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Dynamic Changes and Relevant Factors of Perioperative Deep Vein Thrombosis in Patients with Thoracolumbar Fractures Caused by High-Energy Injuries

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Abstract

Objective: To investigate the dynamic changes and relevant factors of deep vein thrombosis (DVT) in patients with thoracolumbar fractures caused by high-energy injuries.

Methods: From January 2016 to June 2021, a total of 655 patients with thoracolumbar fractures who underwent surgical treatment in our hospital were retrospectively analyzed. The patients were examined by preoperative and postoperative ultrasonography, and divided into thrombus growth group, thrombus invariant group, and thrombus regression group according to the preoperative and postoperative ultrasonographic results. Medical record data, including demographic data, surgical data, and laboratory results, were collected and the differences in various factors among the groups were compared.

Results: DVT was found in 99 patients (15.1%, 99/655) before surgery, including 79 cases of distal thrombus, 7 cases of proximal thrombus, and 13 cases of mixed thrombus. The incidence of postoperative DVT increased to 20.6% (134/655), including 96 cases of distal thrombus, 15 cases of proximal thrombus, and 23 cases of mixed thrombus. Among them, 39.7% had thrombus growth, 49.3% had thrombus basically unchanged and 11.0% had thrombolysis. There were significant differences in age, lower extremity muscle strength, time from trauma to surgery, operation time, blood loss, blood transfusion, and post 3-D-dimer among the three groups.

Conclusions: In patients with thoracolumbar fractures caused by high-energy injuries, the majority of patients with DVT do not change or grow after surgery, and only a few of them have thrombolysis. Younger age, lower extremity motor, and fewer blood transfusion contribute to thrombolysis. Delayed surgical intervention, longer operation time, and higher blood loss can lead to thrombosis growth. Post 3-D-dimer is closely related to the dynamic changes of thrombus.

Keywords

deep venous thrombosis, fracture, high-energy injury, dynamic change, d-dimer

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Introduction

Thoracolumbar fractures are the most common fractures of the spine, accounting for about 90% of spinal fractures.[1–3] These fractures are often caused by high-energy injuries, such as fall injuries, traffic accidents, or industrial trauma. Thoracolumbar fractures caused by high-energy injuries are different from osteoporotic fractures in the elderly, usually at a low age, and most require surgery.[4,5] High energy trauma, immobilization, and operation may lead to vascular injury or slow down the

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venous return, which makes patients susceptible to deep vein thrombosis (DVT).[6,7]

DVT is a common and serious complication in trauma patients, especially in orthopedic trauma patients.[6,8] It is reported that the incidence of DVT after trauma was to be about 9.1% to 11.1%, and it may lead to chronic pain, varicose veins, and post-venous thrombosis syndrome, which can seriously affect the quality of patients' life and even cause fatal pulmonary embolism (PE).[9,10] Therefore, it is important to dynamically monitor changes in venous thrombosis and take preventive or therapeutic measures in time.

Currently, there are few reports on the dynamic changes and relevant factors of DVT in patients with thoracolumbar fractures caused by high-energy injuries. In this study, we aim to investigate the dynamic changes of DVT in patients with thoracolumbar fractures caused by high-energy injuries. Specifically, we examined relevant factors that affect the dynamic changes of thrombus.

Patients and Methods

Study Population

The retrospective study was conducted from January 2016 to June 2021 at Baoding No. 1 Central Hospital. A total of 655 patients were enrolled in the study, including 456 males and 199 females. The causes of injuries included 219 cases of high fall injuries, 301 cases of traffic accidents and 135 cases of industrial accidents. There were 179 cases of thoracic fractures and 476 cases of lumbar fractures. The inclusion criteria were as follows: (1) age older than 18 years; (2) fresh thoracolumbar fractures that require surgical treatments; (3) caused by high-energy injuries; (4) complete medical records. The exclusion criteria were as follows: (1) conservative treatment; (2) old thoracolumbar fractures (>3 weeks); (3) anticoagulation before injury; (4) osteoporotic fractures; (5) a history of previous venous thromboembolism (VTE); (6) combined with other fractures. We defined high-energy injuries as injuries resulting from high fall injuries (>2 m), traffic accidents, or industrial accidents. It was approved by the ethics committee of our hospital and in accordance with the ethical standards of the 1964 Declaration of Helsinki. Informed consent for our study was obtained from all patients.

Prevention, Diagnosis and Grouping of DVT

According to the Chinese guidelines for the prevention of venous thromboembolism in major orthopaedic surgery, all patients in the orthopaedic trauma department of our hospital received Caprini thrombosis risk assessment after admission. All patients in the current study received both mechanical and chemical prophylaxis, as recommended by the Caprini risk model. Mechanical prophylaxis included intermittent pneumatic compression and ankle pump training. All patients received prophylactic anticoagulant with administration of low molecular weight heparin (LMWH) 4100 U (Changshan Production, Hebei, China) once a day. All patients were examined by duplex ultrasound (Philips Medical Healthcare, Armstrong, Netherlands) 1 day before surgery and 3–5 days after surgery. Based on the duplex ultrasound results, patients with DVT were given LMWH injections twice daily to treat DVT and mechanical prophylaxis was stopped immediately. The specific treatment plan is guided by the vascular surgeon.

The occurrence and distribution of DVT were recorded based on the duplex ultrasound results of both lower extremities before and after surgery. DVT was diagnosed in accordance with the Guideline for the Diagnosis and Treatment of Deep Vein Thrombosis (third edition) proposed by the Chinese Medical Association.[11] DVT was classified into three types: proximal DVT (in the popliteal vein or proximally), distal DVT (localized distal to the popliteal vein), and mixed DVT (both central and peripheral thrombosis).

Patients were divided into thrombus growth group, thrombus invariant group, and thrombus regression group based on changes in thrombosis detected by vascular ultrasound. Among them, the thrombus regression group is defined as the complete disappearance of DVT in lower limbs, the mixed thrombus becomes proximal or distal thrombus, and the bilateral thrombus becomes unilateral thrombus. The thrombus invariant group was defined as the lower limb segment where the thrombus did not change significantly, and the thrombus growth group was defined as the new proximal thrombus, the new distal thrombus, the new mixed thrombus, and the distal thrombus progressed to the proximal site.

Data Collection

The demographic data included age, gender, body mass index (BMI), comorbidities (including hypertension, diabetes, and coronary heart disease), time from trauma to surgery, and lower extremity muscle strength. The surgical data included operation time, blood loss, liquid transfusion, blood transfusion, postoperative drainage, and surgical procedures (simple fixation or fixation with decompression). The laboratory variables included fibrinogen (FIB), prothrombin time (PT), thrombin time (TT), activated partial thromboplastin time (APTT), D-dimer at admission, and D-dimer on the third day after surgery (Post 3-D-dimer).

Statistical Analysis

Statistical analysis was performed with the SPSS software (Version 26.0, IBM SPSS Inc., Chicago, IL, USA). The continuous variable data with a normal distribution are presented as mean ± standard deviation, and data with non-normal distribution are shown as median (interquartile range, IQR). Analysis of variance was adopted to assess the differences among normally distributed data of three groups with homogeneity of variance. Otherwise, the Kruskal–Wallis test was utilized. Categorical variables were shown with proportions and compared using the chi-square test. When the test *P* value was significant, pairwise comparisons were performed. Values for $P < 0.05$ were defined as statistically significant.

Results

Incidence and Distribution of Thrombus Before and After Surgery

DVT was found preoperatively in 99 patients, with an incidence of 15.1% (99/655), including 7 cases of proximal thrombus, 79 cases of distal thrombus, and 13 cases of mixed thrombus. The incidence of postoperative DVT increased to 20.6% (134/655), including 15 cases of proximal thrombus, 96 cases of distal thrombus, and 23 cases of mixed thrombus.

Perioperative Changes of DVT Before and After Surgery

581 patients (88.7%, 581/655) had no changes in preoperative and postoperative thrombosis (509 patients without thrombus, 58 patients with distal thrombus, five patients with proximal thrombus, and nine patients with mixed thrombus). Among the 47 cases (7.2%, 47/655) without thrombus before surgery, seven cases (1.1%, 7/655) developed proximal thrombus, 34 cases (5.2%, 34/655) developed distal thrombus, and six cases (0.9%, 6/655) developed mixed thrombus after surgery. Among the 21 cases (3.2%, 21/655) with distal thrombus before surgery, three cases (0.5%, 3/655) developed proximal thrombus, seven cases (1.1%, 7/655) developed mixed thrombus, and 11 cases (1.6%, 11/655) developed no thrombus after surgery. Among the two cases (0.3%, 2/655) with proximal thrombus before surgery, one case (0.15%, 1/655) developed distal thrombus and one case (0.15%, 1/655) developed mixed thrombus. Three patients (0.5%, 3/655) who had mixed thrombus before surgery changed to distal thrombus after surgery (Table 1).

Comparison of Demographic Data and Laboratory Parameters among the Three Groups

The results for demographic data and laboratory parameters in the three groups are displayed in Tables 2 and 3. There were significant differences in age, lower extremity muscle strength, time from trauma to surgery, and Post 3-D-dimer among the three groups (all $P < 0.05$). Notably, thrombus regression group had younger age than either thrombus growth group ($P = 0.001$) or thrombus invariant group ($P = 0.002$). But no significant difference was observed in age between thrombus growth group and thrombus invariant group ($P = 0.440$). Similarly, thrombus regression group had better lower extremity motor than either thrombus growth group ($P = 0.001$) or thrombus invariant group ($P = 0.016$). But there was no significant difference in lower extremity muscle strength between thrombus growth group and thrombus invariant group ($P = 0.097$). The thrombus growth group had longer time from trauma to surgery than either thrombus regression group ($P = 0.033$) or thrombus invariant group ($P = 0.002$). But no significant difference was observed between thrombus regression group and thrombus invariant group ($P = 0.845$). We found no significant difference in D-dimer levels at admission between the three groups. The level of Post 3-D-dimer in thrombus growth group was higher than in thrombus invariant group ($P = 0.039$) and thrombus regression group ($P < 0.001$). The level of Post 3-D-dimer in thrombus regression group was clearly lower than the other two groups ($P = 0.023$) (Table 4). However, there were no significant differences in gender, BMI, hypertension, diabetes, coronary heart disease, FIB, TT, APTT, and PT (all $P > 0.05$).

Comparison of Surgical Data among the Three Groups

Table 5 summarized the surgical data among the three groups. The thrombus growth group had longer operation time than either thrombus regression group ($P = 0.007$) or thrombus invariant group ($P = 0.010$). But no significant difference was observed in operation time between thrombus regression group and thrombus invariant group ($P = 0.256$). The blood loss in thrombus growth group was higher than that in thrombus regression group ($P = 0.011$) and tended to be higher than that in thrombus invariant group ($P = 0.052$). The thrombus regression group had lower blood loss than that in thrombus invariant group ($P = 0.184$), although the difference did not achieve statistical significance. The thrombus regression group had fewer blood transfusion patients than the thrombus growth group and thrombus invariant group ($P = 0.020$ and $P = 0.009$, respectively) (Table 4). No significant difference was observed in blood transfusion between thrombus growth group and thrombus invariant group ($P = 0.732$). There were no differences in liquid transfusion, postoperative drainage, and surgical procedure (all $P > 0.05$).

Table 1. Changes of DVT Before and After Surgery.

		Postoperative thrombosis			
Preoperative thrombosis	Cases (*n*)	Proximal thrombus	Distal thrombus	Mixed thrombus	No thrombus
Proximal thrombus	7	5	1	1	0
Distal thrombus	79	3	58	7	11
Mixed thrombus	13	0	3	9	1
No thrombus	556	7	34	6	509
Total	655	15	96	23	521

Table 2. Comparison of Demographic Data among Groups.

Variables	Thrombus growth group (*n* = 58)	Thrombus invariant group (*n* = 72)	Thrombus regression group (*n* = 16)	*P* value
Age (years)	50.6 ± 11.7	49.1 ± 9.9	39.9 ± 11.4	0.002
Gender (Male/female)	42/16	51/21	11/5	0.955
BMI (kg/m^2)	25.3 ± 3.0	24.7 ± 2.9	25.2 ± 5.6	0.495
Comorbidities				
Hypertension (%)	12/58	9/72	3/16	0.438
Diabetes (%)	2/58	3/72	1/16	0.891
Coronary heart disease (%)	1/58	2/72	1/16	0.669
[a]Lower extremity muscle strength				
≥3	27	44	15	0.003
<3	31	28	1	
Time from trauma to surgery(days)	5.0(3.0)	4.0(2.0)	4.0(2.8)	0.004

[a]Manual muscle test score(0–5).

Table 3. Comparison of Laboratory Results among Groups.

Variables	Thrombus growth group (*n* = 58)	Thrombus invariant group (*n* = 72)	Thrombus regression group (*n* = 16)	*P* Value
D-dimer (mg/L)	2.6(4.6)	2.1(2.3)	1.5(1.7)	0.178
FIB (g/L)	3.5 ± 1.1	3.6 ± 1.0	3.6 ± 0.8	0.914
TT (s)	14.1 ± 1.8	14.5 ± 1.5	14.1 ± 2.4	0.359
APTT (s)	29.4 ± 4.7	28.0 ± 3.4	28.8 ± 2.7	0.157
PT (s)	12.4 ± 1.1	12.1 ± 1.3	12.2 ± 1.8	0.470
Post 3-D-dimer (mg/L)	2.5(2.2)	1.9(1.2)	1.4(0.9)	<0.001

Discussion

Thoracolumbar fractures are the most common spinal fractures, especially fractures caused by high-energy injuries, which are different from vertebral compression fractures in the elderly, often accompanied by vertebral burst, even dislocation and spinal cord injury.[12,13] These fractures usually require surgical internal fixation, which requires firm fixation to restore spinal stability and decompression of the spinal canal to relieve pressure on the spinal nerves.[14,15] DVT is a common complication in trauma patients, particularly those with high-energy fractures. It has been reported that the incidence of postoperative DVT in patients with thoracolumbar fracture is 9%–14%.[16] The Caprini score was validated in surgical patients which integrated inherent risk factors and surgical specific risk factors to stratify DVT risk level.[17] According to the Caprini thrombosis risk assessment model, all patients in the current study were treated with both mechanical and pharmacological prophylaxis. In this study, the incidence of DVT was 15.1% before surgery and increased to 20.6% after surgery. Without standardized anticoagulation, the actual incidence of DVT may be higher.

After the acute onset of DVT, the natural history of the disease is characterized by a dynamic process, which may involve the physiological lysis and expansion of thrombus.[18,19] In this study, the majority of patients with DVT do not change or grow after surgery, and only a few of them have thrombolysis. There is evidence that thrombolysis begins within the first few days after DVT and occurs mainly in single vein thrombosis.[18–20] Preoperative and postoperative venous thrombosis is mainly distal thrombosis, so the likelihood of severe PE due to embolism is low. However, current treatment measures for distal thrombosis are not unique, especially if distal thrombosis occurs prior to surgery, and there is no consensus on whether it is necessary to insert an inferior vena cava filter. A study has shown that if anticoagulation is not used for distal thrombus, 10% of patients will experience thrombosis within 7 days and develop proximally.[21] Thus, in our hospital, LMWH combined with ankle pump training was applied to prevent venous thrombosis in the lower extremities immediately after admission. This study found that the incidence of postoperative DVT was higher than that of preoperative DVT, but distal thrombosis remained predominant, suggesting that preoperative dual preventive measures did not reduce the occurrence of lower extremity DVT. However, there was no significant increase in the incidence of proximal thrombus. For trauma patients, the hypercoagulable state of blood existed from the beginning of the injury, and even lasted throughout the perioperative period, continuous anticoagulation was necessary.[22,23] Patients with thoracolumbar fractures caused by high-energy injuries were bedridden and have reduced lower limb activity after the injury, resulting in slow blood flow and blood stagnation, which was a leading cause of DVT. Although distal thrombus did not usually lead to serious consequences such as fatal PE, it was recommended that this patient was at high risk of developing proximal thrombus and therefore DVT prevention should be actively undertaken during hospitalization. Preoperative

Table 4. Pairwise Comparisons Between Groups.

P Value	Thrombus growth group *versus* Thrombus invariant group	Thrombus growth group *versus* Thrombus regression group	Thrombus invariant group *versus* Thrombus regression group
Age	0.440	0.001	0.002
Lower extremity muscle strength	0.097	0.001	0.016
Time from trauma to surgery	0.002	0.033	0.845
Operation time	0.010	0.007	0.256
Blood loss	0.052	0.011	0.184
Blood transfusion	0.732	0.020	0.009
Post 3-D-dimer	0.039	<0.001	0.023

Table 5. Comparison of Perioperative Variables among Groups.

Variables	Thrombus growth group ($n = 58$)	Thrombus invariant group ($n = 72$)	Thrombus regression group ($n = 16$)	*P* Value
Operation time (min)	166.6 ± 36.7	148.8 ± 40.3	136.6 ± 39.7	0.006
Blood loss (mL)	500.0(525.0)	400.0(280.8)	300.0(95.0)	0.011
Liquid transfusion(ml)	2444.0(550.1)	2250.0(447.6)	2299.4.0(501.6)	0.086
Blood transfusion				
YES	37	48	5	0.028
No	21	24	11	
Postoperative drainage (mL)	400.0(205.3)	450.0(305.0)	315.0(240.0)	0.088
Surgical procedures				
Fixation	32	53	11	0.086
Fixation with decompression	26	19	5	

and postoperative ultrasonography should be performed to see if the location of the thrombus has progressed to the proximal site.

There are three main factors of lower extremity venous thrombosis, namely, hypercoagulability, venous stasis and vascular endothelial injury.[24] For patients with thoracolumbar fracture caused by high-energy injuries, preoperative high energy trauma, pain and surgical injury all can lead to blood hypercoagulability. In such patients, prolonged immobility after injury results in weakened or even complete loss of muscle pump function in the lower limbs, and slow venous reflux leads to venous stagnation. High energy injury may cause vascular endothelial damage, and blood stagnation can lead to the accumulation of a large number of white blood cells between the endothelial cells and the basement membrane, which can also cause damage to the vessels' intima during locomotion.

This study found that the factors influencing the dynamic changes of thrombus included age, lower extremity muscle strength, time from trauma to surgery, operation time, blood loss, blood transfusion and Post 3-D-dimer. Many studies demonstrated that age was a risk factor for DVT.[8,25,26] Our study found that the younger the age, the easier the thrombus to regress. In the opinion of the present authors, younger patients have few underlying diseases, good vascular elasticity, and rapid recovery, so that thrombosis is more likely in younger patients. Similarly, we found that patients with lower extremity motor function were more likely to have thrombolysis. In a prospective study, Torii et al [27] observed that muscle mass and performance was associated with DVT regression. We suggested that lower extremity motor ability can maintain muscle pump function and promote venous return, which in turn promoted thrombus regression. Delayed surgical intervention was considered to be closely associated with DVT.[28,29] Our study showed that longer time from trauma to surgery can lead to thrombosis growth. Therefore, our goal was to perform surgery immediately after the patient's condition was stable. Several authors have demonstrated that operation time and blood loss were risk factors for DVT.[30–32] To the best of our knowledge, longer operation times tended to be accompanied by more intraoperative blood loss, which boosted the clotting state and disrupted the clotting-fibrinolysis system. Our study found that longer operation time and higher blood loss can lead to thrombosis growth, so optimizing surgical procedures and improving surgical techniques may reduce the growth of thrombus. Blood transfusion can increase the blood viscosity and change local hemorheology, which causes the aggregation of red blood cells and platelets, thus promoting the formation of DVT.[33] Our study showed that blood transfusion was closely related to the changes of thrombus before and after surgery, and DVT was more likely to thrombolysis in patients without blood transfusion. The D-dimer is dynamic, so measurements at multiple time points are necessary. Our previous study found that Post 3-D-dimer had the highest diagnostic value for postoperative DVT.[34] This study found that pairwise comparison of Post 3-D-dimer showed statistical differences among the three groups. Therefore, we should focus on the Post 3-D-dimer. For patients with abnormalities, we should review the duplex ultrasound of lower limb veins in time.

There were some limitations to the present study. First, this was a single-center retrospective study which had inherent biases. Second, there are many other factors that affect DVT, but we have not fully collected these indicators. Third, the sample size of our patients was not too large enough. Future prospective, large sample and multicenter studies are needed to confirm our findings.

Conclusions

In patients with thoracolumbar fractures caused by high-energy injuries, the majority of patients with DVT do not change or grow after surgery, and only a few of them have thrombolysis. Younger age, lower extremity motor and fewer blood transfusion contribute to thrombolysis. Longer operation time and higher blood loss can lead to thrombosis growth. Post 3-D-dimer is closely related to the dynamic changes of thrombus.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethics Approval

The Ethics Committee of Baoding No.1 Central Hospital approved this study.

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