Aortic Valve Replacement through a Right Mini-Thoracotomy: Single Center Experience and Literature Review

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ABSTRACT

Background

Aortic valve surgery is increasingly performed through minimally invasive approaches. Upper J hemisternotomy is often preferred to the right anterior mini-thoracormy. The aim of this study was to evaluate the feasibility and perioperative outcomes of this second technique comparing our experience with the literature data.

Methods

From January 2010 to October 2015, 326patients (182 males [55.8%]; median age 75 years, interquartile range 68-80 years, median EuroSCORE 6 (5 to 8) were scheduled for isolated aortic valve replacement through a right anterior mini-thoracotomy. Indications for surgery were degenerative aortic valve stenosis (262), aortic regurgitation (33) and mixed (32). Standard surgical technique and equipment were employed. We retrospectively reviewed patients' outcomes.

Results

Aortic valve replacement was performed through a 4 to 6 cm skin incision at the third intercostal space.

Overall cardiopulmonary bypass time was 58 (IR 49-70) minutes and aortic cross clamp time was 45 (IR 39-57) minutes. In one case intra operative conversion to sternotomy was required for paravalvular leaks which were not safely fixable through the mini thoracotomy approach. In 315 patients (96.6%) a biological prosthesis was implanted, in the remaining 6 a mechanical valve was used.

Median intensive care and hospital stay were 44 (IR: 38-59.5) hours and 7 (IR: 6-8) days respectively. Hospital mortality was 1.8% (6/326).

Conclusions

This study shows that aortic valve replacement performed through a right mini-thoracotomy has encouraging results. The main objections published in the literature concerning the long operative times and the necessity of peripheral cannulation can easily be circumvented with experience and tricks. For this reason in the era of minimally invasive approach we believe that this surgical approach is a safe and attractive alternative to conventional valve surgery.

Keywords: mini-thoracotomy, central cannulation, cross clamp time, biological minimally invasive surgery

INTRODUCTION

In 1960, Harken and Starr firstly performed an aortic valve replacement through a full median sternotomy [1]. Since then, it becomes the treatment of choice for aortic valve disease [2].

However, due to its invasive nature it remains associated with surgical access site complications such as wound infection and sternal dehiscence. This is the reason why, over the last years, minimally invasive surgery as an alternative to standard full sternotomy, has become a common technique in many centres with the aim to achieve superior results compared to standard approaches. Various techniques exist for minimally invasive aortic valve surgery: partial sternotomy (V-shaped, Z-shaped, inverse-T, J-, reverse-C and reverse-L partial) and right mini-thoracotomy at the 2nd or 3th intercostale space) have been developed for AVR since 1993 [3-9].

The right anterior mini-thoracotomy approach for aortic valve replacement is the least common minimally invasive access, adopted only in selected centres. First described by Benetti et al. in 1997, it involves a small, 4 to 6 cm transverse incision in the second or third intercostal space [10]. While technically demanding, it offers excellent cosmetic results and no sternal or costal injury. This approach is the second, after upper hemisternotomy, most frequently used. However, due to limited visualization, CT may be required to verify aortic anatomy and major limits reported regard the very tiny operating field, resulting in longer operating times compared to the standard approach, and the need for peripheral cannulation [5,11,12].

This study describes our comprehensive experience over the last six years showing improvement in results due to the surgeon's learning curve, reaching a totally central cannulation and short operative times in terms of cardiopulmonary bypass and cross clamping time. The surgical technique will be described in detail as well patient's outcome in term of mortality and morbidity. In addition, we provide a systematic review of the literature for surgical consideration and highlight some important concerns that need to be addressed.

MATERIALS AND METHODS

The protocol of this retrospective registry was approved by the local Ethic committee and each patient signed an informed consent for the treatment of personal data.

Patients Selection

From January 2010 to October 2015, 326 patients underwent aortic valve operations at the Maria Cecilia Hospital with a minimally invasive approach thought a right anterior mini thoracotomy. All patients undergoing cardiac surgery are entered into the Cardiovascular Information Registry, which includes a collection of preoperative demographic and co morbidity data, indications for surgery, operative variables, in-hospital complications, and operative mortality.

Median age was 75 years (IR 68-80 years) and 182 were males (55.8%). Indications for surgery were degenerative aortic valve stenosis (262), aortic regurgitation (33) and mixed (32).

There were no contraindications for right minithoracotomy approach other than a previous left pneumonectomy. Patients baseline characteristics are described in table 1.

Table 1: Baseline Characteristics of the Patients.

Age (yr)	75 (68 to 80 years)
Male sex	182 (55.8%)
Body-mass Index	26.9 (24,28 to 30)
Hypertension	226 (69.3%)
Diabetes	62 (19.1%)
Smoking status Current Former	 37 (11.3%) 108 (33.1%)
Chronic lung disease	31 (9.5%)
Renal Failure	19 (5.8%)
Atrial fibrillation	15 (4.6%)
Peripheral arterial disease	19 (5.8%)
Ejection fraction	61 (56 to 66)
Aortic Valve Pathology Stenosis Regurgitation Mixed	 261 (80.1%) 33 (10.1%) 32 (9.8 %)
Euro SCORE ♦	6 (5 to 8)
Sovraortic Vessel Arteriopathy	8 (2.5%)

Counts are presented as number of patients and percentage of total series. Continuous data are presented as median (25 percentile to 75 percentile).

- EuroSCORE= European system for cardiac operative risk evaluation.

Surgical Technique

Anesthesia is provided according to the standard protocol used for conventional aortic valve surgery with the only exception for a double lumen endotracheal tube for intubation. Transesophageal echocardiography was used in all patients for monitoring the heart and valve functions throughout the operation. Two defibrillator pads are placed across the chest wall to guarantee effective electric conduction. The patient is placed in a supine position with an air sac under the right scapula, elevating the right chest slightly in order to achieve optimal exposure of the working field. Right anterior mini thoracotomy is performed through a 4 to 6 cm skin incision at the level of at the 3rd right intercostal space. The CV MICS Sorin Group soft tissue retractor has been used to help spreading the chest wall; at the beginning of our experience a different soft tissue retractor (Edwards ThruPort™ Systems) was used. The pericardium is usually opened 7-8 cm above the phrenic nerve, taking care not to injure it, stay sutures are tight using the Endo close, trocar site closure device (Covidien, Mansfield, MA, USA) so the anulus can get close to the surgeon.

At the beginning of our experience a peripheral cannulation was achieved. Successively a total central direct arterial and venous cannulation was adopted under direct vision using mainly an EOPA arterial cannula (Medtronic,Inc Minneapolis, Minn) in the majority of patients (96%) or a Straightshot (Edwards Lifesciences) in the remaining 13 patients. The straight arterial cannula must be positioned just below the origin of aortic arch, in this way the Chitwood clamp, positioned percutaneously at the origin of the innominate artery, do not hinder the operating field, while the aortic anulus is brought closer to the operator. A three-stage MC2X cannula (Medtronic,Inc Minneapolis, Minn) was placed in the right atrium – inferior vena cava.

The left ventricle was vented, as always, through the right upper pulmonary vein. Continuous carbon dioxide insufflation was used during the operation at a flow of 2 L/min.

The aorta was cross-clamped and hypothermic 4°C blood cardioplegia (St Thomas with procaine) was administered in an antegrade fashion into the aortic root just to stop the heart and then directly into the coronary ostia in case of aortic regurgitation. Only in one patient a crystalloid cardioplegia (Custodiol) was chosen. A normothermic cardiopulmonary bypass was adopted in all patients. A transverse incision of the ascending aorta was performed. The native aortic valve is excised in a single step whenever is possible, reducing the time for decalcification. The prosthesis is sized; the minimally invasive technique does not influence the diameter of implanted prosthesis. During the rinsing of the valve, the first stitch to close the transverse aortotomy is positioned (polypropylene 4-0 double suture). Prosthetic valve is implanted using three running 2-0 (120 cm long) polypropylene sutures starting from the anulus below the right coronary ostium more difficult to expose, the anulus below the left and the non-coronary sinus follow. Sutureless prosthesis was implanted in 5 patients. Ventricular pacing wires were placed on the right ventricle. Aorta was then declamped and the patient weaned from cardiopulmonary

bypass. Intra operative transesophageal echocardiography was used to assess correct prosthesis function. Cannulas were removed and protamine was administered at 1:1 ratio to heparin.

Statistical Analysis

Patients' demographic and operative data are expressed as mean ± standard deviation, medians (interquartile range, IQR, 25th-75th percentiles) or as prevalence percentages, as appropriate. All statistical analysis was performed with SPSS software, version 23.0 (SPSS Inc, Chicago, IL, USA).

RESULTS

Aortic valve replacement was performed through a 4 to 6 cm skin incision at the third intercostal space.

Overall cardiopulmonary bypass time was 58 (IR 49-70) minutes and aortic cross clamp time was 45 (IR 39-57) minutes. In one case intraoperative conversion to sternotomy was required for paravalvular leaks which were not safely fixable through the minithoracotomy approach. In 315 patients (96.6%) a biological prosthesis was implanted (Mitroflow pericardial valves, Sorin Srl, Milano, Italy, (n°263) or Mosaic Porcine Bioprosthesis Medtronic Inc Minneapolis, Minn (n°11) or Perceval Suturless valve, Sorin Srl, Milano, Italy (n°5)), because of the patient's age or preference; in the remaining 6 a mechanical valve was used (Carbomedics, Sorin Srl, Milano, Italy) (Table 2).

Table 2: Intraoperative Data .

Type of Prosthesis	
Biological	315(96.6%)
Mechanical	11(3.4%)
Brand of Prosthesis	
Mosaic	11 (3.4%)
Mitroflow	261 (80%)
Perceval – sutureless	5 (1.5%)
Carbomedics	11 (3.4%)
Crown	38 (11.7%)
Prosthesis diameter	
19	4 (1.2%)
21	52 (16.1%)
23	125 (38.7%)
25	105 (32.5%)
27	37 (11.5%)
Cardiopulmonary bypass time (min)	58 (49 to 70)
Cross-clamp time (min)	45 (39 to 57)

Counts are presented as number of patients and percentage of total series. Continuous data are presented as median (25 percentile to 75 percentile).

Median intensive care and hospital stay were 44 (IR: 38-59.5) hours and 7 (IR: 6-8) days respectively. Hospital mortality was 1.8% (6/326).

Wound infections were reported in a couple of patients. Early complications included one case of paravalvular leak identified intraoperatively with trans-oesophageal echocardiography. Other postoperative outcomes are reported in **Table 3 and 4.** During the hospital stay, one patients had to be reoperated due to early endocarditis.

About 36.5% of the patients were discharged home. The remaining patients were referred to our rehabilitation unit or transferred to another hospital facility to complete the recovery.

Table 3: Early Postoperative Outcome.	
Tracheotomy	6 (1.8%)
Stroke	2 (0.6%)
Sepsis	11 (0.4%)
Reexploration for bleeding	22 (6.7%)
Postoperative Pace Maker	7 (2.1%)
Wound dehiscence	2 (0.6%)
Low output syndrome IABP	4 (1.2%)
Atrial fibrillation	92 (28.2%)
Blood transfusions	159 (48.8%)
Red blood cell units	2 (2 to 4)

Counts are presented as number of patients and percentage of total series. Continuous data are presented as median (25 percentile to 75 percentile).

Table 4: Outcome.	
Ventilation time (hours)	7 (5 to 12)
Intensive Care Unit stay (hours)	44 (38 to 59.5)
Discharged alive	320 (98.2%)
Discharged to Home Rehabilitation Other	 119 (36.5%) 181 (55.5%) 18 (5.5%)
Hospital stay (days)	7 (6 to 8 days)

Counts are presented as number of patients and percentage of total series. Continuous data are presented as median (25 percentile to 75 percentile).

DISCUSSION

To achieve minimal surgical access and reduced trauma, a novel approaches to aortic valve surgery were developed in the mid-1990s, including partial sternotomy (V-shaped, Z-shaped, inverse-T, J-, reverse-C and reverse-L partial) and right mini-thoracotomy at the 2nd or 3th intercostale space. This second technique was developed more recently with the aim to reduce perioperative morbidities and a quicker recovery. Main advantages of this technique are the complete sternal preservation with low incidence of dehiscence or wound infection, excellent cosmetic effect and conversion to full sternotomy feasible and safe. Drawbacks include possible right internal mammary artery injury and longer learning curve comparing other minimally invasive approaches as partial sternotomy. In addition, it may require CT scan prior to surgery to evaluate aortic anatomy and it may cause potential complications after femoral cannulation [5,13].

To reduce this inconveniences, firstly, we try to avoid the femoral vessel cannulation since it is not free from complications. Cardiopulmonary bypass was established with peripheral cannulation at the groin in the first 42 patient to obtain a better operating field view and to gain more confidence with the technique [14]. After this initial series, a total central cannulation was used in the majority of patients (Table 5).

Table 5: Literature review.

Author, year	Study period	No. of patients	Total Central cannulation	CPB time (min)	Cross- clamp time(min)	suturless	VAM (h)	ICU stay (day)	Hospital mortality
De vaumas et al.(2003)	NR	31	68%	92	70	none	22	3	NR
Sharony et al (2004)	1995-2002	233	69.9%	110	79	none	NR	NR	5.6
Wheatley et al (2004)	1998-2002	58 (port-access)	none	113.4	92.7	none	3.6	2.6	1.7
Ruttmann et al (2010)	2006-2009	87	12.6	151.4	96.6	none	10	20	2.3
Brinkman et al (2010)	1996-2009	90 (port-access)	none	108	90	none	9.2	1.9	0
Hiraoka et al (2011)	2007-2010	37 (port-access)	none	139	97	NR	3.4	1.2	2.7
Murzi et al (2012)	2006-2011	100	none	119	83	NR	6	1.2	0
Sansone et al (2012)	2008-2010	50	8%	101.4	74.6	NR	15.4	1.9	0
Fortunato Junior et al (2012)	2006-2011	40	none	142.7	88.6	NR	NR	2.3	5
Ahangar et al (2013)	NR	60	100%	122.1	68.0	NR	NR	1.2	NR
Pineda et al (2013)	2005-2011	36	none	134	90	NR	NR	2	0
Glower et al (2014)	2000-2014	452	None	157	103	NR	NR	NR	1.5
Gilmanov et al (2014)	2004-2014	515	NR	90**-120	56**-88	246	6**-7	1	0.8-1.5*%
Semsroth et al (2015)	2015	166	None	137	93	NR	NR	1	3.8%
Mikus et al (2015)	2015	206	79.6%	64.8	51.8	2	6	2	1.5%
Vola et al (2015)	2015	71	None	91	66	71	10.5	2.7	2.8%
Glauber et al (2015)	2004-2014	593	NR	107	74	302	9.8	1.5	1.5%
Bowdish et al (2015)	1999-2013	294	93%	79	58	NR	NR	2.8	1%

*90 days mortality ** In case of suturless implantation

CPB=Cardiopulmonary bypass time (min), **ICU**= Intensive Care Unit stay, **VAM**= Ventilation time.

In the last years, many study were published comparing minimally invasive approaches versus conventional full sternotomy for aortic valve replacement despite it, limited randomized evidence are available. Recently, a meta-analysis written by Phan et al demonstrated that minimally invasive aortic valve replacement is associated with reduced transfusion incidence, intensive care stay, hospitalization and renal failure. The mortality rate was comparable [15].

The main objection to the right minitoracotmoy approach comparing other minimally invasive technique is the longer operative time. There are several reasons as to why right minithoracotomy is associated with longer operative times (Table 5). Firstly it provides a limited vision of aortic valve due to greater distance from the thoracic access. In our series a cross clamp time less than 40 minutes was obtained in 25% of patients, and 69% had a cross clamp time of less than 50 minutes: these operating times are highly competitive with the literature data concerning minimally invasive aortic valve replacement through upper ministernotomy [16]. These results were possible thanks to a standardized technique, involving a meticulous set-up of the operating field, and to an appropriate training (with the attendant learning curve), which represents an essential prerequisite [17]. The native aortic valve is excised in a single step whenever it's possible, reducing the time for decalcification. During the rinsing of the valve, the first stitch to close the transverse aortotomy is positioned. Prosthetic valve is implanted using three running 2-0 polypropylene sutures starting from the anulus to reduce cross clamp time as does the use of sutureless prosthesis (implanted in 5 patients) [18-20].

Borger et al published the only randomized multicenter trial comparing minimally invasive (through an upper hemisternotomy) suturless valve with conventional sutured valve though a standard full sternotomy [21]. The results showed shorter cross clamp time in the suturless group, but similar for CPB time and no difference in terms of outcome. Interesting are, for sure, the data concerning 515 patients published by Gilmanov at al [22]: operating times are shorter for suturless group (overall cardiopulmonary bypass time was 90 range 78-108.5 minutes and aortic cross clamp time was 56 range 48-72.5 minutes), but hospital mortality, pace maker implantation and incidence of stroke were comparable. In conclusion, minimally invasive surgery and suturless aortic valve are two precious technologies that can be combined to reduce operating times, but limited evidence exists concerning an hypothetical superiority of suturless prosthesis in term of postoperative mortality and morbidity.

Another frequently discussed issue is the apparent needs for a CT scan prior to surgery to evaluate aortic anatomy. In contrast with Glauber and other Authors, we think that a preoperative CT scan to analyze the thoracic "architecture" and the heart anatomy is not essential [23,24]. The ascending aorta can be easily assessed to evaluate the presence of calcified plaques in order to choose the best location for cannulation and clamp, as surgeons usually do in full sternotomy without an increase in the embolic risk as demonstrated by the low incidence of neurologic events (0.6%) (Table 3).

Finally, costs are limited and comparable to the standard approach because the cannulas used are the same as in conventional surgery. Only minimally invasive instruments are necessary. In addition, the advantages reported by a recent meta-analysis in terms of lower hospitalization and ventilation times, incidence of renal failure, and blood transfusion rates may reduce the effective costs [25]. In conclusion, our experience with aortic valve replacement through a right minithoracotomy, in addition to the literature data (table literature), shows good clinical outcomes

in terms of mortality and morbidity. Early mobilization and lower risks of wound complications (mediastinitis or osteomyelitis) are the main advantages. The excellent cosmetic result is unequivocal. Patients with high body mass index or affected by diabetes mellitus or osteoporosis can actually benefit from this approach. In addition, in case of reoperation approached by full sternotomy, very few and lax adhesions are to be found. In contrast with previous reports, our findings suggest that the right anterior minithoracotomy can be applied in all patients with total central cannulation and operative times at least comparable with other minimally invasive approaches [16].

Naturally, large trials are crucial to guide the cardiac surgical community, to the best choice to treat each class of patient.

Limitations of this observational study are due to its retrospective nature. The results may be affected by undetected confounders or procedure bias due to the non-randomized design.

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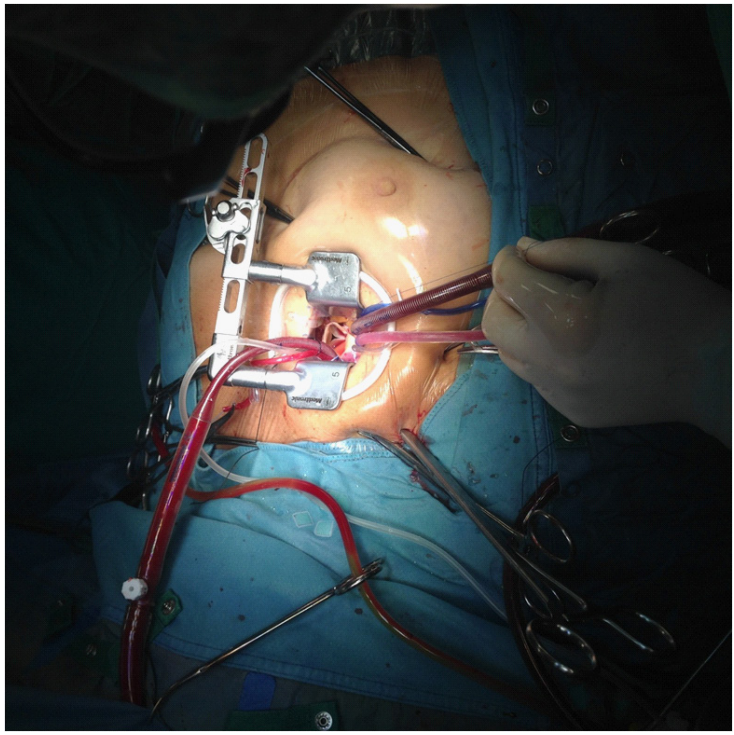

Figure 1: Operative field view during aortic prosthesis implantation.

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