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Root Cause Analysis and Nursing Quality Improvement for PICC Occlusion in an Elderly Critically Ill Patient

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Abstract: Peripherally inserted central catheter (PICC) is widely used in clinical practice. It is mainly suitable for elderly critically ill patients who need long-term infusion of stimulating drugs (such as chemotherapeutic drugs), hypertonic drugs (such as fat emulsion, amino acids), and poor peripheral vascular conditions. Catheter blockage is one of the most common complications during its use, which may lead to treatment interruption, increased risk of infection, prolonged hospital stays, and affected patients' prognosis. In order to improve the quality of nursing care, the cause of PICC blockage in an elderly critically ill patient was analyzed by root cause analysis (RCA). The root cause analysis group was set up to find the near-end cause by time sequence method and the root cause by "5Why" method. Through cause mining, the supervision and assessment mechanism of PICC maintenance quality was re-established, the evaluation standard of PICC and the prevention strategy of blockage were standardized, and the system and process were improved to prevent similar incidents from happening again.

Keywords: PICC Blockage; Root Cause Analysis (RCA); Adverse Events; Critically Ill Patients; Catheter Maintenance; Quality of Care.

1. Introduction

Peripherally inserted central catheter (PICC) refers to a catheter whose tip is located in the superior vena cava or inferior vena cava , which is punctured and inserted through the upper extremity's Basilic vein, median cubital vein, cephalic vein, brachial vein, and external jugular vein (neonates can also pass through the lower extremity's great saphenous vein, cephalic temporal vein, retroauricular vein, etc.)[1]. PICC technology has the characteristics of low invasiveness, convenient operation, long-term indwelling and effective prevention of drug extravasation. It plays a key role in intravenous nutrition infusion, tumor chemotherapy and antibiotic therapy, and provides patients with a safe intravenous treatment access[2].

PICC blockage is one of the most common complications of PICC technique. The main clinical features of PICC blockage are increased infusion resistance, inability to withdraw blood or obstruction of flushing tube. Studies have shown that the incidence rate can be as high as 20.6%, and it is positively correlated with the indwelling time of the catheter. Obstruction not only significantly increased the risk of unplanned extubation (about 34.8%), but also increased the economic and physical and mental burden of patients. It may also induce secondary problems such as catheter-related bloodstream infection and venous thrombosis. If it is not handled properly, it may even lead to pulmonary embolism due to the detachment of emboli, which will threaten the life of patients[3]. Therefore, it is necessary to prevent the occurrence of PICC obstruction in hospital.

Root Cause Analysis (RCA) is a structured retrospective analysis tool for serious adverse events. Its core is to find near-end causes through systematic investigations (such as time series tables and multi-source evidence collection), mine fundamental problems from the system levels of process, system, and resource allocation, and formulate improvement strategies, and finally achieve "non-imputation" continuous quality improvement[4][5][6]. In this paper, RCA was used to analyze a case of PICC blockage in an elderly critically ill patient in a hospital. Although it did not cause serious consequences after treatment, through the analysis of the root cause, the relevant procedures of the event were sorted out, aiming at formulating targeted countermeasures and improving system procedures to prevent similar events from happening again.

2. Clinical Case Review

The patient, female, 72 years old, married, junior high school education. The main reason is "1 month after craniocerebral surgery, shortness of breath for more than half a month" in 2024.He was admitted to hospital on July 12, 2009. Due to a malignant tumor of the brain, the patient underwent surgical treatment in an external hospital on June 12, 2024. After the operation, he was complicated by hydrocephalus, cerebral herniation, and bilateral pneumonia. He underwent decompression of bone flap, ventricular drainage, and tracheotomy. Life support such as surgery, and symptomatic support treatment such as anti-infection, dehydration, epilepsy prevention, sputum resolution, and electrolyte balance were given. After treatment, his condition improved compared with before, and he was admitted to this hospital for further diagnosis and treatment. Physical examination on admission: lethargy, simple instructions, tracheotomy state, intermittent cough and expectoration, and double-chamber PICC in the right upper arm (inserted on June 12, 2024). The examination results on the day of admission showed that leukocytes 13.82 x10 ^ 9/L, C-reactive protein 132.92 mg/L, hemoglobin 55g/L, platelets 59 x10 ^ 9/L, serum potassium 7.14 mmol/L, serum sodium 128 mmol/L, albumin 27g/L, activated partial thromboplastin time APTT 49.2 seconds. Admission diagnosis: Severe pneumonia, postoperative cerebral malignant tumor, cerebral hernia, cerebral edema, anemia, thrombocytopenia, multiple rib fractures, hypertension, hypoproteinemia. The patients are critically ill in the elderly with complicated condition and

many kinds of intravenous drugs. It is necessary to implement comprehensive treatment plans such as infusion of various antibiotics to reduce inflammation, blood transfusion to correct anemia and coagulation dysfunction, albumin transfusion to correct hypoproteinemia, infusion to adjust electrolyte balance imbalance, control blood pressure, and provide nutritional supplements. It is important to maintain the normal function of PICC in patients with poor peripheral vascular conditions during hospitalization, which is important for the continuous treatment of Patients.

3. Problem Definition and Data Collection

3.1. Problem Definition

In this case, PICC was withdrawn, blood was recovered in the main pullback, and there was resistance in the injection, and the accessory canal was completely blocked. No harm was caused to the patient. It was assessed as grade 4 according to the Severity Assessment Matrix (SAC). According to the abnormal event decision tree (IDT) evaluation, it belongs to the system problem.

3.2. Data Collection

The RCA team members include head nurse, liaison nurse of static therapy specialty, nursing team leader, bed nurse, doctor in charge, and pharmacist. The head nurse and the liaison nurse of the static therapy specialty lead the operation of the team and guide the implementation of RCA; The nurse in charge of the bed is responsible for collecting the relevant data of the incident, and the nursing team leader is responsible for coordinating the implementation of RCA steps after quality control and confirmation; The lead physician and pharmacist can answer the concerns of other team members about possible factors (such as drug compatibility contraindications, thrombosis risk) that may cause patients to have PICC blockage. The entire team undergoes RCA training.

Description of the event (Table 1)

Table 1. Event Occurrence Time Series Table

Date	Time	Event Description	Supplementary information
2024.07.12	16:30	The patient, a 72-year-old female, was admitted to the hospital due to "shortness of breath for more than half a month one month after craniocerebral surgery". A double-lumen PICC was introduced into the right upper arm outside the hospital (implanted on June 12, 2024), exposed by 1cm. There was no redness, swelling, bleeding or exudation at the puncture site. The double-lumen injection was smooth and both had blood return.	The patient's condition was complicated, and the family members lost PICC from the other hospital maintenance book
	22:00	On the night of admission, the patient received symptomatic treatment by infusing red blood cell suspension, albumin, meropenem, mannitol, calcium gluconate, Xinhuosu and other drugs through PICC.	The night shift nurse failed to assess the patency and blood return of the patient's PICC catheter during shift handover.
2024.07.13	8:00	The patient's PICC injection was unobstructed, and there was no blood return in both chambers during resuscitation.	1. The patient requires a large variety of drugs and blood products to be infused. 2. The nurse in charge did not pay sufficient attention to the issue of no blood return when performing PICC aspiration. 3. The on-duty nurse failed to flush the catheter as required at regular intervals.
2024.07.16	23:00	There was no blood return when the PICC catheter was aspirated from both lumens. There was resistance when the main lumen was injected and the secondary lumen was blocked.	1.The patient is in a tracheotomy state, with occasional coughing and a large amount of phlegm. Sputum aspiration is required as needed. 2. The situation where nurses failed to hand over PICC during shift handover 3. The nurse in charge of the bed failed to report the problem to the head nurse in a timely manner.
2024.07.17	16:00	Negative pressure perfusion of urokinase (5000U/mL) was performed using the three-way stopcock method to recanalize the PICC accessory tube.	The intravenous therapy team of the department failed to restore the auxiliary tube of the PICC.
2024.07.18	9:00	Invite a consultation from a specialized outpatient clinic for intravenous therapy.	The intravenous therapy specialist nurse successfully recanalized the PICC at the bedside. Blood return was observed in both chambers during resuscitation, and the injection was smooth.

4. Cause Analysis

4.1. Identify Possible Causes

The team members carried out brainstorming, drew fish bone diagrams, and analyzed the possible reasons for the PICC blockage event from five aspects: Human, Machine, Material, Method, and Environment[7]. (Figure 1).

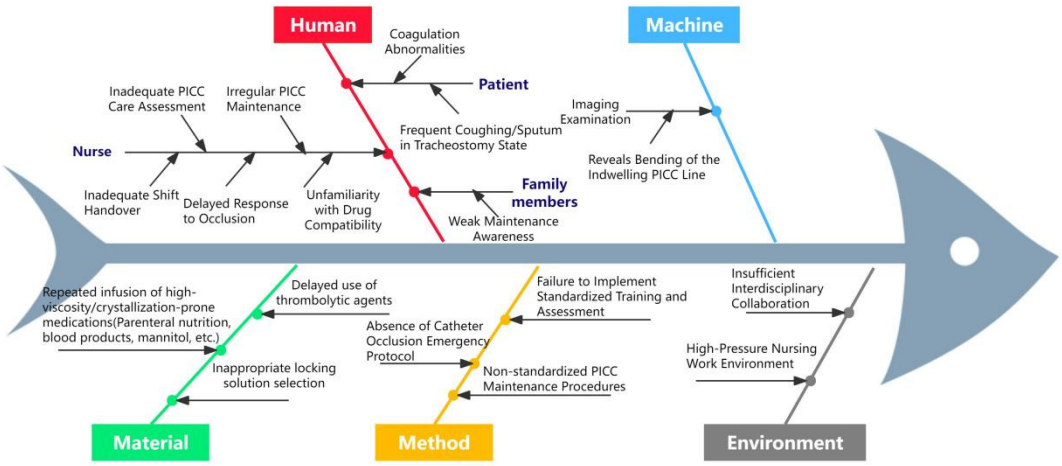

Fig 1. Fishbone diagram of PICC blockage in elderly critically ill patients

4.2. Analyze the Root Cause

Team members applied the "5Why" method to explore the root cause of the problem (Figure 2). Through a series of questions, it is confirmed that the root cause of this incident is: (1) the record writing of PICC evaluation has not been implemented in the post responsibility; (2) No standardized training and examination of PICC; (3) No standardized process of PICC maintenance; (4) No training on the knowledge of compatibility contraindication of commonly used drugs; (5) No contingency plan for PICC pipe blockage.

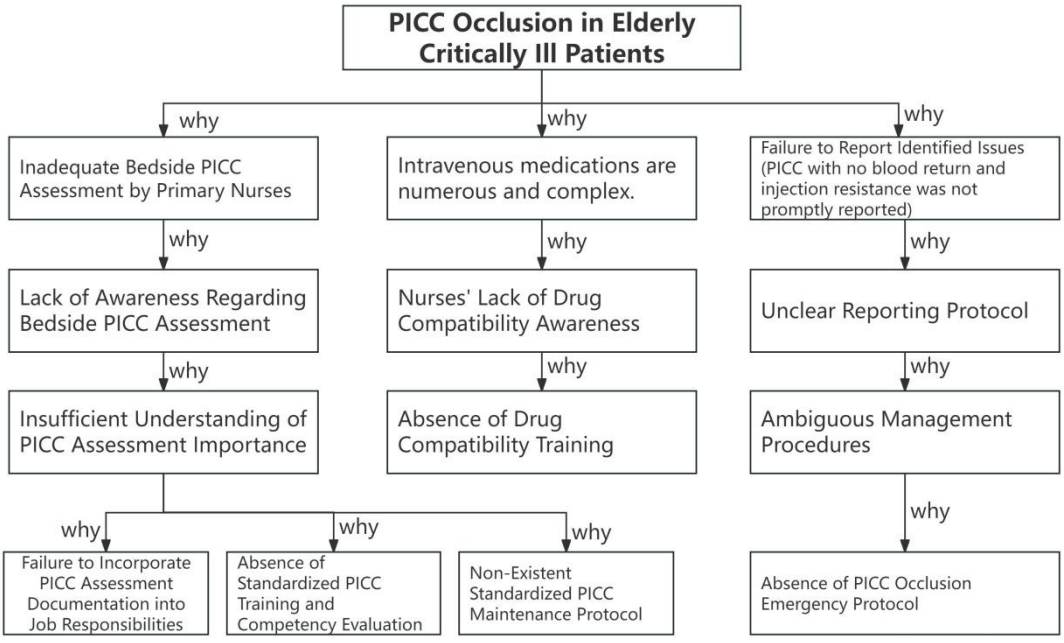

Fig 2. "5Why" Method for Root Cause Analysis

5. Implement Improvement Measure

5.1. Perfecting Job Responsibilities and Establishing Quality Monitoring Mechanism for PICC Evaluation

When each shift is handed over, the patient's whole body and local condition of puncture orifice, catheter retention time, maintenance interval, catheter patency, infusion and blood transfusion must be comprehensively evaluated[8] , and the complications that may exist during PICC retention should be identified early, and the results of PICC assessment should be dynamically reflected in nursing records, and the work content should be included in the corresponding post responsibilities; The head nurse, the liaison nurse of the static therapy specialty and the daily nursing team leader made irregular inspections and on-site supervision, pointed out and corrected irregular behaviors in time, and randomly checked the standardization of PICC maintenance operations. The results of random inspections were used as one of the indicators for monthly performance appraisal. Through repeated inspection and supervision, nurses' awareness of PICC assessment was strengthened.

5.2. Establish a Standardized Training and Assessment System

The content of the training includes: 1) Knowledge related to central venous catheter maintenance: assessment of catheter patency (Patency standard, Assessment timing, Assessment frequency, Assessment method), judgment

method of catheter blockage, classification of catheter blockage, causes of catheter blockage Factors, treatment methods of catheter blockage, tube flushing and sealing techniques, etc.; 2) Compatibility contraindications of commonly used drugs and related precautions; (2) The liaison nurses in the static therapy department should formulate the training plan for central venous catheter maintenance, and then be responsible for the training of all nurses in the department. Pharmacists from the Department of Pharmacy were invited to give lectures, explaining the knowledge of drug compatibility contraindications for commonly used drugs in the department. The whole training was conducted by combining online and offline methods. After the training, the theoretical knowledge and skill operation were assessed to ensure that all staff completed the study and mastered it, and the assessment results were included in the personal performance assessment and annual evaluation of nurses. (3) Full flushing and effective sealing are important measures to prevent central venous catheter blockage, Holding pulse tube flushing and positive pressure tube sealing were included in the contents of nurses' on-the-job training every year and included in the items of nursing quality inspection every quarter.

5.3. Develop PICC Standardized Maintenance Process

The team members referred to the latest authoritative literature[1][8][9] related to central venous catheter maintenance and blockage, invited in-hospital static therapy experts to guide, formulated and implemented the "PICC Standardized Maintenance Operation Procedure" (SOP), and clarified the key maintenance nodes and requirements as follows:

(1) Pipe flushing and pipe sealing: Strictly stipulate the frequency of pipe flushing (such as infusion of high viscosity, easy crystallization liquid, infusion of incompatible drugs must be flushed every 6 to 8 hours), the choice of pipe flushing liquid (0.9% sodium chloride injection is the first choice, and the use of heparin sodium saline with a specific concentration in specific cases must be ordered and clearly marked by the doctor), the amount of pipe flushing liquid (>= 2 times the volume of the catheter plus the volume of the additional device), and the amount of pipe sealing liquid (>= 1.2 times the volume of the additional device), It is mandatory to adopt the technology of "pulse flushing (push-stop-push technique) plus positive pressure sealing" to ensure that there is no drug residue and blood reflux on the inner wall of the catheter.

(2) Assessment of catheter patency: Incorporate the assessment of catheter patency into the core content of each shift of nursing handover and each infusion/ transfusion/ Routine procedures before medication. Refinement of evaluation criteria: not only requires withdrawal to see blood recovery, but also needs to pay attention to the sense of resistance of bolus injection.

(3) Drug infusion management: It is clearly stipulated that after transfusion of blood products, parenteral nutrient solutions (such as fat emulsion, amino acids), hypertonic/viscous drugs (such as albumin, immunoglobulin), and compatible contraindicated drugs, sufficient normal saline must be used immediately. Full pulse flushing of the tube. Establish a quick check-up table for the compatibility and contraindication of drugs commonly used in departments and place them in nurses' stations and treatment vehicles.

(4) Change of dressings and observation of puncture points: Regulate the change frequency of dressings (transparent dressings at least once every 7 days, gauze dressings at least once every 2 days), and observe the main points of puncture points (redness, swelling, heat, pain, bleeding, exudation). Emphasis on maintaining records in a timely, accurate and complete manner.

(5) Education for patients and their families: Formulate standardized publicity and education contents for precautions during PICC hospitalization (such as avoiding compressing the side limb of the catheter, avoiding lifting heavy objects, observing key points, and reporting abnormal conditions, etc.).

5.4. Formulate and Drill PICC Pipe Blockage Emergency Plan

Based on the systematic defects that the PICC blockage incident was not reported and dealt with in time, the "PICC Pipe Blockage Emergency Plan" was formulated and practiced as follows.

(1) Primary treatment (nurse on duty): 1) Stop infusion immediately and evaluate to confirm whether the catheter is discounted, twisted, clamped, etc.; 2) Try to withdraw: violent flushing is strictly prohibited; 3) Using 10ml or more syringes, try pulse flushing tube (0.9% sodium chloride injection).

(2) Intermediate treatment (nursing leader/liaison nurse): If the primary treatment is ineffective, the type of blockage should be judged. 1) Thrombotic blockage: use urokinase thrombolysis according to doctor's advice (5000U/ml, accurately calculate according to the volume of the catheter and inject an appropriate amount of solution, keep it for 30-60 minutes and then withdraw it), strictly follow the usage norms of thrombolytic drugs, and evaluate the coagulation function and bleeding risk of patients; 2) Drug-induced sedimentation blockage: use a specific dissolving agent according to the doctor's advice and confirm the compatibility between the dissolving agent and the material of the catheter[3].

(3) Advanced treatment/report (head nurse/static therapy specialist nurse): If the intermediate treatment is ineffective, invite the static therapy specialist outpatient clinic to consult and deal with it immediately.

(4) If it still cannot be recanalized or there are contraindications (such as suspected catheter-related thrombosis), report to the doctor to evaluate the necessity of extubation. Regardless of whether it is reconnected, fill in the incident report form according to the "Nursing Adverse Events Reporting System" and report to the nursing department.

(5) Regular drills: Organize scenario simulation drills every quarter (focusing on drills of pipe blockage identification, primary and intermediate treatment, and reporting process) to improve nurses' emergency handling capabilities and teamwork efficiency. After the rehearsal, review was carried out to evaluate the effectiveness of the process and the standardization of the nurse's operation, and to continuously optimize it.

6. Improvement Effect

From the improvement to May 2025, 28 patients with indwelling PICC were cared for in our department, none of them had complete catheter occlusion, only 2 patients had incomplete catheter occlusion (manifested as catheter withdrawal without blood return, bolus injection was smooth),

and the incidence of catheter occlusion was significantly reduced compared with before. Through standardized training, the correct rate of tube flushing and tube sealing operations has increased from 80% to 97%, the average score of central venous catheter maintenance assessment has increased from 71 points before training to 93 points, and the average score of commonly used drug compatibility assessment has increased from 69 points before training to 91 points. The general practice nurses have all reached the standard in the assessment (full score 100 points, 90 points reached the standard). According to the "PICC Standardized Maintenance Operation Procedures" and "PICC Pipe Blockage Emergency Plan" formulated, the learning completion rate and clinical implementation rate of general practice nurses are both 100%.

7. Summary

Through RCA analysis, it is clear that the root causes of PICC blockage are lack of job responsibilities, insufficient training and assessment, and lack of standardized procedures. The improvement measures formulated pertinently, including establishing quality control supervision mechanism, standardizing training system, implementing SOP and emergency plan, can reduce the incidence of tube blockage and improve the quality of nursing care. This study confirmed that combining system process improvement with the particularity of highrisk groups is a sustainable path to prevent PICC complications, and provides a replicable quality management paradigm for similar institutions.

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