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Bentall Procedure: A Single Center Experience Over 8 Years

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Abstract **Original Research Article**

Background: Bentall procedure is a well-established surgical technique for the management of aortic root pathologies with significant aortic regurgitation, particularly in patients with aortic dissection or aneurysm. This study aims to evaluate in-hospital early outcomes and perioperative factors associated with Bentall procedures performed at a single tertiary referral center in Malaysia over an eight-year period. ***Methods:*** A retrospective review was conducted on 40 patients who underwent Bentall procedure at Hospital Sultan Idris Shah (HSIS), Selangor, between 2016 and June 2023. Demographic data, operative variables and early postoperative outcomes were analyzed. The primary endpoint was early postoperative mortality. Patients were stratified into two groups: those undergoing isolated Bentall procedures and those undergoing Bentall procedures with concomitant cardiac surgeries. Comparative statistical analyses were performed using SPSS version 28. ***Results:*** Major postoperative complications of both groups were sepsis (55.0%), renal failure requiring dialysis (27.5%), and stroke (17.5%). The overall early mortality rate was 32.5%. Mortality was comparable between patients undergoing isolated Bentall procedures (31.8%) and those with concomitant procedures (33.3%) (p=0.919). However, cardiopulmonary bypass (CPB) and aortic cross-clamp times were significantly longer in the concomitant group (p=0.011 and p=0.002 respectively). Survivors had significantly shorter CPB times (mean 350 vs. 452 minutes; p=0.023) and fewer incidences of reoperation for hemodynamic instability (p=0.031). Survivors also had significantly longer CICU and total hospital stays. ***Conclusion:*** Despite its complexity, Bentall procedure remains a viable and essential intervention for aortic root disease. Mortality is influenced more by overall patient condition and procedural complexity than by the addition of concomitant surgeries alone. Improved outcomes may be achieved through focused aortic teams, surgical experience, and enhanced perioperative care, especially in emergent or resource-limited settings.

Keywords: Bentall Procedure, Mortality, Aortic Root, Aortic Aneurysm, Aortic Dissection, Cardiopulmonary Bypass.

BACKGROUND

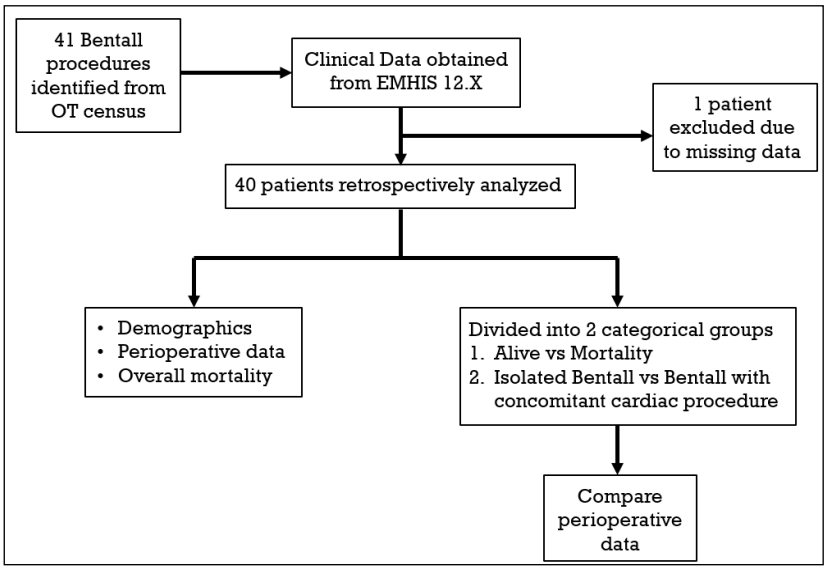
The aortic root is the beginning of ascending aorta, whose disease often presents significant challenges in surgical management. Prior to the 1970s, surgeries involving the aortic root were primarily conducted in emergency settings, and commonly on critically ill patients with acute aortic complications [1]. However, the introduction of the innovative surgical technique by Hugh Bentall in 1968 [2], along with its subsequent long-term success, led to the development of prophylactic surgeries in specialized aortic centers. This shift helped mitigate the risks associated with aortic rupture and dissection [1]. Reported mortality rates for the Bentall procedure range from 2% to 11.2% [3-7]. This study reviews our center's experience with Bentall surgery over an eight-year period between 2016 to 2023.

METHODS

Hospital Sultan Idris Shah (HSIS) in Serdang, Selangor, Malaysia, is a multi-surgeon cardiac center and serves as one of the major cardiothoracic referral centers in the central region. The center handles a wide range of referrals, with a particular focus on aortic pathologies such as dissections and aneurysms.

This retrospective study reviews our center's experience in managing aortic pathologies, with particular emphasis on Bentall procedure. The primary objective of the study is to assess overall mortality rate associated with the procedure. Secondary objective is to investigate whether concomitant cardiac surgeries performed during the Bentall procedure influenced mortality outcomes.

Patients who underwent Bentall procedure at HSIS from January 2016 to June 2023 were identified through operating theatre records. The relevant patient information and clinical data were retrieved from our in-hospital electronic medical database, EMHIS 12.X. Statistical analysis was conducted using SPSS version 28.



Flow chart 1: Methodology

Patient Characteristics

We identified 41 patients retrospectively. One patient was excluded due to incomplete data. Of these patients, 29 (72.5%) patients were male and 11 (27.5%) were female. The mean age at the time of surgery was 40.8 years (19–63 years). 18 patients (47.5%) had hypertension, 3 patients (7.5%) had diabetes mellitus and 13 patients (32.5%) had either preoperative acute kidney injury or chronic kidney disease. Additionally, 13 patients (32.5%) were active smokers.

Ejection fraction (EF) was assessed using the 2020 British Society of Echocardiography (BSE) classification. Of the patients, 19 (47.5%) had a normal EF (≥55%), 7 (17.5%) had a borderline low EF (50-54%), 8 (20.0%) had impaired EF (36-49%), and 6 (15.0%) had severely impaired EF (≤35%). Regarding the timing of surgery, 31 patients (77.5%) underwent emergency surgeries, while 9 (22.5%) had elective procedures. The primary indications for surgery were aortic dissection in 29 patients (72.5%) and aortic aneurysm in 11 patients (27.5%). Preoperative data are summarized in Table 1.

Table 1: Pre-operative Data

Pre-Operative Data (N=40)	
Age [Mean ± SD]	40.8 (SD)
Gender	n (%)
Male	29 (72.5)
Female	11 (27.5)
Hypertension	19 (47.5)
Diabetes Mellitus	3 (7.5)
CKD / AKI	13 (32.5)
Active smoker	13 (32.5)
Ejection Fraction (%)	
Normal ≥ 55	19 (47.5)
Borderline low 50-54	7 (17.5)
Impaired 36-49	8 (20.0)
Severely impaired ≤ 35	6 (15.0)
Timing of operation	
Elective	9 (22.5)
Emergency	31 (77.5)
Aortic Pathology	
Aneurysm	11 (27.5)
Dissection	29 (72.5)

Surgical Technique

The surgical techniques were varied based on the operating surgeon preference and individual patient characteristics. Two types of grafts were utilized at our center: the St. Jude Medical aortic valved graft and the Medtronic ATS aortic valved graft. All of these cases were performed through a median sternotomy approach.

CPB was established either by cannulating distal ascending aorta, femoral artery, or axillary artery for arterial cannulation, and right atrium or femoral vein for venous cannulation. Myocardial protection was achieved through antegrade (directly into the coronary ostia), retrograde or combined anterograde and retrograde intermittent cold-blood cardioplegia. Deep hypothermic circulatory arrest (DHCA) was employed in 22 patients (55.0%).

The coronary buttons were excised and mobilized with a rim of the aortic wall patch. The proximal anastomosis was performed using pledgeted interrupted sutures at the aortic valve annulus. The distal graft-to-aorta anastomosis was completed with continuous suturing, following reinforcement of the aortic wall with a pair of Teflon strips. The coronary button anastomoses were similarly performed using continuous suturing.

Concomitant procedures were undertaken in 18 patients (45.0%). These included coronary artery bypass grafting (CABG) in 4 patients (10.0%), mitral valve surgery in 1 patient (2.5%), tricuspid valve surgery in 1 patient (2.5%), replacement or repair involving the arch in 9 patients (22.5%), and combined CABG with arch surgery in 3 patients (7.5%). Comprehensive operative details are provided in Table 2 below.

Table 2: Operative data

Operative Data	n (%)
Implanted Valve Type	
Mechanical	37 (92.5)
Tissue	3 (7.5)
Concomitant Cardiac Procedure	
None (Isolated Bentall)	22 (55.0)
Mitral valve surgery	1 (2.5)
Tricuspid valve surgery	1 (2.5)
CABG	4 (10)
Arch surgery	9 (22.5)
CABG and Arch surgery	3 (7.5)
Cardiopulmonary bypass	
Operation time (min) [Average (range)]	582.2 (367-845)
Cardiopulmonary bypass time (min) [Mean (SD)]	398.85 (129.26)
Aortic cross clamp time (min) [Mean (SD)]	316.35 (99.30)
DHCA [n (%)]	22 (55.0)

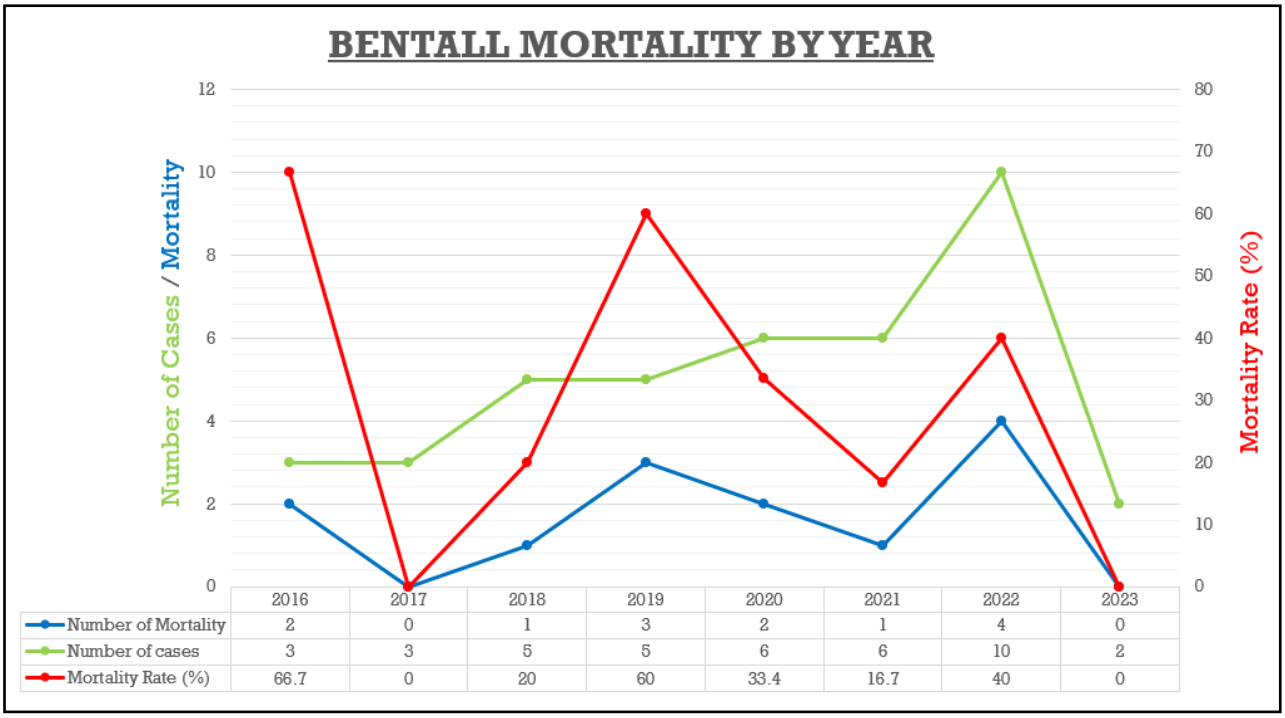
RESULTS

Early outcomes

We looked into the in-hospital early outcomes of all 40 patients in the postoperative period. Our primary endpoint, which looks at the overall mortality, showed that among our 40 patients, 13 patients did not survive, accounting to an overall mortality rate of 32.5%.

Table 3: Mortality rates by year

Year	Number of cases	Number of Mortality	Mortality Rate (%)
2016	3	2	66.7
2017	3	0	0
2018	5	1	20
2019	5	3	60
2020	6	2	33.4
2021	6	1	16.7
2022	10	4	40
2023	2	0	0
Total	**40**	**13**	**32.5**



Graph 1: Number of cases/mortality and mortality rates by year

A slightly higher mortality rate was observed in patients undergoing the Bentall procedure with concomitant cardiac procedures compared to those undergoing the isolated Bentall procedure. In the isolated Bentall procedure group, 7 out of 22 patients (31.8%) passed away, while 6 out of 18 patients (33.3%) in the concomitant procedures group succumbed. However, a Chi-Square test for independence indicated that the difference in mortality rates between the isolated Bentall procedure group and the concomitant procedures group was not statistically significant (p=0.919).

Table 4: Isolated Bentall vs Bentall with other concomitant cardiac procedures, number of cases and mortality rates

	Alive, n (%)	Mortality, n (%)	Total
Isolated Bentall	15(68.2)	7(31.8)	22
Concomitant procedures	12(66.7)	6(33.3)	18

Our post-operative data (Table5) shows 6 (15.0%) patients had chest reopen for bleeding, while 5 (12.5%) were reopened for hemodynamic instability. 9 (22.5%) patients had arrhythmias, 7 (17.5%) had stroke, 11 (27.5%) had renal failure requiring renal replacement therapy (RRT), 11 (27.5%) had hepatitis and 22 (55.0%) went into sepsis. The average total hospital stay was 18.45 days (SD, 17.11), average duration of intubation was 6.63 days (SD, 10.48) and average length of cardiothoracic intensive care unit (CICU) stay was 10.27 days (SD, 12.30).

Table 5: Post-operative Data of all of our patients

Post-Operative Data	n (%)
Reopen	
Bleeding	6 (15.0)
Hemodynamic instability	5 (12.5)
Complications	
Arrhythmias	9 (22.5)
Stroke	7 (17.5)
Renal failure requiring RRT	11 (27.5)
Hepatitis	11 (27.5)
Sepsis	22 (55.0)
Hospital Stay (Days)	
Intubated [Mean (SD)]	6.63 (10.48)
CICU stay [Mean (SD)]	10.27 (12.30)
Total hospital stay [Mean (SD)]	18.45 (17.11)

Note: 1 patient may develop more than 1 complications

For the purpose of comparing perioperative data, the patients were categorized into two groups: survivors and non-survivors. The survivor group had shorter CPB time, with a mean of 350 minutes (SD, 132), compared to 452 minutes (SD, 203) in the non-survivor group (p = 0.023). Additionally, fewer patients in the survivor group (1 patient) underwent chest reopens due to hemodynamic instability, compared to 4 patients (80%) in the non-survivor group (p = 0.031). Conversely, the length of stay in the cardiac intensive care unit (CICU) was significantly longer in the survivor group, with a median duration of 8 days (IQR, 7), compared to a median of 2 days (IQR, 7) in the non-survivor group (p = 0.002). The total hospital stay was also significantly prolonged in the survivor group, with a median of 17 days (IQR, 19), whereas the non-survivor group had a median stay of 3 days (IQR, 7) (p < 0.001). Non-survivor spent lesser days in ICU & hospital because they died early post-op.

Table 6: Survivors vs non-survivors group. Pre-operative data

Preoperative Data	Survivors, n (%)	Non-survivors, n (%)	p value
Total patients	**27**	**13**	
Age [Mean (SD)]	41.37 (13.60)	39.69 (8.55)	0.638
Gender			0.052
Male	17 (58.6	12 (41.1)	
Female	10 (90.9)	1 (9.1)	
Hypertension	11 (57.9)	8 (42.1)	0.217
Diabetes Mellitus	3 (100)	0 (0)	0.538
CKD / AKI	8 (61.5)	5 (38.5)	0.576
Active smoker	8 (61.5)	5 (38.5)	0.576
Ejection Fraction (%)			0.09
Normal ≥ 55	15 (78.9)	4 (21.1)	
Borderline low 50-54	6 (85.7)	1 (14.3)	
Impaired 36-49	4 (50.0)	4 (50.0)	
Severely impaired ≤ 35	2 (33.3)	4 (66.7)	
Timing of operation			0.952
Elective	6 (66.7)	3 (33.3)	
Emergency	21 (67.7)	10 (32.3)	
Aortic Pathology			0.748
Aneurysm	7 (63.6)	4 (36.4)	
Dissection	20 (69.0)	9 (31.0)	

Table 7: Survivors vs non-survivors group. Operative and post-operative data

Operative Data	Survivors, n (%)	Non-survivors, n (%)	p value
Procedure			0.919
Isolated Bentall	15 (68.2)	7 (31.8)	
Concomitant procedures	12 (66.7)	6 (33.3)	
Cardiopulmonary bypass			
CPB time (min) [Median (IQR)]	350 (132)	452 (203)	0.023
Cross clamp time (min) [Median (IQR)]	289 (125)	345 (180)	0.112
Post-Operative Data			
Reopen			
Bleeding	3 (50)	3 (50)	0.37
Hemodynamic instability	1 (20)	4 (80)	0.031
Complications			
Arrhythmias	6 (66.7)	3 (33.3)	0.952
Stroke	4 (57.1)	3 (42.9)	0.662
Renal failure requiring RRT	6 (54.5)	5 (45.5)	0.281
Hepatitis	8 (72.7)	3 (27.3)	0.664
Sepsis	17 (77.3)	5 (22.7)	0.145
Hospital Stay (Days)			
Ventilated [Median (IQR)]	6 (4)	2 (7)	0.245
CICU stay [Median (IQR)]	8 (7)	2 (7)	0.002
Total hospital stay [Median (IQR)]	17 (19)	3 (7)	<0.001

Next, we divided the patients into isolated Bentall and Bentall with concomitant procedure groups. Comparing their perioperative data, we noted there were significantly more aneurysms in the isolated Bentall

group that is 9 (81.8%) patients, versus only 2 (18.2%) patients in the concomitant group, p=0.036.

An independent-sample t-test was run on the CPB time and cross-clamp time data with 95% confidence interval (CI). The results obtained showed that the mean CPB time in those who had isolated Bentall (Mean=353.05, SD=121.365) were significantly lower than those with other concomitant procedures (Mean=454.83, SD=118.759), with the p-value of 0.011 (95% CI). Therefore, showing a significant association between CPB time and number of procedures. The cross-clamp time was significantly different between the isolated Bentall (Mean=273.68, SD=73.978) and concomitant procedure (Mean=368.50, SD=103.072), p=0.002. Therefore, there is significant difference between cross clamp time and number of procedures.

Table 8: Isolated Bentall vs Bentall with concomitant procedure groups. Pre-operative data

Preoperative Data	Isolated Bentall, n (%)	Concomitant, n (%)	p value
Total patients	22	18	
Age [Mean (SD)]	39.36 (13.74)	42.61 (9.81)	0.405
Gender			0.165
Male	14 (48.3)	15 (51.7)	
Female	8 (72.7)	3 (27.3)	
Hypertension	9 (47.4)	10 (62.6)	0.356
Diabetes Mellitus	3 (100)	0 (0)	0.238
CKD / AKI	6 (46.2)	7 (53.8)	0.435
Active smoker	8 (61.5)	5 (38.5)	0.564
Ejection Fraction (%)			0.218
Normal ≥ 55	9 (47.4)	10 (52.6)	
Borderline low 50-54	6 (85.7)	1 (14.3)	
Impaired 36-49	3 (37.5)	5 (62.5)	
Severely impaired ≤ 35	4 (66.7)	2 (33.3)	
Timing of operation			0.476
Elective	6 (66.7)	3 (33.3)	
Emergency	16 (51.6)	15 (48.4)	
Aortic Pathology			0.036
Aneurysm	9 (81.8)	2 (18.2)	
Dissection	13 (44.8)	16 (55.2)	

Table 9: Isolated Bentall vs Bentall with concomitant groups. Operative and post-operative data

Operative Data	Isolated Bentall n (%)	Concomitant n (%)	p value
Cardiopulmonary bypass			
CPB time (min) [Mean (SD)]	353.05 (121.37)	454.83 (118.76)	0.011
Cross clamp time (min) [Mean (SD)]	273.68 (73.98)	368.5 (103.07)	0.002
Post-Operative Data			
Reopen			
Bleeding	5 (83.3)	1 (16.7)	0.197
Hemodynamic instability	2 (40.0)	3 (60.0)	0.642
Complications			
Arrhythmias	4 (44.4)	5 (55.6)	0.705
Stroke	5 (71.4)	2 (28.6)	0.427
Renal failure requiring RRT	6 (54.5)	5 (45.5)	0.972
Hepatitis	6 (54.5)	5 (45.5)	0.972
Sepsis	11 (50)	11 (50)	0.482
Hospital Stay (Days)			
Ventilated [Median (IQR)]	3.5 (7)	6 (4)	0.324
CICU stay [Median (IQR)]	7.5 (5)	7.5 (10)	0.557
Total hospital stay [Median (IQR)]	14.5 (14)	15 (31)	0.533
Condition at discharge			0.919
Alive	15 (55.6)	12 (44.4)	
Mortality	7 (53.8)	6 (46.2)	

DISCUSSION

Bentall surgery remains fundamental for management of aortic root pathologies. Bentall surgery however, has undergone numerous improvisations since its introduction leading to better outcomes with broad applicability [2]. Our review highlights the evolution of

the Bentall procedure and its use in our setting taking into account surgical techniques, concomitant procedures, patient selection and surgical outcome.

Current Practice

In present times, usage of composite grafts with biological or mechanical aortic valves have allowed for surgeries to be tailored according to patient needs. Nevertheless, the choice on valve-types for younger patients weighing between long-term durability and anticoagulation requirements remains a tough decision [8].

One of the most important developments was the transition from the classical inclusion technique to the modern "button" technique, significantly reducing complications such as coronary ostial pseudoaneurysm formation and thromboembolic events [9].

Local Outcomes

Our single-center experience studying 40 patients undergoing Bentall procedures between 2016 and 2023 showed an overall early postoperative mortality rate of 32.5%. While high compared to global benchmarks—where elective Bentall procedures often show early mortality rates below 10% in high-volume aortic centers [10]—our results reflect a real-world cohort including both elective and emergency presentations, as well as concomitant procedures such as CABG. Bentall is technically challenging procedure with steep learning curve, low volume aortic center like us do not perform Bentall on a regular basis. Kálmán Benke *et al.,* reported that it takes 25–30 operations to give the surgeon confidence and experience to acquire better results. [3]

Most importantly, there were no statistically significant differences in mortality between isolated Bentall procedures (31.8%) and Bentall performed with concomitant cardiac procedures (33.3%, p=0.919). However, procedural complexity was clearly associated with longer CPB and cross-clamp times, which were significantly higher in the concomitant group (p=0.011 and p=0.002) as compared with isolated Bentall procedure, aligning with established associations between procedural duration and postoperative morbidity. [11]

Complications of Bentall Surgery

Postoperative complications were common where sepsis occurred in 55% of cases, renal failure requiring renal replacement therapy in 27.5%, and stroke in 17.5%. These findings highlight the significant perioperative burden of Bentall surgery, particularly in resource-limited or emergent settings. The rate of re-exploration for bleeding or hemodynamic instability (27.5% combined) and the incidence of arrhythmias (22.5%) are consistent with existing literature, which identifies these as common complications following complex aortic root surgery. [12]

A deeper analysis revealed meaningful distinctions between survivors and non-survivors. Survivors, compared to those who died, had significantly shorter bypass times (mean 350 vs. 452 minutes, p=0.023) and were less likely to undergo chest re-opening for hemodynamic instability (p=0.031). Intriguingly, survivors had significantly longer CICU and overall hospital stays—possibly reflecting the prolonged post-operative recovery period.

Valve-Sparing Techniques

Alternatives such as valve-sparing aortic root replacement (VSRR), especially David procedure, are gaining traction in younger patients with favorable root anatomy. While this procedure avoids prosthetic valve implantation and long-term anticoagulation, it is a very technically challenging procedures with small margin of error, and hence, not taken up by the masses. Iannacone EM *et.al* concludes that VSRR combined with good cusp repair techniques further improves durability, however Bentall operation remains a durable procedure in young patient but with a price of anticoagulant and thromboembolism related late complications. [13]

The future for Bentall Surgery

Although mostly investigational, there is mounting interest in minimally invasive and endovascular procedures for aortic root repair. The development of new bioprostheses and advances in perioperative management may reduce complications and improve long-term outcomes. Our data suggest that future research should continue to explore modifiable risk factors such as CPB duration and infection control protocols, particularly in settings where complex surgeries are coupled with limited resources in emergent settings. A suggestion for non-aortic centers in developing nations would be to have an aortic team whereby the management of patients requiring Bentall operation can be fine-tuned and executed effectively. A potential drawback of an aortic team would be team burnout and fatigue if all the aortic work were to fall on the same few individuals.

CONCLUSION

In conclusion, Bentall procedure, despite its numerous modifications, remains a gold standard for aortic root replacement. Our study highlights its durability and the considerable early postoperative risks, particularly in complex or emergency cases. Ongoing innovations in surgical technique, prosthesis design, and perioperative care are likely to further improve outcomes. However, careful patient selection, surgical expertise, and long-term follow-up remain essential to optimize results and guide future practice.

Ethical Approval: This case report has been registered under National Medical Research Register (NMRR).

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Conflict of Interest Disclosure: The authors declare no conflict of interest with regards to the content of this report.

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