Received: 23 August 2018 | Revised: 3 September 2018 | Accepted: 12 September 2018

DOI: 10.1111/chd.12680

ORIGINAL ARTICLE

WILEY Congenital Heart Disease

# Right thoracotomy for aortic valve replacement in the adolescents with bicuspid aortic valve

Raffaele Giordano MD, PhD[1] | Massimiliano Cantinotti MD[2] | Giuseppe Comentale MD[1] | Luigi Di Tommaso MD[1] | Gabriele Iannelli MD[1] | Emanuele Pilato MD[1] | Gaetano Palma MD[1]

[1]Department of Advanced Biomedical Science, Division of Adult and Pediatric Cardiac Surgery, University of Naples Federico II, Naples, Italy

[2]Tuscany Foundation G. Monasterio CNR-Regione Toscana, Massa and Pisa, Italy

**Correspondence**
Raffaele Giordano, University of Naples Federico II, Via Pansini 5, Napoli 80131, Italy.
Email: r.giordano81@libero.it

## Abstract

**Background**: In this study, we compared our experience about early and midterm follow-up outcomes for right anterolateral minithoracotomy (RAMT) vs full sternotomy (FS) in surgical aortic valve replacement (AVR) among adolescents with bicuspid aortic valve (BAV).

**Methods**: Patients were retrospectively enrolled from January 2008 to December 2017. Inclusion criteria were patients with BAV who had to undergo to AVR. They were divided in two groups: RAMT and FS. The choice of RAMT was based on individual surgeon's preferences or when expressly requested by patient that was informed of nonconventional approach.

**Results**: We enrolled 61 patients, 23 in RAMT group and 38 in FS group. The mean age was 15.6 ± 1.7 years for RAMT group and 16.1 ± 1.5 years for FS group ($P$ = .23). The RAMT group had a higher prevalence of female gender ($P$ = .04). The patients in the RAMT group had longer cardiopulmonary bypass (115.2 ± 18.5 vs 102.2 ± 16.5 min; $P$ = .006) and cross-clamp time (78.6 ± 18.1 vs 74.3 ± 15.2 min; $P$ = .01). No patients required intraoperative conversion to FS. No differences were found in ventilation times, postoperative intensive care unit (ICU), and hospital length of stay for both groups. Follow-up echocardiograms were available for all patients at median of 5.2 years (range 0.5-9.6 years, median 5.4 years for RAMT and 5.1 for FS) and no patient required reoperation for aortic prosthesis malfunction.

**Conclusions**: Our study shows that RAMT is safe and effective as FS. Although the RAMT operation takes slightly more operation time, it is not associated with major adverse effects.

KEYWORDS
aortic, pediatric cardiac surgery, thoracotomy

## 1 | INTRODUCTION

Surgical aortic valve replacement (AVR) nowadays is one of the most performed procedures in the world because of valve progressive deterioration due to aging or diseases such as hypertension or aortic pathologies.[1] In these cases, the mean age of patients is high but there is a small percentage of cases in which this surgery is performed on young patients for a congenital malformation of the valve. Usually, the chosen approach is the full sternotomy (FS) since it allows not only a suitable positioning of the different devices

  

necessary to extracorporeal circulation but especially a better exposure of the operative field and a high freedom of movement for the surgeon. Nevertheless, use of this type of incision goes inevitably hand in hand with particularly disfiguring outcomes, especially in young girls, with increased surgical risk and long hospital stay; for this reason nowadays mini-invasive approaches are preferred not only for little scars that can easily be masked with the aid of cosmetic surgery techniques but also because they provide faster recovery, shorter hospital stay, less wound infections, postoperative respiratory function improvement due to the preservation of sternum and reduction of postoperative pain, blood loss and blood transfusions related to the reduction of surgical dissection and adhesion formation, as part of pericardium remains closed.[2,3] In this regard, one of the most common congenital heart diseases is bicuspid aortic valve (BAV) with a 0.5%-2% and predominance in males with a M:F ratio of 3:1. BAV is typically made up of two cusps of unequal size with the largest cusp that has a central raphe since the merger of two commissures. Raphe may occur at various levels: in 70.4% of cases is between the right coronary cusp and the left coronary cusp, in 28.2% of cases between right coronary cusp and noncoronary cusp and, then, only in 1.4% of cases between the left coronary cusp and noncoronary cusp.[4] Such abnormalities can sometimes be asymptomatic and be found by chance during a diagnostic test or a routine visit but when associated with important hemodynamic alterations (stenosis, insufficiency, or steno-insufficiency) it must necessarily be corrected to avoid the subsequent deterioration of cardiac function and aortic dilatation.[5] In this retrospective study, we compared our experience of early and midterm follow-up outcomes for right anterolateral minithoracotomy (RAMT) vs a cohort of conventional FS for AVR in adolescents with BAV.

## 2 | MATERIALS AND METHODS

The study protocol was approved by the local Hospital Ethics Committee and informed consent was obtained from the parents/guardians of all patients.

The patients were retrospectively enrolled from January 2008 to December 2017. Inclusion criteria were patients with BAV who had to undergo to an AVR. They were then divided in two groups: RAMT and FS. The choice of RAMT was based on individual surgeon's preferences or when expressly requested by patient that was informed of nonconventional approach. Exclusion criteria were other combined heart surgical procedures, other aortic valve diseases, previous cardiac or thoracic surgery, aortic root dilation.

### 2.1 | Surgical technique

During the time period of the study, the same two surgeons performed AVR and all other parameters that may influence the perioperative management, in particular anesthesia and CPB course, were not modified.

The patient was placed in the lateral decubitus position with the right side elevated 30° to 50°; the right arm was suspended over the head and wrapped to avoid nerve injury. The submammary groove was used for the skin incision. Then a flap of breast tissue and pectoralis muscle was dissected from the underlying chest wall and retracted cephalad, so that the chest cavity could be entered through the third intercostal space. The anterolateral skin incision was about 10-12 cm in length. Care was taken to preserve the right internal mammary vessel. The right lung was retracted posteriorly. The pericardium was opened at least 2 cm anteriorly, parallel to the phrenic nerve.

The patients underwent standard cardiopulmonary bypass with single atrial cannulation and a left ventricular vent placed in the right superior pulmonary vein (Figure 1). Mild hypothermia (32°C) was achieved and a cold blood cardioplegic solution was administered antegrade in all cases to arrest the heart. Acceptable exposure of aortic valve was obtained via a standard oblique aortotomy, and the AVR was performed in almost the same manner as via a FS. The prosthetic valve was implanted with interrupted pledgeted polyester sutures in the supra-annular position (Figure 2). The air in the heart was evacuated easily when the aortic clamp was released slowly and the aortic needle vent was connected to the suction pump. The absence of intracardiac air and the quality of the repair were evaluated by means of transesophageal echocardiography. Cardiopulmonary bypass was discontinued gradually. Hemostasis was performed meticulously. A pleuro-pericardial drain was placed, and the chest was then closed in a routine fashion; the skin was closed with intradermal continuous suture.

### 2.2 | Early outcomes and follow-up

We recorded different outcomes: 30-day mortality, cardiopulmonary bypass, cross-clamp, mechanical ventilation times, postoperative

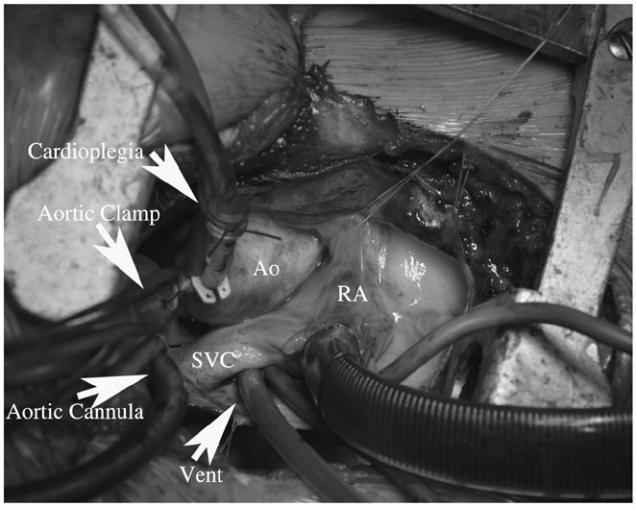


**FIGURE 1** Exposure of the aorta and implantation of the CPB through the thoracotomy. Abbreviations: Ao, aorta; SVC, superior vein cava; RA, right atrium

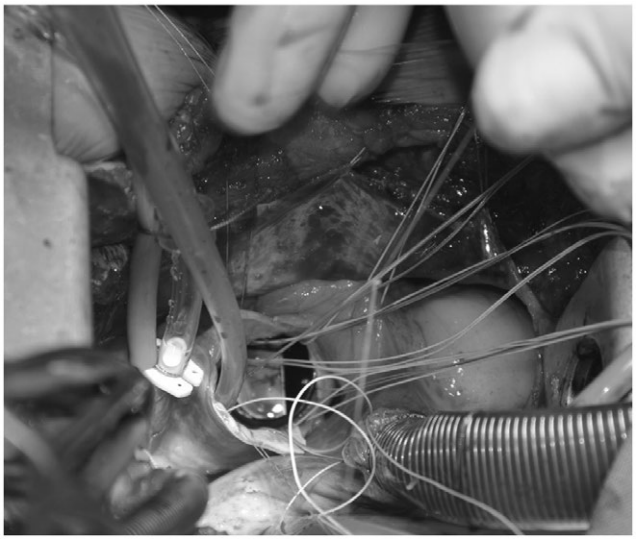

**FIGURE 2** Aortic valve implantation

intensive care unit (ICU) and hospital length of stay, red cell transfusions, reexploration for bleeding and pleural-pericardial effusion.

All patients received an echocardiogram at hospital discharge, then at 30 postoperative days, 3 months, 6 months, and last annually. Transthoracic echocardiography was performed according to standardized protocol,[6,7] by two pediatric cardiologists.

### 2.3 | Statistical analysis

Continuous data are presented as mean ± SD. We compared clinical variables between the two groups by means of the nonparametric Mann-Whitney *U* test (for continuous variables) or the chi-square and Fisher's exact tests (for categoric variables). A *P* value of less than .05 was considered statistically significant. Data were analyzed by means of Statistica 6.0 software (StatSoft, Inc, Tulsa, Oklahoma).

## 3 | RESULTS

In this retrospective study, we enrolled 61 patients, 23 in RAMT group and 38 in FS group. The baseline characteristics are reported in Table 1. The RAMT group had a higher prevalence of female gender (*P* = .04). In the RAMT group, 19 patients (82.6%) had mixed stenosis and regurgitation and 3 patients had isolated aortic stenosis. In the FS group, 30 patients (78.9%) had mixed stenosis and regurgitation, 3 patients had predominantly aortic regurgitation and 5 stenosis. Thirty-day mortality was not found in both groups (Table 2).

The patients in the RAMT group had longer cardiopulmonary bypass (115.2 ± 18.5 vs 102.2 ± 16.5 min; *P* = .006) and cross-clamp time (78.6 ± 18.1 vs 74.3 ± 15.2 min; *P* = .01). No patients required intraoperative conversion to FS. In the RAMT group, one patient (1.9%) required the return to CBP for paravalvular leak, with no difference between the two groups (*P* = .62). In the RAMT group, all mechanical prosthesis were implanted (St Jude Medical, St Paul, Minnesota) (7 size 19 mm, 14 size 21 mm, and 2 size 23 mm), whereas three biological prosthesis (Perimount, Carpentier-Edwards, Irvine, California) were implanted in the FS group (10 size 19 mm, 23 size 21 mm and 5 size 23 mm). Mean diameter of the aortic valve prosthesis was 20.55 ± 1.19 mm in the RAMT group, and 20.72 ± 1.24 mm in the FS (*P* = .60). No differences were found in ventilation times, postoperative ICU, and hospital length of stay for both groups (Table 2). Patients in the RAMT group had lower chest drain output (330 ± 56 mL vs 383 ± 48 mL; *P* = .0001) but this was not associated with a statistically significant difference in the incidence of red cell transfusions between the two groups (11 vs 16 patients; *P* = .86. The incidence of reexploration for bleeding was only one patient in FS group (*P* = .62). The bleeding was not related at the suture line of the aortotomy.

Echocardiograms at discharge were available for all the patients of the study. Follow-up echocardiograms were available for all patients at median of 5.2 years (range 0.5-9.6 years, median 5.4 years for RAMT and 5.1 years for FS). No patient required reoperation for aortic prosthesis malfunction. No difference occurred on the aortic mean gradient between two groups in the echo at discharge

**TABLE 1** Baseline and intraoperative characteristics

| | RAMT (23 pts) | FS (38 pts) | *P* value |
|---|---|---|---|
| Age (y) | 15.6 ± 1.7 | 16.1 ± 1.5 | .23 |
| Weight (kg) | 51.5 ± 4.2 | 53.1 ± 4.4 | .17 |
| Female gender | 16 | 15 | .04 |
| CPB time (min) | 115.2 ± 18.5 | 102.2 ± 16.5 | .006 |
| Cross-clamp time (min) | 78.6 ± 8.1 | 74.3 ± 5.2 | .01 |
| Prosthesis type | | | |
| Biological (%) | 0 (0) | 3 (10.7) | .23 |
| Mechanical (%) | 23 (100) | 35 (92.1) | .23 |

Abbreviations: CPB, cardiopulmonary bypass; FS, full sternotomy; RAMT, right anterolateral minithoracotomy

**TABLE 2** Surgical outcomes

| | RAMT (23 pts) | FS (38 pts) | *P* value |
|---|---|---|---|
| 30-day mortality | 0 | 0 | - |
| Mechanical ventilation (h) | 4.1 ± 1.3 | 4.3 ± 1.1 | .52 |
| ICU stay (h) | 19.5 ± 6.7 | 21 ± 8.5 | .47 |
| Hospital stay (days) | 7.2 ± 1.2 | 7.5 ± 1.1 | .32 |
| Red cell transfusion (*n*) (%) | 11 (47.8) | 16 (42.1) | .86 |
| Chest drain output (mL) | 330 ± 56 | 386 ± 48 | .0001 |
| Reexploration for bleeding (*n*) | 0 | 1 | .62 |

Abbreviations: ICU, intensive care unit; FS, full sternotomy; RAMT, right anterolateral minithoracotomy

(18.3 ± 2.4 vs 17.5 ± 3.1, $P$ = .29) and in the last follow-up (22.5 ± 3.1 vs 21.6 ± 3.3, $P$ = .29).

## 4 | DISCUSSION

Mini-invasive AVR was presented as a new surgical technique[8] in 1996. The most common minimally invasive approach used for AVR operations is the upper partial ministernotomy, followed by the right minithoracotomy approach, and less commonly by the right parasternal approach and transverse sternotomy.[9] Mini-invasive AVR over time it has been successful in the surgical community from both the surgeons and the patients.

This retrospective study evaluate exclusively the outcomes in the adolescents with bicuspid aortic valve which underwent to right thoracotomy for AVR, to our knowledge the only specific present in the literature. The important findings were as follows: (i) the patients in the RAMT group had longer cardiopulmonary bypass; (ii) no patients required intraoperative conversion to FS; (iii) no differences were found in the outcomes examined and (iv) at follow-up no differences were found at echo examination and no patient required reoperation for aortic prosthesis malfunction.

Our policy is to use a mechanical replacement prosthesis when the valve is not repairable and the size of the annulus is adequate. The use of three biological prostheses in the FS group is random and due to the patient's personal requests. Young patients with bicuspid valves frequently require additional aspects to the operation such as treatment of ascending aortic dilation or root enlargement but in this experience there are not reported complex cases, which would still be corrected with FS.

We found significantly shorter aortic cross-clamp and CPB times in the FS group. Also Gilmanov et al[10] in 2013 demonstrated 12-minutes longer cross-clamp times and 13-minutes longer CPB times in the minithoracotomy group. Furukawa et al[11] in 2014 reported a significantly longer cross-clamp time in the ministernotomy AVR group but similar CPB times in both groups. A possible explanation for this difference is the fact that the mini-invasive AVR procedure is more complex, more technically demanding and provides limited exposure either through partial sternotomy or minithoracotomy in comparison with the conventional FS procedure. Nevertheless, we did not observe a statistically significant increase in CPB-related adverse effects in the RAMT group; apparently the slightly longer aortic cross-clamp and CPB times are not clinically relevant in young patients undergoing isolated AVR.

Also in 2014, Miceli et al[12] compared the outcomes of RAMT vs ministernotomy (MS) in 406 adults undergoing mini-invasive AVR. In-hospital mortality was 1.2% with no difference between the two groups and patients undergoing RAMT had a lower incidence of postoperative atrial fibrillation, shorter ventilation time, ICU stay, and hospital stay. No difference was found in terms of cardiopulmonary time, cross-clamping time, postoperative stroke, reexploration for bleeding, or blood transfusion. Their conclusions were that mini-invasive AVR using RAMT was associated with lower postoperative morbidities and a shorter hospital stay than MS.

Recently, in 2017 Balmforth et al[13] constructed "a best evidence topic" to answer the question: in patients undergoing mini-invasive AVR, RAMT or MS were superior in terms of postoperative outcome? A total of 840 publications were found but only 6 represented the best available evidence to answer the clinical question. They concluded that there was a lack of high-quality evidence comparing RAMT and MS for minimally invasive AVR, with no randomized controlled trials to date.[13] The available evidence shows no difference in early mortality between RAMT and MS for surgical AVR. Mostly, in studies that directly compared RAMT and MS, RAMT was found to be associated with reduced length of hospital stay, despite longer cardiopulmonary bypass times and cross-clamp times.[13] One study reported groin complications (10.8%) with the RAMT group, where peripheral cannulation was used, while the other five studies did not comment on groin complications associated with peripheral cannulation. In the only cost-benefit analysis, RAMT was found to carry considerably more cost than MS over and above conventional AVR.[13]

In our experience, our skin incision was slightly greater than other authors but all patients received the CPB implantation totally through the thoracotomy, avoiding the complications of peripheral cannulation (Figure 1). RAMT did not influence the implantation technique but, in our opinion, there are some more challenging maneuvers (ie, aortic cross-clamping or deairing) because of the limited spaces. Probably, a pediatric cardiac surgeon is more confident with this kind of maneuvers because he is usually trained to challenge with a little structures and a narrow operative fields. In addition, many pediatric cardiac surgeons, as in our center, use RAMT to correct several congenital heart diseases even in younger and smaller patients.[14]

However, our study presents some limitations, which should be underlined, such as the retrospective design, the small number of patients enrolled and the time of follow-up not very long. Furthermore, we cannot exclude a possible bias in results due to the variability of the surgeons who choose the surgical technique at the request of the patient subjectively and the variability of cardiologists for the echocardiogram examination at follow-up. Lastly, the slight increase in cross-clamping and CPB times observed in the right minithoracotomy group could be simply due to the learning curve.

A very important aspect for this surgery is the psychology of patients, who are in a very special phase of life such as adolescence. One of the points that was not evaluated and discussed in this study was the better cosmetic results due to the position and small incision and the better patient satisfaction.

In conclusion, our retrospective study shows that RAMT is safe and effective as FS for AVR in the adolescents with bicuspid aortic valve. Although the RAMT operation takes slightly more operation time, it is not associated with major adverse effects. Interestingly, the esthetic benefits required by patients who are satisfied. Accordingly, a large, multicenter, randomized controlled trial is warranted to validate the effectiveness and safety.

## CONFLICT OF INTEREST

None declared.

## AUTHOR CONTRIBUTIONS

RG and MC performed Concept/Design, Data analysis/interpretation and Drafting article. GC, LDT, and GI performed statistics and Data collection. EP and GP performed Critical revision ad Approval of article.

## ORCID

*Raffaele Giordano* http://orcid.org/0000-0002-8046-810X

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**How to cite this article:** Giordano R, Cantinotti M, Comentale G, et al. Right thoracotomy for aortic valve replacement in the adolescents with bicuspid aortic valve. *Congenital Heart Disease*. 2019;14:162–166. https://doi.org/10.1111/chd.12680