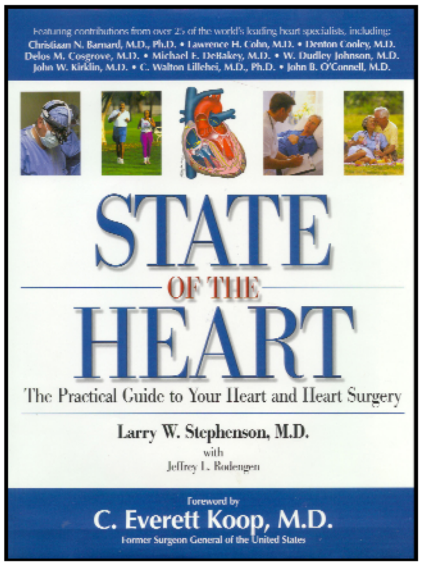

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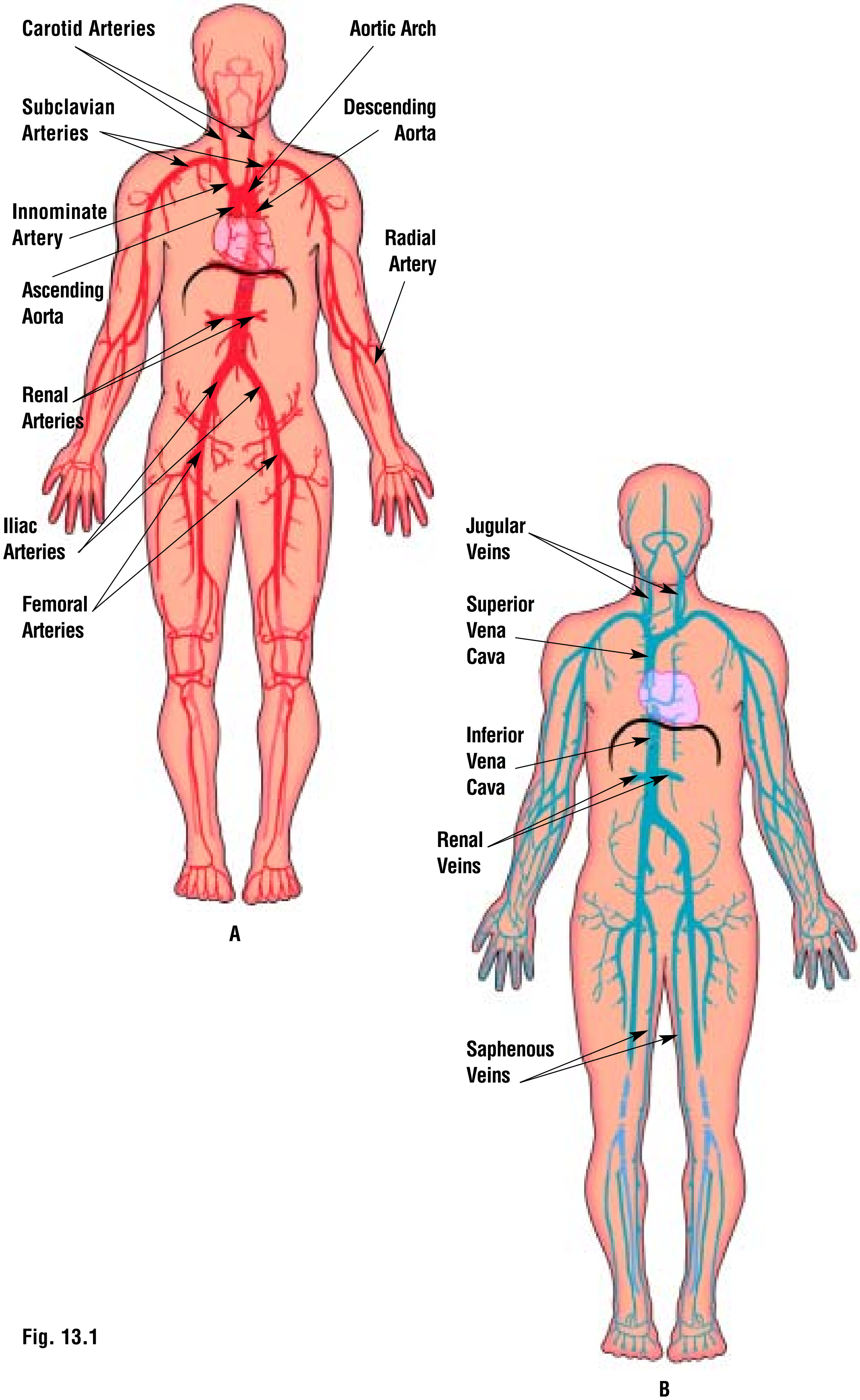

Fig. 13.1

Fig. 13.1: The circulatory system is composed of arteries and veins. The arterial system (A) branches out from the aorta into a highly complex system of vessels that feed the body with rich, oxygenated blood. The venous system (B) is responsible for returning unoxygenated blood to the heart.

CHAPTER THIRTEEN

Aneurysms and Other Blood Vessel Problems

The arterial system carries blood away from the heart to supply the rest of the body with nutrients and freshly oxygenated blood. The wide-ranging arterial delivery system looks much like the branches of a tree, with the main trunk, the aorta, branching directly off the heart (Fig. 13.1). The aorta is one of the body's most important blood vessels, and it is the largest. The aorta is twice the width of an average thumb and strong enough to absorb the entire blood pressure generated by the heart for the duration of life. Imagine a single pipe slightly more than one inch in diameter that carries more than fifteen hundred gallons of blood per day and remains in good repair after decades of continuous use. That is the aorta.

This main blood "highway" originates at the left ventricle, where the aortic valve regulates blood flow into the vessel. From there, the aorta first heads up toward the neck, then makes a U-turn, heading downward through the chest, usually just to the left of the body's midline, and into the abdomen. The region where the aorta makes the U-turn is called the aortic arch.

Immediately after it leaves the heart, the first branches arise from the aorta. These are the coronary arteries, and they supply the heart muscle itself with blood. The next arterial branch is the innominate artery, which originates in the aortic arch and divides into the right subclavian artery, going into the right arm, and the right carotid artery, which heads to the brain. The subclavian artery also gives off the right vertebral artery that goes to the brain.

The third arterial branch is the left carotid artery, which also goes to the brain. Next comes the left subclavian artery, which travels to the left arm and gives off the fourth artery that goes to the brain, the left vertebral artery.

As the aorta courses through the chest, numerous small branches split off to feed the chest muscles, the spinal cord, and other tissues. Just below the heart, a large breathing muscle called the diaphragm separates the contents of the chest from those of the abdomen. The aorta pierces this muscle to enter the abdomen, where the celiac artery branches off to supply the liver, spleen, and part of the stomach. Two mesenteric arteries also branch off in the abdomen and supply blood to the small and large intestines, and the renal arteries branch off and supply the kidneys.

Dacron: Michael DeBakey's Surprise Success

DACRON GRAFTS HAPPENED TO be the best option for repairing the damaged aorta — but no one would have known that in the beginning, least of all the doctor who introduced them. Dr. Michael DeBakey recently told the story of how Dacron came to be the fabric of choice for arterial grafts:

> *"It's an interesting story because another doctor had done studies with a material called Vinyon N, in which he showed that tissue would attach to it. That was what stimulated my thinking of using some kind of a plastic cloth material, and the most common material at that time was nylon.*
>
> *"So I went to the department store to buy a yard of nylon, and it happened that they had just run out, but they said they had a new material called Dacron. That was the first I heard of it, but I looked at it and felt it.*
>
> *"I purchased several yards and cut them in different sizes to make tubes on my wife's sewing machine. I had been taught by my mother as a boy to sew, and I became an expert. These tubes proved highly successful in animals, and although we later obtained sheets of Orlon, Teflon, nylon, and Ivalon, none of these was as good as the original Dacron."*

In 1954, DeBakey was called on to treat a patient with an aneurysm of the abdominal aorta. He implanted the first Dacron graft and remembered that it "worked beautifully."

Thirty years after his early cases, DeBakey still had patients with the original Dacron grafts, although more modern versions of the grafts are used today.

In the lower abdomen, the aorta itself divides into the two large iliac arteries, which supply blood to the pelvis and genitalia. As they enter the legs, these become the femoral arteries, which give off various branches.

The Development of Vascular Surgery

Blood vessel, or vascular, surgery followed a somewhat different pattern of development from heart surgery. In fact, doctors could suture and transplant vessels more than fifty years before the development of open heart surgery because the technique is not necessarily tied to the use of the heart-lung machine, although today some of the major vascular surgical procedures use it.

Many early surgical techniques were pioneered by Dr. Alexis Carrel of Lyon, France. He later traveled to Chicago in 1905, where he and Dr. Charles Guthrie developed a way to join the ends of blood vessels (called **anastomosis**) and a technique to transplant arteries and veins and even organs. Although Carrel's work did not receive immediate attention from more mainstream doctors, he received the 1912 Nobel Prize in Physiology or Medicine for his work with blood vessel surgical techniques and organ transplantation.

World War II set the stage for the next leap forward in blood vessel surgery.

Anastomosis: When two blood vessels are connected. Usually done with stitching but can be done with stapling or other methods.

Blood vessels had of course been injured in previous wars, but World War II saw antibiotics, blood transfusions, and a much higher percentage of formally trained surgeons, factors necessary for vascular surgery to advance. Doctors began to use improved surgical techniques to repair injured blood vessels, and surgeons also successfully treated coarctation of the aorta, a congenital condition in which a portion of the aorta in a newborn child is abnormally narrow.

The 1950s, when the heart-lung machine was in development, were exciting years for blood vessel surgery. Early in the decade, surgeons began to report success in removing aortic aneurysms (Fig. 13.2) and replacing them with segments of aortas from human cadavers. An aneurysm is the abnormal "ballooning" of an artery or other blood vessel. During the Korean War, advancing vascular surgical techniques helped lower the amputation rate from 49.6 percent in World War II to 11.1 percent.

Many of these 1950s techniques in vessel grafting are still in use today for smaller arterial injuries. However, synthetic grafts have mostly replaced biological grafts for replacing larger-diameter arteries. These synthetic grafts were pioneered in 1952 by Dr. Arthur Voorhees at Columbia University, where a team of doctors developed cloth tubes to replace diseased arteries. Over the next ten years, the devices were improved by the introduction of the crimped graft and by Michael DeBakey's introduction of Dacron arterial grafts.

During the 1950s, DeBakey, Drs. Denton Cooley and E. Stanley Crawford, and other members of their team led the way in graft replacements of various segments of the thoracic aorta for aneurysm. Other operations had to wait for the development of the heart-lung machine. The replacement of the aortic arch was one of those and remained beyond the surgeon's knife until 1957, when the same Houston group removed an aortic arch aneurysm and replaced the diseased segment with a reconstituted aortic arch from a human cadaver.

Thoracic Aortic Aneurysms

About two-thirds of the time, aortic aneurysms are discovered accidentally on a routine chest x-ray. About 25 percent to 33 percent of patients with aortic aneurysms have some degree of pain or discomfort in the chest or neck related to the aneurysm expanding and pushing on adjacent structures, including nerves. Sometimes there are other symptoms related to the aneurysm pushing or stretching nearby organs or

Fig. 13.2:
An aortic aneurysm occurs when a section of the major artery balloons out and weakens. It is a very dangerous condition that can be treated in a variety of ways.

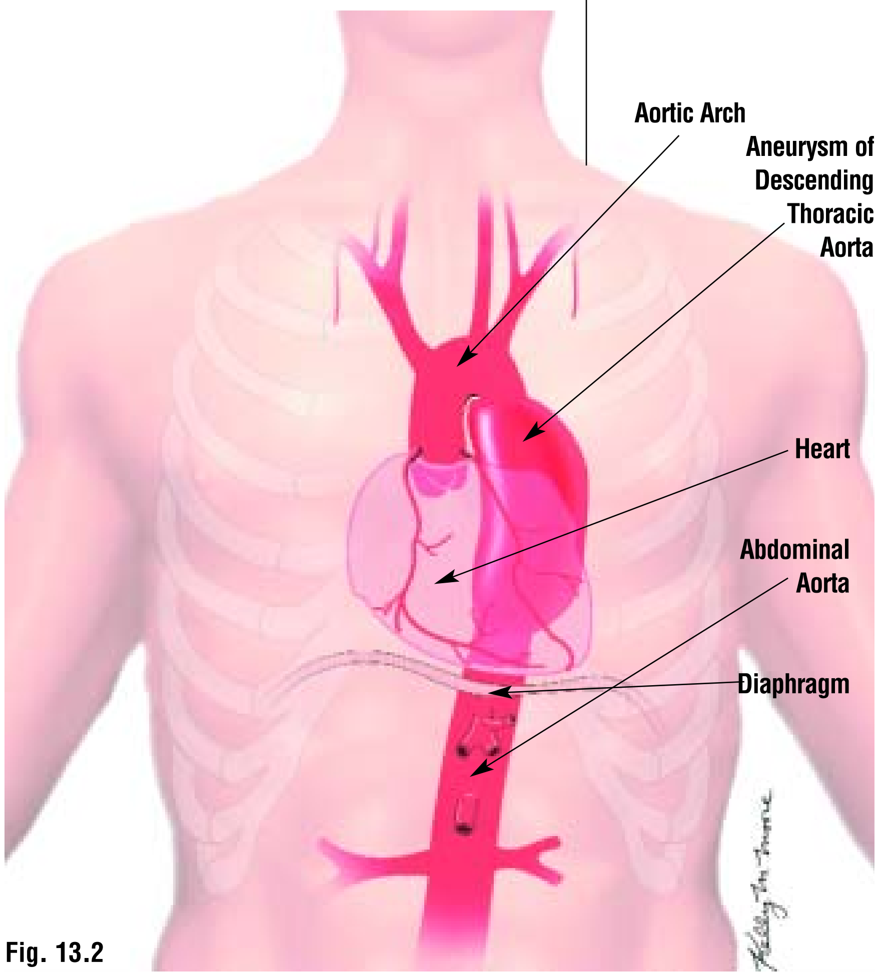

Fig. 13.2

tissue. If an aneurysm is suspected, doctors will obtain a CT of the chest and/or an MRI scan and/or an angiogram of the aorta. Any one of these tests usually confirms the diagnosis.

Aortic aneurysm is a dangerous condition that often requires surgery. It can occur anywhere in the aorta, including the ascending aorta, the aortic arch, the descending aorta, the abdominal aorta, or where the aorta divides and becomes the iliac arteries. Aneurysms tend to enlarge over time, and they are more likely to rupture as they get larger. If they rupture, death is likely to occur fairly quickly. Surgery is recommended if the aneurysm is moderate to large in size, or even if it is relatively small but enlarging quickly.

Surgery to repair an aortic aneurysm tends to become more challenging as the vessel nears the heart. If an aneurysm occurs in the ascending aorta, the heart-lung machine has to be used during graft replacement. If the aortic heart valve is also leaking, a heart surgeon may need to repair or replace it. During replacement of the ascending aorta, the coronary arteries may need to be detached. In that case, they can either be reimplanted directly into the synthetic graft, or they can be bypassed and the bypass graft sewn to the synthetic vascular graft (Fig. 13.3 and Fig. 13.4).

Fig. 13.3

Fig. 13.3: During placement of an arterial graft in the aorta, the diseased section of the ascending aorta and aortic valve is removed, then replaced with a synthetic tube and artificial valve.

Patients who undergo elective surgery for aneurysms of the thoracic aorta have about a 90 percent chance of surviving the procedure, but the risk can be somewhat lower or higher depending on the exact circumstances, such as age, other medical conditions, and so forth. Most patients do well after the surgery and have about a 70 percent to 80 percent chance ten years later of being free of additional problems related to that aneurysm surgery.

If there is an aneurysm in the aortic arch, aortic aneurysm surgery is more serious and risky because of the vessels that arise to feed the brain. There are two common approaches to this kind of surgery. In the first, the heart-lung machine is used to cool the patient's body temperature to 20˚C or even colder. The patient's head may be packed in ice, and while the aneurysm is replaced and the vessels going to the brain are reimplanted, the heart-lung machine is turned off. Keeping the patient cold slows the metabolism and thereby protects the brain. The patient is in a state of hypothermia during which there may be no circulation to the brain, the heart, or the rest of the body for several minutes and sometimes as long as an hour. There are other techniques with which the brain can be supplied with blood during these procedures.

For aneurysms of the descending aorta, various bypass techniques are usually used, and these depend on the surgeon's preference. If an aneurysm is in the abdomen, no special circulatory support is usually needed. The surgeon clamps each side of the aneurysm, opens it, and replaces that segment of the aorta with a synthetic graft, usually of Dacron. If the iliac arteries are involved, a graft divided into two limbs at one end like a pair of pants is used.

Sometimes more than one portion of the aorta is affected by the aneurysm. Some aortic aneurysms involve portions of the aorta in both the chest and the abdomen. These are called thoracoabdominal aortic aneurysms. When these aneurysms are replaced with synthetic grafts, the many arteries that branch off the aorta in that area will usually be sewn back onto the synthetic graft.

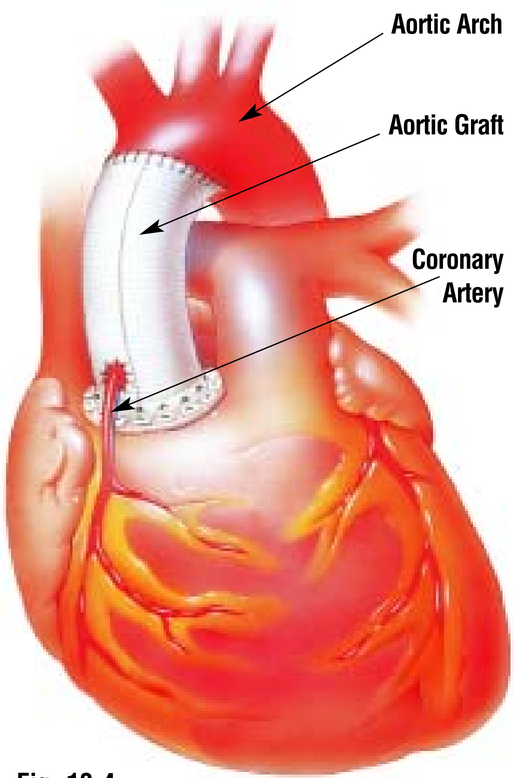

Fig. 13.4

Fig. 13.4: The graft, which replaces a section of the aorta, resembles the aorta in both size and function. The coronary arteries are implanted onto the graft.

Catheter or Stent Treatment of Aortic Aneurysms

During the last several years, stents have been developed to treat aortic aneurysms. These are somewhat similar to the stents used to open a blockage in a coronary artery but much longer. These devices have been used to treat aortic aneurysms in both the abdominal aorta and the thoracic aorta.

The stents are coiled and attached to a catheter that is inserted into an artery in the leg. When the stent reaches the aortic aneurysm, a balloon on the catheter is inflated, which causes the stent to uncoil and form a new channel for the blood, and theoretically cures the aneurysm.

These procedures are being done at relatively few centers. They are still considered experimental and are done with the approval and supervision of the Food and Drug Administration (FDA). The results are encouraging, but these procedures are not yet widely available at most centers performing vascular surgery. Hopefully, as research with these techniques advances, stent procedures for the treatment of aortic aneurysms will become routine and may spare patients major surgery.

Aortic Dissection

Aortic dissection is a condition in which the layers of the aorta separate and begin to come apart, or unravel (Fig. 13.5). There are three layers to the aorta and other arteries. The innermost layer is called the intima. There is a middle layer called the media, and the outer layer is the adventitia. When a dissection occurs, these layers separate. The dissections can start in almost any portion of the aorta and can progress either upstream or downstream. As the tear progresses, it can shear off the aorta's arterial branches, and in some cases the various branches of the aorta are no longer able to supply blood to the organs and tissue beyond that point. This is a serious situation.

Severe chest pain is a cardinal symptom of aortic dissection and occurs in about 90 percent of patients. This pain can initially be confused with that of a heart attack. The location of the pain in the chest can vary depending on where in the aorta the dissection is located and can be in the breast, in the neck, or in the back. It is often described as a "ripping" or "tearing" type of pain. Other signs and symptoms can also be present depending on which organs are no longer getting enough blood. If the outer wall of the aorta ruptures, the patient will go into shock from blood loss, and death usually follows rapidly.

Sometimes the entire aorta, from the aortic valve to the iliac arteries, is involved. Usually, when treating an aortic dissection surgically, the area upstream is repaired. If the ascending aorta is involved, the portion up to and sometimes including the aortic arch is replaced with a synthetic graft.

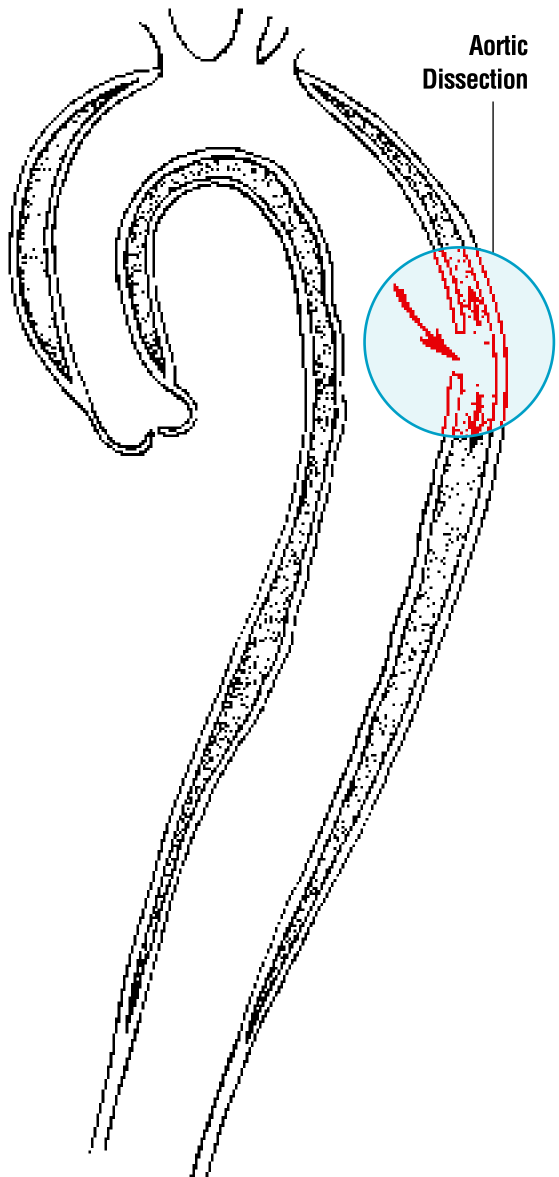

Fig. 13.5

Fig. 13.5: Aortic Dissection: This condition occurs when the interior wall of the aorta begins to weaken and rupture. If caught early enough, it is a treatable condition.

Sometimes the aortic valve also needs to be repaired or replaced.

If the dissection is acute (the aorta has just dissected), the risk of death or severe complications during surgical repair can be quite high. There is also the risk of paraplegia (being paralyzed from the waist down). Without surgery, however, the risk of death and complications is generally higher.

If the dissection starts in the descending aorta and does not involve the ascending aorta, this condition can frequently be treated with medicine to lower blood pressure. Surgery can often be avoided for aortic dissections of the descending aorta only.

Traumatic Aortic Rupture

The aorta can also rupture as a result of trauma, particularly as a result of a car accident in which a person is not wearing a seat belt and hits the chest on the steering wheel. In this case, urgent or emergency surgery is required to repair the tear.

Patients who make it to the hospital alive are those in whom the tear is contained by the adventitia, or outer aortic wall. However, these tears usually need to be repaired relatively soon because there is a high likelihood of the tear rupturing through the adventitia within the first few days after it occurs. In some cases, the tear can be repaired with simple stitches. In many cases, however, the injured portion of the aorta has to be replaced with a Dacron graft. Any time surgery is performed on the aorta, particularly the descending aorta in the chest, there's a chance that a patient may become paraplegic, or paralyzed from the waist down, as a result of the surgery because this is where the blood vessels going to the spinal cord branch off. There are certain techniques that lower the chances of becoming paralyzed, but even in the best hands, this complication occurs.

Atherosclerotic Disease of the Aorta and its Branches

As with the coronary arteries, which can become blocked from atherosclerotic material, the aorta itself can become extensively atherosclerosed (Fig. 13.6). Although, because it is a large vessel, it will not usually become totally blocked, its various branches can become blocked and may need to be bypassed.

In some cases, the atherosclerotic material can be cleaned out of the branches of the aorta (but usually not out of the aorta itself). This procedure is called an endarterectomy. It is performed by opening the artery and using special instru-

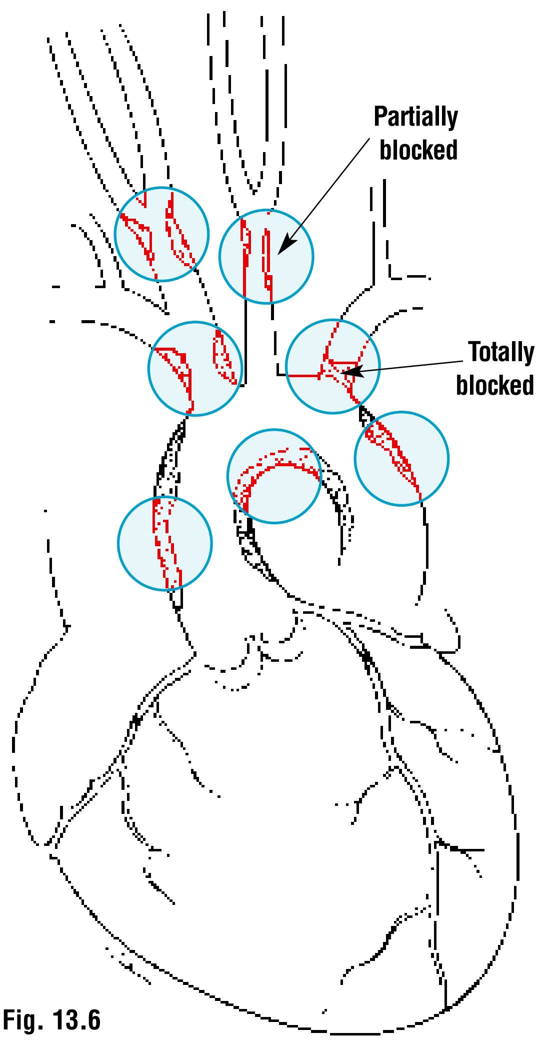

Fig. 13.6

Fig. 13.6: Atherosclerotic material can build up in the aorta's major branches. This can be treated with surgery.

Claudication: Pain, numbness or tiredness in the leg caused when the muscles are not getting enough oxygenated blood.

Fig. 13.7: Clots can also occur in the veins of the leg.

ments to "peel out" the atherosclerotic plaque. Often, the intima, or inner lining of the arterial wall, is removed with this clump of material. The artery wall is then stitched back together. Where the blockage is, how extensive it is, and a number of other factors affect whether the surgeon will choose to bypass the blockage, replace a segment of artery, or perform an endarterectomy. The carotid arteries are particularly suitable for endarterectomy.

When arteries in the leg become clogged, this may cause pain when walking. This is analogous to the angina or chest pain that occurs when there's not enough blood getting to the heart muscle. In this case, the muscles in the leg ache and throb. Patients may have to stop walking and rest until the pain subsides. This condition is called **claudication**, and the pain can come on with minimal exercise or only after prolonged periods of walking or running.

If the arteries to the legs are blocked, a doctor may be able to dilate these arteries with a balloon catheter. If not, an endarterectomy may need to be performed, or segments may need to be replaced or bypassed. This depends on the location of the blockage and other factors.

If the arteries in the leg are severely blocked in all of their subbranches, the area of the leg downstream could actually die and develop gangrene. In certain cases, toes or a portion of the foot or leg may even have to be amputated. Fortunately, in most cases, this is not necessary because of the surgical arterial revascularization techniques that are currently available. In general, if an artery is injured or damaged, it's best to try to fix it or replace it.

Venous Disease

Veins are blood vessels that return blood to the heart, and the atherosclerotic process tends to spare them. Veins also have better collateral channels (accessory blood vessels or routes), so if a vein does become blocked, the blood can usually flow in another direction around the blockage and still get back to the heart.

Blood Clots in Veins

Blood clots can form in the veins just under the skin in the leg or arm (Fig. 13.7). When this occurs, the skin over the vein is often tender and inflamed. The clotted vein under the skin usually feels like a cord. This condition is called superficial thrombophlebitis (superficial, for just under the surface; thrombo for blood clot; phleb for vein; itis for inflammation). This is not generally a serious condition but more of a nuisance. If it occurs in an arm vein while in the hospital, it can be related to an intravenous catheter that had been in the vein for several days. Most of the time, this problem is self-limiting and is treated with aspirin or other drugs that block the activity of the platelets in the blood. If there is considerable inflammation involving skin around the vein, antibiotics may also be prescribed.

Deep vein thrombosis, or DVT, occurs when veins deep in the tissue of the leg or pelvis become blocked with blood clots. It may be caused by lying in bed, crossing your legs for prolonged periods, or other factors. It can result in painful inflammation around the vein. Depending on where the blockage is, patients may need anticoagulant drugs to prevent the clot from getting larger or possibly even drugs that can dissolve the clot. If the clot breaks loose and travels through the heart to the lungs, patients will likely be treated with anticoagulant medicine such as coumadin for many weeks or longer.

Occasionally, veins that have blockages are bypassed, or the clot is removed. With the larger veins, particularly when the vein is injured, a surgeon may repair the vein or bypass the injured area, but under most circumstances, bypasses of veins are not performed, and reconstruction of veins is not commonly done because veins have numerous backup, or collateral, channels. If one portion becomes blocked, the other portions can take over. In addition, atherosclerosis generally does not affect the veins.

If clots continue to develop or if patients cannot take an anticoagulant because they have a bleeding disorder or bleeding ulcers, they may need a filter inserted in the inferior vena cava. Blood clot filters come in different shapes, and all are inserted through a catheter. They prevent larger clots from getting through the vena cava and traveling to the lungs, where they can cause shortness of breath. If the clot is big enough, it may actually block the blood flow to the lungs and could be fatal. When a blood clot goes to the lungs, this is called a **pulmonary embolus**. Most blood clots that travel to the lungs can be dissolved with drugs, but sometimes they need to be removed surgically.

Pulmonary Embolism: This happens when an abnormal piece of material (embolus), such as a blood clot, lodges in one of the blood vessels in the lungs, usually causing damage and possible shortness of breath.

Varicose Veins

A varicose vein is one that has become enlarged and somewhat twisted. Typically, this condition involves the veins in the legs, particularly those just beneath the skin. The valves in the veins become incompetent. These veins become engorged and can look very unsightly. They can also clot off and can be very painful. This can occur during pregnancy. Exercising will ease the burden on the veins. Patients can wear elastic stockings, especially if their occupation requires long periods of standing. They should lose excess weight as well.

There are a number of techniques that can be used to treat varicose veins. The veins can be injected with a chemical agent which causes them to collapse permanently. This is called sclerotherapy, which is a relatively simple and effective way to treat varicose veins. Some of the risks of sclerotherapy include brown spots at the injection sites, clot development in the superficial veins, and a reaction to the injected chemicals. Sometimes, new bursts of small red or purple veins called spider veins occur as a result of the chemical injections. Spider veins can often be removed with laser therapy. In some cases, varicose veins may have to be removed through a surgical procedure, which is referred to as vein stripping. Fortunately, the procedure is straightforward and low in risk.

Venous Insufficiency

Venous insufficiency is a condition in which the valves in the veins in the legs become damaged and incompetent. As a result of this, the legs may swell, particularly in the ankle areas. This is a relatively common condition. It cannot be cured, but there are things that can be done to lessen the problem. Patients need to wear support stockings. Certain exercises help. Long periods of standing should be avoided; when sitting in a chair, patients should elevate their legs. Sometimes other types of treatments are necessary.

In more advanced cases, the skin in the calf and ankle area may break down, and sores called venous stasis ulcers form. There are various treatments available for this condition. In some cases, surgery can be done to repair or replace the damaged valves in the vein.

STENT-GRAFTS: AVOIDING MAJOR AORTIC SURGERY

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THE CONVENTIONAL SURGERY to repair an aneurysm of the descending portion of the thoracic aorta is a major operation. It requires a large incision between the ribs on the left side of the chest and has a substantial risk of death or serious complications, including stroke and lower body paralysis. After surgery, the hospital stay can range from one to two weeks followed by months of convalescence and rehabilitation. It is much more complex and risky surgery than coronary artery bypass graft or heart valve surgery.

Our surgically treated aneurysm patients are very grateful to be alive and free of the risk of aneurysm rupture but usually don't get back to feeling normal until three or more months after the operation. Despite this difficulty, surgical treatment of thoracic aorta aneurysms has saved innumerable lives since the late 1950s — and otherwise these aneurysms are almost universally fatal. Similar to a "blister" on a worn-out car tire, the aneurysm may blow out unpredictably.

Unfortunately, most of the aneurysms do not cause symptoms, such as back or chest pain, until they are very large. They are commonly discovered only serendipitously, for instance when a chest x-ray is ordered to evaluate other symptoms. Patients with thoracic aortic aneurysms often do not have any warning that they have a life-threatening aortic problem until something catastrophic occurs.

Thanks to better diagnostic tests (mostly imaging techniques such as CT, MRI scans, and echocardiography) and longer life spans, the number of patients diagnosed with an aneurysm of the thoracic aorta has grown rapidly over the last decade. Patients at the highest risk of having an aneurysm are middle-aged to elderly people who have a history of high blood pressure; younger individuals born with "weak" aortas that they inherited; and those with a family history of aortic aneurysm or aortic dissection.

In the last two decades, minimally invasive techniques, often using catheters and smaller incisions, have been developed to treat more heart and cardiovascular problems. This treatment results in less pain and trauma to the patient and shorter hospital stays. Indeed, many heart and peripheral arterial problems that ten years ago required a week in the hospital can now be treated on an outpatient basis.

Because the surgery done to repair thoracic aortic aneurysms is so traumatic and the recovery process so long compared with that for many other cardiovascular problems, there is good reason to use minimally invasive techniques. Conventional surgical treatment of aneurysms requires replacing the weakened segment of the aorta with a Dacron tube graft.

To accomplish this using minimally invasive techniques and without opening the chest, the aneurysm must be covered with a tube placed inside the aorta. This blocks the high-pressure blood flow from entering the thin, weakened aneurysmal segment and eliminates the chance of aortic rupture. This inner graft, or "sleeve," must be anchored firmly on either end so it cannot migrate over time.

This device is called a "stent-graft," or covered stent. In a stent graft, an expanding metal stent is used to anchor the synthetic tube graft to the normal aortic wall. This stent is unlike the more commonly used uncovered stents, which are open metal frameworks that crush plaque against the arterial wall and open a bigger channel for more blood flow.

At Stanford University Medical School, we have been exploring the use of endovascular, or in-vessel, stent-grafts to treat various types of aneurysms of the descending thoracic aorta (Fig. 13.8) since 1992. To the surprise of some and the utter amazement of others, these pioneering efforts have been fairly successful. The clinical feasibility of using stent-grafts for descending thoracic aortic aneurysms has been firmly established, even though the learning curve was fairly steep. We learned which specific types of aneurysms are best suited to stent-grafting, which patients could be treated successfully, and many essential technical points about gaining access to the aorta, device design, and stent-graft deployment.

We conducted the first large-scale clinical trial of descending thoracic aortic endovascular stent-graft repair in 103 patients between 1992 and 1997 at Stanford University. The average age of the patients was sixty-nine years. Importantly, 60 percent of cases were judged by a cardiovascular surgeon to be otherwise inoperable.

In this preliminary first-generation study, a primitive self-expanding stent-graft device was used. This "home brew" stent-graft used self-expanding stainless steel covered with woven Dacron. The device was semirigid and quite large in diameter (10mm–15 mm, or more than one-half inch). Various types of aneurysms were treated, including atherosclerotic/degenerative aneurysms, a few aortic dissections, and others. Although the stent-graft was intended to be inserted in the groin by using a small incision and general anesthesia, the large size of this early device and/or arterial blockages in the pelvis and abdomen made this possible in only 58 percent of cases. A larger incision in the left flank was therefore necessary in 30 percent.

Immediate serious complications included fatal aortic perforation in one patient, obstruction of the aortic arch due to buckling of the stent graft in another, stent-graft misdeployment outside the target zone in 3 percent, and a major peripheral arterial injury in 4 percent. The early mortality was 9 percent, which was quite good considering how old and sick many of these patients were.

Early neurological complications, which are the most dreaded complications of this type of major surgery, included paraplegia (paralysis of the legs and lower body) in 3 percent and stroke in 7 percent. The incidence of paralysis was similar to that for open surgical repair. The only risk factor associated with a higher probability of paraplegia was "more difficult surgical access," i.e., the need to insert the stent-graft via the abdominal aorta. We believe the stroke was caused by debris coming loose from the aorta and traveling to the brain in five of the seven cases, but two strokes were due to cerebral hemorrhage. No risk factors for stroke were identified.

The link between the design of our primitive device and stroke is indirectly substantiated by our more recent (1998) experience in an FDA Phase I trial in twenty-three carefully selected patients. We used a new commercial stent-graft called the Thoracic Excluder, built by W.L. Gore and Associates, Inc. In the entire FDA Phase I trial, which included twenty-eight patients, there were no strokes and no cases of paraplegia. We attribute this primarily to advanced design features, but more careful selection of patients could have also played a role. Nonetheless, the ability to avoid using large, stiff catheters and hardware inside the atherosclerotic ascending aorta and arch

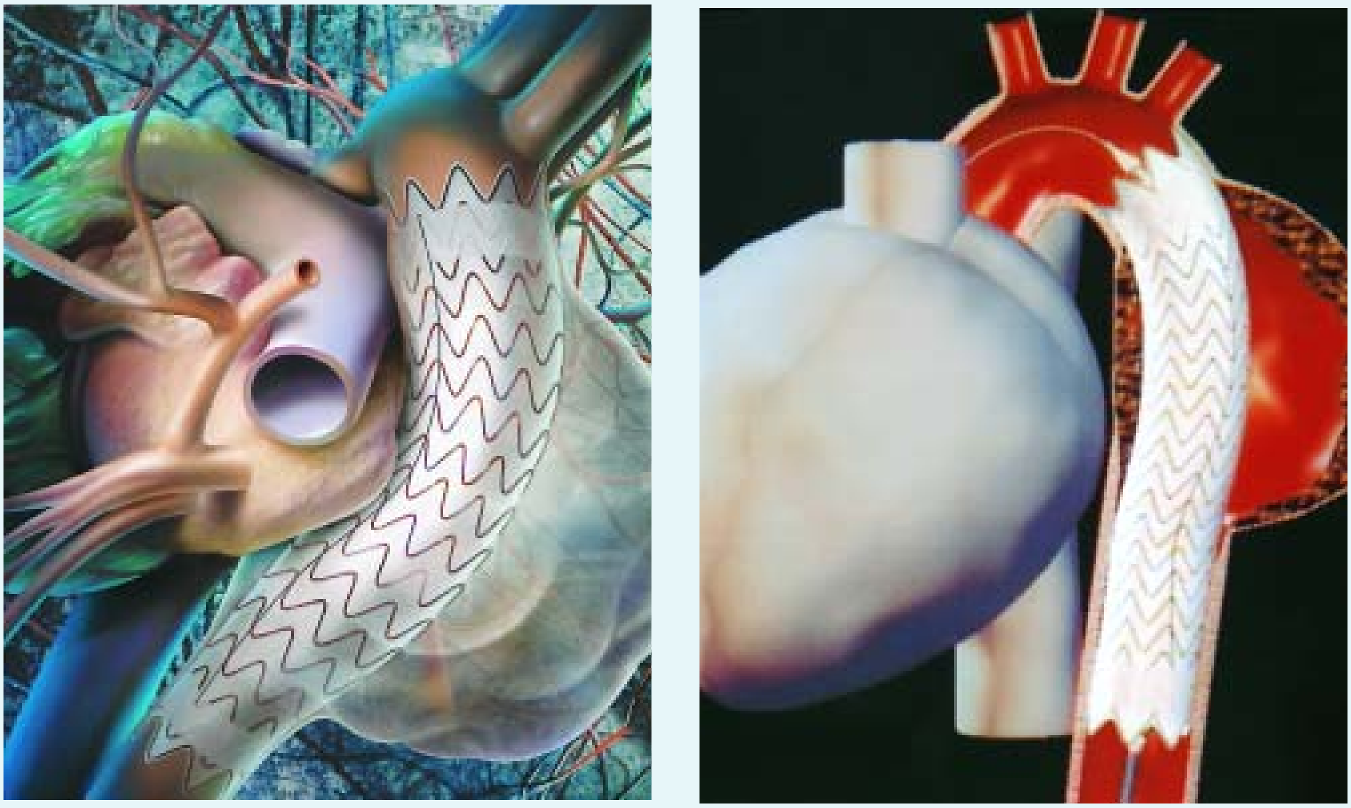

Fig. 13.8: These illustrations show a stent-graft placed in the descending thoracic aorta. After the stent-graft has been placed inside the aneurysm, which can be seen bulging out to the right, blood flow can no longer enter the aneurysm sac. The aneurysm, which becomes a "blind pouch," then clots, and over time, it is hoped this blood clot will turn into scar tissue and the aneurysm sac will shrink. *(Illustration courtesy of W.L. Gore and Associates, Inc.)*

is a key advance. Additionally, this new stent-graft conforms more easily to the curved aortic arch, is more flexible, and is considerably smaller. This gives us reason to expect that the incidence of stroke in the future will be much lower than before.

Given that 60 percent of the initial 103 cases treated with stent-grafts at Stanford University were deemed inoperable, our five-year clinical experience with the first-generation device indicates that endovascular stent-grafting of descending thoracic aortic aneurysms is feasible and relatively safe. The more refined devices available today cause much less trauma and enable more precise stent-graft deployment, which should further reduce the risks and make this procedure more reliable. These major design and technical advances, coupled with the lessons we have learned and more refined patient selection, should mean the results will be even better in the future.

Nonetheless, caution is necessary because very long-term follow-up is required before we can be completely confident this approach is a permanent solution. Only ten years or more of observation of greater numbers of patients will determine if stent-grafting is a durable and effective alternative approach to preventing aneurysm rupture. Until these long-term results are available, our Stanford multidisciplinary group believes younger, low-surgical-risk patients should opt for conventional open surgical graft replacement, which has a forty-year proven track record and is the gold standard. Conversely, stent-grafts are a reasonable option for patients who are not surgical candidates owing to advanced age or other coexisting medical problems and who otherwise cannot be offered any form of treatment.

SURGERY OF THE THORACIC AORTA

By

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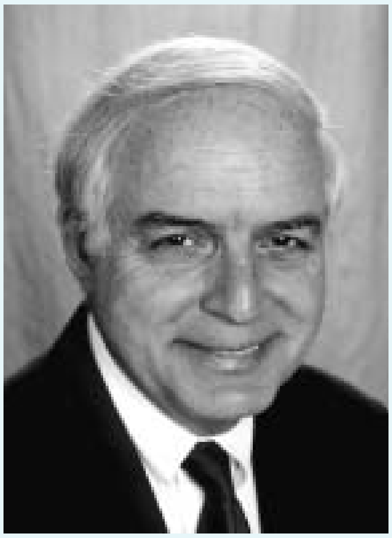

DURING THE LAST DECADE, extraordinary progress has been made in the treatment of aneurysms of the thoracic and thoracoabdominal aorta. We have better diagnostic techniques as well as improved substitutions for the aortic wall and safer systems to protect patients during surgery.

Currently, it is possible to safely cool the brain to low temperatures (12˚ to 15˚C, or 54˚ to 59˚F) by using the heart-lung machine. At these temperatures, the circulation can be totally stopped for up to forty-five minutes (and sometimes even longer) without producing detectable injury to the brain. This allows surgeons to remove diseased segments of the ascending aorta and aortic arch with a mortality in most instances of 10 percent or less and a correspondingly low incidence of brain damage.

Until recently, operations to replace long segments of the descending thoracic or thoracoabdominal aorta were associated with a high risk of death, a high risk of paralysis (up to 40 percent) of the legs (paraplegia), and a risk of kidney failure. Fortunately, however, this risk for this kind of aortic surgery has been lowered. Doctors support the circulation with a pump or a heart-lung machine, and in some instances cool the spinal cord and kidneys during operations. Surgery on these segments of the aorta can now be performed with a mortality of 10 percent or less and a risk of paralysis or kidney failure that does not exceed 5 percent.