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Total arch repair versus hemiarch repair in the management of acute DeBakey type I aortic dissection☆

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Abstract

Objective: In acute DeBakey type I aortic dissection, it is still controversial whether to perform extended aortic replacement to improve long-term outcome or to use a conservative strategy with ascending aortic and hemiarch replacement to palliate a life-threatening condition. **Methods:** Between 1999 and 2009, 188 consecutive patients (93 women; mean age, 57.4 ± 11.7 years) with acute DeBakey type I aortic dissection underwent hemiarch (Hemiarch group; $n = 144$) or total arch replacement (Total arch group; $n = 44$) in conjunction with ascending aorta replacement. Clinical outcomes were compared after adjustment for baseline characteristics using inverse-probability-of-treatment weighting. **Results:** Median follow-up was 47.5 months (range 0—130.4 months) and was 92.0% ($n = 173$) complete. Five-year unadjusted survival and permanent-neurologic-injury-free survival rates were 65.8 ± 8.3% and 43.1 ± 9.7% in the Total arch group, and 83.2 ± 3.3% and 75.2 ± 4.0% in the Hemiarch group, respectively ($P = 0.013$ and <0.001). After adjustment, the Total arch group patients were at greater risks of death (hazard ratio (HR) 2.38, 95% confidence interval (CI) 1.21—4.67; $P = 0.012$), and permanent neurologic injury (HR 3.25, 95% CI 1.31—8.04; $P = 0.011$) compared to the Hemiarch group patients. The risks of the re-operation for aortic pathology or distal aortic dilatation (>55 mm) were similar for both groups (HR 0.33, 95% CI 0.08—1.43; $P = 0.14$). **Conclusions:** Total arch repair was associated with greater morbidity and mortality compared with hemiarch repair in acute DeBakey type I aortic dissection. Rates of aortic re-operation or aortic dilatation were not significantly different between the two surgical strategies. These findings support a conservative surgical approach to circumvent this life-threatening situation.

Keywords: Aorta; Surgery; Mortality; Morbidity

1. Introduction

Although the outcome of surgical repair of acute DeBakey type I aortic dissection has significantly improved during the decades, early mortality and morbidity after surgery still remain high, and the long-term clinical benefits of surgery are often limited by residual dissection in the descending aorta [1—3]. As the residual dissection flap in the descending aorta carries the risk of progressive aortic dilatation, rupture, or requirements for secondary intervention, extensive surgery involving total replacement of the ascending aorta and aortic arch at the initial surgery has been suggested by several groups to decrease the incidence of late aortic complications [4—6]. On the contrary, concomitant distal aortic manipulation has been reported to increase risks of morbidity and mortality; therefore, more conservative surgical strategy limited within the ascending aorta and proximal arch has also been suggested to palliate this life-threatening condition [7—9]. To date, evidences are poor with regard to the optimal surgical management of acute DeBakey type I aortic dissection.

Therefore, we sought to compare the surgical outcomes of total arch replacement with those of hemiarch replacement in patients with acute DeBakey type I aortic dissection.

2. Methods

2.1. Patients

From January 1999 to October 2009, 192 patients with acute DeBakey type I or III-D (retro-A) aortic dissection underwent urgent surgery at our institution. Of them, four patients who underwent surgery as a life-salvaging procedure in preoperative devastating conditions were excluded. Of the total of 188 included patients, 44 underwent total arch replacement, whereas 144 received hemiarch replacement

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in conjunction with ascending aorta replacement. The decision to perform total arch versus hemiarch repair was dependent on individual patient's condition, intimal tearing site, and/or diameter of distal arch but was finally at the attending surgeon's discretion; some authors in this study had preferred the hemiarch repair in acute type I or III-D (retro-A) aortic dissection.

This study was approved by our institutional Ethics Committee/Review Board, and the requirement for informed patient consent was waived by the board owing to the retrospective nature of the current study.

2.2. Definition

Total arch replacement was defined as involving the whole aortic arch, with reimplantation of the arch branch vessels either as an island or as individual branch grafts. Hemiarch replacement included the aortic arch beyond the level of the innominate artery but not involving the arch vessels.

Malperfusion syndromes were defined as having symptoms or signs attributable to disturbed blood flow to end-organ systems. Malperfusion syndromes were classified as acute myocardial infarction, stroke, and visceral or peripheral (limb) malperfusion. Radiographic or intra-operative evidence of dissection involving corresponding aortic branch vessels was required for the diagnosis of malperfusion syndrome. Cardiogenic shock was reported, if the preoperative systolic blood pressure was less than 90 mmHg, the cardiac index was less than 2.0 ml m^{-2}, or the patient required intravenous use of inotropic agent.

2.3. Study end point

Data were obtained until March 2010 during biannual visits to the outpatient clinic. Early mortality was defined as death within 30 days of surgery. Data on vital status, dates of death, and causes of death were obtained from the Korean national registry of vital statistics.

The primary end point of the study was defined as the composite of death and permanent neurologic injuries. Clinical diagnosis of neurologic deficits was made by neurologists and was confirmed by postoperative computerized tomography or magnetic resonance imaging (MRI). Permanent neurologic injury was defined as any kind of postoperative neurologic dysfunction that did not resolve completely. When the dysfunction resolved completely during follow-up, it was regarded temporary. The secondary end point was aortic replacement for residual aortic pathology or distal aortic dilatation with a maximal diameter of more than 55 mm.

2.4. Statistics

Categorical variables are presented as frequencies and percentages, and continuous variables are expressed as mean $\pm$ SD or medians with ranges. Differences in baseline characteristics between patients, who underwent total arch replacement or hemiarch replacement, were compared using the *t*-test or the Mann–Whitney *U* test for continuous variables and the chi-squared test or Fisher's exact test for categorical variables, as appropriate. Cumulative incidence rates of individual and composite outcomes were estimated by the Kaplan–Meier method and compared by the log-rank test. To reduce the impact of treatment selection bias and potential confounding in an observational study, we performed rigorous adjustment for significant differences in patient characteristics by using weighted Cox proportional-hazards regression models and inverse-probability-of-treatment weighting (IPTW) [10,11]. With that technique, weights for patients receiving total arch replacement were the inverse of (1 minus propensity score), and weights for patients receiving hemiarch replacement were the inverse of propensity score. The propensity scores were estimated by multiple logistic regression analysis [10]. All prespecified covariates were included in full non-parsimonious models for hemiarch replacement, versus total arch replacement (Tables 1 and 2). The discrimination and calibration abilities of each propensity score model were assessed by *C* statistics and the Hosmer–Lemeshow test. The model was well calibrated (Hosmer–Lemeshow test; $P = 0.769$) with reasonable discrimination (*C* statistic = 0.894). For multivariable analyses, the Cox models were used to examine the association of two surgical techniques with clinical end points incorporating some important risk covariates, which had significant effects ($P < 0.1$) on each clinical outcome. Results were expressed as hazard ratios (HRs) with 95% confidence intervals (CIs). All reported *P* values are two-sided, and values of $P < 0.05$ were considered to indicate

Table 1. Baseline patient profiles.

	Total arch	Hemiarch	*P* value
Total number of patients	44	144	
Demographic and baseline risks			
Age, year	55.0 ± 12.1	57.6 ± 11.5	0.12
Female gender, *n* (%)	18 (40.9)	75 (52.1)	0.23
Diabetes mellitus, *n* (%)	2 (4.5)	6 (4.2)	0.60
History of CVA or TIA, *n* (%)	1 (2.3)	4 (2.8)	>0.999
Hypertension, *n* (%)	24 (54.5)	92 (63.9)	0.26
Marfan syndrome, *n* (%)	1 (2.3)	7 (4.9)	0.68
Preoperative condition			
Shock, *n* (%)	4 (9.1)	13 (9.0)	>0.999
Malperfusion, *n* (%)	11 (25)	11 (7.6)	0.027*
Acute myocardial infarction	1	1 (b)	
CVA	3	4	
Visceral malperfusion	2[a]	1[b]	
Peripheral malperfusion	6[a]	6[b]	
Intramural hematoma, *n* (%)	1 (2.3)	10 (6.9)	0.22
DeBakey subtype III-D, *n* (%)	18 (40.9)	16 (11.1)	<0.001*
Involvement of aortic dissection, *n* (%)			
Aortic root	36 (81.8)	129 (89.6)	0.17
Coronary artery	3 (6.8)	13 (9.0)	0.65
Arch vessels	27 (61.4)	74 (51.4)	0.25
Visceral artery	9 (20.5)	43 (29.9)	0.22
Renal artery	9 (20.5)	33 (22.9)	0.73
Distal extent of aortic dissection, *n* (%)			0.90
Descending thoracic	3 (6.8)	12 (8.3)	
Abdominal-suprarenal	4 (9.1)	13 (9.0)	
Abdominal-infrarenal	3 (6.8)	16 (11.1)	
Iliac or beyond iliac	34 (77.3)	104 (72.2)	
Diameter of proximal descending aorta, mm	39.6 ± 5.8	37.6 ± 4.8	0.024*

Abbreviations: CVA, cerebrovascular accident; TIA, transient ischemic attack.
[a,b] Two patients had both visceral and peripheral malperfusion
* $P < 0.05$.

Table 2. Operative profiles.

	Total arch	Hemiarch	*P* value
Intra-operative findings			
Intimal tearing sites, *n* (%)			$<0.001^{*}$
Confined to ascending aorta	7 (15.9)	86 (59.7)	
Beyond ascending aorta	33 (75)	35 (24.3)	
Unidentified	4 (9.1)	23 (16.0)	
Operative profiles			
Surgical year, *n* (%)			0.96
1999–2001	10 (22.7)	35 (24.3)	
2002–2004	10 (22.7)	37 (25.7)	
2005–2007	16 (36.4)	48 (33.3)	
2008–2009	8 (18.2)	24 (16.7)	
Arterial cannulation sites, *n* (%)			0.096
Femoral artery	10 (22.7)	51 (35.4)	
Right axillary artery	22 (50.0)	47 (32.6)	
Both femoral and axillary arteries	12 (27.3)	46 (31.9)	
Brain protection, *n* (%)			$<0.001^{*}$
Antegrade cerebral perfusion	27 (61.4)	42 (29.2)	
Selective/non-selective[a]	18/9	41/1	
Retrograde cerebral perfusion	17 (38.6)	99 (68.8)	
Total circulatory arrest	0	3 (2.0)	
Temperature management			0.27
Deep hypothermia, *n* (%)	31 (70.5)	110 (76.4)	
Moderate hypothermia, *n* (%)	13 (29.5)	34 (23.6)	
Lowest esophageal temperature	17.2 ± 4.5	16.3 ± 4.0	0.21
Arch vessel procedure, *n* (%)			
Individual anastomosis	21 (47.7)	NA	
Island technique	23 (52.3)	NA	
Combined procedure, *n* (%)			
Elephant trunk	5 (11.4)	NA	
Aortic root replacement or remodeling	0	8	0.11
Bentall operation	2	6	0.91
Coronary bypassing surgery	3	14	0.56
Femoral-to-femoral bypassing	7	8	0.027^{*}
Others	0	3	0.33
Tear exclusion			0.057
Tear unidentified	4 (9.1)	23 (16.0)	
Incomplete	0	10 (6.9)	
Complete	40 (90.9)	111 (77.1)	

[a] Non-selective cerebral perfusion: cerebral perfusion through both innominate artery and left common carotid artery by separate cannulations.
* $P < 0.05$.

statistical significance. SAS software version 9.1 (SAS Inc, Cary, NC, USA) was used for statistical analysis.

3. Results

3.1. Baseline characteristics and intra-operative profiles

Baseline characteristics of patients are shown in Table 1. Patients in the Total arch group were more likely to have preoperative malperfusion syndrome and DeBakey subtype III-D aortic dissection than those in the Hemiarch group. The proximal descending aorta was larger in the Total arch group, and the intimal tearing sites were more likely to be confined within the ascending aorta in the Hemiarch group. There were no significant differences in the proximal and distal extent of aortic dissection, and the involvement of major aortic branching arteries between the two groups (Table 2).

Antegrade cerebral perfusion was more frequently performed for the Total arch group patients, whereas retrograde perfusion was the preferred method for the Hemiarch group patients. Moderate (lowest esophageal temperature of 20.0–26.5 °C, $n = 47$) or deep hypothermia (lowest esophageal temperature of 11.0–19.8 °C, $n = 145$) was introduced during circulatory arrest according to the methods of cerebral perfusion, in that moderate hypothermia was more commonly used in antegrade cerebral perfusion (43/47, 91.5%), whereas deep hypothermia was the usual strategy for retrograde cerebral perfusion or total circulatory arrest (115/141, 81.6%, $P < 0.001$). Cardiopulmonary bypass and cardiac ischemic and circulatory arrest times were significantly longer in the Total arch group than in the Hemiarch group (cardiopulmonary bypass time: 314.6 ± 100.5 min vs 233.4 ± 90.7 min, $P < 0.001$; cardiac ischemic times: 125.7 ± 111.4 min vs 107.9 ± 64.0 min, $P < 0.001$; circulatory arrest times: 50.2 ± 44.3 min vs 24.6 ± 13.9 min; $P < 0.001$).

3.2. Operative outcomes

Follow-up was complete in 173 patients (92.0%), with a median follow-up duration of 47.5 months (range 0–130.4 months) without an inter-group difference ($P = 0.43$).

3.2.1. Early outcomes

There were 20 early deaths (12.4%) without a significant difference between the two groups (Table 2). Fifty-nine patients (31.4%) were complicated with new-onset neurologic dysfunction including 19 permanent (10.1%) and 40 temporary (21.3%) neurologic injuries. Permanent neurologic injuries included major motor deficit with ($n = 4$) or without ($n = 6$) cognitive dysfunction in 10, paraplegia in two, and coma in six. All coma patients died in-hospital due to brain death ($n = 5$) or pneumonia complicated with sepsis ($n = 1$). Neurologic dysfunction occurred more frequently in the Total arch group than the Hemiarch group, significantly ($P = 0.003$). More patients in the Total arch group were complicated with pneumonia than those in the Hemiarch group ($P < 0.001$).

Forty-four patients required dialysis after surgery. Of them, nine died during the early postoperative course. Of the 35 surviving patients, 34 required dialysis temporarily, whereas one went on to definite hemodialysis.

3.2.2. Late outcomes

There were 24 late deaths including 18 cardiovascular related deaths. Non-cardiovascular causes of death were malignancy in four, underlying end-stage renal disease in one, and traffic accident in one patient. Overall 5-year survival rates were $65.8 \pm 8.3\%$ in the Total arch group and $83.2 \pm 3.3\%$ in the Hemiarch group ($P = 0.013$; Fig. 1). There were two late stroke cases. The patients in the Hemiarch group showed superior freedom from death and permanent neurologic injury compared with those in the Total arch group, significantly (Fig. 2). Of the 19 patients, who had permanent neurologic injuries after surgery, four died during the early postoperative period (<30 days) due to brain death, and another three died in-hospital during 31–149 days due to brain death in one, pneumonia in one, and airway obstruction in one. When survival was evaluated according to presence of permanent neurologic injury, 5-year survival rates with or

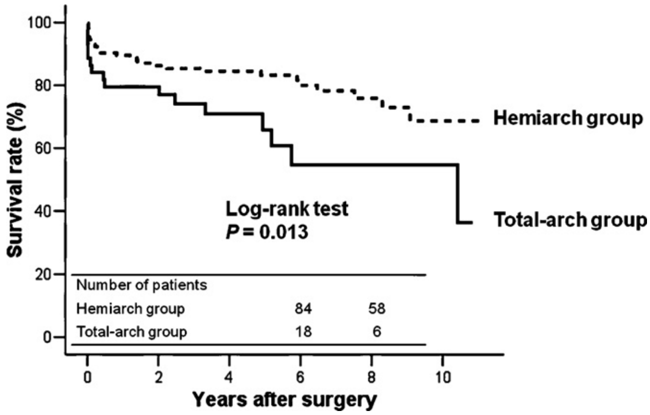

Fig. 1. Kaplan—Meier curves for survival in the Total arch and Hemiarch groups. The 5-year survival rates were 65.8 ± 8.3% in the Total arch group and 83.2 ± 3.3% in the Hemiarch group.

without permanent neurologic injury were 61.1 ± 10.8% and 81.7 ± 3.3%, respectively ($P = 0.0037$).

Seven patients (3.7%) underwent elective aortic re-operations due to residual or progressive aortic pathology during follow-up. Both groups had similar rates of aortic re-operation (Fig. 3). There were no mortality or neurologic complications related to the re-operations. Of the 168 early survivors, computed tomography (CT) follow-up beyond 6 months of surgery was possible in 135 patients (79.8%), and median CT follow-up duration was 32.4 months (range 6.1—132.1 months). CT follow-up in the late period was not done because of late death within 6 months to 1 year in 12 patients, short follow-up period (<6 months) in six, clinical follow-up without CT evaluation in 13, and follow-up loss in two. Of those who did not undergo aortic replacement surgery for distal aortic lesions, 12 had distal aortic dilatation of its maximal diameter exceeding 55 mm without a significant inter-group difference (Table 3). Residual false lumen at descending aorta was completely resolved in 35 patients, completely thrombosed in three, partially thrombosed in 55, and patent in 42. Both groups had similar rates of aortic re-operation and freedom from aortic re-operation or aortic dilatation (>55 mm) (Fig. 4).

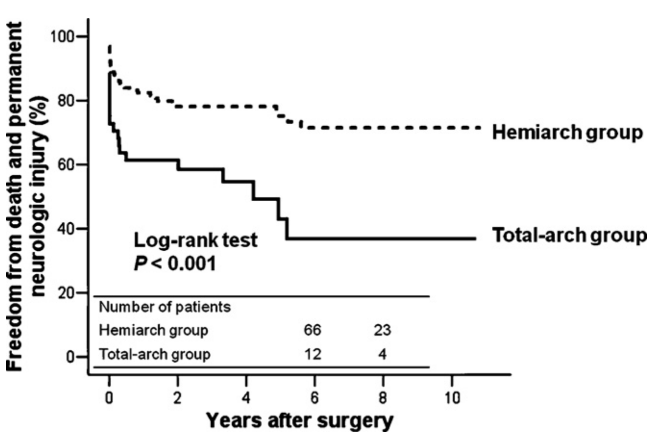

Fig. 2. Kaplan—Meier curves for freedom from death and permanent neurologic injury in the Total arch and Hemiarch groups. The 5-year freedom from death and permanent neurologic injury was 43.1 ± 9.7% in the Total arch group and 75.2 ± 4.0% in the Hemiarch group.

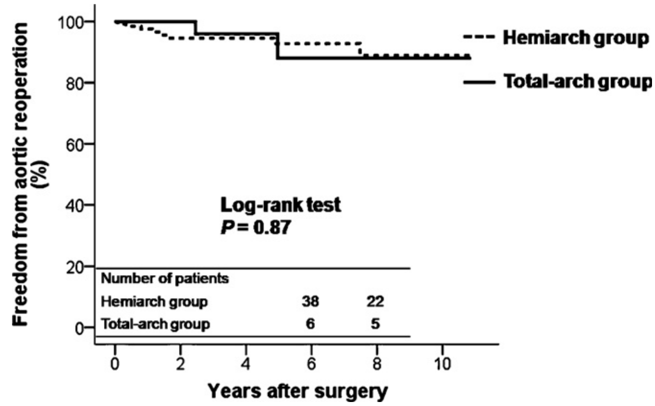

Fig. 3. Kaplan—Meier curves for freedom from re-operation due to residual or progressive aortic pathology. The 5-year freedom from re-operation was 88.0 ± 8.5% in the Total arch group and 92.8 ± 2.8% in the Hemiarch group.

Table 3. Operative outcomes.

	Total arch	Hemiarch	*P* value
Early outcomes			
Early mortality, *n* (%)	6 (13.4) 1 CVA 1 LCOS 2 CVA + LCOS 1 Aortic rupture 1 Bowel ischemia	14 (9.7) 1 CVA 2 LCOS 4 Pneumonia/ sepsis 1 Aortic rupture 2 Bowel ischemia 4 Others	0.58
LCOS, *n* (%)	8 (18.2)	7 (4.9)	0.009*
New neurologic dysfunction, *n* (%)	21 (47.7)	38 (26.4)	0.003*
Permanent neurologic injury	10 (22.7)	9 (6.3)	
Motor deficits ± cognitive dysfunction	5 (11.4)	5 (3.5)	
Paraplegia	1 (2.3)	1 (0.7)	
Coma	2 (4.5)	2 (1.4)	
Temporary neurologic injury	11 (25)	29 (20.1)	
Requirement for dialysis, *n* (%)	13 (29.5)	31 (21.5)	0.27
Visceral ischemia, *n* (%)	2 (4.5)	10 (6.9)	0.74
Bleeding re-operation, *n* (%)	5 (11.4)	11 (7.6)	0.54
Sternal infection, *n* (%)	1 (2.3)	12 (8.3)	0.31
Pneumonia, *n* (%)	21 (47.7)	23 (16.0)	<0.001*
Sepsis, *n* (%)	12 (27.3)	21 (14.6)	0.053
Late outcomes			
Late death, *n* (%)	10 (22.7)	14 (9.7)	0.024*
Late CVA, *n* (%)	1 (2.3)	1 (0.7)	0.37
Re-intervention, *n* (%)	3 (6.8)	20 (13.9)	0.30
Aortic replacement	2 (4.5)	5 (3.5)	>0.99
Descending thoracic aorta	1 (2.3)	3 (2.1)	
Thoracoabdominal aorta	1 (2.3)	2 (1.4)	
Peripheral arteries	1 (2.3)	15 (10.4)	0.090
CT findings on latest follow-up (>6 months), *n*	32	103	0.66
Maximal distal aortic diameter, mm	40.5 ± 9.5	43.1 ± 9.9	0.22
Maximal aortic diameter >55 mm, *n* (%)	2 (4.5)	10 (6.9)	0.57
Residual false lumen, *n* (%)			0.66
None	6 (13.6)	29 (20.1)	
Completely thrombosed	1 (2.3)	2 (1.4)	
Partially thrombosed	13 (29.5)	42 (29.2)	
Patent	12 (27.3)	30 (20.8)	

Abbreviations: CVA, cerebrovascular accident; LCOS, low cardiac output syndrome; CT, computed tomography.
* $P < 0.05$.

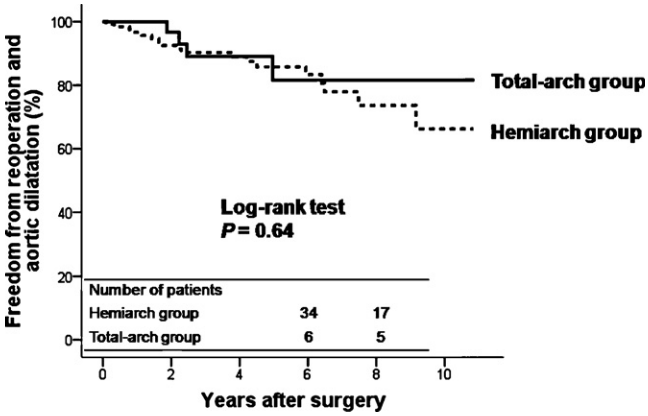

Fig. 4. Kaplan—Meier curves for freedom from distal aortic dilatation (>55 mm).

Sixteen patients required surgical interventions for peripheral artery lesions including 10 axillary-femoral bypassing and six femoral—femoral bypassing (Table 3). Indications for peripheral artery intervention were lower limb ischemia following false lumen obliteration in 12 patients, obstruction of previous femoral—femoral bypassing in three, and graft infection of previous femoral—femoral bypassing in one.

In the subgroup of DeBakey subtype III-D cases (n = 34), there were no significant differences in the rates of primary end point (death + neurologic injury, P = 0.14) or secondary end point (re-operation + aortic dilatation, P = 0.11) between the two groups. In the subgroup of patients, who had intimal tears beyond the ascending aorta (n = 68), the Hemiarch group had superior results in terms of primary end point (P = 0.03) and similar results regarding secondary end point (P = 0.93) compared with the Total arch group.

3.2.3. Adjusted hazards

Table 4 summarizes the cumulative adjusted hazard of adverse outcomes in patients undergoing total arch replacement versus hemiarch replacement, using IPTW and Cox multivariable analysis. When patient outcomes were adjusted using IPTW, patients undergoing total arch replacement were at a significantly greater risk of death (HR 2.38), permanent neurologic injury (HR 3.25), and composite of death and permanent neurologic injury (HR 3.00), compared with those undergoing the hemiarch replacement. The risks of the re-operation for aortic pathology or distal aortic dilatation (>55 mm) were similar for both groups (P = 0.14). When the outcomes were adjusted using Cox multivariable analysis, similar results were obtained for all clinical end points.

Table 4. Hazard ratios (HRs) for clinical outcomes with total arch replacement versus hemiarch replacement.

Outcomes		HR	95% CI	P value
Death	Crude	2.15	1.16—3.98	0.016*
	IPTW	2.38	1.22—4.67	0.011*
	Multi[a]	2.04	1.08—3.88	0.029*
Permanent neurogic injury	Crude	3.97	1.68—9.34	0.002*
	IPTW	3.25	1.31—8.04	0.011*
	Multi[b]	3.46	1.43—8.40	0.006*
Death + neurologic injury	Crude	2.67	1.56—4.57	<0.001*
	IPTW	3.00	1.72—5.24	<0.001*
	Multi[c]	2.55	1.44—4.53	0.001*
Aortic re-operation	Crude	0.88	0.19—4.13	0.87
	IPTW	0.26	0.04—1.76	0.17
	Multi[d]	0.53	0.08—3.34	0.50
Aortic re-operation + aortic dilatation (>55 mm)	Crude	0.77	0.26—2.29	0.64
	IPTW	0.33	0.08—1.43	0.14
	Multi[d]	0.37	0.11—1.34	0.13

* $P < 0.05$. Findings were adjusted by IPTW or by Cox-multivariable analyses. Multivariable analyses incorporated significant covariates influencing each outcome, including [a] age, shock, malperfusion; [b] shock, malperfusion; [c] age, shock, malperfusion; [d] proximal descending thoracic aorta diameter, intimal tear sites.

4. Discussion

The present study found that patients, who underwent total arch replacement, had poorer survival and neurologic outcomes than those who underwent hemiarch replacement in the setting of acute DeBakey type I or III-D aortic dissection. The rate of re-operation for residual aortic diseases was not affected by the type of surgery, and the re-operations could be done without significant morbidity or mortality.

Residual patent false lumen is a well-known risk factor for progressive aortic dilatation and poor long-term outcomes following surgical repair of acute type I aortic dissection, and has been reported to be related with residual intimal tear, leakage from the distal anastomosis site, and reentry in the distal aorta [12—15]. Although complete resection of all entry tears is required for complete thrombosis of the false lumen, initial surgery for acute type I aortic dissection may fail to achieve this objective, particularly in patients with primary entry or reentry located in the descending aorta.

In an effort to maximize the resection of entry tears and to decrease the incidence of residual patent false lumens, several groups reported routine replacement of the total aortic arch for acute type A aortic dissection, irrespective of the site of entry tear [4,12,16,17]. They reported excellent operative outcomes, including very low early mortality rate. Another study showed that compared with ascending or hemiarch replacement, total arch replacement resulted in a lower incidence of partial thrombosis at the descending thoracic aorta, which was revealed to be a significant independent predictor of aortic enlargement, aorta-related re-operations, and poorer long-term survival [14]. Consequently, patients who underwent total arch replacement showed more favorable outcome in terms of progressive aortic enlargement and aortic re-operations than those who underwent ascending or hemiarch replacement. Recently, several groups reported an even more aggressive approach involving total arch replacement and stented elephant trunk implantation in the proximal descending thoracic aorta for acute type A aortic dissection [5,6]. However, the above-mentioned studies in support of aggressive surgical approaches in the setting of acute type A aortic dissection either lack control groups to compare [4,5,12,16] or lack adequate adjustment for baseline risk profiles between the study and control groups [6,17].

Risks of extensive surgery in the acute setting may offset the potential long-term benefits, in that longer duration of cardiac ischemia and circulatory arrest is inevitable in extensive arch surgery compared with a more conservative approach, and this is directly related to cardiac and cerebral injuries as well as organ dysfunction. As concomitant distal aortic arch manipulation has been reported to increase risks of morbidity and mortality from several groups [8,9], a group recommended to replace ascending aorta and hemiarch only whenever the intimal tear is located in the lesser curvature of the transverse arch, to improve overall operative mortality and morbidity [7].

In this study, the most common causes of early death were neurologic complications and low cardiac output syndrome. Although the higher early mortality rate in the Total arch group than in the Hemiarch group was statistically insignificant, the difference in late mortality was significant. This divergence in survival over time between the two groups may be attributable to the difference in the rate of permanent neurologic injury, in that permanent neurologic sequela seems to predispose to late death due to secondary complications. This was evidenced by the findings that overall survival was poorer for those who had permanent neurologic injury than those who did not ($P = 0.0037$).

In the present study, rates of re-operation related to residual or progressive aortic diseases were 7—12% at 5 years among survivors, without an inter-group difference. Our criteria for re-operation included symptoms of chest/back pain or limb ischemia, an aortic diameter of more than 55—60 mm, and progressive dilatation of aorta (>0.5—1 cm year^{-1}). All aortic re-operations could be done electively, and there were no mortality or neurologic complications after the re-operations. We believe that close follow-up using adequate imaging studies (mostly CT) is mandatory to select the appropriate candidates for re-intervention and not to miss the optimal timing of surgery for them.

Nonetheless, there were 12 patients whose residual maximal aortic diameter was greater than 55 mm but who did not undergo aortic replacement surgery. Of them, the maximal aortic diameter was greater than 60 mm in four patients. The reasons of not undergoing surgeries were high operative risks due to co-morbidities or patients' refusal to undergo surgery. In these cases, endovascular intervention may be a good alternative to prevent fatal aortic complications.

The preferential uses of antegrade perfusion in the Total arch group and retrograde perfusion in the Hemiarch group are attributed to surgeons' preference. Six cardiac surgeons performed the surgeries during the study period. Surgeons who had a more aggressive approach (i.e., total arch rather than hemiarch replacement) tend to use antegrade cerebral perfusion, whereas surgeons with a more conservative attitude tend to use retrograde cerebral perfusion. As these cerebral protection strategies may influence the clinical outcomes as confounders, these factors were already incorporated when propensity score was calculated for each patient. Therefore, these factors were already adjusted when comparing the clinical end points between the two groups. Furthermore, types of cerebral perfusion were not associated with neurologic injury-free survival even in univariable analysis in this study ($P = 0.58$).

5. Limitations

This study is subject to the limitations inherent in retrospective work with observational data. The non-randomized design may have affected the results because of unmeasured confounders, procedure bias, or detection bias, even with the use of rigorous statistical adjustment.

This study represents the experience of a single large tertiary referral center, and might not be generalizable to other centers.

6. Conclusions

Total arch repair was associated with greater risks of mortality and permanent neurologic injury compared with hemiarch repair in acute DeBakey type I or III-D aortic dissection. Rates of aortic re-operation or distal aortic dilatation were not significantly different between the two surgical strategies. Re-operations for residual aortic pathology could be safely performed. These findings support a conservative surgical approach to circumvent this life-threatening situation.

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Appendix A. Conference discussion

Dr R. Bonser (*Birmingham, United Kingdom*): I believe that your data show several key and somewhat provocative points. Firstly, that arch replacement alone does not compromise short-term survival necessarily, but is associated with a higher new neurological event rate, particularly a new permanent neurological deficit.

This finding is strengthened by data from your manuscript in that your neurological and temporary neurological deficits were all diagnosed by a neurologist as an independent observer. The observation runs somewhat contrary to current thinking, as actually in your perfusion data a higher proportion of total arch patients had selective antegrade perfusion as a protective adjunct and a higher proportional use of axillary artery cannulation. As the hemiarch group had a higher rate of retrograde cerebral perfusion usage, your data is, in fact, somewhat supportive of Hazim Safi's approach to arch surgery.

In addition, the arch group had an importantly higher incidence of postoperative low cardiac output. Further, the conditional late survival continued to be worse in the total arch group. I believe that that reflects the known effects of neurological and cardiac postoperative complications on late survival rather than a fundamental difference in the patient groups. My take-home message is that extending surgery is inadvisable unless it's clearly clinically indicated.

I've got three questions for you:

1. Can you give a breakdown of the types of neurological deficits that you observed? Were these focal events or were they events suggestive of global brain ischemia?
2. Were there differences in myocardial protection strategies between the groups?
3. Do you think that your results reflect true differences between the tear site in a type I dissection, the extent of the surgery, the efficacy of the brain protection, or different surgical skills and technical differences in practice between your departmental surgeons?

Dr Kim: The answer to the first question is that we divided neurologic complications into permanent ones and temporary ones. Regarding permanent neurological injury, there were major focal neurologic deficits resulting in permanent motor deficit and some had cognitive dysfunction that comprised vegetative state or coma.

And then the answer to your second question about myocardial protection strategy. Six cardiac surgeons operated on the aortic dissection patients and the brain protection strategy and myocardial strategy differed among them. In the absence of significant aortic regurgitation, ordinarily we started with antegrade cardioplegic infusion and then most of the patients underwent retrograde cardioplegic infusion after the cardiac arrest.

And the answer to the third question, the tearing site: because of some selection bias between the two groups, there were more retrograde type A dissections and tear sites located beyond the aortic arch in the total arch replacement group; in the hemiarch group it was located mainly in the ascending aorta or proximal arch. We looked at the data regarding the percentage of exclusion of tear site and found that around 70% of patients in both groups had been excluded for tearing site and then there was no significant difference in the tear site exclusion between the two groups.

Dr Bonser: But in your judgment, looking at all your data, what do you think is the reason for the discrepancy in the results? Do you think it is the site of the tear or the extent of the operation?

Dr Kim: The choice of surgical management was according to the surgeon's preference. There was some tendency towards going on to total arch replacement in cases where the tearing site was located at the distal arch, where malperfusion of the vessels was involved. In cases where the distal arch was large in size, then the surgeons tended to perform total arch replacement, but there was still overlap between the two strategies.

Dr M. Grabenwoger (*Vienna, Austria*): And so the malignancy of the pathology of the aortic dissection was higher in the total arch group?

Dr Kim: Yes.

Dr T. Fischlein (*Nuremberg, Germany*): Was there any difference in neurological outcome when comparing femoral and antegrade cannulation via axillary artery?

Dr Kim: We tried to analyze the influence of arterial cannulation technique or brain protection technique on neurological and survival outcomes, but we didn't find any significant difference on multivariable analysis. Recently, surgeons in our center perform axillary arterial cannulation, but femoral artery cannulation did not affect the neurological outcome in this study.

Editorial comment

Total arch repair versus hemiarch repair in the management of acute DeBakey type I aortic dissection

Keywords: Aorta; Acute dissection; Arch replacement; Surgery

Because of the improvements in the management of acute type A aortic dissection obtained during the last two decades, a controversial debate came out some years ago: Should the replacement of the aorta remain limited as it was traditionally or should we resort to extended aortic replacements?

This issue was perfectly illustrated by two major articles by Westaby et al. on the one hand [1] and Kazui et al. on the