit, (a) no statistical difference noted in EF, (b) (c)(d) show a statistically significant difference between LVEDV, LVESV, GLS measured by echocardiography & CMR, LVEDV LV end-diastolic volume, LVESV LV end-systolic volume, GLS global longitudinal strain.

There is a reasonable correlation (r 0.4 - 0.6) between GLS measured by echocardiography and LV remodeling, see Figure (2)

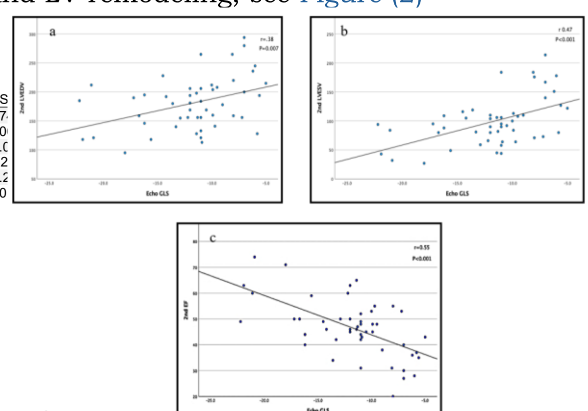

Figure 2. Scatter plot shows a reasonable correlation between GLS measured by echocardiography and (a) LVEDV measured by CMR 2nd visit (b) LVESV measured by CMR 2nd visit (C) EF measured by CMR 2nd visit.

There is a high correlation (r 0.5 - 0.8) between GLS measured by CMR and LV remodeling, see Figure (3).

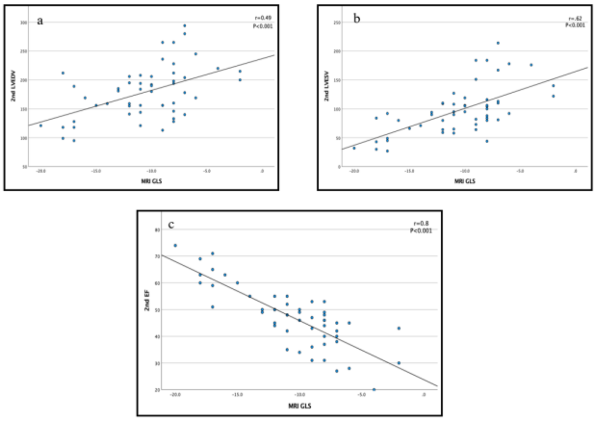

Figure 3. Scatter plot shows a high correlation between GLS measured by CMR and (a) LVEDV measured by CMR 2nd visit (b) LVESV measured by CMR 2nd visit (C) EF measured by CMR 2nd visit

There is a high correlation (r 0.66) between GLS measured by STE and CMRFT. A consistent agreement was noted in the Bland-Altman plot, systematic bias -1.4%, LOA +/- 6.7 %. see Figure (4)

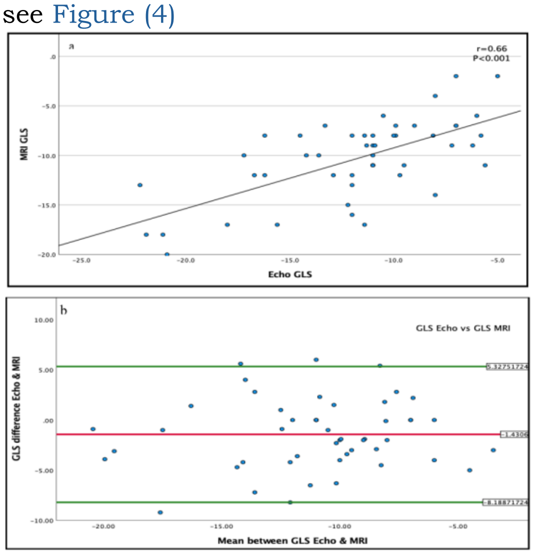

Figure 4. Linear correlation (a) and Bland–Altman plot (b) comparing GLS measured by STE & CMRFT showing high correlation in between, with consistent agreement, systematic bias -1.4%, LOA +/- 6.7 %.

4. Discussion

The current study found that 1) CMRFT strain measurements are correlated well in quantifying deformation when compared with 2D STE; 2) impaired GLS in 2D STE or CMRFT after STEMI can be used as a left ventricular remodeling predictor; and 3) GLS by CMRFT is more reliable than GLS by 2D STE for predicting left ventricular remodeling after STEMI.

We defined adverse left ventricular remodeling as a ≥12 % increase in EDV and ESV (measured by CMR) after a 3-month follow-up. Accordingly, 45% of our patients underwent adverse left ventricular remodeling after a follow-up of three months by CMR.

CMR was utilized as an indicator for remodeling occurrence, replacing echocardiography, which is typically employed, as it is the accepted benchmark for assessing ventricular mass and volumes at the moment.[11]

The cutoff value for considering a patient has adverse LV remodeling is variable across many studies and is influenced by factors such as patient demographics, infarct size, and imaging methodologies.[12,13,14]

Bulluck et al. 2020 defined adverse LV remodeling as a ≥ 12% increase in LVESV and LVEDV by CMR after six months. Bulluck's definition of remodeling was derived from studying worse long-term clinical outcomes for 285 patients after STEMI.[15]

LV remodeling occurs gradually in stages and may continue for more than a year.[16] However, in the modern era, where STEMI is managed with primary PCI and optimal pharmacotherapy, nearly half (48%) of patients have LV remodeling during the first year following the infarction. A majority (64%) undergo LV remodeling within the initial three months following an infarction.[17] Previous studies indicated that 30 to 33% of patients experienced LV remodeling during follow-up.[18]

LV remodeling may result in catastrophic outcomes, including heart failure and malignant arrhythmias.[19] Consequently, the early identification of individuals at elevated risk of LV remodeling holds significant prognostic implications and influences clinical decision-making.

In our study, we could say that CMRFT is more feasible than 2D STE in many aspects. Our study included 53 patients, but GLS cannot be obtained from 4 patients using STE due to poor tracking. A similar problem has been reported in previous studies.[20, 21]

Although STE of global strain by echocardiography provides clinically significant parameters for identifying mild LV dysfunction and offers prognostic insights beyond established or traditional parameters,[22] image quality determines its correctness and dependability.[23] Conversely, Cardiac magnetic resonance imaging affords superb image quality in nearly all patients. This observation may be attributed to the elevated signal-to-noise ratio at the myocardium-LV blood pool interface. Strain measurement is feasible in nearly all individuals by CMRFT, exhibiting a reduced level of variance and higher reproducibility.

A study involving one hundred and six

individuals who had both CMR and 2D/3D STE on the same day found that CMRFT provided the highest practicality for acquiring LV global strain values, followed by 2D STE. Although cardiac magnetic resonance feature tracking analysis took longer than STE analysis, the relatively brief CMRFT analysis time may still be considered time-efficient. The researchers, therefore, propose that CMRFT could potentially serve a significant role in certain clinical scenarios.[7]

Regarding CMRFT reliability, Gao et al. published a study in 2023 that investigated the diagnostic value of CMRFT in suspected acute myocarditis, highlighting its ability to evaluate both global and segmental myocardial strain.[24]

It is also worth mentioning that preceding studies have substantiated CMRFT accuracy against CMR tagging or STE.[25]

In our study, we recorded statistical differences between echocardiography and CMR parameters in volume estimation and GLS, see Figure 1. 2D echocardiography significantly underestimates volumes and strain parameters, mainly due to geometric assumptions and limited imaging planes.

Although there was a moderate correlation between LV volume and function measures in a reasonably large CMR versus echocardiographic comparison research in post-MI patients, there were notable systematic intramodality discrepancies, with echo underestimating volumes and EF. The study recommended that when slight to moderate serial changes in these measures are clinically significant, CMR should be carried out.[26]

A multicenter, open-label study by Rainer et al. documented that LVEDV and LVESV were underestimated by 2D echocardiography compared with CMR. The study suggested contrast administration on 3D echocardiography to improve the determination of LV volumes and reduce interreader variability.[27]

Studies indicate that CMRFT yields more precise and reproducible GLS measurements than 2D STE, particularly in identifying subtle myocardial deformation. Nevertheless, 2D STE remains more accessible and cost-effective, making it an appropriate option for routine clinical practice. Despite these differences, both modalities demonstrate good inter-modality agreement and are valuable tools for evaluating cardiac function.[7, 28]

The fact that STE is based on tracking spots or "speckles" in the myocardium may help to explain some of the discrepancies in results between direct comparisons of STE and CMRFT. However, some of the disparities can be explained by the fact that CMR FT primarily tracks the endocardial boundary itself.[29]

We reported that CMRFT was correlated well with 2D STE (r 0.66) for GLS measurements in post-MI patients, see Figure 4. A consistent agreement was noted; systematic bias was -1.4 % (denoting that, on average, GLS measured by STE 1.4 % less than measured by CMR), with few outliers; however, LOA +/- 6.7%.

Onishi et al. observed this excellent correlation between CMRFT and 2D STE (r 0.81) in their comparative study between 2D STE and CMRFT, although GLS measured by 2D STE was higher than that by CMRFT. LOA was wider than recorded in our study (+/- 8.0%). This difference may be due to changes in loading conditions, which affect strain values. The majority of our patients underwent echocardiography and CMR within 24 hours, unlike a previous study where echocardiography and CMR were done on different days.[25]

Obokata et al. were consistent with previous results (r 0.87) with a narrow LOA +/- 3.6. The participants of this study underwent echocardiography and CMR on the same day.[7]

Although our analysis demonstrated good GLS correlations between CMRFT and 2D STE, the limits of agreement are rather broad. Narrower values than observed have clinical implications in many previous studies.[30,31,32] Therefore, we can assume that global strain values derived from CMRFT and 2D STE are not interchangeable.

It was consistent with what Ananthapadmanabhan et al. concluded in their study in 2021. The study compared multilayer GLS values between CMRFT and 2D STE, showing a good correlation (r 0.685 to 0.687) for endocardial and epicardial strain measurements. Bland-Altman analysis revealed good inter-modality agreement, with absolute limits of agreement ranging from 5.5% to 6.4%.[28]

In our study, we reported a good correlation between GLS values calculated by CMRFT during the acute attack of STEMI and LV remodeling. Correlation was done in relation to both LV volumes (absolute and indexed) and EF% % measured by CMR in patients with three-month STEMI were (r was 0.5 for LVEDV, 0.6 with LVESV, 0.8 with EF % … $P < 0.001$ in all), see figure 3.

The correlation was also evident with 2D STE but to a lesser extent than noted with CMRFT (r was 0.4 for LVEDV, 0.5 with LVESV, 0.6 with EF % … $P=0.007$, $P < 0.001$, $P < 0.001$ consecutively), see figure 2. Based on these results, we concluded that measuring GLS early, either by CMRFT or STE, can be a reasonable marker and early predictor for future LV remodeling, which has a significant clinical impact.

A review published in 2023 by Gao et al. summarized the clinical utility of strain imaging techniques, emphasizing their role in detecting myocardial fibrosis and remodeling. The study highlighted the importance of strain imaging in early risk stratification and prognosis improvement.[33]

A study in 2017 linked 3D GLS robustly with remodeling as well as 3D global area strain (GAS) and global radial strain (GRS).20

Liskza et al. suggested that patients at high risk for LV remodeling may benefit from the significant predictive value that STE performed at the time of discharge and one month after the AMI showed LV strain impairment.[34]

Park et al. considered GLS as a highly reliable indicator of LV remodeling and adverse outcomes in patients with anterior-wall acute MI as soon as the main reperfusion treatment was completed.[35]

A potential explanation of this powerful relation between GLS and remodeling is that GLS mainly represents the contractility of subendocardial fibers, which are more vulnerable to myocardial hypoperfusion and hypoxia than fibers of the middle layer and subepicardial layer.[36] So, GLS could serve as a valuable parameter for future studies aimed at assessing prognostic implications.

4. Conclusion

We concluded that CMR feature tracking (CMRFT) is correlated well with 2D STE in myocardial strain analysis estimation. GLS measured by STE or CMRFT during acute STEMI patients can be a valuable tool for predicting future LV remodeling. Our cohort results were consistent with internationally published data.

Disclosure

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