Abstract: Abdominal aortic aneurysms (AAAs) are a highly asymptomatic vascular pathology with an increasing risk of rupture, leading to high mortality. Upon detection, treatment primarily involves lifestyle changes to slow the growth rate. Aneurysm rupture requires immediate surgical intervention due to its high mortality. Endovascular aneurysm repair (EVAR) is a common treatment option, involving stent placement at the aneurysm site. However, the stent is a foreign body; therefore, it is susceptible to immune response and infection. This case series presents patients with infected endovascular stents following a diagnosis of abdominal infrarenal aortic aneurysm and EVAR. The patients’ follow-ups revealed varying prognoses, complications, and treatments post-infection. These findings are compared with outcomes reported in the medical literature. Preventing aortic stent graft infection through proper aseptic techniques is crucial. This practice reduces patient complications, shortens inpatient hospice stays, and, most importantly, enhances patient quality of life.

Keywords: abdominal aortic aneurysm; endovascular aneurysm repair; endovascular stent; surgical infection; vascular surgery

1. Introduction

Abdominal aortic aneurysm (AAA) is characterized by a focal dilatation in the abdominal aorta exceeding 50% of the vessel’s diameter [1]. Clinical presentations include asymptomatic manifestations, incidental detection, or rupture. The prevalence ranges from 0.5% to 3%, with incidence peaking around age 60. Infrarenal aortic aneurysms are the most common subtype [2,3]. Symptoms arise as the aneurysm enlarges and exerts pressure on adjacent structures. AAA rupture carries a mortality rate of approximately 80%. Treatment approaches vary based on factors such as size and location [3]. Lifestyle modifications and medication are often recommended, while surgical intervention is necessary in urgent cases like rupture. Aortic stent grafting is a common treatment, aimed at restoring vessel morphology by recreating the original blood flow pathway [1]. Endovascular repair manages 86% of these aneurysms, but complications such as graft infection (0.2–5%) and aortoenteric fistula (AEF) development (0.36–1.6%) can occur [4]. These complications require detailed examination for optimum detection and management.

Endovascular aneurysm repair (EVAR) is the primary approach for managing AAA, involving the placement of a stent at the aneurysm site, which adheres and expands against the aortic wall [5,6]. However, these foreign bodies carry the risk of stent-related infections (SRIs) that typically arise from stent colonization by microorganisms via bacteremia, leading to the formation of difficult-to-manage biofilms [7]. SRI represents a severe and costly complication, affecting 2% to 40% of patients undergoing these procedures, and is associated with high morbidity rates [7]. Patients with SRI have a five-year survival rate of approximately 50%, with over 35% experiencing pre-operative complications [8]. Prolonged...
antibiotic treatment can enhance survival rates and prevent reinfection in patients with bacteremia and EVAR, those complicated by arteriovenous or AEF, or antibiotic-resistant bacteria [9,10].

Aortic SRI present limited diagnostic and treatment options [11]. These infections are more prevalent in stents used for AAA, particularly affecting men aged 65 to 73 [12]. Emphasizing preventive measures is crucial, and advancing knowledge on AAA and its management is essential for personalized patient care. Enhancing patient education and optimizing resource allocation are key strategies to ensure timely and appropriate care, facilitate early detection of complications, and ultimately improve treatment outcomes and quality of life [13,14]. In this context, we present a Latin American case series of three patients who developed aortic SRI and AEF following EVAR for AAA.

2. Materials and Methods

2.1. Case Series

A retrospective multicenter case series was conducted on patients with confirmed aortic SRI, as defined by the Management of Aortic Graft Infection Collaboration (MAGIC) criteria (Table 1). The study population was identified from 2018 onwards at three participating institutions: Clínica Colombia, Fundación Santa Fe de Bogotá, and Clínica Simón Bolívar. All patients had previously undergone EVAR for infrarenal AAA.

Each patient was assessed for a range of variables as outlined in the study protocol, including gender, age, type of endoprosthesis, duration of antibiotic therapy, method of reconstruction, presence and description of AEF, surgical duration, requirement for intensive care unit (ICU) admission, length of hospital stay, complications encountered, and mortality outcomes.

The initial medical management approach involved a 7-to-14-day course of antibiotic therapy (meropenem 1g), followed by surgical explantation of the infected aortic graft. Reconstruction was then performed using either a femoral vein or a pericardial bovine graft, as part of the neoaortoiliac system (NAIS) procedure.

Prior ethics committee presentation was not necessary, taking into consideration nonethical patient risk and maximum identity protection measurements. Patient identity is

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**Table 1.** Distribution of MAGIC major and minor criteria among patients with vascular graft/endograft infection (VGEI) [15].

<table>
<thead>
<tr>
<th>MAGIC Criteria</th>
<th>Major Criteria</th>
<th>Minor Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pus (definite by microscopy) around graft or aneurysm sac at surgery</td>
<td>Localized clinical features of VGEI, e.g., erythema, warmth, swelling, purulent discharge, and pain</td>
</tr>
<tr>
<td></td>
<td>Open wound with exposed graft or communicating sinus</td>
<td>Fever $\geq 38^\circ\text{C}$ with VGEI as most likely cause</td>
</tr>
<tr>
<td></td>
<td>Fistula development, e.g., aortoenteric or aortobronchial</td>
<td>Other, e.g., suspicious perigraft gas/fluid/soft tissue inflammation; aneurysm expansion; pseudo-aneurysm formation; focal bowel wall thickening; discitis/osteomyelitis; suspicious metabolic activity on FDG PET/CT; radiolabeled leucocyte uptake</td>
</tr>
<tr>
<td></td>
<td>Graft insertion in an infected site, e.g., fistula, mycotic aneurysm, or infected pseudo-aneurysm</td>
<td>Blood culture(s) positive and no apparent source except for VGEI</td>
</tr>
<tr>
<td></td>
<td>Perigraft fluid on CT scan $\leq 3$ months after insertion</td>
<td>Abnormally elevated inflammatory markers with VGEI as the most likely cause, e.g., ESR, CRP, and white cell count</td>
</tr>
<tr>
<td></td>
<td>Perigraft gas on CT scan $\leq 7$ weeks after insertion</td>
<td>Microorganism recovered from an explanted graft</td>
</tr>
<tr>
<td></td>
<td>Increase in perigraft gas volume demonstrated on serial imaging</td>
<td>Microorganism recovered from an intra-operative specimen</td>
</tr>
<tr>
<td></td>
<td>Microorganism recovered from a percutaneous aspirate of perigraft fluid</td>
<td>Microorganism recovered from a percutaneous aspirate of perigraft fluid</td>
</tr>
</tbody>
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safeguarded, their personal information is also respected and protected within the scope of this retrospective study. No Helsinki Treaty violations were made in this retrospective study.

2.2. Operative Technique

The NAIS procedure offers a novel approach to address the limitations of traditional bypass and grafting techniques by utilizing the femoropopliteal vein for vascular reconstruction. The key objectives of the NAIS procedure are to mitigate risks such as lower-extremity ischemia and reduce abdominal exposure. The surgical procedure starts with a wide incision in the medial thighs, followed by meticulous dissection of the common femoral vessels and femoral vein and artery bilaterally while preserving the integrity of the deep femoral vein. Harvesting of the femoral vein is conducted from 1 cm below the deep femoral vein to Hunter’s canal on both sides. Additionally, leveraging the harvested femoral veins, a bespoke bifurcated autologous graft is meticulously fashioned using 4-0 vascular prolene, facilitating the union of the two femoral veins.

In the subsequent phase, a laparotomy is executed, involving eversion and meticulous dissection of the mesenteric root, exploration of retroperitoneal zone 1, dissection of the infrarenal aorta, identification of the left renal vein, meticulous dissection and repair of the infrarenal aortic neck and common iliac arteries, identification and management of the aortoduodenal fistula, application of proximal and distal clamps on the infrarenal aorta and iliac arteries, and incision of the hernia sac. Excision of the aortoduodenal fistula is performed, accompanied by primary repair of the third portion of the duodenum using mucosal–seromuscular sutures of polydioxanone 3-0.

The explantation of the endoprosthesis is carried out via suprarenal fixation, employing the 20 cc syringe technique and Rochester clamps.

Finally, the reconstruction of the aortoiliac region is accomplished utilizing the NAIS technique, incorporating the custom-made bifurcated femoral vein graft for aortic and iliac parachute end-to-end anastomosis, employing 3-0 prolene sutures (Figure 1) [16].

Figure 1. Neoartioiliac system procedure. (A) Dissection and harvesting of femoral veins. (B) Custom-made bifurcated autologous graft with vascular 4-0 prolene. (C) Identification and resection of the aortoduodenal fistula with duodenum primary repair. (D) Explantation of iliac aortic endograft extensions. (E) Aortic endograft explantation using the syringe technique. (F) Reconstruction of the aortoiliac using the custom-made femoral vein graft.
3. Results

All patients included in the study had a history of hypertension and were former smokers. The aneurysms exhibited a fusiform morphology and were located infrarenally, with no instances of aortic dissection or rupture documented. Aneurysm sizes ranged from 55 mm to 62 mm, and all cases underwent open surgical repair with a maximum procedural duration of 390 min and a peak blood loss of 2500 cc, with no cases requiring reintervention. The average ICU stay was reported to be 3 days.

Furthermore, all patients exhibited systemic infection symptoms such as fever, diaphoresis, asthenia, and adynamia between 3 to 6 months post-procedure. Initially, they were diagnosed and treated for a UTI or pneumonia with the corresponding antibiotic course and subsequently discharged. However, symptoms reappeared a few months later. Both patients who developed a fistula presented with gastrointestinal bleeding and sentinel bleeding. After repeated hospitalizations due to infection, patients were diagnosed with endoprostheses infections and underwent the NAIS intervention, utilizing the femoral vein in two cases and bovine pericardium in one case. Explantation occurred at different times for each patient, specifically in the 6th, 14th, and 18th months after the initial procedure. Two patients presented AEF with associated sentinel bleeding prior to intervention (Figure 2). The overall mortality rate was 66%, with one death attributed to the surgical procedure and another to pneumonia acquired during the hospital stay. High metabolic stress and morbidity attributed to the procedures contributed to the mortality rate for the patients. Table 2 summarizes patients characteristics.

![Figure 2. Diagram illustrating aortoenteric duodenal fistula evidenced in patients with aortic endograft infection. Source: Self-elaborated.](image-url)
Table 2. Patient demographic characteristics and objective outcomes included in the case series.

<table>
<thead>
<tr>
<th>N</th>
<th>Age</th>
<th>Sex</th>
<th>Comorbidities</th>
<th>Aneurysm Characteristics</th>
<th>Graft Characteristics</th>
<th>NAIS Procedure</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>83</td>
<td>F</td>
<td>Chronic Pulmonary Obstructive Disease, Arterial Hypertension</td>
<td>Morphology: Fusiform Location: Infrarenal Size: 55 mm Active Rupture: None</td>
<td>Type: Cook Zenith® Active Infection: Yes Aortoenteric Fistula: None</td>
<td>Surgical Time: 240 min Bleeding: 2500 mL Complications: None</td>
<td>ICU Stay: 1 day Hospice Stay: 0 days Mortality: Yes; secondary to surgical intervention</td>
</tr>
<tr>
<td>2</td>
<td>64</td>
<td>M</td>
<td>Arterial Hypertension, Colorectal Cancer</td>
<td>Morphology: Fusiform Location: Infrarenal Size: 60 mm Active Rupture: None</td>
<td>Type: Medtronic Endurant II® Active Infection: Yes Aortoenteric Fistula: Yes (duodenal with sentinel bleeding)</td>
<td>Surgical Time: 390 min Bleeding: 2000 mL Complications: None</td>
<td>ICU Stay: 4 days Hospice Stay: 3 days Mortality: None</td>
</tr>
<tr>
<td>3</td>
<td>61</td>
<td>M</td>
<td>Chronic Pulmonary Obstructive Disease, Arterial Hypertension</td>
<td>Morphology: Fusiform Location: Infrarenal Size: 62 mm Active Rupture: None</td>
<td>Type: Medtronic Endurant II® Active Infection: Yes Aortoenteric Fistula: Yes (duodenal with sentinel bleeding)</td>
<td>Surgical Time: 330 min Bleeding: 1500 mL Complications: None</td>
<td>ICU Stay: 5 days Hospice Stay: 6 days Mortality: Yes; secondary to nosocomial pneumonia</td>
</tr>
</tbody>
</table>

M: male; F: female; NAIS: neoaortoiliac system; ICU: intensive care unit.

4. Discussion

This retrospective case series study was conducted in a Latin American population and examined the various operative factors associated with surgical management and infection risk in procedures involving the placement of an endoprosthesis. In this case, reconstruction using bovine pericardium and a femoral vein graft successfully restored the patients’ vasculature. Although femoral vein extraction is typically associated with venous insufficiency, the phlebectomy results in this study did not show a correlation with thrombotic processes.

The diagnosis of infected endografts, according to the MAGIC criteria, relies on clinical symptoms, radiological signs of inflammation, and microbial cultures. Studies have indicated an average time frame of 115 to 990 days from the initial procedure to the onset of infection, with approximately 32% of infections detected within the first 3 months post-operation [12]. A significant proportion (71%) of patients require in situ aortic reconstruction. In select cases, extra-anatomical bypass, or the implantation of a new stent alongside the existing one, is performed to address complications such as aortic rupture or aneurysm progression [12]. Antibiotic therapy plays a crucial role in treatment, targeting common pathogens like Staphylococci, Pseudomonas spp., and Enterobacteriaceae. Infections often originate from microbial adhesion and growth on stent biomaterial surfaces, leading to SRI [7,8]. Figure 3 demonstrates a decision adapted algorithm for these cases (Figure 3).

The likelihood of post-surgical infections, their incidence, and associated risks is critical due to the potential for severe and life-threatening complications. Although rare, aortoenteric fistulas following aortic interventions pose a significant mortality risk, with an incidence ranging from 0.5% to 1.5% of cases [17,18]. However, the introduction of EVAR in treating AAA has shown reduced perioperative mortality rates, particularly benefiting high-risk patients with existing comorbidities, instability, or hypotension [19].

As for the NAIS procedure, a study conducted by Nordanstig et al. involving nine patients who underwent elective NAIS procedures secondary to aortic SRI demonstrated that there was no 30-day mortality observed. Additionally, the use of aortic balloon-clamping during the explantation of the infected graft was shown to be feasible for complete removal [20]. Superficial venous extraction and interruption of perforator veins are often ineffective in correcting venous reflux from the thigh to the calf, which is a common cause of venous hemodynamic disorders. This ineffectiveness is due to the pressure gradient-driven blood flow incompetence between the deep and superficial veins, such as the femoral vein. The magnitude of retrograde flow determines the severity of venous disorders,
which can be compensated for to a certain extent. However, when adequate compensation mechanisms are lacking, venous insufficiency can develop, posing a risk factor for deep vein thrombosis (DVT). In fact, two-thirds of patients with primary chronic venous disease present with venous reflux [21–23]. In the current study, despite some patients undergoing phlebectomy of the femoral vein, no findings of DVT were reported.

The development of an AEF in patients involves an abnormal connection between the aorta and the duodenum. This AEF is categorized as a secondary fistula, arising after the treatment of an infrarenal AAA through an endovascular procedure [24]. Typically, the AEF manifests near the proximal suture line or prosthetic graft material, representing a serious complication of aortic repair surgery with a high mortality rate, occurring in 0.5% to 1.5% of cases. Clinical manifestations of AEF commonly include digestive bleeding in 64% to 94% of cases, accompanied by abdominal or lumbar pain [17,18].

Notably, the onset of hemorrhage is often preceded by one or more episodes of mild bleeding, known as sentinel hemorrhage. Studies have shown that exsanguinating hemorrhage occurs in 33% of cases within 6 h after the sentinel bleeding and in 50% within 24 h. This rapid escalation in bleeding is attributed to clot movement through the fistula, exacerbating the hemorrhagic process [10].

A retrospective study by Oikonomou et al. analyzed therapeutic approaches for treating 23 patients with AEF following EVAR. The study revealed a higher perioperative mortality rate among patients who underwent open surgical repair for acute bleeding (66.7%). Notably, primary stent graft implantation was associated with decreased mortality rates [25]. In a separate study, Castronovo et al. reported outcomes in 12 patients who underwent the NAIS procedure for aortic SRI. Their findings indicated a 30-day mortality rate of 25%, attributed to post-operative complications. While one case showed persistence of infection, the complete graft patency rate was 100% [26].

Figure 3. Decision algorithm for aortic native infections and aortic endograft infections. Endovascular aneurysm repair (EVAR), extra-anatomic bypass (EAB), neoaortoiliac system (NAIS), chronic obstructive pulmonary disease (COPD). Source: Modified from [27].

Several limitations are evident when considering the scope of this study. Although the case series is retrospective and multicentric, the absence of a control group and the limited number of cases hinder comprehensive statistical analysis. This introduces selection bias, as convenience sampling was employed for the report. Furthermore, variability in resources across the different hospitals involved, along with the diverse surgical techniques employed by individual surgeons, presents additional challenges. Patient outcomes are influenced by a combination of hospital resources, medical proficiency, and surgical methodologies. Increasing the case volume, standardizing the distribution of hospital resources, and establishing uniform medical and surgical protocols are essential steps to generate data.
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amenable to analysis. Also, the results need to be confirmed with larger cohort studies to confirm the findings presented here due to the low population number for this case series. This approach can facilitate the identification of correlations crucial for improving the management of endoprosthesis aortic infections.

5. Conclusions

Aortic stent graft infection represents a critical consideration in the surgical management of AAA. This paper presents a case series detailing instances where patients undergoing EVAR experienced SRI and subsequent complications, necessitating the removal of the infected stent and administration of antibiotic therapy as standard practice. Comprehensive understanding of AAA pathogenesis and associated complications is essential for tailored and timely patient management, leading to improved outcomes, reduced healthcare costs, shorter hospital stays, quicker recovery times, and enhanced patient well-being. Healthcare providers play a pivotal role in mitigating the economic impact of these infections and enhancing patient outcomes through proactive measures. By addressing stent graft infections effectively, healthcare professionals can not only improve patient care but also alleviate the financial burden associated with such complications.


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Institutional Review Board Statement: Prior ethics committee presentation was not necessary, taking into consideration nonethical patient risk and maximum identity protection measurements. Patient identity is not altered nor vulnerable, and their personal information is also protected and respected within the scope of this retrospective study. No Helsinki Treaty violations were made in this retrospective study.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. Written informed consent has been obtained from the patient(s) to publish this paper.

Data Availability Statement: The data presented in this study are available on request from the corresponding author due to identity protection measurements.

Conflicts of Interest: The authors declare no conflicts of interest.

References