

## Chapter 11. Automated Medication Dispensing Devices

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### **Background**

In the 1980s, automated dispensing devices appeared on the scene, a generation after the advent of unit-dose dispensing (Chapter 11). The invention and production of these devices brought hopes of reduced rates of medication errors, increased efficiency for pharmacy and nursing staff, ready availability of medications where they are most often used (the nursing unit or inpatient ward), and improved pharmacy inventory and billing functions.<sup>1-4</sup> Although the capacity of such systems to contribute to patient safety appears great, surprisingly few studies have evaluated the clinical impact of these devices.

### **Practice Description**

Automated dispensing systems are drug storage devices or cabinets that electronically dispense medications in a controlled fashion and track medication use. Their principal advantage lies in permitting nurses to obtain medications for inpatients at the point of use. Most systems require user identifiers and passwords, and internal electronic devices track nurses accessing the system, track the patients for whom medications are administered, and provide usage data to the hospital's financial office for the patients' bills.

These automated dispensing systems can be stocked by centralized or decentralized pharmacies. Centralized pharmacies prepare and distribute medications from a central location within the hospital. Decentralized pharmacies reside on nursing units or wards, with a single decentralized pharmacy often serving several units or wards. These decentralized pharmacies usually receive their medication stock and supplies from the hospital's central pharmacy.

More advanced systems provide additional information support aimed at enhancing patient safety through integration into other external systems, databases, and the Internet. Some models use machine-readable code for medication dispensing and administration. Three types of automated dispensing devices were analyzed in the studies reviewed here, the McLaughlin dispensing system, the Baxter ATC-212 dispensing system, and the Pyxis Medstation Rx. Their attributes are described below.

- The McLaughlin dispensing system<sup>5</sup> includes a bedside dispenser, a programmable magnetic card, and a pharmacy computer. It is a locked system that is loaded with the medications prescribed for a patient. At the appropriate dosing time, the bedside dispenser drawer unlocks automatically to allow a dose to be removed and administered. A light above the patient's door illuminates at the appropriate dosing time. Only certain medications fit in the compartmentalized cabinet (such as tablets, capsules, small pre-filled syringes, and ophthalmic drops).
- The Baxter ATC-212 dispensing system<sup>6</sup> uses a microcomputer to pack unit-dose tablets and capsules for oral administration. It is usually installed at the pharmacy. Medications are stored in calibrated canisters that are designed specifically for each medication. Canisters are assigned a numbered location, which is thought to reduce mix-up errors upon dispensing. When an order is sent to the microcomputer, a tablet is dispensed from a particular canister. The

drug is ejected into a strip-packing device where it is labeled and hermetically sealed.

- The Pyxis Medstation, Medstation Rx, and Medstation Rx 1000 are automated dispensing devices kept on the nursing unit.<sup>7-9</sup> These machines are often compared to automatic teller machines (ATMs). The Medstation interfaces with the pharmacy computer. Physicians' orders are entered into the pharmacy computer and then transferred to the Medstation where patient profiles are displayed to the nurse who accesses the medications for verified orders. Each nurse is provided with a password that must be used to access the Medstation. Pharmacists or technicians keep these units loaded with medication. Charges are made automatically for drugs dispensed by the unit. Earlier models had sufficient memory to contain data for about one week, and newer models can store data for longer periods.

Studies reviewed did not include the automated dispensing systems manufactured by Omnicell, which produces point-of-use systems that can be integrated into a hospital's information system.<sup>10</sup> Omnicell systems are also capable of being integrated into external support systems that support machine-readable code, drug information services, and medication error reporting systems.

### **Prevalence and Severity of the Target Safety Problem**

Medication errors within hospitals occur with 2% to 17% of doses ordered for inpatients.<sup>5,7,11-14</sup> It has been suggested that the rate of inpatient medication errors is one per patient per inpatient day.<sup>15</sup> The specific medication errors targeted by automated dispensing systems are those related to drug dispensing and administration. Even with the use of unit-doses (see Chapter 11) errors still occur at the dispensing<sup>16</sup> and administration stages<sup>3,17</sup> of the medication use process. For instance, in one large study of 530 medical errors in 10,070 written orders for drugs (5.3 errors/100 orders),<sup>18</sup> pharmacy dispensing accounted for 11% of errors and nursing administration 38%.<sup>3</sup>

### **Opportunities for Impact**

Automated dispensing devices have become increasingly common either to supplement or replace unit-dose distribution systems in an attempt to improve medication availability, increase the efficiency of drug dispensing and billing, and reduce errors. A 1999 national survey of drug dispensing and administration practices indicated that 38% of responding hospitals used automated medication dispensing units and 8.2% used machine-readable coding with dispensing.<sup>19</sup> Three-fourths of respondents stated that their pharmacy was centralized and of these centralized pharmacies, 77% were not automated. Hospitals with automated centralized pharmacies reported that greater than 50% of their inpatient doses were dispensed via centralized automated systems. Half of all responding hospitals used a decentralized medication storage system. One-third of hospitals with automated storage and dispensing systems were linked to the pharmacy computer. Importantly, about half of the surveyed hospitals reported drug distributions that bypassed the pharmacy including floor stock, borrowing patients' medications, and hidden drug supplies.

### **Study Designs**

There were no true randomized trials. One crossover study of the McLaughlin dispensing system randomized nurses to work with the intervention medication system or the control

system.<sup>5</sup> We classified this as a Level 2 study, since, from the patient perspective, the design is that of a non-randomized trial. Other studies included in this review consisted of retrospective observational studies with before-after<sup>6-8</sup> or cross-sectional design<sup>11</sup> (Level 3). The reviewed studies described dispensing systems for orally administered medications, and were published between 1984 and 1995 (see Table 12.1).

### **Study Outcomes**

All studies measured rates of medication errors (Level 2 outcome). Four studies<sup>5,7,8,11</sup> detected errors by direct observation using a methodology that was first described by Barker.<sup>5</sup> Direct observation methods have been criticized because of purported Hawthorne effect (bias involving changed behavior resulting from measurements requiring direct observation of study subjects). However, proponents of the method state that such effects are short-lived, dissipating within hours of observation.<sup>15</sup> Dean and Barber have recently demonstrated the validity and reliability of direct observational methods to detect medication administration errors.<sup>20</sup> Another study, a Level 3 design, determined errors by inspecting dispensed drugs.<sup>6</sup>

### **Evidence for Effectiveness of the Practice**

The evidence provided by the limited number of available, generally poor quality studies does not suggest that automated dispensing devices reduce medication errors. There is also no evidence to suggest that outcomes are improved with the use of these devices. Most of the published studies comparing automated devices with unit-dose dispensing systems report reductions in medication errors of omission and scheduling errors with the former.<sup>7,9</sup> The studies suffer from multiple problems with confounding, as they often compare hospitals or nursing care units that may differ in important respects other than the medication distribution system.

### **Potential for Harm**

Human intervention may prevent these systems from functioning as designed. Pharmacists and nurses can override some of the patient safety features. When the turn around time for order entry into the automated system is prolonged, nurses may override the system thereby defeating its purpose. Furthermore, the automated dispensing systems must be refilled intermittently to replenish exhausted supplies. Errors can occur during the course of refilling these units or medications may shift from one drawer or compartment to another causing medication mix-ups. Either of these situations can slip past the nurse at medication administration.

The results of the study of the McLaughlin dispensing system indicated that though overall errors were reduced compared to unit-dose (10.6% vs. 15.9%), errors decreased for 13 of 20 nurses but increased for the other 7 nurses.<sup>5</sup> In a study of Medstation Rx vs. unit-dose,<sup>8</sup> errors decreased in the cardiovascular surgery unit, where errors were recorded by work measurement observations. However, errors increased over 30% in 6 of 7 nurses after automated dispensing was installed in the cardiovascular intensive care unit, where incident reports and medication error reports were both used for ascertaining errors, raising the question of measurement bias. Finally, in a study primarily aimed at determining differences in errors for ward and unit-dose dispensing systems,<sup>11</sup> a greater error prevalence was found for medications dispensed using Medstation Rx compared with those dispensed using unit-dose or non-automated floor stock (17.1% vs. 5.4%).

## Costs and Implementation

The cost of automated dispensing mainly involves the capital investment of renting or purchasing equipment for dispensing, labeling, and tracking (which often is done by computer). A 1995 study revealed that the cost of Medstation Rx to cover 10 acute care units (330 total beds) and 4 critical care units (48 total beds) in a large referral hospital would be \$1.28 million over 5 years. Taking into account costs saved from reduced personnel and decreased drug waste, the units had the potential to save \$1 million over 5 years. Most studies that examine economic impact found a trade-off between reductions in medication dispensing time for pharmacy and medication administration time for nursing personnel. A common complaint by nurses is long waiting lines at Pyxis Medstations if there are not enough machines. Nurses must access these machines using a nurse-specific password. This limited access to drugs on nursing units decreases drug waste and pilferage.

## Comment

Although the implementation of automated dispensing reduces personnel time for medication administration and improves billing efficiency, reduction in medication errors have not been uniformly realized. Indeed, some studies suggest that errors may increase with some forms of automation. The results of the study of the McLaughlin Dispensing System by Barker et al<sup>5</sup> showed considerable nurse-to-nurse variability in the error rate between the automated system and conventional unit dose. Qualitative data aimed at determining the reason for this variability would be useful. The study by Klein et al<sup>6</sup> indicated little difference in the accuracy of medication cart filling by the Baxter ATC-212 (0.65%) versus filling by technicians (0.84%). Borel and Rascati found that medication errors, largely those related to the time of administration, were fewer after implementation of the Pyxis Medstation Rx (10.4%) compared with the historical period (16.9%).<sup>7</sup> These results are consistent with a more recent study by Shirley, that found a 31% increase in the on-time administration of scheduled doses after installation of the Medstation Rx 1000.<sup>9</sup> In contrast, errors were greater after Medstation Rx in the study by Schwarz and Brodowy,<sup>8</sup> increasing on 6 of 7 nursing units by more than 30%. Finally, Dean et al found half the errors in a ward-based system without automation in the United Kingdom (3.0%, 95% CI: 2.4-3.7%) compared with an automated unit-dose medication distribution system in the United States (6.9%, 95% CI: 5.2-8.5%).<sup>11</sup>

The practical limitations of the systems were illustrated by a variety of process deviations observed by Borel and Rascati.<sup>7</sup> These included nurses waiting at busy administration times, removal of doses ahead of time to circumvent waiting, and overriding the device when a dose was needed quickly. These procedural failures emphasize an often-raised point with the introduction of new technologies, namely that the latest innovations are not a solution for inadequate or faulty processes or procedures.<sup>2</sup>

Although automated dispensing systems are increasingly common, it appears they may not be completely beneficial in their current form. Further study is needed to demonstrate the effectiveness of newer systems such as the Omnicell automated dispensing devices. If the standard, namely unit-dose dispensing, is to be improved, such improvements will likely derive from robotics and informatics. To document impact of automated dispensing devices on patient safety, studies are needed comparing unit-dose dispensing with automated dispensing devices. Until the benefits of automated dispensing devices become clearer, the opportunities for impact of these devices is uncertain.

**Table 11.1. Six studies reviewing automated drug dispensing systems\***

Study	Study Design	Study Outcomes	N	Results
Barker, 1984 <sup>5</sup>	Prospective controlled clinical trial (Level 2)	Errors of omission and commission among number of ordered and unauthorized doses. (Level 2)	1775	96 errors among 902 observations (10.6%) using the McLaughlin dispensing system vs. 139 errors among 873 observations (15.9%) using unit-dose dispensing (control)
Klein, 1994 <sup>6</sup>	Prospective comparison of two cohorts (Level 2)	Dispensing errors in unit-dose drawers to be delivered to nursing units (Level 2)	7842	34 errors found among 4029 doses (0.84%) filled manually by technicians vs. 25 errors among 3813 doses (0.66%) filled by automated dispensing device
Borel, 1995 <sup>7</sup>	Prospective before-after study (Level 2)	Errors observed during medication administration in medications administered (Level 2)	1802	148 errors among 873 observations (16.9%) before vs. 97 errors among 929 observations (10.4%) after Medstation Rx (p<0.001). Most errors were wrong time errors.
Schwarz, 1995 <sup>8</sup>	Prospective before-after study (Level 2)	Errors in medications administered (Level 2)	NA†	Medication errors decreased after automated dispensing on the cardiovascular surgery unit but increased on the cardiovascular intensive care unit.
Dean, 1995 <sup>11</sup>	Cross-sectional comparison (Level 3) of US and UK hospitals with different pharmacy distribution systems	Errors in medications administered (Level 2)	3675	63 errors among 919 observations (6.9%, 95% CI: 5.2-8.5%) in the US hospital using unit doses and automated dispensing vs. 84 errors among 2756 observations (3.0%; 95% CI, 2.4-3.7%) in the UK hospital using ward stock. The absolute difference in error rates was 3.9% (95% CI: 2.1-5.7%).

\* CI indicates confidence interval.

† Study used various denominator data.

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