[UCI]I804:48009-200000502671

의 학 석 사 학 위 논 문

승모판막 수술, 삼첨판막 수술 및 부정맥 수술 함께 한 환자들에서 흉골 절개술과 최소침습 개흉술에 대한 결과 비교 연구

Surgical Outcomes of Mitral Valve and Tricuspid Valve Surgery with Cryoablation: Conventional Sternotomy versus Right Mini-thoracotomy Approach

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이 논문을 의학석사 학위 논문으로 제출함

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국문 요약

배경

최소 침습 성인 심장 수술은 많은 센터에서 일반적인 수술 방법이 되고 있으며 좋은 결과를 보여주고 있다. 하지만 기술적으로 어려운 심장 수술에서 최소 침습 심장 수술의 안정성과 효과는 아직 연구가 더 필요하다.

목적

이 연구는 승모 판막 수술과 삼첨 판막 수술 및 부정맥 수술을 함께 한 환자들에서 흉골 절개술과 최소 침습 개흉술에 대한 임상적 결과 비교 논문이다.

방법

2004 년 4 월부터 2018 년 6 월까지 승모 판막 수술과 삼첨 판막, 부정맥 수술을 함께 받은 525 명의 환자들을 대상으로 하였다. 흉골 절개술과 최소 침습 개흉술 두 군을 비교하였고 Propensity score matching 을 하여 비교하였다.

결과

뇌졸중, 출혈, 폐렴, 감염 등을 포함한 조기 합병증에 대해서는 두 군에서 propensity score matching 전 후로 유의한 차이가 없었다. 부정맥 재발률을 흉골 절개 그룹에서 matching 전

후로 다 높게 나왔다 (before matching: 38.71% vs. 17.21%, HR 0.382, 95% CI [0.264-0.553], p < 0.0001; after matching: 29.49% vs. 17.95%, HR 0.570, 95% CI [0.353-0.920], p = 0.0213). 사망률은 matching 전에 흉골절개 그룹에서 2.9%, 최소침습 개흉술 그룹에서 3.25% 보였다 (HR 1.065,; 95% CI [0.396-2.864], p = 0.9009). Matching 후에는 흉골 절개 그룹에서 1.92%, 최소 침습 개흉술 그룹에서 3.21% 보였다 group (HR 1.600,; 95% CI [0.392-6.528], p = 0.5125).

결론

승모 판막 수술과 삼첨 판막 수술 및 부정맥 수술을 함께 한 환자들에서 최소 침습 개흉술도 효과적이고 안전하게 시행될 수 있다.

차례

Backgrounds

Minimally invasive cardiac surgery (MICS) for adults has become a common approach for valve surgery in many clinical centers with excellent results.[1-5] Compared with conventional surgery, MICS has been shown to provide faster recovery, less pain, a shorter intensive care unit (ICU) and hospital stay, and better cosmetic results. This can be attributed to less spreading of the incisions, which results in less tissue dissection and less damage to the surrounding organs.[2, 3] To date, MICS has been expanded to high-risk patients such as those in the older age groups, those with poor left ventricular function, pulmonary hypertension, respiratory failure or renal failure, and those who have undergone re-operative procedures.[4] However, there is still a lack of studies on MICS that involves multiple valves or concomitant therapeutic interventions for arrhythmia as a joint maneuver. Whether technically demanding cardiac surgery can be performed safely and effectively through smaller incisions remains to be elucidated. In addition, MICS can take greater theatre time and a longer period in cardiopulmonary bypass (CPB) than conventional surgery, when the operative technique is complicated.[5, 6] Furthermore, MICS sometimes causes complications that are not seen in conventional surgery, such as a peripheral vascular problem caused by CPB.[7]

As mentioned earlier, the various strengths and weaknesses of MICS compared to conventional surgery allow the operator to consider which surgical approach should be chosen based on the individual patient's prognosis. Therefore, comparing and studying the surgical outcomes between MICS and conventional surgery may reveal clinically important potential outcomes. This study aimed to compare the clinical outcomes between conventional sternotomy (CS) and right mini-thoracotomy (RT) in patients undergoing mitral valve and tricuspid valve surgery with concomitant ablation for atrial fibrillation.

Materials and Methods

Patients

We reviewed 525 patients who underwent mitral valve with tricuspid valve surgery and simultaneous maze procedure at the Asan Medical Center in Seoul, South Korea, between April 2004 and May 2018. Concomitant atrial septal defect closure and redo open-heart surgery were included. Atrial ablation using microwaves and surgery using the da Vinci® surgical system (IS 3000 da Vinci Si, Intuitive Surgical

Inc., Sunnyvale, CA, USA) were excluded. The CS group consisted of 310 patients (male 35.48%, 61.47 □ 9.91yrs), and the RT group included 215 patients (male 28.37%, 57.25 □ 11.55yrs). This retrospective study was approved by the Institutional Review Board of Asan Medical Center (IRB no. 2020-0375), and the requirement for written informed consent was waived.

Surgical procedures and evaluations

CS was performed under general anesthesia, and CPB was performed with aortic and bi-caval cannulation. Cardiac arrest was induced by cardioplegia under moderate systemic hypothermia. The mitral valve was visualized through a left atrial incision.

The RT was performed with the automated endoscopic system for optimal positioning (AESOP) system (AESOP 3000 Hermes Ready System Robot, Intuitive Surgical Inc., Sunnyvale, CA, USA). Under general anesthesia, double-lung ventilation was typically performed, and single lung ventilation was performed only in case of re-do surgery or when adhesion was suspected. The incision was made along the fourth intercostal space on the anterior axillary line to the mid-clavicular line. In female patients, a sub-mammary incision was made after dissection of the mammary tissue via the fourth intercostal space.

An additional port was made in the third intercostal space for the video scope. A vent cannula was inserted via the same fourth intercostal space, in the mid-axillary line. Arterial cannulation was performed on the ascending aorta or femoral artery, and venous cannulations were made through the femoral vein and internal jugular vein. Cardiac arrest was also induced by cardioplegia, blood cardioplegia or del Nido[6] or histidine-tryptophan-ketoglutarate (HTK-Custodiol; Koehler Chemi, Alsbach-Haenlien, Germany) solution. The mitral valve was visualized through a transseptal incision or a left atrial incision.

We used a modified Cox-Maze III procedure for atrial fibrillation using an argon cryoablation system (ATS CryoMaze Console, ATS Medical Inc., Minneapolis, MN, USA) in both the CS and RT groups. The technique and details have been described in a previous study.[7] We performed the same valve repair or replacement technique in both groups. After weaning from CPB, all the patients underwent intraoperative transesophageal echocardiography. The choice of incision method was decided by the operator, either CS or MICS. Intraoperative anesthetic techniques were performed by the same anesthesiologist for both groups, and postoperative care was also undertaken with the same ICU protocols for the two groups.

Statistical analysis

The statistical differences between the two groups were calculated using the Student's t-test and chi-squared (χ^2) test. Survival and freedom from recurrence of atrial fibrillation (AF), mitral valve regurgitation (MR), and tricuspid valve regurgitation (TR) were compared using the Kaplan-Meier method. All statistical analyses were performed using the SPSS statistical software package (version 20.0, SPSS Inc., Chicago), and statistical significance was set at $p < 0.05$.

The missing values were populated with single values filled by single imputation with the Markov chain Monte Carlo method. A full non-parsimonious model was developed that included all the variables in the table and the interaction terms between variables. Model discrimination was assessed using c statistic (= 0.785), and model calibration was assessed using Hosmer-Lemeshow statistics (χ^2 = 6.1704, p = 0.6281).

Propensity score matching was performed by greedy matching using a caliper width of 0.2 standard deviations of the logit of the propensity score. Absolute standardized differences were used to diagnose the balance after matching. All absolute standardized differences were less than 0.1, after matching.

Before propensity score matching, the median follow-up duration was 30 months in all patients (interquartile range [IQR], 0-163 months). After propensity score matching, the median follow-up duration was 30 months in all patients (IQR, 0-99 months), 31 months in the CS group (IQR, 0-99 months), and 25.5 months in the RT group (IQR, 0-89 months).

Transthoracic echocardiography and electrocardiography were evaluated immediate postoperative, in-hospital, and after 12 months of follow-up. In the outpatient clinic, additional examinations were performed for patients with symptoms such as dyspnea and palpitations.

Early operative outcomes of the groups before matching were compared using the Mann-Whitney U test for continuous outcomes and a logistic regression model for binary outcomes. After matching values were compared using the Wilcoxon signed-rank test for continuous outcomes, using a conditional logistic regression model for binary outcomes. The long-term outcomes of groups before matching were compared using Cox proportional model, and after matching were compared using Cox regression models, with robust standard errors that accounted for the clustering of matched pairs. Operative outcomes before matching were compared using a t-test, and after matching, were compared using a paired t-test.

		Before matching				After matching		
		Sternotomy	Right thoracotomy	p-value	SMD	Sternotomy	Right thoracotomy	SMD
patients number		310	215			156	156	
Age		61.47±9.91	57.25±11.55	<0.0001	-0.39282	59.62±10.30	59.54±10.53	-0.00739
Sex	Male	110 (35.48%)	61 (28.37%)	0.0873	-0.15299	45 (28.85%)	44 (28.21%)	-0.0142
	Female	200 (64.52%)	154 (71.63%)			111 (71.15%)	112 (71.79%)	
kg		59.36±11.09	58.98±10.46	0.6936	-0.03517	59.40±11.11	58.68±10.06	-0.06808
DM		37 (11.94%)	27 (12.56%)	0.8302	0.01899	20 (12.28%)	18 (11.54%)	-0.03921
HTN		65 (20.97%)	49 (22.79%)	0.6184	0.0441	35 (22.44%)	38 (24.36%)	0.04544
Cr		0.93±0.43	0.88±0.23	0.0743	-0.15042	0.887±0.216	0.881±0.238	-0.02768
CKD		3 (0.97%)	3 (1.4%)	0.6928	0.03958	0	0	0
COPD		3 (0.97%)	1 (0.47%)	0.6479	-0.05962	0	0	0
CVA		34 (10.97%)	15 (6.98%)	0.1221	-0.13999	10 (6.41%)	13 (8.33%)	0.07364
Redo surgery		15 (4.84%)	23 (10.7%)	0.0108	0.22021	13 (8.33%)	11 (7.05%)	-0.04813
MV pathology	MS	80 (25.89%)	61 (28.37%)	0.7745	0.06123	44 (28.21%)	45 (28.85%)	0.02389
	MR	154 (49.84%)	101 (46.98%)			71 (45.51%)	70 (44.87%)	
	MSR	75 (24.27%)	54 (25.65%)			41 (26.28%)	41 (26.28%)	
MV surgery	MVR	218 (70.32%)	147 (68.37)	0.6331	-0.04231	110 (70.51%)	108 (69.23%)	-0.02795
	MVP	92 (29.68%)	68 (31.63%)			46 (29.49%)	48 (30.77%)	
TV surgery	DeVega	47 (15.16%)	27 (12.56%)	0.6101	0.06932	18 (11.54%)	19 (12.18%)	0
	TAP	248 (80%)	175 (81.4%)			131 (83.97%)	131 (83.97%)	
	TVR	15 (4.84%)	13 (6.05%)			7 (4.49%)	6 (3.85%)	
Maze_site	Lt. side	93 (30%)	41 (19.07%)	0.0047	-0.25609	32 (20.51%)	34 (21.79%)	0.0314
	Biatrial	217 (70%)	174 (80.93%)			124 (79.49%)	122 (78.21%)	

Table1. Patient characteristics and operative data

SMD, standardized mean difference; DM, diabetes mellitus; HTN, hypertension; Cr, creatinine; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; CVA, cerebrovascular accident; MV, mitral valve; MS, mitral stenosis; MR, mitral regurgitation; MSR, mitral valve stenosis/regurgitation; MVR, mitral valve replacement; MVP, mitral valvuloplasty; TV, tricuspid valve; TAP, tricuspid annuloplasty; TVR, tricuspid valve replacement

Categorical variables were expressed as percentages, and continuous variables were expressed as mean ±standard deviation.

Table 2. Preoperative Echocardiographic parameters

	Before matching				After matching		
	Sternotomy	**Right thoracotomy**	**p-value**	**SMD**	**Sternotomy**	**Right thoracotomy**	**SMD**
LVEF (%)	56.01±9.33	56.33±8.34	0.6938	0.03534	56.18±8.82	56.30±8.04	0.01474
LVIDs (mm)	36.77±7.57	35.40±6.52	0.0272	-0.19407	36.04±7.20	35.42±6.19	-0.09155
LVIDd (mm)	54.04±9.15	52.20±8.29	0.0189	-0.21096	52.90±8.46	52.46±7.76	-0.05375
LA (mm)	61.45±10.50	56.79±8.67	<0.0001	-0.48429	57.85±8.59	57.43±8.83	-0.04767
TRPG (mmHg)	42.54±13.35	40.45±14.17	0.1149	-0.14154	40.30±14.72	41.12±13.51	0.05789
MR Grade			0.4843	0.17291			0.07088
0	41 (13.80%)	33 (16.02%)			23 (14.74%)	26 (16.67%)	
1	28 (9.43%)	16 (7.77%)			17 (10.90%)	15 (9.62%)	
2	31 (10.44%)	31 (15.05%)			22 (14.10%)	23 (14.74%)	
3	51 (17.17%)	31 (15.05%)			25 (16.03%)	24 (15.38%)	
4	146 (49.16%)	95 (46.12%)			69 (44.23%)	68 (43.59%)	
TR Grade			0.0947	0.23859			0.05617
0	0 (0%)	1 (0.47%)			0 (0%)	0 (0%)	
1	4 (1.29%)	4 (1.87%)			1 (0.64%)	1 (0.64%)	
2	44 (14.24%)	41 (19.16%)			27 (17.31%)	29 (18.59%)	
3	110 (35.6%)	87 (40.65%)			69 (44.23%)	65 (41.67%)	
4	151 (48.87%)	81 (37.85%)			59 (37.82%)	61 (39.10%)	

LVEF, left ventricular ejection fraction; LVIDs, left ventricular internal dimension at systole; LVIDd, left ventricular internal dimension at diastole; LA, left atrial dimension; TRPG, tricuspid regurgitation peak gradient; MR, mitral regurgitation; TR, tricuspid regurgitation

Categorical variables were expressed as percentages, and continuous variables were expressed as mean ±standard deviation.

Table 3. Operative Outcomes

	Before matching			After matching		
	Sternotomy	**Right thoracotomy**	**p-value**	**Sternotomy**	**Right thoracotomy**	**p-value**
ACC time (min)	105.04±32.844	114.41±27.41	0.0004	108.51±31.20	111.86±25.70	0.2986
CPB time (min)	155.81±50.77	178.08±46.29	<0.0001	160.16±48.90	173.97±42.92	0.0073

ACC, aortic cross clamp; CPB, cardiopulmonary bypass

Results

Patient Characteristics

The baseline characteristics and preoperative data are shown in Table 1. Redo surgery was more frequently required in the RT group than in the CS group (4.84% vs. 10.7%, p = 0.0108). Other baseline characteristics, including valve pathology and surgery type (replacement or repair), were not significantly different between the two groups. Only bi-atrial ablation was more frequently needed in the RT group (70% vs. 80.93%, p = 0.0047). After propensity matching, the two groups were comparable, with 156 patients in each group.

We also evaluated preoperative echocardiographic parameters (Table 2). Before matching, left ventricular internal dimensions (LVID) were larger in CS group in both end-systole (LVIDs) and end-diastole (LVIDd) (LVIDs, 36.77 ± 7.57 vs. 35.40 ± 6.52, p = 0.0272; and LVIDd, 54.04 ± 9.15 vs. 52.20 ± 8.29, p = 0.0189). Left atrial size was also larger in CS group, before matching (61.45 ± 10.50 vs. 56.79 ± 8.67, p < 0.0001).

Before matching, aortic cross clamping (ACC) time and total CPB time were longer in the RT group than in the CS group (all p < 0.001) (Table 3). In the case of propensity-matched patients, ACC time was not statistically different in the RT group (108.51 ☐ 31.20 min vs. 111.86 ☐ 25.70 min, p = 0.2986), although total CPB time was longer in the RT group (160.16 ☐ 48.90 min vs. 173.97 ☐ 42.92 min, p = 0.0073).

Early Postoperative Outcomes

After propensity matching, the total ventilation time was longer in the CS group (13 (8.5-19) hours vs. 11 (7-14 hours, p = 0.0012). ICU stay and hospital stay were also longer in the CS group (3 (2-4) days vs. 2 (2-3) days, p < 0.0001), (11[–8-16] days vs. 9 [8-12.5] days, p = 0.0014) (Table 4). Acute kidney injury that required dialysis after the operation was more frequent in the CS group (7.05% vs. 1.92%, p = 0.0408). In patients who had low cardiac output syndrome (LCOS) after the operation, which required an extracorporeal membrane oxygenation (ECMO) device or intra-aortic balloon pump (IABP) device, there was no significant difference between the two groups (6.41% vs. 3.85%, p = 0.3096). Other early postoperative outcomes, including stroke, reoperation for bleeding, pneumonia, and infection, were not significantly different between the two groups (all p > 0.13). Early postoperative all-cause mortality was also not different between the two groups (6 [3.85%] vs. 4 [2.56%], p = 0.5232).

Table 4. Early postoperative complications

	Before matching					After matching				
	Sternotomy	**Right thoracotomy**	**OR**	**95%CI**	**p-value**	**Sternotomy**	**Right thoracotomy**	**OR**	**95%CI**	**p-value**
LCOS (%)	24 (7.74)	8 (3.72)	0.461	0.203-1.046	0.0638	10 (6.41)	6 (3.85)	0.584	0.207-1.648	0.3096
Stroke (%)	5 (1.61)	3 (1.4)	0.863	0.204-3.651	0.8415	2 (1.28)	3 (1.92)	1.51	0.249-9.160	0.6543
Reoperation for bleeding (%)	25 (8.06)	13 (6.05)	0.734	0.367-1.469	0.3819	16 (10.26)	10 (6.41)	0.599	0.263-1.365	0.2230
Pneumonia (%)	5 (1.61)	3 (1.4)	0.863	0.204-3.651	0.8415	3 (1.92)	2 (1.28)	0.662	0.109-4.019	0.6543
AKI (%)	22 (7.1)	5 (2.33)	0.312	0.116-0.837	0.0207	11 (7.05)	3 (1.92)	0.258	0.071-0.945	0.0408
Wound infection (%)	7 (2.26)	2 (0.93)	0.406	0.084-1.976	0.2645	5 (3.21)	1 (0.64)	0.195	0.022-1.687	0.1375
Pericardial effusion (%)	5 (1.61)	5 (2.33)	1.453	0.415-5.08	0.5589	3 (1.92)	2 (1.28)	0.662	0.109-4.019	0.6543
SSS or complete AVB (%)	49 (15.81)	26 (12.09)	0.733	0.440-1.222	0.2331	26 (16.67)	18 (11.54)	0.652	0.342-1.246	0.1954
Ventilation time (Hr, median)	14 (9-19)	11 (7-14)			<0.0001	13 (8.5-19)	11 (7-14)			0.0012
ICU stay (Days, median)	3 (2-4)	2 (2-3)			<0.0001	3 (2-4)	2 (2-3)			<0.0001
Hospital stay (Days, median)	11 (8-16)	9 (8-13)			<0.0001	11 (8-16)	9 (8-12.5)			0.0014
Early Mortality (%)	8 (2.58)	5 (2.33)	0.8999	0.290-2.786	0.8533	6 (3.85)	4 (2.56)	0.658	0.182-2.378	0.5232

LCOS, low cardiac output syndrome; AKI, acute kidney injury; SSS, sick sinus syndrome; AVB, atrioventricular block; ICU, intensive care unit

Categorical variables were expressed as percentages, and continuous variables were expressed as mean ±standard deviation.

Table 5. Long term outcomes

	Before matching					After matching				
	Sternotomy	**Right thoracotomy**	**HR**	**95%CI**	**p-value**	**Sternotomy**	**Right thoracotomy**	**HR**	**95%CI**	**p-value**
Stroke	3 (0.97)	2 (0.93)	0.914	0.153-5.477	0.9218	1 (0.64)	2 (1.28)	2.037	0.182-22.753	0.5633
Reoperation	6 (1.94)	3 (1.4)	0.713	0.178-2.853	0.633	3 (1.92)	3 (3.00)	1.010	0.200-5.099	0.9906
Bleeding	11 (3.55)	7 (3.26)	0.949	0.368-2.45	0.9146	4 (2.56)	6 (3.85)	1.499	0.445-5.049	0.5134
Infective endocarditis	2 (0.65)	3 (1.4)	2.001	0.332-12.067	0.4495	1 (0.64)	2 (1.28)	2.052	0.180-23.429	0.5630
Valve thrombosis	0	1(0.47)				0	0			
Ventricular Arrhythmia	0	0				0	0			
PPM insertion	25 (8.06)	13 (6.05)	0.604	0.308-1.184	0.142	12 (7.69)	10 (6.41)	0.765	0.319-1.831	0.5469

AF recur	120 (38.71)	37 (17.21)	0.382	0.264-0.553	<0.0001	46 (29.49)	28 (17.95)	0.570	0.353-0.920	0.0213
MR recur (>gr 2)	21 (6.77)	18 (8.37)	1.179	0.628-2.215	0.609	12 (7.69)	10 (6.41)	0.850	0.366-1.971	0.7045
TR recur (>gr 2)	51 (16.45)	25 (11.63)	0.639	0.395-1.033	0.0674	27 (17.31)	21 (13.46)	0.736	0.417-1.300	0.2913
Late mortality	9 (2.9)	7 (3.26)	1.065	0.396-2.864	0.9009	3 (1.92)	5 (3.21)	1.600	0.392-6.528	0.5125

PPM, permanent pacemaker; AF, atrial fibrillation; MR, mitral regurgitation; TR, tricuspid regurgitation

Categorical variables were expressed as percentages, and continuous variables were expressed as mean ±standard deviation.

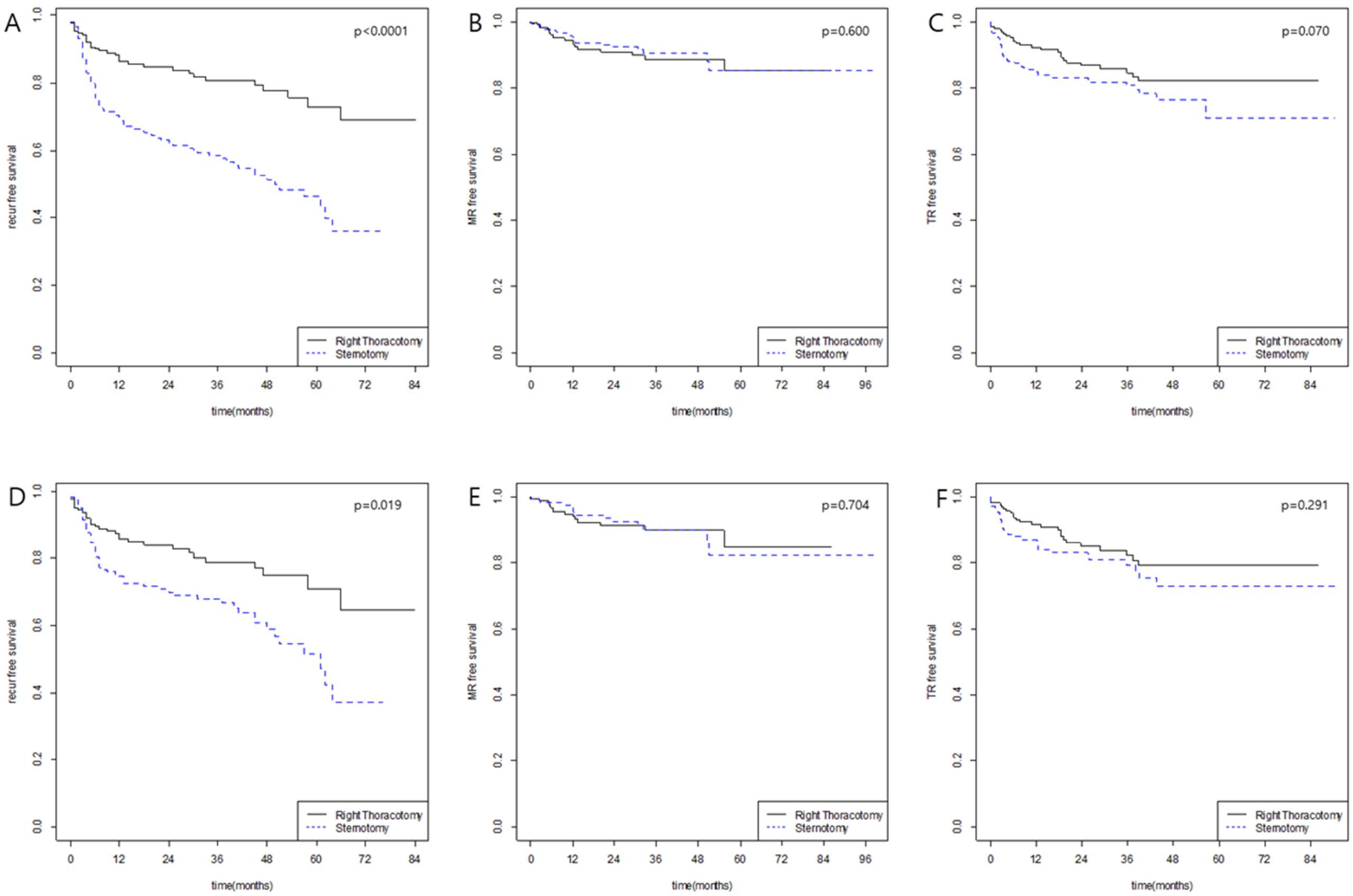

Figure 1. (A) Kaplan-Meier analysis of recurrence of atrial fibrillation between conventional sternotomy group and right thoracotomy group, before matching (B) Kaplan-Meier analysis of recurrence of mitral regurgitation before matching (C) Kaplan-Meier analysis of recurrence of

tricuspid valve regurgitation before matching (D) Kaplan-Meier analysis of recurrence of atrial fibrillation after matching (E) Kaplan-Meier analysis of recurrence of mitral regurgitation after matching (C) Kaplan-Meier analysis of recurrence of tricuspid valve regurgitation after matching

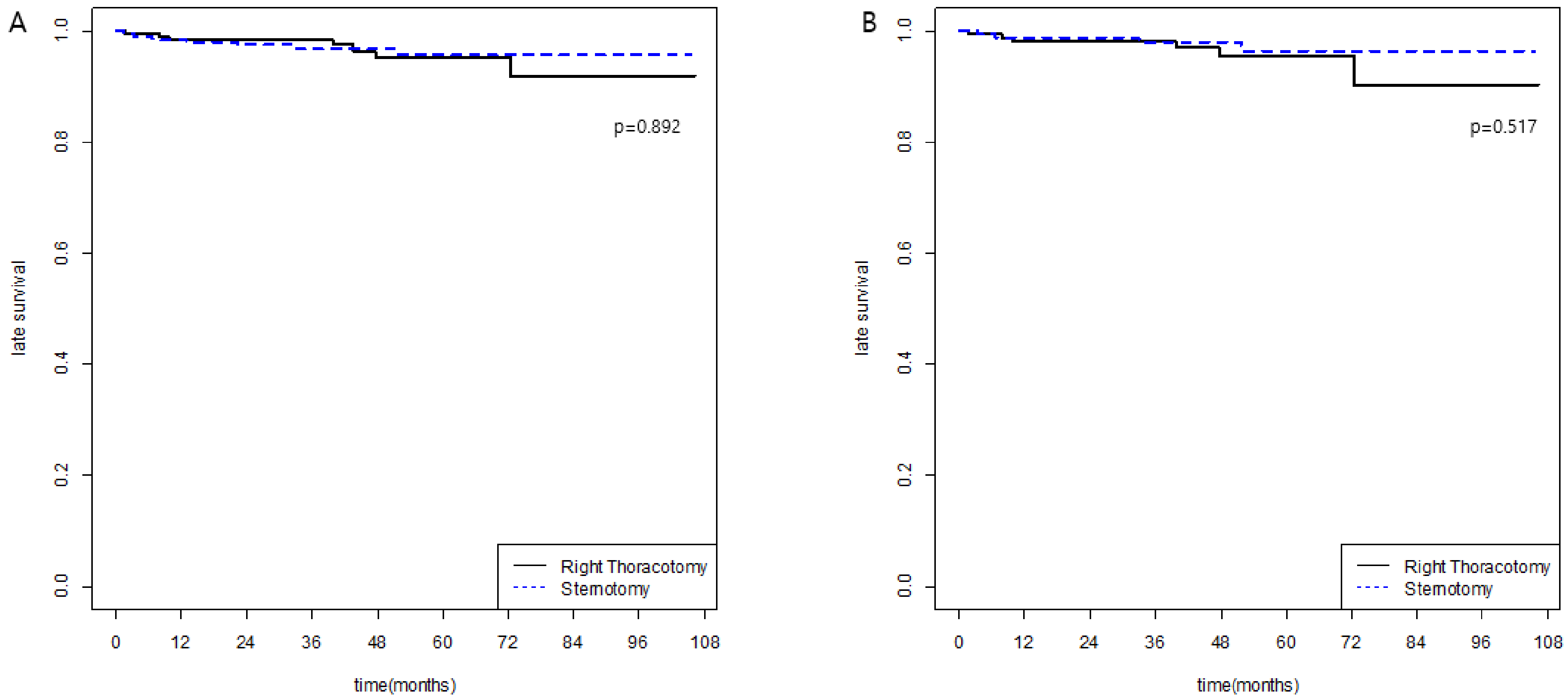

Figure 2. Kaplan-Meier analysis of overall survival curves between conventional sternotomy group and right thoracotomy group. A is for matched patients, B is for unmatched patients.

Long-Term Postoperative Outcomes

There were no statistical differences between the groups before and after matching for long-term complications such as stroke (before and after matching; p = 0.922 and p = 0.563), reoperation (p = 0.633 and p = 0.991), bleeding (p = 0.915 and p = 0.513), and infective endocarditis (p = 0.450 and p = 0.563) (Table 5).

We also evaluated the recurrence rates of AF, MR, and TR. Valve regurgitation was defined as grade 3 or higher on follow-up echocardiography. AF was diagnosed by electrocardiogram or 24 hours Holter monitoring. Notably, recurrence of AF was significantly higher only in the before-matching CS group (38.71% vs. 17.21%, HR 0.382, 95% CI [0.264-0.553], p < 0.0001). Recurrence of MR and TR was not significantly different between the two groups (6.77% vs. 8.37%, HR 1.179, 95% CI [0.628-2.215], p = 0.609 for MR; and 16.45% vs. 11.63%, HR 0.639, 95% CI 0.395-1.033–, p = 0.0674 for TR). After matching, as in the results before matching, the recurrence of AF alone showed a significant difference between the two groups (29.49% vs. 17.95%, HR 0.570, 95% CI [0.353-0.920], p = 0.0213).

The recurrence-free survival curves are shown in figure 1. Freedom from recurrent AF was greater in the RT group by Kaplan-Meier analysis both before (Fig. 1A, p < 0.0001) and after matching (Fig. 1D, p = 0.019). Recurrence-free survival of MR was not statistically different between before (Fig. 1B, p = 0.600) and after matching (Fig. 1E, p = 0.704). In addition, recurrence-free survival of TR was also not significantly different between before (Fig. 1C, p = 0.070) and after matching (Fig. 1F, p = 0.291).

The overall survival graphs are shown in Figure 2. Before and after matching, both graphs showed no statistical differences between the two groups (Fig. 2A, p = 0.892; and Fig. 2B, p = 0.527). All-cause late mortality before matching was 2.9% in the CS group and 3.26% in the RT group (HR 1.07,; 95% CI [0.396-2.864], p = 0.9009). After matching, the all-cause late mortality was 1.92% in the CS group and 3.21% in the RT group (HR 1.60,; 95% CI [0.392-6.528], p = 0.5125).

Discussions

Since Carpentier et al. first introduced video-assisted mitral repair through mini-thoracotomy in 1996 [8], surgical procedures for mitral valve disease have been gradually becoming minimal. In recent years, complicated procedures such as multi-valve surgery have also been performed with minimal invasion.[3] In addition, as surgical techniques and CPB techniques continue to evolve, patients are demanding less invasive heart surgery to quickly return to daily life by reducing post-operative pain and reducing the cosmetic effect of scars.[2, 4, 9] However, surgeons are still facing the dilemma of deciding which surgical technique is optimal for cases where the operation is technically complex. Sometimes, 'minimally invasive' is just a gross misnomer. It usually requires expensive instruments, complex imaging techniques for assessing feasibility, and expensive cannulation techniques compared to conventional cardiac surgery.

Several previous studies have indicated that MICS involves a longer operation time, CPB time, and ACC time than conventional surgery.[1-3, 10, 11] Nevertheless, in the process of selecting an ideal surgical technique, MICS ranks high. Therefore, comparative studies designed to delineate differences in surgical outcomes between conventional methods and MICS may have important clinical implications. This study also showed longer ACC and CPB times in the RT group after propensity score matching, but these did not have an adverse effect on clinical outcome. Previous studies have shown that longer CPB time did not increase the risk of early postoperative complications.[1-4]

We reviewed the outcomes of mitral valve and tricuspid valve surgery with cryoablation. To increase the reliability of the results, we used propensity score matching to balance the groups. We matched preoperative echocardiographic parameters, including left ventricular ejection fraction, left ventricular size, left atrial size, tricuspid regurgitation peak gradient, mitral regurgitation grade, and tricuspid regurgitation grade. However, AF duration, AF type, and amplitude size of AF and AF patterns were not included in propensity score matching because of missing data. Our results indicate that recurrence of AF after ablation surgery was more frequent in the CS group after matching ($p = 0.019$). Moreover, before matching, duration of AF before the operation was greater in the CS group (6.69 ± 6.76 years vs. 4.02 ± 5.30 years, $p < 0.0001$). Long-standing persistent AF was observed in 71.57% and 58.44% of patients in the CS and RT groups, respectively. Persistent AF was observed in 27.78% of patients in the CS group and 40.2% in the RT group ($p = 0.0047$). Amplitude of AF wave size was lower in CS group (0.90 ± 0.85 mm vs. 1.08 ± 0.86 mm, $p = 0.0075$). Fine waves were observed in 71.15% and 62.55% of the CS and RT groups, respectively ($p = 0.0393$). The interpretation of these variables can be so important for the prediction of recurrence of AF because the risk factors for failure of the maze procedure included a larger left atrium, greater preoperative duration of AF, and lower amplitude atrial fibrillatory wave.[12-15] Prolonged AF affects the atrial myocardium with loss of muscle mass, fibrotic changes, atrial expansion, and electrical remodeling.[16] Even before propensity score matching, these parameters would affect the higher recurrence rate of AF in the CS group. We compared AF duration between CS and RT group after propensity matching, CS group was still greater than RT group (6.19 ±

6.82 years vs. 3.88 ± 5.07 years, p=0.001). Therefore, a difference of AF duration would have led to a difference of AF recurrence rate.

In this study, the long-term outcomes of valve complications were not statistically different between the two groups: infective endocarditis, valve thrombosis, and recurrence of MR or TR. The operative technique was the same between the two groups. However, the RT group had less soft tissue dissection, which resulted in decreased trauma, leading to a reduction in inflammation.[17] Inflammation is an important factor in the occurrence or maintenance of AF. Postoperative inflammation can cause oxidative stress and atrial remodeling that results in AF.[16, 18]

MICS should be evaluated not only in terms of the number of outcomes, but also with respect to cardiac function and quality of life after the operation. One of the reasons why patients choose minimally invasive surgery is to improve their physical and psychological well-being. However, postoperative pain and quality of life are difficult to assess, and data collection is difficult. Walther et al. indicated that mini-thoracotomy resulted in more pain during the first two postoperative days[19]. Therefore, we usually apply a local anesthetic using an intercostal catheter or peridural anesthetic before surgery. Svensson et al. also showed that MICS was associated with less pain in the first 24 h after the operation [20]. They also observed postoperative respiratory function. Median time to extubation was shorter in minimally invasive surgery group (4.8 hours [CL, 2.2-10 hours] vs. 5.6 hours [CL, 3.0-14 hours], p = 0.001). Forced expiratory volume in 1 s (FEV1) decreased in the CS group during the first 12 h and increased thereafter. They demonstrated that less surgical dissection and less spreading of the sternum resulted in less pain and better pulmonary function. These parameters are also related to postoperative delirium, and the onset of delirium has been reported to be less frequent in the MICS group[10]. In addition, in terms of patient convenience, postoperative food intake and urinary catheter removal were possible earlier in the MICS group than in the CS group. Therefore, postoperative quality of life and cosmetic satisfaction are important factors for the choice of surgical method for both patients and surgeons.

Limitations

This study has some limitations. This study was retrospective and had an intermediate follow-up duration. In the future, a multi-center study through securing various data will be conducted to expand the scope of the current evaluation. This was a single-center study involving 525 patients from five different surgeons. Each surgeon had a different preference for the approach technique and no definite protocols in the choice of techniques. In particular, surgeon factors, including the level and amount of training, years of experience, or availability of peer support, play a significant role in the surgeon's decision-making. For example, in general, each surgeon is more familiar with a specific procedure according to their comfort level. Therefore, the more experience they have with these procedures, the stronger this factor in their decision-making process. Since this study did not take into account various surgeon factors, it is considered that the collected data and the analysis processes may be affected by surgeon factors.

Moreover, some important variables like AF duration for the recurrence of AF were missed, and propensity score matching was not performed. Inclusion of the drug history of anti-arrhythmics such as amiodarone and beta-blockers would also add value to our study. Further studies are required to unify the protocol for the selection of surgical method, and larger population samples would add a greater degree of significance to the results of the current study.

Conclusion

Our retrospective study that examined the choice of surgical approach between CS and RT showed that minimally invasive cardiac surgery through an RT approach can be performed safely and effectively as compared with the CS approach, even in the event of complex cardiac surgery.

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Abstract

Backgrounds

Minimally invasive surgery for adult heart disease has become a routine approach in many centers with excellent results. However, it remains unclear whether technically demanding cardiac surgery can be performed safely and effectively through limited-size incisions.

Objective

This study aimed to compare the clinical outcomes between conventional sternotomy and the right mini-thoracotomy approach in patients undergoing mitral valve and tricuspid valve surgery with concomitant ablation for atrial fibrillation.

Methods

We reviewed 525 patients who underwent mitral valve surgery with tricuspid valve and maze procedures between April 2004 and June 2018. We compared the conventional sternotomy and right mini-thoracotomy groups. Propensity score matching was performed by greedy matching using a caliper width of 0.2 standard deviations of the logit of the propensity score.

Results

Early postoperative outcomes, including stroke, reoperation for bleeding, pneumonia, and infection, were not significantly different between the two groups before and after matching. The recurrence of atrial fibrillation was greater in the conventional sternotomy group both before and after matching (before matching: 38.71% vs. 17.21%, HR 0.382, 95% CI [0.264-0.553], $p < 0.0001$; after matching: 29.49% vs. 17.95%, HR 0.570, 95% CI [0.353-0.920], $p = 0.0213$). All-cause late mortality before matching was 2.9% in the CS group and 3.26% in the RT group (HR 1.065,; 95% CI [0.396-2.864], $p = 0.9009$). After matching, the all-cause late mortality was 1.92% in the CS group and 3.21% in the RT group (HR 1.600,; 95% CI [0.392-6.528], $p = 0.5125$).

Conclusion

The present study shows that minimally invasive cardiac surgery through a right mini-thoracotomy approach can be performed more safely and effectively as compared with the conventional sternotomy approach in the mitral valve and tricuspid valve with cryoablation surgery.