

# ANEURYSMS

An **aneurysm** is an irreversible dilatation of an artery to at least one and one-half times its normal diameter. The most common sites are (aortic > iliac > popliteal > femoral arteries). The carotid, renal, visceral, and upper extremity arteries can also develop aneurysms.

**Arterial ectasia** refers to localized arterial enlargement less than 50% of normal diameter.

## Classification

### 1. According to shape:-

It is helpful to further classify aneurysms as saccular or fusiform. **Saccular** aneurysms usually arise from a distinct portion of the wall and have a mouth, whereas **fusiform** aneurysms involve the total circumference of the artery and represent a diffuse dilatation.

### 2. According to wall layer involvement :-

Aneurysms may involve all layers of the arterial wall (**true aneurysm**) or only a portion of the vessel wall or surrounding tissue (**false aneurysm**).

**Dissecting aneurysms** most commonly occur in the thoracic aorta with possible involvement of the abdominal aorta.

### 3. According to cause :-

**Aneurysms can be classified as** ☛ nonspecific, ☛ traumatic, ☛ dissecting, ☛ mycotic, ☛ anastomotic, ☛ childhood, and those ☛ associated with pregnancy.

## ☒ Degenerative Aneurysms

The most common type of aneurysm has been called **atherosclerotic**, but since the role of atherosclerosis in aneurysmal disease is unclear, **the term "degenerative" is more appropriate**. This view is supported by histologic evidence that demonstrates degeneration of the arterial wall. **The intima usually is absent** and replaced with compacted fibrin in multiple layers; the **media has fragmented and reduced numbers of elastic lamellae**; and, most important, there is focal loss of elastic tissue. An **imbalance between the two enzymes** important in the metabolism of elastin, **elastase** (degradation) and **α1-antitrypsin** (synthesis), has been identified in patients with aneurysms as compared to occlusive disease. This imbalance becomes even more pronounced in multiple aneurysms and ruptured aneurysms.

## ☒ Traumatic Aneurysms

Many early descriptions of aneurysms dealt with **traumatic** or **false aneurysms** or **pseudoaneurysms**. Most traumatic aneurysms today are due to arterial catheterization or penetrating injuries. These lesions are characterized by a focal defect in the arterial wall, with the hemorrhage contained by the surrounding tissues. With time, a fibrous capsule forms around the hematoma, but a definite risk of rupture is present because the surrounding tissues do not withstand arterial pressures and cannot contain the hemorrhage indefinitely.

## ⊗ Poststenotic Aneurysms

**True aneurysms** (involving all three layers of the normal arterial wall) can occur from the hemodynamic perturbations associated with an arterial stenosis. Aneurysms due to poststenotic dilatation are most often seen in **thoracic outlet syndrome** distal to a cervical rib, distal to **coarctation of the aorta**, and distal to **aortic or pulmonary valvular stenoses**. These aneurysms do not have any preexisting defect but become dilated, possibly as a result of the increased lateral wall pressure suggested by Bernoulli's theorem. Once dilated, these arteries progressively enlarge according to Laplace's law, and reversal of the hemodynamic aberration does not result in regression of the aneurysm.

## ⊗ Dissecting Aneurysms

The primary pathologic process in a dissecting aneurysm is a longitudinal splitting of the layers of the arterial wall. Whether the process begins with hemorrhage within the medial arterial layer or with a tear in the intima is unclear. The end result is a proximal intimal defect that allows blood to flow into a false channel that "dissects" between the intima and the inner two-thirds of the media. A site of reentry can occur distally, allowing blood to flow through the false channel. *External rupture of the outer wall may occur, with exsanguinating hemorrhage.* **Hypertension** is found in 75 percent of patients. Other, less common causes include **Marfan's syndrome**, **Ehlers-Danlos syndrome**, **cystic medial necrosis**, **blunt trauma**, and **cannulation during cardiopulmonary bypass**.

## ⊗ Mycotic Aneurysms

Mycotic aneurysms—i.e., **aneurysms that are infected**—can occur **anywhere** in the body as a consequence of **either**

- **a blood-borne infection (intravascular)** it can be further divided into
  - preexisting aneurysms that become secondarily infected
  - mycotic aneurysms secondary to microbial arteritis

The classic type of this entity is the **syphilitic aneurysm**. The only other bacteria with an affinity for arterial walls are **Salmonella** and **Staphylococcus**, which are now the most common organisms cultured from mycotic aneurysms

- **an infection introduced from outside (extravascular)..**

The most common type of **extravascular infected aneurysm**

- follows a penetrating injury that contaminates the arterial puncture site and infects the resultant hematoma.
- infected anastomotic aneurysm.

Contamination can occur at the time of operation, from erosion of the graft material into the gastrointestinal tract, or from a contiguous hematoma secondarily infected from systemic sepsis.

**Mycotic aneurysms should be suspected in patients with sepsis and with inflammatory changes around a pulsatile mass.** Intravenous antibiotics are begun on the basis of results of blood cultures and clinical history. Since rupture carries a high morbidity and mortality, emergent operation is indicated after the necessary preparations.

## Principles of Operation

The first operative decision in mycotic aneurysm is **whether revascularization is necessary** to prevent tissue loss.

\* If so, a planned two-stage procedure is recommended.

The **initial stage** creates an **extraanatomic bypass** in a remote operative field **through uninfected tissues** using *autogenous tissue* if possible.

The **second stage** consists of **resection of the infected arterial segment**, **debridement** of surrounding tissues, and **irrigation and drainage with a closed perfusion system of 0.1% povidone-iodine solution**.

\* If the need for revascularization is not certain, the infected aneurysm is approached directly. The same principles of **wide excision, debridement, and irrigation** are used. If revascularization is necessary, it is done through uninfected tissues immediately after the wounds are closed and all gowns, gloves, drapes, and instruments have been changed. **Antibiotics are continued for many months**, usually through a long-term indwelling intravenous-access catheter. Patients with Salmonella infections are placed on lifelong treatment.

## ✕ Anastomotic Aneurysms

Since primary healing of a prosthetic anastomosis never occurs, anastomotic integrity depends solely on the strength of the suture line. **Anastomotic aneurysms are the result of a separation between a graft and the host artery, forming a sac that becomes encapsulated with fibrous tissue.** These **false aneurysms** contain no elements of the arterial wall. Most anastomotic aneurysms involve the common femoral artery after aortofemoral bypass.

### Etiology

✱ Any suture material that is degradable or easily broken can produce an anastomotic aneurysm. Silk has been abandoned as a vascular suture material because of its high incidence of late fatigue and subsequent anastomotic breakdown. Polypropylene and braided polyester are the most commonly used suture materials in vascular reconstructions and have not been associated with this complication.

✱ In some instances the sutures may remain intact but an anastomotic false aneurysm occurs as they pull through the arterial wall. This may occur when

- ✱ placement of the sutures fails to incorporate sufficient amounts of arterial tissue
- ✱ excessive tension on the anastomosis from a graft that has been cut too short
- ✱ degeneration of the artery
- ✱ Infection of the graft and neighboring arterial wall
- ✱ artery that has undergone endarterectomy does not have the same tensile strength as the original artery

✱ Biologic grafts treated with formaldehyde or glutaraldehyde to prevent rejection are subject to aneurysmal degeneration. Some of the original prosthetic materials, such as Vinyon-N, nylon, and Orlon quickly lost tensile strength and were abandoned.

✱ **Autogenous grafts** may develop aneurysmal dilatation. Saphenous vein grafts have a 4 percent incidence of aneurysm formation when used in the extremities but a higher incidence when used in the aortorenal position, especially in children. For this reason, autogenous artery (usually hypogastric) is the conduit of choice for pediatric aortorenal bypass procedures.

### Diagnosis

Patients with anastomotic false aneurysms usually present with a **painless pulsatile groin mass**. Rupture into surrounding tissues is unusual except when the aortic anastomosis is involved (10 percent). **Duplex ultrasonography** confirms the diagnosis in the case of peripheral false aneurysm, but **computed tomography** is the test of choice for an abdominal process.

**Arteriography** is necessary to delineate the outflow and assist in the planning of a remedial operation.

*Anastomotic false aneurysms require repair because they may thrombose, embolize, or rupture.*

### Treatment

\* In the case of involvement of **the femoral anastomosis**, the graft often has retracted into the retroperitoneum. An **interposition graft between the old graft limb and the femoral artery** is required, and control of the graft limb should be obtained proximal to the inguinal ligament.

\* False aneurysms involving the proximal anastomosis of an **aortic graft** occur less frequently than false aneurysms at the distal anastomosis. Rupture into the peritoneal cavity or the duodenum may occur, and so repair is indicated. At operation, **proximal aortic control** is best obtained at the supraceliac level.

- **In the absence of infection**, the anastomosis is disconnected, the aorta debrided, and an end-to-end anastomosis is created just below the renal arteries with a new

interposition graft. A flap of greater omentum is used to cover the new anastomoses.

- **When the aortic graft is infected**, the graft should be removed and an extraanatomic bypass performed, routing the new graft through uninfected tissue planes. The procedure is performed in two stages. In **stage one**, **bilateral axillobifemoral grafts** are placed, with each distal anastomosis sewn at an uninfected site (distal superficial femoral or profunda femoris arteries). The aortofemoral graft limbs are then disconnected, the femoral defects are closed, and the ligated graft limbs are tucked beneath the inguinal ligament. In **stage two**, performed several days later, supraceliac aortic control is obtained and the proximal anastomosis is disconnected, removing the graft and oversewing the aortic stump. **Aortic stump blowout**, the major cause of postoperative mortality, occurs in a significant percentage of patients.

## ✕ Aneurysms of Childhood

Aneurysms are rare in children. They are most often attributed to an underlying inherited disorder of connective tissue metabolism but can be acquired as a result of trauma or arteritis.

### Infection

Infectious aneurysms are the most common pediatric aneurysms and usually involve the aorta. **Bacterial endocarditis** is the most common source of infection, and **Staphylococcus and Streptococcus** are the usual offending organisms. The aneurysms often develop in the aorta distal to a *coarctation*. Other predisposing conditions are *umbilical artery catheters* and *bicuspid aortic valves*. Prompt resection and reconstruction is indicated because of the high incidence of rupture.

### Giant Cell Arteritis

This also affects the **aorta** and progresses to **rupture** and death. It is characterized pathologically by **immune complex deposition** in the vessel wall with **complement fixation and neutrophil activation**. This produces **endothelial injury** and **transmural arterial ischemia** from *occlusion of the vasa vasorum*. Degeneration and weakening of the vessel wall occur, with aneurysm formation and rupture.

### Autoimmune Connective Tissue Disease

Children with these aneurysms exhibit the clinical features of an autoimmune process such as **polyarteritis nodosa**. These aneurysms are less than 3 mm in size and involve the arteries of the kidney, liver, and spleen. Rupture causes symptoms specific to the organ involved but may present as shock from intraperitoneal bleeding and the clinical scenario known as "**abdominal apoplexy**." Ligation of the involved artery is indicated, with or without reconstruction.

### Kawasaki Disease

Kawasaki disease or syndrome is also known as the **mucocutaneous lymph node syndrome**. The aneurysms occur in the **axillary, brachial, iliac, and femoral** segments. **Coronary artery aneurysms** occur in 20 to 30 percent of patients and are the most serious manifestation of this disease because of the risk of rupture and sudden death from pericardial tamponade.

## ✕ Aneurysms Associated with Pregnancy

When aneurysms present during pregnancy, they often do so with rupture and shock, with a **mortality rate of 65 percent**. **Splenic artery** aneurysms are the most common, followed by aneurysms of the **renal and iliac arteries**. Pregnancy is also associated with **aneurysmal dilatation in the aorta**, presumably due to **weakening** of the arterial wall from the hemodynamic stresses of pregnancy and delivery. Matrix and elastic tissue abnormalities in the arterial wall have been described during pregnancy, making the vessel susceptible to rupture.

# THORACIC ANEURYSMS

## Etiology and Pathogenesis

An aortic aneurysm can be defined as a localized or diffuse aortic dilatation, usually exceeding 5 to 6 cm in diameter. Aneurysms develop from a weakness or defect in the aortic wall, which has a tendency to dilate progressively.

**The main causative factors associated with aortic aneurysms are** • age, • hypertension, • smoking, • atherosclerosis, • aortic dissection, and • connective tissue disorders Marfan syndrome and Ehlers-Danlos syndrome. Less common causes of thoracic aneurysms include • trauma, • infection (syphilitic or other mycotic), • inflammatory diseases (granulomatous and Takayasu's arteritis), • post-stenotic dilatation, and • autoimmune diseases.

### Causes of Thoracic Aortic Aneurysms

- Nonspecific medial degeneration
- Aortic dissection
- Genetic disorders
  - Marfan syndrome
  - Ehlers-Danlos syndrome
  - Familial aortic aneurysms
  - Bicuspid aortic valves
- Poststenotic dilatation
- Infection
- Aortitis
  - Takayasu's arteritis
  - Giant cell arteritis
  - Rheumatoid aortitis
- Trauma

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## Classification

Aneurysms of the thoracic aorta are best classified in terms of anatomic location; The **four major locations** are

- (1) the aortic root and ascending aorta
- (2) the transverse aortic arch
- (3) the descending thoracic aorta
- (4) the thoracoabdominal aorta.

Aneurysms of the aortic root or ascending aorta are the most common.

**Aortoannular ectasia** is a descriptive term for a degenerative dilatation of the aortic annulus and the sinuses of Valsalva, producing aortic insufficiency and a localized aneurysm involving the aortic root. This lesion often is associated with connective tissue diseases such as Marfan syndrome or Ehlers-Danlos syndrome. **Traumatic aneurysms** may occur after blunt trauma to the chest. They are located just distal to the subclavian artery at the site of insertion of the ligamentum arteriosum.

### Clinical Manifestations

The classic symptom associated with a large or an expanding aneurysm is **pain**, which may be excruciating and severe. With chronic aneurysms the symptoms may be more subtle, such as **chronic pressure** or a low-grade aching pain. New onset of pain in a patient with a known aneurysm is highly significant and may indicate rapid expansion, leakage, or impending rupture.

Large aneurysms may produce **symptoms from compression of adjacent structures**, such as the trachea, mainstem bronchus, superior vena cava, pulmonary artery, recurrent laryngeal nerve, or vertebral bodies.

**Hemoptysis** is a very serious sign, usually indicating **erosion** into the trachea, a mainstem bronchus, or lung tissue. Although unusual, erosion can occur into the superior vena cava or right atrium, causing

acute high-output failure. Compression or erosion of the esophagus creates dysphagia and hematemesis, respectively.

When **ascending aortic aneurysms rupture**, they usually bleed into the pericardial space, producing acute cardiac tamponade and death. **Descending thoracic aortic aneurysms rupture** into the pleural cavity, producing a combination of severe hemorrhagic shock and respiratory compromise. **External rupture** is extremely rare; syphilitic aneurysms have been noted to rupture externally after eroding through the sternum.

The majority of patients with moderate-sized thoracic aneurysms are **asymptomatic** unless significant enlargement has occurred. These aneurysms usually are discovered incidentally in a routine chest radiograph or during catheterization or imaging studies performed for other reasons. Usually there are no physical abnormalities or hemodynamic disturbances, except in aneurysms of the aortic root, which may be associated with aortic valvular insufficiency.

### Diagnostic Studies

**CXR** (Ascending aortic aneurysms produce a **convex shadow to the right of the cardiac silhouette**, **loss of the retrosternal space** in the lateral view. It may be **normal**. Plain chest radiographs may demonstrate **widening of the descending thoracic aortic shadow**, which may be highlighted by a rim of calcification outlining the dilated aneurysmal aortic wall).

magnetic resonance imaging (**MRI**), computed tomography (**CT**), or **echocardiography** are very useful.

**Aortography**, previously the primary diagnostic tool, is seldom necessary because of newer imaging techniques. proximal aortography evaluates the degree of aortic valve insufficiency, the extent of aortic root involvement, coronary ostial displacement, and the relationship of the aneurysm to the arch vessels. The limitations and potential complications of aortography include:-

☛ **it only images the lumen**, and may therefore underestimate the size of large aneurysms that contain laminated thrombus.

☛ **embolization** of laminated thrombus or atheromatous debris.

☛ **stroke**.

☛ **allergic reaction** to contrast

☛ **iatrogenic aortic dissection**

☛ **bleeding at the arterial access site**.

☛ The volumes of contrast can cause significant **renal toxicity**.

When surgery involving the aortic root is necessary, cardiac catheterization usually is indicated to additionally define the degree of aortoannular ectasia and the degree of coronary artery displacement.

### Natural History and Operative Indications

The natural history of aortic aneurysms is one of **progressive enlargement** with **eventual rupture**.

**Factors related to the risk of rupture** include

- **aneurysmal size,**
- **change in size,**
- **age of the patient,**
- **pain,**
- **symptoms of aneurysmal expansion,**
- **smoking, and**
- **chronic obstructive pulmonary disease (COPD).**

Patients with large aneurysms (more than 6 to 7 cm in diameter) with rapid aneurysm expansion or with pain generally underwent elective repair, while others with aneurysms of moderate size were monitored with serial CT scans over approximately 5 years.

### Indications

❖ **elective operative treatment for**

- most thoracic aneurysms larger than 5 to 6 cm in diameter
- when the rate of dilatation exceeds 1 cm/y.

- saccular aneurysms
  - connective tissue diseases once the aneurysm exceeds 4.5 to 5 cm,
  - Smaller ascending aortic aneurysms (4 to 5 cm) are also considered for repair when they are associated with significant aortic valve insufficiency.
- ❖ In contrast, **urgent operations should be considered**
- ✚ Symptomatic patients are at increased risk of rupture and warrant expeditious evaluation. The onset of new pain in patients with known aneurysms is especially concerning, and may herald significant expansion, leakage, or impending rupture.
- ✚ Emergent intervention is reserved for patients presenting with rupture or superimposed acute dissection.

## Preoperative Assessment and Preparation

Most patients undergo a thorough evaluation-with emphasis placed on cardiac, pulmonary, and renal function-prior to undergoing elective surgery.

**Cardiac Evaluation:-** Coronary artery disease, valvular pathology and myocardial dysfunction have important implications when planning anesthetic management and surgical approaches for aortic repair. • **Transthoracic echocardiography**, • **Dipyridamole-thallium myocardial scanning** and • **Cardiac catheterization with coronary arteriography** are obtained if significant valvular or coronary artery disease is identified prior to proximal aortic operations. Patients who have asymptomatic distal aortic aneurysms and severe coronary artery occlusive disease undergo percutaneous transluminal angioplasty or surgical revascularization prior to aneurysm replacement.

**Pulmonary Evaluation:-** In suitable patients, borderline pulmonary function can be improved by implementing a regimen that includes smoking cessation, weight loss, exercise, and treatment of bronchitis for a period of 1 to 3 months before surgery.

**Renal Evaluation:-** Renal function is assessed preoperatively via serum electrolytes, blood urea nitrogen, and creatinine measurements. Patients with severely impaired renal function frequently require at least temporary hemodialysis after surgery; these patients also have a significantly higher mortality rate.

## \* Proximal thoracic aortic aneurysm

Table 21-2  
Surgical Options During Proximal Aortic Surgery

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|--|
| <i>Options for treating aortic valve pathology</i>                         |
| Aortic valve annuloplasty (annular plication)                              |
| Aortic valve replacement with mechanical or biologic prosthesis            |
| Aortic root replacement  |
| Composite valve graft  |
| Aortic homograft   |
| Stentless porcine root   |
| Valve-sparing techniques   |
| Pulmonary autograft (Ross procedure)                                       |
| <i>Options for graft repair of the aortic aneurysm</i>                     |
| Patch aortoplasty  |
| Ascending replacement only   |
| Beveled hemiarch replacement   |
| Total arch replacement with reattachment of brachiocephalic branches       |
| Total arch replacement with separate grafts to each brachiocephalic branch |
| Elephant trunk technique   |
| <i>Perfusion options</i>   |
| Standard cardiopulmonary bypass  |
| Profound hypothermic circulatory arrest without adjuncts                   |
| Profound hypothermic circulatory arrest with adjuncts                      |
| Retrograde cerebral perfusion  |
| Selective antegrade cerebral perfusion                                     |
| Combined antegrade and retrograde cerebral perfusion                       |

## \* Distal Thoracic Aortic Aneurysms

### Surgical options

Two major operative techniques are in use:-

- **Unprotected cross-clamping** is performed with cross-clamps placed proximally and distally without distal perfusion, or with a single proximal cross-clamp with controlled distal exsanguination.
- **In perfusion or shunting techniques bypass or passive shunts** are used to maintain distal aortic perfusion during the cross-clamp time. Perfusion may be done with
  - ✱ left atriofemoral bypass
  - ✱ femoral–femoral bypass with an oxygenator
  - ✱ heparin-bonded shunts may be inserted to bypass the aneurysm from the ascending aorta, left ventricle, or subclavian artery to the distal circulation through the aorta or femoral artery. (E.g. Gott shunt from the proximal to the distal aorta).

Perfusion and shunting techniques have been developed in an attempt to reduce complications of clamping of the descending thoracic aorta, such as left ventricular strain and renal or spinal cord ischemia.

The technique for graft placement is standard.

### Current Strategy for Spinal Cord, Visceral, and Renal Protection During Repair of Distal Thoracic Aortic Aneurysms

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#### *All extents*

- Permissive mild hypothermia (32–34°C, nasopharyngeal)
- Moderate heparinization (1 mg/kg)
- Aggressive reattachment of segmental arteries, especially between T8 and L1
- Sequential aortic clamping when possible
- Perfusion of renal arteries with 4°C crystalloid solution when possible

#### *Crawford extent I and II thoracoabdominal repairs*

- Cerebrospinal fluid drainage
- Left heart bypass during proximal anastomosis
- Selective perfusion of celiac axis and superior mesenteric artery during intercostal and visceral/renal anastomoses