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Review Article

Deep Vein Thrombosis After Anterior Lumbar Interbody Fusion: A Systematic Review and Preventive Strategies

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Abstract

Background: Anterior Lumbar Interbody Fusion (ALIF) is a widely used surgical technique for degenerative lumbar disease, pseudoarthrosis and sagittal imbalance. Although effective, ALIF requires mobilization of major vascular structures, which may increase the risk of Deep Vein Thrombosis (DVT). However, the true incidence and risk factors for thromboembolic events after ALIF remain poorly defined in the literature.

Objective: To present a representative case of postoperative DVT following ALIF and to conduct a systematic review and meta-analysis evaluating the prevalence, associated risk factors and preventive strategies for DVT in patients undergoing ALIF.

Methods: We included a report of 2 cases who developed iliac vein thrombosis after ALIF and performed a systematic review of clinical studies reporting on DVT following ALIF. Searches were conducted in PubMed, Embase and Cochrane Library up to August 2025. Studies were selected according to PRISMA 2020 criteria. Data were extracted on patient characteristics, surgical levels, prophylaxis regimens, DVT incidence and outcomes. Meta-analysis was performed using a random-effects model and publication bias was assessed using Egger's test and funnel plot analysis

Results: A total of 34 studies were included, encompassing 383,496 patients undergoing ALIF. The pooled prevalence of DVT was 0.9%. Despite the low incidence, substantial heterogeneity was observed and funnel plot analysis revealed asymmetry, suggesting a high risk of publication bias. Key factors associated with increased DVT risk included multilevel fusions, L4-L5 level surgeries, intraoperative transfusions, advanced age, intraoperative vein injury and prior VTE history. Preventive strategies reported included mechanical prophylaxis, delayed pharmacologic anticoagulation, routine mobilization and selective use of Tranexamic Acid (TXA).

Conclusion: DVT following ALIF is uncommon but potentially serious. The risk is influenced by surgical complexity and patient-specific factors. This review underscores the importance of tailored thromboprophylaxis, incorporating mechanical and pharmacologic strategies, especially in high-risk individuals.

Keywords: Anterior Lumbar Interbody Fusion (ALIF); Deep Vein Thrombosis (DVT); Tranexamic Acid (TXA)

Abbreviations

ALIF: Anterior Lumbar Interbody Fusion; CI: Confidence Interval; DVT: Deep Vein Thrombosis; LMWH: Low Molecular Weight Heparin; NOS: Newcastle-Ottawa Scale; PE: Pulmonary Embolism; PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses; SCH: Subcutaneous Heparin; TXA: Tranexamic Acid; VTE: Venous Thromboembolism

Introduction

Deep Vein Thrombosis (DVT) and Pulmonary Embolism (PE), collectively known as Venous Thromboembolism (VTE), represent critical postoperative complications associated with significant morbidity and mortality. Although the reported incidence of

symptomatic DVT in spinal surgery ranges from 0.3% to 2.5% depending on the procedure and patient population, the actual burden may be underestimated due to subclinical presentations and heterogeneity in diagnostic approaches. In untreated cases, PE is fatal in approximately 20% to 30% of patients, emphasizing the importance of prevention and early recognition [1-6]. Anterior Lumbar Interbody Fusion (ALIF), a well-established approach for degenerative lumbar disease, pseudoarthrosis and sagittal imbalance, is associated with specific anatomical and surgical challenges that may increase the risk of DVT [7]. The technique requires retraction and mobilization of the iliac vessels, which can lead to venous stasis, endothelial trauma and local inflammation-elements central to the pathophysiology of thrombus formation, known as Virchow's triad. Additional factors such as operative time, number of levels fused, patient immobility and intraoperative transfusion may further contribute to the prothrombotic state [7,8]. Despite these theoretical risks, the literature on DVT and PE specifically after ALIF remains limited. In a recent retrospective cohort study of 179 ALIF patients, Albdewi, et al., observed two thromboembolic events (1.71%)-one DVT and one PE—both occurring in patients who had not received perioperative prophylaxis with Subcutaneous Heparin (SCH) [9]. Interestingly, SCH nor TXA was associated with a statistically significant increase in vascular complications, suggesting potential safety and utility in selected patients. Given the clinical importance of VTE and the lack of ALIF-specific guidelines for risk stratification and prophylaxis, we aimed to present a representative case and conduct a systematic review of the literature to identify risk factors and summarize evidence-based strategies to prevent DVT following ALIF procedures.

Methodology

Clinical Review

Case 1

We report the case of a 46-year-old female patient who underwent ALIF at the L4-L5 and L5-S1 levels for treatment of degenerative disc disease and spondylolisthesis. The patient presented with refractory low back pain and right-sided sciatica, following the L5 and S1 nerve root distribution. Imaging studies revealed right L4-L5 foraminal stenosis and a right posterolateral disc herniation at L5-S1 (Fig. 1). The procedure was performed through a left-sided retroperitoneal approach by a multidisciplinary team, including vascular surgery (Fig. 2). The patient did not use intermittent pneumatic compression during surgery or in the postoperative period but received pharmacological prophylaxis with LMWH according to hospital protocol. On postoperative day 3, the patient developed symptoms consistent with left leg swelling and pain. Doppler ultrasound confirmed the presence of DVT in the left iliac vein. The patient started anticoagulation and was discharged from the hospital on postoperative day 10.

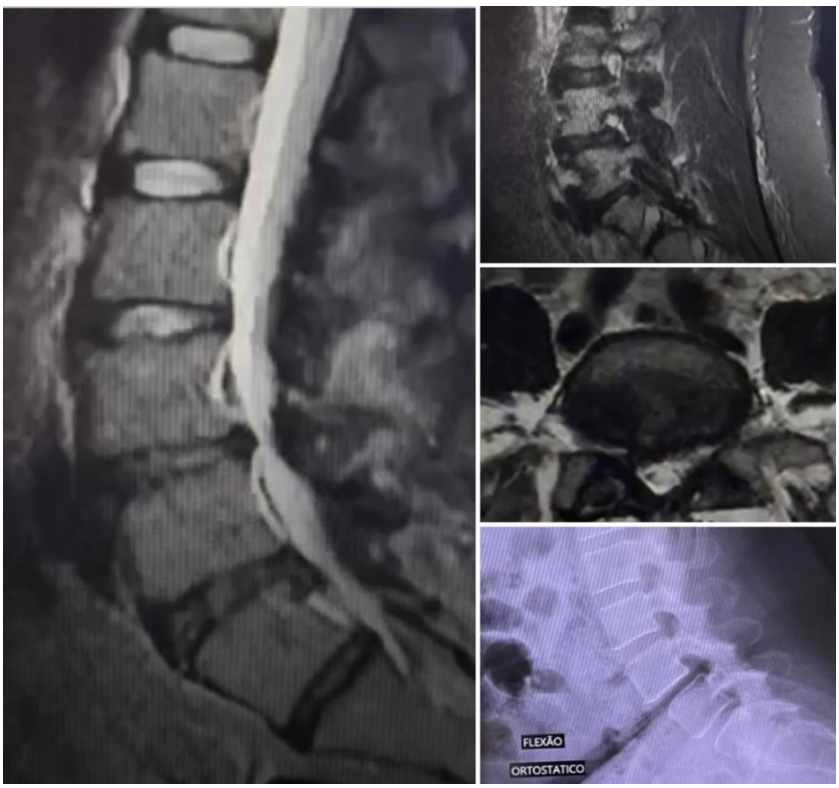

Figure 1: Preoperative images. Right L4-L5 foraminal stenosis and a right posterolateral disc herniation at L5-S1.

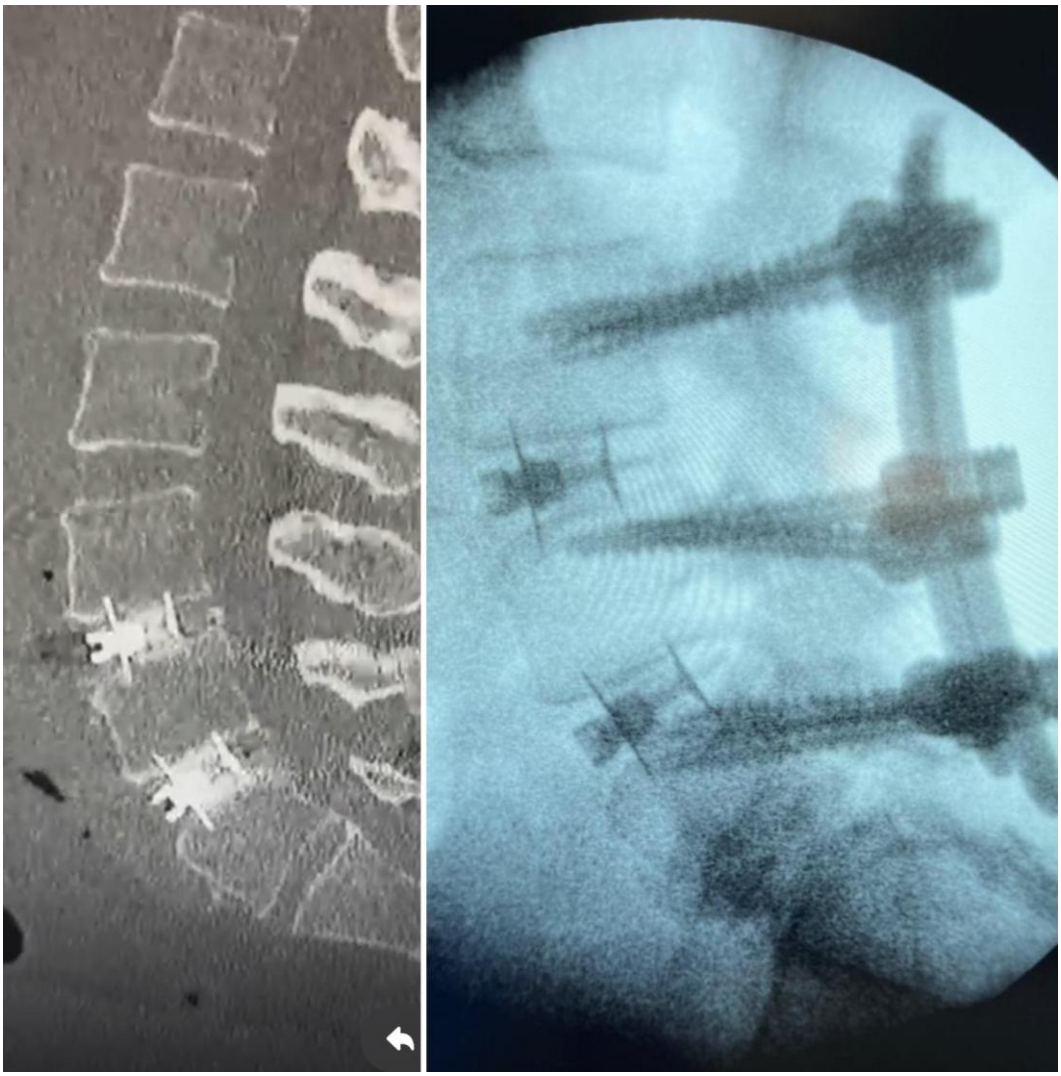

Figure 2: Postoperative images. L4-5, L5-S1 ALIF.

Case 2

A 53-year-old woman presented with a two-year history of bilateral lumbosciatalgia. Examination showed left L5-S1 radiculopathy with a positive Lasègue test and right L5 involvement, along with sagittal imbalance and lumbar straightening. MRI revealed severe L4-S1 degenerative disc disease with nerve root compression. Given the severity of symptoms, she underwent a two-level stand-alone ALIF with placement of two 12-mm cages. She received pharmacological prophylaxis with SCH. Postoperatively, she experienced complete pain relief, with only mild iliac crest discomfort from bone graft harvesting. On postoperative day 12, she developed a left internal iliac vein DVT, diagnosed due to severe leg pain and swelling (Fig. 3). Venous angiography demonstrated a complete occlusion of the vein. It was treated successfully with venous stent placement by a vascular surgeon (Fig. 4).

Figure 3: Left common iliac vein thrombosis after 2 level stand alone ALIF.

Figure 4: The vein occlusion was successfully treated with stenting.

Systematic Review

Protocol and Objectives

This systematic review was conducted in accordance with the PRISMA 2020 guidelines. The primary objective was to evaluate the incidence, risk factors and prevention strategies for DVT in patients undergoing ALIF.

Eligibility Criteria

We included clinical studies (prospective or retrospective), case series and cohort analyses that reported on DVT, PE or VTE following ALIF surgery. Studies were included regardless of language, as long as an English abstract was available. Exclusion criteria included cadaveric studies, biomechanical-only analyses and articles not reporting thromboembolic outcomes.

Search Strategy

A comprehensive search was performed in PubMed/MEDLINE, Embase and Cochrane Library for studies published between January 2000 and August 2025. The following search terms were used: ("anterior lumbar interbody fusion" OR "ALIF") AND ("deep vein thrombosis" OR "venous thromboembolism" OR "pulmonary embolism" OR "DVT" OR "PE"). The complete search strategy, including all database queries and search terms used for PubMed, Embase and Cochrane Library, is available in the Supplementary Material.

Data Extraction and Analysis

Two independent reviewers screened titles and abstracts, followed by a full-text review. The following data were extracted: number of patients, incidence of DVT/PE, prophylactic regimen used (mechanical, pharmacological), risk factors and outcomes. Risk of bias was assessed using the Newcastle-Ottawa Scale for cohort studies.

Results

A total of 229 articles were identified through database searches (PubMed, Embase and Cochrane Library). After removing 71 duplicates and screening 158 titles and abstracts, 64 full-text articles were assessed for eligibility. Thirty-four studies met the inclusion criteria and were included in the final systematic review and meta-analysis (Fig. 5).

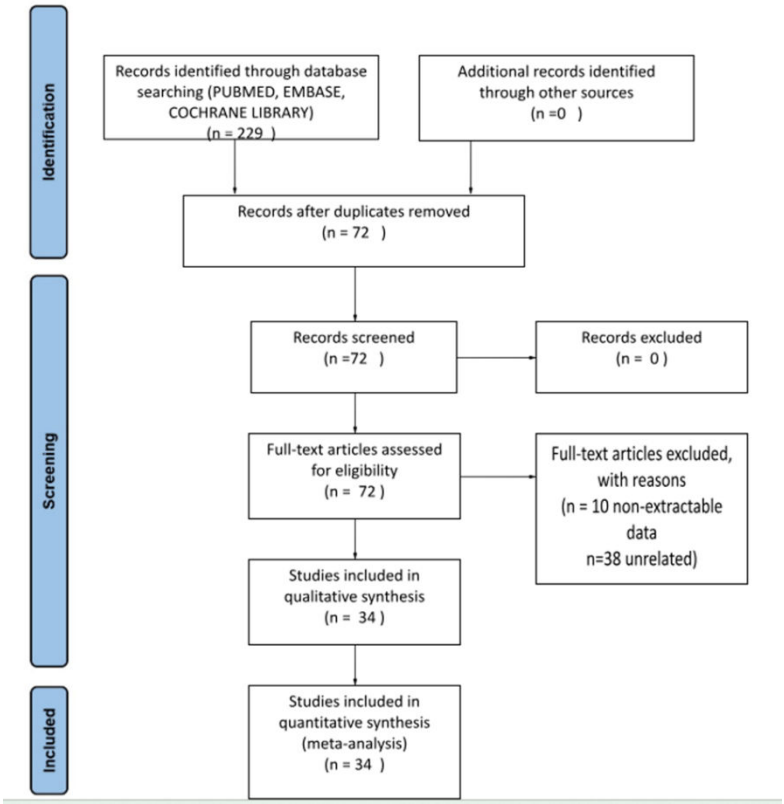

Figure 5: PRISMA flow diagram.

The 34 included studies reported data from a combined total of 383,496 patients who underwent Anterior Lumbar Interbody Fusion (ALIF) procedures. Among these, there were 2287 cases of Deep Vein Thrombosis (DVT). The studies were conducted across various countries, including the United States (24 studies), China (3), Japan (2), South Korea (2), Australia (1), Brazil (1) and Canada (1).

Among the 34 included studies, 13 were based on large administrative databases or national registries, such as the National Inpatient Sample (NIS) or similar sources. These studies generally relied on ICD and CPT codes to define surgical procedures (e.g., ALIF) and outcomes (e.g., DVT, PE). All included studies were assessed for methodological quality using the Newcastle-Ottawa Scale (NOS). The overall quality was acceptable, with a mean NOS score of 7 out of 9, indicating generally low risk of bias across the domains of selection, comparability and outcome assessment.

The publication years ranged from 2005 to 2025. Most studies were retrospective cohort designs. The most common levels operated included L5-S1, L4-L5 or both, with some involving multilevel fusions including L3-L4. Thromboprophylaxis regimens varied: some employed mechanical methods only (e.g., compression stockings), while others included pharmacological agents such as low molecular weight heparin or subcutaneous heparin and a few used Tranexamic Acid (TXA) intraoperatively. Routine versus symptom-triggered Doppler screening also varied. The complete list of the 34 references used for the incidence calculation and meta-analysis is provided in the supplementary material at the end of the article. Meta-analysis using a random-effects model revealed an estimated pooled DVT prevalence of 0.9% (95% Confidence Interval: 0.7% to 1.2%) following ALIF surgery. $I^2 = 92\%$, indicating moderate heterogeneity [S1-34].

Twenty out of the thirty-four studies reported a deep vein thrombosis incidence of less than 1%, though a few smaller series or those using routine Doppler screening identified higher rates. The observed heterogeneity likely reflects variability in diagnostic intensity, prophylaxis protocols and surgical complexity. The forest plot (Fig. 6) demonstrates that while most individual study estimates cluster between 0.3% and 1.5%, a few studies report notably higher or lower rates. The pooled prevalence estimate is centered at 0.9%, represented by the diamond at the bottom of the forest plot.

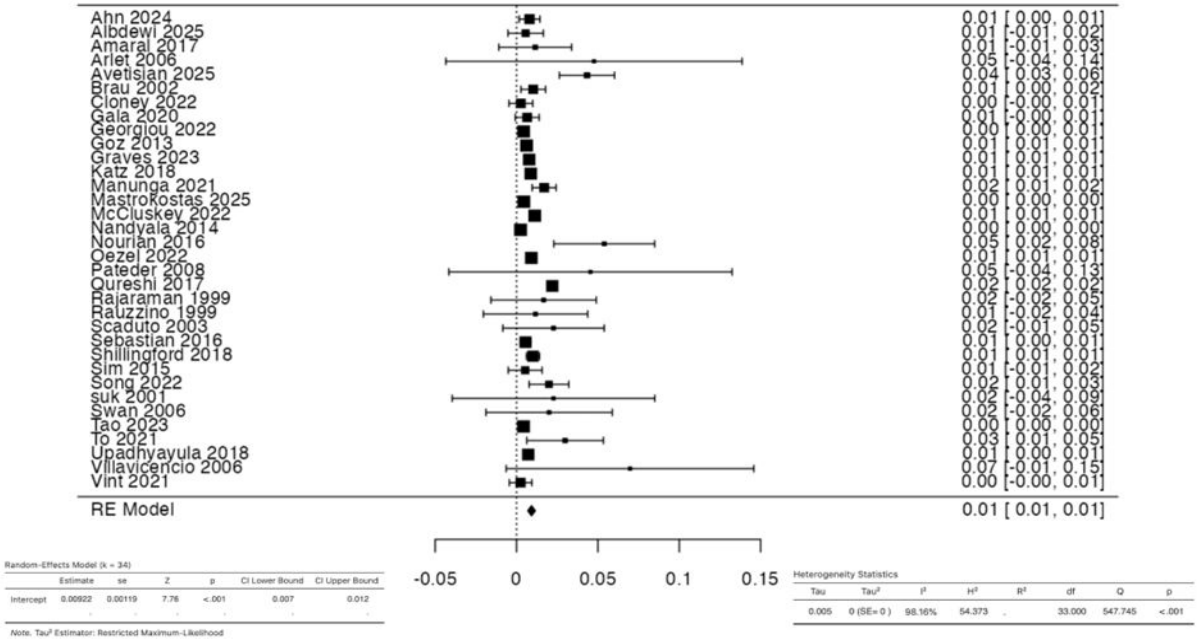

Figure 6: Forest plot - pooled prevalence of 0,9% DVT in ALIF surgeries.

Larger studies tended to report lower DVT rates (e.g., administrative database analyses from the U.S.), possibly due to under-diagnosis in the absence of routine screening. In contrast, smaller series using routine Doppler identified more asymptomatic cases. Visual inspection of the funnel plot reveals asymmetry (Fig. 7), with smaller studies tending to report higher DVT prevalence rates. This suggests potential small-study effects or publication bias, where studies with low or null DVT incidence may remain unpublished.

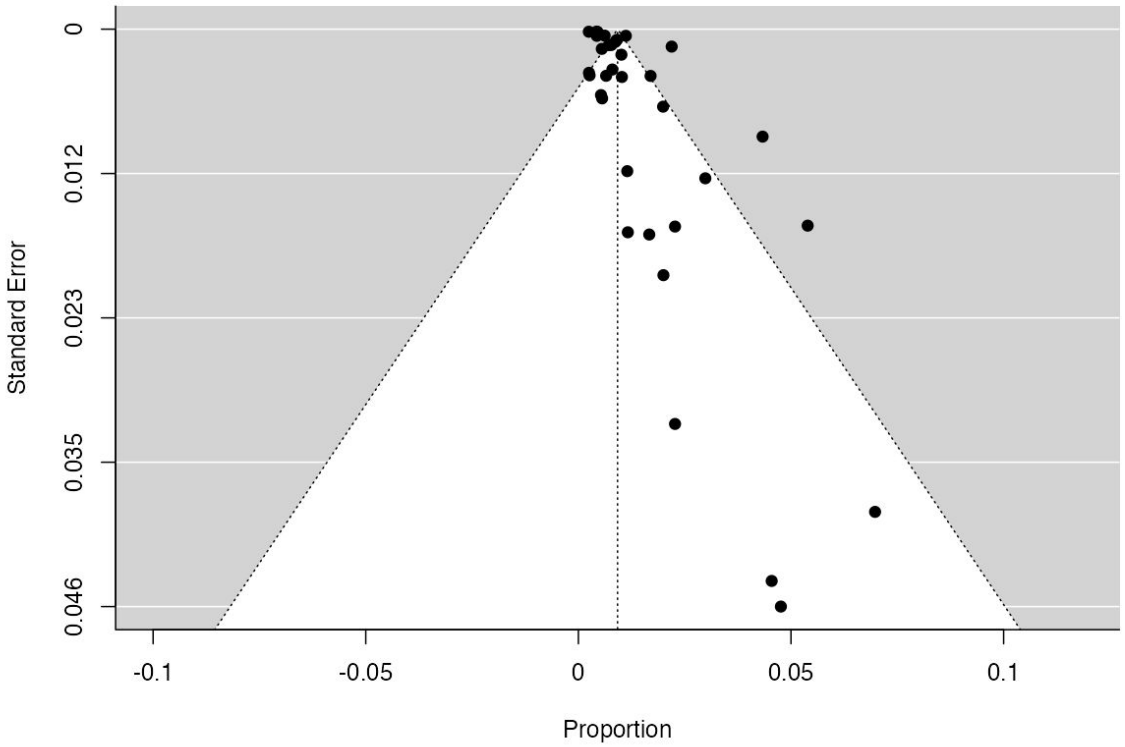

Figure 7: Publication bias analysis - Egger's regression test ($p < 0.001$).

Discussion

Deep vein thrombosis is a potentially life-threatening postoperative complication, especially when it progresses to pulmonary embolism. Although Venous Thromboembolism (VTE) is relatively uncommon after spine surgery, it is a major cause of in-hospital morbidity and mortality and can result in serious clinical consequences when it occurs. Orthopedic procedures are consistently ranked among the highest-risk surgeries for VTE, due to a combination of surgical trauma, tissue manipulation and postoperative immobility. In spinal disorders, pre-existing pain and neurological deficits often impair ambulation, leading to prolonged recumbency and venous stasis, a core component of Virchow's triad. This physiological predisposition, when compounded by surgical insult, may amplify thrombotic risk despite prophylactic measures [1,6,10,11].

An ongoing challenge in anterior spine surgery is the balance between preventing thrombosis and minimizing hemorrhagic complications. This dilemma has gained further complexity with the widespread adoption of Tranexamic Acid (TXA), an antifibrinolytic agent shown to reduce perioperative bleeding and transfusion rates. While TXA is generally considered safe, its mechanism—by inhibiting plasminogen activation and clot degradation has raised theoretical concerns about potentiating thrombotic risk, especially in patients with pre-existing prothrombotic conditions. Although most studies included in this review did not report an increased incidence of DVT associated with TXA use, the available evidence is limited and further prospective research is warranted to determine its safety profile in high-risk subgroups undergoing ALIF [9,12].

This review highlights the multifactorial nature of VTE risk in ALIF procedures and identifies key preventive measures supported by the current literature. The data retrieved from Albdewi, et al., offer an important contribution to the field by directly comparing patients undergoing ALIF with and without prophylactic regimens involving TXA or SCH [9]. Their findings demonstrate that TXA was associated with reduced transfusion rates (0% vs. 20.5% in the control group, $p = 0.034$) without a clear increase in thrombotic events or vascular complications. Moreover, all patients in the TXA group were discharged directly home, suggesting better overall recovery profiles [9]. In terms of absolute thrombotic risk, the incidence of DVT or PE in ALIF appears to remain low (≤2%) in the available literature [1,7,13,14]. When systematic screening for thrombosis is performed, reported rates increase to over 15%, highlighting the likelihood that many cases remain subclinical and go undetected in the absence of overt clinical manifestations4. However, several patient-specific and procedural risk factors must be considered when

planning prophylaxis. These include [2-4,10,15-17]:

Risk factors for VTE in ALIF

- Prior history of VTE or thrombophilia: Strongly associated with increased recurrence risk
- Advanced age and reduced preoperative mobility: Common predictors of venous stasis
- Multilevel fusion procedures: Associated with increased surgical duration and retraction, both of which may elevate DVT risk
- L4-5 level surgeries: Anatomically associated with more complex vascular mobilization than L5-S1, potentially increasing risk
- Intraoperative transfusions: A known risk factor for VTE in spinal and general surgery populations
- Obesity and female sex: Variably associated with increased risk, but less robustly in ALIF-specific data
- Intraoperative venous injury: Clearly associated with an increased risk of thrombosis, likely due to direct manipulation and compression of the vein, as well as the hemostatic strategies employed to control bleeding [18]

Preventive strategies should be tailored to individual risk profiles. In low-risk patients, mechanical prophylaxis with early mobilization may suffice. In moderate- to high-risk cases, postoperative pharmacologic prophylaxis (e.g., LMWH or SCH) is advised, ideally initiated 12-24 hours after surgery to minimize bleeding risks [3,4,12,19]. The use of intraoperative TXA, as suggested by Albdewi, et al., may reduce transfusion requirements without increasing the DVT risk [9]. However, its safety profile in hypercoagulable patients remains to be confirmed in larger, prospective trials.

A recent systematic review evaluated the efficacy of combining Intermittent Pneumatic Compression (IPC) with pharmacologic prophylaxis versus each modality alone for the prevention of venous thromboembolism in surgical patients. The review demonstrated that the combination of IPC and anticoagulation significantly reduced the risk of both Deep Vein Thrombosis (DVT) and Pulmonary Embolism (PE) compared to mechanical prophylaxis alone. When compared to pharmacologic prophylaxis alone, the addition of IPC also resulted in a meaningful reduction in DVT incidence (odds ratio ~0.38), with consistent benefits observed across both orthopedic and non-orthopedic surgical populations. However, the combination strategy was associated with a modest increase in bleeding events, including major bleeding, although the certainty of evidence for bleeding outcomes was rated as very low due to imprecision and heterogeneity across studies. Given the higher thromboembolic risk associated with Anterior Lumbar Interbody Fusion (ALIF) compared with other spine procedures, these findings provide a strong rationale for adopting a multimodal prophylaxis strategy. Integrating mechanical and pharmacologic measures may offer more effective protection against venous thromboembolism in high-risk patients. However, the increased potential for bleeding complications highlights the need for careful patient selection and individualized risk stratification when determining the optimal prophylactic regimen [20].

We propose a risk-adapted algorithm that includes preoperative risk assessment, meticulous vascular handling, intraoperative mechanical prophylaxis, early ambulation and consideration of extended-duration anticoagulation in selected patients. Importantly, routine postoperative screening with duplex ultrasonography is not recommended in asymptomatic patients, but may be justified in those with multiple risk factors or suggestive clinical signs.

Limitations of the study

This study is limited by the paucity of ALIF-specific data, the retrospective design of most included studies and heterogeneity in prophylaxis protocols and diagnostic thresholds. Future prospective multicenter studies are needed to clarify the optimal prophylactic regimen in ALIF and quantify the individual contribution of each risk factor to thrombotic outcomes.

Conclusion

DVT is an infrequent but clinically relevant complication following ALIF, with a pooled prevalence of 0.9% across more than 380,000 patients. Risk is influenced by patient-related and procedural factors, including multilevel surgery, L4-L5 involvement, venous manipulation, prolonged operative time and intraoperative transfusion. Although preventive strategies vary, the combined use of mechanical prophylaxis, early mobilization and delayed pharmacologic anticoagulation appears effective in mitigating risk. The observed publication bias and heterogeneity highlight the need for prospective, standardized studies to better define optimal prophylaxis protocols in ALIF.

Conflict of Interests

The authors declare that there is no conflict of interest related to this study.

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Supplementary Information

Search Strategy

PUBMED 31/09/2025 - 128 results

("ALIF"[All Fields] OR (("anterior"[All Fields] OR "anteriores"[All Fields] OR "anteriorization"[All Fields] OR "anteriorized"[All Fields] OR "anteriors"[All Fields]) AND ("lumbarised"[All Fields] OR "lumbarization"[All Fields] OR "lumbarized"[All Fields] OR "lumbars"[All Fields] OR "lumbosacral region"[MeSH Terms] OR ("lumbosacral"[All Fields] AND "region"[All Fields]) OR "lumbosacral region"[All Fields] OR "lumbar"[All Fields]) AND ("fusion"[All Fields] OR "fusions"[All Fields]))) AND ("DVT"[All Fields] OR "TVE"[All Fields] OR ("thrombose"[All Fields] OR "thrombosing"[All Fields] OR "thrombosis"[MeSH Terms] OR "thrombosis"[All Fields] OR "thrombosed"[All Fields] OR "thromboses"[All Fields]))

EMBASE 31/09/2025 - 72 results

'lumbar interbody fusion'/exp AND ('anterior lumbar interbody fusion'/exp OR 'alif (anterior lumbar interbody fusion)' OR 'anterior lumbar interbody fusion') AND ('deep vein thrombosis'/exp OR 'dvt (deep vein thrombosis)' OR 'acute dvt' OR 'acute deep venous thrombosis' OR 'deep thrombo-phlebitis' OR 'deep thrombophlebitis' OR 'deep vein blood clots' OR 'deep vein thrombophlebitis' OR 'deep vein thrombosis' OR 'deep vein thrombus' OR 'deep venous thrombophlebitis' OR 'deep venous thrombosis' OR 'deep venous thrombus' OR 'recurrent dvt' OR 'thrombosis, acute deep venous')

COCHRANE LIBRARY 31/09/2025 - 29 results

´Lumbar´ AND ´anterior´ AND ´thrombosis´

Study ID	Type	n	DVT (n)	NOS (up to 9)
Ahn 2024	Retro	751	6	9
Albdewi 2025	Retro	179	1	9
Amaral 2017	Retro	87	1	9
Arlet 2006	Retro	21	1	8
Avetisian 2025	Retro	554	24	9
Brau 2002	Retro	684	7	9
Cloney 2022	Database	189	16	8
Gala 2020	Retro	460	3	8
Georgiou 2022	Database	14971	65	7
Goz 2013	Database	22688	140	7
Graves 2023	Database	4768	37	7
Katz 2018	Database	8273	72	7
Manunga 2021	Retro	1178	20	7
Mastrokostas 2025	Database	92800	416	7
McCluskey 2022	Database	38529	430	7
Nandyala 2014	Database	57185	140	7
Nourian 2016	Retro	204	11	7
Oezel 2022	Database	12336	112	7
Pateder 2008	Retro	22	1	7
Qureshi 2017	Database	10895	239	7
Rajaraman 1999	Retro	60	1	8
Rauzzino 1999	Retro	42	0	7
Scaduto 2003	Retro	88	2	7
Sebastian 2016	Retro	2179	12	7
Shillingford 2018	Database	2372	24	7
Sim 2015	Retro	188	1	7

Song 2022	Retro	502	10	8
suk 2001	Retro	21	0	6
Swan 2006	Retro	50	1	6
Tao 2023	Retro	106451	454	7
Tho 2021	Database	201	6	6
Upadhyayula 2018	Database	4325	31	7
Villavicencio 2006	Retro	43	3	7
Vint 2021	Retro	200	0	7
TOTAL		383496	2287	**7**

Main Table: Studies, n and New Castle Ottawa (NOS).

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