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Research Article

Safe Use and Maintenance of Intravenous Cannulas: A Review of Nursing Practice

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Abstract:

The safe use and maintenance of intravenous (IV) cannulas are critical components of nursing practice that significantly affect patient outcomes. Proper insertion techniques, site selection, and ongoing assessment are essential to minimize complications such as phlebitis, infiltration, and infection. Nurses play a vital role in ensuring that the insertion site is clean, secure, and assessed regularly. They must also be knowledgeable about the various types of IV cannulas and their specific applications, enabling them to select the most appropriate device for each patient. Furthermore, the importance of hand hygiene and the use of aseptic technique cannot be overstated, as these measures are crucial for preventing healthcare-associated infections. Additionally, effective maintenance protocols are integral to the long-term success of IV therapy. This includes regular monitoring of the infusion site, timely changes of the IV dressing, and prompt replacement of IV fluids and administration sets as per hospital policies. Educating patients on recognizing signs of complications can foster collaborative care and prompt reporting of any concerns. Continuous professional development and adherence to evidence-based guidelines can enhance nurses' competency in IV cannula management, ultimately resulting in improved patient safety and satisfaction. Regular audits and performance reviews can also identify areas for improvement, ensuring that nursing practice remains aligned with current best practices.

1. Introduction

The advent of intravenous therapy marked a revolutionary advancement in medical science, establishing a direct and immediate route into the human circulatory system. At the heart of this therapeutic modality lies the intravenous cannula, a seemingly simple yet indispensable medical device that has become a cornerstone of modern healthcare delivery. These small, flexible catheters are ubiquitously deployed across the entire spectrum of clinical settings—from bustling emergency departments and intensive care units to routine inpatient wards, outpatient clinics, and even home care environments. Their primary function is to facilitate the precise administration of life-sustaining fluids, critical medications, vital blood products, and essential nutritional support directly into the venous circulation, ensuring rapid onset of action and reliable bioavailability [1]. The profound dependence on this technology underscores its irreplaceable role in resuscitation, surgical care, medical treatment, and palliative support, making it one of the most commonly performed invasive procedures worldwide.

However, the very routine nature of intravenous cannulation presents a pervasive and often underestimated paradox. While essential for care, the insertion of a foreign body through the skin's protective barrier and into the vasculature inherently introduces a constellation of significant risks. These risks transform the cannula from a mere conduit for therapy into a potential source of harm. Chief among these are catheter-related bloodstream infections (CRBSI), which can escalate into severe sepsis, multisystem organ failure, and death. Mechanical and thrombotic complications, including phlebitis (vein inflammation), infiltration, extravasation of vesicant fluids causing tissue necrosis, occlusion, and thrombosis, are frequently encountered [2]. The clinical and economic ramifications of these complications are staggering. They inflict considerable patient morbidity, prolong suffering, extend hospitalization durations, and drive up healthcare costs through additional diagnostics, treatments, and extended bed stays. Furthermore, CRBSIs contribute to the escalating global crisis of antimicrobial resistance by necessitating the use of broad-spectrum antibiotics. Consequently, the management of intravenous cannulas sits at a critical intersection between therapeutic benefit and iatrogenic injury [3].

In this complex landscape, nursing practice emerges as the paramount and definitive factor determining patient safety and outcomes. Nurses are the healthcare professionals most intimately involved with the entire lifecycle of a peripheral intravenous cannula. Their responsibilities encompass the initial assessment and selection of the appropriate device and site, the technical skill of aseptic insertion, the daily diligent maintenance and surveillance, and the timely decision for removal. Every interaction—from flushing the device and changing a dressing to assessing the site for subtle signs of complication—represents a critical intervention point where best practice can either prevent harm or, if neglected, enable it. Therefore, the safe use and scrupulous maintenance of these devices are not merely technical tasks but fundamental components of ethical, high-quality patient care and are central to all patient safety initiatives [4].

2. Importance of Intravenous Cannulas in Healthcare

The peripheral intravenous cannula serves as a vital lifeline in patient care, enabling the rapid and efficient delivery of life-saving treatments. Its importance is multifaceted, encompassing therapeutic, diagnostic, and supportive functions. Therapeutically, intravenous access is crucial for administering antibiotics, analgesics, chemotherapeutic agents, vasoactive drugs, and emergency medications during resuscitation scenarios [5]. The intravenous route ensures immediate bioavailability and precise control over dosage and infusion rates, which is paramount in critical care and perioperative settings. Diagnostically, venous access allows for repeated blood sampling, reducing patient discomfort associated with multiple venipunctures and facilitating timely laboratory monitoring. Furthermore, intravenous cannulas are essential for providing hydration, correcting electrolyte imbalances, and maintaining nutritional status in patients unable to tolerate oral intake. The widespread application of intravenous therapy across diverse patient populations—from pediatrics to geriatrics, and from general wards to intensive care units—attests to its foundational role in medical treatment. However, this very ubiquity necessitates a rigorous approach to safety [6]. Each cannula represents a potential breach in the body's natural barriers to infection, and its presence can instigate local vascular trauma. Consequently, the benefits of intravenous therapy are inextricably linked to the risks posed by improper management. Recognizing this duality is the first step in fostering a culture of safety, where the convenience of vascular access is balanced by an unwavering commitment to minimizing associated harms through exemplary nursing practice [6].

3. Types of Intravenous Cannulas and Their Applications

Understanding the various types of intravenous cannulas is fundamental to selecting the most appropriate device for each clinical situation, thereby enhancing safety and efficacy. Cannulas are typically characterized by their gauge (diameter), length, material composition, and design features. The gauge, denoted by numbers such as 14G (largest) to 24G (smallest), inversely relates to the internal diameter of the catheter. Larger gauges (14G-18G) are used for rapid fluid resuscitation, blood transfusion, or during surgical procedures where high flow rates are required [7]. Smaller gauges (20G-24G) are suitable for routine medication administration, slower infusions, and for patients with fragile veins, such as the elderly or pediatric populations. The length of peripheral cannulas is generally short (less than 3 inches), classified as midline catheters or peripherally inserted central catheters (PICCs) for longer-term needs, though this review focuses primarily on short peripheral intravenous catheters [8]. Material composition has evolved from Teflon to newer materials like polyurethane and Vialon, which are more flexible, less thrombogenic, and associated with lower rates of phlebitis. Modern cannulas also come with safety-engineered features, such as retractable needles or passive safety shields, designed to prevent needlestick injuries—a critical occupational hazard for nurses. Additionally, some are equipped with passive disinfection caps or integrated stabilization platforms. The selection process must be a deliberate nursing decision, considering the prescribed therapy (viscosity, osmolarity, pH), expected duration of treatment, patient's venous anatomy and condition, and the potential for complications. Utilizing the smallest gauge and shortest length suitable for the prescribed therapy is a widely endorsed principle to preserve vascular integrity and promote patient comfort [9].

4. Guidelines for Insertion of Intravenous Cannulas

The insertion of an intravenous cannula is a sterile procedure that requires meticulous planning, technical skill, and adherence to evidence-based guidelines to ensure first-attempt success and reduce insertion-related complications. Comprehensive patient assessment precedes any insertion attempt. This includes evaluating the patient's medical history, current medications (especially anticoagulants), and assessing both upper extremities for suitable veins, avoiding areas of flexion, infection, or compromised circulation. The selection of an optimal site is critical; the distal forearm veins are often preferred over hand or wrist veins due to greater stability and lower complication rates, though clinical context must guide this choice [10]. Rigorous hand hygiene, performed with alcohol-based rub or soap and water, is non-negotiable for the inserter before donning gloves. The use of a standardized aseptic technique bundle is paramount. This bundle includes the application of a >0.5% chlorhexidine in alcohol solution for skin antisepsis, allowing it to air dry completely to maximize its bactericidal effect. The sterile cannula package should not be opened until immediately before insertion, and the practitioner must avoid re-palpating the cleansed site unless wearing sterile gloves. Techniques to aid venodilation, such as warm packs, dependency of the limb, or gentle tapping, can be employed [11]. During insertion, the nurse should anchor the vein

firmly, insert the cannula at a 10-30 degree angle with the bevel up, and advance it smoothly upon flashback of blood. Once the catheter is in the vein, the needle is retracted, and the catheter is advanced fully into the vessel. Immediate pressure should be applied proximal to the catheter tip to prevent blood spillage as the stylet is removed. Successful insertion is confirmed by the free flow of a compatible solution without signs of swelling or resistance. Documentation of the insertion date, time, site, cannula size, and number of attempts is a mandatory nursing responsibility that facilitates ongoing monitoring and timely replacement [12, 13].

5. Aseptic Technique and Infection Control

Infection control is the cornerstone of safe intravenous cannula management, with aseptic technique serving as the primary defense against catheter-related infections. The skin serves as a major reservoir for microorganisms, and cannula insertion breaches this barrier, creating a direct pathway for pathogens into the bloodstream. Therefore, a multi-modal approach to asepsis is essential throughout the catheter's dwell time. As previously emphasized, skin antisepsis with 2% chlorhexidine gluconate in 70% isopropyl alcohol is the gold standard due to its superior residual activity and broad-spectrum efficacy compared to povidone-iodine or alcohol alone [14]. The antiseptic must be applied using a back-and-forth friction scrub for at least 30 seconds and allowed to dry, as this drying time is integral to its microbial kill. Following insertion, maintaining asepsis during all subsequent manipulations of the intravenous system is equally critical. This involves performing hand hygiene and using clean or sterile gloves before any contact with the catheter hub or injection port. The concept of a "closed system" should be maintained; all connections must be secure and disinfected before access [15]. The use of needleless connectors is standard, and their disinfection requires a vigorous scrub with an alcohol-chlorhexidine swab or 70% alcohol pad for at least 5-15 seconds, depending on manufacturer guidelines, and allowing it to dry fully before accessing. This "scrub-the-hub" practice is one of the most effective yet frequently overlooked steps in preventing intraluminal contamination. Furthermore, all components of the administration set, including tubing, filters, and fluids, must be handled aseptically and changed at regular intervals—typically every 96 hours for primary tubing and immediately upon contamination [16]. The integration of passive disinfection caps, which contain antiseptic-impregnated sponges that cover catheter hubs between uses, has shown significant promise in reducing CRBSI rates by providing continuous protection against microbial entry. Nursing vigilance in consistently applying these aseptic measures is a non-delegable duty that directly correlates with patient safety outcomes [17].

6. Securement and Stabilization of IV Cannulas

Adequate securement and stabilization of the intravenous cannula are imperative to prevent mechanical complications such as dislodgement, phlebitis, infiltration, and migration. An unstabilized catheter is subject to pistoning motion (in-and-out movement) within the vein, which irritates the vascular endothelium, promotes thrombus formation, and can introduce skin bacteria into the insertion tract. Traditional methods of securement, such as adhesive tape, are insufficient and inconsistent. Best practice now mandates the use of engineered stabilization devices (ESDs) or purpose-designed securement dressings [18]. Transparent semi-permeable membrane (TSM) dressings are widely recommended as they allow continuous visual inspection of the insertion site without requiring dressing removal. These dressings should be applied using a sterile, aseptic technique, ensuring the catheter hub is also stabilized and the dressing edges are sealed to the skin. For added security, especially in active patients, pediatric populations, or when using larger-gauge catheters, supplemental securement with a manufactured catheter stabilization device is highly beneficial. These devices often include an integrated platform that anchors the catheter hub, significantly reducing movement [19]. The chosen securement method must not compromise site assessment or circulation. Furthermore, the practice of suturing peripheral intravenous catheters is strongly discouraged due to the increased risk of needlestick injury and infection. Proper securement also involves thoughtful management of the tubing; loops of tubing should be secured to the patient's skin away from the insertion site to prevent accidental traction. Regular assessment of the securement device's integrity is necessary, and the dressing should be changed immediately if it becomes loose, soiled, or moist. Effective stabilization is a simple yet profoundly impactful nursing intervention that extends catheter dwell time, enhances patient comfort, and reduces the frequency of unscheduled restarts, thereby conserving venous access and reducing healthcare costs [20].

7. Maintenance and Care of IV Cannulas

Ongoing maintenance of an indwelling intravenous cannula is a continuous nursing responsibility that dictates its functional longevity and safety. A systematic approach to care includes regular site assessment, flushing protocols, and dressing management. The insertion site and surrounding area must be visually inspected and palpated through the transparent dressing at least once per shift, or more frequently according to institutional policy or clinical indication [21]. Nurses should assess for signs of complication, such as tenderness, redness, swelling, warmth, palpable cord, or drainage. Flushing the catheter is essential to maintain patency and prevent occlusion from blood reflux or medication precipitate. The use of a pulsatile flush technique (push-pause motion) with normal saline is recommended, as it creates turbulent flow within the catheter lumen, more effectively clearing residues [22]. The volume of flush should be at least twice the internal volume of the catheter and any attached add-on devices. The "right after" flush is equally important to clear medication from the lumen. The evidence strongly supports the use of pre-filled saline syringes for flushing to reduce contamination risks associated with drawing up saline from multi-dose vials. When the cannula is not in continuous use, it should be locked with a recommended solution; for most peripheral catheters, normal saline is sufficient, though certain situations may warrant heparinized saline, albeit its use is declining due to risks of heparin-induced thrombocytopenia and drug incompatibilities. Dressing changes should be performed using an aseptic technique. A TSM dressing can often remain in place for the duration of catheter dwell unless compromised, but gauze dressings require changing every 48 hours. During any dressing change, the site should be re-disinfected with chlorhexidine and allowed to dry before applying a new sterile dressing. All maintenance activities must be documented, creating a clear record of catheter care and site condition over time [23].

8. Monitoring for Complications

Vigilant monitoring for early signs of complications is a critical aspect of nursing management for intravenous therapy, enabling timely intervention and preventing serious adverse events. Complications can be infectious, mechanical, or thrombotic in nature. Catheter-related bloodstream infection (CRBSI) is among the most severe, potentially leading to sepsis. Early local signs include erythema, purulent discharge, and tenderness at the insertion site [24]. Systemic signs may include fever, chills, or hypotension. Mechanical complications include infiltration, where non-vesicant fluid leaks into subcutaneous tissue, and extravasation, where vesicant or irritant solutions leak, causing potential tissue necrosis. Signs include swelling, coolness, pallor, pain, and decreased flow rate. Phlebitis, inflammation of the vein, is common and graded on scales (e.g., Visual Infusion Phlebitis scale) based on criteria like pain, redness, swelling, and palpable cord [25]. Thrombophlebitis involves clot formation alongside inflammation. Occlusion presents as inability to flush or infuse, often due to thrombotic or non-thrombotic blockages. Nerve injury and hematoma are also possible. Nurses must be trained to recognize these signs promptly [26]. The first action upon suspecting a complication is often to discontinue the infusion and remove the cannula, except in cases of suspected infiltration without vesicant, where some protocols may advise aspiration attempts. For extravasation of vesicants, specific antidotes and management protocols must be initiated immediately. A new cannula should be sited in a different limb. The removed catheter tip may be sent for culture if infection is suspected. Proactive monitoring, coupled with a low threshold for removal, is essential. Auditing phlebitis rates and other complications at the unit level is a valuable quality improvement activity that can drive practice change and reduce harm [[27].

9. Nursing Responsibilities and Best Practices

The nurse's role transcends the technical act of cannulation, encompassing a holistic responsibility for the entire intravenous therapy process. This includes assessment, planning, implementation, evaluation, and education. Key nursing responsibilities include: conducting a comprehensive patient assessment before insertion; selecting appropriate equipment; performing insertion with strict aseptic technique; ensuring proper securement; conducting regular, systematic site assessments; performing evidence-based flushing and dressing changes; recognizing and managing complications; documenting all aspects of care; and educating the patient and family [28]. Best practices are consolidated in clinical practice guidelines from bodies like the Centers for Disease Control and Prevention (CDC), the Infusion Nurses Society (INS), and the World Health Organization (WHO). These guidelines advocate for bundles of care—sets of interventions performed collectively and reliably to improve outcomes. A typical PIVC bundle includes: hand hygiene, maximal barrier precautions during insertion (though full draping is more for central lines, clean technique is vital for peripheral), chlorhexidine skin antisepsis, optimal

site selection, proper securement, and daily review of catheter necessity with prompt removal when no longer needed [29]. The "day of insertion" is often considered day 0, and routine replacement of peripheral cannulas is no longer recommended based solely on duration (e.g., every 72-96 hours). Instead, the CDC and INS recommend replacing cannulas only when clinically indicated, provided no signs of infection or inflammation are present, as this approach conserves veins and may reduce infection risk associated with unnecessary reinsertion. However, this requires diligent nursing assessment [30]. Nurses must also advocate for patients, questioning the continued need for intravenous access during interdisciplinary rounds. Adherence to these best practices requires ongoing education, competency validation, and a supportive institutional culture that provides the necessary resources, such as safety-engineered devices and chlorhexidine supplies [31].

10. Patient Education and Involvement

Empowering patients through education is a fundamental component of safe intravenous cannula management. An informed patient can become an active partner in monitoring their own device, recognizing early warning signs, and adhering to care instructions. Nursing education should begin at the time of insertion and continue throughout therapy. Key educational points include explaining the purpose of the cannula, the expected duration of therapy, and the importance of reporting any discomfort, pain, redness, swelling, or warmth at the site immediately [32]. Patients should be instructed to protect the site from getting wet (using protective covers during bathing), to avoid pulling on the tubing, and to notify staff if the dressing becomes loose, damp, or soiled. For patients discharged with a peripheral cannula (though uncommon), or for those with midline/PICC lines, detailed verbal and written instructions are crucial. Involving patients in the decision-making process, such as discussing preferred insertion sites when possible, can improve cooperation and satisfaction [33]. For pediatric patients, age-appropriate explanations and distraction techniques are essential. Family members or caregivers should also be educated if they will be assisting the patient. Encouraging patients to ask questions fosters a collaborative relationship and reinforces key safety messages [34]. Furthermore, educating patients about the rationale behind nursing actions, such as the "scrub-the-hub" technique before accessing the line, can enhance their understanding and willingness to remind healthcare providers if protocols are overlooked. Patient involvement extends to participation in safety initiatives, such as confirming site markings before procedures. Ultimately, patient education is a powerful tool that extends the nurse's surveillance capabilities beyond scheduled assessments, creating an additional layer of safety in the prevention of intravenous therapy-related complications [34].

11. Challenges in IV Cannula Management

Despite established guidelines, numerous challenges persist in the optimal management of intravenous cannulas in clinical practice. These barriers can be categorized into patient-related, practitioner-related, and system-related factors. Patient-related challenges include difficult venous access due to obesity, dehydration, chronic illness, intravenous drug use, or previous chemotherapy; patient movement or confusion leading to dislodgement; and language or health literacy barriers affecting education [35]. Practitioner-related challenges encompass knowledge deficits regarding current guidelines, skill variability in insertion and maintenance, cognitive overload leading to lapses in aseptic technique, and inconsistent documentation. Perhaps the most pervasive challenges are system-related. These include inadequate staffing levels, which compromise the time available for proper site assessment and care; lack of availability of essential supplies such as chlorhexidine, stabilization devices, or safety-engineered cannulas; conflicting or absent institutional policies; and insufficient training and competency programs [36]. The culture of an organization plays a significant role—where short-term efficiency is prioritized over meticulous practice, compliance with bundles suffers. Furthermore, the high turnover of peripheral cannulas, often due to phlebitis or occlusion before therapy completion, leads to "vascular access exhaustion," a serious problem for patients requiring long-term therapy. Addressing these challenges requires a multi-faceted approach. Strategies include implementing vascular access teams staffed by expert nurses, which have been shown to improve insertion success rates and reduce complications; investing in ultrasound technology for difficult access; developing clear, accessible policies based on current evidence; providing regular, simulation-based training for staff; and fostering a safety culture where every team member feels empowered to speak up about breaches in protocol. Overcoming these obstacles is essential to translating evidence into consistent, high-quality practice at the bedside [37].

12. Future Directions and Innovations

The field of vascular access is continuously evolving, with research and innovation aiming to further enhance the safety and efficacy of intravenous cannula use. Future directions focus on materials science, technology integration, and practice models. The development of novel catheter materials with inherent antimicrobial or anti-thrombogenic properties, such as those impregnated with silver ions or coated with heparin, holds promise for reducing infection and occlusion rates, though cost-effectiveness remains a consideration for peripheral catheters. Smart technology is emerging, including catheters equipped with sensors that can detect early signs of phlebitis or infiltration by monitoring temperature or impedance changes at the site. These could provide real-time alerts to nursing staff. Connector technology is also advancing, with designs aimed at reducing dead space and promoting more effective disinfection. The use of near-infrared vein visualization devices is becoming more commonplace to aid first-attempt insertion success in patients with difficult venous access, particularly in pediatric and oncology populations. From a practice perspective, the trend towards clinically indicated replacement rather than routine replacement is likely to solidify, supported by more robust long-term data. The role of specialized vascular access nurses and teams is expected to expand, potentially becoming a standard in hospitals to centralize expertise. Furthermore, big data and artificial intelligence may play a role in predicting which patients are at highest risk for complications, allowing for pre-emptive interventions. Research continues into optimal flushing solutions, securement methods, and dressing types. Ultimately, the future of safe IV cannula use lies in a synergistic approach that combines technological advancements with strengthened human factors—continuous education, competency assurance, and a relentless focus on evidence-based nursing practice to achieve the goal of zero preventable harm from a seemingly simple device [38].

13. Conclusion

The safe use and maintenance of intravenous cannulas represent a critical nexus between a fundamental nursing procedure and overarching patient safety goals. This review has delineated the comprehensive scope of nursing practice required to mitigate the inherent risks associated with peripheral intravenous therapy. From the initial assessment and aseptic insertion to diligent securement, systematic maintenance, vigilant monitoring, and patient education, each step is interdependent and vital. Adherence to evidence-based guidelines, such as those advocating for chlorhexidine skin antisepsis, proper securement devices, and clinically indicated replacement, is not merely a recommendation but a professional imperative. The challenges in consistent implementation are real, spanning individual, procedural, and systemic domains, yet they are not insurmountable. Through investment in education, resources, specialized teams, and a culture of safety, healthcare institutions can empower nurses to excel in this domain. As innovations in catheter technology and practice models continue to emerge, the core principles of meticulous aseptic technique, continuous assessment, and patient-centered care will remain immutable. In conclusion, the humble intravenous cannula, when managed with the highest standards of nursing expertise and care, fulfills its therapeutic potential while minimizing harm, thereby safeguarding patient well-being and upholding the fundamental ethos of the nursing profession.

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