CLINICAL PRACTICE

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Management of Abdominal Aortic Aneurysms

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This Journal *feature begins with a case vignette highlighting a common clinical problem. Evidence supporting various strategies is then presented, followed by a review of formal guidelines, when they exist. The article ends with the authors' clinical recommendations.*

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A 64-year-old man presents to his primary care physician for a routine physical examination and is found to have a palpable, midepigastric, pulsatile mass. He reports no abdominal or back pain and can easily climb two flights of stairs. His medical history is notable for well-controlled hypertension and hypercholesterolemia. He reports no family history of aneurysms, but he has smoked one pack of cigarettes per day since he was 16 years of age. Ultrasonographic examination reveals an infrarenal abdominal aortic aneurysm measuring 5.7 cm in its largest diameter. How should this case be further evaluated and managed?

THE CLINICAL PROBLEM

Abdominal aortic aneurysms are defined as having an aortic diameter of more than 3 cm. In the United States, the estimated prevalence is 1.4% among people between 50 and 84 years of age, or 1.1 million adults[1-3]; the prevalence is lower among women than among men and lower among Black and Asian persons than among White persons.[3,4] Predisposing factors include advanced age, family history, previous or current tobacco use, hypercholesterolemia, and hypertension; diabetes mellitus is associated with reduced risk.[5] The primary danger is the risk of rupture and death from hemorrhage. Accordingly, the goal of management is to repair the aneurysm before rupture. Although several factors influence the timing and type of repair performed, the single most important predictor of rupture is the diameter of the aneurysm, with the risk increasing with larger aneurysms. In a prospective observational study involving patients with abdominal aortic aneurysm who were not considered to be suitable surgical candidates, the risk of rupture was 1% per year among men with an aneurysm 5.0 to 5.9 cm in diameter and 14.1% per year in men with an aneurysm measuring 6 cm or more in diameter; the respective rates in women were 3.9% and 22.3% per year.[6] Referral to a vascular specialist at the time of diagnosis is important in weighing the risks and benefits of surveillance as compared with elective repair. The timing and threshold for repair as well as the selection of the type of repair are discussed below.

STRATEGIES AND EVIDENCE

TIMING OF REPAIR

Randomized trials showing no survival advantage with surgery over close surveillance for abdominal aortic aneurysms measuring less than 5.5 cm have supported

KEY CLINICAL POINTS

MANAGEMENT OF ABDOMINAL AORTIC ANEURYSMS

- Risk factors for abdominal aortic aneurysm include advanced age, male sex, family history, previous or current use of tobacco, hypercholesterolemia, and hypertension. The risk is lower among patients with diabetes mellitus.
- Repair is recommended for male patients in whom the maximum diameter of the aneurysm is 5.5 cm or more and in female patients in whom the maximum diameter is 5.0 cm or more.
- The results of randomized, controlled trials indicate that endovascular aortic aneurysm repair (EVAR) is associated with a lower risk of perioperative complications and death than open surgical repair.
- The early advantage of EVAR over open surgery is maintained for an average of 2 to 3 years from the time the procedure was performed. There is no long-term advantage regarding survival.
- Although EVAR is associated with a higher risk of reintervention, most such interventions involve minor endovascular procedures. Over a patient's lifetime, open repair is associated with a higher risk of reintervention related to the laparotomy.
- Long-term imaging surveillance with duplex ultrasonography or computed tomographic angiography is recommended in patients who undergo EVAR.

the view that this diameter represents an appropriate threshold for repair and that surveillance for aneurysms with a diameter that is less than 5.5 cm is safe and cost-effective.[7-9] Although intervention thresholds for the surveillance groups in these trials also included rapid growth of the aneurysm (defined as a rate of growth of >1 cm per year), rigorous data are lacking to support repair on the basis of rapid growth.[10] An important limitation of the studies on which the threshold of 5.5 cm is based is that the overwhelming majority of patients enrolled were White men; thus, the generalizability of the findings to women and other races and ethnic groups is unclear. Given the smaller native size of the aorta and the higher incidence of rupture of small abdominal aortic aneurysms among women,[11,12] most experts and guidelines suggest that a smaller diameter of 5.0 cm is an appropriate threshold for repair in women.[1,13]

MONITORING AND TREATMENT

Patients with small abdominal aortic aneurysms measuring 3.0 to 3.9 cm in diameter should be followed with imaging surveillance in the form of duplex ultrasonography every 3 years, whereas those with aneurysms measuring 4.0 to 4.9 cm in diameter should be followed once a year and those with aneurysms that are 5.0 cm in diameter or larger should be followed every 6 months.[14] Smoking cessation is recommended to reduce the risk of growth and rupture. Statins, beta-blockers, and other antihypertensive medications may be indicated to reduce cardiovascular risk, but they have not been shown to reduce growth and should not be prescribed for that purpose.

Among patients with an aneurysm that is large enough to warrant repair, treatment involves either open surgical repair or endovascular aortic aneurysm repair (EVAR). Open surgical repair requires a midline transabdominal or retroperitoneal incision to expose the aorta and the iliac arteries, which are clamped. During open surgical repair, the aneurysmal segment is replaced with a tubular or bifurcated prosthetic graft (Fig. 1). During EVAR, the aneurysm is left intact and blood flow is rerouted through catheter-based deployment of a stent graft, thereby avoiding the sac and making it unnecessary to transiently occlude the aorta (Fig. 2). Most often, a bifurcated, modular stent graft is anchored below the renal arteries in a segment of normal aorta and extended into a normal segment in each of the common iliac arteries. Anatomical suitability for EVAR requires adequate sealing zones, defined as areas of nonaneurysmal, parallel-walled artery above and below the aneurysm, where a stent graft can oppose and be sealed against the artery wall. Additional requirements include adequate diameter of the femoral and iliac vessels to accommodate the introduction of devices and the absence of excessive vessel angulation or severe atheromatous debris, both of which may increase the risk of embolization.

Since the introduction of EVAR in 1991,[15,16] the number of abdominal aortic aneurysm repairs in the United States has increased dramatically, and more than 80% of these procedures

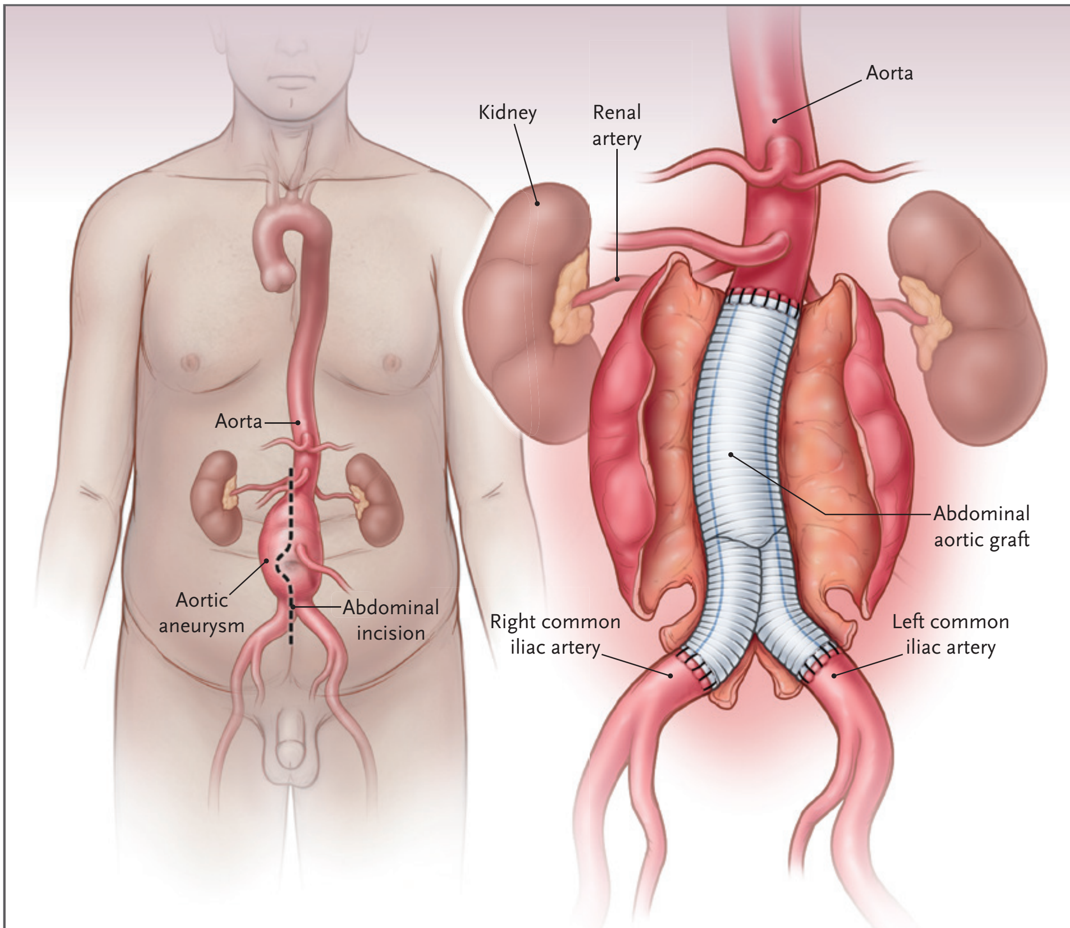

Figure 1. Open Repair of an Infrarenal Abdominal Aortic Aneurysm.
In this procedure, a laparotomy is performed, the aorta is cross-clamped above and below the aneurysm, and a prosthetic graft is sewn in place of the aneurysm.

are now performed with the use of EVAR.[17-19] Many institutions have widely adopted EVAR as the preferred treatment option in patients with suitable anatomy, independent of age or clinical risk, relegating open surgical repair to patients whose anatomy is unsuitable for EVAR.

EVIDENCE GUIDING THE CHOICE OF TREATMENT STRATEGY

The three largest randomized, controlled trials performed to date in which the outcomes of elective open surgical repair were compared with outcomes of EVAR have yielded consistent results.[17,20,21] All three trials showed that 30-day morbidity and mortality were significantly lower with EVAR than with open surgical repair (0.5 to 1.7% vs. 3.0 to 4.7%). Recovery is faster in patients who undergo EVAR (median length of hospital stay in Medicare beneficiaries is 2 days vs. 7 days with open surgical repair).[22] However, the short-term survival advantage of EVAR diminishes during follow-up, such that among the patients who survived beyond 2 to 3 years, survival rates associated with the two procedures were similar, and they remained so during 8 to 10 years of follow-up. Reintervention rates after EVAR were higher than those observed after open surgical repair, but most follow-up procedures were performed with catheter-based techniques; overall, the costs of EVAR were higher than those associated with open surgery.

Data from clinical experience in the United States have supported the findings of these trials. In a propensity-score–matched analysis that in-

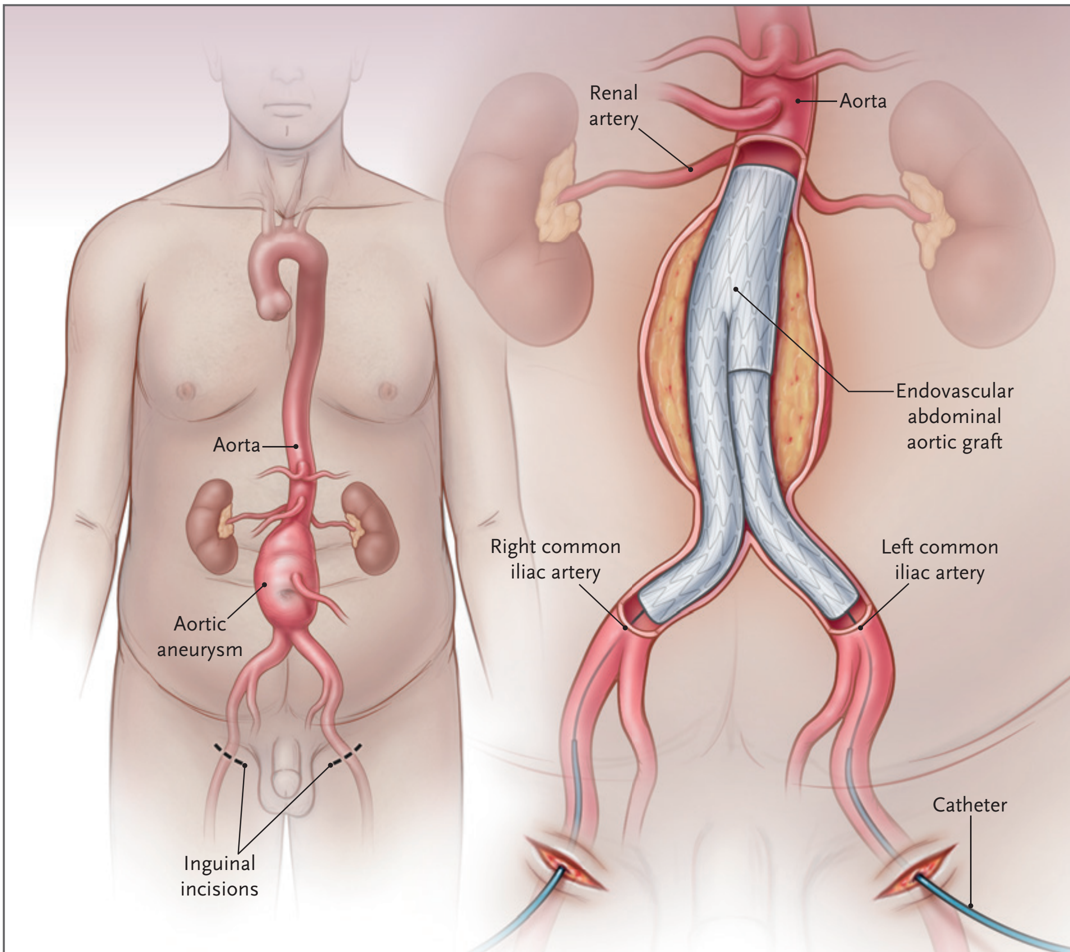

Figure 2. Endovascular Repair of an Infrarenal Abdominal Aortic Aneurysm.
Percutaneous femoral artery access is obtained or small incisions are made to expose the femoral arteries for the purpose of introducing stent grafts, under radiologic guidance, to exclude blood flow to the aneurysm.

cluded more than 44,000 Medicare beneficiaries who underwent abdominal aortic aneurysm repair between 2001 and 2004,[22] the 30-day mortality rate was 1.2% after EVAR and 4.8% after open surgical repair (P<0.001). At 5 years of follow-up, all-cause mortality rates were similar in the two groups, with survival curves converging at 3 years. Reinterventions related to the repair were more frequent among patients who underwent EVAR (9.0% vs. 1.7%; P<0.001). However, surgery for wound-related or laparotomy-related complications, such as incisional hernias or bowel obstructions, was more likely among patients who had undergone open repair (9.7% vs. 4.1%; P<0.001).

The choice of repair strategy should involve shared decision making and should include consideration of the patient's anatomical suitability, operative risk, and willingness to adhere to the lifelong requirement for annual follow-up imaging. Anatomical suitability has been defined for each EVAR device as part of the regulatory approval pathway; lack of adherence to the anatomical instructions associated with each device is associated with worse outcomes.[23] Multiple guidelines recommend lifelong follow-up imaging after EVAR in order to identify and correct aortic or other device-related complications, such as persistent blood flow within the aneurysm sac (e.g., endoleaks) or residual aortic sac enlargement. Postprocedural imaging surveillance is intended to identify serious complications and to prevent death from aneurysm rupture.[1,24] Imaging often includes computed tomographic (CT)

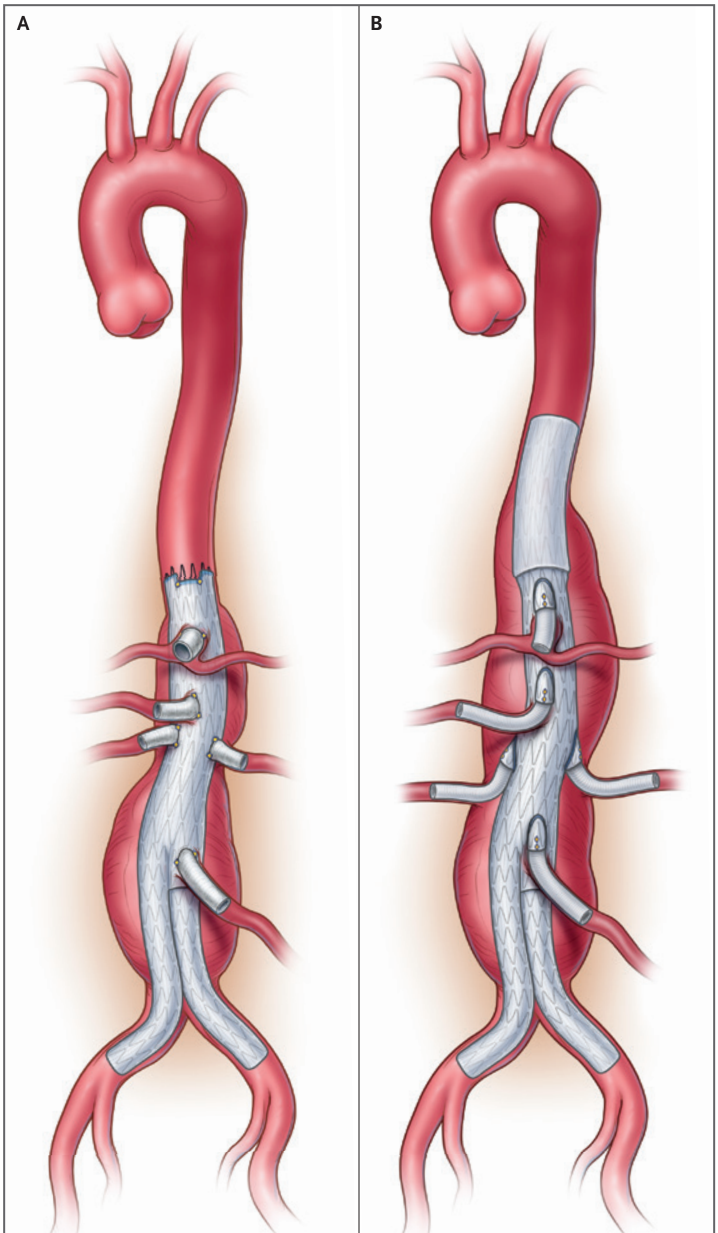

Figure 3. Endovascular Repair of a Complex Thoracoabdominal Aortic Aneurysm.
Fenestrated (Panel A) and branched (Panel B) endovascular repairs of a complex thoracoabdominal aortic aneurysm are shown.[45]

angiography in the first months after EVAR, followed by duplex ultrasonography annually. In some patients, ultrasonography may not be technically feasible (e.g., in patients with a large body habitus), in which case CT angiography or magnetic resonance angiography may be necessary. The risks of radiation exposure and the use of iodinated contrast material should be discussed with the patient. Although the lifetime risk of cancer attributable to exposure to low-dose radiation is much lower in patients older than 65 years of age than in younger patients,[25,26] the effects of exposure to multiple CT studies have not been assessed in large-scale epidemiologic studies. The risks of contrast-induced nephrotoxic effects are low among patients with an estimated glomerular filtration rate higher than 30 ml per minute per 1.73 m^2 of body-surface area.[27]

Rupture of an abdominal aortic aneurysm after EVAR has been documented in 5.4% of patients.[28] The need for reintervention to maintain exclusion of the aneurysm from the circulation and to guard against late rupture has been reported at early, midterm, and long-term follow-up[20] and does not plateau with time; therefore, lifelong follow-up is necessary. In contrast, with open surgical repair, lifelong follow-up is not critical owing to the greater durability of repair and the lesser need for reintervention. After open repair, most vascular surgeons follow patients until they have completely regained their preoperative baseline. Thereafter, patients are typically seen only if a new problem arises, since rupture after open repair is extremely rare.

AREAS OF UNCERTAINTY

It is unclear why trials consistently show that the substantial early survival benefit conferred by EVAR, as compared with open repair, is not maintained beyond 2 to 3 years. Possible reasons are underlying cardiovascular risk; poor adherence to recommendations for follow-up care (which may result from inadequate counseling or insufficient understanding of recommendations)[29]; persistence of an elevated inflammatory state associated with the presence of an intact aneurysm, leading to cardiovascular events (an outcome that requires study)[30]; persistent sac pressurization without endoleak that is identifiable on imaging[30,31]; and device failures.[23,32]

Although stent-graft fatigue explains some device failures, many failures can be explained by inappropriate placement — that is, the stent is placed in a patient whose anatomy is inappropriate for placement according to the instructions for use. Unfavorable anatomy has been reported in 18 to 63% of patients in whom EVAR is performed and is clearly associated with worse

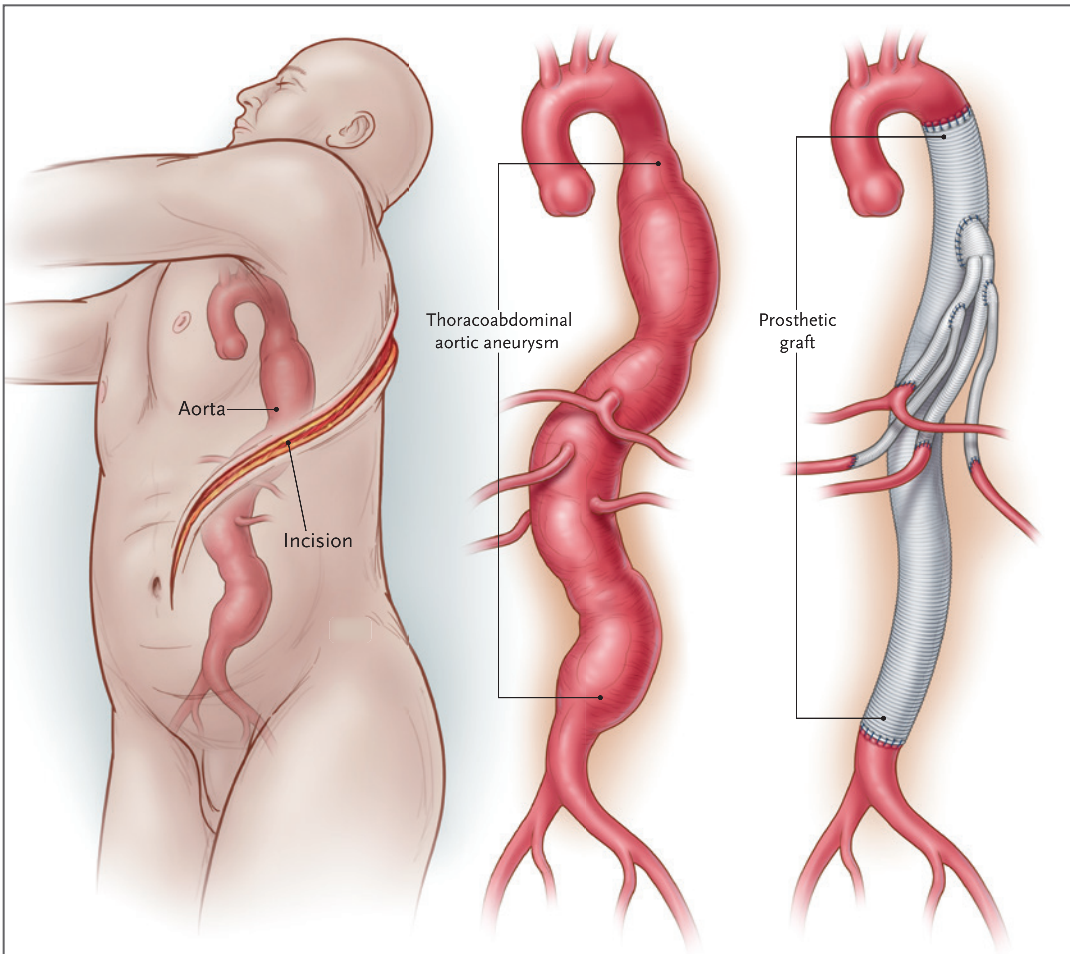

Figure 4. Open Repair of a Complex Thoracoabdominal Aortic Aneurysm.

The chest and abdominal cavities are exposed, the diaphragm is divided, the aorta is cross-clamped above and below the aneurysm, and a prosthetic graft is sewn in place of the aneurysm, with incorporation of the celiac, superior mesenteric, left renal, and right renal arteries.

outcomes.[23,33-36] If the widespread application of this technique continues to grow in patients with unfavorable anatomy, the short-term benefits will be offset by increased rates of treatment failure, costly reinterventions, and the potential for aneurysm rupture at any time during follow-up.

New endovascular technologies are evolving to expand the appropriate use of EVAR to include patients with anatomy that is unsuitable for currently available commercial devices (which are designed to be placed below the renal arteries). These technologies require endovascular incorporation of aortic side branches, such as the renal and mesenteric arteries, with the use of specially designed stent grafts that have fabric openings (reinforced fenestrations) or side arms (directional branches). After implantation of the aortic stent graft, bridging stents are placed between the fenestrations or branches and each target vessel. Both fenestrated and branched forms of endovascular aortic repair — from the aortic arch, through the visceral segment, and to the iliac arteries — have been adopted at large centers around the world devoted to the treatment of complex aneurysms.[37-44] In general, reinforced fenestrations are preferred in patients with aortic aneurysms that are located primarily in the abdomen (e.g., pararenal aneurysms) (Fig. 3A), whereas branched endovascular repair is preferred in patients with aneurysms that extend into the chest (e.g., thoracoabdominal aortic aneurysms [Fig. 3B]), where there is a wider gap between the aortic stent graft and the side branch. Unlike infrarenal EVAR, for which follow-up can usually be performed with the use of abdominal duplex ultrasonography, fenestrated and branched EVAR (FB-EVAR) often requires CT angiography for the purpose of imaging stent grafts extending into the chest, for which ultrasonography cannot be used.

Open surgical repair of these complex aortic aneurysms is technically more challenging and requires more extensive surgical exposure and a longer period of end-organ ischemia during aortic clamping (Fig. 4). For this reason, the associated morbidity and mortality are substantially higher than they are with infrarenal repair of abdominal aortic aneurysms.[45-47] There are currently no known randomized trials in which open surgical repair has been compared with FB-EVAR in patients with complex aortic aneurysms. Single-center and multicenter prospective observational studies have shown lower rates of complications and death with FB-EVAR than have been reported in historical cohorts in which open surgical repair was performed.[37,48,49] For example, according to a study conducted by the U.S. Aortic Research Consortium,[50] the 30-day mortality rate was 1.1% among 893 patients who underwent FB-EVAR for the treatment of pararenal or thoracoabdominal aortic aneurysm, whereas in multiple, large, single-center studies from high-volume centers evaluating open thoracoabdominal aneurysm repairs, 30-day mortality was in the range of 7 to 16%.[45,51,52] Pending further data to inform the effectiveness of FB-EVAR devices, access to these devices remains limited to the relatively few centers in the United States where investigational device exemption studies approved by the Food and Drug Administration are ongoing (e.g., see ClinicalTrial.gov numbers, NCT02050113 and NCT02089607).

GUIDELINES

Guidelines for the management of abdominal aortic aneurysm have been published by the Society for Vascular Surgery (SVS)[1] and the European Society for Vascular Surgery (ESVS).[13] Both documents assign a quality-of-evidence grade B (moderate, SVS) or grade C (low, ESVS), level 2 (weak) recommendation for elective repair of fusiform aneurysms with a diameter of 5.5 cm or more. Given the smaller native size of the aorta in women, the societies assign a quality-of-evidence grade B (moderate, SVS), grade C (low, ESVS), level 2 (weak) recommendation for elective repair of fusiform rupture with a diameter 5.0 cm or more in women. Although the guidelines do not include a recommendation regarding the advantages of open repair as compared with EVAR, the ESVS guidelines recommend EVAR over open repair in most patients with suitable anatomy and reasonable life expectancy (e.g., >2 years).[53] Both guidelines state that no specific medical therapy has been proven to slow the expansion rate of the aneurysm.

Acknowledging the lack of data from randomized trials to inform the outcomes and cost effectiveness of screening first-degree relatives for abdominal aortic aneurysm, both the SVS and the ESVS guidelines recommend that one-time ultrasonographic screening may be considered in first-degree male and female relatives (quality of evidence, grade C [low]; recommendation, level 2 [weak]), although the societies differ with regard to the recommended ages for screening (65 and 50 years of age, respectively). Consistent with the SVS guidelines, the Centers for Medicare and Medicaid Services provide coverage for one-time ultrasonographic screening in men and women with a family history of abdominal aortic aneurysm disease as part of their "Welcome to Medicare" physical examination (also covered are men 65 to 75 years of age if they smoked >100 cigarettes in their lifetime)[54]; we concur with the recommendations in the SVS guidelines. The most recent screening recommendation from the U.S. Preventive Services Task Force is consistent with these guidelines in men, but, in the absence of adequate data, the task force recommends against screening in women who have first-degree relatives who had abdominal aortic aneurysm.[55]

CONCLUSIONS AND RECOMMENDATIONS

The patient in the vignette has an infrarenal abdominal aortic aneurysm with a diameter that is greater than the 5.5-cm cutoff recommended for repair. CT angiography with thin cuts (1 to 2 mm) of the abdomen and pelvis is indicated to determine whether his anatomy is suitable for EVAR, and preoperative assessment of surgical risk should be performed. If the anatomy is amenable to repair with a conventional EVAR device, the most appropriate treatment approach depends on assessment of surgical risk and on patient preferences, which should be addressed in shared decision making. In patients with high surgical risk, EVAR is favored given the relative reduction in short-term morbidity and mortality as compared with open surgical repair. If this patient's surgical risk was determined to be low or intermediate, either EVAR or open repair would be reasonable. We would favor EVAR if he were willing to commit to lifelong imaging surveillance but would otherwise recommend open surgical repair, educating him in regard to its association with an increased risk of short-term illness and death and a longer recovery time. We also would recommend that any first-degree relative of the patient who is 65 years of age or older undergo screening aortic ultrasonography.

Disclosure forms provided by the authors are available with the full text of this article at NEJM.org.

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