Full sternotomy and minimal access approaches for surgical aortic valve replacement: a multicentre propensity-matched study

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Abstract

OBJECTIVES: Surgical aortic valve replacement (AVR) can be performed via a full sternotomy or a minimal access approach (mini-AVR). Despite long-term experience with the procedure, mini-AVR is not routinely adopted. Our goal was to compare contemporary outcomes of mini-AVR and conventional AVR in a large multi-institutional national cohort.

METHODS: A total of 5801 patients from 10 different centres who had a mini-AVR (2851) or AVR (2950) from 2011 to 2017 were evaluated retrospectively. Standard aortic prostheses were used in all cases. The use of the minimally invasive approach has increased over the
years. The primary outcome is the incidence of 30-day deaths following mini-AVR and AVR. Secondary outcomes are the occurrence of major complications following both procedures. Propensity-matched comparisons were performed based on the multivariable logistic regression model.

RESULTS: In the overall population patients who had AVR had an increased surgical risk based on the EuroSCORE, and the 30-day mortality rate was higher (1.5% and 2.3% in mini-AVR and AVR, respectively; \( P = 0.048 \)). Propensity scores identified 2257 patients per group with similar baseline profiles. In the matched groups, patients who had mini-AVR, despite longer cardiopulmonary bypass (81 ± 32 vs 76 ± 28 min; \( P = 0.004 \)) and cross-clamp (64 ± 24 vs 59 ± 21 min; \( P \leq 0.001 \)) times, had lower 30-day mortality rates (1.2% vs 2.0%; \( P = 0.036 \)), reduced low cardiac output (0.8% vs 1.4%; \( P = 0.046 \)) and reduced postoperative length of stay (9 ± 8 vs 10 ± 7 days; \( P = 0.004 \)). Blood transfusions (36.4% vs 30.8%; \( P \leq 0.001 \)) and atrial fibrillation (26.0% vs 21.5%, \( P \leq 0.001 \)) were higher in patients who had the mini-AVR.

CONCLUSIONS: In a large multi-institutional recent cohort, minimal access approach aortic valve replacement is associated with reduced 30-day mortality rates and shorter postoperative lengths of stay compared to standard sternotomy. A prospective randomized trial is needed to overcome the possible biases of a retrospective study.

Keywords: Aortic valve • Aortic valve replacement • Cardiovascular surgery • Heart valve

<table>
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<th>ABBREVIATIONS</th>
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<tr>
<td><strong>AUC</strong></td>
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<td><strong>AVR</strong></td>
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<td><strong>CI</strong></td>
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<td><strong>Mini-AVR</strong></td>
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INTRODUCTION

Treatment of aortic valve disease is rapidly evolving. Aortic valve replacement (AVR) via a full sternotomy is well tolerated and has demonstrated excellent long-term event-free survival and quality of life even in high-risk elderly patients [1]. At the same time the use of minimally invasive surgical approaches, after decades of scepticism, is increasing in the attempt to further reduce postoperative morbidity and to improve patient satisfaction. However, not all cardiac surgeons offer minimal access approach aortic valve replacement (mini-AVR) because there is uncertainty as to whether it offers advantages over conventional AVR.

In 1993, the first mini-AVR was performed through a right thoracotomy [2]. Subsequently, a variety of incisions, including partial lower and transverse sternotomy as well as a parasternal approach, have been adopted. Nowadays, the right anterior thoracotomy and upper hemisternotomy are the predominant approaches for the mini-AVR [3].

At present, there are no guidelines to either recommend or discourage surgeons from using minimally invasive approaches in aortic valve surgery because of the lack of definitive prospective randomized studies. Knowledge is based on retrospective single-centre studies and small randomized controlled trials. In fact, a recent Cochrane meta-analysis could be performed on only 7 small randomized controlled trials and did not show any outcome differences in patients who had AVR via a full sternotomy or an upper hemisternotomy [4].

In order to contribute to the determination of the best surgical strategy for patients undergoing AVR, the aim of the present study was to review early outcomes in a large multicentre cohort of patients who had aortic valve surgery either with full sternotomy (AVR) or mini-AVR.

MATERIALS AND METHODS

Data from 10 Italian cardiac centres were analysed from January 2011 through December 2017. All patients who received first-time isolated AVR through a standard sternotomy or a minimal access approach (partial hemisternotomy or right anterior minithoracotomy) were considered for the analysis.

Clinical and administrative databases are prospectively utilized in all of the centres. All patients signed an informed consent form to allow clinical and administrative data storage and utilization for scientific purposes according to the General Data Protection Regulation (GDPR). Because of the retrospective nature of this study, the local ethics committees waived the need for patient consent.

The primary outcome of the study is the comparison of the incidence of 30-day deaths following AVR and mini-AVR. For discharged patients, the follow-up was performed at internal outpatient clinics or at referral centres. Secondary outcomes included the occurrence of major complications following both procedures: stroke, worsening kidney function, permanent pacemaker insertion, reopening for bleeding, postoperative atrial fibrillation and low cardiac output. All major outcomes were reported according to Valve Academic Research Consortium-2 definitions [5].

The choice of performing a minimal access approach and the type of minimal access approach were based on the preference of the surgeon. The following technique has been described previously [6]. For the minithoracotomy approach, a 6- to 7-cm skin incision was performed and the sternum partially opened in a J-shaped fashion, up to the 3rd/4th intercostal space. Arterial and venous cannulations were usually accomplished through the main surgical site (ascending aorta and right atrium with a double-stage cannula). If the right atrium was difficult to expose, then venous drainage was achieved with a percutaneous venous cannula, advanced through the right femoral vein into the right atrium using the Seldinger technique under transoesophageal echocardiographic guidance. The right anterior minithoracotomy was performed through a 5- to 7-cm incision at the 2nd or 3rd intercostal space without rib resection. The ascending aorta or the femoral artery was used for cannulation, depending on the patient’s anatomy and the surgeon’s preference. Venous drainage was achieved in the fashion described for a ministernotomy. A preoperative computed tomography scan without contrast enhancement was sometime performed to evaluate the
anatomical relationship between the intercostal spaces, sternum, ascending aorta and aortic valve. Vacuum-assisted cardio-
pulmonary bypass was established; a left ventricular vent was
placed through the right superior pulmonary vein or the pul-
monary artery; and the patient was cooled to 34°C. The ascen-
ding aorta was clamped with the external cross-clamp, and
anterograde cardioplegic solution was administered into the
aortic root or selectively into the coronary ostia using warm
blood cardioplegia. In all cases, the surgical field was flooded
with carbon dioxide at a flow of 0.5 l/min. Only standard
stented aortic valve prostheses were implanted (mechanical
prostheses: Carbomedics and Bicarbon families of aortic valves,
Carbomedics/LivaNova, London, UK; biological prostheses: por-
cine Hancock II and MosaicTM, Medtronic, Minneapolis, MN,
USA; pericardial: Carpentier-Edwards, Edwards Lifesciences,
Irvine, CA, USA; Mitroflow and Crown PRT LivaNova/Sorin,
London, UK); no sutureless or rapid deployment valves have
been utilized [6].

Statistical analyses

Data are reported as mean ± standard deviation, median (inter-
quartile range) or percentage for categorical variables. We used
the Student’s t-test to compare continuous variables. Associations
between categorical variables were evaluated using the χ² test.
Because many preoperative variables were different between
groups, we evaluated a propensity score matched cohort using
an automated procedure to pair patients 1:1 from the 2 surgical
approaches. The propensity score was based on the multivariable
logistic regression model for mini-AVR surgery including gender,
age, arterial hypertension, diabetes mellitus, hypercholesterol-
aemia, renal dysfunction, respiratory or lung disease, previous
disabling stroke, history of cancer, atrial fibrillation, peripheral
vascular disease, coronary artery disease, ejection fraction cat-
egory (31–50% and <30% vs >50%) and EuroSCORE. Matching
was performed in a 1:1 ratio by selecting from the 2 groups
patients of the same gender and age (within ±1 year of differ-
ence). All possible pairs were ordered by the absolute difference
in propensity score, selecting those with the lowest value within
a maximum caliper width of 0.25 of the standard deviation of the
linear predictor of the propensity score [7]. For the 579 patients
(273 full sternotomy and 306 minimally invasive approach) for
whom preoperative risk factors were not available, the matching
procedure was based on gender, age and EuroSCORE. The suc-
cess of matching was evaluated by computing absolute standard-
dized differences in the distribution of patient characteristics
in the matched cohort before and after matching. Post-matching
standardized differences <10% indicated successful balance. To
account for the dependence of the matched pairs, between-
group differences after matching were tested with univariate con-
tditional logistic regression models on an indicator variable
denoting the surgical approach. A logistic regression model was
used to evaluate multivariate predictors of death in the overall
population. Odds ratios (OR) with 95% confidence intervals (95%
CI) were estimated. Model calibration was verified by the
Hosmer–Lemeshow test. A P-value <0.05 was considered statis-
tically significant without adjustment for multiple comparisons
among secondary outcomes. Discrimination evaluation was
based on the area under the receiver operating characteristic
curve (AUC). All analyses were conducted using STATA software,
version 14 (StataCorp LP, College Station, TX, USA).

RESULTS

During the study period, 5801 patients underwent AVR in 10
hospitals: in 2950 cases a full sternotomy (AVR) was performed
whereas in 2851 a mini-AVR was the chosen approach. The use
of the mini-AVR has increased over the years; it has become the
most practiced approach (Fig. 1A). Patients in the mini-AVR
group were older and had higher rates of cardiovascular risk, re-
spiratory dysfunction and history of cancer. Atrial fibrillation
was more frequent in the full sternotomy group, which had worse
left ventricular function and a slightly higher EuroSCORE (Table 1).
By using a matching procedure, 2257 patients per group were
paired to select 2 similar subsamples of procedures. The model
used to generate the propensity score had good discrimination
and calibration for predicting the surgical approach (AUC = 0.629
and Hosmer–Lemeshow test, P = 0.337). No differences in demo-
graphic and preoperative data were observed between the 2
matched groups (Table 1). Figure 2 shows the absolute standard-
dized differences of preoperative data before and after matching:
all differences between the AVR and the mini-AVR were present
in the overall population were eliminated in the matched sub-
sample. A total of 111 (1.9%) deaths were observed: 69 (2.3%) in
the AVR group and 42 (1.5%) in the mini-AVR (P = 0.016) with a
temporal trend towards reduction in the number of deaths in the
latter group (Fig. 1B). The EuroSCORE discriminated well between
patients with and without events (AUC 0.736 and 0.719, respect-
ively, for the additive version and the EuroSCORE II). In compari-
son to a full sternotomy, a mini-AVR was associated with fewer
deaths (OR 0.63, 95% CI 0.43–0.93; P = 0.021), adjusting for
EuroSCORE II. Similarly, the mini-AVR remained associated with
fewer deaths (OR 0.60, 95% CI 0.38–0.93; P = 0.023) when we
adjusted for preoperative data. In this full model, predictors of
death were also age (OR 1.05 per year, 95% CI 1.02–1.08;
P = 0.002), renal dysfunction (OR 3.49, 95% CI 1.89–6.46;
P < 0.001), lung disease (OR 4.46, 95% CI 2.88–6.89; P < 0.001),
ejection fraction <30% (OR 1.42, 95% CI 1.62–13.04; P = 0.044)
whereas arterial hypertension, diabetes mellitus, hypercholester-
olaemia, previous disabling stroke, history of cancer, atrial fibril-
lation, peripheral vascular disease and coronary artery disease
did not reach statistical significance. The model had a high level
of discrimination (AUC = 0.782) without deviations in calibration
(Hosmer–Lemeshow test; P = 0.365).

Table 2 shows intraoperative and postoperative data by pro-
cedure in the overall population and in the subgroups of subjects
paired by propensity score. Patients who had the mini-AVR had
longer cardiopulmonary bypass and cross-clamping times, larger
valve sizes, shorter postoperative lengths of stay, a less frequent
postoperative low cardiac output but higher need of blood trans-
fusions and incidence of postoperative atrial fibrillation (Table 2).
These significant differences were observed also in propensity-
matched groups that showed fewer deaths with the mini-AVR
than with the full sternotomy approach. The mini-AVR group
had a lower 30-day mortality rate both in the overall population
and in the propensity score matched patients (1.2% vs 2.0%;
P = 0.036). No difference was detected in worsening renal func-
tion, permanent pacemaker insertion, wound infection,
reopening for bleeding, reintubation, confusion/delirium, stroke and intensive care unit length of stay.

Mortality rates by hospitals and surgeons

Figure 3 shows mortality rates within institutions (Fig. 3A and B) and within operators (Fig. 3C and D) by cases volume and by EuroSCORE II predicted risk. For both approaches, the observed mortality rate was lower than that expected with EuroSCORE II. The mortality rates associated with specific providers and surgeons had greater variability with the full sternotomy than with the mini-AVR (Fig. 3A and C); with the mini-AVR, the mortality rate was more homogeneously low for providers and operators (Fig. 3B and D).

Upper hemisternotomy versus a right anterior thoracotomy

The majority of the operations were upper hemisternotomies (1770 vs 1081). Patients in this group were slightly younger with less renal dysfunction but had a higher incidence of preoperative stroke and worse ejection fractions. However, no differences in the EuroSCORE were evident (3.0 ± 5.3 vs 2.9 ± 4.3 with a right minithoracotomy and an upper ministernotomy, Table 1:

<table>
<thead>
<tr>
<th>Overall</th>
<th>AVR (n = 2950)</th>
<th>Mini-SAVR (n = 2851)</th>
<th>P-value</th>
<th>AVR (n = 2257)</th>
<th>Mini-SAVR (n = 2257)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male gender</td>
<td>5972 (53.0)</td>
<td>3070 (53.2)</td>
<td>1502 (52.7)</td>
<td>0.682</td>
<td>1186 (52.5)</td>
<td>1186 (52.5)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>71.9 ± 11.5</td>
<td>71.6 ± 11.7</td>
<td>72.3 ± 11.3</td>
<td>0.026</td>
<td>73 ± 10</td>
<td>73 ± 10</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>27.5 ± 4.6</td>
<td>27.5 ± 4.5</td>
<td>27.4 ± 4.6</td>
<td>0.732</td>
<td>27.6 ± 4.5</td>
<td>27.4 ± 4.6</td>
</tr>
<tr>
<td>Arterial hypertension</td>
<td>3919 (75.0)</td>
<td>2062 (77.0)</td>
<td>1857 (73.0)</td>
<td>0.001</td>
<td>1529 (75.8)</td>
<td>1558 (77.3)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>990 (19.0)</td>
<td>470 (17.6)</td>
<td>520 (20.4)</td>
<td>0.008</td>
<td>367 (18.2)</td>
<td>389 (19.3)</td>
</tr>
<tr>
<td>Hypercholesterolaemia</td>
<td>2682 (51.4)</td>
<td>1299 (48.5)</td>
<td>1383 (54.3)</td>
<td>&lt;0.001</td>
<td>1011 (50.1)</td>
<td>1050 (52.1)</td>
</tr>
<tr>
<td>Renal dysfunction</td>
<td>193 (3.7)</td>
<td>101 (3.8)</td>
<td>92 (3.6)</td>
<td>0.762</td>
<td>65 (3.2)</td>
<td>73 (3.6)</td>
</tr>
<tr>
<td>Respiratory or lung disease</td>
<td>1036 (19.8)</td>
<td>458 (17.1)</td>
<td>578 (22.7)</td>
<td>&lt;0.001</td>
<td>377 (18.7)</td>
<td>357 (17.7)</td>
</tr>
<tr>
<td>Previous disabling stroke</td>
<td>99 (1.9)</td>
<td>55 (2.1)</td>
<td>44 (1.7)</td>
<td>0.388</td>
<td>37 (1.8)</td>
<td>39 (1.9)</td>
</tr>
<tr>
<td>History of cancer</td>
<td>345 (6.6)</td>
<td>138 (5.2)</td>
<td>207 (8.1)</td>
<td>&lt;0.001</td>
<td>120 (6.0)</td>
<td>111 (5.5)</td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>520 (10.0)</td>
<td>291 (10.9)</td>
<td>229 (9.5)</td>
<td>0.024</td>
<td>209 (10.4)</td>
<td>198 (9.8)</td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>376 (7.2)</td>
<td>187 (7.0)</td>
<td>189 (7.4)</td>
<td>0.538</td>
<td>145 (7.2)</td>
<td>138 (6.8)</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>627 (12.0)</td>
<td>252 (9.4)</td>
<td>375 (14.7)</td>
<td>&lt;0.001</td>
<td>217 (10.8)</td>
<td>219 (10.9)</td>
</tr>
<tr>
<td>Ejection fraction (%)</td>
<td>&lt;0.001</td>
<td>0.978</td>
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Data are reported as mean ± standard deviation or n (%). Renal dysfunction: dialysis or creatinine level >2 mg/dl. Body mass index available for 4236 patients and 3276 paired by propensity score. Risk factors from arterial hypertension to ejection fraction available in 5222 patients and 4032 paired by propensity score. The 2257 pairs were selected by the matching procedure on the basis of age, gender and propensity score (2016 pairs with complete preoperative risk factors) or EuroSCORE (241 pairs missing preoperative risk factors).

AVR: aortic valve replacement; mini: minimal access approach; SAVR: surgical aortic valve replacement.
respectively; \( P = 0.396 \). An upper hemisternotomy required longer cross-clamp times (75 ± 33 vs 84 ± 34 min; \( P < 0.001 \)) and cardiopulmonary bypass times (59 ± 26 vs 66 ± 23 min, \( P < 0.001 \)) as well as a need for more blood transfusions [274 (29.1%) vs 647 (40.0%; \( P < 0.001 \)] compared to a right anterior thoracotomy. No other significant differences in clinical outcomes were observed.

Reopening for bleeding and blood transfusions

We analysed the trends of reopening for bleeding and blood transfusions during the study period in the overall population. In the patients who had the AVR during the years 2011–2014, reopening for bleeding occurred in 2.8% of the patients; in the years 2015–2017, in 2.7% (0.95, 0.60–1.52; \( P = 0.841 \)). In the
patients who had the mini-AVR, reopening for bleeding occurred in 3.9% in the period 2011–2014 and in 2.0% in the period 2015–2017 (0.52, 0.33–0.82; \( P = 0.005 \)). Similarly, in patients who had the AVR in the years 2011–2014, blood transfusions were necessary in 31.4% of the patients whereas in the years 2015–2017, they were necessary in 31.5% (1.0, 0.85–1.18; \( P = 0.98 \)). In the mini-AVR group, blood transfusions were administered in 39.6% in the period 2011–2014 and in 32.0% in the period 2015–2017 (0.71, 0.61–0.84; \( P = 0.001 \)).

**DISCUSSION**

The treatment of aortic valve disease is changing. Since the introduction of transcatheter aortic valve implantation, high- and intermediate-risk patients with aortic stenosis have been increasingly treated with this technique. A recent comparison of surgical treatment with the transcatheter approach in low-risk patients [8] suggests that more patients with aortic stenosis receive a transcatheter valve implant than a surgical replacement. It is therefore of paramount importance to define the best strategy to offer patients undergoing surgical treatment. After decades of scepticism, surgeons are becoming more familiar with the minimal access approaches. Studies have shown that results obtained by reducing surgical exposure and trauma are at least equal to those obtained with a full sternotomy [9].

We investigated a large multicentre cohort of patients who had surgical AVR relatively recently. The minimal access approach was associated with a significant reduction of the 30-day mortality rate. This result was evident after adjustment for the EuroSCORE II, after adjustment for preoperative risk factors and also in propensity score matched groups. This finding is important for several reasons: First, it was obtained recently in a large multicentre cohort. Second, most of the centres and surgeons involved used both operative techniques. Finally, the overall mortality rate was low (1.9%), not only in the patients who had the mini-AVR (1.5%) but also in the AVR group (2.3%), lower than the rate expected from the EuroSCORE II. The observed/expected mortality ratio based on EuroSCORE II was 0.74 in patients who had AVR and 0.52 in those who had the mini-AVR. This finding is in line with the observed/expected mortality ratio after transcatheter aortic valve implantation [10], suggesting that future comparisons between these techniques should be performed with the minimal access approach in the surgical arm [6].

So far only 1 single-centre retrospective study demonstrated a survival advantage of mini-AVR over standard sternotomy. Merk et al. [11], analysing 477 propensity-matched patients in each group, showed that the mini-AVR was associated with a lower

![Figure 3: Hospital mortality rates within institutions by case volume and by EuroSCORE II predicted risk (A and B, respectively) for cardiac surgery centres with more than 50 procedures per approach. Mortality rates for surgeons with more than 20 cases per approach by case volume and by EuroSCORE II predicted risk (C and D, respectively). The dotted lines in (A) and (C) refer to the overall mortality rate. Mini-AVR: minimal access approach-aortic valve replacement.](https://academic.oup.com/ejcts/article-abstract/57/4/709/5606744)
incidence of intra-aortic balloon pump usage and of in-hospital deaths. Moreover, in the other retrospective study and meta-analyses, mini-AVR was never associated with an increased number of deaths; in fact, it was often associated with decreased morbidity rates. Ghanta et al. [12] reported on 1341 patients operated on in 17 hospitals; of the 289 propensity-matched patients who had conventional or mini-AVR, those who had mini-AVR needed fewer blood transfusions, had less time on the ventilator and faster discharge; the operative mortality rate was also lower (0.3% vs 2.1%) although not significantly so due to the small sample size. Similarly, Bowdish et al. [13] reported their single-centre experience comparing a right anterior thoracotomy with a conventional sternotomy showing advantages in terms of less blood product usage, lower wound infection rates and decreased hospital stay.

The reason behind the reduced mortality rate observed in our mini-AVR patients is difficult to determine because the causes of death are unfortunately not reported in the database. It is interesting to note, however, that patients who had the mini-AVR had a significantly lower incidence of low cardiac output syndrome. Interestingly, this finding was also reported in the large meta-analysis by Shehada et al. [9] and in the Leipzig experience [11].

We previously demonstrated that minimal access heart valve surgery, including mini-AVR, is associated with a reduced inflammatory reaction and coagulopathy [14]: IL-6, C-reactive protein, prothrombin factor 1.2 and cardiac troponin I levels were lower than in patients who had a full sternotomy. This result is another possible factor supporting the improved clinical outcomes observed in the patients who had the mini-AVR.

Contrary to expectations driven by previous studies, we observed an increased risk of reopening for bleeding and blood transfusions in the mini-AVR group. Minimizing the opening of the sternum and reducing surgical trauma should decrease blood oozing and the risk of coagulopathy. However, we have noted a significant impact of the study period on reopening for bleeding and blood transfusions, indicating a possible learning-curve effect on this important clinical outcome.

In this study, valve replacements were all performed with standard mechanical or biological prostheses. Sutureless and rapid deployment aortic bioprostheses are producing promising clinical and haemodynamic results by reducing cross-clamp and cardiopulmonary bypass times [15, 16]. It is possible to hypothesize further improvement in the clinical outcome by using these prostheses with the minimally invasive approach. Both upper hemisternotomy and right anterior thoracotomy have been widely used in our population having minimally invasive procedures; no differences in outcomes were apparent between these techniques, although no meaningful adjustments were used. In a previous well-balanced report from our group, no differences in outcomes could be observed between these minimal access approaches [17].

Limitations

Our study has some important limitations. First, the retrospective design contains the bias of the choice of a treatment based on the patient’s clinical state and the physician’s preference. This preference, however, has been predominantly driven by the learning curve: At the beginning of each surgeon’s experience, there is a natural and understandable reluctance to treat all cases using a minimal access approach. Second, follow-up information is unavailable at this time. Third, the choice of the minimal access approach (ministernotomy or right minithoracotomy) was biased by the surgeons’ preferences and might be associated with different perfusion strategies.

CONCLUSION

In conclusion, in a large retrospective multicentre evaluation of patients who underwent AVR between 2011 and 2017, mini-AVR was associated with a significantly lower 30-day mortality rate compared to the full sternotomy approach. The observed/expected mortality ratio based on the EuroSCORE II demonstrated a survival advantage compared to the patient’s risk profile. Patients who had mini-AVR experienced higher rates of postoperative atrial fibrillation and blood transfusions, particularly in the initial observation period. To overcome the possible biases of patients’ and surgeons’ selection of our retrospective study, a large multicentre prospective randomized trial should be performed by experienced surgeons to support our results conclusively; however, such a trial will be difficult to perform and there are enough data in the literature to state that mini-AVR techniques are potential tools to improve patient care.

Conflict of interest: none declared.

Author contributions

Domenico Paparella: Conceptualization; Data curation; Investigation; Methodology; Validation; Writing - Original Draft. Pietro Giorgio Malvindi: Conceptualization; Data curation; Investigation; Validation; Writing - Review & Editing. Giuseppe Santarpino: Investigation; Supervision; Validation; Visualization. Marco Moscarelli: Conceptualization; Investigation; Methodology. Piero Guida: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Writing - Original Draft. Khalil Fattouch: Conceptualization; Investigation; Validation; Visualization. Vito Margari: Conceptualization; Data curation; Writing - Review & Editing. Luigi Martellini: Conceptualization; Supervision; Validation. Alberto Albertini: Investigation; Supervision. Giuseppe Speziale: Conceptualization; Supervision; Validation.

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