Effects of a direct refill program for automated dispensing cabinets on medication-refill errors

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Most acute care hospitals in the United States use automated dispensing cabinets (ADCs) as the core of their medication distribution system. In 2008, an ASHP survey of 527 hospitals found that 82.9% used ADCs.1 If hospitals with fewer than 100 staffed beds are excluded, the percentage of hospitals using ADCs increases to 95–98.7%.1 ADCs offer a variety of benefits to the organization and the user, such as secure and timely access to the most commonly used medications in a specific patient care area and more accurate tracking and capture of charge data for the medications used.

However, the impact of ADCs on medication safety is less well defined, and several reports have indicated that the incorrect use or poor design of ADCs results in medication errors.2,3 ADCs have been the source of almost 15% of all medication-error reports received by the Pennsylvania Patient Safety Reporting System since its inception in 2004.3 In addition, 123 ADC-related medication errors have been reported to the National Medication Errors Reporting Program, operated by the Institute for Safe Medication Practices (ISMP), since 1971.3 In 2008, ISMP identified 12 core processes to ensure the safe use of ADCs: 1. Provide ideal environmental conditions for the use of ADCs, 2. Ensure ADC system security, 3. Use pharmacy-profiled ADCs, 4. Identify information that should appear on the ADC screen.

Purpose. The effects of a direct refill program for automated dispensing cabinets (ADCs) on medication-refill errors were studied.

Methods. This study was conducted in designated acute care areas of a 386-bed academic medical center. A wholesaler-to-ADC direct refill program, consisting of prepackaged delivery of medications and bar-code-assisted ADC refilling, was implemented in the inpatient pharmacy of the medical center in September 2009. Medication-refill errors in 26 ADCs from the general medicine units, the infant special care unit, the surgical and burn intensive care units, and intermediate units were assessed before and after the implementation of this program. Medication-refill errors were defined as an ADC pocket containing the wrong drug, wrong strength, or wrong dosage form.

Results. ADC refill errors decreased by 77%, from 62 errors per 6829 refilled pockets (0.91%) to 8 errors per 3855 refilled pockets (0.21%) (p < 0.0001). The predominant error type detected before the intervention was the incorrect medication (wrong drug, wrong strength, or wrong dosage form) in the ADC pocket. Of the 54 incorrect medications found before the intervention, 38 (70%) were loaded in a multiple-drug drawer. After the implementation of the new refill process, 3 of the 5 incorrect medications were loaded in a multiple-drug drawer. There were 3 instances of expired medications before and only 1 expired medication after implementation of the program.

Conclusion. A redesign of the ADC refill process using a wholesaler-to-ADC direct refill program that included delivery of prepackaged medication and bar-code-assisted refill significantly decreased the occurrence of ADC refill errors.

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5. Select and maintain proper ADC inventory,
6. Select appropriate ADC configuration,
7. Define safe ADC restocking processes,
8. Develop procedures to ensure the accurate withdrawal of medications from the ADC,
9. Establish criteria for ADC system overrides,
10. Standardize processes for transporting medications from the ADC to the patient's bedside,
11. Eliminate the process for returning medications directly to their original ADC location, and
12. Provide staff education and competency validation.

At the beginning of this study, the processes used at the University of California San Diego (UCSD) Health System were aligned with some of these core processes. At this institution, almost all ADCs in the acute care setting required pharmacist review and approval before dispensing medications from an ADC and subsequent administration to the patient (core process #3). UCSD Health System also predominantly used single-drug pockets. These pockets contain only one specific medication (core process #6), thereby decreasing the opportunity for fill errors. In addition, standard safeguards were in place to ensure appropriate stocking of the ADC (core process #7), such as mandatory checks of any drug product to be refilled before it leaves the pharmacy and an additional pharmacist check after refilling the product in the ADC. Despite these efforts, ADC refill errors continued to occur.

A prospective before-and-after study was conducted to determine the impact of a new ADC refill process on medication-refill errors.

Methods

Background. This study was conducted in designated acute care areas of UCSD Health System, a 386-bed academic medical center. A total of 27 ADCs (Pyxis MedStation, CareFusion, San Diego, CA) from the general medicine units, the infant special care unit, the surgical and burn intensive care units, and intermediate units were included in this study. These areas predominantly rely on ADCs for medication distribution, with more than 90% of medications billed to the patient originating in these ADCs.

The typical configuration of the ADC in the acute care areas comprises a cabinet containing predominantly single-drug pockets and some multiple-drug pocket drawers, a refrigerator unit, and an ADC tower containing bins to store large items such as large-volume i.v. bags.

At the time of the study, orders were entered into the computerized prescriber-order-entry system, which was interfaced with the pharmacy information system. Medications could be administered only after the orders were reviewed by a pharmacist. Because the pharmacy information system was interfaced with the ADC, nurses could view only the medications on the ADC that had been verified by a pharmacist.

Pharmacy technicians manually restocked ADCs twice daily (morning and evening) by manually retrieving (“picking”) the medications to be restocked from the pharmacy inventory. Pharmacists visually checked the contents of the retrieved medications before the products left the pharmacy and again after the pockets were restocked. However, the time period between the technician’s refilling of the ADC and the second pharmacist check was variable, depending on the availability of the pharmacist to perform the double check. As a result, the ADC restocking process was suboptimal. Manual retrieval of medications from pharmacy inventory is time-consuming and allows for human error. In addition, the lag between ADC refill and the pharmacist’s check of the ADC is a potential vulnerability, as unchecked (and potentially incorrect) medications remain available for retrieval.

Intervention. In September 2009, the inpatient pharmacy implemented a wholesaler-to-ADC direct refill program. Only unit-of-use packaged medications are available through this program. Figure 1 illustrates the ADC refill process before and after implementation of this program. The wholesaler-to-ADC refill program is offered to hospital pharmacies at an additional charge. In the redesigned process, pharmacy technicians no longer have to manually select most of the ADC refill orders from the central pharmacy supply, and the pharmacist no longer has to check the selected products before refilling the ADC. In addition, the software from the wholesaler-to-ADC direct refill program automatically creates a recommendation when the inventory of a pocket containing medication in the program falls below the prespecified level. The wholesaler prepackages and delivers medications in an ADC pocket-specific bag containing sufficient medication to fit the pocket and a bar code with the identity of the contents. When refilling the ADC, the pharmacy technician scans the bar code on the ADC pocket-specific bag, and the corresponding pocket automatically opens. This eliminates the error-prone step of manually browsing for the product from an alphabetized list in the ADC. The double check of the identity and condition of the refilled medication at the ADC by a pharmacist is still required.

Statistical analysis. The pharmacists performing the ADC refill checks collected data on medication-refill errors before and after implementation of the new program. However, data collection for this study was voluntary. Medication-refill errors were defined as an ADC pocket containing the wrong medication, wrong strength, or wrong dosage.
A check of the expiration date of the medications was included, as the prepackaging step by the wholesaler could result in the acquisition of shorter dated medications. After each ADC refill check, the pharmacist filled out a data collection form capturing the date, ADC location, duration of the ADC refill check, and details of any fill errors (Figure 2). Electronic reports from the ADC were used to capture the number of pockets checked by each pharmacist. Lastly, we used electronic reports to document the type of pockets associated with an error. We based our sample-size calculation on a previous study by Klibanov and Eckel in a similar-sized hospital that used a similar ADC system and refill process. Of the 2858 pockets inspected, this study found a misfill rate of 2.3%. Based on a baseline misfill rate of 2.3% and a power of 80%, we calculated that 6600 pockets would need to be inspected to detect a misfill error reduction of 30%. An interim analysis during the postimplementation period showed an error reduction of more than 70%, larger than was expected. It was then decided that sufficient data had been collected for the study to be adequately powered. Data collection postimplementation was subsequently halted after 3855 refilled pockets had been checked.

Data were entered into spreadsheets (Microsoft Excel, Redmond, WA) for initial analysis and summary statistics. Stata 10 (StataCorp LP, College Station, TX) was used for the power calculation and additional statistical tests. Chi-square analysis was used to compare error rates before and after the intervention. Continuous data were analyzed using the unpaired \( t \) test. The a priori level of significance was set at 0.05.

**Results**

Totals of 6829 pockets in 26 ADCs and 3855 pockets in 24 ADCs were inventoried 5 months before and 18 months after implementation of the new program, respectively. Since we relied on voluntary data collection by the pharmacists assigned to the unit during a fixed data collection period, refill data during the preimplementation and postimplementation periods were not collected from 1 and 3 ADCs, respectively. Data collected during both periods were mostly similar (Table 1), except that medications were more frequently stored in a single-drug pocket during the postimplementation period (73% versus 60% respectively).

### Table 1. Pocket composition in ADCs pre- and postintervention.

<table>
<thead>
<tr>
<th>Type of ADC pocket</th>
<th>Preimplementation</th>
<th>Postimplementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-drug</td>
<td>60%</td>
<td>73%</td>
</tr>
<tr>
<td>Multiple-drug</td>
<td>35%</td>
<td>13%</td>
</tr>
</tbody>
</table>

**Figure 1. Redesign of the automated dispensing cabinet (ADC) refill process before and after implementation of a wholesaler-to-ADC direct refill program.**

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**Before Intervention**

1. Technician
   - Prints ADC refill list

2. Technician
   - Manually picks items

3. Technician
   - Sorts items per ADC for delivery

4. Pharmacist
   - Checks items before ADC refill

5. Technician
   - Goes to the ADC to be refilled

6. Technician
   - Manually selects the drug record of the item to be refilled and pocket opens

7. Technician
   - Refills the pocket with the picked medication

8. Pharmacist
   - Checks if the right drug is filled in the appropriate ADC location

**After Intervention**

1. ADC
   - Automatically places order if ADC pocket falls below par level

2. Wholesaler
   - Picks, checks, and delivers items prepackaged per individual ADC pocket and containing product specific bar code

3. Wholesaler
   - Sorts items per ADC for delivery

4. Technician
   - Goes to the ADC to be refilled

5. Technician
   - Scans the bar code on the prepackaged bag containing the medication to be refilled. Pocket opens automatically.

6. Technician
   - Refills the pocket with the picked medication

7. Pharmacist
   - Checks if the right drug is filled in the appropriate ADC location
51%, \( p < 0.0001 \)). ADC refill errors decreased by 77%, from 62 errors per 6829 refilled pockets (0.91%) to 8 errors per 3855 refilled pockets (0.21%) \( (p < 0.0001) \). The predominant error type detected before the intervention was the incorrect medication (wrong drug, strength, or dosage form) in the ADC pocket (Table 2). Of the 54 incorrect medications found before the intervention, 38 (70%) were loaded in a multiple-drug drawer.

After the implementation of the new refill process, 3 of the 5 incorrect medications were loaded in a multiple-drug drawer. There were 3 instances of expired medications before and only 1 expired medication after implementation of the program.

**Discussion**

ADC refill errors decreased by 77% after implementation of a wholesaler-to-ADC direct refill program without increasing the frequency of expired medication. However, these results should be viewed in light of the study’s limitations. First, this study required extensive data collection, because medication-refill errors are rare. Twenty-nine pharmacists collected data during the preimplementation period, compared with 16 pharmacists during the postimplementation period. Eleven pharmacists collected data during both time periods. Data collection by different pharmacists could have led to differences in the consistency of the data collected. However, the electronic reports used to capture ADC refill data are identical for every ADC. This should result in minor variance only and would not account for the large decrease in ADC refill errors. In addition, the baseline ADC refill error rate in this study (0.91%)
is similar to the rate reported by Klubanov and Eckel\(^5\) (2.3%), further strengthening the validity of this study’s results.

Second, a separate effort to decrease ADC refill errors was focused on increasing the use of single-drug pockets when storing medications in ADCs. As a result of these efforts, medications were more frequently stored in single-drug pockets in the postimplementation period. Scanning the wholesaler prepackaged medication bar code at the ADC automatically opens the correct single-drug pocket, making it almost impossible to refill the incorrect pocket. Multiple-drug pocket drawers, however, are more prone to errors, as these pockets do not contain a lid. The new process requires an additional scan of the bar code in the specified pocket inside the multiple-drug pocket drawer as an added safety feature. It is possible to misplace a medication in the compartment without performing a second scan. During the time of the study, it was not possible to measure scanning compliance when refilling the ADC, which would have quantified this limitation. However, it is unlikely that this potential “work-around” influenced the results of this study: omitting the second scan requires the user to cancel the entire bar-code-assisted refill process and resume the refill using a much more labor-intensive manual process.

Third, the redesigned ADC refill process eliminated two error-prone steps: (1) medications are no longer manually collected by the pharmacy technician in the inpatient pharmacy but are delivered to the ADC prepackaged per pocket and (2) pharmacy technicians no longer have to browse through an alphabetized list on the screen of an ADC for the appropriate pocket. Scanning the bar code on the prepackaged bag automatically opens the appropriate ADC pocket. Both error-prone steps were eliminated at the same time; therefore, it cannot be concluded whether wholesaler-to-ADC prepackaging or the use of bar-code-assisted ADC refilling prevented the most errors.

Not all medications are available through the wholesaler-to-ADC program. Although the percentage of incorrect medication (wrong drug, wrong strength, and wrong dosage form) errors decreased, only 28 (47%) of the medications involved in incorrect medication errors were obtained through the new program. At the time of the study, only medications obtained through the wholesaler-to-ADC program were available for bar-code-assisted ADC refilling, as only these products contained a bar code scannable at the ADC. The decrease in the percentage of errors related to medications not obtained through the wholesaler-to-ADC refill program could potentially be attributed to other changes instituted during program implementation. Nevertheless, there are plans to expand bar-code-assisted ADC refilling to all medications stocked in the ADC to reap the full benefit from the error-reduction potential of bar-coding technology.

### Table 1. Comparison of Data Collected Before and After Implementation of the Wholesaler-to-ADC Direct Refill Program\(^a\)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Before Implementation</th>
<th>After Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. pockets checked</td>
<td>6829</td>
<td>3855</td>
</tr>
<tr>
<td>Type of pocket, no. (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single-drug pocket(^b)</td>
<td>3500 (51)</td>
<td>2821 (73)</td>
</tr>
<tr>
<td>Multiple-drug drawers</td>
<td>3329 (49)</td>
<td>1034 (27)</td>
</tr>
<tr>
<td>No. (%) ADCs(^c)</td>
<td>26 (96)</td>
<td>24 (89)</td>
</tr>
<tr>
<td>Median no. (range) pockets per ADC</td>
<td>169 (3–773)</td>
<td>109 (1–537)</td>
</tr>
<tr>
<td>Median no. (range) pockets per medication check</td>
<td>6 (0–47)</td>
<td>6 (0–50)</td>
</tr>
<tr>
<td>Median duration (range) of medication check, min</td>
<td>3 (0–23)</td>
<td>2 (0–38)</td>
</tr>
</tbody>
</table>

\(^a\)Unless otherwise stated, differences were not significant. ADC = automated dispensing cabinet.  
\(^b\)\(^p\) < 0.0001.  
\(^c\)Since data collection was voluntary, not all 27 ADCs were represented in the analysis.

### Table 2. Comparison of Error Rates Before and After Implementation of Wholesaler-to-ADC Direct Refill Program\(^a\)

<table>
<thead>
<tr>
<th>Error</th>
<th>No. (%) Errors</th>
<th>Before Implementation</th>
<th>After Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wrong drug</td>
<td>30 (48)</td>
<td>1 (13)</td>
<td></td>
</tr>
<tr>
<td>Wrong strength</td>
<td>16 (26)</td>
<td>4 (50)</td>
<td></td>
</tr>
<tr>
<td>Wrong dosage form</td>
<td>8 (13)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>Expired medication</td>
<td>3 (5)</td>
<td>1 (13)</td>
<td></td>
</tr>
<tr>
<td>Other(^b)</td>
<td>5 (11)</td>
<td>2 (25)</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>62 (100)</td>
<td>8 (100)</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)ADC = automatic dispensing cabinet.  
\(^b\)Examples include nonmedication items such as broken glass found in the drawer, loose dividers in the matrix drawer, and technical issues.
of prepackaged medication and bar-code-assisted refill significantly decreased the occurrence of ADC refill errors.

References