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Original Article

Comparative study between standard aortic valve replacement and ministernotomy aortic valve replacement

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Abstract

Objectives
The aim of this study is to evaluate the outcome of the recalled upper minimally invasive aortic valve replacement (MIAVR) J-shaped technique and full standard median sternotomy techniques aortic valve replacement (AVR).

Background
Over the past 20 years, MIAVR has evolved into a safe, well-tolerated, and efficient surgical treatment option for aortic valve disease. It has been shown to reduce postoperative morbidity, providing faster recovery and rehabilitation, shorter hospital stays, and better cosmetic results, as it reduces the incidences of wound infection owing to small incision length, especially in our diabetic fatty Egyptian female patients.

Patients and methods
Between September 2017 and March 2019, this study included 50 patients with isolated aortic valve disease. A total of 25 patients (group A) underwent (MIAVR) J-shaped technique and 25 patients (group B) underwent standard AVR, and they were compared with each other.

Results
In operative data, there were highly significant differences between both groups regarding aortic cross-clamp time, total bypass time, and total operative time ($P < 0.001$). In postoperative data, there were highly significant differences regarding total hospital stay, pain score in the first, second, third, and fourth day to hospital discharge; and patient satisfaction ($P < 0.001$). There was a significant difference in duration of ICU stay ($P = 0.033$). There were no mortalities in both groups.

Conclusion
MIAVR is a feasible procedure despite the narrow operative field that induced long operative times. It is safe with minimal postoperative morbidities, early rehabilitation, and less postoperative pain. Moreover, MIAVR provided cosmetically better wound results, which was immensely satisfying to the patients.

Keywords: Aortic valve replacement, minimally invasive aortic valve surgery, ministernotomy

Introduction

Valvular heart disease presents frequently in association with multiple comorbidities, and the risks of intervention are increasing [1]. The minimally invasive approaches in cardiac surgery were developed aiming to decrease patient discomfort, operative morbidity, length of hospital stay, and total cost, with improved patient satisfaction of wound cosmetic healing and facilitated rapid return to normal life [2]. In aortic valve surgery, standard median sternotomy has been the approach of choice for decades; however, many researchers aimed to develop less invasive procedures, and the most common minimally invasive approach is the partial upper ministernotomy [3].

This technique aims at achieving similar or superior safety and efficacy to conventional surgery with the added advantages of reduced trauma, less pain, less bleeding, less infection, less ICU stay, less hospital stay, better cosmesis, and shorter hospital stay [4].

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Patients and methods

This prospective study was conducted in National Heart Institute and Nasser Institute Hospital between September 2017 and March 2019.

A total of 50 patients were enrolled after informed consent in this study. They had isolated aortic valve disease. Overall, 25 patients (group A) underwent upper ministernotomy aortic valve replacement (AVR) [minimally invasive aortic valve replacement (MIAVR)] J-shaped technique and 25 patients (group B) underwent standard full sternotomy AVR.

Inclusion criteria were as follows:

(1) All adult patients undergoing AVR using prosthetic valves.

Exclusion criteria were as follows:
(1) Patients with other valvular diseases.
(2) Associated ischemic heart disease.
(3) Redo cases.
(4) Associated congenital heart disease.
(5) AVR using bioprosthetic valves.

All patients were positioned in supine position, and necessary peripheral arterial and venous access was installed for hemodynamic monitoring, and then general anesthesia was initiated.

Transesophageal echocardiography probe was inserted for intraoperative assessment of implanted valve and ensuring effective deairing.

A total of 25 patients (group B) underwent standard full sternotomy AVR and another 25 patients (group A) underwent upper ministernotomy AVR J-shaped technique. A skin incision was made starting 2 cm below the suprasternal notch and was extended at midline till the level of the fourth intercostal space. Standard pneumatic oscillating saw was applied to midline manubrio-sternotomy that was extended downward and was deviated gradually to the right side to form a 'J'-shaped incision with the transverse limb at level of the fourth intercostal space, taking care to avoid injury of the right internal mammary artery.

After good hemostasis and dissection of thymic tissue, the pericardium was opened and fixed to the skin by silk suspension sutures on both sides of the wound. Arterial aortic cannula was inserted in highest point of ascending aorta, and venous cannula was inserted via the right atrial appendage. A left ventricular vent was inserted through the right superior pulmonary vein.

Cardiopulmonary bypass (CPB) started, with cross-clamp on, and myocardial protection was achieved by standard moderate systemic hypothermia (28–32°C). Intermittent antegrade cold blood cardioplegia was delivered by the anesthesiologist and topical cooling was done using ice. Transverse or oblique aortotomy was done The aortic valve was excised and replaced by prosthetic valve St Jude using 2/0 ethibond suture with Teflon pledget followed by testing implanted valves leaflet mobility, closure of the aortotomy at the same time of rewarming, de-airing, insertion of two mediastinal tube and pace maker wire before off bypass while the heart is nearly empty (this is one of the most important tricks of this technique), gradual weaning from bypass, off bypass, and hemostasis.

The sternum was closed using sternal wires number 5 with addition of one oblique wire placed between the lower intact segment of the sternum and the angular segment of the incision.

All the patients were followed in the ICU and the ward with daily assessment for hemodynamics, wound infection, and degree of pain by means of a numerical rating scale ranging from 0 (no pain) to 10 (intolerable pain). Postoperative follow-up was done during hospital stay and after discharge in the outpatient clinic after one week, 1, 3, and 6 months regularly, with routine examination of hemodynamics and wound state, and degree of pain every visit. Echo was requested while discharging home and after 1 and 6-month visits.

Statistical analysis

Data were collected, revised, coded, and entered to the Statistical Package for Social Science (IBM SPSS), version 23. The quantitative data were presented as mean, SDs, and ranges when their distribution was found to be parametric. Moreover, qualitative data were presented as number and percentages. The comparison between two independent groups with qualitative data was done by using χ^2 test, whereas comparison between two independent groups with quantitative data and parametric distribution was done by using independent *t* -test. Paired *t* test was used to compare between preoperative and postoperative Echo in the two studied groups. The confidence interval was set to 95% and the margin of error accepted was set to 5%. So, the *P* value was considered significant at the level of less than 0.05.

Preoperative data

Table 1 shows demographic and preoperative data.

In group A, 15 (60%) patients were females and 10 (40%) were males, whereas in group B, 10 (40%) patients were females and 15 (60%) were males, with no statistical significance ($P = 0.157$).

In group A, mean patients' age was 46.12 ± 11.04 years, with range 32–78 years, whereas in group B, it was 47.00 ± 10.46 years, with range of 23–68 years, with no statistical significance ($P = 0.774$).

The mean BMI in group A was 26.98 ± 2.20, with range 22.46–30.12, whereas in group B, it was 26.80 ± 1.69, with range 22.2–29.06, with no statistical significance ($P = 0.746$).

The number of diabetic patients in group A was 12 (48%), whereas in group B, it was 10 (40%), with no statistical significance ($P = 0.569$).

The number of hypertensive patients in group A was 15 (60%), whereas in group B, it was 17 (68%), with no statistical significance ($P = 0.556$).

The number of dyslipidemic patients in group A was five (20%), whereas in group B, it was two (8%), with no statistical significance ($P = 0.221$).

Regarding dyspnea 'NYHA' classification in group A, there were 19 (76%) patients in NYHA class II, four (16%) patients NYHA class III, and two (8%) patients NYHA class VI, whereas in group B, there were 13 (52%) patients NYHA class II, seven (28%) patients NYHA class III, and five (20%) patients NYHA class VI, with no statistical significance ($P = 0.199$).

In group A, four (16%) patients complained of palpitation preoperatively, whereas in group B, five (20%) patients complained of palpitation, with no statistical significance ($P = 0.713$).

Table 2 shows preoperative echo data of both studied groups

Table 1: Demographic and preoperative data

	Upper ministernotomy *n*=25	Full sternotomy *n*=25	Test value	*P*	Significance
Age					
Mean±SD	46.12±11.04	47.00±10.46	0.289[a]	0.774	NS
Range	32-78	23-68			
Sex					
Females	15 (60.0)	10 (40.0)	2.000[b]	0.157	NS
Males	10 (40.0)	15 (60.0)			
BMI					
Mean±SD	26.98±2.20	26.80±1.69	0.326[a]	0.746	NS
Range	22.46-30.12	22.2-29.06			
DM					
No	13 (52.0)	15 (60.0)	0.325[b]	0.569	NS
Yes	12 (48.0)	10 (40.0)			
Hypertension					
No	10 (40.0)	8 (32.0)	0.347[b]	0.556	NS
Yes	15 (60.0)	17 (68.0)			
Dyslipidemia					
No	20 (80.0)	23 (92.0)	1.495[b]	0.221	NS
Yes	5 (20.0)	2 (8.0)			
NYHA					
2	19 (76.0)	13 (52.0)	3.229[b]	0.199	NS
3	4 (16.0)	7 (28.0)			
4	2 (8.0)	5 (20.0)			
Palpitation					
No	21 (84.0)	20 (80.0)	0.136[b]	0.713	NS
Yes	4 (16.0)	5 (20.0)			

Data were presented as means and SD or *n* (%). [a]Independent *t* test. [b]χ^2 test. DM, diabetes mellitus.

Table 2: Preoperative echo data of the two studied groups

	Upper ministernotomy *n*=25	Full sternotomy *n*=25	Test value[a]	*P*	Significance
Transvalvular pressure gradient (mean) (mmHg)					
Mean±SD	46.50±16.41	41.60±12.11	1.200	0.236	NS
Range	24.8-75	30-72			
Left ventricular end-diastolic diameter					
Mean±SD	5.19±0.59	4.96±0.54	1.476	0.146	NS
Range	4.2-6.5	4.2-5.9			
Left ventricular end-systolic diameter					
Mean±SD	3.30±0.59	3.28±0.47	0.106	0.916	NS
Range	2.5-4.9	2.5-4			
Ejection fraction					
Mean±SD	66.08±7.96	66.72±6.70	−0.308	0.760	NS
Range	45-75	54-75			

[a]Independent *t* test

Regarding mean transvalvular pressure gradient across aortic valve (mmHg) in group A, the range was 24.8–75, with mean 46.5 ± 16.41, whereas in group B, the range was 30–72, with mean 41.60 ± 12.11, with no statistical significance ($P = 0.236$).

Regarding left ventricular end-diastolic diameter in group A, the range was 4.2–6.5, with mean 5.19 ± 0.59, whereas in group B, the range was 4.2–5.9, with mean 4.96 ± 0.54, with no statistical significance ($P = 0.146$).

Regarding left ventricular end-systolic diameter in group A, the range was 2.5–4.9, with mean 3.30 ± 0.59, whereas in group B, the range was 2.5–4.0, with mean 3.28 ± 0.47, with no statistical significance ($P = 0.916$).

Regarding left ventricular ejection fraction in group A, the range was 45–75, with mean of 66.08 ± 7.96, whereas in group B, the range was 54–75, with mean 66.72 ± 6.70, with no statistical significance ($P = 0.760$).

Operative data

Table 3 shows operative data of both studied groups.

The range of aortic cross-clamp time (min) in group A was 42–116 min, with mean 81.44 ± 16.92 min, whereas in group B, the range was 45–68 min, with mean 60.04 ± 5.82 min, with a statistical significance ($P < 0.001$). The range of total bypass time (min) in group A was 64–140 min, with mean 107.48 ± 20.06 min, whereas in group B, the range was 70–86 min, with mean 75.76 ± 4.06 min, with statistical significance ($P < 0.001$). The range of total operative time in group A was 175–360 min, with mean 308.48 ± 65.51 min, whereas in group B, the range was 178–258 min, with mean 198.88 ± 18.85 min, with statistical significance ($P < 0.001$).

Postoperative data

Table 4 shows the postoperative data within the studied groups.

The mean duration of mechanical ventilation was 5.20 ± 1.50 h, with range 3–10 h in group A, whereas it was 5.44 ± 1.61 h, with range 3–10 h, in group B, without significant difference. The mean duration of ICU stay was 32.64 ± 12.26 h, with range 24–72 h in group A, whereas it was 40.32 ± 12.43 h, with range 24–72 h in group B. The mean duration of total hospital stay was 5.60 ± 0.76 days, with range 5–8 days, in group A, whereas it was 7.00 ± 1.04 days, with range 6–9 days in group B. The duration of ICU stay and total hospital stay showed significant difference between the two groups ($P = 0.033$ and $= 0.000$, respectively).

In both groups, the inotropic support was used in 24 (96%) patients, with no significant difference between them. Patients did not undergo reopening for bleeding in both groups without significant difference.

Regarding the first, second, third and fourth day till discharge day, pain scores showed highly significant difference between group A and group B ($P < 0.001$). The mean first day pain score was 4.48 ± 1.08, with range 3–7, in group A and 6.20 ± 1.04, with range 5–8, in group B. The mean second day pain score was 1.88 ± 1.09, with range 1–4 in group A and 4.56 ± 0.65, with range 3–5, in group B. The mean third day pain score was 1.40 ± 1.19, with range 0–4, in group A and 4.08 ± 0.81, with range 3–5, in group B. The mean fourth day till discharge pain score was 1.16 ± 1.07, with range 0–4, in group A and 3.28 ± 0.61, with range 2–4, in group B.

Regarding the patient satisfaction scale, there is a highly significant difference between the two groups ($P < 0.001$). In group A, 16 (64%) patients were very satisfied and nine (36%) patients were satisfied. In group B, three (12%) patients were satisfied, 13 (52%) patients were dissatisfied, and nine (36%) patients were very dissatisfied.

There was no mortality in both groups.

Table 5 shows postoperative echocardiography parameter.

There was no significant difference between both groups regarding postoperative echocardiography. The mean transvalvular pressure gradient was 16.60 ± 7.31, with range 8–35, in group A and 14.20 ± 3.62, with range 8–21, in group B. The mean left ventricular end-diastolic diameter was 4.95 ± 0.51, with range 3.8–5.8, in group A and 4.79 ± 0.37, with range 4.3–5.8, in group B. The mean left ventricular end-systolic diameter was 3.40 ± 0.66, with range 2.3–5.4, in group A and 3.30 ± 0.35, with range 2.5–4.2, in group B. The mean ejection fraction was 63.16 ± 8.39, with range 42–77, in group A and 62.56 ± 6.97, with range 52–73, in group B (Figs. 1–3).

Discussion

The minimal invasive approaches in cardiac surgery were developed aiming to decrease patient discomfort, operative

Table 3: Operative data of the two studied groups

	Upper ministernotomy	Full sternotomy	Test value	*P*	Significance
Aortic cross-clamp time (min)					
Mean±SD	81.44±16.92	60.04±5.82	5.981[a]	<0.001	HS
Range	42-116	45-68			
Total bypass time (min)					
Mean±SD	107.48±20.06	75.76±4.06	7.748[a]	<0.001	HS
Range	64-140	70-86			
Operative time (min)					
Mean±SD	308.48±65.51	198.88±18.85	8.039[a]	<0.001	HS
Range	175-360	178-258			

HS, highly significant. [a]Independent *t* test.

Table 4: Postoperative data, pain score, and patient satisfaction among the studied patients

	Upper ministernotomy	Full sternotomy	Test value	*P*	Significance
	n=25	*n*=25			
Duration of mechanical ventilation					
Mean±SD	5.20±1.50	5.44±1.61	−0.545[a]	0.588	NS
Range	3-10	3-10			
Duration of ICU stay					
Mean±SD	32.64±12.26	40.32±12.43	−2.199[a]	0.033	S
Range	24-72	24-72			
Hospital stay					
Mean±SD	5.60±0.76	7.00±1.04	−5.422[a]	0.000	HS
Range	5-8	6-9			
Inotropic support [*n* (%)]					
No	1 (4.0)	1 (4.0)	0.000[b]	1.000	NS
Yes	24 (96.0)	24 (96.0)			
Reopening for bleeding [*n* (%)]					
No	25 (100.0)	25 (100.0)	NA	NA	NA
Yes	0	0			
1st day pain score					
Mean±SD	4.48±1.08	6.20±1.04	−5.721[a]	0.000	HS
Range	3-7	5-8			
2nd day pain score					
Mean±SD	1.88±1.09	4.56±0.65	−10.539[a]	0.000	HS
Range	1-4	3-5			
3rd day pain score					
Mean±SD	1.40±1.19	4.08±0.81	−9.299[a]	0.000	HS
Range	0-4	3-5			
From 4th day to hospital discharge pain score					
Mean±SD	1.16±1.07	3.28±0.61	−8.607[a]	0.000	HS
Range	0-4	2-4			
Patient satisfaction [*n* (%)]					
Very satisfied	16 (64.0)	0			HS
Satisfied	9 (36.0)	3 (12.0)			
Dissatisfied	0	13 (52.0)	41.000[b]	0.000	
Very dissatisfied	0	9 (36.0)			
Mortality					
No	25 (100.0)	25 (100.0)	NA	NA	NA

[a]Independent *t* test. [b]χ^2 test.

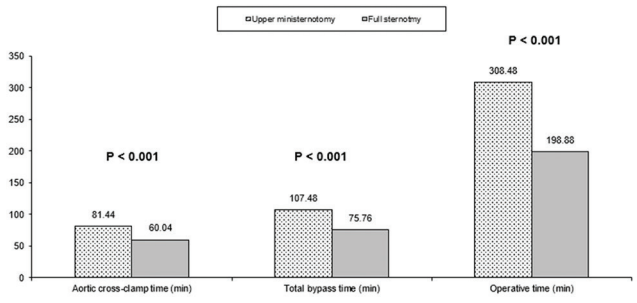

Figure 1: Operative data of the two studied groups.

morbidity, length of hospital stay, and total cost, with improved patient satisfaction of wound cosmetic healing and facilitated rapid return to normal life [5,6]. However, this should not be on the expense of short-term or long-term outcome of the surgical procedure or increases the difficulty of surgical technique[7,8]. Aortic valve disease is common in clinical practice, and surgical treatment is still the best choice procedure for symptomatic patients or patients with ventricular dysfunction [9]. Standard median sternotomy is the classic approach for the surgical treatment of aortic valve diseases, with recalled minimally surgical approaches being a less invasive alternative to conventional sternotomy [10].

Review of the outcome analysis of patients who had the upper ministernotomy approach did not reduce the quality of the procedure, and this technique is safe and effective for AVR [11]. Similarly, Mikus *et al.*[12] documented that minimal access AVR operation through an upper 'J' sternotomy proved to be as safe as the standard procedure in terms of hospital morbidity and mortality rate.

Moreover, Reser *et al.*[13] documented that the advantages of J-shaped upper ministernotomy included less surgical trauma,

Table 5: Postoperative echo parameters in the two studied groups

	Upper ministernotomy	Full sternotomy	Test value[a]	*P*	Significance
Transvalvular pressure gradient					
Mean±SD	16.60±7.31	14.20±3.62	1.471	0.148	NS
Range	8-35	8-21			
Left ventricular end-diastolic diameter					
Mean±SD	4.95±0.51	4.79±0.37	1.308	0.197	NS
Range	3.8-5.8	4.3-5.8			
Left ventricular end-systolic diameter					
Mean±SD	3.40±0.66	3.30±0.35	0.616	0.541	NS
Range	2.3-5.4	2.5-4.2			
Ejection fraction					
Mean±SD	63.16±8.39	62.56±6.97	0.275	0.784	NS
Range	42-77	52-73			

[a]Independent *t* test.

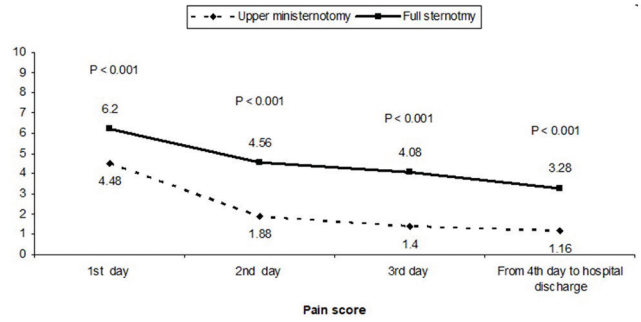

Figure 2: Pain score of the two studied groups at different times of measurement.

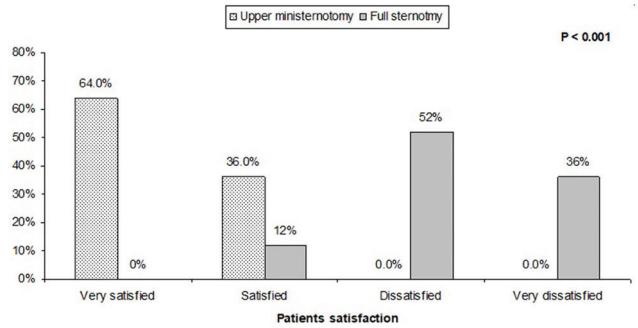

Figure 3: Patient satisfaction among the two studied groups.

bleeding, wound infections, and pain, with faster patients recovery and favorable long-term outcomes even in elderly and redo patients when compared with conventional sternotomy. The increased stability of the thoracic cage allows patients to mobilize early and efficiently.

This study was a two-center experience regarding upper ministernotomy in patients with aortic valve diseases (National Heart Institute and Nasser Institute Hospital). Our study included 50 patients with isolated aortic valve disease. They were 25 (50%) males, of whom 10 (40%) patients underwent MIAVR and 15 (60%) patients underwent standard AVR and 25 (50%) females, of whom 15 (60%) patients underwent MIAVR and 10 (40%) patients underwent standard AVR. This matched with the study by Renata *et al*. [14], which included 26 (70%) males, of whom 17 underwent sternotomy and nine minimally invasive surgery (MIS), and 11 (30%) female patients, of whom five underwent sternotomy and six underwent the MIS, with no statistically significant difference. Moreover, this agrees with Amr [15]; his study included 41 (60%) females and 25 (40%) males, with no statistically significant difference.

Regarding group A in our study, the mean BMI was 26.98 ± 2.20. Patients were included with multiple comorbidities, most commonly diabetes mellitus in 12 (48%) patients, hypertension in 15 (60%) patients, and dyslipidemia in five (20%) patients.

This is similar to Federico *et al*. [4], Amr [15], and Marcin *et al*. [4]. This is important as in patients with multiple comorbidities, the MIS approach can increase the surgical risk owing to prolonged Cardiopulmonary bypass (CPB) and aortic clamping compared with the traditional approach.

Regarding the intraoperative data, group A in our study showed that mean aortic cross-clamp time in minutes was 81.44 ± 16.92, total bypass time in minutes was 107.48 ± 20.06, and total operative time in minutes was 308 ± 48. These findings agree with Renata *et al*. [3], as the mean aortic cross-clamping time was higher for the MIS approach (87.4 ± 19.2 min), and the mean total CPB time was significantly higher in the MIS approach (114.3 ± 23.9 min). Moreover, in the study by Foghsgaard *et al*. [16], the cross-clamp time was 77.7 ± 20.2 min in ministernotomy group and total bypass time was 109 ± 41.3 min in ministernotomy group.

Our study showed that the only limitation for MIAVR surgery was the narrow operative field in comparison with full sternotomy. Thus in MIAVR, there was longer operative theater time owing to long preparation and cannulation time, long CPB time secondary to prolonged deairing time, and longer time consumed for insertion of substernal drain and pace maker wire.

On the contrary, upper ministernotomy provided multiple intraoperative advantages over full sternotomy including

significant reduction of time consumed for hemostasis and lower frequency of need for blood transfusion. In our study, in group A, the average blood loss in the first 24 h in ml was 360 ± 51.6 and total blood loss in ml was 860 ± 164.6. These findings supported those previously reported by Brown *et al.* [17], who found ministernotomy had less blood loss within the first 24 h. Thereafter, Gilmanov *et al.*[18] documented that upper ministernotomy is a safe, reproducible, and effective procedure and reduces the need for blood product transfusion. Recently, Shehada *et al.*[19] reported that MIAVR was associated with lower rate of autologous blood transfusion.

It shall be noted that the smaller incision used in ministernotomy limits the complete exposure of the surgical field, thus increasing the technical difficulty of the procedure, which may have influenced the increased bleeding volume. However, according to the literature, the refinement of the technique according to the surgical team learning curve can contribute to reduced bleeding when ministernotomy is used [20,21].

Furthermore, in our study, patients with upper ministernotomy had less postoperative complication regarding wound healing and duration of mechanical ventilation, with mean of 5.2 ± 1.50 h.

Similarly, Mikus *et al*. [12], Gilmanov *et al.* [18], and Brown *et al.*[17] reported significantly less postoperative mechanical ventilation time in ministernotomy patients. Recently, Shehada *et al.*[19] reported that upper ministernotomy was associated with shorter ventilation times.

Our study also showed that ICU stay was significantly less in ministernotomy group (32.64 ± 12.26 h). This agrees with the study by Amr [15], as ministernotomy ICU stay was 1.9 ± 0.5 days. However, this does not agree with Renata *et al*. [3], as the average length of stay in the ICU was 81.6 ± 20 h for the upper ministernotomy approach. Moreover, we have significantly lower postoperative pain scores in patients with upper ministernotomy. Interestingly, patients having enjoyed satisfactory immediate postoperative outcome manifested as early in-hospital resumption of normal breathing without limitation and early return to physical activity. Such improvement could be attributed to the short sternal wound, thus reducing pain secondary to respiratory movement. Moreover, patients having ministernotomy were allowed to sleep freely without limitation in supine position, owing to wound fixity provided by the lower part of the sternum, thus excluding the possibility of sternal wound mal-union or overriding edges. Moreover, skin wound incision for upper ministernotomy was cosmetically better with good significantly satisfaction scores. This finding was mostly secondary to the significantly shorter length of skin wound and the lower frequency of sternal wound infection with ministernotomy. In support of these findings, Renata *et al*.[3] found that MIAVR compared with conventional surgery provided faster recovery, shorter hospital stay, and better cosmetic results and requires less rehabilitation resources. In the study by Renata *et al*. [3], the average length of hospital stay was 7.1 ± 2.0 days for upper ministernotomy group.

Recently, Fudulu *et al*.[13] reported that MIAVR is a safe and effective procedure and is performed with comparable morbidity and mortality to conventional AVR. MIAVR results in improved ventilator function, reduced wound infection, shorter hospitalization, and a greater proportion of patient being discharged early to home.

Conclusion

We know that recalled surgical techniques require long experience before optimal results are achieved. Surgical recall of AVR through J-shaped partial upper sternotomy is a safe and effective technique that is associated with excellent postoperative outcomes, in terms of mortality, morbidity, shorter hospital stay, and faster recover but only longer durations of cross-clamping and CPB. Therefore, we support that minimal access approach can be used on a routine basis for isolated AVR.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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