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Review

Incidence, Risk Factors, and Outcomes of Iliac Limb Occlusions After Endovascular Aneurysm Repair. A Scoping Review of Literature

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ABSTRACT

Introduction: The objectives of this scoping review were threefold: (1) to assess the incidence and risk factors of iliac limb occlusion (ILO); (2) to evaluate the evidence linking ILO to short- and long-term outcomes in patients undergoing endovascular aneurysm repair (EVAR) for abdominal aortic aneurysm (AAA); and (3) to identify recurring themes and gaps in the literature to guide further research and suggest standardized reporting details for future studies.

Methods: A scoping review methodology was employed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews guidelines. Specific Population, Intervention, Comparison, Outcome questions were developed prior to the literature search. Studies published in English between January 1, 2000, and December 31, 2024, were considered. Inclusion criteria were as follows: (1) studies reporting ILO following standard EVAR; (2) a minimum sample size of 50 patients; (3) at least 1 y of follow-up; and (4) reporting of relevant clinical outcome measures.

Results: Fifty-two studies met inclusion criteria and were analyzed. These included one randomized controlled trial, five prospective registry studies, five prospective non-randomized cohort studies, and 41 retrospective cohort studies. Collectively, these studies evaluated 17,716 patients (15,133 males) who underwent EVAR for AAA. Only half of the studies provided details on timing or clinical presentation of ILO. The diagnosis was primarily clinical, with symptoms reported in up to 93.6% of cases (289 symptomatic and 20 asymptomatic patients). When specified, most patients (64.4%, $n = 154$) presented with

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acute limb ischemia or rest pain, while one third (35.6%, $n = 85$) had claudication. The reported incidence of ILO varied significantly across studies, ranging from 0.86% to 11.20%, with approximately half reporting rates between 3 and 6%. Both patient- and procedure-related factors were associated with increased risk of ILO after EVAR. Several authors emphasized the importance of addressing intraoperative findings– such as iliac stenosis >50%, residual stenosis >50% or kinking of the iliac limb–to help mitigate ILO risk. A total of 385 secondary interventions for ILO correction were reported. Of these, 55.9% ($n = 223$) involved open surgical revascularization, 28.6% ($n = 114$) were hybrid procedures, and 15.5% ($n = 62$) were treated using only endovascular techniques. Notably, only nine studies reported treatment outcomes, including a total of 3713 patients. When provided, treatment results were favorable, with immediate technical success rates ranging from 80% to 100%. *Conclusions:* ILO is one of the most common failure modes of EVAR, with a reported incidence from 0 to 11% during follow-up. Several anatomical and procedural factors have been identified to increase risk of ILO, and increasing evidence supports the use of intraoperative strategies to mitigate risk of these complications. Although secondary interventions are often successfully managed using endovascular or hybrid approaches, further research is needed to refine prevention strategies and improve long-term EVAR durability.

Introduction

Over the past 2 decades, endovascular aneurysm repair (EVAR) has largely supplanted open repair as the preferred treatment for abdominal aortic aneurysms (AAAs), owing to its lower procedure-related morbidity and mortality. Current clinical practice guidelines support EVAR as the first-line option in most patients with favorable anatomy.[1] However, this short-term benefit may come at the expense of long-term durability. Multiple studies, including long-term follow-up from randomized controlled trials, have shown that the initial survival advantage of EVAR is no longer evident beyond 8 y post procedure.[2]

Iliac limb occlusion (ILO) represents one of the most common failure modes following EVAR and can lead to significant ischemic complications in the lower extremities. A previous meta-analysis of 5454 patients reported ILO rates as high as 5.6%. In severe cases—such as those presenting with acute limb ischemia or chronic limb-threatening ischemia—secondary interventions are often necessary and may carry a substantial risk of limb loss or mortality.

Several patient-specific anatomical factors have been associated with increased risk for ILO, along with procedural variables such as stent graft type,[3-6] distal landing zone location in the external iliac artery (EIA),[4,7-9] and technical considerations like excessive oversizing.[10,11] Despite the growing awareness of ILO risk, variability in definitions, surveillance protocols, and outcome measures across studies has made it challenging to synthesize and compare existing evidence.

Scoping reviews[12,13] are a valuable form of evidence synthesis, serving as an important complement to traditional systematic reviews—especially in emerging or heterogeneous fields. They are particularly useful for mapping key concepts, identifying the types and sources of evidence available, highlighting knowledge gaps, and informing future research priorities or the development of systematic reviews and clinical guidelines.[14,15] Accordingly, the objectives of this scoping review were as follows: (1) to assess the incidence and risk factors associated with ILO following EVAR; (2) to evaluate the strength and scope of evidence linking ILO to short-term and long-term clinical outcomes; and (3) to identify recurring themes, research gaps, and areas for improvement in study design and reporting to inform future investigations.

Methods

Search strategy and study design

This scoping review was conducted in accordance with the PRISMA Extension for Scoping Reviews (PRISMA-ScR) guidelines.[16] The PRISMA-ScR checklist is available in Supplementary Table I. Prior to initiating the literature search, the study design and specific PICO (Population, Intervention, Comparison, Outcome) questions were developed to guide eligibility and data extraction (Table 1 and Supplementary Table II). The search aimed to identify relevant English-language studies published between January 1, 2000, and December 31, 2024.

A comprehensive search strategy was employed to capture studies reporting on ILO following standard EVAR. Eligible studies met the following inclusion criteria.

1 Described ILO occurring after standard infrarenal EVAR
2 Included a minimum sample size of 50 patients
3 Reported at least 1 y of clinical follow-up
4 Provided data on pertinent clinical outcome measures, as defined below.

Studies were excluded if they:

1. Included complex aortic repairs (e.g., juxta-/para-/suprarenal AAA, or fenestrated/branched EVAR);
2. Represented duplicate cohorts;

Table 1 – Predefined questions for a literature search of iliac limb occlusion (ILO) in subjects with abdominal aortic after endovascular aortic repair.

Epidemiology	What is the overall incidence of limb occlusion?
Risk factors	Can risk factors related to limb occlusion occurrence be identified?
Diagnosis	What is the clinical presentation of limb occlusion? Can limb occlusion be prevented? What are the diagnostic tools of choice?
Treatment and prognostic impact	What is the preferred modality of reintervention? Is patient survival affected by limb occlusion development?

3. Involved use of experimental, physician-modified, or commercially unavailable devices.

Titles and abstracts were screened independently by two authors (GZ and LF). Full-text review was performed for all potentially eligible studies. Any disagreements regarding inclusion were resolved through discussion with a third author (MD).

Data extraction and evidence synthesis

For each included study, the following data were extracted: study year and country, design, sample size, baseline demographics, anatomical characteristics (as reported in the original studies)—including maximum aneurysm diameter, iliac artery diameters and lengths, proximal neck length, distal sealing zone length, and tortuosity index. Device-related variables (stent graft type and limb diameter/length) and reported outcomes were also collected. Outcomes of interest included short-term (30-d or in-hospital) and mid-to long-term results (≥1 y), specifically incidence of ILO, follow-up duration, and type and frequency of reinterventions.

As per the scoping review methodology, data were synthesized descriptively. No meta-analysis or formal assessment of study quality or bias was performed. Studies were categorized based on whether they identified statistically significant associations between risk factors and the occurrence of ILO. Reported risk factors were subsequently grouped into thematic categories to aid in clarity and interpretation.

Results

Characteristics of included studies

The study selection process is detailed in Figure 1. The initial search identified 1439 studies after duplicate records were removed. Following title and abstract screening, 104 articles were selected for full-text review, with 46 studies meeting the predefined eligibility criteria. An additional six studies were identified through backward citation, yielding a total of 52 studies included in the final analysis[3-11,17-30,31-59] The study characteristics and specific details concerning ILO are provided in Table 2.

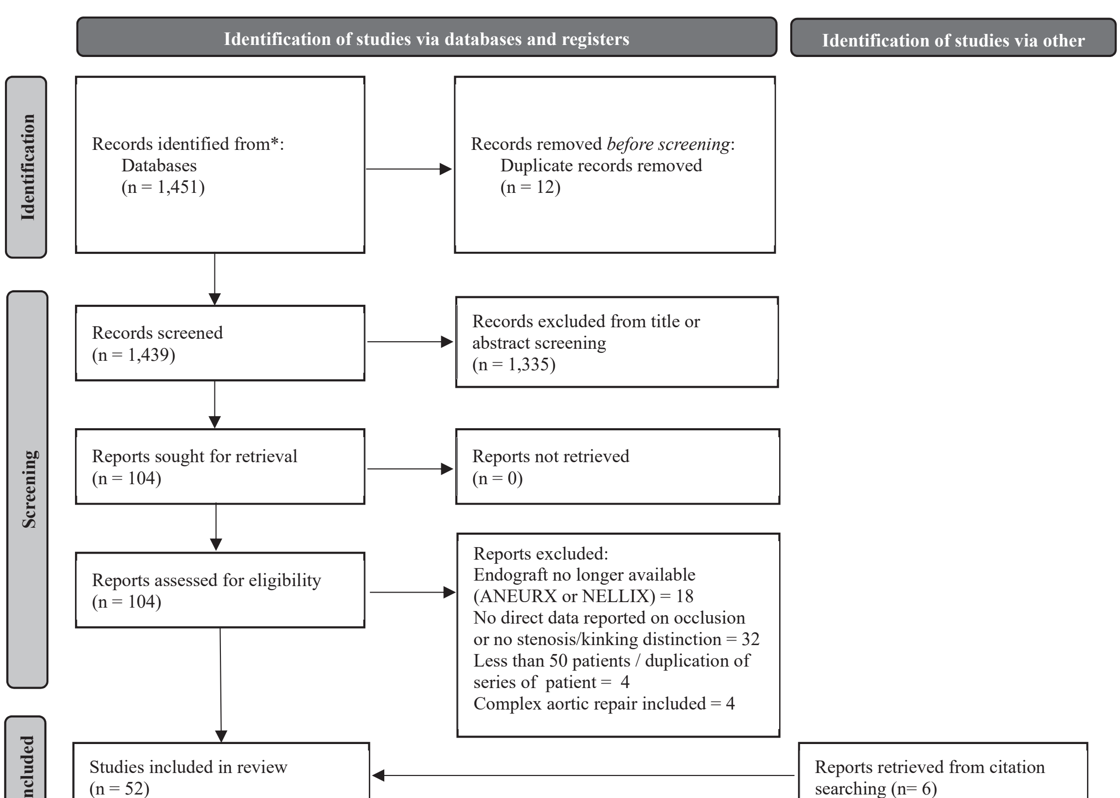

Fig. 1 – PRISMA flowchart of literature selection.

Table 2 – Characteristics of the studies included in the final analysis and detail regarding iliac limb occlusion (ILO).

Study	Year	Patients (n)	Follow-up (months)	Limb occlusion		Symptoms				Timing					
				N	%	Asymptomatic	Unspecified	ALI	Claudication	30 d		<12 months		>12 months	
Abraham_2002	1998-2001	116	12	1	0.9%			1		1	0.86%	0	0.0%		0.0%
Andersen_2019	2006-2016	421	36	12	2.9%	1			11	NR					
Ash_2020	2015-2017	225	12	3	1.3%		3			0	0.0%	3	1.3%		0.0%
Basra_2023	2007-2017	787	NR	50	6.4%	NR				NR					
Bastos Goncalves_2017	2004-2012	341	56	10	2.9%	NR									
Benveniste_2020	2008-2019	188	55	7	3.7%	2		1	5	3	1.6%	3	1.6%	1	0.5%
Bogdanovic_2021	2012-2018	924	37	55	6.0%	NR				NR					
Bonardelli_2022	2005-2019	795	52	14	1.8%	NR				9	1.1%		0.0%	5	0.6%
Bos_2009	1999-2000	92	36	1	1.1%	NR				1	1.1%		0.0%		0.0%
Broda_2022	2015-2018	241	35	27	11.2%	2		21	4	NR					
Catanese_2020	2010-2017	276	32	7	2.5%	1		1	5	4	1.4%	3	1.1%		0.0%
Conway_2012	1996-2010	661	27	31	4.7%				31	14	2.1%	14	2.1%	3	0.5%
Daoudal_2016	2004 - 2013	224	46	11	4.9%		11			NR					
De Athayde Soares_2024	2019 - 2022	156	25	9	5.8%	NR				NR					
De Marino_2021	2010-2018	615	27	16	2.6%			11	5	1	0.2%	7	1.1%	8	1.3%
Donas_2015	2007-2013	712	19	15	2.1%	NR				NR					
Faure_2015	2009-2011	1143	18	42	3.7%	NR				13	1.1%	17	1.5%	12	1.0%
Fujimura_2024	2020 - 2021	133	12	5	3.8%	NR				NR		5	3.8%		
Hatzl_2024	2016 - 2019	273	24	24	8.8%	NR				8	2.9%	3	1.1%	9	3.3%
Isernia_2021	2000-2019	260	54	20	7.7%	2	18			0	0.0%	10	3.8%	10	3.8%
Janho_2019	2004 - 2017	288	60	7	2.4%				7	NR					
Kapetanios_2019	2012-2016	94	15	3	3.2%	NR				1	1.1%	2	2.1%		0.0%
Maleux_2008	1998-2007	288	60	10	3.5%	2		3	4	5	1.7%	2	0.7%	3	1.0%
Mantas_2015	2010-2013	439	18	18	4.1%			11	7	3	0.7%	15	3.4%		
Marone_2024	2020 - 2023	90	14	2	2.2%	NR				NR					
Mertens_2010	1998-2003	143	66	8	5.6%				8	0	0.0%	6	4.2%	2	1.4%
Midy_2020	2012-2013	177	59	14	7.9%	NR				2	1.1%	5	2.8%	7	4.0%
Moulakakis_2017	2010-2015	578	NR	29	5.0%	NR				NR					
Nana_2023	2017-2019	134	12	9	6.7%	NR				NR					
Oshin_2010	1996-2005	295	24	11	3.7%	3			8			8	2.7%	3	1.0%
Pini_2019	2012-2016	533	38	4	0.8%	NR				NR					

(continued)

Table 2 – (*continued*)

Study	Year	Patients (n)	Follow-up (months)	Limb occlusion		Symptoms				Timing					
				N	%	Asymptomatic	Unspecified	ALI	Claudication	30 d		<12 months		>12 months	
Pini_2024	2016-2019	547	44	8	1.5%	NR				0	0.0%	2	0.9%	2	0.9%
Rodel_2018	2003-2015	317	47	31	9.8%	NR				1	0.3%	10	3.2%	20	6.3%
Salemans_2021	2009-2012	165	76	4	2.4%	NR				2	1.2%	2	1.2%	0	0.0%
Shintani_2019	2008-2016	428	30	11	2.6%	NR				5	1.2%	1	0.2%	5	1.2%
Silingardi_2020	1999-2002	73	68	1	1.4%				1	1	1.4%	0	0.0%	0	0.0%
Sirignano_2017	2012-2015	156	20	1	0.6%			1		1	0.6%	0	0.0%	0	0.0%
Sirignano_2019	2010-2012	289	26	12	4.2%		12			NR					
Sivamurthy_2006	1999-2004	248	24	13	5.2%	NR						10	4.0%	3	1.2%
Sobocinski_2015	2010-2013	208	45	8	3.8%	NR				NR					
Taudorf_2014	2000-2010	504	28	18	3.6%	3		6	9			11	2.2%	7	1.4%
Tigkiropoulos_2020	2006-2017	271	72	16	5.9%			4	12	NR					
Torsello_2019	2010-2011	60	27	1	1.7%			1		0	0.0%	0	0.0%	1	1.7%
Troisi_2023	2016-2021	202	26	9	4.5%	NR				NR					
Vacirca_2020	2012-2017	442	33	6	1.4%				6	NR					
Van Gerwen_2024	2001-2020	221	48	11	5.0%	1			6	NR					
Van Zeggeren_2013	2007-2012	496	20	20	4.0%			10	10	7	1.4%	10	2.0%	3	0.6%
Wales_2008	2001-2007	286	16	9	3.1%	NR				6	2.1%	3	1.0%	0	0.0%
Wang_2021	2011-2019	729	34	22	3.0%	NR				NR					
Yuan_2024	2013-2022	66	12	14	2.4%	3		6	5	2	0.3%	10	1.7%	2	0.3%
Zavatta_2021	2014-2019	209	19	6	2.9%		6			NR					
Zeng_2024	2012 - 2022	157	29	18	11.5%			8	10	NR					

The included studies are comprised of one randomized clinical trial, five prospective registry studies, five prospective nonrandomized cohort studies, and 41 retrospective cohort studies. Collectively, these studies evaluated 17,716 patients (15,133 men) with AAA who underwent EVAR. Mean age at the time of surgery ranged between 70.0 and 78.2. The mean follow-up duration varied across studies, ranging from 12 to 76 mo. Notably, almost two third of the included studies ($n = 33$) were published within the last 5 y (Supplementary Figure I). The Talent/Endurant (Medtronic Santa Rosa, CA) and Zenith Flex/Alpha (Cook Medical, Bloomington, IN) devices were used in most procedures, with 34.5% and 36.0% of the total implants, respectively. A comprehensive list of endograft types and the corresponding number of patients treated with each endograft is presented in Table 3.

Diagnosis, incidence, and timing of ILO

Details regarding clinical findings are summarized in Table 2. Only half of the studies provided information on timing or clinical presentation of ILO. The diagnosis was primarily a clinical one, as symptoms were observed in most cases (reported in up to 93.6% of cases with 289 symptomatic compared to 20 asymptomatic patients). When specified, most of the patients (64.4%, $n = 154$) presented with acute limb ischemia or rest pain, while one third (35.6%, $n = 85$) had claudication.

The incidence of ILO varied significantly across studies, with rates ranging from 0.86% to 11.20%. Approximately half of the studies reported occlusion rates ranging between 3 and 6%. Data highlighting the timing of postoperative ILO were provided in 28 studies, involving 9361 patients. These studies documented occlusion events occurring at 30 d, 1 y, and beyond the 1-y postoperative time periods. Overall, among studies that reported timing of events, 69.1% of ILOs occurred within the first postoperative year—of these, 26.2% developed within the first 30 days. The remaining 30.9% of ILOs occurred after the first postoperative year.

Risk factors for ILO

Both patient-related and procedure-related factors were associated with increased risk for ILO after EVAR as outlined below. Data are presented in accordance with the original studies, with statistical values reported as in the respective sources.

Patient-related factors

Iliac artery tortuosity. The impact of iliac artery tortuosity on ILO was evaluated in six studies, involving a total of 2806 patients. Definition of tortuosity varied across studies. Taudorf *et al.*[53] reported specific and clear definition of tortuosity indices: pelvic artery index of tortuosity (PAI) measures tortuosity by dividing the centerline length of the pelvic artery (from the aortic bifurcation to the common femoral artery origin) by the shortest straight-line distance between these points; common iliac artery index of tortuosity (CAI) calculates the tortuosity of the common iliac artery (CIA) by dividing the centerline length of the artery (from the aortic bifurcation to the internal iliac artery origin) by the straight-line distance between these landmarks; double iliac sign indicates severe tortuosity when parts of the iliac vessel appear doubled or more on an axial computed tomography angiography slice, with an angulation exceeding 90° and it is recorded qualitatively as present or absent without further measurements. By analyzing all the three definitions among their cohort, the authors found that the CAI but not PAI was significantly higher in occluded limbs compared with controls ($P = 0.009$), and the double iliac sign was also a significant predictor ($P = 0.003$). In a recent analysis by Yuan *et al.*,[10] CAI ≥ 1.08 was also found to be a significant factor predisposing to ILO. Finally, in a predictive model for ILO, Moulakakis *et al.*[28] identified a significant association with iliac angulation ≥60° (50% *versus* 4.8%, $P < 0.001$). When combined with ≥50% iliac calcification and ≥15% limb oversizing, patients with high composite scores had a 50.7% predicted probability (95% confidence interval (CI): 40.8-60.5) of experiencing at least one limb occlusion.

These definitions were also used by Shintani *et al.*[23] in a Japanese population. However, in their cohort, severe iliac tortuosity was not predictive of ILO. Similarly, Vacirca *et al.*[30] found that tortuosity <90° was not significantly related to occlusion ($P = 1.0$). Interestingly, Basra *et al.*[6] reported greater tortuosity in their control groups compared to occluded EVAR limbs ($P = 0.01$).

External iliac artery diameter. The possible association between EIA diameter and ILO was assessed in six articles, including 3229 patients. Definitions of relevant diameters and their thresholds for risk vary among the different studies reviewed. In fact, 6 mm, 7 mm, 10 mm, and 13 mm were used as cutoff values, as further specified below. Shintani *et al.*[23] found that an EIA diameter ≤10 mm as a significant risk factor for iliac limb complications (hazard ratio [HR] 5.41; $P = 0.01$). Similarly, Faure *et al.*[9] identified a subgroup of patients at high risk for ILO: an EIA diameter ≤10 mm was a strong independent predictor of ILO, with an odds ratio (OR) of developing ILO 15.6 (95% CI: 3.7-64.9) times higher and a reduced 2-y limb patency rate of 96.1% compared to 99.6% in low-risk patients. Bogdanovic *et al.*[4] reported that an EIA diameter <10 mm increased the risk of ILO after EVAR (OR: 4.99, 95% CI: 1.46-16.9). Rödel *et al.*,[40] in their analysis of Anaconda endografts, noted a higher occlusion rate for grafts with distal limb diameters ≤13 mm, with a HR of 0.732 (95% CI: 0.63-0.86; $P < 0.001$). Zavatta *et al.*[43] also showed that EIA diameter <6 mm and concurrent complex iliac anatomical factors (PAI, iliac calcifications and narrow aortic bifurcation) significantly predicted the need for reintervention (HR 7.25; $P = 0.014$), though individual factors like small EIA diameter did not independently increase overall complication rates. Lastly, Sobocinski *et al.*[35] identified EIA diameters <7 mm as a significant predictor of postoperative complications, including ILO (OR: 4.854, 95% CI: 1.484-15.973, $P = 0.009$).

Although growing evidence supports a correlation between EIA diameter and limb occlusion, several authors have failed to demonstrate a similar association with CIA diameter.[6,10,11,26,42,55,60]

Narrow distal aorta. The association between a narrow aortic bifurcation diameter and ILO was explored in six studies (3071

Table 3 – Endograft types used in the included studies.

Study	Excluder C3 (W.L. Gore and associates, Flagstaff, AZ, USA)	Talent/ Endurant (Medtronic Santa Rosa, CA, USA)	Zenith Flex/ Alpha (Cook Medical, Bloomington, in USA)	Ovation (Endologix, Santa Rosa, CA, USA)	AFX (Endologix, Santa Rosa, CA, USA)	Anaconda (Vascutek Terumo, Renfrewshire, UK)	Incraft (Cordis, Baar, Switzerland)	Aorfix, Minos (Microport, Shanghai, China)	Others	NR
Andersen_2019	11		410							
Ash_2020				225						
Basra_2023	2	85	509			79	6	106		
Bastos Goncalves_2017	238	344	5						12	
Benveniste_2020		188								
Bogdanovic_2021	152	457	315							
Bonardelli_2022	144	180	471							
Bos_2009	92									
Broda_2022			241							
Catanese_2020	165	103				6	2			
Conway_2012			661							
Daoudal_2016	11	133	66			14				
De Athayde Soares_2024	89		67							
De Marino_2021	332	30	233	2	14	3	1			
Donas_2015		712								
Faure_2015		1143								
Fujimura_2024			133							
Hatzl_2024			273							
Isernia_2021						260				
Janho_2019	3	271	11			3				
Kapetanios_2019		94								
Maleux_2008	71		187							
Mantas_2015	139	34	155			111				
Marone_2024								90		
Mertens_2010			143							
Midy_2020						177				
Moulakakis_2017	179	51	237	1		111				
Nana_2023										134
Oshin_2010			295							
Pini_2019	131	126	174			102				
Pini_2024	196	118	233							

Rodel_2018						317				
Salemans_2021		165								
Shintani_2019	255	84	89							
Silingardi_2020					73					
Sirignano_2017				156						
Sirignano_2019	86	97	53	18	26	4			5	
Sivamurthy_2006			248							
Sobocinski_2015			208							
Taudorf_2014			504							
Tigkiropoulos_2020						271				
Torsello_2019							60			
Troisi_2023			202							
Vacirca_2020	119	98	127			98				
Van Gerwen_2024	34	160	4	4		8			2	
Van Zeggeren_2013		496								
Wales_2008		133	153							
Wang_2021		729								
Yuan_2024		44					2	9	6	
Zavatta_2021							209			
Zeng_2024		77	3					33	44	
Total grafts n = 17,815	2449 (13.7%)	6152 (34.5%)	6410 (36.0%)	406 (2.3%)	113 (0.6%)	1564 (8.8%)	280 (1.6)%	238 (1.3%)	69 (0.4%)	134 (0.8%)

patients), though most findings were not statistically significant. Definitions of a narrow aortic bifurcation and the thresholds for risk varied among investigations: a cutoff of 20 mm was used in three studies, while in the other three, aortic diameters were compared between patients with and without ILO. Only Catanese *et al.*[52] found an aortic bifurcation <20 mm to be a significant predictor of ILO (OR: 3.21, 95% CI: 1.19-8.69; $P = 0.01$).

Although a narrow aortic bifurcation would intuitively predispose to ILO, some authors have not confirmed a significant association. Bogdanovic *et al.*,[4] Daoudal *et al.*,[42] Faure *et al.*,[9] Taudorf *et al.*[53] and Van Gerwen *et al.*[55] reported no significant association between aortic bifurcation diameter and ILO. However, it should be noted that several authors[4,6,21,25-27,30,38,47,48,59] reported the use of kissing stenting (with bot self-expandable and balloon-expandable stent) or kissing angioplasty with noncompliant balloon to improve endograft limb expansion in narrow distal aorta, as an adjunctive strategy to prevent occlusion. This approach may have contributed to reducing the incidence of limb occlusion, as Isernia *et al.*[27] reported in a study showing a significantly higher rate of freedom from limb occlusion (98.0% *versus* 88.4%) in patients who underwent iliac kissing ballooning (log-rank test, $P = 0.029$). Similar approaches were also supported by Marques De Marino *et al.*,[21] Vacirca *et al.*[30] e Pini *et al.*,[59] demonstrating a significant reduction in ILO occurrence.

Iliac artery calcification. The role of iliac artery calcifications in ILO after EVAR has been investigated in seven studies analyzing 3276 patients, with mixed results. Mantas *et al.*[11] identified circumferential calcifications >50% as a significant risk factor for ILO (OR: 5.87, 95% CI: 1.10-31.32; $P = 0.04$) in a case-control study of 439 patients. Moulakakis *et al.*[28] also found calcifications >50% to be predictive of occlusion (50% *versus* 4.8%; $P < 0.001$). Similarly, Zavatta *et al.*[43] noted calcifications as part of a composite risk factor alongside angulation and oversizing. Conversely, other studies reported no significant impact of calcifications. Broda *et al.*[3] found heavily calcified iliac arteries to be protective against ILO (risk reduction: 15%, 95% CI: −26% to −5%; $P = 0.005$). Vacirca *et al.*[30] also observed no association between calcifications >50% and occlusion. Daoudal *et al.*[42] stated there was no difference in calcification severity between patients with and without occlusion ($P = 0.75$). Similarly, Faure *et al.*[9] and Van Gerwen *et al.*[55] did not find calcifications to be a significant factor.

Procedure-related factors

Extension to the EIA. Landing zones involving the EIA have been identified as a predisposing factor for ILO in several studies. Its role has been investigated by 10 authors in 6493 patients. Conway *et al.*[7] examined ILO in 661 EVAR patients, finding a significantly higher rate of occlusion when the distal landing zone was in the EIA (12% of limbs at risk) compared to the CIA (1%; $P < 0.0001$). They attributed this to the smaller caliber and increased tortuosity of the EIA, which may predispose limbs to thrombosis. This study also reported a higher rate of limb amputation following EIA-related occlusions compared to CIA-related ones ($P = 0.003$). Similarly, a distal landing zone in the EIA was found to be significantly associated with ILO by Daoudal *et al.*[42] (15.4% *versus* 2.1%, $P = 0.006$), Oshin *et al.*[32] (7.7% *versus* 1.2% $P = 0.004$) and Taudorf *et al.*[53] ($P = 0.03$). Bogdanovic *et al.*,[4] in a multicenter study involving 924 patients, reported an increased risk of ILO with EIA landing zones (OR: 5.91, 95% CI: 1.30-26.7).[42] Also, Faure *et al.*,[9] using data from the ENGAGE registry, identified a subgroup of patients at high risk for developing ILO. They found that, in addition to patients with an EIA diameter ≤10 mm, those with a landing zone in the EIA had a significantly increased risk of ILO, 15.6 times higher (95% CI: 3.7-64.9) compared to low-risk patients. Lastly, Pini *et al.*[59] showed that EIA landing was significantly associated with ILO (HR: 17, 95% CI: 1.54-188, $P = 0.020$) and with a lower estimated 5-y freedom from ILO of 75 ± 9% compared with landing in the CIA of 99 ± 0.4%.

Despite these significant findings, an EIA landing zone on its own may not be sufficient to predispose to ILO. In the study by Basra *et al.*, although a higher proportion of patients with iliac limb landing into the EIA was observed in the occlusion group (24% *versus* 14%), the difference was not statistically significant ($P = 0.308$). Mantas *et al.*[11] examined 439 EVAR patients, including cases with EIA as the distal sealing zone, and found no independent association between EIA landing and ILO.

Stent-graft oversizing. Six studies (3513 patients) evaluated the role of stent-graft oversizing on risk for ILO after EVAR, with oversizing >15%, and >20% as the most commonly reported thresholds. Basra *et al.*[6] found that oversizing >20% was present in 50% of occluded limbs compared to 18% in the control group, significantly increasing the risk of occlusion ($P < 0.001$). Moreover, the risk of ILO increased progressively with the degree of oversizing. Yuan *et al.*[46] reported that the mean oversizing in the occlusion group was significantly greater than in the control group (20.2% ± 6.7% *versus* 12.7% ± 4.7%; $P < 0.001$). This association was further supported by Moulakakis *et al.*,[28] demonstrating in their predictive model that oversizing ≥15%, in one or both iliac limbs, contributed significantly (80% *versus* 39.7%, $P = 0.004$) to occlusion risk. Similarly, Mantas *et al.*[11] reported that oversizing ≥15% in the CIA resulted in a fivefold increased risk of occlusion (OR: 5.54, 95% CI: 1.11-27.60, $P = 0.04$). 2810.

In contrast, Catanese *et al.*[52] noted that, while oversizing ≥15% was more common in occlusion cases (57.1% *versus* 8%; $P = 0.005$), it was not an independent predictor in multivariate analysis. Daoudal *et al.*[42] and Faure *et al.*[9] also found no association between oversizing and ILO.

Type of stent-graft and kinking. Stent-graft kinking may compromise luminal patency, resulting in flow-limiting stenosis, thrombus formation, or total graft occlusion. Kinking was identified as a major cause of occlusion in six studies including 3383 patients, two of which specifically analyzed its association. Catanese *et al.*[52] noted kinking as a significant risk factor, with an occlusion rate of 42.9% in limbs with kinking compared to 2% in those without ($P = 0.01$) in their matched case-control analysis. Also, Faure *et al.*[9] identified kinking as one of the strongest independent predictors of ILO, with a lower 2-y patency rate in high-risk patients (96.1% *versus* 99.6%; $P < 0.001$). Similarly, Maleux *et al.*,[41] Sivamurthy *et al.*,[38] Taudorf *et al.*[53] and Bogdanovic *et al.*[4] identified kinking of the endograft limbs as the underlying cause of ILO in 18% to 59% of cases.

There is, however, a correlation between kinking and the type of endograft. Differences in device design and graft material properties influence their susceptibility to kinking, particularly in tortuous vascular anatomies. Eight authors have investigated this issue, analyzing data from 3758 patients. The first findings were reported by Maleux *et al.*[41] in a cohort of 187 Zenith and 71 Excluder implants, where all cases of ILO occurred in patients treated with Zenith stent-grafts, with an occlusion rate of 5%, and kinking identified as the underlying cause in 55% of cases. Conway *et al.*[7] and Shintani *et al.*,[23] further supported these findings. They noted a frequent associations of Zenith stent-grafts with ILO in challenging anatomical settings and a significantly higher EIA-related limb complications with Zenith endografts (7.8% for Zenith devices *versus* 0.66% for Excluder devices, HR 8.67, $P = 0.039$).

Another consistent report was from Bogdanovic *et al.*[4] In a multicenter study of 924 patients, they found that Zenith Alpha stent-grafts were an independent risk factor for ILO (OR: 5.31, 95% CI: 1.97-14.3), with an occlusion rate of 12.4% compared to 0.7% for Excluder and 3.3% for Endurant devices ($P < 0.001$). Later, Basra *et al.*[6] found a significantly higher ILO rate of 9% for Zenith devices compared to 2.5% for Medtronic Endurant and Vascutek Anaconda devices ($P = 0.02$). Also, De Athayde Soares *et al.*[57] observed a higher prevalence of ILO in patients treated with Cook Zenith Flex (9%) than those treated with Medtronic Endurant II (3.4%, $P = 0.045$). These findings were also confirmed by Broda *et al.*[3] and Hatzl *et al.*[5] that analyzed outcomes respectively in 241 and 273 patients treated with Zenith Alpha stent-grafts exclusively, reporting a 3-y ILO rate of 7% and 8.8%, respectively. Notably, in 2020 Cook Medical issued a Field Safety Notice reporting additional measurements with regard to Zenith Alpha limb positioning, to reduce thrombus formation and/or lumen occlusion. In this regard, the analyses conducted by Hatzl *et al.*[5] and Fujimura *et al.*[58] could not identify adverse anatomy or violation of recommendations from the Field Safety Notice as independent risk factors for limb complications.

Strategies for prevention

Some authors suggested that proactive intraoperative management of conditions that may predispose to ILO—such as iliac stenosis >50%, residual limb and/or native iliac outflow vessel stenosis >50% and/or kinking of the iliac limb—may help reduce the incidence of ILO. First reported by Abraham *et al.*,[25] attributing their low rate of ILO (<1%) to the liberal use of adjunctive stenting to address severe iliac tortuosity or calcification, its role was further analyzed by other authors. Applying a protocol for adjunctive angioplasty and/or stenting, Sivamurthy *et al.*,[38] Oshin *et al.*[32] demonstrated a significant reduction in ILO rates, in patients treated with Cook Zenith endografts, from 2.7% to 3.8%, respectively in unstented limbs to 0% in stented limbs ($P = 0.05$; $P = 0.001$). Pini *et al.*[59] reported similar outcomes after implementing a standardized protocol for limb complication prevention during EVAR procedures, resulting in an ILO incidence of 1.2% at a follow-up of 44 ± 23 mo. With a similar protocol, Vacirca *et al.*,[30] found no significant link between tortuosity and occlusion when adjunctive interventions such as iliac stenting were applied. Zeng *et al.*[54] reported a(n) ILO rate of 2% when a bare metal stent was implanted in severe tortuosity iliac anatomy, compared to 15% when not ($P < 0.05$).

Reinterventions for ILO

Details of treatment are presented in Table 4. A total of 385 interventions for ILO remediation were reported. Overall, 55.9% of the patients ($n = 223$) underwent open surgical techniques, 28.6% ($n = 114$) received hybrid procedures, while 15.5% ($n = 62$) were treated using only endovascular methods. Open surgical strategies included surgical thrombectomy alone ($n = 32$), femoral-femoral crossover bypass ($n = 163$), aorto-femoral or bi-femoral bypass ($n = 12$), and axillo-femoral bypass ($n = 16$). Hybrid procedures were characterized by surgical thrombectomy followed by endograft limb relining to correct underlying kinking or stenosis. Catheter-directed thrombolysis (CTD) was performed in 62 patients, with limb stenting used in 87.1% ($n = 54$) to complete the treatment.

Notably, only nine studies[3,7,19,30,38,40,41,47,49] reported treatment outcomes, covering a total of 3713 patients. When provided, treatment results were favorable, with immediate technical success rates ranging from 80% to 100%. Complications included four leg amputations following failed treatment and six deaths due to limb thrombosis. CTD demonstrated a higher failure rate: Van Zeggeren *et al.*[47] reported a CTD failure rate of 44% (5/9), followed by successful open surgical revascularization. Similarly, Vacirca *et al.*[30] reported a failure rate of 25% (1/4), also successfully managed with open conversion.

On this regard it is to mention that recently published small case series, not included in the extracted articles, have reported new endovascular techniques for the ILO treatment with favorable outcomes. Mechanical thrombectomy using the Rotarex system (Becton, Dickinson and Company, Franklin Lakes) was reported by Chaudhuri *et al.*[61] and Simonte *et al.*[62] in a combined total of 29 patients, achieving 100% immediate technical success. Additional stenting or relining to correct the underlying cause of occlusion was required in 82.6%-100% of cases, with no distal embolization and two cases of reocclusion.

Mechanical thrombectomy with the AngioJet system (Boston Scientific, Marlborough, MA) was described by Han *et al.*[63] in 12 patients, with 100% technical success. Endograft relining was required in all cases, and no distal embolization occurred.

Thromboaspiration using the Indigo System (Penumbra, Alameda, CA) was reported by Spath *et al.*[64] in a multicenter series of 17 patients, with 94% technical success, adjunctive procedures in 88% of cases, one distal embolization, and no ILO recurrence.

Discussion

Although numerous studies have explored ILO following EVAR, a comprehensive synthesis of the contemporary

Table 4 – Follow-up, reinterventions, and results of treatment.

Study	Reinterventions	Open surgical Intervention				Hybrid procedure	Endovascular procedure		Results		
		Femorofemoral Crossover	Aorto-iliac	Axillo-femoral	Thrombectomy alone	Thrombectomy and Stenting	Thrombolysis alone	Thrombolysis and Stenting	Technical success	Death	Amputation
Abraham_2002	1	1									
Andersen_2019	11	5	1	3		2					
Ash_2020	3					3			3 (100%)	NR	NR
Basra_2023	NR										
Bastos Goncalves_2017	NR										
Benveniste_2020	7	4		1		2					
Bogdanovic_2021	NR										
Bonardelli_2022	16	11	1		2	2			13 (81.3%)	NR	NR
Bos_2009	1					1					
Broda_2022	23	7	1	1		4	3	7	20 (87.0%)	NR	1
Catanese_2020	6					1		5			
Conway_2012	31	25		3	3				26 (83.9%)	2	NR
Daoudal_2016	11	9	1			1					
De Athayde Soares_2024	9					9					
De Marino_2021	16	3	1			12					
Donas_2015	15	5	1		0	9					
Faure_2015	NR										
Fujimura_2024	4										
Hatzl_2024	24										
Isernia_2021	18	5		2		7		4			
Janho_2019	7	5						2			
Kapetanios_2019	3	1				2					
Maleux_2008	8	3		1		1		3	8 (100%)	NR	NR
Mantas_2015	18	14						4			
Marone_2024	NR										
Mertens_2010	8	4									
Midy_2020	14	5		2	7						
Moulakakis_2017	NR										
Nana_2023	9	2				7					
Oshin_2010	8	7				1					

Pini_2019	4		1					3			
Pini_2024	2	2									
Rodel_2018	27	3	5		5	14			20 (74.1%)	0	NR
Salemans_2021	4	2						2			
Shintani_2019	NR										
Silingardi_2020	1				1						
Sirignano_2017	0										
Sirignano_2019	12							12			
Sivamurthy_2006	11	4			2	3	1	1	10 (90.9%)	1	NR
Sobocinski_2015	NR										
Taudorf_2014	15	8		1		3		3			
Tigkiropoulos_2020	12	7				5					
Torsello_2019	0										
Troisi_2023	4	1				3					
Vacirca_2020	7	2	1					4	6 (85.7%)	0	NR
Van Gerwen_2024	11	4			2	5					
Van Zeggeren_2013	20	5		2	4	4	1	4	16 (80%)	3	NR
Wales_2008	NR										
Wang_2021	NR										
Yuan_2024	10	2			2	3	2	1			
Zavatta_2021	6	5				1					
Zeng_2024	16	2			4	9	1				
Total N	431	163	12	16	32	114	8	54			

evidence has remained elusive. The only previous meta-analysis on this topic was published more than 5 y ago,[65] and since then, several new studies have emerged.[3-6,8,10,17,19,21-23,26,27,29-31,33,34,36,39,40,43,44,48-52,54-59]

In the current endovascular era, ensuring long-term durability remains the ultimate goal of EVAR. Distal stent-graft failure, like proximal failure, should be regarded as a significant complication. Importantly, distal failure can present through two distinct mechanisms—type 1B endoleak and ILO—each leading to different clinical consequences.[13]

This scoping review comprehensively evaluated the incidence, risk factors, and prognosis of EVAR-related ILO. Most of the available data arise from studies with considerable heterogeneity in design, purpose, and outcome reporting. This variability, along with the relatively low overall incidence of ILO, precluded a formal pooled analysis. Despite these limitations, several key findings emerged.

1. Patients undergoing EVAR may face up to a 10% risk of developing ILO during follow-up, particularly when specific anatomical or procedural risk factors are present.
2. Many of these risk factors can be identified during preoperative planning and case selection, and can be managed intraoperatively to reduce ILO incidence.
3. Secondary interventions for ILO—whether open, hybrid, or endovascular—can often be performed successfully.

The most recent clinical practice guidelines on aorto-iliac aneurysm management[1] recommend using the first postoperative computed tomography angiography to stratify

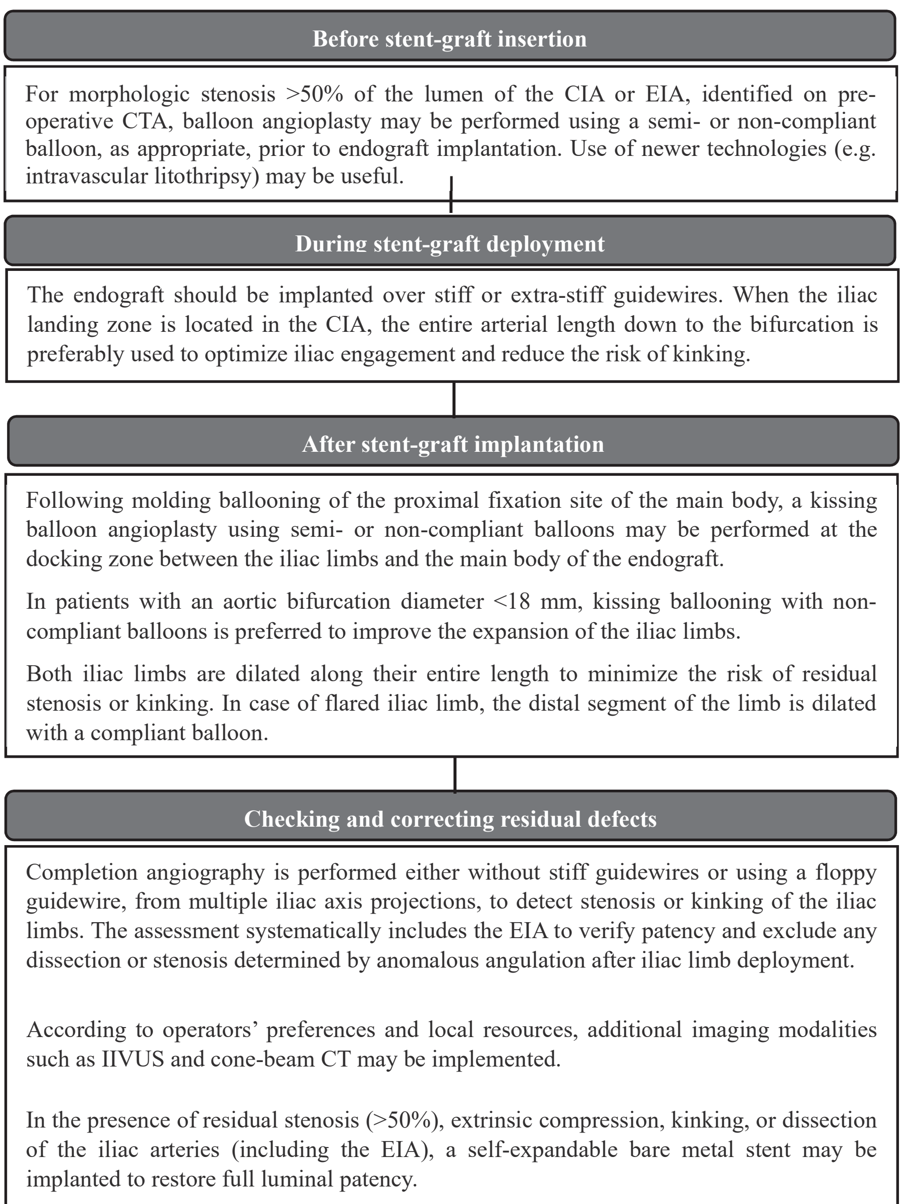

Fig. 2 – Proposed strategy for ILO prevention.

patients based on the risk of late complications, including those related to proximal and distal seal zones. Although much attention has historically focused on the proximal neck, recent efforts—including a Delphi consensus statement[66]—highlight the importance of the distal landing zone as well.

This review identified several distal risk factors associated with ILO, such as smaller iliac diameter, EIA landing zones, and certain stent-graft types. A predictive score proposed by Faure *et al.*[9]—including EIA diameter, kinking, and intraoperative correction—may help stratify patients into low-risk and high-risk categories. Those with high-risk features may benefit from intensified surveillance to catch early signs of failure before clinical deterioration occurs. Nevertheless, associations between individual risk factors and ILO varied across studies. This inconsistency suggests a complex interplay of factors rather than a single dominant cause. Future risk prediction models based on large datasets and artificial intelligence methods may help capture these interactions and improve prognostication. The variability in reported outcomes also underscores the lack of standardized prevention strategies. However, several recent reports suggest that aggressive intraoperative management—such as angioplasty and/or stenting of iliac stenoses >50%, kinks, or severe tortuosity—can reduce ILO rates. Incorporating standardized protocols (Fig. 2) for distal limb optimization into routine EVAR practice may help mitigate risk.

Multiple treatment strategies for ILO exist, including open, endovascular, and hybrid options. While direct comparisons of efficacy are limited, modern endovascular techniques—including totally percutaneous revascularization[62-64]—offer promising minimally invasive solutions. In the authors' experience, when open repair is indicated, hybrid approaches should be favored whenever feasible. These allow intraoperative identification and correction of the underlying culprit lesion after revascularization, potentially reducing the risk of recurrence. The growing availability of hybrid ORs may make this an increasingly common strategy in both elective and emergent settings. Unfortunately, most studies did not report treatment approaches based on the acute *versus* chronic nature of ILO presentation, limiting conclusions regarding optimal management pathways for different clinical scenarios.

The current lack of consensus likely reflects the inherent complexity of distal attachment zones in EVAR. Although more attention is now paid to iliac sealing zones,[13] a standardized lexicon and outcome framework are urgently needed to facilitate meaningful comparison across studies. In this regard, we propose a minimum set of reporting items for future ILO studies (Table 5). Notably, the current Society for Vascular Surgery reporting standards[67] do not provide specific definitions for ILO; hence, only broader definitions of technical and clinical success can be extrapolated to this complication. Our proposed items may help harmonize future studies and strengthen the evidence base.

Study limitations

This review has several limitations. Despite a comprehensive search, some relevant articles may have been missed. The included studies are heterogeneous in design, follow-up definitions, and outcome reporting. Due to this variability, a pooled meta-analysis was not feasible. In addition, many studies overlapped in time frames, making temporal trend analysis difficult. Finally, other potential contributors to ILO—such as adherence to antithrombotic therapy—were not consistently reported and warrant future investigation.

Table 5 – Suggested reporting items for studies reporting iliac limb occlusion (ILO).

Anatomic features	1 Aortic diameter (A; maximum diameter on a centerline view, B; minimum diameter at the aortic bifurcation). 2 Common and external iliac diameter (B; maximum diameter on a centerline view), length (C; measured with the centerline), and tortuosity (D; tortuosity index[28]: Actual length/straight length between two points on the centerline). 3 Presence of calcification >50% of iliac diameter. 4 Internal iliac artery patency.
Technical details	1 Type of endograft (brand, model). 2 Oversize (%) on iliac arteries. 3 Intraoperative adjuncts (e.g. angioplasty ± stenting of iliac component, common or external iliac artery; need for common femoral endarterectomy; device closure failure …). 4 Landing in external iliac artery.
Follow-up	1 Follow-up duration and imaging modalities used. 2 Timing of type ILO occurrence (intra-operative; at first follow-up imaging; late). 3 Clinical presentation.
Reintervention	1 Open conversion (aorto-femoral/femoro-femoral crossover/axillo-femoral bypass) *versus* endovascular (surgical thrombectomy/CTD or other endovascular technique ± stenting/relining). 2 Timing: elective or urgent, planned or unplanned. 3 Technical success and clinical success (as per SVS reporting standards).[29]

SVS = Society for Vascular Surgery.

Conclusions

ILO is among the most frequent modes of EVAR failure, with a reported incidence from 0 to 11%. Anatomical and procedural factors—including iliac tortuosity, small vessel diameter, EIA landing zones, stent-graft oversizing, and device type—play a key role in ILO risk. Intraoperative strategies aimed at correcting these factors may reduce complications. Although most ILO cases can be successfully managed using endovascular or hybrid techniques, further research is needed to refine prevention, optimize long-term outcomes, and standardize reporting practices.

Supplementary Materials

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jss.2025.10.030.

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