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Proximal Aortic Surgery: Upper "J" or Conventional Sternotomy?

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ABSTRACT

Background: While minimally invasive procedures are being used in cardiac surgery, experience with minimally invasive proximal aortic surgery has been limited to certain centers.

Methods: Between January 2010 and March 2015, 54 patients with an upper "J" hemi-sternotomy and 75 patients with a conventional sternotomy due to proximal aortic pathology were included in this study. Forty-five patients from the "J" hemi-sternotomy group were matched with 45 patients from the conventional sternotomy group with respect to age, sex, ejection fraction, diabetes, hypertension, smoking history and operative type. Perioperative variables were in-hospital mortality, surgery for revision, amount of blood loss, requirement for blood transfusion, cardiopulmonary bypass (CPB), aortic cross-clamp and unilateral cerebral protection times, duration of ventilation, and length of intensive care unit (ICU) and total hospital stay.

Results: Patients were between 21-76 years with a mean age of 58.14 ± 11.06 years; 73.3% (n = 66) were male and 26.7% (n = 24) were female. Of all the cases included, 36.7% (n = 33) had isolated ascending aortic replacement, 41.1% (n = 37) had concomitant aortic valve replacement and ascending aortic replacement, and 22.2% (n = 20) had a Bentall procedure. Statistically, the amount of bleeding ($P = .026$), length of ventilation ($P = .001$), ICU ($P = .001$) and total hospital stay ($P = .004$) in the "J" hemi-sternotomy group were all found to be significantly lower than those in the conventional group.

Conclusions: Minimally invasive techniques like an upper "J" hemi-sternotomy can be safely performed without prolonging the aortic clamp time, and with less blood loss, less ventilatory support, and shorter ICU and total hospital stays when compared to conventional methods.

INTRODUCTION

Minimally or lesser invasive procedures are frequently preferred in cardiac surgery for reducing surgical trauma, having a better post-operative period, and preventing poor cosmetic outcomes (Navia 1996; Gilmanov 2015; Phan 2015]. It has been reported that aortic valve and proximal aortic surgery can be safely performed through an upper hemi-sternotomy [Bonacchi 2002; Phan 2014; Borger 2015; Shehada 2016]. However, experience in minimally invasive proximal aortic surgery has been limited to certain centers and has not gained widespread acceptance. Thus, more studies showing the superiority of these techniques over conventional methods are needed. Accordingly, patients undergoing proximal aortic surgery with standard equipment and central cannulation through an upper "J" hemi-sternotomy were compared to patients operated on using conventional techniques in our center. We sought to show the reliability and superiority of this technique over conventional methods.

MATERIALS AND METHODS

Between January 1, 2010 and March 30, 2015, 54 patients with an upper "J" hemi-sternotomy and 75 patients with a conventional sternotomy due to proximal aortic pathology were included in this study. All patients in the conventional group had been operated on before 2014, after which time a J sternotomy became the standard in our clinic for eligible patients. Between 2010 and 2014, only a small number of

Table 1. Matching Criteria

	Sternotomy Type "J" (n=45) Mean±SD	Conventional (n=45) Mean±SD	*P*
Age (year), mean±SD	57.93±12.47	58.36±9.58	.856*
Ejection fraction (%), mean±SD	60.89±6.26	61.91±5.99	.331*
Gender, n (%)			
Male	33 (73.3)	33 (73.3)	.999†
Female	12 (26.7)	12 (26.7)	
Operation, n (%)			
AAR	18 (40.0)	15 (33.3)	.423†
AVR+AAR	18 (40.0)	19 (42.2)	
Bentall	9 (20.0)	11 (24.4)	
Hypertension, n (%)	29 (64.4)	27 (60.0)	.839†
Diabetes, n (%)	8 (17.8)	6 (13.3)	.754†
Smoking history, n (%)	9 (20.0)	8 (17.8)	.999†

*Paired sample t test; †McNemar test. SD, standard deviation; AAR, ascending aortic replacement; AVR, aortic valve replacement.

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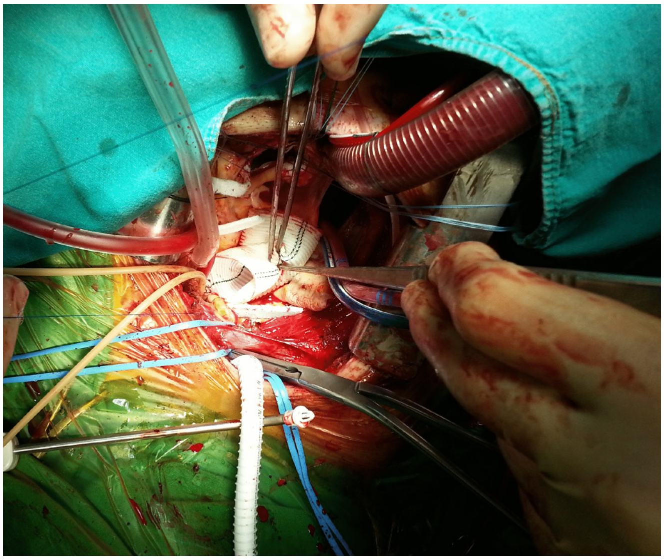

Figure 1. An intra-operative image from an open technique partial aortic arch replacement with the Bentall procedure utilizing unilateral cerebral protection through innominate artery cannulation.

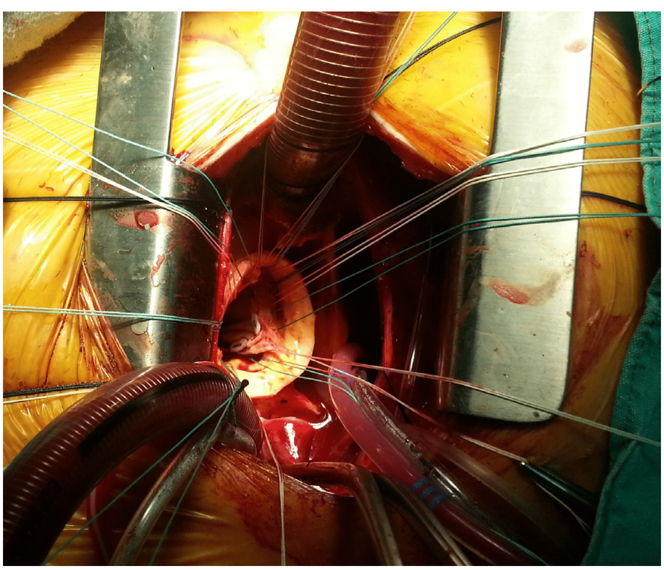

Figure 2. An intra-operative image from a case undergoing aortic valve replacement plus ascending aortic replacement.

sporadic cases had been operated on with J sternotomy, without a specific selection criteria.

Patients with aortic valve sparing surgery, isolated aortic arch surgery, gigantic aneurysms, redo and emergency cases (rupture, dissection, intramural hematoma) were all excluded from the study. Of the 129 patients included in the study, 45 patients from the "J" hemi-sternotomy group were matched with 45 patients from the conventional sternotomy group with respect to age, sex, ejection fraction, diabetes, hypertension, smoking history and operative type. Peri-operative variables

Table 2. Demographics and Operative Types versus Sternotomy

	Sternotomy Type		
	"J" (n=45) Mean±SD	Conventional (n=45) Mean±SD	*P*
Age (years)	57.93±12.47	58.36±9.58	.856*
	n (%)	n (%)	
Gender			
Male	33 (73.3)	33 (73.3)	.999†
Female	12 (26.7)	12 (26.7)	
Operative			
AAR	18 (40.0)	15 (33.3)	.423†
AVR+AAR	18 (40.0)	19 (42.2)	
Bentall procedure	9 (20.0)	11 (24.4)	
AAR+UCP‡	2 (4.4)	2(4.4)	
AVR+AAR+UCP‡	2 (4.4)	2 (4.4)	
Bentall+UCP‡	1 (2.2)	1 (2.2)	

*Paired t test; †McNemar test; ‡Not included in comparison.
SD, standard deviation; UCP, unilateral cerebral protection; AAR, ascending aortic replacement; AVR, aortic valve replacement.

were in-hospital mortality, surgery for revision, amount of blood loss, requirement for blood transfusion, cardiopulmonary bypass (CPB), aortic cross-clamp (X-clamp) and unilateral cerebral protection (UCP) times, duration of ventilation, and length of intensive care unit (ICU) and total hospital stay.

As reflected in Table 1, the two groups were matched with regards to age, gender, ejection fraction, hypertension, diabetes, smoking and operative type, using propensity score matching.

Surgical Technique

The skin incision was started 2 cm below the sternal notch with a maximum length of 8 cm, and in those patients requiring innominate artery cannulation, 10 cm starting from the sternal notch. Sternotomy was made in the figure of a "J" with the tip of the "J" towards the right fourth intercostal space. In the lesser invasive cases, carbon dioxide ($CO2$) was blown onto the surgical field. No additional instruments other than the standard surgical equipment and cannulas were required. In all the patients, cannulations were performed through the mediastinum. The innominate artery was cannulated using a prosthetic graft only in patients who had an open-technique hemiarch and ascending aortic replacement (AAR) under UCP, and in the rest of the patients, aortic cannulation was performed (Figure 1). In patients with UCP, the operations were conducted at 24 °C and with the rest of the patients at 32 °C. Antegrade cardioplegia was used in the hemi-sternotomy cases whereas both antegrade and retrograde cold blood cardioplegia were used in the conventional sternotomy group. All cases had venting through the right superior pulmonary vein.

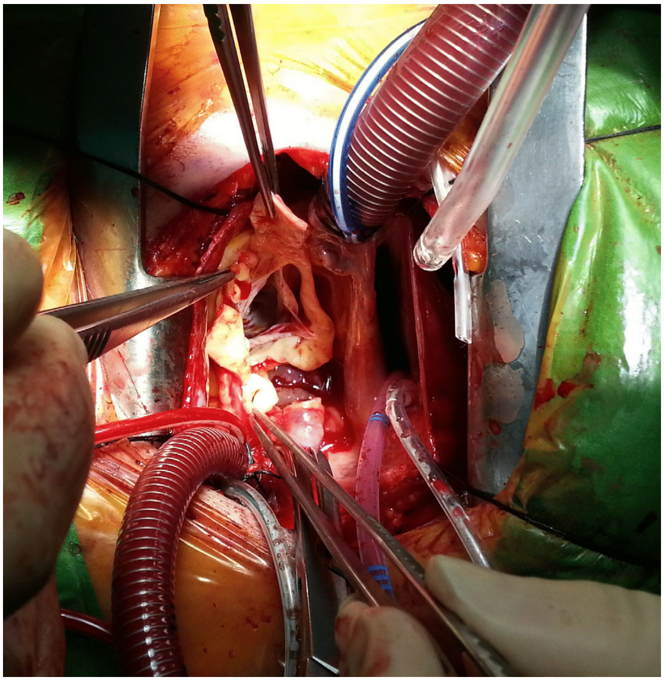

Figure 3. An intra-operative image from a case undergoing the Bentall Procedure.

RESULTS

As reflected in Table 2, the two sternotomy groups were alike with no statistically significant differences in their demographic properties, and the operative types were evenly distributed between groups. In each group, 2 patients undergoing AAR, 2 patients undergoing AAR plus aortic valve replacement (AVR) and 1 patient undergoing a Bentall procedure had UCP during surgery (Figures 2, 3). Table 3 summarizes the peri-operative variables with respective to the operative groups. There were no statistically significant differences between the groups with regard to the X-clamp and UCP time, but the CPB time in the conventional sternotomy group was statistically and significantly lower than in the "J" sternotomy group. Total hospital stay in the "J" sternotomy group was statistically and significantly shorter than the conventional sternotomy group. The amount of bleeding in the "J" sternotomy group was statistically and significantly less than the conventional sternotomy group. The duration of mechanical ventilation in the "J" sternotomy group was statistically and significantly shorter than the conventional sternotomy group. The need for whole blood transfusion in the "J" sternotomy group was statistically and significantly less than the conventional sternotomy group (P = .001) while that of platelets in the conventional group was statistically and significantly less than the "J" sternotomy group (P = .045). There were no statistically significant differences between the groups with regard to the amount of fresh frozen plasma and erythrocyte suspension transfused (P > .05). An ICU stay of 2 days was statistically and significantly more likely with the conventional group than with the "J" sternotomy group

Table 3: Peri-operative Variables versus "J" or Conventional Sternotomy

	Sternotomy Type		
	"J" (n=45) Mean±SD (Median)	Conventional (n=45) Mean±SD (Median)	*P*
CPB time (minute)	97.09±23.32	85.60±28.40	.033*§
X-clamp time (minute)	75.69±22.75	67.42±26.15	.099*
UCP time (minute)	15.80±5.72	16.40±3.36	.461‡
Total hospital stay (day)	4.93±0.91 (5)	7.58±5.48 (6)	.001‡i
Amount of bleeding (ml)	373.33±130.82	463.33±206.26	.026*§
Mechanical ventilation (hr)	3.67±0.80	4.80±1.37	.001i
Whole blood (unit)	1.31±0.76 (1)	1.82±0.49 (2)	.001i
Fresh frozen plasma (unit)	1.04±1.30 (0)	0.82±1.09 (0)	.511‡
Platelets (unit)	0.89±1.68 (0)	0.27±1.01 (0)	.045‡§
Erythrocyte suspension (unit)	0.36±0.61 (0)	0.51±0.76 (0)	.286i
	n (%)	n (%)	
ICU Stay			
1 day	45 (100.0)	36 (80.0)	0.004†§
2 day	0 (0.0)	6 (20.0)	
Revision surgery	2 (4.4)	5 (11.1)	0.453†
In-hospital mortality	0 (0,0)	0 (0,0)	-

*Paired t test; †McNemar; ‡Wilcoxon signed ranks test; §P <0.05 test; iP <0.01. SD, standard deviation; CPB, cardio-pulmonary bypass; UCP, unilateral cerebral protection

(P = .004) while there were no statistical differences between groups with regard to a need for a revision surgery (P > .05).

STATISTICAL ANALYSIS

The Number Cruncher Statistical System (NCSS) 2007 Statistical Software (Utah, USA) was used for the statistics. In addition to definitive statistical methods (mean, standard deviation, median, frequency, rate, minimum, maximum), paired samples t test and Wilcoxon signed ranks tests were used for the two groups' quantitative data comparison of normally and abnormally distributing variables, respectively. The McNemar and Marginal homogeneity tests were used in the comparison of qualitative data. Statistical significance was defined at the levels of P < .01 and P < .05.

DISCUSSION

Minimally invasive techniques have been used in cardiac surgery starting in the 1990s for decreasing surgical trauma, providing a better post-operative course, and offering superior cosmetic results for patients [Cosgrove 1996; Aris 1999]. Among all these techniques, upper mini-sternotomies have been reported to offer a safe and an effective alternative to conventional median sternotomy [Cosgrove 1996; Aris 1999]. There is a wide variety of larger case series, especially for aortic valve surgery utilizing these minimally invasive techniques, but unfortunately studies available for the aorta itself are quite limited [Machler 1999; Mihaljevic 2004]. In those studies that are available, it has been reported that partial upper sternotomy maintains a better post-operative course through decreased surgical trauma [Bonacchi 2002; Phan 2014; Borger 2015; Phan 2015; Shehada 2016]. This method offers a lesser amount of blood loss and decreased length of ICU and total hospital stay when compared to traditional methods [Bonacchi 2002; Mihaljevic 2004; Bakir 2006]. However, a positive effect on peri-operative mortality has not been shown yet. It has been reported that the total operative time has not been prolonged and the operation can safely be performed by experienced surgeons [Deschka 2013]. It has also been reported that the increased expectations of the patients as well as the cardiologists regarding the minimally invasive operations could be met by way of these techniques. Svenson et al. in their 2001 study reported a retrospective case series of 54 patients undergoing aortic arch and complex reoperation surgery and found out that minimal access surgery can safely be utilized with superior post-operative results [Svensson 2001]. In 2007, Tabata et al. showed that minimally invasive aortic surgery does not increase operative time, morbidity and mortality when compared to a conventional group and that it decreased the total hospital stay as well as the need for blood transfusion [Tabata 2007]. In 2009, Deschka et al. reported a retrospective case series of 50 patients and their results were consistent with decreased lengths of mechanical ventilation, ICU and total hospital stay [Deschka 2013].

There was no in-hospital mortality in our study. The total hospital and ICU stay, amount of blood loss, ventilation period, and the need for whole blood transfusion were all significantly less in the minimally invasive group, whereas CPB time and the need for platelets were less with the conventional group. There were no statistically significant differences in between groups with regard to fresh frozen plasma and erythrocyte suspension transfusion, X-clamp and UCP times. None of the patients in the minimally invasive group had to be converted to conventional methods. There were no statistically significant differences between the groups with regard to requirement for a revision surgery. In the post-operative period, it was observed that the patients in the "J" sternotomy group were mobilized more quickly and their cosmetic expectations were fully met.

We had to elongate the skin incision to about 10 cm in those patients whose innominate artery was cannulated with a prosthetic graft through the mediastinum to provide UCP. The incision may not necessarily need to be elongated if a separate subclavian incision prior to subclavian artery cannulation is performed. However, we prefer mediastinal cannulation as we feel more comfortable with it and believe that the amount of blood loss is less. Likewise, femoral cannulation could be performed instead of central cannulation, and that way the incision length could be less than 8 cm but a separate incision and its possible complications have always to be considered. There is a possibility of the right internal thoracic artery being injured during a mini upper "J" sternotomy, and we had to ligate it in two of our patients. Although this leads to a loss of conduit for a possible future coronary bypass, we do not think that this negatively affects the sternal blood supply due to the presence of rich number of collaterals. Similarly, although the inadvertent opening of the right pleura is not desirable, an apicobasal placement of drainage tube through a subxiphoid incision may easily be considered as a solution. In some patients with a deeper chest, it can sometimes be challenging to suture the right superior pulmonary vein venting site. In this situation, one may either use the standard surgical equipment or the longer surgical knot tying kits. We think that it is also important to routinely use CO2 and perform active de-airing measures to eliminate air from cardiac chambers.

An "L" sternotomy can alternatively be considered. The exposure of aortic arch has reportedly been better through this approach [Deschka 2013]. Nevertheless, we do not routinely prefer this approach due to the risk of inadvertent left internal thoracic artery injury as well as inadequate exposure to the aortic valve and its root structures. Likewise, an anterolateral thoracotomy could be an alternative approach but with the requirement for converting to median sternotomy, X-clamp and the CPB times are all reportedly higher [Semsroth 2015].

Due to the superior outcomes achieved by minimally invasive aortic and aortic valve surgeries, J sternotomy has started to be routinely used in our clinic starting in 2014. It is of note to emphasize that all these operations have been performed by a single senior surgeon (in both groups). In addition, to minimize baseline patient characteristics differences, the two groups were matched. Nevertheless, the difference in the timings of the two procedures may cause a small bias in favor of J sternotomy considering that the experience gained by the surgeon would increase over time. However, we do not believe that this would solely explain the favorable outcomes of the J sternotomy group on its own, rather it would have a small impact, if any. With increased experience and parallel to the successfully published peer reviews, we are planning to consider operating on those cases with aortic arch pathologies and those requiring aortic valve sparing surgery with the same minimally invasive method.

As a result, minimally invasive proximal aortic surgery can be safely performed without prolonging the X-clamp time and actually with shorter periods of mechanical ventilation, ICU and total hospital stay when compared to conventional methods.

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