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Right ventricular function as a predictor of morbidity and mortality in post-heart valve surgery

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Abstract

Valvular heart disease (VHD) remains a significant global health concern, with mortality rates ranging from 1% to 15%. In Indonesia, the most prevalent form of VHD is rheumatic heart disease, which is associated with a hospital mortality rate of 6.5% following valve surgery. Previous studies have shown that, post-surgery, morbidity rates remain high: 30.8% of patients experience prolonged intensive care unit stays (>96 hours), 30.67% require extended mechanical ventilation (>24 hours), and 52% need prolonged use of inotropic agents (≥14 days). Right ventricular (RV) dysfunction is closely associated with these three morbidity parameters, as well as with 30-day postoperative mortality. However, limited research in Indonesia has explored the most effective parameters for evaluating RV function as a predictor of postoperative morbidity and mortality following heart valve surgery.

This prospective cohort study was conducted at the Department of Cardiology and Vascular Medicine, Universitas Indonesia, and the National Cardiovascular Center Harapan Kita (NCCHK) from October 2023 to July 2024. During this period, 174 patients with VHD who underwent surgical valve replacement were enrolled. After applying exclusion criteria, 26 patients were excluded, resulting in a final study population of 148 patients. All participants underwent preoperative echocardiographic assessment of RV function, performed by two operators within 1 week prior to surgery. Among the 148 subjects, females comprised the majority (60.1%). Atrial fibrillation (AF) was the most common comorbidity, affecting 62.8% of the cohort. The most frequent morbidity outcome was prolonged mechanical ventilation, observed in 27.7% of cases. Of the total mortality events, 70% were cardiac-related, while the remaining 30% were due to non-cardiac causes. Multivariate analysis revealed that a preoperative S′<10 cm/s was significantly associated with cardiac-related mortality [odds ratio (OR) 3.46; 95% confidence interval (CI) 1.01-11.87; p=0.049]. Additionally, a preoperative S′<11 cm/s was significantly associated with overall clinical outcomes, including both morbidity and all-cause mortality (OR 3.08; 95% CI 1.43-6.65; p=0.004).

In conclusion, S′, an echocardiographic parameter reflecting RV function, demonstrates potential as a predictive marker for postoperative morbidity and mortality in patients undergoing heart valve surgery.

Key words: right ventricular function, echocardiography, heart valve surgery, morbidity, mortality.

Introduction

Valvular heart disease (VHD) is a worldwide health problem with approximately 275,000 surgeries every year and a mortality rate between 1-15%. The main etiology in the USA and most developed nations is degenerative valve disease, represented by calcific aortic stenosis. Degenerative disease is increasing as a result of population aging and is the third most common cardiovascular disease after hypertension and coronary artery disease in industrialized countries. In Brazil, and most likely in many other countries, valvular heart disease is widely prevalent; the major etiology is rheumatic fever. Rheumatic heart disease (RHD) is the most important form of acquired heart disease in children and young adults in developing countries. Even though it is a preventable illness, approximately 19 million people are affected by it. RHD accounts for about 15% of all patients with heart failure in endemic countries, and 30% of them need cardiac surgeries. In RHD, the mitral valve is involved in nearly all cases, and the aortic valve is involved in about 30%. The tricuspid valve is commonly affected but is frequently subclinical and associated with mitral valve disease [1]. In Indonesia, RHD is the most frequently observed form of VHD. Definitive treatment may involve surgical or non-surgical interventions, including valve repair or replacement [2]. In-hospital mortality remains a concern; studies report an operative mortality rate of approximately 5.8% [3,4]. Glaser et al. reported a 30-day mortality rate of 0.8% following valve surgery [5], while Kundi et al. documented 30-day mortality rates between 4.6% and 5.6% after both surgical and transcatheter interventions [6]. In Indonesia, a study by Soesanto et al. found the in-hospital mortality rate after valve surgery to be 6.5% [7]

According to previous studies, postoperative morbidity remains high: 30.8% of patients experience prolonged ICU stays (>96 hours) [8], 30.67% require prolonged mechanical ventilation (>24 hours) [9], and 52% require prolonged inotropic agents (≥14 days) [10]. These three morbidity indicators are clinically significant due to their high incidence and strong association with right ventricular (RV) dysfunction.

RV failure is linked to severe complications such as death, stroke, reintubation, and prolonged ICU stay [11]. Towheed et al. identified RV dysfunction as a strong predictor of increased 30-day post-operative mortality [12]. In the early postoperative period, RV global longitudinal strain (RV–GLS) may serve as a reliable measure of RV function, while traditional markers such as tricuspid annular plane systolic excursion (TAPSE) and S′ may be limited due to transient changes in longitudinal RV function. For preoperative assessment, TAPSE may be unreliable in patients with significant tricuspid regurgitation due to its volume dependence. In such cases, RV–GLS may offer a more robust parameter [13]. Other studies have reported improved right ventricular fractional area change (RV–FAC) following tricuspid valve surgery [14].

Based on the high prevalence of mortality and morbidity after surgical procedures for valvular heart disease, this research was conducted to determine the prediction rates before surgical procedures to improve the morbidity and mortality outcomes after valve surgery. There is no prospective research in Indonesia regarding the role of RV function parameters in echocardiography to predict patient outcomes after surgery. This research is important to carry out as a predictor of right ventricular function on outcomes in the form of mortality and morbidity after heart valve surgery.

Materials and Methods

Overview

This prospective cohort study aims to evaluate right ventricular global longitudinal strain (RV–GLS), right ventricular–pulmonary artery coupling (RV–PAC), three-dimensional right ventricular ejection fraction (3D RVEF), right ventricular fractional area change (RV–FAC), Tei index, S′, and tricuspid annular plane systolic excursion (TAPSE) as prognostic parameters for predicting morbidity and mortality following heart valve surgery.

Participants

The study was conducted at the Department of Cardiology and Vascular Medicine, National Cardiovascular Center Harapan Kita (NCCHK), University of Indonesia, from October 2023 to July 2024. The inclusion criteria for this study were patients aged over 18 years who were scheduled for elective valve repair or replacement surgery due to valve abnormalities, as determined during the institutional valvular surgery conference. Meanwhile, the exclusion criteria included patients with congenital heart disease, coronary artery disease requiring surgical intervention, and patients with aortic disorders that needed vascular surgery. Patients with incomplete baseline data recorded at NCCHK and those diagnosed with left-sided heart failure were also excluded from the study. The sample size formula used consists of three types (depending on the type of independent variable being studied, whether numeric or categorical, and the risk value).

Statistical analysis

A consecutive sampling method was employed in this study. The minimum required sample size was 139 participants. Statistical analyses were conducted to compare predictors between groups with right ventricular (RV) dysfunction and those with mortality, with results expressed as categorical variables in frequencies (n) and percentages (%). Numerical data were assessed for normality using the Kolmogorov-Smirnov test. Data with a normal distribution are presented as mean values with standard deviation, while non-normally distributed data are presented as median values along with minimum and maximum ranges.

Study outcomes, including mortality and morbidity, are reported as categorical variables, indicating the presence or absence of each event. Echocardiographic numerical parameters were converted into categorical variables for analysis. Categorical data were analyzed using the Chi-Square test to evaluate differences in proportions. Variables with a p-value < 0.25 in bivariate analysis were included in the multivariate analysis. A p-value < 0.05 was considered statistically significant. All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS), version 26.

Results

Participant characteristics

Participant characteristics are presented in Table 1. The mean age of the overall sample was 45 ± 12 years, with a predominance of female participants (60.1%). The average body mass index (BMI) was 23.4 ± 4.4 kg/m^2, and the prevalence of smoking was 3.4%. Comorbidity profiles revealed that the most common condition was atrial fibrillation (AF), present in 62.8% of participants, followed by post-operative pulmonary hypertension (37.8%), hypertension (12.8%), dyslipidemia (6.8%), pre-operative pulmonary hypertension (4.1%), type II diabetes mellitus (1.4%), and renal impairment requiring renal replacement therapy (0.7%).

In terms of valve pathology, 40 patients (27%) had single-valve disease, 79 patients (53%) had double-valve disease, and 29 patients (20%) had triple-valve disease.

Preoperative echocardiographic assessment of RV function yielded the following results: the mean 3D right ventricular ejection fraction (RVEF) was 36.7 ± 8.5%, RV fractional area change (RV–FAC) was 35.7 ± 10.6%, and RV global longitudinal strain (RV–GLS) was 16.6 ± 5.2%. The median tricuspid annular plane systolic excursion (TAPSE) was 18 mm (8–33 mm), the Tei index was 0.50 (0.28–2.09), S' was 11 cm/s (5–24 cm/s), and RV-pulmonary artery coupling (RV–PA) was 0.39 (0.10–2.18).

A range of heart valve surgical procedures was performed. Mitral valve procedures included 20 replacements (13%) and 10 repairs (7%). No tricuspid valve procedures were conducted. Aortic valve interventions included 9 replacements (6%) and 1 repair (1%). No pulmonary valve procedures were performed. The majority of cases involved mixed valve procedures, comprising 12 replacements (8%), 8 repairs (6%), and 88 combined repair and replacement procedures (59%).

Regarding prosthesis type, 30 patients (20%) underwent mechanical valve replacements, 10 (7%) received repairs, and 62 (42%) had both repair and replacement. Among those receiving bioprosthetic valves, there were 11 replacements (7%), 9 repairs (6%), and 26 cases (18%) involving both procedures.

Intraoperative data showed a median cardiopulmonary bypass (CPB) time of 118 minutes (range: 42–323 minutes) and a median aortic cross-clamp (ACC) time of 85 minutes (range: 27–217 minutes).

Clinical morbidity outcomes included prolonged mechanical ventilation in 27.7% of patients, prolonged inotropic support in 9.5%, and extended intensive care unit (ICU) stays in 19.6%. Mortality analysis revealed that 70% of deaths were cardiac causes, while 30% were due to non-cardiac causes.

The relationship between right ventricular function echocardiographic parameters and inpatient cardiac mortality incidents in heart valve surgery patients at National Cardiovascular Center Harapan Kita (NCCHK)

To evaluate the relationship between preoperative RV function echocardiographic parameters and inpatient cardiac mortality among patients undergoing heart valve surgery at NCCHK, a bivariate analysis was initially conducted using numerical-to-categorical methods. This approach was chosen due to the absence of established cut-off values for RV function echocardiographic parameters in predicting inpatient cardiac mortality. Consequently, descriptive statistical analysis was first performed to determine the mean or median values of the RV function parameters.

Bivariate analysis was carried out using the independent t-test for normally distributed numerical data, with results presented as mean ± standard deviation. For non-normally distributed data, the Mann-Whitney U test was used, with values reported as median (minimum–maximum).

Prior to the multivariate analysis, RV function parameters and other clinical variables with a p-value < 0.25 were identified. Cut-off values for these variables were then established, followed by a second round of bivariate analysis using the Chi-square test for categorical variables, with results expressed as absolute values and percentages (n [%]).

Variables with p-values < 0.25 included: S′ < 10 cm/s (p = 0.230), RV–pulmonary artery (PA) coupling < 0.39 (p = 0.195), age ≥ 51 years (p = 0.009), cardiopulmonary bypass (CPB) time ≥ 125 minutes (p = 0.030), and aortic cross-clamp (ACC) time ≥ 90 minutes (p = 0.195). These variables were subsequently included in the multivariate analysis.

In addition, RV function echocardiographic parameters with p-values > 0.25 were also retained in the multivariate analysis due to their clinical relevance. The final multivariate model identifying factors associated with inpatient cardiac mortality is presented in Table 2.

The relationship between right ventricular function echocardiographic parameters and clinical outcomes (all-cause mortality and morbidity) in heart valve surgery patients at National Cardiovascular Center Harapan Kita

To evaluate the association between preoperative RV function echocardiographic parameters and clinical outcomes (all-cause mortality and morbidity) in patients undergoing heart valve surgery at NCCHK, a bivariate analysis was initially conducted using numerical-to-categorical methods. This approach was employed due to the absence of established cut-off values for RV function echocardiographic parameters in predicting clinical outcomes. Therefore, descriptive analyses were performed to determine the mean or median values of each RV function parameter.

Bivariate analysis was conducted using the independent t-test for normally distributed numerical variables (reported as mean ± standard deviation) and the Mann-Whitney U test for non-normally distributed variables (reported as median with minimum–maximum values).

Prior to multivariate analysis, RV function parameters and other clinical variables with a p-value < 0.25 were identified, and cut-off values were determined. Subsequently, these variables were reanalyzed in categorical form using the Chi-square test, with results presented as absolute numbers and percentages (n [%]).

The variables identified with p-values < 0.25 included: 3D RVEF < 37% (p = 0.130), TAPSE < 18 mm (p = 0.034), RV-FAC < 36% (p = 0.081), S′ < 11 cm/s (p = 0.010), RV-GLS < 17% (p = 0.063), RV–PAC < 0.39 (p = 0.048), age ≥ 45 years (p = 0.103), AF (p = 0.180), hypertension (p = 0.094), post-procedural pulmonary hypertension (p = 0.001), cardiopulmonary bypass (CPB) time ≥ 122 minutes (p < 0.001), aortic cross-clamp (ACC) time ≥ 85 minutes (p = 0.103), and concomitant tricuspid valve repair (p = 0.193). These variables were subsequently included in the multivariate analysis.

Notably, RV function echocardiographic parameters with p-values > 0.25 were also retained in the multivariate analysis due to their clinical relevance. The final multivariate model of factors associated with clinical outcomes (all-cause mortality and morbidity) during hospitalization is presented in Table 3.

Receiver operating characteristics analysis of inpatient cardiac mortality in heart valve surgery patients at National Cardiovascular Center Harapan Kita

Receiver operating characteristic (ROC) curve analysis identified S′ as a statistically significant echocardiographic parameter of RV function, with an area under the curve (AUC) of 0.639, indicating moderate, fair, or acceptable discriminatory power [15]. The optimal cut-off value was determined to be 10 cm/s, yielding a sensitivity of 57.1% and a specificity of 63.3% (Figure 1).

Receiver operating characteristics analysis of clinical outcomes (all-cause mortality and morbidity) in heart valve surgery patients at National Cardiovascular Center Harapan Kita

Receiver operating characteristics (ROC) curve analysis identified S′ as a statistically significant echocardiographic parameter of RV function, with an area under the curve (AUC) of 0.664, which is interpreted as moderate, fair, or acceptable discriminatory power [15]. The optimal cut-off value was determined to be 11 cm/s, yielding a sensitivity of 65.3% and a specificity of 58.6% (Figure 2).

Discussion

This study demonstrates that 60.1% of patients with heart valve disease underwent heart valve surgery. The predominance of female patients is consistent with the findings of Des Jardin et al., who reported a higher prevalence of rheumatic heart valve disease and degenerative mitral valve disease among women. Similarly, a study by Aluru et al. identified women as the population most affected by heart valve disease globally [16]. In Indonesia, research by Baan et al. also found that heart valve disease primarily affected women, with RHD accounting for 75% of cases [17].

The mean age of patients undergoing heart valve surgery in this study was 45 ± 12 years, which is relatively low compared to similar studies. In a multicenter study by Cheng et al., the average age of patients undergoing heart valve surgery was 68.2 ± 15.2 years [18]. In the United States and most other developed countries, the predominant etiology is degenerative valve disease, which increases with age. In contrast, rheumatic heart disease (RHD) remains the most common cause of heart valve disease among children and young adults in developing countries [1]. In Indonesia, RHD is the leading cause of VHD [2], with Aluru et al. reporting an average age of 28.7 years among patients diagnosed with RHD [16]

In this study, AF was present in 62.8% of patients with heart valve disease, indicating a significant comorbid burden. This finding is consistent with the study by Lanters et al., which reported a higher prevalence of AF among patients with mitral valve disease (26–54%), followed by aortic valve disease (10–13%) [19]. AF is associated with a fourfold increase in mortality risk compared to the general population and has an overall prevalence of 29% [20]. In this study, cardiac-related causes accounted for 70% of mortality, with 91% of these patients having mitral valve disease.

Pulmonary pressure can increase due to several factors such as systemic inflammatory response, pulmonary reperfusion syndrome, and blood transfusion. Administration of protamine can cause pulmonary vasoconstriction in 1.8% of patients, and positive pressure ventilation after CPB can also increase pulmonary pressure. Sudden changes in pulmonary pressure during heart surgery can increase the workload of the right ventricle, leading to right ventricular dysfunction. Acute right ventricular dysfunction causes systemic congestion and eventually leads to circulatory failure [12]. Pulmonary hypertension is a pathology associated with mitral valve disease. The underlying mechanism of pulmonary hypertension in this context reflects the initial effects of increased left atrial pressure and pulmonary vascular congestion. Persistent increased left atrial pressure is associated with changes in the pulmonary vessels, including increased pulmonary vascular resistance and loss of vascular compliance. The prevalence of pulmonary hypertension after mitral valve surgery is 42.3% [21]. This aligns with the characteristics of patients in this study, where the majority were diagnosed with mitral valve disease, with 91% undergoing surgery, and 37.8% experiencing pulmonary hypertension after surgery.

Correlation between S' parameters with inpatient cardiac mortality and clinical outcomes (all-cause mortality and morbidity)

Multivariate logistic regression analysis identified S', an RV echocardiographic parameter, as a statistically significant predictor of in-hospital cardiac mortality. An S' value below 10 cm/s was associated with a 3.46-fold increase in the risk of cardiac mortality ($p = 0.049$) when considering preoperative variables alone, and a 3.86-fold increase ($p = 0.044$) when intraoperative variables were included in the model. In the ROC analysis for cardiac mortality, the AUC for S' was 0.639, indicating a moderate, fair, or acceptable level of discrimination. The optimal cut-off value was determined to be 10 cm/s, with a sensitivity of 57.1% and a specificity of 63.3%. These findings are supported by a study conducted by

Lashin et al., which demonstrated that S' values <10.5 cm/s were associated with a cardiac mortality rate of 85%, compared to 53% for values >10.5 cm/s (p = 0.02). In their analysis, S' also demonstrated moderate predictive accuracy, with a sensitivity of 64%, specificity of 62%, and an AUC of 0.66. [22]

From the multivariate logistic regression analysis identified S', a right ventricular (RV) echocardiographic parameter, as a statistically significant predictor of adverse clinical outcomes, defined as all-cause mortality and morbidity. An S' value below 11 cm/s was associated with a 3.08-fold increased risk of adverse outcomes (p = 0.004) when considering preoperative variables alone, and a 2.26-fold increased risk (p = 0.048) when intraoperative variables were included. In the ROC analysis for clinical outcomes, the AUC for S' was 0.664, indicating moderate, fair, and acceptable discriminative ability [15], with a cut-off value of 11 cm/s. At this threshold, S' demonstrated a sensitivity of 65.3% and a specificity of 58.6%. These findings are consistent with a study by Oketona et al., which found that an S' value <9.5 cm/s was associated with adverse clinical outcomes in affected patients [23].

The main application of S' is in assessing right ventricular function in pulmonary hypertension and pediatric populations [24]. In this study, the prevalence of pulmonary hypertension increased from 4.1% preoperatively to 37.8% postoperatively. One of the key advantages of S' is its rapid acquisition, strong correlation with other measures of global RV systolic function, and ease of use and reproducibility [25]. Moreover, it does not require additional specialized equipment or probes, making it a practical and efficient tool in clinical settings.

Correlation between other right ventricular echocardiography parameters and inpatient cardiac mortality and clinical outcomes (all-cause mortality and morbidity)

In this study, multivariate logistic regression analysis revealed that several right ventricular (RV) echocardiographic parameters—including three-dimensional right ventricular ejection fraction (3D RVEF), tricuspid annular plane systolic excursion (TAPSE), RV fractional area change (RV-FAC), Tei Index, RV global longitudinal strain (RV-GLS), and RV-pulmonary artery (RV-PA) coupling—were not statistically associated with cardiac mortality or adverse clinical outcomes (all-cause mortality and morbidity), with p-values > 0.005.

The use of three-dimensional echocardiography is limited by several factors, including irregular heart rhythms, suboptimal acoustic windows, and abnormal septal motion. In this study, atrial fibrillation was the predominant comorbidity, present in 62.8% of patients [26,27], potentially affecting the reliability of 3D RVEF measurements. Gronlykke et al. reported that inadequate acoustic windows are common in patients following heart valve surgery, further limiting the utility of 3D echocardiography [28]. Additionally, King et al. emphasized that GLS is unsuitable in patients with arrhythmias [29], a finding particularly relevant in this study, where the majority of patients had atrial fibrillation.

According to Soesanto et al., TAPSE was not correlated with mortality following heart valve surgery [30]. Similarly, Zanobini et al. reported that a postoperative decrease in TAPSE is frequently observed after pericardiotomy, which does not reflect a true reduction in RV ejection fraction but rather results from geometric alterations [31]. This was supported by Tamborini et al., who indicated that the decline in TAPSE post-surgery is due to changes in RV geometry rather than actual functional impairment [32]. A study by Sun et al. also found no correlation between TAPSE and postoperative outcomes. TAPSE/PASP was used as a measurement of RV-PA coupling [33,34]. RV-PA coupling in this study was assessed using the TAPSE/pulmonary artery systolic pressure (PASP) ratio, a commonly used surrogate for RV-PA coupling. As such, this measurement is inherently dependent on TAPSE and does not represent an objective measure of RV function independent of its limitations [34].

RV-FAC is most accurately assessed using two-dimensional echocardiography [35]. However, this method is also limited by image quality. In patients with poorly visualized endocardial borders, RV-FAC cannot be reliably measured. Even when image quality is adequate, the distinction between endocardium and trabeculations may compromise measurement accuracy. Nagata et al. noted that despite advancements in echocardiographic technology, image quality often remains suboptimal, particularly in postoperative patients [25,36,37].

The Tei Index is angle-dependent and does not provide a complete representation of global RV function, especially after thoracotomy [38]. Furthermore, in mitral valve surgery, thoracotomy techniques can be used [39]. In this study, the majority of patients undergoing surgery had mitral valve surgery, accounting for 91%.

Correlation between cardiopulmonary bypass and cardiac mortality and clinical outcomes (all-cause mortality and morbidity)

Multivariate logistic regression analysis demonstrated that the duration of cardiopulmonary bypass (CPB) was significantly associated with in-hospital cardiac mortality, with a p-value of 0.001. The receiver operating characteristic (ROC) analysis yielded an area under the curve (AUC) of 0.759, indicating good discriminatory ability [15]. The optimal cut-off value for CPB duration was identified as 122 minutes, with a sensitivity of 81.8% and a specificity of 60.8%. Surgical interventions such as CPB and pericardiotomy have been shown to impair right ventricular (RV) contraction patterns and contribute to RV dysfunction. This dysfunction is a known factor in prolonged intensive care unit (ICU) stays and increased postoperative mortality [40,41].

Clinical applications of tricuspid annulus systolic velocity (s')

- Preoperative S' is the most reliable echocardiographic parameter for predicting clinical outcomes (all-cause mortality and morbidity) as well as in-hospital cardiac mortality.
- S' measured prior to surgery can serve as a valuable tool for selecting patients eligible for elective heart valve surgery.
- An S' value of less than 10 cm/s before surgery is predictive of in-hospital cardiac mortality in patients undergoing elective valve surgery.

- An S' value of less than 11 cm/s before surgery is associated with an increased risk of adverse clinical outcomes (all-cause mortality and morbidity) in this patient population.
- These parameters may complement existing risk stratification tools, such as the Harapan Kita scoring system for predicting morbidity and mortality following valve surgery.

Conclusions

Preoperative S' is a right ventricular function echocardiographic parameter that can serve as a predictor of morbidity and mortality following heart valve surgery. In this study, the majority of the population was in atrial fibrillation (AF); however, the data collection did not differentiate between patients with and without AF. Therefore, further research is needed to investigate the potential impact of AF on right ventricular function parameters, including S'.

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Table 1. Participants' characteristics.

Variable	Value (n=148)
Individual factors	
Sex, n (%)	
Male	59 (39.9)
Female	89 (60.1)
Risk factors	
Age (years)	45±12
Body mass index (kg/m2)	23.4±4.4
Smoking	5 (3.4%)
Comorbidity factors	
Electrocardipography, n (%)	
Atrial fibrillation	93 (62.8)
Non-atrial fibrillation	55 (37.2)
Hypertension	19 (12.8)
Pulmonary hypertension before valvular surgery	6 (4.1)
Pulmonary hypertension after valvular surgery	56 (37.8)
Type-2 diabetes mellitus	2 (1.4)
Dyslipidemia	10 (6.8)
Renal dysfunction that requires renal replacement therapy (RRT) Yes No	 1 (0.7) 142 (99.3)
Types of valvular heart disease, n (%)	
Single valve disease	40 (27)
Double valve disease	79 (53)
Triple valve disease	29 (20)
Echocardiography parameter of left ventricle 2D left ventricle ejection fraction (%)	61±9
Echocardiography Parameter of Right Ventricle 3D RVEF (%) TAPSE (mm) RV-FAC (%) Tei Index S' (cm/s) RV-GLS (%) RV-PA Coupling	 36.7±8.5 18 (8-33) 35.7±10.6 0.50 (0.28-2.09) 11 (5-24) 16.6±5.2 0.39 (0.10-2.18)
Operative procedure, n (%)	
Mitral Replacement Repair	 20 (13) 10 (7)
Tricuspid Replacement Repair	 0 0
Aortic Replacement Repair	 9 (6) 1(1)
Pulmonal Replacement Repair	 0 0

Mixed valve Replacement Repair Replacement + Repair	 12 (8) 8 (6) 88 (59)
Operative type, n (%)	
Mechanic Valve replacement Valve repair Valve replacement+repair	 30 (20) 10 (7) 62 (42)
Bioprosthetic Valve replacement Valve repair Valve replacement+repair	 11 (7) 9 (6) 26 (18)
Operative parameters	
Cardiopulmonary bypass duration (minutes)	118 (42-323)
Aortic cross clamp duration (minutes)	85 (27-217)
Concomitant repair tricuspid Yes No	 84 (56.8) 64 (43.2)
Morbidity, n (%)	
Mechanical ventilation duration Prolonged (>24 hours) Non-prolonged (≤24 hours)	 41 (27.7) 107 (72.3)
Duration of inotropic agents Prolonged (14 days) Non-prolonged (<14 days)	 14 (9.5) 134 (90.5)
Intensive care unit stay Prolonged (>96 jam) Non-prolonged (96 jam)	 29 (19.6) 119 (80.4)
Mortality, n (%)	
In-patient mortality Deceased Alive	 20 (13.5) 128 (86.5)
Cause of mortality Cardiac Non-cardiac	 14 (70) 6 (30)
Complication, n (%)	
Stroke Yes No	 10 (6.8) 129 (87.2)
Redo operation Yes No	 9 (6.1) 139 (93.9)

Table 2. Multivariate analysis logistic regression of cardiac mortality incidents during inpatient care in valve surgery patients at National Cardiovascular Center Harapan Kita.

Variable	**Bivariate analysis**			**Multivariate analysis (pre-operation variable)**			**Multivariate (pre-operation variable + during operation)**		
	OR	**95% CI**	**p**	**OR**	**95% CI**	**p**	**OR**	**95% CI**	**p**
3D RVEF <37%	2.11	0.67-6.63	0.312						
TAPSE <18 mm	1.06	0.35-3.24	1.000						
RVFAC <36%	1.66	0.55-5.06	0.537						
Tei Index <0.50	0.75	0.25-2.28	0.821						
S′ <10 cm/s	2.30	0.75-7.03	0.230	3.46	1.01-11.87	0.049*	3.86	1.04-14.40	0.044*
RV-GLS <17%	1.42	0.47-4.32	0.736						
RV-PA coupling <0.39	0.39	0.12-1.30	0.195	0.29	0.08-1.09	0.066	0.29	0.07-1.17	0.082
Age 51 years	5.31	1.57-17.92	0.009*	5.53	1.58-19.37	0.007*	5.61	1.53-20.49	0.009*
CPB 125 min	4.17	1.24-14.02	0.030*	-	-		5.32	1.44-19.64	0.012*
ACC 90 min	2.47	0.78-7.78	0.195	-	-				

Table 3. Multivariate logistic regression analysis of clinical outcomes (all-cause mortality and morbidity) in heart valve surgery patients at National Cardiovascular Center Harapan Kita (categorical).

Variable	Bivariate analysis			Multivariate analysis (pre-operation variable)			Multivariate analysis (pre-operation variable + during operation)		
	OR	95% CI	p	OR	95% CI	p	OR	95% CI	p
3D RVEF <37%	1.81	0.91-3.62	0.130	1.98	0.93-4.20	0.075			
TAPSE <18 mm	2.24	1.12-4.51	0.034*						
RVFAC <36%	1.97	0.98-3.94	0.081						
Tei Index <0.50	0.80	0.40-1.59	0.640						
S′ <11 cm/s	266	1.31-5.42	0.010*	3.08	1.43-6.65	0.004*	2.26	1.01-5.09	0.048*
RV-GLS <17%	2.06	1.02-4.14	0.063						
RV-PA coupling <0.39	2.14	1.07-4.31	0.048*						
Age ≥ 45 years	1.89	0.94-3.78	0.103	1.98	0.92-4.28	0.082	2.83	1.24-6.47	0.014*
AF	1.77	0.85-3.70	0.180						
Hypertension	2.56	0.97-6.80	0.094	2.97	1.01-8.76	0.049*			
BMI >25 kg/m2	0.80	0.38-1.69	0.691						
2D LVEF <61%	1.30	0.66-2.59	0.561						
Pulmonary hypertension after valvular surgery	3.38	1.65-6.91	0.001*	-			2.84	1.28-6.29	0.010*
CPB ≥122 menit	4.57	2.17-9.62	<0.001*	-			5.75	2.47-13.40	<0.001*
ACC ≥85 menit	1.90	0.94-3.81	0.103	-					
Concomitant repair tricuspid	1.70	0.84-3.46	0.193	-					

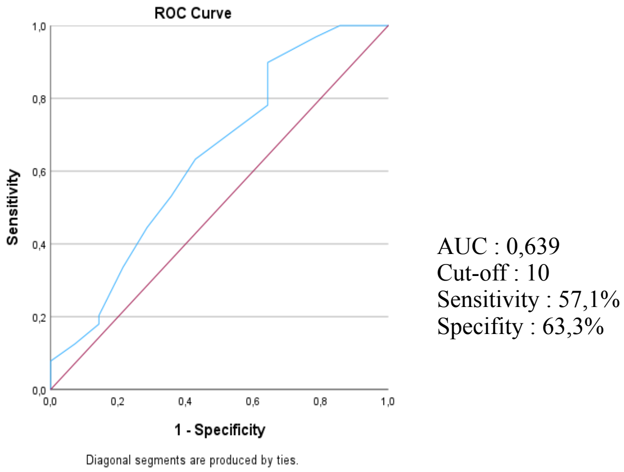

Figure 1. Receiver operating characteristics (ROC) curve of inpatient cardiac mortality in heart valve surgery patients at National Cardiovascular Center Harapan Kita.

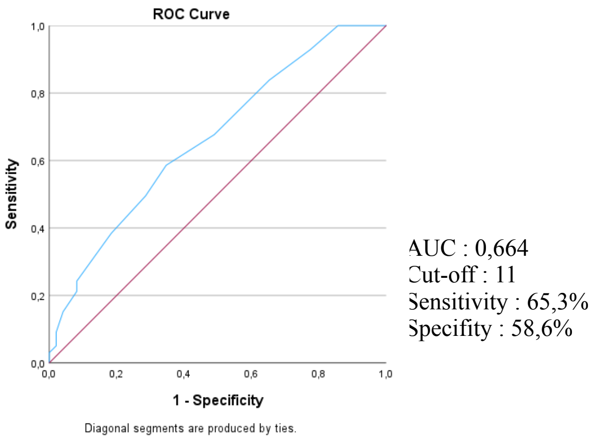

Figure 2. Receiver operating characteristics (ROC) curve of clinical outcomes (all-cause mortality and morbidity) in heart valve surgery patients at National Cardiovascular Center Harapan Kita