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Original Article

# Outcome Analysis and Determinants of Major Adverse Cardiac Events in Young Adults After Coronary Artery Bypass Graft Surgery Who Participated in Early Phase II Cardiac Rehabilitation Program: A single–center study

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**Abstract**

**Background:** Cardiac rehabilitation (CR) program is proven to reduce mortality after coronary artery bypass surgery (CABG). Our study aimed to investigate the determinants of survival in young adult patients after CABG.

**Methods:** This was a single-center, longitudinal study with a survival analysis method from MACE of consecutive patients under 55 years old who underwent CABG and participated in the early phase II CR program between January 2017 and December 2018. The major adverse cardiac events (MACE) rates were determined over a 2-year follow-up time. Cox regression and Kaplan-Meier analysis were used to determine the predictors of the events.

**Results:** 279 patients who fulfilled the inclusion criteria were recruited in this study. MACE happened to 23 (8.45%) of them (3 patients died, 20 patients were hospitalized). Patients who dropped out (12%) from the CR program had a higher risk of developing events (HR 3.86, 95% CI 1.36-10.99). Of those who completed the CR program (245 patients), beta-blocker usage, chronotropic index, resting heart rate, and functional capacity after the CR program independently correlated with MACE. Six-minute walk distance (6-MWD) ≤376 meters was a significant predictor (p=0.001), with a shorter mean survival time of 6 months.

**Discussions:** The early phase II CR program after CABG in young adult patients reduced the risk for cardiovascular mortality, major adverse events, and related readmission. It also increased the survival rate and mean survival time for participants who completed the CR program compared to dropouts. Optimum beta blocker medication, chronotropic index, resting heart rate, and functional capacity after the CR program are essential predictors of survival after CABG in young adults.

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**Keywords:** *Cardiac Rehabilitation, Young adult, Mortality, Major advevse cardiac event, Predictor.*

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## Background

Coronary artery bypass graft (CABG) surgery becomes an option for myocardial revascularisation, especially for patients with more complex coronary anatomy and comorbidities such as diabetes mellitus and renal failure.[1] Compared to percutaneous transluminal coronary angioplasty, CABG is a more invasive procedure with more difficulties. It is associated with potential complications, so it usually needs 2 to 6 weeks of convalescence to recover.[2]

Patients need a full and prompt physical recovery after surgery to allow a fast return to daily life activities, especially at younger and more productive ages. A cardiac rehabilitation (CR) program was recommended for early post-CABG patients and was classified as a class IA recommendation.[3,4] Supervised exercise-based CR is crucial to secondary prevention and reduces hospital admissions and all-cause mortality by 15%–28% in moderate to long-term studies.[5-6]

Furthermore, traditionally, most institutions do not deliver outpatient supervised CR exercise (CR phase II) until 6 weeks after CABG, so functional capacity may decline gradually.[7] In several cardiovascular rehabilitation facilities in Indonesia, the phase II CR program for patients after CABG is implemented earlier, starting within 1 week after hospital discharge. However, there is still a lack of evidence of the benefit of midterm follow-up.

Among the key clinical endpoints in cardiovascular research, major adverse cardiac events (MACE) have emerged as critical markers for evaluating disease progression and therapeutic efficacy. MACE, which encompasses events such as myocardial infarction, stroke, and cardiovascular death, provides a comprehensive framework for assessing patient outcomes beyond traditional measures. Understanding the factors influencing the occurrence of MACE and their implications on overall patient outcomes is essential for improving cardiovascular care. Mortality, as a component of MACE, underscores the severity of these events and highlights the need for integrative approaches in cardiovascular risk management.

From our knowledge, no published study evaluated the effect of early phase II CR program post-CABG in young adults and the determinants of the outcome in this population, especially in Indonesia. This study aimed to investigate the benefit of early phase II CR programs in midterm outcomes and the determinants of event-free survival from MACE in young adult patients after CABG. By emphasizing MACE, including mortality, the study seeks to provide a comprehensive understanding of cardiovascular risk factors and their impact on patient prognosis.

## Methods

### Study design and population

This was a single-center, longitudinal study with a survival analysis. The subjects were patients under 55 years old who underwent CABG at the National Cardiovascular Center Harapan Kita and participated in the early phase 2 CR program between January 2017 and December 2018. The clinical data were obtained from medical records and a registry. The patients were excluded if they underwent combined cardiac surgeries or were contraindicated for exercise programs. Patients who attended less than ten sessions of the CR program were classified as dropouts but still included in the follow-up study. Meanwhile, the survival analysis study included patients who attended at least ten sessions.

We reviewed medical records and database to obtain basic data (sex, age, height, weight, length of stay), clinical characteristics (CAD risk factors, resting blood pressure and heart rate, preoperative left ventricular ejection fraction (LVEF), coronary stenosis severity (number of stenotic coronary arteries), critical events (life-threatening complication during surgery and morbidity during hospitalization), history of CAD medication, functional capacity before and after CR program by 6-minute walk distance (6-MWD) and treadmill test (TMT) parameters (maximum heart rate and blood pressure, 1-minute heart rate recovery abnormality, and chronotropic index). We also evaluate physical activity levels after the CR program by using an international physical activity questionnaire (IPAQ) using telephone interviews at the sixth-month follow-up and the end of 2 years follow-up duration.

### Early phase II cardiac rehabilitation program

Patients registered and started the CR program within the first week after discharge. They attended a

**Table 1.** Baseline characteristics and comparison between drop-out and complete groups.

| Variables | All population N=279 | Cardiac Rehabilitation Program Groups | | p |
|---|---|---|---|---|
| | | Drop out (<10 times) n=34 | Complete (≥ 10 times) n=245 | |
| Demographic: | | | | |
| Age, year (IQR) | 51 (7) | 51 (7) | 51 (6) | 0.92 |
| Male, n (%) | 243 (87%) | 26 (78.1%) | 217 (88.7%) | 0.161 |
| Clinical characteristic: | | | | |
| Malignant arrhythmia, n (%) | 37 (13.2%) | 6 (17.6%) | 31 (12.6%) | 0.181 |
| Shock or massive bleeding, n (%) | 13 (4.8 %) | 2 (5.8%) | 11 (4.6%) | 0.403 |
| In hospital complications, n (%) | 34 (12.1%) | 1 (2.9%) | 33 (13.4%) | 0.166 |
| length of stay, day (IQR) | 6 (3) | 6 (6) | 6 (3) | 0.451 |
| body mass index, kg/m2 (IQR) | 25 (4) | 23.9 (1.6) | 25.5 (4) | 0.412 |
| symptomatic HF, n (%) | 210 (75.1%) | 23 (67.6%) | 187 76.1%) | 0.497 |
| LV EF, % (IQR) | 57 (23) | 58 (15) | 56 (24) | 0.335 |
| Hypertension, n (%) | 154 (55.1%) | 21 (61.7%) | 133 (54.5%) | 0.604 |
| Diabetes, n (%) | 117 (42.6%) | 11 (32.35%) | 106 (43.5%) | 0.395 |
| Medication: | | | | |
| Aspirin, n (%) | 261 (93.7%) | 29 (85.3%) | 232 (94.7%) | 0.236 |
| Clopidogrel, n (%) | 23 (8.2%) | 3 (8.8%) | 20 (8.2%) | 0.737 |
| ACE-inhibitor, n (%) | 254 (91.1%) | 32 (94.1%) | 222 (90.8%) | 0.750 |
| Calcium channel blocker, n (%) | 11 (4.0%) | 1 (2.9%) | 10 (4.2%) | 0.313 |
| Beta blocker, n (%) | 251 (90.0%) | 31 (91.1%) | 220 (89.8%) | 0.900 |
| Statin, n (%) | 256 (91.8%) | 31 (91.1%) | 225 (91.8%) | 0.733 |
| Nitrate, n (%) | 9 (3.2%) | 1 (2.9%) | 8 (3.3%) | 0.944 |
| Phase II CR program | | | | |
| Duration phase II CR, day (IQR) | 20 (12) | | 20 (12) | |
| 6-MWD pre-CR, meter (SD) | 311 (74.3) | 302 (65.8) | 318 (66) | 0.622 |
| 6-MWD post-CR, meter (SD) | 393 (55.9) | - | 394 (56) | - |
| Treadmill test | | | | |
| Resting heart rate, bpm (IQR) | 78 (14) | 75 (18) | 78 (15) | 0.892 |
| Resting SBP, mmHg (IQR) | 107 (20) | 107 (16) | 107 (18) | 0.911 |
| Resting DBP, mmHg (IQR) | 66 (12) | 68 (16) | 66 (11) | 0.956 |
| Max. heart rate, bpm (IQR) | 125 (32) | - | 125 (32) | - |
| Maximum SBP, mmHg (IQR) | 140 (20) | - | 140 (20) | - |
| Maximum DBP, mmHg (IQR) | 80 (10) | - | 80 (10) | - |
| chronotropic index, % (IQR) | 51.7 (27.8) | - | 51.7 (27.8) | - |
| HRR-1, bpm (IQR) | 14 (14) | - | 14 (14) | - |
| Predicted Mets, Mets (IQR) | 7.2 (2.8) | - | 7.2 (2.8) | - |
| Follow up IPAQ | | | | |
| 6-month moderate-high PA (%) | 55.6% | 55.2% | 56.3% | |
| End follow up moderate-high PA(%) | 56.8% | 56.5% | 58.8% | |

Note: IQR: interquartile range; LVEF: left ventricle ejection fraction; ACE: angiotensin-converting enzyme; 6-MWD: six-minute walk distance; SBP: systolic blood pressure; DBP: diastolic blood pressure; HRR-1: heart rate recovery minute 1; TMT: treadmill test; IPAQ: International physical activity questionnaire; PA: physical activity, p: for comparison between Dropout group and Complete group.

**Table 2.** Mid-term outcome of post-CABG patients.

| Outcomes | Total N=279 | Drop out (<10 times) n=34 | Complete (≥ 10 times n=245 |
|---|---|---|---|
| Major adverse cardiac events (composite endpoint) | 23 (8.2%) | 7 (20.5%) | 16 (6.5%) |
| Acute HF | 10 (3.5%) | 4 (11.8%) | 6 (2.4%) |
| NSTEMI | 4 (1.4%) | 1 (2.9%) | 3 (1.2%) |
| Unstable angina pectoris | 5 (1.8%) | 1 (2.9%) | 4 (1.6%) |
| Re-PCI | 2 (0.7%) | 0 (0 %) | 2 (0.8%) |
| Stroke | 2 (0.7%) | 1 (2.9%) | 1 (0.4%) |
| Cardiovascular mortality | 5 (1.8%) | 1 (2.9%) | 4 (1.6%) |

HF: Heart Failure; NSTEMI: Non-ST segment elevation myocardial infarction; PCI: percutaneous coronary intervention.

pre-participation orientation, and medical assessment and underwent a pre-participation six-minute walk test (6-MWT). This early phase II CR program was carried out for a maximum of 12 sessions with 3 to 5 sessions per week. It consisted of several counseling and education sessions regarding risk factor prevention and control, self-care, and supervised exercise program sessions.

Each exercise session took about 60 minutes and consisted of warming up, stretching, and aerobic exercise. The exercise took 30 – 40 minutes on an ergocycle, corridor walk, and/ or treadmill. Warming up and stretching were performed for the first 10 minutes, and relaxation in the last 10 minutes of each exercise session. Exercise intensity was adjusted individually to the increase of 10-20 beats per minute from their resting heart rate and subjective symptoms. The walking distance, ergo cycle workload, and treadmill speed were adjusted gradually for every consecutive exercise session. The exercise sessions were supervised by trained nurses, physiotherapists, and a cardiologist. Post-participation functional capacity tests were performed at the last session using 6-MWT and TMT the next day with standardized protocols.

### Endpoints

The incidence of major adverse cardiovascular events (MACE), including stroke and cardiac-related emergency re-hospitalization, percutaneous transluminal coronary angioplasty (PTCA), repeat CABG, cardiac-related mortality, and all-cause mortality was recorded as an outcome in the 2-year follow-up. All outcome data were collected from the hospital database, medical records, and telephone calls made directly to the patients, their relatives, or caregivers. For these analyses, the time at risk began on the last day of the CR program and ended on the date of the outcome event or on January 31, 2020.

### Statistical Analysis

Continuous data of baseline characteristics and clinical data are reported as mean (SD) if the data distribution is normal, median (IQR) if the distribution is not normal, or proportions by % for categorical data. For bivariate analysis, the Chi-Square test was used to analyze categorical data, and an independent T-Test or Mann-Whitney U test was used to compare the mean of continuous data. Survival was described using the event-free rate by plotting cumulative incidence estimates using a single Kaplan–Meier curve for all patients and a separate Kaplan–Meier curve for patients who complete the CR program and drop out. The Cox proportional multivariate hazard regression model was used to determine the predictors of events and the hazard ratio of each variable and to develop risk score models to predict major cardiovascular events of patients who finished the CR program after CABG. All statistical analysis was conducted using SPSS 20.0.

## Results

The baseline characteristics of all subjects and the comparison between the patients who completed the program (Complete group) and those who dropped out (Drop Out group) are shown in Table 1. Both groups

**Table 3.** Univariate and Multivariate Analysis of Survival from MACE in CABG Patients Under 55 Years Old Completed Early Phase II Cardiac Rehabilitation Program.

| Variable | Univariate Analysis | | | Multivariate Analysis | | |
|---|---|---|---|---|---|---|
| | HR | 95% CI | P value | HR | 95% CI | P value |
| Male | 0.98 | 0.22 □ 4.29 | 0.979 | 0.63 | 0.13 – 3.16 | 0.572 |
| Age | 0.95 | 0.87 – 1.04 | 0.274 | | | |
| Smoker | 1.05 | 0.39 – 2.84 | 0.914 | | | |
| Diabetes Mellitus | 3.10 | 0.88 – 10.88 | 0.077 | 0.31 | 0.08 – 1.16 | 0.083 |
| Hypertension | 0.91 | 0.35 – 2.36 | 0.851 | | | |
| Dyslipidemia | 0.51 | 0.19 – 4.10 | 0.194 | 0.57 | 0.17 – 1.78 | 0.328 |
| Aspirin | 0.64 | 0.08 – 4.85 | 0.668 | | | |
| P2Y12 inhibitor | 1.70 | 0.38 – 7.51 | 0.482 | | | |
| Statin | 0.37 | 0.10 – 1.28 | 0.161 | 0.21 | 0.04 – 1.09 | 0.512 |
| ACE Inhibitor | 0.59 | 0.19 – 1.82 | 0.359 | | | |
| CCB | 2.52 | 0.58 – 11.24 | 0.212 | 4.32 | 0.61 – 31.08 | 0.146 |
| Beta-blocker | 0.20 | 0.07 – 0.54 | 0.002 | 0.15 | 0.31 – 0.72 | 0.018 |
| Diuretic | 0.64 | 0.24 – 1.69 | 0.369 | | | |
| BMI | | | | | | |
| Normal | | | 0.996 | | | |
| Underweight | 0.03 | 0.01– 0.06 | 0.987 | | | |
| Overweight | 0.87 | 0.26 – 2.90 | 0.825 | | | |
| Obesity | 1.01 | 0.33 – 3.10 | 0.978 | | | |
| Malignant arrhythmia complication | 3.42 | 1.10 – 10.57 | 0.033 | 4.52 | 0.96 – 17.58 | 0.079 |
| Shock and massive bleeding | 3.45 | 0.78 – 15.31 | 0.102 | 3.94 | 0.70 – 22.10 | 0.120 |
| In-hospital co-morbid | 1.81 | 0.52 – 6.32 | 0.348 | | | |
| Length of stay | 0.99 | 0.98 – 1.01 | 0.821 | | | |
| % LVEF | 0.98 | 0.96 – 1.02 | 0.635 | | | |
| Higher resting HR | 1.04 | 0.99 – 1.07 | 0.055 | 1.04 | 1.01 – 1.08 | 0.020 |
| Higher maximum HR | 0.98 | 0.95 – 1.01 | 0.196 | | | |
| Abnormal HR recovery min-1 | 1.67 | 0.56 – 4.98 | 0.354 | | | |
| Higher chronotropic index | 0.96 | 0.93 – 0.99 | 0.020 | 0.95 | 0.92 – 0.98 | 0.011 |
| 6-MWD pre-CR | 0.98 | 0.97 – 1.03 | 0.284 | | | |
| 6-MWD post-CR | 0.99 | 0.98 – 1.00 | 0.050 | 0.99 | 0.98 – 1.00 | 0.052 |
| Low physical activity IPAQ | 7.86 | 1.74 – 35.53 | 0.037 | 0.048 | 0.004 – 1.072 | 0.062 |

CI: confidence interval; ACE: angiotensin-converting enzyme; CCB: calcium channel blockers; BMI: body mass index; LVEF: left ventricle ejection fraction; HR: heart rate; 6-MWD: six-minute walk distance; CR: cardiac rehabilitation; IPAQ: International Physical Activity Questionnaire.

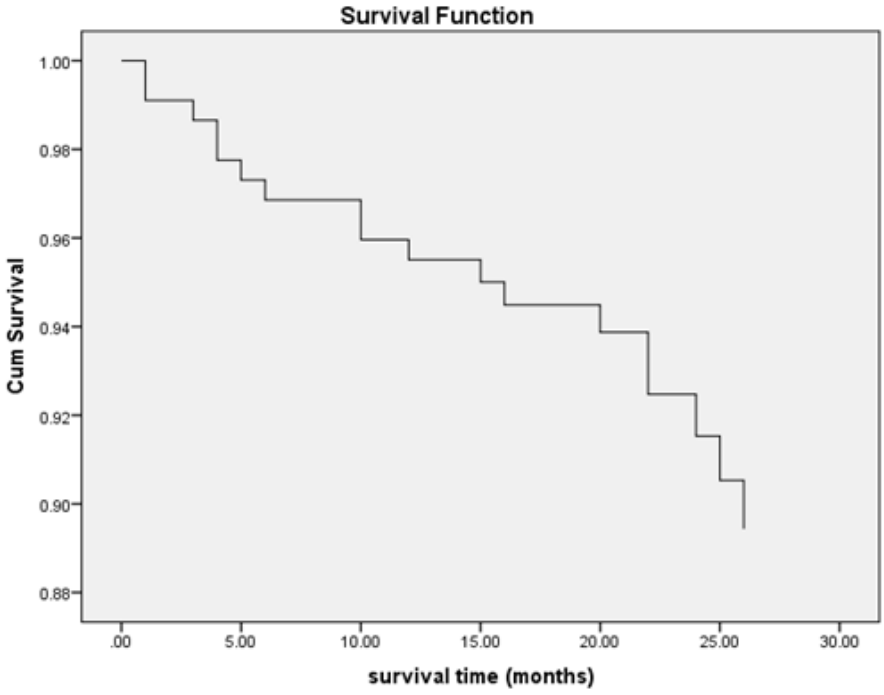


**Figure 1.** MACE Survival Cox regression analysis plot of young adult CABG patients.

had similar demographic, clinical, and medication characteristics. Table 1 also presents 6-MWD, the treadmill test results, and the results of IPAQ of subjects in the Complete group.

This study collected data from 279 patients who met the criteria and 245 (88%) who completed the CR program. The median age of all patients was 51 years old, and the majority were male (87.4%). The median duration of participation in the early phase II CR program was 20 days.

## Outcomes

During the follow-up time (median 25 months), composite MACE occurred in 23 patients (8.2%), consisting of acute heart failure (acute lung oedema or acute decompensated heart failure), acute coronary syndrome, angioplasty, stroke, and cardiovascular mortality in 5 (1.8%) patients (1,8%). Table 2).

## Effect of CR on survival and functional capacity

The survival rate for the composite end-point (all major adverse cardiac events) in 25 months of median follow-up was 91.8% (Figure 1). The Estimated mean survival time/event-free time of the total population of this study was 33.7 months (95% CI: 32.6-34.7 months).

The effect of the CR program on survival was analyzed using Cox regression. Patients who dropped out from the program had a hazard risk of MACE 3.75 (95% CI 1.3 – 10.5, p=0.012) compared to patients who completed the CR program. Kaplan-Meier survival analysis revealed that the mean survival time for the complete CR group was 4 months longer than that of the dropout group. (34 vs 30 months) (figure 2).

The effect of the early exercise-based CR program in 245 patients who completed the CR program was represented by the improvement of 6-MWD, which increased from 318±66 meters to 394±56 meters after the CR program (p<0.001).

## Multivariate analysis of survival predictors in patients who completed CR program

The predictors of survival of patients who completed the CR program were analyzed using univariate and multivariate logistic regression analysis. Variables with p-value <0.25 in the univariate analysis were included in the multivariate logistic regression model. Univariate

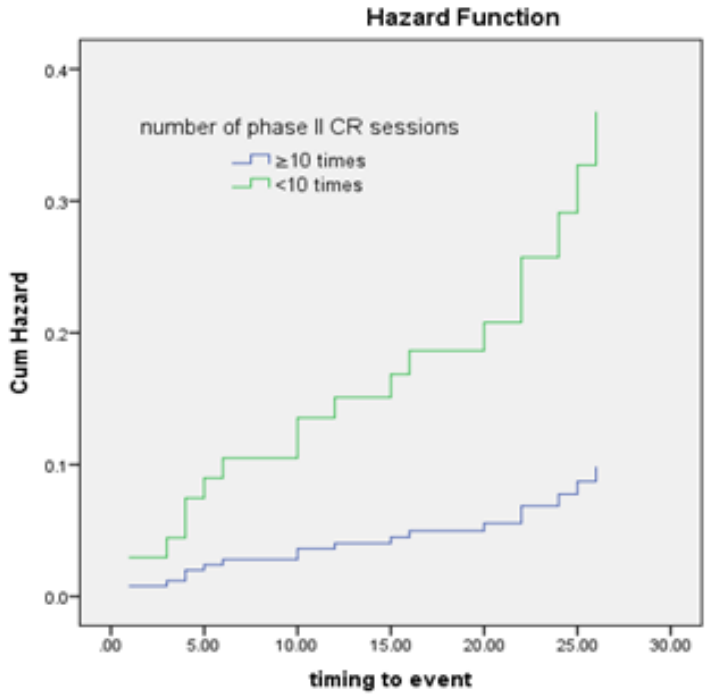


**Figure 2.** Hazard function plot of CR program status between drop out (<10 times) vs complete (≥ 10 times) on MACE outcome.

analysis revealed that diabetes mellitus, dyslipidemia, absence of statin and beta-blocker usage, arrhythmia, shock, massive bleeding, higher resting heart rate, lower chronotropic index, and lower functional capacity were associated with higher adverse cardiac event rates. The model from multivariate Cox regression revealed that only beta-blocker usage, chronotropic index, resting heart rate, and functional capacity (6-MWD) after the CR program were independently correlated with the event (Table 3) with p model=0.009, and good fitness of the data (Hosmer and Lemeshow test p=0.478). The new model explained 79.8% (Nagelkerke R2) of the variance in CAD and correctly re-classified 92.7% of cases.

### Functional capacity and survival outcome

As presented in Table 3, functional capacity, represented by 6-MWD post-CR, was identified as an independent predictor of event-free. The 6-MWD post-CR positively discriminated composite MACE outcome and survival in 25 months follow-up period based on the ROC curve with area under the curve (AUC) 0.65 (P=0.043) with the best cut-off at 376 meters with sensitivity 71% and specificity 65%. (Figure 3) After controlling other confounding factors, 6-MWD post-CR <376 meters had a hazard ratio of 6.2 (1.8 – 11.0, 95% CI, p = 0.001) to develop the event in follow-up duration compared to those with 6-MWD post-CR≥ 376 meters (29 months vs 35 months). The Kaplan-Meier survival function plot can be seen in Figure 4.

## Discussion

In this study, young adults with sufficient CR participation after CABG were associated with a lower hazard ratio or longer adverse event-free than the dropout group. Similar to other studies that suggested patients with good compliance in the CR program obtained similar outcomes in 1-3 years, lower adverse events and mortality, and longer mean survival time.8-11 For young adults, compliance with a hospital-based CR program is a problem because they are at a productive age, and returning to work is one of the barriers. However, the critical consideration for analyzing CR studies is the variety of programs among centers and population characteristics.[12]

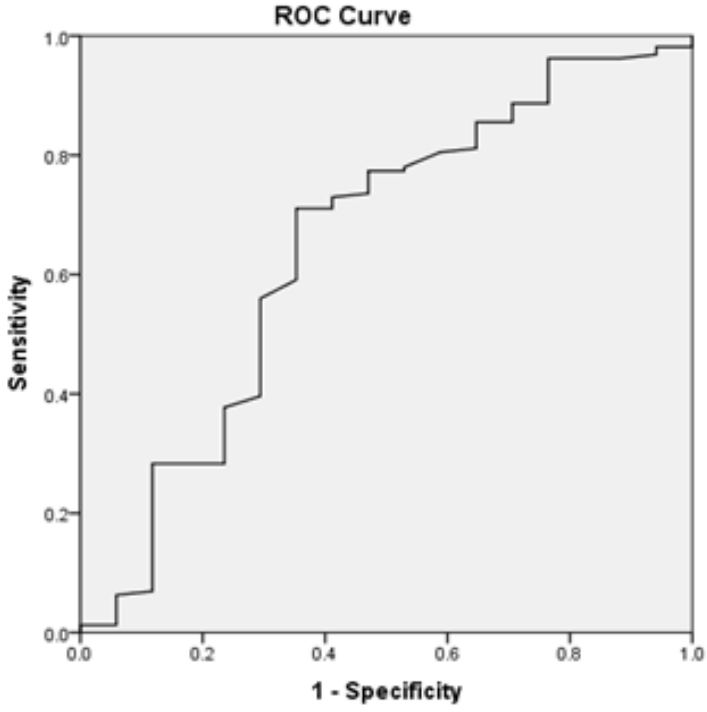


**Figure 3.** ROC curve of 6MWD post-CR cut-off as a predictor of MACE survival.

Our study is the first to analyze the outcome of the CR program after the CABG procedure in Indonesia, particularly in young adults, in which CABG patients are less studied than MI patients. The cut-off is ten sessions as minimum completion (80% of total sessions available) to get greater exposure to educational and exercise benefits in this program. Early phase II CR program enrollment is within 1-2 weeks of hospital discharge rather than 3 months after discharge, as in other centers.[13] The duration of the hospital-based supervised exercise CR program for CABG patients in this study is also shorter, with only 12 sessions and a median duration of only 20 days, compared to other similar studies with a duration of 6 to 12 weeks.[14-17] This shorter period of hospital-based CR will ensure more patient compliance, especially for those referred from remote places. This will also benefit young adult patients who are still employed because lack of time is one of the most common reasons for withdrawing from the CR program.[18]

## Effect of CR on secondary prevention and health behavior

Compliance with medication as a secondary prevention in patients after CABG and PCI is essential, and there is usually a difference between those groups.[19] An analysis to verify if the CR program affected long-term compliance with medication and regular consultation revealed that patients who attended a minimum of 10 sessions of the CR program 1.34 times (OR 1.01 – 1.87, p-0.013) more complied with regular medication consumption and regular check-ups compared to those who drop out in CR (compliance rate 92.2% vs 68.8%). This result suggests that CR benefits not only physical and functional capacity but also health awareness and behavior in the patients, which will help reduce morbidity after CABG in the long term. The multivariate survival analysis revealed that beta-blocker usage, chronotropic index, resting heart rate, and functional capacity were significantly related to composite events.

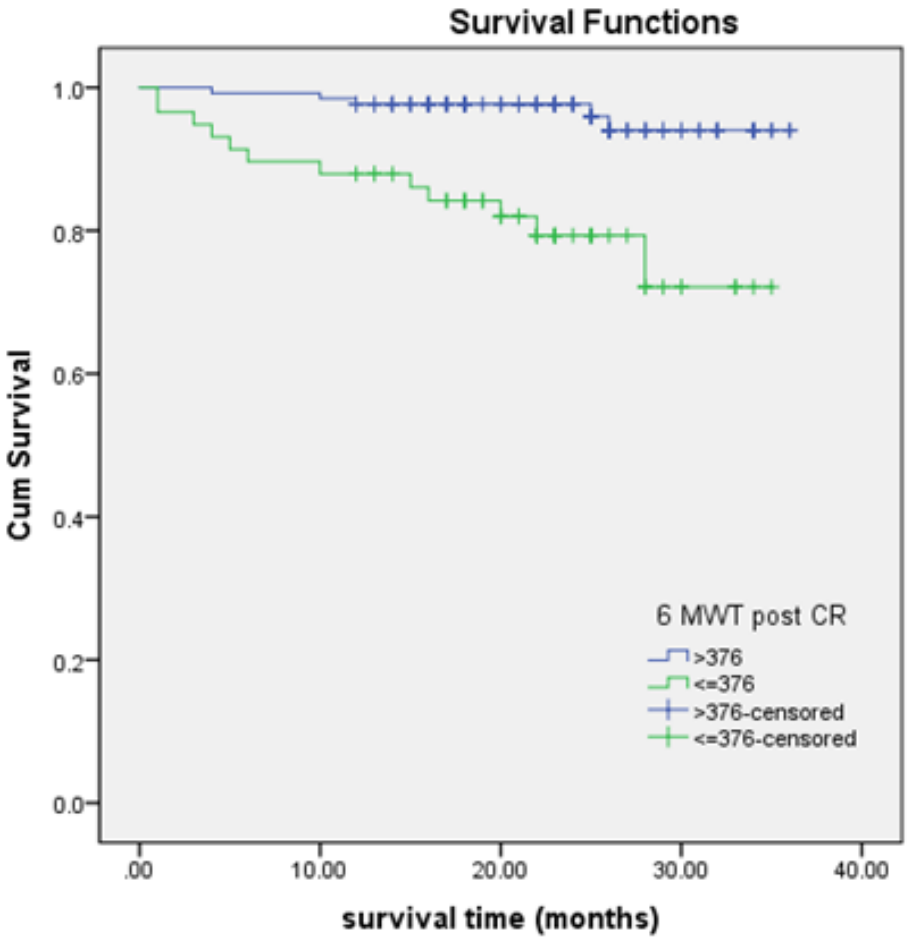


**Figure 4.** Kaplan Meier Survival Curve Analysis for 6 MWT distance post-CR.

### Beta-blocker usage

Our finding suggested that beta-blockers were protective in midterm survival after CABG. This result is consistent with a large cohort study of 5926 patients by Zhang et al., which proved that using beta blockers was associated with a lower risk of long-term mortality and adverse cardiovascular events in patients with or without previous MI undergoing CABG.[20] An observational study by Dayan et al. also revealed that stable angina patients who underwent CABG with preoperative beta-blocker therapy had better overall survival than those without it.[21] This study supports the current guidelines regarding beta-blocker use in CABG patients, including young adults.[4,22]

### Chronotropic index

The chronotropic index (CI) was defined as an index of the maximum predicted HR reserve achieved.[23] This study revealed a higher chronotropic index as an independent protective predictor of survival from composite end-points. With an increment of CI by 1 unit, the risk for the event was reduced by 4%. Our finding was consistent with previous studies that showed impaired chronotropic index or chronotropic response as a risk predictor of cardiovascular mortality or hospitalization,[24-26] including an insight study from an HF-ACTION trial that disclosed a decrease in CI <0.6 was associated with adverse clinical outcomes in HF patients receiving optimal medical therapy.[13] CR programs are also essential in improving recovery from

impaired chronotropic response and contributing to better cardiovascular outcomes.[27]

### Resting heart rate

Another factor that significantly predicted adverse outcomes was resting heart rate. For each bpm resting heart rate increase, the risk of adverse outcomes increased by 4%. This finding was supported by a meta-analysis of 46 studies, which revealed that a higher resting heart rate was independently associated with increased risks of all-cause and cardiovascular mortality.[28] Menown et al., also suggested that a resting heart rate <70 bpm is the target to reduce cardiovascular risk as part of secondary prevention.[29]

### Functional capacity

Good functional capacity has been well known as a protective predictor of medium to long-term cardiovascular mortality and morbidity after CABG, with variation of age dependencies.[9,30,31] In this study, 6-MWD was confirmed as an independent predictor of survival from mid-term composite adverse outcomes in young adults under 55. What made our finding interesting is that the 6-MWD, which was proven to be significantly important is after early CR sessions, rather than the pre-surgery or immediately after surgery 6MWT like in other studies.[30-31] This suggests that exercise-based early phase II CR in our study affects midterm survival prognosis by improving the functional capacity after cardiac surgery. It was also proved by the significant increase in 6-MWD after CR programs (mean difference 76 meters). A study also confirmed that supervised exercise training in CR improved hemodynamic responses and functional capacity in CABG patients.[32] The 6-MWD cut-off in our study was also higher than in the previous study (376 meters vs 300 meters).[31] The difference between these results can be caused by the difference in the age population of the study, which is younger. Thus, younger adults usually have better functional capacity and should aim to achieve higher 6-MWD after the CR program.

### Strengths and Limitations

The study was limited to a single center and only included young adult patients who underwent CABG and participated in the CR program, and the population number was relatively small. Since the follow-up includes phone calls, the accuracy needs to be verified. However, despite the limitations, to our knowledge, this is the first survival analysis study of the CR program, which focuses on young adult patients after CABG in Indonesia and could further emphasize the use of the CR program in Asian populations with unique characteristics.

### Future Implications

As discussed previously, the CR program has been beneficial for short-term, mid-term, and long-term benefits. Early enrollment in an exercise-based CR program after CABG for only 10-12 sessions in young adults has the same positive effect on patient adherence. Thus, it could be implemented as an option for CR after CABG, especially in Indonesia, where the CR program is still underused. Healthcare providers are encouraged to refer patients and to urge patients to attend CR until program completion is accomplished regularly.

## Conclusion

Early phase II CR program after CABG in young adult patients reduced the risk for cardiovascular mortality, major adverse events, related readmission, and an increase in survival rate and mean survival time for participants who completed the CR program. Optimum beta blocker medication, chronotropic index, resting heart rate, and functional capacity after the CR program are essential predictors for survival after CABG in young adults. Further study is needed to prove these findings with a larger population and longer follow-up duration.

## List of Abbreviations

| | |
|---|---|
| CHD | Congenital Heart Disease |
| mPAp | Mean pulmonary arterial pressure |
| mLAP | Mean left atrial pressure |
| PAO2 | Pulmonary Artery Oxygen Saturation |
| PASP | Pulmonary artery systolic pressure |
| PVR | Pulmonary vascular resistance |
| PH | Pulmonary hypertension |
| PVO2 | Pulmonary vein oxygen saturation |
| RHC | Right heart catheterization |
| RVGLS | Right ventricle global lingutudinal strain |

| | |
|---|---|
| TTFV | Trans tricuspid flow velocity |
| TRVmax | Tricuspid regurgitant peak velocity |
| TRmeanPG | Tricuspid regurgitation mean pressure gradient |
| RVOTVTI | Right Ventricular Outflow Tract Velocity Time Integral |

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