Safety and arch complications after hemiarch versus total arch replacement with stented elephant trunk in acute type 1 dissection: Is a stent graft always beneficial?

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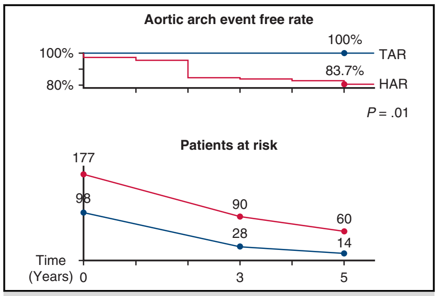
ABSTRACT

Objective: We aimed to determine the efficacy of total arch replacement with stented elephant trunk by comparing it with hemiarch replacement with and without open stent graft for acute aortic dissection type 1.

Methods: We reviewed records of 177 patients who underwent hemiarch replacement (HAR group) (concomitant open stent, 125) and 98 patients who underwent total arch replacement (TAR group) (concomitant stented elephant trunk, 91) for acute type 1 dissection. Compared with the TAR group, the HAR group was older (68.1 vs 60.9 years; $P < .01$) and had more thrombosed false lumen (28.8% vs 4.1%, $P < .01$).

Results: In-hospital death occurred for 7 patients in the HAR group and 1 patient in the TAR group ($P = .17$). More patients in the TAR group had a postoperative thrombosed false lumen, compared with the HAR group (68% vs 54%, $P = .03$). In patients with preoperative nonthrombosed false lumen in the HAR group, the rate of postoperative thrombosis was significantly lower than with versus without an open stent (31% vs 65%, $P = .01$). The rate of freedom from an aortic arch event in the TAR group at 5 years was significantly greater than that in the HAR group (100% vs 83.7%, $P = .01$).

Conclusions: Stented elephant trunk with TAR provided a high rate of false lumen thrombosis and a low incidence of arch events, whereas an open stent during HAR was not beneficial in terms of false lumen thrombosis and arch event prevention. (JTCVS Open 2022;11:14-22)



Total arch replacement with stented elephant trunk was effective for avoiding an aortic arch event. *HAR*, Hemiarch replacement, *TAR*, total arch replacement.

CENTRAL MESSAGE

For type 1 aortic dissection, total arch replacement with stented elephant trunk should be considered first because of the lower incidence of arch complications, compared with hemiarch replacement.

PERSPECTIVE

For patients who can tolerable longer cardiopulmonary bypass and circulatory arrest time, and have extensive branch dissection and narrowed true lumen, total arch replacement should be considered first to avoid a late aortic event and to ensure early survival. Open stent graft insertion concomitant with hemiarch arch replacement was not a reliable alternative for these patients.

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Abbreviations and Acronyms

- AAD = acute aortic dissection
- CT = computed tomography
- ET = elephant trunk
- HAR = hemiarch replacement
- OS = open stent grafting
- SINE = stent graft–induced new entry
- TAR = total arch replacement

▶ Video clip is available online.

In total arch replacement (TAR) for acute aortic dissection (AAD) DeBakey type 1, implantation of stented elephant trunk (ET) in the descending aorta may depressurize the false lumen by the closure of the intimal tear.[1] To obtain such outcomes with minimal surgical risk, previous reports have described the benefit of antegrade open stent grafting (OS) combined with hemiarch replacement (HAR).[2,3]

Since 2007, we have used the approach of OS concomitant with HAR and stented ET with TAR. In this study, we examined the detailed characteristics of AAD DeBakey type 1, including the false lumen status and the extent of dissection to the cervical and the abdominal branches. The purpose of this study was to examine the clinical outcomes of TAR with stented ET and those of HAR with and without OS to establish the indication for each procedure.

METHODS

Patients

We reviewed the clinical records of 275 consecutive patients who underwent surgical treatment for AAD DeBakey type 1 within 14 days after the onset between June 2007 and December 2017. Patients who had DeBakey type 2 and 3b retrograde dissection were excluded. For all these patients, the intimal tear was located in the ascending aorta or the aortic arch proximal to the origin of the subclavian artery. This retrospective study was approved by the institutional review board of the Saitama Medical University International Medical Center, which waived the requirement for written informed consent because this was a retrospective observational study (approval date: January 8, 2018; approval number: number 18-102).

The HAR group consisted of a total of 177 patients who had undergone HAR, defined as an oblique resection of minor curvature of the aortic arch for an entry in the aortic arch; patients who underwent ascending aorta replacement; and patients with the reconstruction of 1 or 2 cervical vessels (Table 1). Of these 177 patients, 125 (71%) underwent antegrade implantation of OS (HAR-OS subgroup), whereas 52 (29%) did not undergo OS implantation (HAR-only subgroup). The TAR group consisted of 98 patients who had undergone replacement of the ascending aorta and aortic arch with reconstruction of 3 cervical vessels. Stented ET was concomitantly implanted in 91 (93%) patients. For the remaining 7 patients, stented ET was not considered beneficial because of the completely thrombosed

TABLE 1. Baseline patient characteristics

	HAR 177	TAR 98	*P* value	HAR 177		*P* value
				HAR-only 52	HAR-OS 125	
Age, y, mean ± SD	68.1 ± 11.7	60.9 ± 12.3	<.01	70.1 ± 11.5	67.3 ± 11.7	.15
Male sex, n (%)	89 (50.3)	60 (63.3)	.04	26 (50.0)	65 (50.4)	.96
Renal failure (creatinine >1.5 mg/dL)	19 (10.7)	15 (15.3)	.27	5 (9.6)	14 (11.2)	.76
Hemodialysis	5 (2.8)	4 (4.1)	.57	1 (1.9)	4 (3.2)	.64
Ejection fraction, %	73.8 ± 10.5	69.1 ± 12.6	<.01	71.4 ± 12.1	74.9 ± 9.6	.05
Aortic valve insufficiency (moderate or greater)	40 (22.6)	29 (32.2)	.26	11 (21.2)	29 (23.2)	.7
Preoperative complications						
Cardiac tamponade	23 (13.0)	6 (6.1)	.08	9 (17.3)	14 (11.2)	.27
Stroke/coma	17 (9.6)	12 (12.2)	.49	7 (13.5)	10 (8.0)	.26
Mechanical ventilation	15 (8.5)	5 (5.1)	.30	4 (7.7)	11 (8.8)	.81
Malperfusion or stenosis of branched artery						
Coronary artery	8 (4.6)	4 (4.1)	.86	4 (7.8)	4 (3.2)	.18
Celiac or mesenteric artery	13 (7.3)	18 (18.6)	<.01	3 (5.8)	10 (8.0)	.66
Renal artery	15 (8.5)	17 (17.5)	.04	3 (5.8)	12 (9.6)	.46
Thrombosed false lumen	51 (28.8)	4 (4.1)	<.01	15 (29.4)	36 (29.3)	.95
Diameter of ascending aorta	49.6 ± 6.2	48.1 ± 6.2	.07	51.1 ± 7.0	49.1 ± 5.8	.06
Cervical branch dissection	95 (53.7)	68 (69.4)	.02	27 (51.9)	68 (54.4)	.78
Location of primary entry						.58
Ascending aorta	149 (84.2)	55 (56.1)	<.01	45 (86.5)	104 (83.2)	.58
Aortic arch, proximal to subclavian artery	28 (15.8)	43 (43.9)	<.01	7 (13.5)	21 (16.8)	.58

HAR, Hemiarch replacement; *TAR*, total arch replacement; *OS*, open stent graft; *SD*, standard deviation.

TABLE 2. Concomitant procedures and operative data

	HAR 177	TAR 98	*P* value*	HAR 177		*P* value†
				HAR-only 52	HAR-OS 125	
Reconstruction of 1 or 2 cervical vessels	26 (15)	–	–	11 (21)	15 (12)	.12
Open stent graft	125 (71)	–	–	–	125 (100)	–
Stented elephant trunk	–	91 (93)	–	–	–	–
Entry resection	177 (100)	98 (100)		52 (100)	125 (100)	.99
Concomitant procedures						
Aortic valve replacement	3 (1.7)	4 (4.1)	.22	0 (0)	3 (2.4)	.25
Aortic root replacement	12 (6.7)	5 (5.1)	.58	5 (9.6)	7 (5.6)	.33
CABG	7 (4.0)	7 (7.1)	.25	5 (9.6)	2 (1.6)	.01
Vascular procedure	5 (2.8)	10 (10)	.01	3 (5.8)	2 (1.6)	.12
Other cardiac procedure	4 (2.3)	3 (3.1)	.69	4 (7.7)	0 (0)	<.01
Operative data						
Cardiopulmonary bypass time, min	203 ± 59	252 ± 62	<.01	209 ± 74	200 ± 51	.38
Cardiac arrest time, min	125 ± 39	149 ± 40	<.01	129 ± 52	123 ± 33	.11
Circulatory arrest time, min	50 ± 13	65 ± 20	<.01	48 ± 11	51 ± 13	.35

HAR, Hemiarch replacement; *TAR*, total arch replacement; *OS*, open stent graft; *CABG*, coronary artery bypass grafting. *HAR versus TAR. †HAR-only versus HAR-OS. The *P* values were calculated with the Fisher exact test.

false lumen of the descending aorta in 5 patients, preoperative cardiogenic shock in 1 patient, and aberrant right subclavian artery in 1 patient.

Computed tomography (CT) was evaluated by at least 2 surgeons before the emergent operation. The location of the intimal tear, the status of the false lumen, and the extent of the dissection were confirmed. Preoperative CT was retrospectively re-evaluated for data collection in this study. The status of the false lumen was classified as thrombosed or nonthrombosed. In preoperative evaluation, "thrombosed" was defined as a false lumen in the ascending aorta, with the arch and descending not opacified using the CT contrast medium in the early and late phases. In postoperative evaluation, "thrombosed" was defined as the thrombosed false lumen in the descending aorta at the level of the aortic valve.

Surgical Management

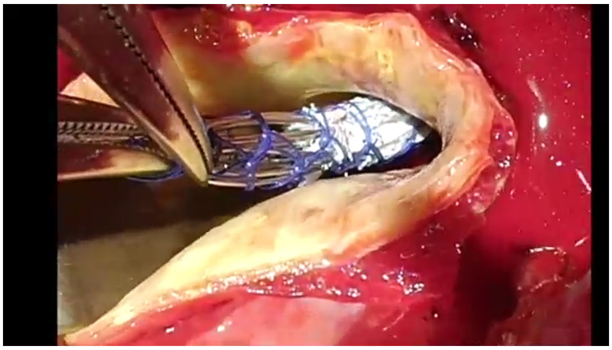
Our standard approach for AAD type 1 was emergent surgical repair, which was usually performed immediately after arrival. Our strategy for AAD has been the following: HAR was chosen when the primary entry was sufficiently resected, for patients older than 75 years, for those with thrombosed false lumen or cardiac risk, and for cases in which additional procedures such as aortic root replacement or coronary artery bypass grafting were necessary, whereas TAR tended to be chosen for patients with stenosis of the true lumen in the descending and abdominal aorta or cervical vessels and when the surgeon had sufficient experience with TAR and AAD. In the latter period, TAR with stented ET was first considered for patients who had no considerable perioperative risk.

Standard cannulation sites were both femoral and right subclavian arteries. Cannulation techniques were the Seldinger technique for the femoral artery and anastomosis of an 8-mm artificial graft for the right subclavian artery. The left subclavian artery was occasionally chosen when the bypass to the left subclavian artery was necessary for TAR with stented ET. Cardiopulmonary bypass was instituted with bicaval drainage. Circulatory arrest was initiated under hypothermia of 22 to 27 °C. Cardioplegia was delivered retrogradely. Antegrade selective cerebral perfusion was performed with cannulation into the 3 branches. The primary entry was identified and resected in all the HAR group patients. For the TAR group patients, the primary entry was resected or excluded by the stented ET. After the distal anastomosis, systemic perfusion was restarted. During rewarming, proximal anastomosis and neck branch reconstruction were performed. The details of procedures were listed in Table 2.

Devices and Management of the Stent Graft

In the HAR group, a stent graft was routinely implanted until 2012, even when the false lumen was entirely thrombosed. The stent graft was implanted through an open distal technique and positioned such that the proximal end was located just distal to the left subclavian artery, and the distal end never exceeded the level of the aortic valve. The stent graft in the HAR-OS group was not fixed or sutured with anywhere but was just placed separately from the artificial graft for the ascending aorta (Video 1). In the TAR group, additional stented ET was our standard procedure (Table 2). Stented ET was anastomosed with the artificial graft from the ascending aorta to the proximal descending aorta. The expected benefits of OS or stented ET were coverage of an unidentified small entry, an enlargement of the true lumen for abundant blood flow to the visceral arteries, and the landing zone for the deployment of a stent graft in the future.

Stent graft devices have been changed periodically as they evolve and receive approval for use. In the HAR group, the homemade stent graft for intraoperative use consisted of Ube woven noncoated thin graft (Junken Medical Co, Ltd) and Gianturco Z stent (William Cook Europe) until 2010,



VIDEO 1. The video shows hemiarch replacement with an open stent graft. During circulatory arrest an open stent graft was deployed antegradely into the true lumen of the descending aorta. The proximal end of the stent graft was placed at just the distal site of the left subclavian artery. Video available at: https://www.jtcvs.org/article/S2666-2736(22)00285-6/fulltext.

whereas the commercialized stent graft, Talent (Medtronic, Inc), was used after 2011 with approval from the institutional review board (approval number; 09-019). To deploy in an antegrade manner during circulatory arrest, Talent was once released and inversely restored by knitting with 3-0 PROLENE. In the TAR group, stented ET was performed using the homemade stent graft before 2012 or J graft Frozenix (Japan Lifeline Co, Ltd) since 2012.

Follow-up Study

An aortic arch event was defined as an open surgery or an endovascular reintervention for pseudoaneurysm of distal anastomosis and for aneurysm formation, rupture, or stent graft–induced new entry (SINE) of the aortic arch or the proximal descending aorta, including aortic-related death. Approximately 55 mm or an increase in the diameter by 5 mm in 6 months was an indication for additional stent grafting or surgical intervention. This indication was strictly adhered to and did not change depending on initial surgical procedures. To examine the effect of OS and stented ET, surgical and endovascular interventions to dilatation or pseudoaneurysm of the proximal anastomosis at the ascending aorta and the aortic root and the dilatation of the descending aorta below the level of the aortic valve were excluded.

Statistical Analysis

Patient data were presented according to treatment assignment. Categorical variables, such as demographic characteristics and medical history, were summarized using the numbers and proportions and were compared using the Fisher exact test. Continuous variables were summarized using means and standard deviations and were compared using Student *t* test.

Longitudinal data were estimated by the Kaplan–Meier method and the difference of 2 groups was compared with the log-rank method. All statistical analyses were performed using JMP 14 (SAS Institute, Inc).

RESULTS

Baseline Characteristics

As shown in Table 1, the HAR group, patients included more women ($P = .04$), were significantly older ($P < .01$), and had more primary entry in the ascending aorta and more thrombosed false lumen ($P < .01$). The TAR group patients had more malperfusion or stenosis of the celiac or the mesenteric artery ($P = .01$) and the renal artery ($P = .04$), and had dissection of any of the cervical branches ($P = .02$). No significant differences were observed in other baseline characteristics and the operative data between the 2 groups (Table 1).

Early Results

Table 3 presents the clinical outcomes and the *P* values calculated with the Fisher exact test. Of 275 patients, 8 (2.9%) in-hospital deaths occurred. The early mortality rate was 4.0% (7/177) in the HAR group and 1.0% (1/98) in the TAR group ($P = .17$) (Table 3). In the HAR group, 7 (4.0%) patients died; the causes of death were low output syndrome in 3 patients, multiple organ dysfunction in 2, pneumonia in 1, and stroke in 1. In the TAR group, 1 patient died of multiple organ dysfunction due to malperfusion of the visceral arteries and lower extremity that was found preoperatively. No significant differences were observed in early complications between the groups (Table 3). New neurologic dysfunction was found in 14 (7.9%) patients in the HAR group and in 3 (3.1%) patients in the TAR group

TABLE 3. Early and rate results

	HAR 177	TAR 98	*P* value*	HAR 177: HAR-only 52	HAR 177: HAR-OS 125	*P* value†	*P* value‡ (TAR vs HAR-only)
In-hospital mortality	7 (4.0)	1 (1.0)	.17	2 (3.9)	5 (4.0)	.96	.24
Within 30 d	5 (2.8)	1 (1.0)	.33	2 (3.9)	3 (2.4)	.6	.24
In-hospital morbidities							
New neurologic dysfunction	14 (7.9)	3 (3.1)	.12	3 (5.8)	11 (8.8)	.5	.42
Paraplegia or paralysis	1 (0.6)	1 (1.0)	.67	0 (0)	1 (0.8)	.52	.46
Cardiac complications	6 (3.4)	3 (3.1)	.88	3 (5.8)	3 (2.4)	.26	.42
Prolonged ventilation (>72 h)	86 (49)	47 (48)	.89	24 (46.2)	62 (50)	.64	.83
New dialysis	15 (8.5)	7 (7.1)	.7	2 (3.9)	13 (10.4)	.15	.42
ICU stay, d	12.7 ± 10.6	10.3 ± 12.4	.09	11.4 ± 10.0	13.3 ± 10.9	.28	.58
Late mortality	34 (19)	2 (2.0)	<.01	8 (15.4)	26 (20.8)	.4	<.01
Aortic-related death	4 (2.3)	0 (0)	.13	1 (1.9)	3 (2.4)	.85	.17
Late aortic arch event	22 (12)	1 (1.0)	<.01	1 (1.9)	21 (16.8)	<.01	.65
Dilatation/rupture of aortic arch	15 (8.5)	0 (0)	<.01	1 (1.9)	14 (11.2)	.04	.17
Pseudoaneurysm of distal anastomosis	3 (1.7)	0 (0)	.16	0 (0)	3 (2.4)	.26	–
Endoleak/stent graft induced new entry	4 (2.3)	1 (1.0)	.46	0 (0)	4 (3.2)	.19	.46
Follow-up period, y	3.7 ± 2.8	2.6 ± 1.9	<.01	3.0 ± 3.0	4.5 ± 2.8	<.01	.39

Cardiac complications included myocardial infarction, atrioventricular block, ventricular fibrillation, cardiac tamponade requiring drainage. *HAR*, Hemiarch replacement; *TAR*, total arch replacement; *OS*, open stent graft; *ICU*, intensive care unit. *HAR versus TAR. †HAR-only versus HAR-OS. ‡TAR versus HAR-only. The *P* values were calculated with the Fisher exact test.

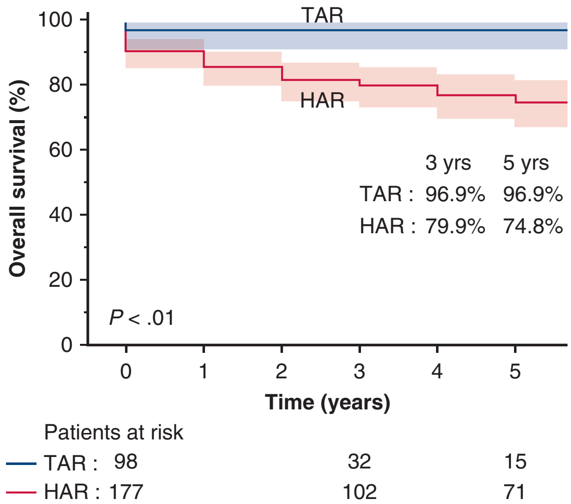


FIGURE 1. The rate of overall 5-year survival rate in the TAR group was 96.9%, significantly greater than 74.8% in the HAR group ($P < .01$). *TAR*, Total arch replacement; *HAR*, hemiarch replacement.

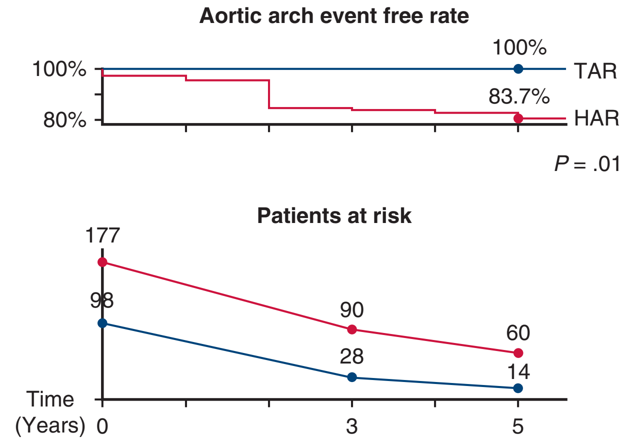


FIGURE 2. Total arch replacement with stented elephant trunk was effective for avoiding an aortic arch event. *TAR*, Total arch replacement; *HAR*, hemiarch replacement.

($P = .12$). Paraplegia occurred after HAR with OS in 1 patient and after TAR with stented ET in 1 patient. No significant differences were observed in the early mortality and morbidity rates between the HAR-only and the HAR-OS subgroups (Table 3).

Late Results

Significant differences were noted in the follow-up periods between the HAR and TAR groups (3.7 ± 2.8, 2.6 ± 1.9; $P < .01$) and between the HAR-only and the HAR-OS subgroups (3.0 ± 3.0, 4.5 ± 2.8; $P < .01$) (Table 3). Late results showed 34 deaths in the HAR group and 2 deaths in the TAR group ($P < .01$) (Table 3 and Figure 1). In the HAR group, the causes of death were aorta related in 4 patients and nonaorta-related in 30 patients (respiratory failure in 9 patients, stroke in 7, heart failure in 4, malignancy in 2, and other causes in 8). In the TAR group, 2 deaths were nonaorta-related (heart failure in 1 patient and an unknown cause in 1 patient).

The rate of aortic arch event, defined as reintervention for pseudoaneurysm of distal anastomosis, for aneurysm formation, rupture, or SINE, and aortic-related death, was significantly greater in the HAR (12%, 22/177) versus the TAR group (1.0%, 1/98; $P < .01$) (Table 3 and Figure 2). Of the 19 patients who underwent additional surgery in the HAR group, 13 patients underwent TAR, 5 patients underwent thoracic endovascular aortic repair without debranching technique, and 1 patient underwent descending aorta replacement. In the TAR group, SINE occurred in 1 patient (1.0%) at the distal end of the stented ET, and additional thoracic endovascular aortic repair was performed 6 years after the primary surgery. Although the HAR group overall had a greater aortic event rate compared with the TAR group, no significant differences were found between the HAR-only subgroup (1.9%, 1/52) and TAR group (1.0%, 1/98; $P = .65$) (Table 3).

Considering the 22 late aortic arch events in the HAR group, 21 occurred in the HAR-OS subgroup, whereas 1 occurred in the HAR-only group ($P < .01$) (Table 3). In the HAR-OS subgroup, a type Ia endoleak and SINE were found in 1 patient each.

The 5-year survival rates for the HAR and the TAR groups were 74.8% and 96.9%, respectively ($P < .01$) (Figure 1). The rates of freedom from aortic arch event at 5 years were 83.7% in the HAR group and 100% in the TAR group ($P = .01$) (Figure 2). Although no significant difference was noted in the rate of survival between the HAR-OS and HAR-only subgroups at 5 years (73.7% vs 79.3%; $P = .86$), the rate of freedom from aortic arch event tended to be greater in the HAR-only subgroup (80.8% vs 95.7%; $P = .06$) (Figure 3).

Evaluation of Preoperative and Postoperative False Lumen Status

Both preoperative and postoperative contrast-enhanced CT were performed for 149 HAR group patients (84.2%) and 95 TAR group patients (96.9%). Postoperative contrast-enhanced CT was not performed in patients with renal dysfunction, poor systemic condition, or age older than 80 years. Postoperative thrombosed false lumen was achieved in 81 of 149 (54.4%) patients in the HAR group and in 65 of 95 (68.4%) in the TAR group ($P = .03$) (Figure 4, *A*). For patients with preoperative nonthrombosed false lumen, postoperative thrombosed false lumen was achieved in 41 of 103 (40%) patients in the HAR group and in 61 of 91 (67%) patients in the TAR group ($P < .01$).

In the HAR group, 28 patients had primary entry extending into the proximal aortic arch (Table 1), and underwent

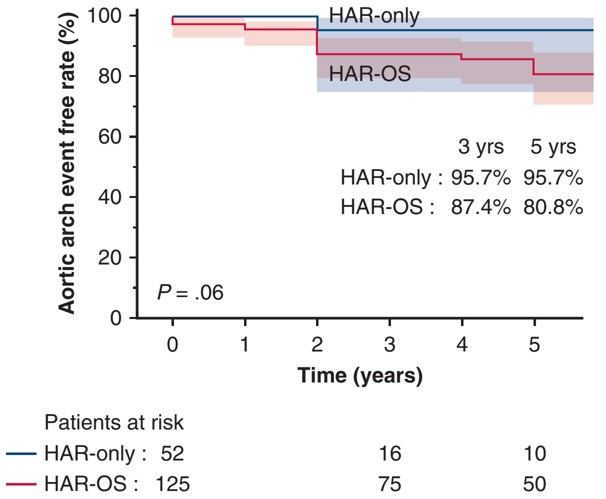


FIGURE 3. The rate of freedom from aortic arch event at 5 years was 95.7% in the HAR-only group and was not significantly greater than 80.8% in the HAR-OS group ($P = .06$). *HAR*, Hemiarch replacement; *OS*, open stent graft implantation.

entry resection. Of these 28 patients, in-hospital mortality occurred in 1 patient (3.6%). During the follow-up period, aortic arch events occurred in 6 of 28 (21.4%) patients and late death occurred in 5 of 28 (17.9%) patients. Consequently, no significant difference was observed compared with patients who had entry in the ascending aorta.

In the subgroup comparison, postoperative thrombosed false lumen was achieved in 69.2% (27/39) in the HAR-only subgroup compared with 49.1% (54/110) in the HAR-OS subgroup ($P = .03$) (Figure 4, *B*). For patients with preoperative nonthrombosed false lumen, postoperative thrombosed false lumen was achieved in 17 of 26 (65%) patients in the HAR-only subgroup and in 24 of 77 (31%) patients in the HAR-OS subgroup ($P = .01$) (Figure 4, *B*).

DISCUSSION

A goal of surgical repair for AAD type 1 may be thrombosis of false lumen to avoid repeated surgical or endovascular intervention.[4,5] After HAR, however, complete thrombosis of false lumen in the proximal descending aorta could be achieved in only 24.6% of the patients.[4] To improve the late outcomes after HAR, addition of OS or stented ET may be an effective option.[2,3] Roselli and colleagues[6] reported that HAR with stented ET provided both operative safety and a favorable remodeling of the aorta. Pochettino and colleagues[7] also reported that stented ET provided lower rates of patent false lumen and repair of thoracoabdominal aneurysm. Possible benefits of OS or stented ET can be presumed. First, closure of small intimal tear and thrombosis of false lumen can be expected. Second, enlarged true lumen will provide sufficient blood flow to the lower body and prevent organ malperfusion and thus improve the early results. Third, it may be a landing zone for future endovascular repair.

The results of this study did not demonstrate the benefit of OS on the thrombosis of the false lumen. Especially for patients with preoperative nonthrombosed false lumen, the rate of thrombosis of false lumen was significantly lower in the HAR-OS subgroup (65% after HAR only, 31% after HAR-OS). Furthermore, in the late results, the presence of OS may cause an aortic arch event. Therefore, in our experience, HAR with OS would not be a reliable alternative to TAR. The reason for the conflicting results with previous reports of HAR with OS may be attributed to discontinuity of OS and the artificial graft in the ascending aorta.

After an extensive aortic repair or TAR, complete thrombosis of the false lumen in the aortic arch and the proximal descending aorta was achieved at a high rate[4] and could reduce the aortic event.[1,5] The potential disadvantages of TAR are its invasiveness and high early mortality rate.[2,8-10] Nevertheless, because the results of previous studies are conflicting, the advantages and disadvantages of TAR over HAR have not yet been fully established.[10,11] Uchida and colleagues[1] noted that TAR with stented ET was recommended for patients with a narrowed true lumen or entry in the proximal descending aorta. Omura and colleagues[5] suggested that TAR should be considered, irrespective of intimal tear location. The length or position of the OS or stented ET should be modified according to the angulation or curvature of the aortic arch to avoid stent graft-related complications.[5,12-14]

In this study, the relatively low mortality rates in both the TAR and HAR groups were attributed to the consistent blood supply to the visceral artery and the lower body by the stented ET or OS. Nonetheless, to avoid aortic rupture in the intensive care unit, blood pressure was strictly maintained at <130 mm Hg, and extubation was frequently postponed for 1 week. Furthermore, continuous hemodialysis was started when creatinine was elevated to approximately 2.0 mg/dL, even if the urinary output was maintained. These approaches were the reasons for the relatively high rates of new dialysis and prolonged ventilation.

In our current strategy, TAR with stented ET is considered first for patients who have no considerable perioperative risk (Figure 5). Most importantly, for patients who had malperfusion of visceral artery and dissection of the cervical vessel, or narrowed true lumen of the descending aorta with nonthrombosed false lumen, TAR with stented ET could be recommended for survival, irrespective of patient age and high perioperative risk. Alternatively, HAR can be preferred when the patients are older than 75 years and have a thrombosed false lumen. Finally, HAR with OS may be feasible only patients at high risk with visceral malperfusion or an intimal tear in the proximal descending aorta.

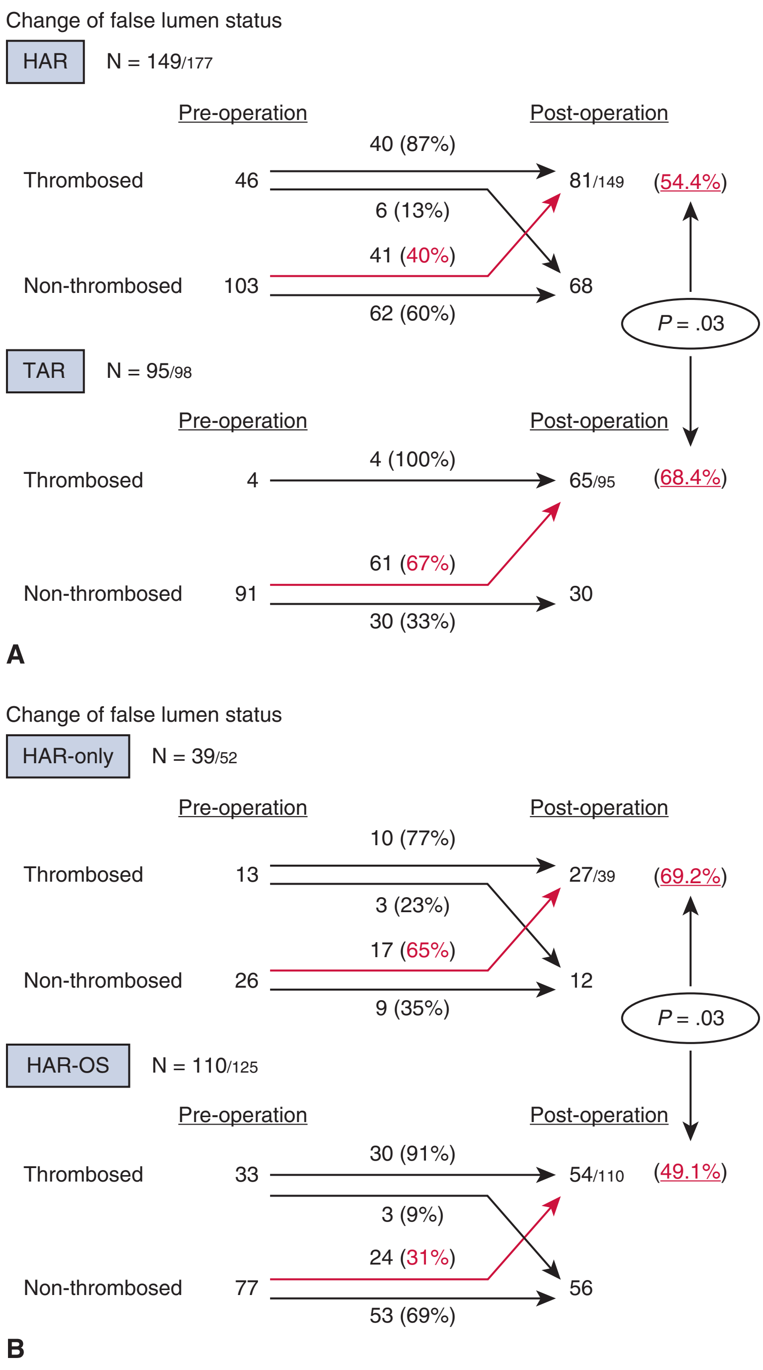


FIGURE 4. Change of the false lumen status before and after surgery in each procedure. The ratio of patients with the postoperative thrombosed false lumen was compared using the Fisher exact test. A, Both preoperative and postoperative contrast-enhanced computed tomography were performed for 149 patients (84.2%) in the HAR group and in 95 patients (96.9%) in the TAR group. Postoperative thrombosed false lumen was achieved in 81 of 149 (54.4%) patients in the HAR group and in 65 of 95 (68.4%) patients in the TAR group ($P = .03$). For patients with preoperative nonthrombosed false lumen, postoperative thrombosed false lumen was achieved in 41 of 103 (39.8%) patients in the HAR group and in 61 of 91 (67.0%) patients in the TAR group ($P < .01$). B, In the subgroup comparison, postoperative thrombosed false lumen was achieved in 69.2% (27/39) in the HAR-only subgroup versus 49.1% (54/110) in the HAR-OS subgroup ($P = .03$). For patients with preoperative false lumen, postoperative thrombosed false lumen was achieved in 17 of 26 (65.3%) patients in the HAR-only subgroup and in 24 of 77 (31.2%) patients in the HAR-OS subgroup ($P = .01$). *HAR*, Hemiarch replacement; *TAR*, total arch replacement; *OS*, open stent graft implantation.

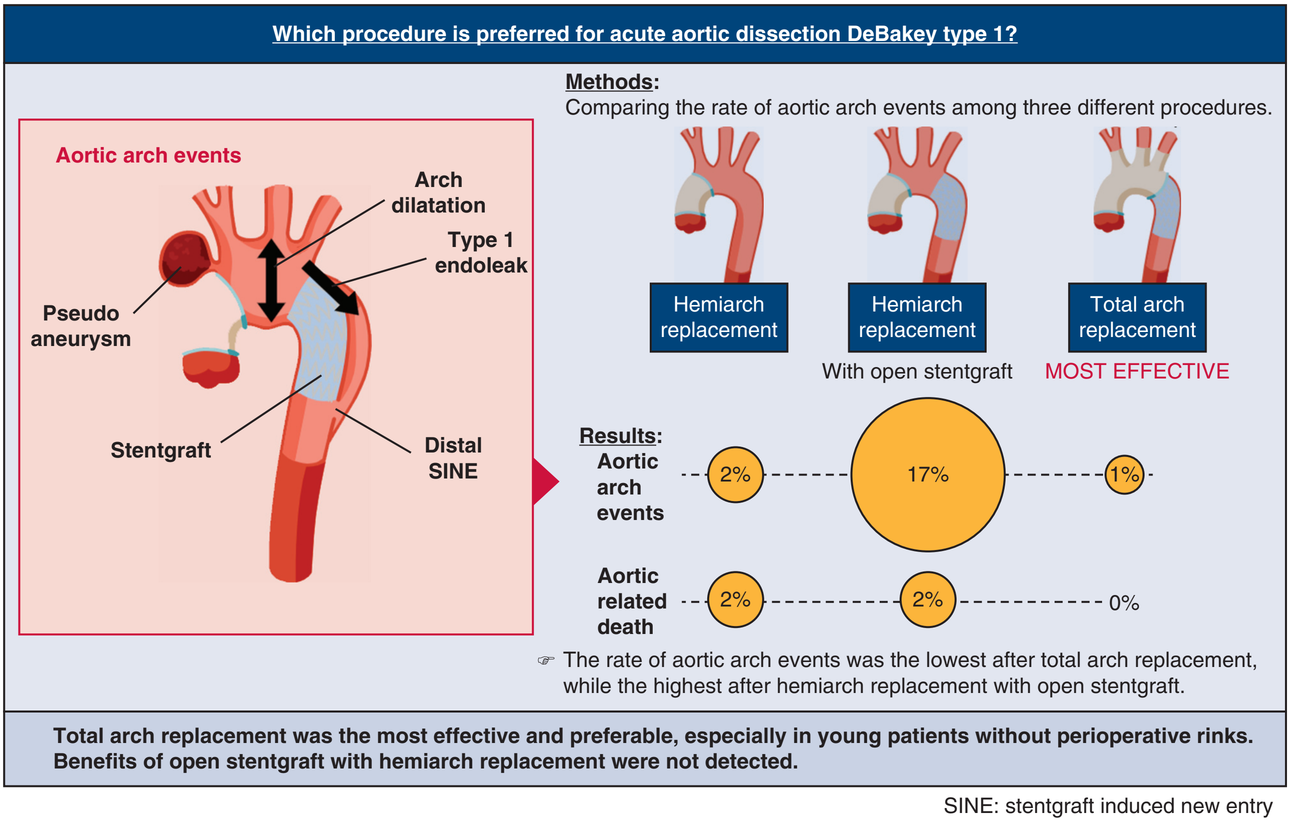


FIGURE 5. The rate of aortic arch event was the lowest after total arch replacement with stented elephant trunk, whereas it was the greatest after hemiarch replacement with open stent graft. *SINE*, Stent graft–induced new entry.

This study has several limitations. First, this study was not prospective and was not randomized. Second, significant differences were present in the demographic characteristics between the 2 groups. The surgeon chose the best strategy for every patient, considering the patient's general condition, status of the false lumen, the extent of dissection, and the surgeon's own operative skills. Selection biases were present, such as those of age, cardiac tamponade, stenosis of abdominal branches, and the location of the primary entry. Third, the experiences of the surgeons varied in these series. Five surgeons operated on these patients, and this factor influenced the selection of procedure and its outcomes. In practice, experienced surgeons tended to choose TAR over HAR. Fourth, the surgical decision-making was based on the preoperative CT and the intraoperative findings. During data collection, we re-evaluated CT retrospectively. Therefore, the diagnosis may be different from the diagnosis at the time of emergent surgery. Fifth, the distal tear would have an important role in the false lumen thrombosis and the efficacy of the additional stent. However, the entry in the descending or abdominal aorta could not be taken into account. Sixth, the diameter and the length of the stent graft may be important; however, the size and length could not be addressed in this study. We do not have reliable data regarding the diameter of noncommercialized so-called handmade stent graft. Seventh, even after TAR with stented ET, in which distal anastomosis was commonly performed at the zone 0 or 1, dilatation or rupture of the remaining aortic arch may occur because of the endoleak or upward flow in the false lumen from the descending aorta. In the present study, surgery or endovascular intervention on the distal descending or abdominal aorta was not addressed because of the difference in the indication of the intervention for patients after HAR and TAR with stented ET. Recently, endovascular repair of the distal descending aorta has been used to close the remaining entry after TAR with stented ET, even without a significant dilatation or rupture. Because stented ET plays a role of the proximal landing zone, additional thoracic endovascular repair is technically easy and safely performed. Such intervention should not be considered as an adverse event but a possible advantage of stented ET. Finally, nonaorta-related deaths are a competing risk for which the analysis does not account.

In conclusion, early and late outcomes after surgery for AAD type 1 have been improved by an additional stent graft procedure. Increasing indications for TAR would be reasonable when combined with stented ET. Placement of OS concomitant with HAR may cause an aortic arch event and would not be a reliable alternative for TAR with stented ET.

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: acute aortic dissection, total arch replacement, hemiarch replacement, elephant trunk, open stent