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Original Article

Using Smart Pumps to Understand and Evaluate Clinician Practice Patterns to Ensure Patient Safety

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Abstract

Background: Safety software installed on intravenous (IV) infusion pumps has been shown to positively impact the quality of patient care through avoidance of medication errors. The data derived from the use of smart pumps are often overlooked, although these data provide helpful insight into the delivery of quality patient care.

Objective: The objectives of this report are to describe the value of implementing IV infusion safety software and analyzing the data and reports generated by this system.

Case study: Based on experience at the Carolinas HealthCare System (CHS), executive score cards provide an aggregate view of compliance rate, number of alerts, overrides, and edits. The report of serious errors averted (ie, critical catches) supplies the location, date, and time of the critical catch, thereby enabling management to pinpoint the end-user for educational purposes. By examining the number of critical catches, a return on investment may be calculated. Assuming 3,328 of these events each year, an estimated cost avoidance would be $29,120,000 per year for CHS. Other reports allow benchmarking between institutions.

Conclusion: A review of the data about medication safety across CHS has helped garner support for a medication safety officer position with the goal of ultimately creating a safer environment for the patient.

Key Words—intravenous infusions, medication safety, patient safety, smart pump

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Health care organizations must determine how to use clinical practice data to address routine clinical, business, and financial issues such as patient safety and quality outcomes. Risk resides with payers and providers, including hospitals, ambulatory care facilities, and physicians' private practices. It is likely that in the future providers will carry the burden of reporting on patients and managing a population's health. An Institute of Medicine report concluded that medical errors are mostly the fault of system failures rather than individuals.[1] Improvements in methods and technologies are useful tools for creating ''a culture of safety'' with the patient at the center.[1]

Safety software installed on intravenous (IV) infusion pumps has been shown to positively impact the quality of patient care through avoidance of medication errors. This decreased error rate also has been associated with cost savings, workflow improvement, and legal risk reduction.[2-4] Through the use of IV infusion pumps equipped with safety software (''smart'' or ''intelligent'' infusion pumps), many high-risk medications can be administered safely. There is evidence that by integrating IV infusion pumps with institutional information systems (eg, electronic medical records, barcode point-of-care, and computerized physician order entry), evidence-based standards could be applied to patient care, thereby increasing patient safety.[5]

Based on results from the *2011 ISMP Medication Safety Self Assessment for Hospitals*, about half of the respondents indicate that they use smart pump technology throughout the organization to intercept and prevent errors due to misprogramming or miscalculation of doses or infusion rates.[6] Another 25% of the hospitals

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use smart infusion pumps in some patient care units. However, this recent report reveals that preventable errors associated with the misprogramming of smart infusion pumps may still occur.

Many facilities have analyzed the impact of implementing smart IV infusion pump technology and have documented reductions in adverse drug event (ADE) rates based upon the reduction in the frequency of infusion rates thought to be associated with harm (ie, exceeding preset soft and hard dosing limits).[2-4,7] The Association for the Advancement of Medical Instrumentation (AAMI) has released a list of actions that hospitals can take to immediately improve medication infusion safety. These actions include ensuring that wireless capability is an essential requirement in purchasing decisions, maximizing the use of smart-pump features and capabilities, and analyzing and using the continuous quality improvement data generated by these infusion systems.[8] All of these recommendations were important in the selection of smart pumps for CHS.

The data captured and stored in smart infusion pumps provide useful analytical tools for evaluating clinical practices. Thorough analysis of these data can contribute to positive changes in practice. Organizations must have a plan for timely review of the data and how they will be used to improve medication safety throughout the facility.[5] The Institute for Safe Medication Practices (ISMP) held a summit to discuss the use of smart infusion pumps. ISMP's recommendations included the development of a multidisciplinary group to translate pump log data analysis to practice. ISMP stated that the information retrieved from the smart infusion pumps may not make sense until clinicians provide the contextual explanation of events revealed by the data.[9]

Although often overlooked, the data derived from the use of smart pumps provide a helpful insight into the potential pitfalls in the delivery of quality patient care. The purpose of this article is to show how analysis of the data and reports from the use of smart infusion pumps aids in understanding and evaluating clinician practice patterns.

CASE STUDY

CHS provides a full spectrum of health care and wellness programs throughout North and South Carolina with a diverse network of more than 650 care locations that include academic medical centers, hospitals, health care pavilions, physician practices, destination centers, surgical and rehabilitation centers, home health agencies, nursing homes, and hospice and palliative care. CHS is one of the nation's largest and most comprehensive systems, with more than 48,000 employees, more than 6,200 licensed beds (acute care and postacute care), and an annual budget exceeding $6.5 billion.

Carolinas Medical Center (CMC) is the largest facility in CHS. An advanced mainframe computer system, computerized physician order entry, and dispensing and robotic machines support medication distribution. Approximately 10,000 doses per day are dispensed from the pharmacy.

Decentralized clinical staff pharmacists are responsible for order verification, pharmacokinetic monitoring and consults, renal dosing, pharmacy interchanges (including IV to PO), and adverse drug reaction reports. In addition, clinical staff pharmacists in the main pharmacy are responsible for order verification for miscellaneous units, compounding, IV preparations, and drug information.

Pharmacists are responsible for assessing various drug therapies and pharmacy services to identify areas of improvement. Medication use evaluations are conducted as quality assessment projects designed to improve medication utilization. All pharmacists participate in the assessment and documentation of ADRs. Clinically significant ADRs are reported to the Pharmacy and Therapeutics (P&T) committee for a focused review.

Smart pump technology works best when accompanied by efforts to improve the safety culture of the hospital, the involvement of the health care team, and the collection of data to show clinicians that the tools actually work. Data collection and feedback are important, because clinicians are empowered by seeing success. Clinician empowerment is an extremely important pillar in creating a strong safety culture.[10] For these reasons, after deciding to purchase the Plum A^+ Pumps with MedNet (Hospira, Inc., Lake Forest, IL), CMC determined that it was important to have a dedicated pharmacy resource to collect and review data from the MedNet safety software program. This person would also be responsible for drug library maintenance and would act as a pharmacy liaison and resource for smart pumps. Initially, this was a single facility-level position that has since grown to support the smart pump drug library that serves multiple facilities.

To support the association between technology implementation and patient outcomes, data output from the infusion pumps are analyzed by quantity and types of alerts to end-users. Executive score cards are created utilizing this data (**Table 1**). The score card provides an aggregate view of compliance rate and number of alerts, overrides, and edits. Specific high-alert

Table 1. CMC executive score card from August 2011 through January 2012

Drug library compliance	No. of total programs	Total alerts	Overrides	Edits	Lower limit alerts	Upper limit alerts	Confirmed infusion	Edit at confirm screen
70.8%	413,078	30,979	26,690	5,083	3,780	27,199	410,482	2,596

Total alerts by drug and top high-alert medications

Drug/concentration	Total programs	Alerts	% Alerts to programs	No. of overrides	No. of edits
Morphine	1,413	408	28.9	393	15
Fentanyl	3,799	689	18.1	680	17
Benzodiazepines (*Ativan*, *Versed*)	3,476	519	14.9	455	64
Heparin	8,021	754	9.4	508	246
Vancomycin	11,590	906	7.8	267	639
Propofol 1,000 mg/100 mL	17,007	1,031	6.1	943	88
Insulin	17,320	966	5.6	915	51

Note: CMC = Carolinas Medical Center.

medications, such as heparin, insulin, and propofol, may be added to the score card for additional review and evaluation. **Table 1** shows that the overall alert rate was 7.5% (30,979/413,078), which is equivalent to approximately 5,163 alerts per month or 172 per day. This represents a large number of alerts when one considers all of the other technologies that have alerts such as monitors, beepers, and so on. The proportions of lower and upper hard limit alerts were 12% (3,780/30,979) and 88% (27,199/30,979), respectively. Of the total alerts, 84% (26,690/30,979) were overridden by the end-user, and 16% were edited to comply with established acceptable rates.

Even in hospitals with strong safety cultures, preventable mistakes occur and the potential for serious errors is widespread. **Table 2** displays examples of serious errors that were averted due to the smart infusion pump technology (ie, critical catches). This information supplies the location, date, and time of the critical catch, thereby enabling nursing management to pinpoint the end-user for educational purposes. Examination in detail of the individual alerts and edits provides strong support of the effectiveness of the safety software in changing end-user behaviors to more appropriate and safer infusion administration. These critical catches are shared at an administrative and nursing unit level.

Cost Avoidance

By examining the number of critical catches, a return on investment (ROI) may be calculated. A total of 1,664 potential serious errors averted due to smart pump technology were documented in a 6-month period at CMC. Medication errors are costly to patients, families, employers, hospitals, health care providers, and insurance companies. One study found that each preventable ADE that took place in a hospital added about $8,750 (in 2006 dollars) to the cost of the hospital stay.[11] Assuming 3,328 of these events each year, an estimate of cost avoidance would be $29,120,000 per year. For other institutions, considering the annual cost of salary/benefits for one pharmacist is estimated at $125,000, the high ROI achieved may be used to justify additional pharmacist staff, even in this era of cost reductions.[12] The savings gained through use of this program may also be used to expand safety and clinical patient programs.

Analysis of Smart Pump Data Reports

Implementation of smart infusion pump technology promotes a safer patient environment by averting IV programming errors and other causes of infusion-related medication misadventures. Actionable data and reports are generated through use of this technology, which were previously unavailable. These reports can play a critical role in continuous quality improvement in medication use.[3]

The smart infusion system collects data from which various reports can be created to provide insight into clinical practice, such as:

- Compliance rate of utilizing the intelligent infusion software
- Identification of medication doses frequently overridden

Table 2. Examples of top critical catches

CCA name	Medication/ concentration	Alert date and time	Limit	Initial dose	Final dose	Variance
Adult ICU	Vancomycin 1,000 mg/250 mL	8/29/2011 12:14	1.25 g/h	251 g/h	1 g/h	10,000%
Adult ICU	Amiodarone 900 mg/500 mL	8/11/2011 21:52	15 mg/min	2,020 mg/min	1 mg/min	10,000%
Adult ICU	Nitroprusside 100 mg/250 mL	9/22/2011 21:25	11 mcg/kg/min	2,525 mcg/kg/min	10 mcg/kg/min	10,000%
Adult ICU	Vasopressin 40 units/250 mL	3/8/2011 15:58	0.4 units/min	220.04 units/min	0.04 units/min	10,000%
Cardiac Unit	Dopamine (renal) 400 mg/250 mL	10/3/2011 23:11	4 mcg/kg/min	544 mcg/kg/min	4 mcg/kg/min	10,000%
Cardiac Unit	Diltiazem 1 mg/1 mL	12/8/2011 10:09	25 mg/h	2,505 mg/h	5 mg/h	9,920%
Adult ICU	Lorazepam 1 mg/1 mL	11/17/2011 15:11	120 mg/h	9,993 mg/h	3 mg/h	8,227%
Adult ICU	Dobutamine 500 mg/250 mL	11/20/2011 17:55	40 mcg/kg/min	2,003 mcg/kg/min	3 mcg/kg/min	4,907%
Adult ICU	Milrinone 40 mg/200 mL	9/11/2011 18:10	0.75 mcg/kg/min	22.22 mcg/kg/min	0.22 mcg/kg/min	2,862%
Adult ICU	Nicardipine (peripheral) 0.1 mg/1 mL	9/25/2011 7:16	15 mg/h	404 mg/h	4 mg/h	2,593%
Adult ICU	KCL (central) 10 mEq/100 mL	9/27/2011 7:32	40 mEq/h	1,022 mEq/h	20 mEq/h	2,455%
Adult ICU	Dobutamine 500 mg/250 mL	10/1/2011 2:53	40 mcg/kg/min	866 mcg/kg/min	6 mcg/kg/min	2,065%
Adult ICU	Insulin 250 units/250 mL	1/17/2012 14:30	50 units/h	404 units/h	4.4 units/h	708%
Adult ICU	Heparin PROTOCOL 25,000 units/250 mL	9/12/2011 0:12	5,000 units/h	40,000 units/h	400 units/h	700%
Adult ICU	Propofol 1,000 mg/100 mL	1/7/2012 17:52	83 mcg/kg/min	555 mcg/kg/min	60 mcg/kg/min	568%
Adult ICU	Midazolam 100 mg/100 mL	10/9/2011 2:51	15 mg/h	100 mg/h	8 mg/h	566%
Adult ICU	Nitroglycerin 50 mg/250 mL	11/26/2011 7:44	400 mcg/min	2,523 mcg/min	23 mcg/min	530%
Adult ICU	Nicardipine (central line) 125 mg/250 mL	12/2/2011 6:35	15 mg/h	93 mg/h	3 mg/h	520%
Adult ICU	Fentanyl 2,500 mcg/250 mL	11/7/2011 9:36	200 mcg/h	400 mcg/min	100 mcg/min	100%

Note: CCA = clinical care area; ICU = intensive care unit.

- Practice trends
- Prevalence of errors sorted by units and medications
- Medications associated with the critical catches

The system provides an ongoing means of evaluating and upgrading a hospital's performance and impact on patient safety. Regular evaluations by nurse administrators, pharmacy and risk management staff, the drug library task force, P&T committee, or a combination of personnel are essential to determine how to make the most of the information gathered.

One way these data may be used is through analysis of the total alerts generated by the smart infusion pump technology over a specified time period. By analyzing these data at CMC, it was clear that the

Table 3. Benchmarking upper hard limits (UHL) with other portal entries

Medication	% Portal entries with UHL
Sodium chloride 3%	86%
Insulin	79%
Lepirudin	72%
Esmolol	69%
Bivalrudin	67%
Propofol	57%
Labetolol	56%
Vecuronium	54%
Isoproterenol	43%
Norepinephrine	39%
Morphine	38%
Fentanyl	37%
Phenylephrine	36%
Epinephrine	34%
Cisatracurium	32%
Epoprostenol	25%

majority of alerts were due to IV fluids. This is concerning because the alarm systems on these devices can also contribute to the occurrence of adverse events. Alarm-related adverse incidents may result from a variety of factors including alarm fatigue, in which staff become overwhelmed by the number of alarms and thus become desensitized. This can lead to missed alarms or delayed alarm response.[9,13] Alarm fatigue can also cause staff to act inappropriately by adjusting alarm limits outside the safe range to reduce the number of alarms or by turning down the volume of alarms to an inaudible level in an attempt to reduce alarm fatigue and reduce stress on the patient and family.[13] Because of information collected, we determined that it was important to increase the upper soft limit of IV fluids from 250 mL/h to 500 mL/h and thereby decrease the most common clinically insignificant alerts in our data.

These data are also useful in their benchmarking capabilities. This program provides insight into how the upper and lower hard limits at CMC compare with other institutions (**Tables 3** and **4**). After reviewing the benchmarking data, we identified the need and opportunity to add hard limits to our library's esmolol and labetalol entries. Since adding these limits, we have identified several significant critical catches, highlighted in **Table 5**.

We continue to look for opportunities to connect these changes to patient outcomes. At CMC, the current electronic connection for the pumps is not patient specific. Therefore patient-specific events are difficult to link to the drug library data. The assumption is that increasing compliance with the use of the library and implementing tighter controls, such as hard limits, positively impact patient safety. This is often demonstrated by a review of the data on edits of high-risk drugs and prevention of unsafe infusion rates.

Updating the Smart Pump Library

After implementing the smart pump technology, the drug library data will need to be updated at regular intervals.[2,3] Examples of updates include increasing or decreasing the number of concentrations of a single drug, adding new medications, or making changes in dosing limits. CHS has adopted a standardized update checklist that has proven to be valuable (**Table 6**).

A specific example of how CHS has used the smart pump data reports to improve patient safety is vancomycin infusions. Vancomycin is considered a high-risk drug due to its adverse drug reactions associated

Table 4. Benchmarking limits with other portal entries

Percent of CCA entries with limit	Carolinas HealthSystem	Safety software portal database
Lower hard limit	3% (42/1,259)	7% (13,606/188,236)
Lower soft limit	70% (878/1,259)	45% (84,474/188,236)
Upper soft limit	78% (981/1,259)	70% (131,795/188,236)
Upper hard limit	40% (506/1,259)	53% (99,585/188,236)

Note: CCA= clinical care area.

Table 5. Esmolol and labetalol critical catches

Esmolol edits						
CCA	**Medication/concentration**	**Limit**	**Limit violated**	**Initial dose**	**Final dose**	**Variance**
ICU	Esmolol 2 g/100 mL	300 mcg/kg/min	Upper hard	1,005 mcg/kg/min	100 mcg/kg/min	235%
ICU	Esmolol 2 g/100 mL	300 mcg/kg/min	Upper hard	101,515 mcg/kg/min	20 mcg/kg/min	10,000%
ICU	Esmolol 2 g/100 mL	300 mcg/kg/min	Upper hard	1,002 mcg/kg/min	225 mcg/kg/min	234%
ED	Esmolol 2 g/100 mL	300 mcg/kg/min	Upper hard	1,009 mcg/kg/min	90 mcg/kg/min	236%
ICU	Esmolol 2 g/100 mL	300 mcg/kg/min	Upper hard	9,060 mcg/kg/min	60 mcg/kg/min	2,920%
ICU	Esmolol 2 g/100 mL	300 mcg/kg/min	Upper hard	500 mcg/kg/min	50 mcg/kg/min	66%
ICU	Esmolol 2 g/100 mL	20 mcg/kg/min	Lower soft	15 mcg/kg/min	150 mcg/kg/min	-25%
ICU	Esmolol 2 g/100 mL	300 mcg/kg/min	Upper hard	250,202 mcg/kg/min	200 mcg/kg/min	10,000%
Labetalol edits						
CCA	**Medication/concentration**	**Limit**	**Limit violated**	**Initial dose**	**Final dose**	**Variance**
ICU	Labetalol 500 mg/100 mL	8.1 mg/min	Upper hard	102 mg/min	2 mg/min	1,159%
ICU	Labetalol 500 mg/100 mL	8.1 mg/min	Upper hard	10 mg/min	0.18 mg/min	23%
ICU	Labetalol 500 mg/100 mL	8.1 mg/min	Upper hard	10 mg/min	8.1 mg/min	23%

Note: CCA= clinical care area; ED = emergency department; ICU = intensive care unit.

with rapid infusion. Before the most recent update, vancomycin was listed in the drug library without specific concentrations (_mg/_mL). Reports showed that nurses sometimes programmed the concentration incorrectly. They would mistakenly program the dose in milligrams instead of grams, triggering the lower soft limit of 0.25 g/h. A pump misprogrammed in milligrams instead of grams can result in a 1,000-times disparity. Due to the pharmacotherapeutic and pharmacokinetic profile of vancomycin, adult doses can range from 750 mg to 2,000 mg, and volumes of fluid may differ by hundreds of milliliters. Because the smart pumps service multiple facilities, a multistep approach was needed to standardize vancomycin preparation and administration at CHS facilities and in the drug library. Pharmacists from multiple facilities agreed that vancomycin prepared at a CHS facility would (a) be rounded to the nearest 250 mg, (b) be prepared in a specific volume dependent on the dose, and (c) be administered at a maximum of 1 g/h. These 3 decisions allowed the CHS drug library task force to approve specific vancomycin entries with upper hard limits and eliminate vancomycin _mg/_mL from the library. This decision improved vancomycin infusion safety at CHS. Utilization of the smart pump data allowed CHS to identify a problem and use a systemwide approach to improve patient safety.

CHS has created an intravenous medication guidelines document. This is a stand-alone reference that is a driving force to support uniform medication usage across multiple facilities and care units. It was developed and is routinely updated by the P&T committee process at all facilities. This document allows us to create medication entries within the clinical care areas of the smart pump drug library that support multiple facilities across the entire health care system. Examples from these guidelines are highlighted in **Table 7**.

DISCUSSION

Findings from a recent study validated concerns raised by patient-safety experts in the United States and Europe that harm resulting from medical care remains very common.[14] At CHS, we are working to improve the safe use of medications through multiple pathways. Current processes include the addition of a system medication safety officer position, which was justified by calculating the ROI of the IV infusion safety software program. The position was created to spearhead the development of a systemwide medication safety program. This effort is in its first year of development and is dependent on the system quality tools. A medication safety council includes representatives from all CHS hospitals and outpatient pharmacy, long-term care, and ambulatory clinics. Monthly meetings of this group focus on the regular review of data to frame medication safety projects. The intent of the CHS quality groups called Quality and Safety Operational Councils (QSOCs) is to harness the good work happening at each facility and adopt it across CHS. The identification of

Table 6. Smart pump infusion update checklist

Infusion Library Preparation

- Pharmacy and Smart Pump Library Task Force review entries and reports for opportunities.
- New medications, changes, updates, and deletions are catalogued for discussion. The changes are approved by the Task Force.
- Recommended changes are shared at all facilities within the Pharmacy and Nursing groups.
  - Pharmacy process:
    - Ensure all changes are in line with the Intravenous Medication Guidelines and medication order entry complexes.
    - Discuss changes at the acute care clinical pharmacy meeting and with the pharmacy leadership team.
    - Use the Pharmacy & Therapeutics Committees at affected facilities to review and endorse changes.
- Once library changes are finalized, the library materials are shared with the Nurse Education Committee for development of materials for nursing roll-out to be completed prior to planned library update.
- The Drug Library Task Force (a group of nurses responsible for library review and approval), Pharmacy, and Clinical Engineering work together to determine a date for the update.
- Final library check is completed:
  - Attendance at Task Force meeting is mandatory. If unable to attend, an alternative person must be sent. All approval changes will require validation of upcoming changes by Clinical Care Area representatives.
  - Task Force to meet at least 2 times before changes are implemented.
  - When changes are entered into the library a double verification process occurs within the Pharmacy.

Infusion Pump Drug Library Update

- Pharmacy, Nursing, and Clinical Engineering work to coordinate the date for the update.
  - Clinical Engineering and Information Services push the library to the server and provide an updated library file to be posted on the Nursing Sharepoint Site.
  - Clinical Engineering controls process of identifying and performing the updates.
  - Pharmacy makes changes and communicates them across the facilities.
  - Nursing supports the update process.
- Communication continues until the update is complete.

Post Drug Library Update

- Any issues identified during the update are taken to the Task Force and Pharmacy.
- All staff monitor new library for issues or the need for changes.

new sources of data and opportunities to standardize processes are key success strategies for improvement. Many of the CHS facilities have the Plum A+ pump as the primary infusion pump for patient care. Much of the effort to improve has focused on the development of the intravenous medication guidelines (**Table 7**) across the 8 facilities. These guidelines enable the multiple facilities in CHS to use the same drug library. Most of the workload required for standardization of concentration, volume, monitoring, and other details is invested in the update and approval of the intravenous medication guidelines. Once the guidelines are updated, it will be much easier to set standard library limits.

Differing practices, concentrations, and types of patients create the need for increased communication and careful planning to ensure the library will support each facility in the best way. Moving forward, the medication safety councils will provide a platform for discussion of key issues, such as which drugs need to be in which clinical care areas, standard concentrations, and hard and soft limits. The medication safety officer's role and responsibility for all CHS facilities will be a nice driver for the application of the data for all the patients in the system. Best practice can be identified and spread in a more expedient manner.

There is the opportunity for reports to be generated at each facility to determine a complete route for the process. Currently the decisions are made from the reports generated from use of the pumps on the server at CMC. There are 4 additional servers across the 8 facilities, allowing for more specific data to be generated. Data can help to make the infusion library safer and increase the ease of programming for nurses as they interface with the devices. In our case, these data provide another opportunity to identify possible sources of harm. The system medication safety officer and smart pump pharmacy liaison meet regularly to discuss the data, recommend changes to the library,

Table 7. CHS intravenous medication guidelines (selected examples)

Medication	Usual adult dose and rate	A	B	C	D	E	F	G	Comments and precautions
Fosaprepitant (*Emend*)	150 mg IV over 20 to 30 minutes	150 mg/ 150 mL NS	NA	+	+	+	+	+	▪ Immediate hypersensitivity may occur during infusion. Per the manufacturer, patients generally respond to discontinuation and it is not recommended to reinitiate infusion
Lacosamide (*Vimpat*)	Initial dose: 50 mg IV bid titrated weekly up to 200 mg IV bid	All doses/ 50 mL NS	NA	+	+	+	+	+	▪ IV therapy may be substituted on a mg-per-mg basis for patients who are temporarily unable to receive oral therapy. ▪ Infuse over 30 to 60 minutes. ▪ Maximum dose of 400 mg/day (300 mg/day recommended for patients with CL_{cr} ≤30 mL/min). ▪ May cause dose-dependent PR interval prolongation; consider an EKG prior to initiation and following titration to steady state for patients with cardiac conduction problems.
Nitroglycerin	5-200^{+} mcg/ min	50 mg/250 mL D5W (glass only)	100 mg/250 mL D5W (glass only)			+ (no titration	+ (no titration)	+	▪ Monitor BP, HR ▪ Titrating: Adjust rate by 5 mcg/ min every 5 min up to 20 mcg/ min; if no response, increase by 10 mcg/min every 5 min. ▪ Weaning: Reduce rate by 5 mcg/ min every 5 min.
Rasburicase (*Elitek*)	4.5 mg IV ONCE over 30 minutes	All doses in 50 mL NS	NA	+	+	+	+	+	▪ Contraindicated in patients with known glucose-6-phosphate dehydrogenase deficiency. ▪ Uric acid blood sample collection after administration of rasburicase must be collected in a pre-chilled tube, placed on ice, and run within 4 hours of sample collection.

Note: Heading abbreviations: A = standard concentration; B = fluid restriction concentration; C = medical/surgical/ rehab bed; D = monitored (noncardiac unit); E = monitored (cardiac unit); F = progressive care bed; G = emergency department, intensive care unit, postanesthesia care unit bed. bid = twice daily; BP = blood pressure; CHS = Carolinas HealthCare System; CL_{CR} = creatinine clearance; D5W = 5% dextrose in water; HR = heart rate; IV = intravenous; NA = not applicable; NS = normal saline.

and look for opportunities to improve patient safety. This connection is a key part of the development of a CHS-wide medication safety program. The executive scorecard and other reports from the database also provide key input to the medication safety program at CHS.

CONCLUSION

The quality of patient care is increased through the use of safety software installed on IV infusion pumps to prevent medication errors. By analyzing the data and reports generated by this software, CHS has been able to provide an additional level of safety to its patients and garner support for a medication safety officer position. An estimate of cost avoidance due to the IV infusion pumps was calculated to be approximately $30 million per year for CHS.

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