Research Summary and Recommendations for Improving the Safe Administration of Multiple Intravenous Infusions

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In 2010, the Ontario Health Technology Advisory Committee requested that HumanEra – an applied human factors research team at the University Health Network – study the topic of safe administration of multiple intravenous (IV) infusions for the purpose of identifying risks and developing risk-mitigating interventions to improve patient safety in Ontario. The research was started under funding by the Ontario Ministry of Health and Long Term Care. Subsequent funding for this work was provided by Health Quality Ontario under the Health Technology Research funding program. The study was conducted over a period of four years and was overseen by the Multiple IV Infusions Steering Expert Panel. The work included the following phases:

- A literature review
- A comparative incident database review (ISMP Canada and FDA Maude)
- A technology scan
- Observational field studies in 12 clinical units across 10 Ontario hospitals (critical care, oncology, emergency)
- Interviews with 13 program coordinators of BScN and Post graduate critical care training programs in Ontario
- Ontario-wide survey of hospital policies and practices related to managing multiple IV infusions
- Controlled simulation lab study (40 ICU participants) to evaluate potential mitigating strategies

The results of this body of work included several detailed research reports and a set of recommendations to improve nursing practice, education, and infusion system design. The recommendations were developed with support from the Multiple IV Infusions Expert Panel and approved by HQO’s Ontario Health Technology Advisory Committee. The reports and recommendations are published and publicly available at: http://www.hqontario.ca/evidence/publications-and-ohtac-recommendations/ontario-health-technology-assessment-series/mivi-phase2b

To promote the dissemination and uptake of these reports, HumanEra has prepared this guidance document summarizing the evidentiary base and recommendations amassed through all the phases of the research. This report also highlights implementation support materials related to each of the recommendations, including a series of interactive eLearning modules, prepared by HumanEra and hosted by the Registered Nurses Association of Ontario, to educate nurses on topics related to secondary IV infusions and shared infusion volume. The eLearning modules can be completed online and can be downloaded into a learning management system. They are available free of charge at the following web link: http://elearning.rnao.ca/

The recommendations made in this document have been modified from the original OHTAC-approved recommendations based on interview and focus group feedback from 7 Ontario hospitals (including both pediatric and adult hospitals) as well as lessons learned from 3 pilot implementation projects. The modifications aim to increase the relevance of the recommendations to a wider audience, recognizing the variability of models of care, technology, patient populations, and resources across Ontario hospitals.

The recommendations in this document are divided into 5 themes:

1. Identifying an IV infusion
2. Setting up and programming multiple continuous IV infusions
3. Managing shared infusion volume
4. Setting up secondary intermittent IV infusions
5. Administering IV pump boluses

An introduction is given at the beginning of each theme to provide the context and evidence for each of the theme’s issues. For each recommendation, there is a discussion of the evidence related to the prevalence of the issues and the effectiveness of the recommendation itself. In some cases the research results from this project, particularly the simulation lab study results, are the first results published on the associated topic. More research is required to effectively address the issues presented in this report and we encourage other organizations to continue this work.

We hope this report initiates discussions in your organization about standardization of nursing practice and education related to multiple IV infusions and provides a supportive base for safety improvement initiatives.
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**Scope**

The following are the inclusion and exclusion criteria for the Multiple IV Infusion Safety Recommendations:

- Recommendations are intended for both adult and pediatric care environments.
- Recommendations consider data collected from ICUs, emergency departments, general wards and oncology environments. It is intended that these recommendations will extend to all clinical environments where nurses administer multiple IV infusions. Operating rooms are not explicitly included in this scope.
- Recommendations are for the administration of IV infusions via volumetric and syringe IV systems and do not include devices for other routes of administration (e.g., enteral, epidural).
- Tubing misconnections between different types of tubing (e.g., IV, epidural, enteral feeding, blood pressure monitoring, endotracheal tubes), though a serious issue, is not included in this scope. For more information on tubing misconnections see the June 2012 issue of The Source or go to http://www.fda.gov/MedicalDevices/Safety/AlertsandNotices/TubingandLuerMisconnections/ucm313275.htm.
- The delivery of patient-controlled analgesia is not explicitly included in these recommendations.
Theme 1. Identifying an IV Infusion

To safely manage IV infusions, nurses must identify the pathway from the IV container to the patient catheter and know which medications are joined together prior to doing any task related to an infusion (e.g., titrating, disconnecting an infusion, adding another IV medication, administering an IV push medication). Accurate and timely identification of an IV infusion is challenging—particularly for patients receiving multiple IV infusions—because the IV tubing becomes tangled and the pathway from the IV bag to the patient is not easily traceable. The resulting visual clutter above and below infusion pumps is commonly referred to as *spaghetti syndrome* (Figure 1).(1-3)

Managing the *spaghetti syndrome* is critical to patient safety because patient harm can arise from the following: a delay in receiving critical medications occurs while a nurse sorts through a complex setup;(2;3) incorrect changes to an infusion pump due to inaccurate identification of the medication or pathway; and medication compatibility and/or shared infusion volume issues (see Theme 3: Shared Infusion Volume) when infusions are connected to the incorrect IV line or port, or incorrect infusions are disconnected.(1-9)

To identify an IV infusion, clinicians must routinely verify an infusion pathway by sliding their hands along the tubing from the IV container (which is labeled with the infusion contents) to the patient’s IV catheter (or vice versa); this is referred to as *line-tracing*. Incidents have occurred because nurses have identified the wrong IV tubing to trace (i.e., physically grabbed the wrong IV tubing) or during the process of line-tracing the correct IV tubing, inadvertently switched to the wrong IV tubing.(3;6)

The potential for line identification errors to occur during line-tracing – particularly when the IV line was obstructed by another line, the patient’s gown, or an incubator - was highlighted in a field study.(2)

The recommendations in *Theme 1. Identifying an IV Infusion* are intended to improve the likelihood of timely and accurate infusion identification.
1. IV Tubing Labeling

Recommendations

Label all primary IV tubing to support line identification, specifically (Figure 2):

1.1 Label primary IV tubing with the name of the infusate at two locations:
   1. Near the infusion pump (not on the pump)
   2. Just above the injection port closest to the patient (i.e., pump side of the port).
   Use pre-printed labels and standardize the labels with respect the format of information (e.g.,
   generic name, tall man lettering).

1.2 Distinguish the “IV push port” (i.e., the port where intermittent IV medications are administered via
   a syringe) by applying a label that is visually prominent and different from all other labels used in the
   bedside environment.

1.3 When multiple IV access ports are being used, indicate (near the infusion pump) the patient access
   port to which an infusion is connected.

a May not be required when infusions are programmed in the drug library of a smart pump that clearly communicates infusion details
   on its display; if the smart pump does not provide a clear, salient, readable information, an adhesive label should be added to the IV
   tubing near the pump (e.g., just below the pump).
b Adhesive labels placed on a pump may not be removed when a medication is discontinued and the pump is reused for a new and
different infusion.
c Adhesive labels placed below an injection port may not accurately reflect the IV tubing contents, because the tubing below the
   connector may contain more than 1 medication.
d IV access information can be indicated using various methods including, but not limited to, adhesive labels and colour-coded line
   organizers.

IV tubing labels do not eliminate the potential for line identification errors and mislabeled infusions can
promote mix-up errors. Current recommended line identification practices, such as always tracing infusion
pathways before making a change to an infusion and during staff hand-off process, must still be promoted.

IV tubing labeling policies and procedures should specify when in the IV set-up/line change workflow IV
   tubing labels should be applied to minimize labeling mix-ups (e.g., each IV tube must be labeled and fully
   connected prior to hanging, programming, or connecting the next infusion).
## Recommendation Implementation

### Example of Recommendation Implementation

![Image of infusion pump and labels]

Figure 2 A) Infusate labels near the pump. B) Infusate labels above the lower injection port. C) IV access specified near the pump and the lower injection port using colour-coded line organizers.

### Self-Assessment

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### Recommendations

1.1 Label primary IV tubing with the name of the infusate at two locations:
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   Use pre-printed labels and standardize the labels with respect the format of information (e.g., generic name, tall man lettering).

1.2 Distinguish the “IV push port” (i.e., the port where intermittent IV medications are administered via a syringe) by applying a label that is visually prominent and different from all other labels used in the bedside environment.

1.3 When multiple IV access ports are being used, indicate (near the infusion pump) the patient access port to which an infusion is connected.

### Legend:

A: There has been no discussion or consideration of this recommendation.
B: This recommendation has been formally discussed and considered, but it has not been implemented
C: This recommendation has been partially implemented in the organization for some or all areas.
D: This recommendation is fully implemented in the organization for some areas.
E: This recommendation is fully implemented throughout the organization

When assessing C-E, consider whether the following statements apply:

- There is an organizational policy and procedure to specify the requirements outlined in the Recommendation.
- Formal education and training about the organizational policy and procedure has been provided to all nurses.
- IV tubing labeling practices are consistent with the organizational policy and procedure.
- The supplies required to comply with the policy and procedure (e.g., pre-printed labels) are available on the unit.
Implementation Resources

- (Appendix A) The Joint Commission’s Standard Procedure for Setting Up Continuous or Intermittent Intravenous Medications. In: The Joint Commission; Lines crossed: Preventing medication errors involving multiple IVs. The Source. May 2014; 2(5); pp.8-11.

Suggested QI Indicator to Monitor Recommendation Compliance

- % IV tubing labeled as per policy and procedure

Discussion of Evidence

Issue Description and Recommendation Rationale

To facilitate the management of IV infusions, nurses must know what medication is infusing in each IV line, what drugs are joined together prior to reaching the patient, and which pump is controlling the flow of each medication. Since most IV tubing is clear, and most IV medications are clear, there are no clues to help support line identification.

A study conducted by the Pennsylvania Patient Safety Authority analyzed 907 incident reports involving IV lines that were submitted to the Pennsylvania Patient Safety Reporting System from June 2004 through August 2013. (11) IV line mix-ups accounted for 9.5% (n = 86) of the reports, and 91.9% of line mix-up errors involved high-alert medications.

Labeling primary IV tubing near the pump and directly above the injection port closest to the patient provides the required visual communication of infusion contents at the locations where changes are made, which facilitates infusion confirmation. An Ontario field study on multiple IV infusion risks revealed that labeling practices varied not only across facilities and across units within a facility, but between individual nurses on the same unit. (2) Some nurses chose to apply line labels where as some nurses did not. Some nurses placed labels near the injection port

Reported Incident
IV phenylephrine was ordered to help manage a patient’s hypotension. While the nurse was getting report at shift change, another nurse administered the medication. The patient later became very unstable and passed away. After the patient’s death, it was discovered that the phenylephrine bag was attached to the IV pump that was programmed for the IV fluid and was administered at a rate of 150 mL/hr. (Incident description adapted from: Aligning the lines: An analysis of IV line errors.11)

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1 Labeling commonly refers to an auxiliary adhesive label, but in this context can also include other tools that communicate line identification information (e.g., drug name on the screen of a smart pump, colour-coded plastic line separator that correspond with each central line catheter lumen).
where as others placed them anywhere along the IV tubing. The results of a survey of Ontario hospital practices related to managing multiple IV infusions explains the variation in practice given that 30% (19 of 64) of respondents have no policy or practice regarding the labeling of IV contents. (12)

In an emergency situation, it is particularly important to quickly identify infusions – particularly the infusion port used to administer intermittent IV medications (e.g., “IV push port” or port associated with the “plain IV line”, if one is setup) – given that urgent changes to therapy may be required and the person(s) caring for the patient may not be the primary nurse and may not be familiar with the infusion setup (e.g., additional support nurses are helping to manage the emergency). Thus, the “IV push port” needs to be prominently and distinctly labeled relative to the other IV tubing labels to promote quick access in the event of an emergency. In Ontario, however, nursing practice related to the use of visually distinct “IV push ports” varies widely (2), and 39% (17 of 44) of respondents to a survey on multiple IV infusion practices indicated they do not label their “plain IV line” at all. Of those that do label their “plain IV line”, 93% (25 of 27) do not use a label that is visually distinct from other labels in the environment. (12)

When multiple IV access ports are in use (e.g., a multi-lumen central venous catheter, multiple peripheral and/or central lines), indicating the patient access port associated with each IV infusion near the infusion pump supports consideration of the impact of modifying an infusion (e.g., titrating) on other infusions connected to the same access port (described in Theme 3. Shared Infusion Volume). During a field study, it was observed that some nurses identify the IV port access associated with each medication by adding tape labels to the IV pump or IV tubing specifying the IV line/lumen through which the medication was infusing. (2) This practice was not common across nurses on a single unit or across facilities.

**Recommendation Evidence**

Type of evidence: Expert consensus and controlled study data

Applying labels to IV infusions is a well-recognized strategy for informing clinicians about infusion setups, placing information where it is needed and reducing memory load. (2; 5; 8) The literature and professional nursing and safety organizations have provided general recommendations supporting the use of IV tubing labels to avoid misidentifying an infusion. (5; 11; 13-19) For example, ISMP (United States) (6) recommends labeling IV tubing with the drug name at the end closest to the patient and near each pump/channel.

Recommendations 1.1 and 1.2 specify the location for IV infusate labels, and the location and design characteristics (i.e., distinguishable from all other labels in the environment) for “IV push port” labels, respectively. These recommendations are based on 2 controlled simulation studies, which showed that using preprinted labels decreased infusion identification time (8) and errors. (20) One study showed that when infusions were organized to minimize tangles (see Recommendations 2.1 on IV system organization), grouped by IV access port using a colour-coded line organizer (Recommendation 1.3) and labeled directly below the pump and directly above the lower injection port (Recommendations 1.1), no infusion identification errors were made compared to a mean error rate of 8% (12 of 156 documentation tasks) when IV tubing were tangled and not labeled. (20)

There is consensus from the Multiple IV Infusions Expert Panel that labeling IV tubing with the name of the infusate near the pump and directly above the lower injection port, labeling the “IV push port” so it is distinguishable from all other labels in the environment, and indicating the IV access associated with each infusion will increase the timely and accurate identification of an infusion and lead to safer care for patients.
2. IV System Organization

Recommendations

Set up multiple IV infusions to facilitate accurate and timely identification and tracing of IV infusions lines, specifically (Figure 3):

2.1 Separate IV infusions and minimize tangles

2.2 Align the IV container (e.g., IV bag) with the corresponding IV pump/channel.

2.3 Use patient gowns with snaps, ties, or Velcro on the shoulders.

⚠️ The presence of infusion organizers and gowns with snaps, ties, or Velcro does not eliminate the need for line tracing. Line tracing should always occur prior to interacting with the infusion system.

⚠️ Metal fasteners/snaps on patient gowns should be avoided to prevent burns (e.g., from magnet in an MRI suite).

Recommendation Implementation

Example of Recommendation Implementation

Figure 3. A) Multiple IV infusions organized using IV tube separators and IV poles with hooks that align the IV bags with the IV pumps. B) Patient gown with snaps along the shoulder to allow for better line tracing.
Self-Assessment

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E: This recommendation is fully implemented throughout the organization

When assessing C-E, consider whether the following statements apply:
- The supplies/tools required to comply with this recommendation (e.g., IV tubing organizers, IV poles with hooks that align with the pumps below, gowns with snaps, Velcro, ties) are available on the unit.
- The supplies/tools are in routine use.

Suggested QI Indicator to Monitor Recommendation Compliance
- % IV poles in the organization with IV container hooks that align with IV pumps/pump channels
- % of patient gowns used with fasteners over the shoulders

Discussion of Evidence

**Issue Description and Recommendation Rationale**

To complete various infusion-related tasks (e.g., disconnect an infusion, administer a manual IV push), nurses must routinely identify and verify an infusion pathway by sliding their hands along the tubing from the IV container to the patient access port (or vice versa) and around various obstructions (e.g., patient gowns, other tubing, pumps). This is referred to as line tracing. Tangled IV tubing and obstructions contribute to line tracing errors because the infusion cannot be traced continuously without lifting a hand off the tubing.

Infusion organizers -- accessories that can be used along the infusion pathway from the IV pole-top to the patient bedside -- aim to reduce inter-infusion tangles and align infusion components, providing clinicians a more organized view of infusions and their pathway. For example, IV tubing guides aim to separate IV tubing and minimize interweaving of tubing below the pump, eliminating the need to lift a hand off the IV tubing when tracing a line. IV poles can be purchased with different IV bag hook arrangements at the top, which vary in the number, type, and physical layout of hooks (e.g., carousel, star, or rake) to help align IV containers with the pumps directly below them, which facilitates timely and accurate infusion identification.(20) There are a variety of approaches to achieving an organized infusion system, and the optimal approach will vary.

**Reported Incident**

“A patient was on an insulin drip at 5mL/hr and a maintenance IV at 100mL/hr. While changing the patient’s gown, the IVs were switched and the patient received the insulin drip at 100mL/hr, or 20 units/hr for approximately two hours. [By late morning,] the BS [blood sugar] was less than 35 [mg/dL], so the insulin drip was turned off, which was when the error was discovered. Hourly finger sticks [were initiated] and dextrose 50% IV [was administered].”

Incident description from: Aligning the lines: An analysis of IV line errors.¹¹
according to the type of pump used and other environmental factors (e.g., room arrangement, presence of incubators, type of patient bed). Hospitals should prioritize line organization as part of an infusion system procurement process and/or consider investigating and implementing an optimized approach to line organization as a quality improvement initiative.

Gowns with snaps, ties, or Velcro on the shoulders should also be considered as part of an infusion organization initiative since these types of gowns allow the sleeves to be opened up prior to line tracing, eliminate the need to switch hands or lift a hand off the tubing when tracing IV tubing between the patient and the pump.

**Recommendation Evidence**

**Type of evidence: Expert consensus and controlled study data**

This recommendation is based on 1 controlled simulation study,(20) which showed that when infusions are organized (as per Recommendation 2.1 above) and labeled (as per Recommendation 1.2-1.2), no infusion identification errors were made compared to a mean error rate of 8% (12 of 156 documentation tasks) when IV tubing were tangled and not labeled.(20) The infusions were organized using the following: IV rake pole-top that mapped the IV container with the corresponding IV pump below Physical guides that grouped tubing by patient access port (guide colours matched access port colours for the central triple-lumen catheter), and separated and minimized IV tubing tangles below the pump and below the lower injection port.

There is consensus from the Multiple IV Infusions Expert Panel that organizing IV tubing according to Recommendation 2 and using patient gowns with snaps, ties, or Velcro on the shoulders will result in fewer line tracing errors and result in safer care for patients.
Theme 2. Setting up and programming multiple primary continuous IV infusions

Setting up and programming an IV infusion refers to the processes of assembling, arranging, and configuring the components required to deliver an IV agent to a patient. Setting up multiple primary continuous IV infusion at the same time is a common task when caring for acutely ill patients, and may be required in the following situations:

- When multiple new IV infusions are prescribed simultaneous initiation (e.g., a new patient is admitted who requires multiple IV therapies).
- When patients are transferred to a new clinical unit and infusions have to be set up again because of differences in infusion equipment (e.g., pump manufacturer/model, IV tubing and connectors), medication concentrations, or decentralized inventory management (requiring that pumps be returned to their home unit). (2; 5; 18) This is a common occurrence when patients transfer between the operating room and critical care environments, but can occur when a patient transfers between any 2 units. (2)
- When all IV containers, tubing, and connectors must be changed as part of a “line change” (a best practice to reduce the risk of infection). (21)

When setting up multiple continuous IV infusions there is greater visual and physical complexity (e.g., more IV containers, pumps, IV tubing, poles) and cognitive load (e.g., managing multiple drug orders) in comparison to setting up a single infusion. (2) A recent study of 907 medication errors involving IV lines reported to the Pennsylvania Patient Safety Authority found that 13.1% (n=119) of the incidents were related to IV rate mix-up errors. (11) In a simulation lab study, (20) nurses were required to complete a line change on 4 IV infusions without auxiliary labels or a standardized protocol for completing a line change. A programming error was associated with 11.7% of the line changes (7 of 60). (20) The presence of multiple IV infusions may not only exacerbate the known risks of setting up 1 infusion (e.g., infusion pump programming errors), but also introduce new hazards including the following:

- Mix-up dosing errors: Error! Reference source not found. shows different types of mix-up errors that have occurred when multiple IV infusions must be set up at one time, which have resulted in medication dosing errors from the pump being incorrectly programmed for the infusate. (1; 2)
- Interruptions in therapy: When multiple continuous IV infusions are connected to 1 access port and need to be set up again (e.g., patient transfer, line change), there is a risk of interrupting therapy during the transition from the old to new infusions. In a controlled simulation study, almost half of the line changes observed included unnecessary interruptions to life-sustaining IV infusions. (20)
- Infection control risks: Each IV infusion creates a potential pathway for infection. As more IV infusions are added, each IV line requires the opening of the IV system at some time during the infusion (changing IV bags, line changes, manual IV push injections).
Figure 4. Setting up and programming multiple primary continuous IV infusions: Inter-infusion mix-up errors

1. IV tubing and pump mix-ups (physical errors): Nurses have mistakenly identified the IV tubing and inserted the wrong tubing into a pump (3;6).

2. Labeling mix-ups: When tubing (or pumps) were labeled all at once for multiple IV infusions, a label was incorrectly placed on an IV component (e.g., placing a label for infusion D on the IV tubing of infusion E and vice versa; (1;2)). This leads to subsequent changes to the wrong infusion. The risk of mix-ups is heightened if labels are applied to infusion pumps and multiport connectors and not removed before changing an infusion (2;6).

3. Drug order and pump mix-ups (cognitive load errors): Multiple IV infusions ordered at the same time create a high cognitive load. A heavy reliance on the clinician’s memory to setup and program all the infusions correctly can result in confusion. (1) Errors have occurred in duplicating an infusion (i.e., 1 ordered medication is set up twice) (3;22) or mixing up pump programming parameters (e.g., dose/flow rate and volume to be infused [VTBI]) (3;6) which results in the same error as an IV tubing and pump mix-up, above (20).

Setting up and programming multiple IV infusions is a high-risk activity. The recommendations in this section are aimed at minimizing the need to re-establish multiple infusions already running (e.g., through greater standardization between sending/receiving units). Several of the recommendations in this theme have also been made by medication and patient safety organizations to reduce adverse drug events (e.g., standardizing drug concentrations across hospital units) and so in some cases the impact of these recommendations are beyond mitigating MIVI safety risks.
3. IV Tubing Date Labels

Recommendations

To minimize unnecessary line changes:

3.1 Label primary IV tubing with pre-printed date change labels. Standardize the content (e.g., start date, discard date, start time), format of information (e.g., mm/dd) and location of the labels to minimize unnecessary line changes.

3.2 Ensure date change information for IV tubing (and related components) is tracked consistently and reliably in all tracking systems (e.g., Kardex and/or electronic documentation systems should capture the same information that is on the IV tubing date labels).

⚠️ The Infusion Nurses Society recommends that nurses should avoid writing directly on an IV bag because certain chemical components of some marking pens can permeate the plastic of the IV bag and there is a risk of smearing the label, which would cause the labeling to be unrecognizable.(21)

Recommendation Implementation

Example of Recommendation Implementation

Figure 5. Pre-printed date labels that specify the content required and the format of the information. Labels are placed in a standard location along the IV tubing.
Self-Assessment

<table>
<thead>
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E: This recommendation is fully implemented throughout the organization

When assessing C-E for Recommendation 3.1, consider whether the following statements apply:
- There is an organizational policy and procedure to specify the requirements outlined in the Recommendation.
- Formal education and training about the organizational policy and procedure has been provided to all nurses.
- The supplies required to comply with the policy and procedure (e.g., pre-printed labels) are available on the unit.
- IV tubing labeling practices are consistent with the organizational policy and procedure.

Suggested QI Indicator to Monitor Recommendation Compliance
- % of IV tubing with a date label applied and consistent with the organization’s Policy and Procedure (and in accordance with Recommendation 3.1).
- % of IV tubing where the content and format of information on the date label matches the content and format of information in other documentation systems (e.g., Kardex, eMAR).

Discussion of Evidence

Issue Description and Recommendation Rationale

A *line change* is a best practice in which all the IV tubing, connectors, and containers are replaced to prevent infection (e.g., guidelines recommend that continuous IV administration sets and add-on devices should be changed every 72 - 96 hours).(23) Fundamental principles of nursing indicate that IV tubing should be labeled with the date and initials of the nurse who hung the IV bag to promote best practice adherence. (24)

However, interviews with critical care unit managers and field observations revealed that IV tubing date labels are not consistently applied and there are non-standard labeling methods (e.g., adhesive IV tubing labels, date written on the drip chamber using a sharpie pen), label fields (e.g., hung date, discard date), date formats (e.g., dd/mm, mm/dd), and placement of date labels (e.g., directly below the IV bag, on the IV bag).(2) IV tubing date change information is also documented in other systems (e.g., medication administration record, flow sheet) and the labeled information and format is sometimes inconsistent with these systems.(2)
Standardizing the materials, content, format of information, and placement of date labels applied to IV tubing promotes clear communication of when a line must be changed. This helps ensure components are not being changed more frequently than recommended in guidelines, which decreases interruptions to therapy (20) a pump must be stopped to replace the tubing), mix-up and programming errors (1;2;6;11;13;22;25) (if more than one IV tubing is not connected to an infusion pump a tubing-pump mix-up error can occur) and increases the risk of infection since each time a line change occurs the infusion system is opened and potentially exposed to bacteria in the environment. (21) Changing IV tubing more frequently than is necessary also has cost implications.

**Recommendation Evidence**

Type of evidence: Expert consensus

There is consensus by the Multiple IV Infusions Expert Panel that standardizing the content, format and location of IV tubing date labels will minimize unnecessary IV tubing changes, thereby minimizing opportunities for interruptions to therapy, mix-up errors, and infection risk, leading to safer care for patients.

**A snapshot of current practice**

In January 2015, two Ontario hospital voluntarily collected data on IV line date labeling. Spot check data were collected on IV set-ups on the critical care units.

At Hospital 1, 42% of primary IV tubing (n=128) had a date label on the IV tubing and 85% of IV tubing with labels (46 of 54) had a pre-printed date label that clearly indicated the start and discard date for IV the tubing. At Hospital 2, 63% (n=49) had date labels. All of the labels were handwritten on blank white stickers and included only one date. There was no standard for the date format so it wasn’t clear whether the date on the IV tubing was the date the tubing was changed or the date it needed to be changed.

Both hospitals have a policy requiring date change labels on all IV tubing.
4. Medication Concentrations

Recommendation

4.1 Standardize medication concentrations across common hospital pathways (e.g., OR-ICU, Emergency-General Internal Medicine), to help minimize the need to re-establish infusions after patient transfers.

⚠️ More than one medication concentration may be required for vesicant medications depending on the type of IV access device (e.g., peripheral catheter vs. central catheter) used for administrations.

Recommendation Implementation

Example of Recommendation Implementation

![Diagram showing standard concentration across hospital pathways (OR-ICU, Emergency-General Internal Medicine)]

Figure 6: A single standard concentration is used throughout the organization.

Self-Assessment

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Implementation Resources

- San Diego Patient Safety Council: Safe Administration of High-Risk IV Medications Toolkit

- Indianapolis Coalition for Patient Safety: High Risk IV Infusion Medication Concentrations and Dosage Units Standardization
  http://indypatientsafety.org/documents/resources/High_Risk_IV_Drug_Concentration_and_Dosage_Unit_Standardization.pdf

- Alberta Health Services Policy Standardized Medication Concentrations for Parenteral Administration
  https://extranet.ahsnet.ca/teams/policydocuments/1/clp-standardized-medication-concentrations-for-parenteral-administration-policy.pdf

- Article describing the standardization of drug concentrations at Wake Forest Baptist Medical Centre in North Carolina:
    http://apsf.org/newsletters/html/2010/summer/03_STPC.htm

- Article describing the process of standardizing medication concentrations between the emergency department, operating rooms, and the intensive care unit:
    http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2532888/

Discussion of Evidence

Issue Description and Recommendation Rationale

When different concentrations of an IV medication are used for the same clinical indications in different areas of the hospital, a new IV infusion must be set-up each time a patient is transferred between units with different standard concentrations. This requires that infusions be stopped, IV tubing discarded, new medication containers and IV tubing be connected to the patient, and infusion pumps re-programmed. In addition to wasted time, resources, and medication, this task carries risks associated with delays in therapy, mix-ups and programming errors,(1,2;5;11;13;22;25;26) and patients who are less stable may experience problems from an interruption in therapy (see Theme 2 introduction). Changing medication concentrations is also associated with

Implementation Success Story

In 2010, Wake Forest University Baptist Medical Centre implemented standardized medication concentrations between the operating rooms and the intensive care units (cardio-thoracic (CT) and medical) that eliminated the need to re-establish existing IV infusions during patient transfers due to different standard concentrations used in each clinical unit. In addition to the increased safety benefits of not interrupting therapy, particularly for unstable patients, this safety initiative reduced the total time to transfer a patient between the OR and CT-ICU from 20 minutes to 5-10 minutes.(26)
shared infusion volume errors (see Theme 3 introduction) and an increased risk of infection from exposing the IV port when connecting the new infusion.

Eighteen percent of surveyed Ontario hospitals identified that when patients are transferred between clinical units (e.g. OR to ICU, Emergency to ICU), a lack of standard medication concentrations between the units required that the receiving unit change medication concentrations for infusions. This issue was also observed during a field study, particularly when patients transfer from an operating room to a critical care unit.

**Recommendation Evidence**

Type of evidence: Expert consensus

Several researchers, and clinical professional and patient safety organizations have published recommendations for organizations to limit and standardize medication concentrations to improve patient safety (26-33) for example, a test of compliance for Accreditation Canada’s Required Operating Practice for high-alert medications (34) includes that “the organization limits and standardizes concentrations and volume options available...”. Standardizing medication concentrations has decreased adverse drug events when used with smart IV infusion pumps and well-designed IV container drug labels. (35) While there has been widespread adoption of the use of standardized concentrations in principle, many hospitals use multiple standard concentrations of a single medication in their formulary, which vary by unit (36). While this may decrease medication concentration errors, it does not eliminate the need to set-up new IV infusions when patients transfer between units due to differing standard concentrations between transferring units.

There is consensus from the Multiple IV Infusion Expert Panel that standardizing medication concentrations across a hospital reduces waste and has numerous safety advantages, including a reduction in the number of infusion set-ups that occur during patient transfers, which reduces opportunities for set-up errors and leads to safer care for patients.
5. Standardization of IV Technology and Inventory Management

Recommendation

5.1 Standardize IV infusion pumps, IV tubing/components between sending and receiving units and have pumps follow and stay with patients to help minimize the need to re-establish infusions after patient transfers.

⚠️ This recommendation is not meant to apply to situations where different pumps are used to distinguish infusions for different patient populations, and those patients will never transfer to a unit that uses a different type of pump (e.g., different pumps used for pediatric vs. adult patients).

⚠️ The hospital’s infusion pump inventory management system is a primary factor for determining whether pumps can transfer with patients. A centralized inventory management system promotes movement of pumps with patients anywhere in the hospital. When individual units own their own fleet of pumps it is possible to allow pumps to remain with the patient if the pumps are modular and the units follow a “give-one, get-one” approach to managing pump inventory during patient transfers. If pumps are not modular (i.e., fixed single, double and triple channel pumps), it is more challenging to support this approach because critical care environments will need more multi-channel pumps whereas general wards will use more single-channel pumps; switching pumps during an ICU-ward transfer will leave the critical care units with too few pump channels.

⚠️ Smart pump drug libraries are usually divided into care areas. A care area is selected at the beginning of the programming sequence, and the medications and concentrations available during the programming sequence are limited to those specified for the care area. When a patient transfers from one unit to another, and the units do not use the same care area profile in the smart pump, the care area must be re-selected. In most infusion pumps, this requires the pump to be stopped.

Recommendation Implementation

Example of Recommendation Implementation

![Image](image.png)

Figure 7A) Different IV pumps are used in the sending and receiving units, requiring the patients infusions to be transferred to new pumps. Figure 7B) The same IV pump is used in the sending and receiving unit, and the pump inventory management system allows the pump to remain with the patient, so no transfer of infusions is required.
**Self-Assessment**

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When assessing C-E for Recommendation 5.1, consider whether the following statements apply:
- A centralized IV pump inventory management system exists or modular pumps are used and pump modules are traded between units during patient transfers.

**Implementation Resources**


- Wolf L and Sigillito N. Improving medical equipment availability at Barnes-Jewish hospital. Available from the Institute of Industrial Engineers at: [https://www.iienet2.org/uploadedfiles/SHS_Community/Improving Medical Equipment Availability at BJH.pdf](https://www.iienet2.org/uploadedfiles/SHS_Community/Improving Medical Equipment Availability at BJH.pdf)

**Discussion of Evidence**

**Issue Description and Recommendation Rationale**

When a patient is transferred and the sending and receiving units use different types of infusion pumps, tubing or IV components, a new infusion must be set-up with the appropriate pump and components for the receiving unit.

Additionally, even when the same type of pump is used between units, if the pump inventory is not centrally managed (i.e., each unit retains their own allotment of pumps rather than share them in a central pool), the receiving unit must set-up all new infusions so the sending unit can bring their pumps back with them.
In both cases, setting up new IV infusions during a patient transfer results in a duplication of work, a waste of supplies, an interruption of the medication therapy, the potential for mix-ups and programming errors, (1;2;6;11;13;22;25;26) and increased risk of infection (see Recommendation 3).(21)
Fifty-eight percent of surveyed Ontario hospitals indicated that patients may have their IV infusions interrupted during transfers from 1 care area to another (e.g. OR to ICU, Emergency to ICU) due to incompatible IV supplies and equipment (e.g., pumps, IV tubing and IV components) and pump inventory policies.(12) This issue was also observed during a field study in situations where patients were transferring from the OR to critical care, from an ambulance to critical care, and from a medicine ward to a critical care environment(2); however, this issue applies to patient transfers between any hospital environments.

**Recommendation Evidence**

Type of evidence: Expert consensus

A single study of a hospital implementation of standardized IV infusion pumps across the organization such that infusion pumps can remain with the patient when they transfer units revealed that nurses no longer needed to discontinue and re-start infusions during patient transfers and that admission times were decreased from 20 minutes to 5-10 minutes as a result(26).

There is consensus from the Multiple IV Infusions Expert Panel that standardizing IV pumps, tubing and IV components, and using a pump inventory control model that allows pumps to stay with the patient as the move throughout the hospital will minimize unnecessary IV infusion set-ups, thereby minimizing wasted resources and opportunities for interruptions to therapy, mix-up errors, and infection risk. This will lead to safer care for patients.

**Implementation Success Story**

A large teaching hospital in Toronto, Canada, implemented a central equipment pool. Equipment deliveries were handled by *materials handlers* (managed by Biomedical Engineering) with a guaranteed delivery time of 20 minutes. Critical clinical areas were allowed to have a “float” of several extra pumps for emergencies. When a pump was returned after use, the *materials handlers* cleaned it and performed minor functional tests. Clinical units were charged a rental fee per day for pumps to discourage hoarding, and to pay the salaries of the *materials handlers*.

Results:

– The number of “no fault found” calls to Biomedical Engineering decreased because the *materials handlers* did front line troubleshooting
– The equipment pool was self-funded from the rental fee
– Clinical units were very satisfied by the central equipment pool and continually requested that other devices be included in the pool
Theme 3. Shared Infusion Volume

Patients routinely require more IV infusions than there are available patient access ports, requiring that multiple IV infusions be connected to a single port.(37;38) Connecting infusions means that there is a shared volume that contains two or more infusates from the point the infusions are connected to the end of the patient catheter where the infusates enter the patient’s bloodstream. This is referred to as shared infusion volume. Shared infusion volume may be of concern in many setups and situations, some of which are shown in Figure 8.

Figure 8: IV Setups Resulting in Shared Infusion Volume (Shared Infusion Volume Shown in Yellow)

- **A:** Primary IV infusions connected below the pump using a lower injection port.
- **B:** Primary and secondary IV infusions connected above the pump.
- **C:** Manual IV syringe push connected to a primary IV infusion below the pump (at a lower injection port).
- **D:** Double strength IV container attached to primary IV tubing containing single strength concentration of the same medication.

Abbreviation: IV, intravenous.

When a patient receives a single infusion, changes to the infusion (e.g., start, stop, change of flow rate) are instantly reflected at the patient’s bloodstream.(38;39) In contrast, when multiple IV infusions are connected to a single access port, changes to an infusion will have a time lag until it is reflected at the patient catheter, and the change will temporarily impact the administration rate of all connected infusions.(38-41) For example, a large increase in the flow rate of 1 connected infusion will instantly increase the flow rate of the
shared infusion volume and deliver a greater amount of all medications in the shared infusion volume until a new steady state is achieved (i.e., when the concentration of medications in the shared infusion volume will no longer change and the patient is receiving the medication dose rates programmed in the infusion pumps that control them).

Without proper consideration, changes to the shared infusion volume may result in unintended patient harm\(^{(39)}\) and a variety of medication errors, such as accidental bolusing,\(^{(37;40;42-44)}\) delay in therapy,\(^{(45)}\) and drug incompatibilities\(^{(45)}\). Shared infusion volume management is of particular concern when infusing concentrated and potent drugs (e.g., vasoactive drugs, inotropics, antiarrhythmics, sedatives, opioids, and paralytics) at low flows, which requires greater consistency and accuracy in administration \(^{(38;39;46)}\) for critically ill and/or pediatric patients.\(^{(41;43;47)}\)

Research literature shows that some nurses do not consider shared infusion volume in their practice.\(^{(2;12;42;48)}\) One contributing factor to this may be the lack of feedback when shared infusion volume-related errors occur because it is not possible to observe changes to fluids in the shared infusion volume. Failure to consider shared infusion volume may result in a discrepancy between expected and observed patient effects when an infusion change is made. If clinicians make premature adjustments to medications (e.g., titrating an infusion flow rate) before the shared infusion volume has cleared, the result may be patient harm and/or further instability.\(^{(40)}\)

When multiple IV infusions are required, increasing the number of patient access ports (e.g., multi-lumen catheters) can minimize the need to connect infusions (infusion can be attached directly to the patient), thereby eliminating shared infusion volume.\(^{(43)}\) However, increasing the number of patient access ports may not be possible and may increase other risks (e.g., infection).\(^{(49)}\) Therefore, the recommendations in this theme are aimed at reducing the amount of shared infusion volume, minimizing its potential impact to patients, and providing education to nurses about best practices for managing shared infusion volume.
6. Infusion Connections

Recommendations

To minimize the amount of shared infusion volume during the set up (Figure 9):

6.1 Connect IV infusions as close as possible to the patient access port.
6.2 Use a single multiport/lead connector when 3 or more IV infusions must be connected (e.g., do not chain 3 IV infusions together using lower IV injection ports).

To minimize the risk of leaks, disconnections and unintended interruptions to infusions (Figure 10):

6.3 Refrain from chaining 3-way stopcocks to join multiple IV infusions.

⚠️ Where possible, refrain from chaining multiport/lead connectors together as this creates additional shared infusion volume and increases the difficulty of infusion identification.

⚠️ This recommendation is intended to restrict the joining of 3-way stopcocks to connect *multiple IV infusions* into a single IV line. It is not intended to limit stopcock use for venous and arterial pressure monitoring or other applications.

⚠️ To reduce the risk of infection, all IV tubing should be replaced when leaks occur at injection sites connections or vents, or when they become contaminated.(1-4)

Recommendation Implementation

*Example of Recommendation Implementation*

Figure 9. A) New medication added to closest appropriate port. B) A multi-lead connectors used to join IV infusions. C) A multi-port connector (without stopcocks) used to join multiple IV infusions.
Figure 10. The use of 3-way stopcocks to join multiple IV infusions is not recommended.

**Self-Assessment**

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When assessing C-E for Recommendations 6.2 and 6.3, consider whether the following statements apply:
- There is an organizational policy and procedure to specify the requirements outlined in the Recommendation.
- Formal education and training about the organizational policy and procedure has been provided to all nurses.
- The supplies required to comply with the policy and procedure (e.g., pre-printed labels) are available on the unit.
- IV set-up practices are consistent with the organizational policy and procedure.

**Implementation Resources**

- Interactive eLearning modules: [http://elearning.rnao.ca/](http://elearning.rnao.ca/)
  o Shared Infusion Volume Part 2: Multiple Continuous IV Infusions

**Suggested QI Indicator to Monitor Recommendation Compliance**

- % patients with 3 or more infusions that are not connected with a multiport/lead connector.
- % patients where high alert34 IV medications are not connected as close as possible to the patient access port.
- % of nurses who have completed the interactive eLearning module (Shared Infusion Volume Part 2: Multiple Continuous IV Infusions) on applicable units.
Discussion of Evidence

**Issue Description and Recommendation Rationale**

When multiple IV infusions must be connected to a single access port, reducing the amount of shared infusion volume minimizes the time lag between when a medication change is initiated and when the change is reflected at the patient’s catheter. It also minimizes the volume of the other connected medications that are temporarily affected by the change in one or more connected infusions.

The amount of shared infusion volume can be minimized by connecting infusions as close as possible to the patient (e.g., use add-on devices such as extension sets judiciously) and using components that minimize the amount of shared volume in which infusions mix (e.g., use multiport/lead connectors with micro bore tubing instead of the lower injection port on IV tubing). This becomes increasingly important once 3 or more infusions are joined together because the shared infusion volume created by branching 3 or more infusions using the lower injection port is large and so safely managing the flow of medications in the shared infusion volume is difficult. However, an observational field study and survey of Ontario hospitals identified variation in how nurses set up and connect IV infusions, often without minimizing the shared infusion volume; (2;12) for example 77% (49 of 64) of survey respondents indicated that they connect multiple infusions by using the lower injection port on IV tubing. (12)

When 3 or more infusion must share a single IV access port, there are different devices that can be used to connect the IV tubing (e.g., 3-way stopcocks, multiport/multi-lead connectors, tubing injection ports). Chaining together 3-way stopcocks is not recommended because this setup is prone to disconnections, (2) and cracks/leaks, (50;51), particularly with certain drug types.(52;53) Evidence collected during a research field study investigating risks associated with administering multiple IV infusions revealed that when IV infusions are joined together using 3-way stopcocks disconnections and cracks causing leaks occur that have resulted in patients receiving insufficient doses of critical medication.(2) Additionally, if stopcocks are inadvertently turned they will restrict the flow of medication, causing delays and interruptions in therapy. Finally, compared to multiport/multi-lead connectors, the use of 3-way stopcocks increases the total number of connections in the IV system, which can increase the number of opportunities for bacteria to enter the IV system, as well as increase the number of spaces where organisms to grow, increasing the chance of blood stream infections.(1-4)

**Stopcock Confusion**

Nurses have reported that they are confused about how stopcocks work and which way to turn them. Working with multiple stopcocks can be confusing for even an experienced nurse. Nursing blogs(1,2) reveal that stopcock use may be particularly problematic for new nurses who are intimidated to ask their preceptor on how to use these deceptively simple devices. Reported stopcock-related errors have included:

- A patient transferred from the OR was not administered their medications (dobutamine and epinephrine) because the stopcock was turned the wrong way
- A patient’s IV infusions of isotropic agents were “flowing out an open stopcock onto [the] floor”

**Recommendation Evidence**

Type of evidence: Expert consensus and controlled study data

Most shared infusion volume research to date has focused on using laboratory and mathematical models to understand the complex drug delivery dynamics emerging from shared infusion volume when a change is made to connected infusions.(37-41;43;54-56) This body of research shows that large shared infusion
volumes with low flow rates of concentrated infusions affect the safe and controlled drug delivery to critically ill patients. The amount of drug accumulated in the shared infusion volume is diluted by increasing infusion flow rates (e.g., increased rate of carrier fluid), but since this practice increases total fluid delivery, it may not be practical for critically ill (particularly pediatric) or fluid-restricted patients. Research models also show that a practical solution to this issue is to minimize the amount of shared infusion volume, which can be achieved by connecting infusions as close as possible to the patient and using IV components with minimal priming volumes (e.g., micro bore tubing and connectors) and/or prevent infusions from mixing (e.g., multi-lumen connectors).[38;39;46;56-59].

Based on this foundation of evidence, there is consensus from the Multiple IV Infusions Expert Panel that connecting IV infusions as close to the patient as possible, using a single multiport/lead connector to join 3 or more infusions, and refraining from using 3-way stopcocks to join multiple IV infusions will reduce the impact of shared infusion volume-related issues and lead to safer care for patients.
7. Medications on the CVP Line

Recommendations

To avoid unintended boluses of medication and interruption in therapy when the central venous pressure (CVP) monitoring line is calibrated, used for measurement, or flushed:

7.1 Avoid connecting a continuous IV medication to a CVP monitoring line.²

7.2 When an intermittent medication is connected to a CVP line, avoid using a transducer to flush the line (or reading the CVP using a manometer), until the medication has cleared all IV tubing (including the connectors) (Figure 11).

Recommendation Implementation

Example of Recommendation Implementation

Figure 11. When intermittent infusions are connected to a Central Venous Pressure Line, the line should not be flushed until the medication has cleared the shared infusion volume.

² IV access constraints associated with infusion setups for paediatric patients may not enable this recommendation.
Self-Assessment

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• Formal education and training about the organizational policy and procedure has been provided to all nurses.
• IV set-up practices are consistent with the organizational policy and procedure.

Implementation Resources
• Interactive eLearning modules: [http://elearning.rnao.ca/](http://elearning.rnao.ca/)
  o Shared Infusion Volume Part 1: Residual Medications

Suggested QI Indicator to Monitor Recommendation Compliance
• % of nurses who have completed the interactive eLearning module (Shared Infusion Volume Part 1: Residual Medications) on applicable units.

Discussion of Evidence

Issue Description and Recommendation Rationale

A CVP line provides IV access that can be used to administer medications. A benefit of the CVP line over other lines is the compatibility of the flush fluid (usually normal saline, heparinized normal saline or D5W)\(^{(2,60)}\) with any medication. However, there are tasks required on the CVP line that cause interruptions to the flow of medications sharing the line (e.g., zeroing the line, removing an air bubble) or cause a fast-flowing bolus of everything in the line (e.g., flushing the line after collecting a blood sample or to produce a clear CVP waveform), both of which result in a serious adverse impact to the patient, depending on the criticality and potency of the medications. Additionally, flushing the CVP line replaces the shared infusion volume with only the flush fluid, causing a delay in the resumption of the medication delivery post flush, which can also be detrimental to the patient if the continuous medication is critical.

Another concern with administering an infusion on the CVP line is that it can impact the pressure reading of an electronic transducer. If the infusion is flowing faster than 50 mL/h, the CVP reading will be greater than the actual pressure for both adult and pediatric CVP catheters.\(^{(2)}\)
Despite these issues, a survey of hospital practices related to administering multiple IV infusions found that 53% (9 of 17) of respondents were allowed to administer continuous IV medications on the CVP line on their unit. (12)

When administering an intermittent medication on a CVP monitoring line, the risks associated with temporary interruptions to the infusion are not as significant since intermittent infusions are typically not life sustaining medications. However, administering an unintended fast bolus of an intermittent medication while completing a CVP-related task (e.g., flushing the line) can result in unwanted effects, which is why it is recommended that when intermittent medications are connected the CVP line the line should not be flushed until all the medication has cleared the shared infusion volume. For the reasons cited above, (61) CVP values should not be taken while the intermittent medication is running if the medication is running faster than 50mL/hr.

**Recommendation Evidence**

Type of Evidence: Expert Consensus

There is consensus from the Multiple IV Infusions Expert Panel that the CVP line should only be used to administer intermittent medications, and use of the transducer to flush the line while the intermittent medication is infusing should be avoided; these recommendations minimize the risk of an unintended bolus of medication and lead to safer care for patients.
8. Medication Concentration Changes

Recommendation

8.1 Use new IV tubing when initiating a new concentration of a continuous IV medication to prevent infusing any of the previous concentration remaining in the tubing at the rate intended for the new concentration.

Recommendation Implementation

Example of Recommendation Implementation

Figure 12: New concentration of a continuous IV medication with new, primed, IV tubing.

Self-Assessment

<table>
<thead>
<tr>
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• There is an organizational policy and procedure to specify the requirements outlined in the Recommendation.
• Formal education and training about the organizational policy and procedure has been provided to all nurses.
• IV set-up practices are consistent with the organizational policy and procedure.
Implementation Resources

- Interactive eLearning modules: http://elearning.rnao.ca/
  - Shared Infusion Volume Part 1: Residual Medications

Suggested QI Indicator to Monitor Recommendation Compliance

- % of nurses who have completed the interactive eLearning module (Shared Infusion Volume Part 1: Residual Medications)

Discussion of Evidence

Issue Description and Recommendation

Rationale

There are clinical situations that require changing the concentration of a continuous IV medication but maintaining the same dose rate. For example, when patients require less fluid volume than they are receiving or when transferring to units that use different standard drug concentrations.

When the concentration of a continuous IV medication is changed, new IV tubing must be connected to the new medication container because otherwise the infusion will contain 2 concentrations: the IV container will contain the new concentration, and the IV tubing and connectors (i.e., shared infusion volume) will contain the old concentration. If the pump is reprogrammed for the new concentration (to maintain the same dose rate), the old medication concentration in the shared infusion volume will be administered at an incorrect dose rate.

A simulation laboratory study(20) investigated how ICU nurses managed the medication in the shared infusion volume when they were asked to double the concentration of a continuous IV medication, but maintain the same dose rate. Instead of hanging a new IV container and tubing with the double strength concentration, 25% (10 of 40) of participants re-used the IV tubing and simply exchanged the single strength IV container for the double strength one; these participants then decreased the pump flow rate to account for the new IV container concentration. However, since single strength medication remained in the IV tubing (i.e., shared infusion volume), the patient was under dosed until the shared infusion volume was replaced with the double strength concentration (see Figure 13).(20) The concentration error made in the simulation study is consistent with an error reported to ISMP Canada that resulted in patient harm.(62)

Reported Incident

ISMP Canada reported an incident where an order was placed to double a critical care patient’s concentration of IV norepinephrine (Levophed) to reduce total fluid intake. The nurse attached a norepinephrine IV bag with double the concentration to the previously used IV tubing. The clinician decreased the infusion rate by half to account for the new double-strength concentration, so that the remaining concentration in the IV tubing infused at half the intended dose. The patient’s systolic blood pressure dropped to 40 mm Hg.

Figure 13. Managing shared infusion volume: doubling of a continuous IV medication concentration.

**Recommendation Evidence**

Type of Evidence: Expert Consensus

There is consensus from the Multiple IV Infusions Expert Panel that new IV tubing should be used each time a medication concentration is changed to prevent over- or under-infusions of medication, and that this practice will lead to safer care for patients.
9. Intermittent Bolus Injection

Recommendations

9.1 Administer residual intermittent medication in the primary IV tubing following an IV bolus injection using the recommended rate for the intermittent medication both to ensure the complete dose is administered at the intended rate and to minimize the effects of drug incompatibilities.

⚠️ This recommendation is particularly significant for pediatric care environments where intermittent bolus injections are routinely less than the shared infusion volume between the injection port and the catheter. There is no standard procedure for flushing the shared infusion volume at the correct rate, and different flushing practices may be required depending on how the intermittent bolus dose is administered (e.g., intermittent IV dose is injected through a lower injection port of a maintenance line, intermittent IV dose is injected through a saline lock, intermittent IV dose is injected into a CVP line).

Recommendation Implementation

Example of Recommendation Implementation

![Diagram of intermittent IV bolus injection](image)

Figure 14. Intermittent IV bolus medication in the shared infusion volume is being flushed at the prescribed rate for the intermittent medication.
Self-Assessment

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- IV set-up practices are consistent with the organizational policy and procedure.

Implementation Resources
- Interactive eLearning modules: http://elearning.rnao.ca/
  - Shared Infusion Volume Part 1: Residual Medications

Suggested QI Indicator to Monitor Recommendation Compliance
- % of nurses who have completed the interactive eLearning module (Shared Infusion Volume Part 1: Residual Medications)

Discussion of Evidence

Issue Description and Recommendation Rationale
Following the administration of a manual IV push of an intermittent medication, some residual intermittent medication will remain in the shared infusion volume (volume between the injection port and the end of the patient catheter). It is important that the residual medication be flushed at the recommended administration rate, particularly for rate and time critical intermittent medications. Not flushing the residual medication means that the patient will not receive the full dose at the scheduled administration time, and it increases the risk of issues related to drug incompatibilities since the next time a medication is administered through that port the two medications will be combined in the shared infusion volume. Also, not administering the flush at the same rate as the prescribed medication means that the patient may receive a portion of the dose too slowly/quickly. This can cause patient harm for certain rate-sensitive medications (e.g., furosemide (Lasix) administered too quickly can cause deafness).

Reported Incident
“After administering an IV push dose of furosemide slowly over 1 minute, a nurse flushed the line with sodium chloride as quickly as possible. As a result, most of the furosemide dose (which was still in the IV tubing and catheter) was administered faster than the intended rate.” Administering furosemide too quickly may contribute to ototoxicity.

In a simulation lab study(20), 33% (13 of 40) of participants did not flush the IV tubing after administering an intermittent medication (i.e., single dose) by manual IV push, resulting in incomplete dose administration and residual medication in the IV tubing. When nurses did flush, 96% (24 of 25) flushed the residual medication in the IV tubing too quickly (i.e., faster than that ordered for the intermittent medication), which may have resulted in patient harm in the situation tested (50mg IV push of furosemide).

**Recommendation Evidence**

Type of Evidence: Expert Consensus and Controlled Study Data

There is consensus from the Multiple IV Infusions Expert Panel that administering residual intermittent medication in the primary IV tubing following an IV bolus injection using the recommended rate for the intermittent medication will improve the safe management of shared infusion volume and lead to safer care for patients.
10. Shared Infusion Volume Education

**Recommendation**

10.1 Educate nurse trainees and registered nurses on shared infusion volume principles, and facilitate the development of skills in shared infusion volume management to minimize medication errors. Include the following topics:

- Setting up infusions to minimize shared infusion volume impact (see Recommendations 6.1 & 6.2)
- Administering an IV infusion via the central venous pressure monitoring line (see Recommendation 7.1 & 7.2)
- Changing the concentration of an IV infusion (see Recommendation 8.1)
- Administering an IV intermittent bolus injection (see Recommendation 9.1)
- Making a change (e.g., stop, titration, start) to an IV infusion connected to other infusions
- Completing a “line change”
- Administering a secondary IV infusion (see Recommendations 13.1, 13.2 & 14.1)

**Recommendation Implementation**

*Example of Recommendation Implementation*

![Interactive e-Learning module about shared infusion volume.](image)

Figure 15. Interactive e-Learning module about shared infusion volume.
**Self-Assessment**

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**Implementation Resources**

- A Interactive eLearning modules: [http://elearning.rnao.ca/](http://elearning.rnao.ca/)
  - Shared Infusion Volume Part 1: Residual Medications
  - Shared Infusion Volume Part 2: Multiple Continuous IV Infusions

**Suggested QI Indicator to Monitor Recommendation Compliance**

- % of nurses who have completed the interactive eLearning modules (Shared Infusion Volume Part 1: Residual Medications and Part 2: Multiple Continuous IV Infusions)

**Discussion of Evidence**

**Issue Description and Recommendation Rationale**

Prior to the adoption of any new tool and/or practice to mitigate shared infusion volume issues, clinicians must have a fundamental understanding of shared infusion volume principles and risks. However, in Ontario, nurse trainees do not receive formal training on shared infusion volume management in the undergraduate nursing degree program and receive some training in the post-graduate critical care nursing program, but the curriculum concepts are not standardized. (2) Research has shown that some nurses do not consider shared infusion volume in their practice (42;48)

To address the gaps in both knowledge and practice related to shared infusion volume, all nurse trainees and registered nurses should be provided with comprehensive shared infusion volume education and opportunities to develop skills in shared infusion volume management.

**Recommendation Evidence**

Type of Evidence: Expert Consensus and Controlled Study Data
Increasing clinicians' knowledge of shared infusion volume principles and risks has been suggested as a way to improve patient safety. (39; 42; 43; 46; 59) This was verified in a simulation laboratory study (20) conducted with ICU nurses. The study revealed that when participants were shown an education module that focused on shared infusion volume fundamental principles, shared infusion volume management practices significantly improved (in comparison to the baseline condition, i.e., before watching the education module), but only when the module explicitly targeted the specific tasks that were evaluated in the simulation and provided users with detailed recommended practices.

For example, when testing the impact of a shared infusion volume training module on shared infusion volume errors when administering a manual IV push of an intermittent medication, significantly more participants flushed the residual medication in the shared infusion volume after watching the education module compared to baseline. However, both before and after watching the education module, there was a high rate of flush rate errors (i.e., flow rate was greater than 5 mL/min or 300 mL/h). The mean flush rates were analyzed using a paired sample dependent t-test; the results showed that participants flushed the IV tubing (and consequently the furosemide in the shared infusion volume) significantly more quickly in the baseline condition (mean, M = 3,401 mL/h) than after watching the education module (M = 1,383 mL/h; t[24] = 2.4, \( P = 0.03 \)). Thus, while the education module did not affect the overall error rate, it did reduce the magnitude of the error by 59\%.(20) This suggests that participants were more conscious that the flush rate impacted the delivery of the furosemide in the shared infusion volume after watching the education module.

The study results underscore the complexity of shared infusion volume and the need for shared infusion volume education to go beyond providing fundamental principles. Shared infusion volume education must help clinicians improve shared infusion volume awareness and clinical decision-making skills.

There is consensus from the Multiple IV Infusions Expert Panel that providing shared infusion volume education to all nurse trainees and registered nurses will improve the safe management of shared infusion volume and lead to safer care for patients.
Theme 4. Setting Up Secondary Intermittent IV Infusions

A secondary IV infusion is a common and convenient way to administer a single dose of medication over a finite duration (several minutes to several hours) using a large-volume infusion pump. Secondary IV infusions are also referred to as piggyback infusions, because they “piggyback” onto an existing primary continuous IV infusion, using the same pump and patient IV access; Figure 16. During a secondary IV infusion, the primary infusion temporarily pauses; when the secondary IV infusion is complete, the pump reverts to the primary infusion flow rate and the primary infusion resumes. For most large-volume infusion pumps, the 2 infusions are administered sequentially (not concurrently).

Most commercially available infusion pumps cannot detect which fluid they are infusing (i.e., not aware if pulling fluid from bag A or B in Figure 16) and cannot detect physical setup errors. Consequently, the onus is on clinicians to set the infusion up so that the pump draws fluid from the correct IV container. (2) To this end, the following prerequisites must be met:

- **Sufficient pressure differential:** The pressure in the secondary infusion must be higher than the pressure in the primary infusion to ensure that the pump draws fluid from the secondary IV container (and not the primary IV container). To create this pressure differential, clinicians must position the primary IV container lower than the secondary IV container (usually using a hook provided with the secondary IV tubing). In addition, the secondary IV tubing must be attached to primary IV tubing that has a pressure-sensitive back check valve to prevent retrograde flow of the secondary solution into the primary IV container.

- **Unclamped secondary IV tubing:** When clinicians initiate a secondary IV infusion, they must open the roller clamp on the secondary IV tubing so that fluid from the secondary IV container can flow. If the roller clamp remains closed, the pump will draw the primary infusion at the rate intended for the secondary infusion. If
this goes unnoticed, the patient will not receive the intended secondary medication or may receive it much later than intended.

Right connection to primary IV infusion: Clinicians must connect the secondary IV tubing to the correct injection port (i.e., above the pump to ensure administration is controlled by the pump) on the correct primary infusion (e.g., a compatible primary infusion, a primary infusion that is a high-alert medication).

Secondary IV infusion setup errors are evident in systematic searches of incident databases (i.e., the ISMP Canada Medication Incident Report database and the US FDA MAUDE database).(1;63-65) Research has also shown that secondary IV infusion setup errors occur frequently.(63;66;67)

The recommendations in Theme 4: Setting Up Secondary Intermittent IV Infusions are aimed at reducing physical setup errors that result in incorrect flow rates of a primary or secondary medication and drug incompatibility issues.
11. Administering High-Flow Rate and/or Large-Volume Secondary IV Infusions

**Recommendation**

11.1 Set-up high-flow rate and/or large-volume secondary intermittent IV infusions using the appropriate set-up procedures defined by the infusion pump manufacturer to prevent unintended concurrent flow of the primary infusion.

⚠️ The size of a secondary IV container and/or rate of a secondary infusion that requires additional setup precautions varies between infusion pump manufacturers. Check with your infusion pump vendor to determine the criteria and appropriate set-up for high-flow rate or large-volume secondary intermittent IV infusions.

**Recommendation Implementation**

*Example of Recommendation Implementation*

![Diagram](image)

Figure 17. Preventing unintended concurrent flow of primary and secondary infusions by: A) Lowering a primary infusion bag using two hooks B) Clamping the primary line.

**Self-Assessment**

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- IV set-up practices are consistent with the organizational policy and procedure.
**Implementation Resources**

- Interactive eLearning modules: [http://elearning.rnao.ca/](http://elearning.rnao.ca/)
  - Secondary IV Infusions: Check the Setup

**Suggested QI Indicator to Monitor Recommendation Compliance**

- % of nurses who have completed the interactive eLearning module (Secondary IV Infusions: Check the Setup)

**Discussion of Evidence**

**Issue Description and Recommendation Rationale**

The expanded clinical use of secondary IV infusions has led to the need for additional setup requirements to ensure they are safely administered. Historically, secondary IV infusions were designed to administer small volumes of medications (e.g., 50–100 mL) at slow flow rates (i.e., < 300 mL/h). More recently, secondary IV infusions have been used to infuse more medications, requiring larger volumes (e.g., 1,000 mL) and/or faster flow rates (e.g., > 500 mL/h). An example where this frequently occurs is in the administration of IV chemotherapy. Larger secondary IV containers and/or higher secondary flow rates (i.e., *non-standard secondary infusions*) affect system fluid dynamics as follows:

As a large secondary IV container empties, the fluid level may reach a height similar to that of the primary IV container (most likely if the primary IV container is lowered by only 1 hook, and particularly if the primary IV container is full). When this occurs, the pressure differential between infusions is no longer sufficient to keep the back check valve closed, and the secondary solution will flow into the primary IV container. Furthermore, without sufficient pressure differential between infusions, the pump will draw an indeterminate mix of fluid from both containers at the secondary rate.

A high secondary flow rate reduces the pressure in the IV line and creates a suction effect that may cause the back check valve to open, allowing concurrent flow of both primary and secondary solutions.

To prevent unintended concurrent flow, nurses must:

- increase the pressure differential between the primary and secondary IV containers (e.g., use a second hook to further lower the primary container); and/or
- clamp the primary IV tubing above the secondary injection port until the secondary IV infusion is complete.

However, in a simulation lab study,(20) when nurses were required to set up a non-standard secondary IV infusion, 87.5% (35 of 40) of participants did not complete these additional requirements to prevent concurrent flow.(20)  

Note: Each pump manufacturer may have varying thresholds for IV container size and/or the secondary flow rate, above which, additional precautions are required to ensure the secondary and primary IV infusions do not mix. Additionally, each manufacturer may also have varying recommended practices for high-flow rate and/or large-volume secondary IV infusion setups based on each pump’s design and the specific tubing used by the hospital. For example, some primary IV tubing used to administer secondary IV infusions (i.e., has a back check valve and upper injection port) do not have a clamp on the tubing above the pump. Therefore, each hospital should work with the infusion pump manufacturer to identify the specific practices that are required to support high-flow rate and/or large-volume secondary IV infusion setups. This is particularly true when migrating to a new infusion pump. Hospitals must verify if the thresholds for IV container size and/or the secondary flow rate are different between the old and the new pumps and train staff accordingly.
**Recommendation Evidence**

Type of Evidence: Expert Consensus

There is consensus from the Multiple IV Infusions Expert Panel that ensuring high-flow rate and/or large-volume secondary IV infusions are administered according to the procedure specified by the IV infusion pump manufacturer; will minimize unintended concurrent flow, leading to safer care for patients.
12. Secondary IV Tubing

Recommendation

12.1 When administering a secondary IV intermittent medication, check compatibility with the previous secondary medication. If compatible, re-use the secondary IV tubing and back-prime from the primary IV bag. (Figure 18)

⚠️ Due to the lack of compatibility data between all combinations of medications, each hospital will need to decide what IV tubing setup procedure (e.g., back-priming, changing the tubing) is appropriate when the compatibility between secondary infusions is incompatible or unknown. Factors such as potential consequences of incompatibility, infection risk, and cost must be considered.

⚠️ When re-using intermittent IV tubing, ensure that the tubing is changed at the recommended frequency as outline in best practice standards.

Recommendation Implementation

Example of Recommendation Implementation

Figure 18. Primary infusion is back-primed into the secondary IV bag (A) prior to attaching a new secondary IV bag (B).

Self-Assessment

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**Implementation Resources**

- Interactive eLearning modules: [http://elearning.rnao.ca/](http://elearning.rnao.ca/)
  - Secondary IV Infusions: Consider the Shared Infusion Volume

**Suggested QI Indicator to Monitor Recommendation Compliance**

- % of nurses who have completed the interactive eLearning module (Secondary IV Infusions: Consider the Shared Infusion Volume)

**Discussion of Evidence**

**Issue Description and Recommendation Rationale**

When a secondary intermittent IV infusion is complete and the IV pump reverts to the primary rate, there is residual medication left in the secondary IV tubing (Figure 18). If the secondary IV tubing is not changed or properly flushed (e.g., using the back priming method)(68) prior to connecting a subsequent secondary IV infusion of a different medication, a compatibility issue (e.g., precipitate forms in the line) could arise.(69)

A simulation lab study(20) investigated nurse practices related to managing residual volume in secondary IV tubing prior to connecting a subsequent, incompatible, secondary IV infusion. The study found that in 32.5% (26 of 80) of instances, secondary IV tubing was re-used without flushing; this would have resulted in mixing of incompatible drugs in the specific scenario conducted during the lab study.(20)

When changing from one secondary IV medication to another, the Infusion Nurses Society recommends that nurses first determine the compatibility between the previous and current secondary IV medications. If the medications are compatible, the secondary IV tubing should be flushed via back priming since this minimizes the need to disconnect the secondary IV tubing.(21)

**Recommendation Evidence**

Type of Evidence: Expert Consensus

There is consensus from the Multiple IV Infusions Expert Panel that residual medication in secondary IV tubing should be eliminated either by replacing the secondary IV tubing or flushing the secondary IV tubing according to their facility’s protocol to minimize risks associated with drug incompatibility. This will lead to safer care for patients.
13. Secondary Infusions and High-Alert Medications

Recommendations

To minimize disruptions of high-alert medications:

13.1 *Do not* connect a secondary infusion to any high-alert primary IV infusion using any port (i.e., the secondary IV port or a medication injection port below the pump). (Figure 19 A and B)

13.2 Do not administer continuous IV infusions as secondary IV infusions. (Figure 19 C)

Recommendation Implementation

*Example of Recommendation Implementation*

![Diagram](image)

Figure 19 Do not connect infusions in the following way: A) A secondary infusion connected to the secondary port of a high-alert primary medication. B) A secondary medication line connected to the lower injection port of a high-alert primary medication. C) A high alert medication administered as a secondary infusion.

Self-Assessment

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Implementation Resources

- Interactive eLearning modules: [http://elearning.rnao.ca/](http://elearning.rnao.ca/)
  - Secondary IV Infusions: Consider the Shared Infusion Volume
**Suggested QI Indicator to Monitor Recommendation Compliance**

- % of nurses who have completed the interactive eLearning module (Secondary IV Infusions: Consider the Shared Infusion Volume)

**Discussion of Evidence**

**Issue Description and Recommendation Rationale**

High-alert medications are drugs that have an increased risk of causing significant patient harm when they are used in error. (28) Examples of high-alert medications frequently administered include sedatives, narcotics/opioids, vasopressors, and anticoagulants.

Continuous high-alert medications should not be administered as secondary IV infusions because the secondary function on an infusion pump is intended for administering intermittent infusions; if a continuous infusion is administered as a secondary infusion, the pump will automatically switch to the primary infusion when the secondary VTBI has completed, resulting in an interruption of the continuous secondary medication.

An Ontario survey, (12) 27% (13 of 49 respondents) indicated that high-alert continuous medications are only administered as secondary IV infusions if absolutely necessary. Nineteen respondents provided comments about which drugs might be used when high-alert medications are administered as secondary infusions and indicated the following: electrolytes, morphine, amiodarone, insulin, and others. (12)

A secondary IV infusion should not be connected to a high-alert continuous primary infusion for 2 reasons: Upon secondary infusion initiation, the pump immediately switches from the programmed primary rate to the secondary rate and pushes the primary medication in the shared infusion volume of the tubing (i.e., the shared infusion volume in the primary tubing downstream of the secondary port) into the patient at the secondary rate. If the secondary rate is significantly higher than the primary rate, the quick administration of the primary medication in the shared infusion volume could cause patient harm.

Research has shown that secondary IV infusion setup errors occur frequently (see Theme 4 introduction), which can affect the administration of the primary medication. An over-dose of a high-alert primary medication due to a secondary IV infusion setup error has been reported to ISMP Canada (along with 7 other errors involving the accidental administration of the primary IV solution when intending to administer a secondary IV infusion). (67)

In an Ontario survey, (12) 17% of respondents (8 of 48) were allowed to attach secondary IV infusions to high-alert primary medications on their unit. An additional 15% (7 of 48) indicated they could, only if absolutely necessary.

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**Reported Incident**

A critical care patient receiving multiple intravenous (IV) infusions through a multi-lumen central catheter had orders for potassium replacement (20mmol of potassium chloride in 100mL to be given by IV infusion over one hour) to treat hypokalemia. The single available intermittent medication line (plain primary line) was infusing another medication and there was no other appropriate IV access available where the potassium could be delivered. The best course of action was determined to be to temporarily stop the insulin infusion (Humulin R 100 units in 100mL) and use the insulin line. The nurse piggybacked the potassium minibag to the secondary port of the primary insulin tubing and programmed the secondary infusion of potassium, but forgot to open the roller clamp. The pump therefore infused solution from the primary (insulin) bag at the rate intended for the secondary (potassium) infusion. Another nurse discovered the error when attending to the pump alarm indicating “air in line”, after the entire minibag of insulin infused. The patient's resulting hypoglycemia and worsening hypokalemia was treated with 50% dextrose and the patient recovered without further complications.

Report adapted from CACCN article Secondary lines require “primary” attention. Available at: https://ismp-canada.org/download/caccn/CACCN-Winter06.pdf
Recommendation Evidence

Type of evidence: Expert Consensus

ISMP Canada recommends not connecting a secondary IV infusion to a high-alert primary infusion.\(^{(67)}\)

There is consensus from the Multiple IV Infusions Expert Panel that prohibiting the connection of a secondary IV infusion to a high-alert continuous infusion and prohibiting the administration of high-alert continuous medications as secondary IV infusions will reduce the risks associated with secondary IV setup errors and lead to safer care for patients.
14 Secondary VTBI Programming

Recommendation

14.1 Identify a standard procedure for administering the complete secondary infusion dose at the intended rate for time and/or rate sensitive secondary medications. Considering the following:

- IV container overfill
- the amount of shared infusion volume/priming volume in the IV setup
- infusion pump programming workflow and constraints
- the tolerable flow rate variability for each medication

⚠️ Do not program the secondary volume to be infused to act as a call back alarm (i.e., do not program the secondary VTBI at less than the actual secondary volume to trigger an alert before the end of the secondary infusion).

⚠️ Accounting for the shared infusion volume is particularly important when the shared infusion volume is greater than 10% of the total secondary IV bag (i.e., secondary IV bag is 250mL or less).

⚠️ There are many practices to ensure complete secondary infusion dose administration at the intended rate; the safest and most effective method will depend on organizational practices and the specific infusion pump used. For example, one potential method is to increase the secondary infusion volume to be infused by the IV container overfill and the shared infusion volume/priming volume. However, depending on the pump in use, the pump may automatically recalculate other parameters, such as the rate; causing unintended consequences. Careful analysis of the benefits and risks is required before making any change to practice.

Recommendation Implementation

Example of Recommendation Implementation

Figure 20. Overfill volume (light green) and shared infusion/priming volume (dark blue) that needs to be accounted for to ensure appropriate rate of delivery for time/rate sensitive secondary medications.
Self-Assessment

<table>
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| 14.1 Identify a standard procedure for administering the complete secondary infusion dose at the intended rate for time and/or rate sensitive secondary medications. Considering the following:  
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  - the amount of shared infusion volume/priming volume in the IV setup  
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Legend:
A: There has been no discussion or consideration of this recommendation.
B: This recommendation has been formally discussed and considered, but it has not been implemented.
C: This recommendation has been partially implemented in the organization for some or all areas.
D: This recommendation is fully implemented in the organization for some areas.
E: This recommendation is fully implemented throughout the organization.

When assessing C-E, consider whether the following statements apply:
- There is an organizational policy and procedure to specify the requirements outlined in the Recommendation.
- Formal education and training about the organizational policy and procedure has been provided to all nurses.
- IV set-up practices are consistent with the organizational policy and procedure.

Implementation Resources
- Interactive eLearning modules: [http://elearning.rnao.ca/](http://elearning.rnao.ca/)
  - Secondary IV Infusions: Consider the Shared Infusion Volume

Suggested QI Indicator to Monitor Recommendation Compliance
- % of nurses who have completed the interactive eLearning module (Secondary IV Infusions: Consider the Shared Infusion Volume)

Discussion of Evidence

Issue Description and Recommendation Rationale

The programmed volume to be infused (VTBI) for a secondary IV infusion determines when the pump reverts to the primary infusion parameters (i.e., primary VTBI and flow rate). Thus, there is a need to ensure the secondary VTBI is programmed to reflect the actual volume of the secondary IV container and the shared infusion volume in the IV tubing below the port where the secondary IV infusion is connected (and primed to) to ensure the complete secondary infusion dose is administered prior to the pump reverting to the primary infusion parameters. However, determining the appropriate VTBI to program for a secondary IV infusion is requires hospitals to address the following two issues:
First, IV containers may be overfilled; one manufacturer overfills some of their IV containers up to 132% of the stated IV container volume, depending on the size of the IV container (e.g., a 25 mL IV bag may be filled with 30 mL ± 3 mL). In addition, medication added to the IV container will further increase the overfill volume if the same amount of diluent is not removed prior to medication injection. Thus, there may be more volume in the IV container than stated.

Second, the shared infusion volume in the primary IV tubing (i.e., volume from the injection port above the pump to the end of the IV catheter) must be cleared prior to the patient receiving the secondary solution (e.g., about 25 mL). That is, although the pump immediately starts the secondary infusion upon programming, the initial part of the infusion (e.g., first 25 mL) is actually administering the primary solution to the patient at the secondary flow rate. Conversely, when the pump reverts to the primary flow rate (i.e., secondary infusion VTBI has counted down to 0 mL), the shared infusion volume will now contain secondary solution, which will be administered to the patient at the primary flow rate.

A VTBI greater than the secondary IV container plus shared infusion volume would lead to the primary infusion being administered at the secondary flow rate after the secondary IV container emptied. Conversely, a VTBI smaller than the secondary IV container plus shared infusion volume would cause the remaining volume in the secondary IV container to be administered at the primary flow rate (Figure 21). Such differences in flow rate would be clinically significant if the primary rate was different from the secondary rate (e.g., a primary KVO rate could cause the secondary infusion not to be completed in the time frame required).

A search of the literature could not find any guidance for clinicians on the appropriate VTBI to program for secondary IV infusions to account for overfill (if present) and shared infusion volume. This is consistent with the nursing practices observed in a simulation lab study. In the study, thirty-one of 240 (12.9%) secondary IV infusions were programmed with a VTBI that was more than 10% greater or less than the IV container volume: 25 (80.6%) were greater than the secondary IV container volume, and 6 (19.4%) were less than the secondary IV container volume. VTBI ranged from 8% to 400% of the secondary IV container volume.
Figure 21. Programmed Secondary Intermittent IV Infusion Parameters Versus Actual Infusion Received By the Patient.

Scenario:
The secondary IV infusion bag has a stated volume of 50 mL, but actually contains 58 mL because of overfill; 5 mL are used to prime the secondary IV tubing, leaving 53 mL in the container when it is hung on the IV pole. The shared infusion volume from the secondary injection port to the patient is 25 mL, which contains primary infusate. The pump is programmed to administer the secondary infusion at 350 mL/h with a VTBI of 50 mL, and the primary infusion will resume at 10 mL/h with a VTBI of 250 mL.

Results:
1. 25 mL of primary infusate in the shared infusion volume will infuse at 350 mL/hr.
2. 25 mL of secondary medication will infuse at 350 mL/hr.
3. 33 mL of secondary medication will infuse at 10 mL/hr.
4. Pump will infuse 217 mL of the remaining 222 mL of primary infusate at 10 mL/hr.

Total time to infuse secondary IV medication is 3 hours 26 min. If the pump were programmed with a secondary VTBI of 83 mL (total volume including overfill and shared infusion volume), the entire secondary infusion would reach the patient in 14 minutes.

Recommendation Evidence
Type of evidence: Expert Consensus

There is consensus from the Multiple IV Infusions Expert Panel that identifying the amount of overfill in secondary IV containers and the shared infusion volume in IV tubing/connectors will support the appropriate administration of time and rate sensitive secondary IV infusions; ensuring complete dose administration at the intended rate. This will lead to safer care for patients.
15. Secondary IV Infusion Education

Recommendation

15.1 Educate all nurses and nurse trainees (e.g., academic, in-service, annual recertification) on the physical principles and best practices related to administering secondary IV infusions to minimize set-up errors. Include the following topics:

- Underlying IV infusion principles (e.g., hydrostatic pressure, role of the back-check valve)
- Setup risks (e.g., IV container height for high-flow rate and/or large-volume secondary intermittent IV infusions)
- Shared infusion volume (see recommendation 10.1, 13.1, 13.2 & 14.1)
- Best practices (e.g., view the activity in infusion drip chambers to verify that the secondary infusion is active and that the primary infusion is not active)

Recommendation Implementation

Example of Recommendation Implementation

Figure 22. Interactive eLearning module about secondary infusion principles

Self-Assessment

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Implementation Resources

- Interactive eLearning modules: [http://elearning.rnao.ca/](http://elearning.rnao.ca/)
  - Secondary IV Infusions: Check the Setup
  - Secondary IV Infusions: Consider the Shared Infusion Volume

Suggested QI Indicator to Monitor Recommendation Compliance

- % of nurses who have completed the interactive eLearning modules (Secondary IV Infusions: Check the Setup and Secondary IV Infusions: Consider the Shared Infusion Volume)

Discussion of Evidence

Issue Description and Recommendation Rationale

Setting up and managing secondary IV infusion requires an understanding of the infusion principles that govern how primary and secondary infusates flow through the IV system. A research study investigating how infusion principles are taught in Ontario nursing programs (2) identified that nurses are trained on how to set up secondary IV infusions (i.e., what to do), but they are not taught the underlying principles from which the rules are derived. This lack of knowledge compromises nurses’ ability to correctly complete setup requirements; especially true for non-standard secondary IV infusions because nurses have to identify and adjust setup requirements to ensure appropriate drug administration. This was verified in a simulation lab study (20) where almost half (19 of 40; 47.5%) of the standard secondary IV infusions were setup with at least 1 error, and 87.5% (35 of 40) of participants made errors setting up non-standard secondary IV infusions.

Recommendation Evidence

Type of evidence: Expert consensus and controlled study data

Educating nurses about secondary IV infusion risks and best practices have been recommended as a way of reducing secondary IV infusion setup errors. (63)

The impact of a secondary IV infusion training module on both knowledge and performance was assessed in a simulation lab study. (20) Participants completed a knowledge test before and after viewing a 10-minute, computer-based education module and then performed secondary infusion tasks in a simulation scenario. After watching the education module, the mean written test score (i.e., knowledge) was significantly higher than the mean baseline score. This translated into significantly fewer setup errors after watching the module for non-standard secondary IV infusions compared to baseline. (20)

Based on the evidence, there is consensus from the Multiple IV Infusions Expert Panel that nurses should receive standardized, education on IV infusion principles, setup risks and best practices to support the safe administration of secondary IV infusions. However, it is important to note that education is not effective at addressing all secondary IV infusion setup errors, because not all errors are related to knowledge gaps. For example, in the simulation lab study, errors in opening the secondary tubing clamp were not significantly reduced after watching the education module; nurses knew the clamp should be open (as evident in the written test results), but many failed to complete this step, likely because of a lapse in attention. (20) As well, education may be limited in its longitudinal effects. Thus, while education on secondary IV infusion principles, risks and best practices is required, other complementary design-related tactics (i.e., secondary clamp closed detectors) are required to design out the potential for secondary infusion setup errors.
Hospitals should consider requesting design solutions to mitigate secondary IV setup errors in requests for proposals when purchasing new infusion technology.
Theme 5. Administering IV Pump Boluses

An IV bolus refers to a 1-time or intermittent dose of IV medication that is administered intravenously to achieve a desired physiological effect. Clinicians often administer an IV bolus dose of medication, but giving a patient an IV bolus is an error-prone activity. Nuckols(22) found that 40% of preventable injuries from IV medication errors involved bolus infusions. Similarly, Fahimi et al (71) found that fast bolus injection was the most common (43.4%) IV medication error. Taxis and Barber(72;73) conducted an ethnographic study and determined that 73% of observed IV boluses contained an error, and the majority were clinically significant. The most common bolus error (95%) was administering it too quickly, which can result in patient harm (including patient death) for some medications.(74)

An IV bolus may be administered in different ways, but all methods have been associated with medication errors; no comparative evidence could be found to identify the safest method. One method involves using a parenteral syringe that is manually injected as an IV push. Another is to prepare a separate IV container and deliver it as a primary or secondary IV infusion. Some issues associated with these practices have already been discussed (Theme 3: Managing Shared infusion volume and Theme 4: Setting Up a Secondary Intermittent IV Infusion). When a patient is already being given a continuous IV infusion of the medication to be bolused, another option is to temporarily increase the infusion pump’s flow rate to administer a more rapid intermittent “top-up” dose (e.g., using a dedicated pump bolus feature or directly changing the rate of the primary continuous IV infusion); this is referred to as an IV pump bolus, and is the focus of this theme.

An IV pump bolus may be more common in certain clinical areas, such as critical care, where a patient is more likely to require an urgent supplemental dose of a medication that is already being infused continuously. An IV pump bolus may also be more likely when a nurse cannot leave the bedside (i.e., to retrieve additional IV medication and other supplies) or the IV medication is not available for preparation (e.g., not available as floor stock or hospital policies impede preparation in clinical areas for urgent “as-needed” doses)(2).

However, medication errors have occurred as a result of the administration of an IV pump bolus. That is, an IV pump bolus may be programmed with the following errors:

- wrong bolus infusion parameters (i.e., bolus VTBI/dose and/or flow rate/duration); and
- wrong primary continuous infusion parameters (i.e., rate) upon bolus completion.

Incidents have been reported of extended bolus administration when an IV pump bolus has been administered by titrating-up the rate of a primary continuous IV infusion without programming a VTBI (i.e., limiting the bolus dose), resulting in medication overdose and patient harm.(2;35;75;76); For example, in an incident reported by a U.S. hospital, an ICU nurse programmed an IV pump bolus of fentanyl by increasing the flow rate to 999 mL/hr and then walked away from the patient bedside due to an interruption. A family member noticed the continually running bolus infusion and brought it to the attention of the nurse after the patient received an estimated 1,100 mcg overdose.(77) Similarly, a nurse disclosed the following incident to researchers during an Ontario field study(2)

It has been proposed that the safest way of administering an IV pump bolus is by using a dedicated pump bolus feature.(2;78;79) ISMP Canada recommends that clinicians “use only the bolus mode feature if it is available on your pump(78). Administering an IV pump bolus using a dedicated bolus feature has the following advantages:

- It requires that a bolus VTBI/dose and flow rate/duration be programmed, limiting the bolus administration.
- It does not alter the primary continuous IV infusion parameters.
It automatically resumes the primary continuous IV infusion after bolus administration, so that there is no delay in continuous IV therapy. It ensures proper volume documentation in the pump.

A simulation lab study (20) confirm that the safest way to administer an IV pump bolus is using a smart IV pump bolus feature. The study compared the error rates when administering an IV pump bolus using three different approaches: 1. Using a traditional pump without a bolus feature (i.e., bolus feature was disabled, as configured at the hospital where participants worked). 2. Using a traditional pump with a bolus feature. 3. Using a smart pump with a bolus feature. In the baseline condition (i.e., traditional pump with bolus feature disabled), there were no incidents of extended bolus administration, as described above (i.e., the bolus dose/VTBI was always programmed). However, 17.9% (7 of 39) of the IV pump boluses contained a programming error (i.e., bolus VTBI or rate error) and 5.1% (2 of 39) had an error with the resumption of the primary continuous IV infusion rate upon bolus completion. (20) When the bolus feature on the traditional pump was enabled, IV pump bolus errors were not significantly reduced in comparison to the baseline condition (10.3% vs 11.5% respectively). However, when participants programmed an IV pump bolus using a dedicated bolus feature on a smart pump, it significantly reduced errors to only 1.3% (without increasing programming time). (20) Thus, the study results suggest that not all IV pump bolus features significantly reduce errors.

The recommendations in Theme 5: IV Pump Bolus specify the design and configuration characteristics for an IV pump bolus feature to minimize the risks associated with administering an IV pump bolus. It is intended that hospitals evaluate the bolus feature on their current pumps against these criteria to identify any potential safety gaps, and that hospitals use these criteria to inform the design requirements and evaluation criteria when purchasing new infusion systems.
16. IV Pump Bolus Feature

Recommendation

Procure\(^1\) and configure a smart pump to administer IV pump boluses\(^2\) with the following risk reduction approaches:

16.1 Can only access the bolus feature for medications that should be boluses with clinically appropriate soft and hard dose and rate/duration limits (defined for each clinical area).

16.1.1 Can directly copy a prescriber’s ordered bolus dose (as indicated on paper or electronic orders) in drug-specific units during pump programming (i.e., no unit conversion calculations required).

16.1.2 Can program the bolus duration (e.g., minutes) instead of the bolus rate (e.g., mL/hr).

16.1.3 Can autopopulate the bolus duration from the drug library.

16.1.4 Can communicate that a bolus infusion is being programmed (rather than a primary or secondary infusion) and provides clear feedback on the bolus status (e.g., bolus is running).

16.2 Include hard upper rate limits for continuous high-alert IV medications (when possible) to prevent the administration of an IV pump bolus by directly increasing the primary continuous IV infusion rate.

Programming an IV bolus by specifying the dose and duration represents a mental shift for nurses who are accustomed to programming an IV bolus by specifying the VTBI and rate and can introduce new transitional errors.\(^2\) Training is required to prepare clinicians for a shift toward direct-order input and to think in terms of an IV bolus in terms of dose and duration rather than VTBI and flow rate.

1\(^{\text{\footnotesize{1}}}\) It is not expected that new infusion pumps should be procured on the basis of this recommendation alone. However, when purchasing new infusion pumps, include this recommendation as part of the evaluation criteria.

2\(^{\text{\footnotesize{2}}}\) An IV pump bolus refers to the use of an IV infusion pump to administer a bolus of a primary continuous medication that is already infusing via an IV infusion pump. Further research is required to determine the safest administration method for boluses of IV fluids, loading doses, and multi-step protocols.

Recommendation Implementation

Example of Recommendation Implementation

Figure 23. Example of a software interface for a pump bolus feature with risk-reduction characteristics.
Self-Assessment

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<td>Can autopopulate the bolus duration from the drug library.</td>
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Legend:
A: This characteristic is not available on the IV pump.
B: The characteristic is available on the IV pump, but not enabled for any medications.
C: The characteristic is available on the IV pump, but not enabled and/or appropriately configured for all applicable medications.
D: The characteristic is available on the IV pump, and is enabled and appropriately configured for all applicable medications.

Implementation Resources

- San Diego Patient Safety Council: Safe Administration of High-Risk IV Medications Toolkit

Suggested QI Indicator to Monitor Recommendation Compliance

- % high-alert medications with a hard upper limit specified in the drug library

Discussion of Evidence

Issue Description and Recommendation Rationale

If an IV pump’s bolus feature is not enabled for a primary continuous medication and that medication is ordered as a bolus, an IV pump bolus can be administered by one of the following three methods: 1. Increasing the primary continuous infusion rate (if allowable by the limits), waiting the length of time to administer the bolus, the decreasing the primary continuous infusion rate back to the original settings. 2.
Reprogramming the primary continuous infusion to the IV bolus rate and VTBI, then reprogramming it back to the primary continuous rate once the bolus is complete. 3. Programming the bolus as a secondary infusion (if allowable based on the drug library configuration, or setting up a separate infusion to administer the bolus. All of these methods increase the likelihood of an error compared to administering the infusion using an IV pump’s bolus feature that has the design characteristics described in Recommendation 16.1. (20) During a field study(2), nurses on a critical care unit that had an IV infusion pump with the bolus feature disabled were observed to opt-out of the dose error reduction system (i.e., not use the drug library) when programming a continuous primary infusion to ensure they could increase the rate and/or use the secondary feature to administer a bolus, if required. This practice has also been described in another published report.(80) Opting out of the dose error reduction system is an unsafe practice because it disables the pump’s ability to detect programming errors that are outside of the library limits.

Additionally, hospitals using smart pumps with a bolus feature should configure the drug library to include hard upper limits for all high-alert medications to prevent the administration of a bolus by increasing the primary rate. This will prevent the occurrence of an uncontrolled bolus dose should an interruption occur while the primary continuous infusion rate is increased.(81)

The data parameters required to program an IV pump bolus vary across IV infusion pumps. In general, when IV pump IV pump bolus programming parameters are congruent with the IV pump bolus medication order, fewer, less complicated steps are required. For example, if the IV bolus order is in drug units (e.g., mg) but the IV infusion pump requires the bolus dose to be specified as a total volume to be infused (VTBI) (e.g., mL), a calculation based on the drug’s concentration is required. This creates opportunities for calculation errors. If, however, the IV pump bolus feature requires the dose to be specified in the same units as the bolus medication order (i.e., units are pre-set in the drug library to match standard bolus order units), the nurse can directly copy the bolus dose from the order to the pump, eliminating opportunities for calculation errors (see

Reported Incident

“A nurse administered a bolus dose of fentanyl by increasing the flow rate for an existing continuous IV infusion of fentanyl to 999 mL/h; however, the volume to be infused was not changed (which would have caused the infusion to stop and an alarm to sound when the intended dose had been administered). The nurse left the patient’s bedside and failed to return within an adequate time, which allowed the infusion to continue to run at 999 mL/h, resulting in a fentanyl overdose.”

Figure 24. Programming an IV pump bolus on a traditional pump (specifying VTBI) and a smart pump (specifying dose).

Another IV pump bolus order-programming mismatch issue is that most IV pump boluses are ordered to infuse over a particular duration, but some IV pumps only allow the user to specify a bolus rate and VTBI. In this case, nurses must calculate the appropriate rate based on the dose and duration, which creates opportunities for calculation errors. Instead of calculating the IV pump bolus infusion rate, a field study and a simulation lab study(20) revealed that some nurses administer an IV pump bolus at the pump’s fastest possible rate, which often exceeds the maximum allowable rate, rather than the specified by hospital policy (i.e., formulary) for the medication and this can sometimes cause patient harm. (2) The same simulation lab study found that if the bolus duration is entered into the pump (either directly or indirectly by using an option to auto populate the duration with the fastest time allowable in the drug library) instead of the rate, it resulted in a 5-fold reduction in the bolus administration speed.(20)

Another type of IV pump bolus programming error is mode errors. Since infusion parameters are programmed in several different modes (e.g., primary programming, secondary programming, bolus programming), there is a risk that IV pump bolus parameters may be programmed in the data fields of the wrong mode (e.g., primary mode), which would result in a drug delivery error with potentially harmful outcomes. This type of error was observed in a simulation lab study. When programming an IV pump bolus, 2 participants (5.1%) altered the rate in the primary mode expecting that they were programming the rate in the bolus mode.(20) For this reason it is important that the programming mode always be salient during programming tasks.

**Recommendation Evidence**

Type of Evidence: Expert Consensus and Controlled Study Data

A controlled laboratory simulation study (20) compared the pump IV bolus programming errors rates using a traditional pump with no bolus feature, a traditional pump with a bolus feature, and a smart pump with a
bolus feature that was designed according to the risk reduction characteristics described in Recommendation 16.1.

While pump bolus programming errors were noted in all conditions, there was a statistical difference in programming errors between experimental conditions. Programming an IV pump bolus using a traditional pump with and without a bolus feature had an error rate of 10.3% (8 of 39 participants) and 11.5% (9 of 39 participants) respectively, whereas programming an IV pump bolus using a smart pump with the design characteristics in Recommendation 16.1 resulted in an error rate of only 1.3% (1 of 39 participants).(20) When participants used the smart pump, there were no bolus VTBI/dose errors, or errors in resuming the primary continuous IV infusion flow rate. The only single error that occurred when programming an IV pump bolus using a smart pump with the design characteristics in Recommendation 16.1 was in entering the bolus duration; a participant entered the bolus flow rate into the duration field without converting the units of measure (i.e., mL/h to time in minutes), so that the bolus was administered over 90 minutes instead of at 90 mL/h (about 3 minutes). When participants used the traditional pump with or without the bolus feature enabled, a wide range of error types occurred. Regardless of the type of pump used (i.e., traditional or smart), the time required to program the bolus was not significantly different.(20)

There is consensus from the Multiple IV Infusions Expert Panel that enabling the bolus feature and specifying appropriate hard and soft programming limits, as well as ensuring there is a hard upper limit for all high-alert primary continuous infusions, will help decrease programming errors and prevent the administration of an uncontrolled bolus. Additionally, hospitals should evaluate their current IV pumps and future IV pumps (during the procurement process) for compliance with the risk reduction characteristics outlined in Recommendation 16.1, and identify the safest possible way of administering an IV pump bolus given the design of the IV pump. This will lead to safer care for patients.


27. Institute for Healthcare Improvement [Internet]. How-to-guide: Prevent harm from high-alert medications Cambridge, MA: IHI; 2012; Available from: www.ihi.org


32. Institute for safe Medication Practices (ISMP) [Internet]. ISMP list of high-alert medications in acute care settings Horsham: ISMP; unknown; Available from: https://www.ismp.org/tools/institutionalhighAlert.asp


51. FDA Maude Database.


64. ECRI Institute. Infusion pump integration: why is it needed, and what are the challenges? Health Devices. 2013 Jul;42(7):210-21.


Appendix A: Standard Procedures for Setting Up Continuous or Intermittent Intravenous Medications

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**Safe Practice:** If a nurse needs to hang multiple intravenous (IV) medications at the same time (for example, a nurse needs to hang 0.9% normal saline at 100 mL/hour and heparin at 900 units/hour), he or she should hang each medication one at a time. The nurse should not start hanging the next medication until the first medication is attached to the patient and he or she has visually confirmed the medication is infusing at the correct rate.

1. After obtaining an IV infusion bag, the nurse should compare the medication and medication concentration in the IV infusion bag to the medication order and ensure that the IV infusion bag matches the order.
   - **Safe Practice:** Using two patient identifiers, confirm that the medication is for the right patient.
   - **Safe Practice:** Confirm the other four rights of the Five Rights of the medication administration process: right medication, right dose, right time, and right route.

2. After priming the IV tubing with the medication, hang the IV infusion bag on the IV pole and connect the tubing to the IV pump.
   - **Safe Practice:** The IV pump cannot confirm that the nurse is hanging the correct medication or medication concentration because the nurse tells the IV pump this information when he or she programs the IV pump. Take a moment to be mindful while hooking the IV infusion bag on the IV pole by visually inspecting the IV infusion bag and pharmacy label to ensure that the correct medication was chosen.

3. Program the IV pump with the correct medication, concentration, volume, and rate.
   - **Safe Practice:** Because the computerized prescriber order entry (CPOE) system is likely not communicating with the IV pump, the nurse has to tell the IV pump the physician’s order by programming the pump. The nurse should double-check the medication order before programing the pump. For high-alert medications, a second nurse should be present to double-check the administration process.

4. Before connecting the IV tubing to the patient’s IV site, trace the line back to the IV infusion bag to confirm that the medication is correct and is being attached to the right intravenous access site.
   - **Safe Practice:** If the nurse is hanging total parental nutrition or any medication that should be infused through a central venous catheter, he or she should ensure that the tubing is attached to the central venous catheter as opposed to a peripheral intravenous catheter.
• **Safe Practice:** If the nurse is programming an epidural pump, he or she should ensure that the epidural tubing is connected to an epidural site and not an intravenous site.

5. After attaching the IV tubing to the correct IV access site and starting the infusion on the IV pump, visually confirm that the medication is infusing into the patient by looking at the drip chamber and watching drops of fluid from the IV infusion bag drip down into the drip chamber. If the pump alarms, address any pump alarms immediately.

• **Safe Practice:** Secondary or piggyback IV infusions that are administered through the IV pump by gravity may not actually infuse if the secondary infusion bag is not hung above the primary infusion bag or if the secondary IV tubing has been inadvertently clamped. After setting up a secondary or piggyback infusion, the nurse should pause to ensure that drops of fluid are dripping from the secondary infusion bag into the drip chamber and that drops of fluid are NOT dripping from the primary infusion bag into the drip chamber.

6. When multiple IV infusions are infusing simultaneously, attach labels with the medication name to the IV tubing in one or more spots on the IV tubing (for example, attach a label to the portion of tubing that is closest to the patient’s IV site and to the portion of the tubing closest to the IV pump).

• **Safe Practice:** Before attaching the medication labels to the IV tubing, the nurse should trace the IV lines back to the IV infusion bag to ensure that he or she is labeling the IV tubing with the correct medication.