J Atheroscler Thromb, 2018; 25: 203-212.
http://doi.org/10.5551/jat.RV17017

Review

Update on the Therapeutic Strategy of Type B Aortic Dissection

Shuichiro Kaji

Department of Cardiovascular Medicine, Kobe City Medical Center General Hospital, Kobe, Japan

Stanford type B aortic dissection (TBAD) is a life-threatening disease. Current therapeutic guidelines recommend medical therapy with aggressive blood pressure lowering for patients with acute TBAD unless they have fatal complications. Although patients with uncomplicated TBAD have relatively low early mortality, aorta-related adverse events during the chronic phase worsen the long-term clinical outcome. Recent advances in thoracic endovascular aortic repair (TEVAR) can improve clinical outcomes in patients with both complicated and uncomplicated TBAD. According to present guidelines, complicated TBAD patients are recommended for TEVAR. However, the indication in uncomplicated TBAD remains controversial. Recent results of randomized trials, which compared the clinical outcome in patients treated with optimal medical therapy and those treated with TEVAR, suggest that preemptive TEVAR should be considered in uncomplicated TBAD with suitable aortic anatomy. However, these trials failed to show improvement in early mortality in patients treated with TEVAR compared with patients treated with optimal medical therapy, which suggest the importance of patient selection for TEVAR. Several clinical and imaging-related risk factors have been shown to be associated with early disease progression. Preemptive TEVAR might be beneficial and should be considered for high-risk patients with uncomplicated TBAD. However, an interdisciplinary consensus has not been established for the definition of patients at high-risk of TBAD, and it should be confirmed by experts including physicians, radiologists, interventionalists, and vascular surgeons. This review summarizes the current understanding of the therapeutic strategy in patients with TBAD based on evidence and expert consensus.

Key words: Acute aortic dissection, Management, Medical therapy, Surgery, TEVAR

Introduction

Acute aortic dissection (AD) is a life-threatening disease, and its prompt and precise diagnosis is essential for proper management. Current therapeutic guidelines for AD recommend that patients with acute AD involving the ascending aorta, known as Stanford type A, should be treated surgically[1-3]. In contrast, patients with AD not involving the ascending aorta (Stanford type B) are treated medically unless they have fatal complications. Most uncomplicated patients with type B AD (TBAD) have favorable short-term prognosis with medical therapy. However, aorta-related adverse events occur during the chronic stage, which worsen the long-term prognosis. Recent advances in thoracic endovascular aortic repair (TEVAR) can improve clinical outcome in patients with both complicated and uncomplicated TBAD, which may affect therapeutic strategy in patients with TBAD. This review summarizes the present recommended therapeutic strategy based on the current evidence and expert consensus[4, 5].

Address for correspondence: Shuichiro Kaji, Department of Cardiovascular Medicine, Kobe City Medical Center General Hospital, 2-1-1, Minatojima-minamimachi, Chuo-ku, Kobe, Japan
E-mail: skaji@theia.ocn.ne.jp
Received: August 31, 2017
Accepted for publication: September 20, 2017

TBAD: Classic AD and Aortic Intramural Hematoma

As described above, TBAD is defined as AD not involving the ascending aorta. The affected part of the aorta includes the arch, descending, and/or abdominal aorta. Clinically, TBAD is subdivided according to false lumen status, as the prognosis differs significantly. Tsai *et al*. divided TBAD into three categories according to false lumen thrombosis: patent, partially thrombosed, and completely thrombosed[6]. Of these, AD with com-

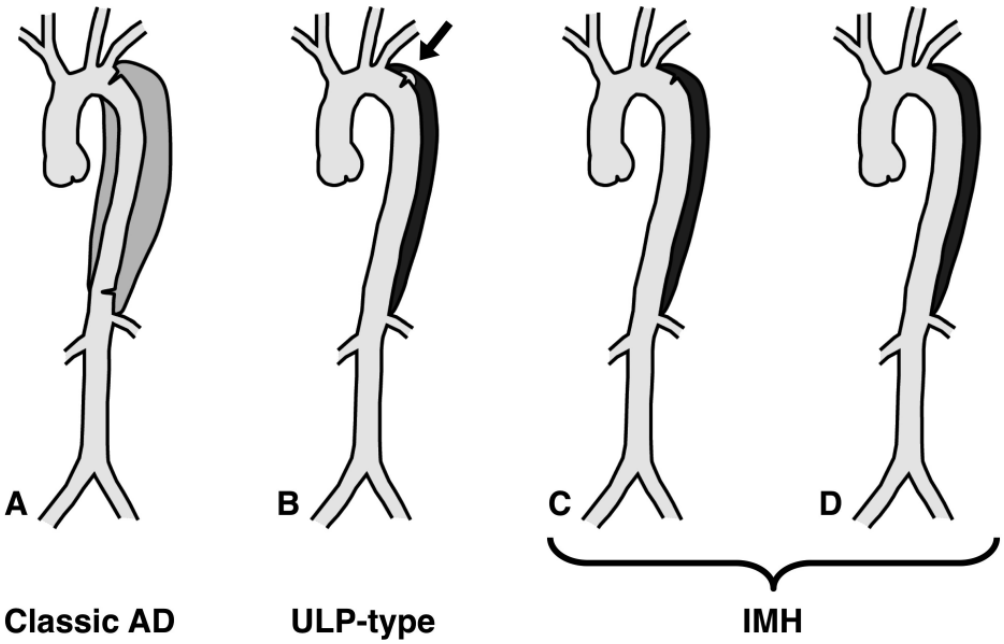

Fig. 1. Variations of Stanford type B aortic dissection

A: Classic aortic dissection or communicating aortic dissection. Apparent longitudinal blood flow is observed in the false lumen. B: Ulcer-like projection develops during clinical course in patients with aortic IMH. In the JCS guideline, this type is designated as ULP-type dissection. C and D: IMH or non-communicating dissection. In C, the patient has thrombosed false lumen and tear but without blood flow. In D, the patient has thrombosed false lumen without tear nor blood flow.
ULP, ulcer-like projection; IMH, intramural hematoma.

pletely thrombosed false lumen is speculated to be the same as aortic intramural hematoma (IMH). On the other hand, AD with patent or partially thrombosed false lumen is designated as classic AD. **Fig. 1** shows the difference between classic AD and IMH.

Aortic IMH was first described in 1920 as "dissection without intimal tear," and it was considered a distinct entity at necropsy[7]. Although IMH has been considered as a precursor of classic dissection[8], recent imaging studies have suggested that IMH may originate from intimal disruption similar to aortic dissection[9]. The similarity between classic AD and IMH has been demonstrated, implying that classic AD and IMH may share the same underlying aortic wall pathology[9, 10]. Because clinically distinguishing between AD without a tear and AD with a tear showing no blood flow in the false lumen is difficult, the Japanese Circulation Society (JCS) guideline prefers avoidance of the use of the term "aortic IMH," which pathologically denotes hematoma in the aortic wall due to rupture of a blood vessel feeding the aorta[2]. This guideline recommends the use of the term "non-communicating aortic dissection." Similar to this idea, we previously proposed a new designation of "aortic dissection with closed and thrombosed false lumen"[11]. Considering the similar aortic pathology in patients with classic AD and IMH, in this review, we discuss both classic AD and IMH, and the term TBAD includes these two disease entities.

Optimal Medical Therapy for TBAD

All patients with TBAD should be initially managed with medical therapy to reduce hemodynamic stress to the aortic wall and avoid fatal complications. In particular, blood pressure control is crucially important to avoid both acute adverse events and chronic aortic dilatation. In acute settings, intravenous calcium-channel blockers, nitroglycerin, and beta-blocking agents should be initiated to lower the systolic blood pressure to 100-120 mmHg. Among these antihypertensive drugs, beta-blocking agents are highly recommended to reduce heart rate and dp/dt. During the chronic phase, current guidelines suggest blood pressure control below 140/90 (US and European guidelines)[1, 3] with lifestyle changes and adequate use of antihypertensive drugs. However, limited evidence is available about which drugs are beneficial for patients with chronic aortic dissection. Previous studies suggested that beta-blocker therapy could improve clinical outcome

in patients with type B aortic dissection[12, 13]. However, observational data from the International Registry of Aortic Dissection reported that beta-blocker has no significant clinical benefit, whereas calcium-channel blocker is associated with improved outcome in patients with TBAD[14, 15]. Although several studies failed to demonstrate the efficacy of beta-blocker therapy, one observational study revealed that tight heart rate control improves clinical outcome in patients with TBAD[16]. This study suggested the importance of heart rate control rather than the use of beta-blocker. Further studies are warranted to clarify the optimal medical therapy in patients with TBAD.

Treatment for Patients with Complicated TBAD

Although patients with TBAD tend to have more stable in-hospital course than patients with type A AD, a considerable proportion of patients with TBAD suffer from fatal complications. Complicated TBAD is defined by the presence of at least one of the following: aortic rupture, persistent or recurrent pain, uncontrolled hypertension despite full medication, and early aortic expansion and malperfusion in cerebral, spinal, visceral, renal, or peripheral vascular territories. These complications are considered to be a major cause of early mortality in patients with TBAD. Afifi *et al.* reported that the early mortality rate of patients with complicated TBAD is significantly higher than that of patients with uncomplicated TBAD (2.6% versus 16.1%, respectively)[17]. TEVAR is considered to be effective for treatment of patients with complicated TBAD. Several studies confirmed the improvement in clinical outcome with TEVAR in patients with complicated TBAD[18-22]. Currently, several meta-analyses report favorable short and mid-term results in patients with complicated TBAD treated with TEVAR[23-25]. Given these results, TEVAR is considered as the gold standard for complicated TBAD, and current guidelines recommend TEVAR for patients with complicated TBAD as Class I indications[1-3]. Although TEVAR is beneficial for complicated patients, those with visceral malperfusion have poorer prognosis[26, 27]. A previous study reported that patients with visceral ischemia have a high risk of mortality and that mortality rates are similar after surgical and endovascular management[27]. These results suggest that early diagnosis and intervention for visceral ischemia seem to be crucial.

Watchful Waiting Strategy with Open Surgery or TEVAR for Patients with Uncomplicated TBAD

The results of open surgical repair of the descending aorta have improved over the last decades, but in-hospital mortality for patients with TBAD remains about 25−50%[18, 28, 29]. The National Survey of Japanese Association for Thoracic Surgery in 2014 including 1039 institutions revealed that the 30-day mortality rates of patients who underwent surgical therapy for acute TBAD including replacement of the arch + descending aorta, descending aorta, and thoracoabdominal aorta for acute AD are 31.3%, 9.8%, and 27.3%, respectively[30]. Considering the relatively high mortality and morbidity, open surgery is delayed until patients with TBAD show dilatation of the affected aorta. Current guidelines recommend surgical intervention for patients with aortic diameter ≥ 55-60 mm[1-3]. According to the same survey in Japan, the 30-day mortality rates of patients who underwent open surgery for chronic TBAD including replacement of the arch + descending aorta, descending aorta, and thoracoabdominal aorta for chronic aortic dissection are 8.1%, 5.3%, and 5.1%, respectively. By contrast, the 30-day mortality rate of patients with chronic TBAD who underwent TEVAR is 1.9%. Elective aortic graft replacement or TEVAR performed by experienced operators carries a low risk of morbidity or mortality. Considering the relatively low mortality rates with open surgery and TEVAR, watchful waiting strategy in TBAD seems to be rational. However, this strategy has several disadvantages. First, lifelong monitoring is necessary to prevent late aorta-related adverse events. The risk of incomplete follow-up is also present. Second, the degeneration of the aortic wall and extensive aortic enlargement may make aortic intervention more complicated and difficult with time.

Current Outcomes of Patients with Uncomplicated TBAD

Several observational studies reported the natural history of TBAD. The investigators of the International Registry of Acute Aortic Dissection (IRAD) reported that the 3-year mortality rates in patients who are treated medically, surgically, or with endovascular therapy and discharged alive with TBAD are 22.4%, 17.2%, and 23.8%, respectively[31]. Other investigators from the US and European countries demonstrated a similar 5-year all-cause mortality rate of 19.3 to 23.4% in patients with uncomplicated TBAD[17, 32]. On the other hand, several centers in Japan demonstrated a relatively lower 5-year all-cause mortality rate

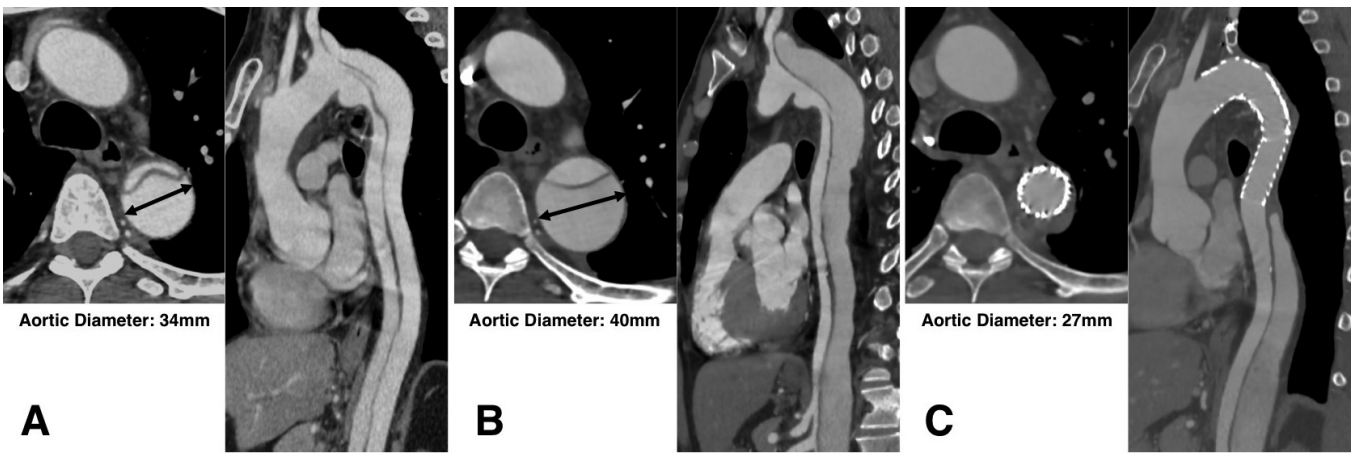

Fig. 2. Successful preemptive TEVAR in a patient with uncomplicated TBAD

A 35-year-old man with classic aortic dissection. A: Axial and sagittal views on CTA imaging at onset, showing a maximum aortic diameter of 34 mm. B: Axial and sagittal views on CTA imaging at 3 months follow-up revealed significant aortic dilatation, showing a maximum aortic diameter of 40 mm. The patient underwent preemptive TEVAR. C: At 2 years after TEVAR, axial and sagittal views on CTA imaging showed favorable aortic remodeling with expansion of the true lumen.

ranging from 12.8 to 13.2%, which is lower than western centers[33, 34]. Although the reason for the differences in the 5-year all-cause mortality in uncomplicated TBAD is unknown, the results suggest that the clinical outcome of optimal medical therapy in Japan might be better than those in the US and European countries. Accordingly, when we consider indications of TEVAR for patients with uncomplicated TBAD, possibly better clinical outcomes among Japanese patients should be taken into account.

Preemptive TEVAR for Patients with Uncomplicated TBAD

Preemptive TEVAR, which is less invasive than open surgery, might be able to improve the clinical outcome of patients with TBAD. However, whether preemptive TEVAR can improve the clinical outcome of patients with uncomplicated TBAD is still debatable. Observational studies revealed that patients with TBAD treated with TEVAR during the acute phase have fewer aorta-related adverse events than those treated with medical management[35, 36]. Until now, only two randomized trials have assessed the clinical impact of preemptive TEVAR. The ADSORB trial compared OMT plus TEVAR with OMT alone for acute uncomplicated TBAD[37]. Although the trial was underpowered for survival and the follow-up duration was short, patients with TEVAR plus OMT showed more improved aortic remodeling. In INSTEAD and INSTEAD-XL trials (extended version), the latter revealed that TEVAR is associated with improved 5-year aorta-specific survival, although early results failed to show the effectiveness of TEVAR in INSTEAD trial[38, 39]. In this study, patients who underwent preemptive TEVAR have favorable aortic remodeling. TEVAR, which can close primary entry tear into false lumen, could induce false lumen thrombosis and aortic remodeling. The study concludes that preemptive TEVAR should be considered to improve late outcome in uncomplicated TBAD with suitable aortic anatomy. The results of these randomized trials have a large clinical impact on TBAD management and encourage preemptive TEVAR in early disease stage. **Fig. 2** shows a representative case of successful TEVAR in a young patient with TBAD. However, the benefit of TEVAR is not apparent until 2 years after therapy in the INSTEAD-XL trial, which raised several issues about management of TBAD. The first issue is identifying which patients with uncomplicated TBAD should undergo TEVAR. The trial suggested the importance of patient selection for TEVAR. The second issue is the unclear optimal timing of TEVAR and open surgery. Currently, the best timing of preemptive TEVAR may be considered as 3-6 months after the onset of TBAD. TEVAR is more effective in subacute phase than in chronic phase because the aorta dilates more severely and the intima becomes less elastic with time. Desai *et al*. reported that severe complications, including retrograde type A AD, are more common in early-acute (within 48 hours from presentation) and delayed-acute (48 hours to 14 days) than in subacute (14 days to 6 weeks)[40]. This study showed that the 30-day mortality rates of early-acute, delayed-acute, and subacute are 12.7%, 6.8%, and 0%, respectively. In contrast, delayed timing of more than 3 months might

Table 1. Predictors of adverse aortic events in patients with uncomplicated type B aortic dissection

	Predictor	References
Clinical	Age < 60 years	46) 61)
	White race	15)
	Heart rate ≥ 60/min	16)
	Marfan syndrome	44)
		6)
	Without calcium channel blockers	15) 14)
Laboratory findings	FDP level ≥ 20 μg/mL on admission	58)
	Peak CRP level ≥ 9.61 mg/dL	59)
Imaging findings	Aortic diameter ≥ 40 mm during acute phase	41) 42)
	Patent FL	41) 50) 51)
	Partially thrombosed FL	6)
	FL diameter of the proximal descending aorta ≥ 22 mm on initial imaging	43)
	Sac formation in partially thrombosed FL	46)
	One entry tear	49)
	FL or intimal tear located at the inner curvature	46)
	An elliptic configuration of the TL	46)
	Ulcer-like projection	11) 51)
	Fusiform index ≥ 0.64	45)
	Large entry tear (≥ 10 mm) located in the proximal descending aorta	44)

FDP, fibrinogen degradation product; FL, false lumen; TL, true lumen; CRP, C-reactive protein.

lead to degeneration of the aortic wall, which hampers aortic remodeling after TEVAR. Moreover, considering the clinical outcomes of open surgery, it might be better to observe and wait until the affected aorta shows significant enlargement in patients with unsuitable aortic anatomy for TEVAR that may lead to serious complications. Further studies are required to determine the optimal timing of TEVAR.

Predictors for Aortic Events in Patients with TBAD: Toward the Best Practice

Considering the limited results of randomized trials, a complication-specific approach, instead of endovascular surgery for all patients with TBAD, remains reasonable. For this purpose, identifying high-risk patients with TBAD who benefit from preemptive TEVAR is crucial. Several risk factors including clinical and imaging parameters have been shown to be associated with early disease progression in patients with TBAD. **Table 1** summarizes the clinical and imaging predictors of aortic events in patients with TBAD.

Anatomical Imaging

An aortic diameter of more than 40 mm is a simple and useful predictor for future aorta-related events[41, 42]. Another important predictor is a false lumen diameter of more than 22 mm[43]. In addition, assessment with transesophageal echocardiography showed that entry tear of more than 10 mm in diameter and proximal entry location are predictive for aorta-related adverse events[44]. Similarly, several morphological parameters of the true and false lumen, such as elliptic configuration of the true lumen and fusiform shape in longitudinal aorta, have been reported to be predictive[45, 46]. In contrast, false lumen thrombosis is a crucial factor for predicting clinical outcome. Tsai *et al*. reported that patients with partial thrombosis have worse prognosis than patients with patent or complete thrombosis[6]. Similarly, Trimarchi *et al*. reported that patients with partial false lumen thrombosis show higher aortic growth rate than patients with other types of false lumen[47]. These studies suggested that a partially thrombosed false lumen should be carefully followed up with close imaging surveillance. However, Sueyoshi *et al*. demonstrated that aortic growth rate is not significantly different between patients with patent and patients with partial false lumen thrombosis[48]. The difference in results may be attributed to the definition of partial thrombosis and patients' background. Interestingly, the number of entry tears connecting the true and false lumen has been reported to be associated with aortic growth rate, and patients with single entry tear show the highest growth rate[49]. Based on their result, Tolenaar *et al*. suggested an important idea why patients with partial false lumen thrombosis have worse

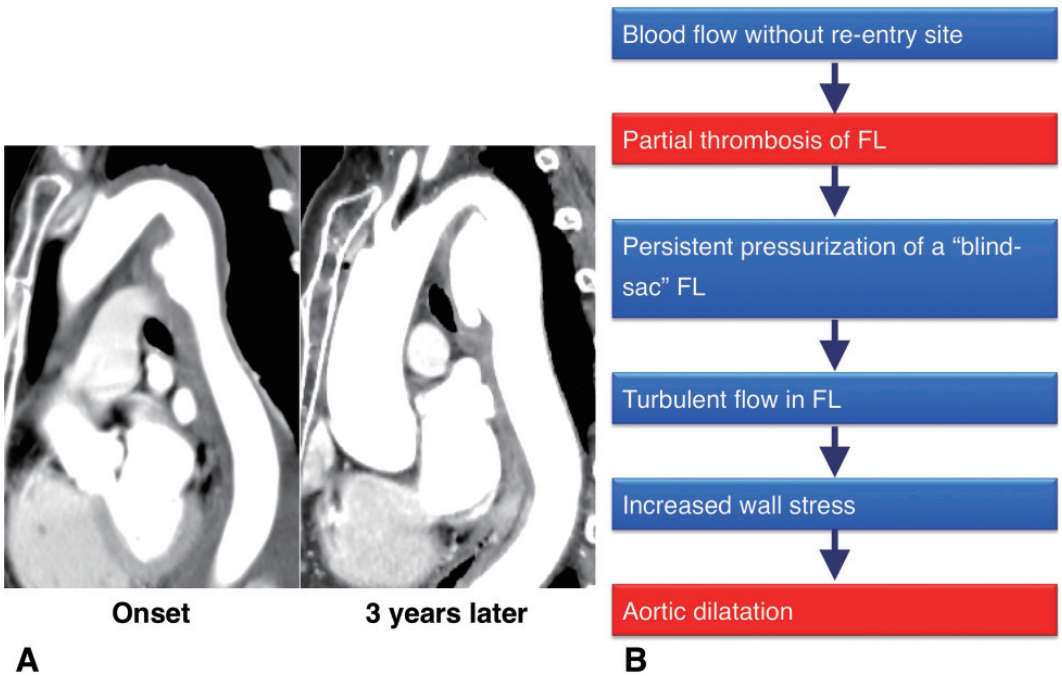

Fig. 3. Aortic enlargement of sac formation in a patient with TBAD

A: A 60-year-old woman with sac formation in the false lumen. Left and right panels show sagittal image at onset and enlargement of the false lumen, respectively. B: Possible explanation of why partial thrombosis of the false lumen leads to aortic dilatation[49].

prognosis[49] (**Fig. 3**). Blood flow without re-entry site, which leads to partial thrombosis of the false lumen, may cause persistent pressurization of a "blind-sac" false lumen. This might also change the normal laminar blood flow into turbulent flow, which leads to increased aortic wall stress.

IMH and Ulcer-like Projection

In comparison with patients with patent or partially thrombosed false lumen, those with TBAD having closed and thrombosed false lumen, which are identical to IMH and characterized by the absence of intimal tear and continuous flow communication, have different clinical features and outcomes[10, 50]. We previously reported that patients with type B IMH have better short- and long-term prognoses than patients with classic AD[51]. Two important clinical features of IMH may contribute to achieve better clinical outcome. First, patients with IMH have less opportunity of branch occlusion and subsequent malperfusion. Previous studies reported that less fatal complications due to branch ischemia occur in patients with type B aortic IMH[10, 51]. This may contribute to the improvement in short-term mortality. Second, thrombosed false lumen may regress and frequently resolve during clinical course[51, 52]. In other words, aortic remodeling occurs more frequently in patients with IMH. These clinical features may be associated with better clinical outcome, but not all IMH patients have favorable prognosis. Patients with ulcer-like projection (ULP), which indicates the flow communication between the true and false lumen, have been reported to be a strong risk factor for future aorta-related events[11, 53]. This is similar to the finding that partial thrombosis of the false lumen is a risk factor of adverse aortic events. Since ULP can be regarded as one large entry into partially thrombosed false lumen, it has a similarity with the abovementioned morphological risk factors, such as partial thrombosis, sac formation, and large and/or one entry. Thus, these findings suggest that partial false lumen thrombosis due to even small flow communication may lead to adverse outcomes, whereas complete thrombosis may invoke remodeling and improve outcomes. TEVAR, which can close and reduce false lumen blood flow inducing complete thrombosis, might be beneficial for patients with partial false lumen thrombosis.

Functional Imaging

Multiple detector computed tomography imaging provides detailed morphology of the affected aorta. However, it does not reveal the functional information of hemodynamics and flow pattern in both the true and false lumen. Magnetic resonance imaging and

echocardiography enable comprehensive evaluation of flow pattern in both lumens and entry. Clough *et al.* demonstrated that four-dimensional phase-contrast magnetic resonance imaging can help visualize and quantify flow characteristics in patients with AD and that stroke volume, velocity, distal dominant entry tears, and helical flow are related to the rate of aortic expansion[54, 55].

Another possible functional imaging modality that can predict clinical outcome in patients with AD is positron emission tomography (PET). PET imaging is based on the distribution of the glucose analogue ^{18}F-fluorodeoxyglucose (^{18}F-FDG), which is taken up with high affinity by hypermetabolic inflammatory cells. The combined anatomic and metabolic information of ^{18}F-FDG-PET/computed tomography has shown potential in the imaging of aortic wall instability and underlying inflammation in aortic disease. A previous preliminary study reported that the greater uptake of ^{18}F-FDG is significantly associated with rupture and progression in patients with AD[56, 57].

Laboratory Findings

Several biomarkers have been reported to be predictive for adverse aortic events. First, fibrinogen degradation product (FDP) level ≥ 20 μg/mL at admission is associated with aortic growth[58]. However, since FDP level is not measured easily in emergency room, it might not be widely available in many institutions. On the other hand, several studies revealed that peak CRP level is a strong predictor in patients with TBAD[59, 60]. The serum CRP level is widely available and can be a less-invasive marker for identifying high-risk patients. However, since CRP is a nonspecific marker, its usefulness might be limited by the fact that it reflects not only the extent of the aortic dissection, but also concomitant inflammatory diseases, such as pneumonia.

Conclusion

The optimal treatment of TBAD remains controversial. TEVAR should be recommended for patients with complicated TBAD. Although optimal medical therapy with aggressive blood pressure lowering is essential for patients with uncomplicated TBAD, we have to consider whether they should be treated with preemptive TEVAR to improve clinical outcomes. High-risk patients should be monitored closely, particularly in the first 6 months and referred for endovascular repair when significant aortic dilatation is observed. If patients have a stable course without aortic dilatation, optimal medical therapy and timely surgery are recommended. With this watchful waiting approach, surveillance with regular radiological imaging is essential. The ultimate goals are patient survival and better quality of life. We should consider carefully the risks and benefits of optimal medical therapy, TEVAR, and open surgery in each patient and determine the treatment strategy by properly balancing them.

Funding

This work was supported in part by the Japan Society for the Promotion of Science KAKENHI Grant Numbers JP16K09487, JP25461097.

Disclosures

The author has no conflict of interest to disclose.

References

1) Hiratzka LF, Bakris GL, Beckman JA, Bersin RM, Carr VF, Casey DE Jr, Eagle KA, Hermann LK, Isselbacher EM, Kazerooni EA, Kouchoukos NT, Lytle BW, Milewicz DM, Reich DL, Sen S, Shinn JA, Svensson LG, Williams DM. 2010 ACCF/AHA/AATS/ACR/ASA/SCA/SCAI/SIR/STS/SVM guidelines for the diagnosis and management of patients with thoracic aortic disease: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines, American Association for Thoracic Surgery, American College of Radiology, American Stroke Association, Society of Cardiovascular Anesthesiologists, Society for Cardiovascular Angiography and Interventions, Society of Interventional Radiology, Society of Thoracic Surgeons, and Society for Vascular Medicine. Circulation. 2010; 121: e266-369
2) JCS Joint Working Group. Guidelines for diagnosis and treatment of aortic aneurysm and aortic dissection (JCS 2011). Circ J. 2013; 77: 789-828
3) Erbel R, Aboyans V, Boileau C, Bossone E, Bartolomeo RD, Eggebrecht H, Evangelista A, Falk V, Frank H, Gaemperli O, Grabenwoger M, Haverich A, Iung B, Manolis AJ, Meijboom F, Nienaber CA, Roffi M, Rousseau H, Sechtem U, Sirnes PA, Allmen RS, Vrints CJ, ESC Committee for Practice Guidelines. 2014 ESC Guidelines on the diagnosis and treatment of aortic diseases: document covering acute and chronic aortic diseases of the thoracic and abdominal aorta of the adult. The Task Force for the Diagnosis and Treatment of Aortic Diseases of the European Society of Cardiology (ESC). Eur Heart J. 2014; 35: 2873-2926
4) Fattori R, Cao P, De Rango P, Czerny M, Evangelista A, Nienaber C, Rousseau H, Schepens M. Interdisciplinary expert consensus document on management of type B aortic dissection. J Am Coll Cardiol. 2013; 61: 1661-1678
5) Nauta FJ, Trimarchi S, Kamman AV, Moll FL, van Herwaarden JA, Patel HJ, Figueroa CA, Eagle KA, Froehlich JB. Update in the management of type B aortic dissection. Vasc Med. 2016; 21: 251-263
6) Tsai TT, Evangelista A, Nienaber CA, Myrmel T, Mein-

hardt G, Cooper JV, Smith DE, Suzuki T, Fattori R, Llovet A, Froehlich J, Hutchison S, Distante A, Sundt T, Beckman J, Januzzi JL Jr, Isselbacher EM, Eagle KA. Partial thrombosis of the false lumen in patients with acute type B aortic dissection. N Engl J Med. 2007; 357: 349-359
7) Mohr-Kahaly S. Aortic intramural hematoma: from observation to therapeutic strategies. J Am Coll Cardiol. 2001; 37: 1611-1613
8) Tsai TT, Nienaber CA, Eagle KA. Acute aortic syndromes. Circulation. 2005; 112: 3802-3813
9) Kitai T, Kaji S, Yamamuro A, Tani T, Kinoshita M, Ehara N, Kobori A, Kim K, Kita T, Furukawa Y. Detection of intimal defect by 64-row multidetector computed tomography in patients with acute aortic intramural hematoma. Circulation. 2011; 124: S174-178
10) Akutsu K, Yoshino H, Tobaru T, Hagiya K, Watanabe Y, Tanaka K, Koyama N, Yamamoto T, Nagao K, Takayama M. Acute type B aortic dissection with communicating vs. non-communicating false lumen. Circ J. 2015; 79: 567-573
11) Kitai T, Kaji S, Yamamuro A, Tani T, Kinoshita M, Ehara N, Kobori A, Kita T, Furukawa Y. Impact of new development of ulcer-like projection on clinical outcomes in patients with type B aortic dissection with closed and thrombosed false lumen. Circulation. 2010; 122: S74-80
12) Genoni M, Paul M, Jenni R, Graves K, Seifert B, Turina M. Chronic beta-blocker therapy improves outcome and reduces treatment costs in chronic type B aortic dissection. Eur J Cardiothorac Surg. 2001; 19: 606-610
13) von Kodolitsch Y, Csosz SK, Koschyk DH, Schalwat I, Loose R, Karck M, Dieckmann C, Fattori R, Haverich A, Berger J, Meinertz T, Nienaber CA. Intramural hematoma of the aorta: predictors of progression to dissection and rupture. Circulation. 2003; 107: 1158-1163
14) Suzuki T, Isselbacher EM, Nienaber CA, Pyeritz RE, Eagle KA, Tsai TT, Cooper JV, Januzzi JL Jr, Braverman AC, Montgomery DG, Fattori R, Pape L, Harris KM, Booher A, Oh JK, Peterson M, Ramanath VS, Froehlich JB, IRAD Investigators. Type-selective benefits of medications in treatment of acute aortic dissection (from the International Registry of Acute Aortic Dissection [IRAD]). Am J Cardiol. 2012; 109: 122-127
15) Jonker FH, Trimarchi S, Rampoldi V, Patel HJ, O'Gara P, Peterson MD, Fattori R, Moll FL, Voehringer M, Pyeritz RE, Hutchison S, Montgomery D, Isselbacher EM, Nienaber CA, Eagle KA, International Registry of Acute Aortic Dissection (IRAD) Investigators. Aortic expansion after acute type B aortic dissection. Ann Thorac Surg. 2012; 94: 1223-1229
16) Kodama K, Nishigami K, Sakamoto T, Sawamura T, Hirayama T, Misumi H, Nakao K. Tight heart rate control reduces secondary adverse events in patients with type B acute aortic dissection. Circulation. 2008; 118: S167-170
17) Afifi RO, Sandhu HK, Leake SS, Boutrous ML, Kumar V 3rd, Azizzadeh A, Charlton-Ouw KM, Saqib NU, Nguyen TC, Miller CC 3rd, Safi HJ, Estrera AL. Outcomes of patients with acute type B (DeBakey Ⅲ) aortic dissection: a 13-year, single-center experience. Circulation. 2015; 132: 748-754
18) Fattori R, Tsai TT, Myrmel T, Evangelista A, Cooper JV, Trimarchi S, Li J, Lovato L, Kische S, Eagle KA, Isselbacher EM, Nienaber CA. Complicated acute type B dissection: is surgery still the best option?: a report from the International Registry of Acute Aortic Dissection. JACC Cardiovasc Interv. 2008; 1: 395-402
19) Ehrlich MP, Dumfarth J, Schoder M, Gottardi R, Holfeld J, Juraszek A, Dziodzio T, Funovics M, Loewe C, Grimm M, Sodeck G, Czerny M. Midterm results after endovascular treatment of acute, complicated type B aortic dissection. Ann Thorac Surg. 2010; 90: 1444-1448
20) Kato N, Shimono T, Hirano T, Suzuki T, Ishida M, Sakuma H, Yada I, Takeda K. Midterm results of stent-graft repair of acute and chronic aortic dissection with descending tear: the complication-specific approach. J Thorac Cardiovasc Surg. 2002; 124: 306-312
21) Zeeshan A, Woo EY, Bavaria JE, Fairman RM, Desai ND, Pochettino A, Szeto WY. Thoracic endovascular aortic repair for acute complicated type B aortic dissection: superiority relative to conventional open surgical and medical therapy. J Thorac Cardiovasc Surg. 2010; 140: S109-15; discussion S142-146
22) Szeto WY, McGarvey M, Pochettino A, Moser GW, Hoboken A, Cornelius K, Woo EY, Carpenter JP, Fairman RM, Bavaria JE. Results of a new surgical paradigm: endovascular repair for acute complicated type B aortic dissection. Ann Thorac Surg. 2008; 86: 87-93; discussion 93-94
23) Moulakakis KG, Mylonas SN, Dalainas I, Kakisis J, Kotsis T, Liapis CD. Management of complicated and uncomplicated acute type B dissection. A systematic review and meta-analysis. Ann Cardiothorac Surg. 2014; 3: 234-246
24) Eggebrecht H, Nienaber CA, Neuhauser M, Baumgart D, Kische S, Schmermund A, Herold U, Rehders TC, Jakob HG, Erbel R. Endovascular stent-graft placement in aortic dissection: a meta-analysis. Eur Heart J. 2006; 27: 489-498
25) Luebke T, Brunkwall J. Outcome of patients with open and endovascular repair in acute complicated type B aortic dissection: a systematic review and meta-analysis of case series and comparative studies. J Cardiovasc Surg (Torino). 2010; 51: 613-632
26) Park WM, Gloviczki P, Cherry KJ Jr, Hallett JW Jr, Bower TC, Panneton JM, Schleck C, Ilstrup D, Harmsen WS, Noel AA. Contemporary management of acute mesenteric ischemia: factors associated with survival. J Vasc Surg. 2002; 35: 445-452
27) Jonker FH, Patel HJ, Upchurch GR, Williams DM, Montgomery DG, Gleason TG, Braverman AC, Sechtem U, Fattori R, Di Eusanio M, Evangelista A, Nienaber CA, Isselbacher EM, Eagle KA, Trimarchi S. Acute type B aortic dissection complicated by visceral ischemia. J Thorac Cardiovasc Surg. 2015; 149: 1081-1086 e1
28) Trimarchi S, Nienaber CA, Rampoldi V, Myrmel T, Suzuki T, Bossone E, Tolva V, Deeb MG, Upchurch GR Jr, Cooper JV, Fang J, Isselbacher EM, Sundt TM 3rd, Eagle KA, Investigators I. Role and results of surgery in acute type B aortic dissection: insights from the International Registry of Acute Aortic Dissection (IRAD). Circulation. 2006; 114: I357-364
29) Lansman SL, Hagl C, Fink D, Galla JD, Spielvogel D,

Ergin MA, Griep RB. Acute type B aortic dissection: surgical therapy. Ann Thorac Surg. 2002; 74: S1833-1835; discussion S1857-1863
30) Committee for Scientific Affairs, The Japanese Association for Thoracic Surgery, Masuda M, Okumura M, Doki Y, Endo S, Hirata Y, Kobayashi J, Kuwano H, Motomura N, Nishida H, Saiki Y, Saito A, Shimizu H, Tanaka F, Tanemoto K, Toh Y, Tsukihara H, Wakui S, Yokomise H. Thoracic and cardiovascular surgery in Japan during 2014: annual report by The Japanese Association for Thoracic Surgery. Gen Thorac Cardiovasc Surg. 2016; 64: 665-697
31) Tsai TT, Fattori R, Trimarchi S, Isselbacher E, Myrmel T, Evangelista A, Hutchison S, Sechtem U, Cooper JV, Smith DE, Pape L, Froehlich J, Raghupathy A, Januzzi JL, Eagle KA, Nienaber CA. Long-term survival in patients presenting with type B acute aortic dissection: insights from the International Registry of Acute Aortic Dissection. Circulation. 2006; 114: 2226-2231
32) Garbade J, Jenniches M, Borger MA, Barten MJ, Scheinert D, Gutberlet M, Walther T, Mohr FW. Outcome of patients suffering from acute type B aortic dissection: a retrospective single-centre analysis of 135 consecutive patients. Eur J Cardiothorac Surg. 2010; 38: 285-292
33) Miyahara S, Mukohara N, Fukuzumi M, Morimoto N, Murakami H, Nakagiri K, Yoshida M. Long-term follow-up of acute type B aortic dissection: ulcer-like projections in thrombosed false lumen play a role in late aortic events. J Thorac Cardiovasc Surg. 2011; 142: e25-31
34) Ueki C, Sakaguchi G, Shimamoto T, Komiya T. Prognostic factors in patients with uncomplicated acute type B aortic dissection. Ann Thorac Surg. 2014; 97: 767-773; discussion 773
35) Fattori R, Montgomery D, Lovato L, Kische S, Di Eusanio M, Ince H, Eagle KA, Isselbacher EM, Nienaber CA. Survival after endovascular therapy in patients with type B aortic dissection: a report from the International Registry of Acute Aortic Dissection (IRAD). JACC Cardiovasc Interv. 2013; 6: 876-882
36) Qin YL, Deng G, Li TX, Wang W, Teng GJ. Treatment of acute type-B aortic dissection: thoracic endovascular aortic repair or medical management alone? JACC Cardiovasc Interv. 2013; 6: 185-191
37) Brunkwall J, Kasprzak P, Verhoeven E, Heijmen R, Taylor P, Trialists A, Alric P, Canaud L, Janotta M, Raithel D, Malina W, Resch T, Eckstein HH, Ockert S, Larzon T, Carlsson F, Schumacher H, Classen S, Schaub P, Lammer J, Lonn L, Clough RE, Rampoldi V, Trimarchi S, Fabiani JN, Bockler D, Kotelis D, Bockler D, Kotelis D, von Tenng-Kobligk H, Mangialardi N, Ronchey S, Dialetto G, Matoussevitch V. Endovascular repair of acute uncomplicated aortic type B dissection promotes aortic remodelling: 1 year results of the ADSORB trial. Eur J Vasc Endovasc Surg. 2014; 48: 285-291
38) Nienaber CA, Rousseau H, Eggebrecht H, Kische S, Fattori R, Rehders TC, Kundt G, Scheinert D, Czerny M, Kleinfeldt T, Zipfel B, Labrousse L, Ince H. Randomized comparison of strategies for type B aortic dissection: the INvestigation of STEnt Grafts in Aortic Dissection (INSTEAD) trial. Circulation. 2009; 120: 2519-2528
39) Nienaber CA, Kische S, Rousseau H, Eggebrecht H, Rehders TC, Kundt G, Glass A, Scheinert D, Czerny M, Kleinfeldt T, Zipfel B, Labrousse L, Fattori R, Ince H, INSTEAD-XL trial. Endovascular repair of type B aortic dissection: long-term results of the randomized investigation of stent grafts in aortic dissection trial. Circ Cardiovasc Interv. 2013; 6: 407-416
40) Desai ND, Gottret JP, Szeto WY, McCarthy F, Moeller P, Menon R, Jackson B, Vallabhajosyula P, Wang GJ, Fairman R, Bavaria JE. Impact of timing on major complications after thoracic endovascular aortic repair for acute type B aortic dissection. J Thorac Cardiovasc Surg. 2015; 149: S151-156
41) Kato M, Bai H, Sato K, Kawamoto S, Kaneko M, Ueda T, Kishi D, Ohnishi K. Determining surgical indications for acute type B dissection based on enlargement of aortic diameter during the chronic phase. Circulation. 1995; 92: Ⅱ107-112
42) Marui A, Mochizuki T, Mitsui N, Koyama T, Kimura F, Horibe M. Toward the best treatment for uncomplicated patients with type B acute aortic dissection: a consideration for sound surgical indication. Circulation. 1999; 100: Ⅱ275-280
43) Song JM, Kim SD, Kim JH, Kim MJ, Kang DH, Seo JB, Lim TH, Lee JW, Song MG, Song JK. Long-term predictors of descending aorta aneurysmal change in patients with aortic dissection. J Am Coll Cardiol. 2007; 50: 799-804
44) Evangelista A, Salas A, Ribera A, Ferreira-Gonzalez I, Cuellar H, Pineda V, Gonzalez-Alujas T, Bijnens B, Permanyer-Miralda G, Garcia-Dorado D. Long-term outcome of aortic dissection with patent false lumen: predictive role of entry tear size and location. Circulation. 2012; 125: 3133-3141
45) Marui A, Mochizuki T, Koyama T, Mitsui N. Degree of fusiform dilatation of the proximal descending aorta in type B acute aortic dissection can predict late aortic events. J Thorac Cardiovasc Surg. 2007; 134: 1163-1170
46) Tolenaar JL, van Keulen JW, Jonker FH, van Herwaarden JA, Verhagen HJ, Moll FL, Muhs BE, Trimarchi S. Morphologic predictors of aortic dilatation in type B aortic dissection. J Vasc Surg. 2013; 58: 1220-1225
47) Trimarchi S, Tolenaar JL, Jonker FH, Murray B, Tsai TT, Eagle KA, Rampoldi V, Verhagen HJ, van Herwaarden JA, Moll FL, Muhs BE, Elefteriades JA. Importance of false lumen thrombosis in type B aortic dissection prognosis. J Thorac Cardiovasc Surg. 2013; 145: S208-212
48) Sueyoshi E, Sakamoto I, Uetani M. Growth rate of affected aorta in patients with type B partially closed aortic dissection. Ann Thorac Surg. 2009; 88: 1251-1257
49) Tolenaar JL, van Keulen JW, Trimarchi S, Jonker FH, van Herwaarden JA, Verhagen HJ, Moll FL, Muhs BE. Number of entry tears is associated with aortic growth in type B dissections. Ann Thorac Surg. 2013; 96: 39-42
50) Akutsu K, Nejima J, Kiuchi K, Sasaki K, Ochi M, Tanaka K, Takano T. Effects of the patent false lumen on the long-term outcome of type B acute aortic dissection. Eur J Cardiothorac Surg. 2004; 26: 359-366
51) Kaji S, Akasaka T, Katayama M, Yamamuro A, Yamabe K, Tamita K, Akiyama M, Watanabe N, Tanemoto K, Morioka S, Yoshida K. Long-term prognosis of patients with type B aortic intramural hematoma. Circulation. 2003;

108 Suppl 1: II307-311
52) Evangelista A, Dominguez R, Sebastia C, Salas A, Permanyer-Miralda G, Avegliano G, Elorz C, Gonzalez-Alujas T, Garcia Del Castillo H, Soler-Soler J. Long-term follow-up of aortic intramural hematoma: predictors of outcome. Circulation. 2003; 108: 583-589
53) Sueyoshi E, Matsuoka Y, Imada T, Okimoto T, Sakamoto I, Hayashi K. New development of an ulcerlike projection in aortic intramural hematoma: CT evaluation. Radiology. 2002; 224: 536-541
54) Clough RE, Hussain T, Uribe S, Greil GF, Razavi R, Taylor PR, Schaeffter T, Waltham M. A new method for quantification of false lumen thrombosis in aortic dissection using magnetic resonance imaging and a blood pool contrast agent. J Vasc Surg. 2011; 54: 1251-1258
55) Clough RE, Waltham M, Giese D, Taylor PR, Schaeffter T. A new imaging method for assessment of aortic dissection using four-dimensional phase contrast magnetic resonance imaging. J Vasc Surg. 2012; 55: 914-923
56) Kato K, Nishio A, Kato N, Usami H, Fujimaki T, Murohara T. Uptake of 18F-FDG in acute aortic dissection: a determinant of unfavorable outcome. J Nucl Med. 2010; 51: 674-681
57) Sakalihasan N, Nienaber CA, Hustinx R, Lovinfosse P, El Hachemi M, Cheramy-Bien JP, Seidel L, Lavigne JP, Quaniers J, Kerstenne MA, Courtois A, Ooms A, Albert A, Defraigne JO, Michel JB. (Tissue PET) Vascular metabolic imaging and peripheral plasma biomarkers in the evolution of chronic aortic dissections. Eur Heart J Cardiovasc Imaging. 2015; 16: 626-633
58) Kitada S, Akutsu K, Tamori Y, Yoshimuta T, Hashimoto H, Takeshita S. Usefulness of fibrinogen/fibrin degradation product to predict poor one-year outcome of medically treated patients with acute type B aortic dissection. Am J Cardiol. 2008; 101: 1341-1344
59) Sakakura K, Kubo N, Ako J, Wada H, Fujiwara N, Funayama H, Ikeda N, Nakamura T, Sugawara Y, Yasu T, Kawakami M, Momomura S. Peak C-reactive protein level predicts long-term outcomes in type B acute aortic dissection. Hypertension. 2010; 55: 422-429
60) Kitai T, Kaji S, Kim K, Ehara N, Tani T, Kinoshita M, Furukawa Y. Prognostic value of sustained elevated C-reactive protein levels in patients with acute aortic intramural hematoma. J Thorac Cardiovasc Surg. 2014; 147: 326-331
61) Sueyoshi E, Sakamoto I, Hayashi K, Yamaguchi T, Imada T. Growth rate of aortic diameter in patients with type B aortic dissection during the chronic phase. Circulation. 2004; 110: II256-261