Original Article

The safety and feasibility of mini-invasive Bentall surgery via right anterior mini-thoracotomy

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Background: The right anterior mini-thoracotomy (RAMT) approach has become a popular technique in cardiac surgery and applied in valve surgery. However, there is very limited evidence on the application of RAMT in the Bentall surgery. In the present study, we aimed to evaluate the safety and feasibility of the RAMT approach in Bentall surgery.

Methods: A retrospective analysis was performed on 27 patients who underwent Bentall surgery between September 2020 and April 2022 in the First Affiliated Hospital of Xi'an Jiaotong University. Follow-ups were undertaken 1 and 6 months after their operations. The baseline, perioperative, and follow-up results were retrospectively analyzed.

Results: A total of 27 male patients aged 48–61 years were included in the study. The operation time ranged from 4.0 to 5.0 hours, with a median of 4.5 hours. The median aortic cross-clamping time was 122 minutes [interquartile range (IQR): 109–145 minutes], and the median cardiopulmonary bypass (CPB) time was 156 minutes (IQR: 143–183 minutes). The median intensive care unit stay was 3 days (IQR: 1.75–4.25 days). The ventilation time ranged from 6.5 to 22.0 hours, with a median of 13.0 hours. The median drainage volume in the first 24 hours was 210 mL. In the following-up data, no deaths or severe complications were observed.

Conclusions: The mini-Bentall procedure through an RAMT approach is a feasible and safe approach with few wounds and good clinical results in patients undergoing aortic root replacement.

Keywords: Aortic root replacement; Bentall procedure; perioperative outcomes; right anterior mini-thoracotomy (RAMT)

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Introduction

Bentall surgery is one of the main treatment options for patients with aortic root diseases. Median sternotomy (MS), which allows excellent exposure of the aorta and aortic root, has been considered the gold standard surgical approach for the Bentall procedure worldwide (1-3). With advances in technology and increased surgeon experience, minimally invasive cardiac surgery has gradually been applied to reduce surgical trauma and achieve better clinical outcomes. The main minimally invasive approaches for cardiac surgery are via mini-sternotomy incision, including the upper hemi-sternotomy approach, right anterior mini-thoracotomy (RAMT), and other partial minimal sternal variations (4-6).

The RAMT approach through the second or the third intercostal space has become a well-established surgical procedure for aortic valve replacement (AVR), with both

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early and long-term benefits, including low postoperative morbidity, fast recovery time, a short hospital stay, and promising cosmetic results (7,8). Only a few centers have reported the use of the RAMT approach in mini-Bentall surgery (9,10). In this study, we analyzed the perioperative data and postoperative outcomes of 27 patients who underwent mini-Bentall surgery with an RAMT in our department while aiming to summarize the characteristics, feasibility, safety, and short-term efficacy of this approach. We present this article in accordance with the STROBE reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-1757/rc).

Methods

Patients

In this single-center, retrospective observational cohort study, the baseline, perioperative, and follow-up data of 27 patients undergoing Bentall surgery via RAMT between September 2020 and April 2022 were analyzed. All patients underwent Bentall surgery for aortic sinus pathology with concomitant aortic valve disease. All surgical procedures were performed by experienced surgeons from the same team in the First Affiliated Hospital of Xi'an Jiaotong University. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by the Ethics Committee of the First Affiliated Hospital of Xi'an Jiaotong University (No. XJTU1AF2021lsk-407), and informed consent was obtained from all participants.

Preoperative evaluation

To exclude surgical contraindications, all participants underwent a series of preoperative examinations, including echocardiography, electrocardiogram, vascular ultrasound, chest computerized tomography (CT), and aorta and coronary computed tomography angiography (CTA). Chest CT and aorta CTA were required for the selection of patients for RAMT.

The inclusion criteria were as follows: (I) the aortic root had an "onion bulb" appearance to the aortic sinus; (II) the ascending aorta was normal or nearly normal in diameter; (III) the distance between the aorta and the left chest wall was less than 10 cm; and (IV) over 50% of the ascending aorta was located on the right side of the sternum.

Patients were excluded if they (I) had infective endocarditis at admission; (II) had previous replacement of the aortic valve; (III) required concomitant valve surgery; (IV) had acute type-A aortic dissection or previous right chest surgery; and (V) had a history of right pleural pathology with adhesions, severe thoracic deformity, severe pulmonary bullous disease, or severe vasculitis and calcification of the ascending aorta wall. Patients whose peripheral percutaneous venous cannulation could not be obtained due to technical difficulties were also excluded.

Operative procedure

Position and preparation

The RAMT approach was performed as described by Johnson *et al.* (10) with minor modifications in the preparation step. The patient was placed in the supine position with a left lateral tilt. External defibrillator pads were placed posteriorly and on the left lateral chest wall (*Figure 1*).

Cardiopulmonary bypass (CPB) establishment

After anesthesia and intubation, venous cannulation (16–18 F) via the right inner jugular vein was performed after one-third heparization (3 mg/kg). The right femoral artery and vein were then exposed through a 4-cm vertical incision in the right groin. Appropriate-sized cannulas were respectively inserted into the common femoral artery and vein using the Seldinger technique. CPB was established with the femoral artery and vein and the right inner jugular vein (*Figure 1*).

Highlight box

Key findings

- The Bentall procedure via right anterior mini-thoracotomy (RAMT) is a safe approach that can be successfully performed on suitable patients.

What is known and what is new?

- The RAMT incision for the Bentall surgery has only been applied in a few centers.
- A total of 27 Bentall procedures via RAMT had been performed in the First Affiliated Hospital of Xi'an Jiaotong University within the past 2 years. To our knowledge, this is the largest number of patients undergoing the mini-Bentall procedure via RAMT incision that has been reported.

What is the implication, and what should change now?

- In this study, we found that patients treated with the Bentall procedure had short hospital stays, low blood loss, better wound healing, low mortality, and improvement in the New York Heart Association functional class, indicating that RAMT is a safe and feasible approach for the Bentall procedure.

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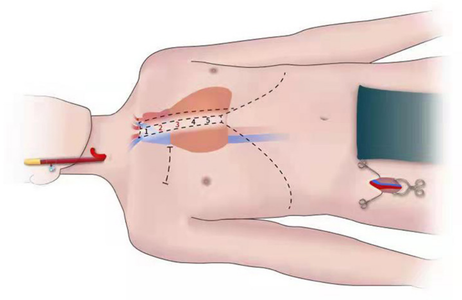

Figure 1 Skin incision and cardiopulmonary bypass establishment were marked on the body surface (the numbers of 1–5 were corresponding to 1–5 ribs, respectively).

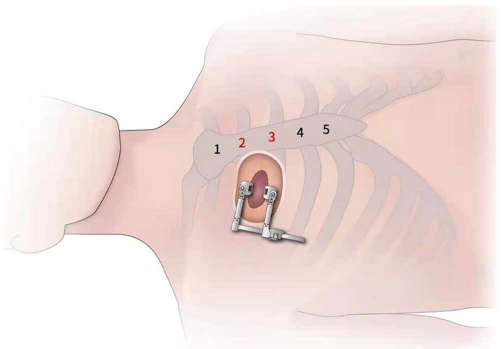

Figure 2 Skin incision made through the intercostal space (the numbers of 1–5 were corresponding to 1–5 ribs, respectively).

Exposure and cardioplegia

A skin incision with a length of approximately 5–7 cm (Figure S1) was placed horizontally along the right second or third intercostal space anteriorly, depending on the location of the aortic annulus relative to the mediastinum (*Figure 2*). A chest retractor was placed for optimal exposure. The pericardium over the aorta was opened vertically, and the incision was extended to the pericardial reflection over the aorta. Pericardial sutures were required for maximum exposure of the operative area, which was hitched tightly with the skin drapes. To enhance heart exposure, a longitudinal incision of 30–40 mm along the right phrenic nerve (inclined to the middle of the sternum) was made in the pericardium. Three stitches were placed on the upper and lower margins of the pericardium and sutured to the skin of the incision. Subsequently, the soft-tissue retractor was implanted into the pericardium through the incision. After being tightened, the heart was pulled to the right intercostal space, facilitating easy operation at the aortic root (Figure S2). After the onset of CPB, the left ventricle venting was inserted into the left ventricle through the right superior pulmonary vein. An aortic cross-clamp was applied through the proximal origin of the innominate artery with a Glauber clamp. Cardioplegia was then delivered directly to the coronary ostia through the transverse aortic root incision.

Placement of the aortic root

The aneurysmal ascending aorta was resected, the aortic valve leaflets were excised, and the annulus was sized. The choice between a biological valve or a mechanical valve is determined by the patient's age, overall health condition, and individual preferences. Once the conduit was secured to the annulus, the right and left coronary buttons were completed using 5-0 polypropylene sutures. Distal anastomosis with the ascending aorta was then performed with 4-0 continuous polypropylene double-layer sutures. Long mineshaft instruments were recommended for the entire anastomosis. Two methods were employed for coronary artery reconstruction: button anastomosis and cavity anastomosis. Button anastomosis involves dissociating and pruning bilateral coronary arteries to create a vessel opening resembling a button. Subsequently, the coronary arteries are anastomosed at the corresponding position on the artificial vessel. Cavity anastomosis involves direct anastomosis of the coronary arteries on the artificial vessel without dissociation. This method is advantageous for hemostasis and wrapping of the residual vessel wall by the artificial vessel, and facilitates the establishment of a right atrium shunt. A knot pusher was used if needed. All suture lines were tightened if they were found loose during aortic cross-clamping. *Figures 3,4* show the suture, valve prosthesis, and conduit.

Weaning off CPB

De-airing was performed under the guidance of transesophageal echocardiography by placing a root cannula in the graft conduit secured by a Pledget Prolene suture. After de-airing, the aortic cross-clamp was removed. The patient was gradually weaned off the bypass. Then, venous cannulation was removed from the right inner jugular vein, and the pouch sutures were tightened (Figure S3). Meanwhile, the femoral cannulas were removed, and the femoral vessels were repaired. After adequate hemostasis, a chest tube was placed through a stab incision in the mid-axillary line. The wound was then closed in layers.

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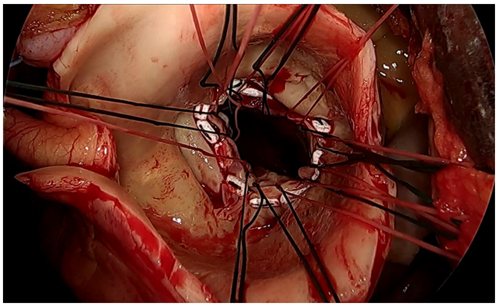

Figure 3 Position of the suture.

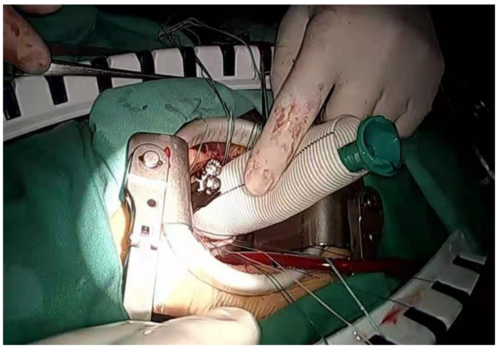

Figure 4 Valve prosthesis and conduit placed through an RAMT incision. RAMT, right anterior mini-thoracotomy.

Figure 5 Skin incision of an RAMT. RAMT, right anterior mini-thoracotomy.

Study protocol

The baseline, perioperative, and follow-up data of all patients were obtained from the institutional database. The definitions and selected variables were in accordance with the Society of Thoracic Surgeons Database. They were followed up by telephone 1 and 6 months after surgery.

Statistical analysis

The data were analyzed using SPSS (v26.0) software (IBM SPSS Statistics, Chicago, IL, USA). Continuous variables were expressed as mean ± standard deviation and compared using Student's *t*-test. Categorical data were shown as total numbers and percentages and compared using the χ^2 test. Non-normally distributed continuous data were expressed as median and interquartile range (IQR). A P value of less than 0.05 was considered statistically significant.

Results

Baseline characteristics

The baseline characteristics of all 27 patients are shown in *Table 1*. All were males, with a median age of 55.0 years (range, 48.0–61.0 years). Among them, four (14.8%) patients had pulmonary hypertension, four (14.8%) had kidney disease, one (3.7%) had diabetes mellitus, 13 (48.1%) had hypertension, seven (25.9%) had cerebral vascular disease, five (18.5%) had coronary artery disease, and eight (29.6%) had arrhythmia. The median left ventricular ejection fraction was 62%, with a median aortic sinus diameter of 55 mm (range, 52–62 mm) and a median ascending aortic dimension of 42 mm (range, 38–46 mm). Notably, all patients (100%) developed aortic regurgitation. One (3.7%) patient was combined with aortic stenosis, and three (11.1%) patients had aortic bicuspid malformation.

Perioperative data

All patients underwent the mini-Bentall procedure with the RAMT approach. The skin incision via RAMT is shown in *Figure 5*. The total surgery time ranged from 4.0 to 5.0 hours, with a median value of 4.5 hours. The median aortic cross-clamp time was 122.0 minutes (IQR: 109.0–145.0 minutes), and the median CPB time was 156.0 minutes (IQR: 143.0–183.0 minutes). The sizes and types of the prosthetic valves and vessels are listed in *Table 2*. During the operation, 13 (48.1%) patients had a right atrial shunt, and one (3.7%) patient was treated with the "button match" coronary artery anastomotic method. Among all 27 cases, six (22.2%) patients underwent combined operations (mitral valvuloplasty or tricuspid

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Table 1 Baseline characteristics

Variables	Value
Number of patients	27
Gender (males)	27 (100.0)
Age (years)	55 (48.0–61.0)
BMI (kg/m^2)	24.2 (22.8–27.1)
GNRI	95.3 (92.3–102.7)
Smoker	19 (70.4)
Drinking	10 (37.0)
Concomitant diseases	
Pulmonary hypertension	4 (14.8)
Kidney disease	4 (14.8)
Diabetes	1 (3.7)
Respiratory disease	8 (29.6)
Hypertension	13 (48.1)
Cerebrovascular events	7 (25.9)
Coronary artery disease	5 (18.5)
Arrhythmia	8 (29.6)
Aortic valve pathology	
Bicuspid aortic valve	3 (11.1)
R	27 (100.0)
Combined R+S	1 (3.7)
NYHA functional class	
II	5 (18.5)
III	16 (59.3)
IV	6 (22.2)
Cardiac index	
LVEF (%)	62.0 (53.0–67.0)
Aorta sinus (mm)	55.0 (52.0–62.0)
Ascending aorta (mm)	42.0 (38.0–46.0)
Area of aortic regurgitation (cm^2)	12.3 (11.0–16.3)
LVEDD (mm)	65.0 (62.0–79.0)
LVESD (mm)	47.0 (40.0–57.0)
Biochemical index	
Hb (g/L)	143.0 (137.0–157.0)
BNP (pg/mL)	1,120.0 (827.0–2,250.0)
ALB (g/L)	39.0 (35.5–41.6)

Data are presented as number, n (%), or median (IQR). BMI, body mass index; GNRI, geriatric nutritional risk index; R, regurgitation; R+S, regurgitation and stenosis; NYHA, New York Heart Association (classification); LVEF, left ventricular ejection fraction; LVEDD, left ventricular endo-diastolic diameter; LVESD, left ventricular endo-systolic diameter; Hb, hemoglobin; BNP, brain natriuretic peptide; ALB, albumin; IQR, interquartile range.

Table 2 Perioperative characteristics

Variables	Value
Operation	
Length of surgery (h)	4.5 (4.0–5.0)
ACC time (min)	122.0 (109.0–145.0)
CPB time (min)	156.0 (143.0–183.0)
Min. body temperature (℃)	30.3 (30.0–31.0)
Blood loss (mL)	150.0 (100.0–200.0)
RBC transfusion rate	16 (59.3)
Size of prosthetic valve (mm)	
Bioprosthetic valve	
23	1 (3.7)
25	10 (37.0)
Mechanical valve	
23	2 (7.4)
25	6 (22.2)
Mechanical valve plus graft	
25	8 (29.6)
Size of graft (mm)	
24	1 (3.7)
25	10 (37.0)
26	4 (14.8)
28	11 (40.7)
30	1 (3.7)
Coronary artery anastomosis	
Cavity anastomosis	26 (96.3)
Button anastomosis	1 (3.7)
Right atrial shunt	13 (48.1)
Concomitant surgery	
MVP or TVP	5 (18.5)
Correction of CHD	1 (3.7)

Data are presented as n (%) or median (IQR). ACC, aortic cross-clamp; CPB, cardiopulmonary bypass; Min., minimum; RBC, red blood cell; MVP, mitral valvuloplasty; TVP, tricuspid valvuloplasty; CHD, congenital defect; IQR, interquartile range.

valvuloplasty: n=5, atrial septal defect repair: n=1). The intraoperative red blood cell (RBC) transfusion rate was 16 (59.3%), and the median intraoperative blood loss was 150.0 mL (IQR: 100.0–200.0 mL). There was no conversion to a full sternotomy incision.

Early postoperative data and clinical complications

The postoperative mechanical ventilation time ranged

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Table 3 Postoperative characteristics

Variables	Value
Length of ICU stay (days)	3.0 [1.75–4.25]
Hospital stay length (days)	15.0 [13–20]
Hospital cost (CNY)	203,551 [160,040–241,684]
Clearance rate of lactate at 6 h (%)	31.25 [–20.3 to 50.0]
Clearance rate of lactate at 12 h (%)	45.83 [5.88–60.0]
Ventilation time (h)	13 [6.5–22]
Analgesics	18 (66.7)
Anticoagulant drugs	8 (29.6)
CRP (mg/L)	36 [17.5–61.2]
Hb (g/L)	115.0 [1106.0–121.0]
BNP (pg/mL)	3,120.0 [1,680.0–6,270.0]
ALB (g/L)	42.9 [39.8–44.4]
Postoperative complications	
Respiratory failure	0
Postoperative arrhythmia	5 (18.5)
Myocardial infarction	0
Pacemaker implantation	0
Cerebrovascular accident	0
Postoperative IABP	0
Acute kidney failure	0
Reoperation for bleeding	3 (11.1)
Wound infections	0
Pneumothorax/subcutaneous emphysema	3 (11.1)
Pulmonary atelectasis	24 (88.9)
Sepsis	0
Rib fracture	0
Pericardial effusion requiring thoracentesis	5 (18.5)
Pleural effusions requiring thoracentesis	7 (25.9)
Paravalvular regurgitation	0
RBC transfusion rate	7 (25.9)
Chest tubes drainage at the first 24 h (mL)	210.0 [135.0–300.0]
Time of drainage tube (days)	5.0 [4.0–9.0]
In-hospital mortality	0

Data are presented as n (%) or median [IQR]. ICU, intensive care unit; CRP, C-reactive protein; Hb, hemoglobin; BNP, brain natriuretic peptide; ALB, albumin; IABP, intra-aortic balloon pump; RBC, red blood cell; IQR, interquartile range.

from 6.5 to 22.0 hours, with a median of 13.0 hours. The median lactate clearance rate at 6 hours after the operation was 31.25%, while that at 12 hours was 45.83%. The median drainage volume in the first 24 hours was 210 mL (IQR: 135–300 mL). Seven (25.9%) patients received RBC transfusions, and three (11.1%) patients underwent exploratory thoracotomy for bleeding. The common postoperative complications were pleural effusion requiring puncture (25.9%), pericardial effusion requiring puncture (18.5%), postoperative arrhythmia (18.5%), and pneumothorax (11.1%). The median intensive care unit stay was 3 days (range, 1.75–4.25 days). The total hospital stay ranged from 13 to 20 days, with a median stay of 15 days. No patients showed significant postoperative complications, including postoperative death, respiratory failure, myocardial infarction, pacemaker implantation, cerebrovascular accidents, intra-aortic balloon pump implantation, or acute kidney failure requiring hemodialysis (*Table 3*).

Learning curve analysis of Bentall via RAMT access

The patients were divided into three groups according to the date of operation. The first nine patients were assigned to Group A, the middle nine to Group B, and the last nine to Group C. Compared with Group A, the patients in Groups B and C showed reduced operation time, aortic cross-clamp time, CPB time, total hospitalization stay, and hospitalization cost. The operation time (P=0.02), aortic cross-clamp time (P=0.005), and CPB time (P=0.006) were significantly different between the Group A and B patients (*Table 4*). However, the differences were not statistically significant between Group A and Group C, neither in Group B and Group C.

Follow-up results

The median follow-up time of all patients was 5 months (IQR: 2.5–12.0 months). The shortest follow-up was 2 months, while the longest was 21 months. The New York Heart Association functional class of the patients had been improved after surgery, with no cases in Class III or IV. The clinical symptoms also improved, with no death or reoperation. At the end of the outpatient visit or telephone follow-up, no case showed poor incision healing or infection. Periprosthetic fistulas occurred in one patient, but no significant aortic valve regurgitation was determined by echocardiography (*Table 5*).

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Table 4 Learning curve analysis

Variables	Group A (n=9)	Group B (n=9)	Group C (n=9)	Groups B *vs.* A		Groups C *vs.* A		Groups C *vs.* B	
				t	P	*t*	P	*t*	P
Operation time (h)	5.22±0.97	4.22±0.66	4.66±1.06	2.546	0.02	1.159	0.26	−1.064	0.30
ACC time (min)	151.89±33.35	112.78±14.83	128.44±23.43	3.214	0.005	1.725	0.10	−1.695	0.11
CPB time (min)	190.56±33.97	148.00±15.28	161.22±28.77	3.427	0.006	1.977	0.06	−1.218	0.24
Hospital stay (days)	18.67±4.69	16.67±5.19	15.11±6.23	0.857	0.40	1.367	0.19	0.575	0.57
Hospital cost (CNY)	230,394±60,759	212,124±50,371	196,652±85,306	0.694	0.49	0.967	0.34	0.469	0.64

Data are presented as mean ± standard deviation. Group A, the first nine patients; Group B, the middle nine patients; Group C, the last nine patients. ACC, aortic cross-clamp; CPB, cardiopulmonary bypass.

Table 5 Follow-up results

Variables	Value
Follow-up	
Number of patients	27 (100.0)
Duration of follow-up (months)	5 (2.5–12)
Reoperation	0
Survival	27 (100.0)
Poor incision healing	0
Aortic regurgitation	0
Paravalvular leakage	1 (3.7)
NYHA functional class	
I	21 (77.8)
II	6 (22.2)

Data are presented as n (%) or median (IQR). NYHA, New York Heart Association (classification); IQR, interquartile range.

Discussion

With the rapid development of minimally invasive cardiac surgery, an increasing number of patients have benefited from this approach. The current minimally invasive cardiac approaches include S-shaped partial sternotomy, upper J incision, upper T incision, right parasternal incision, inferior segment sternotomy, and incisions between ribs (11-14). As multiple processes are involved in the Bentall procedure, such as AVR, coronary anastomosis, and ascending aorta replacement, upper sternotomy has become the main incision for this procedure (13). Johnson *et al.* (10) reported the first Bentall procedure via RAMT, which showed favorable outcomes. However, this approach has only been applied in a few centers. A total of 27 Bentall procedures via RAMT had been performed in our hospital within the past 2 years. To our knowledge, this is the largest number of patients undergoing the mini-Bentall procedure via an RAMT incision that has been reported. In this study, we found that patients treated with the Bentall procedure had short hospital stays, low blood loss, better wound healing, low mortality, and improvement in the New York Heart Association functional class, indicating that RAMT is a safe and feasible approach for the Bentall procedure.

The major advantages of the RAMT approach compared with full or partial sternotomy are shorter hospitalization time, faster functional recovery, and less blood transfusion and sternal complications (7,8,15). Among the 27 cases reported in this study, 22 received their procedure through the right second intercostal incision, while five were through the right third intercostal incision due to the combination of other operations (one for atrial septal repair and four for mitral valve repair). The median aorta occlusion time of these patients was 122 minutes, which was much shorter than that reported by Johnson *et al.* (10) (161.9±32.1 minutes), but longer than that published by Ji *et al.* (9) [95.0 (IQR: 85.5–98.8) minutes]. The CPB and operation time of our patients was 156.0 (IQR: 143.0–183.0) minutes, which was significantly shorter than that reported by Johnson *et al.* (10) (202.9±47.8 minutes) but longer than that presented by Ji *et al.* (9) [138.5 (IQR: 130.5–163.5) minutes]. These differences may be mainly explained by varied surgical experiences in different teams and combined operations. In our center, the rate of minimally invasive surgery is approximately 30–40%.

Coronary artery anastomosis remains the major challenge to the Bentall procedure. Intracavity anastomosis is a common surgical procedure that exhibits high clinical efficacy, especially for the aortic root-right atrium shunt

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(16,17). Another button anastomosis facilitates the exposure of the coronary arteries; however, patients treated with this method are more likely to bleed in the root and coronary anastomosis position, leading to failure in operations (18). In this study, 26 (96.3%) patients underwent intracavity anastomosis, including 13 (48.1%) cases with the right atrial shunt, which ensured the successful completion of the operation and allowed surgeons to gain more experience. Only one patient was treated with button anastomosis without the right atrial shunt.

The learning curve analysis in this study showed a declining trend in the operation time, aortic cross-clamp time, CPB time, total hospital stay, and hospitalization costs of Groups B and C in comparison with Group A, suggesting increased experience of surgeons along with performing this kind of surgery. Therefore, we recommend gaining extensive experience in AVR via RAMT incision before performing the mini-Bentall procedure. However, the operation time, aortic cross-clamp time, and CPB time of Group C were longer than those of Group B, mainly due to a longer operation time in three patients requiring combined operation.

Our follow-up data suggested that the Bentall procedure via RAMT is feasible in selected patients with sufficient preoperative preparation. Chest CT scans and echocardiography need to be performed to assess the eligibility of patients for this method. Preoperative chest CT can not only visualize the positional relationship between the aortic root and the sternum and intercostal space but also exclude patients with pleural adhesions, severe deformities of the chest wall, or severe pulmonary bulla. Echocardiography is used to evaluate the severity of heart valves and heart function. Patients with vessel malformation or calcification in the femoral artery and vein should be chosen carefully according to the examination results.

In this study, the median body mass index of all patients was 24.2 kg/m^2, with a range of 22.8–27.1 kg/m^2. The median diameters of the ascending aorta and aorta sinus were 42 and 55 mm, respectively. The eligibility criteria for this operation are summarized as follows: (I) the patient possesses a markedly dilated aortic sinus and no obvious dilated ascending aorta; (II) the distance between the aorta and the left chest wall is less than 10 cm; and (III) the position of the aorta deviates to the left (i.e., over 50% on the right side of the sternum).

Our study has several limitations. First, it was a single-center observational study, so the results may not be generalizable to the entire population. Hence, future studies with larger sample sizes and longer follow-up times are required to determine the long-term safety and efficacy of the Bentall procedure via RMAT incision. In addition, only male patients were recruited for this study, so female patients should be included in future investigations.

Conclusions

In summary, the Bentall procedure via an RMAT is a safe approach that can be successfully performed on suitable patients.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-1757/rc

Data Sharing Statement: Available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-1757/dss

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-1757/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by the Ethics Committee of the First Affiliated Hospital of Xi'an Jiaotong University (No. XJTU1AF2021lsk-407), and informed consent was obtained from all participants.

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