Original Article

Fate of descending aorta after acute type A aortic dissection repair

Wan Kee Kim[1]^, Tae-Hoon Kim[2], Ha Lee[3], Suk-Won Song[3], Kyung-Jong Yoo[4]

[1]Department of Thoracic and Cardiovascular Surgery, Hanyang University Seoul Hospital, Hanyang University College of Medicine, Seoul, Republic of Korea; [2]Department of Thoracic and Cardiovascular Surgery, Gangnam Severance Hospital, Yonsei University College of Medicine, Seoul, Republic of Korea; [3]Department of Thoracic and Cardiovascular Surgery, Ewha Womans University Aorta and Vascular Hospital, Ewha Womans University College of Medicine, Seoul, Republic of Korea; [4]Department of Thoracic and Cardiovascular Surgery, Severance Cardiovascular Hospital, Yonsei University College of Medicine, Yonsei University Health System, Seoul, Republic of Korea

Contributions: (I) Conception and design: WK Kim, SW Song; (II) Administrative support: KJ Yoo, SW Song; (III) Provision of study materials or patients: H Lee, TH Kim, WK Kim; (IV) Collection and assembly of data: H Lee, WK Kim; (V) Data analysis and interpretation: WK Kim; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Suk-Won Song, MD, PhD. Department of Thoracic and Cardiovascular Surgery, Ewha Womans University Aorta and Vascular Hospital, Ewha Womans University College of Medicine, 260 Gong-hang-dae-ro, Gangseo-gu, Seoul 07804, Republic of Korea. Email: sevraphd@yuhs.ac.

Background: Reports on the residual descending aortic dissection (AD) after acute type A AD (TAAD) repair has been limited. Therefore, we evaluated the fate of descending aorta in patients who underwent acute TAAD repair.

Methods: We reviewed 299 patients (mean: 60.4 years, 51.5% male) patients who received acute TAAD repair between 2009 and 2018, except genetic aortopathy and concomitant surgeries for the descending aorta. Subjects are categorized into classic TAAD (Classic, n=226), retrograde extension of TAAD from the intimal tear in the descending aorta (Retro, n=31), and intramural hematoma (IMH, n=42) types of AD. Interested outcome was expansion rate of descending aorta. Secondary outcome was descending aorta events including surgical repair, interventions, and aortic rupture. To reduce selection bias, baseline variables were adjusted. Multivariable risk analyses were performed to find risk factors of the study outcomes.

Results: In crude analysis, descending aorta in Retro [beta, 2.260; standard error (SE), 0.559] and Classic (beta, 1.542; SE, 0.233) groups expanded faster than IMH (beta, 0.443; SE, 0.491) group. Unadjusted risk of aortic event was significantly higher in the Retro group compared with the IMH [hazard ratio (HR) =4.80; 95% confidence interval (CI): 1.56–14.7] and Classic (HR =2.36; 95% CI: 1.24–4.49) groups. Baseline adjustment did not alter these findings. In multivariable analyses, the presence of intimal tear in the upper thoracic descending aorta (above 7th thoracic vertebra) was significantly associated with the aortic expansion (beta, 2.06; SE, 0.61) and events (HR =8.74; 95% CI: 4.34–17.6).

Conclusions: The descending aorta growth was faster in Retro and Classic than IMH and related with the tear location. Careful assessment on the descending is warranted.

Keywords: Aortic dissection (AD); descending aorta; intramural hematoma (IMH); retrograde extension

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^ ORCID: 0000-0002-1452-8055.

Introduction

A tear of the aortic intima leads the formation of pressurized false lumen in the aortic media which amplify the risk of rupture. Therefore, a swift surgical resection of the segmental aorta with intimal tear is strongly recommended for patients with acute type A aortic dissection (TAAD) (1). It has been thirty years since a paper reporting 21% of surgical mortality rate by Crawford in 1992, and many advances in surgical technique and perioperative managements have improved the surgical aortic dissection (AD) repair outcomes (2). Although contemporary registries still show relatively higher (about 15%) mortality rates, recent publications by the experienced centers report 5–8% of mortality rates (3-7).

Interest remains in the downstream aorta after acute TAAD repair. Patent pressurized false lumen after the surgical repair of acute TAAD has been reported as a risk factor for the descending aorta growth (8). Recent evaluations have shown that the existence of tear in the proximal descending aorta was closely related with the descending aorta dilatation (9,10). These findings were consistent with surgical reports evaluating the descending aorta after surgical repair for the classic type of acute TAAD (11). The fate of descending aorta in patients with the retrograde extension of AD and the intramural hematoma (IMH), however, have been limitedly reported. We hypothesized that these patients may have different features of the descending aorta after surgical resection of the ascending aorta or arch because the false lumen pressure after surgery may be heavily depended on the initial types of AD. Therefore, we aimed to evaluate the change of descending aorta after TAAD repair depending on the types of AD [classic TAAD (Classic), retrograde extension of TAAD from the intimal tear in the descending aorta (Retro), and IMH]. We present this article in accordance with the STROBE reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-920/rc).

Highlight box

Key findings

- The descending aorta expanded faster in the retrograde and classic groups compared with the intramural hematoma group. Tear in the proximal descending aorta was associated with the aortic expansion and events.

What is known and what is new?

- As the surgical outcome of acute type A aortic dissection (TAAD) has improved, interest in the remaining dissection of the descending aorta has been increased. The data on this issue, however, has been limited.
- The descending aorta expanded faster in the retrograde and classic aortic dissection (AD) compared with the intramural. Aortic events (surgery, interventions and rupture) were mostly frequent in the retrograde type of AD. Tear in the proximal descending aorta was associated with the aortic expansion and events.

What is the implication, and what should change now?

- Careful assessment on the descending aorta seems to be crucial to set treatment plan for patients with acute TAAD.

Methods

Study subjects and interested outcomes

From January 2009 to December 2018, 457 adult patients (aged ≥18 years) visited our center for acute TAAD (DeBakey type II were excluded). Among these, 134 (29.3%) patients who received simultaneous procedures on the descending aorta such as elephant trunk or stent insertions at the time of AD repair and 24 (5.3%) patients who were revealed as having genetic aortopathy were excluded. As a result, 299 (65.4%) patients formed the study cohort. Using the latest preoperative computed tomography (CT), study subjects were categorized into three groups depending on the preceding types of AD as follows: (I) Classic (presence of entry tear in the ascending aorta or arch); (II) Retro; (III) IMH. The presence of intimal tear or atherosclerotic ulcer were recorded as follows (Figure S1): (I) upper thoracic aorta (upper than the T7 spine); (II) lower thoracic aorta (between the T7 and the celiac artery); or (III) abdominal aorta (lower than the celiac artery).

Primary interest of the study was set for postoperative expansion of the descending aorta. The secondary outcome was a composite of the aortic events which include aortic rupture, requirement of surgical or endovascular procedures on the descending aorta. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). Institutional Review Board of Gangnam Severance Hospital approved the present study [No. 3-2021-0167 (date: 14-09-2021)]. The requirement for informed consent from individual patients was waived due to the retrospective nature of the study design.

Surgical procedures

All AD repairs were performed in the setting of emergent operations. Details of surgical techniques were as follows.

Artery pressure, venous pressure, body temperatures, and brain oximeter were monitored under general anesthesia.

After sternotomy, we give 200 unit/kg of heparin. During cardiopulmonary bypass (CPB), occasional 50–100 unit/kg of heparin are added to target 400 seconds of activated clotting time. Arterial CPB was inserted via side-graft (8 mm Dacron graft). Surgical extent was basically determined regarding the location of the primary entry site. If the tear existed in arch, the arch was replaced. After distal anastomosis, the lower body perfusion and rewarming were started through the artificial graft. Thereafter, remnant procedures and arch vessel anastomoses were performed.

Follow-up data and evaluation protocols

The first postoperative CT scan was performed before discharge, and thereafter, follow-ups were done at postoperative 3 and 12 months, and every following 2 years (Figure S2). With any evidence of AD progression, the follow-up CT scan was performed shorter than 3 months. When there is any evidence of impending rupture or a significant aortic expansion on the follow-up CT scans, surgical repair or endovascular intervention were planned. The decision whether to perform open surgery or thoracic endovascular intervention was based on the patient's age, comorbidities, and individual anatomic conditions. When a patient with evidence of growing descending aorta suddenly died, the death was regarded as a rupture event.

Our measurement protocols for descending aorta are as follows. The maximal external aortic diameter was measured in the perpendicular axis of aortic course using the enhanced planar CT images. To obtain perpendicular axis, CT images were reconstructed parallel to the vectors of central route of the descending aorta. The reconstructed images were generated by a computer program (Zetta PACS, TaeYoung Soft, Anyang-si, Republic of Korea) under the supervision of radiologists. To reduce inter-observer gap in the measurement, all the measurements were performed by one author, and the other measured it again. If there was a significant difference between two measurements, we consulted to a special radiologist to be confirmed.

Statistical analyses

Baseline profiles including patient demographics, details and extents of prior surgery were listed in the *Table 1* depending on the preceding subtypes of AD. Categorical variables are reported as counts and proportions, and continuous variables are expressed as mean ± standard deviation. When any variable is within 0.05 in Shapiro-Wilk test, it is listed as median and interquartile range (IQR). Comparison among the types of AD were evaluated by analysis of variance (ANOVA) for continuous variables and by the chi-square or Fisher exact test for categorical variables.

To regard random and fixed effects by repetitive measurements of CT scans, the linear mixed model was conducted to evaluate the change of aortic diameters. Expansion rates of descending aorta depending on the types of AD were estimated by random intercept and slope model. Cumulative events of aortic events were evaluated with the Kaplan-Meier method. To reduce selection bias, weighted group comparison methods were applied. For baseline adjustment, statistically significant differences (sex, age, surgical extents in the *Table 1*) were balanced. For the balancing variables among the three groups, multiple treatment propensity-scores were utilized using Toolkit for Weighting and Analysis of Nonequivalent Groups (TWANG) package. The reciprocals of the propensity-scores were obtained by using generalized boosted models through a multiple iteration. Adequate iteration was determined as "n=20,000" in the boosting model depending on balance tests (Figure S3).

Multivariable linear mixed and cox models were conducted to find the predictive factors of the primary and secondary outcomes, respectively. In the univariable analyses, baseline variables, details and extents of the prior surgery were included. P value within 0.1 were included in the multivariable models. Multivariable analyses were performed using a stepwise backward elimination technique (only P value of <0.05 were included for the next analyses). All P values were two tailed. R software of version 3.4.0 (http://www.r-project.org) and SAS of version 9.2 (SAS Inc., Cary, NC, USA) were used for the statistical analysis.

Results

Baseline characteristics, surgical details and early clinical outcomes

The baseline profiles of patients are summarized in the *Table 1*. Mean age of the patients was 60.4±13.6 years, and 145 (48.5%) were female. Of these, 226 (75.6%), 42 (14.0%) and 31 (10.4%) patients were included in the Classic, IMH and Retro groups, respectively. The patients with retrograde AD were youngest (P=0.008) and had lowest proportion of female sex (P=0.003) compared with the patients with other

Table 1 Baseline demographics and clinical variables

Variables	Crude				Weighted			
	Retro	Classic	IMH	P values	Retro	Classic	IMH	P values
Numbers of patients	31	226	42	–	228	292	157	–
Baseline profiles								
Age (years)	54.1±14.2	60.8±13.7	63.0±11.8	0.008	60.4±14.8	60.3±13.8	60.9±11.8	0.97
Female gender	6 (19.4)	117 (51.8)	22 (52.4)	0.003	90.5 (39.7)	141.5 (48.5)	78.3 (49.9)	0.65
Body mass index (kg/m^2)	25.0±2.8	25.7±8.6	25.9±11.1	0.677	24.7±2.82	25.53±8.25	29.03±17.75	0.40
Smoking history	16 (51.6)	87 (38.5)	19 (45.2)	0.31	93.0 (40.8)	121.4 (41.6)	63.0 (40.1)	0.99
Hypertension	18 (58.1)	147 (65.0)	31 (73.8)	0.36	126.1 (55.3)	181.9 (62.3)	109.5 (69.7)	0.51
Diabetes mellitus	0	26 (11.5)	4 (9.5)	0.11	0	30.7 (10.5)	19.3 (12.3)	0.05
Coronary arterial disease	1 (3.2)	10 (4.4)	1 (2.4)	>0.99	11.2 (4.9)	13.5 (4.6)	3.1 (2.0)	0.75
Cerebrovascular disease	0	23 (10.2)	5 (11.9)	0.14	0	27.8 (9.5)	10.1 (6.4)	0.007
Chronic renal failure	1 (3.2)	7 (3.1)	1 (2.4)	>0.99	11.2 (4.9)	8.5 (2.9)	3.6 (2.3)	0.75
Surgical extents of prior surgery								
Hemiarch replacement	13 (41.9)	50 (22.1)	25 (59.5)	<0.001	75.4 (33.1)	85.5 (29.3)	59.1 (37.6)	0.42
1-partial arch replacement	5 (16.1)	45 (19.9)	0		33.3 (14.6)	49.1 (16.8)	0	
2-partial arch replacement	7 (22.6)	45 (19.9)	8 (19.0)		62.7 (27.5)	57.6 (19.7)	45.7 (29.1)	
Total arch replacement	6 (19.4)	86 (38.1)	9 (21.4)		56.9 (25.0)	99.3 (34.0)	52.4 (33.4)	
Other procedures of prior surgery								
Aortic valve replacement	1 (3.2)	2 (0.9)	0	0.33	11.2 (4.9)	2.2 (0.8)	0	0.27
Bentall's operation	3 (9.7)	11 (4.9)	0	0.12	20.8 (9.1)	15.3 (5.2)	0	0.23
Valve sparing root repair	0	2 (0.9)	0	>0.99	0	2.5 (0.9)	0	0.61
Coronary arterial bypass	0	9 (4.0)	0	0.42	0	11.0 (3.8)	0	0.21

Data are presented as mean ± SD or n (%). Retro, retrograde extension of type A aortic dissection from the intimal tear in the descending aorta; Classic, classic type A aortic dissection; IMH, intramural hematoma; SD, standard deviation.

types of ADs. The median of maximal descending aortic diameter was 35.2 mm (IQR, 32.7–38.4 mm). Details of maximal descending aortic diameters depending on the types of AD were depicted in the Figure S4. The distribution of maximal descending aorta diameters were not significantly different among the three groups (P=0.17). The presence of entry tears in descending aorta were listed in the Table S1.

Among a total of 299 patients in the present study, 88 (29.4%), 50 (16.7%), 60 (20.1%) and 101 (33.8%) patients received hemi, 1-partial, 2-partial, and total arch replacements, respectively (*Table 1*). The hemi-arch replacement was more frequently performed in patients with IMH compared with the patients with classic type of AD (P<0.001). During the surgical repair of AD, 3 (1.0%) aortic valve replacements, 16 (5.4%) root replacements and 9 (3.0%) coronary arterial bypasses were combined. Immediate (<48 hours) and early (<30 days) deaths occurred in 7 (2.3%) and 24 (8.0%) patients, respectively. Of these, 4 (1.3%) had the first postoperative CT scans.

Crude study outcomes

The CT follow-up was collected over 644.68 patient-years (PY) in 241 (80.6%) patients. The aortic expansion

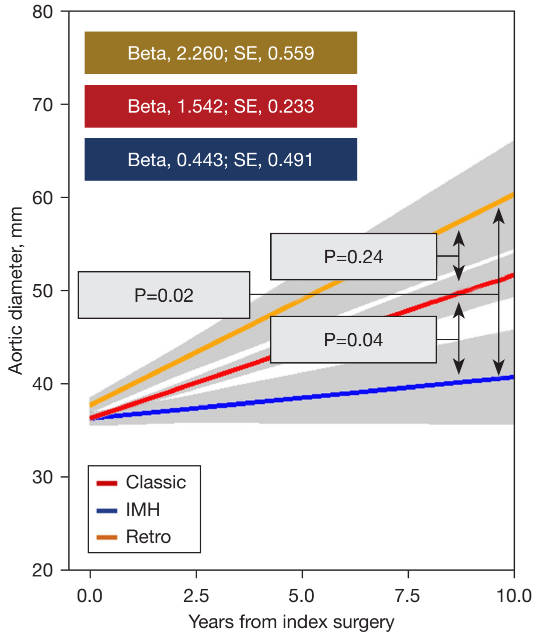

Figure 1 Estimated growth rates of the descending aorta depending on the types of aortic dissection in the follow-up CT scans (unadjusted; red: classic type of aortic dissection; bronze: retrograde type of aortic dissection; blue: intramural hematoma). SE, standard error; Classic, classic type A aortic dissection; IMH, intramural hematoma; Retro, retrograde extension of type A aortic dissection from the intimal tear in the descending aorta; CT, computed tomography.

rates depending on the types of AD were estimated using linear mixed model (*Figure 1*). The IMH group had lower expansion rate of descending aorta [beta, 0.443; standard error (SE), 0.491] after the acute TAAD repair compared with the Classic (P=0.04) and Retro (P=0.02) groups.

Clinical events on the descending aorta were followed up for 972.24 PY. During the follow-up (median 27.9 months; IQR, 6.5–61.8 months), aortic events occurred in 50 (19.8 %/PY) patients including 3 (1.25 %/PY) surgical repairs, 41 (16.05 %/PY) endovascular procedures and 6 (2.51 %/PY) suspicious rupture events (Table S2). *Figure 2* depicts the unadjusted Kaplan-Meier plots for the cumulative rates of secondary outcomes. The 5-year cumulative rate of aortic events were 10.0%±5.5%, 27.5%±4.6%, and 56.9%±10.6% in patients with IMH, classic and retrograde types of ADs. The Retro group had higher risks of descending aorta events compared with the IMH [hazard ratio (HR) =4.80; 95% confidence interval (CI): 1.56–14.7; P=0.006] and Classic (HR =2.36; 95% CI: 1.24–4.49; P=0.009) groups.

Adjustments study outcomes

After weighting, the baseline covariates were well balanced (right column of *Table 1* and Figure S5).

Figure 3 depicts weighted aortic expansion rates

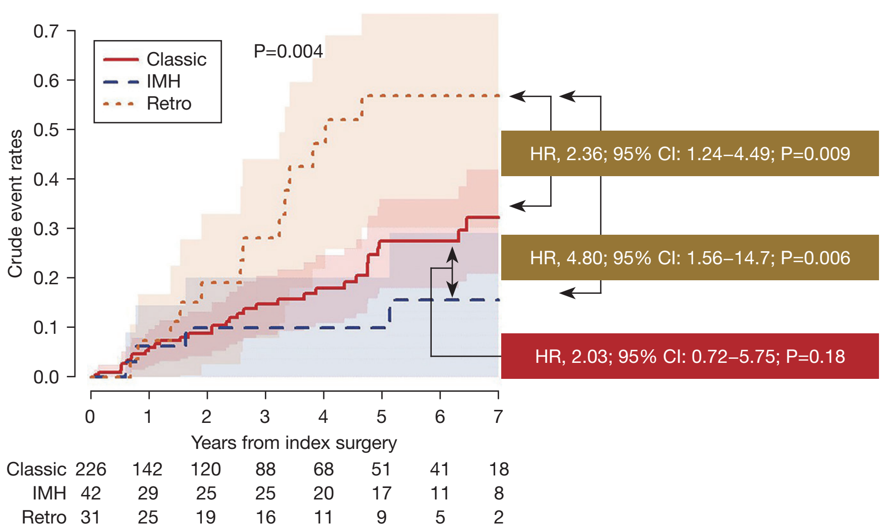

Figure 2 Unadjusted Kaplan-Meier plots for aortic events including follow-up procedures and ruptures of descending aorta depending on the types of aortic dissection (red: classic type of aortic dissection; bronze: retrograde type of aortic dissection; blue: intramural hematoma). HR, hazard ratio; CI, confidence interval; Classic, classic type A aortic dissection; IMH, intramural hematoma; Retro, retrograde extension of type A aortic dissection from the intimal tear in the descending aorta.

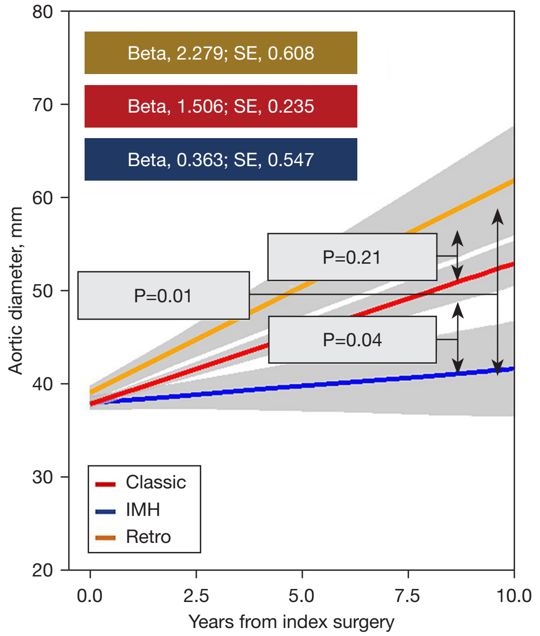

Figure 3 Estimated growth rates of the descending aorta depending on the types of aortic dissection in the follow-up CT scans (adjusted; red: classic type of aortic dissection; bronze: retrograde type of aortic dissection; blue: intramural hematoma). SE, standard error; Classic, classic type A aortic dissection; IMH, intramural hematoma; Retro, retrograde extension of type A aortic dissection from the intimal tear in the descending aorta; CT, computed tomography.

depending on the types of ADs which were estimated by the linear mixed models. In the weighted analyses, the IMH group had significantly lower expansion rate of descending aorta (beta, 0.363; SE, 0.547) compared with the Classic (P=0.04) and Retro (P=0.01) groups.

Figure 4 depicts the adjusted Kaplan-Meier plots for the cumulative rates of secondary outcomes. The Retro group had significantly higher risks of descending aortic events compared with the IMH (HR =5.54; 95% CI: 1.59–19.4; P=0.007) and the Classic (HR =2.33; 95% CI: 1.09–5.01; P=0.03) groups.

Multivariable risk analyses for study outcomes

In a multivariable linear mixed model, older age (P<0.001), female sex (P<0.001), and tear in the upper descending aorta (P<0.001) were significantly associated with the descending aortic expansion (*Table 2*). In a multivariable Cox model, tear in the upper descending aorta (HR =8.74; 95% CI: 4.34–17.6; P<0.001) was a sole significantly risk factor for the aortic events (*Table 3*).

Discussion

The ascending aorta directly buffers the impulse energy originating from the cardiac pulsation, and it is highly

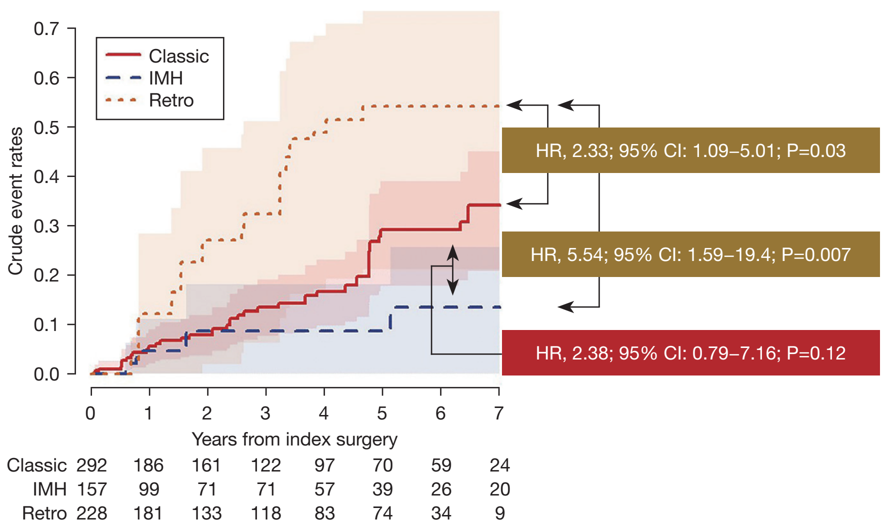

Figure 4 Adjusted Kaplan-Meier plots for aortic events including follow-up procedures and ruptures of descending aorta depending on the types of aortic dissection (red: classic type of aortic dissection; bronze: retrograde type of aortic dissection; blue: intramural hematoma). HR, hazard ratio; CI, confidence interval; Classic, classic type A aortic dissection; IMH, intramural hematoma; Retro, retrograde extension of type A aortic dissection from the intimal tear in the descending aorta.

Table 2 Risk factors of descending thoracic aorta expansion after acute type A aortic dissection repair

Risk factors	Univariable			Multivariable		
	Estimate	SE	P value	Estimate	SE	P value
Age	0.054	0.016	<0.001	0.079	0.022	<0.001
Female	−1.437	0.393	<0.001	−2.715	0.606	<0.001
Total arch replacement	0.581	0.434	0.18	–	–	–
Tear in upper thoracic aorta	2.638	0.402	<0.001	2.061	0.607	<0.001
Tear in lower thoracic aorta	0.739	1.096	0.50	–	–	–
Tear in abdominal aorta	1.264	0.732	0.09	–	–	–

SE, standard error.

Table 3 Risk factors of aortic events on the descending aorta after acute type A aortic dissection repair

Risk factors	Univariable			Multivariable		
	HR	95% CI	P value	HR	95% CI	P value
Age	0.98	0.96–0.99	0.053	–	–	–
Female	0.36	0.19–0.67	0.001	–	–	–
Hypertension	0.79	0.45–1.40	0.42	–	–	–
Retrograde type A aortic dissection	2.62	1.39–4.94	0.003	–	–	–
Total arch replacement	1.05	0.57–1.95	0.88	–	–	–
Tear in upper thoracic aorta	8.73	4.64–16.5	<0.001	8.74	4.34–17.6	<0.001
Tear in lower thoracic aorta	2.70	0.96–7.58	0.059	–	–	–
Tear in abdominal aorta	1.60	0.63–4.07	0.32	–	–	–

HR, hazard ratio; CI, confidence interval.

susceptible for rupture in the existence of dissection. The arch, next to the ascending aorta, may confront shear stress due to the anatomic transformation from cylinder to round. Hence, the Stanford TAAD is indicated for an emergent surgery to replace the dissected aorta in the purpose of preventing rupture event (1,12). On the contrary, the type B AD has been regarded as a milder form of disease than the TAAD and has been customarily treated with the medical therapy first unless it is complicated (12). Nevertheless, early mortality of the patients with type B AD is not negligibly low (5%) in a recent report (13), and even in patients who survived to discharge, a quarter of them die within 3 years (14). Therefore, the remaining dissection in descending aorta may not be regarded as "safe", and we should note the descending aorta even after the successful TAAD repair. In a retrospective data which reviewed patients with eligible CT scans during 20 years of follow-up, only 21.4% had completely thrombosed false lumen after acute TAAD repair (15).

In type B AD, the existence of intimal tear in the upper thoracic descending aorta has been repeatedly reported as a worsening factor on the false lumen patency and clinical outcomes (16-19). In particular, the tear near left subclavian artery is closely related to the distal aortic dilatation (20). As the second or third entry/reentry tears in the descending aorta will become primary entry tear after the elimination of the first entry tear in the ascending or arch, we thought that the fate of descending aorta would be heavily influenced depending on the types of AD. In the present study, the proximal entry tear in the remaining descending aorta (above T7 spine level) were observed in 19.5%, 14.3% and 77.3% of the patients with Classic, IMH and Retro types of AD, respectively. This observation might suggest that the Retro type of AD has a distinct entity from Classic or IMH. We carefully surmise that this gap may be a principal inducer of the gradually stratified growth of descending aorta depending on the types of AD (Retro > Classic > IMH). In this regard, our findings correlate with the prior reports. In a retrospective review over 10 years in acute TAAD repair patients, Kimura *et al.* found the upper thoracic descending aorta was the fastest growing part in patients with the patent false lumen after acute TAAD repair (21).

The tear location in the upper thoracic descending aorta has been reportedly a risk factor of the development of retrograde TAAD from the primary type B AD (22). When the intima was torn, lesser pressure or slower hemodynamic flow in the false lumen might lead intraluminal thrombosis. This explains why some benign types of Retro AD with thrombosed false lumen in the ascending aorta or arch may be feasible for the medical treatment alone (23). On the contrary, the most of Retro patients in the present study might have high pressure and patent false lumen in ascending aorta which lead surgeons to determine open repair. Therefore, the pressure in the false lumen may not be dropped sufficiently even after the replacement of the ascending aorta or arch, and the descending aorta will face a high risk of expansion than other types of AD.

In a report from Rylski and his colleagues, re-operation after the hemiarch replacements for acute TAAD was needed in 6% of patients during 20-year of follow-up (24). Among those re-operations, 78.1% were the descending aorta surgery. This finding consists with prior reports from other centers (21,25). In addition to lessons from the cited studies, our findings highlight the importance of adequate surgical planning with a recognition of the downstream condition as well as the upstream aorta. Given recent advance in the vascular graft materials, we have many options to cover the descending aorta through the sternotomy approach such as the concomitant frozen elephant trunk insertion during the upstream aorta repair (26,27). As acute TAAD repair is a matter of life saving, we agree as well that the tear-oriented limited surgery can be a great treatment option to solve the problem at hand. Nevertheless, we should note the descending, and the timely following intervention should be considered especially for patients with the upper thoracic descending aorta tear.

Limitations

This study is a retrospective observational study. Some postoperative managements such as blood pressure control cannot be unifiable for every individual during follow-up. The absence of data on blood pressure, heart rate, and medication usage may be a hidden confounders for the study outcomes. The goal of systolic and diastolic blood pressure levels, however, have been standardized in the outpatient clinic to lower than 130 and 90 mmHg, respectively. In addition, unmeasurable postoperative general conditions such as alcohol consumption and smoking habits may have influenced study outcomes. There could be unrecognized bias from the aortic diameter in CT scans even we conducted double measurement method by radiologists. Despite our efforts to reduce bias in the aortic measurements, there could be remaining inter- and intra-observer diversity in the measurement. As the most of early mortality (8%) had limited follow-up CT scans, the aorta expansion can be underestimated or overestimated. Finally, regarding ulceration in the IMH group as same as intimal tears in the other groups may be unfair.

Conclusions

The descending aorta growth was faster in Retro and Classic than IMH and related with the tear location. Careful assessment on the tear locations in descending aorta is warranted for the initial acute TAAD repair plan as well as the postoperative follow-up.

Acknowledgments

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-920/rc

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Peer Review File: Available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-920/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-920/coif). S.W.S. serves as an unpaid editorial board member of *Journal of Thoracic Disease* from February 2023 to January 2025. The other authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). Institutional Review Board of Gangnam Severance Hospital approved the present study [No. 3-2021-0167 (date: 14-09-2021)]. The requirement for informed consent from individual patients was waived due to the retrospective nature of the study design.

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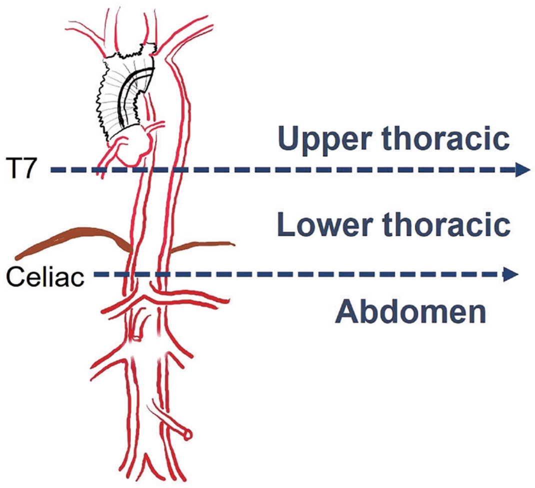

Figure S1 Categorization of intimal tears depending on the location in descending aorta. The tear locations were categorized into proximal, middle, and descending aorta depending on the 7th thoracic spine and the upper margine of celiac trunk.

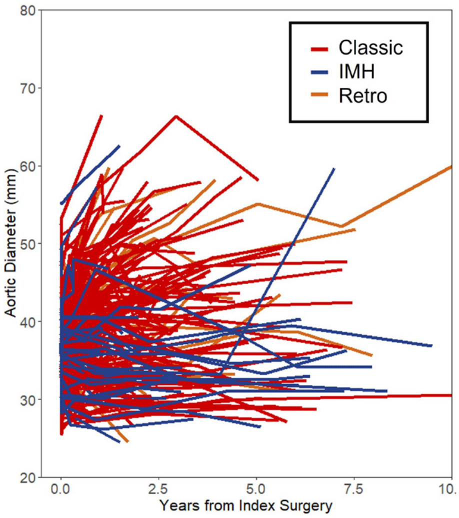

Figure S2 Individual measurements of the descending aorta diameter depending on the types of aortic dissection in the follow-up CT scans (red: classic type of aortic dissection; bronze: retrograde type of aortic dissection; blue: intramural hematoma). Classic, classic type A aortic dissection; IMH, intramural hematoma; Retro, retrograde extension of type A aortic dissection from the intimal tear in the descending aorta; CT, computed tomography.

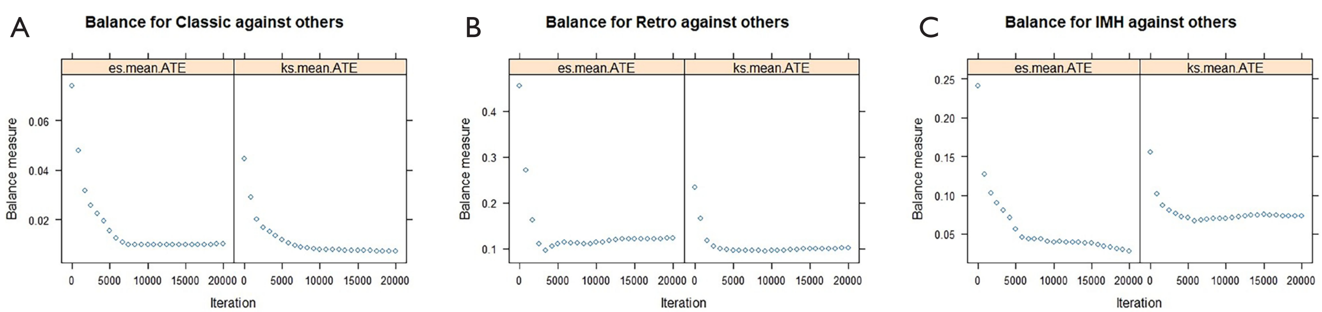

Figure S3 Balance tests to determine iteration in the boosting model for baseline adjustment. (A) Models for the patients with classic type A aortic dissection versus other groups. (B) Models for the patients with retrograde type A aortic dissection versus other groups. (C) Models for the patients with intramural hematoma versus other groups. Classic, classic type A aortic dissection; ATE, average treatment effect; Retro, retrograde extension of type A aortic dissection from the intimal tear in the descending aorta; IMH, intramural hematoma.

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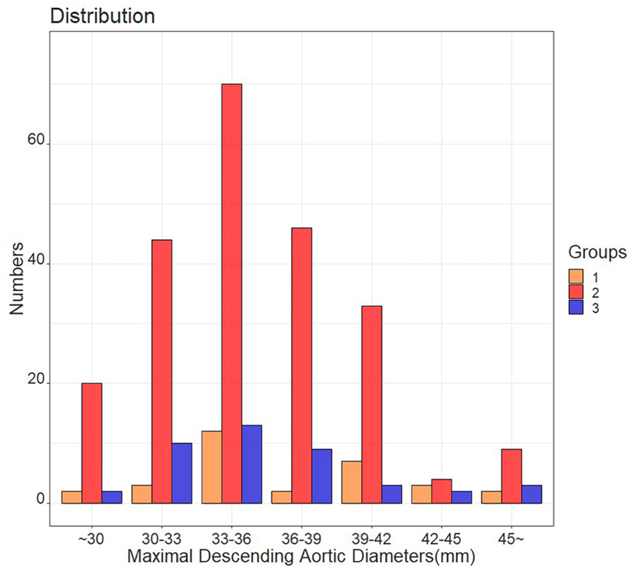

Figure S4 Distribution of descending aorta diameters in overall patients depending on the types of aortic dissection (red: classic type of aortic dissection; bronze: retrograde type of aortic dissection; blue: intramural hematoma). Retro, retrograde extension of type A aortic dissection from the intimal tear in the descending aorta; Classic, classic type A aortic dissection; IMH, intramural hematoma.

Table S1 Intimal tear locations

Intimal tear locations	Retro (n=31)	Classic* (n=226)	IMH** (n=42)	P values
Upper thoracic aorta, n (%)	24 (77.4)	44 (19.5)	6 (14.3)	<0.001
Lower thoracic aorta, n (%)	2 (6.5)	11 (4.9)	1 (2.4)	0.72
Abdominal aorta, n (%)	5 (16.1)	21 (9.3)	1 (2.4)	0.11
Total, n (%)	31 (100.0)	68 (30.1)	8 (19.0)	<0.001

*, eight patients in the classic group had dual intimal tears; **, numbers in the IMH group is counted for the ulcerations. Retro, retrograde extension of type A aortic dissection from the intimal tear in the descending aorta; Classic, classic type A aortic dissection; IMH, intramural hematoma.

Table S2 Aortic events depending on the types of aortic dissection

Aortic events	Retro (n=31)	IMH (n=42)	Classic (n=226)
Total events, n (%/PY)	13 (12.6)	4 (2.5)	33 (4.7)
Surgery	1 (0.97)	0	2 (0.28)
Intervention	10 (9.70)	4 (2.55)	27 (3.82)
Upper thoracic aorta, n	9	4	26
Lower thoracic aorta, n	1	0	4
Abdominal aorta, n	0	0	4
Rupture	2 (1.94)	0	4 (0.57)

Retro, retrograde extension of type A aortic dissection from the intimal tear in the descending aorta; IMH, intramural hematoma; Classic, classic type A aortic dissection.

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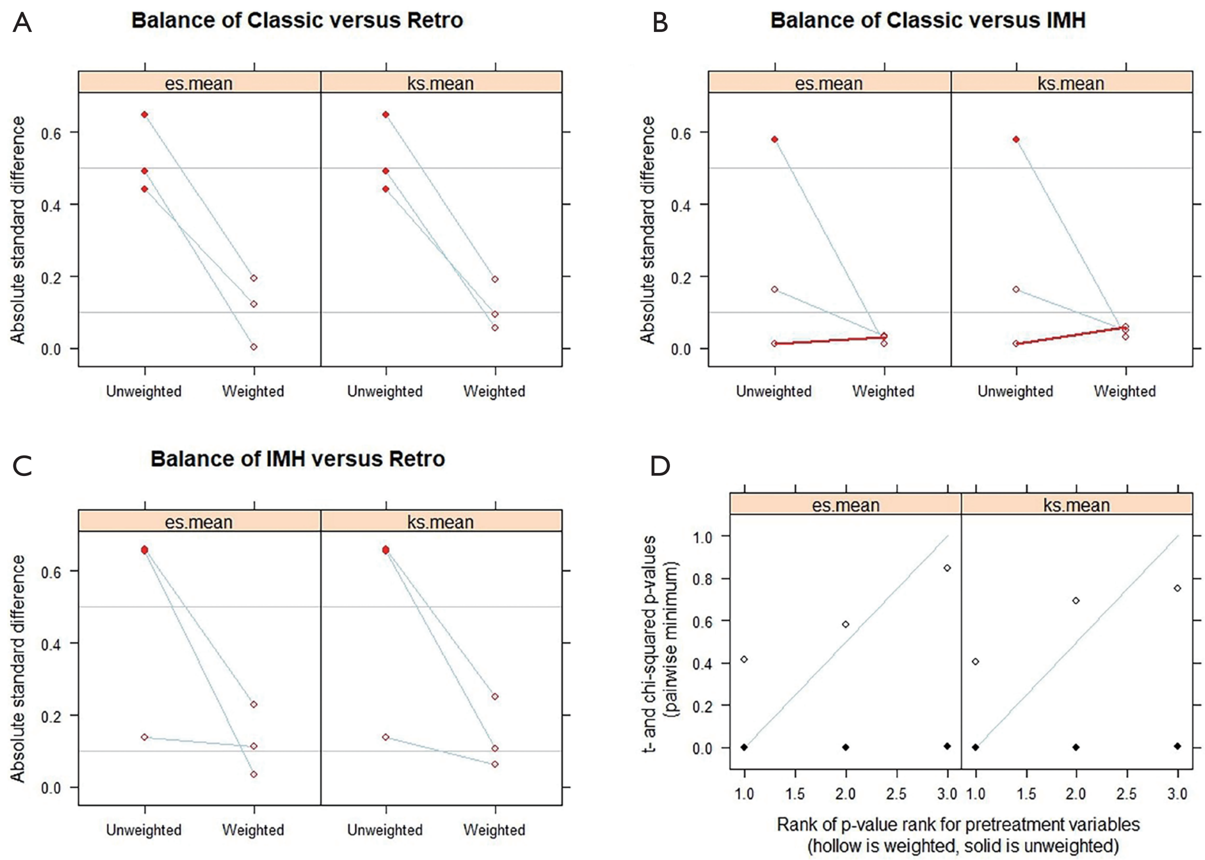

Figure S5 Baseline differences before and after the weighting method. (A) Absolute standardized differences in the classic versus retrograde types of aortic dissection. (B) Absolute standardized differences in the classic versus intramural hematoma types of aortic dissection. (C) Absolute standardized differences in the intramural hematoma versus retrograde types of aortic dissection. (D) Intergroup P values in overall patients. Classic, classic type A aortic dissection; Retro, retrograde extension of type A aortic dissection from the intimal tear in the descending aorta; IMH, intramural hematoma.