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IMPACT OF ISCHEMIA TIME ON REGIONAL WALL MOTION RECOVERY AND LEFT VENTRICULAR EJECTION FRACTION IN PATIENTS UNDERGOING PRIMARY PERCUTANEOUS CORONARY INTERVENTION FOR STEMI

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Abstract

Background: In acute ST-segment elevation myocardial infarction (STEMI), immediate mechanical reperfusion via primary percutaneous coronary intervention (PCI) is critical to limit myocardial injury. However, the time window from symptom onset to reperfusion—Total Ischemic Time (TIT)—directly impacts myocardial salvage. This study compares post-primary PCI changes in the Wall Motion Score Index (WMSI) and Left Ventricular Ejection Fraction (LVEF) between patients presenting early (3 hours) versus those presenting late (> 3 hours) from symptom onset.

Methods: A prospective comparative study was conducted over 12 months at the Faisalabad Institute of Cardiology. One hundred and sixty patients with first-onset

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STEMI successfully treated with primary PCI were divided into two equal groups: Group A (TIT < 3 hours, n=80) and Group B (TIT >3 hours, n=80). Serial transthoracic echocardiography (TTE) was pierformed at 24 hours and 2 months post-reperfusion to evaluate WMSI and LVEF.

Results: The mean age of the cohort was 62.5 +- 11.5 years, with a baseline male predominance (72.5%). Risk profiles and baseline lab parameters (except CK-MB) were evenly matched across both cohorts (p > 0.05). At the 24-hour baseline assessment, no significant differences were observed between Group A and Group B for WMSI (1.35 \pm 0.21 vs. 1.39 +_0.25, p = 0.734) or LVEF (43.40+- 7.31% vs. 42.51%+_ 7.73%, p = 0.64). However, at the 2-month follow-up, Group A demonstrated significantly greater regional wall motion recovery (WMSI: 1.09 +_ 0.23 vs. 1.28 +_ 0.28, p = 0.02) and significantly higher global systolic function (LVEF: 48.43% +_ 7.41% vs. 43.61\% +_ 7.92%, p = 0.02).

Conclusion: A total ischemic time of less than 3 hours is associated with a highly significant recovery of regional wall motion abnormalities and preservation of global left ventricular ejection fraction. Healthcare systems must prioritize reducing pre-hospital and system delays to preserve long-term cardiac performance.

INTRODUCTION

Cardiovascular disease (CVD) remains the leading cause of mortality worldwide, with a massive burden building within developing South Asian nations like Pakistan. Acute ST-segment elevation myocardial infarction (STEMI) represents the most critical manifestation of coronary artery disease. It is characterized by acute atherothrombotic coronary occlusion leading to full-thickness (transmural) myocardial ischemia and subsequent tissue necrosis.

Immediate mechanical restoration of epicardial blood flow via primary percutaneous coronary intervention (PCI) is the gold-standard therapeutic paradigm. While historical operational goals focused heavily on minimizing in-hospital metrics like door-to-balloon time, clinical paradigms have shifted to recognize Total Ischemic Time (TIT)—the absolute duration between symptom onset and

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balloon inflation—as the primary clinical driver of long-term prognosis. Ischemic injury operates on a time-dependent wavefront phenomenon, progressing outward from the subendocardium to the epicardium.

Transthoracic echocardiography (TTE) provides an accessible, non-invasive means to quantify these modifications by mapping regional wall motion abnormalities (RWMA). This is standardly operationalized through the Wall Motion Score Index (WMSI), a robust parameter that evaluates localized contractility and correlates with overall infarct size, remodeling pathways, and Left Ventricular Ejection Fraction (LVEF).

While data have shown the long-term benefits of timely revascularization, there is conflicting clinical literature regarding the exact time thresholds at which myocardial recovery transitions from salvageable to fixed stunning or necrosis. Some trials have reported minimal changes in wall recovery beyond specific thresholds, while others note linear decreases in benefits. This study evaluates the quantitative structural benefits of early reperfusion by directly comparing post-PCI changes in WMSI and LVEF between patients treated within 3 hours of symptom onset and those presenting after 3 hours.

2. Materials and Methods

2.1 Study Design and Setting

This prospective comparative study (quasi-experimental design) was conducted at the Department of Cardiology, Faisalabad Institute of Cardiology, Faisalabad, Pakistan, over a 12-month period following institutional approval.

2.2 Ethical Considerations

The study protocol was approved by the Institutional Review Board and Ethical Review Committee. It complied fully with the ethical tenets of the Declaration of Helsinki. Prior to enrollment, all patients or their legal guardians provided written informed consent in their native language.

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2.3 Study Population and Selection Criteria

The study enrolled patients aged 30 to 70 years presenting with first-onset STEMI who underwent successful primary PCI within 9 hours of symptom onset.

Inclusion Criteria: Patients diagnosed with STEMI between 30 and 70 years of age; symptoms lasting less than 9 hours; patients of both genders; and individuals who provided written informed consent.

Exclusion Criteria: Patients with symptoms lasting greater than 9 hours; historical evidence of previous cerebrovascular accidents (CVA) or pre-existing valvular heart disease; previous coronary revascularization (PCI/CABG); prior history of cardiomyopathy, baseline resting segmental wall motion abnormalities (RWMA), bundle branch blocks, pre-excitation, or permanent pacemakers; presenting ECG with fully formed pathologic Q-waves; bleeding diathesis; or those lost to follow-up

2.4 Operational Protocols and Interventions

Patients were allocated into two parallel comparative cohorts based on their timeline of clinical presentation:

Group A (Early Presenters): TIT < 3 hours from symptom onset to balloon inflation.

Group B (Late Presenters): TIT >3 hours from symptom onset to balloon inflation.

All patients received standardized emergency medical loading therapies consisting of oral aspirin (150–300 mg) and a potent P2Y_{12} inhibitor (Ticagrelor or Clopidogrel), coupled with weight-adjusted intravenous unfractionated heparin (UFH) in the cardiac catheterization laboratory. Primary PCI was executed using standard drug-eluting stent (DES) placement across the identified culprit infarct-related artery (IRA). Pre-dilatation, post-dilatation, and thromboaspiration were performed as clinically required. Multi-vessel coronary artery disease was defined as an angiographic stenosis >50% in non-culprit epicardial vessels.

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2.5 **Echocardiographic Assessment**

Transthoracic echocardiography (M-Mode, 2D, and Color Doppler) was performed within 24 hours of revascularization and repeated at 2 weeks, 1 month, and 2 months post-discharge. Imaging was conducted by two independent consultant cardiologists blinded to the patients' clinical presentation timelines.

The left ventricle was evaluated using a standardized 16-segment model. Each segment's systolic thickening and endocardial excursion were scored according to established guidelines:

* 1 Point = Normokinetic / Hyperkinetic
* 2 Points = Hypokinetic
* 3 Points = Akinetic
* 4 Points = Dyskinetic / Aneurysmal

The composite *Wall Motion Score Index (WMSI)* was mathematically derived as:

Global *Left Ventricular Ejection Fraction (LVEF)* was quantified via standard biometric biplane tracking methods and cross-checked using the verified regional-global validation regression formula:

2.6 Statistical Analysis

Statistical processing was conducted using SPSS version 25.0. Data normality was verified via the Shapiro-Wilk test. Continuous variables are expressed as Mean +_ Standard Deviation and compared using independent-samples t-tests or Analysis of Variance (ANOVA) for serial evaluations. Categorical parameters are expressed as frequencies and percentages (n) and analyzed using the Chi-Square test. A p-value < 0.05 was considered statistically significant.

3. Results

3.1 Demographic and Clinical Baseline Characteristics

A total of 160 patients met the eligibility criteria and completed the study (n = 80 in Group A; n = 80 in Group B). The overall cohort mean age was 62.5 +_ 11.5 years, with no significant variance

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between Group A (63 +_12 years) and Group B (62 +_11 years) (p = 0.564). A substantial baseline male predominance was observed across the trial population, with 116 males (72.5%) and 44 females (27.5%), which was evenly distributed between the cohorts (75.0% vs. 70.0%, p = 0.660).

The allocation of standard cardiovascular risk factors showed no statistically significant differences between groups (Table 1).

Table 1: Baseline Cardiovascular Risk Factor Distribution

	Group A	Group B	Total	P value
Diabetes	36(45%)	33(41.25%)	69 (43.12%)	0.598
Hypertension	41(51%)	43(53.75%)	84 (52.5%)	0.299
Smoking	40(50%)	39(48.75%)	70 (49.37%)	0.800
Family history	15(18.75%)	12(15%)	27 (16.8%)	0.413

3.2 Anatomical and Laboratory Profiles

	Group A	Group B	Total
Anterior	37(46.25)	28(35%)	65 (40.62%)
Inferior	35(43.75%)	41(51.25%)	76 (47.5%)
Lateral	6(7%)	9(11.25%)	15 (9.37%)
Posterior	2(2.5%)	2(2.5%)	4 (2.5%)
Total	80 (100%)	80 (100%)	160

3.3 Serial Echocardiographic Outcomes

Echocardiographic monitoring revealed distinctive functional trajectories between early and late revascularization pathways.

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Table 2: Comparative Serial Echocardiographic Measurements

	Group A	Group B	P value
AT 24 HOURS	1.35±0.21	1.39±0.25	0.734
AT 2 MONTH FOLLOW UP	1.09±0.23	1.28±0.28	0.02
	Group A	Group B	P-value
Ejection fraction at 24 hours	43.40±7.31	42.51±7.73	0.64
Ejection fraction at two months	48.43±7.41	43.61±7.92	0.02

*Indicates statistical significance ($p < 0.05$)

At the 24-hour post-PCI mark, regional and global function parameters between Group A and Group B were statistically indistinguishable, showing similar degrees of baseline myocardial stunning ($p > 0.05$).

However, at the 2-month clinical follow-up, Group A exhibited highly significant reductions in WMSI down to near-normal boundaries (1.09 +- 0.23), whereas Group B showed limited recovery (1.28 +_ 0.28, $p = 0.02$). This regional recovery pattern was mirrored by changes in global systolic function: Group A achieved a significant increase in mean LVEF to 48.43+_ 7.41\%, whereas Group B remained depressed at 43.61+- 7.92% ($p = 0.02$).

4. Discussion

The primary findings of this prospective comparative study show that early revascularization via primary PCI within 3 hours of symptom onset results in superior long-term recovery of regional wall motion and global left ventricular systolic function compared to late revascularization (> 3 hours). These results underscore the time-critical nature of mechanical reperfusion in acute STEMI,

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emphasizing that minimizing total ischemic time remains a primary determinant of myocardial salvage.

The baseline demographic distribution of our cohort—specifically the mean age of 62.5 +_ 11.5 years and a male-to-female ratio of 2.6:1—aligns closely with established epidemiological data for acute coronary syndromes. Endogenous estrogens provide a vascular protective effect in pre-menopausal women by downregulating atherogenic lipids and reducing systemic inflammation, leading to a delayed onset of CAD in female populations.

The comparable distribution of metabolic risk factors, such as diabetes and hypertension, across both presentation arms rules out confounding baseline differences in microvascular disease or pre-existing remodeling. However, the significantly elevated baseline CK-MB levels observed in Group B (223 +_109{ ng/mL} vs. 157 +_ 120{ ng/mL}, p = 0.001) provide clear enzymatic proof of time-dependent myocardial injury. Prolonged coronary occlusion allows the necrotic wavefront to extend from the subendocardium to the epicardium, increasing overall infarct size.

Our serialization of echocardiographic parameters offers insight into the timeline of myocardial recovery. The lack of significant difference in WMSI and LVEF at the 24-hour mark ($p > 0.05$) reflects the confounding impact of acute myocardial stunning. Immediately following reperfusion, viable but dysfunctional tissue coexists with necrotic zones, making early functional differences less distinct.

By the 2-month follow-up, a clear divergence emerged. Patients with a TIT of less than 3 hours achieved near-complete resolution of regional wall motion abnormalities (WMSI: 1.09 +_0.23) and significant improvements in global ejection fraction (LVEF: 48.43% +_ 7.41%). Conversely, late-presenting patients showed persistent regional impairment and limited ejection fraction recovery. These findings match recent work by Seo et al. (2022), who identified 180 minutes as a critical operational threshold for myocardial salvage. Early restoration of blood flow halts cellular necrosis, limits adverse extracellular matrix deposition, and prevents adverse left ventricular remodeling.

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Study Limitations

This investigation is limited by its single-center design and sample size (n=160). Additionally, functional recovery was evaluated using two-dimensional echocardiography rather than cardiac magnetic resonance (CMR) imaging, which is the current gold standard for tissue characterization and precise infarct sizing. The 2-month follow-up period also limits our ability to evaluate long-term ventricular remodeling or late-stage target vessel patency rates.

5. Conclusion

In the modern reperfusion era of STEMI management, a total ischemic time of 3 hours or less from symptom onset is a powerful predictor of regional wall motion recovery and global left ventricular preservation. While primary PCI remains indicated for later presentations up to 12 hours, the amount of salvageable myocardium drops substantially after the 180-minute mark. Healthcare systems must optimize pre-hospital care, streamline emergency medical transport networks, and reduce public response delays to maximize the clinical benefits of primary PCI.

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