Frequency and Duration of Infusion Pump Alarms: Establishing National Benchmarks

Rachel R. Vitoux, Catherine Schuster, Kevin R. Glover, and Mark Dekker

Abstract

Reduction of clinical alarms is a priority due to alarm fatigue and the high incidence of nonactionable alarms, especially those generated from physiological monitors. However, research on infusion pump alarm types and frequencies is limited. The purpose of this study was to establish a baseline for infusion pump alarm frequencies and duration in the hospital setting. Frequency and duration of alarms across 29 hospitals using 11,410 infusion pumps revealed 987,240 alarms associated with 568,164 infusions during a consecutive 60-day period. Pump alarms accounted for only 0.8% of infusion time, with an average of 1.74 alarms per delivery and 0.18 alarms per hour. Average alarm duration was 0:02:38 (h:min:s), with 60% of alarms being addressed within 0:01:08. The most frequent alarms were keep vein open (33.77%), hold expired (27.18%), and downstream occlusion (22.94%). The medical/surgical and intensive care unit (ICU) care areas had the highest number of alarms (41.66% and 39.70% of total alarms, respectively), but pediatrics/neonatal ICU had the highest frequency of alarms per delivery (4.91). Intravenous fluids accounted for 47.16% of total alarms, with an average of 3.03 alarms per delivery, whereas parenteral nutrition and propofol had 6.77 and 6.74 average alarms per delivery, respectively. A higher average number of alarms per delivery occurred on Saturdays (1.74) and Sundays (1.73) compared with weekdays. Infusion pump alarm data collected and analyzed were sufficient to establish a reasonable baseline of infusion pump alarm types and relative frequencies for the device.

Healthcare facilities and patient rooms contain many devices (e.g., physiological monitors, ventilators, pulse oximetry machines, infusion pumps) with audible alarms competing for caregivers' attention. The variety of bedside alarms in intensive care units (ICUs) has increased sixfold during the previous three decades, resulting in reported frequencies of bedside alarms as high as 40 times per hour.[1]

Most evidence on device alarms has focused on electrocardiogram, physiologic monitors, and pulse oximetry in the telemetry and ICU, where alarm incidence is thought to be highest.[1–3] Of these alarms, 80% to 99% have been reported as nonactionable (i.e., defined as true but requiring no clinical intervention). For example, narrowly set monitor thresholds may cause true but clinically insignificant alarms to sound.[2,4] Generally, the high frequency of nonactionable alarms may lead to alarm desensitization among staff, which is universally described as alarm fatigue.[2,5–7] Without proper management, alarms meant to alert clinical staff to potential problems may actually put patients at risk for delayed clinician response or nonresponse to actionable alarms (i.e., alarms that are true and require clinician intervention to address or resolve).[8–10]

Although many physiological monitor alarms are nonactionable and/or self-correcting, infusion pump alarms typically are actionable, indicating a specific condition (e.g., air in line, occlusion, infusion complete), and they will continue to alarm until addressed. Yu et al.[7] reported 10 months of alarm data from one pump at one institution, resulting in a total of 64,511 minutes of alarm activation. Mean resolution times for 83% of alarms were one minute or less; however, 3% of alarms took more than four minutes to resolve. The researchers were concerned about the high prevalence of alarms and longer resolution times during night shifts but did not specify types of alarms. They suggested future work to link pump alarm events to patient safety events. Clearly, more research is required to identify

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the quality of care, patient safety issues, and staff workflow dynamics associated with low proportion, but highly actionable, infusion pump alarms.

In this study, an infusion pump alarm is defined as an audible and visual signal during pump operation that requires intervention from the user for it to be silenced. This is different from a dosing alert, which is a single, nonrepeating message when attempting to program outside the drug library limits.

The purpose of this study was to establish a baseline for infusion pump alarm frequencies and duration in the hospital setting. A robust alarm analysis of thousands of infusion pumps across multiple hospitals is reported. The alarm analysis details the frequency and duration of 987,240 alarms associated with 568,164 infusions during a consecutive 60-day period. Data were collected between April 2014 and February 2017. These data will initiate the necessary benchmarking of infusion pump alarms, allowing evidence-based recommendations to improve actionable clinical alarm management.

Methods

Data were collected and analyzed from 29 hospitals located primarily (n = 25) on the East Coast (Pennsylvania, New Jersey, New York, Maryland, Virginia, North Carolina, and Florida), with the remaining hospitals (n = 4) located in Kentucky, Iowa, and California. The hospitals included 28 short-term acute care hospitals with 62 to 934 staffed beds and one 25-bed critical-access hospital. The departments involved in the study included critical care, emergency, trauma, obstetrics, oncology/infusion, transplant, medical/surgical, operating room/postanesthesia care, catheterization laboratory/special procedures, pediatrics, neonatal intensive care, and palliative care.

All hospitals were using the same large-volume infusion pump (smart pump) model with a proprietary infusion data software application that collects, stores, and displays infusion data in real-time views and reports (Outlook 400ES Safety Infusion System and DoseTrac Infusion Management Software; B. Braun Medical Inc., Bethlehem, PA). This smart pump is intended for use with adult, pediatric, and neonatal patients and is equipped with smart pump dose error reduction software and two-way wireless communication. All hospitals had been using the pump and associated software for a minimum of one month prior to transferring a database copy containing up to 18 months (April 2014 to February 2017) of infusion pump data to the investigator. Data were imported and sent via secure file transfer protocol to a secure central server protected by firewalls, then HIPAA (Health Insurance Portability and Accountability Act) deidentified (as necessary) and merged with a dedicated, secure data repository.

A subset of these data containing a consecutive 60-day time frame (i.e., same quantity of days) for each hospital was used in the statistical analyses. For each hospital, the most recent 60 consecutive days of data available to the researchers were used. Microsoft SQL Server (2012; 11.0.5343.0 X64) was used, and unique code was written to sort the data to complete the descriptive analyses (percent, mean, median, mode, range, and/or frequencies, as appropriate).

The data elements analyzed are listed and defined in Table 1. Eleven types of alarms produce an audible tone and visual message on the pump screen and alarm repeatedly until resolved by a clinician. To be included in the analysis, alarm records had to be complete and have consistent data elements from alarm start to alarm stop. For example, elements such as pump serial number, drug category, rate, dose, volume, and care area cannot be changed during a single alarm state. If any data elements were different or missing from alarm start to stop, the alarm record was excluded.

In addition, all data were cleaned of clinically nonsignificant alarms (i.e., data with little to no clinical value), such as alarms that were greater than 60 minutes or three or fewer seconds in duration. Prolonged alarms are likely to occur outside the patient care area (i.e., while a patient is ambulating off the unit or during biomedical testing and service) and can inappropriately skew the data, resulting in a deceptively higher average alarm duration. Momentary alarms that are three or fewer seconds in duration are likely occurring during pump

Data Element	Operational Definition
Number of hospitals	Number of individual hospitals reporting into each database
Number of pumps in use	Number of unique pump serial numbers in use during the 60-day time frame
Number of deliveries	Number of unique medication deliveries (a single infusion from start to stop) running in the 60-day time frame
Number of alarms	Total number of alarms during the 60-day time frame
Active delivery state	Total time and percent of time pumps in hold, run, alarm, and KVO state; total time from run to off that pump can alarm
Alarm state	Total time and percent of time pumps in alarm and KVO state
KVO state	Total time and percent of time pumps in KVO state
Average alarms per delivery	Total number of alarms/total number of deliveries
Average alarms per hour	Total number of alarms/total time
Average alarm duration	Cumulative duration of all alarm states/total number of alarms
Alarm frequency and duration by alarm type	Number of alarms, percent of total, and average duration for each alarm type (air in line, bag empty, battery empty, check set, door open, downstream occlusion, hold expired, KVO, low flow from container, system error, upstream occlusion)
Alarm frequency and duration by drug category	Number of alarms, percent of total, alarms per delivery, and average duration for each drug
Alarm frequency and duration by care area	Number of alarms, percent of total, alarms per delivery, and average duration for each care area (user selected drug library)
Alarm frequency and duration by day of week	Number of alarms, percent of total, alarms per delivery, and average duration for each day of week

Table 1. Alarm data elements with operational definitions. Abbreviation used: KVO, keep vein open.

programming and, deceptively, can lower the average alarm duration. No additional measures were undertaken to determine whether individual pumps were operating correctly.

Collating data across multiple hospitals and running queries on those data required intricate management of enormous amounts of complex data. A validation protocol was used to direct the collating, cleaning, and assembling of data to ensure the process was valid and reliable.[11] This validation protocol included testing of exclusion criteria using random sampling of infusion records, followed by comparing the data assembly tool output with the data management software database record for the same infusion, testing metrics using a randomly selected day, and comparing the data assembly tool extraction with the data management software database records for the same time period.

Results

A total of 29 hospitals using 11,410 infusion pumps were included in the study. During the 60 consecutive days of use, 568,164 deliveries occurred. The pumps were in an active delivery state for 5,508,384 hours, representing the total potential time the pumps could alarm. The pumps were in an alarm state 0.8% (SD unknown) of the time (43,598 hours) and in a nonalarm state (run and hold) 99.2% (SD unknown) of the time (5,464,786 hours). From a total of 1,036,371 reported alarms, 987,240 were included in the analysis following data cleaning. A total of 49,131 alarms (4.7%) were excluded (37,902 due to incomplete or inconsistent alarm records, 9,884 for duration ≥60 min, and 1,345 for duration ≤3 s). Average alarms per delivery were 1.74, and average alarms per hour were 0.18. Average alarm duration (h:min:s) was 0:02:38 ± 0:05:27 (mean ± SD), with a median duration of 0:00:43. Of alarms, 20% were addressed within 0:00:11, 40% within 0:00:28, 60% within 0:01:08, and 80% within 0:03:19.

The most frequent alarms (Table 2) were keep vein open (KVO; 33.77%), hold expired (27.18%), and downstream occlusion (22.94%). The alarms with the longest average duration (h:min:s) were downstream occlusion (0:03:58), battery empty (0:03:48),

Alarm Type	Percent of Total	Average Duration (h:min:s) Mean ± SD
KVO	33.77	0:02:01 ± 0:03:58
Hold expired	27.18	0:02:23 ± 0:05:17
Downstream occlusion	22.94	0:03:58 ± 0:07:03
Bag empty	8.52	0:03:01 ± 0:06:04
Air in line	3.05	0:02:32 ± 0:05:24
Door open	2.38	0:00:58 ± 0:02:50
System error	1.77	0:02:08 ± 0:04:59
Check set	0.26	0:00:27 ± 0:01:20
Battery empty	0.06	0:03:48 ± 0:06:46
Low flow from container	0.04	0:01:04 ± 0:02:56
Upstream occlusion	0.03	0:00:46 ± 0:02:10

Table 2. Alarms (n = 987,240) by type and duration. Abbreviation used: KVO, keep vein open.

Care Area	No. of Deliveries	No. of Alarms	No. of Alarms per Delivery Mean ± SD	Percent of Total	Average Duration (h:min:s) Mean ± SD
Medical/ surgical	95,126	204,803	2.15 ± 4.80	41.66	0:03:25 ± 0:06:12
ICU	72,106	195,210	2.71 ± 6.11	39.70	0:01:30 ± 0:03:31
ED	8,919	24,684	2.77 ± 5.01	5.02	0:02:46 ± 0:05:21
Pediatrics/ NICU	4,840	23,741	4.91 ± 8.98	4.83	0:01:03 ± 0:02:24
Oncology/ infusion	9,628	15,200	1.58 ± 3.39	3.09	0:01:31 ± 0:03:17
OB/L&D	7,340	12,222	1.67 ± 2.84	2.49	0:01:42 ± 0:03:34
Step down/ telemetry	3,621	9,876	2.73 ± 5.55	2.01	0:03:50 ± 0:06:55
OR/PACU	2,739	4,573	1.67 ± 4.10	0.93	0:00:59 ± 0:02:26
Cath lab/ special procedures*	1,034	1,129	1.09 ± 2.29	0.23	0:01:33 ± 0:04:07
Therapy specific†	200	224	1.12 ± 1.31	0.05	0:03:46 ± 0:06:40

Table 3. Alarms by care area selected within the drug library (n = 491,662). *Includes Imaging and interventional radiology. †Includes epidural, antibiotics, irrigation, and dialysis. Abbreviations used: Cath lab; catheterization laboratory; ED, emergency department; ICU, intensive care unit; L&D, labor and delivery; NICU, neonatal intensive care unit; OB, obstetrics; OR, operating room; PACU, postanesthesia care unit.

and bag empty (0:03:01). The medical/ surgical and ICU areas had the highest alarm frequency based on total alarms (41.66% and 39.70% of total alarms, respectively), but pediatrics/neonatal ICU (NICU) had the highest based on the number of alarms per delivery (4.91) (Table 3). The medical/ surgical care areas also had one of the highest average alarm durations (0:03:25).

The top three drug categories within the drug library with the highest number of alarms based on percent of total were intravenous (IV) fluids (47.16%), heparin (5.58%), and IV piggyback (IVPB; 4.76%), with average alarms per delivery of 3.03, 4.74, and 0.82, respectively (Table 4). Parenteral nutrition and propofol had the highest alarm frequency at 6.77 and 6.74 average alarms per delivery, respectively.

A higher average number of alarms per delivery occurred on Saturdays (1.74) and Sundays (1.73) compared with weekdays (1.29–1.38) (Figure 1). Average alarm duration (h:min:s) by day of the week ranged from 0:02:36 to 0:02:42.

Discussion

The relatively low incidence of pump alarms (0.8% of total infusion time, 1.74 alarms/ delivery, 0.18 alarms/infusion hour) is consistent with other published reports addressing the percent of infusion pumps compared with other medical devices (e.g., physiological monitors). However, because pumps are used on nearly every patient in the hospital, and nearly all pump alarms are actionable, improving actionable alarm management based on the evolving data is important. The sheer number of infusion pumps used and nature of these alarms may contribute to patient harm if staff hesitate to respond due to alarm fatigue.

Direct comparison of various study alarm results should be done with caution. Alarm data are complicated by treatment of data (e.g., inclusion/exclusion principles), pump alarm type and capabilities (e.g., model of infusion pump, number of alarms available), and pump configurations (e.g., pressure settings, KVO and pre-alarms enabled/ disabled). A previous study of 131 large-volume pumps infusing 362,778 hours in an acute care hospital found that pump alarms accounted for approximately 5% of total infusion time,[12] which is a much higher percentage of infusion time than the 0.8% across all hospital units reported in the current study. Yu et al.[7] reported 60,773 alarm

Drug category (Top 25)	No. of Deliveries	No. of Alarms	No. of Alarms per Delivery Mean ± SD	Percent of Total	Average Duration (h:min:s) Mean ± SD
IV fluids	76,469	232,015	3.03 ± 5.61	47.16	0:02:53 ± 0:05:40
Heparin	5,790	27,470	4.74 ± 8.07	5.58	0:03:09 ± 0:05:57
IVPB	28,703	23,434	0.82 ± 1.93	4.76	0:03:00 ± 0:06:19
Propofol	3,447	23,231	6.74 ± 13.25	4.72	0:01:10 ± 0:02:35
Antibiotic	23,607	21,429	0.91 ± 2.05	4.36	0:02:19 ± 0:04:24
Parenteral nutrition	2,486	16,839	6.77 ± 10.57	3.42	0:01:46 ± 0:04:27
RBCs	4,379	11,648	2.66 ± 3.06	2.37	0:01:52 ± 0:03:58
Norepinephrine	3,032	10,027	3.31 ± 6.32	2.04	0:01:00 ± 0:02:16
Insulin	2,410	8,632	3.58 ± 8.63	1.75	0:01:11 ± 0:02:41
KCl	3,603	7,227	2.01 ± 2.55	1.47	0:02:15 ± 0:04:29
Fentanyl	1,402	6,945	4.95 ± 8.53	1.41	0:01:05 ± 0:02:19
Dexmedetomidine	1,060	6,266	5.91 ± 13.32	1.27	0:00:59 ± 0:01:56
Pantoprazole	949	5,755	6.06 ± 7.56	1.17	0:02:18 ± 0:04:47
Magnesium sulfate	3,662	5,506	1.50 ± 2.13	1.12	0:02:16 ± 0:04:29
Chemotherapy	3,604	5,345	1.48 ± 1.95	1.09	0:00:52 ± 0:02:10
Nicardipine	1,178	5,037	4.28 ± 7.87	1.02	0:01:15 ± 0:02:45
Amiodarone	1,420	4,736	3.34 ± 5.10	0.96	0:01:27 ± 0:03:09
Diltiazem	1,378	4,230	3.07 ± 5.29	0.86	0:02:25 ± 0:04:53
Oxytocin	3,204	4,214	1.32 ± 2.30	0.86	0:01:40 ± 0:03:27
Phenylephrine	1,013	4,089	4.04 ± 7.81	0.83	0:01:03 ± 0:02:11
Vancomycin	3,590	3,934	1.10 ± 1.86	0.80	0:02:17 ± 0:04:34
Piperacillin-tazobactam	3,183	2,935	0.92 ± 1.58	0.60	0:02:49 ± 0:05:30
Midazolam	777	2,838	3.65 ± 6.98	0.58	0:00:56 ± 0:02:00
Milrinone	490	2,763	5.64 ± 12.09	0.56	0:01:55 ± 0:04:26
Vasopressin	933	2,203	2.36 ± 4.46	0.45	0:00:47 ± 0:01:39

Table 4. Alarms by drug category selected within the drug library (n = 448,748). Drugs are listed in order of percent of total alarms, only including top 25 drugs. Abbreviations used: IV, intravenous; IVPB, IV piggyback; KCl, potassium chloride; RBC, red blood cell.

events across 44,798 infusion processes, which would calculate to 1.36 alarms per delivery—a slightly lower number than the 1.74 alarms per delivery reported here.

Looking at alarm frequency per hour, Gorges et al.,[13] in an observational study, recorded an average of 0.74 infusion pump alarms per hour in a single ICU, which is higher than the 0.18 alarms per hour that we measured using hospitalwide data. The difference in alarm frequency is not surprising, as it would be expected that ICUs typically would use the most pumps. Kurnat-Thoma and Shah[14] evaluated two weeks of IV pump alarm/alert data across six units and reported 8,761 alarms/alerts and an average of 623.6 alarms/alerts per 24 hours, which would calculate to 26 alarms/alerts per hour. The number of deliveries or infusion processes was not reported.

Data were handled differently among previously published studies. Lee et al.[12] removed files that contained errors and significantly high numbers for each error code, indicating possible software corruption (n = 7). Yu et al.[7] used the entire pump data set. Gorges et al.[13] collected observational data only (as opposed to pump records). Other than Lee et al.[12] describing the removal of seven corrupted files, the other studies mentioned no exclusion of data based on clinical relevance or otherwise; therefore, whether the data were cleaned or modified in any way is unknown.

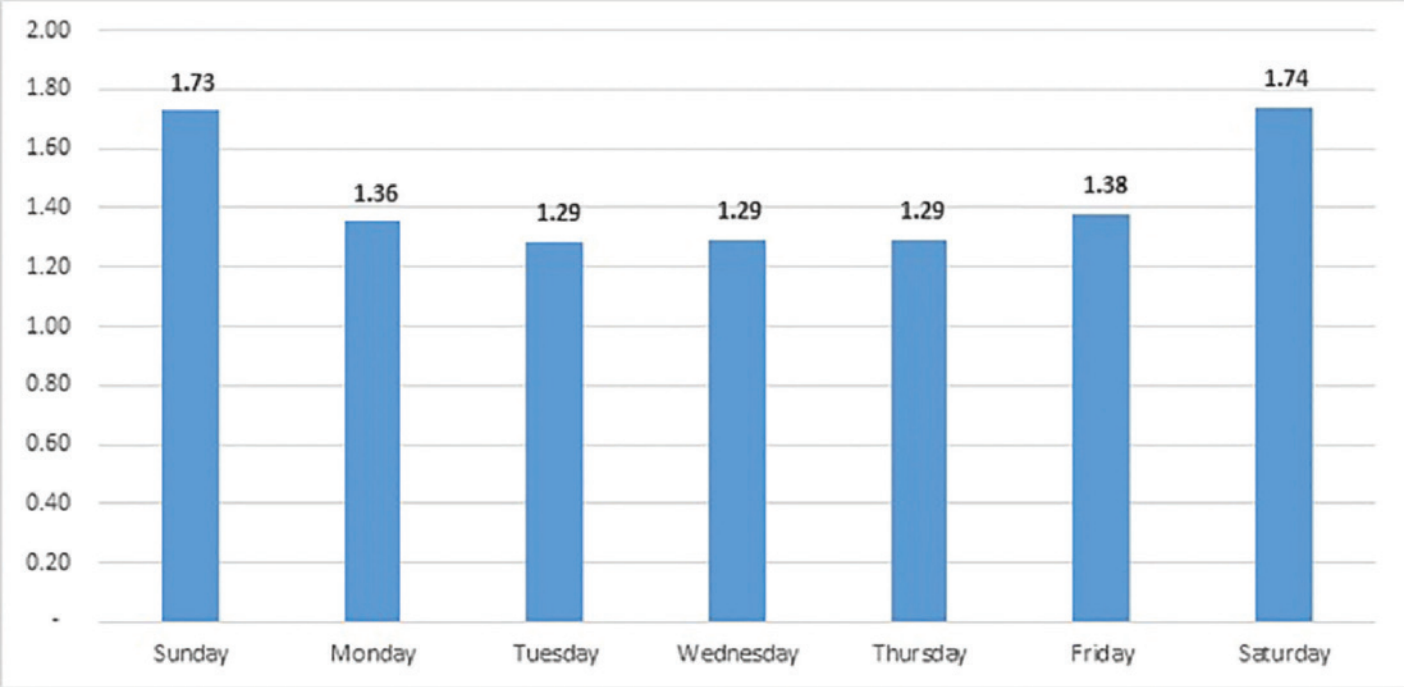

Figure 1. Average alarms per delivery by day of week (n = 987,240)

After excluding what we defined as clinically nonsignificant alarms (duration ≤3 s and ≥60 min), the mean duration of infusion pump alarms was 0:02:38 (h:min:s), with a median of 0:00:43. Gorges et al.[13] reported a substantially lower mean infusion pump alarm duration (43 s [range 1 s to 17.25 min]) using observation in a 12-bed medical ICU. Yu et al.[7] reported that mean alarm resolution was one minute or less for 83% of alarms for a single hospital, while 60% of our alarms were addressed within 0:01:08.

The differences in study methodologies (including sampling and treatment of data) makes it difficult to compare results across studies. Creating standardized operational definitions and measurement methodologies for reporting alarm data will help to better understand and compare infusion pump alarms.

The majority (83.89%) of our study's identified alarms were KVO, hold expired, and downstream occlusion. These alarms potentially can be reduced. KVO and hold expired alarms are anticipated; they alarm based on programmed volume to be delivered and user programmed hold time. Both can be mitigated by the user modifying programmed volumes and adjusting the hold time duration (e.g., to allow time for an IV restart, getting a new IV bag). Assuming each delivery reaches its programmed volume, one would expect approximately one KVO alarm per delivery. Excessive KVO alarms could be due to how clinicians conceptualize the infusion process, what type of infusion is being delivered, the unit environment, and the individualized effect of anticipated alarms on workflow.[15] For example, clinicians might program pumps with volumes that are less than actual bag volumes, due to bag overfill not accounted for, as an intentional buffer to prevent the bag from running dry and air entering the line, or to cause a KVO alarm as a call-back feature.

Downstream occlusion alarms are unanticipated alarms that unexpectedly interrupt delivery. They can be caused by a clamped, kinked, or occluded IV tubing or catheter, IV site placement at a joint (e.g., antecubital, wrist), clogged filter, rapid IV push administration, narrow diameter catheters, and downstream pressure thresholds that are set too low.[16]

Lee et al.[12] looked at another pump model and found that the three most frequent alarms were "occlusion below pump," "on hold," and "no flow above pump." Similar to our study, Kurnat-Thoma and Shah[14] (pump model not identified) found the three most

common alarms/alerts were "infuser idle 2 min," "distal occlusion," and "line A VTBI complete." Frequency of alarms by alarm type were not reported in the other studies. Of note, each model of infusion pump comes with a unique set of alarm types and capabilities; therefore, it is problematic to make direct alarm comparisons between different models of pumps.

The medical/surgical and ICU areas had the highest percent of alarms (81% of alarms combined), and these areas had the most infusion deliveries (167,232 combined, 81% total). However, pediatrics/NICU had the highest ratio of alarms per delivery (4.91). The high pediatric/NICU alarm ratio might be related to this population having smaller lumen catheters, nonpreferred IV sites/tiny veins, crying, and uncontrolled movement, which could increase downstream occlusion alarms. Further exploring alarm characteristics in these care areas will be important to understanding why the alarm ratio is so high. At the time of this analysis, only one study reporting pump alarm data by care area could be found: Kurnat-Thoma & Shah[14] found that the majority of alarms/alerts occurred in the surgical (30.6%) and critical care (25.5%) units. This example signifies the importance of looking at both total alarms and alarms per delivery. Both are important metrics and can help identify where to target alarm management interventions.

Similarly, when looking at alarm frequency and duration by drug category, results can vary widely based on the metric used. For example, IV fluids had highest number of alarms (n = 232,015) and percent of total (47.16%) because they are the most frequently delivered. However, parenteral nutrition and propofol were associated with a higher number of alarms per delivery (6.77 and 6.74, respectively); therefore, investigating drugs with a higher ratio of alarms, in order to determine whether variables exist that make these drugs more prone to alarms, may be more clinically relevant. For example, propofol and total parenteral nutrition with lipids may be associated with more downstream occlusion alarms due to higher viscosity and/or clogged filters. Downstream occlusion alarms also can be caused by IV push administration of drugs such as propofol. Because some drug categories, such as IV fluids, IVPB, antibiotic, parenteral nutrition, red blood cells (RBCs), and chemotherapy, represent groupings of drugs/infusions, discerning which individual drugs in these groupings are primarily contributing to the alarm incidence is not possible. For example, some facilities selected the drug category label RBCs for infusing multiple blood products and chemotherapy can contain a large subset of patient-specific chemotherapeutic agents.

The higher average number of alarms per delivery on Saturdays (1.74) and Sundays (1.73) warrant further investigation. The weekend staff-to-patient ratio may be higher and/or weekend staff may be less experienced than weekday staff. Similarly, Yu et al.[7] observed a higher risk for infusion pump alarm resolution based on care area and time of day, with alarms resolved significantly faster ($P < 0.001$) on day shift (6 a.m. to 6 p.m.) than night shift. A search of available literature revealed no like studies that reported incidence of alarms by day of week or shift.

Each model of infusion pump comes with a unique set of alarm types and capabilities; therefore, it is problematic to make direct alarm comparisons between different models of pumps.

Limitations

The current study had several limitations. Although the data were from 29 different hospitals, they were from one model of infusion pump. Whether other pump models would generate similar results is unknown. Variation in hospital bed size, acuity, number of pumps, and number of deliveries could affect results. Although data from the same total number of days for each hospital was analyzed, the datasets varied in size due to the number of deliveries. A possible alternative approach would be to limit datasets based on total number of deliveries per hospital rather than days.

Conclusion

The infusion pump alarm data collected and analyzed in this study from 29 U.S.-based hospitals using the Outlook 400ES Safety Infusion System via DoseTrac was sufficient to establish a reasonable baseline of infusion pump alarm types and relative frequencies for this device. The results

represent one model of infusion pump; thus, generalizing the results to all other pump platforms should be done with caution. Alarm frequency and characteristics can vary widely depending on pump model, variety of alarm types, selected configuration options, and alarm thresholds set. Therefore, comparing alarm data across different pump models, and even comparing hospitals within a system using the same pump model but with different alarm configurations and clinical practices, is difficult. Establishing consistent industry-wide benchmarks for measuring and reporting alarms will be key, as will each hospital establishing its own unique baseline.

Establishing consistent industrywide benchmarks for measuring and reporting alarms will be key, as will each hospital establishing its own unique baseline.

Collecting, analyzing, and cleaning pump data should follow research principles to ensure accuracy and validity. Inconsistencies with wireless communication, data capture, and major biomedical repairs can result in gaps or inconsistencies in pump alarm reporting and should be addressed. Clinically nonsignificant data require clinical and operational insight to assess and resolve; alarms that occur while the user is programming the pump may skew alarm duration averages to appear much lower overall. We attempted to control for this by eliminating alarms that were three seconds or less or 60 minutes or longer. Creating and establishing standardized metrics, operational definitions, and processes for measuring and reporting alarm data is the first step to understanding and identifying key issues of infusion pump alarms and will promote the growth and development of this area of study.

With benchmark data on pump alarms, we will be better positioned to evaluate whether technological changes can improve alarm management. Possible changes include alarm prioritization, alarm forwarding and delays, real-time monitoring, incorporating patient-specific configurations or options to personalize to hospital practices, and creating more autocorrect features. However, we also need to consider that the addition of technology could increase operational complexity and associated alarm fatigue by adding additional user prompts, programming steps, alerts, or alarms. Further research is critical to understanding the characteristics of pump alarms and how they affect clinicians and patient care so that industry and clinicians can work toward reducing alarm burden in the healthcare environment.

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