# Pictorial Essay

## Pathogenesis in Acute Aortic Syndromes:
## Aortic Aneurysm Leak and Rupture and Traumatic Aortic Transection

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This pictorial essay focuses on the pathophysiology of enlargement and rupture of the atherosclerotic aortic aneurysm and on mechanisms involved in traumatic aortic transection related to deceleration injury.

### Aortic Aneurysm Leak and Rupture

The wall stress related to blood pressure in the nonaneurysmal aorta is relatively low and uniformly distributed, whereas within the aortic aneurysm, regions of high- and low-stress distribution are present [1]. Increased tension stress results in progressive vessel dilatation and weakening of the aortic media. According to Laplace's law, wall tension is proportional to the vessel radius for a given blood pressure. When an artery wall develops a weak spot and expands as a result, it might seem that the expansion would provide some relief, but in fact the opposite is true. The expansion subjects the weakened wall to even more tension. The weakened vessel continues to expand (Fig. 1). A localized weak spot in an artery might gain temporary tension relief by expanding toward a spherical shape because a spherical membrane has half the wall tension for a given radius. Unfortunately, in an expanding aneurysm, forming a near-spherical shape cannot give sufficient tension relief. Aortic aneurysm rupture is believed to occur when the mechanical stress on the wall exceeds the strength of the wall tissue (Fig. 2). Infected aortic aneurysm is a rare lesion, which may progress rapidly to aortic rupture or uncontrolled sepsis with high mortality rate.

Abdominal aortic aneurysms expand at a rate of 2–4 mm per year for aneurysms smaller than 4 cm, 2–5 mm for aneurysms 4–5 cm, and 3–7 mm for those larger than 5 cm. The rupture risk at 4 years is 2%, 10%, and 22%, respectively [2]. Abdominal aortic aneurysm is seen concomitantly in 42.1% of patients with penetrating aortic ulcers and 29.4% of patients with intramural hematomas [3]. Aneurysms in patients with aortic ulcer and intramural hematoma tend to be larger than those associated with classic aortic dissection (6.2 and 5.5 cm vs 5.2 cm, respectively) [3]. In the presence of penetrating aortic ulcer, gradual enlargement of the aorta and extension of intramedial

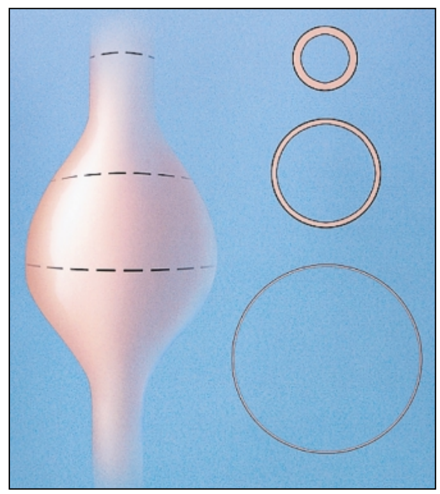

**Fig. 1.**—Drawing shows enlarging aortic aneurysm. First, wall tension is proportional to vessel radius, according to Laplace's law: $T = P \times r$, where $T$ is circumferential wall tension, $P$ is transmural pressure, and $r$ is mean vessel radius. Second, increased tension stress from blood pressure results in progressive vessel dilatation and weakening of aortic media, which lead to enlargement of aortic aneurysm. Third, when mechanical stress on wall exceeds strength of wall tissue, aortic aneurysm ruptures.

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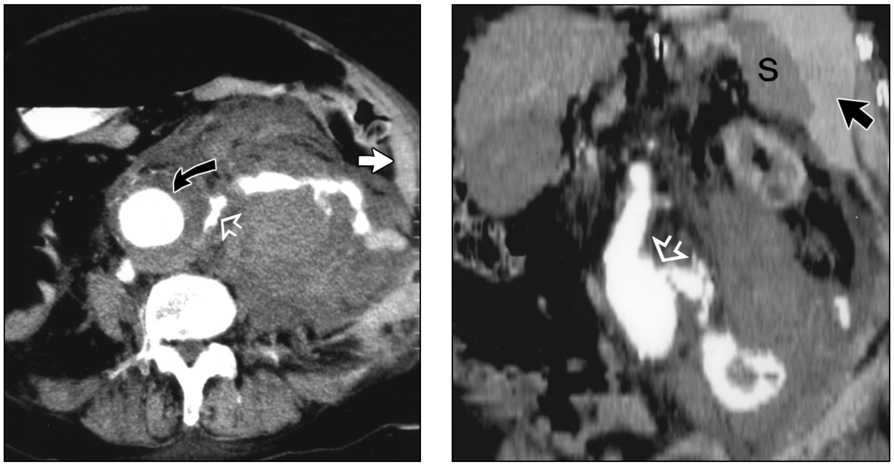


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**Fig. 2.**—79-year-old man with acute rupture of abdominal aortic aneurysm that occurred during CT.
**A,** Contrast-enhanced CT scan obtained at level of extravasation (*open arrow*) shows large left retroperitoneal hematoma and enhanced blood in left paracolic gutter (*solid straight arrow*). Note eccentric intramural hematoma (*curved arrow*) within aortic lumen on side of extravasation.
**B,** Coronal multiplanar reformatted CT image shows aortic rupture with active extravasation from irregular ulcerlike lesion in distal abdominal aorta (*open arrow*). Note enhanced blood (*solid arrow*) around spleen (S) and that spleen is displaced medially.

A B

**Fig. 3.**—76-year-old woman with disseminated tuberculosis and saccular pseudoaneurysm arising from distal descending thoracic aorta.
**A,** Volume-rendered CT scan of axial view of descending thoracic aorta shows large pseudoaneurysm (*straight arrow*) that arises posteriorly and causes flattening of aortic lumen (*curved arrow*).
**B,** Volume-rendered CT scan of left anterior oblique view of aorta shows calcified atherosclerotic plaque (*arrowheads*), limiting superior and inferior extent of pseudoaneurysm.

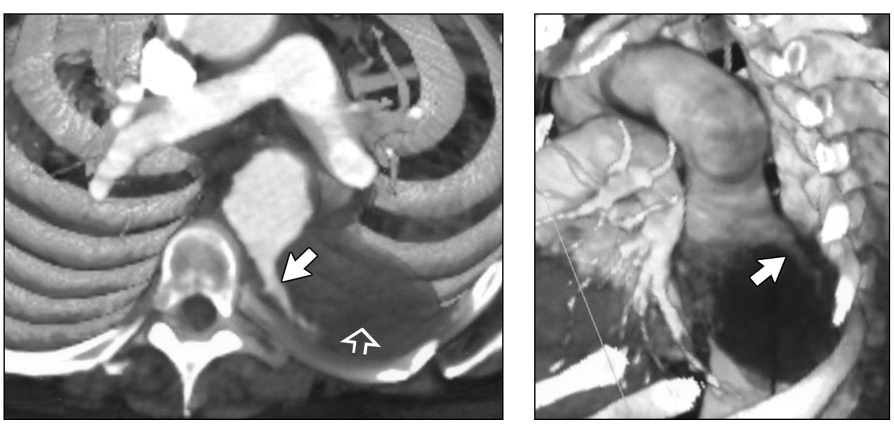

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**Fig. 4.**—71-year-old woman with thoracic aortic pseudoaneurysm due to penetrating atherosclerotic ulcer.
**A,** Volume-rendered CT scan of axial view shows contrast material leaking from aortic lumen (*solid arrow*) into posterior pseudoaneurysm (*open arrow*) of proximal descending thoracic aorta.
**B,** Volume-rendered CT scan of oblique view of pseudoaneurysm shows site of contrast leak (*arrow*).

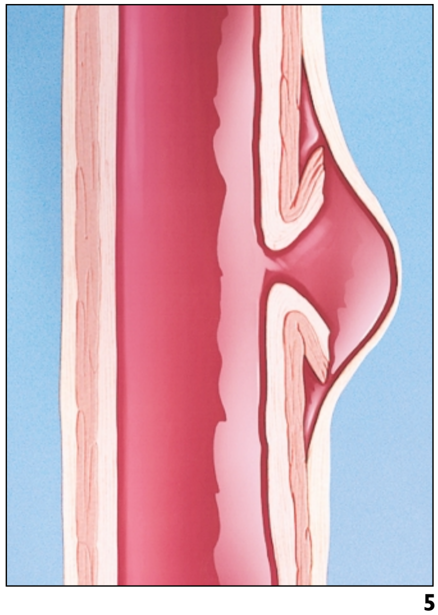

**Fig. 5.**—Diagram shows aortic wall transection with injury to intima and media but with intact adventitia and formation of pseudoaneurysm.

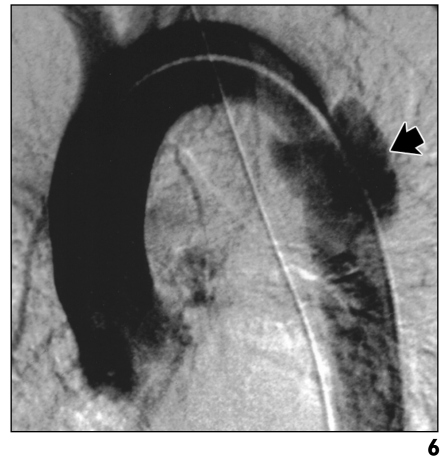

**Fig. 6.**—33-year-old man involved in deceleration injury that caused traumatic transection of aorta. Left anterior oblique thoracic aortogram shows pseudoaneurysm (*arrow*) in classic location, approximately 2 cm distal to origin of left subclavian artery.

hematoma cause stretching of the weakened aortic wall and may lead to a saccular aortic aneurysm or pseudoaneurysm (Figs. 3 and 4). The weakened aortic wall may eventually rupture. Most spontaneous aortic ruptures are believed to be associated with perforation through the atheromatous plaque. The proposed mechanism for rupture is pressure atrophy of the media due to overlying intimal atherosclerotic plaque with localized distention of the aortic wall resulting from intramural hematoma before perforation [4].

## Traumatic Aortic Transection

One of the accepted mechanisms for traumatic aortic rupture from rapid deceleration involves a combination of traction, torsion, and hydrostatic forces created by differential deceleration of thoracic structures. Unequal horizontal shear forces that are applied during high-speed deceleration cause the mobile ascending and descending aorta to lag behind the transverse aortic arch, which is relatively fixed by the brachiocephalic vessels [5]. Deceleration forces place the maximal stress on those segments of the aorta and great vessels at the points of attachments, the aortic isthmus, and the aortic root. Another hypothesis involves the osseous pinch theory [6], which proposes that aortic rupture occurs when the aorta is pinched between the spine and the anterior bony thorax (the manubrium, clavicle, and first ribs) during chest compression caused by abrupt deceleration. The most commonly injured site is just distal to the left subclavian artery. The ligamentum arteriosum and the intercostal vessels fix the distal arch and de-

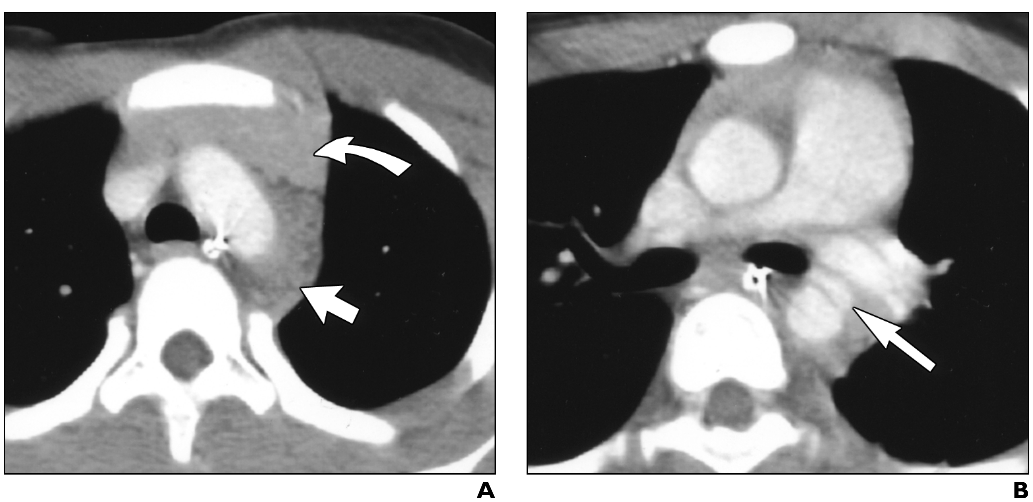

**Fig. 7.**—13-year-old boy who was struck by car while riding his bicycle. Patient sustained subarachnoid hemorrhage; traumatic aortic transection; contusions of liver, spleen, and kidneys; and pelvic and lower extremity fractures.

**A,** Contrast-enhanced CT scan shows periaortic hematoma. Note difference in attenuation between thymus (*curved arrow*) and hematoma (*straight arrow*). Nasogastric tube is not deviated.

**B,** Axial CT scan shows intimal disruption with pseudoaneurysm (*arrow*) filled with contrast material.

**(Fig. 7 continues on next page)**

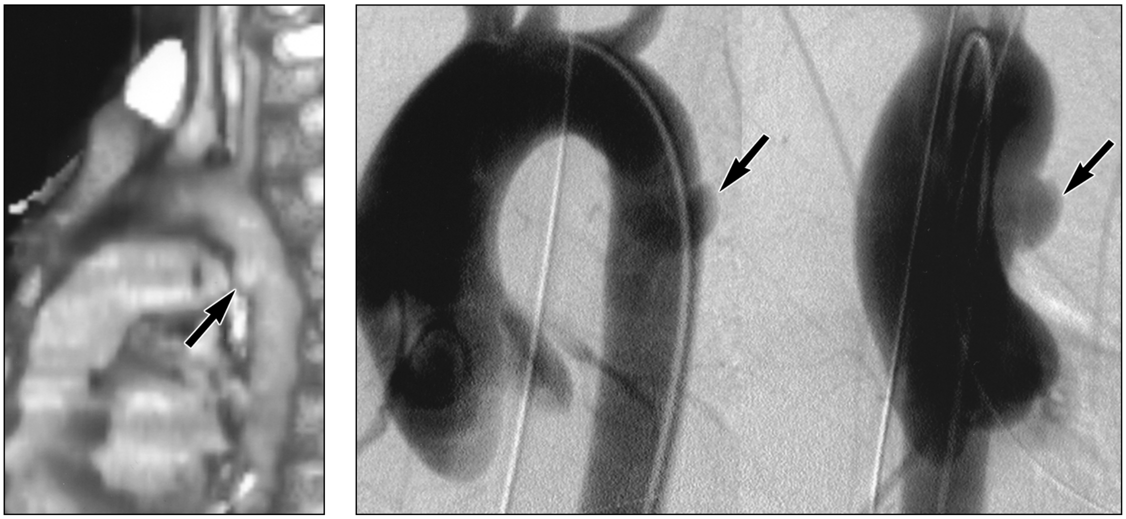

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**Fig. 7. (continued)**—13-year-old boy who was struck by car while riding his bicycle. Patient sustained subarachnoid hemorrhage; traumatic aortic transection; contusions of liver, spleen, and kidneys; and pelvic and lower extremity fractures.
**C,** Volume-rendered CT scan shows small pseudoaneurysm (*arrow*) in classic location distal to left subclavian artery.
**D,** Left anterior oblique and anteroposterior angiograms of thoracic aorta show contained transection of proximal descending aorta (*arrows*), just below level of ligamentum arteriosum.

scending thoracic aorta in apposition to the vertebral bodies. The superior portion of the arch is held in place by the great vessels extending from the thoracic inlet into the neck. Therefore, the relatively fixed proximal descending aorta cannot move away from the bony structures as they pinch and transect it.

In more than 80% of the cases, rupture is complete—through all three layers of the aorta—and results in exsanguination and death at the site where the individual sustains the trauma. The spectrum of findings in incomplete rupture in traumatic aortic transection includes intramural hematoma without intimal tear, intimal tear, abrupt change in the contour of the aorta, diminished caliber of the descending aorta (pseudocoarctation), pseudoaneurysm (Figs. 5–8), and extravasation of contrast material from the aorta.

Aortic ductus diverticulum is an anatomic variant that should not be mistaken for a pseudoaneurysm. This variant typically occurs at the aortic isthmus and presents as a smooth focal bulge that forms gentle, obtuse angles with the aortic wall. It is usually located at the anteromedial aspect of the aorta. Aortic ductus diverticulum is best visualized on angiography or reformatted CT. On axial CT scans, diverticulum has smooth transition between the CT slices and is difficult to diagnose. In contrast, a posttraumatic pseudoaneurysm is variable in shape and usually has sharp margins. On axial images, the transition from a normal aorta to the site of transection is abrupt, with a change in contour, presence of intimal flap, or contrast extravasation.

The most common sites of arterial injuries are aortic rupture alone (81%), aortic arch branches alone (16%), and both aorta and aortic branches (3%). Among the aortic injuries, 96% occur at the aortic isthmus distal to the left subclavian artery, 1% at the aortic isthmus and proximal ascending aorta, 1% at the proximal ascending aorta only, 1% at the distal ascending aorta only, and less than 1% at the descending aorta [7].

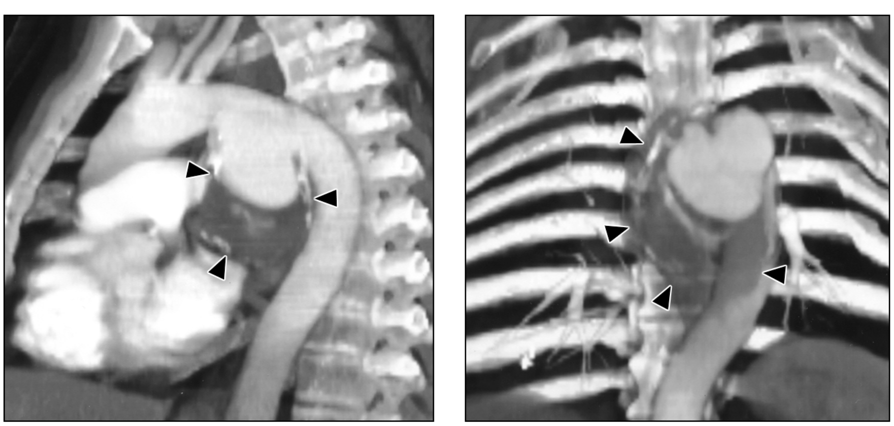

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**Fig. 8.**—69-year-old man involved in severe motor vehicle collision 34 years earlier.
**A,** Volume-rendered CT scan obtained in left anterior oblique projection shows classic location for traumatic aortic transection (*arrowheads*), just beyond origin of left subclavian artery. Pseudoaneurysm is partially thrombosed with peripheral calcifications that indicate its chronic nature.
**B,** Volume-rendered CT scan of anteroposterior view of thoracic aorta shows extent of pseudoaneurysm (*arrowheads*).

## Summary

Diagnostic algorithms in evaluation of aortic emergencies are changing. Catheter angiography has traditionally been the gold standard for evaluating patients with aortic disease. However, currently helical CT plays the dominant and critical role in the evaluation of patients presenting with aortic emergencies. In the evaluation of patients with acute thoracic injuries, helical CT had a sensitivity and negative predictive value equivalent to those of aortography [8]. CT angiography was 100% sensitive and performed better than conventional angiography [9] in the evaluation of aortic aneurysm extent. The advancement in helical CT brings this modality to the forefront of acute aortic imaging as a reliable and noninvasive technique for definitive evaluation of patients with aortic aneurysm and traumatic aortic transection and not just as a screening modality before ordering an aortogram.

## References


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The reader's attention is directed to "Pathogenesis in Acute Aortic Syndromes: Aortic Dissection, Intramural Hematoma, and Penetrating Atherosclerotic Aortic Ulcer," which follows this article.