Intravenous Smart Pump Drug Library Compliance: A Descriptive Study of 44 Hospitals

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Background: Although intravenous (IV) smart pumps with built-in dose-error reduction systems (DERS) can reduce IV medication administration error, most serious adverse events still occur during IV medication administration. Sources of error include overriding DERS and manually bypassing drug libraries and the DERS.

Methods: Our purpose was to use the Regenstrief National Center for Medical Device Informatics data set to better understand IV smart pump drug library and DERS compliance. Our sample consisted of 12 months of data from 7 hospital systems, 44 individual hospitals, and descriptive data from the American Hospital Directory (AHD) for 2015. The aims of the study were (1) to determine whether there are differences in IV smart pump drug library compliance between hospital systems and (2) to provide a broad descriptive overview of relevant trends related to IV smart pump compliance.

Results: For aim 1, we found 3 significant relationships among the 7 hospital systems: systems 3 ($P < 0.001$), 6 ($P = 0.003$), and 7 ($P = 0.002$) had significantly higher IV smart compliance as compared with system 4. For aim 2, the number of drug library profiles was positively correlated ($P = 0.029$) with IV smart pump compliance and the IV smart pump type used was significantly correlated ($P = 0.013$) with IV smart pump compliance.

Conclusions: Our findings support that there are differences in IV smart pump compliance both within and between hospital systems and that IV smart pump type and the number of drug library profiles may be influencing factors. Further research is required to more accurately identify the impact of these factors in this very important area of patient safety.

Key Words: IV smart pumps, medication error, drug library compliance

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BACKGROUND

Overview

In a classic article, the surgeon Gawande[1] describes the concept of slow ideas by comparing the rapid adoption of surgical anesthesia in the mid 1800s with the slower adoption of antiseptic principles. Gawande[1] concludes that there are several contributing factors to the different adoptions including the visibility of the issue and the value to both patients and caregivers. The use and adoption of innovative technology seem to have experienced a similar pattern. Technologies that solve a visible and difficult problem for both patients and caregivers are more likely to experience a rapid adoption cycle. Driven by the need to reduce intravenous (IV) medication administration errors, the adoption of IV smart pumps among health systems in the United States has grown to more than 70%[2,3].

Intravenous smart pumps have since become indispensable in the administration of medication, fluids, and nutrients. Before IV smart pumps, all pump programming required the user to manually calculate the rate of infusion and then input the desired infusion rate into the pump. Because many different units of measurement are used in the administration of IV medications, required manual calculations are complex, which can increase the likelihood of user error.[4,5] In contrast, IV smart pumps now have a built-in dose-error reduction system (DERS) in which the user chooses the desired medication from an approved list and inputs the required patient information. Once the data input has been completed, the IV smart pump calculates the infusion rate. Intravenous smart pumps use drug libraries configured specifically for each hospital or setting in which they are being used. The drug library contains the full list of IV medications and fluids available for use, each with a corresponding DERS, which provides recommended dosing limits to alert the user whether the programmed dose exceeds the configured dosing limits. These limits can be expressed as either hard dose limits (which cannot be bypassed by users at the pump, thereby preventing the user from starting the programmed infusion) or soft dose limits (which provide a warning that the dose may be too high but will still allow users to start the infusion as programmed once the limits have been acknowledged).

Intravenous smart pumps also use drug library profiles, which are simply subsets of the total drug library, configured for different clinical areas. Examples of profiles include anesthesia, critical care, and medical surgical. Profiles make it easier for users to navigate the DERS by customizing the IV medications and fluids to those most commonly used by each clinical area.

A 2014 published report provided a systematic review of the benefits and risks associated with the use of IV smart pumps.[6] The review included an analysis of 22 published studies regarding the use of smart pumps and assessed their impact on adverse drug events (ADEs), cost-effectiveness, and practice implications. The report also identified several areas of concern associated with the use of smart pump technology, including a lack of compliance with the use of the DERS. Because it is not possible to account for every patient's potential IV medication needs when configuring and building individual drug libraries and profiles, IV smart pumps allow end users to bypass the DERS completely and use manual programming as needed. This feature is intended to be used only when the required medication or dose is not available. Compliance is generally defined as the overall percentage of infusions programmed using the DERS versus those programmed manually outside of the DERS.

A 2013 study designed to identify the impact of smart pump implementation in a pediatric intensive care unit analyzed compliance.[7] The overall compliance rate of 78% was calculated on the basis of the number of infusions started using DERS and the total number of infusions started during the study period. The study concluded that the use of smart pumps and compliance to DERS likely prevented potential severe injury to critically ill pediatric patients.

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A similar finding was identified in a 2005 study conducted by Rothschild et al.[8] The study evaluated errors during the implementation of IV smart pumps at a large tertiary care academic medical center. Medical record data were compared with IV smart pump transaction data, and potential medication events were reviewed. The study concluded that the prevention of serious medication infusion errors was muted because of poor compliance with the use of the DERS. Overall, data support that compliance with the DERS varies from 62% to 98%.[2,3,9]

Data support that manual bypassing of DERS, even when the required IV medication is available, is a common source of error.[10–12] A variety of contributing factors have been identified as to why caregivers choose to bypass the demonstrated safety features in smart pumps, including the following: the complexity of the device user interface,[4] the time required to program DERS,[4] the lack of properly harmonized drug entries, and required drug order exceptions.[13] Clinicians report that pump programming is frequently rushed, and they often feel forced to make hasty decisions about overriding alerts because of time constraints and competing work demands[10,14].

Purpose

The purpose of our study was to improve the overall understanding of IV smart pump drug library compliance by using the Regenstrief National Center for Medical Device Informatics (REMEDI) data set to describe end-user compliance.

Aim 1. Are there differences in IV smart pump drug library compliance between hospital systems?

Aim 2. Using data from the REMEDI, we will provide a broad descriptive overview of relevant information and trends related to IV smart pump compliance. We expect that these data will be helpful in 2 ways.

- First, the findings from aim 2 should help inform the results for our main research question.
- Secondly, we hope that the findings from aim 2 will provide a foundation for additional inquiry by other researchers interested in improving patient safety for IV medication administration using IV smart pumps.

MATERIALS AND METHODS

Data Source

The Regenstrief Center for Healthcare Engineering (RCHE) is an interdisciplinary research center located at Purdue University. The RCHE has developed an evidence-based community of practice for medical device informatics, named the REMEDI. This community of practice was developed in response to a request from the Indianapolis Coalition for Patient Safety after one of their member hospitals experienced a serious ADE. Originally known as Infusion Pump Informatics, the REMEDI system was created in 2009. Community members have used the REMEDI system to improve patient safety through the exchange of infusion pump medication administration knowledge, best practices, and IV smart pump data.[15] The REMEDI is built and maintained by RCHE and Information Technology at Purdue and is made possible with primary funding from the Regenstrief Foundation.

A fundamental tenet of REMEDI system operations is that it is driven by the following community members: pharmacists, nurses, researchers, medical device vendors, and others. Through regular meetings, representatives of the member hospitals share their knowledge in a collaborative environment, fostering knowledge development to advance medication administration practice and improve patient safety. In addition to sharing knowledge, member hospitals share the following 3 types of infusion pump data: IV smart pump programming alerts, DERS compliance percentages, and drug limit libraries.

Member hospitals capture their IV smart pump data and upload it using REMEDI's Web-based interface. The uploaded data are stored in a database and are available for users to conduct their own analyses with a simple-to-use, point-and-click interface. These analyses can be conducted on both individual hospital and hospital system levels and are primarily used to enable comparative exams and benchmarking. The tools and shared knowledge allow clinicians to make evidence-based decisions, which foster the development of best practices around IV medication administration safety.

As of March 2017, hospital users representing more than 279 facilities in 23 states have signed up as REMEDI members. Currently, REMEDI system contains information on the use and nonuse, of the DERS, by profile or care area, for more than 106 million infusions. Available data in REMEDI system include detailed information on 30 million DERS programming alerts (e.g., hospital system, facility, date, profile or care area, drug or fluid, action taken by clinician, field limit type, etc.). Membership requirements include signing a membership and data use agreement in addition to agreeing to share knowledge and data with the REMEDI community on a regular basis. The shared data are limited to the operation of IV smart pumps and only include those fields pertaining to drug names, concentrations, and other pertinent values associated with the infusion of medication. Members are required to ensure that no protected health information as defined in the Health Insurance Portability and Accountability Act of 1996 is ever included in the shared data uploaded to REMEDI. The use of the shared data is solely for research and educational purposes, including academic publications and presentations. Shared data can only be included in publications or presentations in aggregate form where individual hospital members cannot be identified unless explicit permission has been granted by the identifiable hospital. Currently, member hospitals do not pay a fee to access REMEDI.

Sample

The aggregated view of the compliance data used in our study was obtained from the REMEDI analytics tool. We included the number of infusions delivered both with and without the use of DERS by month and facility. Although there are slight variations in the way different IV smart pump vendors account for an individual infusion, our operational definition of compliance was simply *the number of infusions delivered using the DERS as defined by each pump vendor, divided by the total number of IV infusion starts and expressed as a percentage*. It is important to understand that true compliance can only be determined at the beside by checking that the programmed medication matches the medication that is actually infusing. However, hospitals routinely use vendor-supplied compliance for their own quality improvement monitoring. In addition, this definition of compliance is what has been most commonly reported in previous research.

We used all available compliance data, generated by pump vendor software packages and uploaded to the REMEDI system by members, for the 12-month period between January 1, 2015, and December 31, 2015. Only hospitals that contributed at least 3 months of compliance data in 2015 were included in the analyses. Additional data used from REMEDI system included IV smart pump vendor, the total number of drug library profiles (subgroups of the drug library often organized by care area and intended to make the overall drug library easier for caregivers to use) used by each hospital, an estimate of the total number of DERS limits defined in each hospital's drug library, number of

drug library version updates during the study period, and total months of data contributed by each hospital.

We then added several additional hospital-level descriptive variables so that the results of our analyses could be placed in a broader context. Our data source was the AHD, a service that provides data and statistics for more than 6000 U.S. hospitals.[16] The information provided by the AHD is derived from numerous databases, including both public and private sources such as Medicare claims data, hospital cost reports, and the CMS "Hospital Compare" database. Search tools allow users to find various types of information that can be used to describe and compare hospitals, such as services provided, use statistics, accreditation status, bed size, discharges, patient days, and financial information. The hospital variables included in our analyses for 2015 included hospital beds, hospital size, discharges, patient days, and hospital length of stay. Definitions for each variable can be found in Table 1.

Method

Intravenous smart pump data were extracted from the REMEDI database by the REMEDI staff, provided to the principal investigator and then uploaded into the software program Statistical Package for the Social Sciences (Version 24; SPSS, Chicago Ill). The hospital descriptive variables obtained from AHD were entered individually into SPSS until the data set was complete. Before running any analyses, data were checked for accuracy by both the principal investigator and the REMEDI staff using a 10% random data check.

DATA ANALYSES AND RESULTS

For aim 1, we began by using a one-way analysis of variance (ANOVA) to answer the main research question: Are there differences in IV smart pump compliance between hospital systems?

The independent variable was the hospital system, and the dependent variable was the percent of IV smart pump compliance with using the DERS. The independent variable included a total of 7 hospital systems, which are shown in Table 2. Also included are the following descriptive data per system: number of hospitals, number of staffed beds; number of infusions, means and standard deviation for IV smart pump DERS compliance, and compliance ranges.

We included a homogeneity of variance test in the ANOVA, and the Levine statistic was significant ($P = 0.008$), indicating unequal variance between the groups. Because of the unequal variance, we then ran the nonparametric Kruskal-Wallis test to compare differences between the groups. The results of the Kruskal-Wallis test were significant ($P < 0.001$) with a decision to reject the null hypothesis. Because the results of the Kruskal-Wallis test and ANOVA ($P < 0.001$) are both significant, we have chosen to report the ANOVA. The overall results are shown in Table 3.

To account for the 7 levels of the independent variable and the resultant multiple comparisons in the ANOVA post hoc analyses, we used a Bonferroni correction. Our significance value was determined by using an initial P value of 0.05 and then dividing it by 7, the number of hospital systems used in our comparisons. This resulted in an adjusted P value of 0.007 or less that was used for significance determination. We found 3 significant relationships: systems 3 ($P < 0.001$), 6 ($P = 0.003$), and 7 ($P = 0.002$) had significantly higher IV smart compliance as compared with system 4.

For aim 2, using data from the REMEDI, we provided a broad descriptive overview of relevant information related to IV smart pump compliance. Descriptive statistics were used, and appropriate measures of central tendency and dispersion were generated for each variable of interest in the study. These data are shown in Tables 4 and 5.

There were a total of 44 individual hospitals included in these analyses, 40 of which were members of a hospital system. Data on hospital size, length of stay, IV smart pump vendor, number of drug library profiles, number of drug limit entries in the DERS library, number of drug library version updates in calendar year 2015, months of available compliance data, number of infusions, and overall DERS compliance were all included for individual hospitals (Table 5). To protect the privacy of individual hospitals, data on the number of staffed beds, annual patient discharges, and total patient days were provided only as combined data (Table 5).

Because our analyses for aim 2 were exploratory in nature, we began with bivariate Pearson correlations between IV smart pump

TABLE 1. Definitions of Variables

Variable	Source	Operational Definition
Infusions delivered using the DERS	REMEDI	The no. infusions delivered using the DERS as defined by each pump vendor
Infusions delivered not using DERS	REMEDI	The no. infusions delivered using the DERS as defined by each pump vendor
Total no. infusions	REMEDI	The sum of infusions delivered using DERS and infusions delivered not using DERS
Compliance	Calculated	Infusions delivered using DERS/the total no. infusions expressed as a percentage
IV smart pump vendor	REMEDI	IV smart pump vendor as provided to REMEDI by each participating member hospital
No. drug library profiles	REMEDI	The no. individual drug library profiles (care areas) available for programming by end users
Months of data	REMEDI	Total months of data available for analyses
Drug library updates	REMEDI	The main drug library is updated as needed to change the medication list, the dosing limits, or both
Hospital beds	AHD	The total no. staffed hospital beds
Hospital type	AHD	The hospital size as defined by no. staffed hospital beds. • Critical access: ≤25 beds • Small: 26–150 • Medium: 151–300 • Large: 301–500 • Very large: 500+
Discharges	AHD	No. annual discharges
Patient days	AHD	Total annual no. patient days
Length of stay	AHD	Average hospital length of stay

TABLE 2. Descriptive Data on the Hospital Systems Included in the Analyses

Hospital System	No. Hospital Facilities	No. Staffed Beds	Total No. Infusions	Mean Compliance	SD	Lowest Compliance	Highest Compliance
1	4	852	116,648	0.74	0.07	0.68	0.83
2	3	938	911,232	0.80	0.10	0.73	0.92
3	12	2200	1,264,274	0.89	0.05	0.75	0.95
4	11	2093	3,630,532	0.67	0.14	0.50	0.88
5	2	573	1,562,062	0.70	0.06	0.65	0.74
6	6	1692	1,610,666	0.87	0.05	0.79	0.94
7	2	189	83,864	0.99	0.00	0.98	0.98
Total	40	8537	9,179,278	—	—	—	—
Average	—	—	—	0.81	0.07	0.73	0.89

compliance and the other variables of interest. The hospital-level variables included the following: type of hospital, number of staffed beds, annual patient discharges, patient days, hospital length of stay, which IV smart pump, number of drug library profiles, number of drug library version updates in 2015, and total number of IV infusions started. Two significant correlations were found.

First, the number of drug library profiles was positively correlated ($P = 0.029$) with IV smart pump compliance. Because these analyses were conducted at the individual hospital level, we wanted to further explore whether the larger hospital systems, all with the same number of drug library profiles, accounted for the significance of this finding. It can be seen by a review of the data points shown in Figures 1 and 2 that the 12-hospital system 5 (hospital ID 15–26) with 10 drug libraries and the 11-hospital system 6 (hospital ID 27–37) with 9 drug libraries likely accounted for the significance of the correlation. Data points for the other 5 systems do not seem to be related. To mitigate for the influence of the 2 large hospital systems on the overall results of the correlation, we ran an additional Pearson correlation between the number of drug libraries at the system level and mean hospital system IV smart pump drug library compliance. We included the 4 individual hospitals, which were not part of a system, for a total of 11 sets of data (the number of drug library profiles and IV smart pump drug library compliance). No significant correlation was found, and the distribution of the data points between these 2 variables can be seen in Figure 2.

The second significant correlation was associated with the type of IV smart pump used by the hospital. The IV smart pump type used was significantly correlated ($P = 0.013$) with IV smart pump compliance. The mean compliance for IV smart pump B (n = 4) was 98%, whereas the mean compliance for IV smart pump A (n = 40) was 79%. However, because of the large difference in the group sizes, we did not conduct further analyses.

DISCUSSION

Our goal was to improve the overall understanding of factors influencing IV smart pump drug library compliance by using data available in REMEDI. Our results have begun to explore 2 factors, which may contribute to IV smart pump compliance: the number of drug library profiles and the type of IV smart pump used by the hospital.

Using Pearson correlation and compliance at the individual hospital level (n = 44), we found a significant correlation ($P = 0.029$) between the number of drug library profiles and compliance. However, that finding was largely influenced by 2 large hospital systems. When these data were analyzed at the hospital system level (n = 11), the correlation was no longer significant. This contrast in statistical significance suggests that compliance varies both within and between hospital systems.

One potential factor to consider is the number of drug library profiles built into the overall drug library. This is often discussed at the administrative level during the initial IV smart pump implementation. One perspective argues that requiring a nurse to scroll through several screens to select the desired drug library profile increases the likelihood of programming what is convenient rather than what is accurate. Conversely, a drug library with a limited number of drug library profiles reduces the options for customizing safety parameters and potentially creating a greater risk of harm to the patient.

The second significant correlation ($P = 0.013$) was related to the IV smart pump type used. There were 2 brands of IV smart pumps included in the data reviewed for this study, each with their own use model, and it is certainly feasible that these differences can have an impact on overall compliance. Although this is the first known study to compare compliance between different IV smart pumps, no conclusions can be drawn from our analyses because of the large difference in group sizes. Clearly, more research is needed to better understand differences in programming issues for end users that result from using different brands of IV smart pumps.

Limitations

The ability to use REMEDI to evaluate a large sample of IV smart pump compliance data provides a unique opportunity to identify potential strategies for improvement in compliance.

TABLE 3. Overall Analysis of Variance for IV Smart Pump Drug Library Compliance Between Hospital Systems

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F_0	P
Hospital system (between groups)	0.433	6	0.072	8.657	<0.001
Residuals (within groups)	0.275	33	0.008		
Total	0.708	39			

TABLE 4. Overview of All Hospitals Included in the Descriptive Analyses

Hospital ID	Hospital Type*	Mean LOS	IV Smart Pump Vender	Drug Library Profiles	2015 Drug Library Updates	Drugs With DERS	Months of Data	Infusions Using DERS	Infusions Not Using DERS	Total No. Infusions	Percent DERS Compliance
1	M	5.9	A	13	3	2142	12	111,817	29,462	141,279	0.79
2	L	4.7	A	13	5	2262	3	97,261	10,628	107,889	0.90
3	M	3.0	A	13	2	1935	12	84,078	11,628	95,706	0.88
4	S	3.0	A	13	2	1413	12	9066	1987	11,053	0.82
5	S	4.3	A	13	3	268	12	243,904	15,405	259,309	0.94
6	VL	4.7	A	13	2	2352	8	855,713	139,717	995,430	0.86
7	S	4.1	A	5	16	1829	4	6558	1364	7922	0.83
8	L	4.4	A	5	16	1829	4	15,720	7535	23,255	0.68
9	L	4.7	A	5	16	1829	4	42,083	13,804	55,887	0.75
10	M	4.1	A	5	16	1829	4	20,518	9066	29,584	0.69
11	S	4.8	A	7	2	1794	12	280,063	105,921	385,984	0.73
12	VL	4.8	A	7	2	1794	12	350,451	115,296	465,747	0.75
13	S	1.0	A	7	2	1794	12	54,855	4,646	59,501	0.92
14	M	3.8	A	8	7	1408	12	119,100	26,163	145,263	0.82
15	S	5.4	A	10	12	1628	4	11,222	1228	12,450	0.90
16	M	5.7	A	10	12	1628	5	104,090	10,425	114,515	0.91
17	M	3.4	A	10	12	1628	5	59,025	7237	66,262	0.89
18	S	3.5	A	10	12	1628	5	7822	944	8766	0.89
19	S	4.4	A	10	12	1628	5	315	18	333	0.95
20	M	4.4	A	10	12	1628	5	100,509	5293	105,802	0.95
21	L	5.0	A	10	12	1628	7	658,969	67,219	726,188	0.91
22	S	3.1	A	10	12	1628	3	56,719	5892	62,611	0.91
23	M	4.2	A	10	12	1628	5	33,344	5133	38,477	0.87
24	M	4.1	A	10	12	1628	4	25,168	8334	33,502	0.75
25	M	4.3	A	10	12	1628	4	39,688	4307	43,995	0.90
26	M	5.5	A	10	12	1628	4	45,982	5391	51,373	0.90
27	M	3.2	A	9	10	1728	12	102,843	103,320	206,163	0.50
28	M	3.9	A	9	10	1728	6	159,967	48,944	208,911	0.77
29	VL	6.5	A	9	10	1728	12	666,984	224,974	891,958	0.75
30	S	2.6	A	9	10	1728	12	5255	723	5978	0.88
31	S	3.6	A	9	10	1728	12	92,071	85,239	177,310	0.52
32	CA	2.2	A	9	10	1728	6	4645	643	5288	0.88
33	L	6.5	A	9	10	1728	12	616,913	373,322	990,235	0.62
34	CA	4.0	A	9	10	1728	12	8322	8431	16,753	0.50
35	L	6.5	A	9	10	1728	12	678,251	210,506	990,235	0.62
36	S	3.9	A	9	10	1728	12	81,593	44,678	126,271	0.65
37	CA	3.7	A	9	10	1728	12	7160	4270	11,430	0.63
38	S	3.8	B	9	6	NA	12	16,418	355	16,773	0.98
39	M	3.8	B	9	6	NA	12	65,673	1418	67,091	0.98
40	M	4.0	A	8	3	NA	9	197,485	33,209	230,694	0.86
41	S	5.4	A	11	11	NA	12	64,853	44,678	126,271	0.65
42	VL	5.4	A	11	11	NA	12	1,081,569	354,222	1,435,791	0.74
43	M	4.7	B	14	13	3735	4	6503	17	6520	0.99
44	VL	5.5	B	10	8	3246	5	206,061	2501	208,562	0.99

*CA: critical access (25 beds); S: small (26–150 beds); M: medium (151–300 beds); L: large (301–500 beds); VL: (500+) beds.

However, there are limitations with these analyses. One limitation is that there are variations between methods used by IV smart pump vendors to report DERS use. These differences cannot be completely accounted for in our analyses. Although we used an operational definition of compliance that was chosen to account for these differences, allow us to compare our results with previous research, and is consistent with the way hospitals generally view compliance data, it is possible that these differences were reflected in our findings.

A second limitation is that the compliance numbers available in REMEDI are limited to what is collected automatically. Inherent in our analyses is the assumption that every infusion programmed using the drug library accurately represents what was actually being

TABLE 5. Combined Hospital Data (N = 44)

	No. Staffed Beds	Annual Discharges	Patient Days
Mean	221	10,091	45,927
SD	172	8168	42,614
Min	35	198	506
Max	771	33,797	168,170

delivered to the patient. However, if an IV smart pump was programmed as "normal saline" but a bag of heparin was infusing, the infusion would have been considered compliant within our data set even though all the safety benefits of the DERS had been bypassed. As previously discussed, this scenario is not uncommon and is perhaps the most serious limitation of IV smart pump use. The development of IV smart pump autoprogramming, which uses bar coding to connect individual IV smart pump channels to the electronic medical record, could help address this issue. However, current models of autoprogramming most commonly require the manual use of barcode scanners to match medications to pump channels and have not yet been broadly deployed. Although this reduces the opportunity for IV smart pump programming errors, it introduces the new potential for human error of medication/pump channel mismatching, a safety issue that has not yet been widely studied. A fully automated model using newer IV smart pump technologies, which eliminates all manual steps, could further improve safety. In the meantime, hospitals must perform routine observational spot checks to identify any differences in vendor-supplied compliance and true compliance.

We were also unable to use the REMEDI data set to correlate compliance to the IV medication error prevention provided by DERS. However, even with that limitation, our data reflect large variations in compliance between both individual hospitals within a system, as well as across different hospital systems. Coupled with what is already known, it is likely that lower compliance is associated with a higher frequency of IV medication administration error. Given the inability of REMEDI data to accurately reflect true compliance, our findings provide only a proximate estimate of actual DERS use, which may overestimate or underestimate true compliance.

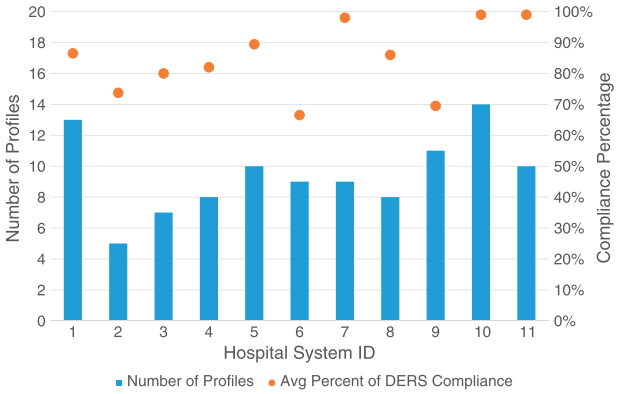

FIGURE 2. The number of drug library profiles and drug library compliance at the hospital system level.

CONCLUSIONS

Drawing on our own personal experience with IV smart pump implementations in clinical practice, several things come to mind as potential factors that could influence IV smart pump compliance from a broader perspective. Perhaps the compliance variations we observed both within and across systems may reflect differences in IV smart pump education, training, drug library and profile configurations, use protocols, and even the safety culture driving practice within individual hospitals.

In conclusion, our findings support that there are significant differences in IV smart pump compliance both within and between hospital systems. Both the IV smart pump type and the number of drug library profiles may be influencing factors. These analyses support that further research is needed to more accurately identify factors influencing the improved safety that IV smart pumps offer within the IV medication infusion process. Our analyses had no association with patient outcomes, which also

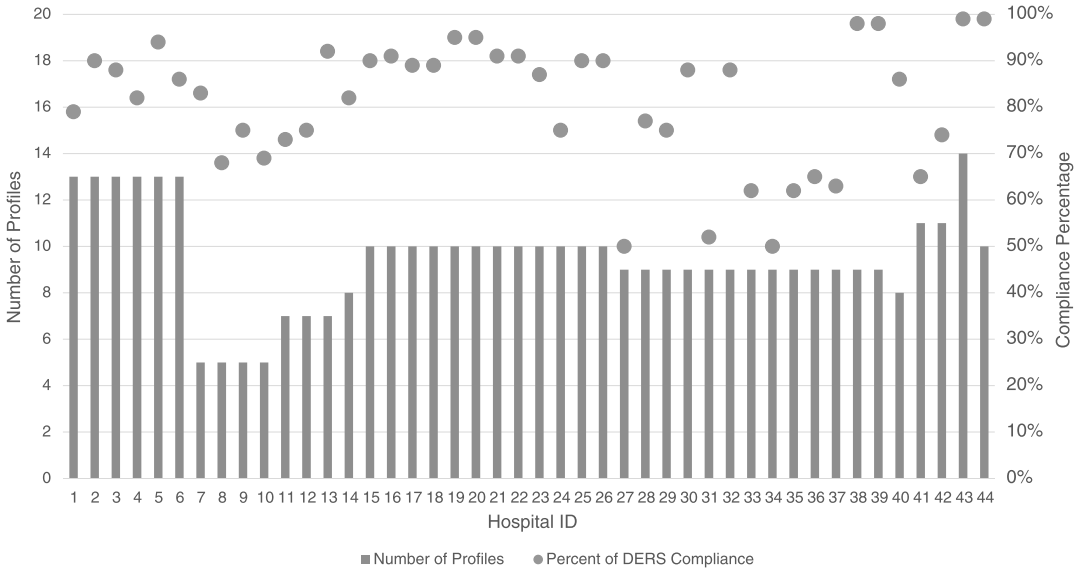

FIGURE 1. Data points for the number of drug libraries and drug library compliance at the individual hospital level.

suggests a need for future work. Analysis of culture, high-risk medication delivery, medication delivery to different patient populations and age groups (adult, pediatric, neonatal), and the usability of IV smart pumps are a few of the many opportunities for future investigation in this important area of patient safety.

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