Original Work

Optimization of Automated Dispensing Unit Inventory and the Impact on Department Waste and Inventory Control

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Abstract

Purpose: To determine if application of a standard inventory formula from literature and manufacturer recommendations will improve automated dispensing cabinet (ADC) inventories by increasing vend:fill ratios, decreasing stock out rates, and improving the percentage of doses from ADCs.

Methods: Seventeen profiled ADCs were optimized over two months. The optimization process included removing medications that had not been dispensed in over 180 days, adding medications that had been repeatedly loaded to the ADC and dispensed from pharmacy, and adjusting the desired par levels for medications within the ADC. The inventory levels were adjusted using a standard inventory formula. The primary outcome was the vend:fill ratio, and secondary outcomes included percentage of stockouts, total number of medications in a machine, percentage of medication doses from the ADC, and number of outdated transactions.

Results: In total, 1,995 medication par values were adjusted in the seventeen machines over a one-month optimization period. The mean vend:fill ratio increased from 8.34 to 9.27. Prior to optimization, 78,684 (86.1%) doses were dispensed from ADCs. Post-optimization, the number of medication doses from ADCs increased to 80,663 (92.4%).

Conclusion: This study confirms that ADC optimization via a standard inventory formula improves vend:fill ratios, stockout percentages, and percentage of doses from ADC.

Automated dispensing cabinets (ADCs) were first used in hospitals in the late 1980s.[1] ADCs are decentralized, computerized medication dispensing systems that enable the storage of medications within hospital units, while also assisting with inventory control, order entry, medication administration, and documentation.[2] They are a gold standard for medication administration. ADCs have been found to enhance workflow efficiency, reduce medication errors, and improve medication administration by increasing access to medications.[1,2] Research has shown ADCs led to lower rates of dispensing errors compared to traditional unit-dose cassettes, fewer errors in drug administration, and fewer missing doses.[1]

Par levels, or the inventory levels of medications stored in an ADC, are commonly listed as maximum and minimum values. Most commonly in pharmacy, inventory levels are estimated by calculating average usage over time. In ADCs, quantities are commonly expressed as a minimum of a 2- or 3-day supply and a maximum of up to a 7-day supply. This approximation comes with issues: amounts for minimum and maximum day supplies can be subjective, usage can fluctuate with prescriber preferences and drug shortages, and quantities may not be updated as usage changes.

There are few published articles about the optimization of ADCs. Mark and Mehta used a days-supply approach to improve ADCs within their hospital to achieve a vend:fill ratio of >11, which is recommended for a tertiary medical center.[3] They did not achieve a vend:fill ratio of greater than 11, but they did increase their ratio from 6.5 to 9.4.[3] Lupi and colleagues evaluated a pharmacist-led ADC optimization program.[4] This group noted lower medication dispenses from central pharmacy and lower stockout rates after optimization.[4] O'Neil and colleagues compared a days-supply method to a standardized formula to improve inventories.[5] They found the formula method improved inventory metrics, including vend:fill ratio and led to a cost savings of $44,981 for the pharmacy department.[5] Literature is lacking in identifying a standard approach to optimizing ADC inventory. This study was designed to replicate the outcomes of a standardized formula found to be beneficial by O'Neil and colleagues.

This study was completed at a not-for-profit, 188-bed tertiary care center with 90 ADCs in Milwaukee, Wisconsin. The tertiary care center uses a cartless medication distribution model that dispenses the majority of medication doses from ADCs, with patient-specific medications stored in ancillary units of the ADC and ordered medications being loaded to ADCs as needed.

For this study, ADC optimization was defined as the modification of inventory and inventory levels within an ADC to improve the medication-use process and increase departmental efficiency. The optimization process was adapted from O'Neil: (1) removing stock of unused medications,

(2) adding medications as standard stock if repeatedly loaded, (3) adjusting desired on-hand inventory levels to decrease refills and "stockouts," and (4) rearranging stock to better suit new quantities.[5] The authors of this study hypothesized that the use of a standardized formula from O'Neil would reduce the number of refills by pharmacy between dose removals by nursing staff, increase the percentage of medications from ADC, and reduce waste of outdated medications.

Methods

Seventeen profiled ADCs (Pyxis, BD, Franklin Lakes, NJ) located within the emergency department, intensive care units, and medical-surgical units were optimized and studied from October 2021 until March 2022. The optimization of each machine required 4 hours to complete and was performed by a pharmacy resident to maintain consistency. It took one month to complete all 17 machines. Data, including vend:fill ratios, stockout percentages, machine inventories, and outdated medications, were collected through BD's integrated analytic Web portal (Knowledge Portal for Pyxis, BD) for a three-month period before optimization occurred and for a two month period after optimization. This study was determined to be exempt by the institutional review board.

Optimization of each machine was based on three-month usage reports generated 24 hours prior to assessing each cabinet. Medications were removed if not dispensed in 180 days and not considered to be an emergent medication. Emergent medications for the ADCs assessed are listed in Table 1. The removal of medications occurred first to free up space in each machine and to decrease the number of expiring, unused medications. Next, medications loaded four or more times were reviewed and added to each machine.

Prior to October 2021, the electronic health record at this facility did not communicate effectively with the ADC software; it did not identify when other medication strengths in ADC inventories could be used for dosing, or what medications were stored in nearby machines. Often, this led to more doses coming from central pharmacy and more medications being pulled for cartfill. In November 2021, a new electronic health record was introduced that had improved interfacing with the ADCs. The new electronic health record provided a reference of medications within each ADC for pharmacists and would link to an ADC that could provide an ordered dose before dispensing a medication from central pharmacy.

For this study, the par level calculations were adapted from standard inventory formulas by O'Neil and colleagues. The minimum par value (Min), or the quantity at which the pharmacy would be alerted to refill the medication, was calculated as the quantity of safety stock (SS) plus the mean average quantity dispensed between deliveries over 24 hours (qLT): Min = qLT + SS.5 The SS value is defined previously by O'Neil and colleagues and the formula is as follows:[5]

The maximum par value (Max) was calculated as the Min value plus a reorder

$$SS = (z)(\sigma qLT)\sqrt{\frac{1}{14}}$$

quantity (ROQ): Max = Min + ROQ.[5] The reorder quantity was also defined previously by O'Neil and colleagues, with the formula as follows:[5]

Medications were refilled on delivery runs completed by pharmacy staff based

$$ROQ = \sqrt{\frac{(qLT)(52)}{2}}$$

on generated reports listing medications at or below minimum par levels. Minimum par values were set to a quantity of at least 2. Items considered bulk, such as topical agents, and electrolyte infusions were excluded from par value assessment since their par values already reflected maximum amount of drug for pocket size.

Study Endpoints

Endpoints of the study included vend:fill ratio, percentage of doses from ADCs, number of outdated medications in each machine, stockout percentages, and overall inventory quantities of each machine. Vend:fill ratio was selected as the primary endpoint. The goal vend:fill ratio was determined to be 11, as noted previously by Mark and colleagues.[3] An improvement in this ratio would mean increasing the amount of times nursing staff pulls a medication while decreasing the amount of times the pharmacy department refills the medication. Vend:fill ratio, number of outdated medications, stockout percentages, and inventory quantities were calculated using the ADC analytic website. Lower stockout rates and lower numbers of outdated medications were considered to represent more appropriate inventory quantities.

TABLE 1. Emergent Medications

Emergent Medications
Adenosine 6 mg/2 mL Vial
Atropine 1 mg/10 mL Syringe
Calcium Chloride 1 g/10 mL Vial
Calcium Gluconate 1 g/10 mL Vial
Dextrose 50% 50 mL Syringe
Diphenhydramine 50 mg/1 mL Vial
Dobutamine 500 mg/250 mL Infusion
Dopamine 400 mg/250 mL Infusion
Epinephrine 1 mg/ 1 mL Vias
Epinephrine 1 mg/10 mL Syringe
Glucose Gel
Glucagon 1 mg/10 mL Kit
Labetalol 20 mg/4 mL Syringe
Nicardipine 40 mg/200 mL Infusion
Nitroglycerin 50 mg/250 mL Infusion
Rapid Sequence Intubation Kit
Sodium Bicarbonate 8.4% 50 mL Syringe
Tranexamic Acid 1000 mg/100 mL Infusion

Results

A total of 1,995 medication par values were adjusted, 50 medications were added, and 138 medications were removed. The mean vend:fill ratio prior to any inventory updates was 8.34, with the ED machines having a ratio of 4.70, the ICUs having a ratio of 7.95, and the Med-Surg units having a ratio of 10.13 (Table 2). After optimization, the average vend:fill ratio increased to 9.27 overall, with the EDs, ICUs, and Med-Surg units increasing to 5.45, 8.43, and 11.34, respectively. Before any inventory changes, approximately

78,684 (86.1%) medications were dispensed from the ADCs each month. After the updates were completed, 80,663 (92.4%) medications were dispensed from the ADCs each month. The number of doses dispensed from each ADC increased. The number of outdated medications increased from 15.8 to 19.5 medications per station. Stockout rates improved from 1.22% overall to 0.91%. The average number of medications in each ADC decreased from 387 to 342 medications. The total number of medications in each of the seventeen stations was reduced.

Discussion

The optimization of ADC inventory by adaptation of standard inventory formula was successful in improving inventory control with ADCs and efficiency within the hospital. Additionally, this study included more than double the number of ADCs as the original findings by O'Neil and colleagues.[5] This study also confirms that a pharmacist-led optimization program, similar to Lupi's study, can decrease stockouts and dispenses from central pharmacy.[4] However, this investigation had several limitations. During the optimization process, the hospital adopted a new electronic health record that had a better interface with the ADC software. The increased number doses from ADC could have been influenced by both the study and the new EHR. Another limitation is the ability of pharmacy staff to adjust par levels at any time throughout the study. Therefore, adjustments could have been changed within days of implementation. However, changing inventories within ADC machines is an ongoing practice and did not appear to substantially influence the improvement in inventory metrics. The number of outdated medications did increase, but it was noted that March 2022 had a high rate of outdated medications. March is considered to be an outlier and following months have had outdated medication quantities similar to February 2022. Trending outdated medications over a longer period of time is predicted to show an overall decrease in outdated medications. More studies completed over a longer period of time are needed to confirm that the formula method of ADC optimization is a valid form of inventory management.

TABLE 2. Pre- and Post-Optimization Automated Dispensing Cabinets Characteristics

Metric	Pre-Optimization	Post-Optimization	Change
Vend:Fill Ratio, overall	***8.34 ± 2.34***	***9.27 ± 2.56***	***0.93***
Emergency Department	4.70 ± 1.09	5.45 ± 0.86	0.75
Intensive Care Units	7.95 ± 0.25	8.43 ± 0.78	0.48
Medical-Surgical Units	10.1 ± 0.45	11.3 ± 0.66	1.2
Doses from ADC, overall percentage	***85.6%***	***92.0%***	***6.40%***
Emergency Department	75.4%	82.4%	7.00%
Intensive Care Units	77.6%	92.0%	14.4%
Medical-Surgical Units	90.2%	93.9%	3.70%
Outdated Drugs per Station, overall	***15.8***	***19.5***	***3.7***
Emergency Department	10.8	10.8	0
Intensive Care Units	20.3	23.0	2.7
Medical-Surgical Units	16.0	18.0	2
Stockout Rates, overall percentage	***1.22% ± 1.08***	***0.91% ± 0.58***	***- 0.31%***
Emergency Department	2.80% ± 1.23	1.51% ± 0.58	- 1.30%
Intensive Care Units	1.13% ± 0.10	1.19% ± 0.46	0.10%
Medical-Surgical Units	0.56% ± 0.15	0.48% ± 0.26	- 0.10%
Number of Medications per Station, overall	***387***	***342***	***- 45***
Emergency Department	217	208	- 9
Intensive Care Units	421	379	- 42
Medical-Surgical Units	447	385	- 62

Conclusion

This study has confirmed that using a standard inventory formula to optimize ADCs has a positive impact on vend:fill ratios and stockout percentages. The results of this study correlate with other literature that a formula-driven inventory optimization process does improve inventory metrics.

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