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RESEARCH

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Investigation of risk factors and outcomes of aortic arch aneurysm repair in octogenarians

Tomoki Cho[1*], Keiji Uchida[1], Shota Yasuda[1], Yasuko Onakatomi[1], Kenichi Fushimi[1], Shotaro Kaneko[1], Tomoyuki Minami[2] and Aya Saito[2]

Abstract

Objective We reviewed the treatment outcomes for aortic arch aneurysms in elderly patients aged > 80 years, and discussed the risk factors for each technique.

Methods Octogenarians who underwent aortic arch aneurysm repair between 2007 and 2021 were included. Fifty-four patients (23 in the total arch replacement [TAR] group and 31 in the thoracic endovascular aortic repair [TEVAR] group) were included in the study. The early- and mid-term outcomes and risk factors for all-cause mortality were examined in each group. To examine timely surgical outcomes, cases of true aneurysms were included, whereas dissected aneurysms and emergency cases due to rupture or other causes were excluded.

Results No significant differences in 30-day mortality (0% in the TAR group and 5.4% in the TEVAR group) and in-hospital mortality (7.7% in the TAR group and 8.1% in the TEVAR group) were observed between the two groups. The survival rates at 5 years were 82% and 65% in the TAR and TEVAR groups, respectively, without significant difference. The aorta-related averted mortality was 91% and 81% in the TAR and TEVAR groups, respectively, without significant difference. No significant difference in the freedom from aortic events was also observed between the two groups. Previous ischemic heart disease was a significant risk factor for all-cause mortality in the TAR group. No significant risk factors were identified in this group.

Conclusion The choice of procedure was reasonable when considering frailty. Endovascular repair may be a good treatment option for patients with a history of ischemic heart disease.

Introduction

The initial surgical strategy for aortic arch aneurysms involves total arch replacement. Advanced age is a risk factor of early postoperative total arch replacement [2, 3]. In recent years, good results for total arch replacement have been reported, even in octogenarians [4, 5]. In addition, many good early results of endovascular repair have been reported in elderly patients, and the choice of surgical technique in elderly patients should be based on consideration of both the risk of surgery and anatomy of the aorta [6, 7].

We select surgical procedures based on frailty and comorbidities to determine if the patient can survive surgery, even in patients aged > 80 years. However, no clear criteria have yet been established for the choice of procedure for the treatment of aortic arch aneurysms in elderly patients aged > 80 years. This study aimed to examine the early and midterm outcomes of aortic arch aneurysms in very elderly patients, identify the risk factors for each procedure, and provide a clear choice of procedure for very elderly patients.

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*Correspondence:
Tomoki Cho
tomoggio@yokohama-cu.ac.jp
[1] Department of Cardiovascular Center, Yokohama City University Medical Center, 4-57 Urafunecho, Minami-Ku, Yokohama 232-0024, Japan
[2] Department of Surgery, Yokohama City University, Yokohama, Japan

Methods

Patient characteristics and definition

The ethic committee at Yokohama city university medical center approved this retrospective study (21 May 2024, F240500012). Because this was observational retrospective study, the need for informed consent was waived.

This retrospective study included 63 patients aged ≥ 80 years who underwent total arch replacement of endovascular repair for aortic arch aneurysms between 2000 and 2021 at our single institution. Patients with true aortic arch aneurysms were included, and those with dissected aortic arch aneurysms were excluded. For endovascular repair, cases of fenestrated or debranching endovascular repair implanted within zone 2 was included, and cases that could have been treated by landing in zone 3 were excluded. Patients with emergency cases due to rupture were excluded. The patients were divided into two groups: those who underwent total arch replacement (TAR group) and those who underwent thoracic endovascular aortic repair (TEVAR group). Demographic information and comorbidity data were collected from electronic medical records. We focused on frailty, which is the ability to survive surgery, and the presence or absence of comorbidities, such as severe chronic obstructive pulmonary disease or malignant disease, as criteria for surgical selection. The clinical frailty scale was introduced in the second clinical trial of the Canadian Study of Health and Aging as a method for experienced clinicians to comprehensively assess fitness and frailty in the elderly [8]. The clinical frailty scale (CFS) is widely used as a decision tool for screening frailty and broadly stratifying the degree of physical fitness and frailty. In this study, we stratified the patients using the CFS (version 2.0), which was revised in 2020 [9]. The standard postoperative follow-up regimen was at 6 months, 1 year, and every year thereafter. Aortic diameter was measured in a plane perpendicular to the centerline.

Endovascular repair

The proximal landing site of the stent graft was determined by securing a proximal neck length of 20 mm from the primary entry and the risk of a bird beak based on the morphology of the aortic arch. All patients received surgery under general anesthesia. When the proximal landing site was needed to cover the brachiocephalic artery or left common carotid artery, a fenestrated stent graft was used; when a fenestrated device was difficult, debranching was performed. The Najuta thoracic stent graft system (SB; Kawasumi Laboratories, Inc., Kanagawa, Japan) was used in all fenestrated cases. When the left subclavian artery was covered, simple closure was performed in patients whose preoperative computed tomography or magnetic resonance imaging scans revealed that the continuity of the left and right vertebral arteries was maintained. Patients with disconnection of the left and right vertebral arteries were treated by bypassing the left common carotid artery and left subclavian artery or the right subclavian artery to the left subclavian artery.

Operative technique of total arch replacement

Total arch replacement was performed through median sternotomy in all cases. From 2000 to 2009, the ascending aorta, axillary arteries, and femoral arteries were used as the blood supply channels. After 2010, total arch replacement was performed using the isolated cerebral perfusion technique reported by Kasama et al. to reduce the risk of postoperative stroke [10].

The primary outcome was all-cause mortality during the follow-up period, including early mortality. The mortality rates were compared between the TAR and TEVAR groups. Aortic-related mortality was defined as aortic dissection, aortic aneurysm rupture, graft infection, hospital death due to an unknown cause, or late death. Aortic events were defined as aortic-related mortality plus additional treatment for retrograde type A aortic dissection, stent graft-induced new entry, or endoleaks. Preoperative and postoperative variables were compared, and the risk factors for all-cause mortality during the follow-up period were identified.

Statistics

All analyses were conducted using the SAS software (version 12.2.0, SAS Institute Inc., Cary, NC, USA). Categorical variables are presented as frequencies (percentages), and continuous variables are presented as medians (interquartile ranges [IQRs]), owing to the non-normal distribution of the variables based on the Shapiro–Wilk test. For the univariate analysis between groups, the χ^2 and Wilcoxon tests were used for categorical and continuous variables, respectively. All P values were two-sided, and significance was set at $P < 0.05$. Kaplan–Meier curves were calculated to analyze long-term outcomes, and the log-rank test was used to describe differences in overall survival, aorta-related mortality, and aortic events.

Results

Preoperative patient characteristics are presented in Table 1. The TAR and TEVAR groups comprised 26 and 37 patients, respectively. The median age was 82 years, 75% of the patients were male, and no significant differences were observed between the two groups. A history of dyslipidemia was significantly more common

Table 1 Comparison of patients' characteristics

	Overall(N = 63)	TAR(N = 26)	TEVAR(N = 37)	P-value
Age	82 [81–84]	82 [81–84]	82 [81–83]	0.929
Male	47 (75)	20 (77)	27 (73)	0.722
Hypertension	43 (68)	21 (81)	22 (59)	0.068
Dyslipidemia	17 (27)	11 (42)	6 (16)	0.022
Diabetes Mellitus	9 (14)	5 (20)	4 (11)	0.318
Ischemic heart disease	15 (24)	7 (27)	8 (22)	0.628
Chronic heart failure	16 (25)	8 (31)	8 (22)	0.414
Neurologic dysfunction	8 (13)	2 (8)	6 (16)	0.304
CKD	12 (19)	7 (27)	5 (14)	0.185
COPD	13 (21)	4 (15)	9 (24)	0.382
Malignancy	17 (27)	3 (12)	14 (38)	0.016
Aneurysm size	63 [59–71]	65 [60–72]	62 [57–71]	0.708
Previous intervention on AAA	10 (16)	5 (19)	5 (14)	0.543
Previous cardiac or thoracic aortic surgery	4 (6)	2 (8)	2 (5)	0.716
Clinical frailty scale (%)				0.049
2	5	10	0	
3	41	55	27	
4	45	30	59	
5	10	5	14	

TAR, total arch replacement; TEVAR, thoracic endovascular aortic repair; COPD, chronic obstructive pulmonary disease; CKD, chronic kidney disease

in the TAR group than in the TEVAR group. Patients with a history of malignancy were selected for TEVAR. On the preoperative clinical frailty scale, the TAR group had the highest rate of CFS 3 (55%), the TEVAR group had the highest rate of CFS 4 (59%), and significantly more patients in the TEVAR group had frailty than that in the TAR group. No significant differences for other variables were observed between the groups. In the TAR group, 4 cases were performed before 2010 and 22 cases were performed after 2010. In the TEVAR group, 12 patients (32%) had debranching TEVAR and 25 patients (68%) had fenestrated TEVAR.

The 30-day mortality was 3.2% (2 of 63) in the overall population, 0% in the TAR group, and 5.4% (2 of 37) for the TEVAR group. Hospital mortality was 7.9% (5 of 63) in the overall population, 7.7% (2 of 26) in the TAR group, and 8.1% (3 of 37) in the TEVAR group, without significant differences in either 30-day or hospital mortality between the two groups. In the TAR group, we recorded one case of pneumonia caused by pulmonary hemorrhage and one case of disseminated intravascular coagulation caused by postoperative pancreatitis. These two cases were one each before and after 2010, and there was no difference between the two time periods. In the TAR group, postoperative stroke occurred in two patients, and both cases occurred after 2010. However, there was no statistically significant difference in the occurrence of postoperative stroke between periods. The hospital deaths in the TEVAR group were as follows: one patient with a history of ischemic heart disease died of heart failure, one patient suffered from multiple embolisms after endovascular repair, and one patient with CFS 5 could not tolerate surgical invasion. Two patients (3.2%) in the TAR group required temporary postoperative dialysis. Postoperative cerebral infarction occurred in two patients (7.7%) in the TAR group and two patients (5.4%) in the TEVAR group, although no significant difference was observed between the groups. Spinal cord ischemia was observed in two patients (5.4%) in the TEVAR group, although no significant difference was observed between the two groups.

Midterm results are presented in Fig. 1. The mean follow-up period was 45 months. The freedom from all-cause mortality rate 5 years postoperatively was 82% in the TAR group and 65% in the TEVAR group at 5 years, without significant difference ($p = 0.239$). The freedom from aortic-related mortality rate 5 years postoperatively was 91% in the TAR group and 81% in the TEVAR group, which was not statistically significant. The rate of freedom from aortic events 5 years postoperatively was 90% in the TAR group and 68% in the TEVAR group, which was not statistically significant. No late aortic-related deaths were observed in the TAR group, and all aortic-related deaths in the TEVAR group were caused by aortic aneurysm rupture from a stent graft-induced new entry or endoleak. Regarding aortic events, one patient

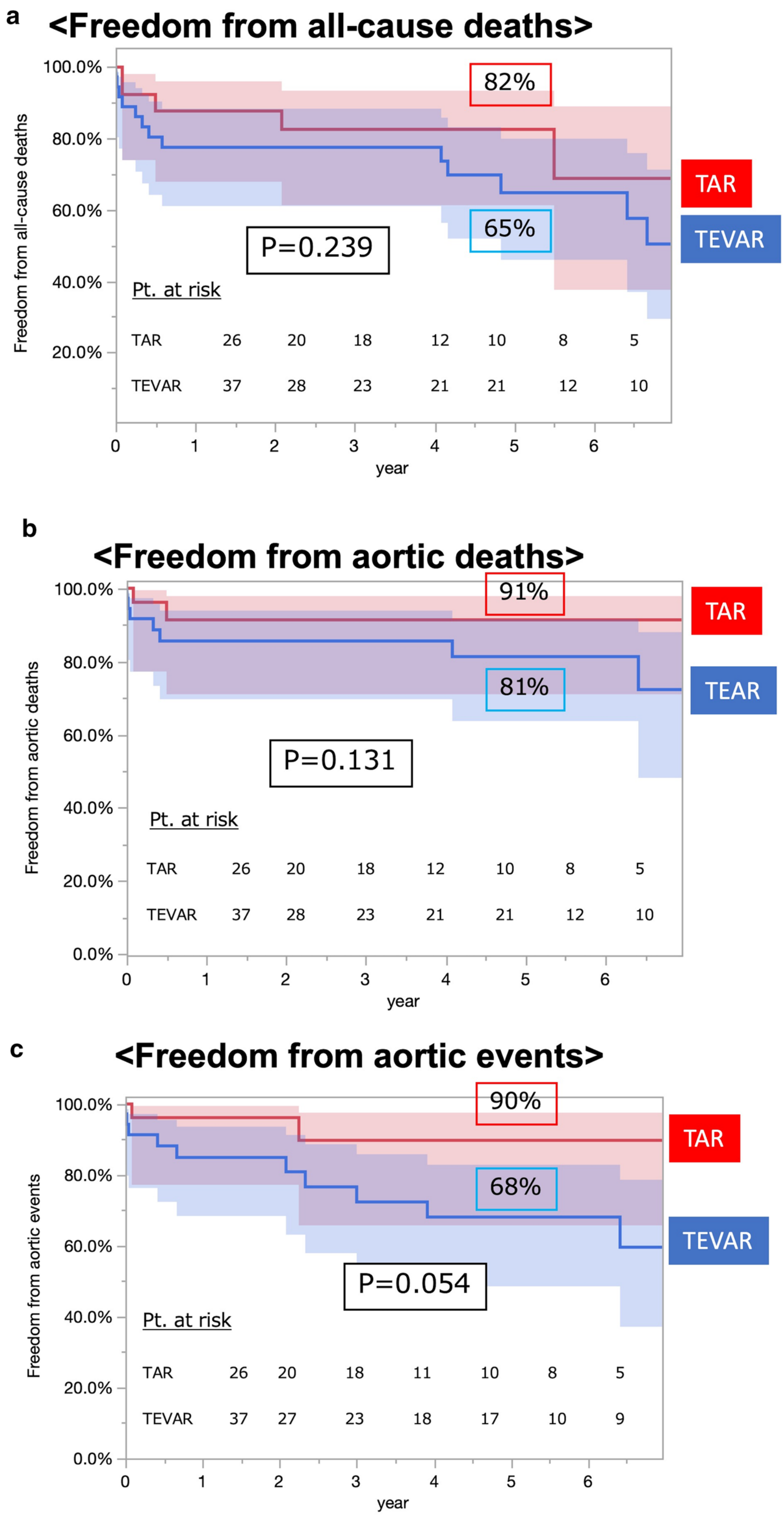

Fig. 1 Midterm results of total arch replacement and endovascular repair were compared using the Kaplan–Meier method. Freedom from **a** all-cause deaths, **b** aortic-related deaths, and **c** aortic events. No significant differences were observed between the two groups in all cases. TAR, total arch replacement; TEVAR, thoracic endovascular aortic repair

in the TAR group had type B aortic dissection. In the TEVAR group, one case of retrograde type A dissection, two cases of stent graft-induced new entry, one case of debranching graft infection, and two cases of coil embolization for endoleaks were observed.

For all patients, risk factors for all-cause mortality were analyzed using Cox regression analysis (Table 2). Ischemic heart disease was the only independent predictor during follow-up (hazard ratio [HR], 6.23; p = 0.013). The risk factors of all-cause mortality were examined for each procedure (Table 3). In the TAR group, chronic obstructive pulmonary disease, malignancy, previous intervention on abdominal aortic aneurysm, and previous cardiac or thoracic aortic surgery were not significant risk factors. Only ischemic heart disease was a significant independent risk factor (HR 16.28; p = 0.036). In the TEVAR group, ischemic heart disease, chronic obstructive pulmonary disease, postoperative spinal cord ischemia, and previous interventions on abdominal aortic aneurysm were not significant risk factors.

Table 2 Predictors of all-cause mortality (entire cohort)

Covariate	HR	95% CI	*P*-value
Male	0.98	0.38–2.59	0.976
Diabetes mellitus	4.68	0.78–28.27	0.092
Ischemic heart disease	6.23	1.46–26.51	0.013
Chronic heart failure	1.70	0.72–4.06	0.229
Neurologic dysfunction	1.53	0.25–9.51	0.645
CKD	1.59	0.51–4.98	0.424
COPD	2.79	0.79–9.78	0.109
Malignancy	1.18	0.40–3.49	0.761
Previous intervention on AAA	1.30	0.45–2.79	0.629
Previous cardiac or thoracic aortic surgery	3.79	0.63–22.84	0.146
TAR	0.46	0.19–1.12	0.087
Perioperative SCI	4.46	0.32–62.71	0.268

CKD, chronic kidney disease, COPD, chronic obstructive pulmonary disease; AAA, abdominal aortic aneurysm; TAR, total arch replacement; SCI, spinal cord ischemia

Discussion

An important issue in the treatment of aortic arch aneurysms in the very elderly is not only to treat aortic arch aneurysms but also to maintain postoperative activities of daily living after treatment. Considering its surgical invasiveness, total arch replacement is not indicated in a certain number of patients. However, no consensus on the ideal treatment for each patient has been achieved because the results of endovascular repair in high-risk patients are not significantly better than those of total arch replacement. The definition of "high-risk" varies, and to assess surgical risk, using indicators based on the patient's frailty and activities in addition to comorbidities is important. In this study, we stratified patients based on the clinical frailty scale and preoperative comorbidities to determine the surgical technique, and further identified the risk factors for each technique based on midterm outcomes. These results may be useful in determining a more appropriate surgical strategy for each patient.

Hybrid endovascular repair using fenestrated devices or debranching has evolved with the development of new devices. Milewski et al. (JTCVS 2010;140:590–7) have reported that hybrid arch repair is a safe alternative to open thoracic surgery and that hybrid arch repair has a lower mortality rate than total arch replacement in high-risk patients aged > 75 years [11]. Pecoraro et al. (Interact Cardiovasc Thorac Surg 2017;24:882–9) have also reported on the efficacy of hybrid endovascular repair using the debranching method in high-risk patients such as the elderly [12]. By contrast, Kurazumi et al. and Pacini et al. have reported no effect on mortality or neurological outcome after total arch replacement, even for elderly patients

Table 3 Risk factors for all-cause mortality by each procedures

Group	Covariate	HR	95% CI	*P*-value
TAR	Male	1.59	0.26–9.57	0.613
	Ischemic heart disease	16.28	1.19–221.29	0.036
	Malignancy	1.61	0.11–22.78	0.723
	COPD	2.31	0.08–65.00	0.622
	Previous intervention on AAA	1.21	0.14–10.78	0.862
	Previous cardiac or thoracic aortic surgery	2.23	0.10–47.79	0.608
TEVAR	Ischemic heart disease	2.13	0.08–51.53	0.640
	Postoperative SCI	61.1	0.37–1017.85	0.115
	Previous intervention on AAA	320.3	1.00–1021.63	0.049
	COPD	4.37	0.17–112.48	0.373

TAR, total arch replacement; TEVAR, thoracic endovascular aortic repair; COPD, chronic obstructive pulmonary disease; AAA, abdominal aortic aneurysm

(EJCTS 2014;46:672–7, EJCTS 2012;42:249,053) [13, 14]. However, various endovascular techniques are not superior to conventional techniques in terms of outcomes in high-risk patients. In this study, no significant difference was observed between the two groups in terms of all-cause or aortic-related mortality at the last follow-up for patients in their 80 s. The results revealed that proper patient stratification and selection of the optimal surgical technique affected postoperative outcomes.

The results of the risk factor analysis for all-cause mortality identified ischemic heart disease as an independent risk factor. Furthermore, in the risk factor analysis by procedure, ischemic heart disease was identified as a significant risk factor in the TAR group, but not in the TEVAR group. These results suggest endovascular repair as an appropriate technique for treating patients with ischemic heart disease. A previous study has indicated that mortality in total arch replacement is high in patients with chronic obstructive pulmonary disease or a history of malignancy (JTCVS 2012;143:1160–6) [15]. However, these factors were not identified as risk factors in the present study. This may have contributed to the appropriate stratification of patients.

In this study, no significant differences in the incidence of postoperative cerebral infarctions were observed between the groups. For total arch replacement, we believe that the isolated cerebral perfusion technique previously reported by our group is currently the greatest possible stroke prevention method at present (Kasama) [10]. However, a certain number of cerebral infarctions cannot be avoided, even with this isolated cerebral perfusion technique based on total arch replacement. Further development of branched devices for endovascular repair will continue. However, the biggest challenge is the prevention of cerebral infarctions. We look forward to further development and evolution of branched devices to prevent cerebral infarction.

This study has some limitations. First, this was a single-center retrospective study, and selection bias may have existed. Second, the sample size was small for a specific cohort of patients, which limited statistical power. Further investigations and follow-ups are needed to select a treatment strategy for aortic arch aneurysms in elderly individuals. Third, patients who were considered at a very high risk and were not candidates for the treatment of aortic arch aneurysms were excluded; therefore, they were not evaluated in this cohort. Lastly, not all the factors affecting survival were evaluated; therefore, relevant or unrecognized factors may have existed.

Conclusion

Endovascular repair may be an appropriate technique to treat aortic arch aneurysms in elderly patients with ischemic heart disease. Therefore, properly stratifying elderly patients and selecting the more appropriate technique are important.

Abbreviations

TAR	Total arch replacement
TEVAR	Thoracic endovascular aortic repair
CFS	Clinical frailty scale

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Author contributions
T.C designed this work and wrote the main manuscript. K.U. and A.S. supervised the manuscript. S.Y., Y.O., K.F., S.K. and T.M. did data curation. Final manuscript was approved by all authors.

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Data availability
Data is provided within the manuscript or supplementary information files.

Declarations

Competing interests
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