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Clinical Study

The Efficacy and Outcome of Ministernotomy Compared to Those of Standard Sternotomy for Aortic Valve Replacement

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Background. Benefits of ministernotomy have been reported but not yet fully established in the current literature. Ministernotomy may be associated with less bleeding, less need for transfusion, and reduced hospital length of stay. *Methods*. We retrospectively evaluated 347 patients who underwent aortic valve replacement between 2007 and 2011 at our institution. *Results*. Standard sternotomy was performed in 303 patients (154 males, 50.8% and 149 females, 49.2%) and ministernotomy in 44 patients (13 males, 30% and 30 females, 70%); most of the patients in ministernotomy group were female (75%) ($P = .0095$). The mean age for ministernotomy patients was 71.8 ± 12.6 years and for sternotomy patients 67.4 ± 13.8 years ($P = .045$). Significant preoperative morbidities (for ministernotomy and sternotomy, resp.) included stroke (11%, $n = 5$ versus 18%, $n = 55$; $P = .39$), PVD (23%, $n = 10$ versus 16%, $n = 49$; $P = .29$), COPD (25%, $n = 11$ versus 17%, $n = 52$; $P = .21$), renal failure (0.0%, $n = 0$ versus 8.8%, $n = 26$; $P = .06$), and previous heart surgery (9%, $n = 4$ versus 9.5%, $n = 29$; $P = 1.0$). Intraoperative blood transfusion was required in 23% of ministernotomy patients ($n = 9$) and 30% of sternotomy patients ($n = 91$), $P = .16$. Major postoperative complications (for ministernotomy and sternotomy, resp.) included exploration for bleeding (4.5%, $n = 2$ versus 6%, $n = 18$; $P = 1$) and adverse neurologic events (4.5%, $n = 2$ versus 1.6%, $n = 5$; $P = .05$). The length of stay (LOS) in the CCU was 75.4 ± 57.1 hours for the ministernotomy group and 125.4 ± 160.3 hours for the sternotomy group ($P = .12$). The LOS was slightly shorter following ministernotomy (9.00 ± 7.78 days) compared to sternotomy (10.0 ± 9.46 days) ($P = .31$). Perioperative mortality was 2.3% ($n = 1$) for ministernotomy and 3.3% ($n = 10$) for sternotomy ($P = 1.0$). The 1-, 3-, and 7-year survival following ministernotomy was 93.8%, 93.8%, and 88.3%, respectively; following sternotomy, these rates were 87.7%, 83.7%, and 82.6%, respectively (95% CI 0.273 to 1.325, $P = .20$). *Conclusion*. Ministernotomy is less invasive and is associated with less perioperative and postoperative bleeding and reduced LOS in CCU and in hospital.

1. Introduction

Although conventional sternotomy for aortic valve replacement (AVR) is the standard in many institutions, minimally invasive techniques are growing in popularity. The ministernotomy may reduce operative blood loss, postoperative respiratory complications, sternal wound infection, cost, and length of stay (LOS) in critical care units (CCU) as well as overall LOS in the hospital. Other advantages include cosmetic benefits such as a smaller incision and keeping the sternum intact in the lower half of the chest [1]. Although some authors have recommended the ministernotomy for AVR [2, 3], others have reported no advantage of minimally invasive AVR in early or midterm followup [4, 5]. This study was undertaken to compare the outcomes of ministernotomy with those of conventional sternotomy.

2. Methods and Statistical Analysis

A retrospective analysis was conducted to compare operative outcomes in a cohort of 347 patients with symptomatic

Table 1: Comparing preoperative characteristics and morbidities between 2 groups.

Preoperative characteristics	Aortic valve replacement Minithoracotomy (n = 44)	Aortic valve replacement Sternotomy (n = 303)	P value
Age (y)	71.8 ± 12.6	67.4 ± 13.8	0.0452*
Sex			
(i) Male	13 (29.5%)	154 (50.8%)	0.0095**
(ii) Female	31 (70.4%)	149 (49.2%)	0.0095**
BMI (kg/m^2)	27.3 ± 5.10	29.7 ± 21.7	0.47
BSA (m^2)	1.78 ± 0.23	1.85 ± 0.23	0.07
Hypertension	36 (82%)	263 (86.8%)	0.36
Diabetes	15 (34%)	122 (40.3%)	0.51
Current smoking	10 (22%)	52 (17.2%)	0.40
Any angina pectoris	4 (9%)	30 (9.9%)	1.00
Previous myocardial infarction	8 (18%)	55 (18.2%)	0.67
Chronic heart failure	14 (31.8%)	101 (33.3%)	1.00
Atrial fibrillation	3 (6.8%)	30 (9.9%)	0.78
Infectious endocarditis	1 (2.2%)	29 (9.6%)	0.15
Stroke	5 (11.3%)	55 (18.2%)	0.39
Peripheral-vascular disease	10 (22.7%)	49 (16.2%)	0.29
COPD/asthma	11 (25%)	52 (17.2%)	0.21
Renal failure requiring dialysis	0 (0%)	26 (85.8%)	0.06
Any previous cardiac surgery	4 (9%)	29 (9.6%)	1.00
HIV infection	0 (0%)	7 (2.3%)	0.60
Hepatitis C infection	1 (2.2%)	30 (9.9%)	0.15
Hematocrit (%)	37.6 ± 4.73	36.1 ± 5.09	0.31
Platelets ($\times 10^3/\mu$L)	243.9 ± 72.3	226.8 ± 81.8	0.22

aortic stenosis who underwent isolated surgical AVR between January 2007 and May 2011 at our institution. The operations were performed using either a standard approach with a median full sternotomy or a ministernotomy and extracorporeal circulation. This retrospective study was approved by the Institutional Review Board at our institution. Patients' demographic data (e.g., preoperative risk factors and postoperative outcomes) were collected. Hospital mortality was defined as death for any reason occurring within 30 days after the operation or any time during the same hospitalization, regardless of the length. The Student t-test was used to compare variables between the two groups. The Kaplan-Meier curve was created to estimate the survival. A $P < .05$ was considered statistically significant. Data analysis was performed with the Graphpad prism program.

3. Description of Technique

The ministernotomy was accomplished through a 5 to 8 cm upper incision and hemisternotomy that began at the sternal notch and went to the 3rd intercostal space (ICS) (occasionally the 4th ICS), extending to the right side. The retractor was applied, and the pericardium was opened. In some instances, this approach did not provide adequate exposure for cannulation of the right atrium (RA); further, a RA cannula may have obscured the small operative space. A difficult-to-access RA may have resulted in conversion to full sternotomy in some cases [6]. If the exposure of the right atrium was suboptimal, we cannulated the superior vena cava and advanced the cannula into the right atrium. This technique provided adequate drainage of the right heart and helped to avoid unnecessary manipulation of the RA and potential injury. A vent and a retrograde cardioplegia remained at the surgeon's discretion. A vent through the aortic valve is a viable option. The other aspects of the AVR remained the same, and the rest of the procedure is performed in standard fashion.

4. Results

Standard sternotomy was performed in 303 patients (154 males and 149 females) and ministernotomy in 44 patients (13 males and 33 females); more female patients underwent ministernotomy (P = .0095). Overall, the ministernotomy patients were older with a mean age of 71.8 ± 12.6 years compared to sternotomy patients with a mean age of 67.4 ± 13.8 years (P = .045). Significant preoperative characteristics for ministernotomy and sternotomy groups are illustrated in Table 1. Preoperative characteristics were similar between both groups; however, 26 patients in the full sternotomy group had end-stage renal disease (ESRD) compared to none in the ministernotomy group (26 versus 0, P = .05), which may explain the better long-term survival following hemisternotomy. The total volume of cell saver retransfusion (mL) was 339.3±147.5 for ministernotomy and 434.3±251 for

sternotomy (P = .0438), which indicated greater blood loss during surgery among patients who had full sternotomy. Intraoperative blood transfusion was higher in sternotomy patients compared to ministernotomy patients: RBC transfusion 31% versus 20% (P = .16), platelets 11.2% versus 6.8% (P = .6), and fresh frozen plasma 7.6% versus 2.2% (P = .34), respectively. Although these differences were clinically relevant, they were not statistically significant, likely due to small sample size in the ministernotomy group. Table 2 shows some of the intraoperative parameters and characteristics of both groups.

Postoperative complications included exploration for bleeding (ministernotomy 4.5%, n = 2 versus sternotomy 5.9%, n = 18; P = 1.0) and stroke (ministernotomy 4.5%, n = 2 versus sternotomy 1.6%, n = 5; P = .05). Eight sternotomy patients (2.6%) (but none of the ministernotomy patients) were readmitted to the CCU (P = .6). Two patients (4.5%) in the ministernotomy group and 21 patients (6.9%) in the sternotomy group required reintubation (P = .75). The LOS in the CCU was 75.4 ± 57.1 hours for the ministernotomy group and 125.4 ± 160.3 hours for the sternotomy group (P = .12). LOS in the hospital was 9.0 ± 7.78 days for the ministernotomy group and 10.0±9.46 days for the sternotomy group, P = .31. Some perioperative characteristics and postoperative complications are provided in Table 3. Perioperative mortality was 2.3% (n = 1) for ministernotomy and 3.3% (n = 10) for sternotomy (P = 1.0). The 1-, 3-, and 7-year survival for ministernotomy was 93.8%, 93.8%, and 88.3%, respectively; for sternotomy, it was 87.7%, 83.7%, and 82.6%, respectively (Figure 1, 95% CI 0.273 to 1.325, P = .20).

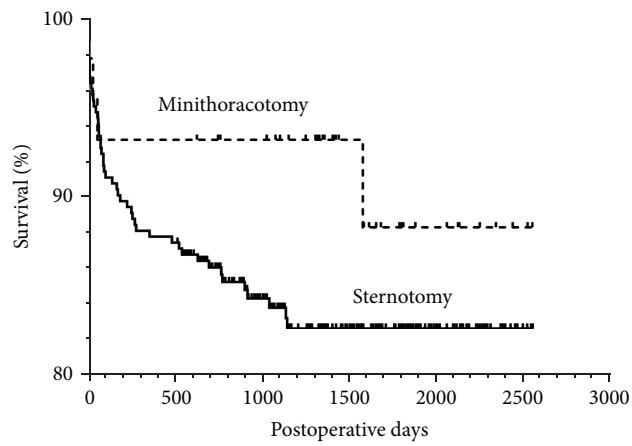

Figure 1: Kaplan-Meier survival curve comparing the long-term survival in both groups (95% CI 0.273 to 1.325, P = .20).

5. Discussion

Ministernotomy may reduce morbidity by limiting the invasiveness of surgical interventions [6, 7]. This approach avoids unnecessary lower mediastinal dissection, thereby reducing blood loss, transfusion needs, and LOS in the CCU and in the hospital. These beneficial effects are accomplished without compromising the safety and efficacy of the AVR [8]. Furthermore, the procedure may reduce the risk of injury to patent grafts in patients who had previous CABG [6, 9]. With a perioperative mortality of 2.3% (n = 1) for ministernotomy and 3.3% (n = 10) for sternotomy (P = 1.0), ministernotomy was not associated with higher perioperative mortality in our series. Our perioperative mortality was comparable to that in the current literature [1, 3, 9–12]. The long-term survival in our series was slightly better following ministernotomy; the 1-, 3- and 7-year survival for ministernotomy was 93.8%, 93.2%, and 88.3%, respectively; for sternotomy, it was 87.7%, 83.7%, and 82.6%, respectively (95% CI 0.273 to 1.325, P = .20); however, this difference in survival did not reach a level of statistical significance. The better survival following ministernotomy in our series might be due to the presence of a higher number of dialysis patients in the sternotomy group (0.0% in the ministernotomy group versus 7.5%, P = .06). However, these results demonstrate that a ministernotomy is unlikely to have a negative impact on long-term survival. Totaro et al. [9] reported a large series with 1,126 procedures using ministernotomy. The perioperative mortality was 4.1%; this was subdivided as 3.8% for redo procedures, 2.8% for isolated first-time AVR, and 6.7% for complex procedures. The authors suggested that minimizing surgical access may be helpful in patients who are undergoing complex surgical procedures, especially redo procedures [9].

We found reduced perioperative blood loss in ministernotomy patients; the total volume of cell saver retransfusion (mL) was lower in the ministernotomy group than in the sternotomy group (339.3 ± 147.5 versus 434.3 ± 251, resp., P = .0438), and accordingly, the intraoperative and postoperative blood transfusions for ministernotomy were less than those for the sternotomy group. However, this difference was not statistically significant. Reduced intraoperative bleeding with ministernotomy has been reported by other authors [5, 12, 13]. Gillinov et al. [13] reported a series of 827 patients who underwent valve surgery through upper ministernotomy; 462 had mitral valve procedures, and 365 underwent AVR. Operative mortality was 0.8% and conversion to full sternotomy was necessary in 2.4%. Blood transfusion was lower with 80% of patients receiving no blood transfusions [13].

MacDonald et al. [14] preformed a propensity match study comparing ministernotomy (n = 65) to full sternotomy (n = 130) for AVR. Ventilation time was significantly lower in ministernotomy (4 hours versus 6 hours; P = .002). The authors found no long-term survival benefit to ministernotomy; however, considering certain advantages of ministernotomy, they recommended this approach in select patients [14]. Their series included a general population of patients. Certain patients with respiratory problems (compared to the general population) may derive greater benefit from ministernotomy. Bonacchi et al. [12] reported that ministernotomy was associated with better respiratory function and allowed for rapid extubation. In our series, ministernotomy was associated with shorter LOS in CCU (75.4 ± 57.1 hours for ministernotomy group and 125.4 ± 160.3 hours for the sternotomy group, P = .12). In addition, the LOS in the hospital was, in our series, slightly shorter following ministernotomy compared to sternotomy (9.00±7.78 days and 10.0±9.46 days,

Table 2: The intraoperative parameters in both groups.

Intra-OP	Aortic valve replacement Minithoracotomy (n = 44)	Aortic valve replacement Sternotomy (n = 303)	P value
Cross-clamp time (min)	91.9 ± 28.3	98.0 ± 31.9	0.23
Perfusion time (min)	128.9 ± 46.9	130.8 ± 45.9	0.80
Longest ischemic interval (min)	23.6 ± 4.42	25.0 ± 8.17	0.30
Total volumen cardioplegic solution (mL)	3689.9 ± 3654.9	3191.7 ± 3069.4	0.37
Total volume cell saver (mL)	339.3 ± 147.5	434.3 ± 251.0	0.0438*
Cardioversion	18 (40.9%)	154 (50.8%)	0.26
Cerebral O_2 saturation (%)	57.1 ± 8.48	60.4 ± 11.7	0.33
Highest lactate (mmol/L)	1.85 ± 0.95	2.79 ± 12.4	0.64
Hematocrit after cardiopulmonary bypass (%)	25.2 ± 3.70	26.8 ± 18.9	0.61
Red blood cell units	9 (20.5%)	94 (31%)	0.16
Platelet units	3 (6.8%)	34 (11.2%)	0.60
Fresh frozen plasma units	1 (2.2%)	23 (7.6%)	0.34
Cryoprecipitate units	1 (2.2%)	6 (2%)	1.00

Table 3: Comparing the postoperative outcome including complications and adverse events.

Post-OP	Aortic valve replacement Minithoracotomy (n = 44)	Aortic valve replacement Sternotomy (n = 303)	P value
Red blood cell units	24 (54.5%)	148 (48.8%)	0.52
Platelet units	7 (15.9%)	43 (14.2%)	0.82
Fresh frozen plasma units	8 (18.2%)	53 (17.4%)	0.84
Cryoprecipitate units	3 (6.8%)	11 (3.6%)	0.40
Any complications	20 (45.5%)	125 (41.3%)	0.63
Atrioventricular block	1 (2.2%)	12 (3.9%)	1.00
Myocardial infarction	0 (0%)	0 (0%)	1.00
Atrial fibrillation	9 (20.5%)	52 (17.2%)	0.67
Cardiac tamponade	0 (0%)	0 (0%)	1.00
Multisystem failure	0 (0%)	4 (1.3%)	1.00
Valve dysfunction requiring re-OP	0 (0%)	1 (0.33%)	1.00
Bleeding requiring re-OP	2 (4.5%)	18 (5%)	1.00
Infection	3 (6.8%)	18 (6%)	
(i) Septicemia	1 (2.2%)	3 (1%)	0.42
(ii) Deep sternal infection	1 (2.2%)	7 (2.3%)	1.00
(iii) Pneumonia	0 (0%)	5 (1.7%)	1.00
(iv) Urinary tract infection	1 (2.2%)	3 (1%)	0.42
Pulmonary embolism	0 (0%)	1 (1%)	1.00
Neurological event	2 (4.5%)	5 (1.7%)	0.05
Gastrointestinal complication	1 (2.2%)	5 (1.7%)	0.56
Renal failure requiring dialysis	0 (0%)	11 (3.6%)	0.37
Reintubation	2 (4.5%)	21 (7%)	0.75
Readmission to ICU	0 (0%)	8 (2.6%)	0.60
Total duration of ICU stay (h)	75.4 ± 57.1	125.4 ± 160.3	0.12
Length of stay surgery-discharge (d)	9.00 ± 7.78	10.0 ± 9.46	0.31
Readmission (<30 days)	5 (11.4%)	47 (15.5%)	0.65

resp., P = .31) although the difference was not statistically significant, which may be due to the smaller number of patients in the ministernotomy group. Reduced LOS in the CCU and reduced overall LOS following ministernotomy have been reported by other authors [1, 12]. Shorter LOS for ministernotomy patients was confirmed in the meta-analysis of Khoshbin et al. [1]. Khoshbin et al. [1] analyzed 4 randomized, controlled trials comparing ministernotomy to full sternotomy. The authors reported significantly shorter ICU stay (by 0.57 days) in favor of the ministernotomy group.

Bonacchi et al. [12] reported that ministernotomy has not only important cosmetic advantages but also beneficial effects on blood loss and transfusion, postoperative pain, reduced ventilation time, and, eventually, sternal stability. In a prospective, randomized study, 80 patients undergoing AVR were randomized into ministernotomy ($n = 40$) or full sternotomy. The postoperative adverse outcomes were similar between the two groups. Mean mediastinal drainage and mean blood transfusions per patient were higher following full sternotomy compared to ministernotomy ($P = .04$). Mechanical ventilation time was significantly longer in full sternotomy patients [12]. However, Calderon et al. [5] found no significant difference in any respiratory parameters between both approaches in a series of 78 patients who were prospectively randomized to have ministernotomy or full sternotomy. However, they did find significantly higher intraoperative blood loss with standard sternotomy ($P < .05$) [5]. Detter et al. [4] compared early and midterm results as well as quality of life (QOL) among patients with ministernotomy or full sternotomy for AVR in a small series ($n = 70$). Patients were propensity-matched for age, sex, ejection fraction, and other preoperative morbidities. The authors did not find any statistically significant differences between the two groups for postoperative ventilation time, transfusion rate, LOS in the CCU or the hospital, or improved QOL, which might be due to the small sample size ($n = 70$) [4].

In a series of 3,180 patients who had isolated valve replacement, Grossi et al. [10] reported that 1,452 of them had (45.7%) aortic replacements. The surgical approaches were standard sternotomy (28%) or the minimally invasive technique (72%). Hospital mortality was 4.0% (sternotomy 5.1% versus ministernotomy 3.4%, $P = .13$). Advanced age, female gender, renal disease, and COPD were independent risk factors for mortality. A minimally invasive approach was not associated with increased stroke in their series. With an overall stroke rate of 2.2% (sternotomy 2.1% versus ministernotomy 2.3%, $P = .82$), there was no significant difference between the two groups [10]. However, in our series, stroke rate for ministernotomy was significantly higher compared to that for sternotomy (4.50% versus 1.65%, resp., $P = .05$). The higher rate of stroke might be explained by the older mean age in the ministernotomy group (71.8 ± 12.6 years versus 67.4 ± 13.8 years; $P = .045$), who were significantly older. The other explanation might be the small number of patients in the ministernotomy group; a small number of complications may produce a large percentage. This observation, while significant, may need further evaluation and validation in larger studies. Table 3 shows the postoperative complications in our series, which are in line with the reported data in the literature [9–12].

ElBardissi et al. [11] reported a series of ministernotomy for AVR in 249 octogenarians. Operative mortality was 3% and postoperative stroke rate was 4% [11]. The authors reported an excellent long-term survival at 5 and 10 years (93% and 77%, resp.) [11]. Advanced age and severe COPD were independent risk factors of inferior survival [11]. A subgroup analysis demonstrated that low-risk patients (low STS and Euro scores) had a better survival: 5- and 8-year survival of 84% and 67%, respectively; in contrast, high-risk patients had 5- and 8-year survival of 74% and 49%, respectively [11]. We agree with ElBardissi et al. [11] and believe that the outcome following ministernotomy versus sternotomy depends on preoperative risk factors. Additionally, a ministernotomy, in addition to cosmetic benefits, may result in reduced need for blood transfusion, improved lung function, and reduced LOS in the CCU and the hospital. The minimally invasive nature of the procedure does not have any negative effects on outcome.

6. Conclusion

Ministernotomy is less invasive and should be preferred in selected patients, particularly in elderly patients with compromised lung function. It is associated with less perioperative and postoperative bleeding, reduced LOS in the CCU and the hospital, and reduced ventilation. Ministernotomy does not impact perioperative mortality and long-term survival.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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