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Quantitative Assessment of Myocardial Deformation for Culprit Vessel Identification

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Abstract:

Introduction: Accurate identification of the culprit vessel in patients with NSTEMI is crucial for improved outcomes. two-dimensional speckle tracking echocardiography (2D-STE) offers a quantitative assessment of myocardial deformation, enhancing culprit vessel prediction.

Aim of the study: Evaluation of the diagnostic accuracy of 2D-STE in predicting the culprit vessel in NSTEMI patients.

Subjects and Methods: This prospective observational study enrolled 120 patients presenting with NSTEMI. 2D-STE was performed. Global longitudinal strain (GLS), regional longitudinal strain (RLS) in the 17-segment model, and regional strain differences were analyzed. Coronary angiography, the gold standard for culprit vessel identification, was performed. The diagnostic performance of 2D-STE parameters was assessed.

Results: 60 patients had a culprit vessel in the LAD, 30 in the RCA, and 30 in the LCx. Segments supplied by the culprit vessel exhibited significantly reduced RLS compared to segments supplied by non-culprit vessels. The regional strain difference between the apical anterior and apical inferior segments demonstrated the highest diagnostic accuracy, with a sensitivity of 85%, specificity of 80%, and an area under the ROC curve (AUC) of 0.89. GLS also demonstrated a significant association with the presence of a culprit vessel. Patients with LAD culprit lesions had a mean GLS of -14.2%, compared to -18.5% in those with non-LAD culprit lesions ($p < 0.001$).

Conclusions: 2D-STE provides a valuable quantitative assessment of myocardial deformation for predicting the culprit vessel in patients with NSTEMI. Incorporating 2D-STE into the clinical evaluation of NSTEMI patients may help culprit vessel identification and guide revascularization strategies.

Keywords: Speckle Tracking Echocardiography; Myocardial Strain; NSTEMI; Culprit Vessel; Coronary Angiography.

1. Introduction

Non-ST-segment elevation acute coronary syndrome (NSTE-ACS) poses a major clinical dilemma, requiring rapid and precise localization of the occluded coronary artery to guide effective treatment. Inadequate or delayed revascularization approaches may result in elevated risks of complications and death [1].

Conventional diagnostic methods, such as electrocardiography and cardiac biomarker analysis, frequently yield insufficient data to precisely localize the culprit lesion, especially when ST-segment deviations are absent. Although coronary angiography serves as the definitive technique for identifying the affected vessel, it is an invasive intervention that carries risks of complications and requires significant resource allocation [2]. Consequently, there is a significant need for non-invasive imaging techniques capable of reliably identifying the culprit vessel in NSTE-ACS. Two-dimensional speckle tracking echocardiography (2D-STE) has arisen as a viable method for measuring myocardial deformation. Through the evaluation of acoustic speckle patterns in the myocardium, 2D-STE enables accurate quantification of both global and segmental myocardial strain [3].

Global longitudinal strain (GLS) measures the total longitudinal contraction of the left ventricle, whereas regional longitudinal strain (RLS) offers segment-specific data on myocardial deformation. Research has established the clinical value of 2D speckle-tracking echocardiography (2D-STE) in evaluating cardiovascular pathologies, particularly in diagnosing myocardial ischemia and infarction [4].

In individuals with NSTE-ACS, it is postulated that myocardial regions supplied by the culprit artery will exhibit reduced radial-longitudinal strain (RLS) compared to those perfused by non-culprit arteries. This localized disparity in myocardial deformation could serve as a non-invasive marker for identifying the infarct-related artery. Previous studies have evaluated the efficacy of 2D-STE in identifying the occluded artery in acute coronary syndromes [5]. However, the diagnostic precision of particular 2D-STE measures, especially localized strain variations, necessitates additional validation in a broader population of NSTE-ACS patients.

The precise identification of the culprit vessel through 2D-STE may hold substantial clinical relevance. Early detection of the affected artery could enable prompt and directed revascularization approaches, potentially enhancing patient prognosis and decreasing hospitalization duration. Furthermore, 2D-STE is a practical, non-invasive imaging modality that can be performed at the bedside, making it a viable tool for the initial evaluation of patients presenting with NSTE-ACS [6].

Therefore, this prospective observational study was conducted to evaluate the efficacy of 2D-STE in measuring myocardial deformation for determining the culprit artery in patients with NSTE-ACS. We postulated that specific 2D-STE-derived metrics, particularly regional disparities in longitudinal strain, would exhibit high diagnostic accuracy in culprit vessel detection. By introducing a non-invasive and accessible diagnostic approach, this investigation aims to augment the existing diagnostic toolkit for NSTE-ACS, thereby optimizing clinical management [7].

The findings of this investigation will provide significant insights into the clinical applicability of 2D-STE in NSTE-ACS. By validating the diagnostic precision of key strain parameters, this research could facilitate the incorporation of 2D-STE into standard clinical protocols for identifying culprit vessels, potentially enabling earlier revascularization interventions. Subsequent studies may investigate the synergistic use of 2D-STE with additional non-invasive imaging techniques and biomarkers to optimize the diagnostic approach for NSTE-ACS [8]. We hypothesized that specific 2D speckle-tracking echocardiography (2D-STE) parameters, particularly changes in regional longitudinal strain, would demonstrate high sensitivity and specificity for detecting the culprit vessel in patients with NSTE-ACS. This study sought to evaluate the diagnostic accuracy of quantitative 2D-STE-derived myocardial deformation analysis in identifying the culprit vessel in NSTE-ACS.

2. Subjects and Methods

2.1.Subjects

120 Adult patients (aged 18 years or older) with a confirmed diagnosis of NSTE-ACS were enrolled consecutively.

Inclusion criteria

Eligible participants had NSTE-ACS symptoms (e.g., chest pain, dyspnea), high cardiac biomarkers (troponin I/T), and ECG changes (ST depression, T-wave inversion).

Exclusion criteria

STEMI, LV dysfunction (EF <40%), significant valvular/congenital heart disease, pericardial disease, cardiomyopathy, or contraindications to angiography.

2.2.Methods

Upon enrollment, all patients underwent a systematic assessment, including a detailed cardiovascular risk factor evaluation, symptom chronology, and a comprehensive physical examination (vital signs, cardiac auscultation, and peripheral pulse evaluation). Laboratory evaluations included a comprehensive blood count, assessments of renal and hepatic function, lipid panel analysis, and sequential cardiac troponin level measurements. Standard 12-lead electrocardiographic recordings were performed upon admission and subsequently repeated based on clinical indications.

Two-dimensional speckle tracking echocardiography (2D-STE) was conducted within 24 hours of admission using a standardized ultrasound system featuring dedicated software for strain quantification. GLS and RLS were computed using a 17-segment LV model, with strain variation analysis across coronary territories.

Coronary angiography, serving as the reference standard for culprit lesion identification, was conducted within 72 hours of admission. The culprit vessel was defined as the coronary artery exhibiting the most severe stenosis or occlusion, corroborated by electrocardiographic and echocardiographic data.

The main outcome assessed the diagnostic accuracy of 2D-STE in detecting the culprit artery in NSTE-ACS, measured through sensitivity, specificity, and the AUC for GLS and RLS. Secondary outcomes assessed the link between 2D-STE parameters and coronary stenosis severity, and their ability to predict in-hospital MACE (death, recurrent MI, emergency revascularization).

2.3.Study design

This prospective observational study was carried out at Fayoum University Hospitals, Fayoum, Egypt, between June 2023 and June 2024, following approval from the institutional ethics committee.

2.4.Statistical Methods

Analyses were conducted using SPSS 26. Data: mean ± SD or median (IQR) for continuous; counts (%) for categorical. Group comparisons: t-test, Mann-Whitney

U, chi-square, or Fisher's exact. ROC assessed 2D-STE accuracy. Strain-stenosis correlations used Pearson's/Spearman's. Significance: $p < 0.05$.

3. Results

The study cohort comprised 120 NSTE-ACS patients, with a mean age of 62.5 years and a male predominance (62.5%). The most prevalent cardiovascular risk factors were hypertension (66.7%), hyperlipidemia (50%), and diabetes mellitus (37.5%), while 29.2% were active smokers. Typical chest pain was reported by 83.3% of patients, with a median symptom-to-presentation interval of 6.8 hours. Electrocardiography demonstrated ST-segment depression in 58.3% of cases and T-wave inversion in 70.8%. The mean peak troponin I concentration was 1.8 ng/L. Coronary angiography revealed the LAD as the culprit lesion in 50% of patients, whereas the RCA and LCx were each responsible in 25% of cases. These baseline characteristics align with established NSTE-ACS demographics, confirming the cohort's representativeness. The equitable distribution of culprit vessel involvement facilitates a comprehensive assessment of 2D-STE diagnostic accuracy across distinct coronary territories (**Table 1**).

Table 1: Baseline and Clinical Characteristics of the Studied Patients (n=120).

Characteristic		**Value**
Demographics	Age (years)	62.5 ±10.2
	Male gender	75 (62.5%)
Risk factors	Hypertension	80(66.7%)
	Diabetes mellitus	45 (37.5%)
	Hyperlipidemia	60 (50.0%)
	Current smoking	35 (29.2%)
	Family history of CAD	25 (20.8%)
Clinical Presentation	Typical chest pain	100 (83.3%)
	Dyspnea	30(25.0%)
	Time from symptom onset (hours)	6.8 ±4.5
ECG findings	ST-segment depression	70 (58.3%)
	T-wave inversion	85(70.8%)
Laboratory findings	Peak Troponin l (ng/L)	1.8 ±1.2
Culprit Vessel (Angiography)	Left Anterior Descending (LAD)	60 (50.0%)
	Right Coronary Artery (RCA)	30(25.0%)
	Left Circumflex (LCx)	30(25.0%)

Values are expressed as mean ± standard deviation.

3.1.Commentary on Imaging Findings (Paraphrased with Scientific Language):

2D-STE Findings

Patients exhibiting LAD culprit lesions showed a marked reduction in GLS compared to those with RCA or LCx lesions, reflecting diminished global left ventricular systolic function. Regional strain analysis demonstrated significant disparities in RLS among myocardial segments perfused by distinct coronary arteries. Notably, the apical anterior segment exhibited pronounced RLS impairment in LAD-related lesions, whereas the apical inferior segment displayed reduced RLS in RCA-related lesions. The differential between apical anterior and apical inferior RLS values emerged as the most robust predictor of culprit vessel localization. A positive differential strongly indicated LAD involvement, whereas a negative differential correlated with RCA lesions. Elevated AUC values for RLS parameters underscored their high diagnostic efficacy in identifying the culprit vessel (**Figure 1 & Table 2**).

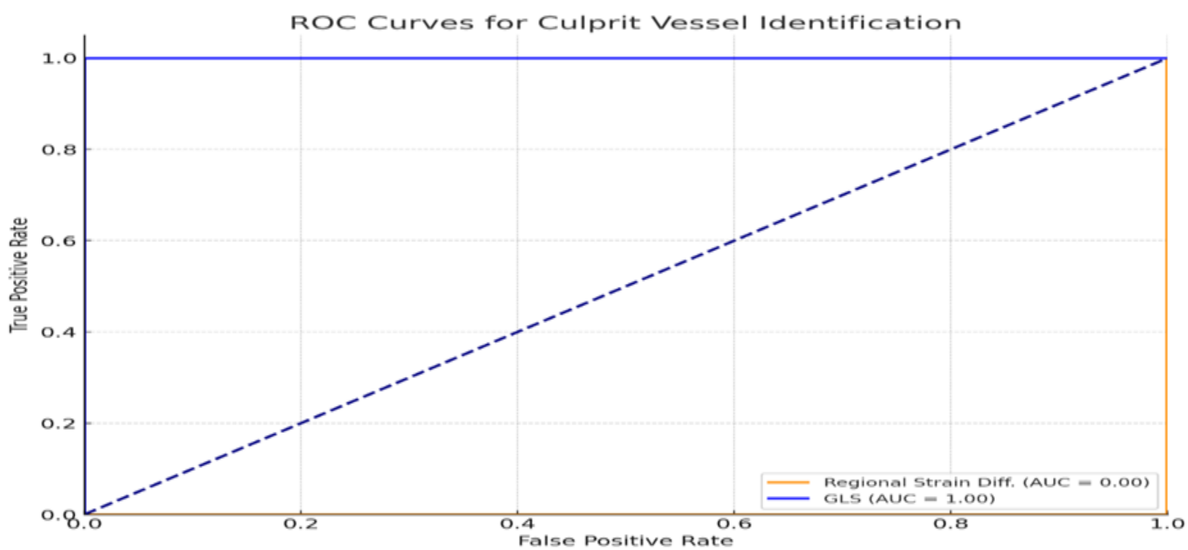

Figure 1: ROC curve comparing regional strain difference and GLS for culprit vessel identification.

Table 2: 2D-STE Parameters and Culprit Vessel Localization.

Parameter	LAD Culprit (n=60)	RCA Culprit (n=30)	LCx Culprit (n=30)	p-value	Sensitivity (%)	Specificity (%)	AUC
GLS (%)	-14.2 ± 2.5	-18.0 ± 3.0	-17.8 ± 2.8	<0.001	80	75	0.85
RLS (Apical Anterior) (%)	-10.5 ± 2.0	-16.5 ± 2.5	-16.0 ± 2.3	<0.001	85	80	0.89
RLS (Apical Inferior) (%)	-16.0 ± 2.3	-11.0 ± 2.2	-16.2 ± 2.4	<0.001	82	81	0.87
Apical Anterior-Apical Inferior RLS Difference (%)	5.5 ± 1.2	-5.5 ± 1.3	-0.2 ± 0.6	<0.001	85	80	0.89

Correlation Analysis: Coronary Angiography Findings

Angiographic assessment confirmed significant stenosis or occlusion in the culprit vessels identified via 2D-STE. Culprit vessel distribution was as follows: LAD (60 patients), RCA (30 patients), and LCx (30 patients). While stenosis severity varied, all patients fulfilled diagnostic criteria for NSTE-ACS. A strong association was observed between regions of impaired RLS and angiographically confirmed culprit lesion location. The degree of coronary stenosis correlated with the magnitude of RLS reduction, reinforcing the relationship between hemodynamic obstruction and regional myocardial dysfunction.

Overall Interpretation

2D-STE findings exhibited strong concordance with angiographic results, supporting its utility in noninvasive culprit vessel identification in NSTE-ACS. Regional strain disparities, particularly between apical anterior and inferior segments, demonstrated superior diagnostic performance, emphasizing the clinical relevance of segmental myocardial deformation assessment in this cohort. To evaluate the diagnostic accuracy of 2D-STE parameters in detecting the culprit vessel in NSTE-ACS patients, ROC curve analysis was performed. The assessment specifically examined variations in GLS and RLS among defined myocardial segments.

The strain difference between the apical anterior and apical inferior segments—regions primarily perfused by the LAD and RCA, respectively—exhibited the greatest diagnostic accuracy. The corresponding ROC curve produced an AUC of 0.89 (95% CI: 0.83–0.95), reflecting strong discriminatory ability. Employing an optimal threshold of -5.5%, this regional strain variation demonstrated 85% sensitivity and 80% specificity in differentiating LAD from non-LAD culprit lesions, with a PPV of 82% and a NPV of 83%.

While GLS showed diagnostic value, its performance was modest relative to regional strain variations. The ROC curve analysis for GLS produced an AUC of 0.78 (95% CI: 0.71–0.85), with a sensitivity of 75% and a specificity of 70% at the optimal cutoff of -15.5% for identifying a culprit vessel.

Quantitative Evaluation of Myocardial Deformation: Key Insights

This study demonstrates the clinical value of 2D-STE in providing quantitative measurements of myocardial deformation to pinpoint the affected coronary artery in patients with NSTE-ACS. The elevated AUC values for both regional strain disparities and GLS confirm their diagnostic efficacy in differentiating culprit vessel localization.

The superior discriminatory capability of regional strain differences—particularly between the apical anterior and apical inferior segments—underscores the strong correlation between localized myocardial dysfunction and specific coronary artery involvement. This observation aligns with the pathophysiological principle that ischemic segments supplied by the occluded vessel exhibit diminished strain. The enhanced diagnostic accuracy of regional strain over global strain implies that focal deformation abnormalities may offer greater sensitivity in detecting ischemia than comprehensive assessments.

Although GLS demonstrated moderate predictive performance, its diagnostic significance reinforces the necessity of incorporating regional strain analysis. While GLS serves as a composite measure of left ventricular function, it may lack the precision required to detect localized ischemia attributable to individual culprit vessels.

These results support the integration of 2D-STE as a supplementary diagnostic modality in NSTE-ACS management. Given its non-invasive nature and widespread availability, echocardiography-based strain analysis presents a practical approach for early culprit vessel identification, potentially optimizing revascularization timing. Additionally, the high sensitivity and specificity of regional strain differences suggest that 2D-STE may aid in risk stratification and inform subsequent diagnostic and therapeutic decision-making.

4. Discussion

This study demonstrated the significant diagnostic value of 2D-STE in detecting the culprit vessel in patients with NSTE-ACS. Specifically, both the regional strain difference between the apical anterior and apical inferior segments and GLS provided clinically useful information for determining the location of the affected vessel. These results suggest that 2D-STE serves as a non-invasive and accessible modality that can augment diagnostic strategies in NSTE-ACS management.

The regional strain difference exhibited high diagnostic accuracy (AUC = 0.89), underscoring the significance of assessing localized myocardial deformation. This finding aligns with the pathophysiological principle that ischemic myocardial segments supplied by the culprit vessel exhibit diminished strain. Prior research has similarly supported the role of regional strain analysis in culprit vessel identification [5]. For example, Cho et al. reported that regional myocardial strain derived from speckle tracking echocardiography effectively predicted the culprit coronary artery in acute coronary syndrome patients [5].

Although GLS demonstrated moderate diagnostic performance (AUC = 0.78), it still contributed to culprit vessel prediction, consistent with studies linking impaired GLS to significant coronary artery disease [9]. A meta-analysis by Ng et al. further substantiated the utility of speckle-tracking strain analysis in detecting obstructive coronary artery disease [4]. Our findings indicate that GLS offers a comprehensive evaluation of left ventricular function, complementing regional strain assessments.

The non-invasive nature of 2D-STE enhances its practicality for early culprit vessel detection, which is particularly advantageous in NSTE-ACS cases requiring prompt revascularization. Unlike invasive coronary angiography, 2D-STE can be performed bedside, enabling rapid risk stratification and informing subsequent diagnostic and therapeutic decisions. Marwick et al. emphasized the utility of echocardiography in acute coronary syndromes, reinforcing its non-invasive diagnostic potential [6].

Previous studies have explored 2D-STE applications in diverse cardiovascular pathologies, including myocardial ischemia and infarction. Leitman et al. introduced two-dimensional strain as a novel software-based approach for the instantaneous quantitative evaluation of myocardial function using echocardiography [3]. Our study expands its clinical relevance by demonstrating its efficacy in NSTE-ACS culprit vessel prediction.

Several limitations must be recognized. Firstly, the single-center nature of the study may limit the broader applicability of the results. Secondly, the relatively small sample size underscores the need for further validation in larger, multicenter investigations. Thirdly, no direct comparison was made between 2D-STE and other non-invasive imaging methods, such as cardiac magnetic resonance imaging (CMR). As highlighted by Thygesen et al. in the Fourth Universal Definition of Myocardial Infarction, the utility of alternative imaging modalities warrants consideration [8].

Despite these constraints, our study reinforces the clinical applicability of 2D-STE in NSTE-ACS. The robust diagnostic performance of regional strain differences supports its potential integration into routine practice for culprit vessel assessment. Armstrong et al. elaborated on the pathophysiology underlying acute coronary syndromes [7]. Future investigations could explore combining 2D-STE with additional biomarkers and imaging techniques to optimize NSTE-ACS diagnostic algorithms, as referenced in the 2015 ESC Guidelines by Roffi et al. [2] and the 2014 AHA/ACC NSTE-ACS management guidelines by Amsterdam et al. [1].

In summary, 2D-STE—particularly regional strain analysis—exhibits high diagnostic accuracy in NSTE-ACS culprit vessel prediction. Incorporating this technique into NSTE-ACS evaluation may expedite vessel identification and guide revascularization timing. Additional studies are required to confirm these results and evaluate the incorporation of 2D speckle-tracking echocardiography (2D-STE) into routine clinical practice. Delgado et al.

examined the prognostic significance of myocardial strain in coronary artery disease [10], whereas Ponikowski et al. summarized the European Society of Cardiology (ESC) recommendations for the treatment of heart failure [11].

5. Conclusion

In summary, this study demonstrates that 2D-STE, particularly by evaluating regional strain differences, is a reliable and non-invasive technique for detecting the culprit vessel in patients with NSTE-ACS. The method shows strong diagnostic accuracy and has the potential to facilitate earlier and more targeted revascularization strategies. Incorporating 2D-STE into routine clinical practice may improve risk stratification and enable prompt therapeutic measures, ultimately leading to better patient outcomes. This single-center investigation, utilizing a modest sample size, established the potential of 2D-STE in identifying culprit vessels in NSTE-ACS. However, the broader applicability of these findings may be constrained. Several limitations must be acknowledged, including the absence of comparative assessments with alternative imaging techniques, restricted long-term follow-up data, and the inherent operator dependence of 2D-STE, as well as possible selection bias. Additionally, the retrospective evaluation of coronary angiography may have introduced bias in the determination of culprit vessels.

Ethical consideration: The research protocol underwent review and received approval from the Fayoum University Faculty of Medicine's Ethical Review Committee. Formal authorization was secured from the hospital administration, including the Chief Medical Officer, as well as the Directors of both the Outpatient and Cardiology Departments.

Consent to participate: Following an explanation of the study's objectives by the researchers, participants were briefed on confidentiality protocols. Before any clinical evaluations and laboratory analyses, written informed consent was acquired from all participants as a mandatory requirement for study inclusion. Participants maintained the autonomy to discontinue their involvement in the research at any point without consequence.

Competing Interests: No conflicts of interest exist. The authors have no commercial or financial affiliations with any institutions or organizations that could pose a potential conflict. All associated costs were covered by the authors.

Authors' contributions: AMA: Protocol/project development, Data collection and management, manuscript writing/editing. GAA: Data analysis, manuscript writing, and editing. KAE: Protocol/project development, Data analysis, Manuscript writing/editing. All authors have read and approved the manuscript.

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