Natural Resources for Human Health
eISSN: 2583-1194

Original Research

Received 05 Aug 2025
Revised 08 Sep 2025
Accepted 22 Sep 2025

Natural Resources for Human Health 2025, Vol. 5 (1s): 64-72

KEYWORDS:
arteriovenous fistula, cannulation, hemodialysis, vascular access, nursing care, infection prevention, hemostasis.

Nursing Strategies for Preventing Complications Associated with Arteriovenous Fistula Cannulation in Hemodialysis Patients

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ABSTRACT: An arteriovenous fistula (AVF) is the preferred vascular access for long-term hemodialysis, yet its survival depends heavily on cannulation technique and consistent nursing practice. Pre-cannulation assessment is the foundation of safe practice: nurses should inspect and palpate the access for thrill and bruit, evaluate the integrity of the vessel

wall, and identify the optimal puncture sites while avoiding aneurysmal, stenotic, or previously used segments. The rope-ladder or buttonhole technique should be applied according to unit protocol, with the rotating-site method distributed along the entire accessible length of the fistula to prevent repeated injury and aneurysm formation. Strict aseptic technique, including thorough skin antisepsis, appropriate needle selection, and timely removal of the tourniquet, further reduces the risk of infection and reduces intimal trauma. Documenting each cannulation—site, needle gauge, direction, and any difficulties—supports continuity among staff and enables early identification of trends that signal access dysfunction. Post-cannulation care is equally critical to complication prevention. Hemostasis should be achieved using appropriate compression—typically 10 to 15 minutes without excessive force—to avoid thrombosis while preventing hematoma and prolonged bleeding. Nurses should educate patients on daily self-monitoring for thrill and bruit, signs of infection such as redness, warmth, or drainage, and the importance of avoiding pressure, venipuncture, or blood pressure measurement on the access arm. Early recognition of complications, including infiltration, hematoma, aneurysm, stenosis, and access-related infection, allows timely referral and intervention before access failure occurs. Structured cannulation training, competency assessment, and ongoing audit of complication rates help sustain high-quality practice. Ultimately, a coordinated nursing approach that integrates rigorous technique, patient education, and continuous surveillance is the most effective strategy for prolonging AVF function and improving dialysis outcomes.

INTRODUCTION

The arteriovenous fistula (AVF) remains the preferred vascular access for maintenance hemodialysis because it is associated with lower complication rates, superior long-term patency, and reduced mortality compared with central venous catheters and arteriovenous grafts. However, AVF survival depends not only on surgical creation and maturation but also on the quality of repeated cannulation performed by nursing staff. Cannulation breaches the integrity of the vascular access at every dialysis session, and suboptimal technique can initiate a cascade of complications including infiltration, hematoma, infection, aneurysm formation, stenosis, and thrombosis. Structured cannulation practices and checklists are therefore central to preserving access function and preventing avoidable harm [1]. Cannulation-related complications are a major contributor to AVF failure and morbidity. Evidence indicates that a substantial proportion of AVF failures are linked to cannulation-related events, and complication rates are inversely correlated with nursing experience, adherence to structured protocols, and consistent use of evidence-based cannulation practices. Repeated unsuccessful punctures, poor site rotation, inadequate aseptic technique, and delayed recognition of access deterioration can all transform a functioning fistula into a failing access. Systematic reviews of cannulation practice emphasise that technique selection, operator skill, and organisational support are modifiable determinants of outcomes [2]. Nursing strategies that standardise pre-cannulation assessment, cannulation technique, aseptic practice, post-cannulation care, surveillance, and patient education are essential for preserving AVF function and improving patient outcomes. Multidisciplinary vascular access services, including dedicated vascular access nursing clinics, have been associated with fewer cannulation complications and improved long-term AVF patency. Nurses are therefore not merely technicians performing punctures; they are frontline guardians of vascular access who translate evidence into daily practice [3].

Cannulation Techniques and Their Implications for Complication Prevention

The choice of cannulation technique is a foundational nursing decision that influences the mechanical trauma inflicted on the fistula wall over time. The rope-ladder technique, in which each cannulation is performed at a different site along the accessible length of the fistula, is recommended by the Kidney Disease Outcomes Quality Initiative as the preferred approach for AVFs because it distributes puncture trauma and reduces the risk of focal wall degeneration [1]. The buttonhole technique, which involves repeated cannulation through a single established tract, was developed to reduce pain and facilitate self-cannulation in patients with limited cannulation segments, but it carries a significantly higher risk of bacteraemia and requires meticulous aseptic care that is difficult to sustain in all clinical settings. An updated systematic review and meta-analysis confirmed that

buttonhole cannulation was associated with a significantly higher risk of bacteraemia compared with rope-ladder cannulation, although local infection rates did not differ significantly between the two techniques [4].

Long-term follow-up data from a unit using buttonhole cannulation for more than two decades demonstrated that AVF-related infections can be reduced to minimal levels only when aseptic protocols are strongly reinforced, adherence is regularly audited, and nursing leadership maintains continuous education and feedback [5]. These findings reinforce that technique selection must be matched to patient anatomy, nursing expertise, and the unit's capacity to sustain rigorous infection control, rather than being adopted as a universal default. The nurse should also consider needle gauge, cannulation angle, and the condition of the outflow vein when planning each puncture. A structured cannulation plan, documented in the patient record and reviewed at each session, helps ensure that all staff follow the same approach and that high-risk sites are avoided [5].

Table 1. Comparison of Common AVF Cannulation Techniques and Associated Nursing Considerations

Technique	Principle	Principal advantages	Principal risks	Key nursing considerations
Rope-ladder	Punctures distributed along the accessible fistula length	Distributes wall trauma; recommended as preferred technique	Requires sufficient cannulation segment; repeated unsuccessful attempts can still cause hematoma	Rotate sites systematically; document puncture sites; avoid area puncture [1]
Buttonhole	Repeated puncture through a single established tract	Reduced pain; facilitates self-cannulation; useful in short fistula segments	Significantly higher bacteraemia risk; requires scab removal and strict asepsis	Restrict to selected patients; reinforce aseptic protocol; monitor for local and systemic infection [4,5]
Area puncture	Repeated punctures in a small, limited region	May be used when accessible segment is very short	High risk of aneurysm, stenosis, and wall damage	Avoid whenever alternative sites exist; close surveillance for aneurysmal dilatation [1]

Cannulation-Related Complications and Their Nursing Prevention

Cannulation-related complications can be broadly categorised as mechanical and infectious. Mechanical complications often begin with a failed puncture or needle misplacement that allows blood to extravasate into the surrounding tissue, producing a hematoma that compresses the fistula and may progress to thrombosis if not recognised and managed promptly. Infiltration is a particularly important nursing concern because it can occur during cannulation or during dialysis if the needle tip migrates, and repeated infiltrations contribute to vessel wall injury, stenosis, and loss of usable access sites. Electronic cannulation atlases have been shown to reduce AVF-related complications by guiding nurses to appropriate puncture sites, recording site rotation, and preventing repeated trauma to the same vessel segment; in one study, the complication rate at three months was 16.30% in the electronic-atlas group compared with 31.76% in the conventional-management group [6].

Needle orientation and securement are also important technical details. A randomised controlled trial comparing needle bevel orientation found that bevel-up and bevel-down insertion were equivalent in terms of haemostasis and puncture-associated pain, suggesting that either orientation may be acceptable provided the needle is securely stabilised and the cannulation is performed without repeated probing [7]. However, the same trial emphasised that secure taping, avoidance of unnecessary needle movement, and careful observation during treatment remain essential nursing measures for preventing infiltration and needle dislodgement. Venous needle dislodgement is a potentially catastrophic event that can lead to rapid blood loss, and preventive strategies include correct needle selection, secure taping, visual monitoring, and prompt response to alarms or blood leakage [8].

Table 2. Common Cannulation-Related Complications and Nursing Preventive Strategies

Complication	Mechanism and clinical features	Nursing preventive strategies

Infiltration / hematoma	Extravasation of blood after needle misplacement or dislodgement; swelling, pain, discolouration	Check flashback and aspirate before flushing; secure needle with chevron taping; observe during treatment; apply ice and rest the access if infiltration occurs [6,8]
Aneurysm / pseudoaneurysm	Focal dilatation from repeated puncture at the same site or excessive pressure	Rotate sites systematically; avoid area puncture; use electronic atlas or cannulation map; monitor for enlarging pulsatile swelling [1,6]
Stenosis	Narrowing from endothelial injury and neointimal hyperplasia at puncture sites	Distribute punctures; avoid deep or traumatic cannulation; participate in surveillance and early referral [1]
Thrombosis	Clot formation secondary to stasis, stenosis, or hematoma	Prevent infiltration and hematoma; avoid prolonged compression; monitor thrill and bruit; report changes promptly [8]
Infection	Contamination during cannulation or scab removal, especially in buttonhole technique	Perform hand hygiene and aseptic skin preparation; allow antiseptic to dry; use clean gloves; remove scabs with aseptic technique; monitor for erythema, pus, or systemic signs [4,5]

Pre-Cannulation Nursing Assessment and Preparation

Before every cannulation, the nurse should perform a structured physical assessment of the AVF and surrounding limb. This assessment includes inspection for redness, swelling, bruising, aneurysm formation, or skin breakdown; palpation for thrill and pulse augmentation; and auscultation for the character and continuity of the bruit. Any new or unexplained finding should prompt a delay in cannulation and referral for further evaluation, because early recognition of a compromised access can prevent thrombosis and access loss. For newly created fistulas, cannulation should not proceed until the access has matured adequately, and initial cannulations should be performed by the most experienced staff using smaller-gauge needles and reduced blood flow rates. Local cannulation policies for new fistulas should define maturation criteria, the first-cannulation pathway, and escalation procedures when maturation is inadequate [9].

The nurse should also confirm the direction of blood flow and the configuration of the fistula, particularly in reverse-flow or proximal radial artery fistulas, so that arterial and venous needle placement is correct and recirculation is minimised. Patient preparation includes explaining the procedure, positioning the arm comfortably, and ensuring that the access limb is clean; the patient should be encouraged to wash the arm with soap and water before cannulation, and the nurse should perform hand hygiene and wear clean gloves. A pre-cannulation checklist can help ensure that assessment, consent, skin preparation, and equipment checks are completed consistently [9].

Aseptic Technique and Infection Prevention

Infection is one of the most feared cannulation-related complications because it can progress to bacteraemia, endocarditis, and access loss. The chain of infection can be interrupted at multiple points during cannulation, and nursing adherence to aseptic technique is the single most important preventive measure. The skin should be prepared with an appropriate antiseptic—chlorhexidine 5 mg/ml or 70% ethanol—and the antiseptic must be allowed to dry completely before puncture. The nurse should disinfect the entire AVF area, either from top to bottom or in a single direction, and should avoid touching the prepared site after antisepsis. Sterile gloves are not routinely required for cannulation, but clean gloves and a no-touch technique around the puncture site are essential. Infection prevention checklists that include pre-cannulation assessment, hand hygiene, skin antisepsis, and post-cannulation site care can standardise practice and reduce avoidable contamination [10].

For buttonhole cannulation, scabs must be removed aseptically and the area disinfected both before and after scab removal, because the buttonhole tract provides a direct route for skin flora to enter the bloodstream. Units using buttonhole cannulation should monitor infection rates continuously and be prepared to revert to rope-ladder cannulation if bacteraemia rates increase [4,5]. Nurses should also ensure that all caps, needles, and connecting devices are disinfected before use and that open systems are minimised. Aseptic technique is not a single step but a sequence of behaviours that must be maintained from hand hygiene through to needle removal and dressing application [5].

Post-Cannulation Haemostasis and Site Care

Haemostasis after needle removal is a critical phase in which improper technique can undo the benefits of a careful cannulation. Needles should be removed at the same angle as insertion, and pressure should not be applied until the needle is completely out of the vessel. Pressure should be applied to both the skin puncture site and the deeper vessel wall puncture site for a sufficient duration, typically at least 10 minutes, without intermittent "peeking" that disrupts clot formation. Excessive or prolonged compression should be avoided because it may promote thrombosis, particularly in accesses with borderline flow. After haemostasis is achieved, a clean dressing should be applied, and the patient should be observed for bleeding or swelling before leaving the unit.

Nurses should document the cannulation sites, needle gauge, number of attempts, and any complications, because this information guides future cannulation planning and helps identify patients who may require ultrasound assessment or referral. Secure haemostasis and careful site care also reduce the risk of needle dislodgement and subsequent infiltration [8]. Patients should be advised to keep the dressing dry and intact for the recommended period and to report any bleeding, swelling, or pain after leaving the unit.

Vascular Access Surveillance and Early Detection of Deterioration

Surveillance is a continuous nursing responsibility that extends beyond the cannulation encounter. Physical examination at every session—inspection, palpation of thrill, and auscultation of bruit—is the first step in detecting a failing access. A healthy AVF should have a palpable thrill along the outflow vein, a low-pitched continuous bruit, and a pulse that augments with compression of the outflow vein; loss of thrill, change in bruit character, or development of a prominent pulsatile swelling should prompt urgent evaluation. Nurses are also well positioned to monitor for hand ischemia, venous hypertension, and aneurysmal dilatation, and to refer patients for duplex ultrasound or angiography when abnormalities are detected [11].

Point-of-care ultrasound is increasingly used by trained nurses to assess AVF depth, diameter, and course before cannulation and to guide needle placement in difficult accesses. Implementation of ultrasound-guided cannulation in community dialysis centres has been associated with a successful cannulation rate of 97%, a reduction in missed cannulation attempts from 3.57 to 2.33 per 100 cannulations, and a 55.5% decline in infiltration incidents [11]. Nurses report that ultrasound increases their confidence and improves teamwork around vascular access, although training and equipment costs remain barriers to widespread adoption [12]. Structured surveillance programmes that combine physical examination with ultrasound assessment have been associated with earlier detection of stenosis and reduced rates of thrombosis [12].

Patient Education and Self-Management

Patient education is a core nursing strategy for preventing cannulation-related complications because much of the daily care of an AVF occurs outside the dialysis unit. Patients should be taught to check the fistula daily for thrill and bruit, to inspect the access arm for redness, swelling, or discharge, and to report any changes promptly. They should also understand the importance of keeping the access arm clean, avoiding constrictive clothing or blood pressure measurement on that arm, and protecting the fistula from trauma. Educational and behavioural interventions delivered by nurses—using booklets, demonstrations, videos, and teach-back methods—have been shown to improve long-term vascular access self-management behaviours, knowledge, and self-efficacy [13].

Patients who are candidates for self-cannulation should receive structured training under nursing supervision, because self-cannulation can increase independence and may reduce complication rates when performed by well-trained patients. Family members or caregivers may also need education if they assist with access care. Written materials should be supplemented by verbal teaching and return demonstration, and documentation of education helps ensure continuity across shifts and units [13].

Nurse Training, Competency, and Simulation

The technical skill of the cannulator is one of the strongest modifiable determinants of AVF outcomes. Initial cannulations should be performed by skilled staff with demonstrated cannulation success, and all dialysis nurses and technicians should receive structured training and supervision before their first independent cannulation attempts. Regular cannulation training updates are necessary to maintain competency, particularly as new evidence emerges about needle orientation, site rotation, and aseptic practice. Monitoring and training programmes have been associated with improved vascular access care quality and

fewer complications, highlighting the importance of continuous competency assessment rather than relying solely on years of experience as a proxy for skill [14].

Simulation-based training is an effective adjunct to theoretical instruction because it allows nurses to practise needle insertion, stabilisation, and complication management without exposing patients to risk. A cluster randomised controlled trial evaluating simulation-based training for AVF cannulation is designed to determine whether procedural simulation reduces adverse events compared with theoretical training alone [15]. Ultrasound-guided cannulation simulators have also been used to improve nurses' confidence and technical accuracy before applying the technique to patients. Units should therefore invest in ongoing competency assessment, peer review of cannulation practice, and refresher training [16].

Bedside Physical Examination as a Structured Surveillance Tool

Physical examination remains the most accessible and cost-effective surveillance method available to dialysis nurses. Reimaging patient safety for dialysis through systematic physical examination of the fistula emphasises that inspection, palpation, and auscultation should be performed at every session and documented in a structured format [15]. A change in the character of the thrill or bruit, new tenderness, or unexplained swelling should trigger escalation. Nurses can use a simple "look, feel, listen" framework and record findings alongside cannulation data, creating a longitudinal record that supports early detection of stenosis, aneurysm formation, and infection [15].

Simulation-Based Training and Procedural Education

Simulation-based education should be integrated into cannulation training programmes rather than used as an optional add-on. Procedural simulation allows nurses to practise site selection, needle insertion, securement, and management of infiltration in a controlled environment. The MuST trial is an example of rigorous evaluation of simulation training for vascular access cannulation and is expected to provide evidence on whether simulation reduces adverse events in routine practice [16]. Simulation should be complemented by supervised clinical practice and competency sign-off.

Thrombosis Prevention and Management

Thrombosis is a serious complication that can lead to access loss and require urgent intervention. Prevention begins with avoiding infiltration, hematoma, and prolonged compression, and with early recognition of stenosis. Nurses should monitor thrill and bruit at every session and report changes promptly. Prevention of arteriovenous access clot formation in individuals receiving hemodialysis requires a combination of careful cannulation, avoidance of hypotension, and surveillance for outflow stenosis [17]. When thrombosis is suspected, the nurse should not attempt cannulation and should escalate immediately for medical and surgical evaluation [17].

Video-Based and Structured Self-Care Education

Video-based education has been particularly effective in improving self-care for AVF patients. A randomised clinical trial of an educational video for AVF self-care demonstrated improvements in knowledge and self-care behaviours compared with routine education [18]. Structured AVF care training has also been associated with better self-care behaviours and fewer complications; one study showed that planned education on AVF care improved self-care behaviours among hemodialysis patients [19]. These findings support the use of multimodal, nurse-led education that includes demonstration, return demonstration, and written materials.

System-Level and Multidisciplinary Strategies

Individual nursing efforts are most effective when embedded in a supportive organisational system. Multidisciplinary vascular access teams that include nephrologists, vascular surgeons, interventional radiologists, and vascular access nurses can coordinate surveillance, cannulation planning, and timely intervention for failing accesses. A dedicated vascular access nursing clinic that provides structured postoperative follow-up, nurse-led ultrasound assessment, individualised cannulation planning, and stratified cannulation protocols has been shown to reduce cannulation-related complications and improve long-term AVF patency [3]. Care bundles that combine staff training, process indicators, and continuous audit can significantly reduce complications and improve the safety and quality of vascular access care; a bundle of care has also been shown to promote AVF maturity in patients with end-stage kidney disease [20].

The use of electronic cannulation atlases is another system-level innovation that supports consistent site rotation, preserves institutional memory about difficult cannulations, and reduces AVF-related complications, particularly as patients age and fistula morphology changes [6]. Evaluating a fistula self-care bundle's effect on hemodialysis patients' complications has further supported the value of structured, nurse-led bundles in reducing access-related complications [21]. UK Kidney Association clinical practice guidelines on haemodialysis vascular access provide a framework for local policy, emphasising assessment, cannulation competence, surveillance, and infection control [22]. These system-level strategies do not replace individual nursing skill but create the conditions in which skilled cannulation can be consistently delivered.

Table 3. Components of a Nursing Care Bundle for AVF Cannulation

Bundle component	Key nursing actions	Expected outcome
Pre-cannulation assessment	Inspect, palpate thrill, auscultate bruit; review cannulation history; confirm maturation	Early detection of complications; appropriate site selection [9,15]
Aseptic preparation	Hand hygiene; clean gloves; antiseptic skin preparation; allow to dry; no-touch technique	Reduced infection risk [10]
Cannulation technique	Rope-ladder rotation; appropriate needle gauge; secure taping; avoid repeated probing	Reduced mechanical trauma and infiltration [1,6]
Post-cannulation haemostasis	Remove needle at insertion angle; apply pressure to skin and vessel sites; avoid excessive compression	Effective haemostasis without thrombosis [8,17]
Surveillance and documentation	Record sites, attempts, complications; monitor thrill and bruit at each session	Continuity of care; early referral [15]
Patient education	Teach daily thrill check; hygiene; protection of access arm; report changes	Improved self-management and early reporting [13,18,19]

Aneurysm Prevention and Guideline Recommendations

Aneurysmal dilatation at the puncture segment is a recognised consequence of repeated cannulation at the same site and of excessive pressure on the vessel wall. Current understanding of aneurysm formation in arteriovenous fistulas emphasises the role of repeated focal trauma, wall degeneration, and outflow stenosis [23]. Nursing prevention therefore focuses on systematic site rotation, avoidance of area puncture, use of cannulation maps or electronic atlases, and prompt referral when a pulsatile swelling is identified. European Renal Best Practice guidelines on vascular access provide recommendations on access monitoring and cannulation that support these nursing practices [24]. The Kidney Disease Outcomes Quality Initiative considers it reasonable to routinely check AV access for aneurysms and pseudoaneurysms and to implement appropriate cannulation techniques to reduce their occurrence [25]. These guideline recommendations reinforce that aneurysm prevention is a shared responsibility between nursing, nephrology, and vascular surgery.

Emerging Technologies and Future Directions

Emerging technologies are expanding the repertoire of nursing strategies for complication prevention. Point-of-care ultrasound is increasingly used by trained nurses to assess AVF depth, diameter, and course before cannulation and to guide needle placement in difficult accesses [11,12]. Plastic cannulas are another innovation that may reduce needle-related trauma and infiltration, particularly in patients who have difficulty keeping the limb still during dialysis or who have a history of needle dislodgement. However, plastic cannulas require specific training and are not suitable for all AVF configurations. Clinical practice guidelines continue to emphasise that technology should supplement, rather than replace, fundamental nursing skills in assessment, asepsis, and cannulation technique [22,24]. Future research should focus on nurse-led randomised trials of cannulation bundles, cost-effectiveness of ultrasound-guided cannulation, and strategies for sustaining competency in high-turnover dialysis units.

CONCLUSION

Preventing complications associated with AVF cannulation is a multifaceted nursing responsibility that begins before the needle is inserted and continues long after haemostasis is achieved. The evidence consistently supports a bundle of strategies: structured pre-cannulation assessment, preference for rope-ladder cannulation with judicious use of buttonhole technique, rigorous aseptic practice, careful needle management and securement, effective post-cannulation haemostasis, continuous surveillance, structured patient education, ongoing nurse training, and system-level support through vascular access teams and care bundles. No single intervention is sufficient; rather, it is the consistent and coordinated application of multiple evidence-based nursing measures that preserves AVF function, reduces infection and mechanical complications, and improves the quality of life of hemodialysis patients. Nurses are the frontline guardians of vascular access, and their knowledge, skill, and vigilance remain the most important safeguards against cannulation-related harm.

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