

 **Original Article** 

Long-Term Outcomes of Open Surgery and Stent Graft Treatment in Patients Undergoing Repeat Thoracic Aortic Aneurysm Repair from Previous Anastomosis Site

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Objective: The purpose of this study was to compare the long-term outcomes of open surgery and thoracic endovascular aortic repair (TEVAR) in patients undergoing repeat thoracic aortic repair from previous anastomosis site.

Methods: From January 2009 to December 2017, 68 patients needed repeat aortic surgery from previous anastomosis site. Twenty-three patients had dissected distal aorta and 45 patients had non-dissected distal aorta. Early and long-term outcomes of open surgery and TEVAR were compared in both groups.

Results: There were no significant differences in patient background between the two treatments in both groups. Open surgery was associated with longer intensive care unit stay, but there was no significant difference in in-hospital mortality in both groups. In patients with dissected distal aorta, there was no significant difference in long-term mortality ($p=0.73$). However, TEVAR was associated with higher risk of reintervention ($p=0.038$). In non-dissected distal aorta patients, acute kidney injury ($p=0.002$) and prolonged ventilation ($p=0.032$) were more often observed in open surgery. However, there were no significant differences in long-term mortality ($p=0.23$) and freedom from reintervention ($p=0.13$).

Conclusions: Long-term outcomes were similar between open surgery and TEVAR in both groups. However, TEVAR in patients with dissected distal aorta was associated with

higher risk, for reintervention.

Keywords: redo TEVAR, thoracic aorta, aneurysm, redo surgery

Introduction

Enlargement of the remaining aorta or formation of pseudo-aneurysm at the anastomosis site is often observed after repair of thoracic aortic aneurysm. Aortic arch reoperation rate of 5% has been reported for those patients who underwent surgery on the ascending aorta with or without involvement of the aortic arch. The indication for repeat surgery included residual arch aneurysm in 50% of patients, aneurysmal formation due to residual aortic dissection in 38% of patients, and graft infection in 9% of patients.¹⁾ Furthermore, in a retrospective chart review of 11 European aortic centers, aortic events occurred in 12.6% of the patients who underwent elective total aortic arch replacement.²⁾

On the other hand, five years freedom from aneurysm-related death in patients undergoing elective thoracic endovascular repair (TEVAR) for degenerative thoracic aortic aneurysms is reported to be from 82.4% to 92.7%. The most common complication among these patients was endoleak, occurring at a rate of 1.4% to 14.8%.³⁾

Due to introduction of stent graft technology, surgical strategy for aortic aneurysm is provided with many options. Staged hybrid operation, combining open surgical repair and endovascular repair, has been reported in treating acute type A dissection and extended aortic aneurysms.^{4,5)} Use of stent graft for a repeat thoracic aortic surgery could be another option of surgical strategy for aortic aneurysm.

The purpose of this study was to compare the long-term outcomes of open surgical treatment and TEVAR treatment in patients undergoing repeat thoracic aortic repair from the previous anastomosis site.


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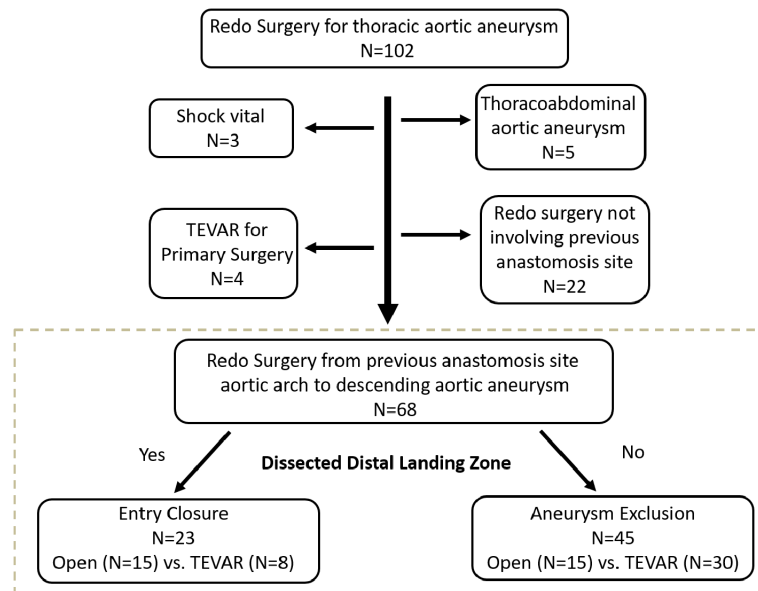


Fig. 1 Flow diagram of the patients included in the study. Sixty-eight patients who underwent repeat surgery from previous anastomosis site were included in the study.

Methods

From January 2009 to December 2017, there were 102 patients in our institution who underwent repeat aortic surgery of the remaining aortic arch to the descending thoracic aorta. Patients who underwent surgery for thoracoabdominal aortic aneurysm; patients who underwent TEVAR for the initial surgery; patients who were in shock before surgery; and for repeat surgery not involving previous anastomosis site were excluded from the study. The remaining 68 patients who needed treatment from the previous anastomosis site were included in the study (Fig. 1). Of these 68 patients, 23 patients had dissected distal aorta and 45 patients had non-dissected distal aorta (Fig. 2). Outcomes of open surgery and TEVAR were compared in these two groups. The primary goal of TEVAR in patients with dissected distal aorta was closure of the major entry, while exclusion of an aneurysm was achieved in patients with non-dissected distal aorta. The study was approved by the Institutional Review Board of Saitama Medical Center, Jichi Medical University (S18-056).

Statistical analysis

Normal distribution of the data was assessed using Kolmogorov–Smirnov test. Continuous data that were normally distributed were analyzed using the Student’s t-test (mean \pm standard deviation [SD]). Mann–Whitney test (median, interquartile range [IQR]) was used for data that were not normally distributed. For categorical variables, Fisher’s exact test was used (n, %). Early outcomes were compared between the two groups including: hospital

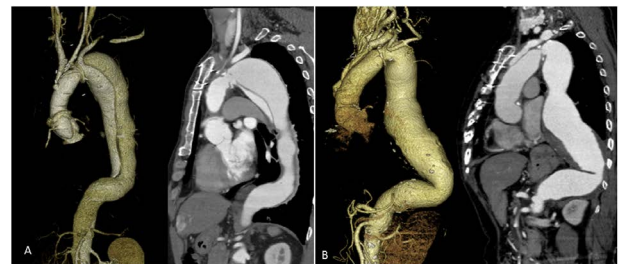


Fig. 2 Representative computed tomography images of patients with dissected distal aorta (A: entry closure group) and non-dissected distal aorta (B: aneurysm exclusion group).

stay; intensive care unit (ICU) stay; in-hospital mortality; sepsis; acute kidney injury; prolonged ventilation; and stroke. Acute kidney injury (AKI) was defined by the KDIGO criteria⁶ and prolonged ventilation was defined as ventilation therapy for more than 48 h after surgery. For the long-term outcomes, all-cause mortality and freedom rate from reintervention were evaluated using the Kaplan–Meier curve and log-rank test. $p < 0.05$ was considered significant, and all analysis was performed using Stata (version 13.1, Stata Corp, College Station, TX, USA).

Repeat surgical procedures

Endovascular treatment was considered in patients with sufficient proximal landing zone of more than 20 mm, with or without debranching of the left axillary artery or left common carotid artery from the right axillary artery. For patients not suitable for endovascular treatment, open surgical repair was considered. For patients who previ-

Table 1 Patient demographics and early outcomes

	Entry closure			Aneurysm exclusion		
	Open surgery n=15	TEVAR n=8	p	Open surgery n=15	TEVAR n=30	p
Age (years)	62.4±9.54	64.3±8.94	0.66	67.8±10.39	69.6±7.93	0.52
Male (%)	9 (60.0%)	4 (50.0%)	0.69	11 (73.3%)	24 (80.0%)	0.71
Angiotensin II receptor blocker (%)	10 (66.7%)	5 (62.5%)	1	7 (46.7%)	15 (50.0%)	1
Calcium channel blocker (%)	11 (73.3%)	5 (62.5%)	0.66	11 (73.3%)	17 (56.7%)	0.34
Beta blocker (%)	14 (93.3%)	6 (75.0%)	0.27	9 (60.0%)	18 (60.0%)	1
HMG-CoA inhibitor (%)	2 (13.3%)	3 (37.5%)	0.3	7 (46.7%)	16 (53.3%)	0.76
Anti-platelet (%)	3 (20.0%)	2 (25.0%)	1	4 (26.7%)	9 (30.0%)	1
Anti-coagulation (%)	4 (26.7%)	3 (37.5%)	0.66	2 (13.3%)	8 (26.7%)	0.46
Creatinine (mg/dl)	0.95 (0.83–1.11)	0.90 (0.80–1.94)	0.85	1.14 (0.82–1.38)	0.92 (0.74–1.14)	0.31
Hemoglobin (g/dl)	12.0±1.74	11.6±1.67	0.54	12.3±1.80	11.8±1.71	0.35
Hyperlipidemia (%)	4 (26.7%)	4 (50.0%)	0.37	7 (46.7%)	16 (53.3%)	0.76
Diabetes (%)	3 (20.0%)	0 (0.0%)	0.53	3 (20.0%)	5 (16.7%)	1
Hypertension (%)	15 (100.0%)	7 (87.5%)	0.35	15 (100.0%)	25 (83.3%)	0.15
Cerebral vascular disease (%)	3 (20.0%)	1 (12.5%)	1	3 (20.0%)	4 (13.3%)	0.67
Pathophysiology						
Initial surgery (dissection: degenerative)	15:0	8:0	1	10:5	12:18	0.12
Repeat surgery (pseudoaneurysm: residual aneurysm)	3:12	2:6	1	4:11	12:18	0.51
Previous surgery			0.23			0.002
Ascending aorta replacement	7 (46.7%)	1 (12.5%)		4 (26.7%)	1 (3.3%)	
Aortic arch replacement	2 (13.3%)	3 (37.5%)		2 (13.3%)	17 (56.7%)	
Descending aorta replacement	2 (13.3%)	3 (37.5%)		5 (33.3%)	1 (3.3%)	
Thoracoabdominal aorta replacement	—	—		3 (20.0%)	5 (16.7%)	
Aortic arch and thoracoabdominal aorta replacement	—	—		1 (6.7%)	5 (16.7%)	
Partial arch replacement	4 (26.7%)	1 (12.5%)		0 (0.0%)	1 (3.3%)	
Surgical time (mins)	510±114.1	217±84.7	<0.001	476±155.5	229±111.4	<0.001
Early outcomes						
Acute kidney injury (%)	5 (33.3%)	0 (0.0%)	0.12	6 (40.0%)	1 (3.3%)	0.002
Spinal cord injury (%)	0 (0.0%)	1 (12.5%)	0.35	0 (0.0%)	1 (3.3%)	1
Infection (%)	5 (33.3%)	1 (12.5%)	0.37	5 (33.3%)	4 (13.3%)	0.14
Prolonged ventilation (%)	4 (26.7%)	0 (0.0%)	0.26	5 (33.3%)	2 (6.7%)	0.032
Cerebral infarction (%)	1 (6.7%)	0 (0.0%)	1	2 (13.3%)	0 (0.0%)	0.11
Vocal cord paralysis (%)	4 (26.7%)	0 (0.0%)	0.26	3 (20.0%)	0 (0.0%)	0.032
Sepsis (%)	1 (6.7%)	1 (12.5%)	1	1 (6.7%)	1 (3.3%)	1
ICU stay (days)	3 (2–4.5)	1 (1–2.3)	0.006	4 (2–8.5)	1 (1–2.0)	<0.001
Hospital stay (days)	23 (13–38)	12.5 (8.3–17.5)	0.067	20 (17–40.5)	10 (9–16.0)	<0.001
In hospital death (%)	0 (0.0%)	1 (12.5%)	0.35	0 (0.0%)	1 (3.3%)	1

ously received ascending aorta replacement, repeat open surgery was performed by a redo median sternotomy. For other patients, repeat open repair of the aortic arch was performed by a left thoracotomy.

Results

The devices used for TEVAR were Najuta (Kawasumi Laboratories, Inc., Tokyo, Japan) (n=6), cTAG (W. L. Gore & Associates, Inc., Flagstaff, AZ, USA) (n=7), Relay (Bolton Medical, Inc., Sunrise, FL, USA) (n=6),

TX2 (Cook Medical, Bloomington, IN, USA) (n=10), Valiant (Medtronic, Minneapolis, MN, USA) (n=6), and Talent (Medtronic, Minneapolis, MN, USA) (n=3). For repeat open surgery, nine patients underwent aortic arch replacement and six patients underwent descending aorta replacement for patients with dissected distal aorta. For patients without dissected distal aorta, 14 patients underwent aortic arch replacement and one patient underwent descending aorta replacement.

The demographics of the patients are shown in Table 1. For patients with dissected distal aorta, the time be-

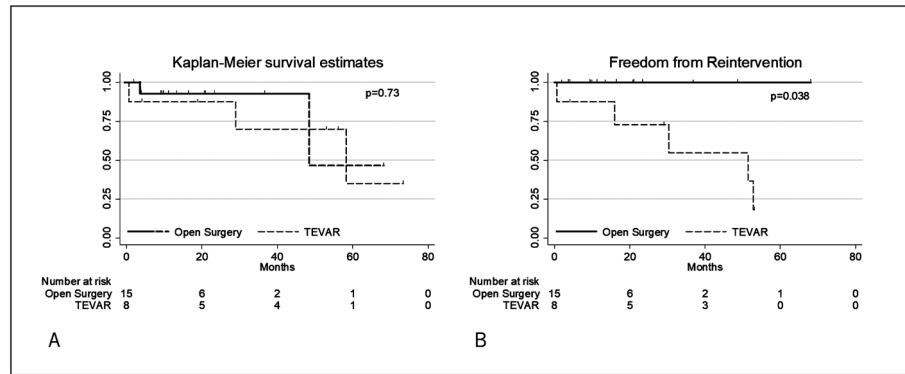


Fig. 3 Long-term outcomes and freedom from reintervention in patients with dissected distal aorta (entry closure group).

The dotted lines following each full (bold) line represent data outside standard error of 10%.

tween repeat surgery and previous surgery was 36.5 months (q25–q75: 18.9–74.0). Of the five patients who underwent aortic arch replacement previously, one patient received frozen elephant trunk and one patient received conventional elephant trunk. There were no significant differences in age (open surgical repair [OSR]: 62 ± 9.5 years vs. TEVAR: 64 ± 8.9 years, $p=0.66$), and medications including angiotensin receptor blocker (OSR: 66.7% vs. TEVAR: 62.5%, $p=1$), calcium channel blocker (OSR: 73.3% vs. TEVAR: 62.5%, $p=0.66$), and beta blocker (OSR: 93.3% vs. TEVAR: 75.0%, $p=0.27$). There also were no significant differences in other medical histories including hyperlipidemia (OSR: 26.7% vs. TEVAR: 50.0%, $p=0.37$), diabetes (OSR: 20.0% vs. TEVAR: 0.0%, $p=0.53$), and hypertension (OSR: 100.0% vs. TEVAR: 87.5%, $p=0.35$). However, surgical time was significantly longer in patients undergoing open surgical repair (OSR: 510 ± 114.1 min vs. TEVAR: 217 ± 84.7 min, $p<0.001$). There was one patient with type 1b endoleak, but there was no type 1a endoleak from previously implanted prosthetic graft.

For the early outcomes, open surgical repair was associated with longer ICU stay (OSR: 3, q25–q75 2–5 days, vs. TEVAR: 1, q25–q75 1–2 days, $p=0.006$). Although there was no statistical significance, hospital stay was also longer in open surgical repair (OSR: 23, q25–q75 13–38 days, vs. TEVAR: 13, q25–q75 8–18 days, $p=0.067$). There was only one in-hospital death from both groups and the cause of death was graft infection (Table 1).

For the long-term outcomes, there was no significant difference in long-term mortality ($p=0.73$). However, TEVAR was associated with higher risk for reintervention ($p=0.038$) (Fig. 3). Causes of deaths included graft infection ($n=1$), cerebral hemorrhage ($n=1$), pneumonia ($n=1$), leukemia ($n=1$), and included unknown cause ($n=1$). For reintervention, four patients underwent endovascular repair due to residual endoleak ($n=1$), stent

graft induced new entry ($n=1$), pseudoaneurysm ($n=1$), and residual re-entry ($n=1$). One patient underwent open surgical repair due to residual endoleak.

The demographics of the patients with non-dissected distal aorta are shown in Table 1. The time between repeat surgery and previous surgery was 28.6 months (q25–q75 6.8–72.0). Of the 19 patients who underwent aortic arch replacement previously, two patients received conventional elephant trunk, but no patient received frozen elephant trunk. There were no significant differences in age (OSR: 68 ± 10.4 years vs. TEVAR: 70 ± 7.9 years, $p=0.52$), and medications including angiotensin receptor blocker (OSR: 46.7% vs. TEVAR: 50.0%, $p=1$), calcium channel blocker (OSR: 73.3% vs. TEVAR: 56.7%, $p=0.34$), and beta blocker (OSR: 60.0% vs. TEVAR: 60.0%, $p=1$). There also were no significant differences in other medical histories including hyperlipidemia (OSR: 46.7% vs. TEVAR: 53.5%, $p=0.76$), diabetes (OSR: 20.0% vs. TEVAR: 16.7%, $p=1$), and hypertension (OSR: 100.0% vs. TEVAR: 83.3%, $p=0.15$). However, surgical time was significantly longer in patients undergoing open surgical repair (OSR: 476 ± 155.5 min vs. TEVAR: 229 ± 111.4 min, $p<0.001$). There was one patient with type 1b endoleak, but there was no type 1a endoleak from previously implanted prosthetic graft.

For the early outcomes, incidence of AKI (OSR: 40.0% vs. TEVAR: 3.3%, $p=0.002$), prolonged ventilation (OSR: 33.3% vs. TEVAR: 6.7%, $p=0.032$), and vocal cord paralysis (OSR: 20.0% vs. TEVAR: 0.0%, $p=0.032$) were more often observed in open surgical repair than in patients treated by TEVAR. Furthermore, open surgical repair was associated with longer ICU stay (OSR: 4 q25–q75 2–9 days, vs. TEVAR: 1, q25–q75 1–2 days, $p<0.001$) and hospital stay (OSR: 20, q25–q75 17–41 days, vs. TEVAR: 10, q25–q75 9–16 days, $p<0.001$). There was only one in-hospital mortality from both groups and the cause of death was graft infection.

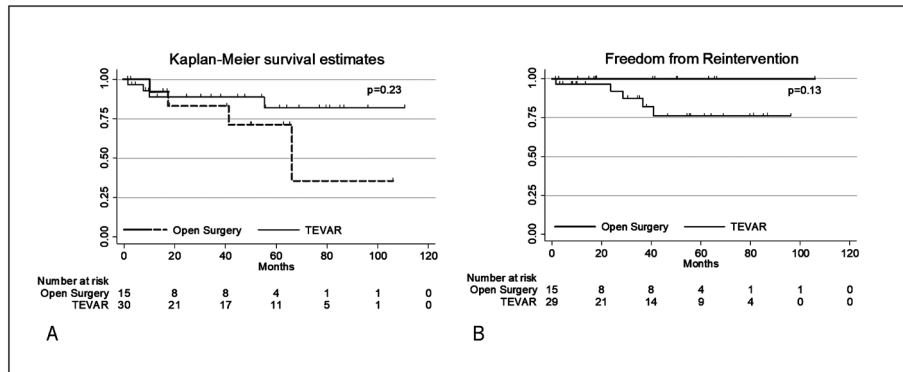


Fig. 4 Long-term outcomes and freedom from reintervention in patients with non-dissected distal aorta (aneurysm exclusion group). The dotted lines following each full (bold) line represent data outside standard error of 10%.

For the long-term outcome, there was no significant difference in long-term mortality ($p=0.23$). Although there was no statistical significance, freedom from reintervention ($p=0.13$) tended to be lower in the TEVAR group (Fig. 4). Causes of death included cerebral hemorrhage ($n=3$), pneumonia or other infections ($n=3$), and unknown cause ($n=2$). For reintervention, five patients underwent endovascular reintervention due to type 2 endoleak ($n=2$), type 1b endoleak ($n=1$), stent migration ($n=1$), and residual aneurysmal rupture ($n=1$). One patient underwent open surgical repair due to pseudoaneurysm.

Discussion

In patients undergoing repeat thoracic aortic repair from previous anastomosis site, patients who underwent open surgical repair were more likely to develop postoperative AKI, vocal cord paralysis, and experience prolonged ventilation. Using previously implanted prosthetic graft as a landing zone for TEVAR was not associated with risk for type 1 endoleak. ICU stay was significantly shorter in patients who underwent TEVAR. Although there were no significant differences in long-term survival, TEVAR in patients with dissected landing zone was associated with higher incidence of reintervention.

The intraoperative and in-hospital mortality of the patients who needed redo surgery for thoracic aortic aneurysm has been reported to be 7.5% and 17.3%, respectively.²⁾ The multivariate analysis from 11 European aortic centers showed that older age at redo surgery was an independent risk factor for in-hospital mortality.²⁾ Redo surgery is associated with technical difficulties mostly due to dissection of adhesion from previous surgery. Endovascular technology provides a new approach in treating this set of patients, in which aortic repair could be performed without redo thoracotomy, thus avoiding a need for dis-

secting adhesion and preventing injury of the surrounding tissues such as lung and esophagus.

Endoleak, a phenomenon specific to endovascular therapy, could be a major concern for repeat TEVAR as it may be associated with further reintervention.⁷⁾ In our series, there was no type 1a endoleak after repeat TEVAR, which showed that using previously implanted prosthetic graft as a landing zone was acceptable. However, freedom from reintervention was significantly lower in patients with dissected landing zone undergoing TEVAR, which may be similar to a pathophysiology of a chronic type B dissection.

In the meta-analysis of treatment of chronic type B aortic dissection,⁸⁾ in hospital mortality rate was better in TEVAR compared to in hospital mortality rate for open surgical repair (3.2% vs. 9.6%). Postoperative incidence of paraplegia (0.43% vs. 4.8%) and stroke (0.82% vs. 5.8%) was also less observed in TEVAR compared to open surgical repair. However, in the propensity adjusted analysis, three years freedom from reintervention was 96.7% in open surgical repair compared to 87.5% in TEVAR.⁹⁾ Similarly, early reintervention rate of 15% to 22% has been reported in patients undergoing TEVAR for chronic type B dissection.^{10–12)}

Sealing entry site by TEVAR is expected to induce aortic remodeling, while persistent false lumen perfusion is reported to be an independent risk factor for progressive aortic enlargement and adverse long-term outcomes.¹³⁾ Endoluminal exclusion of acute type B dissection without endoleak is associated with 80% volume increase of the true lumen and 86% reduction in false lumen at five years after surgery.¹⁴⁾ However, complete false lumen thrombosis in chronic aortic dissection occurs only in 40% to 80% of the patients at the level of the device and in 0%–40% of the patients at the level distal to the device.¹⁵⁾ In a prospective cohort study, VIRTUE registry revealed that patients with subacute dissection (15–92 days) demon-

strated a similar degree of aortic remodeling compared to patients with acute dissection (< 15 days).¹⁶⁾ However, the rate of remodeling was poorer in the chronic phase (> 92 days).¹⁶⁾ In our series, TEVAR in patients with dissected distal aorta was performed at 49.3 months (q25–q75 IQR 9.5–82.9) after the previous surgery. Thus, remodeling of the distal aorta may have been unfavorable. In the meta-analysis of 15 studies, Gambardella et al. reported that type B dissection was the most common pathology for secondary open procedure following TEVAR.⁷⁾ Decreased long-term survival has also been reported in patients without remodeling after TEVAR in chronic type B aortic dissection.¹⁷⁾ Although our study has shown similar long-term survival in patients undergoing TEVAR and open surgery, this might have been achieved due to close follow-up on these patients proceeded when necessary by prompt reintervention procedures.

There are several limitations to this study. This is a retrospective study with a small sample size. Prospective trials with larger samples size should be performed to confirm the results. Furthermore, repeat TEVAR in this study was performed at a chronic phase of aortic dissection. Repeat TEVAR performed at a more acute phase may show better outcomes.

Conclusion

Using previously implanted prosthetic graft was acceptable as a landing zone for repeat TEVAR. Although early outcomes were better in TEVAR, incidence of reintervention was higher in patients with dissected distal aorta undergoing TEVAR. Although similar long-term survival may be achieved via a close follow-up, repeat TEVAR in patients with chronic dissected landing zone should be considered due to the high incidence of reintervention.

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Disclosure Statement

Atsushi Yamaguchi serves as a consultant to Japan Lifeline Inc.; Daijiro Hori, Koichi Yuri, Sho Kusadokoro, Hiroyasu Katayama, and Naoyuki Kimura have no conflict of interest.

Author Contributions

Study conception: DH, KY
Data collection: DH, SK, HK
Analysis: DH, NK

Investigation: DH

Writing: DH

Funding acquisition: DH

Critical review and revision: all authors

Final approval of the article: all authors

Accountability for all aspects of the work: all authors

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