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ORIGINAL ARTICLE

Blood Vessel Prosthesis

Clinical results and medical costs of thoracic endovascular aortic repair in patients over 80 years of age

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Abstract

Thoracic endovascular aortic repair (TEVAR) is expected to be minimally invasive, especially in older patients. However, clinical results of TEVAR in octogenarians including medical costs are limited. Between 2010 and 2016, a total of 57 patients over 80 years of age (mean age 84.1 ± 3.4 years) underwent TEVAR at our hospital. The proximal landing zone (PLZ) was zone 0 in 7 patients (12.3%), zone 1 in 10 patients (17.5%), zone 2 in 9 patients (15.8%), zone 3 in 13 patients (22.8%), and zone 4 in 18 patients (31.6%). The mean follow-up time was 23 ± 19 months (range 1–71 months). The follow-up rate was 96.5%. The hospital mortality rate was 1.8%. Stroke occurred in three patients (zone 0: 2, zone 3: 1, 5.3%). The mean hospital stay was 21.8 ± 21.4 days (range 5–98 days), and the rate of being discharged home was 84.2%. The 1-year and 3-year survival rates were 76.1% and 55.1% and the 1-year and 3-year re-intervention-free rates of the thoracic aorta were 97.6% and 94.5%, respectively. The mean total cost by the time of hospital discharge was ¥5,360,000 ± 2,360,000. The clinical results of TEVAR in patients over 80 years of age are acceptable with early postoperative recovery, low mortality and morbidity, and midterm durability.

Keywords Thoracic endovascular repair (TEVAR) · Octogenarian · Medical costs

Introduction

Conventional surgical repair of a thoracic aortic pathology is an invasive procedure that requires cardiopulmonary bypass or deep hypothermic circulatory arrest. The mortality rate ranges from 2.5 to 17%, and the rate of neurological injury ranges from 4 to 12% [1–7]. Despite advances in surgical techniques and postoperative management, the mortality of octogenarians undergoing conventional open surgical repair for thoracic aneurysm is still considerable [8, 9]. Thoracic endovascular aortic repair (TEVAR) is an alternative treatment for uncomplicated aortic disease of the descending thoracic aorta and has acceptable rates of midterm morbidity and mortality [10, 11]. TEVAR is also expected to have beneficial effects in older patients. However, the durability of the prosthesis has not fully been determined and is thought to be inferior to that of open surgical graft replacement. In the context of an increasing average life expectancy, TEVAR will not be indicated only due to advanced patient age. However, clinical results of TEVAR in octogenarians including long-term follow-up are limited. In addition, current medical costs are increasing because of rapidly escalating healthcare costs in an aging society. An appropriate balance of clinical and financial outcomes of such procedures should be discussed. In the present study, we investigated the clinical outcome of TEVAR in octogenarians, in addition to medical costs.

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Methods

Patients

Between 2010 and 2016, a total of 57 consecutive octogenarians, including two nonagenarians, underwent TEVAR in KKR Sapporo Medical Center, and they were retrospectively reviewed. The indication for TEVAR was overall aortic diameter of 50 mm or greater, saccular-type aneurysm likely to rupture, rapid enlargement of 5 mm within 6 months, or rupture. Dementia, low activity of daily life, and malignancy with poor prognosis were exclusion criteria for surgery. The characteristics of this cohort are shown in Table 1. The mean patient age at the first surgery was 84.1 ± 3.4 years (80–98 years). Twenty-nine patients were men. The aortic pathology was degenerative aneurysm (87.7%: 50/57), chronic aortic dissection (10.5%: 6/57), and pseudo aneurysm (1.8%: 1/57). Emergent surgery was performed in six (10.5%) patients. Comorbidities were a previous history of cerebrovascular disease (5.3%: 3/57), coronary artery disease (21.1%: 12/57), chronic obstructive pulmonary disease (14.0%: 8/57), chronic renal failure (5.3%: 3/57), and cancer (10.5%: 6/57). The mean follow-up period was 23 ± 19 months (range 1–71 months), and the completed follow-up rate was 96.5% (55/57). We obtained informed consent regarding not only the surgery, but also the clinical investigation before surgery. This study was a retrospective study and was approved by our hospital institutional review board.

Table 1 Patient demographics

	N = 57
Age (years)	84.1 ± 3.4 (80–98)
Gender (male/female)	29/28
Body surface area	1.59 ± 0.15
Hypertension	46 (80.7%)
hyperlipidemia	22 (38.6%)
Diabetes mellitus	8 (14.0%)
Aortic pathology	
Degenerative aneurysm	50 (87.7%)
Aortic dissection	6 (10.5%)
Pseudo aneurysm	1 (1.8%)
Aneurysm size (mm)	57.2 ± 12.1 (40–87)
Comorbidity	
Cerebrovascular disease	3 (5.3%)
Coronary artery disease	12 (21.1%)
Chronic obstructive lung disease	8 (14.0%)
Chronic renal failure	3 (5.3%)
Cancer	6 (10.5%)
Previous thoracotomy	3 (5.3%)
Emergent operation	6 (10.5%)
Completed follow-up rate	55/57 (96.5%)
Follow-up period (months)	23 ± 19 (1–71)

Surgical procedure

The details of the surgical procedure varied (Table 2). The proximal landing zone (PLZ) in the first surgery was zone 0 in 7 patients, zone 1 in 10, zone 2 in 9, zone 3 in 13, and zone 4 in 18. The operative procedure regarding zones 0–2 is shown in Table 2. The initial surgical technique varied, including the debranching, chimney technique, and custom-made or surgeon-modified fenestration.

Medical cost

The material cost and the total cost by the PLZ were investigated. The locations of the diseased aorta in most cases are aortic arch and descending thoracic aorta. The aortic arch aneurysm is usually treated by zones 0–2 TEVAR, whereas that in the descending thoracic aorta is treated by zones 3–4 TEVAR. Therefore, the medical costs of zones 0–2 and zones 3–4 TEVAR were also investigated. The medical costs shown in the present study are the in-hospital costs collected from the data of the patients' medical charts.

Statistical analysis

Continuous variables are reported as the mean and standard deviation. Categorical data are reported as counts and percentages. The Kaplan–Meier method was used to assess the intermediate and long-term all-cause and re-intervention rates for the thoracic aorta. Statistical analyses were performed using Statview for Windows, Version 5.0 (SAS Institute, Cary, NC, USA).

Results

Early results

The early results of the surgeries are shown in Table 3. The in-hospital mortality rate was 1.8% (1/57). The patient who died was a 92-year-old woman who underwent emergent TEVAR for a rupture of a chronic type B dissection. The patient had pneumonia post-surgery and died on postoperative day 60. Stroke occurred in three patients (3/57:5.3%), two in zone 0 (2/7:28.6%) and one in zone 1 (1/13:7.7%). All of the three patients showed severe atherosclerotic change in the aortic arch. The average length of intensive care unit (ICU) stay was 2.2 ± 2.8 days (1–17 days; median 1 days). An ICU stay ≥ 7 days was observed in four patients due to complications (two: stroke; one: gastrointestinal bleeding due to pre-existing

Table 2 Summary of the surgery

Proximal landing zone	$N=57$
Proximal landing zone	*n* (%)
Zone 0	7 (12.2%)
Zone 1	10 (17.5%)
Zone 2	9 (15.8%)
Zone 3	13 (22.4%)
Zone 4	18 (31.6%)
Operation time (min)	203 ± 113 (47–455)
Radiation exposure time (min)	35.6 ± 28.0 (9-128)
Contrast volume (ml)	112 ± 56 (20–260)
Blood loss (ml)	598 ± 823 (0–3950)
Access site complications	6 (10.5%)
Operative procedure	
Zone 0 ($n=7$)	*n* (%)
BCA chimney + AxA-AxA-lt LCCA bypass	4 (57.1%)
BCA + LCCA chimney	1 (14.3%)
Fenestrat*ed SG + AxA-AxA bypass	1 (14.3%)
Total debranching bypass	1 (14.3%)
Zone 1 (n = 10)	*n* (%)
2 debranching (AxA-AxA-lt CCA bypass)	6 (60.0%)
1 debranching (AxA-AxA bypass) + LCCA chimney	2 (20.0%)
LCCA chimney	1 (10.0%)
Fenestrated SG + AxA-AxA bypass	1 (10.0%)
Zone 2 ($n=9$)	*n* (%)
1 debranching (AxA-AxA or AxA-LCCA bypass)	7 (77.8%)
LSCA chimney	1 (11.1%)
LSCA coverage	1 (11.1%)

AxA Axillar artery, *SG* stent graft, *LCCA* left common carotid artery, *LSCA* left subclavian artery

Table 3 Early results

	$N=57$ (%)
Hospital mortality	1 (1.8%)
Perioperative morbidity	
Stroke	3 (5.3%) (zone 0; 2; zone1; 1)
Paraplegia	0 (0%)
Pulmonary complication	1 (1.8%)
Other	1 (1.8%)
ICU stay	2.2 ± 2.8 (1–17: median 1 day)
Hospital stay	18.8 ± 19.0 (5–98: median 11 days)
Discharged home	48 (84.2%)

disseminated intravascular coagulopathy; one: Takotsubo cardiomyopathy). The length of hospital stay after surgery was 18.8 ± 19.0 days (5–98 days; median 11 days). The rate of being discharged home was 84.2%.

Midterm results

The mean follow-up period was 23 ± 19 months (range 1–71 months). We observed no evidence of graft collapse or migration, and all of the bypasses were patent at the time of follow-up. All-cause survival was calculated with a Kaplan–Meier survival curve. The survival rate was 76.1% at 1 year and 55.1% at 3 years (Fig. 1a). The survival curve stratified by PLZ is shown in Fig. 1b. There was no significant difference in survival between the groups ($p=0.6593$). The freedom from aorta-related death was 97.5% at 1 year and 97.5% at 3 years. Twenty-three patients died during the time leading up to the follow-up. 13 (13/57: 22.8%) patients died within 1 year after the surgery. The cause of death within 1 year was malignancy (lung cancer: $n=1$, leukemia: $n=2$; all cases were undiagnosed before surgery), infection after discharge (pulmonary: $n=2$, urinary: $n=1$), postoperative pulmonary complications ($n=1$), senility ($n=2$), aortic event ($n=1$), cerebral hemorrhage ($n=1$), and unknown ($n=2$) (Table 4). Freedom from re-intervention for the thoracic aorta after the first TEVAR was 97.6% at 1 year and 94.5% at 3 years (Fig. 2a). During the follow-up period, two

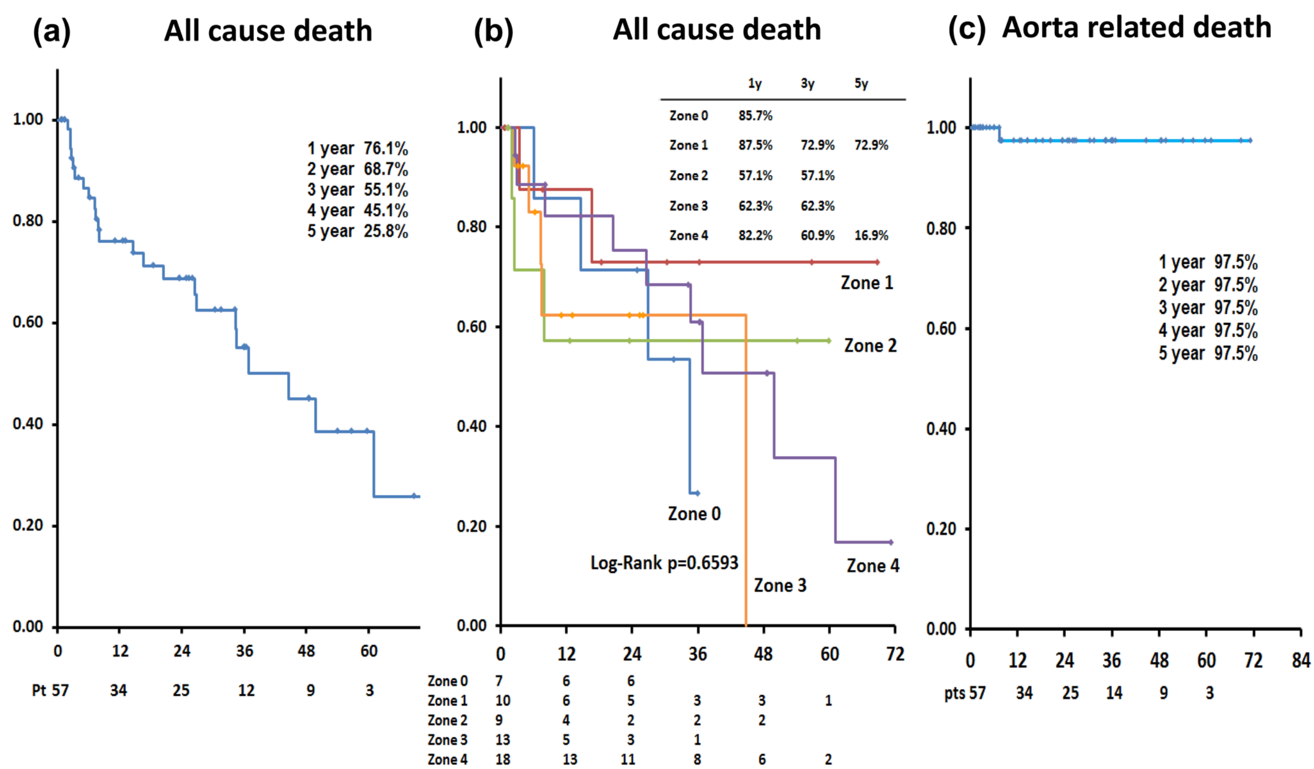

Fig. 1 Overall survival. Kaplan–Meier estimate of **a** all-cause death, **b** all-cause death stratified by the proximal landing zone, and **c** aorta-related death

Table 4 Cause of death

Cause of death	Death within 1 year ($n = 13$)	Death > 1 year ($n = 10$)
Op complication	1 (pneumonia:1)	
Malignancy	3 (lung: 1; leukemia: 2)	1
Infection	3 (pneumonia: 2; urinary: 1)	1 (pneumonia)
Senility	2	2
Aortic event	1	
Cerebral hemorrhage	1	
Unknown	1	6

patients required re-intervention. There was no significant difference in freedom from re-intervention stratified by the PLZ between the groups (log-rank test, $p = 0.6494$, Fig. 2b).

Medical costs

The overall mean total cost by the time of hospital discharge was ¥5,360,000 ± 2,360,000 (Fig. 3a). The cost stratified by the PLZ was ¥7,180,000 ± 2,620,000 for zone 0, ¥4,610,000 ± 820,000 for zone 1, ¥6,020,000 ± 2,130,000 for zone 2, ¥6,000,000 ± 2,900,000 for zone 3, and ¥4,340,000 ± 1,950,000 for zone 4. The material costs, including stent grafts, prosthetic grafts for debranching, and coiling, comprised approximately 40% of the total cost by the time of hospital discharge. The TEVAR cohort is also divided into two groups: zones 0–2 TEVAR, which excludes the distal arch part of the aorta openly surgically repaired by total arch replacement, and zones 3–4 TEVAR, which is repaired by graft replacement of the descending aorta (Fig. 3b). The mean medical costs were ¥5,914,4476 ± 2,079262 and ¥5,082,118 ± 2,517,063 in zones 0–2 and zones 3–4 TEVAR, respectively.

Discussion

Early results

The clinical results of TEVAR in octogenarians in the present series were acceptable, with low mortality (1.8%).

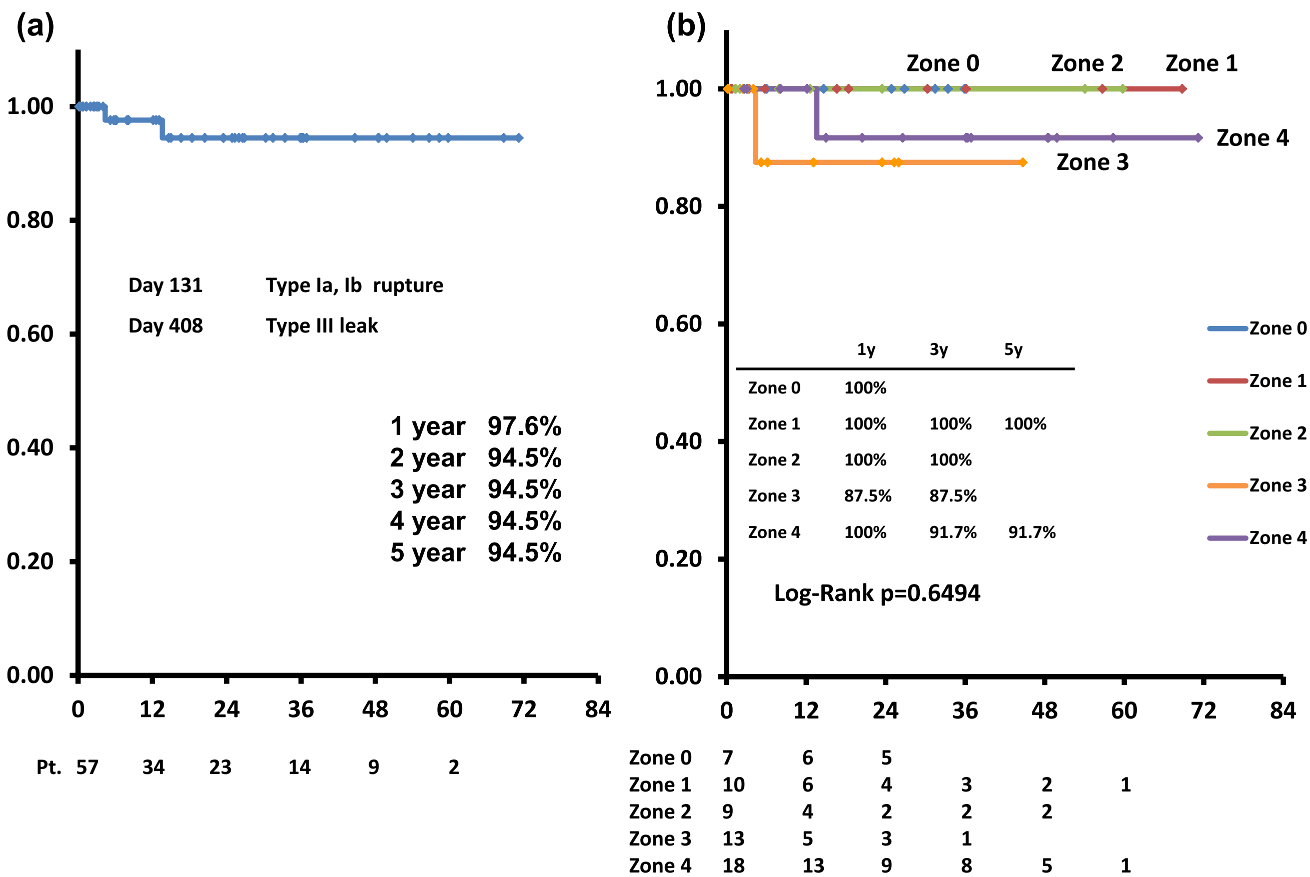

Fig. 2 Freedom from re-intervention. **a** Kaplan–Meier estimate of freedom from re-intervention. **b** Kaplan–Meier estimate of freedom from re-intervention stratified by the proximal landing zone

The mortality of elective cases was 0%. In open aortic surgery, hospital mortality ranges from 2.5 to 12.9% [5–9]. With regard to hospital mortality after TEVAR, Rango et al. reported an excellent surgical outcome of elective TEVAR for descending thoracic aortic disease in octogenarians, with an operative mortality rate of 0% [12]. However, they also reported that the mortality rate was 50% in emergent cases. They concluded that patients older than 75 years of age had three–five times the risk of mortality after emergent TEVAR. The present results of low mortality (1.8%) in octogenarians might be associated with relatively few emergent cases (10.5%).

The rate of serious neurological complications, such as stroke (5.3%), appeared to be acceptable in the present octogenarian series. The reported incidence of stroke after TEVAR involving the cervical branch of the aortic arch ranges from 0 to 28.6% [13–16]. Transient and permanent paraparesis and paraplegia have been reported in approximately 10% of patients who underwent TEVAR for descending thoracic aortic aneurysm, thoracoabdominal aortic aneurysm, and thoracic aortic dissection [17–22].

For patients, especially older patients, the general health status at discharge is a great concern. For older patients, a long-term hospitalization tends to weaken the general health status after discharge and to deteriorate not only the activities of daily living of patients, but also the quality of their family's life. The present result seems to be satisfactory in that more than 80% of patients could be discharged home after 2–3 weeks hospitalization. TEVAR in octogenarians, as expected, might contribute to preserving the activity of daily life of octogenarians after surgery.

Midterm results

Kurazumi et al. [23] reported that aortic arch surgery in octogenarians (open surgery: $n = 15$, TEVAR: $n = 5$) showed a significantly better survival rate compared with medical treatment (5-year survival: 64.5% vs. 14.2%). In the present study, the 1-year and 3-year survival rates were 76.1% and 55.1%, which are consistent with previous reports [12]. The 1-year and 3-year rates of freedom from re-intervention of the thoracic aorta were 97.6% and 94.5% in our study,

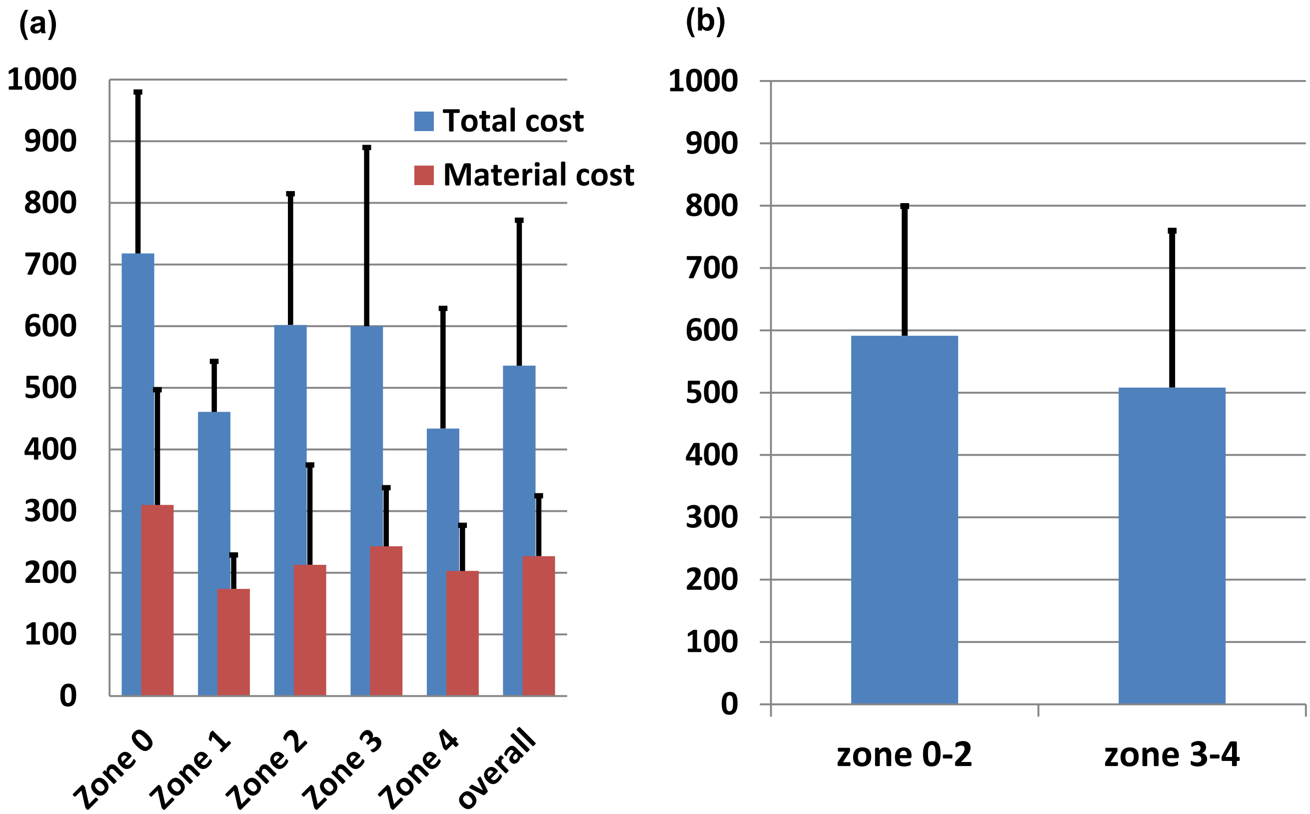

Fig. 3 **a** Medical costs (total cost and material cost) in hospital stratified by proximal landing zone. **b** Medical cost divided into two groups by proximal landing zone; zones 0–2, which excludes arch aneurysm, and zones 3–4, which excludes descending aortic aneurysm

which appeared to be satisfactory. With regard to TEVAR for aneurysms involving arch vessels, Shirakawa et al. [13] reported an excellent surgical result of zone 0 TEVAR in 40 patients (mean age 74.4 ± 7.8 years). They found that the hospital mortality rate was 3% and the stroke rate was 0%, with survival rates of 84.9% and 74.0% at 1 and 3 years, respectively. However, Hiraoka et al. [14] reported that debranching TEVAR for atherosclerotic disease of the aorta requiring PLZ 0 showed a higher rate of stroke and lower rate of survival. They concluded that the clinical feasibility of TEVAR requiring PLZ 0 or emergency surgery is still controversial. Appropriate selection of patients and surgical strategy in view of the general patients' condition and aortic pathology are likely to be associated with the postoperative clinical course.

Medical costs

Medical expenses for older patients are a concern in the aging society because it is becoming a burden of national health care finance. Hospital costs of cardiac surgery in octogenarians are 20–30% higher compared with younger patients with a lower survival rate [24, 25]. A longer survival with good postoperative general condition and a low rate of re-intervention after procedure might contribute to making the surgery cost effective. In the present study, 13 (22.8%) patients died within 1 year after the procedure. The main cause of death within 1 year was malignancy (which was diagnosed after surgery), infection after discharge, and postoperative complications. Chung et al. reported that preoperative leukocytosis, aneurysm diameter, and concurrent debranching independently predict late mortality [26]. Prevention of postoperative complications and infection in the outpatient setting and preoperative screening for malignancy might play a role in making TEVAR a more cost-effective treatment for octogenarians.

Study limitation

There are some limitations of this study. This study was retrospectively reviewed, and the cohort size was relatively small. It also lacked the evaluation of patient frailty. In addition, there was no long-term follow-up data regarding the medical costs after discharge. The surgical procedure depended on the surgeon's preference, and there was no definite algorithm for deciding surgical procedure.

Conclusion

The clinical results of TEVAR in patients older than 80 years of age are acceptable, with early postoperative recovery, low mortality and morbidity, and long-term durability.

Compliance with ethical standards

Conflict of interest All authors have no conflict of interest.

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