Aligning the Lines: An Analysis of IV Line Errors

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ABSTRACT

From July 2004 through August 2013, Pennsylvania healthcare facilities reported to the Pennsylvania Patient Safety Authority 907 events of intravenous (IV) line errors. Reports were analyzed and assigned an error category based on event description. The most common errors occurred during setup and included rate of infusion mix-up or line mix-up (22.6%, n = 205), IV lines not attached to patients (14.6%, n = 132), and errors associated with piggyback infusions (12.8%, n = 116). High-alert medications were involved in 71.0% (n = 644) of all errors, with heparin being the most frequent medication reported (16.6%, n = 151). Nearly half of the reports (48.1%, n = 436) were categorized as harm score D or greater (as defined by the National Coordinating Council for Medication Error Reporting and Prevention), which indicates they reached the patient and required some type of intervention. While it is difficult to determine the exact causes of reported events, more than half of the submitted events involved the setup of IV lines. Risk reduction strategies focused on setting up infusions completely and one at a time, administering high-alert medications as primary infusions, utilizing infusion sets with back-check valves, labeling lines, limiting pump setup to qualified and credentialed personnel, placing IV pumps and epidural pumps on opposite sides of the patient's bed, and raising awareness of the risk of IV errors. (PA Patient Saf Advis 2014 Mar;11[1]:1-7.)

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INTRODUCTION

In 2002, the United States Pharmacopeial Convention reported that high-alert medications were associated with harmful errors and identified intravenous (IV) medications as the top offenders.[1] This risk is heightened exponentially with the simultaneous administration of multiple IV infusions. While safeguards such as independent double checks and smart infusion pumps with dose range checking have been used to reduce the risks associated with the IV administration process, extensive research has yet to be completed on the potential errors that could result from the administration of multiple IV infusions. To date, there are no conclusive interventions to prevent these types of errors. Though practitioners rely on smart infusion pumps to alert them to errors, the safety mechanisms of smart pumps are limited.

One study looked at type, frequency, and severity of medication errors associated with IV pumps and revealed that only 1 in 389 documented errors would have been prevented by smart pump technology.[2] The study also points to the limited ability of smart pumps to prevent errors during the medication-use process, asserting that smart pumps are limited to preventing errors as a result of incorrect programming, which can result in a wrong dose (which does not match the order), wrong medication, wrong patient, or wrong indication.[2] Additionally, the complexity of the nursing environment and unnecessary variability in drug concentrations, dosing units, and dosing limits used in different areas of a hospital further complicate infusion pump programming increasing the risk of error.[3]

The Institute for Safe Medication Practices (ISMP) Canada and Health Technology Safety Research Team evaluated two national incident reporting databases (ISMP Canada's Canadian Medication Incident Reporting and Prevention System and the United States Food and Drug Administration's Manufacturer and User Facility Device Experience database) to reveal several safety issues associated with multiple IV infusions with the potential to cause patient harm.[4] The identified safety issues included secondary infusions, line identification, and line setup and removal. This analysis of IV line event reports offers an exclusive interpretation of IV line errors in Pennsylvania healthcare facilities, identifies common steps in the administration process where errors occurred, identifies medications most commonly involved in IV line errors, and categorizes factors associated with such errors.

METHODOLOGY

When reviewing reports submitted to the Pennsylvania Patient Safety Authority, analysts have the opportunity to further classify reports using a "monitor code" for future querying opportunities. Analysts queried reports categorized as "medication errors" in the Authority's Pennsylvania Patient Safety Reporting System database for those assigned the monitor code "DEV3," representing reports identified as events involving IV lines. The monitor code is assigned by an analyst's manual review of report data and is a limitation of this analysis due to the potential coding variability between analysts.

The query yielded 907 medication error reports submitted to the Authority from June 2004 through August 2013. The reports were evaluated to determine what factors are associated with IV line medication errors. Reports were analyzed and assigned a category of error based on the analyst's interpretation of the event. If an event fit into more than one category, the analysts determined, when possible, the primary reason for the event based on information provided within the report. When a report did not provide sufficient detail to determine a cause, the event was categorized as "unknown." Medication

name, route, patient care area, and harm score were provided by the reporting facility. When medication names were left blank but the name was provided in the event description, the medication name field was adjusted. Analysts made note of events involving a high-alert medication, based on *ISMP's List of High-Alert Medications*.[5]

ANALYSIS

Errors involving IV lines reported to the Authority occurred during IV drug setup and administration. The most frequent types were rate of infusion mix-up or line mix-up (22.6%, n = 205), IV lines not attached to patients (14.6%, n = 132), and errors associated with piggyback infusions (12.8%, n = 116). Almost seven percent (6.9%, n = 63) of reports were determined to have insufficient information to assign an error type. These reports were assigned as "unknown" but remained in the analysis to be categorized based on harm score, medication involved, patient care unit, and patient age.

Of the reported events, 11.1% (n = 101) involved patients under the age of 18. High-alert medications were prescribed in 71.0% (n = 644) of all events. Heparin was the high-alert medication most frequently involved in an event error (16.6%, n = 151), followed by insulin (7.6%, n = 69) and parenteral nutrition (5.2%, n = 47) (see the Table). Intensive care units (30.2%, n = 274) ranked highest among all units where IV line errors were reported, followed by medical-surgical units (14.1%, n = 128) and telemetry units (6.6%, n = 60).

Facilities reported events according to harm scores as defined by the National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP) Index for Categorizing Medication Errors.[6] Nearly half (48.1%, n = 436) of the events were reported as harm score D or greater. This indicates that the majority of patients required extra monitoring or intervention to preclude harm.

Table. Top 10 Prescribed Medications Involved in Intravenous Line Events Reported to the Pennsylvania Patient Safety Authority from July 2004 through August 2013 (N = 907)

MEDICATION NAME	NO. OF EVENTS	% OF TOTAL EVENTS
Heparin*	151	16.6
Insulin*	69	7.6
Parenteral nutrition*	47	5.2
Hydration	33	3.6
Morphine*	32	3.5
FentaNYL*	29	3.2
Vancomycin	27	3.0
Diltiazem*	26	2.9
Potassium chloride*	22	2.4
HYDROmorphone*	21	2.3

* A high-alert medication

Based on the Authority's 2012 annual report,[7] 0.5% of medication errors reported to the Authority in 2012 resulted in harm. In comparison, for this analysis, IV line errors caused patient harm (an assigned harm score of E or above) in 6.2% (n = 56) of all event reports. Nearly all reported errors (95.6%, n = 867) reached the patient.

Rate or Line Mix-Ups

The most frequent error type involved rates of two or more medications that were switched, most likely due to a programming error or an inaccurate line tracing and reconciliation. Event reports that were described as IV line mix-ups accounted for 9.5% (n = 86) of events, and those described as IV rate mix-ups accounted for 13.1% (n = 119) of all reports. Some event descriptions ambiguously assigned cause of error to either the line or the rate, but the result was ultimately the same in that IV medications were administered at the wrong rate of infusion. Together, rate and line mix-ups accounted for 22.6% (n = 205) of the reported events.

Line tracing is a critical step in the setup process for administration of IV medications. An event report was categorized as an IV line mix-up if the event description specifically stated that during setup or exchange, the IV lines of two medications were inadvertently switched. High-alert medications were involved in 91.9% (n = 79) of IV line mix-ups. The medication most frequently involved in this type of event was heparin (26.7%, n = 23). Examples are as follows:

> *A patient with nitroglycerin and heparin infusions complained of a headache. The nitroglycerin was ordered to infuse at 1.5 mL/hr, and the heparin was ordered to infuse at 30 mL/hr. The pump was set correctly, but the lines were crossed and the nitroglycerin was infusing at 30 mL/hr and heparin was infusing at 1.5 mL/hr. STAT labs were obtained, nitroglycerin rate was decreased, and patient was given Tylenol®.*

> *Patient was ordered to have a NSS [normal saline solution] bolus of fluid. The IV lines of the NSS and fentaNYL were mixed up during a code situation, and the fentaNYL was administered at the NSS bolus rate. The amount of fentaNYL administered is unknown, but the error was corrected when it was discovered.*

IV Neo-Synephrine® was added for hypotension and administered by another RN [registered nurse] while I got report. After the patient passed away, it was discovered that the Neo-Synephrine bag was on the line that was programed for the IV fluid and was run in at 150 mL/hr.

Analysts categorized events as an IV rate mix-up if the event description stated that the rates were switched (e.g., drug A was infusing at the rate ordered for drug B and/or drug B was infusing at the rate ordered for drug A). These events accounted for 13.1% (n = 119) of the reports. The majority of rate mix-ups involved high-alert medications (93.3%, n = 111), including heparin (30.3%, n = 36), parenteral nutrition (18.5%, n = 22) and insulin (8.4%, n = 10). Further, analysts reviewed the medication prescribed compared with the medication administered. Results of this analysis showed that when heparin was the prescribed medication, the rate was most commonly switched with the rate for IV hydration (47.2%, n = 17). When parenteral nutrition was prescribed, its rate was most commonly switched with the rate for the concomitant intralipid (77.3%, n = 17). And when insulin was the prescribed medication, its rate was most commonly switched with the rate for IV hydration (70.0%, n = 7), as in the following report:

A patient was on an insulin drip at 5 mL/hr and a maintenance IV at 100 mL/hr. While changing the patient's gown, the IVs were switched and the patient received the insulin drip at 100 mL/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.]

Another error requiring intervention involved the administration of protamine sulfate after a patient's heparin was programmed at the rate ordered for the patient's hydration:

Patient ordered to start on heparin gtt [drip] at 800 units/hr and NSS at 75 mL/hr. The medications and pumps were prepared. The heparin gtt was inadvertently set up on the NSS pump and the NSS was inadvertently set up on the heparin pump. Therefore, the patient received 7,500 units/hr of heparin instead of the intended 800 units/hr. The error was caught approximately one hour after start and was immediately stopped. The physician was notified, [who] ordered a stat PTT [partial thromboplastin time], which resulted [in a level] greater than 210 [seconds]. Protamine sulfate was given, and PTT was reversed. No permanent patient harm was identified from this event.

Another example of an event report in which rates were interchanged is as follows:

A nurse noted the heparin bag was empty, [and the patient was] in need of a new bag. Message was given to RN of patient for the new heparin bag from her medication cart. I went in and saw that they were set up in reverse for IVF [intravenous fluid] and heparin. The IVF infused at 17 mL/hr, [the rate intended for heparin], and heparin infused at 100 mL/hr, [the rate intended for the intravenous fluid]. It was calculated that the patient received approximately 100 mL of heparin at 100 mL/hr, equaling an approximate 1,000 units/hr heparin overdose. This overdosage occurred for approximately one hour. Further review determined that the patient had lost her INT [intravenous needle therapy] site [at midday], another RN assisted in restarting the patient's INT, and the event occurred after the pumps were restarted. The heparin thus ran out within approximately one hour. [The] heparin [was] stopped, physician [was] notified, [and a] stat PTT [was ordered].

IV Line Not Attached to Patient

The second most common event type, based on analyst evaluation, was IV lines not attached to patients. Unattached lines accounted for 14.6% (n = 132) of the reports. The top three medications involved in these errors were high-alert drugs: heparin (16.7%, n = 22), morphine (8.3%, n = 11), and insulin (6.1%, n = 8). The overall results show that high-alert medications accounted for two-thirds (66.7%, n = 88) of all events in which lines were not attached to the patient. For a critically ill patient in need of immediate treatment, the act of not attaching the required medication could result in patient harm or even death. Multiple reports described that these errors resulted in adverse patient events, including elevated blood glucose, uncontrolled pain, and unmanaged hypotension.

Examples of reports in which IV medications were not attached to patients include the following:

[Patient] was to receive IV CISplatin. Upon verification of the drug, it had been running for approximately 20 minutes when the patient's wife noticed a syringe attached to the patient's port. I went to assess the situation and noticed that the tubing had never been hooked up to the patient's port. The patient was lying on his side in bed and was untouched by the fluid, which had been absorbed by the sheets on the patient's bed. Nursing supervisor, patient, and physician were notified. Patient aware of the situation.

I hung the patient's CARBOplatin, programmed it into the pump, and realized [approximately 10 minutes] later, when patient's companion told me that the tubing was leaking onto floor, that I had never connected it to the primary [IV line]. Amount remaining in bag was 75 mL, according to pump. The tubing was resting on pump support not touching anything, so I connected it. The spill

was contained in a small area on the floor next to chair. Spill kit directions followed and disposed of in chemotherapy waste container. [Physician] notified that patient would receive approximately 75% of dose, and she said that would be satisfactory.

Insulin gtt started as ordered for hyperglycemia. Two hours later, glucose was checked as ordered, and the result was greater than 400 [mg/dL]. Upon assessment, noted tubing disconnected. Physician notified and new orders received. Insulin bolus [was administered] and then gtt [started] at 4.5 units/hr. Additional monitoring and glucose testing required. Glucose steadily decreased and [returned to] normal limits.

According to the RN supervisor, patient ordered norepinephrine (Levophed®) IV drip titrate to keep SBP [systolic blood pressure] >90. The patient had an episode of hypotension, BP [blood pressure] = 68/36. House physician ordered IV NSS wide, Trendelenburg, 100% FIO_2 [fraction of inspired oxygen]. While assessing lines, found Levophed infusion disconnected, and the line was reconnected. Hypotension immediately resolved, BP = 128/60. BP remained stable.

Errors Associated with Piggyback Infusions

The Ontario Health Technology Assessment Series publication *Multiple Intravenous Infusions Phase 1b: Practice and Training Scan* defines a secondary infusion as one that is connected upstream of a single pump/pump channel that infuses each bag sequentially.[4] For the purposes of this analysis, infusions that were administered in this manner or referred to as piggyback or secondary in the event description were categorized as a "piggyback infusion." Errors associated with piggyback infusion administration were the third most frequent (12.8%, n = 116) events reported involving IV line error. Heparin was the most common medication involved in piggyback administration errors (10.3%, n = 12). Event descriptions indicated that piggyback infusion errors could occur at several steps in the setup process, including when a secondary IV is connected below the infusion pump, when a secondary IV is hung lower than the primary IV, when IV clamps are left closed, and when the pump is programmed incorrectly for the secondary infusion.

Secondary IV lines attached below the pump were mentioned in 4.3% (n = 5) of the 116 piggyback IV lines errors, as in the following report:

> *IV insulin 100 units/100 mL was infused over approximately 1 hr. IV was connected at the wrong place, piggybacked below the pump. D50 [dextrose 50%] 25 mL was pushed slowly as per protocol.*

Clamps remaining closed were also indicated in several event reports, including the following:

> *Heparin drip was running at 1,400 units/hr (14 mL/hr). A 4 g magnesium rider IV was piggybacked at 25 mL/hr; therefore, heparin drip ran at 25 mL/hr for over 30 minutes as rider had been clamped. Drip stopped [after] approximately 15 mL [heparin] went in. Physician notified and stated to restart drip and monitor for signs and symptoms of bleeding. PTT drawn and sent; no signs or symptoms of bleeding present.*

Analysts noted that several reports included high-alert medications piggybacked to other high-alert medications. Overall, high-alert medications were indicated as either the prescribed or administered medication in 68.1% (n = 79) of the piggyback IV line medication errors. One such incident including heparin and insulin was reported as follows:

> *Insulin gtt started as secondary to heparin gtt due to limited IV access. Air in line noted and back-primed into empty syringe into line B. At this time, the insulin was hooked into the Y port of the heparin line but [was] not running through pump. Clamp on insulin line was opened and infused completely over approximately 15 minutes. Patient's blood sugar monitored closely every 30 minutes, and [patient] eventually placed back on appropriate insulin gtt. Patient's blood sugar did not bottom out.*

RISK REDUCTION STRATEGIES

Evaluation of IV line event reports reveals that these errors occur at multiple steps in the medication administration process. Due to the limited research on IV line errors, these reports offer a unique window into the factors associated with these events. Currently, strategies for reducing risks associated with multiple IV lines are limited, and there is a lack of standardization and guidelines related to IV setup or administration. Health Quality Ontario (HQO) conducted a 12-hospital field study to collect similar data. Their observations, along with recommendations from ISMP and analysis of the events reported to the Authority, have been considered and have resulted in identification of several risk reduction strategies for the prevention of harm during IV administration. While more than twenty categories of error were identified from the Authority reports, the following strategies focus on reported events that comprised the top 50% of errors.

Set Up Infusions Completely and One at a Time

Several events reported to the Authority detailed that the infusion pump was set correctly but that the lines were crossed. Many of the event reports were a result of medications not being attached to the patient and resulted in the patient not receiving the appropriate care or treatment. These errors may have been prevented if the line for the first medication was

inserted into the pump and unavailable prior to the second medication being prepared.

ISMP suggests that "when using multiple-channel pumps, nurses should handle just one IV solution at a time."[8] Physically tracing the line can help ensure that the correct channel has been used to program the infusions. The Joint Commission recommends tracing all lines back to their origin before connecting any devices or infusions.[9] To diminish risks associated with line mix-ups occurring during gown changes, some hospitals use gowns that have snaps, ties, or Velcro on the shoulders and sleeves; this decreases the need to manipulate IV lines while bathing and changing clothes.[4] Developing a consistent process for IV medication setup and standardizing policies and procedures may prevent such errors as IV line and IV rate mix-ups.

Administer High-Alert Medications as Primary Infusions

Research suggests continuous high-alert medications be administered as primary infusions and that no secondary infusions be attached to the dedicated primary line.[4] Both the HQO research and reports submitted to the Authority revealed the error potential with setting up a secondary infusion. Several high-alert medication events reported to the Authority may have been avoided if the high-alert medication was administered as a primary infusion via a dedicated line. Running high-alert medications by means of a secondary line could potentially result in errors associated with primary and secondary line confusion, secondary infusion delay due to no alarm to signify secondary infusion is empty, delay in medication administration due to volume in IV tubing between the secondary port and the end of the primary tubing, and increased risk of subsequent programming and setup errors.[10] In addition, IV line mix-up errors may be prevented by independent double checks of selected medications. ISMP suggests that nurses hang the solution and ready it for infusion and that another nurse independently validate the original order, the patient's identification, the dose and concentration, the insertion site (route), and the pump or channel setting.[8]

Utilize Infusion Sets with Back-Check Valves

A back-check valve is a pressure-sensitive device that prevents the flow of fluid from a higher-pressure line to a lower-pressure line. The infusion system is particularly vulnerable to this problem if the pump is running at a high flow rate or if the primary infusion bag contains a small volume of fluid. The result of backflow is that the actual rate of administration for each of the fluids is indeterminate.[4] When a piggyback or secondary infusion is necessary, lines should only be attached to primary infusion sets with a back-check valve.[4]

Label Lines

Affixing the name of the drug being infused to each IV line (at the end closest to the patient) and above each channel on the pump may help prevent IV line mix-ups.[8] This practice may also help prevent errors if tubing has to be detached from patients during procedures, imaging, or transfer. While the label alone should not be used to identify the medication, the label can aid practitioners in line tracing and independent double checks.

Restrict Pump Operation to Qualified and Credentialed Personnel

Recognize that transfer of patients may require lines to be removed or replaced and infusion pumps to be turned on or off. This introduces opportunities for error that should be mitigated by ensuring that only qualified, credentialed personnel manipulate IV lines or program IV pumps.[11] Trained, licensed practitioners can inadvertently connect the wrong tubing or forget to restart a pump. However, untrained staff (e.g., ancillary personnel, medical or nursing students) are less likely to know and follow safety measures (e.g., tracing IV lines) or to be knowledgeable about the serious ramifications of misconnections. Include prohibitions for these tasks during orientation, and when possible, offer new ancillary staff practice in turning down requests to connect or disconnect medical tubing.[12] Restrict the practice of connecting, disconnecting, pump operation, and pump programming to qualified and credentialed personnel.[12]

Place IV Pumps and Epidural Pumps on Opposite Sides of Patient's Bed

While wrong-route errors were not limited to the switching of IV and epidural infusions, these reports were of particular concern due to the high possibility of patient harm if these routes are incorrect. ISMP has reported this issue on several occasions. ISMP suggests safety strategies such as placing IV pumps and epidural pumps on opposite sides of the patent's bed to better separate the two infusion systems, clearly labeling the pump as "Epidural Only," and using yellow-lined tubing without injection ports for epidural infusions.[13]

Raise Awareness

The reports submitted to the Authority reveal the incidence of errors, the severity of errors, and the frequency with which high-alert medications are involved. Using this information to raise professional staff awareness of the prevalence of IV administration errors is likely to be helpful, as lack of research and data in the field has contributed to low appreciation of this common threat to safety.[8]

CONCLUSION

Analysis of IV line events reported to the Authority revealed that three steps in the administration process were responsible for nearly 50% of errors involving IV lines; however, the analysis also showed that errors can occur at any point. It is difficult to determine the exact causes of the reported events due to wide practice variations for the setup of simple infusions. Both patients and practitioners would benefit from standard guidelines describing safe practices for concomitant administration of medications from multiple IV infusions. It is important to note that more research must be done to determine the exact causes and best risk reduction strategies for IV line mix-up errors.

NOTES

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LEARNING OBJECTIVES

- Identify the most common types of errors associated with intravenous (IV) line events submitted to the Pennsylvania Patient Safety Authority.
- Recognize the rate of occurrence in which IV line events reported to the Authority reached the patient.
- Recall the most frequently involved medications in IV line events.
- Select risk reduction strategies that may prevent IV line events.

SELF-ASSESSMENT QUESTIONS

The following questions about this article may be useful for internal education and assessment. You may use the following examples or come up with your own questions.

1. Which of the following was the most frequent error associated with IV line events reported to the Authority?
   a. Rate or line mix-up
   b. IV line not attached to the patient
   c. Error associated with piggyback infusions
   d. IV medications incompatible
   e. Pump failure
2. According to events reported to the Authority, when heparin was the prescribed medication, with what other IV solution was the heparin rate most commonly switched?
   a. FentaNYL
   b. Insulin
   c. Intralipids
   d. IV hydration
   e. Parenteral nutrition
3. Which of the below statements is true regarding heparin and IV line events reported to the Authority?
   a. Heparin was the second most frequent medication involved in IV rate or line mix-ups.
   b. Heparin was not involved in those events in which IV lines were not attached to patients.
   c. Heparin ranked first among high-alert medications involved in IV line events.
   d. Heparin was the only high-alert medication involved in rate or line mix-up events.
   e. Heparin was the third most frequent medication involved in IV line mix-ups.

Question 4 refers to the following case

A patient who presented with hyperglycemia was ordered to receive an insulin drip. On reassessment, it was noted that the patient's glucose level had increased instead of decreasing, as would be expected with insulin therapy. This unexpected level prompted the nurse to trace the IV line from the pump to the patient's IV access. It was discovered that the IV line had not been attached to the patient. Due to the error, the patient's condition had been left untreated for two hours and additional monitoring was required.

4. Which of the following risk reduction strategies may have prevented this event?
   a. Administering high-alert medications as primary infusions
   b. Setting up infusions completely and one at a time
   c. Restricting pump operations to qualified and credentialed personnel
   d. Utilizing infusion sets with back-check valves
   e. Restricting pump operations for high-alert medications to the ordering physician
5. What percentage of IV line events reported to the Authority reached the patient?
   a. Less than 10%
   b. Less than 50%
   c. Greater than 95%
   d. No IV line events reached the patient
   e. All IV line events reached the patient

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