Despite the advances in medical technology, aortic aneurysms remain a significant cause of death. For instance, a thoracic aneurysm that reaches six centimeters in diameter has a 10% to 20% chance of tearing open each year, and dissections are prone to break apart. “When they rupture, the odds of making it to the hospital and walking out on your own to your previous life are less than 20%,” says Michael R. Jaff, medical director of the vascular center at Massachusetts General Hospital. Meanwhile, among thoracic tear victims who make it to a hospital, half die within 24 hours.

Those unpalatable statistics describe a situation too little changed from the medical world in 1902, when William Osler wrote that “there is no disease more conducive to clinical humility than aneurysm of the aorta.” Even now, after more than a century of revolutionary advances in most areas of medicine, aneurysms and related pathologies continue to humble the profession. Thoracic aortic aneurysms are common, affecting 10 in 100,000 people each year in the United States. And a ruptured abdominal aortic aneurysm is the 13th leading cause of death in the United States, most often occurring in males 65 and older. Some evidence suggests that their incidence has tripled in the past 30 years.

Recently, though, the odds of surviving aortic disease or injury have gotten better. The improvement hasn’t come from new molecular therapies based on our growing understanding of the human genome, nor have there been any new blockbuster drugs aimed at aortic pathologies (although statins and ACE inhibitors help reduce atherosclerosis and hypertension, two suspected risk factors). Instead, the real gains result from nuts-and-bolts refinements in surgery and in the endovascular-stent-graft devices normally inserted via a small incision in the groin and snaked into position through blood vessels.

“Aortic pathologies are basically issues of plumbing, a very delicate and intricate plumbing, and all current therapies are mechanical,” says John Elefteriades, chief of cardiac surgery at Yale-New Haven Hospital. Yet like other, flashier
innovations, those plumbing repairs save lives, and researchers continue to expand this low-tech frontier.

The aorta exits the heart’s left ventricle through the aortic valve. In its first stretch, the complex, tortuously shaped thoracic aorta ascends a short way and arcs like a candy cane with branches going off to the brain, lungs and arms. Then it descends through the chest and tapers into the abdominal aorta, which nourishes the stomach, kidneys and other visceral organs. At the navel, the abdominal aorta branches off like trousers into the legs to supply the lower body.

Researchers still don’t know what makes an aneurysm an aneurysm, molecularly speaking, or why different sections of this plumbing system suffer different maladies. It has been widely assumed that atherosclerosis, in which fatty plaques form on the inner walls of blood vessels, can lead to aneurysms, but in many patients the opposite occurs. The proven risk factors are hypertension, smoking and family history—that is, genetics.

“But what genetically predisposes people to develop aneurysms?” asks Jaff. “What is the genetic expression of a cell in an aneurysm? What goes wrong in the aorta wall that causes it to degenerate? What molecules can we target to prevent an aneurysm from forming or growing? We don’t have answers to any of those questions.”

Still, although the biochemistry remains a mystery, the mechanical aspects of aortic diseases are well understood, and therapies boil down to two options. Surgeons can open the chest to cut out the bad part of the pipe and sew in a new section—a graft made of a sleeve of Dacron or polyester fabric. Or, more recently, physicians may snake a self-expanding device from an incision in the groin through the vascular pipes and deploy a graft that reinforces the weak section.

In 1992, Michael Dake, a vascular radiologist at Stanford University’s Falk Cardiovascular Research Center, was the first to use endovascular-stent-graft technology in the thoracic aorta, and in 2005 the Food and Drug Administration approved the first commercial medical device for that purpose. The devices currently available for use—GORE TAG by W.L. Gore, TX2 by Cook Medical, and Valiant (formerly Talent) by Medtronic—generally consist of a fabric graft sewn to a flexible, self-expanding skeleton made of nitinol (nickel and titanium, a very elastic alloy) or stainless steel. “The graft goes in constrained by a catheter or corset, and once the graft is in position to bridge the lesion, we withdraw the constraining membrane so that it expands,” says Dake. Then blood courses through the center channel created by the fabric.

Patients who receive stent grafts generally spend less time in intensive care, go home sooner and recover much more quickly.
Even now, amid still evolving technology being adapted for additional applications, stent grafts are a source of considerable excitement for those struggling to push back against the ravages of aortic disease and injury. “Endovascular repair for the thoracic aorta is cutting-edge technology that has made a genuine impact on patients,” says Richard P. Cambria, chief of vascular and endovascular surgery at MGH and a co-founder, in 1999, of the hospital’s Thoracic Aortic Center. “It’s the single most important advance in the treatment of these patients in my 30 years in the field.”

One reason endovascular stents have generated so much interest is that open surgery on any part of the aorta is risky, and operating in the chest much more so. “It’s one thing to open the belly and push aside the bowels to operate on the abdominal aorta,” says Jaff. “It’s another thing to open up the chest, deflate the lungs and protect the vessels leading to the brain and spinal cord while manipulating the thoracic aorta.”

Some 10% of patients die during or shortly after open surgery to repair thoracic aortic pathologies, and 5% to 10% of survivors suffer paralysis of the lower body and renal failure (because the procedure can compromise the blood supply to the spinal cord and kidneys). Other complications include stroke, heart attack, respiratory failure, infection and pneumonia.

However, these risks are skewed by urgent and emergency surgeries, which a 2007 analysis by Elefteriades found had nine times the mortality and six times the overall complication rate of elective surgeries. When a procedure can be planned and performed by an expert surgeon at a hospital that handles plenty of such operations, it’s considerably less dicey. “What was an adventure 20 years ago has become a reliable, safe procedure,” says Elefteriades. That’s thanks in part to pharmacological and laboratory improvements in controlling the blood clotting system and to the use of hypothermic cardiac arrest (lowering the body temperature to limit tissue damage in the heart and brain).

Still, many patients with degenerative aortic diseases are simply too old, frail or sick with other diseases to undergo even elective open thoracic surgery. That’s where the newer, less invasive stent graft procedures have an advantage. They result in significantly fewer deaths and severe complications than open surgery does. What’s more, patients who receive stent grafts generally spend less time in intensive care, go home sooner and recover much more quickly.

So far, stent graft devices are approved only for aneurysms in the descending thoracic aorta, the section of the artery that branches downward through the chest. The ascending aorta is more complicated anatomically, and there’s no room there for errors that might impede the flow of blood from the heart or into the vessels leading to the lungs and brain. In contrast, working a stent up from the groin into the descending aorta, while not without risk, has a stronger chance of success. During three industry-sponsored trials in 2007 and 2008, only about 2% of patients died from the procedure. And although mortality rates are higher in emergency operations and in some off-label uses of stents for dissections, ruptures and traumatic tears, studies have shown that endovascular techniques in those situations also benefit patients. “A car crash victim with a torn aorta may have sustained head injuries, broken bones and lung contusions, so that in itself means it’s better to do a minimally invasive procedure as opposed to a big, open operation,” says Cambria.

In developing clinical guidelines for these patients in 2010, the Society for Vascular Surgery found that 9% of patients with traumatic aortic tears who get endovascular repairs die shortly
after the procedure, compared with 19% of those who have open surgery. Another small retrospective study of ruptured aneurysms in 2010 found an 18.4% 30-day mortality rate following endovascular procedure, which the authors wrote was an improvement over the 25% to 30% found in literature on open repair. But that study counted only those patients lucky enough to make it to the emergency room—a distinct minority.

Many researchers now think that the thoracic aorta is the one location—rather than the carotid arteries leading to the head and neck, the arteries in the legs or even the abdominal aorta—in which stent graft technology is clearly superior to surgery. But not everyone agrees, including Elefteriades, who cautions that this technology could be overhyped, with an emphasis on short-term advantages in the absence of demonstrated long-term benefits. Sorting out the relative merits of the two approaches is difficult because there have been no randomized controlled trials comparing stent grafts and surgery for thoracic aortic pathologies, and none are planned.

Nor are there plans to factor cost into the equation, though one presumed advantage of stent grafts over open surgery—that inserting a simple device should cost far less than cutting open a patient to repair an artery—hasn’t materialized. While the combined expense of the stent and its placement is usually less than the price of surgery, the difference is minimal. That’s because, as with many other minimally invasive procedures, the price of a stent graft has more to do with what the market will bear than with what it costs to produce the device.

It’s generally conceded that patients who receive stent grafts, whether in elective or emergency procedures (and including those who have gotten off-label treatments), have a short-term survival advantage over surgical patients. Yet in most studies, just as many stent graft patients as open surgery patients die within about two years. (Younger patients with traumatic tears may be the exception, but there’s no long-term data yet about their survival.)

But a lack of long-term survival advantage doesn’t necessarily represent a failure for stent grafts, because this less invasive procedure has made aortic repair feasible for patients too elderly or too sick for open surgery. These patients probably would have died either from the surgery or from untreated aortic disease. Instead, they now make it through the stent graft procedure—“the big hump,” as Cambria puts it—then live on to die eventually of underlying diseases. As Dake explains, “the mortality rates for stent graft patients catch up with those for surgery because patients with stents still die, but they die later rather than dying right away.”

For stent grafts to work, the patient’s aorta must have a “neck,” or normal section, above and below the lesion to create a “seal zone” to which the stent graft can be anchored. Patients with degenerative aortic disease may not have a good seal zone, and without it the device may leak and require repair—usually with another endovascular procedure. A 2010 meta-analysis of 42 studies involving almost 6,000 patients found that leaks occur in about 12% of endograft patients, although recent redesigns of the graft may lead to better results.
Because leaks are possible, patients must be evaluated with periodic CT scans that expose them to worrisome levels of radiation, particularly with younger trauma patients, who are likely to survive many years. (On the other hand, the aortas of younger patients are less likely to spring leaks, because their aortas tend to be in good shape around the tear zone.) This lack of durability is much less of a problem in the case of surgical repair. “Once you sew in the new part, it’s a done deal,” says Elefteriades. “You never have to worry about that section of the aorta again”—although other sections may develop problems.

The potential for endograft leaks highlights the fact that, just as a patient with many underlying diseases or critical injuries may not be a candidate for open surgery, not everyone will be well suited for endovascular repair. “The limiting factor for open repair is physiology, or general health,” says Dake. “Will the patient survive the operation without major complications? The limiting factor for stent grafts is anatomy. Is the lesion in a place where it can be reached and repaired endovascularly, and is there an intact seal zone above and below the diseased area for attaching the stent graft? Each patient has her own mosaic blend of personal physiology and aortic anatomy, and physicians have to understand those limitations and how they affect what is best for that patient.”

The rule of thumb is that the simpler the aneurysm anatomically, the more likely it can be treated with stent graft technology. But it may be best not to treat some small aneurysms at all, and some patients just may not be fit enough even for an endovascular procedure, suggests Cambria, who is participating in several clinical trials studying endovascular techniques for treating additional aortic pathologies. The next frontier, he says, is to use stents to repair more anatomically complicated thoracic lesions, including those in the thoracic arch and the ascending aorta.

Ultimately, of course, the goal is to go further, understanding not just the plumbing problems inherent in aortic pathologies—an expanding area of medicine—but also their biomedical and genetic properties. Only then will researchers be able to develop diagnostic blood markers to track the course of the disease, which some think could happen within the decade. Ideally, this knowledge would lead to medicines that can intervene in the disease, treating it more directly than do today’s statins and antihypertensives, which merely reduce the risk of developing aortic pathologies.

“We want to apply molecular biology so we can identify and treat susceptible individuals so they are not prone to sudden death and to keep an aneurysm from developing or expanding,” says Elefteriades. “The mechanical basis for treatment has been the pattern of treatment for the past 50 years, and it’s incumbent on us to elevate therapy to a higher level.”

**DOSSIER**


2. “Ruptured Thoracic Aneurysms: To Stent or Not to Stent?” by Joseph S. Coselli and Raja R. Gopaldas, *Circulation*, June 29, 2010. This editorial concludes that while the data seems to favor off-label use of stents for thoracic aortic ruptures, such an urgent procedure poses logistic challenges for hospitals.

3. “Endovascular Aortic Repair Versus Open Surgical Repair for Descending Thoracic Aortic Disease: A Systematic Review and Meta-Analysis of Comparative Studies,” by Davy Cheng et al., *Journal of the American College of Cardiology*, March 9, 2010. The most comprehensive overview to date, this meta-analysis admits the difficulties inherent in comparing incomplete data from 42 studies in 5,888 patients of different ages and health status who received stents for thoracic aortic aneurysms, ruptures, dissections and traumatic tears.