INTEGRATION OF SMART INFUSION PUMPS WITH ELECTRONIC MEDICAL RECORD REDUCES POTENTIALLY CATASTROPHIC MEDICATION DOSING ERRORS

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ABSTRACT

BACKGROUND

'Smart' infusion pumps with built in dose error reduction software (DERS) containing hard and soft limits on prescribing ranges have in retrospect been found to eliminate only some of the medication errors associated with intravenous infusion.[1]

In order to optimize "5 rights" compliance, a greater level of smart pump integration enabling error checking and redundancy at all the contact points in the workflow is required.

Intravenous automated programming (IVAP) that enables the physician order, the medication, and the patient to be verified via barcode scanning at the point of care requires clinical integration of infusion devices with the EMR (CIDER).

OBJECTIVE

The purpose of this study was to determine the impact of CIDER on reducing serious, preventable medication errors, as classified by The National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP) Medication Error Index. Furthermore, we were interested in the impact of CIDER in increasing Drug Library compliance and reducing variability of practice in programming infusion pumps.

CASE STUDY

From January 2013 to February 2014, there were 512,636 programming sequences recorded across three hospitals, 224,763 (44%) during the pre-integration period and 287,873 (56%) during the post-integration period.

CONCLUSION[2]

Incidence of potentially catastrophic dosing errors (PCDEs) across the combined group of three hospitals decreased after CIDER by 52%, from 7.1 errors per 1000 programs to 3.3 per 1000 programs, P<0.001 (Table 1). **Increase in compliance with Drug Library was 156%** between the pre- and post-integration integration periods for combined group of three hospitals from 20% to 51%, P<0.001 (Table 2). Analysis over time shows a clear pivot in both results corresponding to CIDER "Go-live" and is sustained after integration.**Variability in the severity of individual PCDEs also displayed a large and statistically significant reduction.**

All three of these metrics improved at each individual hospital.

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INTRODUCTION

Medication errors associated with intravenous infusion remain a serious threat to patient safety in spite of numerous interventions to reduce their incidence. In order to assure patients receive the right drug in the correct dose by the intended route for the appropriate period of time, a greater level of integration of the infusion device with its environment is needed.

'Smart' infusion pumps with built in dose error reduction software (DERS) containing hard and soft limits on prescribing ranges have in retrospect been found to eliminate only some of the medication errors.[1]

Safer infusion therapy demands error checking and redundancy at all the contact points in the workflow, starting with the physician's order in the electronic medical record (EMR) to the pharmacy where the drug is compounded, converging at the point of care where the provider administers the drug via the device.

Intravenous automated programming (IVAP) allows the physician order, the medication, and the patient to be verified via barcode scanning at the point of care and requires clinical integration of infusion devices with the EMR (CIDER).

Although CIDER can be initially complex and requires resources to support, healthcare facilities agree that it improves patient safety by eliminating potential for human error, and encourages drug library compliance, the use of Barcode Medication Administration Systems (BCMA), and the standardization of nurse workflows.[3] In this study, our primary outcome of interest was the impact of CIDER on reducing serious, preventable medication errors, as classified by The National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP) Medication Error Index.[4]

Furthermore, we were interested in the impact of CIDER in increasing Drug Library compliance and reducing variability of practice in programming infusion pumps.

METHODS

This study took place at three community hospitals with approximately 50, 150, and 350 beds where a Cerner Millenium™ EMR was integrated with Hospira Plum A+® infusion pumps (Model #20792, Hospira MedNet® safety software rev 5.81) from January 1, 2013 to February 1, 2014, and was restricted to the following clinical areas: Cardiovascular ICU, ICU, Neuro Critical Care, MedSurg, Obstetrics, Oncology, and Progressive Care Unit (PCU).

We retrospectively analyzed infusion pump programming records before and after integration of infusion pumps with the EMR to measure the impact of CIDER on incidence of PCDEs. We defined PCDEs as initial programmed doses/rates of intravenous medications considered 'High Alert' medications[5] by the Institute of Safe Medication Practices (ISMP) that were either 100% greater than or 50% less than the final programmed doses/rates.

We hypothesized that these errors were likely to cause patient harm or require medical intervention to preclude harm if undetected. As such, the NCC MERP Medication Error Index would classify these events as 'D' through 'I'.[4] As a secondary outcome, we chose to measure pre- and post-integration compliance with use of the Drug Library (as an opt-in step) when programming the Plum A+ infusion pump. Hospira MedNet safety software includes a Drug Library which is custom built for each Clinical Care Area (CCA) and is standardized as a single drug library across all three of the hospitals studied. Use of a DERS has been shown to reduce medication errors and improve patient safety.[6] If the provider does not choose to opt in to Hospira MedNet when manually programming the Plum A+, that action was deemed 'noncompliant'.

The workflow during the study was as follows. During the pre-integration period, the provider retrieved the physician's medication order from the electronic Medication Administration Record (eMAR) and programmed the infusion pump manually, including patient weight, drug, dose, rate and volume to be infused at the point of care. Compliance with Hospira MedNet® safety software was counted when the provider selected a medication from the Drug List for that infusion. Subsequent programs for that infusion, such as titrations, were also counted as compliant with Hospira MedNet. If the provider bypassed the Drug List, that infusion and subsequent titrations would be noncompliant with Hospira MedNet®.

Post-integration, the provider ensures the "Five rights" verification (right patient, medication, dose, time, route) by signing into the eMAR, and by scanning the barcode on the patient, the medication, and the appropriate pump channel (primary or secondary). The completed order is displayed on the pump and the provider confirms and starts the infusion. **(Figure 1).**

Smart Pump-EMR Integration Workflow Overview

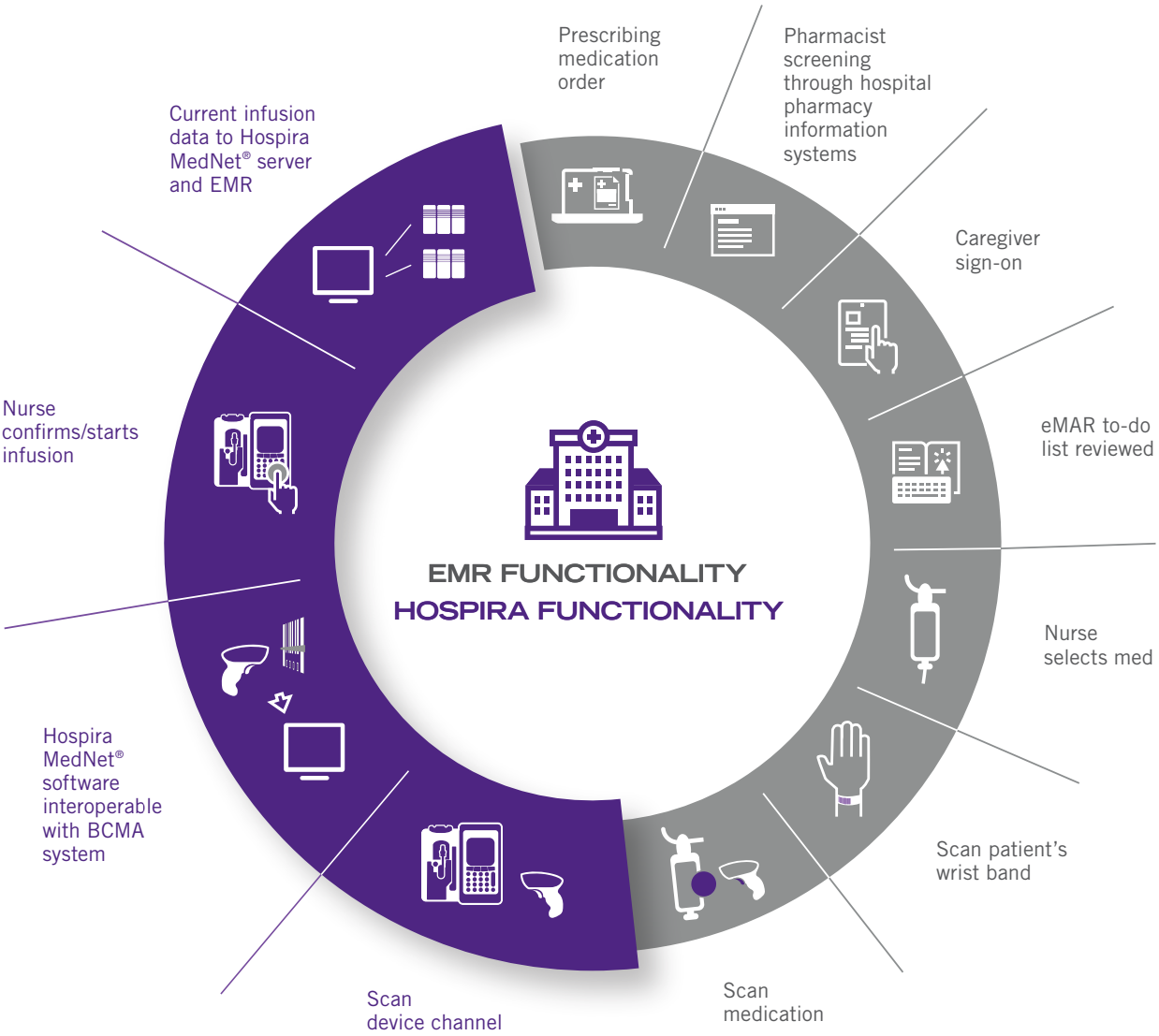

Figure 1. Clinical Workflow in smart pump-EMR integrated environment

This workflow allows the physician order detail, including the fluid/medication and concentration, dose/rate, and volume to be infused (VTBI) to flow from the CPOE through the pharmacy verification process, and on to the point of care where it is automatically programmed on the pump via the barcode scanning process. The drug library alignment process is collaborative and involves the pump vendor (Hospira), the EHR vendor (Cerner), and the hospital pharmacy team. Depending on the degree of alignment required and the availability of resources, it typically takes 3-5 months and includes several rounds of testing, including connectivity and communication between the EMR system and Hospira infusion pumps.

Prior to the 'Go-Live' date, a clinical readiness and impact assessment of IV therapy clinical nursing and pharmacy practice conducted by Hospira Clinical Services identifies variations in clinical practice as well as opportunities for standardization of infusion therapy workflow.

The goal of the assessment is to increase quality of care by reducing variability in infusion therapy clinical practice. This process typically takes two to four weeks and includes a written report on the findings.

All unique Hospira MedNet® Drug Library entries are tested prior to go live to ensure optimization of the integration through verification of required workflows and accuracy of clinical documentation.

STATISTICAL ANALYSIS

Statistical analysis was performed using Minitab® v17 and Microsoft® Excel® 2010. Decrease in the incidences of potentially catastrophic programming errors and increase in compliant programming before and after CIDER were compared for the cohort of hospitals individually and combined using a test for two proportions. Statistical significance was determined using Fischer's Exact Test.

RESULTS[2]

Incidence of PCDEs across the three hospitals combined decreased after CIDER by 52%, from 7.1 errors per 1000 programs to 3.3 per 1000 programs, P<0.001 (Table 1). **Increase in compliance with Drug Library was 156%** between the pre- and post-integration periods for all three hospitals combined from 20% to 51%, P<0.001 (Table 2). **Variability in the severity of individual PCDEs also displayed a large and statistically significant reduction.**

All three of these metrics improved at each individual hospital.

When analyzing data month by month over the study period, **the reduction in PCDEs clearly pivoted around the "Go-live" date and is sustained after integration.**

Potentially Catastrophic Dosing Errors

Programs Pre- vs. Post-CIDER[2]

	Potentially Catastrophic Dosing Error Rate/1000 Programs Pre- vs. Post-CIDER			
	PCDE Rate per 1000 programs			
	Pre-Integration	Post-Integration	Percent Change in PCDE Rate	Pre-Integration vs Post-Integration PCDE Rate
FACILITY 1	9.5	2.6	-73%	p<0.001
FACILITY 2	6.8	3.6	-48%	p<0.001
FACILITY 3	5.3	3.4	-37%	p=0.08
COMBINED ALL*	7.1	3.4	-52%**	p<0.001

* Overall rate including all 3 facilities

**Calculated as (Post-CIDER PCDE rate per 1000 programs – Pre-CIDER PCDE rate per 1000 programs/Pre- CIDER PCDE rate per 1000 programs] x 100

Table 1. Pre- and post-smart pump-EMR integration potentially catastrophic dosing errors (per 1000 programs).

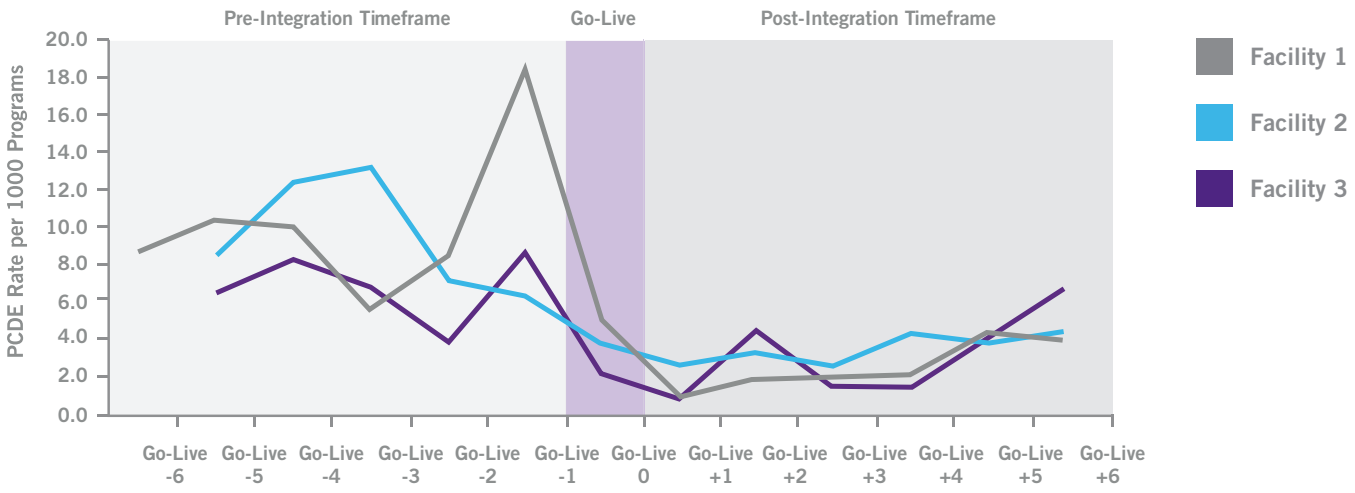

Figure 1. Pre- and post-smart pump-EMR integration potentially catastrophic dosing errors (per 1000 programs).

Hospira MedNet Drug Library Compliance

Pre- vs. Post-CIDER[2]

	Hospira MedNet Drug Library Compliance Pre- vs. Post-CIDER[2]				
	PRE-INTEGRATION		POST-INTEGRATION		
	Number of DL Programs	Drug Library Compliance	Number of DL Programs	Drug Library Compliance	Pre- IVCI vs Post-IVCI Drug Library Compliance
FACILITY 1	7,650	16.9%	24,885	51.5%	p<0.001
FACILITY 2	32,449	19.8%	111,248	51%	p<0.001
FACILITY 3	5,080	31.8%	11,927	56.2%	p<0.001
	Number of DL Programs	Drug Library Compliance	Number of DL Programs	Drug Library Compliance	Percent Change
COMBINED*	45,179	20.1%	148,060	51.4%	156%**

*Calculated as [(# Combined Compliant Programs/# Combined Total Programs) x 100]

**Calculated as [(Post-CIDER Combined % Compliance – Pre-CIDER Combined % Compliance)/Pre-CIDER Combined % Compliance] x 100

Table 2. Pre- and post-smart pump-EMR integration **compliance** with Drug Library.

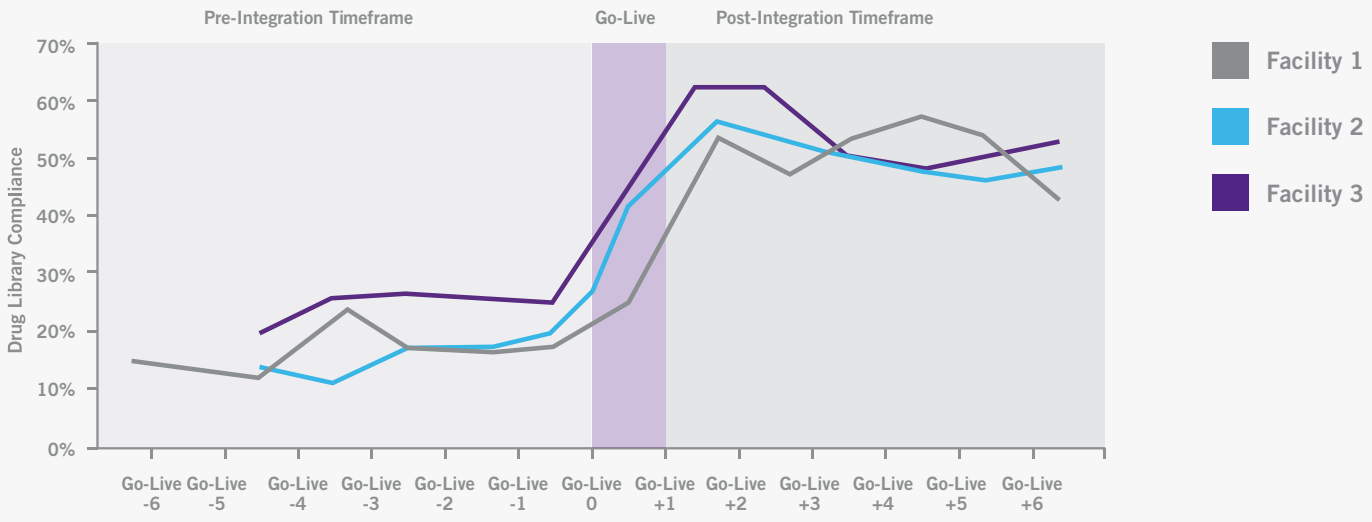

Figure 2. Pre- and post-smart pump-EMR integration **compliance** with Drug Library.

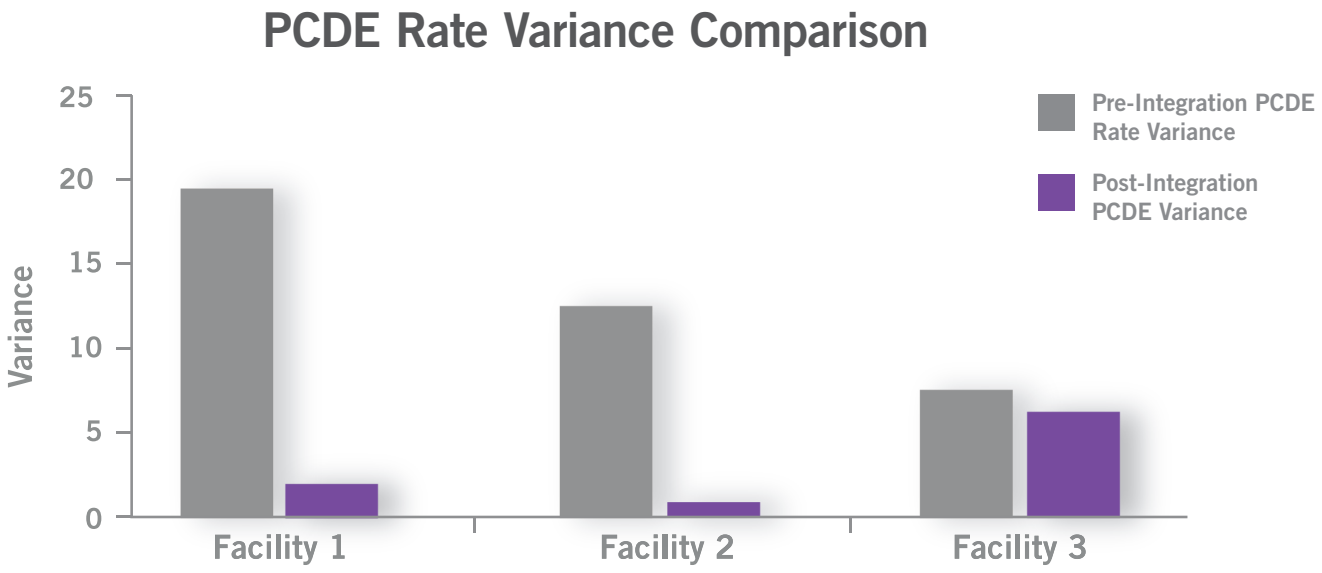

Figure 3. Pre- and post-smart pump-EMR integration PCDE rate variance.

DISCUSSION

Our analysis of programming behavior demonstrates a significant ($p<0.001$) and consistent decrease in the rate of potentially catastrophic programming errors after smart pump-EMR integration. In addition, our data confirms previous work from Prusch and others that integration of infusion devices with the EMR improved compliance with Drug Library use.[6,7]

These improvements are equally significant and sustained in the large hospital as in the two smaller hospitals. Both the reduced range of variance of PCDEs and the narrower confidence intervals in the post-integration data demonstrate that variability in programming is greatly reduced after integration. Reducing variability in practice is an objective for improving the quality of healthcare, as it has also been in other industries.

The safety gains of smart pump-EMR integration address historical infusion risks, including differences between hospitals in how medications are ordered, processed in a hospital pharmacy, and ultimately delivered to a patient. For example, a physician may order a medication in a certain concentration but the pharmacy may fill the prescription at a different concentration for any variety of reasons, e.g., availability and cost. If the nurse fails to notice the difference in the concentrations, an incorrect infusion may be manually programmed into the pump. The barcode scanning process at the point of care provides "Five Rights" verification and mitigates this risk. 'Work-arounds' and idiosyncrasies of workflow in hospitals, units, or practitioners also plays a role in practice variation. Nurses routinely reduce VTBI by 50-100 mL or shorten the duration of the infusion to only 1-2 hours to encourage more frequent assessment of the infusion. Manual admixing of medications still occurs at the unit level by nurses, as does syringe delivery of unit doses.

Both the reduced range of variance of PCDEs and the narrower confidence intervals in the post integration data demonstrate that variability in programming is greatly reduced after integration.

With the implementation of smart pump technology, hospitals are able to better define safety parameters for IV medications. Analysis of the data can provide insight into current processes and actionable items to be included in CQI initiatives.

Sustainability must be carefully considered. Because manual programming should remain an option and is occasionally necessary, end user involvement in the development of process improvements will be critical to successful clinical adoption of the integration.

There are several reasons CIDER did not improve compliance beyond the mid-fifties with use of the Drug Library. There were fluids and medications that were out of scope, such as boluses, blood products and banana bags. Programming of infusions during emergencies such as code blue and rapid response calls was often done manually. In addition, our methodology counted manual titrations to a 'noncompliant' infusion as separate non-compliant events, reducing the overall compliance numbers. Lastly, when use of the Drug Library is optional for manual programming, it is imperative that clinical leadership drive and communicate the expectation that the Drug Library be used for all infusions. In our study, there was an integration learning curve for both leadership and frontline providers, which is not atypical in adoption of new technologies.

There are several limitations in this data set and its interpretation. This study was not a prospective, randomized controlled trial of patient outcomes but a pre- and post-intervention design, which is susceptible to bias.

We were unable to determine programming errors for programming episodes where the Drug Library was not selected, as these 'noncompliant' data entries could not be recovered in the data stream. Thus we were only able to demonstrate that CIDER reduced potentially catastrophic programming errors in the subset of events that was compliant with use of the Drug Library. Although this proportion of programming episodes increased significantly after integration and the proportion of catastrophic errors in this subset was reduced, we cannot conclude the overall number of catastrophic errors was reduced since we had no visibility to the noncompliant proportion of programming events either before or after integration.

We chose to include ISMP High Alert drugs in the medication set most likely to cause harm and affect the NCC MERP classification. However, there are intravenous medications not included in this set that may cause harm, and not every programming error with a high alert drug will lead to harm.

In conclusion, this study adds to the body of evidence that clinical integration of the EMR with infusion devices may offer patient safety advantages and simplify provider workflow. Additional longitudinal studies are needed to confirm these results.

KEY WORDS

- **Medication safety**
- **Adverse drug events**
- **Infusion pump**
- **Smart pump-EMR integration**
- **Human factors**

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