RESEARCH ARTICLE

Biological analysis of predictive nursing effect of lower limb DVT technology in ICU patients

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The incidence of lower extremity deep vein thrombosis (DVT) increases significantly with the increase in the number of patients in intensive care unit (ICU), especially those who are bedridden for prolonged periods and require mechanical ventilation support. This study aimed to explore the preventive effect of the early warning nursing model on DVT in ICU patients. 122 ICU patients were randomly divided into routine care and early warning care groups with 61 cases in each group. The early warning nursing group implemented hemodynamic monitoring, hemorheological index detection, and targeted preventive measures. The results showed that the peak velocity and average velocity of blood flow in the early warning nursing group increased significantly after the intervention as 26.5 ± 4.2 cm/s and 15.3 ± 3.1 cm/s, respectively, which were higher than those in the control group of 22.7 ± 3.8 cm/s and 12.9 ± 2.6 cm/s ($P < 0.05$). Early warning nursing group significantly reduced the whole blood and plasma viscosity ($P < 0.05$). The proportion of medium and high risk of DVT was reduced with the incidence of DVT as 4.92%, which was significantly lower than 16.39% of the control group ($P < 0.05$). The results indicated that the early warning nursing mode could effectively improve the blood circulation indexes of ICU patients, reduce the risk of DVT, and have a positive effect on preventing lower limb DVT in ICU patients, so it is worthy of clinical application.

Keywords: early warning nursing; intensive care unit (ICU); deep vein thrombosis (DVT); biological analysis.

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Introduction

With the deepening of intensive care medicine, people are paying attention to preventing and managing complications in intensive care unit (ICU) patients. Deep vein thrombosis (DVT) as one of the common complications in ICU patients has always been the focus and difficulty of clinical work because of its strong concealment and serious consequences [1, 2]. Effective prevention and management measures are of great significance to improving patients' prognoses and reducing medical costs. ICU patients are a high-risk group for lower limb DVT due to long-term bed rest, multiple organ failure, and surgical trauma [3]. DVT refers to the abnormal coagulation of blood in the deep venous system to form a thrombus, which not only increases the patient's pain and prolongs the hospital stay but may also lead to severe complications such as pulmonary embolism (PE), which seriously threatens the patient's life [4]. Therefore, it is essential to implement adequate preventive measures for DVT in ICU patients. Between 2009 and 2013, several international surveys showed uneven implementation of early activity in ICU patients [5]. Studies showed that only 28% of patients performed bed exercises. The

proportion of standing and walking exercises was 18% each, and patients with mechanical ventilation did not perform these activities [6]. Similarly, Pesser *et al*. suggested that the proportion of out-of-bed activity in early activity was 60% and 40%, respectively [7]. Liu *et al*. reported that 24% of mechanically ventilated patients participated in out-of-bed activities compared with only 8% of endotracheal intubation patients [8]. Wang *et al*. showed that about 70%-71% of ICUs carried out early activities and only about 10% have standardized activity programs [9]. Ren *et al*. reported that Japanese ICU performed better in early activities with 60% of patients being able to sit up at the bedside and 40% of patients performing standing exercises [10]. Although early activity research has been carried out in several provinces in China, it mainly focuses on the effect evaluation and lacks more detailed reports on the development rate. These data highlight the inconsistency in the importance of ICU patients' early activity worldwide and the urgent need for further research and practice [11].

Studies at both domestic and international have revealed that the implementation rate of early activities in ICU varies greatly, which faces many obstacles [12, 13]. The patient-related barriers are the primary concern for healthcare workers when promoting early activities. Effective development strategies should be based on ensuring patient safety, building interdisciplinary teamwork, equipping necessary equipment, carrying out educational and scientific research projects, and training ICU medical staff on typical complications to improve practical ability and ensure the smooth progress of early activities. Comprehensive analysis shows that, although early activity in ICU patients with mechanical ventilation is safe and effective, the effect of symptom improvement is still under determined. High-standard, multicenter, large-sample randomized controlled trials are urgently needed. The different definitions of "early stage" and the standardization of intervention measures and nursing care result in the lack of uniformity of early activity programs and frequency. As an advanced nursing concept, technical predictive nursing emphasizes the adoption of personalized nursing measures through scientific evaluation and monitoring before disease occurrence to reduce disease incidence [14, 15]. Applying technical predictive nursing to intervene the DVT in the ICU can provide patients with more accurate and personalized nursing services. Biological analysis plays a vital role in assessing DVT risk and nursing effects. Detecting biological indicators such as hemodynamics and hemorheology can objectively reflect the patient's blood and vascular health status and provide a scientific basis for nursing decision-making [16].

The incidence of DVT in the lower limbs of ICU patients is a significant concern due to its associated risks including pulmonary embolism and long-term morbidity. This research aimed to address the lack of predictive nursing interventions specifically tailored to this high-risk patient population and to evaluate the biological effects of a predictive nursing intervention designed to prevent lower limb DVT in ICU patients. The research employed a combination of quantitative and qualitative methods including a randomized controlled trial with a sample of ICU patients and used advanced imaging techniques to detect DVT and collected blood samples for biological analysis. By analyzing the changes in biological indexes of ICU patients before and after receiving technical predictive nursing, this study explored the effect of this nursing model on preventing lower limb DVT and provided a reference for clinical nursing practice and evidence-based support for the use of predictive nursing interventions in the prevention of lower limb DVT in ICU patients. The findings would have the potential to inform clinical practice and improve patient outcomes. Furthermore, the biological analysis conducted in this study offers new insights into the mechanisms underlying DVT development and may lead to the development of more effective treatment strategies.

Materials and methods

ICU patient selection and nursing care procedures

A total of 122 ICU patients with 60 males and 62 females, aged 18 to 82 years old with the average of 55 years old, from Hai'an People's Hospital (Hai'an, Jiangsu, China) were involved in this study from May 2020 to March 2022 to explore the effect of technical predictive nursing in preventing lower limb DVT. The reasons for ICU admission included 45 patients for post-surgery monitoring and 77 patients for non-surgical reasons as acute respiratory failure, heart failure, severe infection, liver and kidney failure, and neurological diseases. All procedures of this research were approved by the Ethics Committees of Zhoukou Vocational and Technical College (Zhoukou, Henan, China) (Approval No. ZVTC-20310) and Hai'an People's Hospital (Hai'an, Jiangsu, China) (Approval No. HSAH-IRB-2020-005. A written informed consent was obtained from all participants. All participants were expected to stay in the ICU for no less than 2 days and received colored ultrasound examination to exclude the DVT, while the normal coagulation function and stable vital signs were required for the participants to be involved in this study. To ensure the homogeneity of study subjects and the accuracy of the results, patients with coagulation dysfunction, hematopoietic system diseases, lower limb fractures, serious diseases of the heart, liver, kidney and brain, severe infections or mental disorders were excluded. The participants were divided into control and observation groups with the control group receiving routine care and the observation group receiving systematic nursing intervention including risk identification, risk assessment, and risk treatment. To identify the risks of DVT, the observation group implemented systematic nursing, which included the investigation of personal and family medical history, previous DVT events, lifestyle factors such as smoking and obesity, as well as the type of surgery and expected recovery time. After the patients completed the assessment using Caprini assessment form which covered three dimensions of medical history, surgery, and physical signs with 40 risk factors and each scored from 1 to 5, the risk level of DVT for each patient was determined corresponding to the score with 0 to 1 for low risk level, 2 points for medium risk level, 3 to 4 points for high risk level, and 5 points or more for very high risk level. For low risk level patients, in addition to routine interventions such as vital sign monitoring, skin observation, health education, and psychological counselling, patients were instructed to raise their lower limbs after surgery, start bed activities 6 hours after surgery, and start getting out of bed 24 hours after surgery with 10 minutes each time, three times a day. For medium risk level patients, based on measures for low risk level patients, additional early ankle pump exercise was added and started immediately after the anesthesia awake, while passive ankle pump exercise started even when anesthesia was not awake yet, with 20 to 30 rounds/group, 2 to 3 groups daily. Moreover, straight leg raise workout was performed 20 to 30 rounds/set, 2 to 3 sets daily, and abdominal breathing and chest expansion exercises were conducted 25 times per hour. For high and very high risk level patients, drug prophylaxis should be initiated before operation, and 5,000 IU of low molecular weight heparin should be subcutaneously administered once a day after operation.

Biological measurement and analysis

The potential DVT symptoms of lower limb swelling, pain, and discoloration were closely monitored and examined using the DVT diagnostic model (Figure 1). On the first day of admission to the ICU, D-dimer was tested using Sysmex CA-7000 automatic coagulation analyzer (Sysmex, Kobe, Hyogo, Japan) to assess blood hypercoagulability, while platelet was counted using Coulter LH 750 hematology analyzer (Beckman Coulter, Brea, CA, USA). In addition, the plasma IL-6 level of septic shock patients were measured using a Beckman Coulter AU5800 biochemistry analyzer (Beckman Coulter, Brea, CA, USA) and related kit. The blood flow velocity of femoral and popliteal veins was assessed using GE Vivid E95 color Doppler ultrasound system (GE

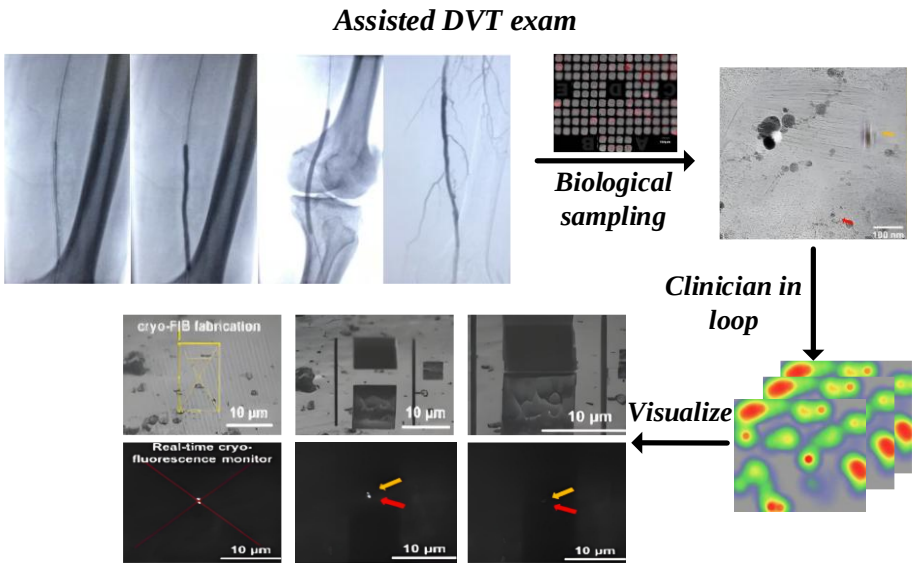

Figure 1. DVT diagnostic model.

Healthcare, Chicago, Illinois, USA). The lower extremity deep vein thrombosis such as thrombus length, diameter, *etc*. before and after the intervention were measured and recorded. Further, the diaphragm thickness of the patients who mechanically ventilated in the ICU was measured using Philips iU22 ultrasound instrument (Royal Philips, Amsterdam, Netherlands), and the ultrasound images were analyzed and processed using Adobe Photoshop CS6 image processing software (Adobe, San Jose, CA, USA). The hand muscle strength was assessed by a handheld muscle strength tester and determined by using Medical Research Council (MRC) muscle strength score.

Observation of lower limb DVT indexes

The first time getting out of bed was an early indicator of the patient's ability to return to mobility. Meanwhile, the length of hospital stay reflected the overall recovery process of the patient and the use of medical resources [17]. The changes in hemodynamic indexes of the femoral vein reflected the dynamic changes of venous blood flow in lower limbs and were important parameters for assessing the risk of DVT. The prothrombin time (PT), fibrinogen (FIB), and activated partial coagulation time (APTT) are indicators of coagulation function and crucial for assessing the blood coagulation status and risk of DVT in patients [18]. The changes in these indicators and the complication rates of lower limb DVT, swelling, and pulmonary embolism were compared between the two groups.

Statistical analysis

SPSS (IBM, Armonk, NY, USA) was employed for the statistical analysis of this study. Student t-test and χ^2 test were used to compare the differences between two groups. *P* value less than 0.05 was defined as a statistically significant difference.

Results and discussion

Early activity intervention for preventing lower limb DVT in ICU patients

The results showed that, after early activity intervention, the D-dimer level in the intervention group significantly decreased to a statistically significant level ($P < 0.05$) (Figure 2), while platelet count remained stable and did not show significant differences ($P > 0.05$). The first time getting out of bed and hospitalization time in the observation group were significantly shortened ($P < 0.05$), and the hemodynamic indexes of the femoral vein were improved ($P < 0.05$), suggesting that technical predictive

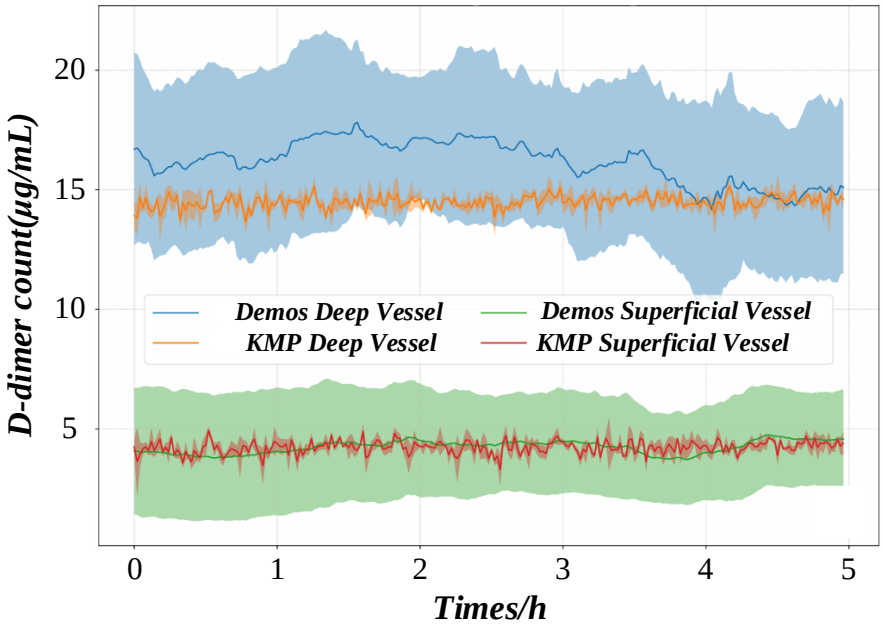

Figure 2. Comparison of patient data before and after intervention. Demos referred to the demographic profile of the study sample. KMP was associated with the core measurement indicators of the study.

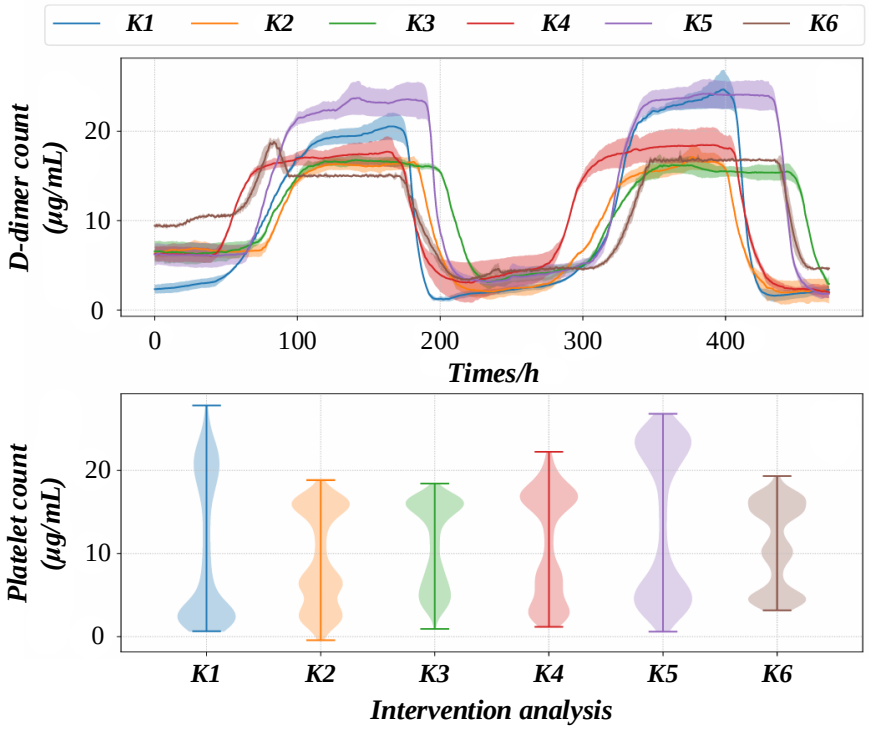

Figure 3. Blood flow velocity distribution before and after patient intervention.

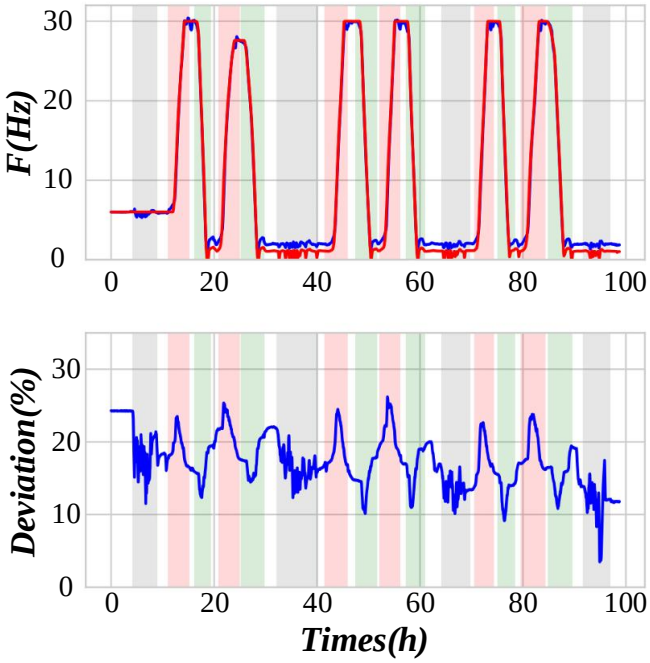

Figure 4. Comparison of VE-US tracking performance.

nursing could help accelerate rehabilitation and improve blood circulation. Regarding coagulation function indexes, the PT, FIB, and APTT in the observation group demonstrated improvement to the normal range after the intervention. The complication rates of DVT, swelling, and pulmonary embolism in the observation group were significantly lower than those in the control group ($P < 0.05$), confirming that technical predictive nursing was effective in preventing DVT in ICU patients. When comparing femoral and rouge vein flow velocity between the two groups before and after the intervention, six key labels (K) were defined including K1 as the baseline measurement, K2 as the effect of the intervention, K3 and K4 as the incidence of DVT, K5 as the blood flow velocity distribution, and K6 as the prompt treatment of patients with DVT. The results showed that there was no significant difference between the groups in K1, while K2 of the intervention group showed significantly increased blood flow velocity before the patient was transferred out of the ICU ($P < 0.05$), which verified the effectiveness of the intervention. K3 and K4 showed DVT incidence of 6.8% and 2.3% in the control group and the intervention group, respectively. Although such difference did not reach a statistically significant level (P = 0.625), it did show the potential benefit of the intervention. K5 showed the blood flow velocity distribution (Figure 3), while K6 demonstrated that all confirmed DVT patients were promptly treated with subcutaneous calcium-sodium heparin at a dose of 0.4 mL or 0.2 mL every 12 hours.

In the ICU admission, muscle strength was tested in both groups to compare the performance of venous elastography guided ultrasonography (VE-US) (Figure 4). The results showed that there was no significant difference in MRC scores between the two groups within 24 hours of ICU admission ($P > 0.05$), but the MRC scores of the intervention group were significantly higher than that of the control group ($P < 0.05$) before being transferred out of the ICU, indicating a positive effect of the intervention on muscle function recovery. Meanwhile, the diaphragm thickness decreased by an average of 6% per day over a 48-hour period in mechanically ventilated patients, which confirmed the linear relationship between ventilation and diaphragm atrophy and

dysfunction. These findings highlighted the importance of early activity in preventing diaphragmatic atrophy and provided direction for future research. The risk of thrombosis and hemorrhage coexist in ICU patients. The incidence rate of DVT is very high and is affected by many factors such as age and malignant tumor [19, 20]. The experimental analysis of lower limb DVT in the control group (Figure 5A) and experimental group (Figure 5B) showed that, although existing guidelines recommend the use of mechanical allergies and anticoagulants to prevent DVT, these methods had limitations and risks, and there was currently no consensus. The results showed that early activity did not significantly reduce DVT (P = 0.625), but the short-term improvement in blood flow suggested potential benefits.

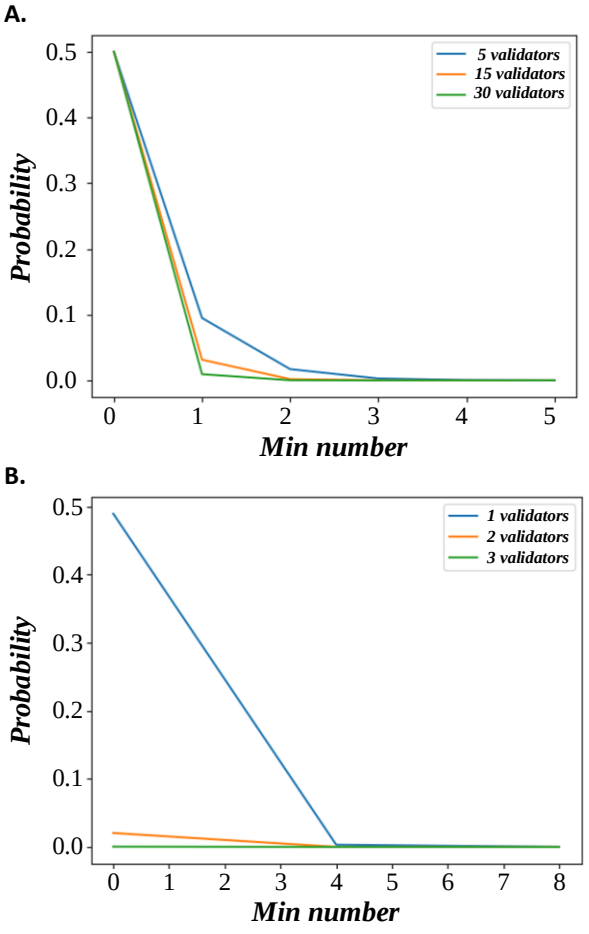

Figure 5. Validator function analysis of lower limb DVT in the control group (A) and experimental group (B).

Preventive effect of systematic nursing intervention on lower limb DVT in ICU patients

DVT is difficult to diagnose early because of its hidden symptoms. In ICU patients, complicated factors such as immobilization, blood hypercoagulability, long-term bed rest, sedation, and other complex factors lead to a low detection rate of DVT [21, 22]. Studies have shown that lower limb exercise and muscle massage can significantly increase blood flow and reduce thrombosis, especially for elderly patients who are bedridden for a long time in ICU, severely ill, or recently operated patients [23, 24]. Mechanical prevention methods such as intermittent air pumps are the first choice for patients who lack bleeding risk and side effects, which can effectively promote venous return and blood circulation and reduce the incidence of DVT. This study identified high-risk individuals, enhanced the alertness of healthcare workers to DVT, combined with standardized assessment tools for early risk assessment of ICU patients. Based on the risk assessment results, the preventive nursing measures were customized and dynamically adjusted to ensure the individualization and flexibility of nursing strategies, which could more effectively respond to changes in patient's conditions and reduce the risk of DVT. Meanwhile, a professional team should be established to conduct continuous tracking and statistical analysis, monitor the intervention effect in time, evaluate the effectiveness of nursing measures, and make timely adjustments according to the data analysis results to optimize the prevention strategy further [25, 26]. Studies have shown that taking systematic and early intervention measures has a significant effect on preventing the occurrence of lower limb DVT in ICU patients, which can not only reduce the incidence of DVT but also reduce the risk of related complications and improve the safety and treatment effect of patients. From the nursing perspective, popularizing this standardized and systematic nursing process is of great clinical significance, which can provide safer and more effective nursing services for ICU patients. ICU patients face the dual challenges of thrombosis and bleeding risk with a high

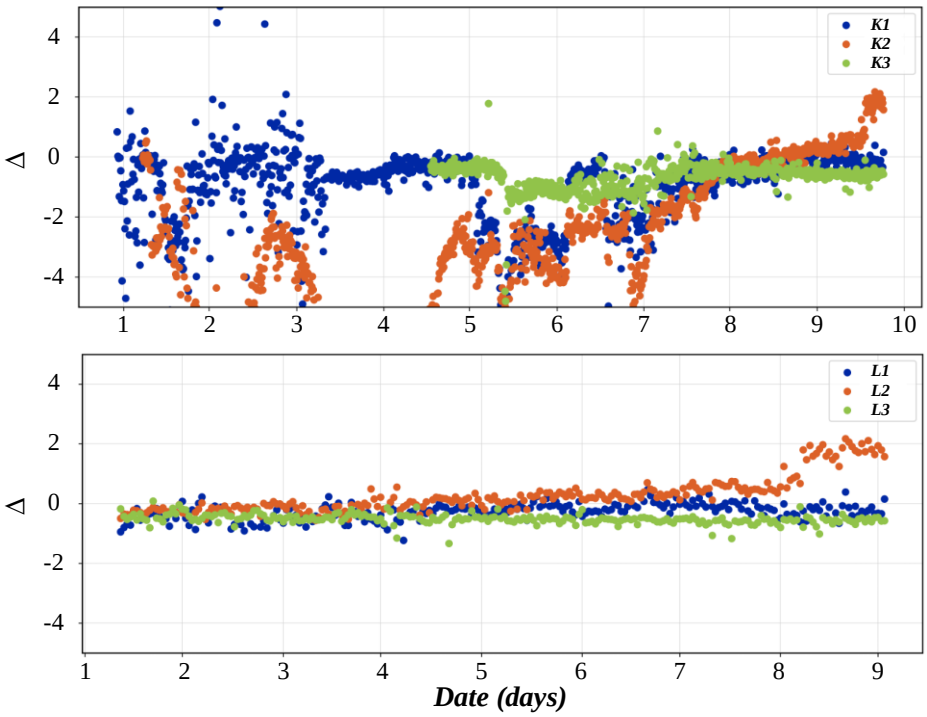

Figure 6. Difference distribution of LST returns.

incidence of DVT, which is influenced by multiple risk factors including age, disease status, and medical intervention. Although existing preventive measures such as intermittent inflatable compression devices, pressure gradient stockings, venous foot pumps, and anticoagulants can reduce the risk of DVT, they do not entirely prevent DVT, and improper use may bring other risks [27, 28]. The results of this study showed that, although early activity intervention did not significantly reduce the incidence of DVT, it could improve blood hypercoagulability and blood flow velocity, suggesting that early activity had a potential effect on preventing DVT. ICU patients with surgery or pregnancy may be complicated and in a high risk of lower limb DVT with the symptoms of pain, edema, and severe pulmonary embolism. Therefore, taking effective preventive nursing measures is very important to reduce risks and ensure patients' safety and smooth recovery after surgery. With the development of medical science and technology and the increasing emphasis on patient safety, it is urgent to explore and implement the systematic preventive nursing strategies in clinics to reduce DVT incidence.

Prevention of other complications

In ICU, early activity and rehabilitation exercises effectively reduce ventilator-associated pneumonia and pressure ulcers but have limited effects on DVT, which may be due to small samples and lack of representativeness [29, 30]. Therefore, randomized controlled trials (RCTs) of large samples are needed to verify the effect of early activity in preventing DVT in ICU patients with mechanical ventilation and to explore the specific form, frequency, time, and long-term effects. This study used LST returns defined as the lower extremity symptoms or signs such as swelling, pain, or warmth being initially improved or resolved after the application of a specific nursing intervention or technique to monitor and assess the effectiveness and durability of nursing interventions for the prevention or management of lower extremity DVT in ICU patients. The results showed that systematic nursing

intervention significantly reduced the incidence of lower limb DVT in ICU patients in the observation group ($P < 0.05$) with K1, K2, K3 as the initial or baseline phase, the intervention implementation phase, the post-intervention evaluation phase and L1, L2, L3 as low, medium, high risk categories, respectively (Figure 6). This effect was attributed to comprehensive risk assessment, hierarchical management, and aggressive preventive measures including anticoagulants for high risk patients. Systematized care not only improved patients' awareness of DVT and promoted their active participation in the recovery process but also emphasized the importance of proper medication use and self-care through education. In addition, the nursing intervention inhibited the coagulation process through pharmaceutical and mechanical measures such as elastic stockings and anti-inflammation to reduce the inflammatory response and abnormal coagulation function after surgery. Therefore, systematic nursing intervention has significantly improved the safety of surgery and the quality of rehabilitation through comprehensive care and has important practical significance for improving the nursing level of ICU patients undergoing surgery.

Effect of predictive nursing intervention on preventing lower limb DVT in elderly ICU patients

The experimental analysis found that predictive nursing intervention was effective, and the incidence of DVT and lower limb swelling in elderly ICU patients was significantly lower than that in the control group, indicating that predictive nursing intervention effectively reduced the risk of DVT and lower limb swelling. Meanwhile, the average and peak velocities of femoral vein blood flow in the observation group were higher than those in the control group ($P < 0.05$), which further verified the positive effects of predictive nursing intervention in promoting blood circulation, preventing lower limb thrombosis, making lower limb blood flow smoother, and reducing the probability of thrombosis formation. The prothrombin time (PT), coagulation time (TT), and activated partial coagulation time (APTT) values between the two groups before and after nursing intervention were compared and showed that, before nursing intervention, the observation group had lower PT, TT, and APTT values, while the control group was slightly higher. However, after nursing intervention, the PT, TT, and APTT values in the observation group significantly increased, while the increase in the control group was relatively small. The results showed that nursing intervention had a significant effect on TT and APTT in the observation group ($P < 0.05$) but not on PT ($P > 0.05$). In the control group, the effects of nursing intervention on PT, TT, and APTT were not significant ($P > 0.05$). The patients' Fugl Meyer motor function score and the National Institutes of Health Stroke Scale (NIHSS) neurological deficit score were evaluated to comprehensively assess the impact of early activity intervention on patient rehabilitation. The Fugl Meyer score is a scale used to assess the recovery of motor function in post-stroke patients with higher scores indicating better motor function recovery, while the NIHSS score is a scale used to assess the severity of stroke with higher scores indicating more severe stroke symptoms. The results showed that the Fugl Meyer score of the observation group was significantly higher than that of the control group, while the NIHSS score was significantly lower than that of the control group ($P < 0.05$). The higher Fugl Meyer score in the observation group indicated better motor function recovery than that in the control group, while a lower NIHSS score indicated relatively mild stroke symptoms. The patients in the observation group had significant improvement in these indicators after receiving early activity intervention. EW gap refers to the difference or discrepancy between the actual care provided and the ideal or recommended care based on evidence-based guidelines or protocols. The analysis of the relationship between EW gaps in this study revealed that predictive nursing could improve patients' motor and neurological function, prognosis, and nursing satisfaction by evaluating high risk factors and implementing targeted

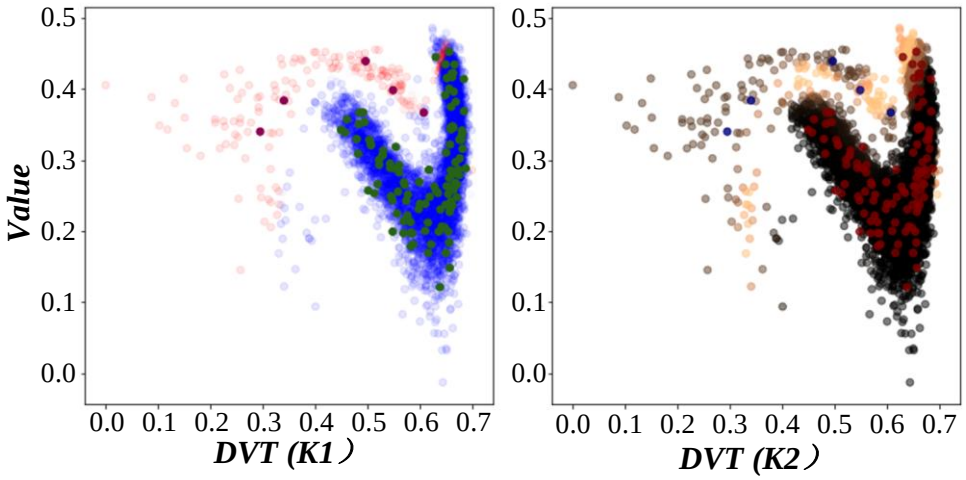

Figure 7. Visualization of DVT after targeted care.

interventions such as posture guidance and functional training. Due to its forward-looking and targeted nature, this nursing model met the diverse needs of patients, promoted disease recovery, and improved quality of life. The high accuracy of risk factor assessment reflected the effectiveness of nursing in identifying DVT risks. The improvement rate including motor function recovery indicated the positive role of nursing, and the improvement in prognosis and nursing satisfaction reflected the comprehensive benefits of nursing. The effectiveness of preventive nursing strategies in managing the risk of lower limb DVT in elderly ICU patients after surgery showed that a comprehensive and strengthened preventive nursing strategy (K2) could significantly reduce the risk of DVT in patients compared to the basic strategy (K1), where K1 and K2 represented the risk level of the patient population receiving basic preventive care such as anticoagulants, elastic socks, *etc*. and more comprehensive and strengthened preventive care strategies such as increasing intermittent pneumatic devices, more intensive rehabilitation training, *etc*., respectively (Figure 7).

Conclusion

Technical predictive nursing was applied in this study to ICU patients for the prevention of lower limb DVT. The incidence of DVT in the observation group was 2.3%, which was significantly lower than that in the control group (6.8%) ($P < 0.05$). The results confirmed that predictive nursing significantly reduced the risk of DVT. Through systematic evaluation, hierarchical management, and comprehensive preventive measures, levels of D-dimer and fibrinogen in the observation group decreased, blood flow accelerated, and the hypercoagulable state of blood was effectively improved. In addition, the observation group's muscle strength scores and neurological function scores were better than those of the control group, further confirming the positive effect of predictive care on promoting patients' rehabilitation. Early postoperative activity promoted lower limb circulation and reduced the risk of thrombosis. Nursing staff made personalized activity plans and monitored the whole process and instructed patients to wear elastic stockings before and after the operation to promote venous return and reduce stasis. The long-term impact of early activity intervention on the prognosis of ICU patients could provide more evidence and robust support for clinical practice. In future research, big data and AI technology could be used to achieve more accurate risk assessment and personalized care. Meanwhile,

strengthening the health education of patients and their families and improving their self-management ability will help enhance the effect of nursing and reduce the consumption of medical resources.

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