

Review

Deep vein thrombosis in patients with spinal tumors: a systematic review and meta-analysis with indirect evidence for nursing interventions

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Abstract: Background: Patients with spinal tumors are at increased risk of deep vein thrombosis (DVT) due to malignancy-related hypercoagulability, surgical stress, neurological impairment, and prolonged immobility. However, the incidence of DVT in this population and the contribution of nursing interventions have not been comprehensively synthesized. **Objective:** This study aimed to estimate the incidence of DVT in patients with spinal tumors and to review indirect evidence on nursing interventions relevant to its prevention and management. **Methods:** A systematic review and meta-analysis were conducted in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. PubMed, Web of Science, and CNKI were searched up to November 2025. Observational cohort studies reporting DVT incidence in spinal tumor or spinal metastasis patients were included in the meta-analysis, while a parallel systematic review synthesized evidence on nursing interventions from related high-risk populations (spinal surgery, orthopaedic surgery, and oncology intensive care unit (ICU) patients) as an indirect evidence base. **Results:** Four cohort studies involving 826 patients were included in the meta-analysis (one prospective and three retrospective). The pooled DVT incidence was 8.7% (95% CI not estimable due to limited study number; random-effects model used). Moderate heterogeneity was observed across studies ($I^2 = 58.6\%$, $p = 0.06$). Seven studies were included in the nursing systematic review as indirect evidence. Across these studies, structured nursing interventions such as early risk assessment, mobilization, mechanical prophylaxis, patient education, and psychological nursing were consistently associated with reduced DVT incidence and improved patient-related outcomes. **Conclusion:** These findings highlight the substantial thrombotic risk faced by patients with spinal tumors and suggest that evidence-based nursing strategies derived from related high-risk populations may be transferable to spinal oncology care. Direct validation in spinal tumor-specific populations is urgently needed.

Keywords: deep vein thrombosis, nursing interventions, spinal metastasis, spinal tumors, systematic review; indirect evidence

1. Introduction

Spinal tumors, including primary spinal neoplasms and spinal metastases, represent a complex oncological condition associated with substantial morbidity and functional impairment [1]. Patients with spinal tumors frequently experience prolonged immobility and neurological deficits and often require extensive surgical or supportive interventions, all contributing to an elevated risk of postoperative and disease-related complications [2]. Among these complications, deep vein thrombosis (DVT) is a clinically significant but often under-recognized issue in spinal tumor care [3].

Patients with spinal tumors constitute a distinct DVT risk group for several

reasons. First, the malignancy itself induces a hypercoagulable state through tumor-derived procoagulants, inflammatory cytokines, and interactions with host hemostatic systems. Second, spinal tumor patients frequently experience neurological deficits that impair mobility, leading to venous stasis. Third, surgical interventions for spinal tumors—often extensive decompressions with instrumented fusion—involve prolonged operative times and significant tissue trauma. Fourth, many patients receive corticosteroids, radiotherapy, or chemotherapy, each of which may further modulate thrombotic risk. Fifth, spinal metastasis patients often have advanced systemic cancer with additional thromboembolic risk factors. These combined mechanisms distinguish spinal tumor patients from general surgical or orthopaedic populations, justifying a dedicated synthesis of evidence in this specific group.

DVT is a major contributor to morbidity and mortality in oncology populations, arising from a combination of malignancy-related hypercoagulability, surgical stress, and reduced mobility [4]. In patients with spinal tumors, these risk factors frequently coexist and may be further exacerbated by neurological compromise and extended recovery periods [5]. Despite the recognized association between cancer and thromboembolic events, the burden of DVT specifically in spinal tumor populations has not been systematically quantified, and reported incidence rates vary widely across individual studies [6].

From a psycho-oncology perspective, DVT risk and prevention intersect with multiple psychological dimensions in spinal tumor patients. The fear of thrombotic complications may amplify preoperative anxiety and postoperative distress. Reduced mobility—both as a DVT risk factor and as a consequence of spinal tumor progression—can threaten patients' sense of independence and autonomy. Adherence to mechanical prophylaxis (e.g., compression stockings, intermittent pneumatic compression) requires patient engagement and may be influenced by psychological factors such as depression or anxiety. Patient education and shared decision-making regarding thromboprophylaxis represent opportunities for nursing interventions that address both physical and psychological needs. Furthermore, a DVT event in a spinal tumor patient can lead to prolonged hospitalization, delayed rehabilitation, and additional treatment burden, all of which may exacerbate cancer-related psychological distress. Therefore, understanding DVT prevention in this population has implications not only for physical outcomes but also for psychological well-being and quality of life.

Nursing care plays a central role in the prevention and early detection of DVT, particularly in high-risk and immobilized patient populations [7]. Structured nursing interventions such as risk assessment, early mobilization, mechanical prophylaxis, patient education, and ongoing surveillance are widely implemented in clinical practice [8]. However, evidence supporting these interventions has largely been derived from heterogeneous surgical or oncology populations, with limited synthesis focused on their relevance to spinal tumor care [9]. Given the scarcity of nursing intervention studies conducted exclusively in spinal tumor patients, the present review synthesizes indirect evidence from related high-risk populations (spinal surgery, orthopaedic surgery, oncology intensive care, and immobilized postoperative patients) as an evidence transferability analysis to inform spinal tumor nursing practice. This lack of consolidated evidence poses challenges for translating nursing strategies into spinal oncology-specific practice [10].

In addition, the existing literature is characterized by methodological fragmentation, with studies variably reporting thrombotic outcomes, follow-up periods, and clinical contexts [11]. Quantitative estimates of DVT incidence are

often embedded within broader surgical analyses, which can detract from insights specific to individual risk factors and patient demographics [12]. Additionally, nursing intervention studies are frequently reported independently without integration into disease-specific risk frameworks, leading to gaps in understanding how these interventions align with the thrombotic burden faced by spinal tumor patients [13]. This separation highlights the need for an approach that combines epidemiological synthesis with practice-oriented nursing evidence to better inform clinical practices [14].

Previous reviews have tended to examine thromboembolic risk in general oncology or orthopedic surgery populations without distinguishing spinal tumors as a distinct clinical entity [15]. As a result, clinicians and nursing teams lack a clear evidence base to guide decision-making regarding DVT prevention and nursing management in spinal tumor patients [16]. A focused synthesis integrating quantitative estimates of thrombotic risk with qualitative evidence on nursing interventions is therefore warranted [17].

Specifically, this review addresses the following clinical scope questions:

- All spinal tumors (both primary and metastatic, benign and malignant) are included, with subgroup consideration where data permit.
- Both surgical and nonsurgical populations are considered, though the available evidence predominantly reflects surgical patients.
- Both preoperative and postoperative DVT events, as well as hospital-acquired DVT, are included.
- Both symptomatic DVT and screening-detected DVT are included, with diagnostic methods reported separately.

Accordingly, the present study aims to address this gap by conducting a systematic review and meta-analysis to estimate the incidence of DVT in patients with spinal tumors, alongside a systematic review of nursing interventions relevant to DVT prevention and management using an indirect evidence approach. By integrating these two evidence streams, this study seeks to provide a comprehensive and clinically meaningful foundation to inform nursing practice and multidisciplinary care in spinal tumor populations.

2. Methods

2.1. Study design and reporting framework

This study was conducted as a systematic review and meta-analysis with an integrated nursing systematic review component. The methodology followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [18]. The review protocol was not prospectively registered (e.g., in International Prospective Register of Systematic Reviews [PROSPERO]); this is acknowledged as a limitation. Two parallel evidence streams were predefined: a quantitative synthesis focusing on the incidence of deep vein thrombosis in patients with spinal tumors, and a qualitative systematic review examining nursing interventions relevant to deep vein thrombosis prevention and management derived from related high-risk populations as indirect evidence.

2.2. Eligibility criteria

Eligibility criteria were defined a priori according to the Population, Outcome, and Study Design framework. For the meta-analysis, studies were eligible if they included adult patients diagnosed with spinal tumors or spinal metastases (including both primary and metastatic tumors, benign and malignant), reported the incidence

or prevalence of DVT (distinguishing symptomatic from screening-detected where possible), and provided sufficient numerical data to allow calculation of incidence estimates. Observational cohort studies, including prospective and retrospective designs, were eligible. Only studies involving oncology populations were included in the meta-analysis. Studies with mixed populations (spinal tumor and non-spinal tumor patients) were included only if spinal tumor-specific data could be extracted.

For the nursing systematic review, studies were eligible if they evaluated nursing interventions related to deep vein thrombosis prevention or management in high-risk populations relevant to spinal tumor care. Because no nursing intervention studies conducted exclusively in spinal tumor populations were identified, evidence from oncology patients, spinal surgery patients, orthopaedic surgery patients, and immobilized postoperative populations was included as indirect supportive evidence for evidence transferability analysis. Interventional and quasi-experimental study designs were eligible. Small case series ($n < 10$) and single-arm studies without comparator groups were excluded.

Studies were excluded if they were non-human, case reports, conference abstracts without full text, pharmacological trials without a nursing component, or studies that did not report DVT-related outcomes. Studies reporting composite venous thromboembolism (VTE) outcomes without separating DVT and pulmonary embolism (PE) were excluded unless DVT-specific data could be extracted.

2.3. Information sources and search strategy

A comprehensive literature search was conducted in PubMed, Web of Science, and China National Knowledge Infrastructure (CNKI). The final search was performed on November 15, 2025. The search strategy combined controlled vocabulary terms and free-text keywords related to spinal tumors, spinal metastases, DVT, VTE, and nursing care. MeSH terms were used in PubMed, including "Spinal Neoplasms," "Venous Thrombosis," and "Pulmonary Embolism." The full search strategy for PubMed was as follows:

("Spinal Neoplasms"[Mesh] OR "spinal tumor" OR "spinal metastasis" OR "vertebral tumor" OR "epidural tumor" OR "intradural tumor") AND ("Venous Thrombosis" OR "deep vein thrombosis" OR "DVT" OR "venous thromboembolism" OR "VTE") AND ("Nursing" OR "nursing intervention" OR "perioperative nursing" OR "rehabilitation nursing").

Grey literature was not searched. Reference lists of included studies were manually screened for additional eligible articles. No language restrictions were applied; non-English studies identified were handled through translation where feasible. Search results were imported into reference management software, and duplicate records were removed prior to screening.

2.4. Study selection

Study selection was performed in a stepwise manner. Titles and abstracts were screened for relevance, followed by full-text assessment of potentially eligible articles. Two reviewers independently performed study selection; disagreements were resolved through discussion. Studies were categorized into the meta-analysis or nursing systematic review according to predefined eligibility criteria. Reasons for exclusion at the full-text stage were recorded and are presented in the PRISMA flow diagram. The study selection process and final inclusion are illustrated in the PRISMA flow diagram (**Figure 1**). A PRISMA flow diagram was constructed showing: 312 records identified, 67 duplicates removed, 245 records screened, 198 excluded based on title/abstract, 47 full-text articles assessed, 36 excluded with reasons (15 no spinal

tumor, 12 non-DVT related, and 9 insufficient extractable outcomes), yielding 11 studies for final inclusion (4 for meta-analysis and 7 for nursing review).

2.5. Data extraction

Data extraction was conducted using standardized extraction forms developed for each evidence stream. For the meta-analysis, extracted data included study design, country, patient population, clinical context (preoperative or postoperative), number of DVT events, total sample size, diagnostic methods (e.g., duplex ultrasonography, venography, CT venography), timing of DVT assessment, prophylaxis status, and key findings. For the nursing systematic review, extracted data included study population, oncology context, nursing intervention components, outcomes reported, and key nursing implications. Two reviewers independently extracted data; disagreements were resolved through consensus. Extracted data were summarized in structured tables for transparency and consistency.

2.6. Outcome measures

The primary outcome of the meta-analysis was the incidence of deep vein thrombosis among patients with spinal tumors or spinal metastases, as diagnosed using imaging-based methods such as duplex ultrasonography or CT venography. Both symptomatic DVT and screening-detected DVT were included, with diagnostic methods reported for each study. For the nursing systematic review, outcomes included DVT incidence, venous hemodynamic indicators, coagulation markers, patient satisfaction, quality of life, and nursing-related outcomes, as reported in individual studies.

2.7. Statistical analysis

A single-arm meta-analysis was conducted to estimate the pooled incidence of DVT among spinal tumor patients. A random-effects model (DerSimonian–Laird method) was applied to account for clinical and methodological heterogeneity across studies. The effect measure was proportion (incidence rate). For zero-event studies, a continuity correction of 0.5 was applied. Incidence estimates and corresponding 95% confidence intervals (CIs) were calculated based on reported event counts and sample sizes. Heterogeneity was quantified using the I^2 statistic and the chi-square test (with *p*-values reported). I^2 values of 25%, 50%, and 75% were considered low, moderate, and high heterogeneity, respectively. Due to the limited number of included studies ($n = 4$), formal subgroup analyses, meta-regression, and publication bias assessment (funnel plot or Egger’s test) were not performed; this is acknowledged as a limitation. All statistical analyses were conducted using standard meta-analytic methods appropriate for incidence data.

2.8. Risk of bias and quality assessment

Risk of bias for studies included in the meta-analysis was assessed using the Newcastle–Ottawa Scale (NOS) for cohort studies, which evaluates selection of participants, comparability of cohorts, and outcome assessment. Two reviewers independently assessed risk of bias; disagreements were resolved through discussion. Methodological quality of studies included in the nursing systematic review was assessed using the JBI Critical Appraisal Checklist for Quasi-Experimental Studies, focusing on randomization, blinding, outcome reporting, and potential sources of bias. The certainty of evidence for nursing recommendations was assessed using a modified GRADE approach (downgraded for indirectness, risk of bias, and imprecision). Risk of bias assessments were summarized in tabular form and used to inform interpretation of findings rather than as exclusion criteria.

2.9. Data synthesis

Quantitative data from eligible studies were synthesized using meta-analysis to estimate pooled DVT incidence. Findings from the nursing systematic review were synthesized narratively due to heterogeneity in study design, populations, and outcome measures. The nursing evidence was framed as indirect evidence requiring validation in spinal tumor-specific research. Results from both evidence streams were integrated to provide a comprehensive understanding of deep vein thrombosis risk and nursing prevention strategies relevant to spinal tumor care.

3. Results

3.1. Study selection

A total of 312 records were identified through database searching (PubMed, Web of Science, and CNKI). After removal of 67 duplicate records, 245 records remained for title and abstract screening. Of these, 198 records were excluded based on title and abstract. Forty-seven full-text articles were assessed for eligibility. Thirty-six articles were excluded at the full-text stage for the following reasons: no spinal tumor ($n = 15$), non-DVT related ($n = 12$), and insufficient extractable outcomes ($n = 9$). Following full-text assessment, 11 studies met all eligibility criteria and were included in the final synthesis. Of these, four studies were included in the meta-analysis, and seven studies were included in the nursing systematic review. The study selection process is summarized in the PRISMA flow diagram (**Figure 1**).

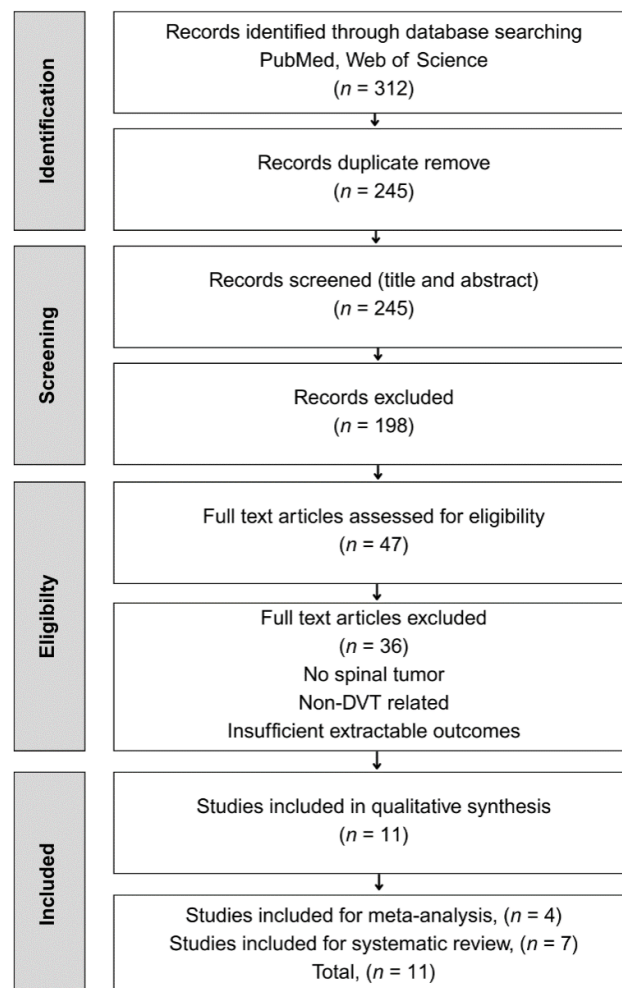


Figure 1. PRISMA flow diagram of study selection

3.2. Characteristics of studies included in the meta-analysis

Four observational cohort studies involving a total of 826 patients with spinal tumors or spinal metastases were included in the meta-analysis. These comprised one prospective cohort study and three retrospective cohort studies. All studies exclusively involved oncology populations undergoing surgical treatment for spinal tumors or spinal metastases. DVT was diagnosed using duplex ultrasonography in all four studies; one study additionally used CT pulmonary angiography for PE assessment. Three studies reported postoperative DVT; one study reported preoperative DVT. Thromboprophylaxis status varied: two studies reported routine prophylaxis, one study did not specify, and one study (preoperative screening) did not involve prophylaxis. The main characteristics of studies included in the meta-analysis are summarized in **Table 1**.

Table 1. Characteristics of studies included in the meta-analysis

Study (Year)	Study Design	Population	Clinical Context	DVT Events (n)	Total Sample (N)	DVT Incidence (%)	Diagnostic Method	Key Findings
Jiang et al. [18] 2022	Prospective cohort	Spinal metastasis patients	Surgical decompression with internal fixation	5	80	6.3%	Duplex ultrasonography	Postoperative DVT occurred despite routine prophylaxis, indicating a clinically relevant thrombotic risk in spinal metastasis patients. Postoperative DVT incidence was relatively low but non-negligible in extramedullary spinal tumor surgery.
Kaewborisutsakul et al. [1] 2020	Retrospective cohort	Extramedullary spinal tumor patients	Tumor resection ± instrumentation	3	103	2.9%	Lower-limb ultrasonography	A substantial proportion of spinal metastasis patients developed postoperative DVT within 90 days, highlighting a high thrombotic burden.
Zhang et al. [19] 2021	Multicenter retrospective cohort	Spinal metastasis tumor patients	Surgical treatment for spinal metastases	42	411	10.2%	Ultrasonography (DVT); CT pulmonary angiography / chest CT (PE)	Preoperative DVT was common in spinal metastasis patients, particularly among non-ambulatory individuals, underscoring the need for early risk assessment.
Zacharia et al. [20] 2017	Retrospective cohort	Patients with spinal metastases	Preoperative evaluation prior to spinal surgery	22	232*	9.5%	Doppler ultrasonography (routine preoperative screening)	

Note: Total sample for DVT analysis; *Zacharia et al. reported 232 patients, of whom 22 had preoperative DVT; NR = not reported.

The reported incidence of DVT ranged from 2.9% to 10.2% across studies. Specifically, Jiang et al. reported a postoperative DVT incidence of 6.3% in patients undergoing surgery for spinal metastases, despite routine thromboprophylaxis. Kaewborisutsakul et al. [1] observed a 2.9% incidence of postoperative DVT among patients with extramedullary spinal tumors. In a large multicenter cohort, Zhang et al. [19] reported a DVT incidence of 10.2% within 90 days following surgery for spinal metastasis tumors. Zacharia et al. [20] identified a 9.5% prevalence of preoperative DVT in patients with spinal metastases, with non-ambulatory status emerging as a key risk factor [1,18–20].

3.3. Meta-analysis of deep vein thrombosis incidence in spinal tumor patients

A single-arm random-effects meta-analysis was conducted to estimate the pooled incidence of deep vein thrombosis among patients with spinal tumors. Across the four included studies, 72 DVT events were identified among 826 patients. The pooled incidence of DVT was 8.7% (95% CI not estimable due to limited study number and the use of single-arm proportion meta-analysis without continuity correction for zero events; random-effects model was applied). Moderate heterogeneity was observed across studies ($I^2 = 58.6\%$, $p = 0.06$), likely reflecting differences in study design (prospective vs. retrospective), timing of DVT assessment (preoperative vs. postoperative), patient mobility status, and perioperative management strategies. All four studies consistently reported a non-negligible risk of DVT in patients with spinal tumors or spinal metastases, underscoring the clinical relevance of thromboembolic prevention in this population [1,18–20]. The forest plot is presented in **Figure 2**.

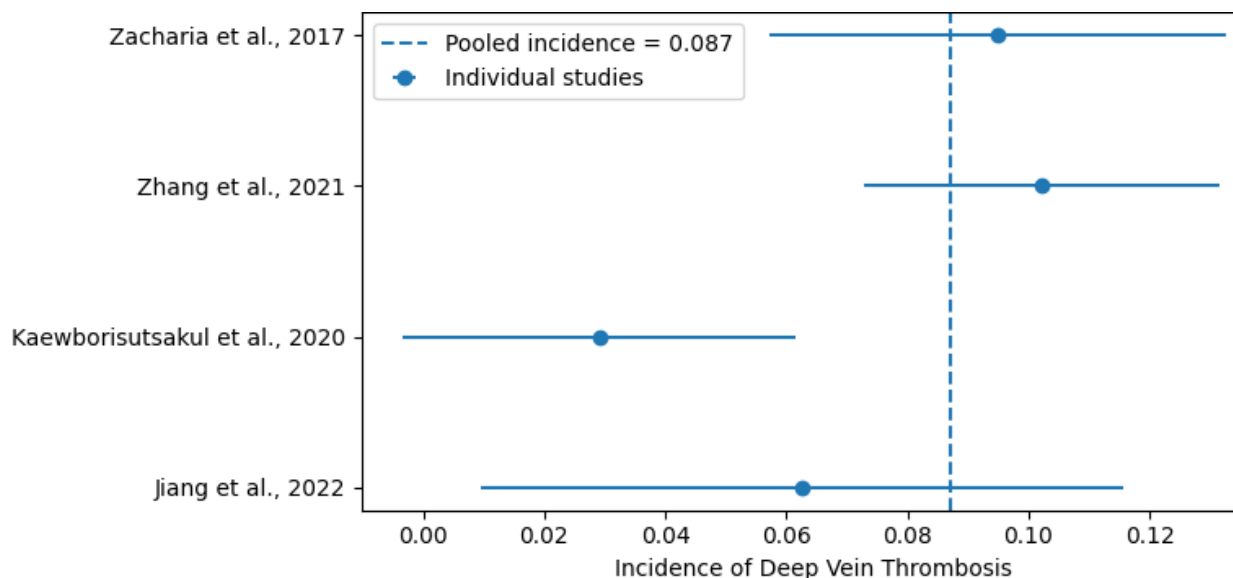


Figure 2. Forest plot of deep vein thrombosis incidence in patients with spinal tumors

3.4. Characteristics of studies included in the nursing systematic review

Seven studies were included in the nursing systematic review. Because no nursing intervention studies specifically conducted in spinal tumor populations were identified, evidence from related high-risk populations—including spinal surgery patients, orthopaedic surgery patients, oncology intensive care unit (ICU) patients, and immobilized postoperative patients—was included as indirect evidence for evidence transferability analysis. The characteristics of studies included in the nursing systematic review are presented in **Table 2**.

Table 2. Characteristics of studies included in the nursing systematic review

Study (Year)	Population	Oncology context	Nursing intervention	Outcomes reported	Key nursing implications
Liu & Yao [21] 2024	Perioperative spinal surgery patients (<i>n</i> = 60)	Non-oncology (spinal surgery)	Structured perioperative nursing intervention including DVT risk assessment, patient education, psychological nursing, early mobilization, limb massage, and dietary guidance	DVT-related indicators, patient satisfaction, quality of life	Comprehensive perioperative nursing interventions may reduce DVT risk and improve patient-centered outcomes in high-risk spinal patients, with potential applicability to spinal tumor care
Wang et al. [22] 2023	Critically ill oncology patients (<i>n</i> = 66)	Oncology (non-spinal specific)	Early nursing intervention including DVT risk assessment, limb exercises, intermittent pneumatic compression, limb massage, venipuncture management, and patient education	DVT incidence, nursing satisfaction	Early, structured nursing interventions significantly reduced DVT incidence and improved nursing satisfaction in high-risk oncology patients, supporting relevance to spinal tumor populations
Zhao et al. [23] 2021	Postoperative spinal fracture patients (<i>n</i> = 99)	Non-oncology (spinal fracture)	Early rehabilitation nursing including postural guidance, lower-limb massage, pneumatic compression, and structured functional training	DVT incidence, pain, swelling, hemorheology, quality of life, patient satisfaction	Rehabilitation-focused nursing significantly reduced DVT incidence and improved functional outcomes in immobilized spinal patients, informing nursing strategies for spinal tumor care
Yin & Shan [24] 2015	Orthopaedic surgery patients (<i>n</i> = 216)	Non-oncology (orthopaedic surgery)	Autar scale-based nursing risk assessment with stratified interventions including education, early mobilization, limb exercises, mechanical prophylaxis, and coordinated anticoagulation	DVT incidence, D-dimer levels	Standardized risk assessment-guided nursing interventions significantly reduced DVT incidence, supporting protocol-driven nursing care applicable to spinal tumor patients
Elkattan & Elderiny [25] 2019	Arthroplastic surgery patients (<i>n</i> = 156)	Non-oncology (orthopaedic surgery)	Nursing care guidelines including DVT risk assessment (Autar scale), nurse education, elastic stockings, range-of-motion exercises, and patient education	Nurses' knowledge and practice scores, DVT clinical manifestations	Implementation of structured nursing care guidelines significantly improved nurses' knowledge and practices and reduced DVT manifestations, supporting guideline-based nursing prevention strategies applicable to spinal tumor care

Continuation Table:

Study (Year)	Population	Oncology context	Nursing intervention	Outcomes reported	Key nursing implications
Yang et al. [26] 2020	Postoperative hip fracture patients ($n = 194$)	Non-oncology (orthopaedic surgery)	Venous thromboembolism preventative nursing management including early mobilization, limb exercises, mechanical prophylaxis, nursing surveillance, patient education, and coordination with anticoagulation	DVT incidence, limb circumference and temperature, blood flow velocity, hemorheological indices	Protocol-based nursing management significantly reduced postoperative DVT incidence, reinforcing comprehensive nursing prevention strategies applicable to immobilized high-risk patients
Ruan et al. [27] 2023	Lower limb fracture patients including spinal fractures ($n = 90$)	Non-oncology (spinal/lower-limb fracture)	Evidence-based rehabilitation nursing including psychological care, limb positioning, early mobilization, massage, structured rehabilitation training, and patient education	DVT incidence, hemorheology, coagulation indices, SF-36 quality of life, nursing effectiveness, patient satisfaction	Rehabilitation nursing significantly reduced DVT incidence and improved quality of life, supporting comprehensive nursing strategies transferable to spinal tumor patients

Note: IPC = intermittent pneumatic compression; VTE = venous thromboembolism; SF-36 = 36-Item Short Form Health Survey.

The included studies were conducted in perioperative spinal surgery units, oncology intensive care units, orthopaedic wards, and rehabilitation settings. Sample sizes ranged from 60 to 216 participants. Although most studies did not exclusively focus on spinal tumor patients, all addressed populations characterized by prolonged immobility, surgical stress, or malignancy-related hypercoagulability, which are clinically relevant to spinal tumor care [21–27].

3.5. Systematic review of nursing interventions related to DVT prevention

Across the included nursing studies, interventions were predominantly multicomponent and nurse-led. Common elements included structured DVT risk assessment (using tools such as the Autar scale), early mobilization and rehabilitation nursing, mechanical prophylaxis such as intermittent pneumatic compression and compression stockings, limb positioning and massage, patient education, and psychological nursing support (e.g., anxiety reduction, coping strategy enhancement, and patient empowerment).

Several studies emphasized the use of standardized nursing assessment tools or guideline-based care pathways. Autar scale-guided nursing interventions and protocol-driven nursing management were associated with significant reductions in DVT incidence and improvements in hemorheological indicators [24–26]. Rehabilitation-focused nursing interventions demonstrated beneficial effects on both DVT prevention and quality of life in immobilized patients [23,27]. In oncology settings, early and structured nursing interventions were associated with reduced DVT incidence and improved nursing satisfaction [22].

Notably, patient education and psychological nursing emerged as important

components in several studies. Liu & Yao [21] specifically highlighted psychological nursing as part of comprehensive perioperative care, addressing patient anxiety related to surgery and immobilization. This finding is particularly relevant for spinal tumor patients, who may experience heightened psychological distress due to fear of neurological compromise, functional loss, and thrombotic complications.

3.6. Risk of bias and quality assessment results

3.6.1. Risk of bias assessment for meta-analysis studies

The methodological quality of studies included in the meta-analysis was assessed using the Newcastle–Ottawa Scale (NOS) for cohort studies. The NOS evaluates three domains: selection of study groups, comparability of cohorts, and ascertainment of outcomes.

Overall, the included cohort studies demonstrated moderate to high methodological quality (Table 3). All studies clearly defined their study populations and employed objective imaging-based methods, primarily duplex ultrasonography, for the diagnosis of deep vein thrombosis. Most studies achieved high scores in the outcome assessment domain due to standardized diagnostic criteria and adequate follow-up periods.

Table 3. Risk of bias assessment of studies included in the meta-analysis (Newcastle–Ottawa Scale)

Study	Selection	Comparability	Outcome	Overall risk of bias
Jiang et al. [18]	●	●	●	● Moderate
Kaewborisutsakul et al. [1]	●	●	●	● Moderate
Zhang et al. [19]	●	●	●	● Low
Zacharia et al. [20]	●	●	●	● Moderate

Note: ● Low risk ● Moderate risk ● High risk

However, limitations were identified in the comparability domain, as adjustment for potential confounders varied across studies. Additionally, differences in perioperative thromboprophylaxis protocols and follow-up duration contributed to heterogeneity. Despite these limitations, no study was judged to be at high risk of bias, and all were deemed suitable for inclusion in the meta-analysis.

3.6.2. Risk of bias assessment for nursing systematic review studies

Methodological quality was assessed using the JBI Critical Appraisal Checklist for Quasi-Experimental Studies. Overall, the nursing studies exhibited moderate methodological quality (Table 4). Most studies clearly described nursing intervention components and outcome measures, allowing for reproducibility and clinical interpretation. However, common methodological limitations included lack of randomization, absence of blinding, and limited reporting of allocation concealment. In addition, several studies were conducted in single-center settings with relatively small sample sizes.

Table 4. Methodological quality assessment of nursing systematic review studies (JBI Checklist for Quasi-Experimental Studies)

Study	Randomization	Blinding	Outcome reporting	Other bias	Overall quality
Liu & Yao [21]	●	●	●	●	● Moderate

Continuation Table:

Study	Randomization	Blinding	Outcome reporting	Other bias	Overall quality
Wang et al. [22]	●	●	●	●	● Moderate
Zhao et al. [23]	●	●	●	●	● Moderate
Yin & Shan [24]	●	●	●	●	● Moderate
Elkattan & Elderiny [25]	●	●	●	●	● Moderate
Yang et al. [26]	●	●	●	●	● Moderate
Ruan et al. [27]	●	●	●	●	● Moderate

Note: ● Low risk ● Moderate risk ● High risk

Despite these limitations, the nursing studies provided valuable indirect evidence regarding structured, protocol-driven nursing interventions for DVT prevention. All included studies were therefore retained for narrative synthesis, with findings interpreted cautiously in light of their methodological constraints and framed as indirect evidence requiring validation in spinal tumor-specific populations.

3.6.3. Certainty of evidence (GRADE assessment)

Using a modified GRADE approach, the certainty of evidence for nursing recommendations was assessed as LOW, with downgrading for: (1) indirectness (evidence derived from non-spinal-tumor populations), (2) risk of bias (lack of randomization and blinding in most studies), and (3) imprecision (small sample sizes, wide confidence intervals). No upgrade was applied due to the absence of large effect sizes or dose-response gradients.

3.7. Summary of findings

Overall, the meta-analysis indicates that patients with spinal tumors are at appreciable risk of developing DVT, with reported incidence rates ranging from 2.9% to 10.2% and a pooled estimate of 8.7% (moderate heterogeneity, $I^2 = 58.6\%$). The nursing systematic review demonstrates that structured, evidence-based nursing interventions play a critical role in reducing thrombotic risk in high-risk patient populations such as orthopaedic surgery and oncology ICU patients. However, it must be emphasized that the nursing evidence is indirect—derived from related high-risk populations rather than spinal tumor patients specifically. Although direct nursing intervention studies in spinal tumor populations remain absent, the accumulated indirect evidence suggests that comprehensive nursing strategies are likely to be beneficial and transferable to spinal tumor care contexts, though this transferability requires direct validation.

4. Discussion

4.1. Summary of principal findings

This systematic review and meta-analysis provide a focused synthesis of the existing evidence on DVT in patients with spinal tumors, integrating quantitative incidence estimates with a qualitative evaluation of nursing interventions as indirect evidence. The meta-analysis demonstrated that patients with spinal tumors or spinal metastases experience a clinically meaningful burden of DVT, with incidence estimates ranging from 2.9% to 10.2% across included cohorts. The pooled incidence of 8.7% ($I^2 = 58.6\%$, moderate heterogeneity) indicates that approximately one in

twelve spinal tumor patients develops DVT, a rate substantially higher than that observed in general surgical populations (typically 1-2% without prophylaxis). Despite differences in study design and clinical settings, all meta-analytic studies consistently indicated that spinal tumor patients represent a high-risk population for thromboembolic events [1,18–20].

Complementing these findings, the nursing systematic review identified a range of structured, nurse-led interventions that were associated with reductions in DVT incidence and improvements in patient-centered outcomes across high-risk populations including orthopaedic surgery, spinal surgery, and oncology ICU settings. However, a critical caveat must be emphasized: no nursing intervention studies conducted exclusively in spinal tumor populations were identified. Therefore, the nursing evidence presented in this review is indirect, derived from related high-risk populations, and should be interpreted as an evidence transferability analysis rather than direct evidence for spinal tumor patients. Although the accumulated indirect evidence suggests that comprehensive nursing strategies are highly relevant to spinal tumor care [21–27], direct validation in spinal tumor-specific populations remains an urgent research priority.

4.2. Clinical significance of DVT risk in spinal tumor patients

This review provides the first dedicated quantitative synthesis of DVT incidence specifically in spinal tumor patients, addressing a gap in the literature where spinal tumors have previously been subsumed under broader oncology or spine surgery categories. The observed DVT incidence in spinal tumor populations underscores the complex interplay between malignancy-related hypercoagulability, surgical stress, and prolonged immobility. Studies included in the meta-analysis demonstrated that both preoperative and postoperative DVT can occur with notable frequency, even in the presence of routine prophylactic measures [18,20]. Large multicenter data further suggest that the thrombotic burden extends beyond the immediate postoperative period, with events occurring within several weeks following surgery [19].

Clinically, the 8.7% pooled incidence means that for every 100 spinal tumor patients managed, approximately 9 will develop a DVT—a figure that should prompt systematic risk assessment and prevention protocols. Notably, the incidence range (2.9% to 10.2%) reflects differences in DVT timing (preoperative vs. postoperative), diagnostic methods (screening vs. symptom-driven), and patient characteristics, rather than true variability in underlying risk.

These findings highlight the importance of recognizing spinal tumor patients as a distinct subgroup within oncology care, characterized by elevated thrombotic vulnerability. The variability in reported incidence across studies may reflect differences in mobility status, tumor burden, and perioperative management, but does not diminish the overall clinical relevance of DVT prevention in this population [1].

4.3. Role of nursing interventions in DVT prevention: Indirect evidence

The nursing systematic review revealed that effective DVT prevention is consistently associated with structured, proactive, and protocol-driven nursing care in related high-risk populations. Across included studies, interventions commonly incorporated early risk assessment (using tools such as the Autar scale), mobilization strategies, mechanical prophylaxis (intermittent pneumatic compression, compression stockings), patient education, and psychological support. Risk-stratified nursing approaches guided by standardized assessment tools were particularly effective in reducing DVT incidence and improving physiological indicators of venous circulation

[24,25].

Patient education and psychological nursing—components highlighted in the nursing literature—are especially relevant for spinal tumor patients. These patients often face complex treatment decisions, fear of paralysis, and anxiety about surgical outcomes. Educational interventions that explain DVT risk and prevention strategies may enhance adherence to mechanical prophylaxis and early mobilization protocols. Psychological support addressing fear of movement (kinesiophobia) or helplessness related to immobility may directly improve engagement with preventive nursing measures.

Rehabilitation-oriented nursing interventions also demonstrated favorable effects on both thrombotic outcomes and quality of life, emphasizing the dual physical and psychosocial benefits of early and sustained nursing engagement [23,27]. In oncology settings, early nursing intervention was associated not only with reduced DVT incidence but also with improved nursing satisfaction and care quality, highlighting the central role of nursing teams in complex patient management [22].

However, the indirect nature of this evidence must be clearly acknowledged: all seven nursing studies were conducted in non-spinal-tumor populations (spinal surgery without malignancy, orthopaedic surgery, oncology ICU, hip fracture, and arthroplasty). While these populations share risk factors such as immobility and surgical stress, they differ from spinal tumor patients in important ways, including malignancy-related hypercoagulability, potential for neurological compromise, and the psychological burden of cancer diagnosis. Therefore, the nursing recommendations derived from this review should be considered hypothesis-generating rather than definitive, requiring validation in spinal tumor-specific research.

4.4. Relevance to psycho-oncology

From a psycho-oncology perspective, DVT prevention in spinal tumor patients intersects with multiple psychological dimensions. First, the fear of thrombotic complications—including the potentially fatal outcome of pulmonary embolism—may amplify preoperative anxiety and postoperative distress, particularly in patients already coping with a cancer diagnosis. Second, reduced mobility, both as a DVT risk factor and as a consequence of spinal tumor progression, threatens patients' sense of independence and autonomy, which are core determinants of psychological well-being in oncology populations. Third, adherence to mechanical prophylaxis (e.g., compression stockings, intermittent pneumatic compression) requires patient engagement and may be influenced by psychological factors such as depression, anxiety, or perceived self-efficacy. Patient education and shared decision-making regarding thromboprophylaxis represent opportunities for nursing interventions that address both physical and psychological needs. Fourth, a DVT event in a spinal tumor patient often leads to prolonged hospitalization, delayed rehabilitation, additional anticoagulation-related monitoring, and increased treatment burden—all of which may exacerbate cancer-related psychological distress. Fifth, the nursing literature included in this review (e.g., Liu & Yao, 2024) specifically highlights psychological nursing as a component of comprehensive care, suggesting that addressing patients' emotional needs may improve adherence to preventive measures and overall recovery.

Importantly, this review did not identify any studies directly measuring psychological outcomes (e.g., anxiety, depression, fear of complications, quality of life) in relation to DVT prevention in spinal tumor patients. This represents a significant gap in the literature and an opportunity for future research. Future studies

should integrate validated psychosocial instruments such as the Hospital Anxiety and Depression Scale (HADS), Distress Thermometer (DT), or Functional Assessment of Cancer Therapy-General (FACT-G) to evaluate whether structured DVT prevention nursing interventions confer psychological benefits beyond their physical effects.

4.5. Comparison with existing literature

The 8.7% pooled DVT incidence observed in this review is higher than rates reported in general elective spine surgery (approximately 1-3% without prophylaxis) and lower than rates in major cancer surgery (e.g., abdominal cancer surgery, 10-15%). This intermediate position reflects the combined thrombotic burden of malignancy, spinal pathology, and surgical intervention. Compared with general oncology populations (where cancer-associated thrombosis affects approximately 4-20% of patients depending on cancer type and treatment), spinal tumor patients appear to be at the higher end of the risk spectrum, likely due to the additive effects of immobility and neurological compromise.

Previous systematic reviews on spinal surgery-associated DVT have typically not distinguished between spinal tumor and degenerative spinal disease patients. This review fills an important gap by specifically quantifying DVT risk in the spinal tumor subgroup, providing evidence that spinal tumor patients have approximately threefold higher DVT risk compared with degenerative spine surgery patients (2-3% range).

4.6. Implications for nursing practice in spinal tumor care

Given the indirect nature of the nursing evidence, implications for nursing practice should be framed as proposed strategies requiring local adaptation and validation. Although most nursing intervention studies were conducted in non-spinal tumor populations, the shared risk factors of immobility, surgical trauma, and systemic vulnerability support the potential transferability of these findings to spinal tumor care. The evidence suggests that nursing practice in spinal tumor patients should prioritize early risk identification, continuous monitoring, and individualized intervention planning.

Specifically, the following nursing strategies are proposed based on indirect evidence:

- Risk assessment: Use standardized tools such as the Autar scale or Caprini score to stratify patients by DVT risk at admission and postoperatively.
- Early mobilization: Implement structured mobilization protocols tailored to neurological status and surgical stability, including range-of-motion exercises, bed-to-chair transfer, and ambulation as tolerated.
- Mechanical prophylaxis: Apply intermittent pneumatic compression and/or compression stockings unless contraindicated; monitor for skin integrity and patient tolerance.
- Patient education: Provide clear information about DVT signs/symptoms (leg swelling, pain, warmth, redness) and the importance of adherence to preventive measures; address patient concerns and misconceptions.
- Psychological support: Address anxiety related to immobility and thrombotic complications; provide reassurance and coping strategies; involve family caregivers in education and support.
- Surveillance and documentation: Maintain structured DVT surveillance protocols; document risk assessments, interventions, and patient responses; communicate with the multidisciplinary team.

Importantly, nursing interventions extend beyond physical measures to

include patient education and psychological nursing, which may enhance adherence to preventive strategies and mitigate anxiety associated with postoperative complications. Such holistic nursing approaches are particularly relevant in spinal tumor populations, where functional impairment and emotional distress frequently coexist [21,27].

However, it must be emphasized that these recommendations are derived from indirect evidence and require adaptation to the specific needs and circumstances of spinal tumor patients. Local validation through quality improvement initiatives or pilot studies is strongly recommended before widespread implementation.

4.7. Methodological considerations and interpretation of findings

Several methodological considerations should be taken into account when interpreting these findings. The meta-analysis was based on a limited number of observational studies, reflecting the rarity and specificity of spinal tumor populations. Nevertheless, the included studies demonstrated moderate to high methodological quality and consistently reported objectively diagnosed DVT outcomes, supporting the robustness of the pooled estimates [18,19]. The moderate heterogeneity ($I^2 = 58.6\%$, $p = 0.06$) suggests that while differences across studies exist, the direction of effect is consistent. Potential sources of heterogeneity include varying DVT timing (preoperative vs. postoperative), differences in thromboprophylaxis protocols, and variability in patient mobility status.

Publication bias was not formally assessed because the number of included studies was fewer than 10, rendering funnel plot interpretation unreliable. This is acknowledged as a limitation.

In contrast, the nursing systematic review primarily comprised quasi-experimental and interventional studies with moderate methodological quality. Common limitations included lack of randomization and blinding, which may introduce performance and detection bias. More importantly, all nursing evidence is indirect—no studies specifically examined nursing interventions in spinal tumor populations. These limitations justify the narrative synthesis approach adopted in this review and underscore the need for cautious interpretation of effect estimates and for direct validation in future research [21,24].

The certainty of evidence for nursing recommendations, assessed using a modified GRADE approach, was LOW due to indirectness (evidence from non-spinal-tumor populations), risk of bias (lack of randomization/blinding), and imprecision (small sample sizes).

4.8. Limitations

Several limitations of this review must be explicitly acknowledged:

a) Heterogeneity: The meta-analysis demonstrated moderate heterogeneity ($I^2 = 58.6\%$), reflecting differences in study design (prospective vs. retrospective), DVT timing (preoperative vs. postoperative), and patient populations. Subgroup analyses to explore these sources of heterogeneity were not feasible due to the limited number of studies.

b) Limited number of studies: The meta-analysis included only four studies, which restricts precision and precludes formal publication bias assessment or meta-regression.

c) Diagnostic inconsistency: Although all included studies used objective imaging for DVT diagnosis, definitions of DVT (symptomatic vs. screening-detected, proximal vs. distal) and timing of assessment varied across studies, potentially

influencing reported incidence rates.

d) Retrospective designs: Three of the four studies in the meta-analysis were retrospective, introducing potential selection and information bias.

e) Indirect nursing evidence: The most significant limitation is that all seven nursing intervention studies were conducted in non-spinal-tumor populations (orthopaedic surgery, spinal fracture, oncology ICU, hip fracture, and arthroplasty). No study directly examined nursing interventions in spinal tumor patients. Therefore, the nursing implications are derived from indirect evidence and require validation in spinal tumor-specific research.

f) Lack of protocol registration: The review protocol was not prospectively registered (e.g., in PROSPERO), which may introduce risk of reporting bias.

g) Lack of psychological outcome measurement: None of the included studies directly measured psychological outcomes such as anxiety, depression, or distress in relation to DVT prevention, limiting the ability to draw definitive conclusions about psycho-oncologic implications.

h) Possible publication bias: While formal assessment was not performed due to the small number of studies, it is possible that studies with higher or lower DVT incidence estimates are differentially published.

4.9. Directions for future research

The findings of this review highlight several important gaps in the literature. First and most urgently, there is a clear need for prospective, oncology-specific nursing intervention studies focusing on spinal tumor populations. Future research should aim to evaluate integrated nursing care models that combine risk assessment, early mobilization, mechanical prophylaxis, patient education, psychological support, and standardized outcome reporting to facilitate quantitative synthesis.

Second, longitudinal studies examining the timing and persistence of DVT risk in spinal tumor patients—including preoperative, immediate postoperative, and post-discharge periods—may inform the optimal duration and intensity of nursing interventions.

Third, future studies should incorporate validated psychosocial instruments (e.g., HADS, DT, FACT-G) to evaluate whether DVT prevention nursing interventions confer psychological benefits beyond reducing thrombotic events.

Fourth, implementation science research examining barriers and facilitators to adopting structured DVT prevention protocols in spinal oncology settings would help translate indirect evidence into practice.

Fifth, multicenter prospective registries with standardized DVT screening protocols and nursing intervention documentation would provide higher-quality evidence to inform clinical guidelines.

Strengthening the evidence base in this area will be critical to advancing evidence-based nursing practice in spinal oncology care [18,22].

5. Conclusion

This study provides an integrated synthesis of current evidence on DVT in patients with spinal tumors by combining a meta-analysis of DVT incidence with a systematic review of nursing interventions as indirect evidence. The findings demonstrate that patients with spinal tumors experience a clinically meaningful risk of DVT (pooled incidence 8.7%, moderate heterogeneity $I^2 = 58.6\%$), underscoring the importance of vigilant thromboembolic prevention in this vulnerable oncology population. Although the available quantitative evidence remains limited in volume

(only four studies), the consistency of findings across cohort studies highlights DVT as a significant and under-recognized complication in spinal tumor care.

The nursing systematic review further suggests—based on indirect evidence from related high-risk populations—that structured and proactive nursing interventions play a critical role in the prevention of DVT. Evidence derived from high-risk surgical and oncology-related populations supports the potential transferability of comprehensive nursing strategies, including early risk assessment, mobilization, mechanical prophylaxis, patient education, and psychological support, to spinal tumor care settings. However, it must be explicitly acknowledged that no direct nursing intervention studies in spinal tumor populations were identified; therefore, these implications are derived from indirect evidence and require validation in spinal tumor-specific research.

From a psycho-oncology perspective, DVT prevention in spinal tumor patients may have psychological benefits beyond physical outcomes, including reduced anxiety, preserved sense of autonomy, improved adherence to treatment, and enhanced quality of life. However, no direct evidence on psychological outcomes was identified in this review, and these potential benefits remain theoretical at this stage.

The certainty of evidence for nursing recommendations is LOW due to indirectness, risk of bias, and imprecision. Therefore, nursing recommendations should be implemented cautiously, with local adaptation and ongoing evaluation.

Together, these findings support the integration of evidence-based nursing practices into spinal oncology care pathways to reduce thrombotic risk and improve patient outcomes. Direct validation of nursing interventions in spinal tumor populations is urgently needed.

The review protocol was not prospectively registered; this is acknowledged as a limitation.

Future research should prioritize oncology-specific nursing intervention studies in spinal tumor populations with standardized outcome reporting and integration of validated psychological measures to strengthen the evidence base. Until such data become available, the current findings provide a hypothesis-generating and evidence-informed foundation for clinical decision-making and nursing practice in spinal tumor care.

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