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Improving Care Delivery: Location Timestamps to Enhance Process Measurement of a Clinical Workflow

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Abstract

Introduction: Traditional quality improvement (QI) strategies to describe workflow processes rely primarily upon qualitative methods or human-driven observations. These methods may be limited in scope and accuracy when applied to time-based workflow processes. This study sought to evaluate the utility of integrating objective time measurements to augment traditional QI strategies using procedural sedation workflow in a pediatric emergency department as an archetype. **Methods:** We applied the FOCUS-Plan-Do-Check-Act framework to reduce the time from arrival to sedation for long-bone fractures. First, we added supplementary framework-defining steps to repeat the Clarifying and Understanding steps. We then extracted objective time-based data from an electronic health record (EHR) system and a real-time locating system (RTLS). We then compared and contrasted the findings of traditional surveys with analyses of timed steps within the sedation workflow. **Results:** When identifying the source of delays, traditional survey techniques yielded ambiguous and even conflicting results based on clinical roles. The timestamps supported 5 measurable clinical role of subworkflows. By measuring the time to completion for 54 sedation cases, workflow patterns and significant bottlenecks were identified. **Conclusions:** Analyzing the time to complete individual tasks provided a more nuanced description of workflow delays and clarity when traditional survey results conflicted. Augmenting traditional QI process maps with EHR and RTLS timestamps better explained workflow bottlenecks, informing the QI team when selecting targets for subsequent Plan-Do-Check-Act work. *(Pediatr Qual Saf 2021;6:e475; doi: 10.1097/pq9.0000000000000475; Published online September 24, 2021.)*

INTRODUCTION

Optimizing timely, quality healthcare delivery in a pediatric emergency department (PED) is critical to improved patient safety, institutional reimbursement optimization, and family experience. Care delivery within the PED often involves complex processes utilizing various healthcare workers, equipment, and physical spaces to provide care throughout the patient visit. Quality improvement (QI) strategies to reduce workflow inefficiencies have identified time-based barriers through largely qualitative methods. The FOCUS-Plan-Do-Check-Act (PDCA) model describes the foundational processes required to identify optimal targets for improvement cycles. After *F*inding a problem, and the *O*rganization of a multidisciplinary team to address it, the team should *C*larify current knowledge of the process and then *U*nderstand the causes of variation before *S*electing a process improvement.[1] Within the Clarify and Understanding steps in time-based clinical workflows, limited quantitative measures have been available for the study or application. Instead, traditional qualitative methods often involve observation-based time studies (ie, shadowing physicians and procedures) and surveying key stakeholders about their perceptions of workflow bottlenecks.

Systematic approaches of qualitative methods (surveys and interviews) and observation-based qualitative methods (shadowing physicians and procedures)

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provide opportunities for clinicians and patients to give contextual feedback that can lead to the adoption or alteration of interventions.[2] However, qualitative methods have several limitations that can lead to biased or inaccurate results. These methods can be expensive, time-consuming, subject to observation bias, and can interrupt workflow. Response rates for resource-intensive surveys are typically low.[3] Additionally, the perception of the passage of time is inconsistent, especially in complex and stressful working environments.[4] An opportunity exists to use electronic sources of time-based data, specifically the electronic health record (EHR).[5,6] EHR timestamps complement location-based timestamps collected by a real-time locating system (RTLS). An RTLS is a collection of technologies used to track the physical location of objects and people in a defined environment in real time. Healthcare settings have experimented with using RTLS in various capacities, from tracking clinician locations to finding patients as they proceed through different locations for their care.[7–9] However, best practices for the most effective and efficient use of RTLS capabilities for clinical workflow have yet to be defined.[10] Nevertheless, this technology can help pinpoint key areas where clinical improvements can be most effective.[11]

Although prior work has demonstrated adequate RTLS sensitivity[12] in clinical environments and the importance of staff education and acceptance of the technology,[13] there are limited studies to date which have evaluated the utility of RTLS to complement traditional QI work in clinical environments. Vankipuram et al[14] hypothesized that a more robust QI study could be conducted by combining the more traditional approaches of interviewing/surveying clinicians and analyzing EHR records with RTLS. They provided a theoretical framework for the associated analytics but did not align theories with a framework for clinical improvement work. Southard et al[15] successfully applied the Six Sigma DMAIC approach to evaluating the impact of an RTLS on operating room turnover time, and their results suggested it was a cost-effective strategy for reducing waste. This project sought to determine whether RTLS can support existing QI methodology to identify workflow delays for targeted interventions. Using such enhanced QI methodology, we aimed to optimize objectivity and provide a more nuanced understanding of the delays in clinical workflows.

Our objective in this study was to develop a framework-defining method that strategically combines EHR and RTLS timestamps for clinical workflow analysis and demonstrates the feasibility of this method in enhancing traditional QI approaches. We employed this methodology to analyze the delays within the PED sedation workflow for long-bone fracture reductions. We hypothesized that healthcare providers would have discordant perceptions of the drivers of delay and that strategic application of impartial timestamps would improve our comprehensive understanding of the drivers.

METHODS

Clinical Setting

This study took place in a large academic urban free-standing children's hospital. The PED at this institution is a level I trauma center, consisting of 40 rooms with 4 of those patient rooms designated for procedural sedation. Approximately 60,000 patients enter the PED annually, and approximately 1,380 undergo procedural sedation. Half of these sedations are for extremity fractures. The patients in this PED range from neonates to 21 years old. All providers use the Epic EHR (Epic Systems, Verona, Wis.). The RTLS used RFID technology. Throughout the ED, 234 centralized ceiling hardware receivers were installed, and virtual walls were created at the threshold of every room. Virtual walls were created to allow for detailed distinctions of spaces within the ED where physical walls did not exist. We attempted to capture all staff and patients by having them wear tags with active RFID readers. Measured system accuracy averaged 3 seconds (range 2–9 seconds) and 1.5 feet into or out of a room or space threshold, with reliable data transfer.

Study Design

This study incorporated a mixed-methods approach to analyze sedation delays. We measured PED staff perceptions of delay with surveys and obtained sedation subprocess timestamps from EHR and RTLS. First, we applied the traditional methodology of the FOCUS portion of the PDCA cycle. Second, we supplemented the traditional data acquisition with the EHR and RTLS timestamp data and evaluated the impact of the timestamps on the Clarifying and Understanding steps in the FOCUS process. The institutional review board evaluated the project and determined that the project did not meet the definition of human subjects research.

Traditional Methodology

We applied the FOCUS-PDCA framework to procedural sedation, a complex clinical workflow from which delays were identified as a common source of frustration for patients and staff. We describe the following the steps before integrating the timestamp data.

F: Finding a process to improve. The time to start the procedural sedation to reduce long-bone fractures was fraught with delays. Delays in the procedural sedation process were explicitly identified as the top driver of dissatisfaction among families presented to our ED. It was also a source of frustration for staff.

O: Organize a multidisciplinary team that knows the process. We created a team consisting of domain-expert physicians, nurses, patient-care assistants, and orthopedic residents to study the process.

C: Clarify current knowledge of a process. During this step, the team created a process map to describe the workflow steps between patient arrival and the onset of the procedural sedation, which correlates to the onset of the orthopedic reduction. At this hospital, PED extremity fracture reductions are performed in designated procedure rooms in the PED. Fracture reduction typically involves intravenous delivery of a sedating medication. Monitoring equipment, a portable fluoroscopic machine, and sedation medication are all utilized during a fracture reduction. Over 40 hours, team members observed the sedation procedures for 8 patient cases and manually documented procedural timestamps on paper. Those 8 cases were clustered based on patient arrivals, resulting in some observation periods with multiple procedures and some with none. Paper data were then transposed into an Excel file. Additionally, we obtained and analyzed baseline data for all sedations during the initial study time frame, using the limited objective timestamps available, including time to provider, time to analgesia, time to sedation order, and the time to sedation start.

U: Understand the causes of variation. To understand the causes of variation in the time required to complete the sedation, the team next created a survey to assess staff perceptions of the drivers most responsible for sedation delay. We distributed the survey to PED physicians and nurses before implementing RTLS, and survey data were statistically summarized. We examined data from nurse and physician responses separately and analyzed the responses collectively, and noted differences between nurse and physician perceptions for further analysis.

Enhanced Methodology

In her description of the FOCUS-PDCA technique, Stoltz states, "FOCUS-PDCA is neither a linear model nor a series of linked actions with a unidirectional flow; rather, it is a dynamic model with interdependent steps. Effective use of FOCUS-PDCA requires ongoing alignment of the steps both forward and backward."[1] After completing the process map and baseline survey results and working in parallel, we used movement data to provide additive, objective detail about the processes described, and revisited the Clarifying and Understanding steps.

C: Clarify current knowledge of a process. Using the process map previously generated and building upon available timestamps from the EHR, we could associate movement timestamps with steps along with the process map, generating time observations for workflow subprocesses, as shown in Figure 1 (also see **Supplemental Digital Content 1, *http://links.lww.com/PQ9/A313***). Locating badges were placed on the sedation medication bin to track medication preparation and the portable fluoroscopic machine. The orthopedic resident, the sedating PED physician, and the PED nurse each wore badges. Neither EHR nor RTLS was able to capture timestamps for all the sedation subprocesses independently. However, by combining the RTLS and the EHR timestamps, the subprocesses could be accurately tracked in parallel (sedating physician performing tasks in parallel with the orthopedic physician) and in series (the patient moved from holding room into a sedation room).

U: Understand the causes of variation. We statistically analyzed the EHR/RTLS timestamps as described in the following section. After separately completing the qualitative survey analysis and the timestamp analysis, we merged the results to examine the overlaps and inconsistencies between perceived and actual causes of sedation delay. This additional layer of analysis provided the basis for drawing out clinical implications and recommending future directions.

EHR/RTLS Timestamp Analysis

We collected sedation patient cases and their EHR/RTLS timestamps and calculated the duration of each step and aggregate time based on the difference between the associated timestamps. To identify workflow delays using timestamp data, we employed a cutoff of the overall duration of patient cases to distinguish "efficient" versus "prolonged" cases. We used the median duration of the first 20 sedation cases collected to define this cutoff. Specifically, we considered a case efficient if the duration from patient arrival in the PED to the start of sedation was less than 180 minutes. Otherwise, a case was considered prolonged. Within each group, we then aggregated the duration of time for each patient's similar subprocess task, statistically analyzed it, and compared it between the 2 groups. To lessen the effect of upstream delays on downstream processes, we compared the duration of time to achieve each subtask between efficient and prolonged cases directly. Since the duration of the subprocesses were not normally distributed, we used the Mann–Whitney U test to examine the difference in the median time of a task between the 2 groups.

RESULTS

Survey Responses

Eighty-eight out of 215 surveys were returned (response rate: 41%), including 41 physicians and 47 nurses. Survey results suggested the top perceived causes of delay were (1) availability of the sedation physician; (2) availability of the orthopedic physician; (3) availability of the nurse; and (4) simultaneous readiness of the 2 parties (Table 1). Cumulatively, these 4 reasons for sedation delay represented 83.0% of the total survey responses (Fig. 2).

When examining the results of nurses and physicians separately, 48.9% of nurses identified the availability of the sedation physician to be a top driver of sedation delay, while only 14.6% of physicians chose that same reason. Additionally, 24.4% of physicians identified the availability of the nurse as a top driver of sedation delay, whereas only 4.3% of nurses responded with that same reason (Table 1). As hypothesized, the inconsistencies between nurse and physician perceptions warranted an additional, objective investigation into the cause of these delays.

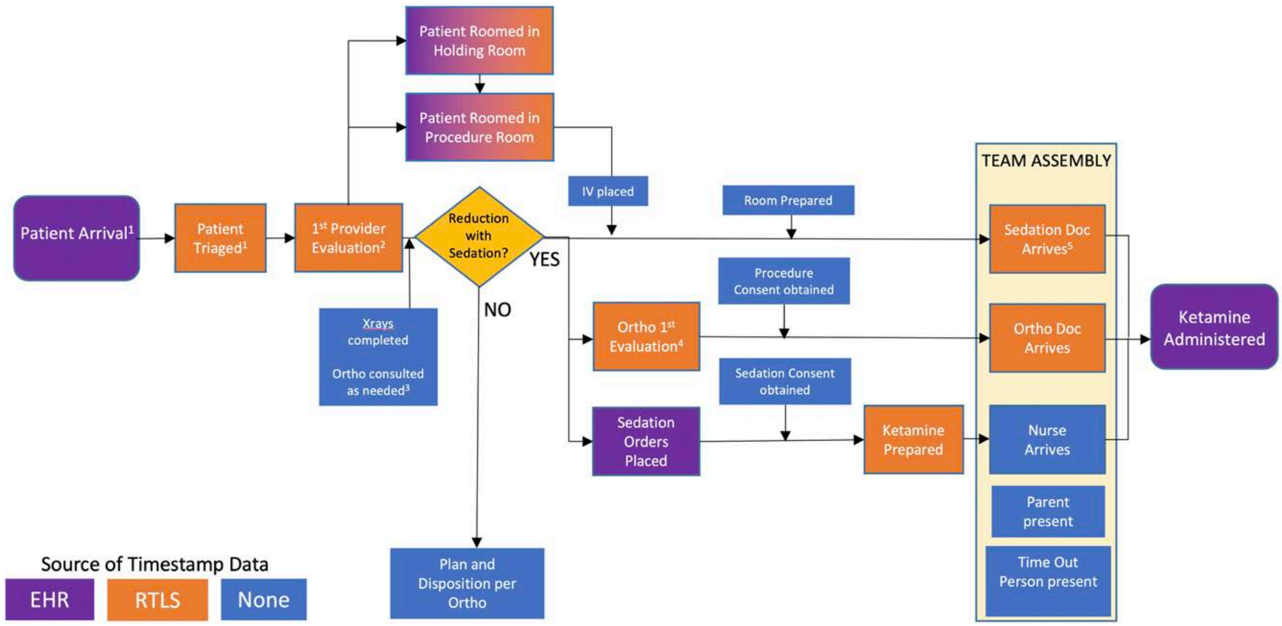

Fig. 1. Process map enhanced by RTLS and EHR timestamps.

Table 1. Survey Results from Nurses and Physicians on Top Perceived Causes of Sedation Delay

	Nurses		Physicians	
Reason for Delay in Sedation	**Number**	**Percentage (%)**	**Number**	**Percentage (%)**
Sedation MD available	23	48.9	6	14.6
Ortho MD available	10	21.3	10	24.4
Nurse available	2	4.3	10	24.4
Simultaneous availability of MDs and RN	5	10.6	7	17.1
Procedure room preparation	6	12.8	4	9.8
Awareness of sedation need	1	2.1	2	4.9
Functional IV	0	0.0	1	2.4
Medication available	0	0.0	1	2.4
Total	47	100.0	41	100.0

Efficient and Prolonged Cases

RTLS increased the number of objective time stamps on our process map from 5 to 17 and allowed the calculation of 15 processes (Table 2). We analyzed a total of 54 patient cases, with 33 (61%) of the cases classified as efficient and 21 (39%) of the cases classified as prolonged. We then calculated the mean and median duration for each process within the efficient and prolonged classifications. We analyzed the difference of medians between efficient (<180 minutes) and prolonged (≥180 minutes) cases with the Mann–Whitney U test (Table 2). The mean duration for the entire sedation workflow for efficient cases was 142 minutes, whereas the mean duration for prolonged cases was 229 minutes.

This analysis identified which subprocesses were statistically longer in the prolonged cases than efficient cases and identified which specific steps were the most significant contributors to the overall delay. The 4 subprocesses identified as the most significant contributors to the total delay included (in order of decreasing contribution): availability of the sedation room, the arrival of the orthopedic surgeon for the initial evaluation, delays in the arrival of the sedating physician to start the procedure, and the time to getting the sedating medication ordered.

DISCUSSION

Principal Findings

In this report, we developed a framework-defining method. We demonstrated its feasibility to enhance the FOCUS-PDCA improvement process, enabling the identification of more objective, accurate targets for subsequent PDCA applications in the context of PED sedation procedures. Incorporating RTLS into a clinical setting where complex, time-sensitive processes occur enabled us to identify several subtle drivers of delay in the procedural sedation process in the PED, empowering more focused future QI interventions. Specifically, movement data were able to clarify conflicting survey results and measure the influence of individual subtasks on process delays.

The EHR and RTLS timestamps provided objective data to describe the workflow delays. The RTLS movement data were valuable to resolve the discrepancies

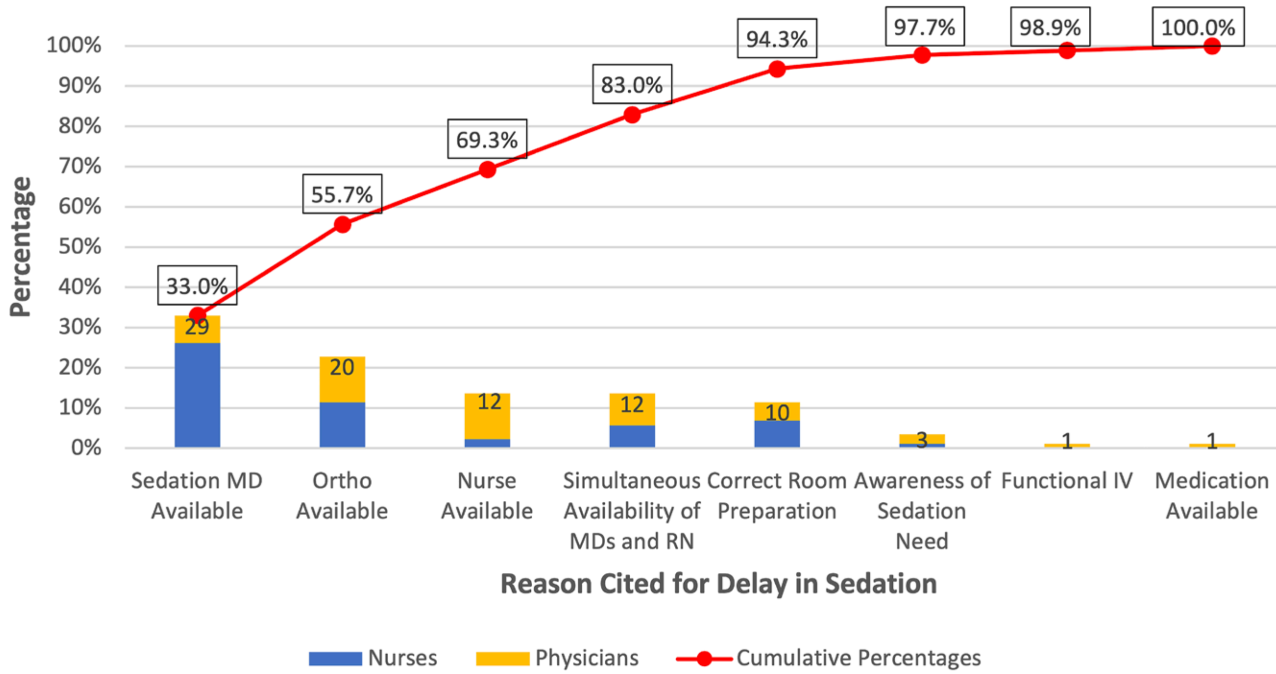

Fig. 2. Sedation process Pareto chart (all providers).

apparent in survey analyses about where bottlenecks occurred. Specifically, the analysis based on task durations supported the nurses' perception that delays in the arrival of the sedating physician to start the procedure were a significant source of delay. Adding to the survey data, the EHR and RTLS timestamps demonstrated the

Table 2. Comparison of Step Duration in Sedation Workflow Process

		Efficient Cases (<180 mins, n = 33)		Prolonged Cases (≥180 mins, n = 21)				
Subworkflow	**Task**	**Mean (min)**	**Median (min)**	**Mean (min)**	**Median (min)**	**Difference of Medians (min)**	**Difference of Medians (%)**	***P****
Patient	Patient placed in sedation room	59.1	50.0	109.7	113.0	63.0	+126.0	0.006†
Patient	Patient wait time	82.6	84.0	119.4	93.0	9.0	+10.7	0.065
First MD/DO or resident MD/DO	Resident first evaluation	42.4	27.7	87.4	57.3	29.7	+107.3	0.020
First MD/DO or resident MD/DO	Resident evaluation to Ketamine order	99.3	93.6	141.7	139.7	46.1	+49.3	0.019
Sedating MD/DO	Sedation doctor first evaluation of patient	62.5	58.5	164.9	166.6	108.1	+184.6	0.000†
Sedating MD/DO	Sedation doctor last entrance presedation	76.4	75.9	61.6	43.0	–32.9	–43.4	0.134
Sedating MD/DO	Sedation doctor wait time in room	2.9	2.5	2.7	2.2	–0.3	–13.3	0.207
Ortho MD/DO	Orthopedic doctor first evaluation patient in room	86.6	76.8	139.4	132.6	55.8	+72.6	0.000†
Ortho MD/DO	Orthopedic doctor arrival for sedation	48.3	44.1	83.4	72.8	28.7	+65.1	0.007†
Ortho MD/DO	Orthopedic doctor wait time in room	6.9	4.5	6.3	4.9	0.5	+10.4	0.458
Medication prep	Ketamine ordered‡	74.4	69.0	125.2	117.0	48.0	+69.6	0.000†
Medication prep	Ketamine prepared	55.5	50.7	89.9	81.3	30.6	+60.4	0.001†
Medication prep	Ketamine given	11.9	10.2	14.0	9.2	–1.0	–9.8	0.433
MD/DO and medication	Ketamine ordered‡	74.4	69.0	125.2	117.0	48.0	+69.6	0.000†
MD/DO and medication	Ketamine order to sedation doctor last entrance	64.5	57.4	101.2	98.8	41.4	+72.2	0.000†

Efficient Versus Prolonged Cases
*Kruskal–Wallis test.
†Significance at $P < 0.01$.
‡Refers to the same process.

relative importance of the delays to initial orthopedic resident evaluation as a more significant driver to global delays than the later step of waiting for them to arrive at the sedation start.

The EHR and RTLS timestamps also showed that all observed subjects (patient, resident, sedation physician, orthopedic surgeon, and medication) contributed to the delay. Each clinical role contained individual processes that showed statistically significant delays between efficient and delayed cases, complementing and extending the findings from the self-reported survey data. The timestamp data allowed a patient-centered view of the visit between arrival and sedation and identifying patient rooming as a critical bottleneck in the process. Staff surveys inconsistently identified this. Additionally, though we chose not to focus upon it in this analysis, the timestamp data clearly describes the "efficient" workflows, notably still 2.6 hours in duration, and provides targets for future time-saving interventions. Last, the timestamp data helped quantify the delays in different subprocesses, providing opportunities to examine the nuanced differences in various types of delays and demonstrate the effectiveness of QI interventions in future studies.

Methodology Implications

Traditional qualitative and quantitative methods led to early gaps in the measurement and understanding of our sedation process. Relying mainly upon the perceptions of time-based processes by healthcare staff, we generated conflicting data with limited objective timestamp data. Historically, the team would then use this conflicting data for the next step in the FOCUS-PDCA strategy: to Select the process improvement target for PDCA cycles. Instead of augmenting the traditional data by manually observing and timing the workflows of health care workers in a handful of cases, we obtained and combined EHR and RTLS timestamps to describe the workflows for 54 cases with minimal effort to the clinical staff.

Fundamentally, we applied multiple objective timestamps to a clinical workflow improvement project in this exercise. The methodology could be replicated for any time-based clinical workflow for which there exists an adequate number of digitally captured impartial timestamps, regardless of the timestamp origin. As EHRs continue to evolve and capture more timestamps passively, it is theoretically and possible to apply this methodology using EHR timestamps alone in some clinical cases. In our use case, however, RTLS movement timestamps added critical details to describe our processes.

We successfully analyzed the objective time measurements to clarify the current knowledge of the process and develop our understanding of the causes of variance. However, we would like to highlight that combing EHR and RTLS timestamps was not trivial. It required significant effort of domain experts to determine the "source of truth," that is, which EHR or RTLS timestamps accurately capture the start or end time of a task. This determination was manual and can be improved by collaborative knowledge accumulation and automated data extraction. QI researchers and practitioners who would like to use our innovative method should prepare for this effort and create a suitable solution for their team and institution.

We acknowledge that RTLS is not widely implemented in emergency departments globally. However, utilization of RTLS and alternative real-time data streams, such as physiologic monitoring data, is increasing.[16] Geers et al[17] found RTLS to be an efficient and effective way to measure "left without being seen" rates. Other innovative projects have used passive tracking to measure naloxone kit penetrance into the community.[18] Our work complements this growing body of the literature.[10] Our institution implemented RTLS to pilot and test multiple use cases, including personnel management, equipment location, and QI support. Ours is one such use case. This work highlights the importance of strategically incorporating additional, preferably objective data streams into traditional QI methodologic approaches. RTLS is an example of one such data stream. As policymakers and hospital leadership move forward with implementing and integrating new technology into clinical workspaces, it will be imperative to develop a deliberate strategy to integrate the learnings within the context of established, rigorous QI research and methodology.

LIMITATIONS

This study has several limitations. First, we analyzed the 5 observed clinical roles separately and did not analyze all tasks together as one sequence. Since clinical work is usually team-based, one delay of a clinical role may introduce another delay. We sought to minimize this effect by defining the start and endpoints of each task that were not dependent on those of other roles nor the tasks which preceded it. Second, although we sought to ensure that staff wore their badges at all times, the completeness of our data is a limitation. We used multiple rounds of staff education, encouragement, and incentives to improve badge-wearing compliance to 100%, 72%, and 71% for orthopedic residents, sedating physicians, and medication tracking, respectively. Due to the complexity of nursing scheduling, we could not guarantee consistent capture of nursing movement, so we excluded nurses from our timestamp analysis. Because we tracked the medication separately and the nurse carried it after it was prepared due to hospital policy, the proxy measure of medication arrival to the room was used to evaluate nursing readiness. Analyses support nursing surveys that nursing readiness was not a significant factor in delaying the initiation of sedation. Additionally, although we could not explicitly account for the many possible demands on physicians and nurses that could account for delays (critically ill patients, patient factors, other procedures, etc.), our RTLS-based framework allowed us to at least accurately account for time and location of relevant staff as it relates to the sedation procedure.

CONCLUSIONS

We developed a framework-defining QI method that enhanced process mapping by incorporating EHR and RTLS timestamps through the FOCUS-PDCA framework. Our future work includes developing QI interventions to address the delays in the sedation process. Because significant manual effort was required for data extraction and cleaning, we also plan to develop a workflow analysis platform to automate the data extraction, manipulation, and analysis. Additionally, we will apply this novel method to other clinically and operationally significant QI work within our PED.

DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

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