Early and late outcomes of repaired acute DeBakey type I aortic dissection after graft replacement

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ABSTRACT

Objective: The present study aimed to determine the impact of the extent of graft replacement on early and late outcomes in acute DeBakey type I aortic dissection.

Methods: Between October 1999 and July 2014, 197 consecutive patients were surgically treated for acute DeBakey type I aortic dissection. The extent of graft replacement (hemiarch, partial, or total arch replacement) was mainly determined by the location of the primary entry. Early and late results were compared in patients after total arch replacement ($n = 88$) and combined hemiarch and partial arch replacement: non-total arch replacement ($n = 109$).

Results: The in-hospital mortality rates of the total arch replacement and non-total arch replacement groups were 10.2% and 14.7%, respectively ($P = .47$). Multivariate analysis revealed preoperative cardiopulmonary resuscitation and visceral organ malperfusion as significant risk factors for in-hospital mortality, but not total arch replacement. During a mean follow-up period of 60 ± 48 months, the 5-year survivals in the total arch replacement and non-total arch replacement groups were $88.6\% \pm 4.2\%$ and $83.8\% \pm 4.4\%$, respectively ($P = .54$). Rates of distal aortic events (defined as freedom from surgery for distal aorta dilation or distal arch diameter expanding to 50 mm) at 5 years were significantly better in the total arch replacement group than in the non-total arch replacement group ($94.9\% \pm 3.5\%$ vs $83.6\% \pm 4.9\%$, $P = .01$).

Conclusions: The operative mortality of patients with acute DeBakey type I aortic dissection treated by total arch replacement was acceptable with good long-term survival after both total arch replacement and non-total arch replacement. The frequency of distal aortic events might be reduced in patients after total arch replacement compared with non-total arch replacement. (J Thorac Cardiovasc Surg 2016;151:341-8)

Decision making for type of graft replacement in acute DeBakey type I aortic dissection.

Central Message

Late distal aortic events might be reduced by TAR in the repair of ADIAD.

Perspective

This study shows that TAR could be performed with acceptable operative mortality in patients with acute DeBakey type I aortic dissection and could reduce late distal aortic events compared with non-TAR. Aggressive TAR could be a reasonable surgical option for patients considered high risk for distal aortic dilation.

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Acute type A aortic dissection is one of the most life-threatening cardiovascular events because it requires immediate surgical repair. Although the surgical outcomes of acute type A aortic dissection historically have been low, they have steadily improved with advances in preoperative diagnosis, surgical technique, and postoperative

management.¹ However, increases in the numbers of patients who survive over the long term after initial aortic surgery have uncovered several late problems.²⁻⁵ The aorta downstream of a replaced graft sometimes becomes dilated, and thus subsequent aortic surgery is necessary. Residual aortic dissection carries the risk of progressive aortic dilation, rupture, or secondary aortic surgery.^{6,7} The likelihood of such adverse aortic events

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Abbreviations and Acronyms

ADIAD	= acute DeBakey type I aortic dissection
CI	= confidence interval
CNS	= central nervous system
CT	= computed tomography
GRF	= gelatin-resorcin-formalin
HR	= hazard ratio
TAR	= total arch replacement

arising during follow-up after surgical treatment of acute DeBakey type I aortic dissection (ADIAD) is considered to be high because of the wide presence of a false lumen. Although hemiarch replacement is the standard surgical approach to ADIAD, this limited graft replacement cannot excise an entry tear that is located in or beyond the aortic arch. Several studies have found that the lack of an excised entry tear and a patent distal false lumen are risk factors for distal aorta expansion.⁸⁻¹⁰ “Tear-oriented surgery” has been widely recommended, and thus total arch replacement (TAR) is sometimes required during the surgical repair of ADIAD. However, extensive graft replacement with TAR is more invasive and carries an increased potential risk of morbidity and mortality. Striking a balance among lifesaving, surgical invasiveness, and optimal long-term outcomes can be challenging when treating this lethal aortic disease. Whether or not long-term aortic events can be more effectively treated by extensive aortic replacement than by limited graft replacement remains controversial. We investigated the early and late impact of extent of surgical graft replacement in patients with ADIAD.

MATERIAL AND METHODS

Between October 1999 and July 2014, 197 consecutive patients with ADIAD underwent aortic replacement at Kobe University Graduate School of Medicine. The extent of graft replacement was based on a tear-oriented strategy and several clinical factors (Figure 1). Patients with aortic arch dilation, patients with severe dissection involving supra-aortic orifices, patients who were younger, and patients with connective tissue disorders with suitable status were treated by aggressive TAR. TAR involved the entire aortic arch, with the arch branch vessels being reimplanted with individual tetra-furcated grafts. TAR was always combined with the elephant trunk technique. Hemiarch replacement included the lesser curvature of the aortic arch beyond the level of the innominate artery but did not involve the aortic arch. Partial arch replacement required reconstruction of only the innominate artery or both the innominate and left cervical arteries. Early and late results were compared between patients who received TAR (n = 88) and patients who received non-TAR, comprising partial arch (n = 12) and hemiarch (n = 97) replacement (non-TAR; n = 109). We obtained informed consent from all patients. The study protocol was reviewed and approved by the institutional database and office records, and the study complied with the Declaration of Helsinki. Patients with connective tissue disorders (7 with Marfan syndrome, 1 with Rendu-Osler-Weber disease) were excluded from this study because the aortic pathology of these patients was different from that

of the normal population with ADIAD. During this study period, we repaired ADIAD in 8 patients with connective tissue disorders using hemiarch replacement with an aortic valve-sparing operation (n = 1), TAR (n = 2), and TAR with aortic valve-sparing operation (n = 5). One patient had hemiarch replacement because of preoperative severe hemodynamic shock, and he was not preoperatively diagnosed with Marfan syndrome. No hospital or late deaths occurred in these patients. Five of them underwent a second operation comprising TAR (n = 1), descending aorta replacement (n = 2), and thoracoabdominal aortic repair (n = 2) for distal aorta dilation or rupture. In addition to these patients, we also excluded those with iatrogenic aortic dissection and those requiring left thoracotomy.

Definition of Clinical Presentation

Cardiogenic shock was defined as preoperative systolic blood pressure less than 90 mm Hg, cardiac index less than 2.0 L/min/m², or a need for intravenous inotropic agents. Malperfusion syndromes were defined as signs or symptoms due to disrupted blood flow to end-organ systems classified as the central nervous system (CNS) and as coronary, visceral, or extremities. CNS disorders caused by malperfusion syndrome were classified as transient or persistent according to the duration of the clinical presentation. The description, 2 territories, refers to malperfusion in 2 organs. Postoperative neurologic dysfunction was considered permanent if it persisted at discharge and was a result of the intraoperative procedure. Transient dysfunction was defined as a temporary loss of orientation, slurred speech, agitation, or poor responses to commands. Neurologic dysfunction caused by preoperative brain malperfusion, deep shock status, and postoperative atrial fibrillation was excluded from this category.

Surgical Procedures

The principal aim of our surgical strategy for treating ADIAD is to excise the primary entry tear. In addition, if patients were considered capable of enduring extensive aortic surgery, TAR with the elephant trunk technique proceeded as described next. We found aortic arch dilation or massive arch dissection regardless of the location of the primary entry tear.

Blood pressure was monitored via bilateral radial lines and 1 femoral arterial line. Brain oxygenation was monitored using near-infrared spectroscopy. Temperature was monitored using tympanic and rectal probes. Arterial cannulation sites were determined according to the patient's status, preoperative organ malperfusion, and the preference of the surgeon, but the femoral artery was the most frequent choice. Cannulation of the ascending aorta using a guidewire has become the first choice if possible because such inflow enables the establishment of antegrade arterial inflow. A venous cannula was inserted into the right atrium, and then a cardiopulmonary bypass was established and systemic cooling was initiated. The left ventricle was vented through the right superior pulmonary vein. During the start of cardiopulmonary bypass, circulation was monitored by arterial pressure, transesophageal echocardiography, and near-infrared spectroscopy parameters. If 1 arterial cannulation site was insufficient for optimal circulation, another was added. If crossclamping was impossible during cooling, distal aortic repair was followed by aortic repair. If the clamp site was free of thrombosis, a crossclamp was placed at the distal ascending aorta. The proximal aorta was repaired first if crossclamping revealed that the circulation as normal.

Proximal Aortic Repair

The aorta was transected 1 cm distal to the sinotubular junction. Proximal reapproximation proceeded using Teflon felt outside and surgical adjuncts such as gelatin-resorcin-formalin (GRF) glue or BioGlue Nippon BXI Inc, Tokyo, Japan inside the false lumen with a

FIGURE 1. Selection of graft replacement.

4-0 polypropylene running suture. We frequently used GRF glue during the study period, but we recently switched to BioGlue because of a risk of GRF-related late complications arising because of excessive formalin.¹¹

Distal Aortic Repair

Hypothermic arrest was obtained at tympanic and rectal temperatures less than 23°C and less than 30°C, respectively, and then the ascending aorta and aortic arch were opened and assessed. If the entry tear in the hemiarch was excisable or a partial arch aortic replacement was needed, the inside and outside of the distal aorta were reinforced with Teflon felt. We do not use surgical adjuncts inside the distal false lumen to avoid the risk of distal organ embolization. When excision of the entry tear in the hemiarch or partial arch replacement was impossible, TAR proceeded using a tetra-furcated branched graft and the elephant trunk technique with another 18- or 20-mm Dacron graft. Our method of protecting the brain shifted from retrograde to antegrade cerebral perfusion during 2002. The details of brain protection during TAR have been reported.¹²⁻¹⁴ Open distal anastomosis proceeded using a 4-0 polypropylene suture with external Teflon felt reinforcement. Another 7- to 10-cm-long graft with a diameter of 18 or 20 mm was applied to the descending aorta during the elephant trunk technique. Teflon felt outside the adventitia was fixed by three 4-0 polypropylene sutures and reapproximation using running sutures. After completion of the distal anastomosis, lower-body circulation was reinitiated through 1 branch of the tetra-furcated graft, the patient was warmed, and the graft was anastomosed to the proximal aortic stump. Blood flow to the heart was then restored, and the left subclavian, left cervical, and innominate arteries of the aortic arch were sequentially reconstructed.

Follow-up

Follow-up information survival, general health status, need for aortic reoperation, rupture, and causes of death were determined from data at

our outpatient clinic via written or telephone contact with patients or relatives, or from local cardiologists.

Computed Tomography Surveillance of Aortic Growth Rates

All patients were assessed by computed tomography (CT) within 14 days after the surgery using contrast infusion if the patients had good renal function. The diameter of the aorta was measured, and the false lumen was examined. The false lumen was diagnosed as patent or thrombosed if blood flow was detectable or undetectable, respectively, in the false lumen during the late phase of CT with contrast infusion. Patients were usually followed up by CT at our outpatient clinic or at one of several neighboring hospitals from 6 to 12 months after hospital discharge and annually thereafter. Segmental aortic growth rates were assessed by postoperative CT twice at least 6 months apart. If patients were assessed by CT more than twice after discharge hospital, the most recent image was used to determine aortic growth rates. If an aortic segment had been surgically treated, the patient was excluded from further aortic growth rate assessment. The aortic arch at the level of the aortic isthmus (proximal) and the descending thoracic aorta at the level of the left atrium in each patient were analyzed. Distal aortic events were defined as additional aortic surgery to treat distal aorta dilation or expansion of the distal arch diameter to 50 mm.

Statistical Analysis

Data were statistically analyzed using SPSS 11.0 software (SPSS Inc, Chicago, Ill). Continuous values are expressed as means $\pm$ standard deviation. Categorical variables were analyzed using the chi-square test, and risk factors for hospital mortality were identified using stepwise logistic regression analysis. Clinically relevant variables with a *P* value less than .2 in univariate analysis were incorporated into the multivariate models. Survival and freedom from surgery for distal aortic dilation and from distal aortic events were assessed using the Kaplan–Meier method, and data were compared using the log-rank test.

TABLE 1. Preoperative status of patients

Variable	Overall n = 197 (%)	TAR n = 88 (%)	Non-TAR n = 109 (%)	P value*
Patients	197	88	109	
Age (means $\pm$ SD)	66 $\pm$ 13	61 $\pm$ 13	70 $\pm$ 11	<.01
Octogenarians	22 (11.2)	4 (4.5)	18 (16.5)	<.01
Male sex	112 (56.9)	62 (70.5)	50 (45.9)	<.01
Body surface area	1.65 $\pm$ 0.22	1.72 $\pm$ 0.23	1.59 $\pm$ 0.18	<.01
Body mass index	23.6 $\pm$ 4.2	24.4 $\pm$ 4.5	22.9 $\pm$ 3.8	.08
Preoperative status				
Shock	35 (17.8)	10 (11.4)	25 (22.9)	.03
Cardiopulmonary resuscitation	14 (7.1)	1 (1.1)	13 (11.9)	.01
Organ malperfusion	81 (41.1)	35 (39.8)	46 (42.2)	.73
CNS	39 (19.8)	14 (15.9)	25 (22.9)	.22
Transient	20 (10.2)	6 (6.8)	14 (12.8)	.25
Persistent	19 (9.6)	8 (9.1)	11 (10.1)	.99
Coronary	12 (6.1)	5 (5.7)	7 (6.4)	.93
Visceral	11 (5.6)	4 (4.5)	7 (6.4)	.80
Extremities	33 (16.8)	19 (21.6)	14 (12.8)	.10
2 territories	14 (7.1)	7 (8.0)	7 (6.4)	.89
Aortic valve insufficiency moderate or more	24 (12.2)	10 (11.4)	14 (12.8)	.75
Serum creatine $\geq$ 2.0 mg/dL	6 (3.0)	3 (2.9)	3 (2.8)	.88
Distal extent of aortic dissection				
Descending thoracic	23 (11.7)	7 (8.0)	16 (14.7)	.22
Abdominal	90 (45.7)	30 (34.1)	60 (55.0)	<.01
Iliac or beyond iliac	84 (42.6)	51 (58.0)	33 (30.3)	<.01

TAR, Total arch repair; SD, standard deviation; CNS, central nervous system.

*TAR versus non-TAR.

RESULTS

Preoperative and Intraoperative Data

Table 1 shows preoperative data from the patients. Age was significantly more advanced and shock was more prevalent in the non-TAR group than in the TAR group. Preoperative organ malperfusion did not significantly differ between the groups. Aortic dissection reached or exceeded the iliac region in 58.0% of patients in the TAR group.

Early Outcomes

Tables 2 and 3 shows intraoperative data and early surgical outcomes. The intraoperative location of the entry tear was classified as the aortic root–sinotubular junction, ascending aorta, ascending aortic arch, distal arch (distal to left subclavian artery), or unknown. The entry tear was located at the distal arch in 27 patients (30.7%) in the TAR group and in none of the non-TAR group. Patients in the TAR and non-TAR groups without shock or organ malperfusion comprised 2.1% (1/48) and 4.1% (2/49), respectively. The incidence of neurologic complications

TABLE 2. Intraoperative data

Variable	Overall n = 197	TAR n = 88	Non-TAR n = 109	P value*
Entry site				
Aortic root sinotubular junction	9 (4.6)	4 (4.5)	5 (5.2)	.77
Ascending	85 (43.1)	17 (19.3)	68 (62.4)	<.01
Ascending aortic arch	53 (26.9)	26 (29.5)	27 (24.8)	.45
Distal arch	27 (13.7)	27 (30.7)	0	<.01
Unknown	23 (11.7)	14 (15.9)	9 (8.3)	.15
CPB duration	212 $\pm$ 83	244 $\pm$ 88	187 $\pm$ 71	<.01
Cardiac ischemic time	119 $\pm$ 46	135 $\pm$ 50	107 $\pm$ 39	<.01
Antegrade cerebral perfusion	147 (74.6)	86 (97.7)	61 (56.0)	<.01
Antegrade cerebral perfusion duration	92.8 $\pm$ 52.4	124.0 $\pm$ 42.5	48.1 $\pm$ 26.6	<.01
Concomitant surgery	14 (7.1)	8 (9.1)	6 (5.5)	.49
Reimplantation	4 (2.0)	3 (3.4)	1 (0.9)	.47
Partial remodeling	1 (0.5)	0	1 (0.9)	.91
Aortic root replacement	2 (1.0)	1 (1.1)	1 (0.9)	.57
CABG	7 (3.6)	4 (4.5)	3 (2.8)	.77
Early results				
30-d mortality	18 (9.1)	6 (6.8)	12 (11.0)	.44
Hospital mortality	25 (12.7)	9 (10.2)	16 (14.7)	.47
New-onset neurologic dysfunction	14 (7.1)	5 (5.7)	9 (8.3)	.67
Temporary	7 (3.6)	3 (3.4)	4 (3.7)	.77
Permanent	7 (3.6)	2 (2.3)	5 (4.6)	.63
Requiring hemodialysis	16 (8.1)	7 (8.0)	9 (8.3)	.85
Mediastinitis	8 (4.1)	3 (3.4)	5 (4.6)	.96
Tracheostomy	11 (5.6)	3 (3.4)	8 (7.3)	.38
Aortic diameter				
Level of distal arch	36.2 $\pm$ 4.9	34.9 $\pm$ 5.1	37.4 $\pm$ 4.4	.01
Level of mid-descending aorta	32.1 $\pm$ 4.0	32.1 $\pm$ 4.1	32.2 $\pm$ 3.9	.95
False lumen patency				
Level of distal arch	43.2%	21.1%	61.6%	<.01
Level of mid-descending aorta	59.3%	52.6%	65.1%	.11

TAR, Total arch repair; CPB, cardiopulmonary bypass; CABG, coronary artery bypass grafting. *TAR versus non-TAR.

did not significantly differ between the 2 groups ($P = .67$). All patients were postoperatively assessed by CT. The rate of contrast infusion was 78.9% (TAR: 86.4%, 76/88, non-TAR: 78.9%, 86/109; $P = .17$). The aortic diameter at the level of the distal arch was significantly larger in the non-TAR group than in the TAR group ($P = .01$). False lumen patency at the level of the distal arch in the TAR group was significantly lower than in the non-TAR group. Table 4 shows the univariate and multivariate analyses' findings for hospital mortality (Table 4). Univariate analysis showed that the

TABLE 3. Early results

Variable	Overall n = 197	TAR n = 88	Non-TAR n = 109	P value*
30-d mortality	18 (9.1)	6 (6.8)	12 (11.0)	.44
Hospital mortality	25 (12.7)	9 (10.2)	16 (14.7)	.47
New-onset neurologic dysfunction	14 (7.1)	5 (5.7)	9 (8.3)	.67
Temporary	7 (3.6)	3 (3.4)	4 (3.7)	.77
Permanent	7 (3.6)	2 (2.3)	5 (4.6)	.63
Requiring hemodialysis	16 (8.1)	7 (8.0)	9 (8.3)	.85
Mediastinitis	8 (4.1)	3 (3.4)	5 (4.6)	.96
Tracheostomy	11 (5.6)	3 (3.4)	8 (7.3)	.38
Aortic diameter				
Level of distal arch	36.2 ± 4.9	34.9 ± 5.1	37.4 ± 4.4	.01
Level of mid-descending aorta	32.1 ± 4.0	32.1 ± 4.1	32.2 ± 3.9	.95
Postoperative CT with contrast infusion	162 (82.2)	76 (86.4)	86 (78.9)	.17
False lumen patency				
Level of distal arch	43.2%	21.1%	61.6%	<.01
Level of mid-descending aorta	59.3%	52.6%	65.1%	.11

TAR, Total arch repair; CT, computed tomography. *TAR versus non-TAR.

significant risk factors for hospital mortality were shock, preoperative cardiopulmonary resuscitation, and malperfusion (persistent CNS, coronary, and visceral malperfusion). TAR was not a significant factor for hospital mortality ($P = .35$; hazard ratio [HR], 0.66; 95% confidence interval [CI], 0.28-1.58). Multivariate analysis showed that significant risk factors for hospital mortality were preoperative

TABLE 4. Univariate and multivariate analyses of hospital mortality

Variable	Univariate		Multivariate	
	P value	HR (95% CI)	P value	HR (95% CI)
Age	.13	1.03 (0.99-1.07)	.08	1.05 (0.99-1.10)
Male	.23	1.72 (0.71-4.20)		
Shock	<.01	9.15 (3.68-22.78)	.07	3.50 (0.90-13.67)
Preoperative CPR	<.01	18.79 (5.61-62.85)	.01	8.25 (1.59-42.78)
Malperfusion (overall)	.02	2.93 (1.22-7.01)		
CNS (transient)	.70	0.74 (0.16-3.42)		
CNS (persistent)	.01	3.86 (1.31-11.35)	.06	3.92 (1.06-14.55)
Coronary	.04	3.90 (1.08-14.09)	.57	1.68 (0.28-10.03)
Visceral	.02	4.49 (1.21-16.64)	.02	6.62 (1.28-34.27)
Peripheral	.50	0.65 (0.18-2.30)		
AR ≥3	.91	0.93 (0.26-3.37)		
Serum creatine ≥2.0 mg/dL	.15	3.65 (0.63-21.07)	.24	3.52 (0.43-29.03)
TAR	.35	0.66 (0.28-1.58)		

HR, Hazard ratio; CI, confidence interval; CPR, cardiopulmonary resuscitation; CNS, central nervous system; AR, aortic regurgitation; TAR, total arch replacement.

FIGURE 2. Survival. TAR, Total arch replacement.

cardiopulmonary resuscitation and visceral malperfusion ($P = .01$; HR, 8.25; 95% CI, 1.59-42.78; $P = .02$, HR, 6.62; 95% CI, 1.28-34.27).

Late Outcomes

We followed up 172 hospital survivors for a mean of 60 ± 48 (range, 1-178) months. Total follow-up volume was 10,257 months. The number of overall late deaths was 24 (TAR, $n = 9$; non-TAR, $n = 15$) and were due to pulmonary ($n = 4$), cardiac ($n = 1$), gastrointestinal ($n = 2$), and renal ($n = 1$) causes and a traffic accident ($n = 1$) in the TAR group, and cerebrovascular ($n = 2$), pulmonary ($n = 7$), and cardiac ($n = 2$), gastrointestinal ($n = 1$) causes, malignancy ($n = 1$), thoracoabdominal aortic aneurysm rupture ($n = 1$), and unknown cause ($n = 1$) in the non-TAR group. The 5- and 10-year survivals of those discharged from hospital were $88.6\% \pm 4.2\%$ and $81.8\% \pm 7.6\%$, respectively, in the TAR group and $83.8\% \pm 4.4\%$ and $76.5\% \pm 5.8\%$, respectively, in the non-TAR group (Figure 2). Long-term survival did not significantly differ between the groups ($P = .54$).

Distal Aortic Events

Three patients underwent aortic surgery for distal aorta dilation in the TAR group. The operations were descending aortic replacement, thoracoabdominal aortic replacement, and stent graft deployment for false aneurysm for distal anastomosis. Nine patients underwent aortic surgery for distal aorta dilation in the non-TAR group (hemiarach, $n = 8$; partial arch, $n = 1$). Eight patients underwent TARs using the re-sternotomy ($n = 6$) and left thoracotomy ($n = 2$) approaches, and 1 patient underwent thoracoabdominal aortic replacement. None of the patients died during surgery for distal aorta dilation in either group. Freedom from surgery for distal aortic dilation at 5 and 10 years

FIGURE 3. Freedom from surgery for distal aortic dilation. TAR, Total arch replacement.

was $94.9\% \pm 3.5\%$ and $91.7\% \pm 4.6\%$ in the TAR group, respectively, and $90.9\% \pm 3.6\%$ and $83.3\% \pm 5.3\%$ in the non-TAR group, respectively (Figure 3), with no significant difference between the groups ($P = .20$). Among the 172 hospital survivors, data from 128 (74.4%) who were assessed by a postoperative CT at least twice 6 months apart were amenable to growth rate analysis. We used CT to monitor 78.5% (62/79) and 71.0% (66/93) of the patients in the TAR and non-TAR groups ($P = .88$). The mean amount of elapsed time between surgery and the most recent CT assessment was 56 ± 40 months (TAR: 51 ± 38 months, range, 6-150; non-TAR, 60 ± 41 months; range, 6-151 months; $P = .24$). There was no patient in the TAR groups whose distal arch exceeded diameter of 50 mm except for patients who

underwent additional aortic surgery for distal aorta dilation. The distal arch was dilated in 8 patients in the non-TAR group. Freedom from distal aortic events at 5 and 10 years was $94.9\% \pm 3.5\%$ and $91.7\% \pm 4.6\%$ in the TAR group, respectively, and $83.6\% \pm 4.9\%$ and $64.3\% \pm 8.0\%$ in the non-TAR group, respectively (Figure 4), with a significant difference between the groups ($P = .01$).

DISCUSSION

We examined the influence of the extent of graft replacement on early and late outcomes in ADIAD. The principal aim of surgical treatment of ADIAD is exclusion of the entry tear. TAR is sometimes required to accomplish this task because entry tears can be located in or beyond the aortic arch. In addition to the entry excision, opportunities sometimes arise in patients with concomitant aortic arch dilation or massive arch dissection, younger patients, and those with connective tissue disorders, because TAR might confer more clinical benefit than limited graft replacement in terms of reducing distal aortic expansion or subsequent second aortic surgery. We consider TAR an important surgical strategy with which to treat this lethal aortic disease.

Although the surgical results of acute type A aortic dissection have steadily improved, the 30-day mortality is still approximately 10% to 20% according to recent analyses of high operative volumes.¹⁵⁻¹⁷ The optimal extent of graft replacement in ADIAD remains debatable. Some authors advocate a conservative strategy and favor limited graft replacement. Kim and colleagues¹⁸ stated that TAR is a significant risk factor for early mortality and neurologic complications and that the rate of secondary intervention for distal aortic dilation does not significantly differ from that of hemiarch replacement. On the other hand, some institutions have experienced good operative outcomes of TAR for acute type A aortic dissection.¹⁹⁻²¹ To directly compare results is difficult because the characteristics of the patients differ, and they are not uniform across all studies. The present study showed that preoperative status considerably influenced early outcomes and that preoperative cardiopulmonary resuscitation and visceral organ malperfusion were significant risk factors for hospital mortality. The hospital mortality rates of stable patients (no shock or organ malperfusion) were acceptable, being 2.1% and 4.1% in the TAR and non-TAR groups, respectively. We believe that applying TAR under all circumstances is overindicated for acute type A aortic dissection. However, we consider that aggressive TAR might be justified for relatively stable patients and that the operative mortality could be acceptable. A recent study¹⁶ of a large series found that more aggressive aortic arch treatment including TAR can be applied without

FIGURE 4. Freedom from distal aortic events. TAR, Total arch replacement.

increasing the perioperative risk associated with limited graft replacement.

The reported 5-year survival of patients who are discharged from the hospital after treatment for acute type A aortic dissection is between 70% and 80%.^{3,4,6,7} Our results were compatible with these findings. After initial surgery, close CT surveillance is important to avoid late aortic events. Halstead and colleagues⁶ reported that approximately 12% of late deaths were due to distal aortic rupture. Fattouch and colleagues⁷ reported that approximately 24% of late deaths were due to distal aortic rupture, and approximately 16% were due to reoperation on the descending aorta. Kimura and colleagues²² reported that approximately 17% of patients died of a ruptured aortic aneurysm in the distal aorta. These studies found that the rate of TAR was approximately 10%. There was 1 aorta-related death in the present study. The patient underwent hemiarch replacement for ADIAD, which was followed by TAR for distal aortic dilation 34 months later. The downstream aorta gradually became dilated, and he died of thoracoabdominal aortic aneurysm rupture 106 months after the initial surgery. He had severe dementia, and his family declined the option of surgical repair of the thoracoabdominal aortic aneurysm.

Taking an aggressive approach to reducing the frequency of distal aortic events is a matter of debate. We found that rates of freedom from distal aortic surgery to treat aortic dilation did not significantly differ between the TAR and non-TAR groups. However, when aortic dilation greater than 50 mm was included, the difference became statistically significant. Postoperative CT showed that the rate of a patent false lumen was significantly higher in the non-TAR group at the level of the distal arch. Many studies have identified a patent false lumen as a risk factor for aortic dilation. We considered that the higher rate of patent false lumen was partially due to anastomotic leak. We previously found that anastomotic leak after hemiarch replacement for acute type A aortic dissection contributes to remnant aortic growth and could be a risk factor for subsequent aortic surgery.²³ Sometimes a longer suture line is needed to excise the entry tear after hemiarch or partial arch repair. Thus, we considered that the occurrence of anastomotic leak was high. On the other hand, the elephant trunk technique stabilizes a distal anastomosis from the inside through the insertion of another graft during TAR. Suture-related problems might have influenced the patent false lumen in the non-TAR group.

We excised the primary entry 100% if it was visible. In addition to tear-oriented surgery, we applied TAR to patients who met our criteria, patients with an enlarged aortic arch, patients with severe dissection involving supra-aortic orifices, younger patients, and patients

with connective tissue disorder (although they were not included in this study) if the patient's condition permitted. These criteria were reported for significant risk factors for distal aortic clinical events after the initial surgery in many studies. If aortic pathologies known for risk factors of late dilation remain untreated and the extent of graft replacement was decided on only a tear-oriented policy, a more distal aortic event might occur in the non-TAR group and deteriorate the long-term survival.

Our mean follow-up period was approximately 5 years. Five years was a relatively short period for younger patients after aortic surgery. For example, life expectancy with the sixties is at least more than 10 years in Japan and other western countries. After the initial surgery, patients are exposed to the continuing risk for aortic dilation. Some of these patients may have to undergo aortic surgery for a worse clinical condition (getting old or having new comorbidities) after several years. Aortic dilation involving aortic arch vessels after the non-TAR procedure sometimes requires complicated aortic surgery; on the other hand, aortic dilation after TAR does not require re-sternotomy and the elephant trunk technique uses the second operation. Thus, TAR has considerable merits regarding future aortic surgery if it can be performed with acceptable mortality.

TAR using the frozen elephant trunk technique recently has been found useful for treating acute type A aortic dissection. Uchida and colleagues²⁴ described 65 patients who underwent TAR using this technique. The estimated hospital mortality rate was 5.0%, and the 5-year survival was 95.3%. The 2- and 5-year rates of freedom from aortic events (affecting the thoracic aorta) were both 95.7%. Our findings with this technique were similar in the TAR group. Using a stent graft for acute dissection has potential problems, such as the risk of new intimal tears and aortic damage, and difficulties with selecting the appropriate graft size. This is because the aortic wall is very fragile during acute aortic dissection. The accumulation of data from more patients and long-term follow-up is necessary to conclude whether more benefit is to be derived from the stented as opposed to the standard elephant trunk technique.

Study Limitations

Our study has several limitations, including the retrospective design and the small study cohort at a single institution. Patient characteristics were not uniform between the TAR and non-TAR groups. A higher proportion of elderly patients and patients with hemodynamic instability were seen in the non-TAR group. Patient selection bias may exist regarding the choice of graft replacement. Not all patients were assessed by CT during follow-up, the length of which differed between the groups.

The fate of a patent false lumen was unclear because contrast infusion was applied to all patients.

CONCLUSIONS

TAR could be performed with acceptable operative mortality in patients with ADIAD. The late outcomes for hospital survivors were favorable in both groups. The incidence of distal aortic events might be reduced by TAR compared with non-TAR.

Conflict of Interest Statement

Authors have nothing to disclose with regard to commercial support.

References

1. Stevens LM, Madsen JC, Isselbacher EM, Khairy P, MacGillivray TE, Hilgenberg AD, et al. Surgical management and long-term outcomes for acute ascending aortic dissection. *J Thorac Cardiovasc Surg.* 2009;138:1349-57.
2. Tsai TT, Evangelista A, Nienaber CA, Trimarchi S, Sechterm U, Fattori R, et al. Long-term survival in patients presenting with type A acute aortic dissection: insights from the International Registry of Acute Aortic Dissection (IRAD). *Circulation.* 2006;114:350-6.
3. Geirsson A, Bavaria JE, Swarr D, Keane MG, Woo YJ, Szeto WY, et al. Fate of the residual distal and proximal aorta after acute type A dissection repair using a contemporary surgical reconstruction algorithm. *Ann Thorac Surg.* 2007;84:1955-64.
4. Zierer A, Voeller RK, Hill KE, Kouchoukos NT, Damiano RJ Jr, Moon MR. Aortic enlargement and late reoperation after repair of acute type A aortic dissection. *Ann Thorac Surg.* 2007;84:479-86.
5. Kobuch R, Hilker M, Rupperecht L, Hirt S, Keyser A, Puehler T, et al. Late reoperations after repaired acute type A aortic dissection. *J Thorac Cardiovasc Surg.* 2012;144:300-7.
6. Halstead JC, Meier M, Etz C, Spielvogel D, Bodian C, Wurm M, et al. The fate of the distal aorta after repair of acute type A aortic dissection. *J Thorac Cardiovasc Surg.* 2007;133:127-35.
7. Fattouch K, Sampognaro R, Navarra E, Caruso M, Pisano C, Coppola G, et al. Long-term results after repair of type A acute aortic dissection according to false lumen patency. *Ann Thorac Surg.* 2009;88:1244-50.
8. Bachet J, Goudot B, Dreyfus GD, Brodaty D, Dubois C, Delentdecker P, et al. Surgery for acute type A aortic dissection: the Hopital Foch experience (1977-1998). *Ann Thorac Surg.* 1999;67:2006-9.
9. Moon MR, Sundt TM III, Pasque MK, Barner HB, Hddleston CB, Damiano RJ Jr, et al. Does the extent of proximal or distal resection influence outcome for type A dissections? *Ann Thorac Surg.* 2001;71:1244-9.
10. Kazui T, Washiyama N, Bashar AH, Terada H, Suzuki T, Ohkura K, et al. Surgical outcome of acute type A aortic dissection: analysis of risk factors. *Ann Thorac Surg.* 2002;74:75-81.
11. Hata H, Takano H, Matsumiya G, Fukushima N, Kawaguchi N, Sawa Y. Late complications of gelatin-resorcin-formalin glue in the repair of acute type A aortic dissection. *Ann Thorac Surg.* 2007;83:1621-6.
12. Okada K, Omura A, Kano H, Sakamoto T, Tanaka A, Inoue T, et al. Recent advancements of total aortic arch replacement. *J Thorac Cardiovasc Surg.* 2012;144:139-45.
13. Okita Y, Okada K, Omura A, Kano H, Minami H, Inoue T, et al. Total arch replacement using antegrade cerebral perfusion. *J Thorac Cardiovasc Surg.* 2013;145:S63-71.
14. Okita Y, Okada K, Omura A, Kano H, Minami H, Inoue T, et al. Surgical techniques of total arch replacement using selective antegrade cerebral perfusion. *Ann Cardiothorac Surg.* 2013;2:222-8.
15. Amano J, Kuwano H, Yokomise H. Thoracic and cardiovascular surgery in Japan during 2011: Annual report by The Japanese Association for Thoracic Surgery. *Gen Thorac Cardiovasc Surg.* 2013;61:578-607.
16. Easo J, Weigang E, Holz PP, Horst M, Hoffmann I, Blettner M, et al. Influence of operative strategy for the aortic arch in DeBakey type I aortic dissection: analysis of the German Registry for Acute Aortic Dissection Type A. *J Thorac Cardiovasc Surg.* 2012;144:617-23.
17. Bekkers JA, Raap GB, Takkenberg JJ, Bogers AJ. Acute type A aortic dissection: long-term results and reoperations. *Eur J Cardiothorac Surg.* 2013;43:389-96.
18. Kim JB, Chung CH, Moon DH, Ha GJ, Lee TY, Jung SH, et al. Total arch repair versus hemiarch repair in the management of acute DeBakey type I aortic dissection. *Eur J Cardiothorac Surg.* 2011;40:881-7.
19. Hirotsani T, Nakamichi T, Munakata M, Takeuchi S. Routine extended graft replacement for an acute type A aortic dissection and the patency of the residual false channel. *Ann Thorac Surg.* 2003;76:1957-61.
20. Ochiai Y, Imoto Y, Sakamoto M, Ueno Y, Sano T, Baba H, et al. Long-term effectiveness of total arch replacement for type A aortic dissection. *Ann Thorac Surg.* 2005;80:1297-302.
21. Watanuki H, Ogino H, Minatoya K, Matsuda H, Sasaki H, Ando M, et al. Is emergency total arch replacement with a modified elephant trunk technique justified for acute type A aortic dissection? *Ann Thorac Surg.* 2007;84:1585-91.
22. Kimura N, Tanaka M, Kawahito K, Yamaguchi A, Ino T, Adachi H. Influence of patent false lumen on long-term outcome after surgery for acute type A aortic dissection. *J Thorac Cardiovasc Surg.* 2008;136:1160-6.
23. Tanaka H, Okada K, Kawanishi Y, Matsumori M, Okita Y. Clinical significance of anastomotic leak in ascending aortic replacement for acute aortic dissection. *Interact Cardiovasc Thorac Surg.* 2009;9:209-12.
24. Uchida N, Shibamura H, Katayama A, Shimada N, Sutoh M, Ishihara H. Operative strategy for acute type a aortic dissection: ascending aortic or hemiarch versus total arch replacement with frozen elephant trunk. *Ann Thorac Surg.* 2009; 87:773-7.

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