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Research Article

Comparative analysis of the Bentall-De Bono procedure according to the surgical approach used. A single-centre trial

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Summary

Background. Cardiac surgeons increasingly favour the adoption of minimally invasive techniques for patients with aortic disease. **Methods.** We retrospectively analyzed the clinical data of 41 patients who underwent the Bentall procedure performed by the same surgical team between January 2014 and February 2024. We compared 10 patients who received the minimally invasive Bentall procedure to 31 patients who underwent a conventional median sternotomy. **Results.** Our operative times are consistent with those documented in the literature: the cardiopulmonary bypass (CPB) duration averaged 170.9 ± 31.62 minutes, and aortic cross-clamping time was 114.8 ± 19.34 minutes for patients with minimally invasive access, compared to 172.36 ± 79.98 and 104.14 ± 31.62 minutes respectively for the patients with standard approach (p = 0.503 and p = 0.194). Mortality in patients with minimal surgical access was one patient or 10%, and with total median sternotomy, it was three or 9.7%, with almost identical results p = 0.976. There was never a re-sternotomy due to bleeding or other reasons, nor a conversion to total sternotomy due to a complication related to the surgical intervention. **Conclusion.** This report highlights that the increasing demand and preference for more minimally invasive techniques in cardiac surgery can be met by careful patient selection in experienced centres without reducing safety or surgical efficacy, even in more complex cardiovascular pathologies.

Key words: Aortic root replacement, Bentall procedure, minimally invasive aortic surgery

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Introduction

Annuloaortic ectasia was initially described in 1961 (Ellis et al. 1961) as an idiopathic enlargement of the upper section of the ascending aorta that affects the aortic annulus. The occurrence of this condition is approximately 10% in patients with isolated aortic regurgitation who are referred for surgical intervention (Gocheva 2001).

For clinical centres with extensive experience, minimally invasive aortic valve surgery has become the gold standard over the years and has almost completely replaced conventional access in this type of procedure. In 1949, Holman and Willett described an incomplete vertical sternotomy involving the cutting of the sternum at the second intercostal space, with the operative goal being

pericardectomy(Holman and Willett 1949). Most authors believe that minimally invasive aortic surgery is feasible and safe in selected patients and can include interventions that use supracoronary prosthetics for complex aortic root operations (Staromłyński et al. 2021). Despite the good results and potential shortening of patient recovery, this approach is not routinely used.

In this study, we share our experience treating ascending aortic disease through the Bentall-De Bono procedure, comparing patients treated with a conventional approach and those undergoing a minimally invasive approach.

Objectives

In this study, we aimed to compare cardiopulmonary bypass duration, the length of aortic cross-clamping, and the use of inotropic agents and/or mechanical cardiac support after surgery. Postoperative complications, as well as ICU stay and hospital stay in patients who underwent the Bentall procedure with classical or minimally invasive surgical access, were also subject to our follow-up.

Materials and methods

Design of the study

We performed a retrospective study at the cardiac surgery department at St. Anna University Hospital, Sofia, Bulgaria. All surgical cases requiring aortic root and aortic valve replacement were initially included between January 2014 and February 2024. We studied 60 patients undergoing aortic valve and ascending aortic root replacement using the Bentall-De Bono procedure. We divided them into two groups based on the type of surgical access: standard median sternotomy or minimally invasive partial sternotomy. After meticulous data evaluation in the group of patients treated with standard access, we excluded another 19 patients due to the emergency surgery for ascending aortic dissection, leaving 41 patients in the study: group 1: Bentall-De Bono surgery with a classic approach (BB, n = 31) and group 2: Bentall-De Bono surgery with minimally invasive access (mBB, n = 10). Notably, during the early period from 2014 to 2018, the Bentall procedure was exclusively performed through a full sternotomy, whereas the team adopted the minimally invasive approach between 2018 and 2024.

Eligibility Criteria

- Inclusion criteria:

  Patients with annuloaortic ectasia who received surgical treatment involving replacement of the aortic valve and ascending aortic root using the Bentall-De Bono technique.

  - Exclusion criteria:
    1. All patients undergoing surgical repair of aortic dissection were excluded from the study due to emergency conditions and higher perioperative risk
    2. All patients undergoing Valve-sparing aortic root replacement.

Operative technique

All procedures were carried out under a standardized general anaesthesia protocol tailored for patients with annuloaortic ectasia. A standard median sternotomy was performed on Group 1 patients. For group 2, we performed an upper partial sternotomy on ten patients: an inverted T type in five patients or 50% and a J type in the remaining five or 50%. As in all patients, the incision ends at the fourth intercostal space. Arterial cannulation was centrally performed in all patients, with the cannula positioned in the proximal section of the aortic arch. The cardiopulmonary bypass machine was introduced after an appropriate activated clotting time (ACT) result was obtained and systemic normothermia was confirmed. Myocardial protection was achieved by a modified del Nido cardioplegic solution using antegrade delivery through the coronary ostia. An additional dose of cardioplegia was provided in all patients undergoing Bentall-De Bono aortic root replacement when cross-clamping time exceeded 60 minutes. The aneurysmal portion of the aorta was excised, and a 1 cm cuff of aortic tissue proximal to the cross-clamp was left. After aortic valve removal, a mechanical valve conduit was implanted in thirty patients, a self-prepared mechanical composite graft was used in nine, and a self-prepared biological composite graft was used in the remaining two. After the preparation of coronary buttons, they were directly re-implanted into the prosthesis using an end-to-wall technique. The distal part of the aortic anastomosis was performed while the aortic cross-clamp was in place. The graft length was determined by filling the heart and stretching the graft upward to align it with the distal ascending aorta.

Demographic characteristics

The average age of the presented cohort was 58.29 ± 12.08 (range 29–75). Of the patients included, 31 (75.6%) were male, and 10 (24.4%) – female (Fig. 1).

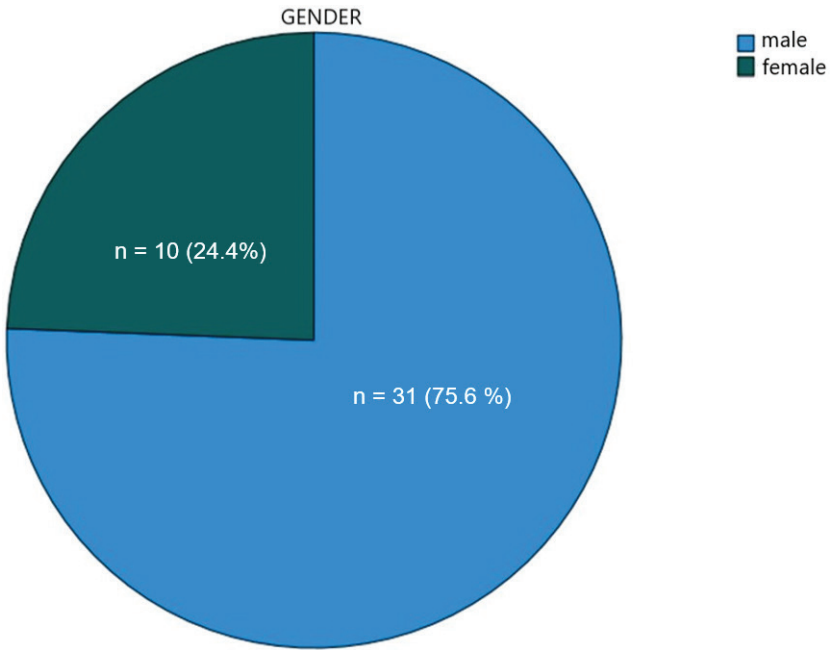

Figure 1. Gender-based frequency distribution.

The men's average age was 56.81 ± 12.03 (range 29–74 years); for women, the average was 52.9 ± 11.59 (range 34–75 years). The largest group of male participants (10) was in the 50–59 years range, followed by 8 in the 40–49 years group, with just one male in both the 20–29 and 30–39 years ranges. For females, the highest number of participants (5) was in the 60–69 years range, while the 30–39 years group had the fewest females, with only one patient (Fig. 2).

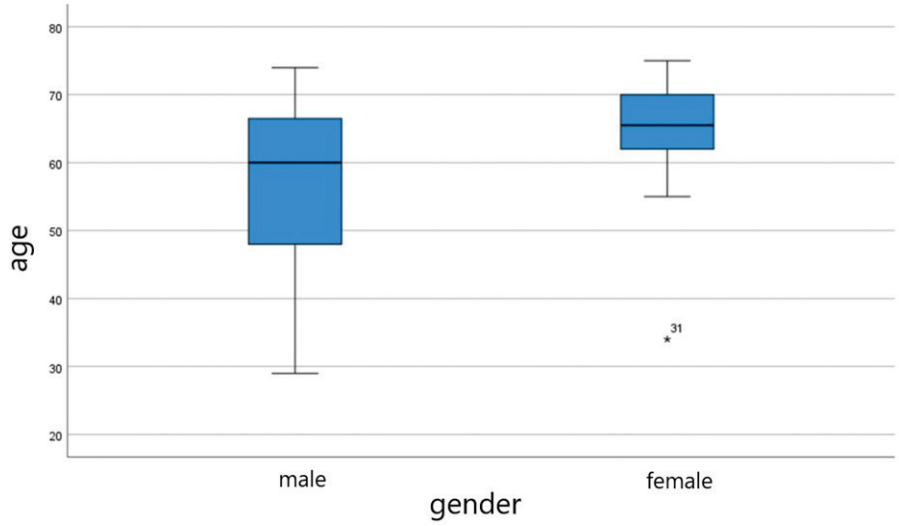

Figure 2. Gender and age-based distribution.

Statistical analysis

The data were analyzed using the IBM SPSS Statistics 27.0 software package and Excel in Office 2021. The results are presented as mean values ± standard deviation and median and difference between upper and lower quartile depending on the data distribution based on descriptive analysis. If the p-value is less than 0.05 (two-tailed) and judged as statistically significant. A single-factor dispersion analysis- One-way ANOVA was applied to compare continuous variables with normal distribution between the groups according to the applied operative access. The Mann-Whitney U non-parametric test was used to compare continuous variables with a distribution different from normal between the groups according to the applied surgical intervention. The percentage distribution of the nominal indicators examined between the groups according to the applied operative intervention was calculated by descriptive analysis. Cross-tabulation with the Chi-Square test was used to compare nominal indicators between groups according to the applied surgical approach.

Results

Descriptive statistics

In this study, the patients were categorized into two therapeutic groups (Fig. 3):

- Bentall-De Bono surgery with a standard access BB, n = 31 (75.6%)
- Bentall-De Bono surgery with minimally invasive access mBB, n = 10 (24.4%).

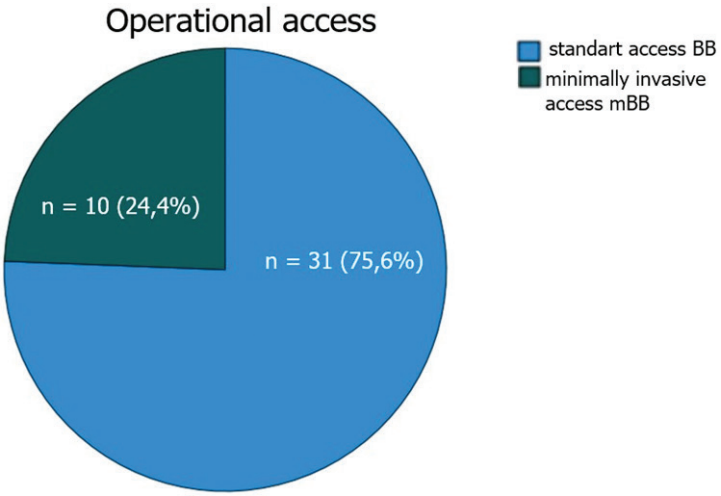

Figure 3. Distribution of research contingent according to the type of operational access.

General characteristics of the groups

A. Table 1 shows that:

- The mean age of the group with standard access was 56.68 ± 10.91, and for those with minimally invasive 63.30 ± 14.66, respectively –. The difference between them is statistically insignificant.
- The two study groups are statistically balanced regarding known confounding factors such as gender and age, which provides a proper basis for subsequent comparisons.

Table 1. Comparative analysis of the study groups based on age (Index A) and gender (Index B).

Index A	Total		Standard maccess		Minimally invasive access		P
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	
Age (years)	58.29	12.08	56.68	10.91	63.30	14.66	0.133
Index B	**N**	**%**	**N**	**%**	**N**	**%**	**P**
Gender							0.645
Men	31	75.6	24	77.4	7	70	
Women	10	24.4	7	22.6	3	30	

B. Regarding the investigated preoperative quantitative characteristics (Table 2):

- With all subsequent indicators included in the table – Eeuroscore, ejection fraction, ascending aorta diameter, aortic root diameter and aortic regurgitation grade the difference between the two groups was statistically insignificant.

Table 2. Comparative analysis of the therapeutic groups based on the investigated preoperative quantitative characteristics.

Index	Standard access					Minimally invasive access					P
	n	$\bar{X}$	SD	median	IQR	n	$\bar{X}$	SD	median	IQR	
Euroscore (%)	21	8.97	8.84	5.06	12.12	7	3.64	2.92	3.36	2.33	0.08
Ejection fraction (%)	31	53.39	10.14	55	18	10	50.3	11.08	50	18	0.418
Ascending aorta diameter (mm)	31	55.45	7.86	55	9	10	57.5	8.76	57	15	0.49
Aortic root diameter (mm)	19	45.05	8.44	44	11	9	46	7.19	45	24	0.669
Aortic regurgitation (grade)	31	2.45	1.03	3	1	10	2.4	0.967	3	1	0.889

Comparative analysis of the therapeutic groups based on the investigated quantitative and categorical intra- and postoperative characteristics

A. The conducted comparative analysis of the therapeutic groups based on the investigated categorical intra- and postoperative characteristics reveals (Table 3) that:
   - For all indicators included in the table: Mechanical ventilation for more than 48 hours, The need for inotropic support, Frequency of use of IABP, New-onset AV block, Need for a permanent pacemaker usage, New-onset myocardial infarction, New-onset stroke, Frequency of major bleeding, Need for re-sternotomy or conversion, Multiple organ dysfunction syndrome and mortality, the difference between the two groups is statistically insignificant.

Table 3. A comparison of the groups based on the assessed categorical intra- and postoperative characteristics.

Categorical Index	Standard access		Minimally invasive access		P
	n	%	n	%	
Mechanical ventilation for more than 48 hours	8	25.8	2	20	0.710
Requirement for inotropic support in ICU					0.444
Absence	8	25.8	2	20	
Moderate doses	15	48.4	7	70	
High doses	8	25.8	1	10	
Frequency of IABP usage	3	9.7	0	0	0.307
New-onset AV block	3	9.7	0	0	0.307
Need for a permanent pacemaker usage	2	6.5	0	0	0.410
Newly developed myocardial infarction	0	0.0	0	0.0	–
Newly developed stroke	0	0.0	0	0.0	–
Frequency of major bleeding	0	0.0	0	0.0	–
Need for re-sternotomy or conversion	0	0.0	0	0.0	–
Multiple organ dysfunction syndrome	1	3.2	1	10	0.387
Mortality	3	9.7	1	10	0.976

B. Concerning the assessed quantitative intra- and postoperative characteristics (Table 4):

There were no statistically meaningful differences between the two treatment groups for any of the factors listed, including postoperative ejection fraction, CPB time, cross-clamping time, ICU stay, and overall hospital stay.

Table 4. A comparison of the therapeutic groups based on the analyzed quantitative intraoperative and postoperative data.

Quantitative	Standard access					Minimally invasive access					P
Index	n	$\bar{X}$	SD	median	IQR	n	$\bar{X}$	SD	median	IQR	
Postoperative Ejection Fraction(%)	28	51.54	10.75	54.5	12	10	49.4	10.47	50.5	19	0.59
CPB time(min)	28	172.36	79.98	156	79	10	170.9	31.62	157	64	0.503
Cross-clamping time(min)	28	104.14	31.65	97	39	10	114.8	19.34	109	39	0.194
Stay in the ICU (days)	31	6.4	7.53	6	1	10	5.16	5.85	4	5	0.591
Hospital stay (days)	31	13.3	7.33	15	52	10	12.16	8.65	11	25	0.71

Discussion

The Bentall-De Bono operation and supracoronary aortoplasty are the most commonly used techniques to replace the ascending aorta. In the Bentall-De Bono procedure, the aortic valve and aortic root are replaced, along with the reimplantation of coronary ostia into the composite graft (Bentall and De Bono 1968). It is considered the gold standard for treating combined aortic valve and aortic root pathologies, particularly when the valve's anatomy is unsuitable for valve-preserving root replacement (Etz et al. 2010). Minimally invasive techniques are becoming more common in cardiac surgery and are being implemented in a broader range of conditions, even very complex aortic surgery. The aim is to reduce surgical trauma while enhancing clinical and cosmetic outcomes. Less operative trauma leads to a reduced systemic inflammatory response, shorter mechanical ventilation times, and shorter stays in the intensive care unit, all contributing to faster recovery and early rehabilitation. While brief periods of respiratory help are added in most cases, brief periods of respiratory help is added, some patients may need prolonged postsurgical mechanical ventilation (PMV), which by definition equals to or is more than 21 days (MacIntyre et al. 2005). In order to reduce the risk of respiratory infections, we accept mechanical ventilation beyond 48 hours for prolonged. Looking at the results, we found a lower frequency of mechanical ventilation beyond 48 hours in patients with minimally invasive access, which was the case in 2 of the patients or 20%, compared to 8 patients or 25.8% with median sternotomy. Regardless of the observed trend, statistical significance was not achieved. The average length of stay in the ICU when we used minimal access was 5.16 ± 5.85 compared to 6.4 ± 7.53 with standard access. For the hospital stay, the trend for a shorter time was also observed, but without significance (12.6 ± 8.65 with minimal access and 13.3 ± 7.33 with standard sternotomy, respectively). These results could probably be explained by the small number of patients in the studied groups, but further studies are needed.

There are few reports on managing aortic root disease using partial upper sternotomy in the scientific literature. Moreover, few authors treat this pathology employing the Bentall-De Bono operation using a ministerotomy. Perrotta reported a cohort of 40 patients diagnosed with aortic root aneurysm and aortic regurgitation and planned for the Bentall-De Bono procedure via partial access (Perrotta et al. 2008). It is noteworthy that three of these patients had an acute Stanford type A dissection, demonstrating that mini-sternotomy can also be used effectively in this acute and complicated setting. The author recorded in-hospital mortality in one patient, which occurred 46 days after surgery. In three other studies involving small cohorts of patients undergoing minimally invasive Bentall-De Bono procedures (31 to 35 each), Hillebrand, Byrne, and Bakir reported aortic cross-clamping times of 113–157 minutes and cardiopulmonary bypass times of 162–193 minutes (Bakir et al. 2007; Byrne et al. 1999; Hillebrand et al. 2018) The times we present are comparable to those presented above: the duration of extracorporeal circulation was 170.9 ± 31.62 and the aortic cross-clamping time was 114.8 ± 19.34 for the patients with minimal access, and respectively 172.36 ± 79.98 and 104.14 ± 31.62 for patients with standard access ($p = 0.503$ and $p = 0.194$). Mortality in the group with minimal operative access was one patient or 10%, while in standard access, it

was three or 9.7%, the results being almost identical p = 0.976. In the studied patients, there were no statistically meaningful differences between the two groups in terms of use of inotropic support, IABP, newly developed AV block, requirement for a permanent pacemaker, new-onset myocardial infarction, new-onset stroke, multiple organ dysfunction syndrome, or mortality. However, a trend towards a lower frequency of these complications was observed with minimal access surgery.

The largest minimally invasive Bentall cohort reported in the literature included 98 patients and was presented by Kampen as part of a single-centre study involving 768 patients who underwent the Bentall procedure (Van Kampen et al. 2023). The team reported eight cases of conversion to total sternotomy. Six of these conversions were due to bleeding, and two were required for emergency CABG due to issues with coronary perfusion. One of the converted patients needed re-examination due to bleeding. There were no reported dialysis cases or patients who died in hospital following the surgery. This experience led them to recommend a relatively low threshold for converting to full sternotomy, especially when the patient's anatomy is unsuitable for minimally invasive technique or complications arise that necessitate complete access to the operative field (Van Kampen et al. 2023). In contrast, our study found no cases of conversion to total sternotomy, likely due to effective patient selection for partial sternotomy.

The upper partial sternotomy access is beneficial and feasible when planned and executed carefully. It offers excellent access to the ascending aorta and aortic arch for cannulation and distal anastomosis while minimizing the risk of dissection or right ventricle injury (Shah et al. 2021). However, prioritizing a cosmetically appealing "shorter incision" at the expense of safety and durable results should be avoided (Van Kampen et al. 2023). If required, converting from partial to full median sternotomy should not be considered a complication, as it is straightforward and can improve patient safety and surgical outcomes.

Conclusions

We observed no notable differences between the two groups regarding CPB times, cross-clamping times, ICU length of stay and overall length of in-hospital stay. The findings emphasize that the growing demand for minimally invasive techniques in cardiac surgery can be addressed through careful patient selection at highly skilled departments without compromising safety or surgical effectiveness, even for more complex cardiovascular conditions.

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statements

The authors declared that no clinical trials were used in the present study.

The authors declared that no experiments on humans or human tissues were performed for the present study.

The authors declared that no informed consent was obtained from the humans, donors or donors' representatives participating in the study.

The authors declared that no experiments on animals were performed for the present study.

The authors declared that no commercially available immortalised human and animal cell lines were used in the present study.

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Author contributions

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Data availability

All of the data that support the findings of this study are available in the main text.

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