

From Skill to Safety: The Role of Simulation-Based Education in Preventing Infusion-Related Errors in Nursing Practice

Jaideep Herbert

International Simulation Consultant, Gurgaon, India

ABSTRACT

Corresponding author

Dr Jaideep Herbert

(Ph.D, MSN, CHSE),
International Simulation
Consultant, Gurgaon, India
E-mail: @herbertjaideep@yahoo.
com

How to cite this article:

Herbert J. From Skill to Safety:
The Role of Simulation-Based
Education in Preventing
Infusion-Related Errors in
Nursing Practice. 2026; J Infus
Nurses Soc India.
01:(01); 43-48

Received: 24-01-2026

Accepted: 04-10-2026

Published: 03-11-2026

Infusion therapy is a high-volume, complex clinical intervention prone to errors across patient identification, medication delivery, vascular access, and device operation. Translating evidence-based standards into consistent clinical behavior requires competencies beyond procedural skills. Simulation-based education addresses this gap by offering a risk-free environment for nurses to practice psychomotor technical skills, clinical judgment, infection control, and non-technical safety behaviors. Integrating realistic clinical scenarios—such as infiltration, extravasation, and pump programming errors—with deliberate practice, structured debriefing, and objective competency validation converts theoretical knowledge into observable safety performance. Evidence indicates that simulation enhances medication safety, error recognition, communication, and situational awareness. When linked with standard operating procedures, clinical audits, and continuous quality governance, simulation transitions infusion training from routine procedural execution to a robust patient-safety system. Bridging theoretical learning and clinical practice through simulation ensures nurses effectively anticipate, detect, and mitigate infusion-related risks before patient harm occurs.

Keywords:

Infusion therapy, Simulation-based education, Patient safety, Nursing competency, Medication errors.

Introduction

Infusion therapy is one of the most frequently performed clinical interventions in modern healthcare and is an essential component of nursing practice across medical, surgical, critical care, oncology, pediatric, neonatal, and home-care settings. Despite its routine nature, infusion therapy involves multiple opportunities for error, including incorrect patient identification, medication and dose errors, inappropriate infusion rates, failure to recognize infiltration or extravasation, catheter-related complications, inadequate aseptic technique, and delayed recognition of clinical deterioration. These events can result in preventable patient harm.^[1,2]

Competence in infusion nursing requires more than theoretical knowledge. Nurses must integrate psychomotor skills, clinical judgment, medication safety, infection pre-

vention, communication, monitoring and timely escalation of complications. Simulation-based education provides a controlled environment in which nurses and nursing students can repeatedly practice these competencies without exposing patients to unnecessary risk. Simulation can also recreate high-risk and low-frequency events such as extravasation, anaphylaxis, infusion pump malfunction, infiltration, catheter occlusion and medication administration errors.^[3]

Evidence increasingly supports simulation as an effective strategy for developing medication-safety knowledge, technical skills, error recognition, clinical judgment, communication and teamwork.^[3,5] However, simulation should not be viewed as a stand-alone intervention. Its greatest value is achieved when it is integrated with evidence-based infusion standards, compe-

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DOI: XXXXXXXXXX

tency validation, structured debriefing, clinical audit, and continuous quality improvement.^[6,7]

This article discusses the relationship between infusion competency and patient safety and proposes a practical framework for using simulation-based education to reduce infusion-related risks in nursing practice.

Infusion therapy is an integral component of contemporary nursing practice. Intravenous medications, fluids, blood products, parenteral nutrition and other therapies are administered through vascular access devices in almost every area of healthcare. The complexity of infusion therapy has increased with the expanding use of peripheral intravenous catheters, midline catheters, peripherally inserted central catheters (PICCs), implanted ports and other vascular access devices.^[6]

The Infusion Nurses Society (INS) identifies evidence-based standards as a framework for safe and consistent infusion therapy across patient populations and healthcare settings.^[6] The standards support clinical decision-making, competency development, organizational policies and quality and safety in infusion practice.^[6,8]

However, having a written standard does not automatically guarantee safe practice. The nurse must be able to translate the standard into observable clinical behavior. This includes selecting and assessing vascular access, performing appropriate hand hygiene and aseptic technique, administering medications correctly, programming infusion devices accurately, monitoring the patient, and vascular access site, identifying complications early and responding appropriately.^[6,9]

The World Health Organization recognizes medication errors and unsafe medication practices as important causes of avoidable harm. Errors may occur at different stages of the medication-use process and can be influenced by both human factors and system-related factors.^[1,2]

This raises an important question for nursing education and clinical governance:

How can nurses be prepared not merely to perform infusion procedures, but to recognize and prevent errors before they reach the patient?

One promising answer is simulation-based education.

From Procedural Skill to Safety Competence

Traditional clinical education often emphasizes whether a learner can complete a procedure. For example, a nurse may be assessed on whether they can insert a peripheral intravenous catheter, administer an intravenous medication or operate an infusion pump.

Although these skills are important, safe infusion practice requires considerably more.

A competent infusion nurse must be able to:

- Assess the patient before therapy
- Verify the medication, dose, route and prescribed rate
- Identify allergies and contraindications
- Select appropriate vascular access
- Assess the vascular access device and insertion site
- Maintain aseptic technique
- Use infusion equipment correctly
- Recognize incompatibilities and potential medication-related risks
- Monitor the patient during therapy
- Identify early signs of infiltration, extravasation, phlebitis, infection or systemic reactions
- Stop an infusion when clinically indicated
- Initiate appropriate emergency measures
- Communicate concerns effectively
- Document the event accurately
- Escalate care according to institutional policy

Therefore, infusion competency is not simply a “**skill**.” It is an integrated combination of knowledge, technical performance, clinical judgment, communication and patient-safety behavior.^[6]

The CDC similarly recommends education and training of healthcare personnel involved in vascular catheter insertion and maintenance, periodic assessment of knowledge and adherence to recommendations, and limiting catheter-related procedures to personnel who demonstrate competence.^[9]

Where Do Infusion-Related Errors Occur?

Infusion-related errors can occur throughout the care pathway rather than at a single point of administration.^[1,2]

1. **Patient identification errors:** Failure to correctly identify the patient can result in administration of the wrong medication or therapy.^[1]
2. **Medication-related errors:**
 - Incorrect medication
 - Incorrect dose
 - Incorrect dilution
 - Incorrect route
 - Incorrect infusion rate
 - Incorrect concentration
 - Failure to identify allergies
 - Incompatibility between medications or solutions; and inadequate monitoring following administration.^[6]
3. **Vascular access errors:** These may include inappropriate device selection, poor assessment of the insertion site, incorrect access technique, catheter dislodgement, occlusion or failure to recognize complications.^[6]
4. **Infection-prevention failures:** Breaks in hand hygiene, aseptic technique, hub disinfection, or catheter maintenance can increase infection risk.^[9]

5. **Infusion pump errors:** Incorrect programming of volume, rate, concentration, or duration can result in under-infusion or over-infusion.^[6]
6. **Failure to recognize complications:** Early recognition is critical in conditions such as infiltration, extravasation, phlebitis, catheter-related infection, and systemic medication reactions.^[6]
7. **Communication and documentation failures:** Incomplete handover, inadequate documentation or failure to escalate deterioration can allow an initial minor problem to become a serious adverse event.^[1]

Why Simulation?

Simulation allows healthcare professionals to experience realistic clinical situations in a controlled learning environment.^[3,4]

The learner can

Prepare → Perform → Recognize → Respond → Reflect → Repeat

This cycle is particularly valuable for infusion nursing because many complications cannot be safely demonstrated on real patients for educational purposes.^[3]

A nurse cannot intentionally create extravasation in a patient simply to teach its management. Similarly, it is inappropriate to create a medication error, infusion pump failure, or acute infusion reaction for learning purposes.^[3]

Simulation solves this problem by creating a realistic but safe environment.

A systematic review of human simulation for medication-error prevention identified scenario design, debriefing, and realism as important elements of effective simulation programs. The review also emphasized that simulation is particularly useful for practicing both routine activities and events that occur infrequently but carry significant risk.^[5]

More recent evidence continues to support simulation as a strategy for developing nursing patient-safety competencies. A 2026 systematic review of 20 studies found that simulation was associated with improvements in medication safety, communication, teamwork, error detection and clinical judgment, with repetitive practice and interprofessional simulation identified as important strategies.^[5]

Simulation as a Bridge Between Knowledge and Practice

One of the persistent challenges in nursing education is the gap between knowing what should be done and actually performing it correctly in a clinical environment. A nurse may know that the infusion site should be assessed regularly.^[4,5]

However, the more important competency is whether the nurse can identify subtle changes at the site, interpret the findings, stop the infusion when required and initiate appropriate action? Similarly, a nurse may know the

definition of extravasation but still hesitate when faced with a deteriorating IV site. Simulation converts theoretical knowledge into observable performance.

A simple competency progression



This progression is particularly important in infusion nursing because the consequences of a seemingly small error can be significant.^[4,5]

Designing an Infusion Nursing Simulation Program

A successful simulation program should not simply place a mannequin in a room and ask nurses to perform an IV procedure. The simulation should begin with clearly defined patient-safety objectives.

Step 1: Identify High-Risk Infusion Activities

The organization should review incident reports, near-miss reports, medication-safety data, infection-control findings, competency assessments, and staff feedback.

Priority areas may include:

- Peripheral IV insertion
- IV medication administration
- Infusion pump operation
- High-alert medication administration
- Vascular access assessment
- Central-line care
- PICC-line management
- Extravasation
- Infiltration
- Phlebitis
- Infusion reactions
- Catheter occlusion
- Infection prevention
- Medication compatibility
- Patient identification
- Emergency escalation.

Step 2: Develop Realistic Clinical Scenarios

The scenario should resemble the nurse's actual clinical environment.

Example-A patient receiving intravenous medication through a peripheral IV catheter reports burning and discomfort at the insertion site. The nurse notices swelling and a change in the appearance of the site.^[6]

The learner must:

1. Assess the patient
2. Recognize the abnormal findings
3. Stop the infusion according to the relevant protocol
4. Avoid inappropriate manipulation of the catheter or site
6. Notify the appropriate clinician
6. Follow the institution's extravasation protocol
7. Document the event
8. Communicate with the patient

Step 3: Include both technical and non-technical skills

Infusion errors are not always caused by lack of technical knowledge.

Human factors such as workload, distractions, fatigue, interruptions, communication problems and environmental conditions can contribute to medication-related errors. WHO specifically identifies both human and system factors as contributors to medication errors.^[1,2]

Therefore, simulation should include:

Technical skills

- IV catheter insertion
- Medication preparation
- Medication administration
- Infusion pump programming
- Vascular access assessment
- Catheter maintenance
- Aseptic technique

Non-technical skills

- Communication
- Situational awareness
- Clinical decision-making
- Teamwork
- Escalation
- Speaking up
- Documentation
- Patient education;

Step 4: Use deliberate practice

A major advantage of simulation is the opportunity for repeated practice.^[5]

In traditional clinical learning, a nurse may encounter a particular complication only occasionally. In simulation, the same scenario can be repeated until the expected behavior becomes consistent. For example:

- **First attempt:** Learner recognizes the problem but delays escalation.
- **Second attempt:** Learner recognizes the problem earlier but misses documentation.

- **Third attempt:** Learner recognizes, responds, communicates and documents appropriately.

Step 5: Make debriefing the heart of simulation

Simulation without debriefing is incomplete.^[3]

After the scenario, the educator should guide the learner through structured reflection.

A useful debriefing sequence is:

- *What happened?* Allow the learner to describe the situation.
- *What were you thinking?* Explore clinical reasoning and decision-making.
- *What went well?* Reinforce safe behaviors.
- *What could have been different?* Identify missed opportunities.
- *What will you do differently next time?* Convert reflection into an action plan.

Simulation Scenarios for Infusion Nursing

A structured simulation curriculum could include the following scenarios: (Table 1)

Table 1: Simulation Scenarios for Infusion Nursing

Simulation Scenario	Key Competencies
Peripheral IV insertion	Patient identification, site selection, aseptic technique, insertion
Difficult IV access	Assessment, escalation, communication
Infusion pump programming	Rate, volume, alarms, troubleshooting
High-alert medication administration	Verification, calculation, monitoring
Infiltration	Early recognition and appropriate intervention
Extravasation	Recognition, immediate response and escalation
Phlebitis	Assessment, prevention and management
Infusion reaction	Monitoring, recognition and emergency response
Central-line care	Aseptic technique, assessment and maintenance
PICC-line complications	Assessment, troubleshooting and escalation
Catheter-related infection risk	Infection prevention and clinical decision-making
Medication incompatibility	Medication safety and prevention
Occluded catheter	Assessment and appropriate response
Emergency infusion reaction	ABC assessment, communication and teamwork
Wrong-rate scenario	Error recognition and corrective action

Technology and the Future of Infusion Simulation

Emerging technologies may further expand infusion nursing education.

Potential applications include

- **Virtual simulation:** Learners can practise decision-making in digital clinical environments.
- **Augmented reality:** Digital information can be overlaid onto physical equipment and procedures.
- **Virtual reality:** Learners can practise complex scenarios and emergency responses in immersive environments.
- **Smart infusion pumps:** Simulation can reproduce programming errors, alarm conditions and troubleshooting situations.
- **Video-based assessment:** Learner performance can be recorded and reviewed during debriefing.

Key Recommendations for Nursing Practice

1. Make infusion competency a measurable clinical competency rather than an attendance-based training activity.
2. Integrate simulation into initial orientation and periodic competency validation.^[7]
3. Use real clinical incidents and near misses to develop simulation scenarios.
4. Include both technical and non-technical skills.
5. Use structured debriefing after every simulation.^[3]
6. Link simulation checklists to current evidence-based standards and institutional policies.^[6,8]
7. Use OSCE or other objective competency assessments to validate performance.^[7]
8. Measure competency retention at defined intervals rather than assuming that one training session is sufficient.
9. Monitor clinical outcomes such as IV complications, medication errors, near misses and infection-related indicators.
10. Create multidisciplinary simulation involving nursing, pharmacy, medical, and quality teams where appropriate.
11. Develop a non-punitive environment in which nurses can report errors and near misses and learn from them.^[1]
12. Use simulation as part of a broader patient-safety and clinical-governance strategy rather than as an isolated educational intervention.

Conclusion

Infusion therapy is often perceived as a routine nursing procedure. In reality, it is a complex clinical process requiring technical proficiency, medication safety, infection prevention, vascular access expertise, clinical judgment, communication, and continuous monitoring.^[6]

The central challenge for nursing education is therefore not simply to teach nurses how to start an IV or administer an infusion, but to develop nurses who can recognize risk, anticipate complications, detect errors, and respond appropriately.

Simulation provides an important bridge between theoretical knowledge and safe clinical performance. It creates a protected environment where nurses can practise high-risk procedures, make mistakes without harming patients, receive feedback, repeat performance, and develop clinical judgment.^[3,5]

Evidence supports simulation for improving medication-safety competencies and broader patient-safety skills, although the evidence also reminds us that simulation alone cannot guarantee reductions in real-world adverse events. Effective programs require realistic scenarios, deliberate practice, structured debriefing, competency validation, and evaluation of clinical outcomes.

For infusion nursing, the opportunity is particularly important. The combination of evidence-based infusion standards, simulation-based education, objective competency assessment, and clinical audit can transform infusion education from a **procedure-focused activity into a patient-safety system**.^[6,8]

Ultimately, the goal is not simply:

“Can the nurse perform the procedure?”

The more important question is:

“Can the nurse perform the procedure safely, recognize when something is going wrong, and act before the patient is harmed?”

That is the journey **from skill to safety**.

Declarations

Funding

The available study record did not report external funding.

Conflict of interest

The available study record did not report any competing interests.

AI-assisted writing disclosure

This manuscript was language-edited with AI assistance; the authors remain responsible for the scientific content, interpretation and final manuscript.

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