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*Article*

# Assessing Effectiveness and Compliance Barriers of Intermittent Pneumatic Compression Devices in Preventing Venous Thromboembolism After Femoral Fracture Surgery

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**Abstract**

**Aims/Background**: Venous thromboembolism (VTE) is a frequent complication following femoral fracture surgery. While intermittent pneumatic compression (IPC) devices serve as an effective mechanical prophylaxis, patient compliance is often suboptimal. This study aimed to investigate the effectiveness of IPC in preventing VTE after femoral fracture surgery and to analyse the key factors influencing patient compliance. **Methods**: This retrospective study included 213 patients with femoral fractures who underwent surgical treatment at Ningbo No.6 Hospital between December 2021 and December 2024. Based on postoperative IPC device usage records from medical charts, patients were divided into a good compliance group (n = 51) and a compliance barrier group (n = 162). Postoperative coagulation parameters [prothrombin time (PT), activated partial thromboplastin time (APTT), thrombin time (TT), fibrinogen (FIB), and D-dimer (D-D)], VTE incidence at 5 days postoperatively, and the length of hospital stay were systematically collected and compared between the two groups. A self-designed questionnaire was used to assess factors influencing IPC compliance barriers. **Results**: Among the 213 included patients who underwent femoral fracture surgery, the incidence of postoperative IPC device compliance barriers was 76.06% (162/213). At 5 days postoperatively, significant differences were observed in all coagulation parameters between the two groups. Specifically, the good compliance group had significantly higher PT, APTT, and TT levels compared with the compliance barrier group (all $p < 0.05$). In contrast, FIB and D-D levels were significantly lower in the good compliance group (all $p < 0.05$). Regarding clinical outcomes, the incidence of VTE in the good compliance group was 19.61%, significantly lower than the 38.27% in the compliance barrier group ($p = 0.014$). Furthermore, the median length of hospital stay in the good compliance group [8.00 (8.00, 17.00) days] was significantly shorter than that in the compliance barrier group [12.00 (9.00, 17.00) days] ($p = 0.009$). The survey results of 162 patients in the compliance barrier group showed that the main obstacles affecting IPC device application compliance were concentrated at the level of patient cognition, experience, and perception. A smaller proportion of patients had concerns about out-of-pocket costs. Healthcare-related factors and device-related factors had a relatively lower impact. **Conclusion**: The use of IPC after femoral fracture surgery can effectively improve the hypercoagulable state, reduce the incidence of VTE, and shorten hospitalization. However, patient compliance is generally low, primarily influenced by insufficient cognition, poor user experience, and low perceived value of treatment. It is recommended to improve compliance through systematic health education, optimizing comfort and convenience of use, strengthening healthcare follow-up and feedback, and ensuring device maintenance and configuration.

**Keywords:** intermittent pneumatic compression device; femoral fracture; venous thromboembolism; patient compliance; barriers

## 1. Introduction

Femoral fractures usually result from high-energy trauma in which a strong external force acts directly or indirectly on the femur, characterized by severe localized pain and abnormal limb movement function [1]. Common approaches for managing femoral fractures include both conservative treatment and surgical intervention. Conservative treatment is often associated with a long cycle, delayed functional recovery, and a high risk of adverse reactions [2]. In contrast, surgical treatment focuses on anatomical reduction and stable fixation of the fracture, which supports early mobilization and promotes the repair process [3,4]. Venous thromboembolism (VTE) is one of the most significant and life-threatening complications in fracture patients. If not effectively controlled and appropriately managed, VTE can lead to long-term disability or even death; therefore, thromboprophylaxis is a critical component of perioperative care in patients with femoral fractures [5,6]. The 2024 "international consensus statement: prevention and management of venous thromboembolism (guidelines based on scientific evidence)" recommends the use of pharmacological prophylaxis (traditional anticoagulant drugs), such as low-molecular-weight heparin (LMWH), combined with mechanical measures during the perioperative period of surgical patients. It further suggests extending the duration of prophylaxis until the patient has regained full ambulation to minimize the risk of postoperative thromboembolic events [7].

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Intermittent pneumatic compression (IPC) devices generate periodic gradient pressure to the lower limbs and are widely used as a mechanical prophylaxis measure for VTE prevention in clinical practice, showing good thromboprophylaxis effects, especially in postoperative patients [8–10]. A growing body of evidence has explored the clinical significance of IPC. Meta-analyses by Fan C *et al*. [11] and Kim NY *et al*. [12] indicate that adjunctive use of IPC devices with pharmacological anticoagulants can further enhance VTE prevention in surgical patients. The study by Kakkos S *et al*. [13] emphasized that combining IPC devices with pharmacological prophylaxis significantly reduced the risk of pulmonary embolism (PE) and deep vein thrombosis (DVT), with stronger evidence reinforcing its impact on DVT prevention. In orthopedic patients, Li C *et al*. [14] reported that in elderly patients with femoral neck fractures, the combination of IPC devices and LMWH could effectively reduce postoperative DVT, improve lower limb blood flow, alleviate vascular inflammation, and enhance treatment safety.

Despite these promising results, the adjunctive value of IPC devices presents several concerns. For example, Duval C *et al*. [15] believed that although IPC devices may provide additional benefit when used in combination with pharmacological prophylaxis, the overall quality of related evidence remains limited, and further high-quality studies are warranted. In critically ill patients, Wang Y *et al*. [16] found that IPC devices were more effective than graduated compression stockings (GCS) in reducing VTE incidence and demonstrated comparable efficacy to LMWH; however, they did not show significant advantages as an adjunctive thromboprophylaxis measure.

Based on the above analysis, although several studies have focused on the efficacy of IPC devices in preventing VTE, the findings remain inconsistent, and most investigations emphasize short-term outcomes. Notably, the mechanical anticoagulant effect of IPC subsides gradually, typically within approximately 10 minutes after discontinuation. Hence, continuous application is generally recommended in clinical practice. However, persistent use is challenging clinically. Patients' adherence is generally suboptimal, and compliance tends to decline over time, particularly during the postoperative recovery period. Despite this, limited investigation has specifically assessed adherence patterns in high-risk populations such as those undergoing surgery for femoral fractures. Furthermore, the underlying barriers that affect compliance in such a cohort have not been thoroughly explored. Therefore, this study aims to evaluate the actual, real-world efficacy of IPC devices in preventing VTE in patients after femoral fracture surgery through a retrospective analysis.

Furthermore, the study intends to identify key factors affecting patient compliance, aiming to provide strategies for improving quality, consistency, and long-term implementation of postoperative VTE prevention and control measures in this vulnerable population.

## 2. Methods

### *2.1 Study Subjects*

This study enrolled 213 patients with femoral fractures who underwent surgical treatment at Ningbo No.6 Hospital between December 2021 and December 2024. Based on IPC device application records, they were divided into a good compliance group (n = 51) and a compliance barrier group (n = 162).

Inclusion criteria for study participant selection were as follows: patients with (1) unilateral femoral fracture confirmed by imaging examination and received surgical treatment; (2) age $\geq$18 years; (3) independent mobility before injury; (4) preoperative lower limb vascular ultrasound confirming absence of DVT or thrombophlebitis; (5) clear consciousness and ability to communicate effectively; and (6) availability of complete clinical data for analysis.

Exclusion criteria included: (1) severe cardiac, pulmonary, hepatic, or renal insufficiency, uncontrolled hypertension, congestive heart failure, pulmonary edema, or other unstable circulatory system diseases; (2) known coagulation dysfunction or recent use of other systemic anticoagulant therapy; (3) severe lower limb arteriosclerosis, ischemic vascular disease, or poor local skin condition (e.g., dermatitis, ulcer, gangrene, infection, recent skin grafting); (4) pathological or old fracture, or combined with malignant tumors and severe immune system diseases; (5) known psychiatric disorder or cognitive dysfunction; and (6) lactating or pregnant women.

### *2.2 Treatment Plan*

A retrospective analysis of the treatment course was conducted for all 213 postoperative patients. As part of the routine clinical care, all patients received standard pharmacological thromboprophylaxis and were advised to use an IPC device. Based on quantitative analysis of IPC device application records documented in nursing charts, patients were divided into two groups: a good compliance group (n = 51) included those who used the IPC device for $\geq$80% of the prescribed daily duration (defined as $\geq$64 minutes out of the recommended 80 minutes per day); a compliance barrier group (n = 162) included patients who used the device for $<$80% of the recommended daily duration or declined its use entirely. The good compliance group (n = 51) consisted of patients who achieved this 64-minute threshold, and all patients in this group actually completed the full prescribed 80 minutes of daily IPC application. The compliance barrier group (n = 162) included patients with daily IPC usage of less than 80% of the recommended duration, as well as those who refused IPC application entirely. In essence, this grouping approach enables a comparative analysis between patients with full IPC adherence and those with inadequate or no IPC use.

Pharmacological prophylaxis: all study participants received low-molecular-weight heparin (Nadroparin Calcium) according to a standardized protocol. A preoperative dose of 2500 IU was administered subcutaneously 1–2 hours before surgery. Starting 12 hours after surgery or after assessing actual drainage output and coagulation function, patients received a daily subcutaneous injection of low-molecular-weight heparin (Nadroparin Calcium), with a single dose of 4000–4100 IU. Anticoagulation treatment was continued until postoperative day 14 or until the patient achieved full ambulation, effectively covering the peak high-risk period for VTE.

IPC device prophylaxis: mechanical prophylaxis was delivered using the Intermittent Pulse Pressure Anti-Thrombosis System (Model MHH800, Sijia Electric, Shenzhen, China). Treatment commenced on the day after removal of the surgical drain. Patients were placed in the supine position, and appropriately sized compression sleeves were applied to the lower limbs. The device was set to deliver gradient compression from the sole towards the proximal thigh at a pressure range of 35–45 mmHg. Each compression cycle consisted of 5–10 seconds of inflation followed by 30–60 seconds of deflation. In practice, IPC treatment was administered twice daily, with each session lasting 40 minutes (i.e., a total of 80 minutes per day). This regimen continued until postoperative day 14 or until full ambulation was achieved.

Early functional exercise protocol: all patients participated in a standardized, phased rehabilitation protocol supervised by the orthopedic team, with adherence documented in nursing records. Phase I (Postoperative day 0–1): after recovery from anesthesia, patients began ankle pump exercises and quadriceps isometric contractions. Phase II (Postoperative days 2–3, as tolerated): assisted active range-of-motion exercises for the knee and hip were initiated, progressing to sitting at the bedside with support. Phase III (Typically commencing on Postoperative day 4): based on fracture stability and surgical assessment, patients started standing and partial weight-bearing ambulation using a walker or crutches. The clinical goal was gradual progression to full weight-bearing as recovery permitted.

The pharmacological prophylaxis protocol (LMWH dosing and duration) and the rehabilitation guidance were standardized and uniformly applied across all 213 patients.

### *2.3 Data Collection*

In this study, data were collected from the hospital medical record system. Extracted variables included (1) Baseline characteristics: baseline data included age, gender, body mass index (BMI), smoking status, marital status, education level, monthly income, and type of medical insurance. Clinical parameters included cause of injury and fracture characteristics (type and anatomical location). Surgical data included time from injury to surgery, surgical method, operative duration, intraoperative blood loss, and intraoperative use of IPC; (2) Coagulation function parameters: coagulation function was evaluated using prothrombin time (PT), activated partial thromboplastin time (APTT), thrombin time (TT), fibrinogen (FIB), and D-dimer (D-D) levels. These measurements were recorded on postoperative day 1 and day 5. These assays were performed using an automated coagulation analyzer (CS-5100, Sysmex, Kobe, Japan); (3) Clinical outcome indicators: primary clinical outcomes included the incidence of VTE within 5 days postoperatively and length of hospital stay. In our institutional treatment protocol, postoperative day 5 is the standard time point for routine vascular ultrasound assessment.

VTE included both DVT and PE. DVT was diagnosed by lower limb vascular color Doppler ultrasonography, characterized by the presence of non-compressible solid low-echo within the vascular lumen. Particular attention was given to the deep veins of the thigh (common femoral, superficial femoral, deep femoral veins, popliteal vein) and calf (posterior tibial and peroneal veins). PE was diagnosed using computed tomography (CT) pulmonary angiography, characterized by filling defects in the pulmonary arteries; (4) Factors influencing IPC compliance: barriers to IPC compliance were assessed using a self-designed questionnaire administered during a follow-up visit scheduled between 4 and 6 weeks postoperatively. This timing allowed patients to reflect on their entire in-hospital IPC experience while minimizing recall bias. The questionnaire covers multiple dimensions, including understanding of VTE and IPC, device-related discomfort, user experience and perceived value, healthcare provider-related factors, device and environmental factors, and social/family support. In this retrospective analysis, questionnaire responses were linked to the documented inpatient IPC usage records to assess the association between observed barriers and actual compliance records.

### *2.4 Statistical Analysis*

Statistical analyses were performed using SPSS 26.0 software (IBM SPSS Corp., Armonk, NY, USA). Categorical variables were presented as frequencies and percentages [$n$ (%)], and comparisons between groups were assessed using the Chi-square test or Fisher's exact test, as appropriate. Continuous variables were assessed for normality using the Shapiro–Wilk test. Normally distributed variables were expressed as mean $\pm$ standard deviation and were compared using the independent samples $t$-test. Non-normally distributed variables were expressed as median with interquartile range [M (P25, P75)] and were analyzed using the Mann–Whitney U test. For within-group comparisons, normally distributed variables were analyzed using paired $t$-tests, and non-normally distributed variables were analyzed using Wilcoxon signed–rank tests. All statistical tests were two-sided, and a $p$-value $< 0.05$ was considered statistically significant.

**Table 1. Comparison of baseline characteristics between the good compliance and compliance barrier groups of patients with femoral fractures.**

| Variable | Good compliance group ($n$ = 51) | Compliance barrier group ($n$ = 162) | $t/Z/\chi^2$ | $p$-value |
|---|---|---|---|---|
| Age (years) | 60.90 ± 15.49 | 58.22 ± 15.46 | 1.079 | 0.282 |
| Gender [$n$ (%)] | | | 0.890 | 0.346 |
| Male | 29 (56.86) | 104 (64.20) | | |
| Female | 22 (43.14) | 58 (35.80) | | |
| BMI (kg/m$^2$) | 24.05 ± 2.30 | 24.05 ± 2.37 | –0.014 | 0.989 |
| Current smoker [$n$ (%)] | 18 (35.29) | 48 (29.63) | 0.582 | 0.446 |
| Marital status [$n$ (%)] | | | 0.851 | 0.837 |
| Divorced | 0 (0.00) | 2 (1.23) | | |
| Widowed | 1 (1.96) | 5 (3.09) | | |
| Unmarried | 2 (3.92) | 7 (4.32) | | |
| Married | 48 (94.12) | 148 (91.36) | | |
| Medical insurance | | | 0.303 | 0.582 |
| Urban employee basic medical insurance | 23 (45.10) | 66 (40.74) | | |
| Fully self-paid | 28 (54.90) | 96 (59.26) | | |
| Education level [$n$ (%)] | | | 1.855 | 0.173 |
| Primary school or below | 25 (49.02) | 62 (38.27) | | |
| Junior high school or above | 26 (50.98) | 100 (61.73) | | |
| Cause of injury [$n$ (%)] | | | | 0.346 |
| Fall | 31 (60.78) | 73 (45.06) | | |
| Traffic accident | 12 (23.53) | 47 (29.01) | | |
| Fall from height | 6 (11.76) | 34 (20.99) | | |
| Heavy object compression | 2 (3.92) | 7 (4.32) | | |
| Others | 0 (0.00) | 1 (0.62) | | |
| Monthly income [$n$ (%)] | | | 5.528 | 0.237 |
| <2000 RMB | 5 (9.80) | 5 (3.09) | | |
| 2000–4000 RMB | 16 (31.37) | 55 (33.95) | | |
| 4001–6000 RMB | 12 (23.53) | 53 (32.72) | | |
| 6001–8000 RMB | 14 (27.45) | 41 (25.31) | | |
| >8000 RMB | 4 (7.84) | 8 (4.94) | | |
| Fracture type [$n$ (%)] | | | 0.074 | 0.786 |
| Transverse fracture | 20 (39.22) | 67 (41.36) | | |
| Non-transverse fracture | 31 (60.78) | 95 (58.64) | | |
| Fracture site [$n$ (%)] | | | 1.337 | 0.720 |
| Femoral neck | 6 (11.76) | 30 (18.52) | | |
| Intertrochanteric | 24 (47.06) | 71 (43.83) | | |
| Femoral shaft | 10 (19.61) | 27 (16.61) | | |
| Femoral condyle | 11 (21.57) | 34 (20.99) | | |
| Time from injury to surgery (h) | 23.00 (16.00, 30.00) | 20.00 (12.75, 29.00) | –1.502 | 0.129 |
| Surgical method [$n$ (%)] | | | 0.034 | 0.853 |
| Internal fixation surgery | 25 (49.02) | 77 (47.53) | | |
| Arthroplasty | 26 (50.98) | 85 (52.47) | | |
| Operative time (min) | 198.00 (132.00, 255.00) | 171.50 (118.75, 237.25) | –1.208 | 0.227 |
| Intraoperative blood loss [$n$ (%)] | | | 0.045 | 0.832 |
| <200 mL | 30 (58.82) | 98 (60.49) | | |
| ≥200 mL | 21 (41.18) | 64 (39.51) | | |
| Intraoperative IPC use [$n$ (%)] | | | 0.285 | 0.593 |
| Yes | 23 (45.10) | 80 (49.38) | | |
| No | 28 (54.90) | 82 (50.62) | | |

BMI, body mass index; IPC, intermittent pneumatic compression. 1 RMB = 0.146 USD.

## 3. Results

### *3.1 Incidence of Postoperative IPC Device Compliance Barriers in Femoral Fracture Patients*

Among the included 213 patients who underwent femoral fracture surgery, 162 participants showed barriers to IPC use, corresponding to a postoperative compliance barrier rate of 76.06%.

**Table 2. Comparison of coagulation function between the good compliance and compliance barrier groups.**

| Variable | | Good compliance group ($n$ = 51) | Compliance barrier group ($n$ = 162) | $t/Z$ | $p$-value |
|---|---|---|---|---|---|
| PT (s) | Postoperative day 1 | 11.77 ± 1.00 | 12.06 ± 1.36 | –1.418 | 0.158 |
| | Postoperative day 5 | 12.91 ± 1.55 | 12.21 ± 1.35 | 3.129 | 0.002 |
| | $t$ | –4.430 | –0.986 | | |
| | $p$ | <0.001 | 0.325 | | |
| APTT (s) | Postoperative day 1 | 28.03 ± 3.59 | 29.66 ± 6.65 | –1.680 | 0.094 |
| | Postoperative day 5 | 33.55 ± 4.31 | 30.73 ± 4.43 | 3.997 | <0.001 |
| | $t$ | –7.033 | –1.697 | | |
| | $p$ | <0.001 | 0.091 | | |
| TT (s) | Postoperative day 1 | 17.75 ± 1.89 | 17.35 ± 1.34 | 1.677 | 0.095 |
| | Postoperative day 5 | 17.96 ± 1.73 | 16.96 ± 2.71 | 2.479 | 0.014 |
| | $t$ | –0.585 | 1.641 | | |
| | $p$ | 0.560 | 0.102 | | |
| FIB (g/L) | Postoperative day 1 | 3.44 (2.52, 4.69) | 3.98 (3.05, 4.79) | –1.495 | 0.135 |
| | Postoperative day 5 | 4.30 (3.13, 5.23) | 4.90 (4.27, 5.57) | –2.984 | 0.003 |
| | $Z$ | –2.487 | –7.015 | | |
| | $p$ | 0.013 | <0.001 | | |
| D-D (ng/mL) | Postoperative day 1 | 5490.00 (1850.00, 15,910.00) | 5950.00 (2805.00, 11,315.00) | –0.323 | 0.747 |
| | Postoperative day 5 | 3600.00 (2650.00, 5410.00) | 4440.00 (2962.50, 6705.50) | –2.332 | 0.020 |
| | $Z$ | –1.807 | –2.561 | | |
| | $p$ | 0.071 | 0.010 | | |

PT, prothrombin time; APTT, activated partial thromboplastin time; TT, thrombin time; FIB, fibrinogen; D-D, D-dimer.

**Table 3. Comparison of clinical outcomes between the good compliance and compliance barrier groups.**

| Variable | | Good compliance group ($n$ = 51) | Compliance barrier group ($n$ = 162) | $\chi^2/Z$ | $p$-value |
|---|---|---|---|---|---|
| VTE [$n$ (%)] | Yes | 10 (19.61) | 62 (38.27) | 6.038 | 0.014 |
| | No | 41 (80.39) | 100 (61.73) | | |
| Length of hospital stay (days) | | 8.00 (8.00, 17.00) | 12.00 (9.00, 17.00) | –2.622 | 0.009 |

VTE, venous thromboembolism.

### *3.2 Comparison of Baseline Characteristics Between the Two Groups*

We compared the baseline characteristics between patients in the good compliance group ($n$ = 51) and those in the compliance barrier group ($n$ = 162). There were no statistically significant differences between the two groups in age, gender, BMI, smoking status, marital status, type of medical insurance, education level, cause of injury, monthly income, fracture characteristics (type and site), time from injury to surgery, surgical method, operative duration, intraoperative blood loss, or intraoperative IPC use (all $p >$ 0.05). These results suggest that the two groups were comparable at baseline (Table 1).

### *3.3 Comparison of Coagulation Function Between the Two Groups*

On postoperative day 1, no statistically significant differences were found between the good compliance group and the compliance barrier group (all $p > 0.05$) in coagulation parameters, including PT, APTT, TT, FIB, and D-D (all $p > 0.05$). However, on postoperative day 5, significant differences were observed in all measured parameters. The good compliance group demonstrated significantly higher PT, APTT, and TT levels compared with the compliance barrier group (all $p < 0.05$). In contrast, FIB and D-D levels were significantly lower in the good compliance group (all $p < 0.05$, Table 2).

### *3.4 Comparison of Clinical Outcomes Between the Two Groups*

Regarding clinical outcomes, the incidence of VTE in the good compliance group was 19.61%, which was significantly lower than the 38.27% found in the compliance barrier group ($p$ = 0.014). Furthermore, patients in the good compliance group had a substantially shorter length of hospital stay, with a median duration of 8.00 (8.00, 17.00) days compared with 12.00 (9.00, 17.00) days in the compliance barrier group ($p$ = 0.009, Table 3).

### *3.5 Evaluation of Factors Influencing Compliance Barriers*

Among 162 patients in the compliance barrier group, questionnaire-based survey results showed that obstacles to IPC device application were linked to patient cognition, perception, and personal experience. Among these, insufficient cognition was the most prominent issue. A total of

**Table 4. Evaluation of factors influencing compliance barriers.**

| Main content | Item | Yes [*n* (%)] | No [*n* (%)] |
|---|---|---|---|
| Insufficient cognition of disease and IPC device | Before treatment, did you not fully understand the serious risk of postoperative VTE? | 113 (69.8) | 49 (30.2) |
| | Were you not very clear about the specific role of the IPC device? | 110 (67.9) | 52 (32.1) |
| | After you could ambulate, did you feel the IPC device was unnecessary? | 126 (77.8) | 36 (22.2) |
| Device-related discomfort | Did you feel the IPC device restricted your movement or getting out of bed? | 110 (67.9) | 52 (32.1) |
| | Were you unwilling to use it due to discomfort like leg pain, numbness, or overheating? | 95 (58.6) | 67 (41.4) |
| | Did the operating noise or sensation of the IPC device affect your rest? | 70 (43.2) | 92 (56.8) |
| | Did you feel the IPC device pressure was too tight, too loose, or the sleeve easily came off? | 65 (40.1) | 97 (59.9) |
| | Were you unwilling to use it due to concerns about or actual skin problems? | 45 (27.8) | 117 (72.2) |
| Poor user experience and low perceived value | Did you feel no obvious effect or benefit after use? | 85 (52.5) | 77 (47.5) |
| | Did you think IPC was no longer needed after receiving anticoagulant medication? | 90 (55.6) | 72 (44.4) |
| | Did you find the process of donning and connecting the IPC device very troublesome? | 75 (46.3) | 87 (53.7) |
| | Were you ever concerned that the IPC leg sleeves were unclean? | 50 (30.9) | 112 (69.1) |
| Healthcare-related factors | Did you feel healthcare staff did not fully explain why the IPC device must be used? | 25 (15.4) | 137 (84.6) |
| | After activity or examination, were you often not reminded to reuse the IPC device? | 20 (12.3) | 142 (87.7) |
| | Did you ever sense that healthcare staff considered this IPC device "optional"? | 18 (11.1) | 144 (88.9) |
| Device and environmental factors | Were you ever unable to use the IPC device because none was available in the ward? | 16 (9.9) | 146 (90.1) |
| | Did you interrupt treatment because the IPC device required plugging in and was inconvenient to move? | 22 (13.6) | 140 (86.4) |
| Social and family factors | Were you concerned about the cost because the IPC device required out-of-pocket payment? | 60 (37.0) | 102 (63.0) |
| | Did your family members also think this IPC device was unnecessary? | 45 (27.8) | 117 (72.2) |

VTE, venous thromboembolism; IPC, intermittent pneumatic compression.

77.8% of patients believed IPC was no longer necessary once they were able to ambulate. Additionally, 69.8% of patients were unaware of the ongoing risk of postoperative VTE, and 67.9% of patients did not clearly understand the preventive role of IPC.

Furthermore, experience-related issues were also common. About 67.9% reported that the device restricted movement, and 58.6% discontinued use due to leg discomfort. Furthermore, 55.6% assumed that anticoagulant medication could replace IPC, and 52.5% felt no obvious benefit from its use. Additionally, financial concerns were reported by 37.0% of patients, particularly about out-of-pocket costs. In contrast, factors related to healthcare staff (11.1%–15.4%) and device-related technical issues (9.9%–13.6%) were found less frequently (Table 4).

## 4. Discussion

This study found a high prevalence of compliance barriers to IPC device use among patients undergoing femoral fracture surgery. Compared with the good compliance group, the compliance barrier group exhibited characteristics consistent with a hypercoagulable state by postoperative day 5. Specifically, they had significantly shorter PT, APTT, and TT, along with substantially higher FIB and D-D levels. These pathophysiological changes were directly associated with poorer clinical outcomes. The incidence of VTE was significantly higher in the compliance barrier group, and their length of hospital stay was considerably longer than that in the good compliance group. Further investigation indicated that non-adherence was primarily driven by patient-related factors. Key contributors included inadequate understanding of postoperative VTE risk and the preventive role of IPC, discomfort during device use, scepticism about its necessity or effectiveness, and reduced vigilance once the patient perceived clinical improvement during hospitalization. Additionally, healthcare system factors and device-related technical concerns appeared to play a comparatively minor role.

This study confirmed that standardized use of IPC in patients after femoral fracture surgery provides clear clinical benefits, including improvement in coagulation parameters, reduction in VTE incidence, and shorter length of hos-

pital stay. These findings are consistent with several previous studies [11–14]. The therapeutic effect of IPC can be explained from both mechanical and biochemical aspects [17–19]. Mechanically, IPC delivers cyclical, gradient pressure to the lower limbs through inflatable sleeves connected to a pump system, stimulating the physiological "muscle pump" function. This process effectively compresses the deep venous lumen, enhances distal to proximal blood flow, and promotes venous return. As a result, venous stasis is alleviated, venous pressure is reduced, and postoperative blood pooling is minimized. The applied external pressure also facilitates interstitial fluid reabsorption into the vascular compartment, contributing to decreased limb edema. Biochemically, the pulsatile shear stress generated by IPC promotes the release of nitric oxide from vascular endothelial cells, promoting vasodilation and improving microcirculatory perfusion. Additionally, IPC enhances endogenous fibrinolytic activity by increasing tissue plasminogen activator (tPA) level while reducing its inhibitors. This shift toward a profibrinolytic state helps limit coagulation factor aggregation and thrombus formation at an early stage. It is worth noting that this study selected the relatively proximate time point of 5 days postoperatively, aiming to more directly examine the association between the intervention (IPC) and early VTE-related outcomes, while minimising the influence of numerous confounding factors such as length of hospital stay, post-discharge conditions, and changes in concomitant medication. Although the risk of VTE persists beyond this period, this study primarily assesses the impact of IPC adherence during the initial high-risk period after surgery.

Within-group comparisons further revealed a differential response between the two groups. In the good compliance group, PT and APTT improved significantly from postoperative day 1 to day 5, suggesting a measurable reduction of the postoperative hypercoagulable state. In contrast, no significant improvement was observed in these parameters in the compliance barrier group. This pattern strongly affirms the biological efficacy of consistent IPC use in ameliorating the early postoperative hypercoagulable state. For some other parameters, such as TT, statistically significant changes were not consistently observed within either group. This likely reflects the complex and dynamic postoperative coagulation milieu, where the strong pro-thrombotic stimulus induced by surgical trauma and tissue injury may counteract or mask subtle improvements from partial IPC use or pharmacological prophylaxis alone. In contrast, the significant changes observed in FIB and D-D within both groups, and the consistent between-group differences at day 5, suggest that these markers may be particularly sensitive for assessing the impact of mechanical prophylaxis during the acute postoperative phase.

In this cohort of patients undergoing femoral fracture surgery, the incidence of IPC compliance barriers reached 76.06%, indicating that non-adherence was common rather than exceptional. The most significant contributing factor was at the patient cognition level. More than two-thirds of patients lacked understanding of the postoperative VTE risk and the working principle of IPC. Particularly noteworthy, 77.8% of patients believed that IPC was unnecessary once they could ambulate, reflecting a misunderstanding that mobility alone eliminates thrombotic risk. This observation highlights a gap in perioperative health education. Addressing this cognitive gap necessitates improved health education methods in clinical practice. Clinicians should explain that ambulation and IPC use are complementary, rather than substitutive, and that early walking does not fully replicate the continuous hemodynamic effects of IPC. Educational materials may benefit from the use of visual aids, simplified diagrams, or short instructional animations. Reinforcing understanding through teach-back methods can further ensure retention. Importantly, education should begin preoperatively and be reiterated postoperatively, particularly at the point when patients resume ambulation, to correct cognitive biases that may arise during recovery.

Experience and perception-related factors also played a crucial role. Discomfort caused by the device (e.g., restricted movement, leg discomfort) and lack of perceived value in treatment effect (e.g., feeling no obvious effect, believing anticoagulants are sufficient) collectively weakened patients' willingness to use the IPC device. These perceptions weaken adherence even when clinical protocols are well established. Addressing this issue suggests improvements in three areas: first, comfort optimization is critical. Selecting appropriately sized, breathable sleeves, protecting pressure-sensitive areas, and adjusting pressure based on patient feedback may reduce intolerance. Second, strengthen the effectiveness of education by visually demonstrating the intervention effects of IPC using charts of the patient's own coagulation parameter changes and clearly explaining its complementary relationship with pharmacological prophylaxis. Third, active communication from nursing staff is critical. Regular assessment of patient comfort, prompt device adjustment, and supportive engagement may enhance adherence and foster a sense of participation in recovery.

Previous studies indicate comparable low adherence rates. Zeng M *et al*. [9] reported that the overall compliance with intermittent pneumatic compression (IPC) therapy was only 29%. Possible reasons include patients or family members not understanding the purpose of treatment, patient intolerance or discomfort during use, and potential adverse reactions at the application site. Reinhard M *et al*. [20] also showed that, during IPC use, local sweating, overheating, restricted movement, and inconvenience in donning and doffing are common issues. Greenall R *et al*. [21] systematically summarized multiple factors affecting IPC compliance, covering patient cognition, physical sensations, healthcare knowledge and behavior, device configuration, and the intensive care environment. Although these findings are consistent with previous studies, this study not only verifies the effect of IPC in femoral frac-

ture patients but also reveals a high compliance barrier rate of 76.06% for the first time and precisely identifies "patient cognitive misconceptions" as the core barrier, providing a direct target for clinical intervention. Notably, although healthcare-related factors (e.g., insufficient education, lack of timely reminders) and device factors (e.g., insufficient quantity, inconvenience for mobility) accounted for a relatively lower proportion of impact in this study, reflecting certain improvements in these areas, continuous optimization is still needed. Future efforts should strengthen healthcare providers' proactive service awareness while further ensuring daily maintenance and rational configuration of devices to systematically improve the clinical compliance of IPC therapy. It is worth noting that there appears to be a discrepancy between our protocol and the patient questionnaire findings: while the protocol specifies the use of IPC until full ambulation is achieved, 77.8% of patients in the Compliance Barrier Group considered IPC "unnecessary once they were able to walk". This suggests that some patients equate "being able to walk" with "no longer being at risk". These findings highlight that ensuring patients understand the underlying rationale is crucial for maintaining treatment adherence.

Furthermore, for patients diagnosed with DVT, management was adjusted according to standard therapeutic protocols. Prophylactic anticoagulation was switched to therapeutic anticoagulation, which included either bridging therapy from low-molecular-weight heparin to warfarin or the use of direct oral anticoagulants. IPC was continued as an adjunctive mechanical measure when not contraindicated. Previous use of IPC did not modify the therapeutic strategy once DVT was confirmed.

This study has several limitations that should be acknowledged. First, as a single-center retrospective study, the data were derived from existing medical records and may be affected by incomplete documentation. Although no significant differences were found in baseline characteristics between the two groups, we acknowledge the high potential for unmeasured confounding factors inherent in observational studies. Compliance behavior is complex and likely influenced by factors not captured in our dataset, such as individual patient motivation, pre-existing health beliefs, quality of nurse-patient interactions, postoperative pain levels, or family involvement. These factors may have influenced both adherence and clinical outcomes. Furthermore, all patients were treated within the same medical institution, where nursing protocols, device models, and patient demographics were relatively uniform. While this consistency reduces internal variability, it may limit the external generalizability of the findings. Finally, although the compliance questionnaire was developed based on clinical experience and relevant literature to ensure content breadth, it did not undergo formal psychometric validation or reliability testing. Future multi-center, prospective studies incorporating validated assessment tools are needed to confirm and extend these findings.

## 5. Conclusion

In summary, IPC use following femoral fracture surgery was associated with significant clinical benefits, such as improvement in postoperative hypercoagulable state, a significant reduction in VTE incidence, and shorter hospital stays. These results reinforce its role as an important component of perioperative thromboprophylaxis. However, low adherence to IPC remains a critical barrier in routine clinical practice. Insufficient cognition of VTE risk and device function, uncomfortable experience during use, and underestimation of treatment value are key links hindering the standardized use of IPC devices. These factors collectively undermine the consistent implementation of an otherwise effective intervention. Therefore, it is recommended to implement planned health education during the perioperative period, strive to improve the comfort and convenience of IPC device use for patients, strengthen proactive follow-up and timely feedback from healthcare providers, and ensure proper maintenance and rational configuration of related equipment.

## Key Points

• The incidence of compliance barriers to IPC device use in patients after femoral fracture surgery was as high as 76.06% (162/213).

• Standardized use of the IPC device effectively improved the hypercoagulable state (increased PT, APTT, and TT levels; decreased FIB and D-D levels).

• Standardized use of the IPC device reduced the risk of VTE after femoral fracture surgery and shortened the hospital stay.

• The survey revealed that insufficient cognition was the primary factor leading to patient non-compliance with the IPC device, followed by device-related discomfort and low perceived value.

## Availability of Data and Materials

The data used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

## Author Contributions

LM and JNC designed the research study and wrote the first draft. LM and JNC performed the research. LM and JNC analyzed the data. Both authors contributed to the important editorial changes in the manuscript. Both authors read and approved the final manuscript. Both authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

## Ethics Approval and Consent to Participate

This study received approval from the Ethics Committee of Ningbo No.6 Hospital (Approval No.: 2025-L-081). All questionnaires were administered following the acquisition of written informed consent from the participants.

The research procedures adhered strictly to the principles of confidentiality and anonymity, in compliance with the principles of the Declaration of Helsinki.


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## Conflicts of Interest

The authors declare no conflicts of interest.

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