TECHNOLOGY

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Pump away high-risk infusion errors

Manual programming errors cause two of three infusion pump-related deaths in hospitals each year.[1] A missed key or misplaced decimal can carry dramatic consequences. In 2003, George Washington University Hospital, a 370-bed teaching hospital in Washington, D.C., chose new intravenous (I.V.) pumps to increase safety measures and improve cost-effectiveness. The hospital's new infusion system safety requirements included:

- on-board drug library per care area
- standardized drug concentrations
- dose calculator
- drug-specific dosing limits
- automated programming via pump-based bar coding
- outcome data on dose limit alerts.

Reducing critical I.V. errors

Thirty-five percent of all medication errors that result in significant harm are the result of I.V. pump errors, with the most common error being incorrect programming of the infusion parameters into the pump.[2] New sophisticated infusion systems (smart pumps) provide advanced drug libraries that allow an institution to specify medications to list in department-specific categories, to establish standardized concentrations for these medications, and to set minimum and maximum dosing parameters for each medication.

When a clinician programs the pump for a particular therapy, he selects the medication and the standardized concentration, rather than manually entering these parameters. In doing so, fewer keystrokes result in a decreased chance for programming errors. Additionally, limiting the number of options that a clinician is able to select by department reduces the potential for error.

Instituting dosing limits

When a clinician programs an I.V. pump at a rate or dose outside the dosing parameters, the pump automatically notifies the practitioner that he is outside the established limits and prompts the clinician to confirm and authorize the dosage. At George Washington University hospital, we believe that this reminder, or double check, significantly improves I.V. medication safety. Further, we believe that limits should provide clinicians with the ability to exercise critical thinking and appropriately surpass limits as patient status dictates. For example, when a hemodynamically unstable patient receiving epinephrine is rapidly declining, to prevent death, that patient will require titration of epinephrine well above published maximum limits.

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Improving medication safety

We selected and implemented a safety infusion system that met our safety requirements. From its history logs, we were able to collect and analyze data about averted medication errors.

The purpose of this retrospective study was to determine the frequency and trends of averted I.V. medication errors. Ultimately, with this information, we were able to implement methods for improving medication safety and patient care.

- **Methodology** - Five hundred fifty infusion pumps with the new dose limiting technology were in use throughout George Washington University Hospital. Historical data were evaluated from a sample of 150 pumps over a period of 5 months, or 131 days (10/20/04 to 3/14/05). Dose alert logs and operational logs were extracted and analyzed from each of the 150 pumps. The operational logs contain a listing of all dose entries, including initiation of a therapy, rate/dose changes, and alarms. The dose alert logs contain a record of the dose alerts, including medication name, medication dose, dosing parameters or limits, date, time, department, and device for all dose alerts throughout the 5-month period. Dose alerts are defined as programmed doses that are above or below the established dosing parameters and, when prompted to confirm the entry, the clinician responds "no." Initially we identified this as a near miss, interpreting a "no" response as interception of a poten-

tial programming error. However, after analysis of dose alert and operational logs, we learned that not all "no" responses were near misses or potential programming errors that could've led to an adverse drug event.

• **Results -** Of 150 pumps in use during 131 days, a total of 122 dose alerts were identified out of approximately 43,000 total doses. Doses are defined as any time a new dose was entered into the infusion pump, including initiation of therapy and subsequent titration. Of the 122 alerts, 27 alerts indicated programming below the dose limit, and 95 were above the dose limit. Of those above, 20 were less than 10% above the maximum dosage limit, 27 were between 10% and 50% above the maximum limit, and a little more than half were greater than 50% above the maximum limit.

Medications associated with dose alerts were consistent with the Institute for Safe Medication Practices' high-risk list.[3] The highest number of dose alerts occurred with propofol, which was implicated in 27 alerts. (See "Dose alert frequency by medication.")

Evaluating the relationship between dose alerts and time of day and time of year (month) didn't reveal any trend. Further, data collection and analysis over a longer period of time are warranted to determine if there's a relationship between these variables.

• **Discussion** - Not all dose alerts represented a halting of a potential medication error. In many cases, exceeding the maximum dose limit was appropriate to the patient therapy. Highly compromised and rapidly declining patients will often require titration dosing of medications well above published maximum limits, such as propofol, fentanyl, norepinephrine, and epinephrine.

Data in the operational logs demonstrated that in some instances the clinician initially responded "no" when prompted to confirm a programmed dose outside the dosing limit, but after confirmation of the dose, he then reentered the same dose. In these cases, the dose alert acted as a double-

check system for the clinician.

Of the 122 dose alerts, seven clearly documented cases of potential dosing errors were averted that could've led to a significant patient event:

Case 1: Milrinone was programmed for 10 mcg/kg/min or more than 13 times the maximum dose range (dose range 0.38 to 0.75 mcg/kg/min), but after receiving an alert, was reprogrammed at 0.4 mcg/kg/min.

Case 2: Nesiritide was programmed at 1.1 mg/kg/hour or more than 36 times the maximum dose (0.01 to 0.03 mcg/kg/min). When the nurse exceeded the dose limits, the pump generated an alert, and the clinician reprogrammed the pump at 0.01 mcg/kg/min.

Case 3: Fentanyl was originally programmed at 5.36 mcg/kg/hr, then immediately decreased to 1 mcg/kg/hr after the dose alert.

Cases 4 and 5: Vasopressin was being administered for sepsis. Confusion in proper dosing of this drug has been noted at our institution. The most commonly used application at this time is supportive therapy for septic shock at a dose maximum of 0.04 units/min. Previously, vasopressin was used in severe gastrointestinal bleeding at a dose of 0.4 units/min. One averted error in dosing vasopressin would've been 2.5 times the maximum, and a second averted error would've been 10 times the maximum dose for sepsis (range 0.02 to 0.04 units/min).

Case 6: While the majority of oxytocin dose alerts didn't represent near misses, one dose alert did avert a potential error when a dose of 138.7 mU/min caused an alert and was corrected by the clinician. The remaining 17 oxytocin dose alerts occurred because the maximum limit for oxytocin was set too low (20 mU/min) when the drug library was initially programmed. Subsequently, the maximum limit was raised to 40 mU/min.

Case 7: The initial programmed heparin dose of 350 units/hr was below a therapeutic adult delivery rate as defined by our heparin protocols.

We also identified 10 limit-exceeding doses of insulin, four limit-exceeding doses of heparin, and seven limit-exceeding doses of cisatracurium. We felt these were associated with a practice of administering a bolus dose by increasing the rate of the pump without consistently setting a time or volume limit.

Dose alert frequency by medication

# Alerts	Medication	# Alerts	Medication
27	Propofol	3	Milrinone
18	Oxytocin	3	Nesiritide
14	Fentanyl	2	Nitroglycerin
10	Insulin	2	Diltiazem
7	Cisatracurium	1	Aminocaproic acid
7	Norepinephrine	1	Amiodarone
5	Epinephrine	1	Lidocaine
5	Heparin	1	Lorazepam
4	Esmolol	1	Magnesium
4	Furosemide	1	Nicardipine
4	Vasopressin	1	Phenylephrine

Findings

After reviewing the data, we found the following:

1. Not all dose alerts are near misses. Reviewing only data or logs that represent the "no" responses to doses programmed outside the limits doesn't tell the entire story. It's critical to review the operational logs or the events leading up to and after the dose alert to accurately determine whether a dose alert was a near miss or a therapeutic dose. Often, when our clinicians received an alert, they didn't confirm the dose initially, but upon checking the dose, they reprogrammed the pump for the same dose. If we'd looked solely at the number of dose alerts in which the dose wasn't accepted, we would've assumed we had a falsely higher incidence of averted errors.
2. Dose alerts serve as a double-check system. Even with the high incidence of exceeding dosing parameters with medications like propofol and fentanyl, we elected not to increase the maximum dosing parameters. The purpose of the dose alert feature remains a critical double check for our clinicians when dosing at such high levels.
3. Dosing limits improve patient safety. Our new infusion pumps have enabled our hospital to improve patient safety through the prevention of potential medication errors. Seven serious dosing errors were averted that could've led to significant adverse drug events (ADEs). Medication errors that result in ADEs result in an average increased length of stay of 4.6 days and cost approximately $4,700 per admission.[4] Therefore, averting these seven errors represents a

potential savings of $32,900 for our hospital in extended length alone, excluding the cost of treatment and potential liability. If we assume that the pumps we reviewed were indicative of all pump use at our hospital, we could extrapolate that we avoided costs of $338,000 over a year.

Next steps

The technology that sets dosing limits has enabled our hospital to be alerted to potential medication hazards. As a result of implementing these technologies and evaluating the data logs, we learned that some simple changes in our practice could immediately improve patient safety and staff efficiencies. We conducted education and training on best practices for loading dose and bolus therapies and the appropriate dose ranges for vasopressin.

Questions that warrant further exploration include:

1. Is there a relationship between the number of averted dosing errors and the shift or time of day? Weekend versus weekday? Time of year?
2. Is there a relationship between the number of averted dosing errors and the number of critical I.V. medications infusing simultaneously?
3. Are there times that errors occur when the nurse hits a dose limit and responds "yes?"
4. How will the use of pump-based bar coding affect results looked at in this study?

As we move forward with our safety improvement initiatives, the dose alert data we obtained from the pumps will serve as benchmark data for future quality improvement efforts and Joint Commission on Accreditation of Healthcare Organizations documentation. As part of our organizational commitment to safety and our role as a leader in the safe delivery of quality healthcare for our patients, we strive to identify and implement educational and practice improvement initiatives. M

References

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