Advancements in Endovascular Aneurysm Repair for Various Types of Abdominal Aortic Aneurysms

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Asymptomatic abdominal aortic aneurysm (AAA) is a common and potentially life-threatening condition. It should be repaired before its rupture, because ruptured AAA is nearly uniformly fatal. Elective repair is the most effective management for rupture prevention. Two methods of aneurysm repair are currently available, open surgery and endovascular aneurysm repair (EVAR). Open surgery is capable of treating various complexities of aneurysms, but EVAR is preferred in many cases due to its minimal invasiveness. Although it is not indicated for all patients, various advancements in endovascular treatment strategies allow for active treatment with EVAR in our department. This review article describes these advancements in EVAR.

Key words: abdominal aortic aneurysm, endovascular aneurysm repair, Snorkel technique, coil embolism

Introduction

Asymptomatic abdominal aortic aneurysm (AAA) is a common and potentially life-threatening condition. Ruptured AAA is nearly uniformly fatal. Fifty percent of patients with ruptured AAA will reach the hospital for treatment, of which 30 to 50 percent will die in the hospital. Therefore, elective repair of AAA should be performed even if the patient is asymptomatic. While open repair is the most effective management to prevent rupture, it is also associated with risks. Endovascular aneurysm repair (EVAR) has lower perioperative mortality rate than open repair. However, EVAR is not indicated for all cases. According to the guideline by The Japanese Circulation Society, cases in which EVAR is performed should be selected according to several anatomical characteristics to achieve optimal outcome. These anatomical indications include: a proximal neck with enough length (>10-15 mm) and little angulation (<60 degrees), an iliac artery with enough thickness (>6-7 mm diameter) without tortuosity or calcification, and a distal neck with enough length (>10 mm). Nevertheless, cases outside of these indications are actively treated with EVAR using novel techniques and strategies in our department. This review article describes these advancements in EVAR.

AAA repair

Asymptomatic AAA repair is effective in preventing rupture. Two methods of aneurysm repair are currently available, open surgery and EVAR (Figure-1).

Open surgery repair

Open aneurysm repair involves replacement of the diseased aortic segment with a tube or...
bifurcated prosthetic graft through a midline abdominal or retroperitoneal incision. It is the most effective method of rupture prevention, which has been performed since it was first described in 1952. Any type of aneurysm can be treated with an open surgery repair. However, it is highly invasive for patients, and therefore may not be suitable in all cases.

**Endovascular repair**

EVAR involves the placement of modular graft components delivered via the iliac or femoral arteries to line the aorta and exclude the aneurysm sac from the circulation. The procedure uses X-ray fluoroscope, floating X-ray table, operating monitor and contrast medium injector in the operating theatre (Figure-2). Compared with open AAA repair, EVAR is associated with a significant reduction in perioperative mortality, primarily because EVAR does not require operative exposure of the aorta or aortic clamping. However, EVAR has anatomical constrains, which inhibits some types of
Complicated cases

Several aortic measurements are important for determining the feasibility of EVAR and for stent-graft sizing. There are four types of AAA that are difficult to treat using the standard EVAR procedure. These include: AAA with a short neck, AAA with an angulated neck, AAA with stenosis and tortuous access route, and AAA with bilateral iliac aneurysms (Figure-3). We utilize advanced techniques for these difficult cases so patients can receive endovascular treatment despite such complications.
The diameter of the required stent-graft is determined by measuring the diameter of the aortic neck and adding 15 to 20 percent. Under-sizing the stent-graft will lead to an inadequate seal and failure to exclude the aneurysm. Selecting a stent-graft with an additional 15 to 20 percent to the measured aortic neck diameter should provide sufficient radial force to prevent device migration. The aortic neck length should be at least 10 to 15 mm to provide an adequate proximal landing zone for stent-graft fixation. In our institution, aneurysms with neck lengths shorter than 10 mm can be treated using the snorkel technique. This technique involves cannulating a branching artery to extend the proximal landing zone. Pre-operative enhanced CT revealed that while the length from the left renal artery to the aneurysm was only 5 mm, the length from the right renal artery to the aneurysm was 11 mm. Therefore, we were able to extend the proximal landing zone by inserting a bare stent through the left renal artery which was positioned parallel to the aortic stent graft away from the aneurysm. The simultaneous inflation of two balloons, or the kissing balloon technique, was used to deploy of the open stent-graft and the bare stent. Post-operative enhanced CT shows alignment to the angulated aorta and the abdominal aortic aneurysm has disappeared.

**Short neck**

The ideal angle of the aortic neck for endovascular treatment is less than 60 degrees. Angles that are greater lead to difficulties in implantation, kinking, endoleak, and potential distal device.
migration. Severe angulation (over 60 degrees) is generally considered to be a contraindication to EVAR. However, the ability to place a device in aneurysms with significant angulation at the neck is ultimately determined by the conformability of the specific device type and its delivery characteristics. In our institution, these types of aneurysms are treated with Endurant II using the push up anatomical deployment technique, which is suited for aneurysms with severely angulated proximal landing zones. With this technique, the suprarenal stent is deployed after the deployment of the first two stent-grafts. Once the secure fixation of the suprarenal stent is achieved, each stent-graft is pushed up and deployed one by one to conform to the severe angulation of the vessel. Figure-5 illustrates an aneurysm with proximal neck angulation of 98 degrees which was treated using this technique. Post-operative enhanced CT shows the stent-graft is perfectly conformed to the angulated aorta and the abdominal aortic aneurysm has disappeared without endoleak.

**Stenosis and tortuous access route**

Suitable iliac artery morphology is also required for endograft placement. The iliac arteries should have minimal amount of calcification and tortuosity, and no significant stenosis or mural thrombus should be present in the distal graft landing zones. The common iliac artery is the preferred distal attachment site, but the external iliac artery can also be used. For example, the external iliac artery is used for distal fixation when treating a common iliac artery aneurysm. A minimal external iliac artery diameter of 6 mm is needed to allow safe passage of the endograft delivery sheath. The common iliac artery diameter should measure between 8 and 22 mm, and the length of normal diameter common iliac artery into which the limbs of the endograft will be fixed should measure at least 10 mm to achieve an adequate seal. Focal narrowing and mild angulation can be overcome with standard guidewire and catheter techniques, while diffuse narrowing or significant calcification is

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**Figure-6** Example of an aneurysm with stenosis and tortuous access route treated using balloon angioplasty with stent-graft.

A. Pre-operative enhanced CT shows the left external iliac artery has 90% stenosis and hard calcification. B. Intra-operative angiography shows left external iliac artery has 90% stenosis. C. The stent graft is deployed followed by a balloon angioplasty inside the stent-graft. D. Complete angioplasty inside stent-graft using a balloon. E. Post-operative angiography shows left external iliac artery stenosis has been reduced from 90% to 0%. F. Post-operative enhanced CT shows left external iliac artery stenosis has improved.
more problematic. In such cases, we utilize a combination of balloon angioplasty and stent-graft in our institution. Figure-6 illustrates a case in which the left external iliac artery with 90% stenosis and hard calcification was treated using this technique. The stent graft was first deployed, followed by a balloon angioplasty performed inside the stent-graft to assist complete deployment of the stent graft. Post-operative enhanced CT shows improvement in the left external iliac artery stenosis.

**Bilateral iliac artery aneurysms**

Internal iliac artery aneurysms are most commonly treated with a combination of embolization and stent-grafting. Adequate coil embolization of an internal iliac artery aneurysm requires interruption of the blood flow both entering and exiting the aneurysm to effectively arrest flow within the aneurysm sac. Embolization of the internal iliac artery which interrupts pelvic blood flow is associated with a 12 to 55 percent risk of buttock claudication and a 1 to 13 percent risk of erectile dysfunction. In a study of 48 patients with iliac aneurysms undergoing bilateral coil embolization of the internal iliac arteries, post-procedural buttock claudication developed in 42 percent of patients initially and was persistent in one-third of these patients at one year. Impotence occurred in 14 percent of patients, and there were no cases of buttock necrosis or ischemic colitis. When bilateral embolization is chosen, a staged approach with one to two weeks between procedures may allow the development of pelvic collaterals. In the first stage, either of the internal iliac artery aneurysms is embolized, and in the second stage, the other internal iliac artery aneurysm is embolized in conjunction with aortic endografting, if needed. Many clinicians prefer staged repair when bilateral internal iliac artery aneurysms complicate endovascular aortic aneurysm repair. However, two
small nonrandomized studies that compared simultaneous with sequential embolizations of internal iliac artery aneurysms found lower rates of ischemic complications with simultaneous embolization.\textsuperscript{10} \textsuperscript{11} Embolization limited to the main trunk of the internal iliac artery resulted in a significantly reduced ischemic complication rate of 16% versus 55% of patients who had a more distal embolization of the internal iliac artery. This indicates that precise positioning of embolization is the key to minimizing ischemic complications. In our institution, two techniques are used to limit embolization within the main trunk of the internal iliac artery and distal to the aneurysm, without interrupting peripheral blood flow of the branching vessels. The first technique is the double wire and pull through technique, which is useful in cases with severe angle between the bilateral common iliac arteries (Figure-7). The technique enables a 6 Fr Destination sheath to be inserted from the right common iliac artery to the left common iliac artery, where it is held with increased back-up support. Then, a 5 Fr KMP catheter can be guided into the left internal iliac artery for coil to be placed at the desired position. A faster and more precise positioning is achieved with the second technique called the balloon anchor technique (Figure-8). Here, a 5.5 Fr Fogarty thru-lumen catheter is inserted into the internal iliac artery to expand the vessel diameter with a balloon for additional back-up support. This allows the 6 Fr Destination sheath to be directly cannulated to perform embolization using Amplatzer Vascular Plug II. After the stent-graft placement, angiography showed the left common iliac artery aneurysm had disappeared.

Conclusions

There have been a variety of technical advancements in EVAR as reviewed in this article. They have helped to make endovascular repair more effective and widely applicable for various types of
abdominal aortic aneurysms.

Reference

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