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Article

Laparoscopic Transperitoneal Repair for the Management of Type II Endoleak After Endovascular Abdominal Aortic Aneurysm Repair

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Abstract

Background: Type II endoleak (T2EL) remains a significant cause of reintervention after endovascular aneurysm repair (EVAR). Current strategies for T2EL management remain suboptimal with low long-term efficacy. Thus, this study aimed to evaluate the feasibility and outcomes of laparoscopic transperitoneal branch artery ligation for T2EL management. **Methods**: This study included 6 patients with persistent T2EL and aneurysm sac expansion who underwent laparoscopic ligation of the culprit vessels, including the inferior mesenteric, lumbar, and median sacral arteries, at our center between January 2021 and January 2024. Preoperative basic clinical characteristics, operative data, postoperative outcomes, and complications of the patients were recorded and analyzed. **Results**: The median operative time was 225 minutes (range: 120–360 min) with blood loss of 300 mL (range: 50–500 mL). All patients achieved complete ligation of targeted vessels (median of 5 vessels per patient), with 100% success for the inferior mesenteric artery (IMA) and 50% for the median sacral artery. One patient developed a lymphatic fistula that was managed conservatively. At a median follow-up of 13.5 months (range: 4–54 months), all patients exhibited sac regression (median reduction: 3.5 mm; range: 1–8 mm). Complete endoleak resolution was observed in 4 cases (66.7%), while 2 had asymptomatic persistent T2EL without expansion. No reinterventions or mortality occurred. **Conclusions**: Laparoscopic transperitoneal branch artery ligation represents a promising, albeit preliminary, option for managing embolization-refractory T2EL. Our findings suggest that laparoscopic T2EL repair may provide durable sac stabilization in selected patients; however, the limited sample size underscores the need for larger studies to clarify patient selection criteria and long-term durability.

Keywords: aortic aneurysm; abdominal; endoleak; laparoscopy; minimally invasive surgical procedures; mesenteric arteries; ligation

1. Introduction

Over the past two decades, endovascular aneurysm repair (EVAR) has become the standard of care for abdominal aortic aneurysm (AAA), offering superior early outcomes, including reduced perioperative mortality and shorter hospital stays [1]. However, long-term data reveal significant limitations, with stent graft-related complications and the need for secondary reintervention remaining substantially higher than those of open repair. Large-scale studies, including the EVAR trial 1 [2], the EVAR trial 2 [3], the Veterans Affairs (VA) Open versus Endovascular Repair (OVER) trial study [4], and Medicare data analyses [5], demonstrate that EVAR is associated with an increased long-term aneurysm-related mortality, an elevated rate of secondary aneurysm sac rupture, and more reinterventions related to the management of the aneurysm or its complications.

Among these complications, type II endoleak (T2EL), which refers to retrograde flow from branch arteries into the aneurysm sac after EVAR, resulting in incomplete exclusion of the sac from systemic circulation, accounts for 25% of all EVAR reinterventions and poses a persistent risk of sac enlargement [6]. Current strategies for T2EL management include observation, transarterial embolization, translumbar/transabdominal direct puncture embolization, and surgical ligation. Prophylactic intraoperative embolization of side branches (e.g., inferior mesenteric or lumbar arteries) during initial EVAR has shown mixed results, with some studies reporting reduced endoleak incidence but no significant difference in sac regression rates [7,8]. For persistent endoleak, transarterial embolization via the superior mesenteric or iliolumbar arteries achieves technical success in 60–80% of cases, although recurrence rates reach 20–50% within one year [9,10]. Direct sac puncture (translumbar/transabdominal) demonstrates higher technical success (97%) and lower recurrence (15%) compared to transarterial embolization, but carries risks of visceral injury and rectus sheath hematomas [11]. Emerging techniques like open laparotomy repair show promise in cases of re-rupture [12]. Notably, non-interventional observation remains appropriate for stable aneurysms, as 80% of T2EL resolve spontaneously within six months without sac growth [13].

Laparoscopic approaches have emerged as a minimally invasive alternative for AAA repair, offering advantages in both primary treatment and post-EVAR complications. Initially described for elective open aneurysm repair, laparoscopic techniques enable aortic clamping and graft placement through small abdominal incisions, with reported outcomes comparable to conventional open surgery [14,15]. More recently, laparoscopy has been adapted for challenging post-EVAR scenarios, particularly for T2EL repair, where it provides direct visualization for precise branch artery ligation (inferior mesenteric/lumbar arteries) without the morbidity of full laparotomy [16]. The technique also shows promise in complex anatomy unsuitable for endovascular reintervention [17]. While requiring specialized training, laparoscopic AAA repair represents an evolving middle ground between endovascular and open approaches, particularly for younger patients needing durable repair or those with hostile anatomy [18].

This article reports our center's experience with laparoscopic management of T2EL following EVAR and evaluates the efficacy and safety of laparoscopic techniques for this condition.

2. Materials and Methods

2.1 Patients

This is a retrospective observational study utilizing data from the prospectively maintained clinical database of Peking University People's Hospital. The study was approved by the Institutional Review Board of the hospital, and informed consent was obtained from all participants. We analyzed 6 cases in which laparoscopic transperitoneal repair was performed at our center between January 2021 and January 2024. All of which presented with persistent endoleaks identified during post-EVAR surveillance. Surgical indications followed commonly accepted criteria and were applied uniformly at our center: (1) aneurysm sac expansion of >5 mm within six months; (2) persistent sac enlargement despite 6–12 months of surveillance; or (3) a T2EL persisting for >24 months accompanied by any degree of sac growth. The study excluded patients with suspected or confirmed type I or type III endoleaks on preoperative imaging. All preoperative imaging was reviewed by two attending vascular surgeons. Aneurysm sac diameter was measured using axial contrast-enhanced computed tomography (CT) at the level of maximal transverse diameter.

2.2 Procedure

The procedure was performed under general anesthesia with the patient in a 60° right-sided jackknife semi-supine position. After making a skin incision along the left rectus abdominis adjacent to the umbilicus, pneumoperitoneum to 12–14 mmHg was established using a Veress needle. A 10-mm optical trocar was placed for the 30° laparoscope, followed by placement of one 10-mm chief working port (left rectus abdominis, two fingerbreadths below the umbilicus) and two 5-mm assisting ports (left midclavicular subcostal and anti-McBurney's positions).

The dissection proceeded through the left Toldt's fascia into the retroperitoneum via the paracolic gutter. Through the pre-renal fatty tissue plane, we exposed the infrarenal aorta while preserving the left ureter. The root of the inferior mesenteric artery (IMA) was identified anteriorly and doubly ligated proximal to the left colic artery branch using two Hem-o-lok® clips (#51114V, Teleflex, Morrisville, NC, USA) for each vessel.

Guided by the IMA and aortic bifurcation landmarks, we performed a posterior dissection that revealed lumbar arteries and the median sacral artery originating from the aneurysmal wall. Each vessel was secured with one or two clips (titanium (#003304, Teleflex, Morrisville, NC, USA) or Hem-o-lok®) and transected, as shown in Fig. 1. A 24-Fr retroperitoneal drain was placed before closure.

2.3 Follow-up

All patients require lifelong radiographic and clinical surveillance following aortic aneurysm repair. In line with current society guidelines, comprehensive risk factor modification was implemented for all patients, including strict smoking cessation counseling, blood pressure control targeting <130/80 mmHg, and statin therapy. The standardized imaging protocol consisted of contrast-enhanced CT angiography (CTA) at 1 and 6 months and annual contrast-enhanced CT scans for stable conditions. For patients with chronic kidney disease (estimated glomerular filtration rate <60 mL/min/1.73 m^2), contrast-enhanced CT was substituted with duplex ultrasonography combined with non-contrast CT to assess aneurysm size and stent-graft integrity. A decrease in the maximum aneurysm diameter on serial CT images or duplex ultrasonography during follow-up was defined as sac regression.

3. Results

The cohort comprised 6 patients with persistent T2EL following EVAR, whose baseline characteristics are detailed in Table 1. Regarding preoperative antiplatelet therapy, 5 patients (Patients 1, 3, 4, 5, and 6) were taking aspirin before surgery. Among them, 4 patients (Patients 1, 4, 5, and 6) discontinued aspirin after the operation, but 1 (Patient 3) continued taking aspirin due to cardiovascular risk-benefit considerations. Preoperative IMA diameters measured on CT were as follows: Patient 1: 3 mm; Patient 2: 4 mm; Patient 3: 4 mm; Patient 4: 2 mm; Patient 5: 3 mm; and Patient 6: 3 mm. No patient underwent prophylactic embolization of the IMA before EVAR.

The median operative time was 225 min (range: 120–360 min), and the median intraoperative blood loss was 300 mL (range: 50–500 mL). Laparoscopic ligation successfully secured a median of 5 culprit vessels per case (range: 3–8), achieving 100% ligation of the IMA (6/6) and 50% ligation of the median sacral artery (3/6) (Table 2). One

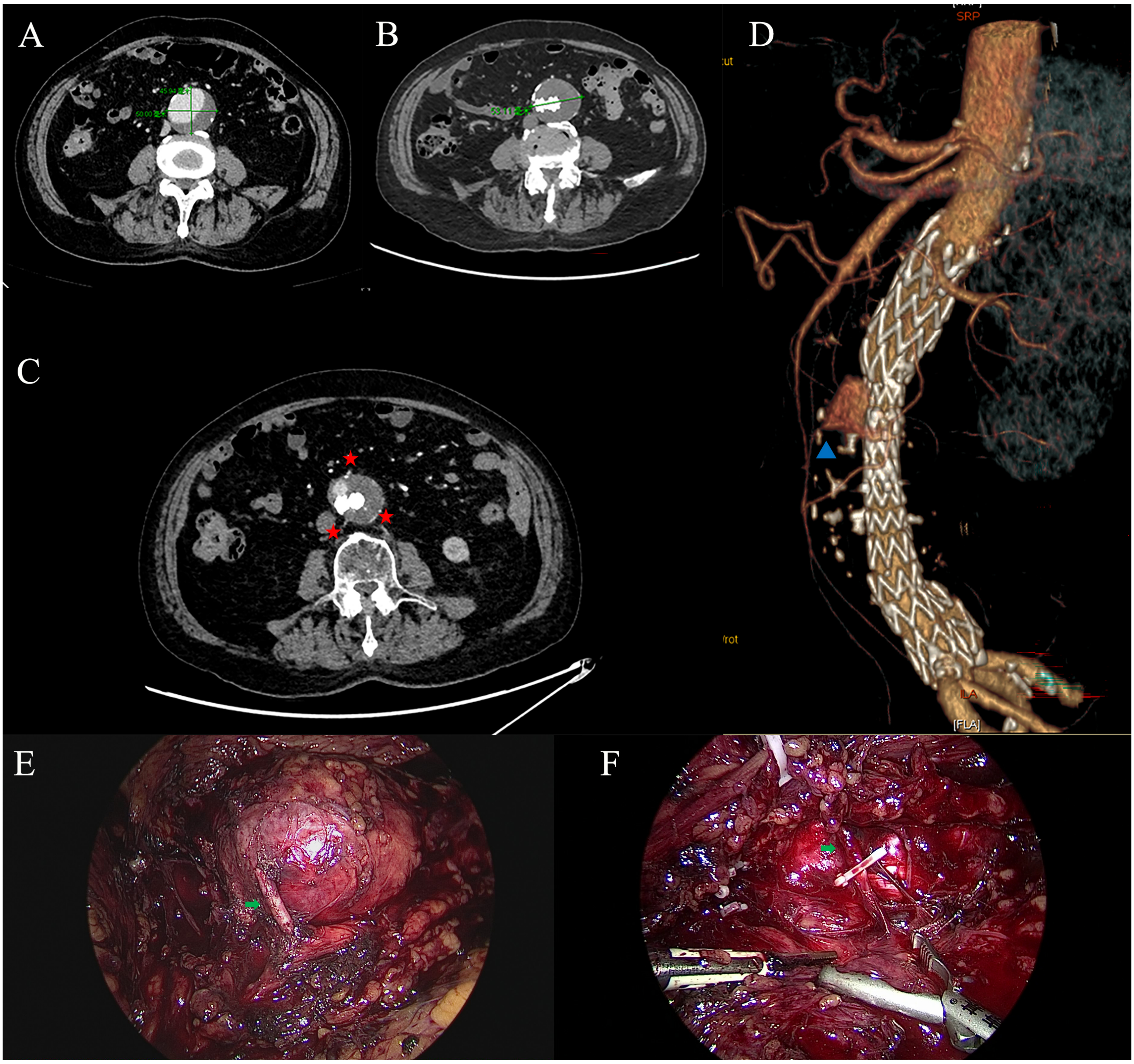

Fig. 1. Preoperative and intraoperative findings in a patient with persistent type II endoleak (T2EL) after EVAR. (A) Pre-EVAR CT angiography demonstrating an abdominal aortic aneurysm measuring 50 mm in maximal diameter. (B) CT scan obtained 24 months after EVAR showing aneurysm sac enlargement to 53 mm. The green markers illustrated the diameter of the aneurysmal sac. (C) Venous-phase contrast-enhanced CT demonstrating persistent opacification of the aneurysm sac, likely originating from the IMA and lumbar arteries. The red asterisks showed the 3 original vessels (Ventral: the inferior mesenteric artery; Dorsal: the two lumbar arteries) of sac opacification. (D) Three-dimensional CT reconstruction confirming contrast inflow from the superior mesenteric artery–related collateral pathways. The blue triangle showed the blood communication between the superior mesenteric artery and the inferior mesenteric artery related to the endoleak. (E) Intraoperative laparoscopic view showing identification and double-clip ligation of the IMA at its origin. (F) Laparoscopic exposure and clip ligation of lumbar arterial branches arising from the posterior aneurysm wall. The green triangles in E&F showed the exposed lumbar artery before and after ligation and transection. EVAR, endovascular aneurysm repair; CT, computed tomography; IMA, inferior mesenteric artery.

patient developed postoperative chylous drainage through the retroperitoneal drain, which resolved with conservative management, including limiting oral intake and enteral nutrition for 1 week, culminating in drain removal without complications. No perioperative mortality occurred.

During a median follow-up of 13.5 months (range: 4–54 months), all patients demonstrated aneurysm sac regression (median reduction: 3.5 mm; range: 1–8 mm), as shown in Fig. 2. Follow-up imaging revealed complete endoleak resolution in 4 cases (66.7%), while 2 patients

Table 1. Characteristics of patients undergoing laparoscopic transperitoneal repair for the management of type II endoleak after EVAR.

Patient ID	Gender, age	Comorbidity	Aneurysm diameter before initial EVAR/mm	Duration from EVAR to laparoscopic repair/months	Aneurysm diameter before laparoscopic repair/mm
1	M, 76	Hypertension, CHD	50	24	53
2	M, 78	Hypothyroidism	55	77	70
3	M, 78	CHD, DM	53	18	56
4	M, 71	CHD	60	108	102
5	M, 76	Hypertension, CHD	56	32	63
6	M, 84	Hypertension, CHD	57	14	59

Abbreviation: M, male; CHD, coronary heart disease; DM, diabetes mellitus; EVAR, endovascular aneurysm repair.

Table 2. Outcomes of patients undergoing laparoscopic transperitoneal repair for the management of type II endoleak after EVAR.

Patient ID	Ligated culprit vessels	Follow-up after laparoscopic repair/months	Type II endoleak	Aneurysm diameter at follow-up/mm	Diameter change/mm
1	IMA+4LA+MSA	54	Residual endoleak	49	–4
2	IMA+4LA+MSA	23	Residual endoleak	69	–1
3	IMA+2LA+MSA	6	Complete resolution	55	–1
4	IMA+3LA	9	Complete resolution	94	–8
5	IMA+2LA	4	Complete resolution	58	–5
6	IMA+6LA+MSA	18	Complete resolution	56	–3

Abbreviation: IMA, inferior mesenteric artery; LA, lumbar artery; MSA, median sacral artery.

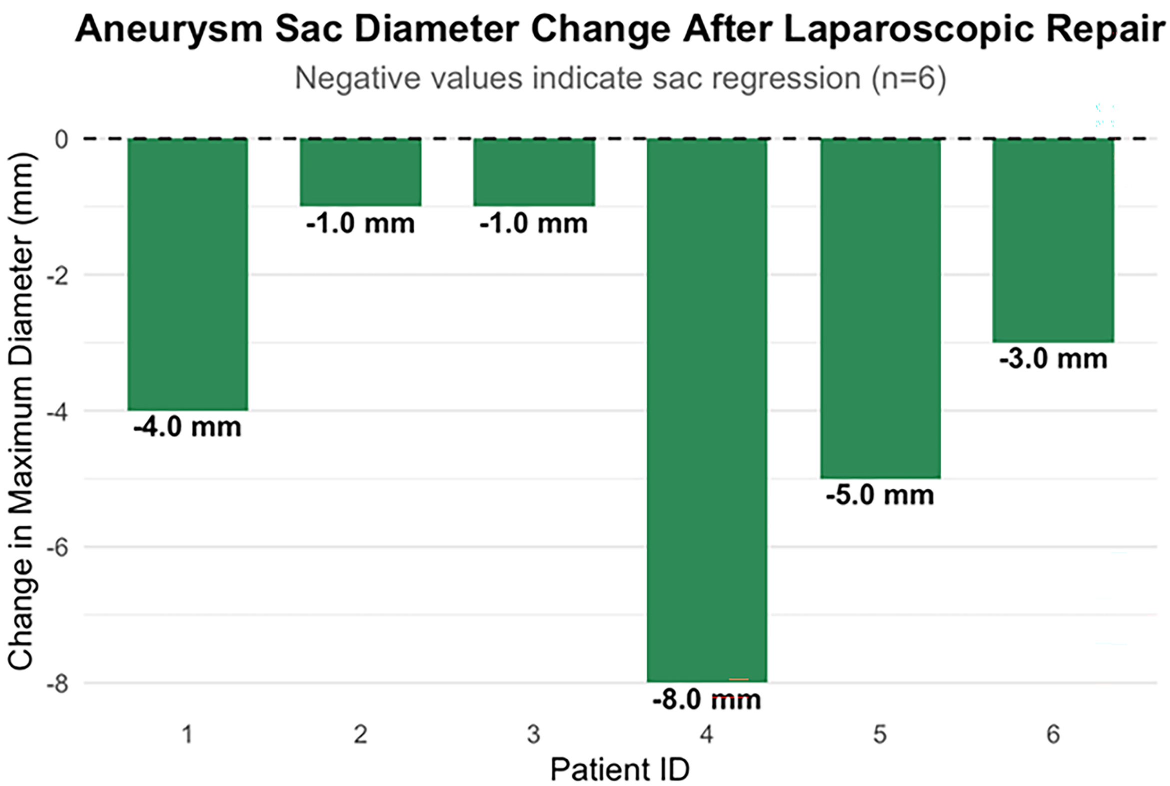

Fig. 2. Change in aneurysm sac diameter before and after laparoscopic transperitoneal branch vessel ligation. Serial imaging demonstrates that all six patients experienced aneurysm sac regression during follow-up. The degree of sac reduction varied among patients, with decreases ranging from 1 mm to 8 mm, illustrating consistent but individualized postoperative responses.

retained asymptomatic T2EL without sac expansion. Notably, no secondary interventions or deaths were recorded during the study period.

4. Discussion

T2EL remains one of the most common causes of persistent aneurysm sac perfusion following EVAR. The most frequent sources of T2EL post-EVAR are the IMA and lumbar arteries. Other possible contributors include internal iliac, median sacral, and accessory renal arteries. The key to managing T2EL lies in identifying and occluding the sources of reflux. Given their minimally invasive nature and rapid recovery, transarterial or translumbar embolization has traditionally been the first-line intervention. Despite some progress, the success rates of embolization remain suboptimal. Moulakakis *et al*. [19] reported technical success rates of only 50% for translumbar and 67% for transarterial approaches. Additionally, 24% of cases require reintervention during long-term follow-up [20]. There is an urgent need for alternative surgical strategies for cases that are refractory to embolization.

The introduction of laparoscopic techniques marks a significant milestone in the history of surgery with widespread applications in general surgery, urology, and gynecology. Laparoscopic aortic surgery, which involves performing aortic anastomoses with laparoscopic instruments, has emerged as a viable alternative to open or endovascular repair for infrarenal AAAs or aortoiliac occlusive disease [21]. Compared to endovascular therapy, laparoscopy offers direct visualization, precise branch vessel management, absence of radiation, and definitive repair. Some authors have explored laparoscopic sac puncture for pressure monitoring, thrombin injection, or thrombectomy with sac plication.

In this study, we successfully managed post-EVAR T2EL using laparoscopic techniques and summarized our key insights as follows:

4.1 Preoperative Imaging for Anatomic Characterization

Modern imaging modalities for diagnosing endoleak include ultrasound, contrast-enhanced ultrasound (CEUS), magnetic resonance angiography (MRA), contrast-enhanced CT, CTA, and digital subtraction angiography (DSA). Each technique has distinct advantages. Ultrasound is non-invasive, radiation-free, and cost-effective for routine surveillance, while DSA—though highly accurate—is invasive and typically reserved for embolization procedures [22]. In our experience, triple-phase contrast-enhanced CT (non-contrast, arterial, and venous phases) is the most critical preoperative tool. It assesses stent-graft apposition at proximal and distal zones to exclude Type I/III endoleaks. The venous-phase imaging enhances T2EL detection by capturing delayed contrast filling, while high-resolution CT also traces branch vessels communicating with the aneurysm sac to identify potential leak sources. Furthermore, 3D reconstructions from arterial-phase CT provide intuitive visualization of aneurysm morphology, stent integrity, and branching vessel courses, offering invaluable guidance for laparoscopic planning.

4.2 Surgical Approach and Laparoscopic Planes

Reported approaches for laparoscopic T2EL repair include retroperitoneal and transperitoneal routes. Wisselink *et al*. [23] were the first to describe retroperitoneoscopic ligation of lumbar arteries and IMA after failed embolization. Most operators, however, now favor the transperitoneal approach. For isolated IMA or internal iliac artery leaks, direct transperitoneal access with retroperitoneal dissection suffices [24,25]. However, simultaneous addressing of IMA, lumbar, and median sacral arteries demands greater technical nuance. We advocate the transperitoneal retrocolic-prerenal approach for these complex cases, as it provides superior exposure of posteriorly originating lumbar arteries and circumvents the restricted workspace associated with pure retroperitoneoscopy. By fully mobilizing the left colon and splenic flexure, substantial operating space is created. In our cases, we employed a hybrid strategy that combined both transperitoneal and retroperitoneal techniques.

4.3 Localization of Target Vessels and Intraoperative Success Assessment

The goal of the procedure is the complete ligation of all refluxing branches. A preoperative CT scan is essential for identifying target vessels, which include the IMA, lumbar, median sacral, or internal iliac arteries. Communicating with the sac. During the operation, use the origins of the IMA and aortic bifurcation as landmarks to guide lumbar artery localization. Some centers employ intraoperative DSA to confirm occlusion [26,27], while others rely on postoperative CTA or ultrasound within 24 hours to one week [28–30]. We utilize combined contrast-enhanced CT and CEUS within one week postoperatively. Novel techniques such as indocyanine green fluorescence imaging (as reported by Porta *et al*. [31]) may enable real-time vessel mapping and efficacy assessment. Future advancements like 3D printing and image fusion could further enhance procedural precision.

A key observation in our series is that all patients demonstrated some degree of sac regression during follow-up, with four out of the six patients achieving complete resolution of the endoleak. However, two patients continued to exhibit residual T2EL despite successful ligation of all pre-identified feeding arteries. The occurrence of persistent endoleaks is primarily attributable to the inherent resolution limitations of standard preoperative CT imaging, which may fail to detect subtle anatomical contributors. Specifically, small accessory lumbar branches (often $<$1–2 mm), retrograde flow from unrecognized branches of the internal iliac or median sacral arteries, and complex anatomical variations (e.g., multiple ostia) can form low-pressure backfilling channels that are invisible on conventional CT scans. To overcome these limitations and enhance detection sensitivity, alternative preoperative diagnostic modalities such as CEUS or Time-resolved magnetic resonance angiography (4D-MRA) have shown promise in visualizing low-flow endoleaks and dynamic blood flow that static CT might miss [32,33]. Furthermore, a pivotal direction for future management lies in the integration of preoperative CT data with intraoperative fluoroscopy (Fusion Imaging) [34]. By overlaying the 3D reconstructed CT model onto the live 2D fluoroscopic screen, this technology allows for real-time 'roadmapping' of small, elusive vessels that are invisible on standard DSA. This approach not only compensates for the limitations of preoperative screening but also holds potential for navigating the laparoscopic localization and ligation of refluxing branches.

4.4 Limitations

Despite the favorable perioperative outcomes observed in this study, the small cohort size and relatively short follow-up period limit the strength of our conclusions. Larger studies with standardized imaging protocols and longer surveillance are needed to better define patient selection criteria, quantify long-term success rates, and assess durability. When considering the risk of recurrence, it is vital to identify anatomical or clinical predictors of persistent T2EL following laparoscopic repair in future research.

5. Conclusions

In summary, laparoscopic transperitoneal ligation represents a promising alternative for managing embolization-refractory T2EL. While our early results demonstrate technical feasibility and encouraging short-term outcomes, broader evidence is required to establish its optimal role within the treatment algorithm for post-EVAR endoleaks.

Availability of Data and Materials

The datasets upon which the manuscript conclusions are based in the current study are available from the corresponding author (email: zhangxuemin128@126.com) upon reasonable request.

Author Contributions

WL and XZ designed the research study. WL, YL, JL, TZ, and XZ performed the research. YL, JL, and TZ provided help and advice on the data collection. WL and JL analyzed the data. WL drafted the manuscript. All authors contributed to the critical revision of the manuscript for important intellectual content. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

This study was approved by the Ethics Committee of Peking University People's Hospital (2022PHB420-001). All patients/participants or their families/legal guardians gave their written informed consent before they participated in the study. The study was conducted in accordance with the Declaration of Helsinki.

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Conflict of Interest

The authors declare no conflict of interest.

Declaration of AI and AI-Assisted Technologies in the Writing Process

During the preparation of this work, the authors used DeepSeek-V3.2 in order to check spelling and grammar. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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