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Acute Aortic Syndromes

Thomas T. Tsai, MD; Christoph A. Nienaber, MD; Kim A. Eagle, MD

In 1760, Dr Nicholls, physician to King George II, first described on necropsy an acute aortic dissection. Over the course of more than 200 years, we have developed a growing awareness and understanding of acute and chronic aortic syndromes. Recent advances in imaging and therapeutic techniques have further emphasized the importance of early diagnosis of acute aortic syndromes, which continues to be crucial to survival. However, we continue to be uncomfortable in the diagnosis and management of this highly lethal disorder. In the present report, we review the etiology, pathophysiology, clinical presentation, outcomes, and therapeutic approaches to acute aortic syndromes. In each section, we summarize the most clinically relevant issues as “take home points” (THPs) to affirm their importance in the diagnosis and management of this disorder.

Pathophysiology

Acute aortic syndrome is the modern term that includes aortic dissection, intramural hematoma (IMH), and symptomatic aortic ulcer. In the classic sense, acute aortic dissection requires a tear in the aortic intima that commonly is preceded by medial wall degeneration or cystic media necrosis.¹ Blood passes through the tear separating the intima from the media or adventitia, creating a false lumen. Propagation of the dissection can proceed in antegrade or retrograde fashion from the initial tear involving side branches and causing complications such as malperfusion syndromes, tamponade, or aortic valve insufficiency.^{2–5}

Both acquired and genetic conditions share a common pathway leading to the breakdown in the integrity of the intima. All mechanisms that weaken the media layers of the aorta will eventually lead to higher wall stress, which can induce aortic dilatation and aneurysm formation, eventually resulting in intramural hemorrhage, aortic dissection, or rupture. The factors culminating in a clinical dissection are quite diverse. The most common risk condition for aortic dissection is hypertension, with chronic exposure of the aorta to high pressures leading to intimal thickening, fibrosis, calcification, and extracellular fatty acid deposition. Furthermore, the extracellular matrix may undergo accelerated degradation, apoptosis, and elastolysis with eventual intimal disruption, most often at the edges of plaques.^{1,6–8}

Marfan's syndrome, vascular Ehlers-Danlos syndrome, annuloaortic ectasia, bicuspid aortic valve, and familial aortic

dissection are genetic conditions that often cause acute aortic syndromes. A common denominator to these different genetic disorders is a similar pathophysiology that includes a dedifferentiation of vascular smooth muscle cells and enhanced elastolysis of aortic wall components, leading to a compromised intima and aortic dissection.⁹ Given this genetic predisposition, a detailed family history in patients diagnosed with acute aortic syndromes or sudden death is particularly important in assessing the need for family screening.

THPs: Pathophysiology

1. All mechanisms weakening the media layers of the aorta lead to higher wall stress, which can induce aortic dilatation and aneurysm formation, eventually resulting in intramural hemorrhage, aortic dissection, or rupture.
2. Acute aortic dissection requires a tear in the aortic intima that commonly is preceded by medial wall degeneration or cystic medial necrosis.

Epidemiology

Knowledge regarding the incidence of aortic dissection in the general population is limited. Studies suggest an incidence of 2.6 to 3.5 cases per 100 000 person-years.^{2,10,11} In a review of 464 patients from the International Registry of Acute Aortic Dissection (IRAD), two thirds were male, with a mean age for all patients of 63 years.¹² Although less frequently affected by acute aortic dissection, women were significantly older than men, with a mean age of 67 years.¹³

There are many risk conditions for aortic dissection (Table 1). The most common predisposing factor in IRAD was hypertension (72%) (Table 2). A history of atherosclerosis was present in 31% of patients and a history of cardiac surgery in 18%. In the total registry, 5% and 4% of acute aortic dissections were thought to be related to Marfan's syndrome and iatrogenic causes, respectively.¹² Analysis of the young patients with dissection (<40 years of age) revealed that younger patients were less likely to have a history of hypertension (34%) or atherosclerosis (1%) but were more likely to have Marfan's syndrome, bicuspid aortic valve, and/or prior aortic surgery.¹⁴

From the Department of Internal Medicine, Division of Cardiology, University of Michigan Medical Center, Ann Arbor (T.T.T., K.A.E.), and Department of Internal Medicine, Division of Cardiology, University Hospital Rostock, Rostock, Germany (C.A.N.).

Reprint requests to Kim A. Eagle, MD, Albion Walter Hewlett Professor of Internal Medicine, Clinical Director, Cardiovascular Center, University of Michigan, 300 N Ingalls, 8B02 Ann Arbor, MI 48109-0477. E-mail keagle@umich.edu
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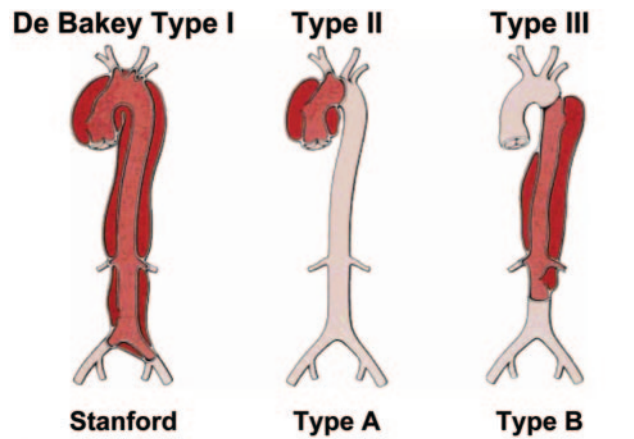
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TABLE 1. Risk Conditions for Aortic Dissection

Long-standing arterial hypertension
● Smoking, dyslipidemia, cocaine/crack
Connective tissue disorders
● Hereditary vascular disease
● Marfan syndrome
● Vascular Ehlers-Danlos syndrome (type 4)
● Bicuspid aortic valve
● Coarctation of the aorta
● Hereditary thoracic aortic aneurysm/dissection
Vascular inflammation
● Giant cell arteritis
● Takayasu arteritis
● Behcet's disease
● Syphilis
● Ormond's disease
Deceleration trauma
● Car accident
● Fall from height
Iatrogenic factors
● Catheter/instrument intervention
● Valvular/aortic surgery
● Side or cross-clamping/aortotomy
● Graft anastomosis
● Patch aortoplasty
● Aortic wall fragility

THPs: Epidemiology

1. Acute aortic dissection is a disorder afflicting men more than women in their fifth and sixth decades. The most common risk condition is hypertension.
2. Patients with aortic dissection at a young age (<40 years old) are less likely to have hypertension and more



DeBakey

- Type I** Originates in the ascending aorta, propagates at least to the aortic arch and often beyond it distally.
- Type II** Originates in and as confined to the ascending aorta.
- Type III** Originates in the descending aorta and extends distally down the aorta or, rarely retrograde into the aortic arch and ascending aorta.

Stanford

- Type A** All dissections involving the ascending aorta, regardless of the site of origin.
- Type B** All dissections not involving the ascending aorta.

Figure 1. The most common classification systems of thoracic aortic dissection: Stanford and DeBakey. Reproduced with permission from Reference 54, Copyright 2003, American Heart Association. All rights reserved.

likely to have Marfan's syndrome, bicuspid aortic valve, or prior aortic surgery.

3. Risk conditions for aortic dissection are diverse.

Types of Aortic Syndromes

Classification

The Stanford classification of aortic dissection distinguishes between type A and type B (Figure 1).^{15,16} In type A, the

TABLE 2. Demographics and History of Patients With Acute Aortic Dissection

Variable	n* (%)	Type A, n (%) (N=289)	Type B, n (%) (N=175)	P, Type A vs B
Demographics				
Age, mean (SD), y	63.1 (14.0)	61.2 (14.1)	66.3 (13.2)	<0.001
Male	303 (65.3)	182 (63.0)	121 (69.1)	0.18
Patient history				
Marfan syndrome	22/449 (4.9)	19 (6.7)	3 (1.8)	0.02
Hypertension	326/452 (72.1)	194 (69.3)	132 (76.7)	0.08
Atherosclerosis	140/452 (31.0)	69 (24.4)	71 (42)	<0.001
Prior aortic dissection	29/453 (6.4)	11 (3.9)	18 (10.6)	0.005
Prior aortic aneurysm	73/453 (16.1)	35 (12.4)	4 (2.3)	0.006
Diabetes	23/451 (5.1)	12 (4.3)	11 (6.6)	0.29
Prior cardiac surgery	83 (17.9)	46 (15.9)	37 (21.1)	0.16

N=464.

*Denominator of reported responses is given if different than stated in the column heading.

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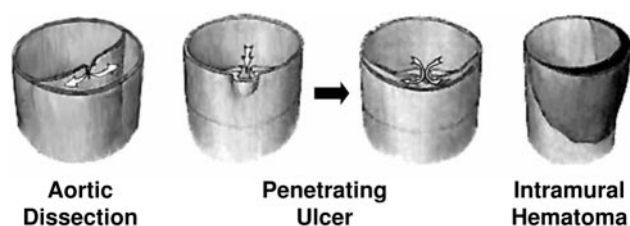


Figure 2. Schematic of aortic dissection (left), penetrating ulcer (middle), and IMH (right). Reprinted from Reference 22, Copyright 1997, with permission from Elsevier.

dissection involves the ascending aorta. In type B, only the descending aorta is involved. The DeBakey classification subdivides the dissection into 3 types, with type I dissection involving the entire aorta, type II dissection involving only the ascending aorta and arch. Advanced imaging technology has defined precursors or “variants” to frank aortic dissection such as IMH, penetrating aortic ulcers, and localized intimal tears (Figure 2).^{17–22}

Classic Aortic Dissection

Acute aortic dissection is characterized by the rapid development of an intimal flap separating the true and false lumens.^{2,23–25} The dissection can spread from the intimal tear in an antegrade or retrograde fashion, often involving side branches and causing malperfusion syndromes, tamponade, or aortic insufficiency.^{2,26–28} Once a patient survives to hospital discharge, further prognostication based on clinical and imaging parameters is challenging. Spontaneous false lumen thrombosis (better prognosis), evidence of persistent communication, and/or a patent false channel (worse prognosis) may be used to estimate late risk of expansion.^{5,25,29,30}

Variants

Intramural Hematoma

Aortic IMH is considered a precursor of dissection, originating from ruptured vasa vasorum in medial wall layers and resulting in an aortic wall infarct that may provoke a secondary tear, causing a classic aortic dissection (Figure 2).^{20,21} It is similar to classic dissection in its natural history in that IMH may extend, progress, regress, or resorb.^{19,20,31–33} Whereas IMH resorption has been reported in $\approx 10\%$ of cases, resorption of aortic dissection has rarely been reported.^{2,17,18,29,34} Most (50% to 85%) are located in the descending aorta and are typically associated with hypertension.^{35–37} Although clinical manifestations of IMH are similar to acute aortic dissection, IMH tends to be more of a segmental process; therefore, radiation of pain to the head or legs is less common. Chest pain is more common with ascending (type A) IMH; upper or lower back pain is more common with descending (type B) lesions.³³ Nonetheless, the diagnosis of IMH versus acute aortic dissection cannot be made clinically. IMH is a tomographic imaging diagnosis in the appropriate clinical setting.

Plaque Rupture/Penetrating Atherosclerotic Ulcer

Deep ulceration of atherosclerotic aortic plaques can lead to IMH, aortic dissection, or perforation.^{38–42} Noninvasive im-

aging has further elucidated this disease process that often further complicates IMH and appears as an ulcerlike projection into the hematoma. In association with IMH, limited series have reported seeing penetrating atherosclerotic ulcers almost exclusively in patients with type B IMH.⁴² Symptomatic ulcers with signs of deep erosion are more prone to rupture than others. In these patients, endovascular stent grafting is emerging as an attractive therapeutic modality.

THPs: Types of Aortic Syndromes

1. Stanford type A and DeBakey type I and II aortic dissections involve the ascending aorta and are usually managed surgically.
2. IMH is considered a precursor to classic dissection and usually originates from ruptured vasa vasorum in the media. Treatment is similar to classic aortic dissection.
3. Penetrating atherosclerotic ulcer can lead to aortic dissection or perforation. In association with IMH, these ulcers are seen almost exclusively with type B IMH.

Natural History and Prognosis

Type A (Proximal) Dissection

Acute aortic dissection of the ascending aorta is highly lethal, with a mortality of 1% to 2% per hour early after symptom onset.^{23,43} The risk of death is increased in patients who present with or develop complications of pericardial tamponade, involvement of coronary arteries causing acute myocardial ischemia/infarction, or malperfusion of the brain.^{2,26,28,30,44} Other predictors of increased in-hospital death include age ≥ 70 years, hypotension or cardiac tamponade, kidney failure, and pulse deficits (Table 3).²⁸ Less appreciated predisposing factors for type A dissection include prior cardiac and valvular surgery (15%) and iatrogenic dissection occurring during cardiac surgery or catheterization (5%). Iatrogenic aortic dissection carries a mortality that is slightly higher than noniatrogenic (35% versus 24%).^{1,12,45–48}

Data from the largest registry of acute aortic dissection showed that in the absence of immediate surgical repair, medical management alone is associated with a mortality of nearly 24% by 24 hours after presentation, 29% by 48 hours, 44% by day 7, and 49% by 14 days. Even with surgical repair, in-hospital mortality rates are 10% by 24 hours, 12% by 48 hours, 16% by 7 days, and nearly 20% by 14 days (Figure 3). The most common causes of death are aortic rupture, stroke, visceral ischemia, cardiac tamponade, and circulatory failure.^{28,49,50}

Type B (Distal) Dissection

Acute aortic dissection affecting the descending aorta is less lethal than type A dissection. Patients with uncomplicated type B dissection have a 30-day mortality of 10% (Figure 3).¹² However, patients who develop ischemic complications such as renal failure, visceral ischemia, or contained rupture often require urgent aortic repair, which carries a mortality of 20% by day 2 and 25% by day 30. Similar to type A dissection, advanced age, rupture, shock, and malperfusion are important independent predictors of early mortality.^{13,26,51} Chronic use of crack cocaine appears to predispose patients to

TABLE 3. Independent Predictors of In-Hospital Death

Overall Model Variable	Overall Type A, %	Among Survivors, %	Among Deaths, %	Parameter Coefficient	P	OR for Death (95% CI)
Age >70 y	35.2	30.0	46.1	0.53	0.03	1.70 (1.05–2.77)
Female	34.5	30.7	42.7	0.32	0.20	1.38 (0.85–2.27)
Abrupt onset pain*	84.5	82.3	89.0	0.96	0.01	2.60 (1.22–5.54)
Abnormal ECG*	69.6	65.2	79.5	0.57	0.03	1.77 (1.06–2.95)
Any pulse deficit*	30.1	24.7	41.1	0.71	0.004	2.03 (1.25–3.29)
Kidney failure†	5.6	2.9	11.9	1.56	0.002	4.77 (1.80–12.6)
Hypotension/shock/tamponade*	29.0	20.1	47.1	1.09	<0.0001	2.97 (1.83–4.81)

OR indicates odds ratio; CI, confidence interval.

*On presentation; †on presentation and before surgery.

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acute aortic dissection with a predilection to the descending aorta.^{52,53}

Intramural Hematoma

The natural history of acute IMH continues to be debated. In patients with symptoms consistent with acute aortic dissection, acute IMH accounts for 5% to 20% of cases.^{17,18} Regression is seen in ≈10% of patients, but progression to classic aortic dissection occurs in 28% to 47% of patients and may carry a risk of rupture in 20% to 45% of cases.⁵⁴ Studies in Asian patients from Japan and Korea have suggested that IMHs reflect a more benign condition in which aggressive medical therapy and serial imaging may allow watchful waiting and the avoidance of surgery in some patients.^{55–57} For type A IMH, this suggestion could not be verified in white patients. In IRAD, which registered 1010 patients with acute aortic dissection, 58 (5.7%) had IMH.⁵⁸ This cohort tended to be older (68.7 versus 61.7 years; $P<0.001$) and more likely to have distal aortic involvement (60.3% versus 35.3%; $P<0.0001$). The investigators demonstrated an association between increasing hospital mortality and the proximity of IMH to the aortic valve, regardless of medical or

surgical treatment (9 of 12 deaths occurred in the ascending aorta) (Figure 4).

THPs: Natural History and Prognosis

1. Acute aortic dissection of the ascending aorta (type A) is highly lethal, with a mortality of 1% to 2% per hour after symptom onset. Without surgery, mortality exceeds 50% at 1 month.
2. Uncomplicated (type B) descending dissections have a 30-day mortality of 10% and may be managed medically or by stent grafting in the future.
3. IMH of the ascending aorta has a prognosis similar to type A dissection. Conversely, IMH of the descending aorta has a prognosis similar to type B dissections.

Clinical Manifestations

New challenges in the diagnosis of acute aortic syndromes have evolved since the advent of advanced diagnostic and therapeutic modalities. The clinical manifestations are diverse and overlap, with a broad differential diagnosis requiring a

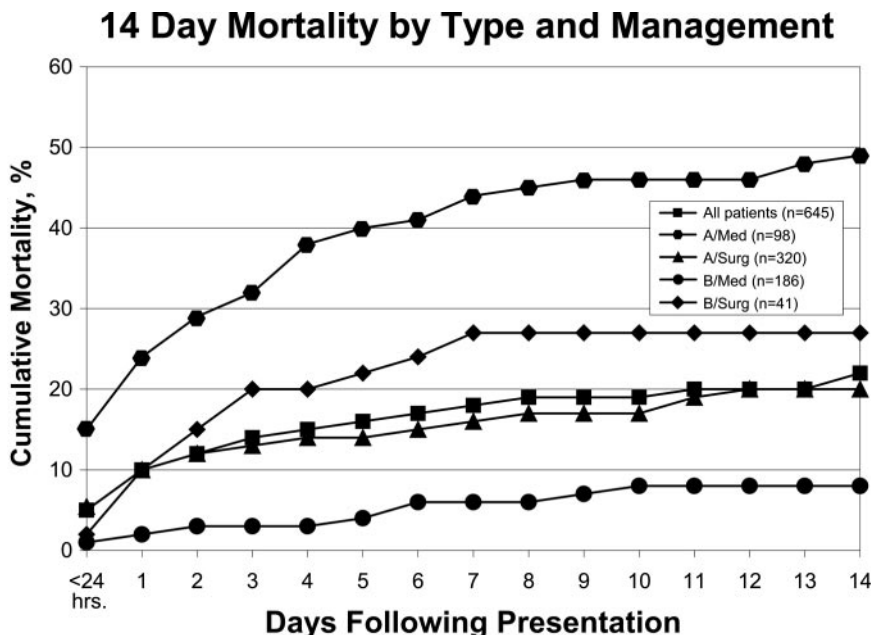


Figure 3. Fourteen-day mortality in 645 patients from the IRAD registry stratified by medical and surgical treatment in both type A and B aortic dissection. Adapted with permission from Reference 12, Copyright 2000, American Medical Association. All rights reserved.

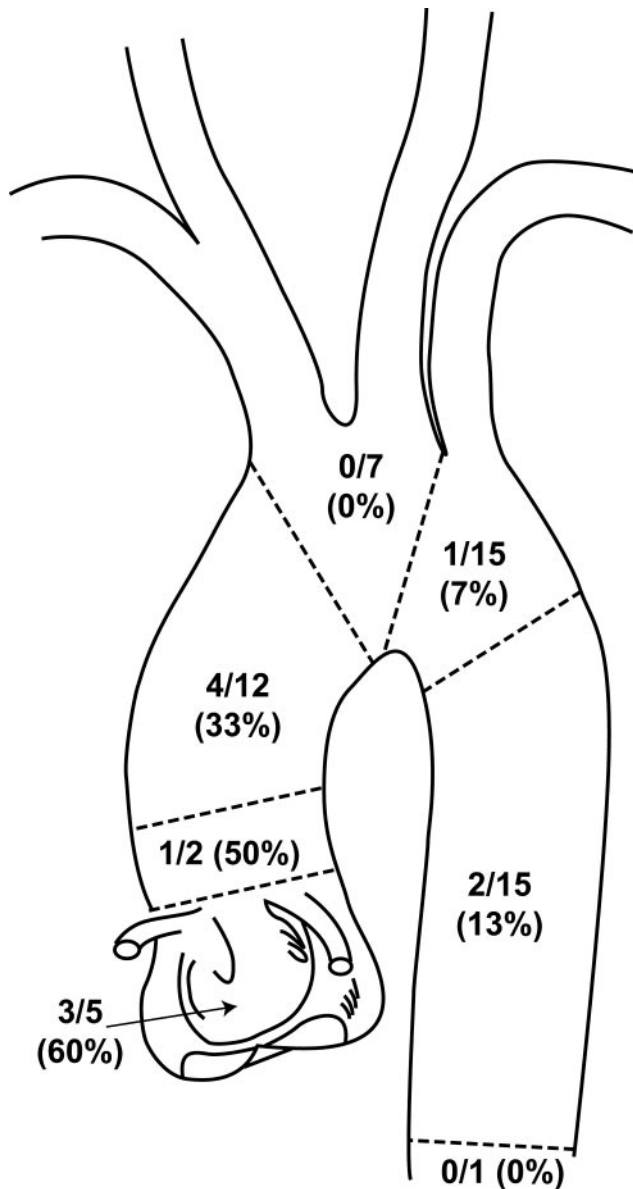


Figure 4. In-hospital mortality for IMH according to site of origin. IMH was defined after the first imaging test failed to demonstrate IMH or dissection but the second test confirmed IMH or the first study showed IMH but no evidence of dissection. Reproduced with permission from Reference 58, Copyright 2005, American Heart Association. All rights reserved.

high clinical index of suspicion to pursue and aggressively treat this disorder.

Patients with aortic dissection typically present with the cataclysmic onset of chest and/or back pain of blunt, severe, and sometimes radiating nature. However, in contrast to classic teaching, tearing, ripping, or migratory were not common descriptors of pain in IRAD; rather, the sudden onset of severe, sharp pain was the single most common presenting complaint. Furthermore, 4.5% of patients denied any pain on presentation. Chest pain was significantly more common in patients with type A dissections (79% versus 63% of type B dissections), whereas both back pain (64% versus 47%) and abdominal pain (43% versus 22%) were signifi-

cantly more common in type B dissection.¹² Hypertension is the most common risk condition associated with aortic dissection, although it is less commonly present at the time of presentation, particularly in patients with type A proximal dissections (36% versus 70% for type B dissection).

Syncope is a well-recognized symptom of acute aortic dissection, often indicating the development of dangerous complications such as cardiac tamponade, obstruction of cerebral vessels, or activation of cerebral baroreceptors. Syncope was reported in 13% of patients in IRAD.⁴⁴ These patients were more likely to die in the hospital (34% versus 23% without syncope) and were more likely to have cardiac tamponade, stroke, neurological deficits, and a proximal dissection. Pulse deficits have also been studied in IRAD. A pulse deficit has been described in 19% to 30% of patients with an acute type A dissection compared with 9% to 21% with a type B dissection.^{12,26,27} These patients have a higher rate of in-hospital complications and mortality than those without a pulse deficit.

Clinical symptoms in the elderly, the young, and women have also been evaluated. Thirty-two percent of 550 type A patients enrolled in IRAD were >70 years of age.⁵⁹ Similar to acute coronary syndromes, typical symptoms (abrupt onset of chest or back pain) and signs (aortic regurgitation murmur or pulse deficits) of dissection were less common among the elderly. In-hospital mortality was higher among older patients (43% versus 28%), and logistic regression analysis identified age >70 years as an independent predictor of hospital death for acute type A aortic dissection. Young patients (age <40 years old) in the registry made up 7% of the cohort but did not differ from the rest of the group with regards to presenting clinical characteristics.¹⁴ Female gender constituted 32% of the IRAD cohort and was significantly older and presented later than men. Furthermore, symptoms of coma/altered mental status were more common in women, whereas pulse deficits were less common.¹³

Recently published from IRAD was a study comparing patients that presented with predominantly abdominal pain (4.6%) compared with patients presenting with more typical symptoms. Patients presenting with abdominal pain experienced a higher mortality than those with more typical symptoms (28% versus 10.2%; $P=0.02$) and a trend toward a delay in diagnosis.⁶⁰ This further emphasizes the atypical symptomatology for some patients and the possibility for acute aortic dissection to mimic other disorders such as stroke, myocardial infarction, vascular embolization, and abdominal pathology. Therefore, diagnosis of this disease requires a high index of suspicion of an aortic dissection in patients who have appropriate risk factors.

THPs: Clinical Manifestations

1. Aortic dissection has a wide range of clinical presentations. Sudden onset of severe sharp pain was the single most common presenting complaint; however, a significant number of patients have atypical symptoms.
2. Variation in pulse and/or blood pressure is a significant finding related to impaired blood flow to an organ or limb induced by the original dissection or by propaga-

tion of the dissection. This finding helps identify patients with aortic dissection.

3. Syncope is a well-recognized symptom of acute aortic dissection, often indicating the development of dangerous complications such as cardiac tamponade and cerebral hypoperfusion.

Diagnostic Strategies

Initial Diagnostic Steps and Decisions

ECG

An ECG should be performed in all patients. This test helps differentiate pain from acute myocardial infarction, for which treatment may include anticoagulation, in contrast to aortic dissection, for which anticoagulation would be contraindicated. Both may coexist and can be further clarified only by adequate suspicion and further diagnostic testing. A normal ECG is seen in one third of patients with coronary involvement; the remainder have nonspecific ST-T-segment changes or typical ST depression or elevation or T-wave inversion.⁶¹ In an IRAD review of 464 patients, the ECG was normal in 31%, showed nonspecific ST and T-wave changes in 42%, showed ischemic changes in 15%, and showed evidence of an acute MI in 5% of patients with an ascending aortic dissection.¹²

Chest X-Ray

Conventional chest radiography may show widening of the aorta with aortic dissection. Other findings include widening of the aortic contour, displaced calcification, aortic kinking, and opacification of the aortopulmonary window.⁶² A routine chest x-ray will be abnormal in 60% to 90% of cases with suspected aortic dissection. However, 10% to 20% of patients will have a completely normal chest x-ray. Because of the limited sensitivity, additional imaging studies are required in almost all patients (98% in IRAD).^{12,26,62}

Imaging Studies

Diagnostic imaging studies in the patient with suspected aortic dissection has the following goals: Confirmation of the diagnosis, tear localization, extent of aortic dissection, classification of aortic dissection, and indicators of emergency (pericardial, mediastinal, or pleural hemorrhage). Additional information not crucial in immediate management includes arch vessel and side-branch involvement.

There has been a shift from an invasive (aortography) to a noninvasive diagnostic strategy for evaluating suspected thoracic aortic dissections. Most patients require multiple imaging studies to diagnose and characterize aortic dissection. In IRAD, the initial study was computed tomography (CT) in 61%, echocardiography in 33%, aortography in 4%, and MRI in only 2%. The mean number of studies performed per patient was 1.8.¹²

Transthoracic Echocardiography

Transthoracic echocardiography (TTE) has limited value for evaluation of the entire thoracic aorta for dissection but is highly useful in identifying proximal aortic dissection and thus may screen for type A dissection in patients with shock. It is limited, however, in visualizing the distal ascending, transverse, and descending aortas in a substantial number of

patients. Nonetheless, TTE continues to be paramount in the assessment of cardiac complications of dissection, including aortic insufficiency, pericardial tamponade, and regional left ventricular systolic function and wall motion.

Transesophageal Echocardiography

Advantages of transesophageal echocardiography (TEE) for the detection of aortic dissection include the close proximity of the esophagus to the thoracic aorta and its ability to visualize with high spatial resolution the distal ascending, transverse, and descending aortas. Although it requires esophageal intubation, TEE is portable and can be performed and immediately interpreted in <10 minutes. The diagnosis of aortic dissection is confirmed when 2 lumens are separated by an intimal flap that can be visualized within the aorta. Tears can be identified and differentiation between the true and false lumen can be achieved. By 2D TEE, the intimal tear can be identified in 61% of patients.⁶³ Furthermore, variants of acute aortic syndromes such as IMH and atherosclerotic penetrating ulcers can also be identified. Overall, the European Cooperative Study Group and others showed that TTE and single and biplane TEE reach a sensitivity of 99% with a specificity of 89%, positive predictive accuracy of 89%, and negative predictive accuracy of 99%.⁶⁴

CT Scan

Spiral CT scanning is readily available in most emergency departments, is performed rapidly, and demonstrates aortic anatomy with great clarity. The diagnosis is based on the demonstration of an intimal flap that separates the true lumen from the false channel. In addition to making the initial diagnosis, CT can also assess the extent of aorta involvement and depict involvement of visceral and iliac arteries. The average sensitivity exceeds 95% with specificities of 87% to 100%.^{65,66} Spiral CT may be more accurate than MRI or TEE in the detection of aortic arch vessel involvement. The disadvantages of standard CT are that the intimal tear is seen in <75% of cases and that the site of entry is rarely identified.⁶⁷ Additionally, potentially nephrotoxic iodinated contrast is required, and there is no capability to assess for aortic insufficiency or to evaluate involvement of the coronary arteries.

MRI Study

MRI is a highly accurate diagnostic tool for the detection of acute aortic dissection. Although MRI has the highest accuracy, sensitivity, and specificity for all types of acute aortic syndromes, it was used in <5% of patients in IRAD.¹² The reasons included the limited availability of MRI, especially on an emergent basis, and the issues surrounding patient inconvenience and limited applicability (MRI cannot be performed on patients with claustrophobia, pacemakers, aneurysm clips, or other metal devices). For these reasons, MRI is used as a second diagnostic study when a first imaging study is not adequate or the true diagnosis remains uncertain. Also, MRI contrast agents have a more favorable safety profile than iodinated contrast agents.

Aortography

Retrograde aortography was the first accurate diagnostic tool to assess patients with suspected aortic dissection and was

considered the diagnostic standard of care in the 1960s through 1980s. With the advent of more accurate noninvasive diagnostic techniques, aortography currently is rarely performed. The specificity for diagnosing aortic dissection is >95%, but its sensitivity is lower than other techniques, $\approx 90\%$.^{64,68}

Coronary Angiography

In some patients, delineation of the coronary anatomy is desirable before invasive surgery. Although noninvasive imaging technology is improving, the gold standard remains coronary angiography. Not surprisingly, the concomitant presence of coronary artery disease at the time of diagnosis of aortic dissection is $\approx 25\%$.⁶⁹ It is unclear whether there is any perioperative or postoperative benefit to doing preoperative coronary angiography for all stable patients.⁷⁰ Mortality after surgery for aortic dissection seems unrelated to myocardial ischemia; therefore, we cannot conclude that revascularization intraoperatively would change postoperative outcomes.

THPs: Diagnostic Strategies

1. Contrast-enhanced spiral CT scanning, TEE, and MRI are all extremely accurate in the diagnosis of acute aortic dissection.
2. Selection of a diagnostic test for suspected aortic dissection requires consideration of both the information required and the access to and experience with the imaging modality at the institution.
3. In IRAD, CT scan was used most frequently as the first test in 61% of cases, and TTE or TEE was used as a secondary technique in 56% of the cases. An average of 1.8 methods was used to diagnose acute aortic dissection.

Status of Biomarkers for Aortic Dissection

The development of a reliable method for serum diagnosis of acute aortic dissection is extremely attractive, given the relative frequency of chest pain in patients presenting to emergency departments but the relative infrequency of aortic dissection. The most promising biomarker to date for diagnosing acute aortic dissection is an assay of circulating smooth muscle myosin heavy chain protein, a protein that is released from damaged aortic medial smooth muscle and elevated in the early hours after acute aortic dissection.⁷¹ In patients presenting within 3 hours of symptom onset with proximal dissection, the sensitivity approached 91% with a specificity of $\approx 98\%$ compared with healthy volunteers. Additional biochemical markers are under intense study, including acute-phase reactants such as the white blood cell count, C-reactive protein, fibrinogen, and D-dimer.⁷²

More recently, soluble elastin fragments have been measured in the serum of patients with acute aortic dissection.⁷³ However, measurement of serum elastin fragments is a tedious process, and patients who have developed thrombosis of the false lumen do not have characteristic elevations in this protein, limiting its diagnostic capability in this cohort of acute aortic syndromes. Thus, there currently is no readily available, reliable, bedside biomarker assay for acute aortic dissection. However, recent experiences with inflammatory

TABLE 4. Initial Management of Patients With Suspected Aortic Dissection

Recommendation*	Class
ECG: documentation of ischemia	I
Heart rate and blood pressure monitoring	I
Pain relief (morphine sulfate)	I
Reduction of systolic blood pressure with β -blockers (intravenous metoprolol, esmolol, or labetalol)	I
In patients with severe hypertension despite β -blockers, additional vasodilator (intravenous sodium nitroprusside to titrate blood pressure to 100–120 mm Hg)	I
In patients with obstructive pulmonary disease, blood pressure lowering with calcium channel blockers	II
Imaging in patients with ECG signs of ischemia before thrombolysis if aortic pathology is suspected	II
Chest x-ray	III

*All recommendations are level of evidence C

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proteins and those related to the tensile elements in the aortic wall hold promise for identification of a future serum biomarker or panel of markers that may aid in the more rapid diagnosis of acute aortic dissection.

THPs: Status of Biomarkers for Aortic Dissection

1. A biomarker identifying acute aortic syndromes would be highly attractive in differentiating chest pain syndromes for which management is vastly different.
2. Biomarkers are under intense study, but there currently is no readily available, reliable, bedside biomarker assay for acute aortic dissection.

Treatment

General Principles

Acute dissections involving the ascending aorta are considered surgical emergencies. In contrast, dissections confined to the descending aorta are treated medically unless the patient demonstrates progression of dissection, intractable pain, organ malperfusion, or extra-aortic blood.

Initial Medical Therapy

The primary objective is to normalize blood pressure and to reduce the force of left ventricular ejection (dp/dt), which are the main determinants of dissection extension and rupture. β -Blockers as a group of agents have the most desirable effect and should be titrated to reduce the patient's heart rate and blood pressure to the lowest tolerable levels while ensuring adequate cerebral, coronary, and renal perfusion. For most patients, a blood pressure between 100 and 120 mm Hg with a heart rate <60 bpm is attainable. In patients with potential intolerance to β -blockers (those with asthma, bradycardia, or signs of heart failure), esmolol seems to be a reasonable choice because of its short half-life to test the patient's reaction to β -blockers. Less is known about the role for calcium channel blockers. However, in patients who are truly β -blocker intolerant, drugs such as verapamil or diltiazem

may be useful for reducing blood pressure while not causing a reflex tachycardia (Table 4).

If β -blockers alone do not control blood pressure, vasodilators are ideal additional agents. However, they should not be used as monotherapy before the use of β -blockers because vasodilators increase the force of left ventricular ejection, thereby leading to an increased aortic wall stress. Sodium nitroprusside is typically the first vasodilator of choice in patients who continue to be hypertensive despite β -blocker therapy. Pain may also contribute to hypertension and tachycardia, making pain control, usually with morphine sulfate, an important aspect of management.

In patients with low and even normal blood pressure at presentation, possible volume depletion from hemorrhage into the false lumen, pericardial space, mediastinum, or pleural space must be considered. These patients at times need to be intubated before rapid tomographic imaging for swift diagnosis and treatment. If pericardial tamponade is diagnosed, pericardiocentesis as an initial therapeutic step before surgery may be harmful because it reduces intrapericardial pressure and therefore may cause recurrent pericardial bleeding and sudden death.⁷⁴

THPs: Treatment: Medical Stabilization

1. The primary goal of medical therapy is to decrease the force of left ventricular contraction (dP/dt) and systemic blood pressure, which are the main determinants of dissection extension and rupture.
2. β -Blockers first, other antihypertensives such as vasodilators, and adequate analgesia should be initiated to keep systolic blood pressure <120 mm Hg and heart rate <60 bpm.
3. Patients with hemodynamic instability at presentation in whom aortic dissection is strongly suspected should be intubated and rapidly sent to diagnostic imaging and surgical therapy.

Definitive Therapy

Ascending (Type A) Aortic Dissection

Acute ascending aortic dissections (Stanford type A or DeBakey type I or II) should be treated as a surgical emergency because these patients are at a high risk of life-threatening complications. Medical management alone is associated with a mortality of nearly 20% by 24 hours and 30% by 48 hours. Surgical treatment aims to treat or prevent the common and lethal complications such as aortic rupture, stroke, visceral ischemia, cardiac tamponade, and circulatory failure. Fifty years ago, Dr DeBakey introduced effective surgical techniques that dramatically improved the prognosis of patients presenting with acute type A aortic dissections. His techniques encouraged (1) excision of the intimal tear, (2) obliteration of entry into the false lumen, and (3) reconstitution of the aorta with interposition of a synthetic graft with or without reimplantation of the coronary arteries.¹⁶ In addition, restoration of aortic valve competence is paramount in patients who develop aortic insufficiency. This can be achieved by resuspension of the native aortic valve or by aortic valve replacement and is dependent on the size of the

TABLE 5. Surgical Therapy of Acute Type A (Type I and II) Aortic Dissection

Recommendation*	Class
Emergency surgery to avoid tamponade/aortic rupture	I
Valve-preserving surgery—tubular graft if normal-sized aortic root and no pathological changes in valve cusps	I
Replacement of aorta and aortic valve (composite graft) if ectatic proximal aorta and/or pathological changes of valve/aortic wall	I
Valve-sparing operations with aortic root remodeling for abnormal valves	IIa
Valve preservation and aortic root remodeling in Marfan patients	IIa

*All recommendations are level of evidence C.

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aortic root and the condition of the aortic valve. Table 5 outlines the recommendations from the European Society of Cardiology task force on the surgical treatment of acute type A aortic dissections.⁴³

Operative mortality for ascending aortic dissections at experienced centers with large surgical series varies widely between 15% and 35%, still below the 50% mortality with medical therapy.^{12,59,75–78} Adjunctive measures such as profound hypothermic circulatory arrest and selective retrograde perfusion of the head vessels have been used in the surgical management of arch repair of an open distal anastomosis with good outcomes.⁴⁶ The use of both hypothermic circulatory arrest and retrograde perfusion has yielded survival rates at 3 and 5 years of $75 \pm 5\%$ and $73 \pm 6\%$. However, a retrospective comparative evaluation of surgical strategies using profound hypothermic circulatory arrest versus no profound hypothermic arrest patients found no difference in survival and distal operation rates, with total 30-day, 1-year, and 5-year survival estimates of $81 \pm 2\%$, $74 \pm 3\%$, and $63 \pm 3\%$. Although definitive treatment of acute type A aortic dissections includes surgery, only 80% of patients in IRAD underwent surgery. The main reasons cited for medical therapy were comorbid conditions, old age (mean, 80 years), and patient refusal.

THPs: Treatment: Type A Dissection

1. Surgery provides definitive treatment for patients with type A acute aortic dissection.
2. The aim of surgery is to prevent aortic rupture and pericardial tamponade and to relieve aortic regurgitation.
3. In general, implantation of a composite graft in the ascending aorta with or without reimplantation of coronary arteries is performed.
4. A large variety of surgical approaches exists.

Descending (Type B) Aortic Dissection

In the current era, endovascular interventions for acute descending (type B) aortic dissection is reserved for complications of the disease because surgical repair has no proven superiority over medical or interventional treatment in stable patients. Patients with uncomplicated aortic dissections confined to the descending thoracic aorta (Stanford type B or DeBakey type III) are at present treated with medical therapy but may be considered candidates for endovascular therapy in

the near future. Medical treatment consists of invasive hemodynamic monitoring, β -blockade, and arterial vasodilators if needed to keep systolic blood pressure <120 mm Hg. Pain control with morphine sulfate is also important to attenuate the sympathetic release of catecholamines to pain with resultant tachycardia and hypertension. Once the patient is stable, oral β -blockers and other antihypertensive medications are continued under close follow-up with imaging and clinical assessment in 6-month intervals.

In a series of 384 patients with type B dissections from IRAD, 73% were managed medically. In-hospital mortality for these patients was 10%.²⁶ The reported long-term survival rate with medical therapy is \approx 60% to 80% at 4 to 5 years and \approx 40% to 45% at 10 years.^{79–81} Survival is best in patients with noncommunicating dissections.

Indications for operation in patients with acute type B aortic dissections are generally limited to the prevention or relief of life-threatening complications. These complications include aortic rupture, ischemia of limbs and organ systems, persistent or recurrent intractable pain, progression of dissection, aneurysm expansion, and uncontrolled hypertension. In most series, operations for acute type B aortic dissections carry a higher mortality that historically ranges between 35% and 75%. Furthermore, because patients treated surgically are primarily those with a complicated course, the short-term mortality for such patients is higher than with medical therapy.²⁶

THPs: Treatment: Type B Aortic Dissection

1. Patients with uncomplicated aortic dissections confined to the descending aorta are at present best treated with medical therapy.
2. Medical therapy includes β -blockers, other antihypertensives, and adequate analgesia to keep systolic blood pressure <120 mm Hg.
3. The indications for endovascular interventions in type B dissection are accepted for persistent or recurrent pain, aortic expansion, dissection progression, and end-organ malperfusion syndromes.

Intramural Hematoma

Similar to type A and B aortic dissection, surgery is advocated in patients with type A IMH and initial medical therapy in patients with type B IMH. A meta-analysis of 143 patients found that patients with lesions of the ascending aorta had a lower mortality with surgery than medical treatment (14% versus 36%). Patients with lesions of the descending aorta had a similar mortality with medical or surgical therapy (14% versus 20%).³⁶ The cardiology and surgical community has generally concluded that acute IMH involving the ascending aorta should be managed surgically because of an unacceptably high mortality with medical treatment.^{17–21,31,58,82} Given these uncertainties, until further studies are definitive, many experts recommend aortic repair for acute IMH of the ascending aorta similar to type A dissection and aggressive medical therapy for IMH in the descending aorta similar to type B dissection.⁸²

THPs: Treatment: IMH

1. Surgery is advocated in patients with acute IMH involving the ascending aorta.
2. Aggressive medical therapy is advocated in patients with acute IMH involving the descending aorta.

Interventional Therapy by Stent-Graft Placement and/or Fenestration

Endovascular stent grafting has been successfully used in patients with abdominal and thoracic aneurysms and has been explored as a less invasive alternative in patients with stable type B aortic dissections. Furthermore, stent-graft placement and/or fenestration has also been applied to treat aortic branch occlusions resulting from malperfusion syndromes in both type A and B acute aortic dissections.⁸³

Aims of treatment include reconstruction of the thoracic aortic segment containing the entry tear, induction of thrombosis of the false lumen, and reestablishment of the true lumen and side-branch flow. The exact role of percutaneous fenestration and stent placement in acute aortic dissection is still evolving. Patients with acute aortic dissection may have life-threatening complications manifested by end-organ ischemia. The mortality rate of patients with renal ischemia is 50% to 70% and as high as 87% in mesenteric ischemia.^{27,84,85} Although the surgical success rate at reversing peripheral pulse deficits is high, the surgical in-hospital mortality rates in the setting of end-organ ischemia remain as high as 89%.^{86–88} As such, percutaneous management of this complication has emerged as a viable therapy before or after definitive surgical management if needed.

In 384 patients with acute type B aortic dissections in IRAD, 46 (12%) were managed with endovascular stent grafting, which was similar to the number of patients treated with surgery (56, 15%).²⁶ Only 3 (6.5%) died during the initial hospitalization. Nienaber et al⁸⁹ compared the outcome of stent grafting with surgery in a nonrandomized evaluation of 24 patients with chronic type B aortic dissection with at least 1 indication for surgery. Stent-graft placement resulted in no morbidity or mortality, whereas surgery for type B dissection was associated with 4 deaths (33%) and 5 serious adverse events within 12 months. Dake et al⁹⁰ studied the placement of endovascular stent grafts across the primary entry tear in 19 patients with acute aortic dissection (4 patients with type A, 15 with type B). Dissections involved aortic branches in 14 of the 19 patients (74%), and symptomatic compromise of multiple branch vessels was observed in 7 patients (37%). Placement of stent grafts across the primary tear was technically successful in all 19 patients. Complete thrombosis of the false lumen was achieved in 15 patients (79%). Revascularization of ischemic branch vessel was successful in 76% of the obstructed branches. Three of 19 patients (16%) died at 30 days without further death during the subsequent average follow-up of 13 months.

The European Society of Cardiology Task Force on Acute Aortic Dissection released its recommendations for the indications for stent graft and/or fenestration in 2001 (Table 6).⁴³ Additionally, in high-risk patients not suitable for surgery because of age, comorbid conditions, or personal preference,

TABLE 6. Interventional Therapy in Aortic Dissection

Recommendation*	Class
Stenting of obstructed branch origin for static obstruction of branch artery	Ila
Balloon fenestration of dissecting membrane plus stenting of aortic true lumen for dynamic obstruction	Ila
Stenting to keep fenestration open	Ila
Fenestration to provide reentry tear for dead-end false lumen	Ila
Stenting of true lumen	
To seal entry (covered stent)	IIb
To enlarge compressed true lumen	Ila

*All recommendations are level of evidence C.

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endovascular repair offers palliative treatment to those who otherwise would have been left to follow the natural history of the disease.

THPs: Treatment: Endovascular Therapy

1. Endovascular stent grafts have been used successfully as a less invasive procedure for patients with surgical indications for chronic type B aortic dissections.
2. Endovascular therapies continue to evolve in the treatment of malperfusion syndromes in type A and B aortic dissections and serve to complement or sometimes replace the need for open surgical procedures.

Long-Term Follow-Up

The 10-year actuarial survival rate of patients with an aortic dissection who leave the hospital has ranged from 30% to 60% in different studies.^{75–81} The long-term approach to these patients begins with an understanding that dissection of the aorta represents a systemic problem with the aortic media and the milieu in which it is bathed. Thus, the entire aorta and its branches are predisposed to dissection, aneurysm formation, and/or aortic rupture in the future. Systemic hypertension, advanced age, aortic size, and the presence of a patent false lumen are all factors that identify a higher risk of complications. Therefore, the 3 main management issues in these patients include medical therapy to minimize aortic wall stress; serial imaging to detect signs of dissection progression, redissection, or aneurysm formation; and reoperation when indicated.

All patients should receive lifelong treatment of hypertension. β -Blockers are the treatment of choice, with a recommended goal blood pressure of <120/80 mm Hg for most patients.^{91–93} Regular assessment of the aorta should be performed 1, 3, 6, 9, and 12 months after discharge and every 6 to 12 months thereafter, depending on aortic size.⁴³ The most important imaging findings are aortic diameter, signs of aneurysm formation, and hemorrhage at surgical anastomoses or the stent-graft site. This aggressive strategy highlights the observation that both hypertension and aortic expansion/dissection are common and not easily predicted in the first months after discharge.

In 12% to 30% of patients, repeated surgery is required usually because of extension or recurrence of dissection at the

previous site of intervention, localized aneurysm formation remote from the site of repair, graft dehiscence, aortic regurgitation, or infections.^{30,94} Because of the predilection for the diseased aorta to become aneurysmal in a location distinct from the area of dissection, imaging of the entire extent of the aorta from time to time is necessary.

THPs: Follow-Up

1. Close follow-up by a specialized team includes the assessment of signs of aortic expansion, aneurysm formation, signs of leakages at anastomoses/stent sites, and malperfusion.
2. Excellent blood pressure control of <120/80 mm Hg is paramount to prevent complications.
3. After hospital discharge, regular outpatient visits and imaging should be performed at 1, 3, 6, 9, and 12 months and every 6 to 12 months thereafter, depending on aortic size.

Conclusions

Much has been learned about the risk factors, clinical characteristics, diagnosis, and management of acute aortic dissection over the last decade. Technological advances in imaging techniques and a better understanding of the pathobiology of acute aortic dissection have led to the discovery of variants of aortic pathologies now called acute aortic syndromes. Furthermore, diverse surgical and percutaneous strategies to treat aortic syndromes are continuing to improve and evolve. As a result of knowledge and interest in this area, the outcomes of patients treated for acute aortic syndromes have improved. However, there is still much work to be done. The use of care pathways that facilitate efficient and streamlined care similar to acute coronary syndromes or strokes has the potential to improve patient outcomes. Serum biomarkers offer hope for easier identification of patients with acute aortic syndromes as opposed to acute coronary disease. Finally, with continued enthusiasm in learning more about this disorder in concert with continued improvements in the diagnosis and management of this disease, further advances are inevitable.

Disclosures

None.

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