Association between sternotomy versus thoracotomy and the prevalence and severity of chronic postsurgical pain after mitral valve repair: An observational cohort study

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Abstract

Objective: Differences in the prevalence and severity of chronic postsurgical pain (CPSP) after cardiac surgery via thoracotomy versus sternotomy are not well understood.

Design: An observational cohort study.

Setting: A tertiary care hospital.

Participants: Four hundred and twenty-eight patients (sternotomy: 192 patients, thoracotomy: 236 patients) who underwent mitral valve repair.
Interventions: A questionnaire about the severity of surgical wound pain evaluated with a numerical rating scale (NRS) was sent. NRS responses for current pain, peak pain in the last 4 weeks, and average pain in the last 4 weeks were evaluated.

Measurements and Main Results: The main outcomes were the severity of CPSP evaluated using NRS and the prevalence of CPSP. CPSP was defined as pain > 0 that developed after a surgical procedure. During the median follow-up of 29 months, 79 patients complained of CPSP. (sternotomy: 15 patients, thoracotomy: 64 patients) Multivariable ordinal logistic regression showed that NRS responses for current pain (adjusted odds ratio (aOR), 3.17; 95% CI, 1.64–6.12; P = 0.001), peak pain in the last 4 weeks (aOR, 2.00; 95% CI, 1.11–3.61; P = 0.021), and average pain in the last 4 weeks (aOR, 2.21; 95% CI, 1.31–3.72; P = 0.003) were significantly higher in patients who underwent thoracotomy. Multivariable logistic regression showed that thoracotomy is an independent predictor of CPSP (aOR, 3.63; 95% CI, 1.67–7.88; P = 0.001)

Conclusions: The prevalence and severity of CPSP were higher among patients who underwent mitral valve repair via thoracotomy than sternotomy.
Key words: Chronic postsurgical pain, minimally invasive cardiac surgery, thoracotomy, sternotomy, mitral valve repair.

Introduction

Chronic postsurgical pain (CPSP) has gained increasing recognition because its prevalence has been reported to be higher than previously thought. CPSP has also been shown to worsen patient quality of life. Recently, minimally invasive cardiac surgery with right thoracotomy has been increasingly used in patients with mitral valve diseases because it has been shown to reduce postoperative mortality, postoperative bleeding, transfusion volume, duration of ventilation, and length of hospital stay. However, little is known about the prevalence and severity of CPSP among patients after minimally invasive cardiac surgery with thoracotomy. Chronic post-thoracotomy pain is an established late complication. It has a reported prevalence of 65%, which is higher than the prevalence of chronic pain after other surgeries. Among patients undergoing cardiac surgery, chronic post-sternotomy pain is a common complication and the prevalence has been reported to be as high as 39%. One explanation why the reported prevalence of CPSP is higher with thoracotomy than with sternotomy is based on epidemiological studies and potential differences in background factors of study participants. Therefore, we considered it desirable to compare the prevalence of CPSP using cohorts with similar backgrounds. Namely, we hypothesized that the prevalence and severity of CPSP are higher among
patients after mitral valve repair via thoracotomy versus sternotomy. To test this hypothesis, we conducted a prospective observational study to clarify the prevalence and severity of CPSP among patients after minimally invasive mitral valve repair via thoracotomy versus conventional mitral valve repair via sternotomy.
Methods

Study registration and ethical considerations

We adhered to the Declaration of Helsinki. After this study was approved by our institutional ethics committee (registration number, M30-175-2), it was registered with the University Hospital Medical Information Network Clinical Trials Registry (registration number, UMIN000041002). Written informed consent was obtained from all study participants postoperatively.

Study population and pain assessment

In this single-center questionnaire survey, consecutive patients who underwent mitral valve repair in conjunction with other cardiac surgery via thoracotomy or sternotomy between January 2014 and March 2020 were included. A brief summary of the study, consent form, and questionnaire were sent to prospective study participants in July 2020 because CPSP was defined as pain that develops after a surgical procedure and persists at least 3 months after surgery in the World Health Organization’s International Classification of Disease, 11th revision. 10 We awaited replies with the questionnaire for 2 months. The
questionnaire consisted of two components. One component was a numerical rating scale (NRS) to assess the prevalence and severity of postsurgical pain. NRS is an 11-point scale ranging 0 to 10, where 0 indicates no pain and 10 indicates the worst pain ever experienced. NRS has been shown to be valid and reliable tool for assessment of pain intensity.\textsuperscript{11,12} The following three variables were assessed using NRS: current pain, peak pain in the last 4 weeks, and average pain in the last 4 weeks. If a patient complained of pain > 0, this was considered to indicate the onset of CPSP. If a patient complained of pain > 3, this was considered to indicate the onset of moderate CPSP.\textsuperscript{13} The other component was the Japanese version of the painDETECT questionnaire (PDQ-J) to assess the characteristics of postsurgical pain (nociceptive, neuropathic, and mixed). The painDETECT questionnaire is a simple patient-based screening questionnaire to determine the prevalence of neuropathic pain components. The painDETECT questionnaire is scored on a 40-point scale ranging from −1 to 38, where 12 or lower indicates nociceptive pain, 13–18 indicates mixed pain, and 19 or greater indicates neuropathic pain. The PDQ-J is the painDETECT questionnaire translated into Japanese.\textsuperscript{14,15}

Surgical procedures

Surgical indications for mitral valve repair were discussed by the institutional heart team comprising of cardiologists, radiologists, and surgeons, according to the guidelines.\textsuperscript{16} Median full sternotomy was the standard procedure for mitral valve repair surgery in our institution. Indications for mitral valve surgery via thoracotomy were based on the absence
of severe lung disease, severe peripheral artery disease, calcification or dilatation of the aortic root or ascending aorta, moderate to severe aortic regurgitation, severe left ventricular dysfunction, coronary artery disease requiring revascularization, previous cardiac surgery, right-sided lung surgery, or severe endocarditis. In the right thoracotomy surgery, we entered the pleural space via a 5-7 cm skin incision through the fourth intercostal space. In addition, the videoscope was inserted through a small stab incision at the third intercostal space in the anterior axillary line. Subsequently, visceral pleura of the fourth intercostal space was widely opened so that 4th and 5th ribs were preserved without extensive tension by the retractor.

Anesthetic management

All patients underwent general anesthesia. After monitoring of electrocardiographic activity, oxygen saturation with a pulse oximeter, body temperature, regional saturation of oxygen in the frontal region of the head, and noninvasive blood pressure, anesthetic induction was performed with midazolam, remifentanil, and rocuronium. The trachea was orally intubated using a single-lumen tube for patients who underwent sternotomy, or using a double-lumen tube for patients who underwent thoracotomy to allow for one-lung ventilation. Patients were mechanically ventilated in volume control mode. An arterial line, central venous line, and pulmonary artery line were inserted. Arterial pressure, central venous pressure, and pulmonary arterial pressure were continuously monitored. A transesophageal echocardiography probe was inserted unless the patient had a
contraindication. Anesthesia was maintained with propofol (5–7 μg /kg/hour), remifentanil (0.4–1 μg /kg/minute), and rocuronium (6–8 μg /kg/minute). Intraoperative arterial pressure, central venous pressure, and pulmonary arterial pressure were controlled within the normal range by the attending anesthesiologist. Remifentanil was administered in the range of 0.4–1 μg /kg/minute. Before discontinuation of remifentanil infusion, 300–700 μg of fentanyl was administered. The attending anesthesiologist determined the amount of fentanyl administered. Corticosteroids were not administered during cardiopulmonary bypass. Neither neuraxial anesthesia nor peripheral nerve block was performed intraoperatively. After the surgical procedures, the tracheal tube was changed to a single-lumen tube and patients were transferred to the intensive care unit under general anesthesia.

Postoperative pain management

During the intensive care unit stay, intravenous acetaminophen (15 mg/kg) was administered every 6 hours until postoperative day 2. Opioid-based intravenous patient-controlled analgesia was not used. For breakthrough pain, intravenous pentazocine (150 mg) was administered. After resumption of oral intake, oral loxoprofen (60 mg) was used as a rescue dose until hospital discharge. After discharge, oral loxoprofen (60 mg) was used as needed.

Statistical analysis
First, to assess the distribution of NRS responses among patients who underwent sternotomy versus thoracotomy, medians and interquartile range (IQR) were presented. Between-group differences in NRS responses were evaluated by a multivariable ordinal logistic regression model using data from all study participants. Second, to assess the prevalence of CPSP among patients with sternotomy versus thoracotomy, the number of patients who complained of CPSP and moderate CPSP were identified. Multivariable logistic regression was used to compare the odds of CPSP in each group. Multivariable ordinal logistic regression and logistic regression models adjusted for the following 7 factors as independent variables: surgical procedure (sternotomy or thoracotomy), age, sex, body mass index, operation year, preoperative Society of Thoracic Surgeons (STS) score, and operative time. These variables, which are possibly associated with the prevalence and severity of CPSP, were selected on the basis of previous studies and the availability of data elements in our institutional clinical records. Third, as a sensitivity analysis, the multivariable ordinal logistic model and multivariable logistic regression model were applied to patients who answered the questionnaire. In all multivariable models, missing data were imputed with the multiple imputation method using the “aregImpute” function in the rms package in R. Internal validation using the bootstrap method with 200 replications was performed to assess overfitting of the regression model. The number of explanatory variables was based on event incidence and the bootstrap optimism-corrected calibration slope. Continuous variables were summarized as medians and interquartile ranges. Between-group differences were assessed using Wilcoxon rank sum test. Categorical and ordinal variables were summarized as numbers and percentages (%). Between-group
differences were assessed using chi-square test. All statistical analyses were performed with a 2-sided significance level of 5% using R 3.6.0 (The R Foundation for Statistical Computing, Vienna, Austria).

Results

Characteristics of study participants

Among 435 potential participants, 7 patients were excluded because they died before the questionnaire was sent. Consequently, 428 patients were included in the study. Table 1 summarizes the characteristics of the study patients. No patients were converted from thoracotomy to sternotomy. Of the 276 patients (64.5%) who answered the questionnaire, 126 patients underwent sternotomy and 150 patients underwent thoracotomy. Table 2 shows the baseline characteristics of patients stratified by questionnaire response status. There were no significant between-group differences except for age. Among patients who answered questionnaire, median [IQR] length of intensive care unit stay was significantly shorter in the thoracotomy group than the sternotomy group (2 [2, 3] versus 3 [2, 3]; P < 0.001), and median [IQR] length of hospital stay was significantly shorter in the thoracotomy group than the sternotomy group (7 [7, 8] versus 12 [10, 14]; P < 0.001).

Distribution of NRS responses
The distribution of NRS responses is shown in Figure 1. Median [IQR] NRS response for current pain was 0 [0, 0] in the sternotomy group and 0 [0, 1] in the thoracotomy group. Median [IQR] NRS response for peak pain in the last 4 weeks was 0 [0, 0] in the sternotomy group and 0 [0, 2] in the thoracotomy group. Median [IQR] NRS response for average pain in the last 4 weeks was 0 [0, 0] in the sternotomy group and 0 [0, 1] in the thoracotomy group.

Multivariable ordinal logistic regression showed that NRS response for current pain (adjusted odds ratio, 3.17; 95% confidence interval (CI), 1.64–6.12; \( P = 0.001 \)), NRS response for peak pain in the last 4 weeks (adjusted odds ratio, 2.00; 95% CI, 1.11–3.61; \( P = 0.021 \)), and NRS response for average pain in the last 4 weeks (adjusted odds ratio, 2.21; 95% CI, 1.31–3.72; \( P = 0.003 \)) were significantly higher in patients who underwent thoracotomy.

Prevalence of CPSP

During the median follow-up of 29 [IQR: 12, 49] months, 79 patients complained of CPSP (sternotomy: 15 patients, thoracotomy: 64 patients) and 12 patients complained of moderate CPSP (sternotomy: 2 patients, thoracotomy: 10 patients). The prevalence of CPSP was 11.9 % (95% CI: 6.8–18.9%) in the sternotomy group and 42.7% (95% CI: 34.6–51.0%) in the thoracotomy group. The prevalence of moderate CPSP was 1.6% (95% CI: 0.2–5.6%) in the sternotomy group and 6.7% (95% CI: 3.2–11.9%) in the thoracotomy group.
Multivariable logistic regression showed that thoracotomy (adjusted odds ratio, 3.63; 95% CI, 1.67–7.88; P = 0.001) was an independent predictor of CPSP (Table 3). In terms of moderate CPSP, the result of internal validation showed that the multivariable logistic regression model was overfitted because the low event rate reduced the reliability of statistical models.

Characteristics of CPSP

Among 64 patients who reported CPSP in the thoracotomy group, 52 patients (81.2%) had nociceptive pain, 1 patient (1.6%) had neuropathic pain, and 11 patients (17.2%) had mixed pain. Among 15 patients who reported CPSP in the sternotomy group, 14 patients (93.3%) had nociceptive pain and 1 patient (6.7%) had mixed pain.

Sensitivity analysis

Sensitivity analysis with data from patients who answered the questionnaire yielded results similar to those with the full cohort data. Multivariable ordinal logistic showed that NRS responses for current pain (adjusted odds ratio, 4.83; 95% CI, 2.27–10.27; P < 0.001), peak pain in the last 4 weeks (adjusted odds ratio, 3.17; 95% CI, 1.67–6.02; P < 0.001), and average pain in the last 4 weeks (adjusted odds ratio, 3.67; 95% CI, 1.91–7.07; P < 0.001) were significantly higher in patients who underwent thoracotomy. Multivariable logistic
regression showed that thoracotomy (adjusted odds ratio, 5.07; 95% CI, 2.36–10.89; P < 0.001) was an independent predictor of CPSP (Table 4).

Discussion

This study showed that patients who underwent thoracotomy had significantly higher pain scores than patients who underwent sternotomy. Moreover, the prevalence of CPSP was higher in patients who underwent thoracotomy and thoracotomy is an independent predictor of CPSP. These results confirmed our hypothesis that the prevalence and severity of CPSP are higher after mitral valve repair via thoracotomy versus sternotomy.

To date, various demographic, clinical, and surgery-related factors have been shown to be risk factors of CPSP. Age, comorbidities, preoperative pain, and duration of surgery were consistently identified risk factors for CPSP in multiple studies. Surgery type has been also shown to be a risk factor, and pain physicians agree that thoracotomy is a high-risk procedure for CPSP. However, since these common perceptions are based on clinical experiences and epidemiological studies, differences in patient background might have affected the observed prevalence of CPSP. One strength of this study is that we compared whether surgical incision site type changes the prevalence of CPSP among
patients with the same disease. Few studies have directly assessed the impact of surgical procedures on the prevalence and severity of CPSP.

Our results about the prevalence and the severity of CPSP showed the disadvantage of minimally invasive mitral valve repair via thoracotomy. This could be explained by the difference in the prevalence and severity of CPSP by surgery type. It has been reported that the prevalence of CPSP among patients after thoracotomy is higher than after other types of surgery including sternotomy, and that patients experience severe pain after thoracotomy.\textsuperscript{2}\textsuperscript{,}18,21 Post-thoracotomy pain has been shown to be severe because it has multifactorial etiology including afferent nociceptive input from the skin incision, costochondritis, rib injury from retraction, acute intercostal neuralgia, and damage of the pulmonary pleura.\textsuperscript{23}\textsuperscript{,}25 Studies have been shown that patients who underwent thoracotomy with small versus conventional skin incisions have comparable rates of CPSP.\textsuperscript{26}\textsuperscript{,}28 Consequently, it is acceptable that the patients in this study who underwent thoracotomy had a higher prevalence of CPSP and more severe CPSP. This study also demonstrated that patients who underwent mitral valve repair with thoracotomy have shorter intensive care unit stays and hospital stays and smaller transfusion volumes than patients with sternotomy, which was concordant with previous studies.\textsuperscript{4}\textsuperscript{,}7 These advantages of cardiac surgery with thoracotomy could be pronounced if we could overcome the disadvantage of CPSP.

The higher incidence of CPSP in the thoracotomy group might be the result of an inappropriate analgesia regime for acute postsurgical pain because it has been reported that the severity of acute postsurgical pain is highly predictive of CPSP.\textsuperscript{29}\textsuperscript{,}30 On the other hand,
the prevalence of CPSP in the sternotomy group seemed to be lower than the prevalence reported in previous studies, \textsuperscript{8,9} indicating that our postoperative analgesia regime might have been appropriate. Taken together, the use of more effective early postoperative analgesia regimens, such as opioid-based intravenous patient-controlled analgesia, epidural anesthesia, and peripheral nerve block, might decrease the postoperative prevalence and severity of CPSP after cardiac surgery. In fact, one meta-analysis showed that regional anesthesia, mainly thoracic epidural anesthesia, has a preventive effect on CPSP after thoracotomy. \textsuperscript{31} Since paravertebral block has been shown to be as effective as epidural anesthesia for patients undergoing thoracotomy \textsuperscript{32}, paravertebral block would be a good choice because of its reliable effectiveness and safety even with surgery involving cardiopulmonary bypass. \textsuperscript{33} In future studies, the effectiveness of regional anesthesia on CPSP should be verified among patients undergoing cardiac surgery via thoracotomy.

This study had several limitations. First, because the questionnaire response rate was 64.5\%, our results might have been different if responses from other patients were available. However, the literature suggests that a response rate of 50–60\% or greater is optimal and nonresponse bias becomes minimal within this range of response rate. \textsuperscript{34} Moreover, we tried our best to obtain unbiased results by evaluating differences in patient characteristics using questionnaire responses and performing sensitivity analyses. Second, since mitral valve repair via thoracotomy was introduced more recently than mitral valve repair via sternotomy, the possibility of time bias could not be eliminated completely. Our results suggest that the prevalence of CPSP decreases by more than 50\% at 1 year after surgery (Table 3). However, in order to minimize the effect of time, we treated operation
year as an explanatory variable in the multivariable analyses. Third, some important preoperative variables that are possibly associated with the incidence of CPSP such as preceding pain, psychosocial factors, and intensity of acute postoperative pain were not available. We could not exclude the possibility that patients in the thoracotomy group could have been at higher risk for these factors. Fourth, we could not adjust for the effect of postoperative activity level. Faster mobilization after the surgery might have exacerbated the prevalence and severity of CPSP among patients undergoing thoracotomy than those undergoing sternotomy. Finally, since this study was conducted at a single institution, the results should be interpreted with caution. If the postoperative analgesia regimen was different, the results could have been different.

In conclusion, the prevalence and severity of CPSP were higher among patients who underwent mitral valve repair via thoracotomy versus sternotomy. Aggressive perioperative analgesia should be considered in patients undergoing minimally invasive cardiac surgery. Adding regional analgesia might lead to an overall decrease in CPSP; this should be verified in future studies.

Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.
References


31. Levene JL, Weinstein EJ, Cohen MS, et al. Local anesthetics and regional anesthesia versus conventional analgesia for preventing persistent postoperative pain in


Figure legends

Figure 1
Distribution of NRS responses

Abbreviation: NRS, numerical rating scale.

<table>
<thead>
<tr>
<th>Preoperative variables</th>
<th>N=428</th>
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</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>63 [53, 71]</td>
</tr>
<tr>
<td>Male gender, number (%)</td>
<td>286 (66.8)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
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<tr>
<td>Operation year, number (%)</td>
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</tr>
<tr>
<td>2014</td>
<td>68 (15.9)</td>
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<tr>
<td>2015</td>
<td>78 (18.2)</td>
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<tr>
<td>2016</td>
<td>61 (14.3)</td>
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<td>2017</td>
<td>55 (12.9)</td>
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<td>2018</td>
<td>76 (17.8)</td>
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<tr>
<td>2019</td>
<td>60 (14.0)</td>
</tr>
<tr>
<td>2020</td>
<td>30 (7.0)</td>
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<tr>
<td>STS score (%)</td>
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<tr>
<td>Hypertension, number (%)</td>
<td>199 (47.3)</td>
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<tr>
<td>Hyperlipidemia, number (%)</td>
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<tr>
<td>COPD, number (%)</td>
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<tr>
<td>Dialysis, number (%)</td>
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<tr>
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<td>1 (0.3)</td>
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</tr>
<tr>
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<td>---------</td>
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<tr>
<td>LVDd (mm)</td>
<td>58 [53, 61]</td>
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<tr>
<td>LVDs (mm)</td>
<td>36 [32, 40]</td>
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<tr>
<td>FS (%)</td>
<td>35 [32, 41]</td>
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<tr>
<td>BNP (pg/mL)</td>
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<tr>
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<tr>
<td>Serum Cr (mg/dL)</td>
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</table>

**Intraoperative variables**

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<tr>
<th>Thoracotomy, number (%)</th>
<th>236 (55.1)</th>
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</thead>
<tbody>
<tr>
<td>Operative time (minutes)</td>
<td>231 [190, 279]</td>
</tr>
<tr>
<td>Anesthesia time (minutes)</td>
<td>315 [279, 365]</td>
</tr>
<tr>
<td>CPB time (minutes)</td>
<td>117 [91, 146]</td>
</tr>
<tr>
<td>Transfusion (mL)</td>
<td>1505 [0, 2563]</td>
</tr>
<tr>
<td>Intraoperative fentanyl dose (mcg)</td>
<td>760 [0, 1663]</td>
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**Concomitant surgery**

<table>
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<tr>
<th>AVR, number (%)</th>
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<tr>
<td>TAP, number (%)</td>
<td>95 (22.2)</td>
</tr>
<tr>
<td>Maze, number (%)</td>
<td>119 (27.8)</td>
</tr>
<tr>
<td>CABG, number (%)</td>
<td>27 (6.3)</td>
</tr>
<tr>
<td>Myectomy, number (%)</td>
<td>3 (0.7)</td>
</tr>
<tr>
<td>LAA closure, number (%)</td>
<td>70 (16.4)</td>
</tr>
</tbody>
</table>

**Postoperative variables**

| Length of ICU stay (days) | 3 [2, 3] |
Length of hospital stay (days) 8 [7, 12]

Table 1
Characteristics of study participants

Values in brackets describes interquartile range

Abbreviations: BMI, body mass index; STS, Society of Thoracic Surgeons; COPD, chronic obstructive pulmonary disease; ASO, arteriosclerosis obliterans; LVDd, left ventricular diastolic diameter; LVDs, left ventricular systolic diameter; FS, fractional shortening; BNP, brain natriuretic peptide; Cr, creatinine; CPB, cardiopulmonary bypass; AVR, aortic valve replacement; TAP, tricuspid annuloplasty; CABG, coronary artery bypass graft; LAA, left atrial appendage; ICU, intensive care unit.

<table>
<thead>
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<th>Answered questionnaire (N=276)</th>
<th>Did not answer questionnaire (N=152)</th>
<th>P</th>
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<tr>
<td><strong>Preoperative variables</strong></td>
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<tr>
<td>Age (years)</td>
<td>65 [55, 72]</td>
<td>60 [52, 69]</td>
</tr>
<tr>
<td>Male gender, number (%)</td>
<td>187 (67.8)</td>
<td>99 (65.1)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>22 [20, 24]</td>
<td>22 [20, 25]</td>
</tr>
<tr>
<td>Operation year, number (%)</td>
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</tr>
<tr>
<td>2014</td>
<td>45 (16.3)</td>
<td>23 (15.1)</td>
</tr>
<tr>
<td>2015</td>
<td>47 (17.0)</td>
<td>31 (20.4)</td>
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<td>Year</td>
<td>Hypertension, number (%)</td>
<td>Hyperlipidemia, number (%)</td>
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<tr>
<td>------</td>
<td>--------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>2016</td>
<td>39 ( 14.1)</td>
<td>84 ( 31.0)</td>
</tr>
<tr>
<td>2017</td>
<td>36 ( 13.0)</td>
<td>64 ( 42.7)</td>
</tr>
<tr>
<td>2018</td>
<td>52 ( 18.8)</td>
<td>44 ( 29.3)</td>
</tr>
<tr>
<td>2019</td>
<td>38 ( 13.8)</td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td>19 (  6.9)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**STS score (%)**
- 2016: 1.0 [0.5, 2.1]
- 2017: 0.7 [0.5, 1.8]
- 2018: 0.133

**Hypertension**
- 2016: 135 (49.8)
- 2017: 64 (42.7)
- 2018: 84 (31.0)

**Hyperlipidemia**
- 2016: 44 (29.3)
- 2017: 44 (29.3)
- 2018: 44 (29.3)

**COPD**
- 2016: 15 (5.6)
- 2017: 9 (6.2)
- 2018: 15 (5.6)

**Dialysis**
- 2016: 6 (2.7)
- 2017: 4 (3.2)
- 2018: 4 (3.2)

**ASO**
- 2016: 1 (0.4)
- 2017: 0 (0.0)
- 2018: 0 (0.0)

**Malignancy**
- 2016: 2 (0.7)
- 2017: 2 (1.4)
- 2018: 2 (1.4)

**BNP (pg/mL)**
- 2016: 69 [27, 147]
- 2017: 63 [30, 158]
- 2018: 63 [30, 158]

**HbA1c (%)**
- 2016: 5.6 [5.4, 5.9]
- 2017: 5.6 [5.3, 5.9]
- 2018: 5.6 [5.3, 5.9]

**Serum Cr (mg/dL)**
- 2016: 0.90 [0.76, 1.04]
- 2017: 0.86 [0.70, 1.00]
- 2018: 0.86 [0.70, 1.00]

**Thoracotomy, number (%)**
- 2016: 150 (54.3)
- 2017: 86 (56.6)
- 2018: 150 (54.3)

**Operative time (minutes)**
- 2016: 233 [191, 276]
- 2017: 229 [189, 285]
- 2018: 233 [191, 276]

**Anesthesia time (minutes)**
- 2016: 316 [279, 363]
- 2017: 314 [280, 368]
- 2018: 316 [279, 363]

**CPB time (minutes)**
- 2016: 116 [90, 144]
- 2017: 119 [93, 149]
- 2018: 116 [90, 144]

**Transfusion (mL)**
- 2016: 953 [0, 1780]
- 2017: 487 [0, 1520]
- 2018: 953 [0, 1780]

**Intraoperative fentanyl dose (mcg)**
- 2016: 600 [500, 800]
- 2017: 700 [600, 800]
- 2018: 600 [500, 800]

**AVR, number (%)**
- 2016: 9 (3.3)
- 2017: 0 (0.0)
- 2018: 9 (3.3)
TAP, number (%) 57 (20.7) 38 (25.0) 0.361
Maze, number (%) 77 (27.9) 42 (27.6) 1
CABG, number (%) 18 (6.5) 9 (5.9) 0.971
LAA closure, number (%) 47 (17.0) 23 (15.1) 0.710

Postoperative variables
Length of ICU stay (days) 3 [2, 3] 3 [2, 3] 0.793
Length of hospital stay (days) 9 [7, 12] 8 [7, 12] 0.232

Table 2

Characteristics of study participants stratified by questionnaire response status

Values in brackets describes interquartile range

Abbreviations: BMI, body mass index; STS, Society of Thoracic Surgeons; COPD, chronic obstructive pulmonary disease; ASO, arteriosclerosis obliterans; BNP, brain natriuretic peptide; Cr, creatinine; CPB, cardiopulmonary bypass; AVR, aortic valve replacement; TAP, tricuspid annuloplasty; CABG, coronary artery bypass graft; LAA, left atrial appendage; ICU, intensive care unit.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Adjusted odds ratio</th>
<th>95% confidence interval</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thoracotomy</td>
<td>3.63</td>
<td>1.67–7.88</td>
<td>0.001</td>
</tr>
<tr>
<td>Age</td>
<td>1.26</td>
<td>0.86–1.84</td>
<td>0.232</td>
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<tr>
<td>Male gender</td>
<td>0.86</td>
<td>0.50–1.49</td>
<td>0.596</td>
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<tr>
<td>Body mass index</td>
<td>0.81</td>
<td>0.54–1.21</td>
<td>0.307</td>
</tr>
<tr>
<td>Operation year</td>
<td></td>
<td></td>
<td>0.158</td>
</tr>
</tbody>
</table>
### Table 3

Multivariable logistic regression results

Abbreviation: STS, Society of Thoracic Surgeons.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Adjusted odds ratio</th>
<th>95% confidence interval</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thoracotomy</td>
<td>5.07</td>
<td>2.36–10.89</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Age</td>
<td>1.07</td>
<td>0.66–1.74</td>
<td>0.773</td>
</tr>
<tr>
<td>Male gender</td>
<td>0.64</td>
<td>0.33–1.23</td>
<td>0.126</td>
</tr>
<tr>
<td>Body mass index</td>
<td>0.70</td>
<td>0.44–1.10</td>
<td>0.124</td>
</tr>
<tr>
<td>Operation year</td>
<td></td>
<td></td>
<td>0.029</td>
</tr>
<tr>
<td>2014</td>
<td>0.10</td>
<td>0.03–0.39</td>
<td></td>
</tr>
<tr>
<td>Year</td>
<td>STS Score</td>
<td>95% CI</td>
<td>p-Value</td>
</tr>
<tr>
<td>------</td>
<td>-----------</td>
<td>--------</td>
<td>---------</td>
</tr>
<tr>
<td>2015</td>
<td>0.13</td>
<td>0.04–0.50</td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td>0.13</td>
<td>0.03–0.49</td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td>0.12</td>
<td>0.03–0.45</td>
<td></td>
</tr>
<tr>
<td>2018</td>
<td>0.20</td>
<td>0.06–0.68</td>
<td></td>
</tr>
<tr>
<td>2019</td>
<td>0.22</td>
<td>0.06–0.80</td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td>1.00</td>
<td>Referent</td>
<td></td>
</tr>
</tbody>
</table>

Preoperative STS score: 0.98, 95% CI: 0.72–1.34, p-Value: 0.917
Operative time: 1.23, 95% CI: 0.82–1.34, p-Value: 0.313

Table 4

Sensitivity analysis results

Abbreviation: STS, Society of Thoracic Surgeons.