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Traumatic spine fractures and concomitant venous thromboembolism: A systematic review

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ABSTRACT

Objective: Venous thromboembolism (VTE) associated with bony fractures have been documented in the literature. However, the literature is not very exhaustive when it comes to VTE associated with traumatic spine fractures. Thus the purpose of this systematic review analyzing the incidence of VTE associated with spinal trauma.

Methods: An electronic search strategy was elaborated in Pubmed, Cochrane Library and Google Scholar (page 1–20) since inception till November 2023.

Results: Twelve studies were included with three prospective clinical studies, seven retrospective studies, one observational cohort study, and one propensity-matched analysis. These involved 256,107 subjects with 6039 concomitant VTE (2.4 %). Potential risk factors included age, D-dimer levels, length of hospital stay, associated spinal cord injury, location of the vertebral trauma and other baseline patient-dependent characteristics.

Conclusion: This review found that the rate VTE in spinal trauma patients was 2.4 % (6039/256107). To optimize care, clinical decision making should be tailored to each patient using a combined approach of imaging, laboratory findings, and serial physical examinations.

1. Introduction

The incidence of vertebral fractures is increasing in the recent years. An incidence of 24–90 cases of traumatic spine injury/100,000 person per year was reported,[1,2] with half of them affecting the thoracolumbar junction. High-energy fall (39 %) and traffic accidents (26.5 %) are the most frequent causes of spinal fractures.[3] They are more frequent in men with an average age of 30 [4]. However, this incidence of traumatic vertebral fractures tends to decrease with age with the increase of osteoporotic fractures.[5] Spinal fractures have a significant impact on the patient's quality of life, leading to a health-related and a socio-economic burden. Due to high velocity trauma, these fractures are often associated to other injuries such as brain and thoracic injuries, which can increase the patient's morbidity and mortality.[3,6] Furthermore, the fracture of vertebrae can be associated with the injury of the spinal cord and can cause neurological symptoms such as tingling, numbness, weakness or paralysis of the limbs and other complications.

One of the most common complications of traumatic fractures is deep vein thrombosis (DVT) which can lead to Pulmonary Embolism (PE).[7] It was reported that the DVT incidence could be as high as 29.09 % in pelvic and acetabular fractures and 29.8 % in hip fractures.[8,9] When it comes to spinal trauma, it is widely acknowledged that they constitute a substantial risk factor for DVT due to systemic hypercoagulability, potential vascular endothelium injury, venous stasis as well as the presence of neurological impairment.[10,11] However, literature is not very informative about the association between DVT with its resulting PE and spinal trauma fractures. Furthermore, the clinical guidelines published in 2009 by the North American Society of Spine Surgeons were not able to establish the rate of VTE in spinal trauma highlighting the necessity of this information.[12] To this end, this systematic review will be the first to

Abbreviations: VTE, Venous thromboembolism; DVT, Deep vein thrombosis; PE, Pulmonary embolism; DUS, Duplex Ultrasonography; LMWH, low molecular weight heparin; ASIA, American spinal injury association.

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investigate the presence of this association.

2. Material and methods

2.1. Search strategy

The PRISMA standards were followed in this investigation to study the association between Venous Thromboembolism (VTE) and spina traumatic injuries. PubMed, Cochrane, and Google Scholar (page 1–20) searches were updated to November 2023 in search of the qualified papers. Using Boolean Operators, a combination of the keywords "Deep Vein Thrombosis" OR "DVT" "Pulmonary Embol*" OR "PE" OR "Venous thromboembolism" OR "VTE" AND "Spin*" AND "Trauma" OR "Fracture" OR "Injury" was used. Reference lists from papers and online searches were also used to look up the literature. The data was extracted by one author, and the article selection was verified by a different author. The PRISMA flowchart provides a summary of the article selection process [Chart 1].

Inclusion criteria were (1) randomized controlled trials, prospective clinical trials, retrospective studies, case series, meta-analyses; (2) studies where patients had both spinal traumatic injuries and VTE. The studies with the following characteristics were excluded from this study: (1) case reports, narrative or systematic reviews, theoretical research, conference report, expert comment, and economic analysis; (2) non-relevant outcomes (such as the management of such injuries) or missing data.

2.2. Data extraction

Two reviewers determined the eligibility of the studies independently. Extraction of the analyzed data was made from the included studies, and it consisted of two parts. The first part consisted of the basic information containing the name of the authors, the title, the publication year, the journal, the volume, the issue, the pages, the study design, the sample size, and the different types of bias suspected in each study. The second part consisted of prevalence of the studied association and its possible risk factors. Any arising difference between the investigators was resolved by discussion.

2.3. Risk of bias assessment

Two authors independently assessed risk of bias using the ROBINS-I tool for assessing risk of bias in non-randomized studies of interventions.[13] Studies that had a critical risk of bias were excluded.

3. Results

3.1. Characteristics of the included studies

Twelve studies[11,14–24] met the inclusion criteria with three prospective clinical studies, seven retrospective studies, one observational cohort study, and one propensity-matched analysis, and were included in this systematic review. These involved 256,107 subjects with 6039 concomitant VTE [Table 1].

3.2. Prevalence

The pooled prevalence of VTE in spinal trauma patients is 2.4 % (6039/256107) (the prevalence of DVT and PE in spinal trauma patients being 2.25 %, and 0.56 % (4360/193614, and 1331/236914) respectively.

Masuda et al(2015) [22]: Concomitant DVTs in 268 patients with traumatic cervical Spinal Cord Injury (SCI) was seen in 22 patients (8.2 %).

Piotrowski et al (1996) [19]: 98 patients with spinal fractures were inrolled showing concomitant DVT in 14 of patients (14 %).

Ma et al (2021)[11]: the presence of preoperative DVT in 2432 patients with spinal fractures requiring surgery was assessed and showed a prevalence of 108 (4.44 %) preoperative DVTs.

Wang et al(2020) [14]: In 429 patients with thoracolumbar fractures caused by high-energy trauma it was seen that 62 (14.45 %) of them suffered from preoperative DVTs. Patients with thoracic fractures had a preoperative DVT incidence of 24.59 %, whereas those with lumbar fractures had a preoperative DVT incidence of 11.04 %.

Bahloul et al(2011) [18]: 11 patients with spinal trauma were enrolled whom 4 patients suffered from concomitant PE (32.35 %).

Jeremitsky et al(2013) [16]: in a total of 37,964 patients with isolated spine injuries the prevalence of PE in 140 (0.37 %).

Prabhakaran et al(2020) [24]: this study included a total 15,752 elderly patients who suffered from spinal injury with 312 (2 %) of them showing

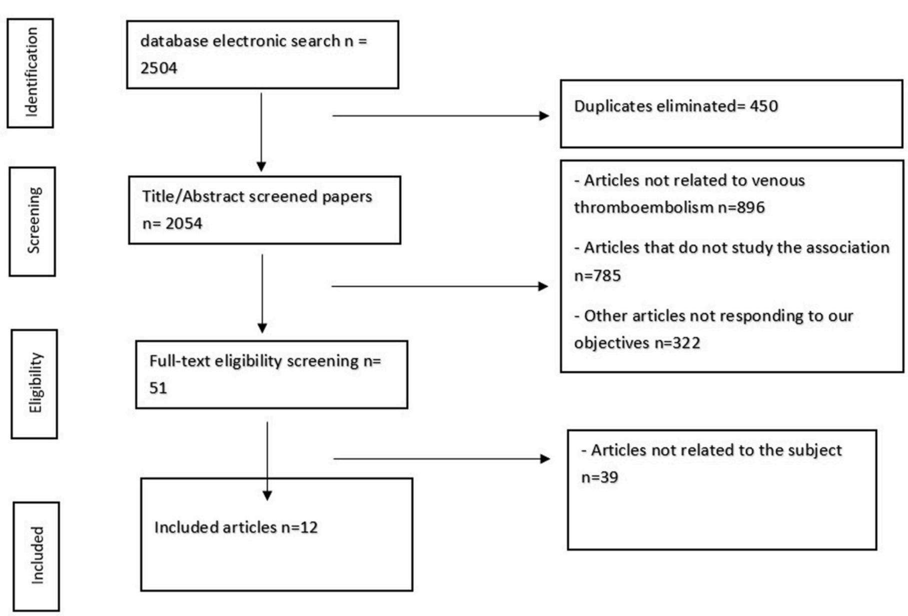

Chart 1. PRISMA flowchart for article selection process.

Table 1
Main characteristics and findings of the included studies.

	Methods	Participants	Associated Venous thromboembolism (VTE)
Masuda et al, 2015	Prospective clinical study	268	22 with DVT
Piotrowski et al, 1996	Prospective clinical study	98	11 % with DVT (with risk factors) 3 % with DVT (without risk factors)
Bahloul et al, 2011	Prospective clinical study	11	32.35 % with PE
Jeremitsky et al, 2013	Retrospective study	37,964	0.36 % with PE
Cloney et al, 2018	Retrospective study	195	14 with DVT 6 with PE
Prabhakaran et al, 2020	Retrospective study	15,752	312
Samuel et al, 2018	Retrospective study	190,192	3422 with DVT only 1056 with PE only 316 with DVT and PE
Ma et al, 2021	Retrospective study	2432	108 with DVT
Kim et al, 2012	Retrospective study	176	20
Wang et al, 2020	Retrospective study	429	62 with DVT
Meissner et al, 2003	Observational cohort study	38	16
Khan et al, 2018	Propensity-matched analysis	8552	4.7 % with DVT 1.5 % with PE

Table 2
Summary of the prophylaxis used by the included studies.

	Prophylaxis used
Ma et al 2021	Prophylactic LMWH in the first 24h of admission unless contraindicated
Wang et al 2020	Prophylactic LMWH + Mechanic prophylaxis
Kim et al 2012	Only in patients diagnosed with VTE (subcutaneous unfractioned heparin and/or LMWH)
Bahloul et al 2011	No
Piotrowski et al 1996	53.4 % of patients received prophylactic subcutaneous heparin (5000 U every 12 h) unless contraindicated
Khan et al 2018	All patients received LMWH or UFH; divided into early group (<48 h) and late group (>48 h), based on timing of initiation.
Meissner et al 2003	71.1 % of patients were taking prophylaxis on admission; 91.8 % of patients were taking prophylaxis by day 3.
Masuda et al 2015	Mechanical prophylaxis on admission before ultrasound, **NO prophylaxis after US**.
Samuel et al 2018	–
Prabhakaran et al 2020	1. 43.5 % of VTE patients were on LMWH for prophylaxis. 2. 30.6 % of VTE patients were on heparin for prophylaxis. 3. 35.7 % of patients who did not have VTE were on LMWH for prophylaxis. 4. 15.8 % of patients who did not have VTE were on heparin for prophylaxis.
Cloney et al 2018	48.7 % of spine fracture patients received chemoprophylaxis.
Jeremitsky et al 2013	–

concomitant VTE.

Kim et al(2012) [17]: 20 out of 176 patients with spine fracture developed VTE (11.36 %).

Cloney et al(2018) [15]: this study reported that 18 of the 195 patients (9.2 %) having surgery for spinal fractures developed a VTE.

Samuel et al(2018) [23]: In this study, 190,192 patients with vertebral fractures were included. Of these, 4794 patients (2.5 %) developed venous thromboembolism (VTE) during hospitalization. Specifically, 71 % presented with deep vein thrombosis (DVT) only, 22 % with pulmonary embolism (PE) only, in other words 7/1000, and 7 % were diagnosed with both DVT and PE. These percentages suggest that the incidence of VTE in these patients is relatively low, raising the question of whether anticoagulant treatment is unnecessary for a large proportion of them.

Khan et al (2018) [20]: 8552 patients with spinal trauma had a DVT prevalence of 402 patients (4.7 %) and PE occurrence of 128 patients (1.5 %).

Meissner et al(2003) [21]: 16 out of 38 patients (42.1 %) with spine fracture showed a concomitant VTE. However, after being included in a logistic regression model, spine fracture proceeded not to be a significant independent predictor of VTE.

3.3. Possible risk factors

Age: *Samuel et al (2018)*[23]: the occurrence of VTE after spinal trauma was associated with older age with the highest odds for patients aged 70–79 (*P*-value<0.001), 60–69 (*P*-value<0.001), and 50–59 (*P*-value<0.001), compared to patients aged 18–29. A finding supported by other studies.[16,19,24] *Meissner et al* (2003)[21] and *Bahloul et al* (2011) [18]: this risk of VTE occurrence increases starting the age of 40 years old. However, other studies could not demonstrate a significant finding between the difference of the prevalence of concomitant VTE in association with age.[11,17,22]

D-Dimer: *Ma et al (2021)*[11] and *H. Wang et al(2020)* [14]: An increased incidence of DVT in patients with spinal trauma was associated with a higher concentration of D-dimer. However, the cutoff point for D-dimer concentration varies between studies. Ma et al.[11] found a cutoff point of D-dimer >1.08 μg/ml, whereas Wang et al.[14] reported a cutoff point of D-dimer >1.81 mg/L.

Masuda et al(2015)[22]: According to multivariate logistic regression combining clinical and laboratory markers, only the D-dimer level at two weeks after injury was a reliable predictor of DVT development. The 16 g/dL D-dimer threshold was shown to be the best one for prediction.

Length of hospital stay: In addition, the length of hospital stay was found to be a common risk factor in some studies.[16,19,23] They showed that longer inpatient length of stay was most strongly linked to an increase in VTEs in the multivariate analysis, with a *P*-value<0.001 for stays longer than 28 days (compared to 0–3 days).[23]

Fracture level: *Khan et al(2018)* [20]: the DVT rate was highest in patients with multiple-level vertebral fractures (5.6 %), followed by patients with an isolated lumbar spine injury (5 %). Accordingly, patients with multiple-level vertebral fractures had the greatest prevalence of PE (2.1 %), which was then followed by patients with lumbar spine fractures (1.9 %).[20]

Samuel et al(2018) [23]: Contrarily, there was no association between the level of vertebral fracture and VTEs. In addition, they demonstrated that the association of a spinal cord injury, complete or incomplete, was a VTE risk factor in spine trauma patients, which was approved by Ma et al.[11] who mentioned that American Spinal Injury Association (ASIA) Impairment Scale grade A/B had significantly independent association with DVT. However, the severity of paralysis in another study was not found to be a significant risk factor of DVT.[22] Nevertheless, immobilization >3 days post-trauma remained as a significant independent predictor of VTE.[21]

Other: *Samuel et al(2018)* [23]: the increased rate of VTE in spine trauma was related to obesity, masculine sex, malignancy, coagulopathy, and multiple associated non-spinal injuries. Concerning obesity (>120 % and >130 % of ideal body weight in men and women, respectively), it was also approved by *Meissner et al(2003)*,[21] proving it as a significant independent predictor of VTE.

Kim et al (2012) [17]: malignancy and obesity, were not found to be predictors of VTE upon multivariate analysis.

Moreover, studies have shown that increased ventilator days were also associated with higher odds of developing VTE.[17,24] Also, delay to duplex ultrasonography (DUS) screening (in each day), albumin level <3.5 g/dL, and delayed initiation of thromboprophylaxis each day resulted in an increased risk of VTE.[11,20] In addition, in post-traumatic elderly patients, it was stated that frailty and transfusion of plasma products in the first 24 h of admission, associated with spine trauma were independent predictors of developing VTE.[24]

3.4. Prophylaxis (Table 2)

Ma et al (2021) [11]: Prophylactic LMWH was prescribed within the first 24h of admission unless the spine surgeon determined an emergent need for spinal cord decompression, or any other robust contraindication.

Wang et al(2020) [14]: All patients received a combination of chemical (LMWH) and mechanical prophylaxis.

Kim et al(2012) [17]: Mechanical/Chemical prophylaxis was given after the management of patients diagnosed with VTE. Therefore, no prophylaxis after the trauma.

Bahloul et al(2011) [18]: No prophylaxis was given.

Piotrowski et al (1996) [19]: Patients were given prophylaxis with subcutaneous heparin (5000 U every 12 h) unless contraindicated (46.6 %).

Khan et al (2018) [20]: All patients received prophylaxis: Patients were divided into two groups based on timing of initiation of thromboprophylaxis: Early (<48 h) and Late (≥48 h). In fact, 1.7 % of patients who received early prophylaxis developed DVT, and 0.8 % of patients who received early prophylaxis developed PE while 7.6 % of patients who received late prophylaxis developed DVT, and 2.2 % of patients who received late prophylaxis developed PE.

Meissner et al(2003) [21]: Most patients received prophylaxis, only 28.9 % of patients were not taking prophylaxis on admission. In fact, 33.3 % VTE occurred in patients with prophylaxis while 21.4 % VTE occurred in patients without prophylaxis ($p = 0.25$).

Masuda et al(2015) [22]*:* Mechanical prophylaxis was used on admission strictly before ultrasound. After that, no prophylaxis (mechanical or chemical) was used on any patient, except for patients with pre-existing anticoagulant therapy.

Prabhakaran et al(2020) [24]: 43.5 % of VTE patients were on LMWH for prophylaxis, 30.6 % of VTE patients were on heparin for prophylaxis, 35.7 % of patients who did not have VTE were on LMWH for prophylaxis, and 15.8 % of patients who did not have VTE were on heparin for prophylaxis.

Cloney et al(2018) [15]: 48.7 % of spine fracture patients received chemoprophylaxis.

The two remaining studies by *Samuel et al(2018)*[23] and *Jeremitsky et al(2013)*[16] did not mention the use of prophylaxis.

The pooled analysis shows that 6.3 % (730/11,549) with prophylaxis ended up having a VTE after spinal trauma.

4. Discussion

VTEs including DVT and PE are common and serious complications in hospitalized patients following traumatic events, particularly in orthopedic patients with traumatic fractures. These events are associated with significant morbidity, mortality, and discomfort.[8,25] Virchow's triad is the most credible theory explaining the pathophysiology of DVT formation. It comprises three factors: changes in normal blood flow, damage to the blood vessel lining, and alterations in blood viscosity or hypercoagulability. These factors work together to cause DVT.[26] Furthermore, there is a high correlation between PE and DVT, but it has been observed that only around 20 % of patients with PE had a previously identified DVT.[16,27,28] This could be attributed to the fact that once the diagnosis of PE is established, further investigation for DVT may not be deemed necessary.[16]

In our study involving 256,107 patients with vertebral trauma and/or fracture, the rate of inpatient VTE was approximately 2.4 %. This is consistent with other studies showing an incidence of 2.1 %,[29] and 2.5 %[23] but higher rates might be seen such as 3.6 %.[30] These findings are particularly relevant to the hypercoagulability state in patients with spine fractures, in whom all components of the Virchow triad are present. This specific population of patients has an increased risk of developing VTEs due to various factors such as systemic hypercoagulability, prolonged immobilization due to longer hospitalization, and direct mechanical injury to the veins or injury to the spinal cord causing venous stasis due to subsequent paralysis.[14,22,31] Therefore, it has been shown in other studies that patients with spinal fractures with an ASIA grade of A/B had a higher occurrence of DVT compared to those graded C–E.[11,32] In fact, DVT represents a prevalent complication following traumatic spinal cord injury (TSCI), with occurrences reported in 50–100 percent of untreated cases, typically peaking between 72 h and 14 days post-injury. Notably, the degree or severity of TSCI does not distinctly correlate with the risk of DVT. In fact, any patient experiencing motor deficits due to TSCI is susceptible to venous thromboembolism (VTE). Consequently, it is recommended that all individuals with spinal cord trauma receive prophylactic treatment to mitigate this risk.[33,34] Furthermore, *Prabhakaran et al(2020)*[24] showed that the patients who developed VTEs during hospitalization were more severely injured (had a higher mean injury severity score, lower Glasgow Coma Scale scores, and lower systolic blood pressure upon initial vital sign evaluation). This may be due to a combination of factors including post-injury immobility and endothelial damage resulting in venous stasis.

The development of VTE is influenced by various factors, including individual characteristics and surgical procedures.[15] In the included studies, the most frequently accepted risk factor for the VTE was the increased patients' age,[16,18,19,21,23,24] however the specific cut-off age which incremented that risk varied from study to study. *Samuel et al (2018)*[23] showed that this risk would start to rise after the age of 50, while other studies suggested that it may start at the age of 40 [18,21]. On the other hand, some studies did not find any significant evidence of a variation in the occurrence of concomitant VTE in relation to age.[11,14,17,22] One of the reasons is that high-energy spine traumas are mostly seen in younger patients.[14]

Moreover, studies have indicated that there is a correlation between a higher level of D-dimer and a higher likelihood of developing deep vein thrombosis (DVT) in patients who have experienced spinal trauma.[11,14] Nevertheless, the threshold for the D-dimer level varies around 1.08 [11] and 1.81 mg/L.[14] Despite that, only the D-dimer level at two weeks after injury was a reliable predictor of DVT development, while stating that conducting screening tests prior to two weeks following an injury may be too premature as there is a possibility of failing to detect developing DVT that are still in their initial stage of formation.[22]

The location of the fracture may as well influence the incidence of DVTs. In fact, a study showed that the occurrence rate of DVT in patients with thoracic fractures (24.59 %) was greater compared to those with lumbar fractures (11.04 %). This could be attributed to the fact that individuals with thoracic fractures tend to have weaker motor ability in their lower extremities.[14]: Another study demonstrated that the VTE rate was highest in patients with multiple-level vertebral fractures (5.6 % for DVT and 2.1 % for PE), followed by patients with an isolated lumbar spine injury (5 % for DVT and 1.9 % for PE).[20] This could be attributed to the higher frailty of the patient as well as the higher surgical invasiveness as it was shown to increase VTE rates.[12]

Furthermore, general health risk factors and personal medical antecedents such as obesity, malignancy, coagulopathy, multiple associated non-spinal injuries, in addition to the masculine sex, were all found to be associated with an increased rate of VTE in spine trauma patients.[23] Likewise, higher odds of developing VTE were shown to be associated with increased ventilator days[17,24] with every extra day spent on ventilator resulting in 8 % higher odds of developing VTE,[24] with each day of delay in performing a duplex ultrasonography (DUS) which is linked to an 11 % increased chance of DVT even when prophylactic anticoagulation is administered,[11] with hypoalbuminemia (<3.5 g/dL) as it triggers hyperfibrinogenemia and platelet aggregability,[35,36] and delayed initiation of thromboprophylaxis each day.[20] Also, frailty, which is defined as a combination of age-related decline in functionality and the burden of coexisting medical conditions, was identified as the most influential individual factor for predicting the occurrence of VTE in geriatric patients who have sustained trauma.[24]

In addition, across three studies, no prophylaxis was administered, while in five studies, all patients received prophylaxis (either chemoprophylaxis with LMWH or subcutaneous heparin, mechanical prophylaxis, or both). In one study, approximately half of the patients received prophylaxis, and in the last study, most patients received prophylaxis, but both groups experienced VTE events; 33.3 % were on prophylaxis, and 21.4 % were not, with no significant difference noted. Thus, it seems that administering prophylaxis after spinal trauma does not significantly alter the likelihood of experiencing a VTE. However, it's essential to approach this information with caution due to the low number of articles discussing prophylaxis thoroughly. Furthermore, this should not be applied to patients suffering from an additional spinal cord injury where the risk of VTE is higher.

4.1. Recommendations

Tailoring treatment plans should be a priority, necessitating a comprehensive risk evaluation that takes into account various factors. These factors include age, distinguishing between elderly individuals with multiple comorbidities and younger patients without significant medical history. Additionally, considerations should extend to the nature of the spinal cord injury, the presence of multiple vertebral fractures, the level of injury within the thoracic region, duration of hospitalization, ventilator dependency, and other pertinent risk elements such as diabetes or a history of DVT or PE. The combination of these variables is pivotal for optimal patient management. Consequently, in complex cases, a multidisciplinary approach is the most effective strategy for addressing the multifaceted needs of the patient. In fact, spinal cord injury is one of the most important risk factors for the development of VTE.[33,34] Pharmacological prophylaxis using anticoagulant medication, such as low molecular weight heparin (LMWH) or unfractionated heparin, adjusted for patient-specific factors, should be administered in this case.[10] Additionally, mechanical prophylaxis through intermittent pneumatic compression devices and the use of graduated compression stockings should be employed to enhance blood circulation and prevent venous stasis. When a spinal cord injury is involved, level I evidence demonstrates that a combination of both chemical and mechanical prophylaxis is recommended.[33,34] Regular monitoring of coagulation parameters, early mobilization, and a collaborative approach involving various specialists are crucial components of effective DVT prevention.[10] Education for patients and healthcare providers about prevention measures and vigilant follow-up to assess the efficacy of interventions are also vital in mitigating the risk of VTE.

4.2. Strengths and limitations

This study presents with some strengths, mainly the number of included studies, and the extensive search method used and included going through three databases. However, in the included studies, most of the links established between the variables and the occurrence of DVT were correlation and not causation; many studies mentioned were limited by the modality of VTE detection and screening. Furthermore, variable rates of vertebral fractures-related VTE were reported in the included studies which could be explained by the difference in the locations of the vertebral fractures among the patients in the different studies, the rate of associated spinal cord injury, and other factors that could affect the occurrence of VTE.

5. Conclusion

The association between DVT, its resulting PE, and spinal traumatic fractures is common and potentially devastating if misdiagnosed or treated late. Numerous risk factors, such as age, D-dimer levels, and length of hospital stay, contribute to the development of VTEs in this setting. To optimize care, clinical decision-making should be individualized using imaging, laboratory findings, and serial physical examinations. More high-quality studies are needed to establish better management algorithms to prevent VTE in patients with traumatic spine injuries.

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Informed consent

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Ethical approval

Not applicable.

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Daniel Murtada: Writing – original draft. **Mohammad Daher:** Writing – original draft. **Marven Aoun:** Writing – original draft. **Antoine Mouawad:** Writing – original draft. **Gaby Kreichati:** Writing – review & editing. **Khalil Kharrat:** Writing – review & editing. **Amer Sebaaly:** Writing – review & editing, Conceptualization.

Declaration of competing interest

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