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Intravenous Therapy

A Review of Complications and Economic Considerations of Peripheral Access

ABSTRACT

Despite the growing frequency of intravenous (IV) injections, establishing peripheral IV access is challenging, particularly in patients with small or collapsed veins. Therefore, patients often endure failed attempts and eventually become venous depleted. Furthermore, maintaining patients' vascular access throughout treatment is difficult because a number of complications including phlebitis, infiltration, extravasation, and infections can occur. The aim of this article is to review the use of the IV route for administering therapy, identify and analyze key risks and complications associated with achieving and maintaining peripheral IV access, examine measures to reduce these risks, and discuss implications for nurses in clinical practice.

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The history of intravenous (IV) therapy dates back to the Middle Ages. The first experiments with IV injections were carried out in the 1600s using quills and bladders of animals as instruments.[1] During the cholera epidemic of 1831-1832, Dr Thomas Latta pioneered the use of IV saline infusion.[2] In the 20th century, 2 world wars established a role for IV therapy as routine medical practice.[3]

IV delivery of blood and blood products, drugs with poor bioavailability by oral or other routes, and parenteral nutrition are used in emergency, acute care, or perioperative situations. Hemodialysis, central venous pressure monitoring, and introduction of contrast agents for imaging of the circulatory system also necessitate vascular access. Short-term IV access is used widely for hydration, restoring electrolyte balance, delivering blood or blood products, anesthesia, and some antibiotic therapy. In some cases, IV delivery is used to overcome side effects or poor patient compliance (eg, replacing oral bisphosphonate therapy for osteoporosis with a once-yearly IV infusion of bisphosphonate).

By the 1990s, it was estimated that more than 85% of hospitalized patients in the United States received IV therapy, and the practice expanded to other outpatient services and physicians' offices while becoming a major home care modality. A 1990 nursing survey found that 75% of a nurse's hospital time was spent providing IV

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therapy services.[3] Today, many drugs must be injected via the IV route because of limitations of drug solubility or bioavailability or because of tissue irritation. In addition, parenteral hydration is usually delivered intravenously. Each year in the United States, hospitals and clinics purchase 150 million intravascular devices to administer intravenous fluids, medications, blood products, and parenteral nutrition fluids, to monitor hemodynamic status and to provide hemodialysis.[4] It is likely that the number of patients who require IV therapy will increase as the population ages and more IV therapeutics become available.[5]

USE OF THE IV ROUTE FOR ADMINISTERING THERAPY

The IV route ensures that the prescribed medicine concentration is delivered directly into the systemic circulation, which is termed "one hundred percent bioavailability" and avoids the need for absorption; problems with malabsorption or drug inactivation by the gut are also avoided. IV administration overcomes any nothing-by-mouth or fasting requirements and may also overcome a patient's refusal to take oral medication.[6]

There are 3 general types of peripheral IV (PIV) administration: bolus injection, intermittent infusion, and continuous infusion, and each has inherent benefits and risks (Table 1). The rationale for choice is based on knowledge of the medication and its therapeutic effect.[6]

PROBLEMS IN ESTABLISHING IV ACCESS

Americans are living longer, and the extensive baby boom generation is approaching retirement age. The percentage of the population older than 65 years is predicted to increase more sharply than any other age group—from 13% in 2010, to 19.3% by 2030, to 20.2% by 2050.[7] As the population grows older, it becomes more likely that the population will develop health conditions requiring IV injections and cannula insertions, making venous access increasingly difficult with each successive hospitalization. In addition to aging veins, a number of other factors complicate the process of establishing venous access and contribute to venous depletion in hospitalized patients (Table 2).[8,9] For example, more than one-third of the population is now considered obese,[10] which poses significant challenges for successful venous access.[8] Peripheral venous access also can be difficult if the patient is dark skinned, an IV drug abuser, or hypotensive, or if he or she has multiple injuries limiting the number of limbs available for use.[9]

Pediatric patients also pose considerable problems in establishing venous access—not only because of the smaller size and greater fragility of their veins but also because of their greater restlessness, communication difficulties, and lack of cooperation.

TABLE 1

Means of Peripheral Intravenous Drug and Fluid Administration[6]

Treatment	Bolus Injection	Intermittent Infusion	Continuous Infusion
Rationale	• Quick response needed • High blood concentration required • Patient is fluid overloaded • Drug is not chemically stable in solution	• High blood concentration required • Patient is fluid overloaded • Drug is not chemically stable during continuous administration (eg, benzylpenicillin) • Reduces risk of adverse reactions, for example, with bolus antibiotics	• Constant blood level required • Constant effect required
Risks	• Anaphylaxis/anaphylactoid reactions • Speed shock • Infiltration or extravasation • Phlebitis	• Anaphylaxis/anaphylactoid reactions • Infiltration or extravasation • Phlebitis • Fluid overload • Infusion error—too fast or slow	• Anaphylaxis/anaphylactoid reactions • Infiltration or extravasation • Phlebitis • Fluid overload • Infusion error—too fast or slow • Incorrect infusion rate—overdose

TABLE 2

Factors Contributing to Venous Depletion in Hospitalized Patients[8,9]

• Extremes of age (ie, elderly and pediatric patients)	• History of multiple venous cannulations
• Obesity	• Previous vein injury
• Dark skin	• Limited use of specific limbs due to mastectomy, stroke, contractures, or injury
• Smoking	• Peripheral venous disease
• History of IV drug use	• Phlebitis
• Hypotension	• Infiltrations
• Long periods of bed rest	• Blood clots
• Inactivity	• Hematomas
• Major surgery	• Use of certain medications, including birth control pills

COMPLICATIONS ASSOCIATED WITH IV THERAPY

A number of complications including phlebitis, thrombophlebitis, infiltration, extravasation, and infections are associated with IV therapy. Among other factors, the knowledge and experience of the nurse inserting the cannula can play a major role in preventing these complications. Nurses who have the skill and expertise required for insertion of IV catheters, as well as knowledge regarding their postinsertion care and maintenance, can significantly influence patient outcomes.

Phlebitis and Thrombophlebitis

Phlebitis is an inflammation of the wall of a vein; when a blood clot in the vein causes the inflammation, the condition is termed *thrombophlebitis*. The condition is characterized by pain, erythema, swelling, and palpable thrombosis of the cannulated vein.[11]

The most frequent complication of PIV infusion is phlebitis, which may occur at rates as high as 50%[12] or even as high as 75% in patients with infectious diseases; however, the incidence rate in patients who do not have diabetes, burns, or a need for urgent catheter insertion is approximately 20%.[13] A number of risk factors have been implicated in the development of phlebitis (Table 3).[11-13] Patients who are female or who have poor-quality peripheral veins, insertion in the lower extremity, or the presence of underlying medical conditions, including cancer and immunodeficiency, are at increased risk for phlebitis.[11]

Whereas 1 study found that insertion of catheters in the veins around the elbow increased the risk of phlebitis,[14] most sources agree that phlebitis occurs more frequently when the catheter has been inserted in a lower extremity.[11] The Centers for Disease Control and Prevention (CDC) recommends that, in adults, an upper-extremity site should be used for catheter insertion instead of a lower-extremity site. The CDC further recommends that a catheter inserted in a lower-extremity site be replaced with one in an upper-extremity site as soon as possible. In pediatric patients, the upper or lower extremities or the scalp (in neonates or young infants) can be used as the catheter insertion site.[15]

Duration of catheterization also has been suggested as a predictor of infusion-related phlebitis.[11] Therefore, the CDC recommends, in adults, that short peripheral venous catheters be replaced no more frequently than every 72 to 96 hours to reduce the risk of phlebitis.[15] The Infusion Nurses Society (INS), which sets the standards of practice for IV nursing care,

TABLE 3

Risk Factors for Peripheral Vein Infusion-Related Phlebitis[11-13]

Patient-Specific Risk Factors	Catheter-Specific Risk Factors	Other Risk Factors
Female gender	Duration of catheterization	Characteristics of infusate (eg, low pH, high osmolality, presence of microparticulates)
Age ≥ 61 years	Large-gauge catheter	Inexperience of the person inserting the catheter
Poor-quality peripheral veins	Teflon catheter	Insertion in the emergency room
Underlying medical disease (diabetes, infectious diseases, cancer, immunodeficiency)	Insertion of catheter in the lower extremities	Changing gauze dressings more frequently than every 48 hours

stated in its 2011 *Infusion Nursing Standards of Practice* that the nurse should consider replacement of the short peripheral or midline catheters when clinically indicated.[16]

The risk of phlebitis is increased when a large-gauge catheter is used, possibly because of the physical trauma caused by the insertion of a large-bore catheter into a relatively short, narrow vein. The material of the catheter may contribute to the risk of phlebitis, too. Newer polyurethane (PEU) catheters have been associated with a 30% to nearly 50% reduction in the incidence of phlebitis compared with catheters made of tetrafluoroethylene-hexafluoropropylene (Teflon).[17]

The solution being infused may also be responsible for phlebitis. A low-pH and high-osmolality solution, such as hypertonic dextrose, is acidic and irritant and induces phlebitis.[8,18] In addition, certain medications, such as potassium chloride, barbiturates, phenytoin, and many cancer chemotherapeutic agents, have been implicated in the development of infusion-related phlebitis.[17] IV antibiotics, such as vancomycin, amphotericin B, and most β-lactams, have been associated with a 2-fold increased risk, which may be attributable to the presence of microparticulates in the antibiotic solutions.[11]

The CDC recommends the removal of peripheral venous catheters if the patient develops signs of phlebitis (eg, warmth, tenderness, erythema, or palpable venous cord).[15] Both the INS Phlebitis Scale and the Visual Infusion Phlebitis Score are tools that can be used for monitoring infusion sites and determining when a PIV catheter should be removed.[19,20]

Treatment for phlebitis is usually heat and analgesia; however, anti-inflammatory agents can be beneficial in reducing inflammation at the cannula site.[6] In addition, heparin and corticosteroids, alone or as a combination therapy, have been investigated, as well as topical nitroglycerin.[21]

Infiltration and Extravasation

Other complications of IV therapy include infiltration and extravasation. *Infiltration* is defined as the inadvertent leakage of a nonvesicant solution into surrounding tissue, and *extravasation* is the inadvertent leakage of a vesicant solution into surrounding tissue. Infiltration and extravasation can be caused by mechanical, physiologic, or pharmacologic factors. Mechanical factors (occurring either during initial catheter insertion or while the catheter is in place) and physiologic factors (relating to preexisting or emerging vein problems) can be contributing factors. Regardless of the mechanism, specific management of infiltration and extravasation is usually determined by the pharmacologic characteristic of the offending infusion.[22]

Unfortunately, many nurses associate extravasation only with cytotoxic chemotherapy agents (such as doxorubicin, paclitaxel, and vinca alkaloids), not realizing that there are a number of noncytotoxic drugs, including phenytoin, sodium bicarbonate (>5%), calcium chloride and gluconate, amphotericin B, acyclovir, ganciclovir, digoxin, diazepam, potassium (>40 mmol/L), dextrose 50%, cefotaxime, and mannitol, that can also cause tissue necrosis.[23]

The incidence of infiltration and extravasation is hard to determine because of limited reporting; however, extravasation injury from cancer chemotherapy is reported to be 11% in children and 22% in adults.[24] One study found that, of all the complications associated with peripheral cannulas, 33.7% occurred as a result of infiltration.[23]

Common signs and symptoms of IV infiltration include

- Cool skin temperature at the site of cannula insertion
- Skin that looks blanched, taut, or stretched or that the patient says feels “tight”
- Edema at the insertion site
- Discomfort; tenderness
- Change in quality and flow of the infusion or the injection
- IV fluid leaking from the insertion site[23-25]

Signs and symptoms of extravasation are the same as those of infiltration but also include burning/stinging pain, redness followed by blistering, tissue necrosis, and ulceration.[23]

Both infiltration and extravasation can have serious consequences including full-thickness skin loss and muscle and tendon necrosis.[22] The patient may need surgical intervention resulting in large scars, experience limited function, or even require amputation. Another long-term effect is complex regional pain syndrome, a neurologic syndrome requiring long-term pain management.[24]

These complications occur when the catheter is not properly inserted into the vein, when the lining of the vein has been damaged and swells, or when a clot forms within the vein, preventing the infusate from flowing forward. Infiltration and extravasation can occur when the cannula punctures or erodes through the opposite wall of the vein. Infiltration and extravasation may also occur if the catheter is pulled out of the vein during patient movement or because it wasn’t secured well.[25] A number of risk factors have been implicated in the development of infiltration and extravasation, as shown in Table 4.[22,23]

As soon as infiltration or extravasation has been identified, the infusion should be stopped.[22,23,25] Other management recommendations have not been definitively established and depend partly on the type of infusate. As a rule, however, after the infusion has been stopped, the IV tubing should be disconnected from the device (leaving the catheter in place), and an attempt should be made to aspirate the residual drug from the IV device.[22,23] In some institutions, antidotes are administered to either localize and neutralize the drug or to

TABLE 4

Factors Contributing to the Risk for Infiltration and Extravasation[22,23]

Patient-Specific Risk Factors	Catheter-Specific Risk Factors	Pharmacologic Factors	Other Risk Factors
Small, fragile, or thrombosed veins	Large catheter size relative to vein size	Solutions with very high or very low pH	Inexperience or lack of skill of the person inserting the catheter
Patient activity	Insertion into site that is likely to be affected by movement (eg, the dominant hand or areas of joint flexion)	Solutions with very high or very low osmolarity	
Lymphedema	Unstable catheter or poorly secured access needle	Vasoconstrictive potential	
Age (elderly and pediatric patients are at increased risk)	Multiple venipuncture sites	Cytotoxic substances	
Obesity	Catheter port separation or catheter fracture		
Underlying chronic medical disease (diabetes, peripheral vascular disease, cancer)			
History of multiple IV cannulations or venipunctures			

Abbreviation: IV, intravenous.

spread and dilute the drug. Examples of antidotes are steroids (reduction of inflammation), hyaluronidase (rapid diffusion of the extravasated fluid and promotion of drug absorption), dimethyl sulfoxide (applied topically for extravasation of cytotoxic drugs such as anthracyclines), and dexrazoxone (a topoismoerase II catalytic inhibitor that reduces size and duration of the wound of some anthracycline drugs).[23]

Nursing interventions for infiltration or extravasation include elevation of the affected limb and application of cold (for infiltration or extravasation of hyperosmolar fluids) or heat (for extravasation of vinca alkaloids, such as vinblastine and vincristine, and epipodophyllotoxins, such as etoposide).[22,24] Elevation of the affected limb may aid in reabsorption of the infiltrate or extravasated vesicant by decreasing capillary hydrostatic pressure. Local cooling (ice packs) aids in vasoconstriction, thus theoretically limiting drug dispersion. The use of local warming therapy (dry heat) is based on the theory that it increases vasodilation, thus enhancing dispersion of the vesicant agent and decreasing drug accumulation in the local tissue. When infiltration or extravasation occurs, it is important for the nurse to estimate the volume of infiltrated fluid on the basis of the hourly flow rate and the length of time the problem has been evident and to document it.[22]

Infection

Another complication found with PIV therapy is the development of infection, which can range from the minor irritation of a localized site infection to increased morbidity and mortality from bloodstream infection, or septicemia.[6] Although the incidence of local or bloodstream infections associated with PIV catheters is usually low, serious infectious complications produce considerable annual morbidity because of the frequency with which such catheters are used. However, the majority of serious, catheter-related infections are associated not with peripheral catheters but with central venous catheters, especially those placed in patients in intensive care units (ICUs).[15,17]

Although the incidence of IV infusion-related infections is difficult to determine, studies have shown that between 5% and 25% of peripheral catheters are colonized by skin organisms at the time of removal.[11]

Common signs and symptoms of local infusion-related infection include

- Erythema
- Pus
- Warmth
- Induration
- Palpable venous cord

- Pain
- Venous thrombosis[6]

Signs and symptoms of systemic infection include chills, fever, malaise, headache, tachycardia, nausea, and vomiting.[6]

A number of risk factors have been implicated in the development of IV infusion-related infection (Table 5).[26] For example, the material of the cannula can affect susceptibility for infection because infectious organisms are more likely to adhere to certain catheter materials than others. Therefore, PEU catheters are associated with a lower risk for infection than those made of Teflon.[27]

Although giving an IV injection or starting an IV is a common activity for nurses, it is important to recognize that inserting a cannula has many risks that can be avoided with the appropriate aseptic technique, selection of catheter, insertion technique, and maintenance of the line while the patient is being infused.

IMPLICATIONS FOR NURSES

Nurses are at the forefront in providing IV therapy; their knowledge and skill can minimize infusion-related complications and affect patient safety, satisfaction, health care costs, and length of hospital stay. The Certified Registered Nurse Infusion (CRNI®) credential is the only nationally accredited certification for infusion nursing.[28] Certification requires passing a national certification examination and completing at least 1600 hours of clinical experience in infusion therapy within the previous 2 consecutive years (www.incc1.org). Most RNs who practice infusion therapy but are not certified have a bachelor of science in nursing and at least 2 years in a medical or surgical clinical setting.

Economic Considerations

Because financial resources are limited at every institution, economic evaluations are helpful in understanding the cost-effectiveness of IV therapy—and can suggest ways in which nurses can help reduce health care costs while enhancing quality of care for their patients.

The Resource Group (Dallas, TX) created a nursing process model for determining primary (direct nursing) costs of in-office IV infusions.[29] They observed 78 patients receiving IV infliximab (a monoclonal antibody treatment for rheumatoid arthritis, ankylosing spondylitis, psoriatic arthritis, psoriasis, ulcerative colitis, and Crohn's disease) in rheumatology or gastroenterology practices. All procedure times required to prepare, administer, monitor, and complete the infusion were recorded as well as postservice activities including cleanup and charting. All tasks were performed according to INS policies and procedures. The average time for the complete procedure was 129.7 minutes per patient. Any time spent attending to more than 1 patient, such as during monitoring, was divided by the number of patients involved. At an average hourly cost of labor of $31.80 (derived using national salary rates obtained from the US Bureau of Labor Statistics and weighted according to the proportion of RNs, licensed practical nurses, nurse practitioners, and physicians performing the 78 procedures), the average cost per procedure for direct patient care was predicted to be $69.[29]

In another study, the costs of IV treatment in hospitalized patients in Switzerland who required IV therapy were randomized 1:1 to receive either a peripherally inserted central catheter (PICC) or a PIV catheter. Regarding the analysis of cost-effectiveness, the cost of PICC use was evaluated at $690 per patient, whereas the cost of PIV catheter use was $237. Nurses spent

TABLE 5

Risk Factors for Developing Peripheral Vein Infusion-Related Infection[26]

Patient-Specific Risk Factors	Catheter-Specific Risk Factors	Other Risk Factors
Patient immunocompromised	Insertion of catheter in the lower extremities; joint-flexion areas	Lack of aseptic technique and good hand hygiene
Extremes of age	Large-gauge catheter	Inexperience of the person inserting the catheter
Associated chronic disease (diabetes, cancer, vascular insufficiency, etc)	Teflon catheter	Insertion in the emergency room
Patient immunosuppressed	Duration of catheterization	Ineffective or insecure dressing
Medical interventions and drug therapies		
Malnourishment		

4.1 hours per patient handling the PICCs and approximately 5.5 hours with PIV catheters. This represented a patient cost for nurses' salaries of $165 for PICCs and $219 for PIV catheters. Costs resulting from catheter complications were not included in this analysis.[29]

It is important to note that the skillful ability to achieve venous access on the first try can have a significant impact on health care costs. The most labor-intensive activity in IV therapy is initial placement of the catheter, which averages 10 to 20 minutes but in difficult access situations may take much longer, requiring multiple attempts and alternate sites. The number of attempts to successfully place a PIV catheter influences labor and supply costs.[30]

IV delivery has been shown to be considerably more costly than delivery of the same agent subcutaneously (SC). A survey of 28 oncology practices determined an average cost of $30.18 for nursing labor to deliver alemtuzumab by SC injection compared with $113.13 for IV infusion. Labor included both delivery and observation. For SC delivery, 57% of respondents said that fewer than 30 minutes of labor were involved, and 43% reported 30 to 120 minutes. For IV infusion, time for labor was estimated at less than 4 hours by 75% of respondents and 4 to 6 hours for the remaining 25%. In addition, costs of consumable supplies were reported to be substantially more for IV compared with SC delivery.[30]

Nurses also should be aware that infusion-related complications can significantly affect health care costs. Complications of IV therapy are costly in terms of patient quality of life, morbidity, mortality, and treatment expense, especially when there is an extended hospital stay. This is especially evident for catheter-related bloodstream infections. For each episode of infection, hospitalization is prolonged by 7 to 14 days, and survivors average an additional 24 days in the hospital. Estimates of the added cost of treatment range from $3000 to $56 167.[31]

Liability Issues

Increasingly, nurses are named as defendants in malpractice actions, many of which involve administration of IV fluids and medications. More than 2% of medical practice liability claims involve peripheral catheters, and claimants have been awarded up to $10 million per claim.[22] Nurses who deliver IV therapy are subject to litigation for failure to monitor and assess the patient's clinical status, prevent infection, use equipment properly, or protect the patient from avoidable injury. In the event of a claim, complete and accurate documentation is important for an effective legal defense.

CONCLUSIONS

There are many reasons to provide IV therapy, such as when a continuous blood level of drug is needed, and IVs are very commonly used. Despite the increasing frequency of IV injections and catheter insertions today, establishing PIV access can be challenging, particularly in patients with small or collapsed veins. Therefore, patients often endure failed attempts and eventually become venous depleted. In addition, preserving patients' vascular access throughout their treatment is difficult because a number of complications can occur, including phlebitis, thrombophlebitis, infiltration, extravasation, and infection. One of the most costly complications in terms of mortality and expense is infection. Although mortality rates associated with bacteremia or candidemia have improved, the rate of sepsis continues to climb. Individual improvements in catheter materials, prophylaxis for and treatment of complications, and practice policies are difficult to associate with statistically significant improvement in outcomes. However, advances in training, monitoring, and documentation, as well as adoption of multifaceted policy "bundles," have improved overall safety and reduced costs. For many therapies, alternative delivery methods may further improve patient safety and quality of life and save considerable resources.

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