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Minimally invasive aortic valve replacement: a comparison of results with the traditional technique

Minimally invasive aortic valve replacement: a comparison of results with the traditional technique

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Abstract

Objective: **Minimally invasive heart surgeries are approaches used to reduce trauma, to give better cosmetic results and to reduce hospital costs with the same safety as conventional surgery. This study was designed to compare the operative results from patients who underwent minimally invasive aortic valve replacement with those who were submitted to the standard procedure.**

Method: **The operative and immediate postoperative results of 12 consecutive patients who received minimally invasive isolated aortic valve replacements from June 2002 to February 2003 were compared to 12 patients who underwent to traditional approach in the same institution. The minimally invasive access used was superior median hemisternotomy where cardiopulmonary bypass was established through ascending aorta and right atrium cannulation, similar to the traditional technique.**

Results**: The demographics of the patients were similar in both groups. There were no significant differences between aortic clamping time, total bypass time and operating time. The skin incision length was statistically shorter in the minimally invasive group. In the postoperative course, the mechanical ventilation time and the total hospital stay were shorter, but not statistically significant, in the minimally invasive group. The morbidity was the same in two groups.**

Conclusions: **This surgical approach provides adequate exposure of the cardiac structures necessary to perform a safe valve replacement. With the same instruments used in the traditional surgery we can offer the benefits of a less invasive access with the same efficiency as in the conventional approach without adding any risks to our patients.**

Descriptors: **Aortic valve, surgery. Heart valve prosthesis implantation, methods. Heart valve diseases, surgery. Thoracotomy, methods. Surgical procedures, minimally invasive surgery.**

Resumo

Objetivo: **As cirurgias cardíacas minimamente invasivas foram desenvolvidas para proporcionarem, através de acessos limitados, menores traumas, melhores resultados estéticos e diminuição nos custos hospitalares com a mesma segurança das cirurgias tradicionais. O estudo teve como objetivo**

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comparar os resultados peri-operatórios dos pacientes submetidos à troca de valva aórtica por meio dos acessos minimamente invasivo e convencional.

Método: **Doze pacientes consecutivamente submetidos à troca de valva aórtica isolada por acesso minimamente invasivo, a partir de junho de 2002, tiveram seus dados pré-operatórios, operatórios e pós-operatórios imediatos comparados com os 12 pacientes anteriormente operados na mesma instituição submetidos ao mesmo tipo de operação, porém com acesso convencional. O acesso minimamente invasivo utilizado foi a hemiesternotomia mediana superior e a instalação da CEC foi através da canulação da aorta ascendente e do átrio direito, semelhante à técnica tradicional.**

Resultados: **Os dados demográficos foram semelhantes nos dois grupos de pacientes. Não houve diferença significativa entre os tempos de isquemia, de CEC e do tempo total do procedimento. O tamanho da incisão da pele foi significativamente menor no grupo minimamente invasivo. No pós-operatório, embora tenham sido menores os tempos de ventilação mecânica e o tempo total de permanência hospitalar, estes dados não mostraram diferença significativa. A morbidade pós-cirúrgica foi semelhante entre os dois grupos.**

Conclusões: **Esta abordagem oferece adequada exposição das estruturas necessárias para uma segura troca valvar e com o mesmo instrumental utilizado na cirurgia tradicional podemos oferecer as vantagens de um acesso menos invasivo com a mesma eficiência da cirurgia tradicional sem acrescentar riscos aos nossos pacientes.**

Descritores: **Valva aórtica, cirurgia. Implante de prótese de valva, métodos. Doenças das valvas cardíacas, cirurgia. Toracotomia, métodos. Procedimentos cirúrgicos minimamente invasivos.**

INTRODUCTION

Aortic valve surgery is traditionally performed by the total median sternotomy approach with direct cannulation of the aorta and right atrium for cardiopulmonary bypass (CPB). From 1966 numerous publications reported alternative methods utilizing less invasive surgical techniques [1,2]. Follow-ups of these patients suggest that the simplified access reduces pain and the postoperative morbidity without prejudicing the surgical results, as well as diminishing the hospital costs [3].

In valve surgeries, the term minimally invasive can only be applied to the type of access (skin incision, partial sternotomy and hemithoracotomies), as currently the installation of the CPB is indispensable. On the other hand, in coronary artery bypass surgery, this denomination is stressed much more in relation to the use of CPB or not. In this case the procedure is considered to be greatly responsible for aggression or invasion of the organism [4].

To evaluate the results of patients submitted to partial sternotomy, we compared the surgical and postoperative results of patients who underwent the two procedures (total and hemisternotomy) with the aim of determining if the aortic valve can be routinely treated by the minimally invasive access.

METHOD

A comparison of two groups of patients was made. The first group, the Mini Group, consisted of 12 consecutive patients submitted to aortic valve replacement in isolation from June 2002 using a minimally invasive access – superior median hemisternotomy. The second group, the Total Group, consisted of 12 consecutive patients who had previously undergone aortic valve replacement using the total sternotomy technique in the same hospital. Patients submitted to aortic valve replacement associated with other procedures such as coronary artery bypass surgery or mitral valve surgery and reoperations were excluded from both groups. The proposed procedure was carefully explained to all the members of the Mini Group and all authorized the surgery as well as their inclusion in the study protocol.

No statistical difference was evidenced between the pre-operative demographic data and the diseases of both of the groups as is demonstrated in Table 1.

Table 1. Preoperative data:

Data	Total Group	Mini Group	p-value
Gender -male	58.3%	66.66%	ns
Age	54.6	55.7	ns
Ejection fraction (%)	35%	33%	ns
Gradient (mmHg)	65	77	ns
Functional class (NYHA)			ns
I/II	33.3%	41.66%	
III/IV	66.6%	58.33%	
Physiopathology			ns
Stenosis	58.33%	50%	
Insufficiency	25%	25%	
Double lesion	16.66%	25%	

Legend: NYHA = New York Heart Association; ns = not significant

All the operations using hemisternotomy were performed by the same surgeon (ALT) and the total sternotomies were performed by two surgeons in the same hospital (ALT and LSF).

All the patients were accompanied by one surgeon (ALT) during hospitalization and during re-examination on the 30th postoperative day in the outpatients' clinic, where clinical, electrocardiographic and echocardiographic examinations were performed.

Surgical technique

With the patient in the supine position, duly anesthetized and monitored (invasive arterial blood pressure, central venous blood pressure, ECG, naso-pharyngeal temperature, pulse oximetry, and urinal output), intubation was performed using a single-lumen orotracheal cannula and after antisepsis the access was made as described below.

• UPPER PARTIAL HEMISTERNOTOMY (MINI GROUP):

Incision: A 7- to 10-cm median incision was made in the skin, beginning at the second intercostal space as is illustrated in Figure 1. The sternum was sectioned with an oscillatory saw for sternal incisions to the 4th intercostal space and transversally extended to the left intercostal space (Figure 2). The sternum was opened using a Finochetto rib retractor (approximately 7 cm) and the pericardium, after a longitudinal incision, was drawn together with the skin to improve access to the ascending aorta and the right atrium (Figure 3).

Cannulation (Figure 4): All the patients were cannulated directly in a manner similar to conventional surgery. For aortic cannulation a tied cannula was used so as not to permit its constriction due to the position of the surgical field. Venous return was obtained by cannulation of the right atrial auricula with a single 2-phase venous cannula. The patients were then cooled to 32 ºC. The first chilled dose of blood cardioplegia solution was infused after total ascending aorta clamping and further infusions were made at 15-minute intervals directly in the coronary ostia.

Valve exposure: Transverse aortotomy was performed and extended towards the non-coronary sinus. In each commissure, three sutures of 2-0 ethibond were made so as to suspend them under tension, lifting the aortic valve for better access to its annulus (Figure 4). When necessary a catheter was used for left ventricle suction through the left superior pulmonary vein.

Maneuvers to remove air: The heart chambers were gradually filled with blood, during prosthesis anchoring and aortorrhaphy. Before aortic de-clamping, the lungs were manually inflated to completely remove the air from the left chambers.

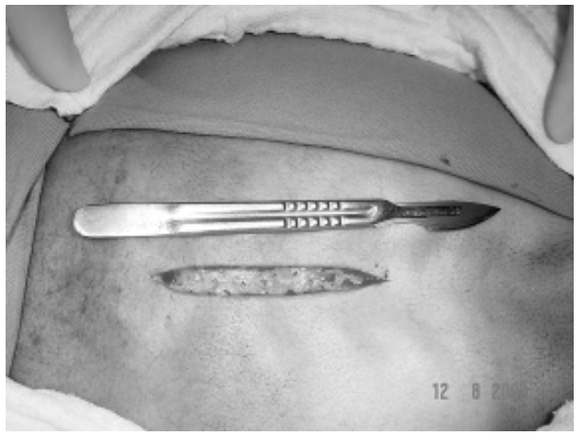

Fig. 1 - Photograph of the initial skin incision (patient 1).

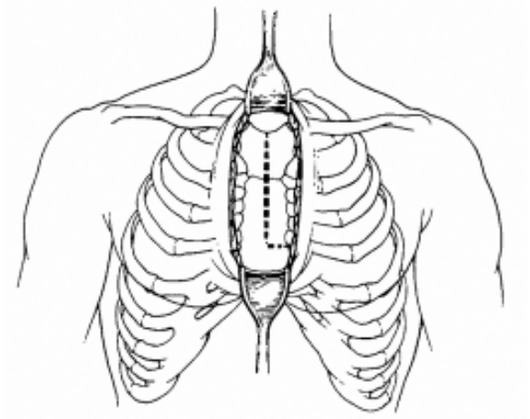

Fig. 2 - Design of the upper median hemisternotomy

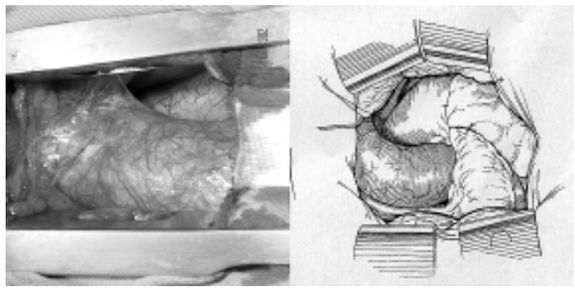

Fig. 3 - Photograph and design demonstrating access to the ascending aorta from the perceptive of the surgeon.

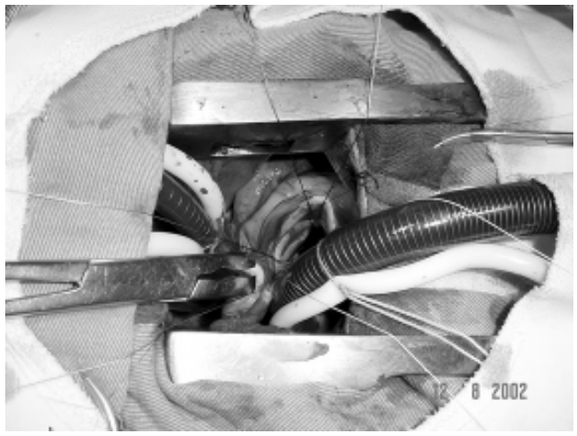

Fig. 4 - Photograph demonstrating cannulation of the ascending aorta and right atrium and access to the aortic valve (patient 1).

Following this, the thorax was shaken from side to side using fast movements, aiming at removing any air bubbles caught in the trabeculations and chordae tendineae of the left ventricle. This was followed by continuous suction at the aortic root with the patient in the accentuated Trendelenburg position and only then the aorta was de-clamped.

With the patient hemodynamically stable, the arterial circuit was disconnected, but kept in position and the remaining volume of blood in the oxygenator was replaced via the venous cannula to the right atrium. This maneuver always enables residual air bubbles to be caught in the arterial cannula or suctioned at the aortic root, with the patient still in the Trendelenburg position. When electric cardioversion is necessary, it can be performed with infant internal pads directly on the heart. Still during the phase of hemodynamic stabilization, when a widening of the QRS complex is observed on the cardiac monitor, the patient was maintained under CPB with a higher arterial pressure until complete remission of the complex width is evidenced.

After the end of the procedure, a mediastinal tubular drain was placed on the median line with a long homeostatic clamp. Initially the sternum was closed using five steel wires, with one to join the left transversal incision, two on the sternal manubrium and two in the proximal intercostal spaces. In the last four cases of our cohort, we observed that the closure of the transverse incision of the left hemisternum was not necessary and the sternum was closed using four transversal steel wire sutures. The rest of closure was performed as normal, layer by layer.

Total sternotomy (Total Group)

The median incision of the skin was performed from the 2nd intercostal space to the point of the ensiform appendix (approximately 20 cm). The ascending aorta and the right atrium were directly cannulated for the installation of the CPB. The other surgical procedures were similar to the procedures described above.

Statistical analysis

The data are presented as means ± standard deviation. Quantitative variables were compared using the student t-test. The chi-squared test was utilized for qualitative variables. A p-value of 0.05 was considered significant. The Cálculos Estatísticos for Windows V.1.8 software developed by Braile and Godoy was utilized.

RESULTS

As is demonstrated in Table 1, the two groups did not present with statistically significant differences in relation to the preoperative data (gender, age and type of aortic physiopathology).

The most commonly used prostheses in both groups were metallic (Total Group 58.33%; Mini Group 66.6%) and the mean prosthesis size was 24.5 mm and 25.2 mm for the Total and Mini groups respectively, also not demonstrating statistical difference. The types and sizes of prostheses employed are shown in Table 2, together with other surgical data.

Table 2. Operative data

Data / variables	Total Group	Mini Group	p-value
Metallic prostheses	7	8	ns
Biological prostheses	5	4	ns
Prosthesis size	24.5	25.2	ns
Operative time	115 min	125 min	ns
Clamping time	40 min	47 min	ns
CPB time	53 min	55 min	ns
Incision size	18.2 cm	7.6 cm	$p<0.05$

Legend: ns = not significant

The operative times (total operative time, CPB time and aortic clamping time) were statistically similar in both groups. The only operative data, which was demonstrated to have a significant difference, was the size of the incision in the skin. In the Mini group the mean length was 7.6 cm and in the Total group it was 18.2 cm (p-value < 0.05).

None of the 12 patients in the Mini group required conversion to the total technique. In all patients the aortic and right atrium cannulation was easily achieved and it was possible to maintain a stable CPB without problems of drainage or difficulties with the position of the cannulae. They did not interfere in the adequate access of the operative field.

Postoperative evolution

Although the procedure was similarly satisfactory in both of the groups, shorter intubation, mechanical ventilation and hospital stay times were seen in the postoperative recovery of the Mini group (Table 3). The same anesthesia protocol and the same cares in the postoperative unit was used for both groups, attempting to maintain the same criteria for the removal of drains, central catheter, vesical catheter, endovenous infusion and the period in which prophylactic antibiotics were used. With this, the time of stay in the postoperative unit did not alter significantly.

Table 3. Postoperative data:

Data / variables	Total Group	Mini Group	p-value
Intubation (hours)	4	3:25	ns
ICU (hours)	40	33	ns
Hospitalization (days)	6	5	ns
Drainage (mL)	350 (100-450)	270 (50-900)	ns
Complications			
Use of intra-aortic Balloon (%)	0	1 (8.33%)	ns
Re-operation bleeding	1 (8.33%)	1 (8.33%)	ns
Atrial fibrillation	0	2 (16.7%)	ns
Endocarditis	1 (8.33%)	0	ns
Pericardium effusion	0	1 (8.33%)	ns
Mortality	0	0	-

Legend: ns = not significant

Subjective complaints of the patients within the first few days after surgery were evaluated, and less algid complaints, lower doses of analgesics and a greater disposition for physiotherapy and early walking in the partial sternotomy patients were clearly observed. These patients could sit earlier and with greater safety, with a greater facility to move the upper limbs, enabling them to perform personal hygiene and to eat without help on the first postoperative day.

There was no hospital mortality in either the groups and postoperative complications are illustrated in Table 3. No complication can be directly linked to the type of access utilized in the evolution of the patients. In this cohort no adverse neurological events were observed which could be attributed to air embolia.

During the outpatient clinic return appointment, all the patients presented with excellent scarring of the wound without any complications (Figure 5). Even obese patients and those with prominent breasts, as could be observed in two patients of the Mini group, with body mass indexes greater than 30 kg/m^2, the cosmetic result was very satisfactory.

Fig. 5 - Final aspect of the incision on the 30th postoperative day (Patient 1).

COMMENTS

As was demonstrated in the anatomic studies by REARDON et al. [5], the aortic valve is located at the halfway point of the sternum to the left, just below the third intercostal space. Many alternative incisions have been described aiming at less invasive access which can provide the same security when performing heart valve operations [6,7]. Division of the upper half of the sternum gives the surgeon direct access to the ascending aorta and to the right atrial appendix, enabling its direct cannulation. In 1996, GUNDRY et al. [1] proposed hemi-sternotomies, then denominated as mini-sternotomy, as the preferred access for the correction of congenital heart disease and isolated valve operations in adults. They considered this approach advantageous allowing utilization of the regular equipment used in traditional surgeries as it does not need cannulation of the femoral veins, as well as enabling the rapid conversion to total sternotomy. Since then, this access has been widely used in different institutions [3,8-10].

In all patients of this cohort, the installation of the CPB could be performed by cannulation of the ascending artery and the right atrium without difficulties, with the

same materials normally utilized. Venous drainage was always satisfactorily maintained, which allowed maintenance of the CPB in the most stable manner possible. Thus, inguinal incision used for both venous and arterial femoral access was avoided. A new incision always signifies the risk of further complications [1]. Several surgical teams have been using vacuum venous drainage (with a negative pressure of 50 mmHg in the venous reservoir), which allows the utilization of thinner venous cannulae and reduces the priming volume of the machine by eliminating the necessity of filling the venous lines.

Routinely, following the described maneuvers, central or peripheral neurologic deficits that can be attributed to embolism are not observed. Other methods to completely remove air were widely studied, such as control by transesophageal echocardiography during air removal maneuvers to identify air pockets retained inside the heart chambers [10-12]. As this apparatus was not available, we exhaustively attempted to guarantee that the maximum possible of air was removed during the CPB phase. Another maneuver recommended by the Cleveland Clinic is continuous use of CO_2 in the pericardial cavity to maintain the heart chambers filled with CO_2 that is rapidly defused in the blood and potentially reduces the risk of embolization [2]. We consider these techniques as alternatives that aim at minimizing the potential of neurological complications, although from the results reported we believe that the maneuvers presented here are satisfactory as long as they are rigorously followed.

Since the first operations, very little has changed in the routine employed with the traditional access and thus the same operative time can be maintained using the two approaches. No significant difference was observed in the total operative time or the CPB time, therefore greater risks, implicated with longer anesthesia or myocardial ischemia times, are not being taken [13].

Depending on the protocol utilized, the patients can be extubated and be released from hospital earlier [14]. For logistical reasons in our institution, until now fast-track protocols have not been introduced and, owing to this, hospitalization times and ICU-stay times were similar in both groups.

Although in the cohort presented, no increase of the sternotomy was necessary, the simplicity of conversion of the hemisternotomy to the conventional approach was stressed by DIAS et al. [15], in which in their cohort conversion was necessary in three cases (15%). These cases included intraoperative infarction requiring revascularization of the anterior interventricular branch, laceration of the right ventricle and myocardial dysfunction attributed to pericardial compression. Authors such as LIU et al. [16] stated that the surgical exposure and access of the ascending aorta are better with accesses that do not totally dissect the anterior mediastinum, as the heart remains in a relatively anterior position. They emphasize also that mini-incisions make opening and closing of the sternum easier and quicker.

Interesting results were observed by EHRLICH et al. [17], when they tried to investigate if patients wanted to be submitted to aortic valve replacement using mini-incisions. After explaining to the patients the advantages and disadvantages of both the approaches, the majority opted for total sternotomy. The main arguments were concern were to provide the greatest access to the heart and to have the operative time as short as possible. The patients who chose mini-incision were significantly younger, when the cosmetic aspects are much more important.

The transversal anterior thoracotomy at the 3rd or 4th intercostal space results in an excellent operative field to access the ascending aorta. This approach also presents the esthetical advantage of not leaving a scar in the upper portion of the chest, which is therefore less visible, although ligation of the two internal thoracic arteries is necessary. However, indication of this technique should be restricted to older patients with few risk factors of obstructive coronary heart disease, who have normal coronary cineangiographies obviously, and this still can be a potentially negative factor in sternal healing owing to the reduction of blood irrigation [18].

The mini-thoracotomy also sacrifices at least one of the internal thoracic arteries, requiring the resection of one or two costal cartilages, which has a tendency to accentuate pain in the postoperative period, as well as increase the risk of other complications such as pulmonary herniation and pleural adhesions [9]. This approach also implicates selective pulmonary intubation and cannulation of the femoral vessels. Other alternative incisions were described such as the inverted L-type and the horizontal H-type, however these have been less studied and are not widely used [15,19-21].

The incision described here has potential advantages such as preserving the ventilatory function by maintaining part of the sternum stable and facilitating early physiotherapeutic exercises with a greater safety for the patient. It reduces the pain mainly by impeding great separation of the sectioned sternal bone. With the total median sternotomy, the most common pain reported by patients is back pain, due to traction of the costal arches and thoracic ligaments. Clearly, smaller incisions are cosmetically more acceptable for patients. The

smaller wounds reduce trauma and the potential for operative infection, blood loss and sternal dehiscence [16]. This approach preserves all the advantages of the median approach and still has the potential to correct other diseases, such as mitral valve operations, both by the left atrium roof or by the interatrial septum (Guiraudon's approach), as already described by many authors.

Reoperation by median sternotomy should be less difficult, due to the fact that the pericardium below the sternum remains intact, protecting the heart during a new approach [22]. The first patient of this cohort required reoperation 10 months after the first surgery owing to early dysfunction of the biological prosthesis (severe aortic stenosis). This patient did not belong to the presented series due to exclusion by the selection criteria. Using the same access, it is possible to observe the facility of freeing heart parts protected by the pericardium, when there is a necessity of intervention to access the coronary arteries for example.

CONCLUSIONS

With this initial series, it is possible to demonstrate that the minimally invasive approach (upper median partial sternotomy) does not alter the morbidity or mortality of patients undergoing aortic valve replacement. This procedure is reproducible and safe and its results are comparative to the conventional method.

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