Innovations in Medication Preparation Safety and Wastage Reduction: Use of a Workflow Management System in a Pediatric Hospital

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ABSTRACT

Background: USP <797> regulatory requirements have mandated that pharmacies improve aseptic techniques and cleanliness of the medication preparation areas. In addition, the Institute for Safe Medication Practices (ISMP) recommends that technology and automation be used as much as possible for preparing and verifying compounded sterile products.

Objective: To determine the benefits associated with the implementation of the workflow management system, such as reducing medication preparation and delivery errors, reducing quantity and frequency of medication errors, avoiding costs, and enhancing the organization's decision to move toward positive patient identification (PPID).

Methods: At Texas Children's Hospital, data were collected and analyzed from January 2014 through August 2014 in the pharmacy areas in which the workflow management system would be implemented. Data were excluded for September 2014 during the workflow management system oral liquid implementation phase. Data were collected and analyzed from October 2014 through June 2015 to determine whether the implementation of the workflow management system reduced the quantity and frequency of reported medication errors. Data collected and analyzed during the study period included the quantity of doses prepared, number of incorrect medication scans, number of doses discontinued from the workflow management system queue, and the number of doses rejected. Data were collected and analyzed to identify patterns of incorrect medication scans, to determine reasons for rejected medication doses, and to determine the reduction in wasted medications.

Results: During the 17-month study period, the pharmacy department dispensed 1,506,220 oral liquid and injectable medication doses. From October 2014 through June 2015, the pharmacy department dispensed 826,220 medication doses that were prepared and checked via the workflow management system. Of those 826,220 medication doses, there were 16 reported incorrect volume errors. The error rate after the implementation of the workflow management system averaged 8.4%, which was a 1.6% reduction. After the implementation of the workflow management system, the average number of reported oral liquid medication and injectable medication errors decreased to 0.4 and 0.2 times per week, respectively.

Conclusion: The organization was able to achieve its purpose and goal of improving the provision of quality pharmacy care through optimal medication use and safety by reducing medication preparation errors. Error rates decreased and the workflow processes were streamlined, which has led to seamless operations within the pharmacy department. There has been significant cost avoidance and waste reduction and enhanced interdepartmental satisfaction due to the reduction of reported medication errors.

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Medication preparation for pediatric patients is a very labor-intensive process.¹ It requires manual manipulation of the product to deliver the prescribed dose. Pediatric doses can vary from neonatal to adult dosing, as some pediatric patients can be within adult dosing ranges. Safe pediatric dosing requires weight-based calculations such as mg/kg, mcg/kg, and per m². This creates a variability of doses resulting in a wide range of volumes. Although some standardized protocols exist at pediatric hospitals, as many as 70% of medication doses are manually prepared by technicians and verified by pharmacists.

USP <797> regulatory requirements have mandated that pharmacies improve aseptic techniques and cleanliness of the medication preparation areas.² Pharmacists have used several methods to ensure that correct medication products are selected during medication preparation. Most commonly hospitals utilize technicians to select correct medication products. Pharmacists are responsible for visually inspecting the source ingredients and final product. Unlike with unit-dosed oral solids or commercially prepared injectable doses, it is very difficult to identify most injectable and oral liquid doses as they look similar.³ Barcode technology in product preparation, dispensing, and administration alleviates the potential for error. In addition, the Institute for Safe Medication Practices (ISMP) recommends that technology and automation be used as much as possible for preparing and verifying compounded sterile products.⁴

BACKGROUND

Prior to the implementation of the workflow management system at Texas Children's Hospital, pharmacists verified medication orders utilizing Epic's inpatient computerized physician order entry (CPOE) system. Once pharmacists verified medication orders, the medication labels would automatically print in the appropriate pharmacy satellites for medication preparation. The technicians would obtain the medication labels from the printer to prepare medication doses as appropriate. The pharmacy department utilized pharmacy batches to prepare multiple medications during designated times.

For oral liquid and injectable medication preparation, technicians obtained the printed medication orders off the oral liquid or injectable batch printers, respectively. The technicians would select the correct medications to prepare each medication label. Once the technicians prepared the medications, they would leave the source medication bottle near the prepared medications and medication labels. The pharmacists would check the final products to ensure they were prepared appropriately. A common error associated with this process was that technicians sorted and mixed up oral and injectable medication labels. This contributed to oral medications being erroneously prepared as injectable medications and vice versa. Medication misfills occurred when technicians prepared multiple medications at one time. Although the time needed to sort medication labels for preparation varied between pharmacy batches, it was significant as it impacted the time available for medication preparation and delivery. Even though there were processes in place to minimize reported medication errors, it was determined that the pharmacy department needed to utilize automation and technology to effectively reduce these medication errors.

The primary purpose of choosing to implement the workflow management system was to improve the provision of quality pharmacy care through optimal medication use and safety by reducing medication preparation and delivery errors. The workflow management system interfaced with the computerized physician order entry system. The goal was to reduce the quantity and frequency of reported medication errors and to determine other benefits associated with the implementation of the workflow management system, such as cost avoidance and the ability to support the organization's decision to move toward positive patient identification (PPID). The implementation of the workflow management system also provided an opportunity to track medication deliveries throughout the hospital.

With the implementation of the workflow management system, our department established a process that allows electronic recording of the entire process from medication preparation to dispensing. The use of the workflow management system minimized wrong

product selection, standardized the medication dilution process, and archived digital images of each medication preparation phase. Not only did this allow for tighter control of our standard operating procedures, it also allowed for more robust follow-up on reported medication errors, individual performance accountability, and the opportunity to trace lot numbers for medication recall events.

METHOD

Implementation

The workflow management system core implementation team initially consisted of 3 pharmacy operation managers, 3 technician managers, an assistant director of application and technical services, a health-system pharmacy administrative resident, and 2 representatives from the pharmacy computer support team. Due to pharmacy organizational structure changes during the initial implementation phase, an assistant director of pharmacy operations, another pharmacy operations manager, and another technician manager were added to the team. The assistant director of application and technical services led the pharmacy computer support team in determining all application testing, building, and testing of equipment. To minimize costs, the implementation team manually configured the workflow management system workstations. Several members of the implementation team visited other organizations to observe the system in use and to interview the leadership and staff to understand challenges and barriers. Questions were prepared and submitted in advance of the site visits to ensure that the meetings were beneficial and productive. The knowledge gained from the site visits assisted the members of the implementation team in establishing the timeline and developing an action plan. The members of the implementation team also analyzed peer-reviewed articles of similar institutions with an intravenous workflow management system.⁵ It was determined that the workflow management system would be used for the preparation and verification of oral liquid medication doses with an implementation date of September 23, 2014. An implementation date of January 13, 2015 was set for the preparation and verification of injectable medications.

Obstacles, such as educational timelines and budgeting for an appropriate number of technician and pharmacist full-time equivalents (FTEs), were documented and addressed with the development of the action plan. The implementation team presented

the action plan to the pharmacy leadership team to obtain additional feedback and guidance as appropriate. It was determined that significant buy-in would be needed from the staff, so the team strategically marketed all of the benefits to the pharmacy department prior to the implementation. The team hosted a day for the pharmacy department to ensure everyone had an opportunity to observe and prepare a medication utilizing the workflow management system. There were food options, activities, games, and giveaways available during the day to promote attendance at the event. Leaders from outside the pharmacy department were also invited to learn the benefits of the workflow management system. Patient safety T-shirts were given to the staff prior to the implementation of the workflow management system, with the expectation that everyone would wear them during the go-live periods.

An analysis of anticipated workload, due to expected time increases in medication preparation, was conducted to project the number of additional technician and pharmacist FTEs needed for the implementation of the workflow management system. The pharmacy batch times were increased from 6 batches a day to 10 batches a day to streamline the anticipated workload.

The implementation team worked to determine the number of the workflow management system workstations that would be needed in each pharmacy area and the physical space and locations needed for the placement of the workstations, television monitors, printers, and sort stations in the pharmacy areas. New workflows were designed to specifically address the processes of medication preparation, pharmacist verification, medication sorting, and medication delivery. Visual educational flyers that showed step-wise medication preparation techniques and picture sequences were laminated and posted in the pharmacy areas. Additional educational materials were posted on the pharmacy department shared drive for immediate access.

Another obstacle the team faced was the fact that the pharmacy department utilized a PINNACLE compounding system for the preparation of large volume intravenous fluids. The workflow management system did not interface with the PINNACLE compounding system. An additional workflow was created to include large volume intravenous fluids that were prepared via PINNACLE in the workflow management system pictures as appropriate during medication preparation.

A training lab was created utilizing a pharmacy satellite that contained several workflow management system workstations for oral and injectable bar-coded medications. A 70-inch television was added to the training lab to visually display custom workflow management system queues such as the medication doses waiting for preparation, medication doses pending pharmacist verification, and medication doses pending sorting prior to delivery. Additionally 70-inch televisions were added to the pharmacy areas during the implementation of workflow management system to assist the front-line staff in managing the workflow. The televisions were used as a status board to monitor when medication doses were approved and ready for distribution to the floor. The implementation team set a goal to ensure that 80% of the front-line staff obtained hands-on workflow management system training prior to the go-live date. The implementation team exceeded the goal by having 85% of the front-line staff trained prior to the go-live date. The staff were given the opportunity to express concerns, offer feedback, and ask questions during their training periods. Superusers were also identified and assisted the implementation team with educating the front-line staff. Educational checklists were created to ensure consistent training for all front-line staff.

The implementation team collaborated with nursing leadership to determine how to utilize the workflow management system to support the organization's decision to move toward PPID and how to educate the nursing department. It was determined that pharmacy needed to place the workflow management system labels on the final prepared medication syringes in a specific way to ensure that the PPID barcode would be easily available for nurse scanning. Prior to the implementation of workflow management system, pharmacy dispensed all medications in a medication envelope. Medications that were going to be prepared via workflow management system were dispensed in clear, plastic zipper lock bags. Medications that were not going to be prepared via the workflow management system were dispensed in medication envelopes. Both nursing and pharmacy departments were educated about these changes. Medication delivery tracking was also discussed with nursing leadership to ensure they were aware of all the changes that would impact the nursing department. All additional nursing education was e-mailed to nursing leadership for them to share with their teams.

Prior to the go-live dates, pharmacy leaders signed up for day, evening, and night shifts to observe specific critical success factors necessary for the successful

implementation of the workflow management system. Leadership observation tools (LOTs) were created to ensure all leaders and superusers were consistent in observing critical success factors during the go-live period. On the Mondays before the go-live periods, the implementation team reviewed the action plan to ensure everything was marked off as completed. Re-education packets were also shared with the pharmacy department to ensure everyone was aware of the resources available for successful implementation of the workflow management system. The pharmacy computer support team set-up a command center to address any technical issues that might occur during the go-live periods. Pharmacy leaders met at a specific time during the afternoon to share observations, discuss critical success factors, and to determine whether continued leadership support was needed. The go-lives for both the oral liquid and injectable medications were successful.

Performance Evaluation Methods

Prior to the implementation of the workflow management system at Texas Children's Hospital, data was collected and analyzed from January 2014 through August 2014 in the pharmacy areas in which the system would be implemented. Data were excluded for September 2014 during the workflow management system oral liquid implementation phase. Data were also collected and analyzed from October 2014 through June 2015 to determine whether the implementation of the workflow management system reduced the quantity and frequency of reported medication errors. Data collected and analyzed during the study period included the quantity of doses prepared, number of incorrect medication scans, number of doses discontinued from the workflow management system queue, and the number of doses rejected. Data were also collected and analyzed to identify patterns of incorrect medication scans, to determine reasons for rejected medication doses, and to determine a reduction in wasted medications.

Statistical Analysis

Statistical significance was determined by utilizing a *t* test for dependent means. Error rates from January 2014 through August 2014 were placed in the pre-implementation group. Error rates from November 2014 through June 2015 were placed in the post-implementation group. Data analyses were performed using Microsoft Excel 2013.

Performance Evaluation Results

During the 17-month study period, the pharmacy department dispensed a total of 1,506,220 oral liquid and injectable medication doses. From October 2014 through June 2015, the pharmacy department dispensed 826,220 medication doses that were prepared and checked via the workflow management system. Of those 826,220 medication doses, there were 16 reported incorrect volume errors. In addition to the incorrect volume errors, there were 4 reported mislabeling errors. Of the 4 reported mislabeling errors, 3 errors involved medication doses that were sent to the nursing units before the pharmacists completed the final check of the medications. One of the 4 reported mislabeling errors was dispensed to the nursing unit with a final check label on the wrong medication. To reduce the occurrence of these types of errors, pharmacy managers utilized pharmacy huddles twice a week to educate the pharmacy department.

Error rates were calculated as doses in error per 10,000 doses dispensed prior to the implementation of the workflow management system and retrospectively during the study period. The error rate prior to implementation averaged 9.8 errors per 10,000 doses dispensed. The error rate after implementation averaged 8.2 errors per 10,000 doses dispensed. The average overall error rate reduction was 1.6 errors per 10,000 doses dispensed. This was statistically significant ($p = .003224$; $p \leq .05$).

Prior to the implementation of the workflow management system, the pharmacy department averaged an oral liquid and injectable medication reported error 2.7 times per week. The greatest number of consecutive days without a reported oral liquid or injectable medication error was 7. After the implementation of the workflow management system, the average number of reported oral liquid medication and injectable medication errors decreased to 0.4 and 0.2 times per week, respectively. The greatest number of consecutive days without a reported oral liquid or injectable medication error was 48 days.

Workload and Full-Time Equivalent Assessment

As previously mentioned, an FTE assessment was conducted to anticipate the number of pharmacists and technicians that would be needed after the implementation of the workflow management system. Time and motion studies were used to validate and confirm the time workload factors associated with each category of medications. Dispense reports were analyzed to determine the number and type of medications that printed during each hour in

order to assess the workload. Technician nonpreparation time such as garbing and medication delivery time was calculated. Time cushion was calculated by adding 10% to the amount of time for preparation, scanning, and delivery to create a workload variance while maintaining 90% staff productivity. Anticipated pharmacist verification and checking factors were also assessed prior to the implementation of the workflow management system.

FTEs were calculated by multiplying the number of shifts per week with the number of worked hours per day divided by 40 hours. Pharmacists work 10-hour shifts and technicians work 8-hour shifts. Utilizing all of the information and taking into account the increase of batches a day, a total of 1.75 pharmacist FTEs and 12.2 technician FTEs were added for the implementation of the workflow management system. An additional pharmacist shift was added to the FTE grid to be staffed 7 days a week working 10 hours a day. Eight technician shifts were added to the FTE grid to be staffed 7 days a week working 8 hours a day. An additional technician shift was added to the FTE grid to be staffed 5 days a week working 8 hours a day.

DISCUSSION

The implementation of the workflow management system has given our pharmacy department the opportunity to retrospectively review the medications that are reportedly prepared in error. Since implementation in September 2014, there have been 7 reported medication errors that were later reviewed and found to be invalid. Pharmacy leaders shared the pictures of the invalid medication error reports with nursing leadership during follow-up of reported medication errors.

Prior to the implementation of the workflow management system, medication doses that were discontinued after the medication labels were printed in the pharmacy batches were prepared by the pharmacy technicians. In addition, these doses were difficult to remove during the tossing and sorting phases prior to medication delivery. As a result, there was significant wastage associated with dispensed discontinued medication doses.

After the implementation of the workflow management system, medication doses that were discontinued, after the medication orders entered the queue, were automatically removed. This led to a decrease in discontinued medication doses that were prepared and delivered. During the study period, there were a total of 10,498 medications that were incorrectly

scanned by the pharmacy staff. The medications were automatically rejected by the workflow management system, thus preventing wrong product preparation. Of the 10,498 incorrect medication scans, 5,312 (50.6%) were oral liquid medications and 5,186 (49.4%) were intravenous medications. The frequency of incorrect medication scans for both oral liquids and intravenous medications decreased over the study period. The average number of monthly doses prepared using the workflow management system increased 12%, from 84,682 doses per month during the first 3 months to 96,222 doses per month during the last 3 months.

Cost avoidance was calculated by determining the average costs of oral liquid medications and injectable medications that were discontinued prior to medication preparation. The potential for preparing incorrect oral liquid and intravenous medication doses was also factored into the cost avoidance calculations by including incorrectly scanned medications prior to medication preparation. Cost avoidance for oral liquid medication doses during the study period totaled approximately \$171,521.56. Cost avoidance for injectable medication doses during the study period totaled approximately \$297,050.51. Cost avoidance totaled approximately \$468,572.07 for both oral and injectable medications.

CONCLUSION

The implementation of the workflow management system was significant for our organization, which was able to achieve its purpose and goal of improving the provision of quality pharmacy care through optimal medication use and safety by reducing medication preparation errors. Error rates decreased and the workflow processes were streamlined, which has led to seamless operations within the pharmacy department. There has been significant

cost avoidance and waste reduction reported since the implementation of the workflow management system. Implementation has enhanced interdepartmental satisfaction due to the reduction of reported medication errors. Additional benefits include significant time savings and pharmacy productivity. Pharmacists have the liberty to remotely verify medication orders as opposed to being physically present in the pharmacy areas. As a result, the pharmacy department has been able to provide quality pharmacy care and customer service through optimal medication use and safety.

The organization plans to expand the scope of the workflow management system to additional pharmacy satellites. Additional medication types, such as intravenous admixtures, have been scheduled to be phased into the workflow management system. Medication dose delivery tracking has also been scheduled to be implemented.

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The authors declare no conflicts of interest.

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