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Relationship Between the Incidence of Deep Vein Thrombosis During Hospitalization and the Energy of Injury in Tibial Plateau Fractures

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Abstract

This study aimed to investigate the relationship between the incidence of deep vein thrombosis (DVT) during hospitalization and the energy of injury in tibial plateau fractures (TPFs). One hundred and forty patients were enrolled between September 1, 2014, and October 1, 2017. According to Schatzker's classification, they were classified into the low-energy (type I-III) and high-energy (type IV-VI) groups. For DVT evaluation, duplex ultrasonography was performed in the lower extremities preoperatively and postoperatively. The location and changes of DVT were recorded. All patients underwent mechanical and chemical thromboprophylaxis. The incidence of DVT in TPFs was 36.43% and 46.43% preoperatively and postoperatively, respectively. The DVT incidence was 31.75% (20/63) in the low-energy group and 40.26% (31/77) in the high-energy group preoperatively, and 44.44% (28/63) in the low-energy group and 48.05% (37/77) in the high-energy group postoperatively. There was no significant difference between the 2 groups preoperatively ($P = .298$) and postoperatively ($P = .785$). The days between operation and discharge ($P = .016$), blood loss during surgery ($P = .016$), and preoperative D-dimer level ($P = .02$) showed differences between the 2 groups. Additionally, 29 new thrombi (14 [48.28%] in the high-energy group and 15 [51.72%] in the low-energy group) appeared and 16 preoperative thrombi disappeared postoperatively. Despite mechanical and chemical thromboprophylaxis, the DVT risk in patients with TPFs remains high. Although the DVT incidence is not significantly different between high-energy and low-energy injuries, the occurrence of DVT should be carefully monitored.

Keywords

deep vein thrombosis, tibial plateau fracture, low-energy injury, high-energy injury, Doppler ultrasonography

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Introduction

A tibial plateau fracture (TPF) is a sophisticated type of injury in trauma/orthopedics medicine and can cause severe complications despite surgical treatment. Tibial plateau fractures constitute 1% of all fractures and 8% of fractures in the elderly.[1] The incidence of such fractures follows a bimodal distribution, primarily occurring either in younger individuals as a result of high-energy mechanisms (such as motor vehicle accidents) or in elderly patients with osteoporotic bone after a low-energy fall. Tibial plateau fractures are often associated with a poor prognosis because of the associated factors such as cartilage destruction and soft-tissue envelope damage, as well as complications including compartment syndrome, postoperative infection, knee instability or stiffness, and posttraumatic osteoarthritis.[2-5] Moore et al performed one of the earliest studies investigating complications and clinical results after the surgical management of TPFs and found that infection was the

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most common complication following operative fixation of these injuries.[6] Such complications result in prolonged hospitalization and delayed recovery after TPFs. A prolonged period of extremity elevation and limited mobility may place patients at an increased risk for the development of deep vein thrombosis (DVT) both preoperatively and postoperatively.

Venous thromboembolism (VTE), which includes DVT and pulmonary embolism, is a principal cause of morbidity and mortality in all hospitalized patients, particularly in the setting of trauma.[7] It can lead to chronic pain, secondary varicose veins, and ulcers, which can seriously affect the quality of life of patients and even cause fatal pulmonary embolism.[8] Abelseth et al found a high incidence of DVT in femoral fractures and TPFs and suggested that patients with older age and longer operative time may require anticoagulation prevention.[9] Therefore, screening for DVT and preventing its occurrence during hospitalization have received extensive attention. Anticoagulant prophylaxis is currently considered as one of the most effective methods to decrease the risk of lower-extremity DVT.[10] The American College of Chest Physicians Evidence-based Clinical Practice Guidelines recommend that patients undergoing major orthopedic surgery should be administered low-molecular-weight heparin (LMWH) to prevent lower-extremity DVT.[11]

In addition, Kempton et al have shown that the energy of injury in TPFs reasonably predicts the severity of the fracture (the greater the energy of the injury, the more severe the fracture).[12] Wang et al[13] found that patients with ankle fracture due to high-energy injury are more likely to develop thrombosis than patients with non-high-energy injury. Kock et al[14] also proposed that high-energy injury increases the risk for DVT. However, in TPFs, the relationship between the occurrence of thrombus and the energy of injury is still unclear. The main purpose of our study was to investigate the changes in DVT and the relationship between the incidence of DVT during hospitalization and the energy of injury in TPFs.

Materials and Methods

The study was approved by the institutional review board of Xi'an Jiaotong University, and signed informed consent was obtained from each subject. The data of 140 patients who underwent surgery at our trauma center from September 1, 2014, to October 1, 2017, were retrospectively analyzed. The inclusion criteria were as follows: (a) age ≥18 years, (b) fresh TPFs (within 3 weeks of injury) requiring surgical treatment, (c) willingness to receive anticoagulant therapy to prevent DVT and to provide signed informed consent, and (d) availability of preoperative and postoperative ultrasonography results. The exclusion criteria were as follows: (a) late TPFs (injuries lasting for >3 weeks that required surgery), (b) open soft tissue fractures, (c) severe medical conditions that preclude undergoing surgery, (d) poor compliance, and (e) refusal to participate in the study.

We collected the clinical data of 140 patients with TPFs between September 1, 2014, and October 1, 2017. All patients admitted to the hospital were routinely assessed for thromboembolism risk according to the risk assessment profile with thromboembolism scores.[15] A thromboprophylaxis regimen consisting of chemical (LMWH; GlaxoSmithKline Co, Brentford, United Kingdom) and mechanical (pneumatic compression with foot pump; Beijing HONEST Mechanical and Electrical New Technology Co. Ltd, Beijing, China) methods was administered to each patient before and after surgery. The pneumatic compression was stopped if DVT was diagnosed. Low-molecular-weight heparin was applied subcutaneously (4100 U once a day) in all patients during hospitalization. Low-molecular-weight heparin was stopped at least 12 hours before surgery and restarted 12 hours after surgery. All patients who developed proximal DVT were treated with anticoagulation therapy (LMWH, 4100 U every 12 hours) during hospitalization followed by rivaroxaban after discharge (prophylactic dose: 10 mg once a day, therapeutic dose: 20 mg once a day) for 3 months.

To detect DVT preoperatively and postoperatively, we examined both lower extremities using Doppler ultrasonography. The diagnosis of DVT was made according to the criteria of Dauzat et al.[16] The study of Lapidus et al indicated that ultrasonography has high sensitivity and specificity in detecting lower-extremity DVTs.[17] Deep vein thrombosis were classified into 3 types: central (femoral and iliac veins), peripheral (calf muscle, fibular, and anterior/posterior tibial veins), and mixed (popliteal vein; a combination of central and peripheral DVTs). When a central or mixed DVT was detected on ultrasonography, an inferior vena cava filter was inserted to prevent fatal pulmonary embolism, followed by orthopedic surgery.

For the assessment of the initial injury, planning management, and prediction of prognosis, orthopedic surgeons widely use Schatzker's classification system, which divides TPFs into 6 types.[18] Each increasing numeric category indicates an increased level of energy imparted to bone, thereby reflecting increased fracture severity.[19] According to Schatzker's classification system, the patients were divided into 2 groups: low-energy group (type I-III) and high-energy group (type IV-VI).

Statistical Analysis

The Statistical Package for Social Sciences software version 19 (IBM, Chicago, Illinois) was used. Data are presented as means and standard deviations, unless otherwise specified. The data were assessed for normal distribution. An independent-sample t test was conducted for continuous variables, and the χ^2 test was performed for categorical variables. Values of $P < .05$ were considered significant.

Results

A total of 140 patients with TPFs were included (Table 1). The median age was 48 (range 19-79) years, and 85 patients (60.7%) were men and 55 (39.3%) were women. There were 63 patients in the low-energy group and 77 patients in the high-energy group. Of the 140 patients, 11 fell from a height of ≥2

Table 1. Patient Characteristics According to Injury Energy Classification of Tibial Plateau Fractures.

	Low Energy	High Energy	Overall	*P*
Number of patients	63	77	140	
Age (years)	49.48 ± 13.58	45.57 ± 12.12	47.33 ± 12.90	.075
Sex				
Female	29	26	55	.139
Male	34	51	85	
BMI (kg/m^2)	22.88 ± 3.85	22.89 ± 3.71	22.88 ± 3.76	.986
Medical morbidity				
Hypertension, n (%)	9 (14.29)	8 (10.39)	17	.483
Diabetes, n (%)	3 (4.76)	3 (3.90)	6	.801
Coronary heart disease, n (%)	10 (15.87)	11 (14.29)	21	.794
Malignancies, n (%)	2 (3.17)	1 (1.30)	3 (2.14)	.588
RAPT score	7.59 ± 2.75	7.90 ± 2.85	7.76 ± 2.80	.518
Duration of surgery (min)	131.83 ± 69.05	145.47 ± 86.27	139.33 ±7 9.01	.311
Time in hospital (days)	9.56 ± 2.54	11.94 ± 4.18	10.86 ± 3.72	<.001
Mechanisms				
Fall injury (≥2 m)	3	8	11	
Traffic accident injury	23	37	60	.103
Other causes of injury	37	32	69	
ASA classification				
1	22	26	48	.577
2	35	47	82	
3	6	4	10	
Blood loss during the operation (mL)	129.68 ± 142.14	208.96 ± 224.43	173.29 ± 195.24	.016
Liquid infusion (mL)	1892.06 ± 648.65	1953.25 ± 671.91	1925.71 ± 659.89	.587
Duration of tourniquet (min)	86.43 ± 45.64	93.38 ± 39.72	90.25 ± 42.47	.337
Serum markers				
D-dimer at admission (mg/L)	8.07 ± 12.16	11.97 ± 24.37	10.22 ± 19.86	.250
D-dimer before the operation (mg/L)	1.21 ± 2.32	2.39 ± 3.38	1.86 ± 3.00	.02
D-dimer at 1 day after the operation (mg/L)	4.10 ± 4.54	5.26 ± 5.25	4.74 ± 4.96	.171
Bone grafting during surgery	43	49	92	.567

Abbreviations: ASA, American Society of Anesthesiologists physical status; BMI, body mass index; RAPT, risk assessment profile for thromboembolism.

m, including 8 in high-energy group; 60 were injured in traffic accidents, including 37 in high-energy group; and 69 had other causes of injury, including 32 in high-energy group. All patients underwent surgery, and 92 patients underwent bone graft surgery. The average time interval between fracture and operation and between operation and discharge was 7.64 ± 4.62 and 5.46 ± 2.26 days, respectively. None of the patients had pulmonary embolism and abnormal bleeding events associated with lower-extremity DVT. In addition, we found no significant differences in age (P = .075), sex (P = .139), hypertension (P = .483), diabetes (P = .801), coronary heart disease (P = .794), duration of surgery (P = .311), days between fracture and operation (P = .331), American Society of Anesthesiologists physical status classification (P = .577), cause of injury (P = .103), bone grafting during surgery (P = .567), and other factors between patients in the low-energy group and those in the high-energy group. However, patients in the high-energy group had a greater number of days from operation to discharge than those in the low-energy group (P = .016). The amount of blood loss during surgery (P = .016) and preoperative D-dimer level (P = .02) also showed differences between the high-energy group and the low-energy group.

Preoperative DVT in the Low-Energy and High-Energy Groups

A total of 140 patients underwent ultrasonography of both lower extremities before surgery (Table 2). The incidence rate of DVT was 36.43% (51/140) in patients with TPFs. We analyzed each type of TPF and found that the DVT incidence was 31.75% (20/63) in the low-energy group and 40.26% (31/77) in the high-energy group. Further, among the 51 (36.43%) DVT cases, 2 (1.43%) were central DVTs, 4 (2.86%) were mixed DVTs, and the remaining 45 (32.14%) were peripheral DVTs. It is worth mentioning that of the 51 patients with TPFs with DVT, 6 (11.76%) had DVT in both lower limbs. More importantly, we found that the high-energy group had a slightly higher incidence rate of DVT than the low-energy group. However, statistical analysis showed no significant difference between the 2 groups (P = .298).

Postoperative DVT in the Low-Energy and High-Energy Groups

A total of 140 patients underwent ultrasonography of both lower extremities after surgery (Table 3). The incidence rate

Table 2. Preoperative Deep Vein Thrombosis in the Low-Energy and High-Energy Groups.

	No Thrombosis	Thrombosis	Overall	Incidence Rate (%)	*P*
Number	89	51	140	36.43	
Types					
I	15	8	23	34.78	
II	11	5	16	31.25	
III	17	7	24	29.17	
IV	18	9	27	33.33	
V	16	13	29	44.83	
VI	12	9	21	42.86	.298
I-III (low energy)	43	20	63	31.75	
IV-VI (high energy)	46	31	77	40.26	

Table 3. Postoperative Deep Vein Thrombosis in the Low-Energy and High-Energy Groups.

	No Thrombosis	Thrombosis	Overall	Incidence Rate (%)	*P*
Number	75	65	140	46.43	
Types					
I	13	10	23	43.48	
II	9	7	16	43.75	
III	13	11	24	45.83	
IV	14	13	27	48.15	
V	14	15	29	51.72	
VI	12	9	21	42.86	.785
I-III (low energy)	35	28	63	44.44	
IV-VI (high energy)	40	37	77	48.05	

of DVT was 46.43% (65/140) in patients with TPFs. We analyzed each type of TPF and found that the DVT rate was 44.44% (28/63) in the low-energy group and 48.05% (37/77) in the high-energy group. Further, among the 65 (46.43%) DVT cases, 1 (0.71%) was a central DVT, 2 (1.43%) were mixed DVTs, and the remaining 62 (44.29%) were peripheral DVTs. It is worth mentioning that of the 65 patients with TPFs with DVT, 10 (15.38%) had DVT in both lower extremities. More importantly, we found that the high-energy group had a slightly higher incidence rate of DVT than the low-energy group. However, statistical analysis showed no significant difference between the 2 groups ($P = .785$).

Dynamic Changes of DVT Between Preoperatively and Postoperatively

We investigated the incidence of DVT in 140 patients with TPFs from the preoperative to postoperative periods and found changes in DVTs in 45 patients (32.14%) but not in 95 patients (67.86%). Among them, 29 new thrombi were detected and 16 preoperative thrombi disappeared postoperatively. Among the 29 new thrombi, 14 (48.28%) were in the high-energy group and 15 (51.72%) were in the low-energy group. Among the 16 thrombi that disappeared, 9 (56.25%) were in the high-energy group and 7 (43.75%) were in the low-energy group (Figure 1). In addition, the 29 new thrombi were all peripheral DVTs. The 16 thrombi that disappeared included 13 peripheral DVTs, 1 central DVT, and 2 mixed DVTs (Figure 1).

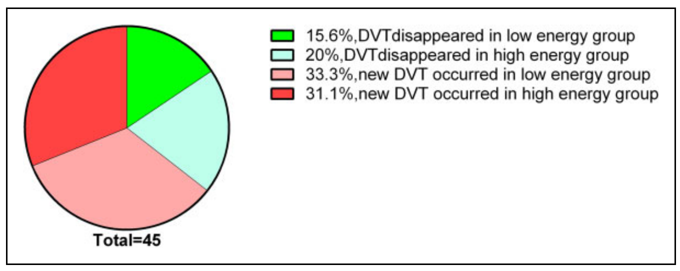

Figure 1. Dynamic changes of deep vein thrombosis from the preoperative to postoperative periods.

Discussion

We retrospectively investigated the changes in DVT and the relationship between the incidence of DVT during hospitalization and the energy of injury in TPFs. We found that the incidence rate of DVT in TPFs was 36.43% and 46.43% preoperatively and postoperatively, respectively. Our results also showed that most of the preoperative and postoperative thrombi were peripheral DVTs. Most previous studies[20-23] only focused on symptomatic VTE or did not investigate distal DVTs. Wang et al[7] reported that the incidence rate of DVT in TPFs was 23.9% and 45.3% preoperatively and postoperatively, respectively. With respect to the incidence of DVT, our findings are similar to those of Wang et al. However, Wang et al did not discuss the occurrence of thrombus in TPFs from the perspective of the energy of injury. Our study is the first to analyze the occurrence of thrombus in TPFs from this perspective.

It is generally believed that high-energy damage can cause a systemic body stress response resulting in a hypercoagulable state and damage to the intima of the blood vessels, thereby increasing the risk of DVT. Previous studies[13,14,24-26] have also shown that high-energy injury can lead to an increased incidence of lower-extremity DVT in patients with pelvic-acetabular, hip, and spine fractures. However, our statistical analysis showed no significant differences in preoperative or postoperative DVT between the high-energy group and the low-energy group of patients with TPFs. We attributed this result to the following reasons: (a) The destructive effect of TPFs is usually rarely transmitted to above the knee joint; thus, there is less damage to the proximal blood vessel and surrounding soft tissues. (b) Muscle activity around and below the knee joint is limited after TPFs; however, proximal muscles such as the quadriceps can undergo contraction training, which accelerates venous return. (c) All patients were restricted from physical activity and drug intake, had swelling, and received pain relief for swollen limbs, all of which had a certain effect on the thrombus, in addition to the possibility of reducing the incidence of thrombosis in both the low-energy group and the high-energy group. (d) Age was found to be an essential risk factor by Makhdom et al and Goel et al for DVT in patients with lower-extremity fractures.[27,28] Shibuya et al[29] found that the average age of patients with a DVT was 51 years and the average age of those without a DVT was 43 years. In our study, the average age of 140 patients was 47.33 $\pm$ 12.90 years. We considered that the difference in DVT between the high-energy and low-energy groups may not be too obvious in younger patients. (e) Thrombosis and injury energy may be related; however, no statistical difference was noted in our study. Nevertheless, this does not mean that the result is meaningless. Instead, it may be related to the composition of the present study population.

Although we did not find a correlation between the energy of TPF injury and thrombosis, we found 3 risk factors according to differences between the high-energy and low-energy groups. The number of days between admission and discharge, blood loss during surgery, and preoperative D-dimer level showed differences between the 2 groups, which may be because the patients in the high-energy group had complex fracture types, massive surgical trauma, and longer postoperative recovery. Niikura et al[30] concluded that D-dimer level can be used as a VTE screening tool in patients with fractures caused by high-energy injuries, which our results also confirmed.

In addition, we investigated the dynamic changes of DVT from the preoperative to postoperative periods in patients with TPFs. Although radical thrombus prophylaxis and treatment was performed in patients with TPFs, we found that new DVTs occurred in 33.3% of the low-energy group and 31.1% of the high-energy group. Conversely, DVT disappeared in 15.6% of the low-energy group and in 20% of the high-energy group. Recent data arising from registries and nonrandomized studies have suggested that most distal DVTs do not extend to the proximal veins and have an uneventful follow-up when left untreated.[31] This is also supported by the fact that most high-energy and low-energy TPFs are concentrated in the distal part of the calf and proximal DVT rarely occurs. Although all thrombus changes occurred in peripheral DVTs in this study, the overall incidence of DVT significantly increased, especially in the high-energy group. Therefore, prophylaxis and treatment for DVT should not be neglected in patients with TPFs, especially in those with high-energy injury, prolonged hospitalization, or high amount of blood loss during the operation.

Our study had several potential limitations. First, the results may be biased by our single-center, retrospective study design. Second, we excluded some patients with incomplete information. In addition, lower-extremity venous ultrasonography was used as the diagnostic standard. Although this modality is noninvasive and reproducible, its diagnostic accuracy is inferior to that of venography, which also had a certain effect on the results. Therefore, a multicenter prospective study with a large sample size will help further explore the role of DVT in TPFs and the relationship between the incidence of DVT during hospitalization and the energy of injury in these fractures.

Conclusions

In conclusion, the incidence of DVT in TPFs is high during hospitalization; however, most thrombi are localized distal to the knee. Although the incidence of DVTs in patients with TPFs is not significantly different between high-energy and low-energy injuries, the occurrence of DVT should still be carefully monitored.

Declaration of Conflicting Interests

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