Medication use is a complex process and comprises medication prescribing, order processing, dispensing, administration, and effects monitoring. Key elements that affect the medication-use process and the interrelationships among these elements form the structure within which medications are used. The storage of drug products is part of one of the key elements of the medication-use process.

Implementing a well-organized drug-storage system, as well as standardizing and limiting the availability of multiple doses and concentrations of drugs in patient care areas, can reduce the risk of medication errors. However, events reported to the Pennsylvania Patient Safety Authority describe how breakdowns in the storage of medications have contributed to drug product mix-ups. More than 200 events have been reported to the Authority from June 2004 through October 2009 that indicate drug storage as a contributing factor to the event. Analysis reveals that nearly 73% of the events reached the patient. The most frequently reported event type was wrong drug (99 [46%] of the events reported). Events occurred in more than 50 different units, indicating that drug storage issues can and do occur throughout a facility. Strategies to address these problems include carefully selecting drugs stocked in each patient care area based upon the needs of each patient care unit and staff expertise, storing individual medications in a separate bin or in a bin with dividers between different products, sequestering chemicals currently used for compounding in a section of the pharmacy, and requiring periodic review of storage areas throughout the organization by a pharmacist or pharmacy technician.

From events reported from June 2004 through October 2009, analysts identified 215 medication error events implicating drug storage as a contributing factor to the event. Breakdown of these events by harm score, which is adapted from the National Coordinating Council for Medication Error Reporting and Prevention harm index, shows that 156 (73%) of the events reached the patient (harm index = C to I), and 53 (25%) of the events resulted in harm significant enough to require additional treatment.

The five most common medication error event types represented 171 (80%) of the 215 events, with the most commonly reported event type being wrong drug (46%) (see Table 1). “Other” represented the second largest category of event types (14%). Ten (33%) of these events appear to have involved either stocking the wrong drug/dosage form in an ADC bin or removing the wrong drug/dosage form from the ADC. The “other” events also included error types such as extra dose, monitoring error—documented allergy, and unauthorized drug.

Table 2 lists events by the top five units in which the event occurred, representing more than half (53%) of the total events. The top three units associated with involved in a medication error (e.g., ADC, inpatient pharmacy, floor stock), this reporting mechanism does not include fields that facilities can use to capture the role that storage may have played with medication errors. However, routine review and analysis of medication error events reported to the Authority indicated that the storage of a drug can play a role in these events. In response, analysts have created standardized monitor codes that could be entered into the program database to record/note those events in which an organization explicitly states that drug storage may have played a role in the event. These monitor codes, along with the phrase “next to,” were then used to query the data to identify trends and risk reduction strategies.

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these errors include the medical/surgical unit (21%), the pharmacy (14%), and the medical unit (7%). However, events occurred in more than 50 different care areas (e.g., ambulatory surgery, anesthesia, labor and delivery, medical/surgical unit, imaging, operating room [OR], pharmacy, psychiatric unit, skilled nursing unit), indicating that drug storage issues can and do occur throughout a facility.

**Patient Care Areas**

**Floor Stock**

While the primary storage of drug products is in the pharmacy or central supply department, there are a number of items that are stored in patient care areas (e.g., medical/surgical unit, emergency department [ED]). Typically, these are frequently used drugs, such as hydration solutions. Other drugs (e.g., opiates) may also be stored in patient care areas in locked cabinets or ADCs. However, facilities should evaluate what other drug products are often stored as part of floor stock. For example, high-alert medications (e.g., concentrated electrolytes, labetalol injection), especially those that require intravenous (IV) admixing or compounding, should not be stored in patient care areas, as these can cause serious harm when used in error.

The classic example of error-prone floor stock storage of a drug involved concentrated potassium chloride vials. In the 1980s and 1990s, many patients were seriously harmed, and a number of them died, as a result of errors that occurred when concentrated potassium chloride vials were stored in patient care areas. Sometimes the errors in these cases were due to knowledge deficits about the dangers of rapid IV administration of concentrated potassium or, more often, were mental slips or wrong drug selection when choosing a vial of medication. Patient safety organizations called for the removal of concentrated potassium chloride vials from patient care areas, and in 2002, the Joint Commission published a National Patient Safety Goal (NPSG) mandating accredited hospitals follow suit. Limiting access to this drug has reduced fatal errors.

Information contained in 97 (45%) of the 215 events reported to the Authority indicated that the events involved drug products stored as floor stock. Seventy-three (75%) of these events reached the patient. Some of these events show problems when multiple concentrations of the same drug are stored in close proximity in the same storage area. Other events demonstrate problems when multiple-dose containers are stored and used as floor stock rather than pharmacy providing patientspecific doses. Examples of events reported to the Authority include the following:

[I] gave patient 10 mg of morphine as opposed to 2 mg of morphine because the boxes of 10 mg were next to the 2 mg of morphine in the drawer. The boxes are identical in color. I did not immediately sign out the medication because I was distracted by other patient events at the time of medication dispensing.

The patient was ordered Trandate® 10 mg IV push. The nurse removed Trandate multidose vial from ACUDOSE [ADC] and administered 10 ml of medication (50 mg) IV push. The physician was notified. IV fluids were administered, and the patient was monitored.

There have been occurrences of harmful events involving floor stock storage of drugs reported elsewhere. One such event occurred when an anesthesiologist from an OR placed a vial of atracurium, a neuromuscular blocking agent (N MBA), in the refrigerator near vaccine vials of similar appearance. Seven infants were subsequently administered atracurium subcutaneously instead of hepatitis B vaccine. The infants developed respiratory distress; five infants recovered, one sustained permanent injury, and another died.

The Institute for Safe Medication Practices (ISMP) noted that NMBAs had never been available as floor stock in the nursery.

**Night Closet**

In hospitals where 24-hour pharmacy services are not available, nurses need access to limited supplies of essential medications during off hours. To help safeguard this need, the Joint Commission has established a medication management standard that requires that accredited facilities limit after-hours, nonpharmacist access to supplies of medication to a secure location or a night/weekend cabinet outside the pharmacy. Additionally, medications that are made available should be limited to only those drugs approved by the hospital. Despite these standards, some facilities continue to allow nurses access to the entire pharmacy inventory after hours. The accessibility and variety of medications available, as well as a potential lack of an independent double check of the original order to the obtained medication, contribute to medication errors.

Information contained in 88 (41%) of the 215 events indicated the involvement of drug products that were stored in some type of night closet or after-hours pharmacy area. Sixty-seven (76%) of these events reached the patient. The most frequently reported event type for cases involving night closet storage was wrong drug. This event type accounted for 39 (44%) of these

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**Table 2. Top Five Care Areas Associated with Drug Storage Issues (n = 113) from June 2004 through October 2009**

<table>
<thead>
<tr>
<th>CARE AREA</th>
<th>NUMBER</th>
<th>% OF TOTAL EVENTS (N = 215)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical/surgical unit</td>
<td>45</td>
<td>21%</td>
</tr>
<tr>
<td>Pharmacy</td>
<td>30</td>
<td>14</td>
</tr>
<tr>
<td>Medical unit</td>
<td>15</td>
<td>7</td>
</tr>
<tr>
<td>Acute specialty rehab unit</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>Emergency department</td>
<td>11</td>
<td>5</td>
</tr>
</tbody>
</table>
events. Two examples of wrong drug errors submitted to the Authority are as follows:

Order for Xopenex 1.25 mg nebs three times a day. Xanex 1.25 mg was pulled from night locker and given to patient.

Lovastatin 20 mg by mouth ordered. Lovenox 30 mg subcutaneous was removed from pharmacy night box by the supervisor. The nurse gave the medication.

While none of the reported events describe incidents of patient injury, serious harm and even death can occur when safeguards are not in place for night closet storage and access. In 2007, ISMP reported a case in which a patient presented to a critical access hospital extremely short of breath. His physician had prescribed an IV dose of furosemide. However, the pharmacy was closed, so a nurse entered the secured section of the pharmacy to obtain the drug. She mistakenly selected a vial of potassium chloride instead of furosemide, both of which were kept on adjacent shelves just above the floor. She took the vial to the care area, withdrew the medication, and administered it to the patient. An erroneous association of potassium on the label with the potassium-excreting diuretic likely resulted in the nurse’s failure to recognize the error until she went back to the pharmacy to document removal of the drug. The patient died as a result of this error.

Pharmacy

The pharmacy department, including the central pharmacy and any satellite pharmacies, is the primary location where drugs are purchased, stored, prepared, and dispensed. This results in a large volume of drug products being stored in one area of the facility. Also, many pharmacy departments order from a single wholesaler that offers preferred, low-cost products. For example, a wholesaler may purchase all hydralazine, a highly potent medication, from one vendor and all labetalol, a low-cost medication, from another vendor. This makes it more difficult to establish a consistent and effective system for controlling the medications. Also, many wholesalers use automated systems to control the medications, which may result in an increased risk of labeling errors. For example, a wholesale may purchase all hydralazine, a highly potent medication, from one vendor and all labetalol, a low-cost medication, from another vendor. This makes it more difficult to establish a consistent and effective system for controlling the medications.

Pharmacy

Refrigerator

Refrigerators, in both pharmacy departments and patient care areas, are locations of drug storage. Refrigerators present unique challenges to safeguarding drug product storage, such as limited space or lacking built-in discrete pockets or bins. Also, depending on the location of the refrigerator, it may be used to store manufacturer-packaged products for floor stock use, as well as patient-specific or patient-labeled products. This increases the risk of lookalike products being stored in the pharmacy. Thirty (14%) of the 215 storage-related events implicated pharmacy as location of the error, making pharmacy the second most often reported location of these errors (see Table 2). Often, the facilities that reported these events identified, within the error description, that side-by-side storage of the drug products contributed to the event. Examples include the following:

A nurse received a syringe containing a red liquid, and the label read that the medication was “Dilantin 60 mg.” The nurse knew that Dilantin® was an orange liquid and not red. The syringe was brought to pharmacy, and she obtained the correct medication (Dilantin). The medication in the original syringe was phenobarbital. Pharmacy investigated and found that the medications were positioned next to each other, and the names looked the same to the pharmacy tech (phenobarbital and phenytoin). These medications are separated in the satellite pharmacy, but they ended up next to each other on the counter, and the incorrect bottle was selected.

When a nurse retrieved Senokot®, she realized that the medication in the syringe was clear; Senokot is dark brown. The syringe was returned to the pharmacy, and the correct medication was dispensed. An investigation revealed that the medication was sodium bicarbonate, which is stored next to the Senokot.

A patient was ordered Neomycin®. When the nurse went to give the medication, [the nurse] noted that naproxen had been sent. The pharmacy was contacted, and the correct medication was sent. The medications were stored near each other in pharmacy (in) alphabetical (order), and the pharmacy technician had inadvertently selected the wrong med. Pharmacist did not check the med prior to leaving the pharmacy.

In the book Medication Errors, Cohen and Smetzer describe how unsafe storage of mivacurium, an NMBA, next to the antibiotic metronidazole resulted in several patients receiving mivacurium by mistake. One patient died while three others went into respiratory arrest. A review of the event found that lookalike, foil-wrapped, premixed IV products had been stored next to one another in the bulk IV storage area. Several other factors contributed to the mix-up and eventual administration of mivacurium, including the following: (1) the addition of mivacurium to the hospital formulary was not communicated to all staff; (2) prior to mivacurium being added to the formulary, metronidazole was the only premixed IV product with a foil overwrap; and (3) the products in the bulk IV storage area were organized alphabetically, and mivacurium was placed next to metronidazole.
20 mg vials. Both medications are stored in the refrigerator in the pharmacy. The error was caught when the drug reached the floor. The pharmacist was alerted, and the correct medication was then dispensed.

A TPN [total parenteral nutrition] additive was to be famotidine 20 mg. A vial of fosphenytoin 100 mg/2 ml was accidentally used in the compounding. The error was caught during required review by the pharmacist. The reporter noted that both vials are similar in appearance, and both are a 2 ml size. The medications were stored next to each other in the refrigerator due to a temporary move of the IV room outside the pharmacy. Now that the IV room has returned, these two products are again segregated into two different refrigerators.

Many examples have also been published by national patient safety organizations. For example, a respiratory therapist in a pediatric intensive care unit obtained what he thought was a sterile water vial to prepare a nebulizer treatment. Fortunately, he noticed that he had grabbed a vial of the NMBA atracurium that someone had inadvertently returned to a respiratory box in the refrigerator. The atracurium and sterile water vials both had similar purple color accents.

Errors related to unsafe storage of medications in refrigerators have caused serious patient harm and death. One such case involved intrathecal injection of an undiluted dose of rifampin to a 32-year-old woman. The physician ordered vancomycin 20 mg intrathecally each evening and rifampin 450 mg IV each morning for a central nervous system staphylococcal infection. The pharmacy placed both the evening dose of vancomycin and the morning dose of rifampin in syringes next to each other in the refrigerator. A medical student removed both syringes, thinking that, together, they contained a single dose of intrathecal vancomycin, and administered the medication. He also did not notice the label on the rifampin syringe that stated the medication need to be diluted in 250 mL of fluid prior to administration. The patient experienced nystagmus, nausea, and vomiting, and within a few days developed left hemiparesis and required mechanical ventilation.

Risk Reduction Strategies

Healthcare facilities should take steps to safeguard the storage of drug products throughout the institution. This includes storing and dispensing medications according to manufacturers’ guidelines for temperature, light, and expiration date. Consider the strategies described below, which are based on a review of events submitted to the Authority, as well as observations at ISMP and in the literature.

Patient Care Areas

- Carefully select drugs stocked in each patient care area by considering the needs of each patient care area and the expertise and familiarity of staff with specific drugs, with the risk of error associated with each drug, and with the age and diagnoses of typical patients being treated on the units.

- Review the list of items that staff from each patient care area can order manually or automatically through materials management. Ensure that pharmaceutical products cannot be provided without prior pharmacy agreement and supervision.

- Ensure that drugs stocked in patient care areas are available in the least number of doses, concentrations, and forms that will meet essential patient needs between replenishment (not to exceed 72 hours).

- Ensure that drugs, including emergency medications, stocked in patient care areas are in age-specific, ready-to-administer, unit-dose forms (i.e., are not stored in bulk containers).

- Ensure that NMBAs are not available as floor stock and/or in ADCs (except in OR/anesthesia stock).

- When possible, dispense NMBAs from the pharmacy as prescribed for patients. Outside the pharmacy, limit access to these agents to the OR, ED, and critical care units where patients can be properly ventilated and monitored.

- When NMBAs must be available as floor stock, have the pharmacy department assemble the vials in a sealed box with warnings affixed as noted below. Sequester the boxes in both refrigerated and non-refrigerated locations.

- Place vials, bags, and syringes of drug products in a sequestered bin for immediate pharmacy pickup after the drug has been discontinued or the patient has been discharged or transferred.

- Use strategies of product separation and segregation to improve safe drug storage. Store individual medications in a separate bin or in a bin with dividers between different products. Label each section in a manner that clearly identifies the drug stored within.

- If using ADCs, convert the large matrix drawers to drawers with locking lids, which enables limiting drug removal to the product selected on the ADC screen.

- Isolate medications used by respiratory therapists into one location in the ADCs (e.g., one matrix drawer), and restrict therapist access to those drawers only.

- Review guidelines for the safe use of ADCs, such as those from ISMP (available at www.ismp.org/Tools/guidelines/ADC_Guidelines_Final.pdf) and the American Society of Health System Pharmacists (available at www.ashp.org/DocLibrary/BestPractices/AutoITGdlADDs.aspx), to enhance
organizational practices related to ADC stocking, drug dispensing, storage, and administration.

For additional strategies to safeguard the use of ADCs, review the September 2005 Patient Safety Advisory article “Problems Associated with Automated Dispensing Cabinets.”

**Pharmacy**

- Remove and discard unnecessary hazardous bulk chemicals from the chemical/compounding storage area, particularly those that have not been used within the last 6 to 12 months. Ensure permanent, secure labeling of hazardous chemicals. Apply large cautionary labels to products as appropriate (e.g., “MUST BE DILUTED,” “FOR COMPOUNDING USE ONLY”).

- Segregate those chemicals currently used for compounding, and continue to store them in a fully sequestered section of the pharmacy.

- Segregate and store electrolytes for IV compounding together in one location: the IV preparation area.

- Store sterile water bags away from medication supplies. Never allow IV compounding products to leave the pharmacy’s sterile compounding area. Segregate these solutions, and store them with warnings to not distribute them outside the pharmacy.19,21

- Sequester and affix warning labels to vials of NMBAs stocked in the pharmacy. Be sure the warning labels do not obscure the vial label in any way.

- Maximize the pharmacy’s ability to provide patient-specific unit-dose solid and liquid medications (either commercially obtained or prepared by the pharmacy) throughout the institution.

- Ensure that all medications are stored in individual labeled bins within easy access (and visualization) for all staff.

- Investigate implementing technologies such as barcode on dispense in the pharmacy to reduce the risk of selecting the wrong medication from stock.

**Quality Processes**

- Require periodic review by a pharmacist or pharmacy technician of storage areas in the organization, including the pharmacy and patient care areas (e.g., ED, radiology, OR, medication rooms) to identify potential storage issues.

**Notes**


Self-Assessment Questions

The following questions about this article may be useful for internal education and assessment. You may use the following examples or come up with your own.

1. Four of the following five areas were included in a list of the top five locations associated with errors involving the storage of drug products. Select the location that was NOT reported as one of the top five locations.
   a. Acute specialty rehab unit
   b. Emergency department
   c. Medical/surgical unit
   d. Medical unit
   e. Operating room

2. The most frequently reported type of medication error involving the storage of drug products is:
   a. wrong dosage form.
   b. wrong dose/overdosage.
   c. wrong drug.
   d. wrong strength/concentration.
   e. wrong time.

3. All of the following are true about access to drug products after the pharmacy is closed EXCEPT:
   a. Nearly 41% of events related to drug storage that were reported to the Authority involved drug products that were stored in some type of night closet or after-hours pharmacy area.
   b. The Joint Commission permits facilities to allow non-pharmacists access to the pharmacy after hours.
   c. Roughly 76% of events reported to the Authority involving drug products stored in some type of night closet or after-hours pharmacy area reached the patient.
   d. Medications that are made available for staff access after hours are limited to those approved by the hospital.
   e. The accessibility and variety of medications available after hours, as well as a potential lack of an independent double check of the original order, contribute to medication errors.

4. All but one of the following are effective strategies to reduce the risk of medication errors involving drug storage. Select the INEFFECTIVE strategy.
   a. If using automated dispensing cabinets (ADC), organize stock using large matrix drawers.
   b. Isolate medications used by respiratory therapists into one location in the ADCs (e.g., one matrix drawer), and restrict therapist access to those drawers only.
   c. Ensure that drugs stocked in patient care areas are available in the least number of doses, concentrations, and forms that will meet essential patient needs between replenishment periods.
   d. Apart from the pharmacy, limit access to neuromuscular blocking agents to the operating room, emergency department, and critical care units where patients can be properly ventilated and monitored.
   e. Require periodic review by a pharmacist or pharmacy technician of storage areas in the organization, including the pharmacy and patient care areas.

5. A nurse received a syringe containing a red liquid and the label read “Dilantin 60 mg.” The nurse knew that Dilantin® was an orange liquid and not red. The medication in the original syringe was identified as phenobarbital. The pharmacy’s investigation found that the medications were positioned next to each other in the pharmacy, and the names looked the same to the pharmacy technician (phenobarbital and phenytoin).

Select the appropriate strategy to help prevent this event from reoccurring.
   a. Ensure that drugs stocked in patient care areas are in age-specific, ready-to-administer, unit-dose forms.
   b. Educate pharmacy staff that these two products will be stored next to one another.
   c. Store therapeutically similar products together on pharmacy shelves.
   d. Implement barcode on dispense technologies in the pharmacy.
   e. Apply large cautionary labels that read “MUST BE DILUTED” or “FOR COMPOUNDING USE ONLY” to hazardous bulk chemicals as appropriate.
The Pennsylvania Patient Safety Authority is an independent state agency created by Act 13 of 2002, the Medical Care Availability and Reduction of Error ("Mcare") Act. Consistent with Act 13, ECRI Institute, as contractor for the Authority, is issuing this publication to advise medical facilities of immediate changes that can be instituted to reduce Serious Events and Incidents. For more information about the Pennsylvania Patient Safety Authority, see the Authority's Web site at http://www.patientsafetyauthority.org.

ECRI Institute, a nonprofit organization, dedicates itself to bringing the discipline of applied scientific research in healthcare to uncover the best approaches to improving patient care. As pioneers in this science for nearly 40 years, ECRI Institute marries experience and independence with the objectivity of evidence-based research. More than 5,000 healthcare organizations worldwide rely on ECRI Institute’s expertise in patient safety improvement, risk and quality management, and healthcare processes, devices, procedures and drug technology.

The Institute for Safe Medication Practices (ISMP) is an independent, nonprofit organization dedicated solely to medication error prevention and safe medication use. ISMP provides recommendations for the safe use of medications to the healthcare community including healthcare professionals, government agencies, accrediting organizations, and consumers. ISMP’s efforts are built on a nonpunitive approach and systems-based solutions.