

Current Research Progress of Central Venous Catheter-Associated Fibrin Sheath Prevention and Nursing Care

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Abstract: With the popularization of central venous catheterization in recent years, the problems arising from intravenous therapy have gradually increased. Fibrin sheath is the complication with the highest incidence rate in central venous catheterization, which has always been a major problem in intravenous therapy. So the prevention and treatment of fibrin sheath has become a hot spot of research in recent years. Hence, this paper summarizes the research on fibrin sheath in recent years.

Keywords: Central venous catheterization; Fibrin sheath; Clinical care

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1. Introduction

Since the 1990s, the technique of peripherally inserted central catheter (PICC) has been used in China. This technique is favored for its tiny incision, easy handling, and long access period, as well as for preventing problems such as drug leakage. Therefore, it is used in a large number of applications such as the intravenous administration of nutrients, chemotherapy, and antimicrobial use. According to statistics, as many as millions of people rely on this type of central venous cannulation to provide a safe route for intravenous fluids each year due to the need to undergo urgent or chronic medical treatment^[1]. However, with the widespread use of PICCs, there is an increasing number of associated complications such as thrombosis, infection, phlebitis, and fibrin sheaths, with fibrin sheaths having the highest incidence rate of 38%–100%. Findings have shown that fibrin sheath formation occurs in almost all types of central venous catheter access, which is the most common factor contributing to impaired catheter function. In addition, it can lead to a range of complications, such as secondary infections, thrombogenesis, catheter removal, and pulmonary embolism. Therefore, the prevention, care, and treatment of fibrin sheath are particularly important. This article summarizes the concept, incidence, formation mechanism, clinical diagnosis, treatment, prevention, and care of fibrin sheath after PICC placement as follows.

2. Fibrin sheath concept, incidence, and formation mechanism

2.1. Concept

The fibrin sheath is a thin film structure covering the surface of the PICC catheter through a variety of elements such as smooth muscle cells, erythrocytes, thrombus endothelial cells, and collagen. The concept was first introduced in France in 1964, and subsequent studies have found that the condition starts at the junction of the catheter and the vein wall. The fibrin sheath is tightly bound to the vein wall, making it difficult to detach even when the catheter is removed. One study showed that failures due to fibrin sheaths accounted for about 1.3% of first-time catheter placement problems, which rose to 76% after an average of 98 days of follow-up. Fibrin sheaths begin to develop at the junction of the catheter and the vein wall within the first 24 hours after placement of the tube, and then expand toward the vessel wall, a process that takes about five to seven days to complete. According to the results of animal experiments, the fibrin sheath can grow from 48% to 80% within 7 days after the placement of the catheter, while it can increase from 71% to 100% at 14 days, and remain between 33% and 100% for 30 days without interruption ^[3,30].

2.2. Incidence

The foreign literature describes the autopsy results of 55 patients with subclavian vein catheters. In that study, fibrin sheaths were found in all specimens, even within 24 hours of catheter insertion ^[4]. Since the diagnosis of fibrin sheath is difficult at present and color ultrasound has some limitations, clinical reports are not common.

2.3. Mechanism of formation

Although the principle of fibrin sheath formation remains debatable, two sets of theories have been proposed to explain the phenomenon. First, it has been proposed that the fibrin sheath is a thrombus that undergoes protein precipitation and further development. Secondly, another theory emphasizes the triggering effect of a foreign body such as a catheter. When a catheter is inserted, it causes injury to the vessel wall and triggers the growth and movement of smooth muscle cells, while endothelial cells begin to extend toward the surface of the catheter to cover their exterior. Eventually, the catheter becomes surrounded by a film-like substance ^[5,6].

3. Clinical diagnosis

3.1. Imaging

Imaging currently has no gold standard for the diagnosis of fibrin sheaths ^[7]. In clinical practice, color Doppler ultrasound or venography is usually used for examination and diagnosis. Color Doppler ultrasound is favored because it is non-invasive, low-risk, and cost-effective. However, some scholars have noted that color Doppler ultrasound may not be able to accurately identify all lesions due to interference from bone, gas, or other tissues. In contrast, venography techniques have a higher specificity and sensitivity in diagnosing fibrin sheaths. However, the cost of the venography technique is high and patients may have allergic reactions to the reagent, so these factors limit its wide application in clinical practice ^[2]. Taking various factors into account, color Doppler ultrasound is currently preferred in the clinical diagnosis of fibrin sheaths, but when encountering complex or special circumstances, physicians may consider using venography or transcatheter venography to obtain more accurate diagnostic results. In the future, as technology continues to advance and costs decrease, it is believed that more diagnostic methods will be developed to provide a more comprehensive and accurate means of diagnosing fibrin sheaths.

3.2. Laboratory tests

There is a close relationship between fibrin sheaths in the blood and serum von Willebrand factor (vWF), which reflects the function of the vascular endothelium. Serum vWF can reveal the functional status of the vascular endothelium, especially when the endothelium is damaged. The damage of the endothelium can contribute to the production of large quantities of vWF and its release in the blood, which helps to activate the platelets and gradually adheres to the underside of the damaged endothelium to promote the production of collagen fibers, however, it also increases the risk of thrombosis formation risk ^[11,12]. Additionally, the increasing levels of D-dimer (DD), a cross-linked fibrin, means that the body's clotting ability is increasing, and can also indicate whether thrombosis is occurring in the body ^[13,14]. Therefore, serum vWF and DD are used as a theoretical basis for the possibility that fibrin sheath formation may lead to an increased risk of thrombosis, and the serum vWF and DD levels are significantly higher in those with fibrin sheaths. Predicting fibrin sheaths by laboratory tests is a very important tool, and in combination with ultrasound diagnosis, which is more accurate and reliable, further improves efficiency and reduces the risk. Hence, this method has great practical application for predicting the occurrence of fibrin sheaths ^[15].

4. Treatment modalities

4.1. Drug therapy

Drug therapy is applied after fibrin sheath formation, and commonly used drugs include urokinase, streptokinase, and tissue-type fibrinogen activator (tPA). Studies generally agree that tPA is the safest and most effective drug choice for the treatment of fibrin sheaths. However, despite the initial effectiveness, it has been shown that after months or weeks of treatment, fibrin sheath formation can reappear on the catheters, which in turn may lead to problems with catheter occlusion ^[16]. In 1994, Aire *et al.* conducted a randomized controlled study of central venous catheters in which dysfunction occurred ^[17]. The results showed that catheters treated with tPA had a recanalization rate of 89% compared to 59% with urokinase treatment. Another study by Aipanich *et al.* in 2010 on patients with hemodialysis catheter dysfunction showed that the catheter recanalization rate was as high as 95.3% after 1 mg of tPA was added to 50 mL of saline pushed intravenously into the hemodialysis tubing and observed for 2 hours ^[18]. In addition, the study by Meng *et al.* showed that after sealing the catheter with 125,000 IU of urokinase dissolved in 100 mL of saline, and then dripping it into the catheter at a rate of 10 gtt/min to 15 gtt/min, recanalization of all catheters occurred ^[19]. However, it is worth noting that the fibrin sheath remained after the sealing method, whereas the drip method resulted in the disappearance of the fibrin sheath in 70% of the catheters and a reduction in 30%. The study by Zhang *et al.* explored the use of 4% sodium bicarbonate solution injected into the catheters of patients with fibrin sheaths, which was retained for 30 minutes and then repeated twice, and their catheter recanalization rate reached 83.3% ^[20]. As for prevention, a study by Wu *et al.* showed that based on routine heparin sealing, regular rt-PA sealing was not only effective in preventing catheter obstruction but also in reducing the incidence of fibrin sheaths, demonstrating its safety and efficacy ^[21].

In conclusion, despite the effectiveness of drug therapy in the treatment of fibrin sheaths, there is still a risk of recurrence and catheter blockage. Therefore, future studies should further explore more durable and effective treatments to reduce patients' pain and medical costs.

4.2. Extraction

When extubation difficulty or catheter occlusion occurs, extubation should not be forced. The cause of extubation difficulty should be determined by imaging, the extubation difficulty should be graded, and the way to extubate should be analyzed.

4.2.1. Determining the difficulty level of extubation

The difficulty level of extubation can be determined according to whether there is a pulling sensation or elastic contraction during extubation. The specific classification is as follows: Grade I indicates that there is no pulling sensation during the extraction; Grade II is that the pulling force will be felt during the process of extraction; when it reaches Grade III, not only the pulling force can be felt but also the phenomenon of elastic contraction will be produced; and when it reaches Grade IV, the process of extraction will become stagnant and difficult to be extracted out. Among them, only grade I is a situation without any extraction distress, while the rest of the grades represent some difficulties in extraction ^[22].

4.2.2. Methods of extraction

In the case of difficult catheter removal, warm therapy, calming emotions, psychological counseling, and physical massage should be used to try to solve the problem. If the catheter still cannot be successfully removed, further blood color Doppler imaging or X-ray testing can be used to determine whether there is a thrombus or catheter bending problem, or that the cause of it is due to the fibrin sheath. The catheter is then pulse-cleaned using a 5% sodium bicarbonate solution containing 20 mL of sodium bicarbonate, and then sterile liquid paraffin is applied to the pinhole site and held for two minutes to make it smoother before the catheter removal process begins. During this process, the operator should avoid anxiety and violent behavior, so as not to lead to catheter breakage. Once the catheter is found to have the phenomenon of elastic contraction, it should be temporarily loosened, wait until it is fully recovered, and then re-adjust the angle of turning while pulling outward. This is repeated until the completion of the whole process ^[9].

4.3. Surgical excision

Traditional fibrin sheath stripping is performed by puncturing the femoral vein to reach the central vein, which in turn strips the fibrin sheath from the surface of the catheter. Although the short-term therapeutic efficiency is more than 95%, studies have shown that the fibrin sheath fragments produced during stripping may enter the bloodstream, thereby triggering the risk of pulmonary embolism. In addition, it has been noted that this surgical approach does not achieve a complete recovery, and patients need to undergo reoperation after an average of 4-5 months.

In 2007, Reddy *et al.* proposed an innovative, minimally invasive technique that was designed to eliminate fibrin sheaths and intraluminal thrombi ^[23]. Under the precise guidance of angiography, the surgeon applies folded metal wires forming loops into the central venous catheter up to its end. Subsequently, these wire loops are used to snare and remove the fibrin sheath from the surface of the catheter. Studies have shown that this technique has successfully restored hemodialysis catheter function in seven cases where tPA treatment was ineffective, with an efficiency rate of 100%. This minimally invasive technique is not only more cost-effective than conventional fibrin sheath stripping but also avoids the need for femoral vein puncture and anesthesia, which significantly improves the patient experience and speed of recovery ^[24-25].

5. Status of care

5.1. Early prevention

5.1.1. Pipe flushing care

Early prevention has an extremely important impact on reducing fibrin sheath formation. Among them, standardized catheter flushing can effectively reduce the generation of fibrin sheaths. Research results show that the implementation of standardized catheter maintenance and management can significantly reduce the

probability of fibrin sheath production ^[26]. This is mainly because when pulsation occurs, the cyclonic flow triggered by the difference in pressure is effective in removing substances adhering to the catheter surface, which in turn avoids the risk of catheter occlusion and inhibits the formation of fibrin sheaths.

The expert consensus states that nurses should check drug properties before injections. During the infusion of two or more medications, there is a need to verify that the medications are not incompatible. Blood products, parenteral nutritional fluids, and medications that are at risk of precipitation can lead to clogging of the tubing. Nursing staff need to thoroughly clean each infusion line using a 0.9% sodium chloride solution or replace it with new infusion equipment. Loss of catheter function is indicated when problems are encountered such as failure to recover blood smoothly, delayed backflow of blood, slowed infusion rate, significant resistance felt during injection or inability to enter medications, frequent clogging of electronic IV pumps with alarms, and development of intravasation/extravasation or swelling/leakage at the needle ^[27-28]. Each channel should be tested using 0.9% sodium chloride solution and cleaned thoroughly to look for possible blockage problems. Then, by observing whether each channel can be easily emptied and whether blood can be successfully recovered, whether the problem is a partial or total blockage can be determined. When the catheter could not be reopened, imaging methods were applied to determine the cause of the catheter blockage and treated accordingly ^[29].

Early prevention is essential to reduce fibrin sheath formation. By implementing standardized catheter flushing strategies and the active role of nurses in preventing catheter occlusion, the probability of fibrin sheath formation can be significantly reduced to ensure the safety of patient treatment. At the same time, timely management measures are essential when catheter function is impaired.

5.1.2. Electronic grip

According to the findings of Min, the use of electronic grip strength devices and grip training methods can effectively increase the infusion rate of patients, reduce the occurrence of catheter-related side effects, and help prevent the formation of fibrin sheaths. The study added the use of an electronic grip strength device to the traditional handgrip exercise, which was performed following the alternating gripping and releasing pattern 25 times per minute, with each movement lasting two minutes, followed by a five-minute rest, for a total of 30 minutes, in six cycles per day, at 7:00 a.m., 10:00 a.m., 3:00 p.m., 6:00 p.m., 9:00 p.m., and 12:00 p.m., with at least fifteen minutes between the two time periods ^[30]. Of course, the use of the traditional clenched-fist exercise method, with the same duration, can also be effective in preventing the occurrence of catheter-related complications.

5.2. Thrombolytic care

The findings of Wang *et al.* showed that when urokinase thrombolytic therapy is performed, especially when urokinase intravenous drip is used, the patient's limb blood circulation and vital indicators need to be closely monitored, and the patient's bleeding risk is determined through blood sampling and checking the prothrombinogen time ^[31].

5.3. Extraction nursing

5.3.1. Psychological care

When a patient has a nervous or anxious reaction to the need to remove a catheter, their sympathetic nerves become active, as well as repetitive stimulation of the vagus nerve, which may lead to vasospasm and constriction of blood vessels, thus increasing the degree of difficulty in removing the catheter ^[33]. In addition, a study showed that negative emotional and mental stress faced by patients during their stay in the hospital can be

effectively alleviated by providing psychotherapy, which helps them to adjust to a positive state and enhances their ability and determination to overcome the disease^[32]. Therefore, before extubation, nurses need to explain to patients the potential risks of fibrin sheaths, the reasons for extubation, the process, precautions, and possible reasons for extubation difficulties. During the extubation process, the nurse should actively calm the patient, relieve his or her anxiety and tension, maintain communication with the patient, and guide the patient to face the extubation procedure and subsequent treatment with a positive and calm mindset^[34].

5.3.2. Assessment of patients

Before extubation, nurses should assess the patient's general and local conditions through laboratory test results and ultrasound to understand the local vascular condition and observe their psychological state if necessary, so that whether the patient can be extubated and the best time for extubation can be determined^[35].

5.3.3. Adjustment of body position

To ensure the smooth progress of extubation, nurses need to assist patients in adjusting to the appropriate position before extubation. During extubation, the patient's sleeves should be elasticized and tightened to ensure ease of operation. At the same time, the patient should remain in a lying position, with the upper limb of the affected side abducted at 90° to the trunk, which helps to reduce the friction between the catheter and the vessel wall, thus reducing the difficulty of extubation^[36].

If any obstruction is encountered during the extraction operation, the nurse should immediately pause the operation and carefully check whether the localization of the patient's upper limb is compressed. Once compression is detected, the position of the patient's body and arm should be quickly adjusted to ensure that the upper limb is kept at a right angle to the torso and spread outward as much as possible, to reduce the pressure on the vessel wall and improve the success rate of extubation.

The implementation of these measures not only helps to ensure the smoothness of the extubation process but also reduces the patient's discomfort and improves the overall quality of care. Nurses should always maintain a high degree of professionalism and responsibility when performing this operation to ensure patient safety and comfort.

5.3.4. Physical therapy

When there is resistance to extubation, extubation should be stopped. Wet hot compresses, water bag hot compresses, local massage, and other methods can be used to relieve vasospasm. A 45°C wet towel can be used for the local hot compress for 30 minutes, or a hot water bag can be used for 10 minutes to prevent scalding skin. Alternatively, a 15-minute local massage can be performed on the affected upper arm^[31]. This can promote local vasodilatation, reduce muscle spasms, promote muscle relaxation, relieve local pain, and improve the success rate of extubation^[37].

5.3.5. Extubation nursing focus

Before extubation, it is necessary to ensure that the patient adopts the appropriate position and reduces his or her nervousness through verbal reassurance. During the whole process, close observation of the patient's vital signs is essential to ensure that the extubation process has no adverse effects on the patient.

During extubation, the operator should avoid dragging the tube over a long distance and should always place their hand near the needle in a steady and gentle motion. The recommended extraction speed is two to three centimeters per second of movement, and the entire extraction procedure should last at least twenty seconds or more to minimize irritation of blood vessels and tissues.

If resistance is encountered during extubation, the operator should stop immediately and check to see if pressure is exerted at the puncture point. If pressure is present, the patient needs to be repositioned to reduce the pressure. At the same time, DSA or X-ray chest imaging can be used to clarify the problem and provide a basis for further adjustment and treatment. To stimulate circulation, warm compresses and beverages may be used. If these measures do not work, ultrasound techniques may be considered to find the cause. In specific cases, such as thrombosis in the catheter, the appropriate amount of urokinase can be injected two hours before removing it.

In the event of an emergency where the catheter breaks, a tourniquet should be immediately applied 5–10 cm above the break, and a DSA X-ray or chest X-ray should be performed to determine the location of the broken catheter. Subsequently, the interventional department should be contacted for consultation to develop the best management plan. Throughout the catheter extraction process, nurses and doctors need to maintain a high degree of vigilance and communication to ensure that each step of the operation is accurate, thus ensuring the safety of patients ^[36].

5.3.6. Postoperative care

After the operation, patients are instructed to rest in bed, avoid strenuous activities of the affected limbs, eat more high protein, high vitamin food, and drink more water. It is necessary to carefully monitor whether venous thrombosis, infection, and other complications have occurred. The nurse should not only observe the patient's vital signs, coagulation function, and wound condition but also check whether the affected limbs are swollen, whether the skin color has changed, as well as whether there are chills, fever, and systemic discomfort ^[36]. In conclusion, postoperative care requires comprehensive attention to all aspects of the patient, timely detection and treatment of potential problems, to ensure that the patient can successfully recover. At the same time, educating the patient and improving their self-care ability is also one of the important measures to promote recovery.

6. Summary

Fibrin sheath is indeed a complex and often overlooked problem. Its presence may not only lead to difficulties in extubation but may also have long-term effects on the patient's vascular function. Therefore, care and observation of fibrin sheaths are particularly important. The current problems and recommendations for the study of fibrin sheath are as follows. The prophylaxis of fibrin sheath has been proven to be effective in animals, and there are fewer research reports on the prophylaxis of human fibrin sheath ^[25]. Therefore, it is recommended to increase research on preventive measures for human fibrin sheaths to find more effective interventions. Formation mechanisms and risk factors of fibrin sheaths are not fully understood, which limits the in-depth understanding of the problem and effective treatment. Therefore, more research is needed to reveal the underlying biological processes and influencing factors. There is insufficient clinical emphasis on fibrin sheath formation, and studies have shown that up to one-third of patients with central venous catheterization suffer catheter malfunctions due to non-infectious complications, but there is rarely a complete examination of the composition and biological evolution of catheter-associated sheaths ^[3]. When there is difficulty in extubation or a poor flow in central venous catheterization, the clinic will treat the problem as a thrombus, and when thrombolytic therapy is ineffective, only then the presence of fibrin sheath formation will be considered. It is recommended to raise the awareness of clinicians and nurses about fibrin sheaths so that they can recognize and deal with the problem when it occurs. Currently, treatment for fibrin sheaths relies on thrombolytic therapy and surgical resection, but these methods are not specific to fibrin sheaths. Therefore, more specific and targeted treatment guidelines and protocols are needed to improve patient outcomes. The routine maintenance

of catheters mainly focuses on preventing thrombosis, and there is a lack of nursing programs for fibrin sheaths. It is recommended that appropriate nursing guidelines be developed, including routine cleaning of the catheter, regular inspections, and early identification of fibrin sheaths to reduce their occurrence and mitigate their effects. Although pharmacologic or surgical treatments can temporarily restore catheter function, fibrin sheaths are still at risk of re-occurring, and there are also a few cases of fibrin sheaths that are not manageable or treatable with existing treatments^[25]. This suggests the need for more sustained and comprehensive treatment strategies, as well as closer follow-up and monitoring. In summary, fibrin sheath is a problem that requires more attention and research. By gaining a deeper understanding of its formation mechanisms, risk factors, and effective treatments, clinical staff can better manage catheters to reduce their impact on patients and improve their quality of life.

Disclosure statement

The authors declare no conflict of interest.

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