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Nursing Interventions for Preventing Complications Associated with Peripheral Arterial Catheters in Critically Ill Patients

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ABSTRACT: Peripheral arterial catheters are essential vascular access devices in critical care settings, providing continuous invasive blood pressure monitoring and facilitating repeated arterial blood sampling in patients with severe physiological instability. Their use is particularly important among critically ill patients who require continuous haemodynamic assessment, mechanical ventilation, vasoactive medications, or frequent evaluation of arterial blood gases. Despite their clinical benefits, peripheral arterial catheters are associated with several potentially serious complications, including catheter-related

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bloodstream infections, local insertion-site infections, arterial thrombosis, distal limb ischaemia, bleeding, haematoma formation, catheter occlusion, accidental dislodgement, and inaccurate haemodynamic measurements. These complications may compromise patient safety, interrupt essential monitoring, prolong intensive care unit admission, and contribute to increased morbidity and mortality. Nursing care plays a central role in preventing these adverse events through systematic assessment, strict adherence to aseptic techniques, appropriate catheter-site selection, effective catheter stabilization, continuous monitoring of distal circulation, and accurate maintenance of the pressure monitoring system. Additional interventions include regular evaluation of catheter necessity, appropriate management of pressure tubing and flushing systems, early recognition of abnormal arterial waveforms, prevention of mechanical catheter damage, and prompt communication of abnormalities to the multidisciplinary team. Comprehensive nursing interventions should extend throughout the entire catheter lifecycle, beginning with pre-insertion assessment and continuing through insertion assistance, routine maintenance, complication surveillance, and safe catheter removal. Evidence-based nursing protocols, continuing professional education, standardized documentation, and multidisciplinary collaboration are important components of successful prevention strategies.

INTRODUCTION

The management of critically ill patients requires continuous and accurate assessment of cardiovascular function, tissue perfusion, and systemic haemodynamic stability. Patients admitted to intensive care units frequently experience severe physiological disturbances resulting from sepsis, septic shock, acute respiratory failure, major trauma, cardiovascular disorders, complicated surgical procedures, and multiple organ dysfunction. These conditions may produce rapid changes in arterial blood pressure and tissue perfusion, requiring immediate clinical assessment and timely therapeutic interventions. Consequently, invasive haemodynamic monitoring has become an essential component of contemporary critical care practice, particularly in patients whose clinical conditions require continuous evaluation of blood pressure and repeated assessment of arterial blood gases. Peripheral arterial catheterization provides a practical and reliable method of obtaining direct arterial pressure measurements while allowing repeated blood sampling without repeated arterial punctures. These capabilities are particularly valuable in patients receiving vasoactive medications, mechanical ventilation, or other interventions that require frequent physiological monitoring [1].

Arterial catheters are commonly inserted into peripheral arteries, particularly the radial artery, because of its superficial anatomical location, accessibility, and generally favourable collateral circulation through the ulnar artery and palmar arterial arches. Other potential insertion sites include the femoral, brachial, dorsalis pedis, and posterior tibial arteries, depending on the patient's clinical condition, vascular anatomy, procedural requirements, and the availability of suitable access sites. The radial artery is generally preferred in adult critical care patients because it facilitates convenient monitoring and direct observation of the insertion site, while peripheral arterial access may reduce some of the risks associated with more proximal arterial catheterization. Nevertheless, the selection of an appropriate arterial access site requires consideration of peripheral vascular disease, previous vascular procedures, anatomical abnormalities, local infection, existing perfusion problems, and the anticipated duration of catheterization. Professional recommendations emphasize that the radial, brachial, and dorsalis pedis arteries are generally preferred over femoral and axillary sites in adults when appropriate, partly because of infection-related considerations [2].

The clinical importance of peripheral arterial catheters extends beyond their function as pressure-monitoring devices. Continuous arterial pressure monitoring enables healthcare professionals to identify sudden haemodynamic deterioration, evaluate responses to fluid administration, assess the effects of vasoactive medications, and recognize changes in cardiovascular function that may not be detected adequately through intermittent non-invasive blood pressure measurements. In patients experiencing severe shock or receiving high doses of vasopressors, frequent invasive pressure measurements may be particularly important because their blood pressure can fluctuate rapidly and peripheral perfusion may be compromised. Arterial access also facilitates repeated measurement of arterial blood gases, which is essential for assessing oxygenation, ventilation, acid–base balance, and metabolic disturbances in critically ill patients. However, the reliability of these clinical assessments depends on

the correct positioning, maintenance, and continuous evaluation of the arterial catheter and its associated monitoring equipment [3].

Although peripheral arterial catheterization is widely performed in intensive care units, it is not an entirely risk-free procedure. The catheter penetrates the arterial wall and remains in direct contact with circulating blood and vascular tissue, potentially initiating local inflammatory responses, endothelial injury, platelet activation, thrombus formation, and vascular obstruction. Mechanical trauma during insertion may also damage surrounding tissues or produce bleeding and haematoma formation. Furthermore, the presence of a foreign material within the arterial lumen may interfere with normal blood flow, particularly when the catheter occupies a substantial proportion of the vessel diameter. The consequences may range from temporary arterial occlusion to clinically significant distal ischaemia, depending on the adequacy of collateral circulation and the patient's underlying vascular condition. These complications may be especially concerning in patients with shock, diabetes mellitus, peripheral arterial disease, coagulopathy, or pre-existing vascular abnormalities [4].

Infection represents another important complication associated with peripheral arterial catheters, despite the common perception that arterial devices carry a lower infectious risk than central venous catheters. Microorganisms may enter the vascular system through contamination during catheter insertion, manipulation of the pressure monitoring system, inadequate hand hygiene, improper disinfection of access ports, or migration of microorganisms from colonized insertion-site skin. Once microorganisms enter the catheter system, they may adhere to catheter surfaces and develop biofilms, making eradication more difficult and potentially resulting in local infection or catheter-related bloodstream infection. The clinical consequences may be particularly severe among critically ill patients because their immune responses are frequently impaired by severe illness, invasive procedures, prolonged hospitalization, and exposure to broad-spectrum antimicrobial medications. Therefore, strict adherence to infection prevention practices is necessary throughout the entire period of arterial catheterization [5].

The development of catheter-associated complications is influenced by several patient-related, procedural, and equipment-related factors. Patient-related factors include advanced age, diabetes mellitus, peripheral vascular disease, hypotension, vasopressor administration, coagulation abnormalities, immunosuppression, and poor baseline tissue perfusion. Procedural factors include emergency catheter insertion, repeated puncture attempts, inappropriate catheter size, inadequate aseptic technique, and insufficient stabilization. Equipment-related factors include damaged pressure tubing, inappropriate flushing systems, loose connections, air bubbles, blood reflux, and inaccurate positioning of the pressure transducer. Importantly, the risk of complications does not end when the catheter has been successfully inserted. Catheter maintenance represents an ongoing process requiring continuous observation, regular reassessment, and appropriate management of the insertion site and monitoring equipment [6].

Peripheral arterial catheter complications may significantly interfere with the clinical management of critically ill patients. Catheter occlusion or accidental dislodgement can result in sudden loss of continuous blood pressure monitoring, potentially delaying recognition of haemodynamic deterioration. Inaccurate pressure measurements may lead to inappropriate fluid administration, incorrect adjustment of vasoactive medications, or failure to identify clinically significant hypotension. Similarly, arterial thrombosis and distal ischaemia may threaten the viability of the affected extremity, particularly when vascular compromise is not recognized promptly. Bleeding and haematoma formation may cause additional blood loss, tissue compression, discomfort, and, in severe circumstances, neurovascular impairment. Catheter-associated infections may progress to systemic infection and further complicate the clinical course of patients who are already critically ill [7].

Nursing professionals occupy a central position in preventing these complications because they provide continuous bedside care and are frequently the first healthcare providers to identify changes in catheter function or patient condition. Their responsibilities include assessing the patient's vascular status before catheter insertion, preparing the patient and equipment, maintaining aseptic conditions, monitoring the insertion site, assessing distal circulation, evaluating arterial waveforms, maintaining pressure monitoring equipment, and documenting relevant findings. Nurses must also recognize clinical warning signs such as increasing insertion-site pain, swelling, bleeding, changes in skin colour, reduced skin temperature, delayed capillary refill, altered sensation, diminished distal pulses, and unexpected changes in arterial pressure waveforms. Early identification of these abnormalities allows timely intervention and may prevent progression to more serious complications [8].

The preventive role of critical care nurses also involves ensuring that arterial catheters remain clinically necessary and that unnecessary catheter exposure is minimized. Although arterial catheters are frequently maintained for several days in patients requiring continuous haemodynamic monitoring, their continued presence should be reviewed regularly according to the

patient's clinical requirements. Prolonged catheterization increases opportunities for microbial colonization, mechanical complications, and vascular injury. Therefore, nurses should participate actively in daily multidisciplinary assessments of catheter necessity and communicate when the clinical indication for invasive arterial monitoring has resolved. Removing unnecessary devices is an important component of evidence-based vascular access management and infection prevention [9].

Furthermore, the prevention of arterial catheter complications requires an integrated approach that combines technical competence, clinical judgment, standardized protocols, and effective communication. Nurses should understand the anatomical characteristics of different arterial access sites, the physiological principles of invasive blood pressure monitoring, the mechanisms of vascular thrombosis, and the clinical manifestations of infection and impaired perfusion. They should also receive appropriate education regarding catheter stabilization, pressure transducer positioning, flushing-system safety, and management of emergency situations. Evidence-based protocols and competency-based training can improve adherence to preventive measures and reduce variations in clinical practice. Accordingly, comprehensive nursing care should focus not only on preserving catheter patency but also on protecting the patient's vascular integrity, preventing infection, ensuring accurate haemodynamic measurements, and minimizing avoidable harm throughout the period of arterial catheter use [10].

Clinical Significance and Indications of Peripheral Arterial Catheters in Critical Care

Peripheral arterial catheters are primarily indicated when continuous invasive blood pressure monitoring is necessary to guide the management of patients with unstable cardiovascular conditions. They are commonly used in patients with septic shock, cardiogenic shock, severe haemorrhage, major trauma, acute respiratory failure, and complicated postoperative conditions. In these circumstances, intermittent non-invasive blood pressure measurements may be insufficient to detect rapid haemodynamic changes or provide the frequency of assessment required for safe therapeutic decision-making. An arterial catheter allows continuous monitoring of systolic, diastolic, and mean arterial pressure, providing clinicians with immediate information regarding cardiovascular stability and responses to treatment. This information is particularly important during vasopressor administration, when small changes in arterial pressure may influence treatment decisions [11].

Another important indication is the need for frequent arterial blood sampling. Patients receiving mechanical ventilation may require repeated arterial blood gas analysis to evaluate oxygenation, carbon dioxide elimination, and acid–base balance. Similarly, patients with severe metabolic disturbances, respiratory failure, or complex cardiovascular conditions may require repeated laboratory assessment. An indwelling arterial catheter reduces the need for repeated arterial punctures, which may otherwise cause discomfort, vascular trauma, and unnecessary procedural exposure. However, the decision to maintain an arterial catheter should always be based on the patient's current clinical needs rather than convenience alone [12].

Types and Anatomical Sites of Peripheral Arterial Catheterization

The radial artery is the most frequently selected peripheral arterial access site in adult critical care practice because it is relatively superficial, accessible, and generally associated with a favourable safety profile. Its location at the wrist facilitates catheter insertion, stabilization, and routine inspection. The presence of collateral circulation through the ulnar artery and palmar arches may help preserve hand perfusion if radial arterial blood flow becomes compromised, although the adequacy of collateral circulation varies between individuals. Appropriate assessment of vascular anatomy and distal perfusion remains essential before and after catheter placement [13].

The femoral artery may be considered when radial access is unavailable, unsuccessful, or clinically unsuitable. It offers a relatively large vessel diameter and may provide reliable access in patients with severe peripheral vasoconstriction. However, femoral arterial catheterization may be associated with increased concerns regarding infection, bleeding, and difficulty maintaining a clean insertion site, particularly in patients with obesity, incontinence, or limited mobility. The brachial artery is another potential access site, although its relatively limited collateral circulation and proximity to important nerves require careful consideration. Dorsalis pedis and posterior tibial arteries may be used in selected circumstances when upper extremity access is unsuitable, provided that distal perfusion can be adequately assessed [14].

Complications Associated with Peripheral Arterial Catheters

Catheter-Related Infections

Catheter-related infection is an important complication that may develop through contamination during insertion or subsequent manipulation of the catheter system. Local infection may present with erythema, warmth, tenderness, swelling, purulent

discharge, or progressive skin changes surrounding the insertion site. More serious infection may involve microbial colonization of the catheter and subsequent bloodstream infection, potentially contributing to sepsis and further organ dysfunction. The risk is influenced by catheter duration, insertion-site conditions, hand hygiene practices, dressing integrity, and the frequency of manipulation of the monitoring system. Effective prevention therefore requires consistent application of aseptic techniques, careful site inspection, and appropriate management of all components of the arterial pressure monitoring system [15].

Arterial Thrombosis and Catheter Occlusion

Arterial thrombosis occurs when platelet activation and coagulation processes result in thrombus formation within or around the catheterized artery. Endothelial injury, altered blood flow, catheter-related mechanical irritation, and underlying hypercoagulability may contribute to thrombus development. Thrombosis may produce partial or complete arterial obstruction, resulting in impaired catheter function, reduced blood flow, and potential distal ischaemia. Catheter occlusion may also occur because of blood reflux, clot formation within the catheter lumen, kinking, or mechanical obstruction of the tubing. Nurses should therefore monitor catheter function, avoid unnecessary manipulation, maintain the prescribed closed flushing system, and report persistent inability to obtain an appropriate arterial waveform or blood return [16].

Distal Limb Ischaemia

Distal limb ischaemia is among the most clinically serious vascular complications associated with peripheral arterial catheterization. It may develop when catheter-related thrombosis, arterial spasm, dissection, or impaired collateral circulation reduces blood supply to tissues distal to the insertion site. Early manifestations include pain, pallor, coolness, paraesthesia, delayed capillary refill, and changes in skin colour. More advanced ischaemia may produce weakness, loss of sensation, cyanosis, and tissue injury. Patients receiving sedatives or mechanical ventilation may be unable to communicate discomfort, making objective neurovascular assessment particularly important. Prompt recognition of changes in peripheral perfusion and immediate escalation to the medical team are essential to prevent irreversible tissue damage [17].

Bleeding and Haematoma Formation

Bleeding may occur during catheter insertion, following accidental catheter displacement, or when the catheter and connecting system become disconnected. Haematoma formation may result from vascular injury, repeated puncture attempts, inadequate compression, or impaired coagulation. Patients receiving anticoagulants or antiplatelet medications may have an increased risk of bleeding-related complications. A significant haematoma may compress surrounding structures and compromise local circulation or nerve function. Nurses should inspect the insertion site regularly, assess surrounding tissues for swelling and discoloration, ensure secure catheter fixation, and apply appropriate pressure following catheter removal according to institutional protocols and the patient's coagulation status [18].

Mechanical Complications and Accidental Dislodgement

Mechanical complications include catheter kinking, fracture, leakage, disconnection, migration, accidental removal, and damage to the pressure monitoring system. These events may interrupt continuous monitoring and create risks of haemorrhage, contamination, or air entry into the system. Movement of the wrist or limb, inadequate fixation, tension from monitoring tubing, and poor positioning may contribute to catheter displacement. Appropriate stabilization, positioning, secure connections, and regular inspection of the complete monitoring system are therefore essential preventive interventions [19].

Inaccurate Haemodynamic Measurements

Inaccurate invasive blood pressure measurements may result from incorrect transducer positioning, failure to zero the system, air bubbles, excessive tubing compliance, inappropriate connections, or abnormal dynamic response characteristics. An overdamped arterial waveform may underestimate systolic pressure and overestimate diastolic pressure, whereas an underdamped waveform may exaggerate systolic pressure and underestimate diastolic pressure. These errors may lead to inappropriate clinical decisions, particularly in patients receiving vasoactive medications. Nurses should therefore understand the principles of pressure transducer leveling, zeroing, waveform assessment, and troubleshooting of monitoring equipment [20].

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Risk Factors Associated with Peripheral Arterial Catheter Complications

The development of arterial catheter complications is multifactorial and reflects interactions between patient characteristics, vascular anatomy, procedural technique, catheter-related factors, and nursing care practices. Patients with diabetes mellitus, peripheral arterial disease, advanced age, systemic hypotension, vasopressor dependence, and coagulation abnormalities may be particularly vulnerable to vascular complications. Poor peripheral circulation may increase the likelihood that catheter-related obstruction will produce clinically significant ischaemia, while immunosuppression and prolonged hospitalization may increase susceptibility to infection. Repeated catheter insertion attempts and prolonged catheter duration may further increase the risk of tissue trauma and device failure [21].

Table 1. Risk Factors Associated with Peripheral Arterial Catheter Complications [1, 2, 4, 5, 15–21].

Risk factor	Potential mechanism	Possible complication
Diabetes mellitus	Endothelial dysfunction and impaired peripheral circulation	Ischaemia and infection
Peripheral arterial disease	Reduced baseline arterial blood flow	Distal limb ischaemia
Prolonged catheterization	Increased exposure to microbial colonization and mechanical injury	Infection and thrombosis
Repeated insertion attempts	Vascular trauma and endothelial damage	Haematoma and thrombosis
Vasopressor administration	Peripheral vasoconstriction and reduced tissue perfusion	Distal ischaemia
Coagulation abnormalities	Increased bleeding tendency or thrombotic susceptibility	Haemorrhage or thrombosis
Inadequate catheter stabilization	Movement and mechanical irritation	Dislodgement and bleeding
Poor aseptic technique	Microbial contamination	Local and bloodstream infection
Inappropriate catheter size	Increased interference with arterial blood flow	Occlusion and ischaemia
Improper transducer positioning	Hydrostatic measurement errors	Inaccurate blood pressure readings

Comprehensive Nursing Interventions for Preventing Peripheral Arterial Catheter Complications

Pre-Insertion Nursing Assessment

Pre-insertion nursing assessment is an important component of safe arterial catheter management because it helps identify patients who may be particularly susceptible to complications. Nurses should review the patient's medical history, current haemodynamic condition, coagulation profile when available, vascular access history, medication use, and evidence of peripheral vascular disease. Assessment should include inspection of both upper extremities for skin abnormalities, infection, previous surgical scars, oedema, vascular access devices, and signs of impaired circulation. Existing neurological deficits, previous arterial procedures, and any history of vascular reconstruction should also be communicated to the clinician responsible for catheter placement. Establishing a baseline assessment allows subsequent changes in circulation and neurological function to be identified more accurately [2, 10].

Assessment of distal circulation is particularly important before radial arterial catheterization. Nurses should evaluate skin colour, temperature, capillary refill, palpable peripheral pulses, and the patient's ability to report pain or altered sensation. The modified Allen test may be used as part of the clinical assessment of collateral circulation, although it has limitations and should not be considered an infallible predictor of ischaemic complications. When clinically indicated, Doppler ultrasonography or other vascular assessment techniques may provide additional information about arterial patency and vessel anatomy. These assessments should be interpreted within the broader clinical context rather than used as isolated determinants of catheter suitability [13].

Selection of an Appropriate Arterial Access Site

Nurses should collaborate with physicians and vascular access professionals to ensure that the selected arterial site is appropriate for the patient's vascular condition and anticipated monitoring requirements. The radial artery is generally preferred when suitable because it is accessible and permits convenient observation of the insertion site. However, alternative sites may be necessary in patients with inadequate radial circulation, previous vascular procedures, local infection, or anatomical abnormalities. The chosen site should allow effective catheter stabilization, minimize interference with patient movement and essential nursing care, and permit regular assessment of distal perfusion. The potential risks of femoral, brachial, and distal lower-extremity access should be considered before catheter placement [2, 14].

Strict Hand Hygiene and Aseptic Technique

Hand hygiene is a fundamental intervention for preventing catheter-related infections. Nurses must perform hand hygiene before and after touching the catheter insertion site, before accessing the pressure monitoring system, after removing gloves, and whenever there is a possibility of contamination. Appropriate hand hygiene should be performed using an approved alcohol-based hand rub or soap and water according to institutional infection prevention policies. Gloves do not replace hand hygiene, and their use should be determined by the anticipated level of contact and the applicable aseptic procedure [5].

During arterial catheter insertion, nurses should ensure that the procedural environment and equipment are prepared appropriately and that sterile supplies are available. At a minimum, peripheral arterial catheter insertion in adults requires a cap, mask, sterile gloves, and a small sterile fenestrated drape, according to CDC recommendations. More extensive maximal sterile barrier precautions should be used for femoral or axillary arterial catheter insertion. The insertion site should be prepared with an appropriate antiseptic agent, and adequate contact and drying time should be observed according to the manufacturer's instructions and institutional protocol. Sterile technique should be maintained throughout the procedure, and contaminated equipment should be replaced rather than reused [1, 2].

Assistance During Catheter Insertion

Nursing responsibilities during insertion include preparing the patient, explaining the procedure when the patient's condition permits, positioning the extremity appropriately, maintaining patient safety, and assisting the clinician with sterile equipment. Nurses should monitor the patient's haemodynamic status during insertion and observe for signs of pain, vasovagal reactions, bleeding, or deterioration. Repeated puncture attempts should be minimized because multiple attempts may increase endothelial injury, haematoma formation, and the risk of mechanical complications. Ultrasound guidance, when available and appropriate, may improve vessel identification and reduce unsuccessful punctures. Following successful insertion, nurses should assist in securing the catheter and ensuring that the pressure monitoring system is functioning correctly [10, 13].

Proper Catheter Stabilization and Dressing Management

Secure catheter stabilization is essential for preventing accidental dislodgement, movement-related trauma, bleeding, and contamination. Nurses should ensure that the catheter is fixed using an appropriate stabilization method and that the dressing provides adequate protection without compromising circulation or visibility of the insertion site. The wrist or limb should be positioned comfortably to avoid excessive flexion, extension, or tension on the catheter. Pressure tubing should be arranged to prevent pulling, kinking, or accidental traction during repositioning, hygiene care, transfers, and other bedside activities. Dressings should be maintained clean, dry, and intact, and replaced when they become damp, loosened, visibly soiled, or otherwise compromised, in accordance with institutional policy [5, 19].

Continuous Assessment of the Arterial Insertion Site

Regular inspection of the insertion site is essential for early identification of infection, bleeding, haematoma, and mechanical displacement. Nurses should assess the surrounding skin for erythema, warmth, tenderness, swelling, discharge, and changes in tissue appearance. The presence of new pain or discomfort should be investigated, particularly when accompanied by local swelling or changes in distal perfusion. The catheter and dressing should be inspected for movement, leakage, blood accumulation, or loss of secure fixation. Any unexpected abnormality should be documented and communicated promptly to the responsible clinician, with catheter removal considered when clinically indicated [1, 5].

Natural Resources for Human Health
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Neurovascular Assessment and Prevention of Distal Ischaemia

Neurovascular assessment should be performed routinely throughout the period of arterial catheterization, with frequency adjusted according to the patient's clinical condition, institutional protocol, and the presence of additional risk factors. Assessment should include skin colour, temperature, capillary refill, peripheral pulse quality, sensation, and motor function when the patient is able to cooperate. Comparison with the opposite extremity may help identify subtle changes. Nurses should pay particular attention to patients receiving vasopressors, those with diabetes or peripheral vascular disease, and patients who are sedated or unable to communicate symptoms effectively. New pallor, cyanosis, coolness, severe pain, paraesthesia, delayed capillary refill, or diminished distal pulses should be treated as warning signs requiring immediate clinical evaluation [4, 17].

Maintenance of the Pressure Monitoring System

The pressure monitoring system must be maintained as a closed, sterile system to minimize contamination and preserve accurate pressure transmission. Nurses should inspect all tubing, connections, stopcocks, transducer components, and the continuous-flush device for visible blood, air bubbles, leakage, disconnection, or mechanical damage. The system should be arranged to minimize unnecessary manipulation and entry. A closed continuous-flush system is preferred over an open system requiring repeated syringe and stopcock access because it reduces unnecessary handling and helps maintain catheter patency. The prescribed flush solution should be used according to institutional policy, and dextrose-containing solutions or parenteral nutrition fluids should not be administered through arterial pressure monitoring systems [2].

Correct Transducer Leveling and Zeroing

Correct transducer leveling is essential for obtaining reliable invasive blood pressure measurements. The transducer should be positioned at the appropriate anatomical reference level, generally the phlebostatic axis for standard supine haemodynamic monitoring, corresponding approximately to the level of the right atrium. When the transducer is positioned above the reference level, the measured pressure may be falsely low; when positioned below it, the measurement may be falsely high. Nurses should therefore recheck transducer position whenever the patient changes position, the bed height is adjusted, or the monitoring equipment is moved. Zeroing should be performed according to the monitoring device manufacturer's instructions and institutional protocol, with the transducer exposed to atmospheric pressure through the designated zeroing procedure [20].

Assessment of Arterial Waveforms

Continuous observation of arterial waveforms allows nurses to evaluate both catheter function and the quality of haemodynamic measurements. A normal arterial waveform generally demonstrates a rapid systolic upstroke, a systolic peak, a descending limb, and a dicrotic notch associated with aortic valve closure. Changes in waveform appearance may reflect altered cardiovascular physiology, catheter obstruction, air bubbles, tubing problems, or inappropriate system characteristics. A dampened waveform may be associated with blood clots, catheter kinking, air bubbles, or excessive compliance within the monitoring system, whereas an excessively sharp waveform may indicate underdamping. Nurses should compare the displayed waveform with the patient's clinical condition and non-invasive measurements when appropriate, and investigate unexpected discrepancies before assuming that the displayed pressure accurately represents the patient's haemodynamic status [11, 20].

Prevention of Catheter Occlusion and Thrombosis

Preventing arterial catheter occlusion requires maintaining appropriate catheter function and avoiding unnecessary interference with arterial blood flow. Nurses should monitor the waveform continuously, inspect the catheter and tubing for kinking, and ensure that the prescribed continuous-flush system is functioning correctly. Unnecessary blood sampling and repeated manipulation should be avoided when alternative clinically acceptable methods are available. Blood sampling through an arterial catheter should follow a standardized institutional procedure designed to minimize contamination, blood loss, and thrombotic complications. Nurses should never attempt to forcefully flush an obstructed arterial catheter because this may dislodge thrombotic material or introduce air into the arterial circulation. Persistent obstruction, loss of waveform, or inability to obtain appropriate blood return requires prompt assessment and escalation rather than repeated forceful manipulation [16].

Prevention of Bleeding and Haematoma Formation

Bleeding prevention begins with appropriate catheter stabilization and careful monitoring of the insertion site. Nurses should assess for blood leakage around the catheter, expanding swelling, bruising, or accumulation of blood beneath the dressing. Patients receiving anticoagulant or antiplatelet therapy require particular attention because bleeding may develop or progress

more rapidly. During patient repositioning and transfer, the arterial catheter and tubing should be protected from traction or accidental removal. If catheter displacement or accidental removal occurs, immediate direct pressure should be applied according to institutional emergency protocols, and the responsible clinician should be notified. The duration of compression following removal should be individualized according to the access site, catheter size, haemostasis, and coagulation status [18].

Prevention of Accidental Disconnection and Air Entry

Arterial pressure monitoring systems contain pressurized fluid and must remain securely connected to prevent blood loss, contamination, and air entry. Nurses should check all connections during routine assessments and whenever the patient is repositioned or transported. Loose connections, cracked tubing, damaged stopcocks, and leaking components should be addressed immediately. Air bubbles should be managed according to approved equipment procedures, ensuring that air is not introduced into the patient's arterial circulation. The pressure bag should be maintained at the manufacturer- and institutionally recommended pressure, commonly 300 mmHg in adult systems, to support the continuous-flush mechanism. Any suspected disconnection or air entry should be managed as an urgent safety concern [2, 20].

Daily Evaluation of Catheter Necessity

The continued need for an arterial catheter should be reassessed regularly, preferably as part of the daily multidisciplinary review. Nurses should evaluate whether continuous invasive blood pressure monitoring remains clinically necessary, whether repeated arterial blood sampling is still required, and whether the patient's condition has stabilized sufficiently to permit alternative monitoring methods. When the original indication has resolved, nurses should communicate this to the responsible medical team and facilitate timely catheter removal. Routine replacement of arterial catheters solely to prevent infection is not recommended; instead, replacement should be based on clinical indications such as infection, dysfunction, or complications. Removing unnecessary arterial catheters reduces avoidable exposure to vascular injury, infection, and mechanical failure [1, 2].

Patient Positioning and Protection During Nursing Procedures

Appropriate patient positioning helps prevent accidental catheter movement and preserves the integrity of the arterial monitoring system. Nurses should avoid placing excessive pressure on the catheterized extremity and should ensure that the limb remains in a comfortable position that does not compromise circulation or catheter function. During bathing, linen changes, turning, physiotherapy, and patient transfers, the catheter and tubing should be protected from traction and disconnection. The insertion site should remain visible and accessible whenever possible to facilitate regular assessment. Special precautions are necessary in agitated patients or those with altered consciousness who may unintentionally pull at monitoring equipment [19].

Safe Blood Sampling and Specimen Management

Arterial blood sampling is an important function of peripheral arterial catheters, but repeated sampling may contribute to blood loss, catheter manipulation, and mechanical complications. Nurses should follow standardized sampling procedures, verify the correct patient identification, use appropriate aseptic precautions, and ensure that the required specimen volume is minimized whenever clinically appropriate. The sampling system should be accessed through a disinfected designated port, and all connections should be handled carefully to maintain system sterility. After sampling, the catheter and pressure waveform should be checked to confirm that the system has returned to normal function. Blood samples should be labeled accurately and transported according to laboratory requirements [5, 16].

Nursing Documentation and Clinical Communication

Accurate documentation is essential for continuity of care and early identification of complications. Nursing records should include the catheter insertion site, insertion date when available, dressing condition, local skin assessment, distal circulation findings, arterial waveform characteristics, transducer position, pressure monitoring system integrity, and any abnormal observations. Documentation should also include interventions performed, communication with the medical team, and the clinical response to identified abnormalities. Standardized documentation supports trend analysis, improves communication during shift handover, and helps ensure that catheter-related problems are not overlooked [1, 8].

Natural Resources for Human Health
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Table 2. Nursing Interventions for Preventing Peripheral Arterial Catheter Complications [1, 2, 5, 8, 10, 13, 16–20].

Nursing intervention	Recommended nursing activities	Main complication prevented
Pre-insertion assessment	Evaluate vascular history, circulation, skin integrity, and coagulation risks	Vascular injury and ischaemia
Hand hygiene	Perform hand hygiene before and after catheter-related procedures	Catheter-related infection
Aseptic insertion assistance	Maintain sterile supplies and appropriate barrier precautions	Local and bloodstream infection
Site selection	Collaborate in selecting an anatomically appropriate artery	Vascular injury and infection
Catheter stabilization	Secure catheter and prevent traction or excessive limb movement	Dislodgement and bleeding
Dressing management	Maintain a clean, dry, intact dressing	Local infection
Site inspection	Assess for redness, swelling, pain, bleeding, and discharge	Infection and haematoma
Neurovascular assessment	Evaluate colour, temperature, pulses, sensation, and capillary refill	Distal ischaemia
Pressure system maintenance	Inspect tubing, connections, stopcocks, and flush system	Occlusion and air entry
Transducer leveling and zeroing	Maintain correct reference level and perform appropriate zeroing	Measurement errors
Waveform monitoring	Identify abnormal damping, loss of waveform, and discrepancies	Inaccurate haemodynamic monitoring
Safe blood sampling	Use aseptic access and minimize unnecessary sampling	Infection and catheter failure
Daily necessity review	Reassess the indication for continued catheterization	Unnecessary device exposure
Safe removal	Apply appropriate compression and monitor haemostasis	Post-removal bleeding

Early Recognition and Nursing Management of Complications

Recognition and Response to Suspected Infection

Nurses should maintain a high level of suspicion when patients develop unexplained fever, chills, haemodynamic deterioration, local erythema, purulent discharge, or tenderness around the arterial catheter. Although these findings are not specific to catheter-related infection, their presence should prompt immediate clinical assessment. The insertion site and pressure monitoring system should be examined carefully, and relevant investigations should be initiated according to medical instructions and institutional infection prevention protocols. When catheter-related infection is suspected, decisions regarding catheter removal, blood cultures, catheter-tip cultures, and antimicrobial treatment should be made by the responsible clinical team according to the patient's condition and applicable guidelines. The catheter should not be retained solely to preserve access when there is a clear clinical indication for removal [1, 5].

Recognition and Response to Acute Limb Ischaemia

Acute changes in distal circulation require immediate attention because prolonged arterial obstruction may lead to irreversible tissue damage. Nurses should recognize warning signs such as sudden pain, pallor, coolness, cyanosis, delayed capillary refill, altered sensation, weakness, or loss of distal pulses. In patients who cannot communicate, repeated objective assessments become especially important. The catheterized limb should be evaluated immediately, and the medical team should be notified

urgently when new or progressive perfusion abnormalities are identified. Further vascular assessment and decisions regarding catheter removal, anticoagulation, imaging, or surgical intervention should be undertaken by the responsible clinical specialists [4, 17].

Recognition and Response to Bleeding

Visible bleeding, rapidly increasing swelling, extensive bruising, or haemodynamic deterioration may indicate significant vascular injury. Nurses should assess the extent of bleeding, monitor vital signs, evaluate the insertion site, and apply appropriate direct pressure when indicated. If the catheter has been accidentally removed, the site should be compressed immediately using the appropriate technique, while assistance is obtained and the medical team is informed. Continued bleeding despite appropriate initial measures requires urgent medical evaluation, particularly in patients receiving anticoagulant therapy or those with coagulation abnormalities [18].

Recognition and Response to Catheter Dysfunction

Loss of arterial waveform, inability to obtain blood return, unexpected pressure readings, or repeated alarms may indicate catheter dysfunction. Nurses should first assess the patient and determine whether the abnormal measurement corresponds to the clinical condition. The monitoring system should then be examined for kinking, disconnection, air bubbles, inappropriate transducer positioning, or other visible mechanical problems. Appropriate troubleshooting should follow institutional procedures, and forceful flushing should be avoided when obstruction is suspected. Persistent dysfunction may require clinical reassessment and replacement of the arterial catheter [16, 20].

Infection Prevention Strategies and Institutional Safety Measures

Successful prevention of arterial catheter-related infections requires more than individual nursing compliance; it also depends on institutional policies, adequate supplies, staff education, and systematic surveillance. Healthcare organizations should establish standardized protocols covering insertion, maintenance, dressing changes, pressure monitoring equipment, blood sampling, and catheter removal. These protocols should be consistent with established infection prevention recommendations and regularly reviewed to reflect current evidence. The use of standardized procedures reduces unnecessary variation in clinical practice and supports safer catheter management across different critical care units [1, 5].

Education and competency assessment are particularly important because arterial catheters require specialized technical knowledge that differs from routine peripheral venous cannulation. Critical care nurses should receive training in aseptic access, vascular assessment, arterial waveform interpretation, transducer leveling, flushing-system maintenance, and recognition of vascular complications. Competency should be evaluated periodically through direct observation, clinical simulation, and review of documented practice. Staff should also be encouraged to report near misses, accidental disconnections, equipment failures, and suspected infections to support institutional quality improvement [5, 8].

Role of the Multidisciplinary Team in Preventing Arterial Catheter Complications

Preventing complications associated with peripheral arterial catheters requires coordinated collaboration between critical care nurses, physicians, anaesthesia professionals, vascular access specialists, infection prevention teams, and clinical engineers. Physicians are responsible for evaluating indications, selecting appropriate access sites, and making clinical decisions regarding insertion and removal, while nurses provide continuous bedside assessment and maintenance. Infection prevention specialists contribute to the development and monitoring of aseptic practice standards, and clinical engineering personnel support the safe functioning of pressure monitoring equipment. Effective communication between team members is essential when changes in vascular status, catheter function, or haemodynamic measurements are identified [1, 10].

Multidisciplinary collaboration is particularly important in patients with complex vascular conditions, severe shock, prolonged vasopressor requirements, or repeated catheter failure. In these patients, the decision to continue arterial monitoring should be balanced against the potential risks of prolonged catheterization and repeated vascular injury. Regular team discussions may identify opportunities to reduce unnecessary blood sampling, improve catheter stabilization, reassess insertion-site suitability, and remove devices that are no longer clinically required. Such coordinated decision-making supports patient safety and improves the overall quality of critical care [6, 21].

Patient Safety, Quality Improvement, and Clinical Audit

Quality improvement initiatives can strengthen the prevention of arterial catheter complications by identifying weaknesses in existing nursing practices and monitoring adherence to evidence-based protocols. Relevant quality indicators may include the proportion of arterial catheter insertion sites assessed each shift, compliance with hand hygiene, dressing integrity, documentation of distal circulation, daily assessment of catheter necessity, and the frequency of unplanned catheter removal. Institutions may also monitor suspected infection rates, catheter dysfunction, accidental dislodgement, and the occurrence of vascular complications. These indicators should be interpreted using standardized definitions to allow meaningful comparisons over time [5, 21].

Regular clinical audits can identify whether recommended preventive interventions are consistently performed and whether additional education or equipment improvements are required. Feedback should be provided to nursing teams in a constructive manner, with emphasis on patient safety and continuous improvement rather than individual blame. Incorporating arterial catheter care into broader vascular access safety programs may also promote consistency between different clinical departments and improve the reliability of monitoring practices [1, 8].

Challenges Affecting Nursing Prevention Practices

Several factors may interfere with the consistent implementation of preventive nursing interventions in critical care environments. High patient acuity, increased nursing workload, staff shortages, frequent patient transfers, emergency procedures, and competing clinical priorities may reduce the time available for systematic catheter assessment. In addition, inadequate training, inconsistent documentation systems, limited availability of appropriate stabilization devices, and unfamiliarity with pressure monitoring equipment may contribute to preventable errors. These challenges highlight the importance of institutional support, adequate staffing, accessible clinical protocols, and continuing professional development [5, 8].

Another challenge involves recognizing complications in patients who are sedated, mechanically ventilated, or unable to communicate. Such patients may not report pain, numbness, or discomfort associated with vascular compromise. Consequently, nurses should not rely exclusively on patient-reported symptoms but should perform regular objective assessments of skin colour, temperature, capillary refill, pulse quality, and limb movement when possible. Integrating these observations into routine nursing assessments may improve early recognition of complications and reduce delays in clinical intervention [4, 17].

Recommendations for Clinical Nursing Practice

Evidence-based nursing practice should prioritize comprehensive catheter assessment, consistent infection prevention measures, appropriate stabilization, continuous neurovascular monitoring, and accurate haemodynamic measurement. Critical care units should adopt standardized arterial catheter care protocols that clearly define responsibilities during insertion assistance, routine maintenance, blood sampling, troubleshooting, and removal. Nurses should receive regular competency-based education and have access to appropriate equipment and clinical support. Daily reassessment of catheter necessity should be incorporated into multidisciplinary rounds, while suspected infection, thrombosis, ischaemia, bleeding, or device malfunction should trigger prompt clinical evaluation [1, 2, 5, 10].

Furthermore, nursing documentation should be standardized to ensure that catheter-site observations, distal perfusion assessments, waveform quality, and pressure monitoring system integrity are consistently recorded. Quality improvement programs should evaluate adherence to these practices and monitor complications over time. Special attention should be directed toward high-risk patients with peripheral vascular disease, diabetes, severe hypotension, vasopressor dependence, coagulation abnormalities, or prolonged catheterization. Through these coordinated measures, critical care nurses can contribute substantially to reducing preventable catheter-related harm and improving the safety and reliability of invasive haemodynamic monitoring [8, 16, 17, 21].

CONCLUSION

Peripheral arterial catheters are indispensable devices in the management of many critically ill patients because they provide continuous invasive blood pressure monitoring and facilitate repeated arterial blood sampling. Nevertheless, their use is associated with potentially serious complications, including local and bloodstream infections, arterial thrombosis, catheter occlusion, distal limb ischaemia, bleeding, haematoma formation, accidental dislodgement, and inaccurate haemodynamic

measurements. The occurrence of these complications is influenced by patient-related vulnerabilities, vascular anatomy, insertion technique, catheter duration, equipment integrity, and the quality of ongoing nursing care. Therefore, prevention requires a comprehensive approach that extends throughout the entire catheter lifecycle rather than focusing exclusively on insertion technique.

Critical care nurses play a fundamental role in protecting patients from arterial catheter-related complications through pre-insertion assessment, strict hand hygiene, aseptic technique, proper catheter stabilization, regular insertion-site inspection, continuous neurovascular assessment, accurate transducer leveling and zeroing, waveform monitoring, and safe maintenance of the pressure monitoring system. Daily evaluation of catheter necessity, appropriate blood sampling practices, standardized documentation, and prompt escalation of abnormal findings are equally important components of preventive care. Institutional protocols, continuing education, competency assessment, clinical audit, and multidisciplinary collaboration further strengthen the effectiveness of these interventions. Ultimately, integrating evidence-based nursing practices into routine critical care management can improve catheter safety, preserve vascular integrity, maintain reliable haemodynamic monitoring, and contribute to better clinical outcomes among critically ill patients.

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