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Original Article

Efficacy and Optimal Timing of Endovascular Treatment for Type B Aortic Dissection

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Objectives: To determine the efficacy and the optimal timing of thoracic endovascular aortic repair (TEVAR) for closing the primary entry in uncomplicated patients with chronic type B aortic dissection and a patent false lumen (FL).
Methods: Thirteen patients underwent TEVAR for aortic dissection between 2008 and 2012. These patients had chronic dissection with a patent FL and expansion of the aorta. Early TEVAR was performed for five patients within 1–7 months from the index dissection (TEVAR-EC group) and delayed TEVAR was performed for eight patients within 1–16 years (TEVAR-DC group). Changes in the diameters and volumes of the true lumen (TL) and FL and the aortic remodeling were assessed by multidetector computed tomography for 3 years after TEVAR.
Results: The reduction rate of FL in the thoracic aorta was notably higher in the TEVAR-EC group than in the TEVAR-DC group regardless of the presence or absence of distal retrograde flow. There was a significant TL expansion despite different timings of TEVAR.
Conclusions: Early TEVAR resulted in good prognosis and preferable aortic remodeling in uncomplicated patients with chronic type B aortic dissection and a patent FL, and we recommend early TEVAR within seven months after the index dissection.

Keywords: type B aortic dissection, thoracic endovascular aortic repair, aortic remodeling, uncomplicated case

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Introduction

Although uncomplicated, acute, type B aortic dissection has been treated by aggressive medical therapy, the long-term outcome of medical therapy alone was reported to be suboptimal with a high mortality rate at 5 years.[1)] False lumen patency including an ulcer-like projection seems to be associated with a 20%–50% delayed expansion of the false lumen at 4 years between the thoracic and thoracoabdominal aorta, and it would necessitate further invasive treatments and lead to poor outcomes.[2–4)] For example, after aggressive long medical treatments, we had to perform extended graft replacement for thoracoabdominal aorta through large Stoney's incision, that resulted in high incidence of paraplegia and poor in hospital mortality. Data from historical series shows that these operations were associated with a high mortality rates ranging 9%–33%.[5)] Recently, some published manuscripts have reported a trend toward improvements in morbidity and mortality, and centers that perform a high volume of aortic surgery report mortality rates ranging 2%–13% and spinal cord ischemia 2%–17%.[5–6)] However, it is not yet enough satisfied.

The goal of treatment for type B aortic dissection is to achieve false lumen regression and to be free from late further interventions and aortic events. Thoracic endovascular aortic repair (TEVAR) represents a novel concept and has the potential for improving suboptimal outcomes of chronic type B aortic dissection.[7)] However, long-term results and optimal timing of TEVAR for type B aortic dissection are unknown.

We hypothesized that treating type B aortic dissection as early as possible, that is, closure of the primary entry before aneurysmal dilatation, would lead to a significant advantage for the above crucial issues. The purpose of this study was to evaluate the efficacy of TEVAR for type B aortic dissection and to determine the optimal timing of TEVAR for leading patients with particularly uncomplicated type B aortic dissection to the goal.

Table 1 Characteristics and mid-term results in patients with chronic aortic dissection with patent false lumen

	TEVAR-EC	TEVAR-DC
Characteristics		
Uncomplicated	5	8
Complicated	0	0
TEVAR indication	5 (40 mm≦)	8 (50 mm≦)
• Expansion of the aorta		
Average age (y)	55.8 ± 12.6 (38–75)	60.9 ± 13.0 (45–77)
Male/female (n)	4/1	8/0
Mean interval (months)	3.4 ± 2.6 (1–7)	67.6 ± 67.8 (19–192)
Results		
Successful primary entry closure	4	8
Aortic events		
• Early type 1 endoleak	1	0
• Mid-term new intimal tear	0	1
Paraplegia/paraparesis	0	0
Hemodialysis	0	0
Secondary intervention	0	0
Mid-term deaths	1 (lethal arrhythmia)	1 (gastric cancer)

TEVAR: thoracic endovascular aortic repair; EC: early closure; DC: delayed closure

Methods

To clarify the mid-term prognosis of patients with chronic type B aortic dissection and a patent false lumen (FL) who received TEVAR, clinical outcome, morphologic changes and behavior of type B aortic dissections were retrospectively evaluated for 3 years after TEVAR. Changes in the diameters and volumes of the true lumen (TL), FL and whole lumen (WL) were assessed on multidetector computed tomography (MDCT) scans for 3 years after TEVAR. Informed consent was obtained from all study participants. The study conformed to the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of Tokushima University (#2236).

Patient selection and indication of TEVAR

Thirteen patients underwent TEVAR for uncomplicated type B aortic dissections between 2008 and 2012, and they were enrolled in this study (**Table 1**). Thirteen patients had chronic dissection with a patent FL and expansion of the aorta. TEVAR was indicated for five patients with a diameter of ≥40 mm at the index dissection within seven months (Early TEVAR, TEVAR-EC) and for eight patients with a diameter of ≥50 mm more than 1 year from the index dissection (Delayed TEVAR, TEVAR-DC). Patients in whom the celiac artery, superior mesenteric artery or both renal arteries originated from the FL only were excluded. The average age of the thirteen patients who received TEVAR treatment was 58.9 ± 12.6 (38–77) years. Twelve of the patients were males.

TEVAR techniques

Primary entry closure was performed by using a handmade stent graft (UBE graft including a Ziantruco Z stent) for two patients from 2002 to 2008 and by using commercially available endovascular devices, GORE TAG for nine patients and Excluder Cuff for two patients (W. L. Gore & Associates, Inc.), from 2008 to 2012.

To select the most suitable commercially available stent graft for each patient, we used the size of the aorta at the proximal landing zone as the most crucial factor. We measured the diameter of the TL at the proximal landing zone calculated by its internal circumference using MDCT. We arranged stent grafts around 100%–120% of the diameter as an appropriate size for TEVAR regardless of the interval from the index dissection. If there was a difference of more 20% between the circumference of the proximal landing zone and that of the distal landing zone, taper-type stent grafts were used. The mean diameter of GORE TAG® stent grafts used was 31.2 ± 0.9 mm (31–34 mm).

The femoral artery could usually accommodate a 22 Fr. stent-graft system, which was advanced over a 260-cm stiff wire navigated in the true lumen under fluoroscopic guidance. The stent graft was deployed with systolic pressure lowered to 80–100 mmHg. After deployment, gentle inflation of the balloon was performed if proximal wall apposition was incomplete. Care was taken to prevent undue tension to the dissecting aorta, that is, the distal landing zone of the stent graft was placed in the straight portion of the descending aorta. Simultaneous additional TEVAR for distal re-entry was performed for one patient with a patent FL with distal retrograde flow in TEVAR-EC group.

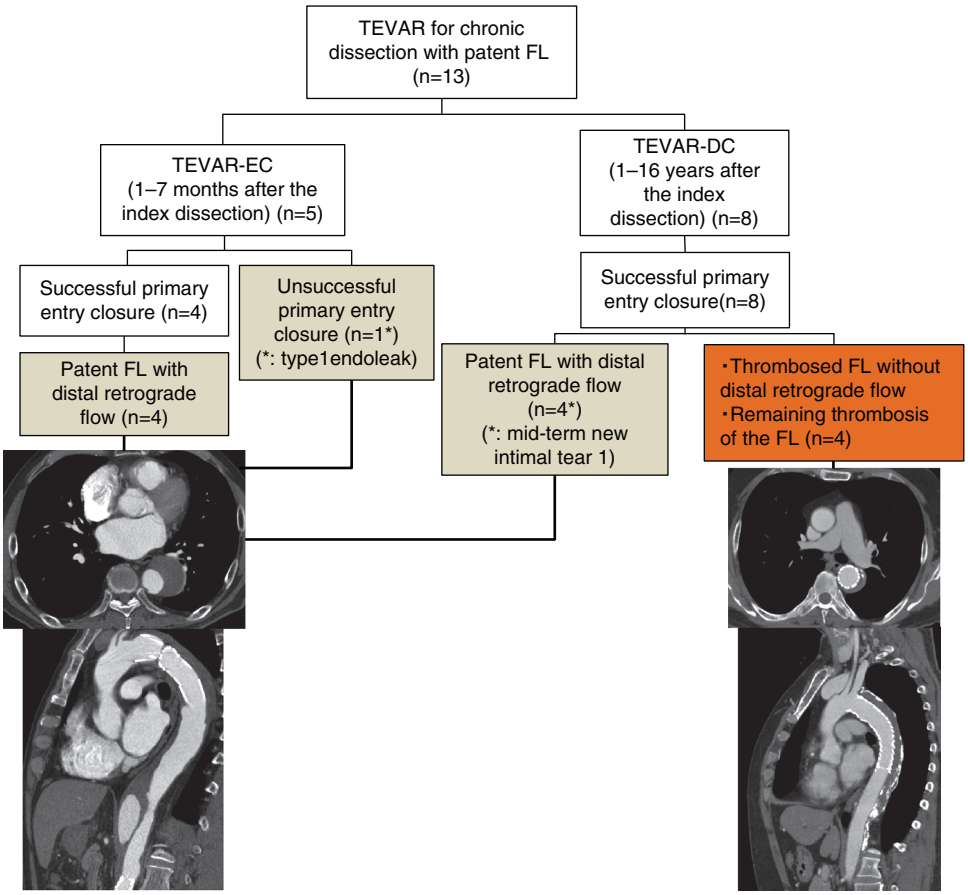

Fig. 1 Aortic remodeling process after TEVAR. The aortic remodeling processes were recognized approximately as two types of thrombosed FL without distal retrograde flow (four patients shown in orange column) and patent FL with distal retrograde flow (nine patients shown in brown column) at 3 years after TEVAR. TEVAR: thoracic endovascular aortic repair; FL: false lumen

Assessment of aortic remodeling after TEVAR

Positive aortic remodeling of TEVAR for closing the primary entry in uncomplicated patients with type B aortic dissection was defined as FL reduction and TL expansion of the thoracic aorta. Preprocedural and follow-up MDCT scans was conducted periodically for 3 years after TEVAR to assess the quantitative and qualitative changes of aortic remodeling. The postoperative diameters of the TL, FL and WL were measured in the transectional plane of the largest aorta between the descending thoracic aorta and the terminal aorta. The diameter of the preoperative oval or crescent-shaped TL was calculated by its internal circumference divided by π. Volume changes of the TL, FL and WL from the descending thoracic aorta to the terminal aorta were calculated using OsiriX software version 1.4.2, 64 bits (Pixmeo sarl, Bernex, Switzerland).

In addition, the relationship between each patient's morphological diversity of type B aortic dissection and aortic remodeling following TEVAR was analyzed morphologically using MDCT scans for 3 years after TEVAR.

Statistical analysis

Statistical analysis was performed with the two-way ANOVA and the paired t-test. Graphical analysis was conducted using GraphPad software, Prism 6 (GraphPad Software Inc. USA). All results were expressed as means ± standard deviation (SD). A value of $p < 0.05$ was considered statistically significant.

Results

Clinical outcomes

Type 1 endoleak occurred in one patient at TEVAR operation and successful primary entry closure was achieved in 12 patients (12/13, 92%). There was no hospital death or paraplegia/paresis. A new intimal tear occurred at the distal end of stent graft implantation in another patient 1 year after TEVAR. Although there were no both aorta-related mortality and secondary intervention during follow-up interval, there were only two mid-term deaths due to lethal arrhythmia and gastric cancer.

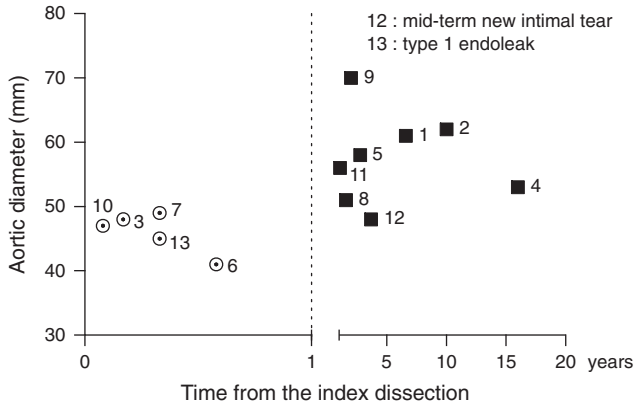

Fig. 2 Timing of TEVAR in thirteen patients with chronic dissection with a patent FL and expansion of the aorta. Relationship between time from the index dissection and diameter of the largest aorta before TEVAR in thirteen patients who had chronic dissection with a patent FL and expansion of the aorta. Time from the index dissection ranged from 1 month to 16 years. Open circles show patients who had TEVAR-EC during a period of 1–7 months after the index dissection and closed squares show patients who had TEVAR-DC during a period of 1-16 years after the index dissection. One patient (#12) had a new intimal tear and another patient (#13) had type 1 endoleak. #: patient number; TEVAR: thoracic endovascular aortic repair; FL: false lumen; TEVAR-EC: early TEVAR; TEVAR-DC: delayed TEVAR

Aortic remodeling process after TEVAR

The aortic remodeling processes were recognized approximately as two types of thrombosed FL without distal retrograde flow and patent FL with distal retrograde flow at 3 years after TEVAR (**Fig. 1**). A thrombosed FL without distal retrograde flow was observed in four patients, and the remaining nine patients had a patent FL with distal retrograde flow (TEVAR-EC: 5 patients, TEVAR-DC: 4 patients).

(1) *Comparison of changes in diameters and volumes after early TEVAR and after delayed TEVAR.*

TEVAR for thirteen patients who had chronic dissection with a patent FL and expansion of the aorta was performed 1 month to 16 years after the index dissection (**Fig. 2**). TEVAR-EC was performed for five patients at 1 to 7 months after the index dissection, and TEVAR-DC was performed for eight patients at 1 to 16 years after the index dissection. Type 1 endoleak occurred in one of the patients who received TEVAR-EC, and a new intimal tear occurred in one of the patients who received TEVAR-DC. Two patients with aortic events of type 1 endoleak and new intimal tear after TEVAR were excluded from these morphological assessments using MDCT scans on the way.

In the remaining eleven patients who had chronic dissection with a patent FL and expansion of the aorta, changes in diameters and volumes of the TL, FL and WL around TEVAR were analyzed individually. The diameter and volume of the FL were clearly reduced after TEVAR. Apparently positive aortic remodeling in each patient was achieved more efficiently by TEVAR-EC than by TEVAR-DC. Therefore, to determine the efficacy and the optimal timing of TEVAR for type B chronic aortic dissection with a patent FL and expansion of the aorta, changes in the diameters and volumes of the TL, FL and WL in the TEVAR-EC group were compared to those in the TEVAR-DC group for three years after TEVAR.

The average intervals from the index dissection to TEVAR were 3.4 ± 2.6 (1–7) months in the TEVAR-EC group and 67.6 ± 67.8 (19–192) months in the TEVAR-DC group. The mean follow-up intervals were 30.0 ± 6.9 (24–36) months in the TEVAR-EC group and 29.1 ± 9.4 (12–36) months in the TEVAR-DC group. The diameters and volumes of the FL were significantly reduced after both TEVAR-EC and TEVAR-DC ($p < 0.05$) (**Fig. 3**). The diameters of the TL were significantly increased after both TEVAR-EC and TEVAR-DC ($p < 0.05$). The volumes of the WL were significantly reduced after TEVAR-DC ($p < 0.05$).

There were significant differences between FL and WL reductions in diameter after TEVAR-EC and those after TEVAR-DC ($p < 0.05$), but there was no difference between TL expansion in diameter after TEVAR-EC and that after TEVAR-DC. There was no significant difference between FL reduction in volume after TEVAR-EC and that after TEVAR-DC, and there was significant difference between TL expansion in volume after TEVAR-EC and that after TEVAR-DC ($p < 0.05$).

(2) *Comparison of changes in diameters and volumes in two types of thrombosed FL without distal retrograde flow and in patent FL with distal retrograde flow after TEVAR.*

Changes in the diameters and volumes of in patients who had a thrombosed FL without distal retrograde flow were compared to those in patients who had a patent FL with distal retrograde flow (**Fig. 4**). The diameters and volumes of the FL of both types were significantly reduced after TEVAR ($p < 0.05$), and the diameters of the TL of both types were significantly increased after TEVAR ($p < 0.05$). The volumes of the WL of both types were significantly reduced after TEVAR ($p < 0.05$). Regardless of the presence or absence of distal retrograde flow, significant reduction of the FL and significant expansion of the TL were observed.

Discussion

In our study, both a significant regression of false lumen and a good clinical outcome were observed for three years after TEVAR for type B aortic dissection, therefore, the effectiveness and usefulness of TEVAR for type B aortic dissection were highly supported.[1,8–13)]

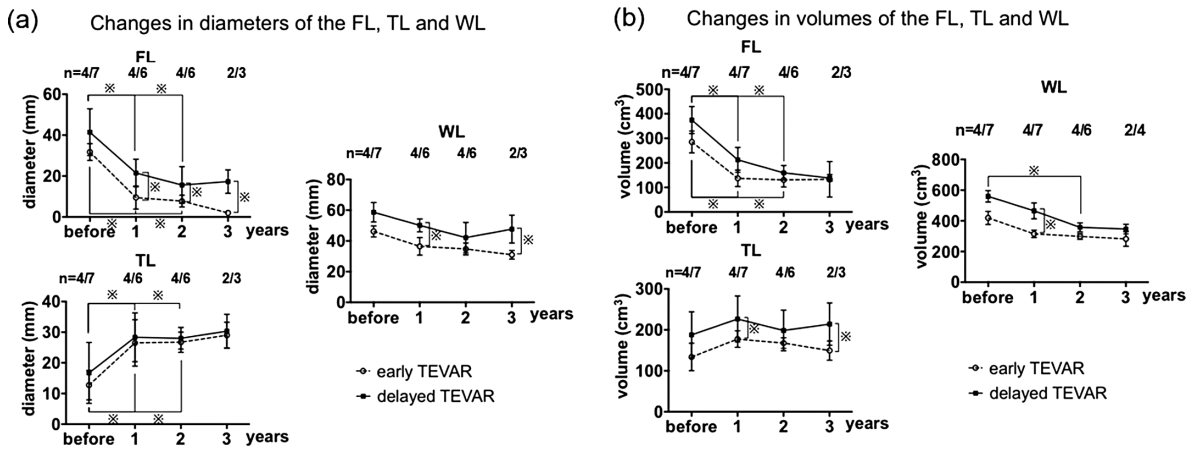

Fig. 3 Comparison of changes in the diameters and volumes between in the TEVAR-EC group and in TEVAR-DC group of patients who had chronic dissection with a patent FL and expansion of the aorta. (**a**) Changes in the diameters of the FL, TL and WL in the TEVAR-EC group and TEVAR-DC group for three years after TEVAR are shown. (**b**) Changes in the volumes of the FL, TL and WL in the TEVAR-EC group and TEVAR-DC group for three years after TEVAR are shown. The diameters and volumes of the FL were significantly reduced after both TEVAR-EC and TEVAR-DC ($p < 0.05$). The diameters of the TL were significantly increased after both TEVAR-EC and TEVAR-DC ($p < 0.05$). The volumes of the WL were significantly reduced after TEVAR-DC ($p < 0.05$). There were significant differences between FL and WL reductions in diameter after TEVAR-EC and those after TEVAR-DC ($p < 0.05$), but there was no difference between TL expansion in diameter after TEVAR-EC and that after TEVAR-DC. There was no significant difference between FL reduction in volume after TEVAR-EC and that after TEVAR-DC, and there was significant difference between TL expansion in volume after TEVAR-EC and that after TEVAR-DC ($p < 0.05$). The rates of FL reduction in the thoracic aorta were notably higher in the TEVAR-EC group than in the TEVAR-DC group. TEVAR: thoracic endovascular aortic repair; TEVAR-EC: early TEVAR; TEVAR-DC: delayed TEVAR; FL: false lumen; TL: true lumen; WL: whole lumen

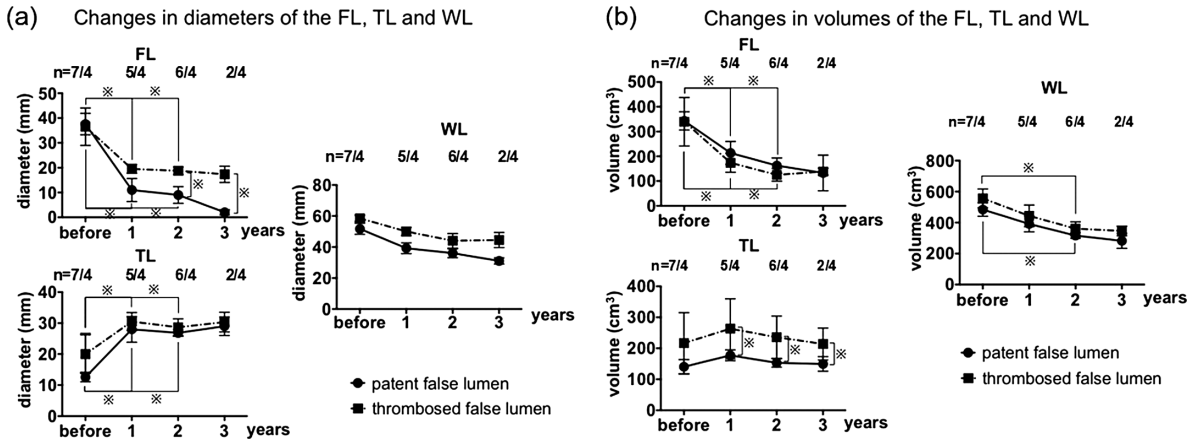

Fig. 4 Comparison of changes in the diameters and volumes between two types of thrombosed FL without distal retrograde flow and a patent FL with distal retrograde flow after TEVAR of patients who had chronic dissection with a patent FL and expansion of the aorta. (**a**) Changes in the diameters of the FL, TL and WL for three years after TEVAR in patients who had a patent FL with distal retrograde flow and patients who had a thrombosed FL without distal retrograde flow are shown. (**b**) Changes in the volumes of the TL, FL and WL for three years after TEVAR in patients who had a patent FL with distal retrograde flow and patients who had a thrombosed FL without distal retrograde flow are shown. The diameters and volumes of the FL of both types were significantly reduced after TEVAR ($p < 0.05$), and the diameters of the TL of both types were significantly increased after TEVAR ($p < 0.05$). The volumes of the WL of both types were significantly reduced after TEVAR ($p < 0.05$). Regardless of the presence or absence of distal retrograde flow, significant reduction of the FL and significant expansion of the TL were observed. TEVAR: thoracic endovascular aortic repair; FL: false lumen; TL: true lumen; WL: whole lumen

However, the optimal timing for TEVAR remains unclear.[14] It was reported that the FL was reduced at a high rate if the enforcement entry was closed within six months after the index dissection.[15] TEVAR within three months after the index dissection was found to provide benefits including ongoing aortic elasticity with better remodeling.[7,16–18] Theoretically, the earlier the primary entry is covered, the more favorable should be aortic remodeling.[19] However, concerning all-cause death and aorta-specific mortality for type B aortic dissection, TEVAR within one month after the index dissection was inferior to optimal medical treatment.

We favored the timing of TEVAR without a fragile intimal flap and with stable hemodynamics and localized improvement of inflammatory reaction beyond the acute phase, and we achieved similar aortic remodeling with significantly greater reductions in the diameter and volume of the FL by TEVAR within seven months after the index dissection. Positive aortic remodeling after TEVAR for type B aortic dissection seemed to progress if there was no leakage or new tear, though there was a difference in the time courses of aortic remodeling. Firstly, the rates of FL reduction in the thoracic aorta were notably higher in the TEVAR-EC group than in the TEVAR-DC group. Secondly, even in the patients with a patent FL and distal retrograde flow after TEVAR, there was an appropriate expansion of the TL and significant regression of the FL of the thoracic aorta during the 3-year follow-up period. Thirdly, favorable morphological changes were also observed after TEVAR-DC, although the diameters and volumes of the FL gradually decreased. Fourthly, complete FL thrombosis without distal retrograde flow occurred in patients who received TEVAR-DC. Finally, there was no significant difference between regression of the volume of the FL in patients who had a thrombosed FL without distal retrograde flow and that in patients who had a patent FL with distal retrograde flow.

Taking into account hemodynamic instability with pain, thin intimal flap and fragile inflammatory aortic wall during the acute phase, these results imply that TEVAR-EC performed for stable, uncomplicated type B aortic dissection under optimal medical treatment for a few months after the index dissection will be successful and should promote positive aortic remodeling changes. Positive aortic remodeling, regardless of the healing process, will be expected in most patients if entry closure has been done. Therefore, we consider TEVAR-EC to be a reasonable treatment strategy and we recommend early TEVAR within seven months after the index dissection beyond the acute phase.

Limitations

Firstly, this was a preliminary study with a small sample size. Secondly, early TEVAR was performed for patients with type B aortic dissection during the period from one month after the index dissection to seven months after the index dissection. Even within seven months, patients who were elapsed more than three weeks following the index dissection are typically chronic, and patients in acute or subacute phase were not included in the TEVAR-EC group. Therefore, it is necessary to further validate the efficacy and optimal timing of TEVAR for closing the primary entry for type B aortic dissection with a larger sample size and with comparisons between different timings of TEVAR.

Conclusions

Early TEVAR resulted in good prognosis and preferable aortic remodeling with expansion of the true lumen and reduction of the false lumen. Although further analysis of long-term results is needed, early TEVAR within seven months after the index dissection may be a useful treatment strategy for type B aortic dissection.

Conflict of Interest

All authors have declared that no conflict of interest exists.

Author Contributions

Study conception: HK, EF, TK
Data collection: HK
Analysis: HK, EF
Investigation: HK, FC, HS, TK
Writing: HK, TK
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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