

Prevention and management of type II endoleaks after endovascular aneurysm repair

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Abstract

Endovascular aneurysm repair (EVAR) has emerged as a pivotal technique in managing abdominal aortic aneurysms. As with any medical intervention, EVAR poses inherent risks of complications. Among various post-EVAR complications, a major one is endoleaks, characterised by periprosthetic leakage. Various types of endoleaks exist, with type II being the most commonly observed, resulting from blood reperfusion into the aneurysm sac through the lumbar and/or inferior mesenteric artery (IMA), median sacral, or accessory renal arteries. Due to the low-pressure nature of type II endoleaks, consequences may range from patients being asymptomatic to experiencing life-threatening situations. The risk of aneurysm rupture in cases of isolated type II endoleaks is relatively low, estimated at 0.5% to 2.4%. Therefore, routine observation is generally recommended, and intervention is reserved for situations where there is a persistent increase in the aneurysm sac diameter by more than 5 mm over 6 months or the occurrence of other complications, such as rupture of the aneurysm sac. If detected during the procedure, type II endoleaks often resolve spontaneously, making immediate treatment unnecessary. Factors contributing to the persistence of such leaks include an active IMA, a high number and diameter of active lumbar arteries, and ongoing anticoagulant treatment. The long-term effects of type II endoleaks vary, with the aneurysm sac shrinking in 25% of patients, remaining unchanged in the majority of patients (50–70%), and enlarging in a few patients (12%). Treatment options, if needed, encompass diverse methods such as embolisation of the IMA or lumbar arteries using coils, occluders, or tissue adhesives, injection of polymers directly into the aneurysmal sac, or laparoscopic clipping of the IMA and lumbar arteries. However, the efficacy of these methods varies, with the aneurysm continuing to grow in 60% of patients, often necessitating repeat procedures or even graft removal and traditional surgery. Despite extensive research on type II endoleaks, therapeutic considerations remain unresolved. Moreover, the importance of intervention, optimal timing of procedures, most effective diagnostic methods, and treatment modalities for type II endoleaks remain controversial.

Keywords: aorta, aneurysm, EVAR, endoleak, embolisation

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Introduction

Endovascular abdominal aortic aneurysm repair (EVAR) has evolved into a pivotal technique for treating abdominal aortic aneurysms [1]. Its origins trace back to 1987 when Nicolai Volodos in Kharkiv became the world's first surgeon to dissect an aortic aneurysm using an endovascularly inserted endoprosthesis. Subsequently, in 1991, Parodi and colleagues presented and detailed the technique of percutaneous graft implantation [2, 3]. Since then, there has been a rapid proliferation of its widespread utilisation, supported by numerous studies validating its efficacy compared to traditional methods [4, 5]. In many countries, the predominant approach to managing abdominal aortic aneurysms is through EVAR [3, 6].

As with any medical procedure, EVAR is associated with the risk of complications. A major complication after EVAR is endoleaks, which are characterised by periprosthetic leakage [7]. An endoleak is defined as the persistence of active blood flow into the aneurysm sac after the procedure. Various endoleak types are recognised, with types I–V being the most commonly described. Many patients experiencing complications after EVAR exhibit type II endoleaks, resulting from blood reperfusion into the aneurysm sac, typically from the inferior mesenteric artery (IMA) or lumbar arteries [7, 8]. Given the low-pressure nature of this leak, its consequences can range from asymptomatic cases to potentially life-threatening situations for patients [1].

Ultee et al. emphasised that the risk of aneurysm rupture in the presence of an isolated type II endoleak is relatively low, estimated within the range of 0.5–2.4% [9]. Therefore, routine observation is recommended in most cases, and intervention is only warranted if there is a persistent increase in the aneurysm sac diameter by more than 5 mm over 6 months or if other complications arise, such as aneurysm sac rupture [10].

Epidemiology

Type II endoleaks involve the retrograde filling of the aneurysm sac with blood from active lumbar arteries and/or the IMA, median sacral, or accessory renal arteries. This complication stands as the most prevalent problem following endovascular abdominal aortic aneurysm repair [8, 10]. Previous studies have reported that this complication occurs perioperatively in 25% of patients [11, 12].

If detected during the procedure, treatment is typically unnecessary, as half of such endoleaks spontaneously resolve [12]. The risk of recurrence within 6 months of the procedure varies between 10% and 15% [11–13]. Several factors heighten the risk of

persistent leaks, including an active IMA, a substantial number and diameter of active lumbar arteries, and ongoing anticoagulant treatment [12, 13].

The long-term effects of type II endoleaks exhibit variability, with the aneurysm sac shrinking in 25% of patients, remaining unchanged in the majority of patients (50–70%), and enlarging in a few (12%) patients [11, 12, 14]. Some leaks may manifest late, even 6 months or more after EVAR, potentially causing aneurysm enlargement, though rapid dilatation is rare [13, 14].

If treatment becomes necessary, various methods are employed: embolisation of the IMA or lumbar arteries using coils, occluders, or tissue adhesives; injections of polymers directly into the aneurysmal sac; or laparoscopic clipping of the IMA and lumbar arteries. However, the efficacy of these methods varies, with the aneurysm continuing to enlarge in 60% of patients, often necessitating repeat procedures or even implant removal and classical surgery [12, 14]. Type II endoleaks rarely result in aneurysm rupture; more commonly, this occurs due to unrecognised type I or III leakage [15]. The choice of an appropriate management strategy should consider various factors, such as the aneurysm size, the type and calibre of arteries causing the leak, and whether to pursue primary EVAR or secondary intervention. A differentiated management approach appears both efficient and cost-effective [14, 16].

Risk factors

Post-endovascular aortic aneurysm repair, vigilant patient monitoring is imperative due to the potential risk of leakage or graft migration. Among the various types of postoperative complications, type II endoleaks emerge as a prevalent concern, affecting 10–44% of patients treated with this method and representing the most common form of leakage. Research indicates that patients with type II endoleaks may experience elevated pressure within the aneurysm sac, thereby heightening the risk of rupture [17, 18]. Notably, type II endoleaks are less frequent among younger patients and those with chronic obstructive pulmonary disease (COPD). Conversely, embolisation of the internal iliac arteries and extension of the graft limb to the external iliac artery were associated with an increased risk of such leaks. Importantly, while type II leaks might necessitate secondary interventions, they do not appear to impact the long-term survival of patients [19].

In a study conducted by Abularrage et al. [20] involving 832 post-EVAR patients, type II endoleaks were diagnosed in 23% of cases (136 patients). Identified risk factors in this study included advanced age, warfarin use, and paradoxically, smoking demonstrated a protective effect against type II endoleaks. Additio-

nally, patients with a patent IMA, more patent lumbar arteries, a larger aneurysm diameter, and fewer thrombi in the aneurysm sac were more prone to developing type II endoleaks [8, 20].

Conversely, a meta-analysis by Guo et al. [21], based on 504 examinations involving 36,588 individuals, reported that 22% of patients experienced type II endoleaks after EVAR. Factors associated with type II endoleaks included age, smoking, patency of the inferior mesenteric artery, maximum aneurysm diameter, and the number of patent lumbar arteries. Notably, other factors such as sex, diabetes, hypertension, anticoagulants, antiplatelet drugs, hyperlipidaemia, chronic kidney disease, type of graft material, and COPD were not associated with type II endoleaks.

A comprehensive analysis of risk factors for type II endoleaks reveals key determinants [8, 19, 20]. Active smoking emerges as a factor reducing the incidence of type II leakage, corroborated by studies conducted by other authors [20, 21]. Conversely, factors such as embolisation of the internal iliac arteries, distal extension of stent graft limbs to the external iliac arteries, advanced age, and the absence of COPD were found to increase the risk of type II endoleaks. A study by Schanzer et al. [18] showed that only 42% of patients who underwent pre- and post-EVAR computed tomography had anatomical conditions conforming to the strictest criteria specified by EVAR device manufacturers, while 69% of them met the more liberal criteria. Moreover, 41% of patients suffered from aneurysm sac enlargement at 5 years after EVAR, suggesting that qualification outside the manufacturer's indications represents a significant risk of leakage often combined (simultaneous type I and type II leakage) in such situations. Factors that increase the risk of aneurysm sac enlargement include endoleaks, patients aged > 80 years, certain anatomical characteristics of the aorta and iliac arteries (aneurysm neck diameter \geq 28 mm, aneurysm neck angle \geq 60, and common iliac artery diameter \geq 20 mm). Other studies have shown that between 24% and 55% of patients with type II endoleaks experienced aneurysm sac enlargement at mid-term follow-up, suggesting the need to consider reoperation [18–20]. Importantly, type II endoleaks may occur not only perioperatively but also at any time after EVAR surgery.

Public health implications

The effects of treating abdominal aortic aneurysm with endovascular and classic open surgical repair (OSR) have been thoroughly analysed in terms of the impact on patients' quality of life (QOL) and treatment-associated costs. Endovascular aneurysm repair has been introduced as an alternative to more invasive OSR

[22]. Short-term postoperative evaluations reveal that patients treated with the EVAR method rate their QOL higher compared to those treated with the OR method. However, six months after the procedure, patients treated with the OR method exhibit better QOL [22]. Regarding post-EVAR complications, data on type II endoleaks are crucial. A study by Steinmetz et al. [23] showed that 18.5% of patients had type II endoleaks shortly after the procedure, but only 7.2% of patients had these endoleaks for \geq 6 months. The average total cost of treating type II endoleaks is \$6,695.50 (excluding the cost of the stent graft implantation procedure) [23]. Notably, endoleaks did not affect the overall survival of patients [23]. From an economic standpoint, the study by Epstein et al. [24] suggests that, particularly in European centres, EVAR may not prove cost-effective in the long term. When compared to conventional surgery, EVAR has demonstrated itself to be a more expensive method [24].

Taken together, while endovascular treatment offers short-term QOL benefits, long-term data indicate potential complications and higher costs when contrasted with surgery. This highlights the need for a comprehensive approach in choosing an aneurysm treatment, considering the QOL, costs, and potential complications.

Diagnosics of type II endoleaks using different imaging modalities

Computed tomography with angiography (CTA)

CTA has long served as the standard for monitoring patients after EVAR, providing high spatial resolution. However, CTA has certain limitations in diagnosing type II endoleaks. In a meta-analysis comparing CTA with contrast-enhanced ultrasound (CEUS), CTA achieved a sensitivity of 70% and specificity of 98% [25]. Despite technological advancements, some type II endoleaks may elude detection by CTA [26]. Moreover, the substantial cost per CTA scan poses a challenge in the context of frequent post-EVAR patient monitoring [22].

Colour Doppler ultrasonography (CDUS)

CDUS combines traditional brightness-mode (B-mode) imaging with Doppler ultrasonography to provide detailed information on the anatomical features of the aorta and stent graft [27]. Modern technologies, such as 3D CDUS, offer even more accurate diagnostics [28]. The advantages of CDUS over CTA, particularly in terms of result consistency among different examiners, have been emphasised [29]. In detecting type II endoleaks, CDUS may yield superior results compared to CTA [30].

Contrast-enhanced ultrasonography (CEUS)

CEUS is based on CDUS, incorporating a contrast agent administered intravenously [31]. Modern contrast agents, such as perfluorocarbons and sulphur hexafluoride, allow more accurate imaging of blood flow. In comparison to CTA, CEUS demonstrates an impressive sensitivity of 93–99% and a specificity of 100% in identifying endoleaks after EVAR [32]. For detecting type II endoleaks, CEUS may prove more effective than CTA [33].

Magnetic resonance angiography (MRA)

MRA is an imaging technique that is performed in multiple stages [34]. Most protocols start with axial imaging using a T1-weighted gradient-echo sequence. MRA shows similar sensitivity to CTA and in some cases, such as in those of EVAR using nitinol is superior to CTA in detecting type II endoleaks [35]. Nevertheless, MRA has some drawbacks that limit its widespread use, especially concerning motion interference and metallic artefacts [36].

Modern imaging methods and nuclear medicine

Modern imaging technologies, such as 3D DUS and CEUS, are becoming increasingly used in diagnosing endoleaks after EVAR [37]. Although 3D DUS and CEUS are not generally available, their development is promising. Available data indicate that the accuracy of nuclear medicine methods in detecting and classifying endoleaks after EVAR is not yet comparable to CTA [38].

Taken together, the diagnosis of type II endoleaks after EVAR necessitates precise and reliable imaging methods. While CTA has been the standard for years, modern technologies such as CDUS, CEUS, and MRA offer alternative options that can be more sensitive and specific in detecting type II endoleaks [25]. The choice of the appropriate method depends on various factors, including equipment availability, cost, and patient characteristics [22].

Treatment of patients with type II endoleaks

Type II endoleaks pose a significant challenge in the endovascular treatment of abdominal aortic aneurysms, requiring scientific evidence to support the efficacy and safety of various treatment methods. Previous research indicates that easily identifiable variables, such as IMA patency and the number of patent lumbar arteries, are associated with the risk of type II endoleaks [20, 38, 39]. This knowledge is crucial for identifying patients at higher risk of leakage. Considering these findings, there exists a subgroup of patients for whom perioperative

interventions, including IMA or lumbar artery embolisation, or selective embolisation of the aneurysm sac, may be worth considering reducing the risk of type II endoleaks. Treatment decisions must be tailored to each patient, weighing all available data, risks, potential benefits of intervention, and the patient's preferences. Some authors argue that type II endoleaks may not necessitate intervention. Greenhalgh et al., analysing data from 2,000 patients after EVAR, concluded that there was no difference in clinical outcomes between patients with type II endoleaks and those without these endoleaks [40].

Despite the challenges posed by type II endoleaks in the EVAR method, most patients with such leaks do not require additional interventions and achieve satisfactory long-term results [41]. Various centres employ different criteria when deciding on intervention for type II endoleaks. For instance, the Miami Cardiac and Vascular Institute considers a 5-mm enlargement of the aneurysm sac as an eligibility criterion for intervention in patients with type II endoleaks [42]. Conversely, Mascoli et al. performed intraoperative embolisation of the aneurysm sac in patients at increased risk of type II endoleaks, identifying the presence of six or more patent vessels originating from the aneurysmal sac or a clot volume of less than 40% of the total volume of the aneurysm sac as risk factors for endoleaks [43]. These findings indicate the lack of standardised criteria to qualify patients with type II endoleaks for intervention.

Various methods of vascular embolisation have been described for type II endoleaks. The classic approach involves transarterial embolisation of the IMA (via the colic artery) or the lumbar artery, where embolisation may target only the problematic vessel, the aneurysmal sac, or both the aneurysm sac and the vessel. The technique entails inserting a catheter into the aorta, typically through the femoral or brachial artery [44, 45]. In some cases, if access through the femoral or brachial artery is impossible or inadequate, the catheter can be inserted by directly pricking a branch of the internal iliac artery (superior gluteal artery) in a translumbar approach [46]. If the catheter is inserted into the main vessel (superior mesenteric or internal iliac artery), the vessel responsible for the leak — the IMA or the lumbar artery — is selectively catheterised using a microcatheter. If the appropriate site is reached, angiography is performed to precisely localise the endoleak and an embolisation agent is injected into the vessel to block the leak. After completing embolisation, the efficacy of the procedure is confirmed angiographically.

Another method is the translumbar access (translumbar technique), involving direct puncture from the lumbar access of the aneurysm sac at the level of the leak under CT guidance. Puncture is executed with

a biopsy needle (e.g., Chiba needle) approximately 4–5 finger widths from the posterior midline. The aneurysm sac is punctured, and an embolisation agent (e.g., polymeric) is administered after inserting a microcatheter into the leak site [46].

A study conducted by Haulon et al. [39] demonstrated that percutaneous embolisation is an effective and safe method for treating type II endoleaks. Another study by Lagios et al. focused on the use of translumbar infusion of N-butyl-2-cyanoacrylate (NBCA) to address type II endoleaks [47]. Successful translumbar embolisation was achieved in all 25 patients. On duplex ultrasound performed the day after the procedure, the leak resolved in 22 patients (88%), while the remaining three patients required repeated embolisation. The study affirms the safety and efficacy of NBCA injection in treating type II endoleaks.

A meta-analysis conducted by Guo and his team [38] aimed to compare the efficacy of percutaneous embolisation with transarterial embolisation after EVAR. Although the differences in the efficacy of these methods were not statistically significant, the technical success rate was notably higher in the group of patients undergoing percutaneous embolisation. The study suggests that percutaneous embolisation is more effective in eliminating endoleaks in follow-up examinations, potentially due to technical difficulties in precise catheterisation of the target vessel, strongly influenced by favourable arterial anatomy.

Overall, percutaneous embolisation stands out as one of the primary methods for treating type II endoleaks after endovascular treatment of abdominal aortic aneurysms. In recent years, various methods for treating them have been developed and extensively studied. While the available treatments show promising results, further research is necessary to confirm their efficacy in the long term.

Strategies to reduce the risk of type II endoleaks and mitigate their effects

Early detection and intervention

Type II endoleaks, the most common complication post-EVAR, necessitate the development of effective strategies for primary prevention to minimise early and late complications, enhancing overall patient outcomes.

One approach to reducing the risk of type II endoleaks involves injecting fibrin glue, with or without a micro coil, into the aneurysm sac during the EVAR procedure [48, 49]. Another approach is primary pre- or intraoperative embolisation of the IMA and lumbar arteries [43, 50]. Manunga et al. demonstrated that IMA embolisation before EVAR protects against

type II endoleaks and reduces the need for secondary interventions [51]. This procedure, with high technical success and minimal complications, is effective in preventing complications. Natrella et al. introduced the embo-EVAR technique [44], involving intraoperative embolisation of the aneurysm sac using coils and/or fibrin glue or polymer (Shape-Memory Polymer). This procedure, performed through a catheter left in the sac after graft implantation, incurs an average additional cost of approximately €1,500.

The embo-EVAR technique proves effective in preventing both type I and type II endoleaks and associated complications. Burbelko et al. [45] evaluated the effectiveness of embolising the IMA and lumbar arteries before EVAR to prevent type II endoleaks, with vessel diameter > 2.5 mm as an indication for embolisation. No type II endoleaks were observed in the group of 37 patients embolised, while nine out of 38 non-embolised patients exhibited type II endoleaks. This indicates that embolisation before EVAR was highly effective in preventing type II endoleaks. Routine vascular embolisation before EVAR remains controversial, as indicated by Väärämäki et al. [52], who found no benefit in routine IMA embolisation. Mascoli et al. propose that selective embolisation of the aneurysm sac during EVAR is safe and effectively reduces the risk of type II endoleaks [53], though further long-term studies are essential to validate these findings. Sidloff et al. highlighted that patients with isolated type II endoleaks have equivalent aneurysm-related mortality rates [54]. Using new diagnostic methods based on artificial intelligence (AI) may reduce the risk of type II endoleaks [55]. However, current research in this area remains insufficient.

Taken together, diverse techniques and methodological approaches aim to reduce the risk of type II endoleaks post-EVAR. The choice of the appropriate method depends on individual patient characteristics, aneurysm morphology, technology availability, and operator experience. Early detection and intervention for type II endoleaks are crucial for ensuring optimal outcomes for patients.

Conclusions

Despite extensive study, therapeutic challenges related to type II endoleaks persist. Controversies surround the value of intervention, optimal timing, effective diagnostic methods, and treatment approaches. Understanding the complexities of type II endoleaks after EVAR is vital for vascular surgery specialists, necessitating further research to better predict risks and develop optimal management strategies [7, 8, 18–21].

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