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Improvement of exercise capacity after early phase II cardiac rehabilitation in patients who undergo rheumatic mitral valve surgery

Ade Meidian Ambari[1], Budhi Setianto[1], Anwar Santoso[1], Basuni Radi[1], Bambang Dwiputra[1], Eliana Susilowati[2], Fadila Tulrahmi[2], Pieter A. Doevendans[3,4], Maarten Jan Cramer[3]

Abstract

Background: Rheumatic heart disease still become a major concern in developing countries. Recent studies showed the benefits of early phase II cardiac rehabilitation (CR) on improving the exercise capacity but the evidence in patients after rheumatic mitral valve surgery due to rheumatic heart disease is limited. This study aims to investigate the effects of early phase II CR program on increasing exercise capacity in the rheumatic mitral valve surgery patients.

Methods: This is a cohort retrospective study. A review of medical records identified 254 patients who underwent early phase II CR after rheumatic mitral valve surgery between July 2009 – June 2019. Effects of CR was assessed by 6 Minutes Walking Distance (6MWD) pre and post early phase II CR and peak oxygen uptake (VO_2 peak) calculated by Cahallin formula. In this study, we observed and analyzed the increasing of 6MWD and VO_2 peak.

Results: Our findings showed that 6MWD and VO_2 peak increased significantly in these patients after early phase II CR program ($p = 0.001$). Mean of 6MWD increased from 316.3 ± 71.7 meters to 378.6 ± 60.3 meters and VO_2 peak increased from 7.7 ±2.4 mL/kg/min to 8.9 ± 2.2 mL/kg/min. The mean difference of 6MWD was 62.3 meters and VO_2 peak was 1.2 mL/kg/min. There was a strong correlation between VO_2 peak and 6MWD ($r = 71\%$; $R^2 = 51\%$; $p = 0.001$).

Conclusion: Early phase II CR in patients with Rheumatic Mitral Stenosis after mitral valve surgery improved the exercise capacity. Based on 6MWD, we can predict the value of VO_2 peak patients with rheumatic mitral stenosis surgery patients.

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Keywords: Cardiac rehabilitation, rheumatic mitral stenosis, 6MWD, VO_2 peak

[1]Department of Cardiology and Vascular Medicine Faculty of Medicine Universitas Indonesia, National Cardiovascular Center Harapan Kita, Indonesia
[2]Research Assisstants of Preventive Cardiology, National Cardiovascular Center Harapan Kita
[3]Department of Cardiology, University Medical Center Utrecht, The Netherlands
[4]The Netherlands Heart Institute Utrecht The Netherlands

Correspondence:
Ade Meidian Ambari
Department of Cardiology and Vascular Medicine Faculty of Medicine University of Indonesia, National Cardiovascular Center Harapan Kita
Email: dr_ade_meidian@yahoo.co.id

Introduction

Rheumatic Heart Disease (RHD) is a major burden disease, especially in developing countries. Based on total cases summarized by WHO, it was found about 79% cases in developed countries [1]. Rheumatic mitral stenosis had a significant impact on morbidity and mortality. In many countries such as Asia, the incidence rate of rheumatic fever is about more than 10 cases per year[1].

Cardiac rehabilitation as has been known to improve cardiopulmonary function, endurance capacity in patients with cardiovascular disease as well as pos heart surgery patients. Beside its benefits of reducing blood lipid level, blood pressure, body weight, smoking habit, it training has multiple other potentially beneficial effects including improving endothelial function and myocardial flow reserve.[2–7] Cardiac rehabilitation also could improve exercise capacity and reduce morbidity in post-heart valve surgery patients.[8] Cardiac rehabilitation (CR) consists of 3 phases: the phase I is in-hospital rehabilitation. In this phase, the patient would be given low-intensity exercise, education, risk control, and encouragement to step up in phase II CR. Phase II is outpatient rehabilitation and supervised by the cardiac rehabilitation team. Phase II aimed to increase the strength and patient get stronger and active after leaving the hospital. Phase III is long term rehabilitation of phase II CR (home-based). In this phase, the cardiac rehabilitation team will give a prescription for specific exercise based on METS result in phase II and improve their quality of life [9,10].

There are 2 ways to assessing exercise capacity status in patient with heart disease. First, the 6-minute walk test (6MWT) is one of the field walking test that usually used to examine patient because easy to administer and inexpensive. This test aims to see functional capacity by instruct patient to walk quickly over 6 minutes to get maximal distance [11]. Maximal distance reflects patients physical ability. Second, VO2 is a gold standard parameter for aerobic capacity that measured by Cardiopulmonary Exercise Testing (CPET) beside 6MWT. CPET is an expensive method that needs equipment, professional trainer, and not all hospital provides this test to examine their patient [12].

This study investigated the increase of exercise capacity before and after phase II cardiac rehabilitation, measured with 6 Minute Walking Test (6MWT) in patients with rheumatic mitral valve stenosis in Department of Cardiology and Vascular Medicine, University of Indonesia, National Cardiac Center Harapan Kita Hospital Jakarta, Indonesia

Methods

Study Design and Data Source

We conducted an observational cohort retrospective study to evaluate the current use of early phase II CR among post MVR patients. We obtained data regarding CR use among post-Mitral Valve Surgery patients in the National Cardiovascular Center Harapan Kita Hospital Jakarta Indonesia from July 2009 – June 2019. The institutional review board of National Cardiovascular Center Harapan Kita Hospital, faculty of medicine, University of Indonesia granted the study.

Study Setting and Participants

The study population included patients from early phase II CR in the National Cardiovascular Center Harapan Kita Hospital Jakarta, Indonesia.Patients who came to preventive and rehabilitative instalation for phase II CR following the MV surgery who were previously MS due to RHD were included in this study. RHD MS patients with other valves abnormality were also included in this study. RHD patients wthout MS were excluded from this study.

Measurements

Rheumatic valve diseases were diagnosed using the World Heart Federation criteria for RHD.[13] A comprehensive 2-dimensional color Doppler echocardiographic evaluation was performed, and Mitral stenosis patients in the subcategory B of definite RHD Category, which is defined as mitral stenosis with a mean gradient ≥4mmHg and at least two morphological changes of RHD of the MV. Typically, leaflets are thickened and the posterior leaflet is relatively immobile and moves parallel during diastole with the anterior MV leaflet. Our institutional review board approved the retrospective analysis of the subjects' clinical data. After surgery, all patients underwent phase II CR. CR aims to improve physical, psychological, and general functioning during the recovery period after cardiovascular events. It comprises an integrated

multidisciplinary approach involving physical exercise, lifestyle modification, control of risk factors, and psychological intervention.

In the present study, phase II CR was performed in a specialized CR center of the Harapan Kita National Cardiovascular Center in Jakarta, Indonesia. Phase II CR was performed 2 weeks after mitral valve surgery in patients with RHD. The Phase II CR program consisted of a minimum of 12 sessions. The phase II CR program consisted of aerobic and resistance exercises. The aerobic exercise comprised 30 minutes on a treadmill, ergo-cycle, or arm-cycle. Resistance exercise is not always performed, but individualized in some patients, and was not begin until 2-3 weeks after the aerobic exercise was adapted. Resistance training is contraindicated in patients with: unstable angina, uncontrolled hypertension (systolic blood pressure ≥160 mm Hg and/or diastolic blood pressure ≥100 mm Hg), uncontrolled dysrhythmias, a recent history of congestive heart failure that has not been evaluated and effectively treated, severe stenotic or regurgitant valvular disease, and hypertrophic cardiomyopathy. The recommended beginning resistance exercise is with 1- to 2-lb dumbbells or wrist weights. The program consists of 8 to 10 exercises, 2 to 3 days per week, with 1 set of 10 to 15 repetitions to moderate fatigue (RPE 12 to 13, somewhat hard). Patients will progress by 1- to 2-lb increments every 1 to 3 weeks depending on signs or symptoms and adaptation to training. . [14,7]

To carry out the 6MWT before and after the phase II CR program, we referred to the American Thoracic Society's guideline.[15] The test was performed indoors. The patient was instructed to wear comfortable clothing and shoes for walking and to avoid vigorous exercise for 2 hours before the test. Warm-up exercises were not performed before the test. The patient was then instructed to sit on a chair adjacent to the start point of the 6MWT for 10 minutes before the start. During this time, the patient's pulse and blood pressure were measured. Baseline dyspnea and overall fatigue were measured using the Borg scale in the standing position. The timer was set to 6 minutes and the lap counter to zero. Patients were instructed to walk as far as they could in the hallway for 6 minutes. Slowing down, stopping, and resting were permitted if necessary. Leaning against the wall was also permitted while resting. Patients were shown how to carry out the 6MWT before they started the test, and they started when they felt ready.[15] VO_2 peak in this study was calculated using Cahallin fromula [16] as follows:

VO_2 peak= (6MWD x 0.06) – (0.104 x age) + (0.052 x weight) + 2.9

Statistical Analysis

Bivariate analysis between pre and post phase II CR were analyzed using paired t-test to see mean difference of 6MWD and VO2 peak. Correlation and linear regression analysis were analyzed to determine the correlation value obtained from both variables and see predicted values of the dependent variable on the independent variable. Significance level of this study was $p \leq 0.05$. All statistical analysis performed with SPSS software.

A total of 254 patients was followed-up in this study, with the baseline characteristics that was summarized in Table 1. As much as 87% of the study participants performed 12 sessions of the phase II CR, while the other 13% patients failed to achieve a minimum of 12 sessions of phase II CR. But there was no significant difference of the outcomes from individuals who completed 12 sessions compared to the individuals who did not achieved the minimum of 12 sessions phase II CR. The average of phase II CR duration in our study was 42,38 days.

Both 6MWD and VO_2peak of the patients were significantly increased after the phase II CR. ($p = 0.001$), with the 6MWD improvement from 316.3±71.7 meters to 378.6 ±60.3 meters and the VO_2peak improvement from 7.7±2.4 ml/kg/min to 8.9±2.2 ml/kg/min.

Result

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Table 1. Baseline characteristics of subjects

Variables	Total (n = 254)
Demographics	
Sex, n (%)	
- Female	159 (62.6)
- Male	95 (37.4)
Age, y	41.6 ± 10.3
BMI, kg/m2	28.5 ± 64.2
SBP, mmHg	105.7 ± 54.7
DBP, mmHg	62.4 ± 10.7
HR, bpm	83.7 ± 15.7
Risk Factors	
Smoker, n (%)	48 (18.9)
Diabetes, n (%)	17 (6.7)
Hypertension, n (%)	19 (7.5)
Dyslipidemia, n (%)	12 (4.7)
CAD History, n (%)	7 (2.8)
CVA History, n (%)	3 (1.2)
Aortic Regurgitation, n (%)	69 (40.8)
Mitral Regurgitation, n (%)	64 (38.1)
Tricuspid Regurgitation, n (%)	134 (79.3)
Pulmonic Regurgitation, n (%)	48 (28.7)
Medications	
ACEI, n (%)	225 (88.6)
Bblocker, n (%)	198 (78.0)
Statin, n (%)	12 (4.7)
Surgery	
Left Atrium Surgery, n (%)	46 (18.1)
Surgery Type, n (%)	
MVr	6 (2.4)
MVR	248 (97.6)
Echocardiographic Examination	
Ejection Fraction, %	56.4 ± 11.4
Left Atrium Size, mm	50.3 ± 9.9
LVIDd, mm	47.8 ± 8.3
LVIDs, mm	33.0 ± 7.3
TAPSE, mm	14.0 ± 6.1

CAD coronary artery diasease, CVA cerebrovascular attack, ACEI Angiotensin converting enzyme inhibitor, MVr mitral vale repair, MVR mitral valve replacement, BMI body mass index, SBP systolic blood pressure, DBP diastolic blood pressure, HR heart rate

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In this result on Table 2, we found that strong and positive relationship between 6MWD post and VO_2peak post (r = 0.715, p = 0.001). Based on coefficients B, it can be interpreted that VO_2 peak post will increase by 2.7 mL/kg/min if 6MWD post increases every 100 meters.

Discussion

Cardiac rehabilitation program is one of the effective methods for patients after mitral valve surgery to increase exercise capacity. Our study demonstrated that there was significant improvement of the exercise performance and peak VO_2 after the phase II Cardiac Rehabilitation Program (CR) (p = 0.001). 6MWT was used to describe the exercise performance of rheumatic heart disease patients after mitral valve surgery, and the peak VO_2 was calculated using Cahallin formula. 6MWT still become the easy and reproducible test

Table 2. Correlation and Linear Regression of VO2 peak Post as Dependent and 6MWD Post as Independent

Variable	Coefficients B	r	R2	p value
6MWD post	0.027	0.715	0.511	0.001

CAD coronary artery diasease, CVA cerebrovascular attack, ACEI Angiotensin converting enzyme inhibitor, MVr mitral vale repair, MVR mitral valve replacement, BMI body mass index, SBP systolic blood pressure, DBP diastolic blood pressure, HR heart rate

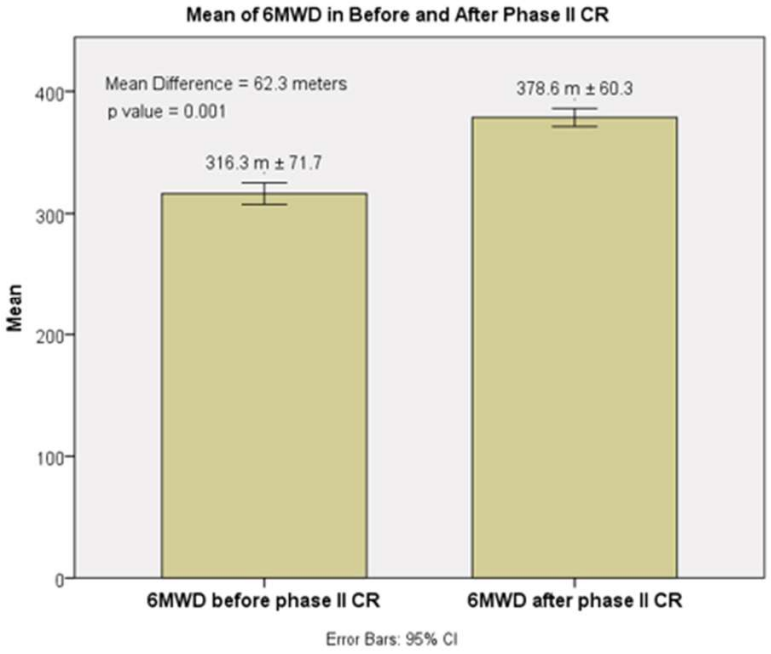


Figure 1. Mean of 6MWD in before and after phase II CR

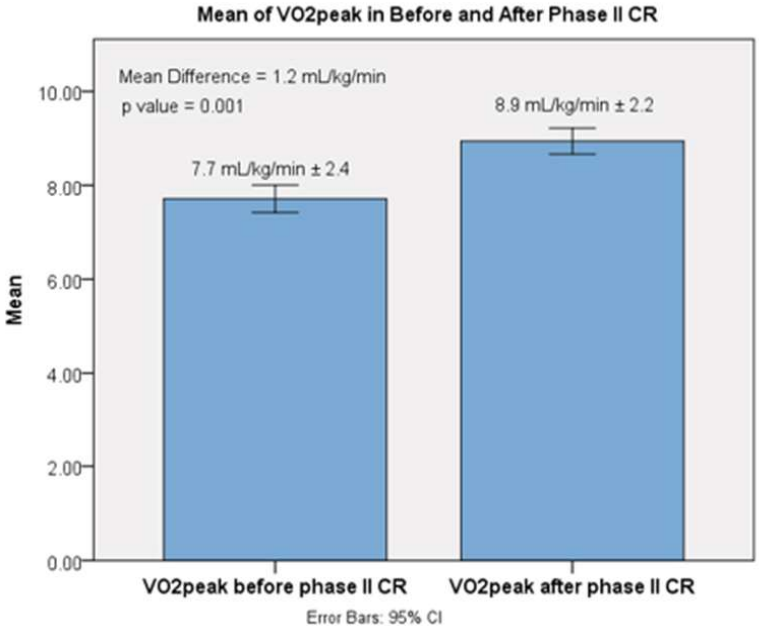
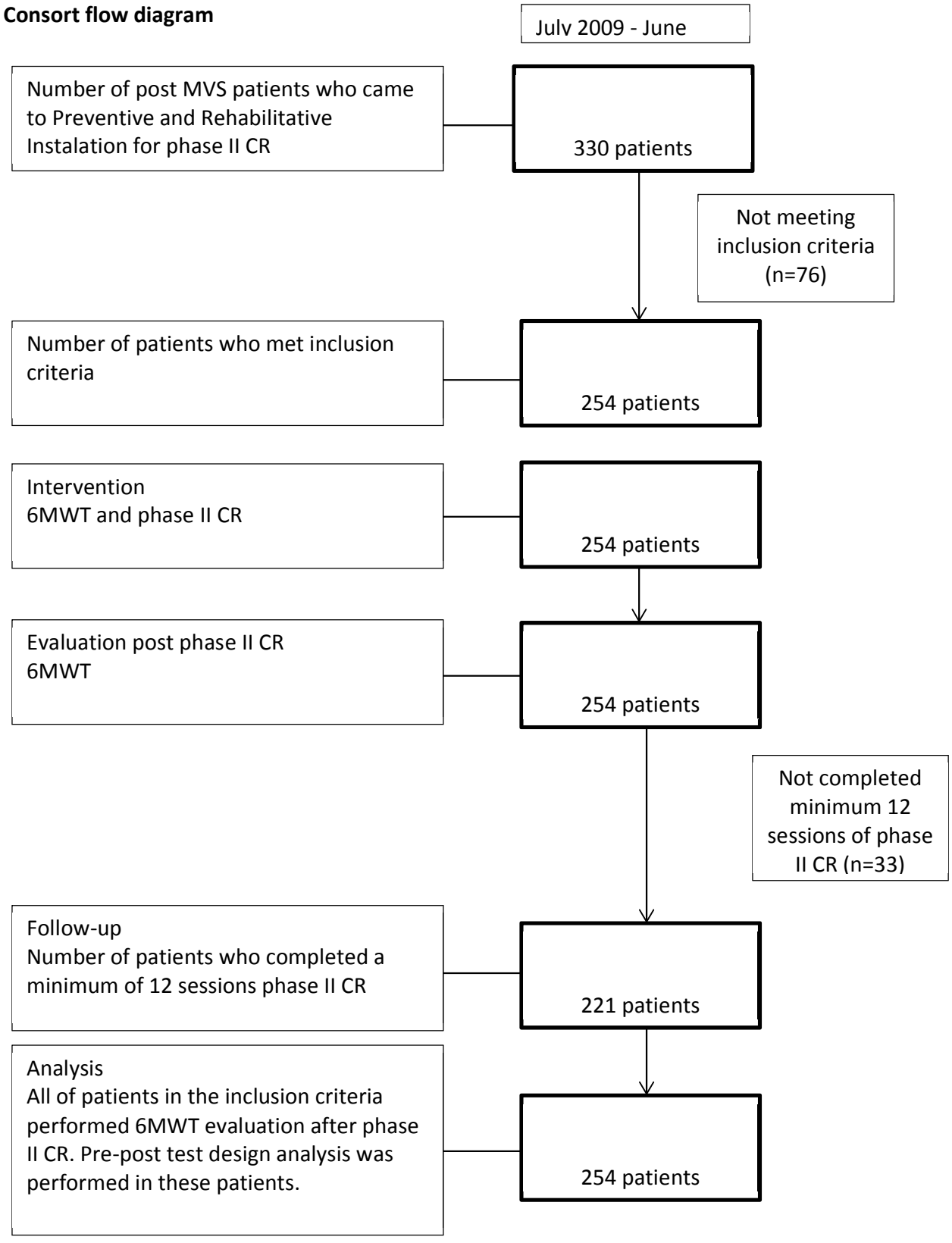


Figure 2. Mean of VO2peak in before and after phase II CR

Consort flow diagram



yet reliable to describe the exercise performance and the functional capacity. Although the peak VO_2 was not directly measured using cardiopulmonary exercise testing (CPET), but the results of our study showed a strong correlation of the 6-minutes walking distance with the calculated peak VO_2. Our results were also in accordance with the other studies that investigated the functional capacity using the direct measurements of the peak VO_2. Pollmann et al [17] reported that patients who completed 12 weeks of CR increased their VO_2 peak (21.6 ± 8 vs 24.8 ± 9; p = 0.001) and 6MWD (349 ± 110 vs 393 ± 121; p = 0.01) whereas Savage et al 8 compared the effect of CR by dividing into 3 groups: mitral valve surgery (MVS), coronary artery bypass grafting (CABG), and mitral valve surgery combined with coronary artery bypass grafting. Results showed that all groups experienced an increase of VOpeakx especially MVS group (17.2 ± 5.1 to 20.7 ± 6.1; p < 0.001). Based on other clinical studies about CR after MVS, patients will lack confidence and difficulties to get on daily living after surgery so CR have good impacts for patients such as in their quality of life [18]. Sibilitz et al investigated 6MWD in 1 month and 4 months of patients with CR and not allowed to participate in CR by signing consents in this trial study. It showed patients that participated in CR has increased their 6MWD from 546.8 meters to 595.2 meters. Morover, patients not allowed in CR programme has increased their 6MWD too from 542.9 meters to 594.5 meters [19]. Voller et al and Zanettini, et al compared 6 MWD and found that mean difference of 6MWD patients at discharge test was significantly improved before at admission test [20,21.] Samples in this study were patients with transcatheter aortic valve replacement surgery. Both of those studies found that post CR patients with any types of surgery such as transcatheter aortic valve replacement or surgical aortic valve replacement have significant improvements in 6 MWD at admission and discharge test.

In rheumatic mitral stenosis patient, there had been a decrease in the functional capacity before the surgery, and there are several changes of hemodynamics after the surgery. Despite the improvements after mitral valve surgery, the functional capacity and the exercise performance of these patients were still far from normal; but near normal values of 6MWD and peak VO_2 in these patients were achieved after the early phase II CR.[22] A study from Russel et al.[23] Showed that there were no signifficant difference between the survival outcome of rheumatic vs non-rheumatic valve disease patients following mitral valve surgery. This study also explained that there were no difference of the survival outcome between the patients whose mitral valve were repaired and replaced. A similar results were found in our study that the types of the mtral valve surgery, whether it was repair or replacement, did not interfere the outcome of the exercise capacity improvement.

Our study used Cahallin formula to measure the peak VO_2, to predicts the VO_2peak. Functional capacity is the ability to perform aerobic work as defined by the maximal oxygen uptake (VO_2peak¬), it reflects the ability to sustain the aerobic metabolism for daily activities.VO_2 max is the product of cardiac output and arterio-venous Oxygen difference at physical exhaustion.[24] Under physiologic conditions, the opening of the mitral valve during ventricular diastole will let the blood flow from the left atrium to the left ventricle, with the equal pressure in the left atrium and left ventricle. The presence of mitral stenosis in patient with RHD causes an impediment of the blood flow from the left atrium into the left ventricle, thus requires the atrial kick to flow the blood. The high left atrial pressure is then transmitted to the pulmonary vasculature that will lead to pulmonary hypertension. The sustainment of the high atrial pressure results in the increase of atrial size that will cause the diminishing of atrial kick. So, in the severe mitral stenosis with the loss of atrial kick, the cardiac output will also decrease.[25] Most patients with severe rheumatic mitral stenosis require surgical intervention, with the mitral valve repair or mitral valve replacement. The decrease of the cardiac output in these patients will cause the decrease in the functional capacity, alongside with the performance for their daily activities. Several physiological adjustments occurred after mitral valve surgery, that also could influence the functional capacity and exercise performance. Luthra et al [26] reported early changes in pulmonary function after mitral valve surgery, that remained until 3 months after the surgery. There were reductions in forced vital capacity, forced expiratory volume in 1 second, and peak expiratory flow rates. This study also showed a reduction in the total lung capacity and diffusion

capacity especially in patients with preoperative NYHA Class of III and IV. Bayat et al demonstrated hemodynamic changes after mitral valve surgery in patients with or without pulmonary hypertension.[27] This study showed that the pulmonary artery pressure was increased for approximately 3 mmHg immediately after the surgery, and then followed by a significant decrease for approximately 30 mmHg in patients after undergoing mitral valve replacement in patients without pulmonary artery hypertension. Nevertheless, immediate reduction of the pulmonary artery pressure was not significant in perioperative mitral valve replacement that overt pulmonary artery hypertension; their pulmonary pressure decreased gradually depends on the severity. Another study showed unique findings; Jahns et al assessed the hemodynamic of post-mitral valve surgery patients at rest and during exercise using Doppler and catheterization. They showed that there was a postoperative decline in the pulmonary artery and pulmonary wedge pressure, but those declines did not reach the normal range. While the exercise was followed by a significant increase in cardiac output but with remained unchanged of pulmonary resistance. They suggested that these hemodynamic abnormalities were not a consequence of obstruction to flow across the valve prosthesis, but more likely due to only partial resolution of the pulmonary vascular bed because of the long-standing valve disease.[28] Therefore, although the overall patients with rheumatic heart disease had hemodynamic and physical capacity improvements, cardiac rehabilitation is still needed to sustain these improvements.

Our study performed the early phase II CR, which was 2 weeks after the surgery and consisted of 12 sessions of aerobic and resistance training in some of the patients, but by restraining the movements of the upper extremity. 13% of these patients did not complete the minimum of 12 sessions, but there were no infernce to the 6MWD ad survival outcome. Early pahe II CR that was performed in our study (2 weeks after the surgery), because most of the patients from many regions in Indonesia could not wait until 1 months to come back to their hometown or require more transportation fee to come back after 1 month. Our centre is a national cardiovascular centre, so the patients could come from any regions from Indonesia. Most of the patients who could not complete the minimum 12 sessions were because of the limitation to stay whether because of the acomodation fee or the urge to go back to their hometown. These outcomes were similar to the study from Meurin et al that performed the early exercise training 3 weeks after the mitral valve surgery [29]. Submaximal exercise test can be performed 2 weeks after surgery, while a symptoms limited (maximal exercise) test can be performed after 3-4 weeks. [30] Aerobic and resistance training could give stimulation to the human body to adapt and alter the resting physiological process, to meet the increased exercise-induced physiological demands. This process is characterized by significant changes in Oxygen uptake and delivery to the exercising muscles accompanied by the increased of cardiac and pulmonary function in synchrony with the vasculature. Repeated exercise results in long term physiological adaptations which are essential to managing the requirements of repeated aerobic and resistance exercise, thus improving the physiological system involved in the exercise, such as the cardiovascular, metabolic, and respiratory systems.[31] Our study presents the importance of phase II CR following the mitral valve surgery in rheumatic heart disease patients. The limitation of this study is the indirect measurements of the maximal VO_2 to reflects the functional capacity, and this study is a pre-post test study without a control group to compare the effect of the early phase II CR. Although the measurement of the functional capacity was indirectly using the Cahalin formula, this study showed a significantly strong correlation between the 6MWD and the VO_2 peak. This result proved that 6-minutes walking distance measurement is an easy yet effective method to estimate the exercise performance and physical capacity. The lack of a control group was because only few patients refused to undergo the phase II CR

Conclusion

Early phase II CR in patients with Rheumatic Mitral Stenosis after mitral valve surgery improved the exercise capacity. Based on 6MWD, we can predict the value of VO_2 peak patients with rheumatic mitral stenosis surgery patients.

Disclosure

None to declare.

Publication Approval

All authors read and approved the final manuscript

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This paper received no specific grant from any funding agency, commercial or not-for-profit sectors.

Ethical Clearance

The Ethical Committee of the National Cardiovascular Center, Harapan Kita, Jakarta, Indonesia approved this study, with ethical code LB.02.01/ VII/358/KEP.062/2019.

List of abbreviations

6MWD	: 6 minutes walking distance
6MWT	: 6 minutes walking test
CABG	: Coronary artery bypass graft
CPET	: Cardiopulmonary testing
CR	: Cardiac rehabilitation
MVS	: Mitral valve surgery
NYHA	: New york heart association
RHD	: Rheumatic heart disease
VO2 peak	: peak oxygen uptake

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