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Advances in the Study of Venous Thrombosis Associated with Peripherally Inserted Central Venous Catheters

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Abstract

In clinical practice, the incidence of venous thrombosis associated with Peripherally Inserted Central Catheters (PICCs) is notably high. However, there is limited literature addressing the related nursing measures for this complication. This article provides a comprehensive review of the mechanisms, treatment options, and nursing interventions for catheter-related thrombosis. By enhancing clinical nurses' understanding of this condition, the review aims to contribute to reducing the incidence of venous thrombosis and improving patient outcomes.

Keywords

Peripherally Inserted Central Venous Catheter (PICC), Venous Thrombosis, Formation Mechanism, Nursing Interventions, Review

1. Introduction

A Peripherally Inserted Central Catheter (PICC) is a type of catheter whose tip is positioned in the superior or inferior vena cava under ultrasound guidance, typically inserted through peripheral veins such as the basilic vein, median cubital vein, cephalic vein, brachial vein, or external jugular vein [1]. Due to their ease of operation, cost-effectiveness, and clinical utility, PICCs are widely used in medical practice. However, various complications can arise during catheter indwelling, among which Deep Vein Thrombosis (DVT) associated with PICC placement is one of the most common [2]. Statistical data indicate that symptomatic venous thrombosis occurs in 2% to 6% of patients with PICCs, while asymptomatic venous thrombosis is observed in over 40% of cases [3]. This article reviews current clinical research on the formation mechanisms, treatment, and nursing care of PICC-related thrombosis.

The aim is to enhance clinical nurses' understanding of this complication, improve their nursing skills for patients with PICCs, and ultimately reduce the incidence of adverse outcomes [4].

2. Mechanisms of Thrombosis

In 1856, the scholar Virchow proposed three major factors contributing to thrombosis: venous endothelial damage, slow blood flow, and a hypercoagulable state of blood [5]. Based on the location of thromboembolism, catheter-associated thrombosis can be classified into three types: peri-catheter sheath thrombosis, vascular appendage thrombosis, and catheter lumen thrombosis [6]. Catheter-associated thrombosis poses significant challenges to both patients and healthcare professionals due to its high incidence, insidious onset, and prolonged treatment duration.

Currently, numerous animal and clinical studies have demonstrated that PICC placement induces endothelial damage, delayed venous blood return, and hypercoagulability, all of which are closely associated with PICC-related thrombosis. Additionally, risk factors for catheter-related thrombosis include thrombocytosis, reduced antithrombin levels, endothelial injury caused by venipuncture, prolonged bed rest, and venous compression [7]. PICC insertion can disrupt the normal local blood flow in the catheterized vein through multiple mechanisms, such as disturbing laminar blood flow, altering vessel diameter, reducing blood flow velocity and volume, and generating eddy currents and turbulence, all of which may contribute to thrombosis. Furthermore, the venipuncture process can cause mechanical damage to the venous wall, leading to platelet activation, aggregation, and adhesion, as well as an increase in procoagulant substances and a decrease in anticoagulant substances. The exposure of tissue factor activates the extrinsic coagulation pathway, while the catheter itself, as a foreign body, triggers and activates the coagulation system [8].

3. Diagnostics

Patients with catheter-related venous thrombosis often present with no obvious clinical symptoms. However, clinical manifestations vary depending on the site of embolism [9] [10].

3.1. Intracranial Vascular Embolism

Patients may experience head and neck pain, dizziness, transient blackouts, and in severe cases, hemiplegia and aphasia.

3.2. Limb Embolism

Symptoms include unilateral limb warmth or coldness, skin redness, numbness, edema, and pain.

3.3. Organ Embolism

Swelling and pain in the affected organs may occur; pulmonary thrombosis can

lead to respiratory difficulties and cyanosis. Intestinal artery thrombosis may manifest as severe abdominal pain, among other symptoms.

Currently, color Doppler ultrasonography is the most commonly used method for diagnosing Deep Vein Thrombosis (DVT) associated with Peripherally Inserted Central Venous Catheters (PICCs). When color ultrasound cannot confirm the diagnosis, venography is often employed; however, venography is an invasive procedure and technically challenging [11]. D-dimer testing is also widely used in the diagnosis of venous thrombosis. A D-dimer level higher than 200 μg/L suggests that the thrombus is in the acute phase or indicates the presence of a new thrombus [12]. However, while D-dimer is highly sensitive for detecting venous thrombosis, its specificity is low. For instance, elevated D-dimer levels can also occur in conditions such as cancer or infection [13]. Therefore, further research is needed to identify novel biomarkers for the diagnosis of venous thrombosis. Additionally, laboratory markers such as prothrombin time, fibrinogen levels, and platelet count can be used to preliminarily assess the risk of thrombosis in patients and support the confirmation of thrombosis.

4. Treatment of Venous Thrombosis

4.1. Thrombolytic and Interventional Therapy

Thrombolytic therapy is commonly used in clinical practice. Drugs such as urokinase, streptokinase, and reteplase are administered to dissolve existing thrombi and achieve vascular recanalization [14]. Among these, Low Molecular Weight Heparin (LMWH) has minimal effects on platelets, thrombin, and other coagulation factors, providing maximal antithrombotic efficacy with a low risk of bleeding. Its effectiveness and safety are well-established, making it a representative drug for anticoagulation therapy in clinical settings [15] [16].

4.2. Interventional Therapy

While interventional therapy can reduce the risk of post-thrombotic syndrome in the lower extremities, its role in treating catheter-related bloodstream infections remains unclear [17].

4.3. PICC Removal

PICC catheters can contribute to clot proliferation, and their timely removal should be considered upon detection of thrombosis. Current guidelines do not recommend immediate PICC removal; however, in cases where anticoagulation is contraindicated or bloodstream infections are present, the PICC should be removed immediately if persistent symptoms such as arm pain or swelling occur [18] [19].

5. Prophylaxis of Venous Thrombosis

5.1. Pre-Catheterization Risk Assessment and Nursing Measures

Before PICC catheterization, a comprehensive risk assessment of the patient is

essential. The incidence of thrombosis is particularly high within the first three days after catheter placement. As the primary operators of PICC catheterization, nurses' technical proficiency directly impacts the incidence of post-catheterization complications. Therefore, nursing managers should enhance the training of specialized nurses in key techniques, with a particular emphasis on reinforcing the principles of aseptic operation. Continuous learning and knowledge updates, adopting advanced techniques and equipment from leading regions, selecting appropriate vessels and puncture sites, and improving catheter placement and nursing skills are critical to reducing complications [20]. For patients, regular Doppler ultrasound examinations should be conducted to effectively prevent thrombosis.

5.2. Prophylactic Use of Anticoagulant Drugs

The prophylactic use of anticoagulant drugs requires close monitoring of coagulation-related indicators in hospitalized patients [21] [22]. Based on the results of coagulation tests, the dosage of anticoagulants should be adjusted promptly to ensure safe and effective anticoagulation therapy. Patients should be evaluated for signs of bleeding, such as gingival bleeding and skin petechiae, as well as accompanying symptoms like dizziness and fatigue. Currently, Low Molecular Weight Heparin (LMWH) is the most commonly used anticoagulant in clinical practice [23]. Additionally, rivaroxaban has been recognized as a highly effective anticoagulant [24]. Clinical studies have demonstrated that rivaroxaban achieves an efficacy rate of 90.70% in treating thrombosis. It exhibits high bioavailability and can enhance antithrombotic effects when used in combination with warfarin [25]. However, excessive use of anticoagulants may increase the risk of bleeding, while insufficient dosing may fail to achieve the desired therapeutic outcomes. Therefore, both before and after anticoagulant administration, patients' coagulation function should be regularly tested to evaluate the anticoagulation effect and bleeding risk. If bleeding is detected, immediate measures should be taken to control it, and physicians should be promptly notified for further management. Patients should also be advised to avoid trauma and collisions to prevent bleeding complications [26].

5.3. Non-Pharmacological Interventions

The US INS guidelines recommend prioritizing non-pharmacological treatments whenever possible [27]. If patients exhibit signs of thrombosis, such as arm pain or swelling, timely removal of the catheter should be considered. Additionally, patients should be advised to engage in appropriate daily exercises to prevent thrombosis. For the first 24 hours after catheter insertion, patients should avoid activities that involve bending the elbow, eating, combing hair, or forceful clenching and unclenching of the hand. Elevating the punctured limb during sleep can also help prevent edema [28]. Studies have shown that upper limb exercises, such as grip ball training (holding a hand-held ball for 2 seconds followed by 2 seconds

of relaxation as a cycle), can significantly improve venous blood flow. These exercises promote blood circulation in the upper limb veins and reduce muscle compression on blood vessels, thereby effectively lowering the risk of PICC-related thrombosis [29].

5.4. Enhancing Patient Health Education and Functional Exercise

Enhancing patient health education and functional exercise plays a crucial role in the prevention and treatment of thrombosis. First, positive behavioral changes should be encouraged to improve patient compliance. Regular follow-up visits or health education activities should be conducted to systematically assess patients' risk of venous thrombosis and implement targeted nursing interventions [30]. Second, the current "Internet + nursing services" model can provide advanced and effective continuity of care, ensuring better care services for discharged patients. Finally, traditional health education can be integrated with the PDCA (Plan-Do-Check-Act) cycle management model to optimize the content and delivery of health education, thereby promoting the implementation of established measures and reducing the incidence of venous thrombosis [31].

5.5. Moxibustion Therapy

Moxibustion, as described in the Yellow Emperor's Classic of Internal Medicine, states: "Bone paralysis is severe, and those with affected veins experience blood stagnation and poor circulation". Moxibustion is a traditional Chinese medical therapy that involves burning moxa (dried mugwort) to create heat and stimulate specific points on the body. It is used to treat conditions caused by poor qi and blood circulation, such as paralysis, by applying warm stimulation to warm the meridians and promote blood flow [32]. According to traditional Chinese medicine principles, applying moxa sticks to key acupoints, including Neiguan (PC6), Quchi (LI11), Jianyu (LI15), and Shenque (RN8), can enhance local blood circulation, alleviate blood stagnation, and reduce the incidence of PICC-related venous thrombosis [33].

6. Summary

In clinical practice, the incidence of venous thrombosis following PICC placement is relatively high, but there are limited reports on related nursing measures. This article reviews the formation mechanisms, treatment methods, and nursing interventions for catheter-related thrombosis, aiming to enhance clinical nurses' understanding of this complication and reduce the incidence of venous thrombosis. Through comprehensive risk assessment, prophylactic use of anticoagulants, enhanced patient health education, and non-pharmacological interventions such as traditional Chinese moxibustion therapy, the occurrence of PICC-related venous thrombosis can be effectively reduced. Future research should further explore novel biomarkers and optimize nursing strategies to better prevent and manage this complication.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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