HELLENIC REPUBLIC
National and Kapodistrian University of Athens
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FACULTY OF HEALTH SCIENCES
MEDICAL SCHOOL

JOINT POSTGRADUATE STUDY PROGRAM
«ENDOVASCULAR TECHNIQUES»

SUBJECT: ENDOLEAK TYPE III

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ABSTRACT
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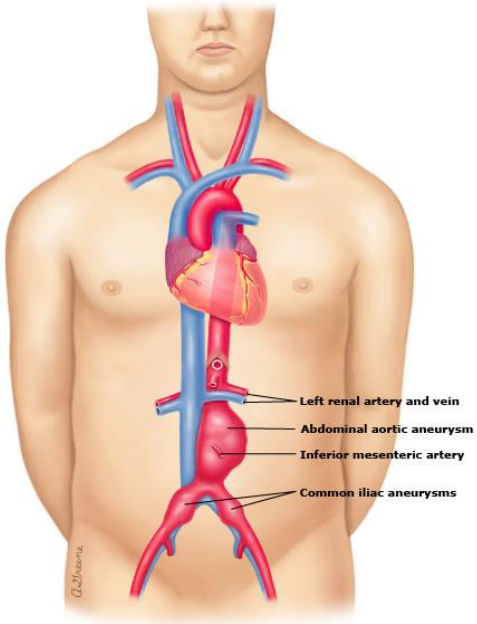
1.ABDOMINAL AORTIC ANEURYSM
1.1 DEFINITION

Abdominal aortic aneurysm (AAA) is the most common true arterial aneurysm. A true aneurysm is defined as a segmental, full-thickness dilation of a blood vessel that is 50 percent greater than the normal aortic diameter [1]. False aneurysms of the abdominal aorta can also occur but are much less common and are usually due to a traumatic or infectious etiology.



In most adults, an aortic diameter >3.0 cm is generally considered aneurysmal. Normal aortic diameter varies with age, sex, and body habitus, but the average diameter of the adult human infrarenal aorta is approximately 2.0 cm; 95 percent of the adult population has an aortic diameter ≤3.0 cm [1]. Thus, for the majority of patients, an infrarenal aorta with a maximum diameter ≥3.0 cm is considered aneurysmal [1-2]. For men, diameter alone defines the presence of an AAA and predicts clinical events. However, for women, although the aorta is still considered aneurysmal when its diameter exceeds 3.0 cm, the diameter is less predictive of clinical events. An aortic size index (ASI), calculated as diameter (cm)/body surface area (m2), is more predictive of clinical events than absolute aortic diameter in females [3].
For the purposes of this discussion:

●Small aneurysms have a diameter <4.0 cm

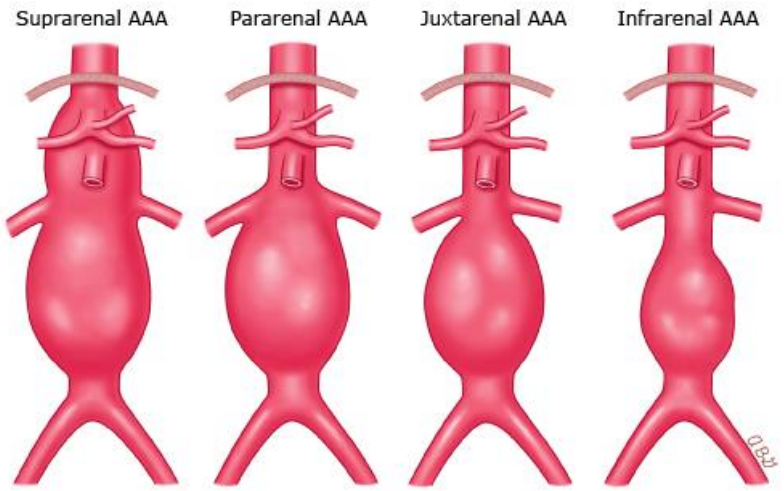
●Medium aneurysms have a diameter between 4.0 and 5.5 cm

●Large aneurysms have a diameter >5.5 cm

●Very large aneurysms have a diameter ≥6.0 cm

The natural history of AAA is one of progressive expansion, which is variable and depends upon aneurysm diameter and other factors, the most important of which is ongoing smoking.

AAAs can be described relative to the involvement of the renal or visceral vessels. Several classification schemes have been described. We use the following definitions to describe AAA



●Suprarenal aneurysm – The aneurysm involves the origins of one or more visceral arteries but does not extend into the chest.

●Pararenal aneurysm – The renal arteries arise from the aneurysmal aorta, but the aorta at the level of the superior mesenteric artery is not aneurysmal.

●Juxtarenal aneurysm – The aneurysm originates just beyond the origins of the renal arteries. There is no segment of nonaneurysmal aorta distal to the renal arteries, but the aorta at the level of the renal arteries is not aneurysmal.

●Infrarenal aneurysm – The aneurysm originates distal to the renal arteries. There is a segment of nonaneurysmal aorta that extends distal to the origins of the renal arteries.

AAA most often affects the segment of aorta between the renal and inferior mesenteric arteries; approximately 5 percent involve the renal or visceral arteries. Up to 40 percent of AAAs are associated with iliac artery aneurysm(s) [1-3].

1.2 EPIDEMIOLOGY

The estimated prevalence of abdominal aortic aneurysm (AAA) in developed countries is between 2 and 8 percent and is higher in males (4 to 8 percent in those older than 50) compared with females (1 to 1.3 percent). Based on screening, approximately 1,000,000 individuals in the United States have an AAA [5]. The prevalence of AAA increases with age in both men and women, although the age-related increase is more pronounced in men [4]. Ultrasound screening studies have shown that 4 to 8 percent of older men have an occult AAA [5]. Because the incidence of AAA rises sharply in individuals over 60 years of age, the future prevalence of AAA could increase substantially in association with the aging population. Other studies suggest that a reduction in the prevalence of smoking may have the opposite effect.

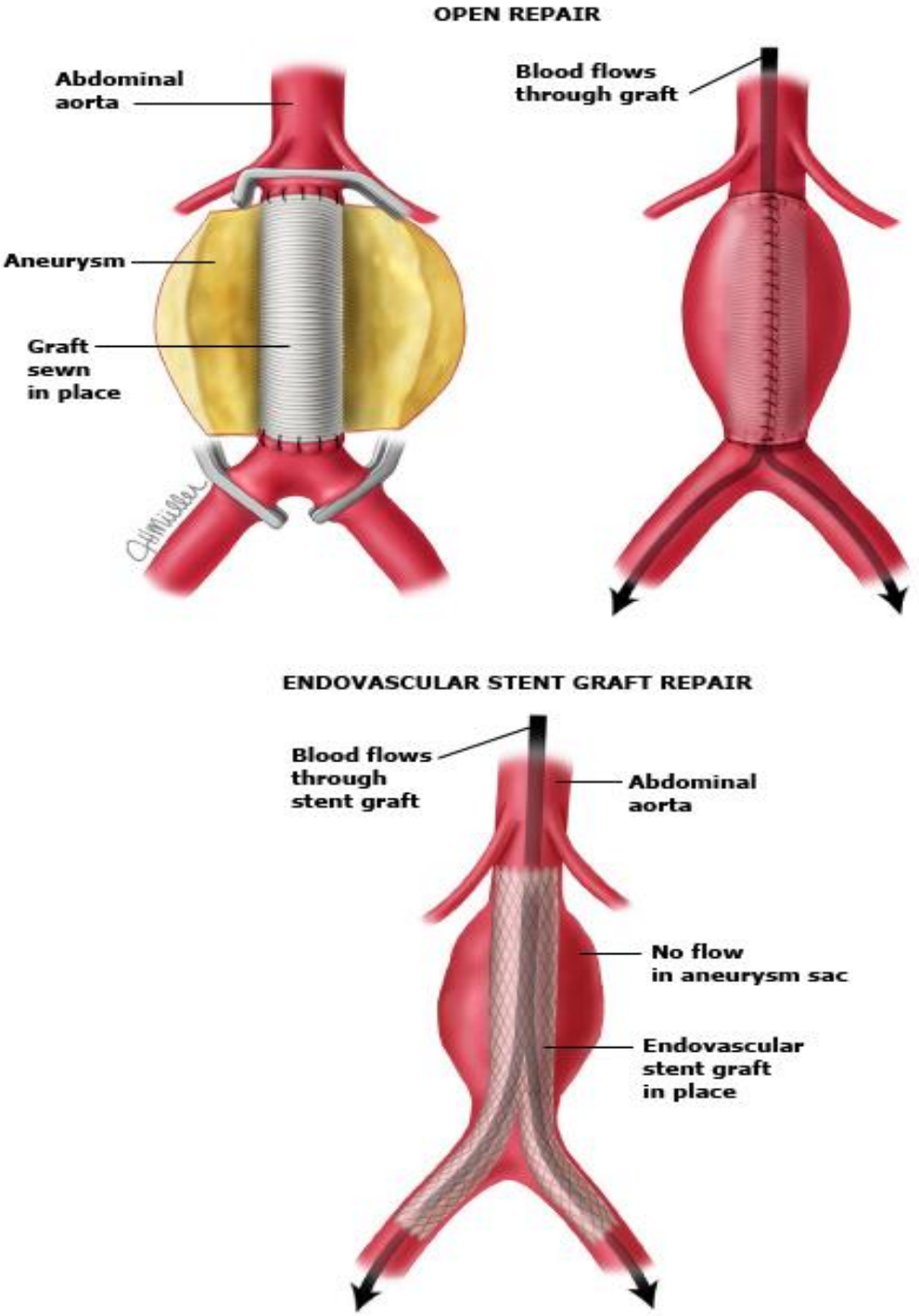
In the 2010s, death from rupture of an AAA was estimated to occur in approximately 7000 patients per year in the United States. AAA-associated mortality has decreased by nearly 50 percent since the early 1990s. Although the specific reasons for this decline are unknown, the declining prevalence of cigarette smoking in the adult population, the increasing awareness and impact of government-sponsored screening programs for identifying early disease, and an increase in the use of endovascular repair of AAA, particularly in the older patients, all may have played a role in this decline [5].

1.3 AAA REPAIR

Aneurysm repair can be accomplished using open surgical or endovascular techniques. Endovascular aneurysm repair is associated with a lower risk of perioperative morbidity compared with open repair for asymptomatic, symptomatic, and ruptured abdominal aortic aneurysm (AAA). Long-term mortality following elective AAA repair is not significantly different between the techniques. Guidelines from major medical and surgical societies recommend an individualized approach to the patient when choosing between open and endovascular repair, taking into account the patient's age, risk factors for perioperative morbidity and mortality, anatomic factors, and experience of the surgeon [1-2]. Given the need for lifelong surveillance with endovascular repair, younger patients with low operative risk may benefit more from open surgical repair, whereas older patients and those with high operative risk may benefit more from endovascular repair, provided their aortoiliac anatomy is appropriate.

Open surgical 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. With technical

refinements for open AAA repair, complications such as acute renal failure, distal embolization, wound infection, colonic ischemia, false aneurysm formation, aortoduodenal fistula, graft infection, and perioperative bleeding have become less common following routine elective surgery but remain significant issues following emergent open AAA repair.



Endovascular repair — Endovascular aneurysm repair (EVAR) involves the placement of modular graft components delivered via the iliac or

femoral arteries to line the aorta (figure 6) and exclude the aneurysm sac from the circulation. EVAR requires fulfillment of specific anatomic criteria. With contemporary techniques, including custom-made fenestrated and branched devices, most patients can be considered candidates for EVAR in experienced endovascular centers.

Some anatomic features of the aorta or iliac arteries may preclude the ability to place an aortic endograft. Endovascular repair may not be anatomically feasible if the aortic neck is occupied by thrombus, there is circumferential calcification at the level of the aortic neck, or both iliac arteries are too small for the intended device. Endovascular repair of juxtarenal or suprarenal aortic aneurysm is not possible where advanced devices and technical expertise are not available.

2. HISTORY

The use of endovascular grafts initiated for the first time by Volodos in 1986 (6). Later in 1991, Juan Parodi published a series of endovascular abdominal aortic repairs (EVAR), with the use of endovascular stent grafts made of Dacron, using common femoral artery as access point.(7) Thus, it was proved that the endovascular approach of aortic aneurysms could exclude the aneurysmal sac and decreased the risk of rupture.

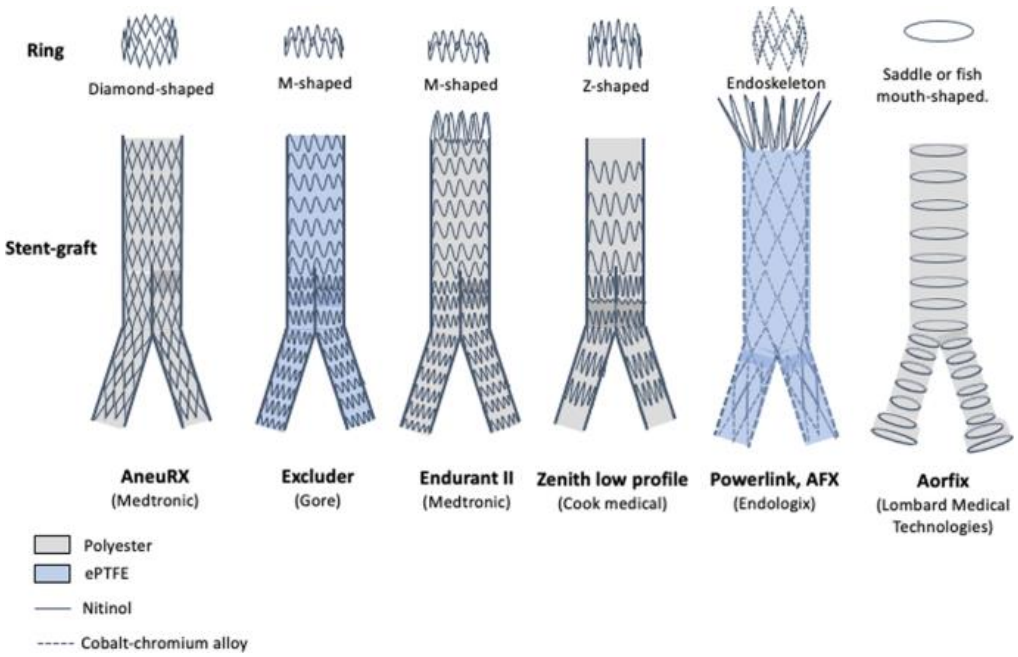
From the early 1990, EVAR has dramatically changed the treatment of aneurysms for doth the abdominal and thoracic aorta. Every new stent graft generation is more advanced and their indications for use (IFU) address to more complicated anatomy. Thus, at the end of 1999, fenestrated grafts and branched grafts were used for the first time, expanding the endovascular surgery to juxtarenal aneurysms, thoracoabdominal aneurysms, dissections and other conditions of abdominal and thoracic aorta. (8)
At first, fenestrated endografts were used in order to extend the area suitable for sealing for infrarenal aneurysms with short neck. The first results from multicenter studies, confirmed the integrity of the proximal sealing zone and the incorporated arteries. As a result, the use of

fenestrated endografts expanded to aneurysms with more complex anatomy, until complete thoracoabdominal repairs were possible. (9) Initially, fenestrations were sealed with the use of uncovered balloon-expandable stents. But Mohabbat et al. showed better results of patency with covered stent grafts (10).
Regarding enlarged aneurysms in which the stent graft is much larger than visceral aorta, fenestrations were not adequate. Thus, the concept of branched endograft was developed, with a cuff of fabric attached to the main body of the device, providing therefore a longer landing zone. (11)
Development of a minimally invasive option for the treatment of complex aneurysms, dissections or other aortic diseases is nowadays feasible and is crucial for patients presenting with multiple comorbidities, making open repair high risk.

3. ENDOVASCULAR DEVICES

Endovascular aneurysm repair refers to the insertion of endovascular graft components, usually via a femoral approach. The endovascular graft is constructed by the in vivo delivery and deployment of the device components in an established order determined by the specific anatomy of the patient. Upon deployment, the endograft expands, contacting the aortic wall proximally and the iliac vessels distally, excluding the aneurysmal aortic sac from blood flow and pressure.

Although there are significant variations in endovascular graft design, three types of components are common to all: a delivery system, main body device, and device (limb) extensions.



Delivery system — The various endograft components are typically delivered through the femoral artery, either by direct surgical cut-down or percutaneously. If the femoral artery is too small to accommodate the delivery system, access can be obtained by suturing a synthetic graft of appropriate diameter (often 10 mm) to the common iliac artery to create an iliac conduit through a retroperitoneal incision. The size of the delivery system varies depending upon the device diameter required to provide proper endograft fixation.

Main device — The main body device for the abdominal aorta is usually bifurcated. Endovascular grafts rely primarily upon outward radial force in the proximal graft to maintain the positioning of the graft. Fixation systems may also include barbs or a suprarenal uncovered extension. Bifurcated abdominal aortic grafts require adjunctive placement of iliac artery limbs to complete the graft and seal. The iliac limbs on the main body device vary in length depending upon whether the graft is a two- or three-component graft. Two-component grafts have one short and one long iliac limb. Three-component devices have one short limb and one limb of variable length.

Endovascular grafts for the abdominal aorta are generally bifurcated; however, some situations require the use of a unibody (i.e., not bifurcated) graft, also known as an aorta-uni-iliac (AUI) device. These grafts are used in patients with severe unilateral iliac artery stenosis or occlusion. AUI devices can also be used for the treatment of some ruptured aneurysms. A bifurcated-to-unilateral graft conversion kit can

be used in the situation when contralateral iliac artery access or contralateral gate cannulation is difficult or impossible. This kit effectively turns a bifurcated main body graft into a unilateral graft by covering or occluding one of the iliac limbs proximally. After deployment of an AUI device, a plug may be inserted into the contralateral iliac artery to prevent retrograde flow of blood into the aneurysm sac, if needed. The contralateral extremity typically requires a femoro-femoral crossover bypass for perfusion.

Extensions — One or more extension devices may be needed to provide a complete proximal or distal seal. Following the deployment of the main device and any necessary contralateral limbs or extensions, an aortogram is performed to assure that the endograft has completely excluded the aneurysm from the circulation. The term "endoleak" was coined to describe the persistence of blood flow into the aneurysm. If additional ballooning of the device does not firmly appose the graft to the aortic wall and eliminate a type I endoleak, placement of additional proximal aortic or iliac extensions may be needed.

Characteristics of abdominal endovascular devices

Endograft	Materials graft/support	Suprarenal fixation	Active proximal fixation/hooks	Native aortic neck diameter (range in mm)	Native iliac diameter (range in mm)	Maximum bifurcated main body device/introducer sheath diameter (French, OD)	Potential advantages
AFX2 (Endologix)	PTFE/cobalt chromium alloy	Yes	No	18 to 32	10 to 23	17	Anatomic fixation at bifurcation, low profile
Alto (Endologix)	PTFE/nitinol*	Yes	Yes¶	16 to 30	8 to 25	15	Low profile, short aortic neck (7 mm below the lowest renal artery), short iliac seal zone (10 mm)
Aorfix (Lombard)	PTFE/nitinol	No	Yes	19 to 29	8 to 19	22	Flexibility, angulated neck
Endurant (Medtronic)	Polyester/electropolished nitinol	Yes	Yes	19 to 32	8 to 25	20	Indications include short (10 mm) aortic neck, angulated neck
Excluder (Gore)	PTFE/nitinol	No	Yes	19 to 32	10 to 18.5	20	C3 delivery system, ability to recapture and reposition body, delivery sheath with hemostatic seal
Incraft (Cordis; investigational device in the United States)	Polyester/nitinol	Yes	No	27 to 31	10 to 24	16	Ultra low profile
Terumo aortic	Polyester/nitinol	Yes	Yes (dual)Δ	17 to 32	8 to 20	19	Minimize modular disconnection; Detachable sheath; delivery system allows cranial or caudal adjustment; late repositioning
Zenith (Cook Medical)	Polyester/stainless steel	Yes	Yes	18 to 32	8 to 20	26	Spiral Z flexible limbs
Zenith fenestrated (Cook Medical)	Polyester/stainless steel	Yes	Yes	19 to 31	9 to 21	20	Juxtarenal aneurysm
Removed from US market◇							
Ovation (Endologix)	PTFE/nitinol	Yes	Yes	16 to 30	8 to 20	15	Low profile, proximal sealing ring

OD: outer diameter; PTFE: polytetrafluoroethylene.

* Nitinol suprarenal stent and iliac limbs; fill polymer in aortic body; primary seal ring, secondary support ring, and leg support rings; platinum-iridium alloy radiopaque markers.

¶ Eight anchors on the bare suprarenal stent.

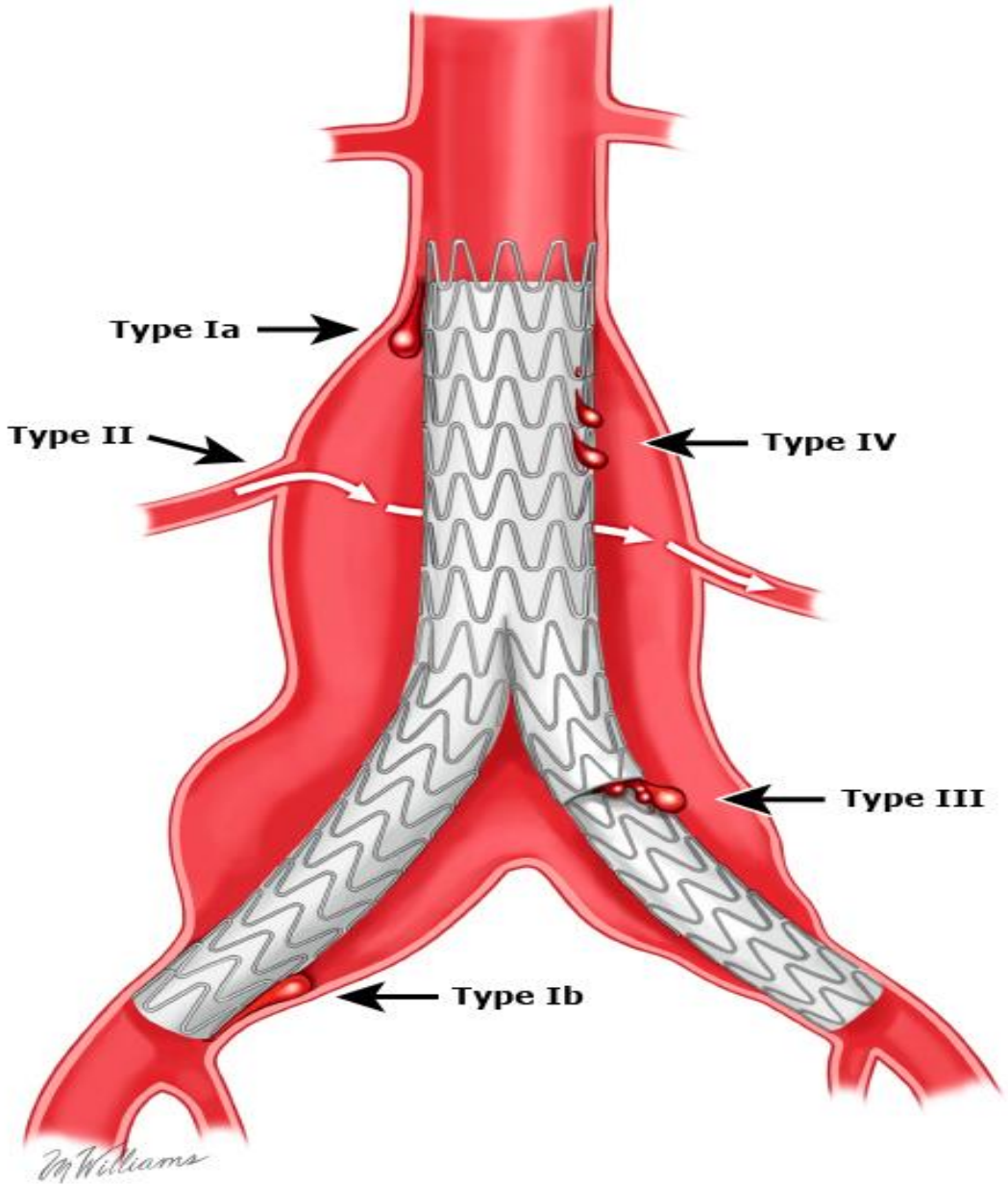
Δ Suprarenal and infrarenal fixation.

◇ Devices in this section may be available elsewhere.

Data from:

4. ENDOLEAKS

Endoleak is defined as persistent flow of blood into the aneurysm sac after device placement and indicates a failure to completely exclude the aneurysm [12]. Following completed endovascular repair, the diagnosis of endoleak is made either with completion arteriography or on follow-up imaging, usually computed tomography (CT), that demonstrates blood outside the bounds of the endograft. For some types of endoleak, the source can be difficult to determine. Color flow duplex or selective arteriography may be needed to establish the diagnosis. Endoleak is associated with a continued risk for aneurysm expansion or rupture. The most common types of endoleak (I and II) are usually managed successfully with the placement of additional stents or embolization techniques, but sometimes open surgery is needed. Type III endoleaks may be more commonly seen with certain endografts and require either relining with another graft or open surgical conversion to prevent rupture.



The types of endoleak are classified by the source of the [13]. The type of endoleak determines the magnitude of intrasac pressure.

●Type I endoleak is due to an incompetent seal at the proximal or distal attachment sites. Type I leak can occur immediately after device placement or can develop later over time.

•Type Ia – Proximal type I endoleak typically reflects incomplete apposition of the stent-graft to the aortic neck. Contributing factors include mural thrombus; a short, angulated, dilated, severely calcified, or reverse-tapered aortic neck; and incorrect device sizing. The use of an endograft with or without suprarenal fixation does not seem to affect the risk of type I endoleak.

•Type Ib – Distal type I endoleak is usually due to incorrect sizing of the

iliac limbs or inadvertent deployment of the endograft limb, often because of excessive iliac tortuosity within the more proximal, larger iliac vessel.

Late type Ia or type Ib endoleak can develop as a result of conformational changes in the aneurysm sac, aneurysmal degeneration of the aortic neck or iliac arteries, severe angulation at the fixation sites, or graft migration. Patients requiring large proximal diameter devices (34 to 36 mm) to seal dilated aortic necks or flared iliac limbs (>20 mm) to seal wide iliac arteries are reported to have a higher risk of late type 1a or 1b endoleak, respectively.

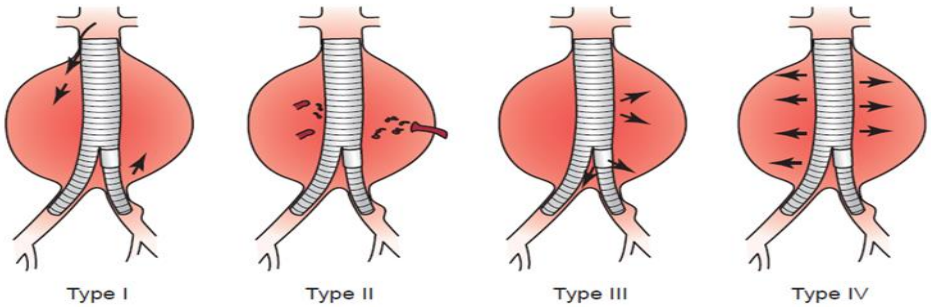
●Type II endoleaks are due to the presence of a patent inferior mesenteric artery or patent lumbar branches or, in the case of thoracic aortic aneurysm repair, patent intercostal arteries. These allow retrograde flow into the aneurysm sac. The incidence of type II endoleak has been correlated with the number of patent aortic branches prior to endovascular repair of the aneurysm.

●Type III endoleaks are due to a junctional leak, disconnection of the endograft components (type IIIa), suture breaks, metal ring fracture, or holes in the endograft fabric (type IIIb). As with type I endoleak, type III endoleaks can occur early or late.

●Type IV endoleak is defined as increased graft wall "porosity" leading to exudation of plasma components across the wall of the endograft.

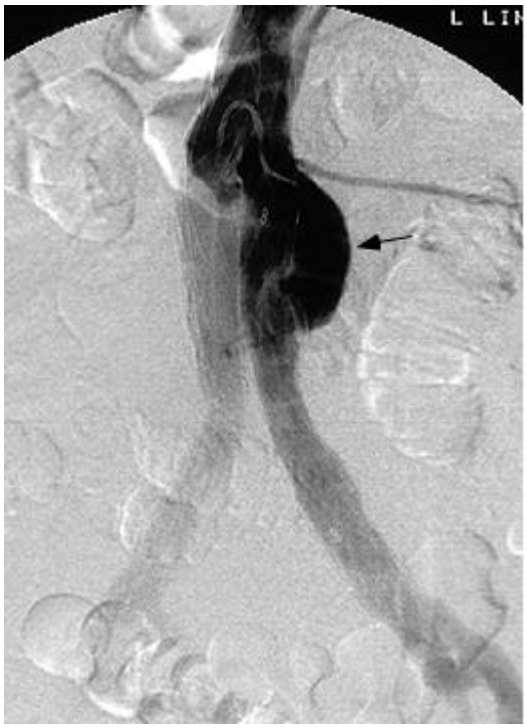
●Continued aneurysm sac expansion without a demonstrable endoleak on any imaging modality is referred to as endoleak of undefined origin but has also been termed type V endoleak or endotension.

While there is little controversy over type I and III endoleaks, reports conflict regarding the natural history, detection and follow-up, optimal timing, and type of treatment for type II endoleaks. The most common types of endoleak (I and II) are usually managed successfully with the placement of additional stents or embolization techniques, but sometimes surgery is needed.



5. ENDOLEAK TYPE III

Type III endoleak — Type III endoleaks are due to a junctional leak or disconnect of the endograft components (type IIIa) or holes in the endograft fabric (type IIIb) [14].



As with type I endoleaks, type III endoleaks can occur early or late.

●Early type III endoleaks are leaks between endograft components noted on completion arteriography. These are most often due to insufficient overlap between graft components or inadequate balloon expansion at the junctions of the endograft components.

●Late type III endoleaks can develop months to years later, with partial or complete separation of endograft components. Late type III endoleaks have been related to conformational changes in the aneurysm sac, endograft migration, and/or dilation of aortic and iliac attachment sites [15]. The dominant forces on modular endovascular graft components are directed laterally and increase with aortic or endograft angulation [16.17]. The resulting endograft displacement is more prevalent with larger aneurysms and is associated with an increased incidence of type IIIa (and type I) endoleaks.

The reported incidence of type IIIa endoleaks across multiple endograft platforms is 2 to 3 percent [17]. The incidence of type III endoleak was relatively high with early generation endografts, which were susceptible to material fatigue, fabric rents, and limb disconnection. The improved

technology and testing of later-generation endografts have nearly eliminated material failure, and longer overlap zones with larger inserts have decreased the occurrence of limb disconnections. In 2017, the Food and Drug Administration reported an apparent increase in the occurrence of Type III endoleaks, potentially related to early-generation graft materials, but also to the presence of calcified plaque and inadequate overlap between graft components. The recommendation was to consider lifelong surveillance of patients who have been treated with EVAR and consider type III endoleaks in the differential diagnosis of patients who present with symptoms of potential aneurysm expansion or rupture. With device improvements, it is likely that type IIIa endoleaks are more common compared with type IIIb endoleaks. These are more prevalent with complex fenestrated EVAR procedures that have an increased number of endograft junctions.

The most serious consequence of type III endoleak is pressurization of the aneurysm sac with subsequent expansion of the aneurysm and rupture. In an analysis of EUROSTAR registry data, patients with late type III endoleak had an almost nine-times-greater risk of aneurysm rupture compared with other registry patients, even when compared with those who had a type I endoleak. As such, type III endoleaks are at least as serious type I endoleaks and should be treated as soon as they are identified to prevent the possibility of aortic rupture. Endograft uncoupling can also obstruct aortic blood flow, leading to AAA thrombosis and acute lower extremity ischemia.

Endovascular treatment is typically straightforward, involving the deployment of additional stent-graft components to seal the fabric defect or bridge the disconnected components. The main technical challenge is cannulation of the main body gate, which can be particularly difficult if the components are offset. Once cannulation has been accomplished, a new iliac limb graft can be deployed. Another option is to deploy a new bifurcated stent-graft, thereby rebuilding an entirely new device within the existing device. This technique is appropriate for situations of significant migration from the proximal landing zone or in cases of multiple component separations.

6.DIAGNOSIS

The diagnosis of endoleak is frequently made at completion arteriography during endovascular aortic repair (EVAR) but may be identified on follow-up imaging that demonstrates blood outside the bounds of the endograft. For some types of endoleak, the source can be difficult to determine.

Post-EVAR imaging protocols to detect endoleaks and/or endograft

migration rely on computed tomographic (CT) angiography, given its availability and standardization. CT angiography can provide sac size and volume measurements, which can help guide surveillance and management, particularly when an endoleak cannot be clearly identified [18]. Duplex ultrasound with or without contrast as well as magnetic resonance (MR) angiography have been suggested as alternative imaging modalities [20]. In systematic reviews, MR imaging detected more endoleaks compared with CT angiography, particularly type II leaks. Duplex ultrasound is less expensive and safer and may be more sensitive for the diagnosis of endoleaks [20].

Duplex ultrasound has the specific advantage of detecting flow direction of endoleaks, facilitating identification of the type of endoleak; Doppler waveforms may even be able to predict the natural history of type II endoleaks. Contrast-enhanced ultrasound (CEUS) may have better accuracy, particularly for endoleak detection and classification. In meta-analyses, the accuracy of CEUS was comparable to CT angiography, if not better, particularly for the detection of late type II endoleaks [20]. In the latest review, which included 26 studies, the pooled sensitivities and specificities of CEUS for all endoleaks were 0.94 (95% CI 0.89-0.97) and 0.93 (95% CI 0.89-0.96), respectively. The pooled sensitivities and specificities for type I and type III endoleaks were higher at 0.97 (95% CI 0.8-1.00) and 1.00 (95% CI 0.99-1.00), respectively. Unfortunately, ultrasound accuracy is operator-dependent, and technical difficulties limit its universal application, particularly in patients with large body habitus. Wireless pressure sensors implanted during endovascular aneurysm repair have shown some value in monitoring intrasac pressure, but sufficient data supporting their use are still lacking [21].

Most type I and type III endoleaks will be identified with completion arteriography. Some type II endoleaks may also be identified during the completion angiogram, provided that delayed images are taken.

Component separation associated with type III endoleak can be identified with plain abdominal films and confirmed with CT angiography. It may not be easy to distinguish component separation from a type I or type II endoleak, and it is even more difficult to differentiate type II endoleak when the source of the leak is a fabric tear. Type III endoleak is usually easily recognized with conventional arteriography but may require selective limb imaging with contralateral limb balloon occlusion.

7.PREVANTION STRATEGIES

Endoleaks are best prevented by proper patient and device selection.

Types I and III endoleaks in large part can be avoided by careful stent-graft size selection, ensuring adequately long landing zones proximally and distally and generous graft overlapping in the setting of modular stent-grafts. Assuming appropriate patient selection and graft sizing, measures to prevent type I endoleak include correcting radiologic parallax to ensure correct positioning and appropriate balloon inflation of the attachment sites once the device is correctly deployed.

PART 2

1. INTRODUCTION

Endovascular aneurysm repair (EVAR) has gained wide acceptance as the most common and usually preferred method for the treatment of aortic aneurysms. As graft technology has advanced, EVAR is now associated with lower 30-day mortality and morbidity rates as well as earlier discharge compared with traditional open aneurysm repair [7, 22. 23]. However, EVAR is also associated with higher reintervention rates compared with open repair, and endoleaks are the most common indication [24]. Endoleak is defined as a persistent arterial perfusion of the aneurysm sac after endovascular treatment and was categorized in four types by White et al [25] The most modern definition of type III endoleak is found in the reporting standards, which describe it as leakage between endograft components or fabric disruption (fig1) [26]. Two subtypes are included in type III endoleak, type IIIa endoleak is described as a disconnection between the main body and the contralateral limb but can also be due to disconnection of the iliac limb from the ipsilateral distal extension or of a proximal cuff from the endograft main body. Type IIIb includes disruption of the fabric of the endograft, such as fabric tears and stent fractures, and is further subdivided into holes > 2 mm or < 2 mm. The underlying mechanism of the fabric defects is still being debated and may include processes occurring during the initial procedure where the fabric is damaged by the tip of a stent displaced by severe angulation of the neck or by friction through heavily calcified, tortuous iliac arteries. Another potential cause of intraoperative-related fabric defects might be excessive pressure during ballooning [27]. It is likely that as the durability of EVAR improves, a further very late fabric defect based on biologic degeneration may occur, like older open prosthetic grafts. Similar to type I endoleaks, type III endoleaks can be classified as either early or late. Early type IIIa endoleaks are diagnosed on completion angiography and are attributed to either insufficient overlap between graft components or inadequate balloon expansion. Early type IIIb endoleaks are rare with modern devices and entail a preexisting endograft fabric tear or injury to the endograft during placement or manipulation. Late type III endoleaks develop months to years later, with a median time interval of 5.6 years [28]. Late type IIIa endoleaks are generally attributed to conformational change in the aneurysm sac leading to component separation, endograft migration, or dilation of aortic and/or iliac attachment sites. Large aneurysm size, especially over 6.5 cm, has consistently been associated with late development of endoleaks in both TEVAR and EVAR, including type III endoleaks [29].
The purpose of these study is to determine the incidence and the risk factors of type III endoleak after EVAR intervention.

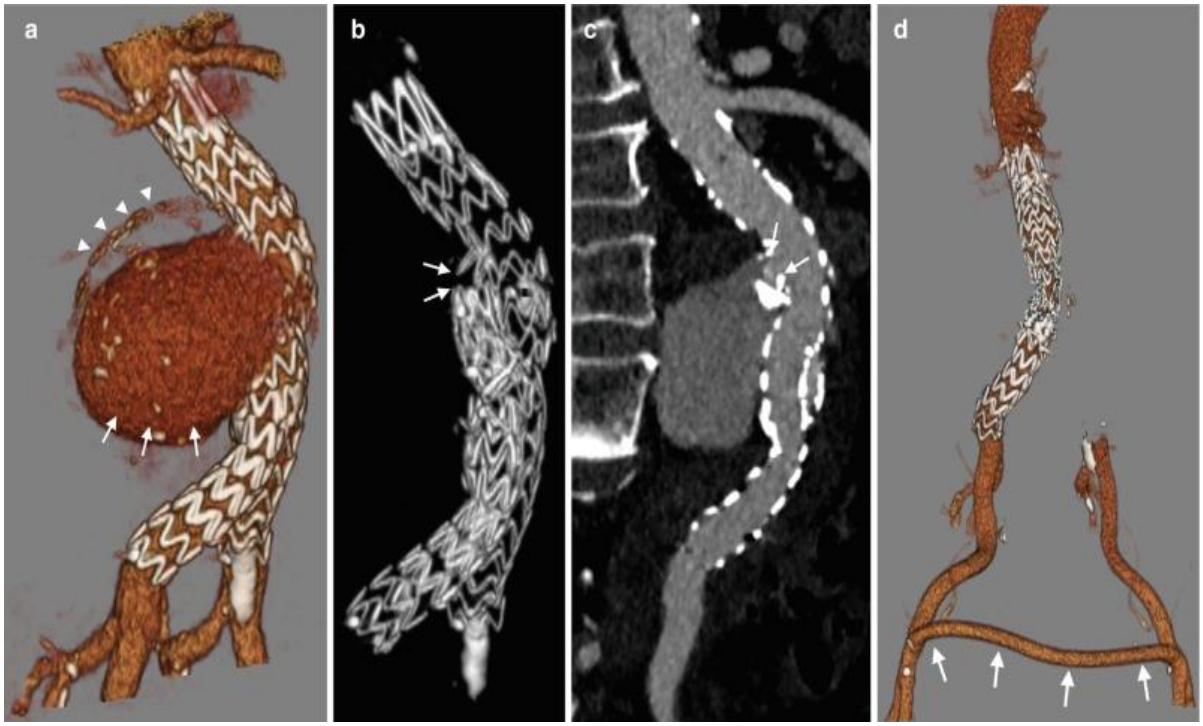


Figure 1: Endoleak type III

2. MATERIAL AND METHOD

Search strategy

An electronic search on Pubmed and Google Scholar was performed to identify all studies reporting type III endoleak after EVAR. Search terms included “endoleak III” or “endoleak 3” or “endoleak after EVAR” or “type III endoleak”. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed for the systematic review design [30].

Inclusion criteria

Inclusion criteria were all original reports (randomized controlled trial, prospective and retrospective case series) describing type III endoleak after EVAR. Only studies written in English were included. No studies were excluded based on date of publication. Abstracts were excluded from this review. Duplicated publications, reports with insufficient information, and opinion and revision articles were excluded.

Data extraction

Two independent observers (KK, SG) analyzed the titles and abstracts of all identified reports. For study titles that met set criteria, full texts of the articles were retrieved and read for details. Nonagreement in any article was discussed with a third author for the final decision. Outcomes of each study were itemized in a tabular format for easy comparison and analysis (Table I).

The data included publication metrics (name of first author), the number of treated patients, the number of types III endoleaks detected, the type of endovascular device, the duration of follow up.

3. RESULTS

In the initial search, 112 articles were identified. All unique articles were identified after duplicates were removed. After title and abstract reading by two authors (K.K and S.G.), 38 studies were selected for full-text reading. After full-text reading, 16 studies were excluded, 10 were referred to type III and type I endoleak as one side effect and the extraction of data for only type III was not possible, 4 was about iliac branches and 2 were early results of the same study, so they did not meet inclusion criteria about type III endoleak after EVAR. Finally, 22 studies were included for final analysis. The flow diagram is detailed in Figure 2.

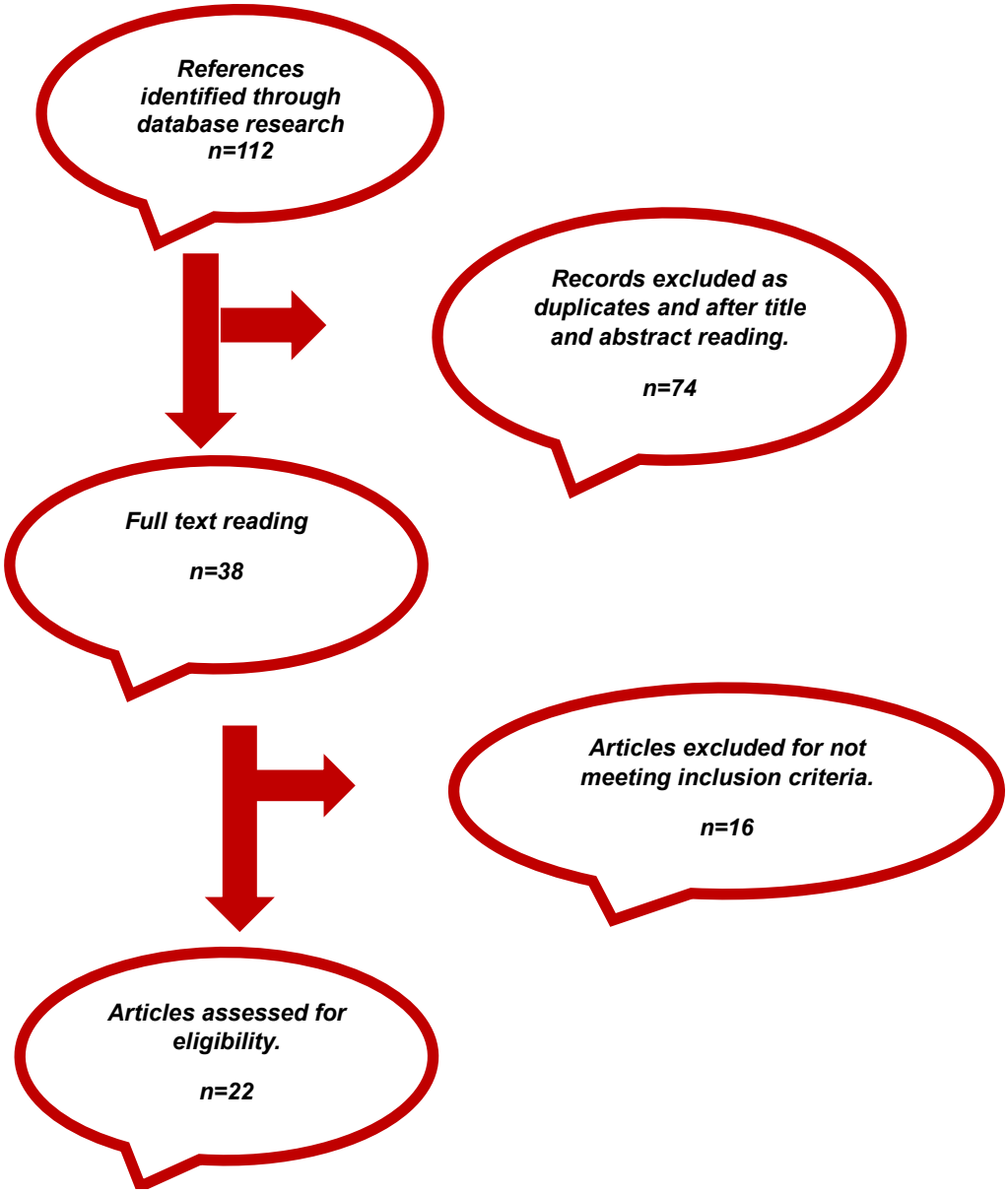


Figure 2: Flow diagram

Incidence of III Endoleak

The selected articles included a total of 6980 patients. All patients were treated with EVAR. Indication for operations included infrarenal aneurysms. Type III endoleak is recorded to 75 cases and thus the incidence rate is estimated to be 1.07% (75/6980). Also, from 22 studies only 9 showed endoleak type III 41%.

Type of infrarenal AAA

In most articles the selected patients for EVAR had asymptomatic AAA 95.4% (20/22). Except in two studies symptomatic patients were included. In one study (Bove et al) one endoleak type III was found. The other study that included symptomatic patients had 16 endoleak type III 2.2(16/703). But there is no data regarding if the inclusion of symptomatic patients, played any part in endoleak type III.

Endovascular Devices

All of studies provided information about the devices that were used. The most common used devices are Talent 32 % (7/22), Excluder 27% (6/22), Zenith 27% (6/22), Endurant 18% (4/22). One study (Ouriel et al) also notes that in zenith group versus Aneurx, zenith group had endoleaks due to component disunion.

Endoleaks type III treatment

Not all articles gave specific details if the endoleaks are treated and the type of intervention. The 48% of endoleaks were treated (36/75) but for many articles we don't have enough data. Also, the type of intervention when it is noted 44% (4/9) is endovascular but not many details in most cases are provided.

Follow Up

The mean follow up from all the studies is 29 months. the range of mean follow up between studies varies from 1 month to 15 years. The majority of studies had follow up at 1month, at 6 months at 12 months and the yearly 73% (16/22) and with CT.

Tables

REFERENCE	PATIENTS	TYPE OF AAA	TYPE III ENDOLEAK	DEVICE	MEAN FOLLOW UP (MONTHS)	TREATMENT	TREATMENT
Wang et al 2008	188	asymptomatic	0	powerlink	22		
Faries et al 2002	368	asymptomatic	2	talent	7,2	2	endovascular
Alric et al 2003	23	asymptomatic	0	chuter	72,5		
Ouriel et al 2003	703	asymptomatic and symptomatic	16	Ancure, AneuRx, Excluder, Talent, and Zenith	11		
Bove et al 2003	37	asymptomatic and symptomatic	1	transrenal fixation-Talent	28,5	1	endovascular
Carpenter et al 2004	222	asymptomatic	0	Lifepath	11		
Peterson et al 2007	235	asymptomatic	0	Excluder	60		
Jordan et al 2009	78	asymptomatic	0	powerlink	60		
Makaroun et al 2011	150	asymptomatic	0	Endurant	12		
Mehta et al 2014	161	asymptomatic	0	Ovation	12		
Mehta et al 2014	153	asymptomatic	1	Aptus (endoanchors)	40,8	1	endovascular
Lal et al 2015	439	asymptomatic	6	AneuRx, Excluder, Zenith, Ancure, EndologixO	108	6	
Carpenter et al 2018	333	asymptomatic	0	Nellix	24		
Rodel et al 2009	61	asymptomatic	0	Anaconda 2nd	24		
Weale et al 2010	31	asymptomatic	0	Aorfix	12		
Stokmans 2012	1262	asymptomatic	6	Endurant		5	endovascular
Tang et al 2013	1172	asymptomatic	13	Endurant (1089 bif-83 uni)	12	6	endovascular
Greenhalgh-Patel et al 2018	626	asymptomatic	25	AneuRx, Excluder, Zenith, Talent,Ancure, Endologix, Quantum or Teramed	84	15	
Mensel et al 2012	71	asymptomatic	1	Talent vs Endurant	1		
Becquemin et al 2011	150	asymptomatic	0	Zenith, Talent, Excluder, Powerlink	36		
Hatzl et al 2021	347	asymptomatic	0	Zenith	1	1	
Prinssen et al 2004	170	asymptomatic	5	Zenith, Talent, Excluder, Other	1		

Table 1

4. DISCUSSION

In daily practice EVAR is gaining ground in treatment for aortic aneurysms. As graft technology has advanced, EVAR is now associated with lower 30-day mortality and morbidity rates as well as earlier discharge compared with traditional open aneurysm repair [7,23, 52]. But secondary intervention in EVAR is like the sword of Damocles for the procedure. One of the main reasons for reintervention are endoleaks. The incidence of type III endoleak, as described in randomized controlled trials including the EVAR 1 trial [48] and the OVER trial [42] or in prospective registries like the EUROSTAR registry,[52] ranges from 3% to 4.5% and includes different types of endograft implants. There was a relatively high incidence of early and late type III endoleaks in first- and second-generation endografts (mainly Stentor [MinTec, Inc.] or Vanguard [Boston Scientific Corporation] devices). The incidence ranged from 8% to 12%, probably because of the small overlap recommended for early multicomponent stents, as well as a slow-to-emerge understanding of the importance of affixing the fabric onto the stent. However, using currently available endografts, the incidence of type III endoleaks can be reduced to 1%, keeping in mind that the follow-up period with these types of endografts is shorter. Ouriel et al mentions tha Zenith device had more serious endoleak type III vs Aneurx that needed intervention due to parts disunion [34].
Type III endoleak is a rare complication that has been mostly described in case reports or small case series. Our study showed that endoleak type III was present at 1.07% of EVAR procedures (75/6980).

After EVAR placement, the updated 2017 guidelines from the SVS recommend surveillance imaging with CT scan at 1 month, 6 months, 12 months, and yearly thereafter. Type III endoleaks are often asymptomatic, with most diagnosed-on surveillance imaging, and rarely due to high clinical suspicion. Those with rapid aneurysm sac growth or aneurysm rupture may present with abdominal pain and hemodynamic instability. Some small series have suggested that 10% of those with a type III endoleak present with aneurysm rupture. The same surveillance was followed in most studies in this review 73%.

Early type IIIa endoleaks should be diagnosed on completion angiography, is highly variable depending on the study (60– 90%), and many early type IIIa endoleaks may be first seen on follow-up. Both computed tomographic angiography (CTA) and ultrasonography are commonly used for post EVAR surveillance, with the diagnosis of a late endoleak being made when these images demonstrate contrast or blood flow within the sac but outside of the endograft.

Although they are rare, type III endoleaks should be considered serious because they lead to blood flow into the aneurysm, which repressurizes the sac and can result in secondary aortic rupture. They are also associated with a nearly nine times increased risk of aortic rupture, emphasizing the need for

early repair after imaging diagnosis. Although in our studies there was no rupture or complication from endoleak type III. Recent literature has supported that selective type III endoleaks can spontaneously resolve after a fenestrated EVAR, but observation alone of type III endoleaks is currently only recommended in those patients who are either unfit or refuse intervention.
In EVAR -1 trial from 25 endoleaks type III the 15 were treated [49]. Also, in Tang et al study from 13 endoleaks type III the 6 were treated [48].

This study has important limitations. Associations between the type of the aortic stent-graft and the incidence of type III endoleak could not be investigated since the included articles did not provide adequate information. Also the many studies used 1st generation devices or devices that has been withdrawn (Carpenter et al 2018- Nellix) or has been recalled (Wang et al,Jordan et al – Powerlink, Faries et al 2002- Talent etc). This can affect the analysis.Moreover in most studies the patients that were treated with EVAR had non symptomatic aneurysm. Today many ruptured or symptomatic aneurysm are treated with EVAR it is important to know the prevalence of type III endoleak in these cases. There are also still many open questions about type III endoleaks, (e.g., proper timing of intervention, differences between early and late type III endoleaks etc.) that could not be adequately investigated by the present review study.

5.CONCLUSION

Endoleaks are the most frequent complication after EVAR and the most common indication for secondary intervention. Type III endoleaks are an uncommon subgroup that are less common in newer generation devices. Most literature in the area is based on first- and second-generation devices which had a higher rate of type IIIb endoleak compared with third generation devices. Like type I endoleaks, type III endoleaks lead to a pressurized aneurysm sac, and up to 10% of those with a type III endoleak present with aneurysm rupture. Society guidelines recommend that all diagnosed type III endoleaks should be repaired. In the modern device era, type III endoleaks are most often associated with endograft component separation (type IIIa), and the majority are treated by endovascular techniques to stent over the junctional endograft defect. However, these endovascular reinterventions are not free of adverse events and endoleak recurrence can occur, and further investigation should be conducted in order to be fully understood and detect all the risk factors of III endoleak appearance.

Abstract:

Objective: Endovascular aneurysm repair (EVAR) has gained wide acceptance as the most common and usually preferred method for the treatment of aortic aneurysms. It is associated with lower 30-day mortality and morbidity rates, as well as faster discharge.[1-5] However, EVAR is also associated with higher reintervention rates compared with open repair, and endoleaks are the most common indication. Different types of endoleak can be observed after EVAR. In this study the focus is on type III endoleak. A type III endoleak is a type of endoleak that occurs when there is a defect or misalignment between the components of an endograft. The purpose of these study is to determine the incidence and the risk factors of type III endoleak after EVAR intervention.
Methods: A systematic review of the published literature was conducted using the PubMed and Google Scholar databases and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A total of 22 studies were found to be eligible and were included for further analysis.
Results: The overall incidence of type III endoleak was 1.07%. in most studies the patients had asymptomatic aneurysm with favorable anatomy. The most common used devices are Talent 32 % (7/22), Excluder 27% (6/22), Zenith 27% (6/22), Endurant 18% (4/22). The 48% of endoleaks were treated (36/75) but for many articles we don't have enough data. Also, the type of intervention when it is noted 44% (4/9) is endovascular but not many details in most cases are provided. The mean follow up from all the studies is 29 months.
Conclusion: Type III endoleak after EVAR is presented with a low incidence. Further investigation is needed in order to fully understand the risk factors associated with the occurrence of type III endoleaks.

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