



A retrospective study: do patients with left ventricular ejection fraction $\leq 50\%$ benefit from heart valve surgery?

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Background: Left ventricular ejection fraction (LVEF) is an indicator of heart failure, and it is controversial whether patients with reduced preoperative left ventricular ejection fraction can benefit from heart valve surgery. We aimed to assess the differences in clinical characteristics after surgery in patients with different grades of reduced preoperative LVEF to guide clinical management.

Methods: A total of 100 heart valve disease patients with low LVEF ($\leq 50\%$) who had undergone valve surgery in the Department of Cardiology. The patients were divided into three groups according to their LVEF measured by echocardiography before surgery, with LVEF $\leq 40\%$ as group A, $40\% < \text{LVEF} \leq 45\%$ as group B, and $45\% < \text{LVEF} \leq 50\%$ as group C. Clinical characteristics such as postoperative LVEF values, oxygenation index, liver function and inflammatory index, intra-aortic balloon pump (IABP) utilization rate, and mortality were compared among the three groups of patients.

Results: There was no statistically significant difference in the preoperative baseline data between the three groups of patients ($P > 0.05$). The clinical outcomes of patients in group A ($n=28$) were similar to those of patients in groups B ($n=39$) and C ($n=33$) ($P > 0.05$). The vasoactive-inotropic score (VIS), postoperative ventilator use time, length of stay in the care unit, IABP use rate, and mortality rate on the first postoperative day were higher in group A. By comparing the preoperative and postoperative (within 48 hours and 3 months after surgery) cardiac echocardiograms of the three groups, we learned that LVEF increased, LV end-systolic internal diameter and LV end-diastolic internal diameter decreased, and ventricular remodeling improved after surgery compared with the preoperative period ($P < 0.05$). The postoperative improvement was more obvious in group A than in groups B and C. Three months after surgery, LVEF increased to 55%, the LV end-systolic internal diameter decreased to 39 mm, and the LV end-diastolic internal diameter decreased to about 55 mm in each group ($P > 0.05$).

Conclusions: Patients with heart valve disease and low LVEF should be actively treated with heart valve surgery, which can significantly improve the patient's left ventricular reverse remodeling and cardiac function, thereby facilitating survival.

Keywords: Valvular heart disease (VHD); left ventricular ejection fraction (LVEF); valve replacement; clinical outcome

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Introduction

Left ventricular ejection fraction (LVEF) is calculated from end-diastolic volume (EDV) and end-systolic volume (ESV) measurements with the following formula: $LVEF = (EDV - ESV)/EDV \times 100\%$. LVEF is the most commonly used clinical index to evaluate LV systolic function, with normal values of 54–74% in women and 52–72% in men. In general, LVEF 40–50% is considered mildly reduced, 30–40% is considered moderately reduced, and <30% is considered severely reduced (1). Low LVEF reflects decreased cardiac function [decreased cardiac volume, elevated pro-brain natriuretic peptide (pro-BNP)], LV remodeling (enlarged LV, increased EDV and ESV, etc.), and carries a very high risk of perioperative surgery and postoperative mortality (2,3). In the Society of Thoracic Surgeons cardiac surgery risk model (STS-CSR), a 10% reduction in LVEF was associated with a 1.09-fold increase in surgical mortality (4). The survival of patients with valvular heart disease (VHD; including aortic stenosis, aortic valve closure insufficiency, mitral stenosis, and mitral valve closure insufficiency) is impaired when LVEF <60%, so aggressive surgical procedures, especially surgical treatment of heart valves, are of great importance (5). Typically, LVEF $\leq 40\%$ was previously considered a contraindication for heart valve surgery; however, with recent improvements in anesthesia and extracorporeal circulation techniques, as well as improved postoperative monitoring, more and more cardiac centers have relaxed the contraindications, allowing

more patients with severe valvular disease and low LVEF to be effectively treated. Yammine *et al.* (6) found that in patients undergoing repeat aortic valve replacement (AVR), low LVEF ($\leq 35\%$) was associated with increased operative mortality compared with LVEF $>35\%$ and the presence of renal insufficiency, resulting in very low cumulative survival. Macedo *et al.* (7) found that in patients with poor LVEF, the results of heart valve beating replacement surgery were similar to those using conventional heart surgery. Current studies on whether patients with low LVEF benefit from cardiac surgery have mostly focused on coronary artery bypass grafting (8,9), however, studies related to heart valve disease have not been elucidated. In addition, the exploration of low LVEF thresholds for patient benefit from surgery has rarely been reported.

As a result, this study evaluates the clinical efficacy of heart valve surgery in patients with VHD and low LVEF by means of a retrospective analysis, thus providing a basis for clinical practice. We present the following article in accordance with the STROBE reporting checklist (available at <https://jtd.amegroups.com/article/view/10.21037/jtd-22-1345/rc>).

Methods

A total of 100 patients with VHD with low LVEF ($\leq 50\%$) who had undergone valve surgery in the Department of Cardiothoracic Surgery of the First Affiliated Hospital of Guangxi Medical University from January 2019 to December 2021 were collected, including 69 males and 31 females. There were 97 cases with a median chest incision and 3 cases with a small right anterolateral incision assisted by thoracoscopy, and valve surgery was performed under general anesthesia with medium and low temperature extracorporeal circulation. AVR was performed in 46 cases, mitral valve replacement (MVR) in 33 cases, double valve replacement (DVR) in 31 cases. The patients had 20 MVRs and 28 tricuspid valvuloplasty. A total of 22 cases has a preoperative history of hypertension, 9 cases had a history of diabetes mellitus, 2 cases had a history of hyperthyroidism, 2 cases had a history of cerebral infarction, 39 cases had a history of smoking, 40 cases had a history of arrhythmia, and 37 cases had a history of pericardial effusion. Patients were divided into three groups according to LVEF measured by the last cardiac echocardiogram before surgery, with LVEF $\leq 40\%$ for group A, $40\% < LVEF \leq 45\%$ for group B, and $45\% < LVEF \leq 50\%$ for group C. There were no statistically significant differences in the baseline

Highlight box

Key findings

- In patients with a low LVEF of $\leq 50\%$, cardiac surgery favors survival with significant improvement in cardiac systolic function compared to preoperative.

What is known and what is new?

- In some patients, a lower LVEF is a contraindication to heart valve replacement surgery and is associated with higher operative mortality and complications.
- The low LVEF group, moderate LVEF group and retention of LVEF group had similar degrees of postoperative valve anatomic recovery, with patients with lower LVEF showing more significant improvement in myocardial remodeling after heart valve surgery.

What is the implication, and what should change now?

- For patients with low LVEF, physicians should appropriately relax the range of indications for heart valve surgery and give aggressive surgical treatment.

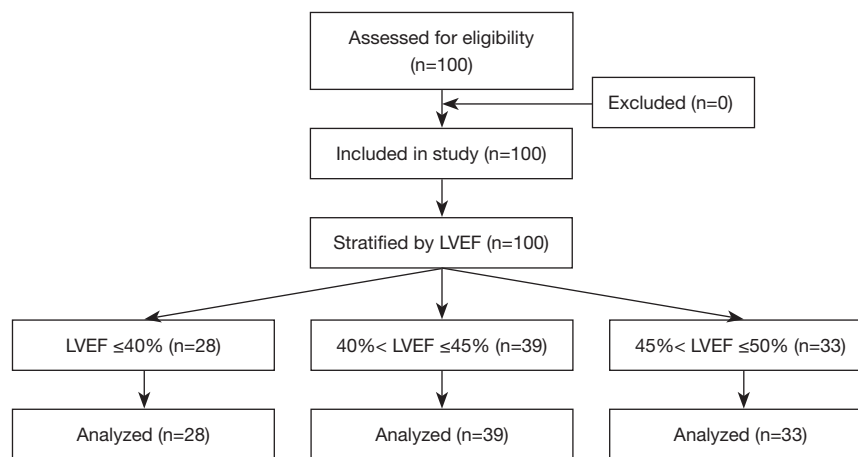


Figure 1 Patient flow diagram illustrating the study design. LVEF, left ventricular ejection fraction.

clinical characteristics of the three groups. Due to the study design as an explorative pilot trial, no formal sample size calculation was performed. *Figure 1* shows a flow chart of this study.

Inclusion and exclusion criteria

The inclusion criteria were based on patient history and signs, and all patients (age >18 years) had cardiac echocardiography receipts collected by two senior cardiac ultrasonographers at our hospital (The First Affiliated Hospital of Guangxi Medical University, Nanning, China) after outpatient and hospital admission, with a clear diagnosis of heart valve disease and two ultrasound findings suggesting LVEF $\leq 50\%$. Patients were excluded according to contraindications for surgery, otherwise they had undergone heart valve surgery. The ultrasound machine model used was the Philips IE33. The exclusion criteria were as follows: patients who were extubated with ventilator-assisted breathing before surgery; patients who had undergone concurrent coronary artery bypass grafting; patients who had undergone a second valve replacement; patients who had undergone nonstop valve replacement; and patients who had undergone valve interventions (e.g., transcatheter aortic valve implantation, transcatheter edge-to-edge repair technique).

Data collection

The patients' clinical data were retrospectively analyzed. The general data included gender, age, height, body mass index (BMI), diabetes mellitus, hypertension, cerebrovascular

disease, hyperthyroidism, smoking history, preoperative arrhythmia, combined pericardial effusion, New York Heart Association (NYHA) classification, and pro-BNP level. The collected surgical data included time of extracorporeal circulation, time of aortic block, intraoperative blood transfusion (red blood cells and plasma), and type of surgery. The postoperative clinical data included oxygenation index, albumin (ALB), total bilirubin (TBiL), supersensitive C-reactive protein (CRP), procalcitonin (PCT), maximal vasoactive drug score (VAS) on the first postoperative day, vasoactive-inotropic score (VIS), duration of postoperative ventilator use, length of stay in the care unit, and the use of an intra-aortic balloon pump (IABP). The echocardiographic measurements included cardiac output (CO), LVEF, left ventricle end-systolic dimension (LVESD), and left ventricle end diastolic dimension (LVEDD). The number of deaths of patients in the three groups was collected. All the patients who died from any cause during hospitalization after heart valve surgery and the patients who died outside the hospital after the family members of critically ill patients gave up treatment and signed for automatic discharge were classified as death cases.

Statistical analysis

SPSS 26.0 statistical software was used for data analysis, and the Kolmogorov-Smirnov test was used for each group to analyze whether the data conformed to the normal distribution. Measurement data conforming to the normal distribution were expressed as mean \pm standard deviation. Differences between two groups were compared using the independent samples *t*-test, preoperative-postoperative comparisons were performed using the paired samples

Table 1 Comparison of preoperative clinical data of the three groups (mean ± standard deviation)/median (P25, P75)

Clinical data	Group A (n=28) (LVEF ≤40%)	Group B (n=39) (40% < LVEF ≤45%)	Group C (n=33) (45% < LVEF ≤50%)	H/F/χ ²	P value
Gender (%)					
Female	5 (17.86)	15 (38.46)	11 (33.33)	3.36	0.186
Male	23 (82.14)	24 (61.54)	22 (66.67)		
Age (year)	51.25±8.54	52.95±11.34	53.12±11.42	0.283	0.754
Height (cm)	166.82±7.47	162.18±8.86	163.41±7.42	2.804	0.066
BMI (kg/m ²)	22.338 (19.4, 25.0)	21.484 (20.5, 23.5)	22.471 (20.0, 25.8)	0.399	0.819
Diabetes (%)	2 (7.14)	4 (10.26)	3 (9.09)	0.193	0.908
Hypertension (%)	6 (21.43)	7 (17.95)	9 (27.27)	0.913	0.633
Cerebrovascular diseases (%)	0 (0.00)	1 (2.56)	1 (3.03)	0.813	0.666
Hyperthyroidism (%)	0 (0.00)	1 (2.56)	1 (3.03)	0.813	0.666
Smoking history (%)	15 (53.57)	11 (28.21)	13 (39.39)	4.411	0.11
Preoperative arrhythmia (%)	10 (35.71)	17 (43.59)	13 (39.39)	0.429	0.807
Pericardial effusion (%)	6 (21.43)	18 (46.15)	13 (39.39)	4.396	0.111
NYHA (%)					
II	12 (42.86)	14 (35.90)	9 (27.27)	4.518	0.34
III	8 (28.57)	18 (46.15)	18 (54.55)		
IV	8 (28.57)	7 (17.95)	6 (18.18)		
Pro-BNP (pg/mL)	5,928.0 (2,336.0, 8,179.8)	2,942.5 (1,429.0, 5,445.8)	2,783.5 (1,616.8, 4,360.0)	5.116	0.077

LVEF, left ventricular ejection fraction; BMI, body mass index; BNP, brain natriuretic peptide; NYHA, New York Heart Association.

t-test, and comparisons between 3 or more groups were performed using ANOVA. Measurement data with a non-normal distribution were expressed as median *M* (P25, P75). Differences between two groups were compared using the two independent samples nonparametric test, and differences between 3 or more groups were compared using the multiple independent samples nonparametric test. Statistical data were expressed as composition ratio (%), and the chi-square test was used for comparisons between groups. Differences were considered statistically significant at *P*<0.05.

Ethical statement

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by the Ethics Committee of the First Affiliated Hospital of Guangxi Medical University [No. 2022-KY-E-(308)]. Individual consent for this retrospective analysis was waived.

Results

Comparison of baseline data among the three groups

According to LVEF grouping, there were 28 patients in group A, including 2 patients with 27% ≤ LVEF <30%, 7 patients with 30% ≤ LVEF <35%, and 19 patients with 35% ≤ LVEF ≤40%. There were 39 patients in group B and 33 patients in group C. The preoperative baseline data including gender, age, height, BMI, diabetes mellitus, hypertension, cerebrovascular disease, hyperthyroidism, smoking history, preoperative arrhythmia, combined pericardial effusion, NYHA classification, and pro-BNP were compared and were not significantly different between groups (*P*>0.05). The proportions of patients with B-type natriuretic peptide precursor (pro-BNP) and NYHA class IV in group A were respectively higher than those in groups B and C, reflecting that the lower the LVEF, the more severe the disease and the worse the cardiac function (Table 1).

Table 2 Comparison of intraoperative and postoperative data of the three groups (mean \pm standard deviation)/median (P25, P75)

Operation information	Group A (n=28) (LVEF \leq 40%)	Group B (n=39) (40% < LVEF \leq 45%)	Group C (n=33) (45% < LVEF \leq 50%)	H/F/ χ^2	P value
Cardiopulmonary bypass time (h)	130.5 (112.3, 158.3)	135.0 (92.0, 166.0)	130.0 (95.5, 161.0)	0.063	0.969
Aortic occlusion time (h)	98.36 \pm 35.84	98.51 \pm 33.43	97.85 \pm 49.36	0.003	0.997
Red blood cells were transfused intraoperatively (U)	0.75 (0.0, 2.0)	0.0 (0.0, 2.0)	0.0 (0.0, 2.5)	0.163	0.992
Intraoperative plasma transfusion (mL)	400.0 (265.0, 467.5)	370.0 (190.0, 420.0)	400.0 (95.0, 465.0)	0.88	0.644
Operation type					
MVR (%)	5 (17.86)	13 (33.33)	15 (45.45)	8.144	0.086
AVR (%)	16 (57.14)	15 (38.46)	15 (45.45)		
DVR (%)	7 (25.00)	11 (28.21)	3 (9.09)		
Oxygenation index	327.64 \pm 107.14	308.25 \pm 132.69	312.22 \pm 181.50	0.155	0.857
ALB (g/L)	37.43 \pm 6.70	37.53 \pm 6.25	37.53 \pm 6.25	0.101	0.904
TBiL (μ mol/L)	27.4 (20.4, 34.0)	25.1 (17.0, 34.8)	24.1 (16.6, 32.2)	1.422	0.491
CRP (mg/L)	48.59 (10.0, 70.3)	28.39 (11.6, 64.2)	32.1 (14.1, 99.2)	1.212	0.545
PCT (ng/mL)	19.28 (6.1, 31.4)	13.18 (3.9, 24.2)	18.05 (7.0, 66.1)	3.315	0.191
Pro-BNP (pg/mL)	2,957.0 (1,592.0, 3472.0)	1,088.0 (524.4, 2,849.0)	1,580.0 (873.2, 2,983.0)	7.5	0.024*
Postoperative day VIS max	11.0 (10.0, 16.0)	10.0 (8.0, 13.0)	10.0 (8.0, 15.0)	5.734	0.057
Duration of ventilator use after surgery (h)	30.0 (16.3, 74.3)	25.0 (14.0, 47.0)	24.0 (12.0, 49.5)	1.051	0.591
Length of stay in the care unit (h)	86.75 (40.6, 155.0)	62.0 (40.0, 85.1)	47.21 (27.8, 73.8)	5.492	0.064
IABP (%)	5 (17.86)	2 (5.13)	1 (3.03)	5.241	0.073
The number of deaths (%)	1 (3.57)	1 (2.56)	3 (9.09)	1.77	0.413

, $P < 0.05$. VIS = dopamine (μ g/kg·min) + dobutamine (μ g/kg·min) +10 millinone (μ g/kg·min) +100* epinephrine (μ g/kg·min) +100* norepinephrine (μ g/kg·min) +10,000* pituitrin (U/kg·min). LVEF, left ventricular ejection fraction; MVR, mitral valve replacement; AVR, aortic valve replacement; DVR, double valve replacement; ALB, albumin; TBiL, total bilirubin; CRP, C-reactive protein; PCT, procalcitonin; BNP, brain natriuretic peptide; VIS, vasoactive-inotropic score; IABP, intra-aortic balloon pump.

Comparison of intraoperative and postoperative data of the three groups

The time of extracorporeal circulation, time of aortic block, intraoperative blood transfusion (red blood cells and plasma), and type of surgery were compared among the three groups, and there were no statistically significant differences among the three groups ($P > 0.05$). There were no statistically significant differences in the comparison of oxygenation index, ALB, TBiL, CRP, and PCT in the three groups of patients within 24 hours after surgery. Patients in group A had a higher maximal VIS on the first

postoperative day, longer postoperative ventilator use, and longer time in the intensive care unit than patients in groups B and C. The rate of IABP was higher than in groups B and C respectively, but this was not statistically significant ($P > 0.05$). The pro-BNP level on the first postoperative day was higher in group A than those in groups B and C, respectively. The comparison between each of the two groups was performed ($P = 0.024$), indicating a statistically significant poorer postoperative cardiac function in group A patients in the early postoperative period. Group C had a higher mortality rate than groups A and B, but this was not statistically significant ($P > 0.05$; *Table 2*).

Table 3 Comparison of preoperative and early postoperative cardiac ultrasound among the three groups

Group	Cardiac ultrasound	Paired (mean ± standard deviation)		Difference value (pre-operation and within 48 hours after surgery)	P value
		Pre-operation	Within 48 hours after surgery		
Group A (n=28) (LVEF ≤40%)	CO (L/min)	8.64±2.78	8.26±3.20	0.38	0.51
	EF (%)	35.68±3.21	47.14±9.47	-11.46	<0.001
	LVESD (mm)	58.57±10.05	47.25±10.78	11.32	<0.001
	LVEDD (mm)	71.43±11.34	62.14±10.97	9.29	<0.001
Group B (n=39) (40% < LVEF ≤45%)	CO (L/min)	8.43±3.23	7.00±2.33	1.43	<0.001
	EF (%)	43.23±1.39	51.38±9.44	-8.15	<0.001
	LVESD (mm)	50.92±9.21	40.77±10.78	10.15	<0.001
	LVEDD (mm)	65.67±11.63	55.36±12.36	10.31	<0.001
Group C (n=33) (45% < LVEF ≤50%)	CO (L/min)	8.93±3.59	7.10±2.28	1.83	<0.001
	EF (%)	47.91±1.40	54.56±7.74	-6.65	<0.001
	LVESD (mm)	47.61±7.84	40.34±7.26	7.27	<0.001
	LVEDD (mm)	64.27±9.99	55.03±9.18	9.17	<0.001
All of the patients	CO (L/min)	8.69±3.20	7.39±2.61	1.3	<0.001
	EF (%)	42.62±5.20	51.21±9.26	-8.6	<0.001
	LVESD (mm)	51.97±9.96	42.46±10.09	9.51	<0.001
	LVEDD (mm)	66.81±11.31	57.17±11.29	9.64	<0.001

LVEF, left ventricular ejection fraction; CO, cardiac output; EF, ejection fraction; LVESD, left ventricle end-systolic dimension; LVEDD, left ventricle end diastolic dimension.

Comparison of preoperative and early postoperative (within 48 hours) cardiac echocardiographic measurements in the three groups

When comparing the preoperative and early postoperative (within 48 hours after surgery) cardiac echocardiographic measurements of the three groups, patients in group A did not have significant CO changes ($P=0.51$). Patients in groups B and C showed a significant decrease in CO after surgery ($P<0.001$). LVEF increased, LVESD and LVEDD decreased, and ventricular remodeling significantly improved in all three groups compared with the preoperative period ($P<0.001$; *Table 3*).

Comparison of preoperative and 3-month postoperative cardiac ultrasound measurements in the three groups

In the comparison of cardiac echocardiographic measurements before and 3 months after surgery in the three groups, CO was reduced and valve structure was

significantly changed in all groups compared with before surgery ($P<0.001$), LVEF increased, LVESD and LVEDD decreased, and ventricular remodeling improved in all three groups compared with the preoperative period ($P<0.001$; *Table 4*).

Comparison of preoperative and postoperative (within 48 hours and 3 months after surgery) cardiac echocardiographic measurements in each group

When comparing preoperative and postoperative (within 48 hours and 3 months postoperatively) cardiac echocardiographic measurements in each group, the preoperative CO in the three groups was not significantly different ($P=0.81$). The comparisons of LVEF, LVESD, and LVEDD among the three groups of patients showed statistically significant differences ($P<0.05$). In the early postoperative review of cardiac echocardiographic measurements, the comparison of CO among the three groups of patients showed no statistically significant

Table 4 Comparison of echocardiography between the three groups before surgery and 3 months after surgery

Group	Cardiac ultrasound	Paired (mean ± standard deviation)		Difference value (pre-operation and 3 months after surgery)	P value
		Pre-operation	3 months after surgery		
Group A (n=28) (LVEF ≤40%)	CO (L/min)	8.64±2.78	6.71±1.87	1.93	<0.001
	EF (%)	35.68±3.21	54.04±13.58	-18.36	<0.001
	LVESD (mm)	58.57±10.05	40.46±9.26	18.11	<0.001
	LVEDD (mm)	71.43±11.34	56.32±7.15	15.11	<0.001
Group B (n=39) (40% < LVEF ≤45%)	CO (L/min)	8.43±3.23	6.63±2.09	1.8	<0.001
	EF (%)	43.23±1.39	53.82±12.55	-10.59	<0.001
	LVESD (mm)	50.92±9.21	39.95±13.37	10.97	<0.001
	LVEDD (mm)	65.67±11.63	55.31±14.04	10.36	<0.001
Group C (n=33) (45% < LVEF ≤50%)	CO (L/min)	8.93±3.59	6.47±1.61	2.47	<0.001
	EF (%)	47.91±1.40	58.88±10.86	-10.97	<0.001
	LVESD (mm)	47.61±7.84	37.67±8.03	9.94	<0.001
	LVEDD (mm)	64.27±9.99	55.18±7.13	9.09	<0.001
All of the patients	CO (L/min)	8.66±3.20	6.60±1.85	2.06	<0.001
	EF (%)	42.66±5.20	55.55±12.36	-12.89	<0.001
	LVESD (mm)	51.97±9.91	39.34±10.63	12.63	<0.001
	LVEDD (mm)	66.82±11.25	55.55±10.26	11.27	<0.001

LVEF, left ventricular ejection fraction; CO, cardiac output; EF, ejection fraction; LVESD, left ventricle end-systolic dimension; LVEDD, left ventricle end diastolic dimension.

difference ($P=0.11$). The comparisons of LVEF, LVESD, and LVEDD among the three groups of patients showed statistically significant differences ($P<0.05$). At 3 months postoperatively, cardiac echocardiographic measurements were repeated again, and a comparison of CO among the three groups of patients showed no statistically significant difference ($P=0.87$). The comparisons of LVEF, LVESD, and LVEDD among the three groups of patients were found to be $P>0.05$. There was no statistically significant difference between the three groups (Table 5).

Discussion

This is a single-center retrospective analysis comparing outcomes and survival after heart valve surgery in patients grouped by LVEF in 2 main ways. First, the outcomes of heart valve surgery in VHD patients with LVEF ≤40% were similar to those of VHD patients with LVEF >40%, with no statistically significant differences in time to extracorporeal circulation, time to aortic block, or intraoperative

transfusion. There were also no statistically significant differences in the comparison of oxygenation index, ALB, TBiL, CRP, and PCT in the three groups within the 24 hours after surgery. A higher VIS score, postoperative ventilator use time, length of stay in the care unit, IABP use rate, and mortality rate on the first postoperative day reflected the disease is serious and difficult to treat, but were not statistically significant. The pro-BNP level on the first postoperative day was significantly higher in group A than those in groups B and C, reflecting the poor postoperative cardiac function and severe condition of group A patients. Second, by comparing the preoperative and postoperative (within 48 hours and 3 months after surgery) cardiac echocardiographic examinations of the three groups, we learned that the LVEF increased, LVESD and LVEDD were both smaller than before, and ventricular remodeling was improved after surgery. Furthermore, the lower the LVEF was, the more obvious the improvement was after surgery, and at 3 months after surgery, the LVEF of patients in each group reached about 55%. Three

Table 5 Comparison of preoperative and postoperative data among the three groups (mean \pm standard deviation)

Cardiac ultrasound	Group A (n=28) (LVEF \leq 40%)	Group B (n=39) (40% < LVEF \leq 45%)	Group C (n=33) (45% < LVEF \leq 50%)	F value	P value
Pre-operation					
CO (L/min)	8.64 \pm 2.78	8.43 \pm 3.23	8.93 \pm 3.59	0.21	0.81
EF (%)	35.68 \pm 3.21	43.23 \pm 1.39	47.91 \pm 1.40	268.04	<0.001**
LVESD (mm)	58.57 \pm 10.05	50.92 \pm 9.21	47.61 \pm 7.84	11.58	<0.001**
LVEDD (mm)	71.43 \pm 11.34	65.67 \pm 11.63	64.27 \pm 9.99	3.54	0.03*
Early postoperative period (within 48 hours)					
CO (L/min)	8.26 \pm 3.20	7.00 \pm 2.33	7.10 \pm 2.28	2.23	0.11
EF (%)	47.14 \pm 9.47	51.38 \pm 9.44	54.56 \pm 7.74	5.16	0.01*
LVESD (mm)	47.25 \pm 10.78	40.77 \pm 10.78	40.34 \pm 7.26	4.69	0.01*
LVEDD (mm)	62.14 \pm 10.97	55.36 \pm 12.36	55.03 \pm 9.18	3.98	0.02*
Three months after surgery					
CO (L/min)	6.71 \pm 1.87	6.63 \pm 2.09	6.47 \pm 1.61	0.14	0.87
EF (%)	54.04 \pm 13.58	53.82 \pm 12.55	58.88 \pm 10.86	1.8	0.17
LVESD (mm)	40.46 \pm 9.26	39.95 \pm 13.37	37.67 \pm 8.03	0.62	0.54
LVEDD (mm)	56.32 \pm 7.15	55.31 \pm 14.04	55.18 \pm 7.13	0.11	0.9

*, $P < 0.05$; **, $P < 0.01$. LVEF, left ventricular ejection fraction; CO, cardiac output; EF, ejection fraction; LVESD, left ventricle end-systolic dimension; LVEDD, left ventricle end diastolic dimension.

months after surgery, patients in each group had an LVEF of approximately 55%, LVESD of 39 mm, and LVEDD of 55 mm, with no statistically significant differences between the groups, reflecting the fact that patients with VHD with lower LVEF benefit more from heart valve surgery. Therefore, even in patients with low LVEF, heart valve surgery should be performed aggressively.

VHD is caused by stenosis and/or regurgitation of the heart valves due to multiple causes. In the early and middle stages of heart valve disease, the stenosis or regurgitation causes changes in heart chamber structure, intra-atrial chamber pressure, and intra-pulmonary vascular pressure, but myocardial contractility does not show a significant decrease, and clinical symptoms generally do not appear. In the middle and late stages, due to abnormal heart valve function, the corresponding neurohumoral regulation function causes changes in volume pressure load and abnormal myocardial structure or function, in which Myocardial cells and myocardial interstitial fibrotic changes, so that myocardial compliance decreases, local diastolic function decreases, resulting in progressive myocardial damage loss of compensation, myocardial remodeling

further deteriorates, the late stage of valvular disease myocardial contractility decreases, which in turn causes changes in the overall systolic and diastolic function of the heart, the clinical manifestations are mainly left heart insufficiency, mostly manifested as a decrease in LVEF. At this time, the hemodynamic impact of valvular factors can aggravate the symptoms of heart failure, manifesting as cardiac cachexia, heart failure, and even death. Drug therapy cannot fundamentally address the problem of heart valve disease, and surgery is still the definitive and effective treatment. Valve replacement surgery is the surgical treatment for VHD and is indicated primarily on the basis of clinical symptoms and hemodynamic development. LVEF, the most commonly used clinical index for evaluating LV systolic function, is also an indication for surgery (10).

It has been suggested that lower LVEF is a key factor for poor prognosis, and patients with VHD and low LVEF tend to have enlarged left ventricles, increased myocardial remodeling, and existing irreversible pathological damage to myocardial cells, which predispose them to postoperative arrhythmias and low cardiac output syndrome, with high mortality and complications (11-14). In this study, there

were no statistically significant differences between the three groups in terms of extracorporeal circulation time, aortic block time, intraoperative blood transfusion (red blood cells and plasma), and type of surgery, and no statistically significant differences in the comparison of oxygenation index, ALB, TBiL, CRP, and PCT in the three groups within 24 hours after surgery. These findings reflect that anesthesia, myocardial protection, extracorporeal circulation, and surgical techniques are mature and advanced technologies, and the risk of anesthesia and surgery is relatively lower in patients with lower LVEF. However, pro-BNP, maximal VIS, postoperative ventilator use time, and length of stay in the care unit were longer in group A than in patients in groups B and C on the first postoperative day, and the IABP use rate was higher than in patients in groups B and C. These findings indicate that patients in group A were sicker than patients in groups B and C, reflecting the difficulty of postoperative recovery and longer recovery time in patients with lower LVEF. This may be mainly due to the fact that heart valve surgery is a mature procedure in China, and the diagnosis and treatment techniques for heart valve disease have continued to improve in the last decade. First, with the continuous advances in echocardiography, CT, MRI, and imaging technologies, the diagnosis of VHD has become more accurate and preoperative assessment more established. Second, with the high incidence of VHD in China and the high number of surgeries each year, the clinicians' surgical techniques have become more skilled, and the improvement of surgical skills has optimized the aortic block time and extracorporeal circulation time, and the appropriate intraoperative treatment of valves has also promoted the recovery of cardiac function in patients after surgery. For example, the posterior valve tissue and subvalvular structures are preserved as much as possible during MVR (15,16). Continuous improvements in anesthesia, intraoperative myocardial protection, extracorporeal circulation, and postoperative monitoring, especially the use of IABP, extracorporeal membrane oxygenation, and other adjunctive devices, have led to smoother surgical management of heart valve disease. These improvements in treatment techniques have led to a gradual reduction in mortality.

There have been several studies of cardiac surgery in patients with low preoperative EF. In a study that included 485 patients with severe aortic valve closure insufficiency undergoing AVR, they were divided into three groups according to LVEF: the low LVEF group (LVEF $\leq 35\%$), moderate LVEF group ($36\% < \text{LVEF} < 50\%$) and retention

of LVEF group (LVEF $> 50\%$). Statistical analysis found that the operative mortality rate was 1.9%, with similar mortality rates between the groups (0% in the low LVEF group, 2.1% in the moderate LVEF group, and the LVEF group was 2.0%). The low EF group showed a large degree of postoperative reverse remodeling, with LV diameter at diastole decreasing from 6.7 to 5.1 cm in diastole and from 5.2 to 3.6 cm during contraction, and EF also improved significantly (mean 30% to 49.5%). The results showed that patients in the low LVEF group had similar postoperative outcomes and survival to those in the moderate LVEF group or the preserved LVEF group, and patients in the low LVEF group who underwent AVR developed postoperative LV reverse remodeling. This result suggests that reduced LVEF may not be a contraindication to surgery (17). Another study divided patients with severe aortic valve closure insufficiency with LVEF $\leq 35\%$ into surgical and pharmacological groups. The mean follow-up time of the study cohort was 6.58 years and the mean survival of patients in the surgical group was 6.31 years, with a 1-year survival rate of 88%. The average survival time of patients in the medication group was 0.5 years, and a 1-year survival rate was 65%. The absolute mortality rate at the end of follow-up was 27.8% in the surgical group compared to 91.8% in the drug-treated group. These results indicate a large benefit of surgery in patients with low LVEF (18). This is a similar finding to other studies of MVR as well as minimally invasive valve replacement surgery (19-21). Overall, patients with VHD and low LVEF have severe perioperative disease and a difficult postoperative recovery, but surgical valve treatment over pharmacological treatment is beneficial for survival (22-26). This is identical to the data of the present study.

Previous studies have shown that heart valve surgery leads to myocardial reverse remodeling of the cardiac structure and improves the functional status of patients (17,27-29), and similar results were obtained in the present study. In the present study, preoperative and postoperative (within 48 hours and 3 months after surgery) cardiac echocardiographic measurements showed a decrease in CO in all groups compared with the preoperative period, it was considered that there was false high row due to anatomical changes before operation, and the valve anatomy was recovered after operation, when CO is true cardiac output and can accurately reflect cardiac function. However, there was no statistically significant difference in the comparison between the preoperative and postoperative groups (within 48 hours and 3 months after surgery), as the degree of

recovery of valve anatomy after surgery was similar in all groups. The LVEF increased, LVESD and LVEDD decreased, and ventricular remodeling improved in all three groups compared with the preoperative period, and the lower the LVEF, the more pronounced the postoperative improvement. At 3 months postoperatively, LVEF increased to 55%, LVESD decreased to 39 mm, and LVEDD decreased to 55 mm in all groups, with no statistically significant differences between the groups, reflecting the fact that patients with VHD and lower LVEF had more significant improvement in myocardial remodeling and benefit from cardiac insufficiency after heart valve surgery.

In this study, the number of cases in group A was limited (the lowest LVEF was 27%, 2 cases were $27\% \leq \text{LVEF} < 30\%$, and 7 cases were $30\% \leq \text{LVEF} < 35\%$). The reasons for this are twofold: (I) valve interventions have been emerging in recent years and have brought great benefits to VHD patients with low LVEF (30), and our traditional nonstop valve replacement surgery also has some advantages in patients with low LVEF (31-33). Therefore, more surgical options are available for these patients; (II) the follow-up period of patients in this study was short, and the long-term results need to be further studied.

Conclusions

In conclusion, in patients with low LVEF, even though the perioperative period of valve surgery is severe and postoperative recovery is difficult, surgical treatment is beneficial for survival, and active surgical treatment should be considered. With the correction of valve anatomy, patients' left ventricular volume was reduced and the systolic function of the heart significantly improved compared with the preoperative period.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at <https://jtd.amegroups.com/article/view/10.21037/jtd-22-1345/rc>

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at <https://jtd.amegroups.com/article/view/10.21037/jtd-22-1345/coif>). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by the Ethics Committee of the First Affiliated Hospital of Guangxi Medical University [No. 2022-KY-E-(308)]. Individual consent for this retrospective analysis was waived.

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