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Review

Adjunctive Procedures for Challenging Endovascular Abdominal Aortic Repair: When Needed and How Effective?

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Endovascular aneurysm repair (EVAR) is now considered the first choice treatment modality for abdominal aortic aneurysm (AAA) treatment. Advocates for endovascular strategies will try to treat all AAA by EVAR, regardless if the anatomy is conducive for treatment or not. However, the long-term outcomes of EVAR outside the instructions for use (IFU) due to a hostile aneurysmal neck or iliac artery anatomy are known to be poor. The EVAR procedures can be classified according to the technical difficulty, IFU, and need for visceral revascularization: standard, adjunctive, and complex EVAR. The situation required for adjunctive procedures can be classified as the following four steps: a hostile neck (i.e., short or severely angled); large inferior mesenteric or lumbar artery; tough iliac artery anatomy, such as a short common iliac artery and stenotic external iliac artery; and limitations in vascular access. This article will discuss the adjunctive procedures to overcome hostile aneurysm neck and unsuitable iliac artery anatomy.

Key Words: Abdominal aortic aneurysm, Endovascular procedures, Outside the instructions for use, Adjunctive

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INTRODUCTION

Endovascular aneurysm repair (EVAR) is widely performed for treating abdominal aortic aneurysm (AAA) due to its lower invasiveness and early mortality rate compared to open aneurysm repair (OSAR). Many researchers compared the outcomes of EVAR vs OSAR, and a recent meta-analysis confirmed that the early survival benefits of EVAR are reversed after 3 years [1]. When choosing the treatment modality, surgeons should consider the long-term durability, reintervention rate, all-cause mortality, and cost-effectiveness [2,3]. Also, the availability of devices, economic status, and medical insurance system should be considered [4,5]. The physician's and patient's preferences also affect repair method selection [6]. A recent trend shows that many surgeons in the Unites States of America and South Korea prefer EVAR for AAA repair in 70%-80% of cases.

The major limitation of EVAR is anatomic feasibility to prevent endoleaks. EVAR outside the instructions for use (IFU) usually shows worse long-term results [7]. But, in many cases, adjunctive procedures can be applied to overcome the anatomic limitations while preventing future type 1 endoleaks.

Advocates for endo-frist strategies are willing to figure out various techniques to overcome the limitations [7,8]. Here, various adjunctive techniques are discussed to prevent type 1 endoleaks at the proximal and distal landing zone.

THREE CATEGORIES OF EVAR: STANDARD, ADJUNCTIVE, AND COMPLEX

There is no consensus on the stratification of EVAR according to the technical complexity, although many clinicians use these terms, such as adjunctive and complex [9,10]. In this study, EVAR was classified into three groups according to the IFU, use of adjunctive procedures, and use of specialized endograft or staging procedures of debranching. Standard EVAR is defined as performing EVAR off-the-shelf without any adjunctive procedures, usually performed in AAA patients with suitable anatomy within the IFU [11]. Complex EVAR is defined as EVAR for juxtarenal or pararenal AAA which requires revascularization of the visceral arteries, including branched EVAR, fenestrated EVAR, physician-modified endograft, and chimney, snorkel or periscope techniques [9]. Adjunctive EVAR is defined as standard EVAR followed by adjunctive procedures to prevent endoleaks from the proximal and distal landing zones, including Palmaz stenting, endoanchor or glue embolization for the proximal landing zone, and internal iliac artery (IIA) embolization or revascularization for the distal landing zone, which is usually performed in AAA patients outside the IFU.

Therefore, understanding the characteristics of a hostile aneurysm neck and unfriendly iliac arteries are critical to perform EVAR with adjunctive procedures [12].

ANATOMIC CHARACTERISTICS OF AAA IN ASIAN AND KOREAN POPULATION

Asian people have different anatomical characteristics of AAA as compared to Caucasians. Common iliac artery (CIA) length is significantly shorter in Asians, which can be translated as Asians having more limitations in selecting a distal landing zone [13,14]. The average length of the CIA in Koreans was 35 to 37 mm, which seems to be enough for standard EVAR [15]. However, due to the frequent iliac involvement of the disease, it is not long enough for standard EVAR in many cases [16].

For the neck anatomy, Caucasians have longer aneurysmal necks (33.0 vs. 28.4 mm), and a greater aneurysm to aortic axis angle (153° vs. 142°), which indicates that Asians have a more hostile anatomy.

In a retrospective review of AAA anatomy at our center, aortic neck anatomy was categorized into four types according to the length and angle: type A (defined as ≥10 mm and ≤60°; 73.7%), type B (≥10 mm and >60°; 21.2%), type C (<10 mm and ≤60°; 4.0%), and type D (<10 mm and >60°; 1.2%) (unpublished data). These data show that less than 5% of AAA cases are candidates for complex EVAR, and around 20% may require adjunctive EVAR. The consensus on the definition of a hostile neck is needed and the long-term risk of each factor should be evaluated [17].

ADJUNCTIVE PROCEDURES TO OVERCOME A HOSTILE NECK AND UNFRIENDLY ILIACS

1) Unfriendly iliac arteries

Many adjunctive procedures are commonly performed during EVAR. Yun and Park [18] reported that up to 51% of EVAR cases required adjunctive procedures for iliac arteries. Among them, IIA embolization was most common (37%), followed by angioplasty for small external iliac artery (EIA). A higher prevalence of adjunctive procedures for iliac arteries also reflects the anatomical characteristics in Asians [19].

① Internal iliac artery exclusion

Nowadays, IIA occlusions during EVAR are considered routine procedures in some hospitals. About 25% of pa-

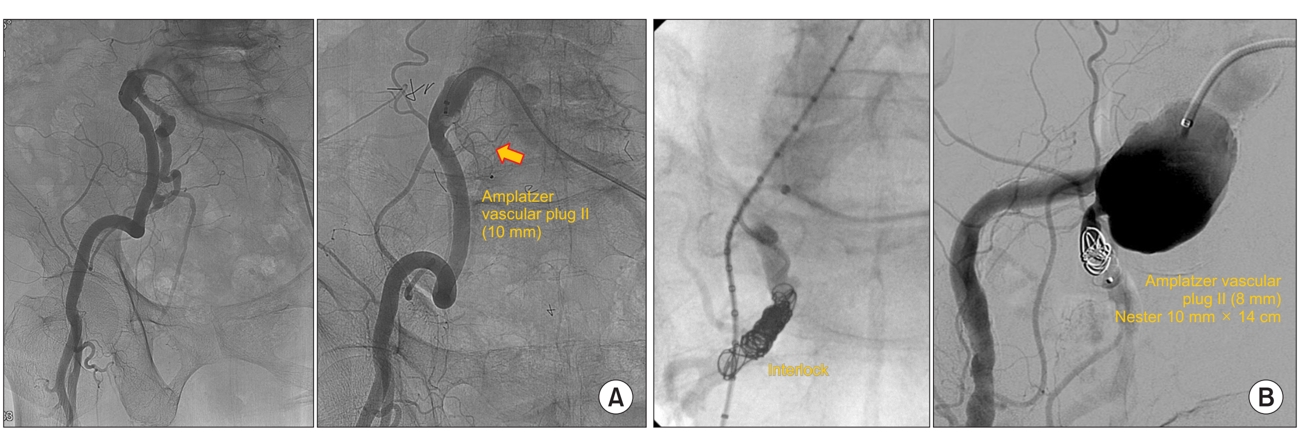

Fig. 1. Angiography showed the embolization of the internal iliac artery with a vascular plug (A) and coils (B).

tients underwent at least one IIA embolization in our institution during the last two years (unpublished data). This number is not surprising because all EVAR devices were initially designed for the anatomy of patients in Western countries [20-22].

Vascular plugs and embolic coils are commonly used, and sometimes graft coverage alone can be done (Fig. 1). IIA embolization can cause buttock claudication or pelvic ischemia, especially when performed on both sides [23]. A systemic review showed that IIA exclusion was done in 15% of EVAR cases, which was lower than the 30% observed in Korean data [19]. Buttock claudication occurred in 27% of patients and resolved in 48% after 22 months. Acute pelvic ischemia associated with iliac embolization can result in fatal complications, and lead to severe quality of life impairment. Therefore, the complications should never be considered as a benign or inevitable condition [24]. Overall 10% of men developed erectile dysfunction [25]. Therefore, IIA exclusions must be discussed in depth with patients and their family [26]. The incidence of buttock claudication was not statistically different between vascular plugs and embolic coils [27]. However, the plug has a shorter procedure and fluoroscopic time. The key technique to reduce the incidence of pelvic ischemia is deploying the embolic material at the most proximal IIA as possible, regardless of the devices selected [28].

Coverage alone seems to be the best option for the exclusion of IIA in terms of buttock claudication [29]. Coverage alone showed the lowest incidence of buttock claudication (12.9%) [19]. However, coverage alone may lead to late type 1b endoleaks, which are very difficult to treat by endovascular means. Therefore, coverage alone should be carefully selected by weighing the risk of buttock claudication and endoleaks caused by continuous degenerative disease [30]. Bilateral IIA exclusion should be avoided because it can cause fatal complications, including colon or gluteal necrosis [31]. Sequential embolization was introduced to decrease these complications and to induce collateral formation and maintain the gluteal flow [32]. It takes over a month to build up enough arterialization to supply the gluteal area, therefore, repeated procedures should be done with a time interval of at least 1 month [33,34].

② Surgical revascularization of IIA

In order to maintain flow to the IIA after endograft extension to the EIA, transposition of IIA to distal EIA or distal EIA-to-IIA bypass can be performed in cases not suitable for iliac branch devices (IBDs). Concomitant unilateral IIA embolization and contralateral EIA-to-IIA bypass can decrease the risk of pelvic ischemia [35]. The bypass is usually performed through a hockey-stick incision, without opening the peritoneum [36]. Transposition is preferred when the IIA is healthy and movable, otherwise an expanded polytetrafluoroethylene (PTFE) graft is used (Fig. 2). A preoperative computed tomography scan provides anatomical information to select the optimal operative method [37].

Another hybrid technique of EVAR exclusion with open IIA revascularization can be used [38]. This method consists of aortouniiliac (AUI) endograft and crossover femoro-femoral bypass for EVAR without a suitable distal sealing zone [39]. Long-term patency of the extraanatomic bypass was a concern but a recent study reported the feasible long-term patency (96% at five years) and low mortality rate (4% at 30 days) [38].

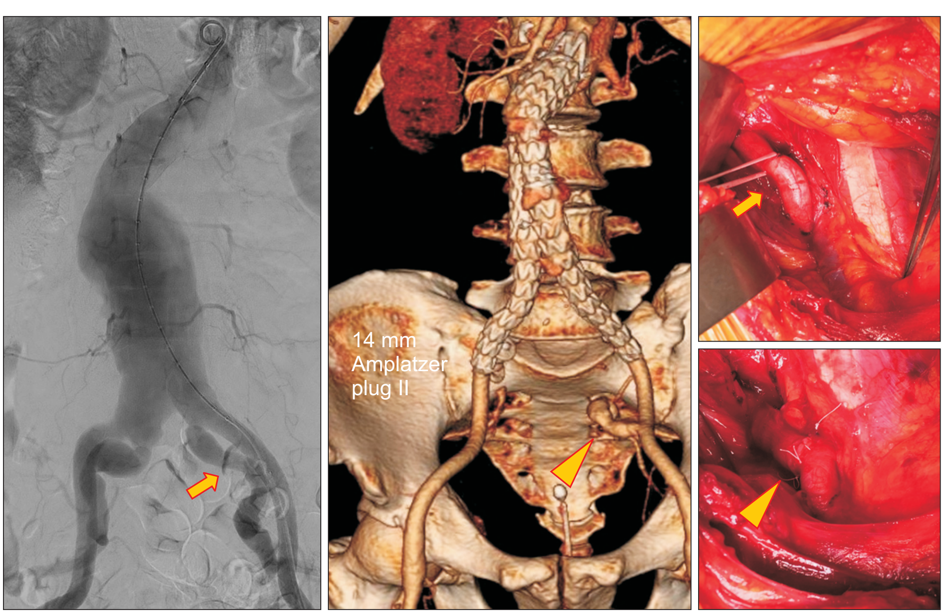

Fig. 2. Angiography and operative picture showed the short common iliac artery on both sides and a long healthy left internal iliac artery (IIA) (arrows). After embolization of the right IIA with a vascular plug, endovascular aneurysm repair was performed with an extension of both limbs down to the external iliac arteries (EIAs). The left IIA was revascularized by transposition to the distal EIA (arrowheads).

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③ Endovascular revascularization of IIA: IBD

The implantation of IBD during EVAR has shown excellent feasibility and outcomes for anatomically eligible patients [40]. Bilateral IBD implantation goes one step further to improve pelvic blood flow and reduce buttock claudication [41]. The technical success (95%) and patency (97.8% at one year) of bilateral IBDs were comparable to those of unilateral IBDs [42]. However, the major obstacle to using IBD is finding patients with a suitable anatomy based on the IFU. The common reason for exclusion is a short IIA landing zone, which necessitates design modifications for next-generation IBD [43].

2) Aneurysmal neck

Needless to say, the length and angle of the aneurysmal neck is the key factor affecting the success of EVAR [44]. Generally, the length of the neck should be more than 10 mm, but a minimum of 4 mm can be included for EVAR when using the Endurant II and Helix-FX EndoAnchors (Medtronic, Santa Rosa, CA, USA) [45]. With an aneurysmal neck <4 mm, OSAR or complex EVAR such as FEVAR or chimney are better choices [46,47].

The angle of the aneurysmal neck is another key factor in selecting proper EVAR devices [8,48]. The neck angle can be divided into an α and β angle (Fig. 3) [49]. Although the association of the α and β angle with type 1a endoleaks is different according to the EVAR devices, severe neck angulation increases the rate of type 1a endoleaks [50]. Also, different types of proximal fixation systems may have an impact on graft stability in patients with a challenging neck anatomy [51].

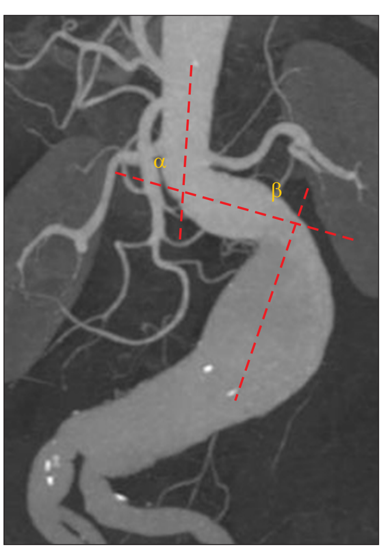

Fig. 3. Computed tomography angiography showed the suprarenal angle (α) and infrarenal angle (β) of the aneurysm neck.

① Oversizing

To avoid adjunctive neck procedures, determining the degree of endograft oversizing is important, especially in EVAR outside the IFU [49]. Depending on the type of procedure and aortic neck diameter, the oversizing rate can affect the long-term results of EVAR [52,53]. Studies showed that 10% to 20% oversizing regime is safe and preferable [54]. Oversizing >30% negatively impacted the outcome of EVAR, resulting in greater migration and AAA expansion. However, the relationship between oversizing and neck angulation is unknown. Interventionalists tend to choose oversizing in EVAR for angulated necks than unangulated (21.4 vs. 16.1, P=0.01), albeit the role of this oversizing in reducing type 1a endoleaks is unknown [49].

② Push-up technique and anatomical deployment

The push-up technique with the Endurant stent-graft system can be used for angled short aortic necks without using additional devices [55]. No matter how flexible the endografts are, they cannot fully contact along the tortuous aortic inner wall after deployment. Therefore, the intentional folding of the stent-graft creates redundant fabric so that it can increase contact with the aortic inner wall. Also, a stent deployed along the angulated neck is called an anatomical deployment. The presence of a space between the stents and controlled released system of the Euduarnt enables this technique. After first releasing the suprarenal fixation, a gentle upward force is applied. When pushing upward, care should be taken so that the endograft bifurcation is not deployed in the aortic neck. After observing Dr. Dohi's procedure at Juntendo University Hospital in Tokyo for controlling the folding and movement of the spindle, anatomical deployment was tried in my center. It was successfully implanted in a patient with a severely angled neck, but it required a lot of expertise to get enough folding along the aortic inner wall.

③ Endoanchor

Helix-FX EndoAnchor is a common method for treating type 1 endoleaks and endograft migration [56,57]. In addition to treating endoleaks, prophylactic use of the EndoAnchor has been noted for hostile necks to reduce reintervention [45,58]. Although the IFU of the Endurant device mentioned that EVAR could be done in patients with an aortic neck of at least 4 mm, the risk of type 1 endoleaks remains. Preemptive use of the EndoAnchor for hostile neck anatomy may reduce proximal neck complications [59].

Fig. 4. A cuff stent-graft was deployed first for the kilt technique, but suprarenal fixation was far away from the aortic wall (arrow). Angiography on the right shows a fully deployed aortic graft after inserting the main body. There was no type Ia endoleak.

④ Telescoping technique and kilt technique

The telescoping technique using AFX2 (Endologix Inc., Irvine, CA, USA) was designed for overcoming challenging AAA with a severe infrarenal angle (β angle). AFX2 is deployed to the aortic bifurcation and then stacked in proximal pieces [60]. Despite several strengths, AFX2 has inferior flexibility depending on the direction because all skeletal nodes are connected. If two or more proximal pieces are stacked along the course of the angle, stents can be stably deployed along with the shape of the tortuous aorta [61].

If an EVAR device other than the AFX2 is selected for severe β angled aneurysms, the kilt technique can be applied [62]. The dictionary definition of a kilt is a type of skirt traditionally worn by men in Scotland. An aortic cuff stent-graft is initially deployed in the β angled segment like a skirt or kilt before being deployed in the main body endograft. This cuff allows for straightening of the aorta and increasing the neck length, providing an additional sealing zone [63]. However, sometimes upward fixation or the upper part of the cuff may not completely contact the aortic wall (Fig. 4). Therefore, it should be attempted after careful evaluation of the three dimensional anatomy of the neck and AAA [64].

⑤ Glue and coil embolization for type Ia endoleak

Choosing only EVAR in AAA patients with a high probability of developing type Ia endoleaks is not a good option. However, EVAR can be the only option in some patients unfit for surgery [65]. When type 1a endoleaks are observed in the complete angiography as expected, additional ballooning and observation is suggested [66,67]. Aneurysmal rupture due to persistent type 1a endoleaks is rare, and most of them resolve within 1 year [68]. This strategy is beneficial to both surgeons and patients by reducing radiation exposure and contrast media [69], but serial image follow-up is mandatory.

The effectiveness of sac embolization for type 1a endoleaks has raised doubts on the long-term durability and persistent sac enlargement [70]. Marchiori et al. [71] reported that the freedom from sac enlargement rate was 76%, and reintervention-free survival rates at 24 months were 68%.

CONCLUSION

EVAR with adjunctive procedures not only burden the surgery itself but also increase the incidence of endoleaks (hazard ratio [HR], 4.56) and aneurysm-related mortality (HR, 9.38) [72]. Choosing only EVAR in AAA patients with hostile anatomy is not a good option. However, EVAR may be the only option in some patients unfit for surgery. When performing EVAR outside the IFU, surgeons should carefully evaluate the neck and AAA anatomy to reduce future endoleaks or migration. There are various adjunctive procedures to overcome hostile neck anatomy and unfriendly iliac arteries. Interventionalists should learn these new techniques and optimize procedures using novel ideas.

CONFLICTS OF INTEREST

The author has nothing to disclose.

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