Changes In Myocardial Work Index Before And After Complex Percutaneous Coronary Intervention In Patients With Chronic Coronary Syndrome

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ABSTRACT:

Background: Complex coronary lesions in chronic coronary syndrome (CCS) may cause persistent myocardial dysfunction despite successful revascularization. Myocardial work index (MWI) integrates myocardial deformation with estimated left ventricular pressure and may provide additional information beyond conventional echocardiographic measures.
Objective: To evaluate changes in global work index (GWI), global constructive work (GCW), global wasted work (GWW), and global work efficiency (GWE) before and three months after complex PCI.
Methods: This prospective observational analytic study included 30 patients with CCS who underwent successful elective complex PCI. Echocardiography was performed within 24 hours before PCI and at three months. MWI parameters were primary outcomes, while EF and GLS were secondary outcomes. Paired comparisons used the paired-samples t-test or Wilcoxon signed-rank test as appropriate.
Results: GWI increased from 1266.90 ± 81.08 to 1483.40 ± 188.71 mmHg%, and GCW from 1542.70 ± 180.95 to 1849.60 ± 206.58 mmHg%. GWW decreased from 248.50 to 214.00 mmHg%, while GWE increased from 88.00% to 91.00%. All changes were significant ($p<0.001$). EF increased from 54.50% to 58.50%, and GLS improved from −13.00% to −17.50% (both $p<0.001$).
Conclusion: Successful complex PCI was associated with significant improvement in MWI parameters, EF, and GLS at three months, suggesting improved myocardial mechanical performance after revascularization.

Keywords: chronic coronary syndrome, complex PCI, myocardial work index, pressure–strain loop, speckle-tracking echocardiography

1. Introduction

Chronic coronary syndrome (CCS) encompasses patients with established coronary artery disease who may continue to experience myocardial ischemia despite stable clinical presentation. When coronary anatomy is technically challenging, revascularization may require complex percutaneous coronary intervention (PCI). In this study, complex PCI included left main intervention, CTO intervention, two-stent treatment of a bifurcation lesion, placement of at least three stents, a cumulative stent length exceeding 60 mm, or multivessel PCI performed during the same procedure.

An acceptable angiographic result after PCI does not automatically mean that myocardial mechanics have completely normalized. EF can remain within the preserved range even when subtle ventricular dysfunction is present, whereas GLS can detect impaired longitudinal deformation but remains dependent on loading conditions. MWI adds a hemodynamic component by combining myocardial strain with an estimated left ventricular pressure curve, thereby offering a different perspective on ventricular performance (Chan et al., 2020; Manganaro et al., 2020).

The pressure–strain loop generates four complementary indices. GWI summarizes total ventricular work during the cardiac cycle; GCW describes work that contributes to effective contraction; GWW quantifies work performed during ineffective shortening or lengthening; and GWE expresses the proportion of total work that is constructive. These measures have been investigated in coronary artery disease and in patients undergoing revascularization (Lustosa et al., 2021; Fortuni et al., 2022).

Data describing serial MWI measurements in patients with CCS undergoing complex PCI are still limited. We therefore assessed the change in GWI, GCW, GWW, and GWE from the pre-procedural examination to three months after successful PCI. EF and GLS were analyzed in parallel as conventional measures of left ventricular systolic function.

2. Methodology

Design and setting. A prospective observational pre–post study was conducted in the Department of Cardiology and Vascular Medicine and the Echocardiography Laboratory of Dr. Soetomo General Academic Hospital, Surabaya, Indonesia.

Participants and sampling. Consecutive eligible patients with CCS undergoing elective complex PCI were recruited, yielding 30 participants for the final analysis. The complex-procedure definition followed the study protocol and included left main PCI, CTO PCI, two-stent bifurcation PCI, use of three or more stents, total stent length above 60 mm, or multivessel treatment in one session. Procedural success required an acceptable angiographic result, including TIMI 3 flow and no major procedural complication.

Echocardiographic assessment. Each participant underwent echocardiography before intervention and again at the three-month follow-up. MWI was derived from transthoracic speckle-tracking images using pressure–strain loop analysis. GWI, GCW, GWW, and GWE constituted the primary echocardiographic outcomes; EF and GLS were secondary outcomes. The systolic blood pressure obtained during the examination was used in the non-invasive estimation of left ventricular pressure.

Statistical analysis. Analyses were performed with IBM SPSS Statistics version 29. The Shapiro–Wilk test was used to examine distributional assumptions. For the pre–post comparison, normally distributed variables were analyzed with a paired t-test, whereas the Wilcoxon signed-rank test was applied when normality was not met. Associations between clinical characteristics and changes in MWI were examined using Pearson or Spearman correlation as appropriate. Statistical significance was defined as $p<0.05$.

3. Results

Thirty patients were included in the final analysis. Mean age was 59.40 ± 5.94 years and mean systolic blood pressure was 132.20 ± 13.01 mmHg. Median SYNTAX score was 30.00 (28.00–31.00). Twenty-one patients (70.0%) were

men. Hypertension was present in all patients, diabetes mellitus in 19 (63.3%), dyslipidemia in 24 (80.0%), and a history of smoking in 14 (46.7%). All patients received antiplatelet, beta-blocker, ACE inhibitor/ARB/ARNI, and statin therapy; 9 patients (30.0%) received MRA therapy.

Table 1. Baseline characteristics of the study population

Variable	Value	n (%)
Age, years	59.40 ± 5.94	
Systolic blood pressure, mmHg	132.20 ± 13.01	
SYNTAX score	30.00 (28.00–31.00)	
Male sex		21 (70.0)
Hypertension		30 (100.0)
Diabetes mellitus		19 (63.3)
Dyslipidemia		24 (80.0)
Smoking history		14 (46.7)
MRA use		9 (30.0)

All MWI parameters changed significantly three months after PCI. Mean GWI increased from 1266.90 ± 81.08 to 1483.40 ± 188.71 mmHg%, and mean GCW increased from 1542.70 ± 180.95 to 1849.60 ± 206.58 mmHg%. Median GWW decreased from 248.50 (234.75–275.50) to 214.00 (200.50–234.75) mmHg%, while median GWE increased from 88.00% (85.50–89.00) to 91.00% (88.75–91.25). All changes were statistically significant ($p<0.001$).

Table 2. Changes in myocardial work and conventional echocardiographic parameters

Parameter	Before PCI	3 months after PCI	p-value
GWI, mmHg%	1266.90 ± 81.08	1483.40 ± 188.71	<0.001
GCW, mmHg%	1542.70 ± 180.95	1849.60 ± 206.58	<0.001
GWW, mmHg%	248.50 (234.75–275.50)	214.00 (200.50–234.75)	<0.001
GWE, %	88.00 (85.50–89.00)	91.00 (88.75–91.25)	<0.001
EF, %	54.50 (47.75–56.00)	58.50 (49.00–60.00)	<0.001
GLS, %	−13.00 (−14.00 to −11.00)	−17.50 (−18.00 to −15.00)	<0.001

The boxplots demonstrate higher GWI and GCW, lower GWW, and higher GWE after PCI, consistent with improved myocardial mechanical performance and efficiency.

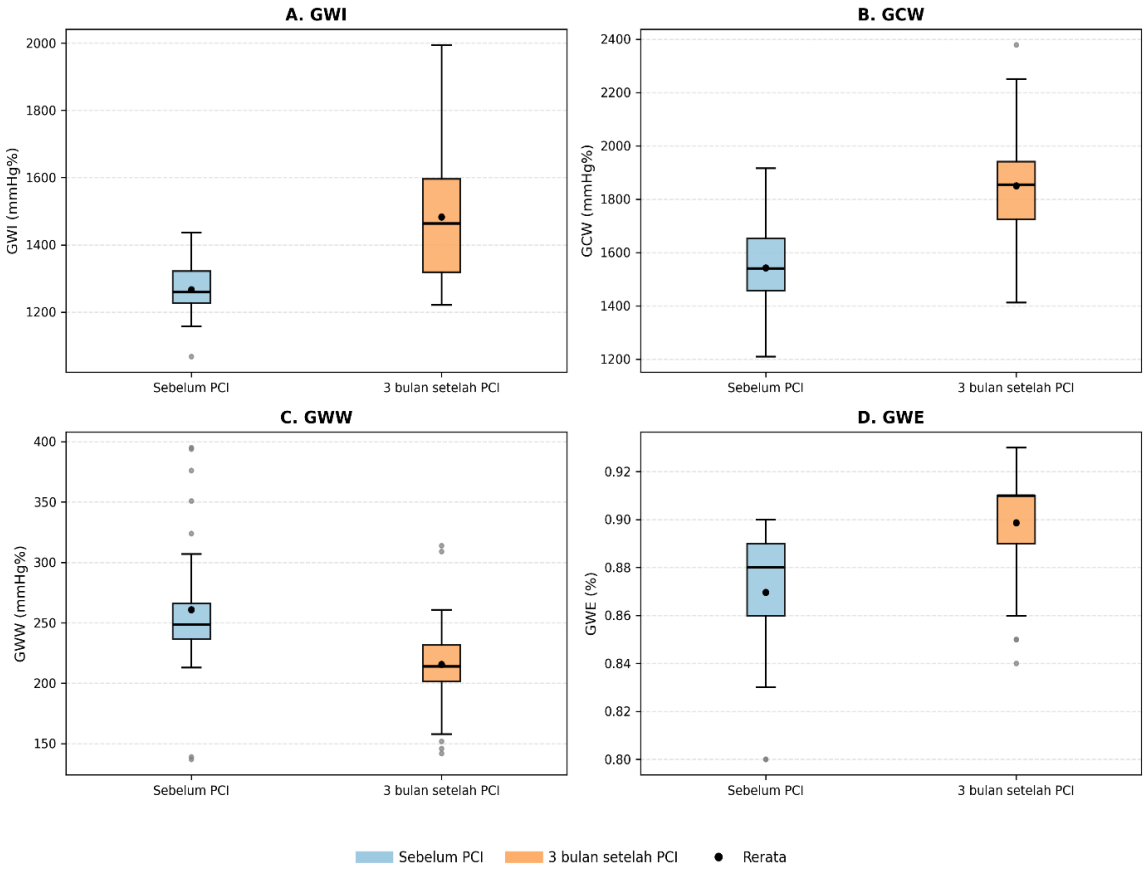

Figure 1. Changes in GWI, GCW, GWW, and GWE before and three months after complex PCI.

EF increased from a median of 54.50% (47.75–56.00) before PCI to 58.50% (49.00–60.00) at three months, while GLS improved from −13.00% (−14.00 to −11.00) to −17.50% (−18.00 to −15.00); both changes were statistically significant ($p<0.001$).

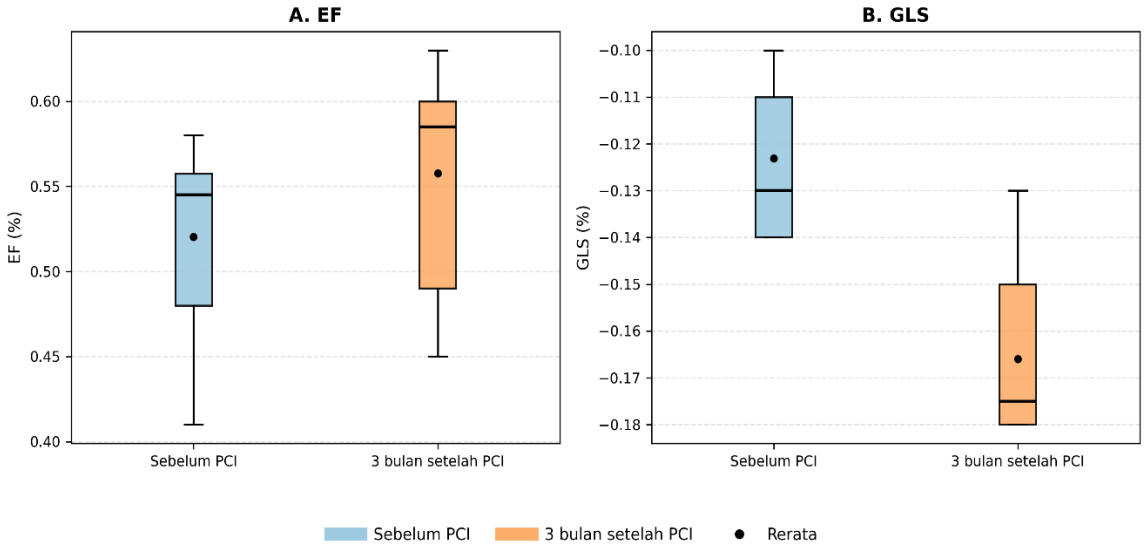

Figure 2. Changes in EF and GLS before and three months after complex PCI.

In exploratory correlation analysis, age was positively correlated with change in GWI ($r=0.534$, $p=0.002$). Age was not significantly associated with changes in GCW, GWW, or GWE. Systolic blood pressure and SYNTAX score were not significantly associated with changes in any MWI parameter.

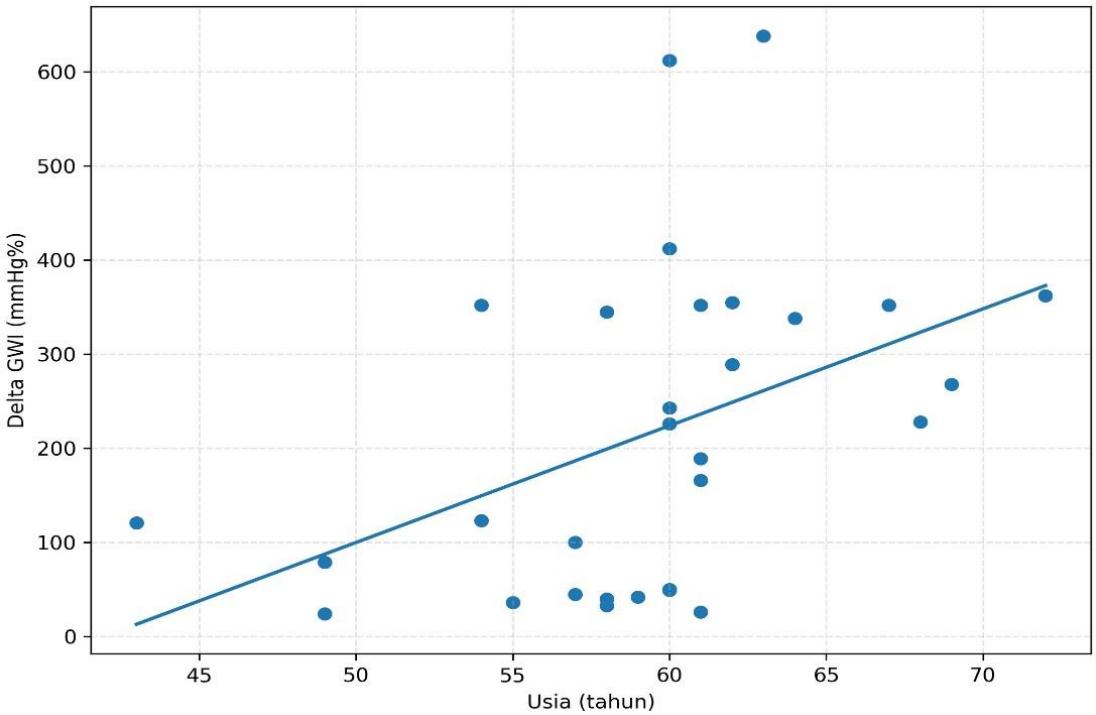

Figure 3. Scatter plot showing the relationship between age and change in GWI.

Diabetes mellitus, dyslipidemia, and smoking history were not significantly associated with changes in MWI. MRA use was significantly associated with change in GWI ($p<0.001$), but not with changes in GCW, GWW, or GWE.

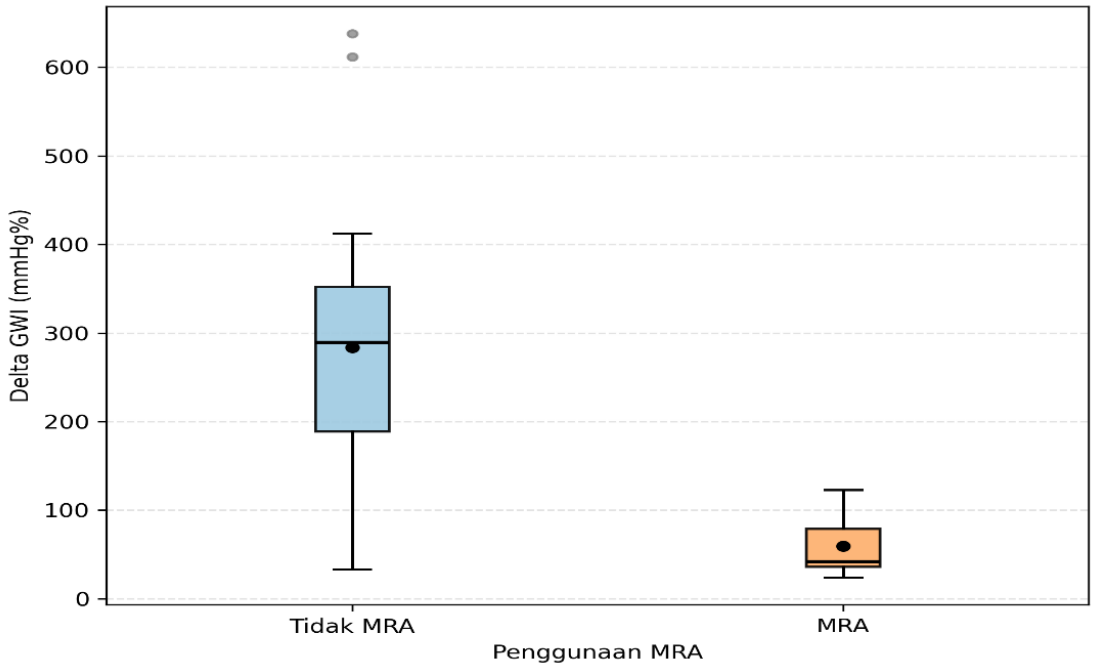

Figure 4. Change in GWI according to MRA use.

4. Discussion

The main observation was a consistent improvement across all four myocardial work indices at the three-month assessment. After complex PCI, GWI and GCW were higher, whereas GWW was lower and GWE was higher. Taken together, this pattern suggests that the

post-intervention ventricle performed a greater proportion of effective mechanical work.

The rise in GWI and GCW indicates greater overall and effective myocardial work after revascularization. At the same time, the fall in GWW and rise in GWE indicate a reduction in mechanically inefficient contraction. One possible explanation is recovery of dysfunctional but viable myocardial segments after restoration of coronary perfusion, although myocardial viability was not directly measured in this study.

The findings are consistent with previous studies demonstrating that myocardial work can provide functional information after coronary revascularization. Fortuni et al. reported an association between myocardial work, particularly GCW and GWE, and reverse left ventricular remodeling after coronary revascularization. Jin et al. also demonstrated differences in myocardial work parameters according to microvascular perfusion after revascularization. Although those populations differed from the present CCS cohort, the findings support the potential sensitivity of MWI to changes in myocardial function after revascularization (Fortuni et al., 2022; Jin et al., 2022).

The parallel improvement in EF and GLS supports the interpretation that ventricular systolic performance improved during follow-up. The shift of GLS toward more negative values is compatible with better longitudinal shortening. MWI, however, contributes information that EF and GLS alone cannot provide because it combines deformation with estimated ventricular pressure and distinguishes effective from ineffective work (Chan et al., 2020; Boerma et al., 2021).

Age showed a positive correlation with change in GWI. This finding may reflect differences in baseline myocardial impairment or cumulative cardiovascular burden in older patients, but the observational design does not allow a causal interpretation. Systolic blood pressure and SYNTAX score were not significantly associated with MWI changes, suggesting that anatomical complexity and the measured hemodynamic load do not necessarily translate directly into the magnitude of functional recovery over three months.

MRA use was associated with change in GWI, but not with the other MWI parameters. This result should be considered exploratory because treatment was not randomized and the study was not designed to evaluate the causal effect of MRA. Similarly, the absence of significant associations for diabetes, dyslipidemia, and smoking may reflect the limited sample size and distribution of clinical characteristics.

From a clinical perspective, serial MWI may be useful when evaluating ventricular response after technically complex revascularization. It can be interpreted alongside EF and GLS to determine not only whether systolic function has changed, but also whether myocardial work has become more efficient. Adequate image quality and standardized blood-pressure measurement remain important for reproducible assessment.

Several limitations should be considered. The sample was relatively small and came from a single institution, and there was no non-revascularized comparison group. Consequently, the observed pre–post differences cannot be attributed exclusively to PCI. MWI is also sensitive to image acquisition, tracking quality, and the blood pressure used for pressure–strain calculations. Finally, the three-month follow-up does not address longer-term changes, and direct measures of ischemic burden, viability, microvascular function, and completeness of revascularization were not incorporated.

5. Conclusion

In patients with chronic coronary syndrome and complex coronary lesions, successful complex PCI was associated with significant improvement in myocardial work three months after the procedure. GWI, GCW, and GWE increased, while GWW decreased. Improvements in EF and GLS supported improved left ventricular systolic function. MWI may therefore serve as a useful complementary echocardiographic parameter for functional assessment after complex PCI,

although larger controlled studies with longer follow-up are needed.

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8. Author Declaration

The authors confirm that this manuscript is based on the authors' original academic work. The authors declare no conflicts of interest.