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Upper Hemisternotomy Versus Full Sternotomy for Aortic Root Replacement: A Propensity Score–Matched Study

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Abstract

Background

Aortic root replacement (ARR) is typically performed via full sternotomy (FS). However, upper hemisternotomy (UHS) may provide sufficient exposure to the proximal aorta with the potential for faster recovery. This study compares outcomes between patients undergoing ARR via UHS and those undergoing FS.

Methods

A retrospective analysis was performed on patients who underwent ARR between June 2014 and June 2025 by a single surgeon. Patients undergoing UHS were matched 1:1 by propensity score with patients undergoing FS. Preoperative characteristics and intraoperative and postoperative outcomes were assessed.

Results

A total of 172 patients were identified, of whom 72 matched pairs were included in the analysis. After matching, median cardiopulmonary bypass times were significantly shorter in the UHS group (174 [IQR, 160–199] vs 197 [IQR, 163–231] min; *P* = 0.02), whereas aortic cross-clamp times were similar between groups (150 [IQR, 132–166] vs 155 [IQR, 132–197] min; *P* = 0.12). Compared with the FS group, the UHS group had shorter intensive care unit and hospital stays (3 [IQR, 2–4] vs 4 [IQR, 3–6] days, *P* < 0.001; and 6 [IQR, 5.0–8.3] vs 7.5 [IQR, 6.0–10] days, *P* = 0.003, respectively). There was no significant difference in 1-year (*P* = 0.50) and 5-year (*P* = 0.68) survival between groups.

Conclusions

The UHS approach is safe and feasible for ARR, with faster recovery and outcomes otherwise comparable to FS.

BACKGROUND

Aortic root replacement (ARR) is a technically demanding procedure traditionally performed via full sternotomy (FS), which provides broad exposure to the proximal aorta and heart. Minimally invasive approaches remain uncommon because of greater technical complexity, constrained exposure, and a steep learning curve.[1–8] We have previously demonstrated the feasibility of upper hemisternotomy (UHS) for supracoronary ascending aortic and aortic valve replacement (AVR), as well as proximal aortic and hemiarch replacement.[1,2]

Previous reports of UHS for ARR, including both composite graft (Bentall) and valve-sparing (David) procedures, have been limited by small, relatively dated cohorts, heterogeneity in surgeons, patient populations, and operative techniques, as well as incomplete follow-up.[3–9]

Accordingly, we compared the preoperative characteristics and intraoperative, postoperative, and midterm outcomes in a contemporary propensity-matched cohort of patients undergoing ARR via UHS or FS, with all procedures performed by a single surgeon.

METHODS

Patient selection

From June 2014 to June 2025, 172 consecutive patients underwent elective or urgent ARR by a single surgeon (K.A.P.). Indications included an aortic root diameter ≥ 5 cm or ≥ 4.5 cm in the presence of a bicuspid aortic valve. Ascending aortic replacement was also performed when the tubular ascending aorta measured ≥ 4 cm, demonstrated significant aneurysmal degeneration intraoperatively, or when the patient had a connective tissue disorder. Patients with pliable bicuspid or tricuspid aortic valve cusps and no stenosis, fenestrations, or calcification underwent the David procedure; all other patients underwent the Bentall procedure, except for one patient with infective endocarditis who received a subannular Freestyle stentless porcine aortic root bioprosthesis (Medtronic, Minneapolis, MN, USA).

Patients requiring concomitant cardiac procedures (e.g., coronary artery bypass grafting [CABG] or mitral valve surgery), hemiarch or total arch replacement with hypothermic circulatory arrest, selective sinus replacement, or emergent surgery, including acute type A aortic dissection (ATAAD) repair, were excluded. To minimize selection bias between the UHS and FS groups, exclusions were largely limited to procedures not performed via UHS by the surgeon.

Patients were identified from a prospectively maintained aortic registry and analyzed retrospectively. Follow-up data were obtained from the registry, hospital and outpatient records, and online obituaries. The Institutional Review Board approved the study on September 13, 2023 (iRISID-2023-2417) and waived informed consent because of the retrospective design.

Data analysis

The primary outcomes were operative mortality and 1- and 5-year survival. Secondary outcomes included stroke, duration of mechanical ventilation, prolonged ventilatory support (PVS), reintubation, re-exploration for bleeding, cardiopulmonary bypass (CPB) and aortic cross-clamp (ACC) times, blood product utilization, intensive care unit (ICU) and hospital length of stay (LOS), freedom from reoperation, and left ventricular ejection fraction.

Operative mortality was defined as in-hospital or 30-day postoperative death. Ever-smoking was defined as any prior or current history of cigarette smoking. Stroke was defined as a persistent neurological

deficit lasting ≥ 72 hours, and PVS as mechanical ventilation > 48 hours postoperatively. Complications were defined according to Society of Thoracic Surgeons Adult Cardiac Surgery Database criteria.

Statistical analysis

Preoperative characteristics and intraoperative and postoperative outcomes were analyzed. Propensity score-matching was performed to generate comparable cohorts using 1:1 nearest-neighbor matching without replacement. Propensity scores were estimated with logistic regression incorporating age, sex, body mass index, left ventricular ejection fraction, comorbidities (diabetes, hypertension, coronary artery disease, ever-smoking, chronic obstructive pulmonary disease, peripheral artery disease, and cerebrovascular disease), New York Heart Association class, degree of aortic insufficiency, prior cardiac surgery, prior aortic surgery, presenting symptoms, surgical indication and urgency, and aortic root and ascending aortic diameters. Matching used a caliper width of 0.2, and standardized mean differences assessed post matching balance.

Categorical variables are presented as frequencies and percentages. Normality was assessed with the Kolmogorov-Smirnov test; continuous variables were nonnormally distributed and are reported as medians with interquartile ranges (IQR). Categorical variables were compared using Pearson χ^2 or Fisher exact tests, and continuous variables with the Mann–Whitney U test. Survival was analyzed using Kaplan–Meier methods and compared with the log-rank test. A 2-sided $P < 0.05$ was considered statistically significant. Analyses were performed using R version 4.4.1 (R Foundation for Statistical Computing, Vienna, Austria).

Surgical technique

Our approach has been previously described in detail.[4,5] The UHS is performed through a 6-inch J-shaped incision extending from 2 cm below the sternal notch to the third or fourth intercostal space, exiting laterally to the right. Under transesophageal echocardiographic guidance, the proximal aortic arch opposite the innominate artery is directly cannulated using the Seldinger technique. The right common femoral vein is cannulated with a 25-Fr long cannula (Bio-Medicus; Medtronic, Minneapolis, MN, USA), advanced into the superior vena cava under transesophageal echocardiographic guidance, and connected to a smaller right atrial cannula in a “Y” configuration when additional drainage is required. In FS patients, the right atrium is directly cannulated.

After aortic cross-clamping, 2 L of Custodiol histidine–tryptophan–ketoglutarate (HTK; Essential Pharmaceuticals LLC, Durham, NC, USA) or del Nido cardioplegia (Capstone Perfusion, Inc., Bedford, MA, USA) is administered antegrade through the aortic root and/or directly into the coronary ostia. In cases of severe aortic insufficiency, 1 L of cardioplegia is initially delivered antegrade into the aortic root, followed by 1 L administered directly into the coronary ostia in UHS patients. Retrograde cardioplegia is not used in UHS because of limited visualization. A main pulmonary artery vent is used in UHS, whereas

a right superior pulmonary vein vent was primarily used in FS. Carbon dioxide insufflation is routinely used.

The Freestyle aortic root bioprosthesis was implanted using the full-root replacement technique. Our Bentall and David techniques, including key hemostatic strategies, have also been previously reported.[4,5] The COR-KNOT® automated suture fastener (LSI Solutions, Victor, NY, USA) is used to anchor the Valsalva or composite graft. Mechanical or bioprosthetic conduits (either self-assembled or prefabricated using the KONECT RESILIA™ conduit [Edwards Lifesciences, Irvine, CA, USA]) are selected based on age and patient preference. Coronary reconstruction was performed using the button technique whenever feasible; however, modified Cabrol-type reconstruction with 6-, 8-, or 10-mm interposition grafts was liberally employed in cases of low-lying or anomalous coronary ostia, significant displacement, or limited mobility due to fragility, adhesions, or dissection.[10]

When ascending aortic replacement is indicated, the ascending aorta is divided, an appropriately sized straight Dacron graft is selected, and the distal anastomosis is performed approximately 1 cm proximal to the ACC site. After trimming both grafts to size, the graft-to-graft anastomosis is performed. Before tying down the anastomosis, the patient is placed in Trendelenburg position, the ACC is removed while CPB flows are reduced, and the graft is de-aired. The anastomosis is then secured. The patient is weaned from CBP, and hemostasis is ensured. After protamine administration, the residual distal ascending aorta extending to the innominate artery, including the cannulation and ACC sites, is wrapped with a Dacron sleeve. The wrap is secured to itself and the proximal arch adventitia. During closure, FS is closed with steel wires, whereas UHS is typically closed using steel wires supplemented with rigid plate fixation.

RESULTS

Preoperative characteristics

Before matching, 85 patients underwent UHS and 87 underwent FS; ever-smoking was more frequent in the UHS group than in the FS group (46% vs 28%; $P = 0.03$), whereas prior aortic surgery was more common in the FS group (13% vs 4%; $P = 0.04$). After matching, 72 patients remained in each group with comparable preoperative characteristics. Preoperative characteristics of the matched and unmatched cohorts are shown in Table 1. Both matched cohorts were predominantly male (89% vs 89%; $P = 0.97$). Median age was 60 years (IQR, 51–67) in the UHS group and 60 years (IQR, 52–67) in the FS group ($P = 0.97$). The incidence of hypertension (73% vs 73%; $P > 0.99$), ever-smoking (44% vs 32%; $P = 0.17$), bicuspid aortic valve (32% vs 25%; $P = 0.46$), prior cardiac (17% vs 15%; $P > 0.99$) or aortic surgery (3% vs 6%; $P = 0.68$), and urgent procedures (6% vs 4%; $P > 0.99$) were similar between groups. Median ejection fraction was 60% (IQR, 55–65) in both groups ($P = 0.95$), and the most common surgical indication was degenerative aneurysm (93% vs 92%; $P = 0.70$). Median aortic root diameter was 5.1 cm (IQR, 4.7–5.3) vs 5.0 cm (IQR, 4.7–5.3), respectively ($P = 0.65$), and median ascending aortic diameter was 4.5 cm (IQR,

4.1–5.0) vs 4.6 cm (IQR, 3.9–4.9), respectively (*P* = 0.84). Other preoperative characteristics are presented in Table 1.

Intraoperative Outcomes

Table 2 summarizes intraoperative outcomes in the matched cohort. Median CPB time was shorter in the UHS group compared with the FS group (174 [IQR, 160–199] vs 197 [IQR, 163–231] min; *P* = 0.04), whereas ACC time was similar (150 [IQR, 132–166] vs 155 [IQR, 132–197] min; *P* = 0.12).

In UHS patients, Bentall procedures with bioprosthetic conduits were more common (71% vs 47%; *P* = 0.007), whereas the David procedure was less common (19% vs 39%; *P* = 0.02) **(**Table 2**)**. A Freestyle root was used in one patient (1%) during FS with infective endocarditis. Right coronary artery reconstruction as a button was performed in 76% vs 82% of cases and as an interposition graft in 24% vs 18% of cases in the UHS and FS groups, respectively (*P* = 0.54). Left coronary artery reconstruction as a button occurred in 94% vs 88% of cases and as an interposition graft in 6% vs 12% (*P* = 0.24).

COR-KNOT® and single-dose cardioplegia were used in all cases (Custodiol-HTK from 2014 to January 2020, followed by del Nido thereafter due to a change in surgeon preference). Blood product utilization was similar between groups: packed red blood cells (0 [IQR, 0–1] vs 0 [IQR, 0–1] U; *P* = 0.70), fresh frozen plasma (0 [IQR, 0–2] vs 1 [IQR, 0–2] U; *P* = 0.54), cryoprecipitate (0 [IQR, 0–2] vs 0 [IQR, 0–1] U; *P* = 0.26), and platelets (1 [IQR, 0–2] vs 1 [IQR, 1–2] U; *P* = 0.06) for UHS and FS groups, respectively.

Postoperative outcomes

Postoperative outcomes are shown in Table 3. Operative mortality was similar between groups (0% vs 1%; *P* > 0.99). Median duration of mechanical ventilation was shorter in the UHS group (1 [IQR, 1–1] vs 1 [IQR, 1–1.8] days; *P* = 0.003). The incidence of stroke (0% vs 1%; *P* > 0.99), PVS (8% vs 7%; *P* > 0.99), re-exploration for bleeding (1% vs 3%; *P* > 0.99), pneumonia (1% vs 7%; *P* = 0.21), pulmonary embolism (0% vs 1%; *P* = 0.49), pleural effusion (3% vs 4%; *P* > 0.99), and reintubation (0% vs 3%; *P* = 0.50) were comparable between the UHS and FS groups **(**Table 3**)**. The UHS group demonstrated shorter ICU (3 [IQR, 2–4] vs 4 [IQR, 3–6] days; *P* < 0.001) and hospital LOS (6 [IQR, 5.0–8.3] vs 7.5 [IQR, 6.0–10] days; *P* = 0.003) compared with the FS group.

Mid-term outcomes

The UHS group had a longer median echocardiographic follow-up period than the FS group (6.6 [IQR, 2.9–7.8] vs 2.4 [IQR, 1.3–6.2] years; *P* = 0.01). Left ventricular ejection fraction was similar between groups (60% [IQR, 55–65] vs 60% [IQR, 55–61]; *P* = 0.18) **(**Table 3**)**.

Median clinical follow-up was 7.1 years (IQR, 3.6–8.6) in the UHS group and 2.0 years (IQR, 1.1–4.6) in the FS group *(P* < 0.001) (Table 3**)**. Freedom from reoperation was comparable (99% [71/72] vs 97%

[70/72]; *P* > 0.99), as was freedom from all-cause mortality (96% [69/72] vs 92% [66/72]; *P* = 0.49). One-year survival was 100% versus 97% (2 deaths; *P* = 0.50), and 5-year survival was 97% (2 deaths) versus 94% (4 deaths; *P* = 0.68). Kaplan–Meier analysis demonstrated no difference in overall survival between the groups in the overall cohort (log-rank *P* = 0.14; Fig. 1).

DISCUSSION

In 72 matched patient pairs undergoing ARR via UHS versus FS, the UHS approach was associated with significantly shorter CPB time (− 23 min; *P* = 0.04), ICU (− 1 day; *P* < 0.001), and hospital LOS (− 1.5 days; *P* = 0.003), as well as duration of mechanical ventilation (*P* = 0.003). Other outcomes—including operative mortality, 1- and 5-year survival, ACC time, blood product utilization, incidence of re-exploration for bleeding and stroke, freedom from reoperation, and left ventricular ejection fraction—were comparable between groups.

Similarly, in a meta-analysis of 2,765 patients across eight studies, mini-sternotomy ARR was associated with shorter CPB time (− 7.9 min; *P* = 0.009) and reduced ICU and hospital LOS (− 0.9 days; *P* = 0.0009 and − 0.85 days; *P* = 0.03, respectively), with no differences in ACC time, incidence of re-exploration for bleeding and stroke, or duration of mechanical ventilation.[7] In a separate systematic review and meta-analysis of 21 studies including 2,908 minimally invasive and 3,456 conventional ARR patients, minimally invasive approaches were associated with shorter mechanical ventilation duration (− 4.72 hours; *P* < 0.001), lower blood transfusion requirements (− 0.50 units; *P* < 0.001), and shorter ICU (− 0.46 days; *P* < 0.001) and hospital LOS (− 1.65 days; *P* < 0.001).[9] Other outcomes, including CPB and ACC times, morbidity, mortality, and reintervention rates, were comparable between groups. These data, together with our findings, support the safety and efficacy of minimally invasive approaches, demonstrating faster recovery and feasibility in patients requiring complex coronary reconstruction [30.6% (22/72)] and reoperative surgery [19.4% (14/72)] within the UHS cohort.

In the UHS cohort, CPB (median 174 min) and ACC (median 150 min) times were longer than those reported in a meta-analysis of minimally invasive UHS ARR (mean CPB 101.7 min; mean ACC 76.1 min).[7] The longer operative times likely reflect the technical complexity of our UHS cohort, including cases requiring modified Cabrol-type coronary reconstruction in 30.6% (22/72) of patients and reoperative surgery in 19.4% (14/72) of patients. Further, CPB time was significantly shorter in the UHS group than in the FS group (− 23 minutes; *P* = 0.04). A greater proportion of patients in the FS group underwent the David procedure, which is generally more technically demanding and time-consuming than the Bentall procedure. Consequently, the shorter CPB time and comparable ACC time observed in the UHS group may be partially attributable to differences in procedural technical complexity between groups. Additionally, these findings may reflect a favorable learning-curve effect, as the surgeon had accumulated extensive experience with FS ARR and UHS AVR before performing the first UHS ARR procedure. The use of COR-KNOT® is particularly advantageous in UHS, where manual knot tying can be challenging within the deep, confined space of the aortic root. In addition, Custodiol-HTK and del Nido cardioplegia facilitate a streamlined operative workflow by providing up to 180 and 90 min, respectively,

of single-dose myocardial protection.[11,12] Also, antegrade single-dose cardioplegia delivery into the aortic root, followed by direct coronary ostial delivery in cases of severe aortic insufficiency, avoids retrograde coronary sinus catheterization, which can be technically challenging in UHS.

In all patients, bleeding prevention strategies included assessment of coronary button integrity after reimplantation using high-pressure cardioplegia injection into the aortic root and reinforcement with Teflon felt.[3–5] The distal anastomosis is reinforced with Teflon felt and pledgeted sutures. During Bentall procedures, the residual aortic wall is circumferentially tacked to the valved conduit sewing ring with a running suture.[4] Patients also receive a 10 g loading dose of aminocaproic acid, followed by a continuous infusion at 1 g/h throughout the procedure. An additional 10 g is administered via the CPB circuit. The right pleural space is opened to mitigate the risk of cardiac tamponade in UHS cases.

The ideal UHS candidate is an elective, young to middle-aged patient without significant comorbidities. These patients benefit most from reduced surgical trauma and limited sternal spreading, particularly those with connective tissue disorders. Additional advantages include reduced dissection and adhesion formation, as well as improved chest wall stability and cosmesis. Early surgeon experience should be grounded in high-volume FS ARR and UHS AVR, with a stepwise progression to more heterogeneous and technically complex UHS procedures.[1–5] In our practice, UHS is not appropriate for patients with ATAAD, those requiring concomitant CABG or total arch replacement with hypothermic circulatory arrest, or those with prior CABG and patent grafts crossing the midline. In these cases, broad exposure, meticulous coronary assessment in ATAAD, and intraoperative flexibility necessitate FS.[13]

Limitations

This analysis is limited by its retrospective design. Selection bias is inherent, as the study reflects a highly selected, nonrandomized cohort, and exclusion of concomitant and emergent cases limits generalizability to higher-risk populations. Despite propensity score matching, residual confounding cannot be excluded, as unmeasured factors—including surgical era, which may reflect the surgeon's learning curve and evolving expertise, procedural technical complexity, and patient preference—were not accounted for in the matching process. All procedures were performed by a single experienced aortic surgeon, which limits generalizability but also minimizes inter-surgeon variability and reduces surgeon-related confounding. Temporal changes in technique and perioperative management over the study period may have influenced contemporary outcomes. Regarding the apparent discrepancy in follow-up duration between groups, this reflects the earlier adoption of UHS for appropriately selected cases, which were subsequently followed longitudinally over a longer period, whereas FS cases included a larger proportion of more recent operations performed.

CONCLUSIONS

The UHS approach for ARR was associated primarily with reduced ICU and hospital LOS, while operative mortality and 1- and 5-year survival were comparable to those of the propensity-matched FS group.

These findings require validation in a larger prospective randomized trial.

Abbreviations

ACC
Aortic cross-clamp
ARR
Aortic root replacement
ATAAD
Acute type A aortic dissection
AVR
Aortic valve replacement
CABG
Coronary artery bypass grafting
CPB
Cardiopulmonary bypass
FS
Full sternotomy
ICU
Intensive care unit
IQR
Interquartile range
LOS
Length of stay
PVS
Prolonged ventilatory support
UHS
Upper hemisternotomy

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the principles of the Declaration of Helsinki. The study protocol was approved by the Institutional Review Board of the Jefferson Office of Human Research Protection. Approval was obtained September 13, 2023 (IRB number: iRIS ID 2023-2417). As this research was a retrospective, non-interventional, observational study of de-identified information, the requirement for informed consent was waived.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Tables

Table 1. Preoperative characteristics

	Unmatched Cohort			Matched Cohort			
Characteristics	**UHS**	**FS**	***P***	**UHS**	**FS**	**SMD**	***P* value**
	N = 85	N = 87	**value**	N = 72	N = 72		
Age (years), median [IQR]	61 [51—67]	58 [51—67]	0.386	60 [51—67]	60 [52—67]	0.012	0.974
Male, n (%)	76 (89%)	77 (89%)	>0.999	64 (89%)	64 (89%)	0.000	0.974
Diabetes, n (%)	10 (12%)	5 (6%)	0.186	5 (7%)	4 (6%)	-0.057	>0.999
Hypertension, n (%)	63 (74%)	62 (71%)	0.804	52 (73%)	52 (73%)	0.000	>0.999
CAD, n (%)	12 (14%)	7 (8%)	0.231	8 (11%)	6 (8%)	-0.094	0.780
Ever-smoker, n (%)	39 (46%)	25 (28%)	**0.030**	32 (44%)	23 (32%)	-0.260	0.170
COPD, n (%)	8 (9%)	7 (8%)	0.793	6 (8%)	6 (8%)	0.000	>0.999
PAD, n (%)	6 (7%)	2 (2%)	0.278	3 (4%)	1 (2%)	-0.160	0.621
CVD, n (%)	10 (12%)	7 (8%)	0.453	4 (6%)	5 (7%)	0.057	>0.999
Bicuspid aortic valve, n (%)	26 (31%)	21 (24%)	0.437	23 (32%)	18 (25%)	-0.150	0.460
Marfan syndrome, n (%)	3 (4%)	3 (3%)	>0.999	3 (4%)	3 (4%)	0.000	>0.999
BMI (kg/m^2), median [IQR]	28.4 [25.2—31.3]	28.5 [25.9—31.2]	0.377	28.1 [25.2—30.5]	27.6 [25.6—30.5]	-0.043	0.889
NYHA class, n (%)			0.498			0.140	0.896
I	56 (66%)	64 (74%)		50 (70%)	52 (73%)		
II	13 (15%)	14 (16%)		10 (14%)	11 (15%)		
III	12 (14%)	7 (8%)		9 (13%)	6 (8%)		
IV	4 (5%)	2 (2%)		2 (3%)	2 (3%)		
Aortic insufficiency, n (%)			0.316			0.056	0.867

None	27 (32%)	30 (21%)		15 (21%)	13 (18%)		
Mild	19 (22%)	15 (17%)		14 (20%)	17 (24%)		
Moderate	15 (18%)	24 (28%)		25 (35%)	26 (37%)		
Severe	24 (28%)	18 (21%)		17 (24%)	15 (21%)		
Symptoms at presentation, n (%)							
None	39 (46%)	33 (38%)	0.367	42 (58%)	48 (67%)	-0.170	0.389
Shortness of breath	20 (24%)	25 (29%)	0.546	18 (25%)	16 (22%)	-0.065	0.844
Chest pain	11 (13%)	8 (9%)	0.474	8 (11%)	6 (8%)	-0.099	0.587
Prior cardiac surgery, n (%)	15 (18%)	21 (24%)	0.390	12 (17%)	11 (15%)	0.038	>0.999
Prior aortic surgery, n (%)	3 (4%)	11 (13%)	**0.048**	2 (3%)	4 (6%)	0.140	0.681
LVEF (%), median [IQR]	60 [55—65]	60 [55—65]	0.336	60 [55—65]	60 [55—65]	0.005	0.947
Indication for surgery, n (%)							
Degenerative aneurysm	81 (95%)	80 (92%)	0.535	67 (93%)	66 (92%)	0.098	0.696
Chronic dissection	2 (2%)	6 (7%)	0.278	2 (3%)	3 (4%)	0.076	>0.999
Infective Endocarditis	4 (5%)	4 (5%)	>0.999	3 (4%)	3 (4%)	0.000	>0.999
Urgent, n (%)	7 (8%)	10 (11%)	0.611	4 (6%)	3 (4%)	-0.065	>0.999
Aortic root size (cm), median [IQR]	5.1 [4.7—5.4]	5.0 [4.7—5.3]	0.728	5.1 4.7—5.3]	5.0 [4.7—5.3]	0.021	0.649
Ascending aorta size (cm), median [IQR]	4.5 [4.1—4.9]	4.6 [3.9—5.0]	0.771	4.5 [4.1—5.0]	4.6 [3.9—4.9]	0.038	0.837

BMI = body mass index; CAD = coronary artery disease; COPD = chronic obstructive pulmonary disease; CVD = cerebrovascular disease; FS = full sternotomy; IQR = interquartile range; LVEF = left ventricular ejection fraction; NYHA = New York Heart Association; PAD = peripheral arterial disease; SMD = standardized mean difference; UHS = upper hemisternotomy

Table 2. Intraoperative outcomes

Outcomes	**UHS**	**FS**	***P* value**
	N = 72	N= 72	
Composite graft ARR (Bentall), n (%)			
Bioprosthetic conduit	51 (71%)	34 (47%)	**0.007**
Mechanical conduit	7 (10%)	9 (13%)	0.792
Valve-sparing ARR (David), n (%)	14 (19%)	28 (39%)	**0.017**
Freestyle aortic root bioprosthesis, n (%)	0 (0%)	1 (1%)	>0.999
CPB time (min), median [IQR]	174 [160—199]	197 [163—231]	**0.041**
ACC (min), median [IQR]	150 [132—166]	155 [132—197]	0.121
Coronary reconstruction, n (%)			
Right button	55 (76%)	59 (82%)	0.538
Right interposition graft	17 (24%)	12 (18%)	
Left button	68 (94%)	68 (88%)	0.244
Left interposition graft	5 (6%)	9 (12%)	
Blood product utilization (U), median [IQR]			
PRBC	0 [0—1]	0 [0—1]	0.695
FFP	0 [0—2]	1 [0—2]	0.543
Cryoprecipitate	0 [0—2]	0 [0—1]	0.259
Platelets	1 [0—2]	1 [1—2]	0.057

ACC = aortic cross-clamp; ARR = aortic root replacement; CPB = cardiopulmonary bypass; FFP = fresh frozen plasma; FS = full sternotomy; IQR = interquartile range; PRBC = packed red blood cells; UHS = upper hemisternotomy

Table 3. Postoperative and mid-term outcomes

Outcomes	UHS	FS	*P* value
	N = 72	N = 72	
Ventilator time (days), median [IQR]	1 [1—1]	1 [1—1.8]	**0.003**
ICU length of stay (days), median [IQR]	3 [2—4]	4 [3—6]	**<0.001**
Hospital length of stay (days), median [IQR]	6 [5.0—8.3]	7.5 [6.0—10]	**0.003**
Postoperative complications, n (%)			
Prolonged ventilation	6 (8%)	5 (7%)	>0.999
Pneumonia	1 (1%)	5 (7%)	0.209
Pleural effusion	2 (3%)	3 (4%)	>0.999
Re-intubation	0 (0%)	2 (3%)	0.497
Pulmonary embolism	0 (0%)	1 (1%)	0.493
Re-exploration for bleeding	1 (1%)	2 (3%)	>0.990
Stroke	0 (0%)	1 (1%)	>0.990
30-day mortality, n (%)	0 (0%)	1 (1%)	>0.990
1-year mortality, n (%)	0 (0%)	2 (3%)	0.497
5-year mortality, n (%)	2 (3%)	4 (6%)	0.681
Freedom from all-cause mortality, n (%)	69 (96%)	66 (92%)	0.494
Freedom from reoperation, n (%)	71 (99%)	70 (97%)	>0.999
Ejection fraction (%), median [IQR]	60 [55—65]	60 [55—61]	0.176
Follow-up echocardiography (years), median [IQR]	6.6 [2.9—7.8]	2.4 [1.3—6.2]	**0.007**
Follow-up time (years), median [IQR]	7.1 [3.6—8.6]	2.0 [1.1—4.6]	**<0.001**

FS = full sternotomy; ICU = intensive care unit; IQR = interquartile range; UHS = upper hemisternotomy

Figures

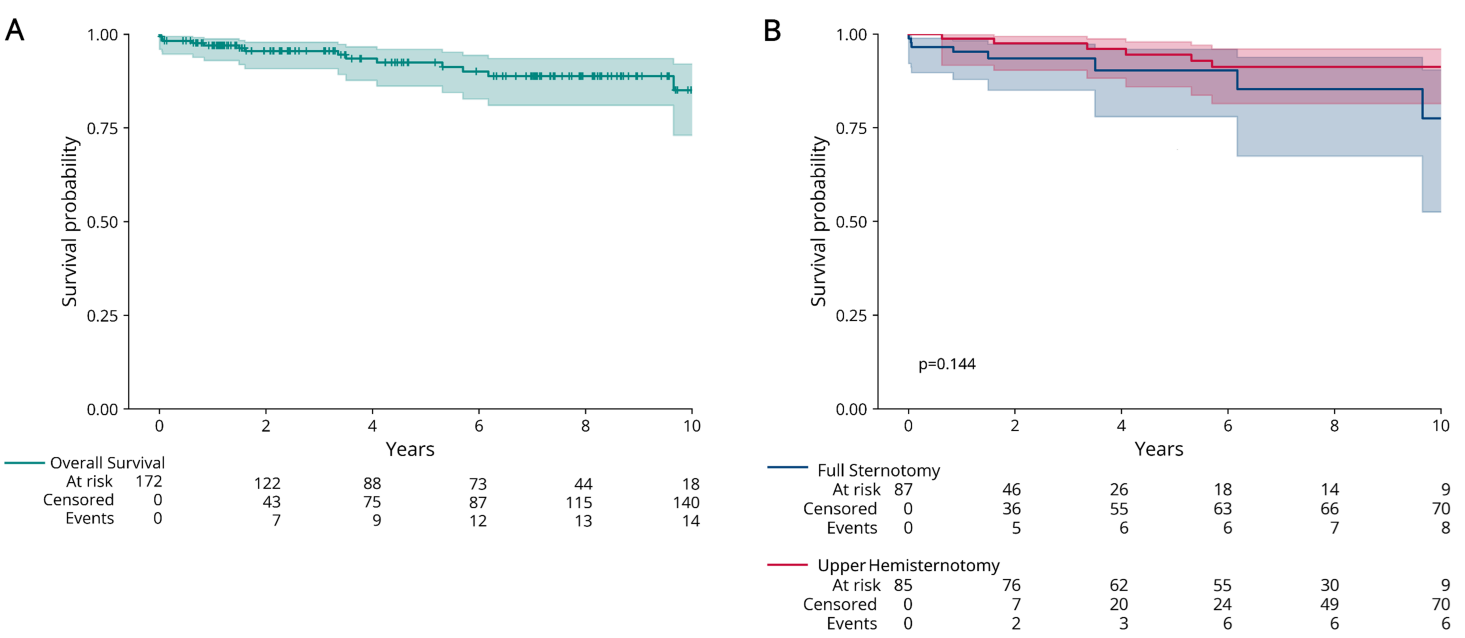


Figure 1

Kaplan-Meier survival analysis with 95% confidence intervals for all patients undergoing aortic root replacement (Panel A) and stratified by surgical approach (Panel B).