In situ total aortic arch replacement for infected distal aortic arch aneurysms with penetrating atherosclerotic ulcer

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Background: We present a series of patients who underwent in situ total aortic arch replacement for infected distal aortic arch aneurysms.

Methods: Between 2002 and 2013, 9 patients with infected distal aortic arch aneurysms underwent total aortic arch replacement using antegrade selective cerebral perfusion. There were 4 male and 5 female patients with a mean age of 72.7 ± 9.0 years. All patients had penetrating atherosclerotic ulcer in the distal aortic arch, which formed saccular aneurysms. Four patients had preoperative hoarseness. Maximum preoperative white blood cell count was $10,211 \pm 4375/\mu\text{L}$, and mean serum C-reactive protein concentration was 12.7 ± 7.2 mg/dL. Causative microorganisms were identified by blood culture or aortic wall culture and were as follows: *Candida albicans*, *Pseudomonas aeruginosa*, *Edwardsiella tarda*, *Streptococcus dysgalactiae*, *Listeria monocytogenes*, *Staphylococcus aureus* (2 cases), and unknown (2 cases). Radical debridement with in situ total aortic arch replacement was performed in all patients, followed by the omental flap grafting in 7 patients. All surgery was performed on an urgent or emergency basis.

Results: Average cardiopulmonary bypass time and lower body circulatory arrest time were 199.7 ± 50.7 minutes and 66.6 ± 13.8 minutes, respectively. There was no in-hospital mortality, but 1 patient died of asphyxia 5 months after hospital discharge. Freedom from recurrence of infection was 100%.

Conclusions: Surgical treatment with the combination of radical debridement with in situ total aortic arch replacement using antegrade selective cerebral perfusion and omental flap grafting was a reliable procedure for the treatment of infected distal aortic arch aneurysms. (J Thorac Cardiovasc Surg 2014;148:2096-100)

Although treatments of aortic arch aneurysm have been improving during the past decade,^{1,2} infected aneurysms are one of the most intractable aortic pathologies, which complicate the surgical procedure and might cause recurrence of infection with high mortality. Controversy continues over the role of in situ reconstruction,³ extra-anatomic bypass,⁴ or thoracic endovascular aortic repair (TEVAR),⁵⁻⁷ and there are few studies that have focused on the reconstruction of infected aortic arch aneurysms. We describe a series of cases treated with radical debridement of infected aortic walls followed by in situ reconstruction combined with omental flap grafting and advanced antibiotic therapy based on sensitivity data.

MATERIALS AND METHODS

A retrospective review of the cardiovascular surgical database at Kobe University Graduate School of Medicine was performed for the period from January 2002 to August 2013. The medical records were reviewed for preoperative risk factors, operative records, intraoperative events, and postoperative course. This retrospective study was approved by the institutional review board at Kobe University (#1490). The need for individual consent was waived. During the period noted, consecutive 423 patients underwent total aortic arch replacement (TAR) using antegrade selective cerebral perfusion through a median sternotomy, and 9 (2.1%) of them with a mean age of 72.7 ± 9.0 years had infected aortic arch aneurysms. The diagnosis of infected aneurysms was made by a combination of clinical presentation, blood test, computed tomography (CT) imaging, positive bacterial growth on blood/aortic tissue culture, intraoperative Gram staining, and inflammatory change in the pathologic specimens. Transverse contrast-enhanced CT generally demonstrated an irregular multiloculated arterial wall, periaortic edema, a periaortic soft-tissue mass, or periaortic gas.⁸ Patients with aortic arch aneurysms-associated bronchial fistula or esophageal fistula were excluded in this study, because the former was difficult to diagnose as infectious aneurysms, and the latter was treated by a completely different surgical strategy. Patient profiles are shown in Table 1. Preoperative CT scan demonstrated that all patients had penetrating atherosclerotic ulcer (PAU) in the distal aortic arch, which formed saccular aneurysms (Figure 1). PAU was defined as a focal contrasted-filled outpouching of the aorta through intimal calcified plaque using CT scan. Four of 9 patients had preoperative hoarseness. All patients had ongoing fever before surgery. The duration from the infection onset was 36.6 ± 56.9 days (range, 0 day to 6 months). Preoperative blood culture was positive in 3 of 9 patients. Five of 9

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Abbreviations and Acronyms

CRP	= C-reactive protein
CT	= computed tomography
PAU	= penetrating atherosclerotic ulcer
TAR	= total aortic arch replacement
TEVAR	= thoracic endovascular aortic repair

patients had undergone antibiotic therapy before surgery, and the duration ranged from 9 days to 6 months.

The standardized surgical procedure of TAR used at Kobe University Graduate School of Medicine has been reported.² Surgical indication and urgency were determined by the type of aneurysm (saccular) with clinical symptom (chest pain, back pain, and sudden development of hoarseness) and active infection (ongoing fever, increased white blood cell count, and C-reactive protein [CRP] level) despite the use of antibiotics. All patients underwent TAR on an urgent/emergency basis (1.8 ± 2.1 days after admission). After cardiopulmonary bypass was established, tympanic temperature had decreased to 20°C to 23°C , and rectal temperature was less than 30°C , the aortic arch was opened and antegrade selective cerebral perfusion was started. The distal aortic arch or the descending aorta was transected at the distal clear level of the infected aneurysms, followed by debridement of the infected tissue and aneurysmal wall, and copious saline irrigation. Intraoperative Gram staining was performed in 6 of 9 patients, and resected aneurysm walls were subjected to both tissue culture and pathologic examinations in all patients. Intraoperative Gram staining was positive in 3 of 6 patients, and culture of resected aortic wall was positive for bacterial growth in 7 of 9 patients. A gelatin-impregnated quadrifurcated Dacron graft (Gelweave, Vascutek Ltd, Terumo Corp, Scotland, UK, or J Graft Shield Neo, Japan Lifeline, Tokyo, Japan) was used. Rifampicin soaking of the gelatin-sealed Dacron graft was performed in 8 of 9 patients. After completion of the distal anastomosis of the prosthetic graft, lower body circulation was restarted through a branch graft, and the tympanic/rectal temperature was rewarmed early to 33°C . The proximal anastomosis of the graft was completed followed by coronary reperfusion. Finally, the aortic arch vessels were reconstructed. In 7 of 9 patients, the omental flap was prepared and installed around the prosthetic graft to separate the surrounding tissue after debridement.

Subsequently, the causative microorganisms were identified by blood culture or aortic wall culture and were as follows: *Candida albicans*, *Pseudomonas aeruginosa*, *Edwardsiella tarda*, *Streptococcus dysgalactiae*, *Listeria monocytogenes*, and *Staphylococcus aureus* (2 cases). Negative culture was obtained in 2 patients (numbers 5 and 6). Intravenous antibiotic therapy based on sensitivity data was continued for 6 weeks postoperatively, and prolonged antibiotic therapy was continued according to the clinical course (fever), blood test parameters (WBC and CRP levels), and CT imaging.

Statistical Analysis

Continuous variables were expressed as mean $\pm$ standard deviation. Survival and freedom from recurrence of infection were assessed by the Kaplan–Meier method using SPSS software (SPSS Inc, Chicago, Ill).

RESULTS

Average operation time was 507.3 ± 163.9 minutes, cardiopulmonary bypass time was 199.7 ± 50.7 minutes, myocardial ischemic time was 92.0 ± 16.7 minutes, lower body circulatory arrest time was 66.7 ± 13.8 minutes, and antegrade selective cerebral perfusion time was 136.4 ± 29.6 minutes. Average minimum tympanic and

rectal temperatures were $21.6^{\circ}\text{C} \pm 1.3^{\circ}\text{C}$ and $26.3^{\circ}\text{C} \pm 1.4^{\circ}\text{C}$, respectively. The 30-day mortality and in-hospital mortality were 0%. Average duration of postoperative hospital stay was 47.0 ± 33.8 days. No newly developed neurologic deficits were observed. One patient had refractory methicillin-resistant *Staphylococcus aureus* pneumonia, followed by tracheostomy. Two patients (numbers 5 and 7) had iatrogenic hoarseness caused by radical debridement of infected aneurysmal walls, and 3 patients had atrial fibrillation. None of the patients experienced persistent bacteremia.

Follow-up was completed in all cases, and average duration of follow-up was 25.0 ± 23.6 months (range, 0.8–69.7 months). One late death (patient number 2) occurred 5 months after the operation and was caused by asphyxia. Freedom from recurrence of infection was 100% during the follow-up (Figure 2).

Representative findings of pathology of the resected aortic walls demonstrated infiltration of neutrophils, formation of abscess (Figure 3, A and B), and the presence of gram-positive cocci by Gram staining (Figure 3, C).

DISCUSSION

Infected aortic aneurysm is a rare but formidable medical condition associated with mortality ranging from 4.3% to 36%.^{3,9,10} Weis-Muller and associates¹¹ demonstrated that the mortality was highly dependent on the status of rupture at the time of surgery, but the ratio in patients with contained rupture was still as high as 30%. There are few sporadic reports that have specifically focused on the infected aneurysms located in the aortic arch, with a reported mortality ranging from 0% to 10%.^{3,10} There is no known reliable strategy for the treatment of infected distal aortic arch aneurysms. The current study provided information regarding the clinical presentation of this sample of patients and their profiles, as well as satisfactory outcomes, including survival and freedom from recurrent infection.

Presenting symptoms are often nonspecific. All patients had consistent fever, and the final diagnosis was obtained by CT scan. Four of 9 patients (numbers 1, 2, 4, and 6) (44.4%) had progressive hoarseness, and 7 patients had a history of chest and back pain. Tokmaji and colleagues¹² demonstrated that preoperative progressive hoarseness was a rare clinical presentation,¹² but in the patients in this study the incidence was as high as 44.4%.

With regard to aortic pathology, although a recent report by Nathan and associates¹³ demonstrated PAU location in the aortic arch in 7% and in the descending thoracic aorta in 62%, all patients in this study had PAU with severe calcification in the distal aortic arch. Stellmes and associates⁷ also showed that PAU was a cause of aortic pathology in the native aortic infection. However, whether PAU is likely to be associated with infection remains controversial.

TABLE 1. Patient profiles

No	Age, y	Sex	DM	Maximum WBC, μ L	Maximum CRP, mg/dL	Clinical symptoms except fever and comorbidity	Microorganism	Preoperative antibiotics	Duration on antibiotics	Culture			Omental flap grafting
										Blood	Gram staining	Aortic tissue	
1	61	M	No	8000	5.73	Hoarseness, chest pain, iliopsoas muscle abscess, history of left CIA aneurysm (<i>Salmonella</i>)	<i>Candida albicans</i>	Yes	6 mo after iliac operation	Negative	NA	Positive	Yes
2	79	M	No	5700	0.89	Hoarseness	<i>Pseudomonas aeruginosa</i>	Yes	17 d	Negative	NA	Positive	No
3	79	M	Yes	12,200	17.6	Back pain Laryngeal cancer tracheostomy	<i>Edwardsiella tarda</i>	Yes	12 d	Negative	Positive GPC	Positive	Yes
4	59	F	Yes	14,700	20.6	General fatigue Hoarseness	<i>Streptococcus dysgalactiae</i>	No	NA	Positive	Negative	Positive	Yes
5	64	F	No	7400	17.8	Back pain Infected AAA	Unknown	Yes	9 d	Negative	Negative	Negative	Yes
6	79	F	No	9400	15.1	Hoarseness, back pain CAD	Unknown	Yes	18 d	Negative	Negative	Negative	Yes
7	75	F	Yes	4300	10.1	Chest pain Liver cirrhosis Child–Pugh type A, AF	<i>Listeria monocytogenes</i>	No	NA	Positive	Positive GPR	Positive	Yes
8	84	F	No	12,600	20.4	Back pain Osteoporosis, on steroid	<i>Staphylococcus aureus</i>	No	NA	Positive	Positive GPC	Positive	Yes
9	74	M	Yes	17,600	6.1	Back pain Left side hemothorax	<i>S aureus</i>	No	NA	Negative	NA	Positive	No

AAA, Abdominal aortic aneurysm; AF, atrial fibrillation; CAD, coronary artery disease; CIA, common iliac artery; CRP, C-reactive protein; DM, diabetes mellitus; GPC, gram-positive coccus; GPR, gram-positive rod; NA, not applicable; WBC, white blood cell.

In the current study, 2 of 9 patients (numbers 5 and 6) had a negative culture for both blood and resected pathology tissue sections, and in these cases the diagnosis was determined by clinical presentation, blood test, and CT imaging. Microscopic findings in these patients showed the formation of lymphoid follicle (number 5) and neutrophil filtration (number 6) in the resected aortic wall, which also suggested the presence of infection. Negative blood cultures have been reported in up to 25% of cases and may be due to antibiotic pretreatment or anaerobic organisms, which could also account for negative culture results of the resected pathology tissue sections.^{9,14} In the current study, we also speculate that the long duration of preoperative antibiotics therapy ranging from 9 days to 6 months in 5 of 9 patients caused the low incidence of bacteremia (3/9, 33.3%).

In the early reports, extra-anatomic bypass was selected just to avoid prosthetic graft infection.⁹ We believe that infected aneurysms in the aortic arch are not anatomically amenable to extra-anatomic bypass, and in situ replacement

of TAR is the preferred method of selection as long as aggressive debridement of any infected tissue and the aneurysmal wall is performed. TAR for the treatment of infected aortic arch aneurysms is still a surgical challenge for organ protection because deep hypothermic circulatory arrest time is prolonged because of the requirement of the aggressive debridement with severe inflammation and more distal anastomosis. Indeed, average deep hypothermic arrest time was longer in the current study compared with our previous report (66.6 ± 13.8 minutes vs 42.4 ± 27.8 minutes).² Hsu and Lin³ have reported excellent outcomes for the treatment of infected aortic arch in 10 patients. However, they applied retrograde cerebral perfusion under deep hypothermia for 80 minutes, and consequently 3 patients (30%) had hypoxic encephalopathy. Antegrade selective cerebral perfusion is a preferable brain-protection method under prolonged circulatory arrest time.

Previous reports showed a recurrence of infection even after eradication by resection of the infected aortic wall and

FIGURE 1. Preoperative findings of CT scan. All patients had PAU with calcification in the distal aortic arch, which formed saccular aneurysms. The aneurysm of patient number 8 was growing in a caudal direction onto the pulmonary trunk. The aneurysm of patient number 9 ruptured into the left pleural cavity with the formation of a hemothorax.

in situ replacement using a prosthetic graft. Some reports advocated that covering the prosthetic graft with an omental flap around it decreased the risk of recurrence of infection during follow-up.^{10,15,16} Although we prefer to apply the omental flap in every case unless there is a history of laparotomy (patient number 9), 1 patient (number 2) did not undergo omental flap grafting because we did not suspect the presence of infection because there were no positive data for infection in the blood test results (elevated WBC counts and serum CRP concentration) before surgery.

In this case, infection of the aortic aneurysm was identified postoperatively by aortic wall culture.

TEVAR is an emerging minimally invasive treatment. In a recent report, Stellmes and associates⁷ demonstrated the efficacy of TEVAR in 6 patients for suspected aortic infection in an emergency treatment situation. In their study, TEVAR was performed as a bridge treatment in 3 of the 6 patients, and eventually open conversion was required. We believe that TEVAR is useful as an alternative treatment for patients with circulatory collapse or fistula

FIGURE 2. Survival and freedom from recurrence of infection. The survival curve (*left*) and freedom from recurrence of infection (*right*).

FIGURE 3. Representative findings of pathology of resected aortic walls. A, Hematoxylin–eosin staining (patient number 8). Asterisk shows the media of the aortic wall. Arrowheads demonstrate the abscess formation, and arrows demonstrate hemorrhage in the outgrowth adventitia. B, Hematoxylin–eosin staining in large scale (patient number 8) demonstrates infiltration of neutrophils and lymphocyte growth. C, Gram staining (patient number 9) demonstrates the intramural presence of gram-positive cocci.

to the adjacent tissue, such as the bronchus or the esophagus,^{17,18} to improve a patient's condition while awaiting open repair.

Study Limitations

This was a retrospective study from a single center. The mean follow-up period was short (25.0 ± 23.6 months; range, 0.8–69.7 months).

CONCLUSIONS

This study provided information regarding the clinical presentation, the patients' profile, and the aortic pathology of infected aortic arch aneurysms. Surgical treatment with a combination of radical debridement followed by in situ TAR with omental flap grafting was a reliable procedure.

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