The Heart Surgery Forum #2019-2369
22 (6), 2019 [Epub December 2019]
doi: 10.1532/hsf.2369

Online address: http://journal.hsforum.com

Baseline and Outcome Characteristics of Multiple Valve Surgery Compared with Single Valve Procedures in Mainland China: A Multicenter Experience

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ABSTRACT

Background: To compare baseline and outcome characteristics of multiple valve surgery with single-valve procedures in a multicenter patient population of mainland China.

Methods: From January 2008 to December 2012, data from 14,322 consecutive patients older than 16 years who underwent heart valve surgery at five cardiac surgical centers (except pulmonary valve operations) were collected. The patients were divided into seven subgroups according to the type of valve procedures, and baseline characteristics and postoperative outcomes were contrasted between all seven combinations of single-valve and multiple-valve procedures involving aortic, mitral, and tricuspid valves. Two independent logistic regression analyses were performed and multivariable risk factors for mortality were compared, with emphasis on single-valve versus multiple-valve surgery.

Results: Baseline characteristics for MUV procedures (n = 8945) shared many differences to those for single-valve procedures (n = 5377). Proportion of females, chronic obstructive pulmonary disease, cerebrovascular disease, renal impairment, congestive heart failure, NHYA class III-IV, atrial fibrillation, pulmonary hypertension, and decreased ejection fraction were more common in MUV subgroups, and smoker, hypertension, dyslipidemia, active infectious endocarditis, and coronary bypass graft was less frequent. In-hospital mortality was higher for MUV as compared with single-valve procedures (2.4% versus 1.6%, P = .007). Preoperative independent predictors for mortality of patients undergoing MUV procedures were age, chronic obstructive pulmonary disease, diabetes mellitus, renal dysfunction, dialysis, congestive heart failure, cardiogenic shock, NYHA class III-IV, mitral stenosis, tricuspid regurgitation, mitral valve replacement, and concomitant CABG. However, risk factors for mortality were relatively different between single-valve and MUV procedures.

Conclusion: Baseline characteristics and epidemiology were different between MUV and single-valve procedures. The in-hospital mortality and postoperative complications for MUV procedures remained considerably higher and determinants of mortality were relatively different across procedures types. These findings serve as a benchmark for further studies, as well as suggest a continued search for explanations of MUV outcomes.

Received December 30,2018; received in revised form May 5, 2019; accepted June 13,2019.

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Supported by Public Welfare Fund of Health Ministry (200802096).

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INTRODUCTION

Valvular heart disease (VHD) is the most frequently acquired cardiac disease in China, and it also remains frequent in developed countries because of the predominance of degenerative valvular diseases [Nkomo 2006]. To our knowledge, rheumatic and degenerative valve disease may affect multiple valves and require double or triple valve surgery [Alsoufi 2006]. In addition, patients with prosthetic valve dysfunction frequently require multiple valve surgery owing to extensive fibrosis and calcification at the base of the heart, progress of cardiac disease in the remaining heart valves, and functional tricuspid valve regurgitation secondary to severe left-side valvular dysfunction [Feindel 2003; De Oliveira 2005; Dreyfus 2005].

Despite improvements of surgical techniques and perioperative care, multiple valve (MUV) surgery still carries a risk of mortality and morbidity. In North America, MUV surgery comprises only 12% of valve procedures and its mortality is more than twice that of single valve operations and accounts for as many as a third of operative deaths after valve surgery [Lee 2011; Vassileva 2014]. Although predictors for morbidity and mortality have been well documented for single-valve procedures [Nowicki 2004; Hannan 2013; O'Brien 2009; Shahian 2009], especially aortic and mitral valves, the determinants of adverse outcomes for MUV surgery have been less well defined.

The epidemiology of heart valve disease in China is different from that of western industrialized countries. Rheumatic heart disease, which does not influence a particular valve, remains the key cause of heart valve disease at our institutions. Hence, multiple valve procedures are common in China. The purpose of this study was to evaluate baseline characteristics and outcomes for MUV surgery compared with those of patients undergoing single valve procedures in a multicenter patient population of mainland China.

Table 1. Perioperative Baseline Characteristics of Patients Undergoing Single- versus Multiple-Valve Procedures

Variable	Single Valve A (n = 2391)	Single Valve M (n = 2743)	Single Valve T (n = 243)	Double Valve AM (n = 1747)	Double Valve MT (n = 4266)	Double Valve AT (n = 134)	Triple Valve AMT (n = 2798)	*P*
Age, y, mean	51.1	49.6	50.1	51.1	49.1	50.2	<.0001	
60-69, %	23.9	21.2	46.6	18.2	16.1	20.7	25.2	17.0
≥70, %	7.6	4.5	1.6	4.5	3.6	3.9	2.5	
Female, %	29.2	54.3	59.9	53.6	63.6	42.7	56.7	<.0001
Smoker, %	23.1	14.8	10.2	16.4	11.3	14.6	14.8	<.0001
Hypertension, %	30.0	19.3	10.7	14.3	12.2	17.5	9.5	<.0001
Diabetes mellitus, %	4.8	5.5	4.8	4.1	5.0	2.0	3.4	.143
Dyslipidemia, %	25.4	23.1	12.3	22.5	22.8	18.4	20.4	.034
COPD, %	4.8	4.6	6.4	3.3	6.5	7.8	6.4	.018
Cerebrovascular disease, %	2.2	6.0	3.2	5.4	6.1	1.0	6.4	<.0001
Peripheral vascular disease, %	1.6	1.9	0.5	1.1	0.9	0.0	1.7	.023
Renal function, %								
eGFR 60-90 (mL/min/1.73 m^2)	27.4	32.9	30.5	34.7	34.5	36.9	34.2	<.0001
eGFR 30-60 (mL/min/1.73 m^2)	9.4	12.1	5.9	11.2	14.1	9.7	13.2	
eGFR<30 (mL/min/1.73 m^2)	0.5	0.6	1.6	1.0	0.4	0.0	0.6	
Dialysis	0.5	0.6	1.1	0.7	0.5	1.0	0.7	
Active infectious endocarditis, %	4.4	5.3	1.6	5.1	1.2	10.7	3.0	<.0001
Previous valve surgery, %	2.9	4.7	42.2	2.4	7.9	26.2	3.2	.220
Cardiogenic shock, %	0.1	0.2	0.0	0.1	0.1	1.0	0.3	.392
Congestive heart failure, %	8.7	11.5	10.2	13.3	15.8	17.5	16.8	<.0001
NHYA class III-IV,%	44.2	55.3	55.6	62.2	61.9	69.9	65.1	<.0001
Atrial fibrillation, %	4.7	34.9	48.1	40.8	66.7	36.9	65.4	<.0001
Pulmonary hypertension, %	16.1	51.9	39.0	54.8	59.3	50.5	61.3	<.0001
Myocardial infarction, %	1.0	1.9	0.5	0.6	0.4	0.0	0.3	<.0001
Number of diseased coronary vessels,%								
One	2.8	3.0	2.1	1.8	2.0	1.0	1.3	<.0001
Two	1.4	2.1	0.0	1.0	0.7	0.0	0.5	
Three		1.7	2.7	0.5	0.4	0.9	1.0	0.3
Left main disease, %	0.7	0.8	0.5	0.3	0.3	0.0	0.3	<.0001
Status								
Nonelective sugery, %	0.8	0.6	0.6	0.2	0.3	2.9	0.4	.117
Ejection fraction								
Mean, %	60.5	64.0	62.0	60.9	60.8	57.8	59.2	<.0001
40-49, %	7.6	3.8	2.7	7.8	6.3	16.5	9.3	
30-39, %	3.3	1.1	1.1	2.5	0.9	3.9	2.5	
≤30, %	0.4	0.1	0.5	0.1	0.1	1.0	0.2	
Valve lesion								
MS, %	2.0	43.5	4.8	69.0	70.5	4.9	80.9	<.0001
MR, %	5.7	64.9	7.5	43.1	52.6	14.6	50.5	<.0001

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Table 1 [CONT]. Perioperative Baseline Characteristics of Patients Undergoing Single- versus Multiple-Valve Procedures

Variable	Single Valve A (n = 2391)	Single Valve M (n = 2743)	Single Valve T (n = 243)	Double Valve AM (n = 1747)	Double Valve MT (n = 4266)	Double Valve AT (n = 134)	Triple Valve AMT (n = 2798)	*P*
AS, %	56.4	3.1	3.7	59.3	3.1	37.9	52.6	<.0001
AR, %	68.0	1.1	1.6	67.8	2.2	69.9	65.2	<.0001
TS, %	0.1	0.2	2.7	0.4	0.7	1.9	2.0	<.0001
TR, %	2.6	10.4	85.6	12.9	67.0	62.1	55.9	<.0001

A indicates aortic; COPD, chronic obstructive pulmonary disease; eGFR, estimated glomerular filtration rate, calculated using the Cockroft-Gault formula: for men: weight (kg)×(140-age[y])/(72 × serum creatinine [mg/dL]); for women: weight (kg) ×(140-age[y]) × 0.85/(72 × serum creatinine [mg/dL]); M, mitral; NYHA, New York Heart Association; R, moderate/severe regurgitation; S, stenosis; T, tricuspid.

PATIENTS AND METHODS

Study Population and Data Collection

In this multicenter retrospective study, all 14,322 patients older than 16 years who underwent single or multiple valve surgery at five cardiac surgical centers during the period from January 2008 to December 2012 were included. The cardiac surgical units participating in this study included Fu Wai Hospital in Beijing, An Zhen Hospital in Beijing, Changhai Hospital in Shanghai, Zhongshan Hospital of Fudan University in Shanghai, and Guangdong Cardiovascular Institute in Guangzhou. Patients were excluded if they had CABG, atrial fibrillation undergoing various ablation procedures, or pulmonary valve surgery because of their small numbers. Patients with concomitant aortic root reconstruction, aortic aneurysm, cardiac trauma, or other major noncardiac procedures were also excluded. The 4-year sample of patients was grouped by the seven types of valve operations: aortic (A), n = 2391; mitral (M), n = 2743; and tricuspid (T), n = 243, aortic plus mitral (AM), n = 1747; mitral plus tricuspid (MT), n = 4266; aortic plus tricuspid (AT), n = 134; and triple valves (AMT), n = 2798.

Information on patients and the procedural risk factors for all patients were collected from the local computerized database designed by the Department of Cardiothoracic Surgery, Changhai Hospital, Shanghai, China. This multicenter retrospective study was supported by Public Specialty Fund of Health Ministry (200802096). The review of these records was approved by our institutional committee for human research.

Outcome Endpoints

The outcome endpoints of this study were 30-day mortality and major morbidity characteristics including (1) cerebrovascular accident (CVA): a central neurologic deficit persisting longer than 72 hours; (2) renal failure (RF): a new requirement for dialysis; (3) prolonged ventilation (Vent): required mechanical ventilation for 48 h or more, either continuously or in total after reintubation; (4) reoperation for any reason (Reop); and (5) prolonged postoperative length of stay (PLOS): length of stay (LOS) more than 14 days (alive or dead).

Statistical Analysis

Statistical analyses were performed with SPSS version 19.0 (SPSS, Chicago, Illinois, USA). Continuous variables were expressed as mean, and categorical variables were expressed as percentages. Statistical analysis was performed by Kruskal-Wallis tests for continuous variables with respect to age, renal function, and ejection fraction (EF) and Pearson chi-square test for categorical variables. A P value of less than .05 was considered significant.

Missing data are uncommon in our study, with a frequency of less than 1% missing for most variables. Model variables with more than 1% missing were body surface area (BSA) (4.02%), body mass index (BMI) (4.02%), serum creatinine (3.23%), and left ventricular ejection fraction (EF) (4.62%). To make full use of the available data, missing values were replaced by the single imputation technique [Little 2002] before the risk score was calculated. For example, binary risk factors were modeled as yes versus no, or missing. Thus, missing values were analyzed as if the endpoint did not occur. Missing data on categorical variables were imputed to the lowest risk value. Missing data on continuous variables were imputed to the conditional median.

The distributions of patient characteristics and outcomes for each of the seven subgroups were analyzed and compared. Three different logistic regression models, based on the entire cohort, single-valve, and MUV procedures were used to compute odds ratios (ORs) for in-hospital mortality for the various preoperative risk factors, using standard approaches [Hosmer 2000]. Major morbidity characteristics for each subgroup were also examined and compared.

RESULTS

Perioperative Baseline Characteristics

The perioperative baseline characteristics of patients who underwent single-valve and MUV procedures are shown in Table 1. As Table 1 shows, the most baseline characteristics in single-valve procedures were different from those in MUV procedures. The mean age for the entire cohort was 50.4 years and the patients older than 60 years were more common

Table 2. The Epidemiology and Valve Procedures of Patients Undergoing Single- versus Multiple-Valve Procedures

	Single Valve A (n = 2391)	Single Valve M (n = 2743)	Single Valve T (n = 243)	Double Valve AM (n = 1747)	Double Valve MT (n = 4266)	Double Valve AT (n = 134)	Triple Valve AMT (n = 2798)	*P*
Epidemiology								
Rheumatic valve disease, %	17.4	48.8	46.8	82.6	75.5	32.5	88.1	<.0001
Degenerative valve disease, %	31.8	32.2	2.4	7.9	18.1	21.3	5.9	<.0001
Congenital valve disease, %	38.7	2.6	16.1	3.9	1.6	25.0	2.7	<.0001
Infective endocarditis, %	7.5	6.3	3.2	7.0	2.0	10.0	4.5	<.0001
Ischemic valve disease, %	0.1	2.3	0.0	0.4	0.6	0.0	0.3	<.0001
Functional valve disease, %	6.8	6.8	29.0	8.0	60.4	60.0	52.2	<.0001
Traumatic valve disease, %	0.0	0.1	2.4	0.0	0.0	1.3	0.0	.050
Iatrogenic valve disease, %	0.1	0.1	0.0	0.0	0.1	1.3	0.1	.775
Prosthetic valve dysfunction, %	1.4	1.3	3.2	0.6	1.8	10.0	1.3	.549
Valve Procedures								
AVRepair	0.3	0.0	0.0	0.3	0.0	4.9	1.8	<.0001
AVR	99.7	0.0	0.0	99.7	0.0	95.1	98.2	<.0001
MVRepair	0.0	31.3	0.0	11.2	11.5	0.0	5.9	<.0001
MVR	0.0	68.7	0.0	88.8	88.5	0.0	94.1	<.0001
TVRepair	0.0	0.0	50.3	0.0	98.7	91.3	97.9	<.0001
TVR	0.0	0.0	49.7	0.0	1.3	8.7	2.1	.001
Concomitant CABG, %	6.4	7.2	2.1	2.5	2.7	2.9	2.0	<.0001
Concomitant AF ablation, %	0.3	12.4	1.1	13.0	10.8	2.9	6.7	<.0001

A indicates aortic; AF, atrial fibrillation; AVRepair, aortic valve repair; AVR, aortic valve replacement; CABG, coronary artery bypass graft; M, mitral; MVRepair, mitral valve repair; MVR, mitral valve replacement; T, tricuspid; TVRepair, tricuspid valve repair; TVR, tricuspid valve replacement.

in single-valve procedures. Women underwent MUV procedures more often than men compared to single-valve procedures: AM (53.6%), MT (63.6%), and AMT (56.7%). Smoker, hypertension, and dyslipidemia were more common in single aortic valve procedures (23.1%, 30.0%, and 25.4% respectively) and less common in MUV procedures (average 13.5%, 11.8%, and 21.9% respectively). The patients undergoing MUV procedures more often had chronic obstructive pulmonary disease (COPD) and cerebrovascular disease than those undergoing single-valve procedures, whereas COPD for single tricuspid valve procedures was similar to that for MUV procedures. The patients undergoing MUV procedures more often had renal dysfunction than those undergoing single-valve procedures; however, renal failure with dialysis was similar between the single-valve and MUV procedures. The patients undergoing single-valve procedures more often had active endocarditis than those undergoing MUV procedures, whereas incidence of endocarditis was highest in aortic plus tricuspid valve population (10.7%). Although the proportion of the patients with New York Heart Association class III/IV and congestive heart failure was higher for the MUV procedures, the single-valve and MUV procedures were similar with respect to cardiogenic shock and ejection fraction. Very few patients were operated in a non-elective status for both the single-valve and MUV procedures. Patients undergoing MUV procedures had a higher incidence of atrial fibrillation and pulmonary hypertension and a lower incidence of coronary disease and myocardial infarction than those undergoing single-valve procedures. Only diabetes mellitus, peripheral vascular disease, and previous valve surgery were similar between single-valve and MUV procedures.

Epidemiology and Valve Procedures

The epidemiology and valve procedures of patients who underwent single-valve and MUV procedures are shown in Table 2. As Table 2 shows, rheumatic valve disease remains the key cause of heart valve disease within both single-valve and MUV procedures except for single aortic valve procedures. Meanwhile, patients undergoing MUV procedures more often had functional tricuspid valve disease. Compared with MUV procedures, patients undergoing single aortic or mitral procedures more often had congenital valve disease and degenerative valve disease. Patients undergoing single-valve procedures had a higher incidence of infective endocarditis and ischemic valve disease than those undergoing MUV procedures. With respect to valve procedures, aortic valve

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Table 3. The Mortality and Postoperative Complications of Patients Undergoing Single- versus Multiple-Valve Procedures

	Single Valve A (n = 2391)	Single Valve M (n = 2743)	Single Valve T (n = 243)	Double Valve AM (n = 1747)	Double Valve MT (n = 4266)	Double Valve AT (n = 134)	Triple Valve AMT (n = 2798)	*P*
In-hospital mortality, %	2.1	1.0	3.7	1.9	2.4	5.8	2.4	.007
Postoperative complications								
CVA	1.1	0.8	2.1	1.3	0.9	0.0	1.2	.742
RF	1.5	1.1	1.6	1.3	1.7	3.9	1.8	.105
Vent	4.3	3.9	11.8	5.7	6.3	15.5	7.5	<.0001
Reop	2.8	2.1	3.2	2.4	3.4	3.9	4.5	.001
PLOS	3.5	3.6	11.2	3.9	5.3	75.7	6.4	<.0001

A indicates aortic; CVA, cerebrovascular accident; M, mitral; PLOS, prolonged postoperative length of stay; Reop, reoperation for any reason; T, tricuspid; Vent, prolonged ventilation.

replacement (AVR) and mitral valve replacement (MVR) remain the key treatment for both the single-valve and MUV procedures, especially for aortic valve disease. Mitral valve repair (MV Repair) was performed in more than 30% of patients undergoing single mitral valve procedures for mitral regurgitation. Tricuspid valve repair (TV Repair) was performed in more than 95% of patients undergoing MUV procedures who had functional tricuspid valve disease, compared with nearly 50% of patients undergoing single tricuspid valve procedures. Moreover, the patients undergoing MUV procedures were more likely to have concomitant atrial fibrillation ablation procedures, whereas they had a lower incidence of coronary artery bypass graft (CABG) than those undergoing single-valve procedures.

Mortality and Postoperative Complications

The in-hospital mortality and postoperative complications of patients who underwent single-valve and MUV procedures are shown in Table 3. As Table 3 shows, mortality for MUV procedures (AM, MT, AT, and AMT) (2.4%) was higher than that for single-valve procedures (A, M, and T) (1.6%, $P = .007$). Patients undergoing MUV procedures also had a higher incidence of three postoperative complications (Vent, Reop, and PLOS) than those undergoing single-valve procedures, especially for aortic plus tricuspid valve procedures. Postoperative CVA and RF were similar between single-valve and MUV procedures. However, in-hospital mortality and three postoperative complications (CVA, Vent, and PLOS) for single tricuspid valve procedures were even higher than that for MUV procedures.

Various preoperative risk factors and odds ratios (ORs) from the two multivariable analyses are presented in Table 4. As Table 4 shows, age, renal failure with dialysis, NHYA class III-IV, mitral stenosis, tricuspid regurgitation, and concomitant CABG are preoperative risk factors for in-hospital mortality of patients undergoing single-valve and MUV procedures. However, there were also some differences in preoperative risk factors for in-hospital mortality between single-valve and MUV procedures. Chronic obstructive pulmonary disease (COPD), diabetes mellitus, renal dysfunction, congestive heart failure, cardiogenic shock, and mitral valve replacement (MVR) are preoperative risk factors for in-hospital mortality of patients undergoing MUV procedures, whereas ejection fraction, atrial fibrillation, non-elective status, and aortic valve replacement (AVR) are preoperative risk factors for in-hospital mortality of patients undergoing single-valve procedures.

DISCUSSION

Significant advances in surgical care for patients with valvular heart disease have taken place in recent years, and outcomes in heart valve surgery seem to be improving [Gillinov 2003; Rankin 2006; Talwar 2007; Brown 2009; Gammie 2009; Vassileva 2012; Chatterjee 2013]. In the area of aortic valve disease, falling mortality and major perioperative morbidity rates have been documented [Brown 2009], primarily those with adverse risk profiles and advanced age [Bhudia 2007]. Within the area of mitral valve surgery, declining mortality has also occurred [Gammie 2009; Chatterjee 2013] due to increased application of valve repair as the preferred surgical approach for the correction of mitral valve disease [Savage 2003; Nowicki 2003; Rankina 2013]. Although there are improvements in operative and myocardial protection techniques, mortality for MUV procedures remains twice as high as that for single-valve procedures [Lee 2011; Vassileva 2014]. Thus, the goal of this study was to define differences in baseline characteristics and outcomes for MUV procedures compared with those of patients undergoing single-valve procedures, which could also address outcome improvement.

Unsurprisingly, baseline characteristics in MUV procedures were different from those in single-valve procedures. The patients undergoing MUV procedures included a greater proportion of females, and were more likely to have chronic obstructive pulmonary disease, cerebrovascular disease, renal impairment, congestive heart failure, NHYA class III-IV, atrial fibrillation, pulmonary hypertension, and decreased

Table 4. Multivariable Odds Ratios for In-Hospital Mortality of Patients Undergoing Single- vs Multiple-Valve Procedures

Preoperative Risk Factor	ORs for In-Hospital Mortality	
	Single-Valve Procedures (n = 5377)	Multiple-Valve Procedures (n = 8945)
Age		
60-69years	2.11	1.73
≥70years	4.22	3.46
Ejection fraction		
40-49%	1.99	NA
30-39%	3.98	NA
<30%	5.97	NA
COPD	NA	1.92
Diabetes mellitus	NA	1.38
Renal function		
eGFR 60-90 (mL/min/1.73m^2)	NA	1.23
eGFR 30-60 (mL/min/1.73m^2)	NA	2.46
eGFR 30 (mL/min/1.73m^2)	NA	3.69
Renal failure with dialysis	14.12	1.23
Congestive heart failure	NA	1.73
Cardiogenic shock	NA	4.85
NHYA class III-IV	1.90	3.41
Atrial fibrillation	2.91	NA
Mitral stenosis	0.38	1.22
Aortic stenosis	NA	NA
Tricuspid regurgitation	2.39	1.43
Nonelective status	6.84	NA
MVR	NA	0.46
AVR	2.20	NA
Concomitant CABG	3.41	2.69

A indicates aortic; AVR, aortic valve replacement; CABG, coronary artery bypass graft; COPD, chronic obstructive pulmonary disease; eGFR, estimated glomerular filtration rate, calculated using the Cockroft-Gault formula: for men: weight (kg)×(140-age[y])/(72 × serum creatinine [mg/dL]); for women: weight (kg) ×(140-age[y]) × 0.85/(72 × serum creatinine [mg/dL]); M, mitral; MVR,mitral valve replacement; NA, not applicable; NYHA, New York Heart Association; T, tricuspid; TVR, tricuspid valve replacement.

ejection fraction at the time of surgery. Our results were different from the findings of Vassileva et al [Vassileva 2014], who had analyzed outcomes of patients undergoing MUV surgery compared with those of single-valve procedures during a 15-year period using the Society of Thoracic Surgeons (STS) Database. In North America, surgery for multiple-valve disease comprises approximately 12% of valve cases and major differences in baseline characteristics and outcome parameters were not observed between the different valve categories. The reason for these differences may be that the epidemiology of heart valve disease in China was different from that of North America countries. In our study population, MUV procedures account for more than 60% of all valve procedures and 80.8% of the patients undergoing MUV procedures had rheumatic valve disease compared with 36.0% in single-valve procedures. Degenerative valve disease and congenital valve disease also remained the key cause of heart valve disease for patients undergoing single-valve procedures (32.5% and 17.8%, respectively). Due to these different epidemiologies, there are most likely differences in baseline characteristics, operative procedure, and postsurgical treatment.

More tricuspid valve repair is another option. Mortality for tricuspid valve surgery remains considerable and significantly lower for repair than for replacement [Vassileva 2012]. In our study, tricuspid regurgitation (TR) accounted for more than 80% of MUV procedures and approximately 80% of MUV patients with tricuspid regurgitation underwent tricuspid valve repair. However, tricuspid valve repair was not performed in 10.4% of single mitral valve disease and 12.9% of MUV disease. To our knowledge, the outcome of isolated tricuspid valve surgery is poor because RV dysfunction has already occurred at that point in many patients [Shiran 2009]. Meanwhile, in-hospital mortality and postoperative complications for single tricuspid valve procedures were even higher than that for MUV procedures at our institutions. Hence, there is room to perform increasing tricuspid valve repair for mitral valve and MUV disease and tricuspid annuloplasty with a ring at the initial left-sided valve surgery [Shiran 2009].

In the two multivariable logistic regressions, preoperative risk factors for in-hospital mortality were relatively different across single-valve and MUV procedures (Table 4). The main factors associated with in-hospital mortality of patients undergoing MUV procedures were similar to other reports based on the STS Database [Vassileva 2012; Rankin 2013; Suri 2006] and some general conclusions appear warranted: age, advanced NYHA class, COPD, diabetes mellitus, congestive heart failure, cardiogenic shock, renal failure with dialysis, tricuspid regurgitation, and concomitant CABG.

However, there are also some different and surprising findings in this study as follows: (1) Contrary to other studies, non-elective surgery was not found to be a predictor for mortality of patients undergoing MUV procedures. The reason is not entirely clear, and one explanation could be that the rate of non-elective surgery in MUV procedures is lower (0.4%), and it seems challenging to be statistically comparable in non-elective and elective surgery. (2) In this study, we did not find that reoperation was associated with in-hospital mortality across procedural types. This may be supported by some previous studies that had suggested that cardiac reoperations can be performed safely in certain patient populations [Suri 2006; Zegdi 2008; Jaussaud 2009]. However, other findings also emphasized the importance of designing MUV procedures that minimize the need for reoperation, such as avoiding tissue valves in younger patients. (3) We included

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the type of procedure as risk factors and found that mitral valve replacement was associated with in-hospital mortality in MUV procedures. The reason could be that all those patients had longer cardiopulmonary bypass times and aortic cross-clamp times, which may play a role in higher MUV mortality. Hence, optimal myocardial protection was clearly important [Jaussaud 2009] and improvements in cardiopulmonary bypass could reduce total body injury for longer MUV pump runs [El-Essawi 2010].

There are several limitations in our study. First, although our clinical research was based on a multicenter population of mainland China, the possibility existed of selection bias for hospitals with better outcomes. Consequently, improvement in mortality might be underestimated if centers with better outcomes were more likely to have participated at earlier times [Taylor 2005]. Second, as a retrospective investigation, the incorrect and missing data in the original medical records could not be re-collected and the definition of some risk factors maybe not be the same in different institutions, which could affect the result. Therefore, the findings of this study need to be interpreted within the limitations of the observational design.

In conclusion, baseline characteristics and epidemiology in MUV procedures were different from those in single-valve procedures. The in-hospital mortality and postoperative complications for MUV procedures remained higher, making this topic a prime candidate for outcome improvement. Determinants of in-hospital mortality were relatively different across procedures types and there were also some that differed from other reports based on the STS Database. Finally, further in-depth analysis of the various MUV combinations may identify specific areas for quality improvement.

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