Prognostic factors associated with postoperative adverse outcomes in patients with aortic valve prolapse

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Abstract

Background and aim: Aortic valve (AV) cusp prolapse and subsequent aortic insufficiency (AI) are 2 of factors leading to left ventricular (LV) enlargement and decreased LV function. Aortic valve replacement (AVR) has been the standard surgical procedure for AI. However, few data is available on the prognosis of these patients undergoing AVR procedure, especially in Chinese population. The study aims to evaluate the potential risk factors affecting the mid-term adverse outcomes after AVR.

Methods: One hundred thirty-four patients (mean age: 46.7 years old) with AV cusp prolapse and severe AI who all received surgical aortic valve replacement were recruited in our hospital between January 1, 2009 and December 30, 2017. The clinical characteristics, echocardiography parameters, as well as operative parameters were obtained. The primary endpoint included death, heart failure development, and reoperation.

Results: There were 14 adverse events altogether with the primary endpoint during a median follow-up of 8.6 (6–10) months. The multivariable Cox regression analysis revealed that baseline LVEDD (hazard rate, HR=1.08, 95% CI: 1.01–1.15, P=.021), moderate pulmonary hypertension (HR=9.36, 95% CI: 1.81–48.28, P=.008), and the time of assisted mechanical ventilation (HR=1.01, 95% CI: 1.00–1.01, P=.022) were independently associated with the primary endpoint. Kaplan–Meier survival curve showed a significant worse survival free of the endpoint for patients with LVEDD≥70 mm, indexed LVEDD≥37.3 mm/m^2 (the mean in this study), indexed LVESD≥25 mm/m^2 or baseline LVEF <50% (all P<.05).

Conclusion: Baseline enlarged LV dimensions, low LV function, moderate pulmonary hypertension, and prolonged assisted mechanical ventilation may predict the poor mid-term postoperative outcomes for AV cusp prolapse patients undergoing AVR procedure.

Abbreviations: ACCT = aortic crossclamp time, AI = aortic insufficiency, AOV = the velocity of AV, AV = aortic valve, AVP = aortic valve cusp prolapse, AVR = aortic valve replacement, BSA = body surface area, CAVB = complete atrioventricular block, CI = confidence interval, CPB = cardiac pulmonary bypass, ESC/EACTS = European Society Of Cardiology/European Association For Cardio Thoracic Surgery, HF = heart failure, HR = hazard rate, HTK = Histidine–Tryptophan–Ketoglutarate, IE = infective endocarditis, IQR = interquartile range, LV = left ventricular, LVEDD = left ventricular end-diastolic diameter, LVEF = left ventricular ejection fraction, LVESD = left ventricular end-systolic diameter, NYHA = New York Heart Association.

Keywords: aortic insufficiency, aortic valve replacement, bicuspid aortic valve, factor

1. Introduction

Chronic aortic insufficiency (AI) often develops in a slow manner with a low morbidity during relatively a long asymptomatic stage. However, some patients with severe AI evolve into left ventricular (LV) dilation, systolic dysfunction, and eventually heart failure. In 1991, Bonow et al[1] reviewed 104 asymptomatic patients with severe chronic AR and arrived at a conclusion based on multivariate Cox analysis that age, initial LV end-systolic dimension, rate of change in end-systolic dimension, and ejection fraction predicted the outcome of death or symptom.

El Khoury et al[2] have previously described a mechanistic classification for AI. AV cusp prolapse is type II (cusp prolapse) mechanism of AI. AV prolapse (AVP) has been defined as downward displacement of cuspal material below a line joining the edge points of aortic valve leaflet. The prevalence of AV cusp prolapse as an isolated lesion in the general population is quite low, about 1.2%.[3] It was even less common in patients with trileaflet AVs and those without ascending aortic dilatation. Cohen et al[4] have reported that 69% of patients with eccentric AI jet in a mixed population with AI. Cusp prolapse can be found in isolation or in many kinds of conditions, such as degenerative process related to ageing and hypertension, the late stage of type I lesions, or valvular damage in infective endocarditis (IE). For AV cusp prolapse patients with leaflet thicken and damage, AV replacement (AVR) has been the effective procedure for the treatment of AI. However, few Chinese data is available with respect to the prognosis of the AV cusp prolapse patients after AVR. Therefore, the aim of the study is to evaluate the potential prognostic factors of worse outcome for these patients undergoing AVR.

2. Methods

2.1. Study design and patient selection

One hundred thirty-four patients with AV cusp prolapse diagnosed by echocardiography and undergoing AVR, consecutively recruited from Beijing Anzhen Hospital between January 1, 2009 and December 31, 2017 according to the inclusion and exclusion criteria. The interventional indications of chronic AI are reviewed according to 2017 ESC/EACTS guideline for the management of valvular heart disease, and it relates to symptoms, status of the LV or dilatation of the aorta.[5] These patients had different degrees of lesions in the morphology and structure of the aortic valve, including leaflet thickened by calcification or fibrous tissue deposition, and cusp damage by vegetation or aortic dissection. All the patients in the study were voluntary with complete clinical data. Exclusion criteria were as follows, including severe liver and kidney diseases, death before surgery, and incomplete data. The research protocol was approved by the Institutional Review Board at Beijing Anzhen Hospital and all subjects signed the written informed consent form of the surgery and for the participation of the study.

2.2. Data collection

Before surgery, all these patients have been given adequate medical treatment to improve the preoperative condition. The baseline characteristics were collected, including age, gender, comorbidity, disease course, hospital stays, New York Heart Association (NYHA) functional classification, blood pressure, heart rate, comorbidity, as well as the echocardiogram parameters (left ventricular end-diastolic diameter (LVEDD), left ventricular end-systolic diameter (LVESD), left ventricular ejection fraction (LVEF), the velocity of AV (AOV)). The baseline echocardiography was obtained within 1 week before operation. In addition, we will calculate the indexed LV dimensions, equal to LV dimensions divided by body surface area (BSA) [BSA = $0.0061 \times$ Height (cm) + 0.0128 + Weight (kg) − 0.1529)]. Pulmonary artery systolic pressure was estimated by the velocity of tricuspid regurgitation, categorized into 3 groups: systolic pulmonary artery pressure between 40 and 60 mm Hg in mild

group, 60 to 80 mm Hg in moderate group, and ≥80 mm in severe group. Meanwhile, surgery-related parameters were obtained, including cardiac pulmonary bypass (CPB) time, aortic cross-clamp time (ACCT), the time of assisted mechanical ventilation, and surgical methods.

2.3. Surgical aortic valve replacement

Beijing Anzhen Hospital was listed into the first group of the National Clinical Research Center of Cardiovascular Diseases, boasting China's leading cardiovascular treatment and research. The heart surgeries were performed by the experienced teams, consisting of cardiac surgeons and cardiac anesthesiologists.

2.4. Patients were lying in a supine position

After anesthesia, thoracotomy was performed for the patients, then CPB was established, blocking the ascending aorta and superior and inferior vena cava, and Histidine–Tryptophan–Ketoglutarate (HTK) was poured to make heart arrest. Meanwhile, the pericardial cavity was partially placed with ice debris. The aorta is dissected, and the aortic valve, aortic sinus, and ascending aorta were evaluated. Then remove the aortic valve leaflets, perform the replacement of prosthetic valves, and suture autologous valve ring and the artificial valve ring together. If there is aortic sinus aneurysm or ascending aortic aneurysm, Bentall procedure was needed, that is combination of valve prosthesis, aortic graft replacement, and left and right coronary artery graft. The distal end of the artificial blood vessel was anastomosed to the distal end of the ascending aorta. If the valve prosthesis was well operated, the aortic incision was sutured using a 4-0 prolene line. The heart was resuscitated. The cardiopulmonary bypass was stopped and the pericardial and mediastinal drainage tubes were placed. Close the chest layer by layer and focus on the patients' vital signs, then send them to the ICU.

2.5. Follow-up and postoperative adverse events

During the follow-up period, echocardiography was detected again for the subjects. In addition, primary endpoints we also observed in the study were a combined endpoint of cardiac death, heart failure (HF), new onset of complete atrioventricular block (CAVB), and reoperations. HF included new onset of HF and progression of HF. The former was defined in patients who never had HF symptoms, but developed at least NYHA functional class III during follow-up. The latter was defined when patients were already at NYHA functional class II symptoms at baseline, but progressed to NYHA functional class III or IV at follow-up. The occurrence of events and time was recorded according to medical records and contact with patients or family members.

2.6. Statistical analysis

The continuous variables for following Gaussian distribution were expressed as mean ± standard deviation and compared using t test between 2 group, while the non-Gaussian variables were expressed as median (interquartile range (IQR)), compared using nonparameters test between groups. The noncontinuous variables were expressed as percent (%). Chi-square test or Fisher exact test was performed to compare the variables between 2 groups. Univariable and multivariable Cox regression analysis

were used to evaluate the predictors of the endpoint and hazard ratios (HR) and 95% confidence interval (CI) were calculated. The independent variables included age, gender, NYHA functional class, hospital stay, comorbidity, echocardiography parameters at baseline, and surgery-related parameters. The multivariate regression analyses were performed using forward stepwise (likelihood ratio). To avoid collinearity, 2 separate multivariate analyses were performed to assess the independent prognostic value of left ventricular dimensions and indexed left ventricular dimensions. Kaplan–Meier curves were constructed to assess the survival free from the endpoint and compared by log-rank test using GraphPad Prism for Windows (version 7.00, GraphPad Software, Inc). The cutoff value for LVEDD or indexed LVESD was set according to 2017 ESC/EACTS Guidelines for the management of valvular heart disease.[5] The Statistical Package for Social Science, version 22 for Windows (SPSS22.0, IBM Corp) was used for statistical analyses. Statistical significance was achieved with a 2-tailed value of $P < .05$.

3. Results

Table 1 shows a descriptive overview of the baseline characteristics of all the patients with AVP. The mean age is 46.7 years old, and the proportion of male is 84.3%. Bicuspid aortic valve accounts for 36.6% of the etiology of AVP, 21.6% for infective endocarditis, 20.2% for AV degeneration, and 8.9% for aortic sinus aneurysm. What's more, a small proportion of these patients have takayasu arteritis, Behcet disease, or Marfan syndrome.

For the trileaflet valve, prolapse of the right coronary cusp (51/88, 58.0%) is significantly more common than noncoronary (26/88, 29.5%) and left coronary cusps (11/88, 12.5%). In the bicuspid valve patients, there were no significant differences in prolapse of left anterior leaflet (20/47, 42.6%) and right posterior leaflet (17/47, 36.2%). We did not find echo reports for 5 patients in the hospital system due to system update. But we have confirmed that the patients' diagnosis met the enrollment criteria according to the surgical reports. Therefore, based on the echo data from 129 patients, the features in the echocardiography consist of the enlargement of LV and the relatively fast AOV (Table 2).

Operative parameters and specific surgical procedures were depicted in detail in Table 3. The median time of CPB, ACCT, and time of assisted mechanical ventilation are 113 minutes, 82.0 minutes, and 21.0 hours, respectively. There are 87.4% of patients with only AVR, and 11.3% with Bentall procedures. For the patients with AVR, the valve type is dominated by mechanical valves (87.4%). Other detailed procedures were presented in Table 3.

During a median follow-up of 8.6 (6–10) months, echo revealed that the left ventricle diameter was smaller than that before operation (all $P < .05$). Meanwhile, there were 14 adverse events altogether, including 4 deaths, 2 cases with heart failure, 2 of CAVB with permanent pacemaker implantation, and 6 cases received the reoperation: 3 underwent AVR due to prosthetic valve dysfunction; One with repair of prosthetic valve anastomotic fistula; And exploratory thoracotomy was conducted for another 2 patients with cardiac tamponade, cardiac arrest. The univariate Cox regression models in Table 4 show that NYHA class III to IV, moderate pulmonary artery hypertension, baseline LVEDD, LVESD, LVEF, indexed LVEDD, indexed LVESD, LVEDD≥70 mm, and time of assisted mechanical ventilation are associated with postoperative poor prognosis. The forward

Table 1

The baseline characteristics of all the patients with aortic valve prolapse.

Variables	N	Value
Age (y)	134	46.70 (13.56)
Male (n, %)	134	113 (84.33)
Hospital stay (d)	134	15.00 (7.00)
Disease course (mo)	134	4.00 (21.50)
NYHA (n, %)	134	
Class I	–	9 (6.71)
Class II	–	80 (59.70)
Class III	–	39 (29.10)
Class IV	–	6 (4.48)
SBP (mm Hg)	134	128.97 (14.34)
DBP (mm Hg)	134	64.69 (12.70)
HR (bpm)	134	79.61 (8.43)
Disease status		
Valve degeneration (n, %)	134	27 (20.15)
Aortic dissection type A (Standford) (n, %)	134	3 (2.24)
Infective endocarditis (n, %)	134	29 (21.64)
Paravalvular abscess	134	13 (9.70)
Pulmonary valve involvement	134	2 (1.49)
Redundant or tearing leaflet (n, %)	134	7 (5.22)
Malformation of the aortic valve (n, %)	134	49 (36.57)
Bicuspid aortic valve (n, %)	134	47 (35.07)
Takayasu disease (n, %)	134	2 (1.49)
Behcet disease (n, %)	134	3 (2.24)
Aortic sinus aneurysm (n, %)	134	12 (8.96)
Marfan syndrome (n, %)	134	3 (2.24)
VSD (n, %)	134	7 (5.22)
ASD/PDA (n, %)	134	4 (3.00)
CAD (n, %)	134	12 (8.96)
RHD (n, %)	134	1 (0.75)
Atrial fibrillation (n, %)	134	8 (5.97)
Hypertension (n, %)	134	35 (26.12)
Diabetes (n, %)	134	3 (2.24)

ASD = atrial septal defect, CAD = coronary artery disease, DBP = diastolic blood pressure, HR = heart rate, NYHA = New York Heart Association, PDA = patent ductus arteriosus, RHD = rheumatic heart disease, SBP = systolic blood pressure, VSD = ventricular septal defect.

Table 2

The echocardiographic features of all the patients with aortic valve prolapse.

Variables	N	Value
LVEDD (mm)	129	66.00 (12.00)
LVESD (mm)	129	45.00 (11.50)
Indexed LVEDD (mm/m^2)	129	36.00 (8.06)
Indexed LVESD (mm/m^2)	129	24.20 (8.01)
LVEF (%)	129	58.00 (11.00)
LVEF≥ 50% (n, %)	–	111 (86.05)
LVEF < 50% (n, %)	–	18 (13.95)
AOV (cm/s)		196.00 (79.00)
MV prolapse (n, %)		8 (6.20)
Pulmonary arterial hypertension (n, %)	129	–
No	–	105 (81.40)
Mild	–	15 (11.63)
Moderate	–	9 (7.00)

AOV = the velocity of aortic valve, Indexed LVEDD = LVEDD/body surface area, Indexed LVESD = LVESD/body surface area, LVEDD = left ventricular end-diastolic diameter, LVEF = left ventricular ejection fraction, LVESD–left ventricular end-systolic diameter, MV = mitral valve.

Table 3

The operative and postoperative parameters of all the subjects.

Operative parameters	Value (N = 134)
CPB time (min)	113.00 (56.00)
ACCT (min)	82.00 (44.00)
Time of assisted mechanical ventilation (h)	21.00 (26.00)
IABP (n, %)	3 (2.24)
ECMO (n, %)	1 (0.75)
Only AV replacement (n, %)	117 (87.31)
Bentall (n, %)	17 (12.69)
Minimal invasive surgery (n, %)	5 (3.73)
Aortic valve type (n, %)	–
Mechanical valves	118 (88.06)
Bioprothetic valves	16 (11.94)
Size of prosthetic ring (mm)	23.27 (1.61)
VSD surgery (n, %)	
VSD+Valve replacement	4 (3.00)
Previously VSD surgery	3 (2.24)
MV replacement (n, %)	22 (16.42)
MV repair (n, %)	17 (12.69)
TV repair (n, %)	10 (7.46)
RFCA (n, %)	5 (3.73)
AAO replacement or repair (n, %)	5 (3.73)
CABG (n, %)	8 (5.97)
Sun's procedure (n, %)	2 (1.49)
PCI (n, %)	1 (0.75)
Pacemaker (n, %)	6 (4.48)
Closure of ASD/PFO/PDA (n, %)	4 (3.00)
Overall postoperative events (n, %)	14 (10.4)
Death (n, %)	4 (2.99)
New onset CAVB (n, %)	2 (1.49)
Reoperation (n, %)	6 (4.48)
Heart failure (n, %)	2 (1.49)
Postoperative LVEDD (mm)	51.64 (7.56)
Postoperative LVESD (mm)	35.49 (7.84)
Postoperative LVEF (%)	55.81 (9.68)
Postoperative AOV (cm/s)	234 (61.5)

AAO = ascending aorta, ACCT = aortic crossclamp time, AOV = the velocity of aortic valve, ASD = atrial septal defect, AV = aortic valve, CABG = coronary artery bypass grafting, CAVB = complete atrioventricular block, CPB = cardiac pulmonary bypass, ECMO = extracorporeal membrane oxygenation, IABP = intra-aortic balloon pump, LVEDD = left ventricular end-diastolic diameter, LVEF = left ventricular ejection fraction, LVESD = left ventricular end-systolic diameter, MV = mitral valve, PCI = percutaneous coronary intervention, PDA = patent ductus arteriosus, PFO = patent foramen ovale, RFCA = radiofrequency catheter ablation, TV = tricuspid valve, VSD = ventricular septal defect.

Table 4

Univariate Cox regression analyses to identify parameters associated with primary endpoints.

Variables	Univariable analysis	
	HR (95% CI)	P value
Gender		
Male	1	
Female	0.42 (0.06, 3.19)	.400
Age	1.01 (0.97, 1.05)	.653
NYHA		
Class I–II	1	
Class III–IV	3.09 (1.06, 8.99)	.039
Pulmonary artery hypertension		
Without or mild	1	
Moderate	4.90 (1.35, 17.81)	.016
Hospital stay	1.04 (0.99, 1.08)	.083
Aortic valve type		
Mechanical valves	1	
Bioprothetic valves	0.56 (0.07, 4.31)	.580
Disease course	1.00 (0.99, 1.01)	.808
Valve degeneration		
No	1	
Yes	1.80 (0.56, 5.76)	.323
Infective endocarditis		
No	1	
Yes	0.94 (0.26, 3.36)	.920
Bicuspid aortic valve		
No	1	
Yes	0.90 (0.30, 2.70)	.857
CPB	1.01 (0.99, 1.01)	.142
ACCT	1.01 (0.99, 1.02)	.506
Time of assisted mechanical ventilation	1.01 (1.00, 1.01)	.001
Baseline LVEDD	1.07 (1.02, 1.12)	.007
Baseline LVESD	1.08 (1.03, 1.14)	.001
Indexed LVEDD	1.08 (1.01,1.17)	.029
Indexed LVESD	1.11 (1.03,1.19)	.007
Baseline LVEF	0.92 (0.87, 0.97)	.001
LVEDD group		
<70 mm	1	
≥70 mm	5.92 (1.60, 21.87)	.008
Aortic velocity	1.00 (0.99, 1.01)	.779
CAD		
No	1	
Yes	0.83 (0.11, 6.32)	.854
Atrial fibrillation		
No	1	
Yes	1.23 (0.16, 9.44)	.839
Takayasu+Behcet's+Marfan		
No	1	
Yes	2.15 (0.48, 9.63)	.317

ACCT = aortic crossclamp time, CAD = coronary artery disease, CPB = cardiac pulmonary bypass, LVEDD = left ventricular end-diastolic diameter, LVEF = left ventricular ejection fraction, LVESD = left ventricular end-systolic diameter, NYHA = New York Heart Association.

stepwise Cox regression models revealed that baseline LVEDD (HR = 1.08, 95% CI: 1.01–1.15, P = .021), moderate pulmonary hypertension (HR = 9.36, 95% CI: 1.81–48.28, P = .008), and the time of assisted mechanical ventilation (HR = 1.01, 95% CI: 1.00–1.01, P = .022) are independently associated with the worse outcomes (Table 5). In patients with LVEDD < 70 mm, the cumulative survival rates free of the primary endpoint at 1, 2 years follow-up were 97.6% and 89.5%, respectively. However, in patients with LVEDD ≥ 70 mm showed significantly worse outcome with survival rates free of primary endpoint of 82.2% at 1 year, 68.5% at 2 years (Log-rank 9.26 P = .002). Similarly, patients with indexed LVEDD ≥ 37.3 mm/m^2 (the mean in this study), indexed LVESD ≥ 25 mm/m^2 or baseline LVEF < 50% had poorer primary endpoints (Fig. 1). But for the LVEF, the result may relate to the small number of the patients with LVEF < 50% (only 18 patients). In addition, the longest follow-up time for these patients is 20 months.

Table 5

Step-wise multivariable Cox regression analyses to evaluate the parameters associated with the primary endpoint.

Variables	Multivariable analysis	
	HR (95% CI)	P value
Baseline LVEDD	1.08 (1.01, 1.15)	.021
Moderate pulmonary hypertension	9.36 (1.81, 48.28)	.008
Time of assisted mechanical ventilation	1.01 (1.00,1.01)	.022

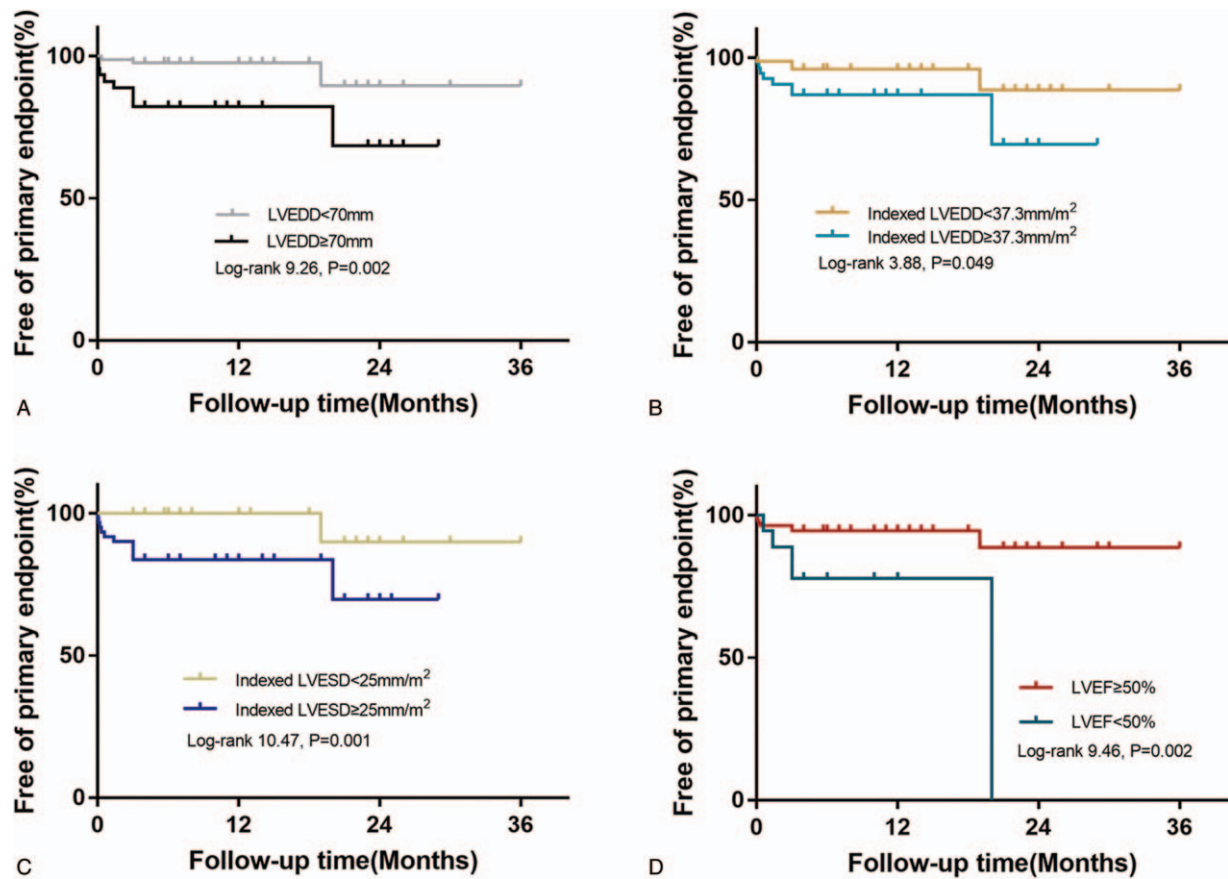LVEDD = left ventricular end-diastolic diameter.

Figure 1. Kaplan–Meier analyses to evaluate the survival free of primary endpoint in different groups divided by LVEDD, indexed LVEDD, indexed LVESD, or LVEF (Note: 18 patients with LVEF < 50% and with longest follow-up time of 20 months for the group of patients in (D)). LVEDD = left ventricular end-diastolic diameter, LVEF = left ventricular ejection fraction, LVESD = left ventricular end-systolic diameter.

4. Discussion

AV cusp prolapse, described as type II dysfunction of AI, is the relatively common mechanism and will be the focus of the current research. The study is a single-center retrospective cohort study based on 134 AV cusp prolapse patients from Beijing Anzhen Hospital over the past 9 years. AVP is seen in patients with various cardiac disorders, bicuspid aortic valve as a most common cause, followed by infective endocarditis and valve degeneration. We found that baseline LVEDD, moderate pulmonary hypertension, and the time of assisted mechanical ventilation are independently associated with the postoperative worse outcomes. When LVEDD is considered a continuous variable, each unit increase in LVEDD is independently associated with increasing by 8% of the risk of poor outcomes. A large preoperative LVEDD, indexed LVEDD, indexed LVESD, and a low EF are important predictors of primary endpoint. Based on the sample size of patients with LVEF < 50%, it needs to be cautious to arrive at such conclusion.

According to the current studies, AV repair is an efficient procedure to provide durable midterm or long-term outcome for the patients with isolated AV cusp prolapse or along with aortic dilatation.[6,7] However, the AVs in our participants were of poor quality. So we evaluate the prognostic factors associated with postoperative worse events in the patients with AV cusp prolapse undergoing AVR during a median follow-up of 8.6 months, which has little research in this field, especially in Chinese population. Therefore, our results have

been indirectly supported by the related studies on AVR due to severe AI. Brown et al[8] figured out that at a mean follow-up of 3.3 years, larger indexed left ventricular systolic and diastolic dimensions were associated with late mortality in patients who received AVR for AI, but decreased EF and increased LV dimensions were not. One reported that a low preoperative EF was an independent predictor of all-cause death and cardiac death. Moreover, a large preoperative LVESD was an important predictor of all-cause death and cardiac death, but a large preoperative LVEDD was not.[9] Other studies have shown that a low preoperative EF and great LVESD enlargement was associated with a poor long-term prognosis after AVR.[10,11] All these results are consistent with our data, but the mean follow-up period is too short to examine the association between long-term prognosis of patients undergoing AVR procedure. The preoperative indexed LV dimensions can predict early recovery of LV function, and preoperative LV function determines early recovery of LVEDD after AVR,[12,13] which may provide good outcomes for these patients.

Pulmonary hypertension is a complex disease characterized by restricted flow through pulmonary circulation, which results in an increase right ventricular afterload, further leading to progressive right ventricular dysfunction and failure.[14] In the perioperative period, pulmonary hypertension is a known risk factor for adverse outcomes in cardiac surgery because of challenging hemodynamic management during perioperative period.[15,16] In our study, moderate pulmonary hypertension was an independent predictor of mid-term worse prognosis.

However, the conclusion was arrived with insufficient evidence based on the small sample size. Therefore, further research will be needed to investigate the effect of pulmonary hypertension on the prognosis of these patients.

We also figured out that the prolonged assisted ventilation was independently although weakly associated with mid-term poor outcomes. In the current research, there was little data reporting the relationship between prolonged assisted ventilation and poor outcome in patients undergoing AVR. But prolonged assisted ventilation after major cardiac surgeries has been shown to adversely affect postoperative outcome and survival and is associated with incremental health costs.[17–19] Therefore, our study shed light on the condition of prolonged assisted ventilation as an important prognostic factor in the AVR setting.

Several limitations of this study need to be mentioned. Firstly, not all factors related to the outcomes in the population are taken into account, such as whether or not the skilled surgeons and other unknown factors. Secondly, there are several causes associated with AV cusp prolapse, which may affect the outcomes. Although we have taken etiologies of AVP into account in the regression model and not found its association with the outcomes, population heterogeneity is an inescapable problem in the study, which is also one of the most common limitations of retrospective analysis. Thirdly, the event number is small, which may affect the result of the Cox regression multivariate analysis. This is also associated with small sample size in our study. Another limitation is unavoidable selection bias of the population.

In conclusion, bicuspid aortic valve and infective endocarditis are 2 mostly common etiologies for AV cusp prolapse patients from single-center data over the past 9 years. Baseline LVEDD, moderate pulmonary hypertension, and prolonged assisted mechanical ventilation are independently associated with the postoperative worse outcomes. A large preoperative LVEDD, indexed LVEDD, indexed LVEDD, and a low EF are important predictors of primary endpoint.

Author contributions

Data curation: Yanping Ruan, Xiaowei Liu.
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