Optimization of Automated Dispensing Cabinets at a Large Academic Medical Center

by

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Abstract

The COVID-19 pandemic struck healthcare workers with burnout and left hospitals with extreme staffing shortages. To minimize complications and prevent medication errors during this time, inpatient pharmacies have attempted to increase the availability of medications stored on nursing units. Automated Dispensing Cabinets (ADCs) simplify medication dispensing by working directly with the electronic health record to dispense medications ready for administration. A unique challenge of ADCs is their volatile usage, dependent on medication shortages, provider preference, and individual patient needs. As a result, optimization of ADC inventory is an emerging focus of pharmacy departments as health systems look to maximize efficiency of medication dispensing. At Allegheny General Hospital in Pittsburgh, Pennsylvania, all inpatient profiled ADCs at were optimized during the transition from Pyxis™ES to Omnicell® in the fall of 2021. The following metrics were used to assess efficiency: percentage of cabinet-dispensed medications, vend-to-refill ratios, and stock out percentages. Three months of data for the above metrics were pulled from Pyxis™ES and used as a baseline. Medication par levels in Omnicell® cabinets were then adjusted per usage rates. The metrics were collected again after three months of new par levels in the new cabinets and assessed for increased availability of medications. When compared to baseline, the optimized metrics showed an increased in availability of medications in the cabinets by eight percent. The public health significance of this

study lies with the streamlining of medication delivery while contributing to the creation of an error-free healthcare system.

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1.0 Background

Plan-Do-Check-Act, or PDCA, was first conceptualized in the mid twentieth century by W. Edwards Deming[1] and provides a foundation for quality improvement processes. Since its introduction, PDCA has been used to model automation, production lines, and most notably, is part of the American Society of Quality Toolbox and Lean methodology. Beginning with 'plan', PDCA is cyclical, continuous, and comprised of four parts. The planning stage consists of objectives and establishing a process design. This is followed by 'do', in which preliminary action is taken on the plan. In the third step (check), data is collected, monitoring takes place, and an evaluation is made on the initial plan. Finally, 'act' implements the plan in full and signals the end of one complete PDCA cycle.

Automation of inventory is a key operational feature of inpatient pharmacies. Generally, automation solves one of three problems: securing and dispensing medication on nursing units; vertically storing medication, such that valuable counter space is not used for medication storage; and maintaining an electronic pathway to validate accuracy of dispensed medication. Automated Dispensing Systems (ADS) are a way of decentralizing medication storage in hospitals without compromising security or accuracy of dispensing. A complete ADS consists of a virtual "brain"

Figure 1

and Automated Dispensing Cabinets (ADCs), also referred to as cabinets, which are strategically placed near nursing stations on the hospital unit to ease dispensing and administration. The brain virtually tracks inventory movement within ADCs through barcode scanning, such that a user is able to view ADS inventory for the entire hospital (or health system) from a single sign-on.

ADS are a relatively new technology, only having been introduced to hospitals in the 1980s[2]. Therefore, reliable data on optimizing inventory with ADCs is still being collected and analyzed. This project contributes to advancing optimization of pharmacy automation, specifically, validating metrics with the intent of yield optimization.

Applying PDCA to pharmacy automation, ADCs are the core of secure medication inventory management. At Allegheny General Hospital (AGH), a 500-bed tertiary medical center in Pittsburgh, Pennsylvania, at least two profiled ADCs are positioned on every nursing unit (up to four in two intensive care units (ICUs)) and utilized largely to track medication movement. This is done through record of transactions with 'par' values, or pre-determined minimum and maximum quantities set for each medication. Once a medication reaches its minimum value, the inpatient pharmacy is notified for refill. The maximum value is the ideal quantity of a medication held in the cabinet. We theorized that these par values can be adjusted to optimize ADC inventory.

A newer feature of ADS is the ability to manipulate data collected from ADCs. Pyxis™ES is an ADS that uses the minimum and maximum par values of each medication to calculate a vend-to-refill ratio and stock-out percentage. The vend-to-refill ratio compares the number of times a medication is pulled from the cabinet for administration by nursing (vend) to the number of times a medication is refilled by a pharmacy team member. For example, heparin is a commonly used anticoagulant that is stored in almost every ADC at AGH. When a patient is ordered a heparin drip, the nurse retrieves it from the cabinet for administration, and the cabinet acknowledges holding one less heparin drip. In any given cabinet, the vend-to-refill ratio establishes the rate at which heparin drips are removed (vended) compared to the rate of refilling heparin drips from central pharmacy. The stock-out percentage indicates the number of times a medication stocks out of the cabinet compared to the number of times a medication is dispensed from the cabinet. For example, once all the heparin drips have been removed from the cabinet, the cabinet sets a virtual message to the central pharmacy inventory manager (Pharmogistics®) alerting a technician that the cabinet has stocked-out of heparin drips.

The first two metrics, vent-to-refill ratio and stock-out percentage represent only the medications dispensed from ADCs. Due to the sheer number of possibly ordered medications for a patient, stocking every medications in each ADC is not achievable. A third metric, percent utilization, is used to depict the percentage of total medication dispenses that come from medication stocked in ADCs. Every evening, 24 hours of patient-specific medications that are not stocked in ADCs have to be individually filled in central pharmacy and then delivered to the floor for the next day, a process commonly referred to as cart fill. Percent utilization compares the number of total medication orders dispensed from profiled ADCs on the floor to the number of medications filled during cart fill.

As hospitals continue to battle staffing shortages, inventory optimization becomes an

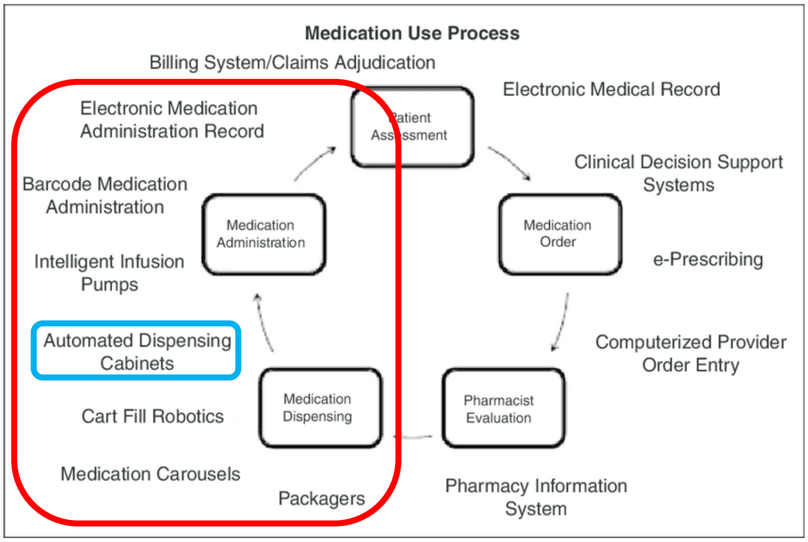

Figure 2[19]

essential safety function. A quick glance at the medication use process (Figure 2) reveals abundant opportunities for error as medications move from the pharmacy up to the floor, and finally are administered to a patient. Barcode scanning technology enables maintenance of an electronic pathway from dispensing to administration, which is one of the major goals of pharmacy automation, as well as a National Patient Safety Goal (NPSG) for hospitals.[4] It is important for hospitals such as AGH to meet NPSGs as they are directly tied to The Joint Commission (TJC) standards for accreditation. Centers for Medicare & Medicaid Services (CMS) then uses TJC accreditation to evaluate hospitals and health systems.[5]

Adjusting medication par values based on usage specifically targets maximizing the medication quantity on-hand in each profiled ADC, such that the cabinet formularies are reflective of the needs of the patient population seen on that unit. This streamlines medication administration from a nursing standpoint, as *most* of the commonly ordered patient medications are already on the unit. Integration of the Electronic Health Record (EHR) and ADCs allows medication orders to be virtually sent from the inpatient pharmacist verification screen to the profiled ADC where the nurse is able to pull the medication out under the patient's name. As much as possible, this strategy minimizes the steps involved when pulling patient-specific medications individually (cart fill) and permits pharmacy departments to instead focus on other clinically relevant tasks. For example, pharmacists at AGH are each assigned a unit of the hospital to review and adjust medications according to patients' kidney function and evaluate patient medication lists for intravenous (IV) to oral therapy conversions if they do not require IV therapy, which is much more costly.[6]

Traditionally, nursing-to-patient ratios on standard medical-surgical hospital floors are maximized at 5 or 6:1.[7] Since the SARS-CoV-2 (COVID-19) pandemic, hospitals have seen ratios of up to 10:1.[8] The strain of these higher ratios (>6:1) puts patients at risk of adverse complications from nothing more than the hospital stay itself.[9,10] While automation cannot replace a bedside nurse, using automation to negate fill errors and maintain the integrity of secure electronic workflows permits nursing to focus on the needs of the patient at bedside rather than acquisition of their medication.

2.0 Methods

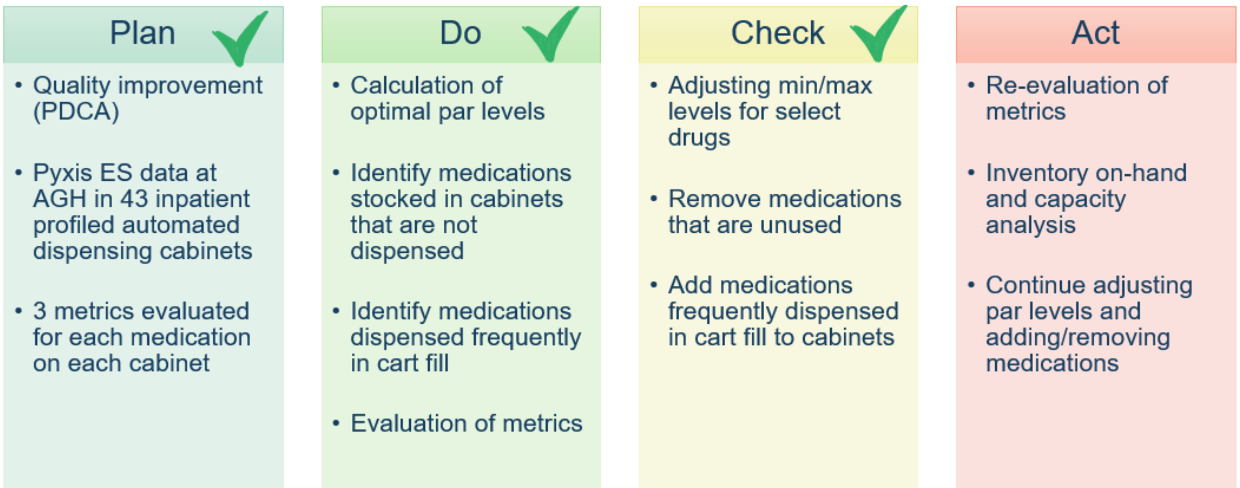

Figure 3 Project Design

Beginning with "plan," the primary objective was to optimize profiled ADCs on inpatient nursing units. Optimization was measured using three metrics or key performance indicators (KPIs): vend-to-refill ratio, stock-out percentage, and percent utilization of cabinets. All three metrics were calculated at baseline for each medication in each profiled ADC. Based on universally-accepted assumptions among large academic medical centers, an average vend-to-refill ratio of 11, stock-out percentage of less than three percent, and percent utilization of over 85% would yield optimized metrics at a large academic medical center such as AGH.[11] Figure 3 outlines the general project design: to achieve these target metrics, par levels for medications in each cabinet were adjusted, and the same metrics were re-evaluated after adjustment to determine if the primary outcome was achieved.

In the fall of 2021, the hospital switched from Pyxis™ ES to Omnicell®, and AGH had an opportunity to optimize ('do' phase) all ADCs at once. Three months of Pyxis™ ES data was obtained from BD Knowledge Portal on all inpatient profiled ADCs before the transition. From this data, an average vend-to-refill ratio (8.89), average stock-out percentage (4.55%), and percent utilization (81%) was calculated. Notable exclusions from each cabinet were non-standard medications and non-medication items.

After preliminary analysis and baseline metric calculation, it was decided that a priority group of medications would be targeted for par value adjustment. Logically, this group was comprised of medications with a vend-to-refill ratio greater than 11 and stock-out percentage of greater than three percent. This priority group was divided into four medication categories (see Figure 4): antidotes and rare use; mid-large size and regular use; small size and regular use; and small size and high use. From there, each category was assigned new par values determined by a combination of cabinet space and use. Par levels were also subject to additional adjustment guided by the average five to seven day supply (maximum value) and highest daily dose (minimum value) of the medication.

Percent utilization (Figure 5) was addressed in two parts – analysis of medications not dispensed in the past 90 days from ADCs and medications frequently dispensed in cart fill. These were identified using Pyxis™ES reports. Two medications (aluminum hydroxide/magnesium hydroxide

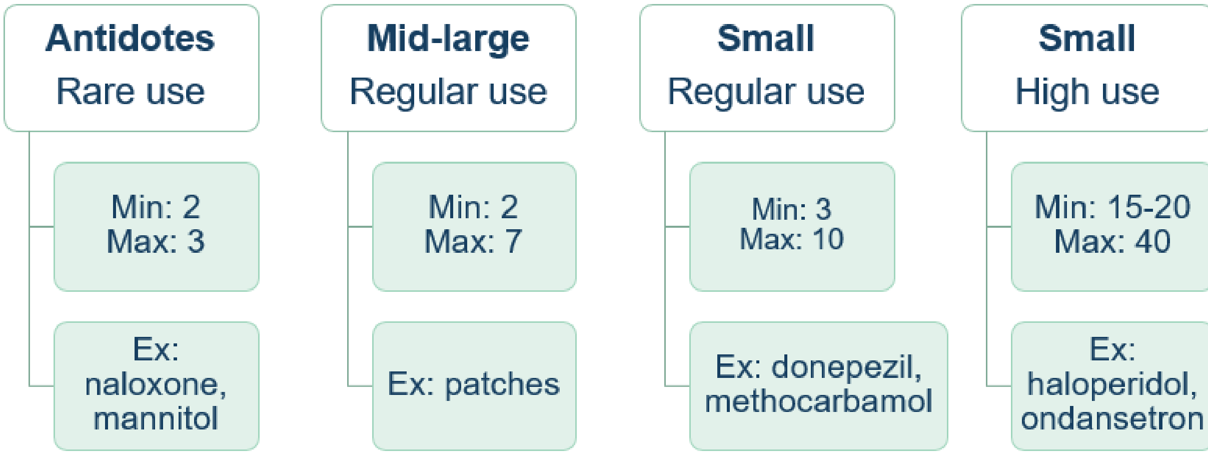

Figure 4

and all strengths of warfarin) were excluded due to necessity of antidote and variable dosing. All medications pending removal from cabinets on ICUs had ultimate approval from the respective ICU clinical pharmacist. Additionally, medication use was analyzed from a unit-wide perspective and it was determined that a medication would only warrant removal if it remained unused in all ADCs on the unit. Medications identified to be filled during cart fill more than twice weekly were added to the respective cabinet.

After all profiled ADCs at AGH were transitioned from Pyxis®ES to Omnicell®, the 'check' phase began. Par values were adjusted, medications were added and removed as indicated, and all Omnicell® ADCs recorded transactions for three more months. At the conclusion of three months, each metric was calculated again, marking the end of the 'check' phase.

The 'act' phase of PDCA was essentially an extension of the 'check' phase. After attempted recalculation of each metric, par values were adjusted for all other medications according to their respective category. Percent utilization metrics were each reevaluated and additional medications were both added and removed from cabinets.

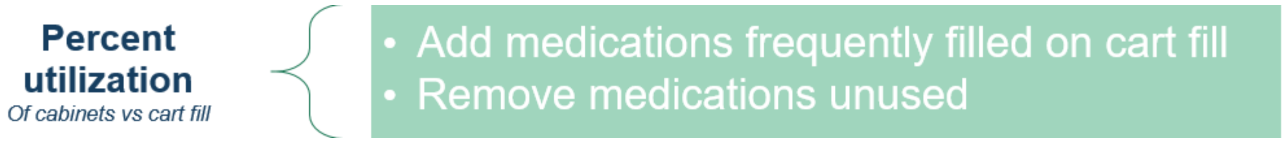
Percent utilization
Of cabinets vs cart fill
• Add medications frequently filled on cart fill
• Remove medications unused

Figure 5

3.0 Results

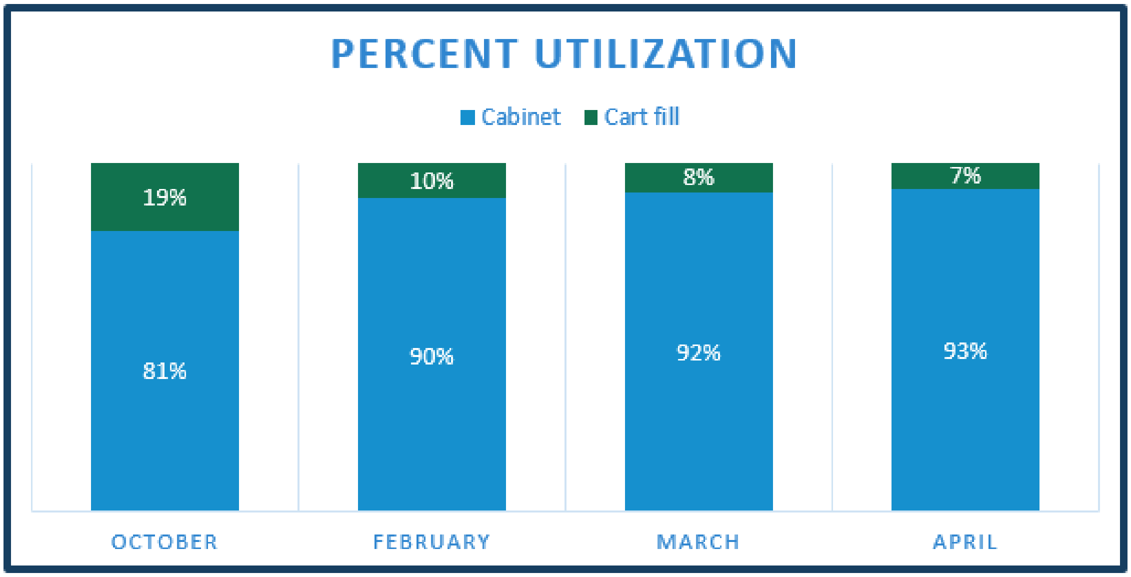

Figure 6 October 2021-April 2022 Percent Utilization

Medications were removed from 43 cabinets and added to 41 cabinets on 17 units, respectively. Two units were excluded due to under-utilization and additional analysis of cabinet formulary. The total number of medications removed was 329 and the total number of medications added was 147. The only medication removed from all cabinets was ziprasidone 20 mg capsules. Figure 6 depicts the change in percent utilization of cabinets from October 2021 to April 2022, in which ADC dispensing increased by 8% to a total of 93%.

Figure 7 shows each of the metrics broken down by their respective algorithm for how par levels were determined in each medication group. There were 294 medications identified in the priority group for par level adjustment. Since each unit and its respective cabinets had different formularies, the number of medications per cabinet with adjusted par values varied. The

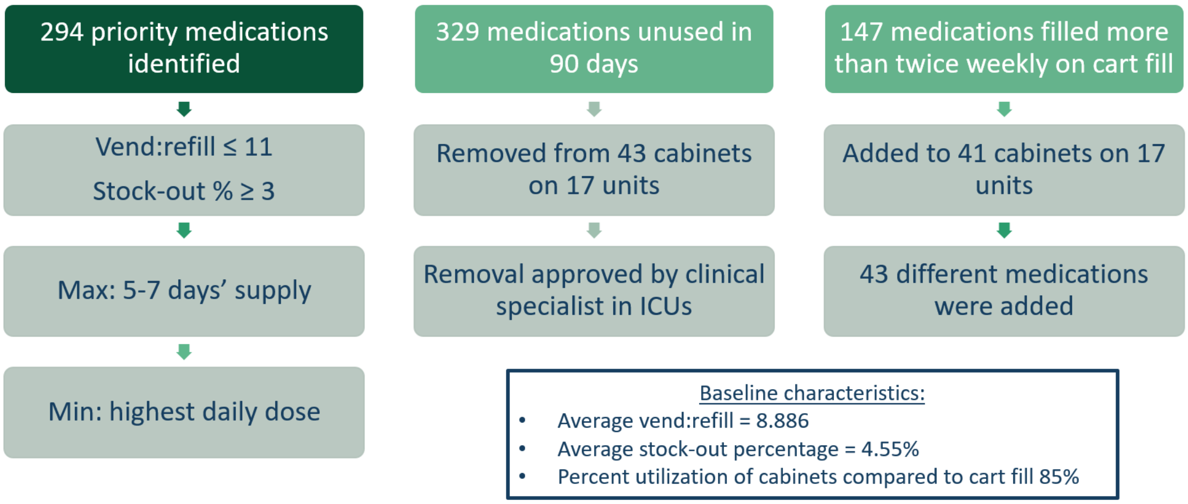

Figure 7 Par Level Algorithm

medication most frequently adjusted was haloperidol lactate 5 mg/1 mL vial, which was adjusted on 18 cabinets to expand stock in those cabinets. Over the course of this project, there were a few medications (most notably, premixed heparin drips) on national shortage and therefore unavailable to be measured. We also discovered that recalculation of vend-to-refill and stock-out percentage metrics was not reasonably possible with the available ADC cabinet reports in Omnicell®. Whereas BD Knowledge Portal calculated these metrics automatically, Omnicell® did not, and manual calculation would have been required for over 30,000 medications.

Analysis of these results stimulated the 'plan' phase, and the PDCA cycle began again. We continued to adjust Medication par levels according to usage and add or remove medications from cabinets as appropriate.

4.0 Discussion

We achieved an 8% improvement in percent utilization, thus meeting a primary objective of this optimization project. However, we could not recalculate vend-to-refill ratio and stock-out percentage due to limitations of Omnicell® report software. After optimization, percent utilization of cabinets was 93%. We found a correlation between percent utilization and anecdotal evidence of increased availability, but there was inadequate data to show a relationship between percent utilization and or an increase in clinical productivity, respectively.

Correspondence with AGH staff pharmacists after adjustments were made in January of 2022 was reflective of decreased time for cart fill. They also reported receiving less requests for medication re-dispense. Previously, three pharmacists and two technicians were able to complete cart fill in four to five hours. After optimization, cart fill was completed in under two hours. Requesting medications for re-dispense also creates potential for medication errors. Fewer re-dispensed medications would, theoretically, decrease the opportunity for double dosing or lost medications. While these were not directly measured in the study, they are congruent with the results of increased percent utilization of cabinets. Additional automation optimization data in the future would consider objectively measuring productivity and reassessing workflow.

Inpatient pharmacies rely on KPIs to dictate workflows and inventory management; this study is evidence that not all electronic systems will measure the same metrics.[12] As seen in the AGH transition from Pyxis™ES to Omnicell®, the vend-to-refill and stock-out percentage metrics were not calculated by both ADC servers. It will be crucial for health care teams to identify KPIs that are relevant to their respective ADCs when considering automation optimization.[12]

There were several limitations to this study. The first and largest being that the KPIs chosen were unable to be re-evaluated after implementation of Omnicell®. However, these metrics are not specific to availability of medications on nursing units. Therefore, the primary objective was still achieved based on the 8% improvement of percent utilization. Future optimization metrics would ideally be easily translated between ADC servers. Second, national medication shortages may have interfered with data collection and metric calculation. As medications phase in and out of popularity in clinical practice, maintaining inventory will also change. An optimal frequency for metric re-evaluation was not decided in this study.

In using the PDCA model to approach automation optimization, we identified percent utilization as an achievable metric for hospitals changing between ADC servers. One of the key aspects of this model is the ability to test a set of assumptions in the "Do" phase. For this project, it would have been unreasonable to adjust every single par value for every medication in every cabinet without confirmation that the effort would be worthwhile. Enter PDCA, and a representative sample of the total (n) underwent preliminary testing to validate each of the metrics used. Moving forward, AGH has a foundation of reliable data with which future inventory management decisions may be made.

The Public Health relevance is in the benefit of more medications available on nursing units, discussed earlier, and reduced time for cart fill. Inpatient pharmacies have also suffered from staffing shortages, forcing pharmacy departments to reprioritize assigned responsibilities in lieu of more immediate problems.[13,14] Each nursing unit at AGH is diligently inspected by a pharmacist every 6-12 months for outdated medications, inappropriately stored medications, and other regulatory requirements. This is a universal practice for pharmacy departments, as pharmacists are responsible for the integrity of any dispensed medication. Reducing time for cart fill allows pharmacists to use any extra time to attend to these required duties.

As we move towards a fully automated pharmacy inventory, pharmacists can transition their focus on clinical interventions and appropriate guideline-directed therapy, rather than operational tasks. Areas such as medication reconciliation, adjusting medications according to kidney function[15], and IV to oral conversions are a few examples of clinical interventions that contribute to better patient outcomes, and consequently, better value-based care.[16] Inefficiencies in health care lead to increased costs.[17] For example, a patient taking pantoprazole for a gastrointestinal bleed will need pantoprazole 40mg twice daily for the entirety of their hospital stay. The IV formulation of pantoprazole is about eight times as expensive as the oral tablet formulation[6] and the patient really only needs the IV formulation until their imaging is clear, which generally only takes 3-4 days, depending on the severity. Without pharmacists reviewing these medications for switches such as these, hospitals and health systems end up paying substantially more for equivalent treatments. The example patient will most likely have a hospital stay that extends beyond 3-4 days, so paying eight times more for a twice daily drug adds up when reimbursement rates are the same, regardless of which medication formulation is used. Ultimately, a fully automated pharmacy inventory permits pharmacy technicians and pharmacists to practice at the top of their licenses to provide the most efficient patient care.

Fewer centrally filled medication orders also yields decreased delivery time for technicians. Currently at AGH, technicians make nine medication deliveries consisting of Omnicell® ADC replenishment and patient-specific medication orders hospital-wide from 0630-2300 every day. As the hospital continues to collect automation data and develop its processes, it was not realistic to change any workflows as part of this project. In the future, a continuously optimized and automated inventory process would rework inpatient pharmacy workflows to allow pharmacy technicians to dedicate more time to perform medication histories at the bedside and other inventory management tasks.

5.0 Conclusions

Models such as PDCA can be used to initiate cyclical improvement processes. Continuous inventory analysis using KPIs can be used to identify changes in medication use and adjust ADC replenishment strategies as needed. Optimization of pharmacy automation relies heavily on choosing the appropriate KPIs for an institution and individualizing the optimization process to reflect the capabilities and strengths of the institution.

In the future, medications with variable dosing (e.g., warfarin, prednisone, insulins) may require reassessment of ADC cabinet formularies. Research on how these medications should be managed may be beneficial, given their dynamic usage and variable dosing. Additional operational initiatives may include a dashboard display in central pharmacy that tracks percent utilization would help identify a frequency at which re-evaluation should occur. Hospital-specific cabinet metrics could be displayed and key shortages highlighted on a large screen for central staff pharmacists' and technicians' reference.

Automation optimization of ADCs is just the beginning of department-wide clinical service expansion and medication safety initiatives. The future of value-based care and efficiency will rely on pharmacy technicians and pharmacists practicing at the top of their licenses and participating in clinical care. Every opportunity to involve a pharmacist in clinical care yields improvement in the patient experience.[17] Minimizing operational burden with automation is the key for healthcare organizations focused on providing safe, value-based care.

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