Short- and long-term results of total arch replacement: Comparison between island and debranching techniques

Eilon Ram, MD,[a,b] Christopher Lau, MD,[a] Arnaldo Dimagli, MD,[a] Ngoc-Quynh Chu, MD,[a] Giovanni Soletti, Jr, MD,[a] Mario Gaudino, MD,[a] and Leonard N. Girardi, MD[a]

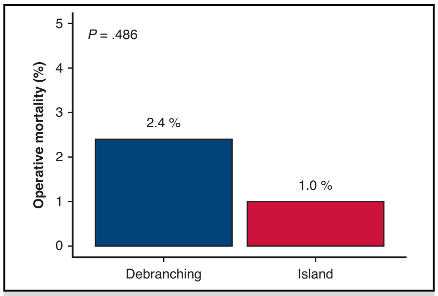
ABSTRACT

Objective: The 2 most acceptable techniques for reimplantation of the supra-aortic vessels in total arch replacement include the branched graft technique (debranching) or en bloc technique (island). We aim to review our experience with total arch replacement and report short- and long-term outcomes from a high-volume center dedicated to surgery for the thoracic aorta.

Methods: The aortic surgery database was queried to identify all consecutive patients undergoing total arch replacement between 1997 and 2022. Of the 426 patients who underwent total arch replacement, 303 (71%) received the island technique and 123 (29%) received the debranching approach. Operative and long-term outcomes were compared using multivariable models.

Results: The debranching group was younger (64 ± 14 years vs 69 ± 12 years, $P = .001$), had undergone more previous cardiac operations (54.5% vs 27.4%, $P < .001$), and had more connective tissue disorder (20.3% vs 4.6%, $P < .001$). The debranching approach was associated with longer total circulatory arrest time (47 ± 15 minutes vs 37 ± 10 minutes, $P < .001$) and cardiac ischemic time (116 ± 41 minutes vs 100 ± 37 minutes, $P < .001$). More patients in the debranching group received blood products intraoperatively or postoperatively (56.1% vs 42.9%, $P = .018$). All other early outcomes did not differ between groups. Overall operative mortality was 1.4% (2.4% vs 1%, $P = .486$); the incidence of major postoperative complications was 6.3% (5.7% vs 6.6%, $P = .897$). Ten-year survival was 80% (78% vs 80.9%, log-rank $P = .356$). Multivariable Cox regression analysis demonstrated that neither surgical approach was associated with survival advantage (hazard ratio, 1.18; 0.73-1.89; $P = .495$).

Conclusions: Debranching requires a longer operative time, with similar early and long-term outcomes. Preoperative comorbidity, not surgical technique, predicts major adverse events and long-term survival. (JTCVS Techniques 2023;20:10-9)



Bar graph displaying the operative mortality according to procedure type.

CENTRAL MESSAGE

Total arch replacement achieves excellent operative outcomes and durability by both debranching and en bloc island reimplantation of the arch supra-aortic vessels with appropriate patient selection.

PERSPECTIVE

Total arch replacement with reimplantation of the supra-aortic vessels requires the debranching technique or en bloc island technique. By preferentially performing island reimplantation in older patients with comorbidities and arch debranching in younger patients with CTD and less comorbid conditions, both techniques provide similar early outcomes and long-term durability.

From the [a]Department of Cardiothoracic Surgery, Weill Cornell Medicine, New York, NY; and [b]Sackler School of Medicine, Tel Aviv University, Tel Aviv, Israel.

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Address for reprints: Eilon Ram, MD, Department of Cardiothoracic Surgery, Weill Cornell Medicine, New York, NY 10065 (E-mail: lok9031@med.cornell.edu).

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The first successful total aortic arch replacement, more than 60 years ago, was done using a homograft.[1] Since then, surgical procedures of the arch have become standardized, and satisfying outcomes can be achieved due to improved perfusion strategies, the introduction of hypothermic circulatory arrest, and advancements in neuroprotective strategies.[2,3] Nevertheless, prosthetic total arch replacement remains a complex surgical procedure requiring meticulous technique and can be performed with selective bypass grafting of the supra-aortic vessels (debranching) or with an island

Abbreviations and Acronyms
- CI = confidence interval
- CTD = connective tissue disease
- HR = hazard ratio
- MAE = major adverse event
- OR = odds ratio

reimplantation technique (en bloc) containing the ostia of the innominate artery, left carotid artery, and left subclavian artery as a Carrel patch. Results vary across a wide spectrum of techniques.

Currently available data on the outcomes of separate graft and island reimplantation techniques vary in different series. The operative mortality range between 6% and 20% using the supra-aortic vessels debranching technique and between 6% and 16% using the island reimplantation technique. The reported stroke rate ranges between 3% and 9% using either approach.[4-7] The potential advantage of using the debranching technique, which eliminates all aortic tissue in the arch, did not show any difference in the cumulative probability of aortic reintervention in previous publications with up to 15 years of follow-up.[7]

The purpose of this study was to review our experience with total arch replacement using the debranching or island technique and report short- and long-term outcomes from a high-volume center dedicated to surgery for the thoracic aorta.

MATERIAL AND METHODS

Patient Population

From May 1997 to December 2022, 1491 consecutive patients in our department underwent arch replacement surgery under circulatory arrest, of whom 426 had total arch replacement. Within this group, 303 (71%) underwent the island technique and 123 (29%) underwent the debranching approach. All baseline characteristics, operative data, and 30-day outcomes were prospectively collected and completed for all patients. All clinical and echocardiographic follow-up information was updated before the analyses for the current study using the hospital electronic medical record. The mean clinical follow-up duration of the entire cohort was 57.4 ± 52.8 months. The mean echocardiography follow-up duration was 55.2 ± 52.4 months and was completed for 60.1% of the patients.

The study was approved by the Weill Medical College of Cornell University Ethics Committee (Protocol No 1607017424; September 1, 2021). The requirement for informed consent was waived because of the retrospective nature of the study.

Surgical Procedure

All patients underwent surgery through a median sternotomy. Standard cardiopulmonary bypass was established by cannulation of the aortic arch, and venous return was established by cannulation of the superior and inferior vena cavae through the right atrium using 2 separate straight cannulas. For acute dissections, femoral cannulation was used earlier in the series, but direct ultrasound-guided true lumen cannulation of the arch was used in recent years. Myocardial protection was achieved by using antegrade cold blood cardioplegia. Cerebral protection was achieved using deep hypothermic circulatory arrest (18 °C) for the arch replacement and retrograde cerebral perfusion during the circulatory arrest period. The core temperature determination is measured in the bladder. In addition, we measure the blood and tympanic temperature. Near-infrared spectroscopy is used to monitor symmetric cerebral perfusion.

Early in our experience, we based our decision on island versus debranching technique mainly on degree of separation and distance between the arch vessel ostia. Patients with splayed-out vessels were repaired with debranching and those with closely spaced arch vessels received an island repair, because it was technically easier to perform an island reimplantation in a smaller space. However, we noted that patients with connective tissue disease (CTD) were at increased risk of developing patch aneurysms of the supra-aortic arch vessels or visceral Carrel patches after thoracoabdominal aneurysm repair due to degeneration of the residual intervening aortic tissue. We transitioned to a more aggressive use of debranching in patients with CTD regardless of the distance between their arch vessels. Nevertheless, patients presenting on an emergency basis or with high-acuity situations are more likely to have island reimplantation.

All arch repairs begin with resection of the lesser curvature of the arch and assessment of the arch vessel ostia, followed by a final determination for using an island or debranching technique. The island technique was done starting with transection of the arch distal to the subclavian artery. The distal aortic anastomosis is performed, followed by the 3-vessel Carrel patch anastomosis,[8] using a continuous 3 to 0 or 4 to 0 polypropylene suture line reinforced with circumferential interrupted 4 to 0 polypropylene pledgeted stitches to achieve hemostatic suture lines. For this approach, we use the Hemashield Platinum Dacron graft (Maquet) with a single 10-mm perfusion side branch to provide distal aortic perfusion. The debranching technique was performed similarly for the distal aortic anastomosis followed by anastomosis of each of the supra-aortic vessels separately using a prefabricated 4-Branch Hemashield Platinum graft (Maquet) with or without an elephant trunk for future descending aortic intervention (Figure 1). The order of anastomoses was the subclavian artery, left carotid artery, and innominate artery. Patients with an extensive arch aneurysm extending into the descending thoracic aorta were repaired with a similar technique using a Gelweave Siena graft with 4 prefabricated branches and a modifiable sewing skirt (Terumo Aortic). The decision on which repair to perform was left to the discretion of the individual surgeon.

Arch anastomoses are always completed before resuming cardiopulmonary bypass. After the arch reconstruction is completed, cardiopulmonary bypass was reinstituted through the side-branch, retrograde cerebral perfusion was discontinued, and systemic warming to 36 °C was initiated. Proximal anastomosis and any concomitant procedures were completed during the rewarming phase.

Statistical Analysis

Data are presented as mean ± standard deviation for normal distribution or median (interquartile range) for non-normal distribution. Continuous variables were tested with the Kolmogorov–Smirnov test for normal distribution. Categorical variables are given as frequencies and percentages. A chi-square test was used for comparison of categorical variables between supra-aortic vessels reimplantation strategies (island and debranching); a Student *t* test was performed for comparison of normally distributed continuous variables between the groups, and Mann–Whitney *U* test was used for non-normal distribution. The Kaplan–Meier survival analysis was performed to compare long-term mortality and reintervention by the surgical strategy among patients who underwent total arch replacement, with statistical differences tested by the log-rank test.

A major adverse event (MAE) was defined as the occurrence of stroke, use of renal replacement therapy, deep sternal wound infection, postoperative myocardial infarction, or mortality. To identify factors associated with MAE, a multivariable logistic regression model was constructed. Candidate covariates are provided in Table 1. Variables that were associated with one of the groups ($P < .1$ in Table 1) were included in the

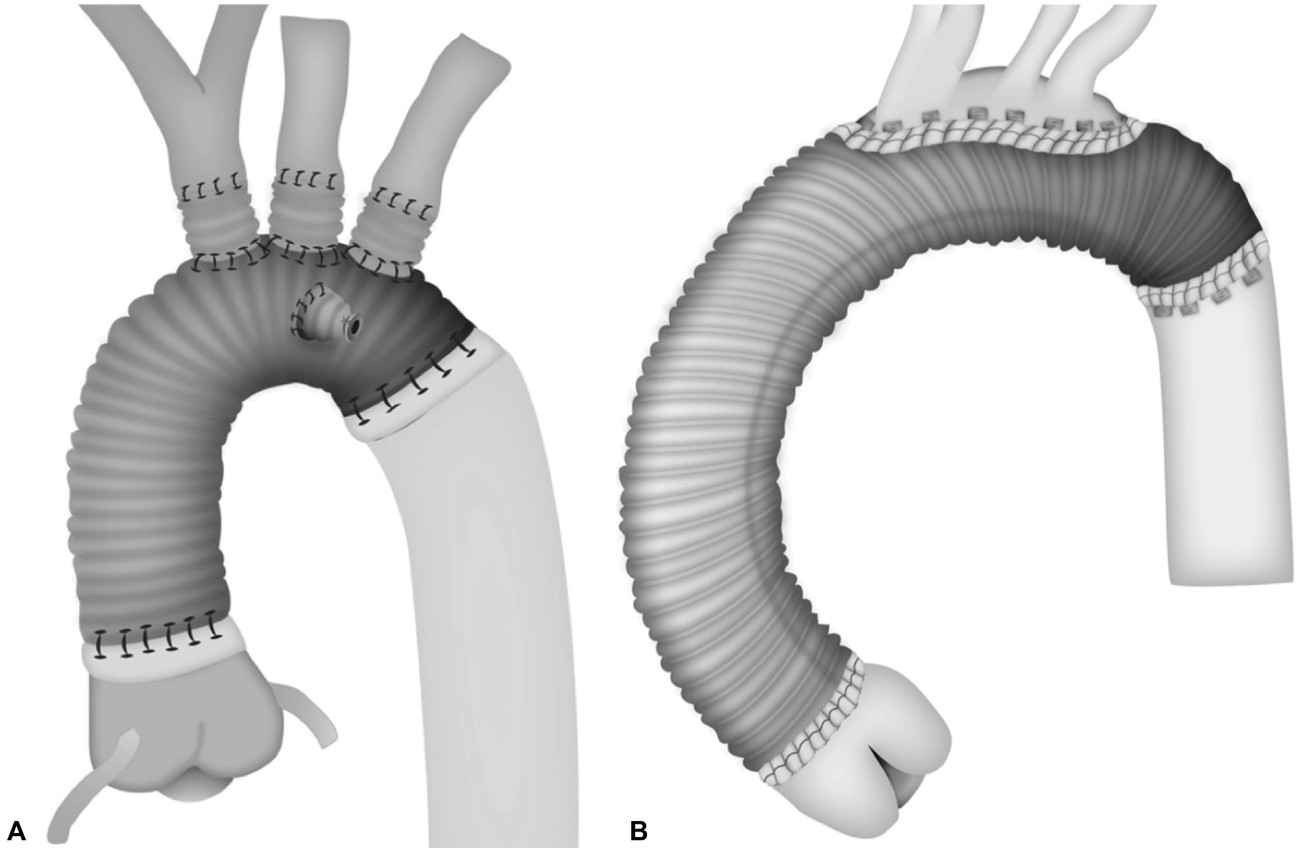

FIGURE 1. Illustration of the surgical technique used for total arch replacement: A, Supra-aortic vessels separate graft techniques (debranching). B, Supra-aortic vessels island reimplantation techniques (en bloc).

regression model. In addition, we included prespecified clinically significant variables in the model. The variables included in the final model were age, family history of aortic disease, prior ischemic heart disease, diabetes mellitus, history of stroke, renal impairment, prior surgery, and aortic vessels reimplantation strategy. Results are presented as odds ratio (OR), 95% confidence interval (CI), and *P* value.

A Cox proportional hazard model was performed to assess the association between the operation type and the all-cause 10-year mortality in the entire study population adjusted for potential confounders, using a stepwise selection process. Similar to the logistic regression models, candidate covariates are provided in Table 1. Variables that were associated with one group ($P < .1$) were included in the Cox regression model. In addition, we included prespecified clinically significant variables in the model. The following variables were included in the model: age, family history of aortic disease, prior ischemic heart disease, diabetes mellitus, history of stroke, renal impairment, prior surgery, chronic obstructive pulmonary disease, and arch vessels reimplantation strategy. The results are presented as hazard ratio (HR), 95% CI, and *P* value. For nonfatal outcomes, the competing risk of death was taken into account using the Fine-Gray model.[9]

RESULTS

Baseline Characteristics

The debranching group was younger (64 ± 14 years vs 69 ± 12 years, $P = .001$), had undergone more previous cardiac operations (54.5% vs 27.4%, $P < .001$), had more previous descending thoracic aorta or thoracoabdominal aortic aneurysm repair (8.9% vs 2.6%, $P = .009$), and had more CTD (20.3% vs 4.6%, $P < .001$) compared with the island group. Other baseline characteristics did not differ between the groups (Table 1).

Operative Data

An elephant trunk graft was implanted less frequently in the debranching group than in the island group (23.6% vs 34.7%, $P = .034$). Although there were similar concomitant procedures (48% vs 52.1%, $P = .500$), and despite similar cooling (35.7 ± 4.1 minutes vs 35.2 ± 4.3 minutes, $P = .319$) and warming (68.1 ± 11 minutes vs 67.6 ± 13.2 minutes, $P = .728$) times, the debranching approach was associated with longer total circulatory arrest (47 ± 15 minutes vs 37.2 ± 10.5 minutes, $P < .001$), cardiac ischemic time (115.9 ± 41.4 minutes vs 101.2 ± 36.5 minutes, $P < .001$), and cardiopulmonary bypass time (172.2 ± 38 vs 153.3 ± 33.7 minutes, $P < .001$) (Table 2).

In-Hospital Outcomes

More patients in the debranching group received blood products intraoperatively or postoperatively (56.1% vs 42.9%, $P = .018$). Overall operative mortality was 1.4%,

TABLE 1. Patient demographics and data*

Variable	Island N = 303	Debranching N = 123	P value
Age (mean ± SD), y	68.7 ± 11.9	64.1 ± 13.8	.001
Sex (female)	131 (43.2)	51 (41.5)	.821
Family history of aortic disease			.001
None	288 (95)	107 (87)	
Previous aneurysm	8 (2.6)	3 (2.4)	
Previous dissection	7 (2.4)	13 (10.6)	
Smoking			.841
Current smoker	24 (7.9)	8 (6.5)	
Previous smoker	153 (50.5)	65 (52.8)	
Never smoked	126 (41.6)	50 (40.7)	
Hypertension	290 (95.7)	118 (95.9)	1.000
Diabetes	39 (12.9)	13 (10.6)	.417
Ischemic heart disease	35 (11.6)	10 (8.1)	.386
COPD	59 (19.5)	22 (17.9)	.809
Prior stroke	63 (20.8)	31 (25.2)	.386
Peripheral vascular disease	27 (8.9)	11 (8.9)	1.000
Atrial fibrillation	32 (10.6)	13 (10.6)	1.000
Renal impairment	48 (15.8)	23 (18.7)	.566
Previous operation	83 (27.4)	67 (54.5)	<.001
Previous DTA/TAAA repair	8 (2.6)	11 (8.9)	.009
CTD	14 (4.6)	25 (20.3)	<.001
Aneurysm size (cm) (mean ± SD)	6.3 ± 1.3	6.4 ± 1.3	.525
Acute dissection	36 (11.9)	15 (12.2)	1.000
Ejection fraction (%) (mean ± SD)	49.6 ± 7.7	49.3 ± 7.9	.696
Bicuspid aortic valve	16 (5.3)	5 (4.1)	.781

SD, Standard deviation; *COPD*, chronic obstructive pulmonary disease; *DTA*, descending thoracic aorta; *TAAA*, thoracoabdominal aorta aneurysm; *CTD*, connective tissue disease. *Categorical variables are reported as frequency (percentage), and continuous variables are reported as mean ± SD.

TABLE 2. Operative data*

Variable	Island N = 303	Debranching N = 123	P value
Elephant trunk	105 (34.7)	29 (23.6)	.034
Graft size (mm) (mean ± SD)	27.3 ± 1.9	27 ± 1.8	.129
Cooling time (min) (mean ± SD)	35.2 ± 4.3	35.7 ± 4.1	.319
Warming time (min) (mean ± SD)	67.6 ± 13.2	68.1 ± 11	.728
Circulatory arrest time (min) (mean ± SD)	37.2 ± 10.5	47 ± 14.9	<.001
Cardiopulmonary bypass time (min) (mean ± SD)	153.3 ± 33.7	172.2 ± 38	<.001
Crossclamp time (min) (mean ± SD)	101.2 ± 36.5	115.9 ± 41.4	<.001
Concomitant procedure	158 (52.1)	59 (48)	.500
Aortic root replacement	56 (18.5)	36 (29.3)	
Composite valve graft	47 (15.5)	32 (26)	
Valve-sparing root replacement	9 (3)	4 (3.3)	
Aortic valve replacement	112 (37)	41 (33.3)	
Mitral valve repair/replacement	18 (5.9)	6 (4.9)	
Tricuspid valve repair	5 (1.7)	5 (4.1)	
Coronary artery bypass grafting	55 (18.2)	20 (16.3)	
Atrial fibrillation ablation	8 (2.6)	1 (0.8)	
Septal myectomy	1 (0.3)	0 (0)	
PFO closure/congenital	9 (3)	2 (1.6)	

SD, Standard deviation; *PFO*, patent foramen ovale. *Categorical variables are reported as frequency (percentage), and continuous variables are reported as mean ± SD.

the incidence of permanent neurological deficit was 2.6%, transient neurological deficit rate was 1.6%, and MAEs occurred in 6.3%, with no significant difference between the groups (Table 3). Risk factors for MAE were diabetes (OR, 3.93; 1.47-9.91; $P = .005$) and previous surgery (OR, 3.12; 1.24-8.05; $P = .016$). The type of supra-aortic vessels implantation approach was not associated with MAE (OR, 0.64; 0.23-1.6; $P = .3660$) (Figure 2).

Long-Term Clinical and Echocardiographic Outcomes

Ten-year survival was 80% (78% vs 80.9%, log-rank $P = .356$) (Figure 3). Multivariable Cox regression analysis demonstrated that the age of the patient (HR, 1.04; 1.02-1.06; $P < .001$), previous operation (HR, 1.8; 1.12-2.9; $P = .016$), chronic obstructive pulmonary disease (HR, 2.51; 1.55-4.07; $P < .001$), and lower left ventricle ejection fraction (HR, 0.97; 0.94-0.99; $P = .014$) were risk factors for late mortality, rather the surgical technique (HR, 1.18; 0.73-1.89; $P = .495$).

Reintervention was performed in similar rates in both groups (20.3% vs 18.2%, HR, 1.04; 0.87-1.25; $P = .638$) in a mean of 38.7 ± 43.4 months after the initial operation (39.4 ± 48.5 months vs 38.4 ± 41.5 months, $P = .926$) (Figure 4). A following thoracoabdominal aorta repair was the most common reintervention (N = 58, 13.6%), followed by a thoracic endovascular aortic repair (N = 10, 2.3%) and a repeat sternotomy aortic replacement (N = 6, 1.4%). These results were consistent for both the early and late periods of our study and regardless of the acuity of presentation (Tables E1 and E2). The mean ejection fraction and aortic valve functioning were similar between the groups (Table 4).

DISCUSSION

Our findings, derived from a high-volume center dedicated to surgery for the thoracic aorta, provide several important implications regarding replacement of the entire aortic arch. First, we have shown that in our practice, we use

TABLE 3. Operative outcomes*

Outcome	Overall N = 426	Island N = 303	Debranching N = 123	*P* value
Operative mortality	6 (1.4)	3 (1)	3 (2.4)	.486
Cerebrovascular accident	11 (2.6)	7 (2.3)	4 (3.3)	.827
Transient ischemic attack	7 (1.6)	6 (2)	1 (0.8)	.661
Permanent pacemaker implantation	8 (1.9)	6 (2)	2 (1.6)	1.000
Respiratory complications				.359
>48 h intubation	10 (2.9)	7 (2.7)	3 (3.6)	
Pneumonia	6 (1.8)	4 (1.6)	2 (2.4)	
Reintubation	6 (1.8)	4 (1.6)	2 (2.4)	
Tracheostomy	10 (2.9)	5 (2)	5 (6)	
Renal complications				.182
Acute tubular necrosis	7 (2.1)	4 (1.6)	3 (3.6)	
Renal replacement therapy	6 (1.8)	3 (1.2)	3 (3.6)	
Sternal wound infection				.261
Superficial	7 (2.1)	7 (2.7)	0 (0)	
Deep	1 (0.3)	1 (0.4)	0 (0)	
Reexploration for bleeding	16 (3.8)	13 (4.3)	3 (2.4)	.529
Myocardial infarction	1 (0.2)	1 (0.3)	0 (0)	1.000
Atrial fibrillation	105 (24.6)	80 (26.4)	25 (20.3)	.232
MAEs†	27 (6.3)	20 (6.6)	7 (5.7)	.897
Patients transfused	199 (46.7)	130 (42.9)	69 (56.1)	.018
Packed red blood cells	170 (39.9)	114 (37.6)	56 (45.5)	.161
Fresh-frozen plasma	113 (26.5)	71 (23.4)	42 (34.1)	.032
Platelets	122 (28.6)	78 (25.7)	44 (35.8)	.050
Cryoprecipitate	62 (14.6)	36 (11.9)	26 (21.1)	.021

MAE, Major adverse event. *Categorical variables are reported as frequency (percentage). †MAEs include mortality, stroke, new renal replacement therapy, deep sternal wound infection, and myocardial infarction.

the debranching approach more commonly in younger patients with heritable thoracic aortic disease, who may be at increased risk for late aneurysmal patch degeneration. A more expedient en bloc island reimplantation was used in older patients with more comorbidities. In our experience, operative mortality and postoperative stroke occurred in 1.4% and 2.6%, respectively, with no difference between patients who had undergone island patch implantation or separate supra-aortic vessels implantation. Di Eusanio and colleagues[5] reported an overall hospital mortality of 6.8%, postoperative stroke rate of 3.5%, and transient neurologic dysfunction in 5.4%, and it was not dependent on the arch vessels reimplantation technique. Furthermore, Shrestha and colleagues[6] did not find a difference in 30-day mortality (16.1% vs 10.6%, P = not significant) or stroke rate (3.8% vs 4.3%, P = not significant) between island and branched grafts.

The largest series to date comparing island and debranching approaches for reimplantation of the arch vessels, derived from the ARCH registry, reported on 3345 patients who underwent total arch replacement.[4] Unadjusted hospital mortality rate was significantly higher for the island cohort compared with the debranching cohort (15.9% vs 9.8%, $P < .001$), and no difference was reported in the stroke rate (8.8% vs 7.1%, $P = .12$) or temporary neurological deficit rate (6.6% vs 5.8%, $P = .47$). However, after propensity score matching analysis, the mortality difference was abolished ($P = .710$), indicating that the difference in unadjusted mortality was due to comorbid conditions rather than repair technique. In our series, by using a selective approach to the arch strategy, we achieved similar results in both groups. The more conservative and quicker island reimplantation was performed in the older patients with comorbid conditions and no CTD. Performing island reimplantation in older patients without CTD optimizes operative outcomes by decreasing the surgical insult but does not compromise long-term durability and need for reoperation. Extensive arch debranching was performed in the younger patients with CTD and less comorbid conditions, who had a longer life expectancy (and time for the aorta to grow) and potential increased risk for patch aneurysm. Performing more extensive debranching operations in the younger patients is possible without compromising operative outcomes because they have less comorbidities and

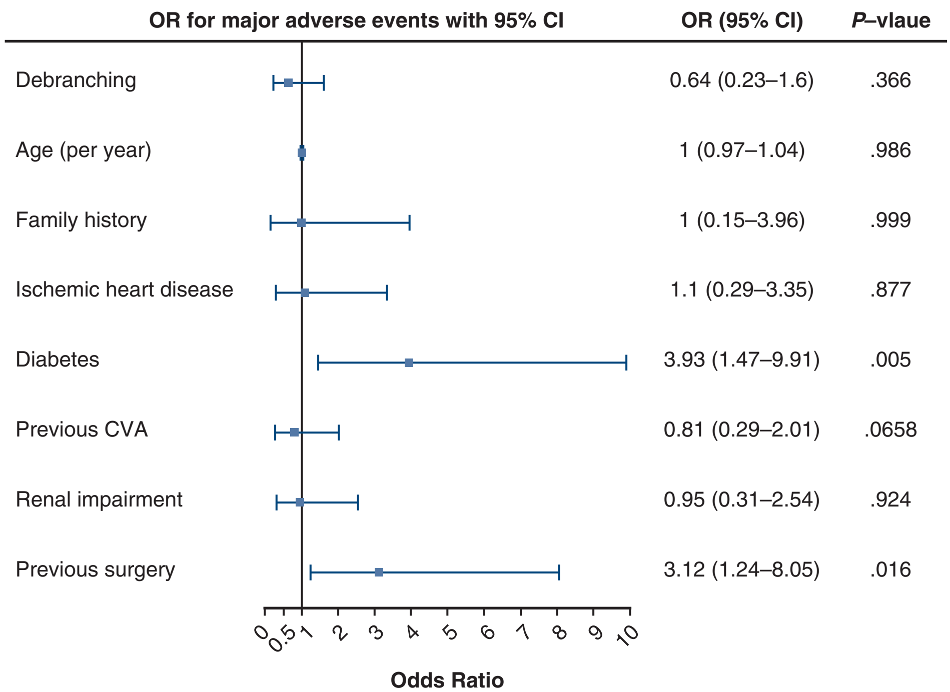

FIGURE 2. Multivariable logistic regression analysis of risk factors for MAE.* *OR*, Odds ratio; *CI*, confidence interval; *CVA*, cerebrovascular accident. *MAEs include mortality, stroke, new renal replacement therapy, deep sternal wound infection, and myocardial infarction.

can tolerate lengthier surgeries. We have previously shown that using a similar tailored selective approach to type A dissection repair, adjusting the procedure to reduce operative risk, excellent results are attainable even in high-risk patients.[10]

Second, reattachment of the supra-aortic vessels with separate grafts requires longer circulatory arrest time and is associated with more bleeding and transfusion requirement. However, it does not carry increased operative mortality, neurological events, or any other MAEs.

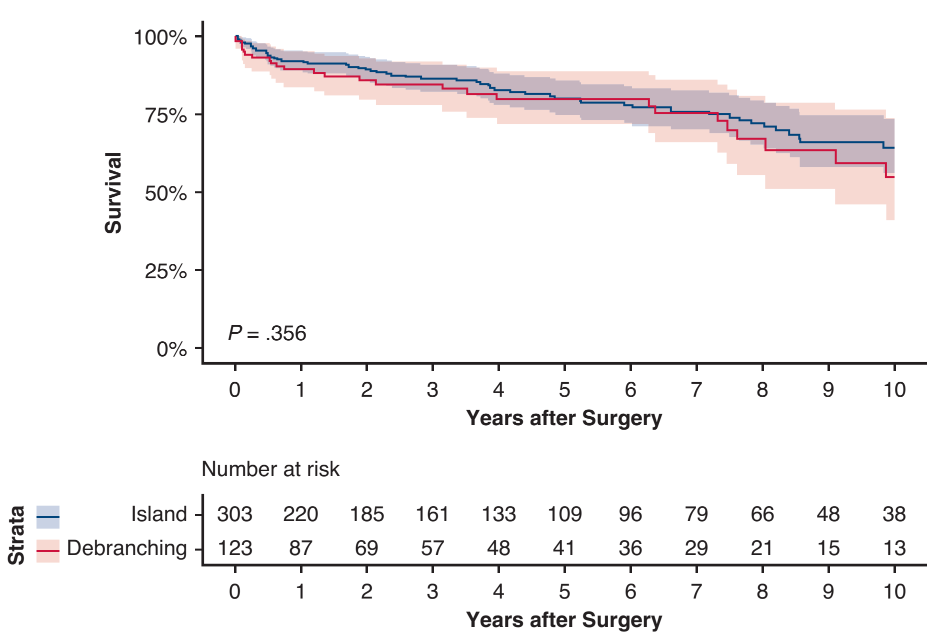

FIGURE 3. Overall 10-year survival curves by supra-aortic vessel implantation strategy using Kaplan–Meier method (95% CI).

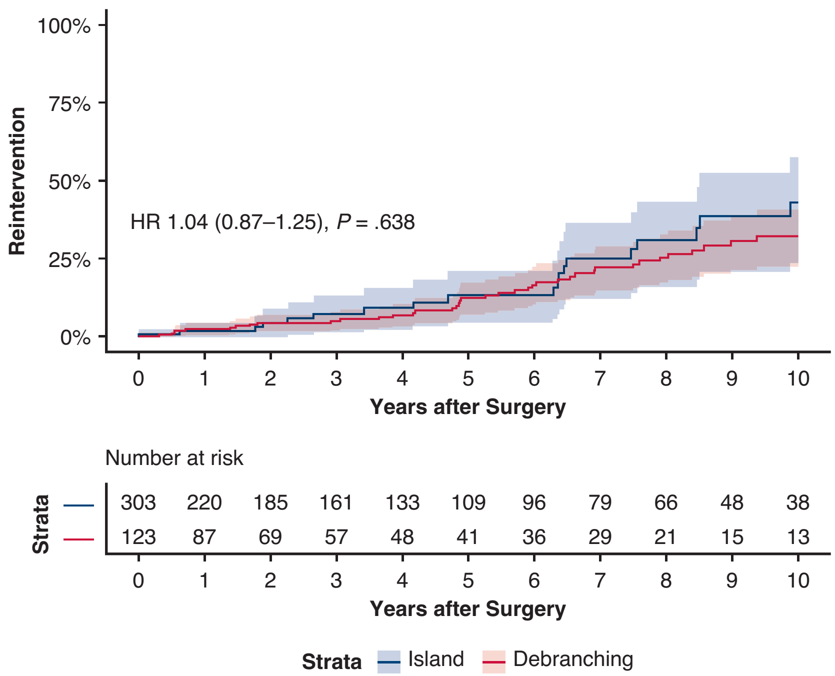

FIGURE 4. The 10-year hazard for reintervention using competing risk of death after total arch replacement by supra-aortic vessel implantation approach (95% CI). *HR*, Hazard ratio.

TABLE 4. Follow-up outcomes*

Outcome	Overall N = 426	Island N = 303	Debranching N = 123	*P* value
10-y survival	341 (80)	245 (80.9)	96 (78)	.356†
Reintervention	80 (18.8)	55 (18.2)	25 (20.3)	.340†
Reintervention				.717
Open procedures	67 (15.7)	47 (15.5)	20 (16.3)	
Percutaneous approach	13 (3.1)	8 (2.6)	5 (4.1)	
Time to reintervention (mo) (mean ± SD)	38.7 ± 43.4	38.4 ± 41.5	39.4 ± 48.5	.926
Ejection fraction (%) (mean ± SD)	59.4 ± 10.7	59.5 ± 10.2	59.2 ± 11.6	.854
Ejection fraction				.403
Normal (≥55)	211 (82.4)	137 (82)	74 (83.1)	
Mild (>40, <55)	28 (11)	21 (12.6)	7 (7.9)	
Moderate (30-40)	8 (3.1)	5 (3)	3 (3.4)	
Severe (<30)	9 (3.5)	4 (2.4)	5 (5.6)	
Aortic valve insufficiency				.527
None/trivial	196 (76.6)	124 (74.3)	72 (80.9)	
Mild AI	53 (20.7)	37 (22.1)	16 (18)	
Moderate AI	6 (2.3)	5 (3)	1 (1.1)	
Severe AI	1 (0.4)	1 (0.6)	0 (0)	
Aortic valve stenosis				.243
None/trivial	242 (94.5)	155 (92.8)	87 (97.8)	
Mild AS	9 (3.5)	8 (4.8)	1 (1.1)	
Moderate AS	3 (1.2)	3 (1.8)	0 (0)	
Severe AS	2 (0.8)	1 (0.6)	1 (1.1)	

SD, Standard deviation; *AI*, aortic insufficiency; *AS*, aortic stenosis. *Categorical variables are reported as frequency (percentage), and continuous variables are reported as mean ± SD. †The statistical method used was the log-rank test.

Debranching required a mean of 9.8 additional minutes of circulatory arrest time, but the overall circulatory arrest time in the debranching group remained within the known limits of safety with adjunctive retrograde cerebral perfusion. Abjigitova and colleagues[7] showed a higher hospital mortality rate in their series when they used separate grafts compared with the en bloc technique (19.5% vs 8.5%, $P = .077$). However, they had a significant proportion of patients who received neither adjunctive antegrade nor retrograde cerebral perfusion, and circulatory arrest times were well out of the safe duration in the debranching group. We have previously shown that retrograde cerebral perfusion provides protection even for long circulatory arrest time greater than 60 minutes.[11] However, prolonged hypothermia does seem to lead to increased coagulopathy requiring transfusions.

Although we found no difference between the techniques in the risk of MAE (OR, 0.64; 0.23-1.6; $P = .366$), in our cohort diabetes was found as a significant risk factor for the composite end point of MAE (OR, 3.93; 1.47-9.91; $P = .005$). This is not surprising because it is a well-known risk factor for each one of the components of the composite outcome. Furthermore, we believe that diabetes is also a marker for other comorbidities as well. Of note, our group has looked at diabetes in thoracoabdominal aortic aneurysm repairs and found that it was associated with more spinal cord injury and mortality.[12]

Third, the supra-aortic arch vessel attachment approach does not affect the long-term survival or need for reintervention. Shrestha and colleagues[6] found no difference in survival at 4 years (61.7% vs 60.7%), and reintervention rates on the distal aorta were similar (29.8% vs 20%). All reinterventions in the island group were in the distal aorta, and no arch reinterventions were required. Survival is more strongly predicted by comorbidities and cardiovascular risk factors. In the matched cohorts of the ARCH study, there was no difference in long-term survival between groups.[4] In our study, given the similar risk profiles in our 2 cohorts, long-term survival difference was not apparent. Reintervention was driven more by the distal aorta than the aortic arch reconstruction technique. According to our data, with only 1.4% of patients requiring repeat sternotomy aortic repair, we can be confident that an island reimplantation is a durable approach when arch vessels are not significantly separated. Similar to our type A dissection analysis, in which reintervention was actually lower after hemiarch reconstruction, the need for reintervention is largely related to patient risk factors such as CTD rather than the arch reconstruction technique.[10]

Last, retrograde cerebral perfusion is a safe method of cerebral protection allowing complex aortic arch operations to be performed with excellent results in terms of mortality and neurologic outcomes.[13-15] It produced adequate protection and favorable outcomes despite longer circulatory arrest times in the debranching group. We have reported previously on stroke rate of 1% to 2% also in cases of greater than 50 minutes of circulatory arrest time using retrograde cerebral perfusion.[11] Furthermore, other large series have reported a stroke rate of 0% to 4% using retrograde cerebral perfusion during deep hypothermic circulatory arrest.[16-18]

Although most studies comparing island and debranching techniques used antegrade cerebral perfusion as their main brain protection strategy combined with hypothermic circulatory arrest,[4-7] we use retrograde cerebral perfusion solely in all of our circulatory arrest cases. The main reason we continue to use this approach rather than changing to antegrade cerebral perfusion is to avoid manipulation of the aortic arch vessels, which often have significant atherosclerosis. Furthermore, retrograde cerebral perfusion has the potential benefit of retrograde flushing of debris from the aortic arch vessels. Cannulating and snaring them risk debris flowing into the arch vessels while perfusing the brain. Our low incidence of neurologic injury confirms the efficacy of this approach.

Study Limitations

There are several significant limitations to this study. First, this is a retrospective, single-center, observational study that introduces inherent biases that cannot be perfectly corrected by multivariable analysis. Second, because all operations took place in a high-volume aortic center where aortic arch replacement is commonly performed, these findings may not be generalizable to other centers with low volume that might benefit from a less-extensive repair in patients. Third, all operations were performed with retrograde cerebral perfusion, and the results may not apply to other circulatory arrest techniques. Fourth, we did not have complete information on the main cause of death during follow-up; therefore, we could not report on the aortic-related mortality. Fifth, the decision on which repair to perform was left to the discretion of the individual surgeon, a factor that could have affected results based on differences in preference for certain surgical techniques among the individual surgeons.

CONCLUSIONS

Total arch replacement using retrograde cerebral perfusion was confirmed to be an effective method with excellent results in both debranching and island techniques for supra-aortic vessel implantation. Debranching requires a longer operative time, with similar early and long-term outcomes. Preoperative comorbidity, and not surgical technique, predicts MAEs and long-term survival.

Conflict of Interest Statement

The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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Key Words: aortic aneurysm, aortic arch replacement, debranching, en bloc, island

TABLE E1. Sensitivity analyses by era of surgery

Outcome	Island	Debranching	
	Years 1997-2012		
	N = 155	**N = 52**	
Operative mortality	2 (1.3%)	0 (0%)	*P* = .997
MAE*	11 (7.1%)	3 (5.8%)	OR, 0.75 (0.15-2.82), *P* = .686
10-y survival	112 (72.3%)	38 (73.1%)	HR, 0.9 (0.49-1.67), *P* = .740
Reoperation	31 (20%)	11 (21.2%)	HR, 0.97 (0.74-1.26), *P* = .806
	Years 2013-2022		
	N = 148	**N = 71**	
Operative mortality	1 (0.7%)	3 (4.2%)	*P* = .195
MAE*	9 (6.1%)	4 (5.6%)	OR, 0.69 (0.16-2.48), *P* = .587
10-y survival	133 (89.9%)	58 (81.7%)	HR, 1.82 (0.76-4.35), *P* = .177
Reoperation	24 (16.2%)	14 (19.7%)	HR, 1.23 (0.93-1.63), *P* = .145

HR, Hazard ratio; *MAE*, major adverse event; *OR*, odds ratio. *MAEs include mortality, stroke, new renal replacement therapy, deep sternal wound infection, and myocardial infarction.

TABLE E2. Sensitivity analyses by acuity of presentation

Outcome	Island	Debranching	
	Elective surgery		
	N = 267	**N = 108**	
Operative mortality	3 (1.1%)	3 (2.8%)	*P* = .483
MAE*	18 (6.7%)	7 (6.5%)	*P* = 1.000
10-y survival	220 (82.4%)	83 (76.9%)	HR, 1.33 (0.8-2.21), *P* = .268
Reoperation	50 (18.7%)	21 (19.4%)	HR, 1.11 (0.91-1.35), *P* = .314
	Emergency surgery due to acute type A aortic dissection		
	N = 36	**N = 15**	
Operative mortality	0 (0%)	0 (0%)	NA
MAE*	2 (5.6%)	0 (0%)	*P* = .889
10-y survival	25 (69.4%)	13 (86.7%)	HR, 0.65 (0.14-3.11), *P* = .592
Reoperation	5 (13.9%)	4 (26.7%)	HR, 0.66 (0.35-1.23), *P* = .190

MAE, Major adverse event; *HR*, hazard ratio; *NA*, not available. *MAEs include mortality, stroke, new renal replacement therapy, deep sternal wound infection, and myocardial infarction.