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의학석사 학위 논문

승모판막 재수술에서의

최소늑간절개술 대 정중흉골절개술

Mini-Thoracotomy Approach Versus Conventional Sternotomy

for Reoperative Mitral Valve Surgery

After a Previous Sternotomy

울산대학교 대학원

의학과

권예리

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지도교수 김준범

이 논문을 의학석사학위 논문으로 제출함

2021년 2월

울산대학교 대학원

의학과

권예리

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국문 요약

연구 목적

승모판막 재수술에서 우측 최소늑간절개술은 승모판막의 시야를 더 향상시킬 수 있으며, 따라서 재-정중흉골 절개술로 전환하는 것의 위험을 줄일 수 있다. 본 연구는 승모판막 재수술에서 최소늑간절개술과 정중흉골절개술의 임상 결과를 비교하고자 하였다.

연구 방법

2002년부터 2018년까지 서울아산병원에서 승모판막 재수술을 시행받은 환자 730명 중, 대동맥판막 수술이나 관상동맥 우회수술을 함께 시행받은 환자들을 제외한 380명 (나이: 56.0±14.8) 의 환자들이 확인되었다. 본 연구는 최소늑간절개술을 통해 승모판막 재수술을 시행한 환자 168명 (MINI 군) 과 정중흉골절개술을 시행받은 환자 218명 (STERN 군)을 propensity score를 이용한 inverse probability of treatment weighting 으로 보정하여 비교하였다.

연구 결과

보정 후 두 군 간에 조기사망, 만기사망, 저심박출증후군, 출혈로 인한 재수술의 위험도에는 통계적으로 유의한 차이가 없었다. STERN 군에 비해 MINI 군에서

24시간 이상 인공호흡기의 사용 위험이 유의하게 낮았으며, 수혈량도 유의하게 적었다. 또한 중환자실 재원 일수와 총 재원 일수도 STERN 군에 비해 MINI 군에서 유의하게 짧았다.

결론

승모판막 재수술에서 최소늑간절개는 전통적인 정중흉골절개의 가능한 대안으로 여겨진다.

차례

Glossary of abbreviations

MV, mitral valve

CPB, cardiopulmonary bypass

ACC, aortic cross clamp

CT, computed tomography

LCOS, low cardiac output syndrome

MCS, mechanical circulatory support

IPTW, inverse-probability-of-treatment weighting

PS, propensity score

SMD, standardized mean difference

Introduction

Redo cardiac surgery via median sternotomy is technically challenging because of the risk of damaging critical cardiac structures that are tightly adhered behind to the sternum (such as the ascending aorta, brachiocephalic vein, right atrioventricle, and coronary bypass graft in patients who have previously undergone coronary artery bypass graft surgery).[1,2] Redo sternotomy may also be difficult in patients who have previously had mediastinitis or sternal wound infections. With the improving postoperative outcomes and life expectancies, the number of reoperative valve surgeries has also increased. According to Park et al., 13.5% of all cardiac procedures at the Mayo clinic required repeat median sternotomies.[3]

Right mini-thoracotomy mitral valve (MV) surgery has excellent short- and long-term results that are comparable to a conventional sternotomy. During redo MV surgery, right mini-thoracotomy may help minimize the intraoperative risk of redo sternotomy by offering enhanced visualization of the MV without extensive mediastinal dissection.[4,5] According to previous studies[4,5], right thoracotomy for reoperative MV is safe; however, limited information is available regarding direct comparison of outcomes of mini-thoracotomy to sternotomy. We compared the postoperative clinical outcomes of mini-thoracotomy with those of full sternotomy in patients who underwent redo MV surgery.

Patients and Methods

Patients

From January 2002 to July 2018, 730 consecutive adult patients underwent reoperative MV surgery after a previous sternotomy at our institution. We identified 380 patients (aged 56.0±14.8 years, 228 women) after excluding those who underwent concomitant aortic valve or coronary bypass surgeries that required a sternotomy approach (Figure 1) and grouped patients based on the surgical procedure used—mini-thoracotomy (MINI group; n=162) or conventional sternotomy (STERN group; n=218). All data were obtained from the medical records.

The primary outcomes of interest were early and overall mortality. Early mortality was defined as death occurring within 30 days post-operation or in the same hospitalization of operation. The secondary outcomes of interest included low cardiac output syndrome (LCOS) requiring mechanical circulatory support (MCS), in-hospital stroke, postoperative bleeding requiring exploration, new-onset dialysis, prolonged ventilation (>24 hours), and the amount of blood products transfused during hospitalization. Recurrent mitral regurgitation (MR) was defined as either beyond the moderate degree of MR, with paravalvular leakage on follow-up echocardiography or reoperation of MV because of mitral regurgitation.

Follow-up data were obtained until July 01, 2020. Patients without clinical events were censored at the end of the follow-up. Follow-up was completed for 78.9% of patients (n=300). Vital status was checked through the institutional medical records and the National Population Registry of the Korea National Statistical Office.

This study was approved by the Asan Medical Center Ethics Committee and Review

Board (No: 2019-1617), which waived the requirement for informed patient consent because of the retrospective nature of the study.

Surgical Technique

Patients in the MINI group received a thoracoscopy-guided, right anterolateral 7–10 cm incision through the fourth intercostal space. The patients were placed in the left semi-lateral decubitus position with the right chest elevated at approximately 30°. Arterial cannulation was performed using the femoral artery, and venous cannulation was performed via the femoral vein and right internal jugular vein for cardiopulmonary bypass (CPB). No patients underwent rib resection. The ascending aorta was cross-clamped with a transthoracic clamp, and anterograde cardioplegia was delivered into the aortic root (except in nine patients in whom fibrillatory arrest was employed). Patients were generally systemically cooled to 28 at the esophagus.

Patients in the STERN group underwent repeat median sternotomy with the standard oscillating saw surgical technique. All patients underwent preoperative heart computed tomography (CT); if there was close proximity of the posterior sternal table and ascending aorta on the CT, femoral CPB was initiated before sternotomy, at the discretion of each surgeon, to mitigate the risk of aortic rupture during sternal reentry.

Statistical Analysis

Statistical analysis was performed using R version 3.6.3 (R Foundation for Statistical

Computing, Vienna, Austria; https://www.r-project.org/). Continuous variables were presented as mean ± standard deviation (SD) or median (interquartile range, IQR), and categorical variables were presented with proportions or frequencies. Between-group differences were compared using Student's t-test and the Pearson's chi-square test. Statistical significance was set at $P<0.05$.

Clinical outcomes in the MINI and STERN groups were compared after adjusting with inverse probability of treatment weighting (IPTW) based on propensity score (PS) to avoid selection bias. The PS was defined as the probability of a patient undergoing mini-thoracotomy in either group based on the baseline and operative profiles. PS was estimated using multiple logistic regression analysis incorporating all the covariates listed in Table 1 and the concomitant procedures. In the IPTW technique, patients in the MINI group were weighted by the formula 1/PS, whereas those in the STERN group were weighted by the formula 1/(1-PS). IPTW adjustments were performed based on the trimmed stabilized weight with robust standard errors. The balance for all covariates in Table 1 was assessed using the standardized mean difference (SMD), for which a difference of <10% was considered to indicate a good balance.

For the analyses of time-related events, a cumulative incidence function was generated using a competing risk model with all-cause death as a competing variable.

Results

Patients

Patients' baseline characteristics including echocardiographic variables are provided in Table 1. Patients in the STERN group were significantly older (55± 15 vs. 51±14 years; P=0.02) and had a significantly higher prevalence of peripheral arterial occlusive disease (1.2% [2/162] vs. 6.4% [14/218], P=0.03) than those in the MINI group.

Operative data

Operative data are summarized in Table 2. There was no difference in previous operation types including coronary artery bypass graft (8.0% [13/162] vs. 6.0% [13/218], P=0.56) between groups, except mitral valve repair which was more frequently performed in the MINI group (43.2% [70/162] vs. 31.7% [69/218], P=0.03). The number of previous sternotomies was not different in the two groups (P=0.60, Supplemental Table E1). Underlying mitral valve pathologies were not different between groups (P=0.25). In degenerative MV, 31 patients had posterior leaflet prolapse (15 in MINI vs. 16 in STERN), 40 had anterior leaflet prolapse (14 in MINI vs. 26 in STERN), 18 had bileaflet prolapse (10 in MINI vs. 8 in STERN), 35 had mitral stenosis, and the pathology of 15 patients was not characterized with respect to the leaflets on echocardiography.

MV replacement was more frequently performed in the STERN group, whereas MV repair was more frequently performed in the MINI group (both P<0.01). Concomitant procedures included tricuspid valve surgery in 162 (42.6%), surgical ablation in 76 (20.0%), and atrial septal defect closure in 15 (3.9%) patients without significant between-group differences (Figure 1). The mean CPB time was 173 ± 60 min in the MINI group and 183 ±

86 min in the STERN group (P=0.19). The mean aortic cross clamp (ACC) time was 88 ± 38 min in the MINI group and 99 ±43 min in the STERN group (P=0.01).

The type of cardioplegic solution was described in Supplemental Table E3. Histidine-tryptophan-ketoglutarate (HTK, Custodiol®) solution was used 87.7% [142/162] in the MINI group, whereas blood cardioplegia was used 45.0% [98/218] in STERN group, followed by HTK (37.2%, [81/218]).

Two patients in the MINI group required conversion to full-sternotomy—one because of poor visualization of the operative field and the other because hemothorax was observed in the left chest on transesophageal echocardiography after completion of MV surgery. However, after conversion to full-sternotomy, no bleeding focus was identified; this may have been due to left pleural entry during the case. Hence, irrigation was performed in the left thoracic cavity and drainage tube was inserted.

Nine patients in the MINI group underwent fibrillatory arrest instead ACC. Aortic cross-clamps were not performed on seven patients because of severe adhesion. In addition, aortic cross-clamps were not performed in the other two patients owing to previous coronary bypass graft.

Two patients in the MINI group who initially attempted to undergo mitral valve repair showed more than moderate mitral regurgitation on intraoperative transesophageal echocardiography, following a second cardiopulmonary bypass to replace the valve. No patient failed mitral valve repair in STERN group.

Clinical outcomes

Before adjustment, the risks of early major complications as well as early mortality (4.3%

[7/162] vs. 11.0% [24/218], P=0.03) were lower with the MINI group than in the STERN group for most of the individual outcomes (LCOS, 5.6% [9/162] vs. 12.4% [27/218], P=0.04; early stroke, 6.8% [11/162] vs. 14.2% [31/218], P=0.03; new-onset dialysis, 6.2% [10/162] vs. 17.0% [37/218], P<0.01; prolonged ventilation, 15.4% [25/162] vs. 33.0% [72/218], P<0.01; postoperative bleeding requiring exploration, 7.4% [12/162] vs. 10.1% [22/218], P=0.47). The MINI group required less transfusion of red blood cell (RBC) (unit) (5.00 [3.00, 8.00] vs. 7.00 [4.00, 11.75], P<0.001), platelet (unit) (10.00 [0.00, 10.00] vs. 10.00 [0.00, 20.00], P<0.001), and fresh frozen plasma (FFP) (unit) (3.00 [0.00, 5.00] vs. 4.00 [2.00, 8.00], P<0.001) compared to the STERN group. The intensive care unit (ICU) stay duration (day) (2.00 [1.00, 3.00] vs. 3.00 [2.00, 7.00], P<0.01) and hospital stay duration (day) (8.00 [6.00, 13.00] vs. 14.00 [8.00, 29.00], P<0.01) were shorter with the MINI group than in the STERN group (Table 3).

The IPTW balanced all measurable baseline variables (SMD <0.1) between the two groups (Figure 2). After adjustment, there were no significant between-group differences in the risks of early mortality (5.3% vs 9.8%, P=0.16), LCOS (6.4% vs 10.2%, P=0.23), early stroke (7.7% vs 12.8%, P=0.15), and postoperative bleeding requiring exploration (7.4% vs 8.7%, P=0.66), and new-onset dialysis (9.9% vs 14.4%, P=0.36). However, the MINI group experienced a significantly reduced risk of prolonged (>24 hours) ventilation (17.7% vs 27.9%, P=0.04; odds ratio 0.56, confidence interval 0.33-0.92, P=0.02) and significantly reduced need for transfused blood products (RBC, 5.00 [3.00, 9.00] vs. 7.00 [4.00, 11.00], P=0.003; platelet, 10.00 [0.00, 10.00] vs. 10.00 [0.00, 20.00], P=0.014; FFP, 3.00 [0.00, 5.00] vs. 4.00 [1.00, 7.00], P=0.027). The ICU (2.00 [1.00, 3.00] vs. 2.00 [2.00, 6.00], P<0.001) and hospital stay durations (9.00 [7.00, 16.00] vs. 12.67 [8.00, 26.20], P=0.001) remained significantly shorter in the MINI group than in the STERN group (Table 3 and Table 4).

During the median follow-up of 68.4 (35.8–126.2) months, overall mortality occurred in 96 (25.3%) patients—28/162 (17.3%) in the MINI group and 68/218 (31.2%) in the STERN group (P<0.01, Figure 3A). There was no significant difference between groups after adjustment (20.4% vs. 28.0%, P=0.14, Figure 3B). The causes of hospital and late mortalities are detailed in Supplemental Table E2. There was no difference in MR recurrence between groups before adjustment; MV repair—7/33 (21.2%) vs. 6/21 (28.6%) (P=0.78); MV replacement—3/129 (2.3%) vs. 13/197 (6.6%) (P=0.14).

Discussion

This study compared the clinical outcome of mini-thoracotomy with those of full sternotomy in patients undergoing reoperative MV surgery. The major findings in this study were as follows: (1) there were no significant between-group differences for early and overall mortalities; (2) the MINI group required less transfusion of blood products than the STERN group; (3) the MINI group had a lower rate of prolonged mechanical ventilation (>24 hours) than the STERN group; and (4) ICU and hospital stay durations were shorter in the MINI group than in the STERN group.

Significant risks related to repeat median sternotomy during reoperative cardiac surgery are well-recognized.[1,2] The main advantage of the right mini-thoracotomy compared to repeat sternotomy is avoidance of injury related to sternal reentry or dissection. However, the optimal approach for MV surgery in patients with a previous sternotomy is controversial, particularly for those who are candidates for the mini-thoracotomy approach. Several studies have reported reoperative MV surgery outcomes related to mini-thoracotomy. Arcidi et al. reported 15-year outcomes of mini-thoracotomy in patients who underwent reoperative MV surgery and found that mini-thoracotomy was comparable to full sternotomy, with 3% early mortality.[6] According to Romano et al., reoperative MV surgery via mini-thoracotomy is safe and effective based on the outcomes of 450 patients.[5] The former study included long-term results, [6] and the latter study involved a relatively large patient cohort. [5] Our data were obtained from 380 patients intermediate term results with median follow-up of 5.7 years.. Additionally, we adjusted our patients' data with IPTW to directly compare outcomes of mini-thoracotomy with those of sternotomy.

A meta-analysis by Daemen et al. has suggested that mini-thoracotomy is associated with reduced mortality compared to sternotomy for reoperative MV surgery.[7] However, because the authors did not control for potentially confounding factors within the studies included in the meta-analysis, the study patients may have exhibited significant differences at baseline, which could, in theory, affect study outcomes. In our cohort, crude early and late mortality were higher in the STERN group than in the MINI group; however, there were no statistically significant between-group differences after IPTW adjustment.

Reoperative MV surgery using mini-thoracotomy has been associated with reduced transfusion requirements compared with median sternotomy. This is consistent with our findings, regardless of the blood product type transfused. According to Romano et al., this difference was attributable to improved coagulopathy that resulted from mild hypothermia (32).[5] However, in our study, patients in the MINI group was systemically cooled to 28□; hence, this explanation was not applicable to our results. According to Barbero et al., the reduced need for transfusion in the MINI group could be because mini-thoracotomy allowed the surgeon to avoid major cardiac structures.[8] In this context, minimal surgical dissection may have contributed to less bleeding and reduced need for transfusion of blood products, thus preventing possible complications related to massive transfusions.

The rate of postoperative prolonged mechanical ventilation (>24 hours) was lower in the MINI group than in the STERN group, although the procedure required an additional incision at the right intercostal space. Arcidi et al. demonstrated that minimally invasive MV surgery was associated with reduced need for mechanical ventilation and reduced hospital stay duration compared with full sternotomy.[6] According to Romano et al., lower transfusion requirement probably indicated less hemodynamic instability, favoring early extubation.[5] Moreover, shorter mechanical ventilation time would likely correspond to shorter ICU and hospital stay durations and faster postoperative recovery, consistent with our study results even after adjustment.

In this study cohort, 85.8% (326/380) of patients underwent MV replacement. 32.4% (123/380) of patients underwent mitral valve surgery for previous prosthetic valve failure. Moreover, among the rest of the patients, 13.7% (52/380) had rheumatic mitral valve disease, and 13.4% (51/380) had infective endocarditis. According to Watkins and colleagues, rheumatic valve disease is more frequent in South Korea compared with that in the Western world.[9] These factors contributed to the high MV replacement rate in this study cohort.

Unlike the previous report by Burfeind et al. who found that CPB time was approximately 50 minutes longer with the minimally invasive approach than with the full sternotomy,[10] CPB time did not significantly differ between the groups in our study. ACC time was shorter in the MINI group than in the STERN group, despite the MV repair rate being higher in the MINI group (20.4% vs. 9.6%, $P<0.01$) in our study. This may have resulted from better exposure of the MV during mini-thoracotomy. However, because our institute commonly performed the minimally invasive approach, the influence of each surgeon’s experience could not be ruled out. Ricci et al. mentioned that at the beginning of their career, MV replacement was favored over repair for cases in which complex MV repair was required.[11]

Safe separation of the aorta seems to be a key for reoperative MV surgery via mini-thoracotomy from our institution’s experience. The foremost step is to complete the separation of the aorta to the sternum on one-lung ventilation and cardiopulmonary bypass. Upon placing the wound retractor, the separation of the aorta to the superior vena cava and the pulmonary artery can be easily achieved. In cases which separation of the aorta is difficult due to dense adhesion, a fibrillatory arrest can be performed instead of a clamped arrest. The aortic root vent cannula is placed even in fibrillatory arrest for air evacuation after the procedure.

The current study has several limitations. This study was a retrospective study, with inherent shortcomings, despite IPTW data analysis. As mentioned above, because our institute has plenty of experience with the minimally invasive approach, the results of this study may not be generalizable to other institutes that are less familiar with minimally invasive approaches. Also, this study included eight surgeons and the approach was decided up to each surgeon's preference. Because there was no established decision making-protocol with regard to approach, operative profiles, including each surgeon's preferences, would be difficult to control.

Conclusions

In the setting of redo MV surgery, the mini-thoracotomy approach demonstrated excellent postoperative outcomes comparable—or even superior (prolonged ventilation, transfusion, length of stay)—to the sternotomy approach. Therefore, this approach may serve as a viable alternative to conventional sternotomy when performing redo MV surgery (Figure 4).

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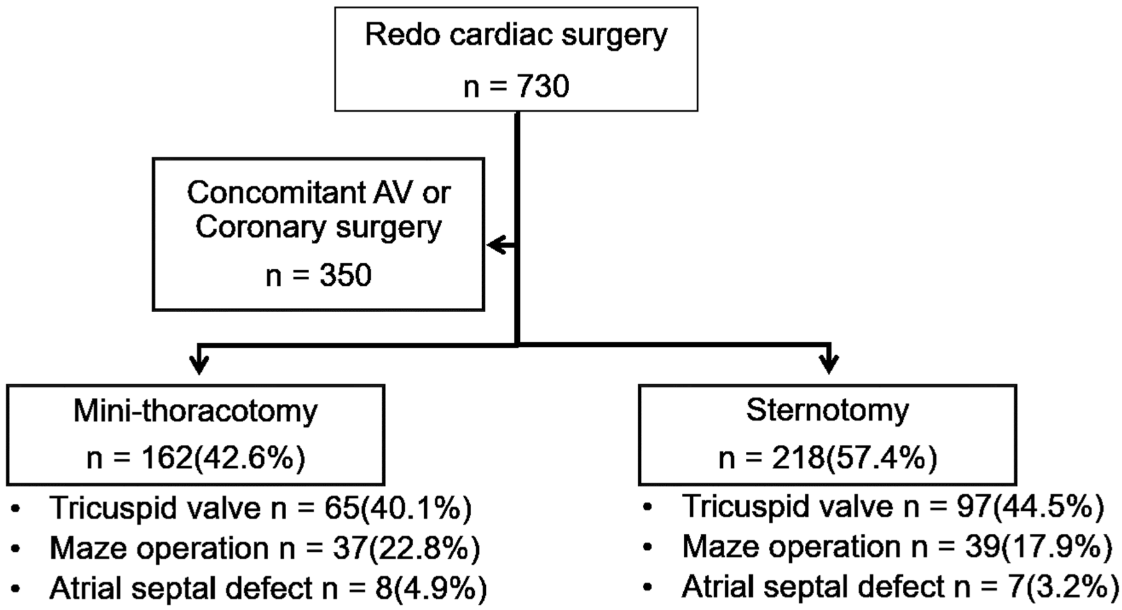
Figure Legends

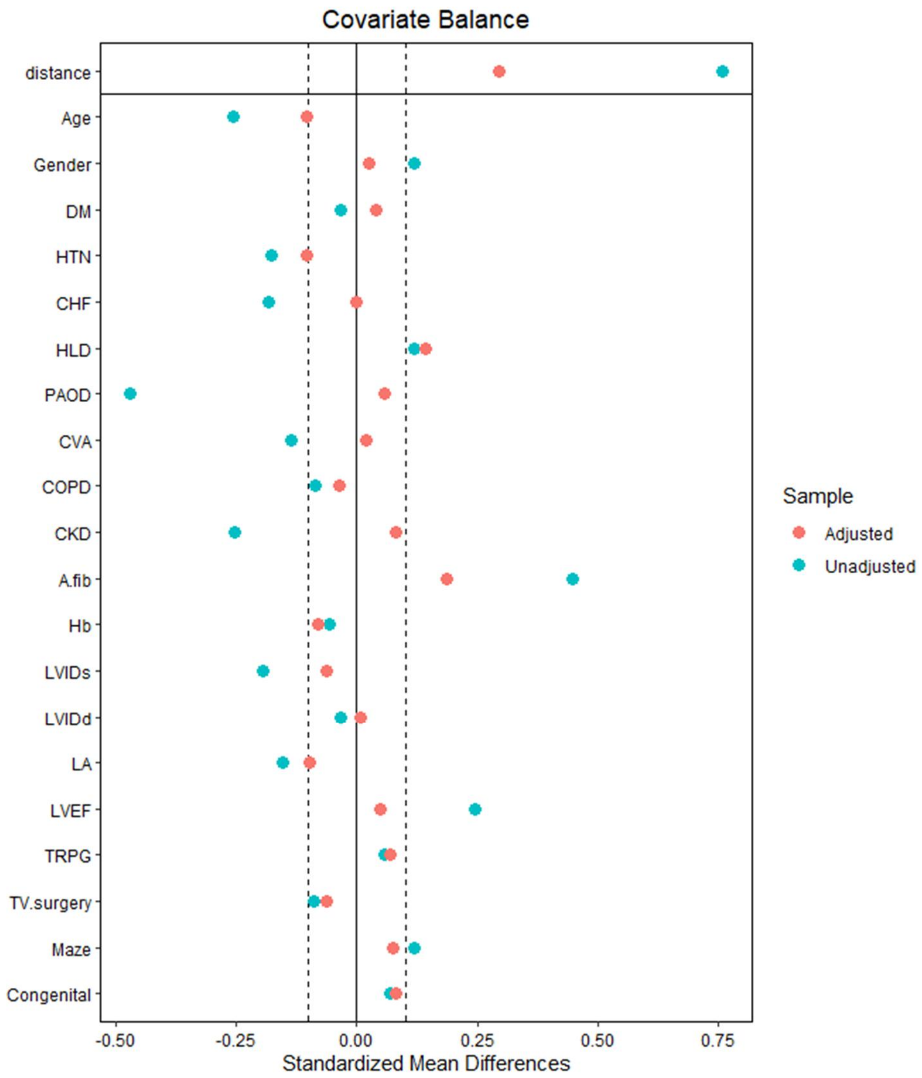
Figure 1. Study flow and patients' characteristics



From January 2002 to July 2018, 730 consecutive adult patients underwent reoperative MV surgery after a previous sternotomy at our institution. We identified 380 patients after excluding those who underwent concomitant aortic valve or coronary bypass surgeries that required a sternotomy approach. Among these, sternotomy and mini-thoracotomy approach was used in 218 (STERN group) and 162 (MINI group) patients, respectively. Concomitant procedures included tricuspid valve surgery, surgical ablation, and atrial septal defect closure without significant between-group differences.

AV: aortic valve

Figure 2. Love plot for balance in baseline characteristics

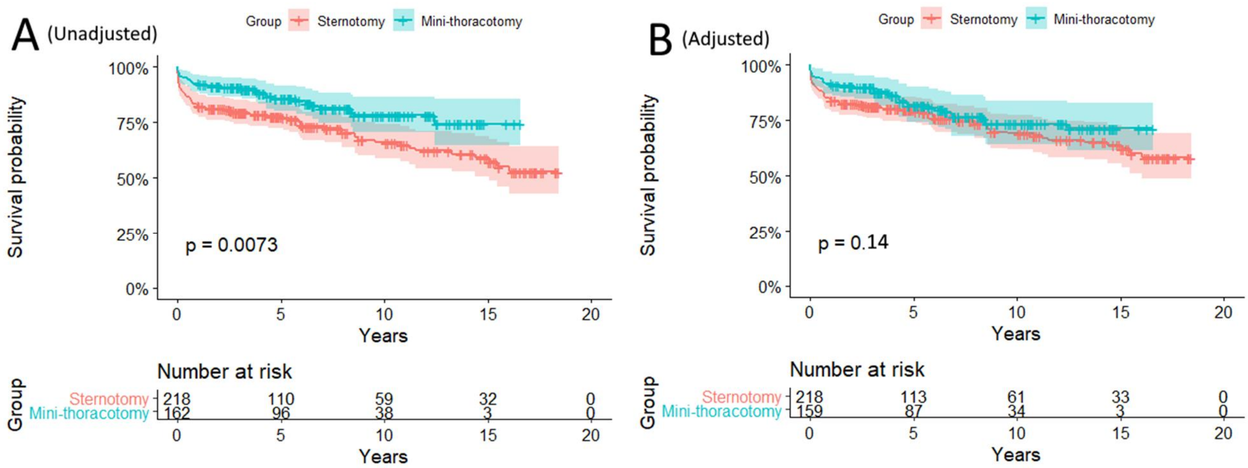


This Love plot displays absolute standardized differences comparing 17 baseline characteristics and concomitant procedures of 380 pre-match and 377 adjusted with inverse probability of treatment weighting based on propensity score patients undergoing reoperative mitral valve surgery. An absolute standardized difference of 0% indicates no residual bias and values <10% indicate inconsequential bias.

DM, diabetes mellitus; HTN, hypertension; CHF, congestive heart failure; HLD, dyslipidemia; PAOD, peripheral arterial occlusive disease; CVA, cerebrovascular accident;

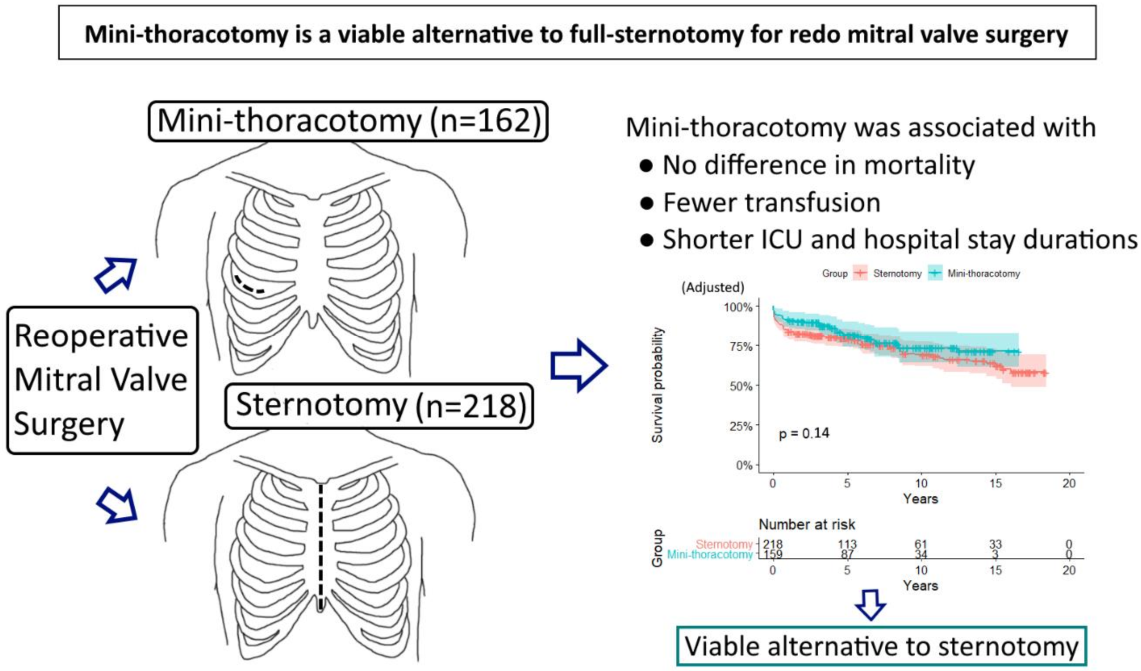
COPD, chronic obstructive pulmonary disease; CKD, chronic kidney disease; A.fib, atrial fibrillation; Hb, hemoglobin; LVIDs, left ventricular end-systolic dimension; LVIDd, left ventricular end-diastolic dimension; LA, left atrium; LVEF, left ventricular ejection fraction; TR, tricuspid regurgitation; PG, pressure gradient; TV, tricuspid valve

Figure 3. Survival curve of patients by subgroup



(A) During the median follow-up of 68.4 (35.8–126.2) months, overall mortality occurred in 28/162 (17.3%) in the MINI group and 68/218 (31.2%) in the STERN group (P=0.007). (B) Survival curve after adjustment with inverse probability of treatment weighting; There was no significant difference between groups, MINI vs. STERN (79.6% vs. 72.0%, P=0.14);

Figure 4. Graphical abstract



We compared the clinical outcomes in patients who underwent redo mitral valve surgery via mini-thoracotomy (n=168) with those in patients via sternotomy (n=218) after inverse probability of treatment weighting based on propensity scores. There were no significant between-group differences in the risks of early and late mortality. The mini-thoracotomy group underwent fewer transfusions than the STERN group. Intensive care unit and hospital stay durations were shorter in the MINI group than in the STERN group. Therefore, mini-thoracotomy is a viable alternative to conventional sternotomy for redo mitral valve surgery.

ICU, intensive care unit

Tables

Table 1. Preoperative baseline characteristics between the mini-thoracotomy and sternotomy groups

Variable	Before Weighting (Original)				After Weighting (IPTW)			
	MINI (n=162)	**STERN (n=218)**	P-value	SMD	**MINI (n=159)**	**STERN (n=218)**	P-value	SMD
Age	51.5±14.2	55.1±15.0	0.02	0.25	53.7±14.5	53.3±15.6	0.81	0.03
Female sex	103 (63.6)	125 (57.3)	0.26	0.13	96.6 (60.7)	130.5 (59.9)	0.94	<0.01
Diabetes mellitus	19(11.7)	28 (12.8)	0.87	0.03	20.0 (12.5)	26.6 (12.2)	0.92	0.01
Hypertension	35 (21.6)	63 (28.9)	0.14	0.17	41.0 (25.8)	56.3 (25.8)	0.99	<0.01
Heart failure	14 (8.6)	30 (13.8)	0.17	0.16	16.8 (10.6)	25.5 (11.7)	0.76	0.04
Dyslipidemia	23 (14.2)	22 (10.1)	0.13	0.13	17.4 (10.9)	27.5 (12.6)	0.66	0.05
PAOD	2 (1.2)	14 (6.4)	0.03	0.27	6.1 (3.8)	9.2 (4.2)	0.91	0.02
Cerebrovascular accident	17 (10.5)	32 (14.7)	0.29	0.13	18.0 (11.3)	27.3 (12.5)	0.74	0.04
COPD	5 (3.1)	10 (4.6)	0.63	0.08	6.1 (3.9)	8.0 (3.7)	0.94	<0.01
Chronic kidney disease	4 (2.5)	14 (6.4)	0.12	0.19	8.8 (5.6)	10.3 (4.7)	0.80	0.04
Atrial fibrillation	81 (50.0)	120 (55.0)	0.38	0.10	84.6 (53.1)	114.9 (52.7)	0.94	<0.01
Hemoglobin (g/dL)	11.8±2.3	11.9±2.3	0.58	0.06	11.9±2.4	11.9±2.2	0.90	0.02

Echocardiographic data								
LVESD (mm)	34.0 ± 7.5	35.5±8.5	0.08	0.18	34.4±7.6	35.1±7.9	0.39	0.09
LVEDD (mm)	52.4 ± 8.5	52.7±8.3	0.75	0.03	52.4±8.5	52.4±7.8	0.94	<0.01
LA diameter (mm)	52.8 ± 10.8	54.4±11.1	0.14	0.15	54.3±11.4	54.0±10.9	0.85	0.02
LVEF (%)	59.5 ± 6.9	57.9±9.7	0.06	0.20	58.9±7.3	58.7±9.0	0.83	0.02
Peak TRPG, mmHg	42.4 ± 19.8	41.2 ± 17.8	0.55	0.06	42.5 ± 19.5	41.5 ± 18.3	0.66	0.05

Values are n (%), or mean ± standard deviation, unless otherwise indicated.

IPTW, inverse probability of treatment weighting; SMD, standardized mean difference; PAOD, peripheral arterial occlusive disease; COPD, chronic obstructive pulmonary disease; LVESD, left ventricular end-systolic dimension; LVEDD, left ventricular end-diastolic dimension; LA, left atrium; LVEF, left ventricular ejection fraction; TR, tricuspid regurgitation; PG, pressure gradient

Table 2. Patients' operative data

	MINI (n=162)	STERN (n=218)	P value
Previous surgery			
Coronary artery bypass graft	13 (8.0)	13 (6.0)	0.56
Mitral valve replacement	57 (35.2)	95 (43.6)	0.12
Mitral valve repair	70 (43.2)	69 (31.7)	0.03
Tricuspid valve	31 (19.1)	45 (20.6)	0.82
Aortic valve replacement	19 (11.7)	30 (13.8)	0.67
Aorta	4 (2.5)	10 (4.6)	0.42
Congenital anomaly	19 (11.7)	25 (11.5)	1.00
Underlying mitral valve pathology			0.25
Degenerative	59 (36.4)	80 (36.7)	
Rheumatic	28 (17.3)	24 (11.0)	
Infective	16 (9.9)	35 (16.1)	
Congenital	6 (3.7)	9 (4.1)	
Previous prosthetic valve failure	53 (32.7)	70 (32.1)	

Mitral valve surgery			
Mitral valve replacement	129 (79.6)	197 (90.4)	<0.01
Mitral valve repair	33 (20.4)	21 (9.6)	<0.01
Concomitant procedure			
Tricuspid valve	65 (40.1)	97(44.5)	0.46
Maze operation	37 (22.8)	39 (17.9)	0.29
ASD closure	8 (4.9)	7 (3.2)	0.56
Emergency	10 (6.2)	21 (9.6)	0.30
CPB time (min)	172.6±59.9	183.0±86.3	0.19
ACC time (min)	88.3±37.9	99.0±42.7	0.01

Values are n (%), or mean ± standard deviation, unless otherwise indicated. ASD, Atrial septal defect; CPB, Cardiopulmonary bypass time; ACC, Aortic cross-clamp time

Table 3. Early and overall clinical outcomes of the mini-thoracotomy and sternotomy groups

Outcomes	Before weighting			After weighting		
	MINI (n=162)	**STERN (n=218)**	P-value	**MINI (n=159)**	**STERN (n=218)**	P-value
Early Outcomes	***No. of patients (%)***			***Percentage (%) of patients***		
Early death	7 (4.3)	24 (11.0)	0.03	5.3	9.8	0.16
Early complications						
LCOS requiring MCS	9 (5.6)	27 (12.4)	0.04	6.4	10.2	0.23
Early stroke	11 (6.8)	31 (14.2)	0.03	7.7	12.8	0.15
Surgical bleeding	12 (7.4)	22 (10.1)	0.47	7.4	8.7	0.66
New-onset dialysis	10 (6.2)	37 (17.0)	<0.01	9.9	14.4	0.36
Prolonged ventilation (>24hrs)	25 (15.4)	72 (33.0)	<0.01	17.7	27.9	0.04
Transfusion	***Median value [interquartile range],***					
Red blood cell (unit)	5.00 [3.00, 8.00]	7.00 [4.00, 11.75]	<0.01	5.00 [3.00, 9.00]	7.00 [4.00, 11.00]	<0.01
Platelet (unit)	10.00 [0.00, 10.00]	10.00 [0.00, 20.00]	<0.01	10.00 [0.00, 10.00]	10.00 [0.00, 20.00]	0.01
Fresh frozen plasma (unit)	3.00 [0.00, 5.00]	4.00 [2.00, 8.00]	<0.01	3.00 [0.00, 5.00]	4.00 [1.00, 7.00]	0.03
ICU stay (day)	2.00 [1.00, 3.00]	3.00 [2.00, 7.00]	<0.01	2.00 [1.00, 3.00]	2.00 [2.00, 6.00]	<0.01
Length of stay (day)	8.00 [6.00, 13.00]	14.00 [8.00, 29.00]	<0.01	9.00 [7.00, 16.00]	12.67 [8.00, 26.20]	<0.01

Overall outcomes	No. of patients (%/patient-year)			Percentage (%) of patient-year		
All-cause death	28 (17.3)	68 (31.2)	<0.01	20.4	28.0	0.14

LCOS, low cardiac output syndrome; MCS, mechanical cardiac support; ICU, intensive care unit; MR, mitral regurgitation

Table 4. Risk analyses on the clinical outcomes between the mini-thoracotomy and sternotomy groups

Outcomes	Original			IPTW-adjusted		
	OR	95% CI	P-value	OR	95% CI	P-value
Early Outcomes						
Early death	0.37	0.14-0.83	0.02	0.52	0.21-1.14	0.12
LCOS requiring MCS	0.42	0.18-0.88	0.03	0.60	0.27-1.27	0.19
Early stroke	0.44	0.20-0.88	0.03	0.57	0.27-1.12	0.12
Surgical bleeding	0.71	0.33-1.46	0.37	0.84	0.38-1.76	0.65
New-onset dialysis	0.32	0.15-0.65	<0.01	0.66	0.34-1.23	0.20
Prolonged ventilation (>24hrs)	0.37	0.22-0.61	<0.01	0.56	0.33-0.92	0.02
Overall outcomes						
All-cause death	0.46	0.28-0.75	<0.01	0.66	0.40-1.06	0.09

IPTW, inverse probability of treatment weighting; OR, odds ratio; CI, confidence interval; LCOS, low cardiac output syndrome; MCS, mechanical cardiac support

Abstract

Objectives

Right mini-thoracotomy may enhanced mitral valve (MV) visualization during redo MV surgery, thereby minimizing the risk of conversion to redo median sternotomy. We compared the clinical outcomes of mini-thoracotomy for redo MV surgery with those of full sternotomy.

Methods

Of the 730 consecutive adult patients who underwent redo MV surgery between 2002 and 2018 at our institution, we identified 380 patients (age: 56.0±14.8 years) after excluding those who underwent concomitant aortic valve or coronary artery surgeries. We compared the clinical outcomes in patients who underwent mini-thoracotomy (MINI group; n=168) with those in patients who underwent sternotomy (STERN group; n=218) after inverse probability of treatment weighting based on propensity scores.

Results

After adjustment, there were no significant between-group differences in the risks of early and late mortality, low cardiac output syndrome, and re-exploration due to bleeding between the groups. The MINI group exhibited a significantly reduced risk of prolonged (>24 hours) ventilation and underwent fewer transfusions than the STERN group. Intensive care unit and hospital stay durations were shorter in the MINI group than in the STERN group.

Conclusions

Mini-thoracotomy is a viable alternative to conventional sternotomy for redo MV surgery.