

FINDINGS



MEDICATION SAFETY:

Mitigating Risk in Healthcare Facility Design

A Module on a Safety Risk Assessment Component

THIS SAFETY MODULE INCLUDES:

Backgrounder

Design Strategies

Issue Brief

This module was created as a supplement to the Safety Risk Assessment (SRA) toolkit and other SRA-related Issue Briefs, Backgrounders, and Top Design Strategies. This toolkit is not intended to be a guarantee of a safe environment; the environment is one part of a safety solution that includes operational policies, procedures and behavior of people. It is intended for use with collaborative input of project- and facility-based expertise.

The Safety toolbox is made available through a partnership with



This document will be updated in 2018 to be a stand-alone reference under the Grainger sponsorship.



BACKGROUND

MEDICATION SAFETY ZONES

In 2010, the USP-NF issued a standard for physical environments that promote safe medication use (United States Pharmacopeia, 2010). Medication safety zones were identified as a key component to reduce medication errors, along with considerations for standardization, lighting, sound and noise, workspace organization, and mitigating interruptions/distractions.

See the associated Issue Brief for additional detail.

Understanding Medication Safety

Medication errors, the most common medical error, may adversely impact healthcare outcomes, as indicated in Institute of Medicine (IOM) reports such as “Crossing the Quality Chasm” and “To Err Is Human” (IOM Committee on Quality of Health Care in America, 2001; Kohn, Corrigan, & Donaldson, 1999). It was estimated that between 380,000 and 450,000 preventable adverse drug events (ADEs) occurred annually in U.S. hospitals (IOM et al., 2007). ADEs refer to any injuries resulting from medication use, including physical harm, mental harm, or loss of life (Bates et al., 1995). ADEs have been found to directly contribute to increased morbidity and mortality, prolonged hospitalizations, and higher costs of care (Kohn et al., 1999).

An understanding of historical data can help identify and assess current issues around medication errors and define how operational and physical environment conditions may overlap. Historical data should be evaluated to ascertain all conditions that contribute to medication errors in the facility. However, a healthcare organization should particularly evaluate its own historical data of medication errors to identify existing physical environment conditions (e.g., lighting levels, workspace organization) that could be related to medication errors in both inpatient and outpatient areas.

The number and locations of medication safety zones (MSZs) should be clearly identified. An MSZ is defined as a critical area for medication management: where medications are prescribed; where orders are entered into a computer or transcribed onto paper documents; and where medications are prepared, dispensed, or administered (United States Pharmacopeia (USP), 2010). Examples include work surfaces of medication carts, nursing units, any location where prescribing decisions are made, work surfaces of an automated medication dispensing device, pharmacy, and the patient bedside. Identifying these zones early on is critical to the development of design solutions. These spaces, whether a pharmacy, medication preparation room, or mobile work area, should be designed in a manner that facilitates correct choices. To optimize the interactions of the people working in the space and other elements of the system, human factors and



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principles should guide the organization of the space (both overall units and individual rooms). Four principles that guide the organization of space are outlined by Sanders and McCormick (1993):

- Importance principle: The most essential items should be placed in the most convenient locations;
- Frequency-of-use principle: Items used most often should be located in areas where they can be easily found to avoid workarounds;
- Function principle: Items that are related to the same function (e.g., syringes, needles, and alcohol swabs) should be grouped together; and
- Sequence-of-use principle: Items should be located in the order that supports the correct task sequence needed to perform the task correctly.

Design should support this organization. Design strategies should also address standardization (where possible), lighting, sound and noise, workspace organization, mitigation of interruptions and distractions, and the incorporation of technology to reduce the risk of error at all steps along the medication management process.



References

- Bates, D. W., Cullen, D. J., Laird, N., Petersen, L. A., Small, S. D., Servi, D., . . . Edmondson, A. (1995). Incidence of adverse drug events and potential adverse drug events: Implications for prevention. *JAMA*, 274(1), 29–34.
- IOM, Committee on Identifying and Preventing Medication Errors, Aspden, P., Wolcott, J., Bootman, J., & Cronenwett, L. (2007). *Preventing medication errors: Quality chasm series*. National Academies Press. Retrieved from http://www.nap.edu/catalog.php?record_id=11623
- IOM Comm. on Quality of Health Care in America. (2001). *Crossing the quality chasm: A new health system for the 21st century* (Consensus). Washington, DC: Institute of Medicine.
- Kohn, L., Corrigan, J., & Donaldson, M. (Eds.). (1999). *To err is human: Building a safer health system*. Washington, DC: National Academy Press.
- Sanders, M. S., & McCormick, E. J. (1993). *Human factors in engineering and design* (7th ed.). New York: McGraw-Hill Education.
- United States Pharmacopeia (USP). (2010). General Chapter (1066) physical environments that promote safe medication use. *United States Pharmacopeia, National Formulary, USP 34–NF 29*. Retrieved from http://www.usp.org/sites/default/files/usp_pdf/EN/USPNF/c1066.pdf



TOP DESIGN STRATEGIES

OVERVIEW

Design decisions to mitigate the risk for medication errors range from large-scale decisions (e.g., unit layout) to more detailed decisions (e.g., material selection). Clearly identify the purpose, associated work tasks, and workflow in the functional and operational program for each medication safety zone in order to design ergonomic and efficient workspaces.

Safety Risk Assessment: Medication Safety

Design Strategies

The following design solutions are a brief summary of the content found in the SRA Issue Brief “Medication Safety: Mitigating Risk in Healthcare Facility Design.” They are organized by building design category.

Unit Layout

- Provide space for the key tasks identified in the functional program to reflect the number of staff expected to work in the medication safety zone (MSZ).
- Consider standardizing the design for clinically similar areas in the workspace with regard to medication-related equipment, information technology, and supporting materials (e.g., labels, medication instructions) required to support the workflow for those tasks described in the functional program.
- Provide a visible sharps container accessible to personnel within the MSZ.

Room Layout

- Clearly identify the purpose, associated work tasks, and workflow in the functional and operational program for each MSZ in order to design ergonomic and efficient workspaces.
- Locate the MSZs out of circulation paths and use visual and/or physical barriers to reduce distractions and interruptions, without compromising the main clinical function in the MSZ.
- Design the MSZ to enable the clear visualization (i.e., labeling information) and organization of medication-related products in the MSZ workspace (e.g., use of adjustable fixtures, drawer and storage design, counter height, and designs to minimize work surface clutter). (This consideration is also relevant under interior design.)



Interior Design/Finishes

- Use visual clues, such as a change in floor color, to delineate an MSZ or “no interruption” zone.
- Use sound-absorbing materials (when permitted by infection control guidelines) to reduce noise levels in the MSZ.
- Design the MSZ to enable the clear visualization (i.e., labeling information) and organization of medication-related products in the MSZ workspace (e.g., use of adjustable fixtures, drawer and storage design, counter height, and designs to minimize work surface clutter). (This consideration is also relevant under room layout.)

Mechanical (HVAC)/Electrical

- Consider the different factors that may impact the sound quality and noise levels in MSZs, including layout, HVAC, and building system design.

Lighting

- Provide task lighting at the patient point of care so that visual confirmation of the correct patient (i.e., reading an arm band), medication, dosage, and the administration site is not compromised. This includes consideration of mobile medication-dispensing carts, when used.
- Position or shield lighting to minimize glare on the computer monitor that may make it difficult to read the screen accurately.
- Provide transitional lighting for those MSZs found in patient care areas to avoid sudden contrasts between dark and bright areas.
- Specify lighting fixtures that can be easily cleaned and maintained.
- Specify United States Pharmacopeia lighting levels for the different tasks in the MSZ, including:
 - Designated computer entry and handwritten order processing locations,
 - Pharmacy medication filling and checking,
 - Pharmacy patient counseling,
 - Sterile compounding and preparation,
 - Storeroom for pharmacy medication,
 - Medication preparation area, and
 - Medication administration work areas (including the patient room).



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Technology Integration

- If an automated dispensing system for medication administration is being implemented, consider associated workflows and design of the MSZ.
- Design spaces for the integration of information technology required for medication safety (e.g., barcode readers, CPOE).
- Design spaces to enable point-of-care barcode verification to reduce errors in the transcription and administration of medication.
- Identify and provide the space needed for medication-associated equipment (e.g., barcode readers, mobile medication carts) and safety technology (e.g., CPOE) in inpatient and outpatient MSZs. (This consideration is also relevant under room layout.)
- Enable ready access to clinical information, both patient-specific and medication-related, through the organization of the MSZ workspace.

Additional Resources

Chaudhury, H. P., & Mahmood, A. P. (2007). The effect of environmental design on reducing nursing and medication errors in acute care settings. Concord, CA: The Center for Health Design. Retrieved from <https://www.healthdesign.org/chd/research/effect-environmental-design-reducing-nursing-and-medication-errors-acute-care-settings>

United States Pharmacopeia (USP): General Chapter (1066) physical environments that promote safe medication use. Retrieved from http://www.usp.org/sites/default/files/usp_pdf/EN/USPNF/gc1066PhysicalEnvironments.pdf

Facility Guidelines Institute: Update #2: Medication safety zones. Retrieved from http://www.fguidelines.org/pdfs/FGI_Update_MSZ_130926.pdf

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MEDICATION SAFETY:

Mitigating Risk in Healthcare Facility Design

An Issue Brief on a Safety Risk Assessment Component

INSIDE YOU WILL LEARN ABOUT:

The current state of evidence-based design on designing to mitigate the risk of medication errors.

Programming and layout plans to minimize medication errors.

Design decisions to create a safer medication safety zone.

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This brief is a summary of information gathered during the development of The Center for Health Design Safety Risk Assessment (SRA) toolkit as it pertains to the topic of Medication Safety. See the associated Backgrounder for additional context.

Safety Risk Assessment for Healthcare Facility Design: Medication Safety

January 2017

Executive Summary

The work environment is often identified as a contributing factor to medication errors (Chaudhury, Mahmood, & Valente, 2009; Mahmood, Chaudhury, & Valente, 2011). According to recent standards issued by the United States Pharmacopeia (USP) (2010), there are five key conditions that contribute to risk in medication safety: workspace organization, lighting, interruptions and distractions, sound and noise, and medication safety zones.

Design considerations to mitigate risk and improve medication safety include:

- Workspace organization informed by all of the work tasks that will be performed in the space;
- Medication safety zones (i.e., work surfaces in a medication room, countertops on medication carts, automated dispensing cabinets, locations where prescribing decisions are made, pharmacies, and patient bedsides) that accommodate the number of workers and the range of tasks, while:
 - Decreasing the potential for interruptions and distractions through visual or physical separation
 - Controlling noise through the selection of HVAC systems, equipment, acoustical absorbing materials, and physical layout
 - Providing appropriate illumination with focused task lighting and transition lighting to avoid light and dark spots in these areas
 - Standardizing placement of items, where possible, to reduce cognitive load on the staff, increase efficiency, and reduce errors;
- Providing clear visualization of medications by minimizing clutter through drawer and storage design, lighting design, counter height, use of adjustable fixtures, and workspace design;



- Accounting for technology and potential future technology that will impact workflow and layout planning, including provision of cabling and electrical outlets; and
- Design for safe sharps use and disposal to minimize needlestick injuries, reduce contamination from blood and body fluids, minimize postural stress and injury, and minimize the risk of accidental or unauthorized access by others.

MEDICATION SAFETY ZONES

A medication safety zone is a “critical area where medications are prescribed, orders are entered into a computer or transcribed onto paper documents, or medications are prepared or administered” (United States Pharmacopeia, 2010). Medication safety zones can occur in multiple locations throughout a facility and should be able to accommodate the number of workers and the range of tasks. Physical and visual separation can mitigate the risk of interruptions and distractions.

These latent conditions can, in part, be mitigated by a facility design that addresses the unit layout, room layout, interior design/finishes, lighting, furnishings, and integration of technology. Solutions should also take into account the organizational and clinical policies and procedures, as well as the workflow and behavior of the staff who engage in medication preparation and delivery.

Mitigating the Risk of Medication Errors With Environmental Design

Unit Layout

It is important that the unit layout enables the fulfillment of the defined tasks of medication prescription, preparation, and delivery in the most efficient manner possible. This should be referenced in the functional and operational program provided for the project to understand the work tasks and workflows that are anticipated for the space (Grissinger, 2012; United States Pharmacopeia (USP), 2010). This is linked to increased efficiency and reduced fatigue, which can have an impact on errors, although empirical evidence on specific strategies to improve efficiency is lacking.

Research supports that sensory/perceptual interference (e.g., interruption by a co-worker) can impair error-free performance due to the cognitive load of switching tasks (i.e., time to reorient to the task after being interrupted) or prospective memory failure (i.e., forgetting where you left off). Being interrupted can result in both procedural failures (e.g., failure to read labels, check patient ID, or record administration on medication charts) and clinical errors (e.g., wrong drug, dose, formulation, or strength) (Anthony, Wiencek, Bauer, Daly, & Anthony, 2010; Chaudhury et al., 2009; E. A. Flynn et al., 1999; L.



To reduce cognitive load, designing for medication safety should include standardization of the medication safety zone.

Flynn, Liang, Dickson, Xie, & Suh, 2012; Mahmood et al., 2011; Pluyter, Buzink, Rutkowski, & Jakimowicz, 2010). There is a high probability of interruptions occurring when medication preparation activities take place in or near a circulation zone (such as a corridor) or where other activities also take place (such as a clean utility room). The additional traffic in the room can increase the potential for distractions and interruptions. Medication safety zones should be located away from areas with heavy staff, patient, or family activity.

In many areas of the hospital, minimizing technological sources of distraction, like overhead paging systems, may not be feasible, since they may relate to the communication of urgent situations. In the case of medication preparation spaces, best practice recommendations suggest that interruptions and distractions be minimized by providing staff with the ability to control and manage their exposure to external disturbances. For example, interruptions and distractions to workers while using medication carts can be minimized by providing access to a medication preparation room, or by providing designated spaces for mobile carts within workspaces.

Room Layout

The space provided for the medication safety zone should be able to accommodate the number of workers and the range of tasks, while also adhering to the recommended design features to decrease interruptions and distractions, mitigate noise, and provide the appropriate task lighting and workspace organization (Grissinger, 2012; United States Pharmacopeia (USP), 2010). As with unit layout, this is linked to increased efficiency and reduced fatigue, which can have an impact on errors. As medication safety zones can occur in multiple locations throughout the facility, standardization of the medication safety zone should be approached within the context of standards used within the system. If no standards exist for medication safety zones in the system, efforts should be made to set standards. Design researchers argue that standardization of patient care environments and equipment can help to reduce cognitive load on the staff, increase efficiency, and reduce errors. This premise can be extended to the organization of the workspace and the placement of items in relation to each other.

Although not strictly an errors issue, careful design of sharps containers in medication safety zones pertains to the overall construction of a safe



SHARPS SAFETY

Sharp devices such as needles, phlebotomy devices, and scalpels present a risk of exposure to blood-borne pathogens like human immunodeficiency virus (HIV), hepatitis B, and hepatitis C, among others. Careful disposal of sharp devices that have been contaminated with blood or body fluids is important for the prevention of infection to healthcare workers, patients, and others in the healthcare environment. Ergonomic design that supports optimal use and access to sharps containers can mitigate the risk of injury associated with sharps.

environment. Recommendations include a clear view of the opening to help staff dispose of sharps accurately and avoid needlestick injuries (i.e., to view how full the container is, and to see if there are any sharps near or coming through the opening). There should be an effort to reduce surface contact with sharps containers to preclude infection associated with contamination from blood and body fluids. Locations should be identified so as to avoid excessive reaching or awkward postures, and staff should not be obstructed by any other equipment or furniture. Height and reach distances should be established by ergonomic/anthropometric tables for the fifth percentile of the population (i.e., the container should be located below shoulder height and within forward reach when using a pinch grip). Finally, staff should have safe access to sharps containers while reducing access by young children or individuals with cognitive impairment.

Interior Design/Finishes

Risks associated with interruptions and noise can be mitigated through interior design and selection of finishes. For example, the simple use of visual cues, such as a demarcation on the floor, can help to define a “No Interruption Zone,” especially in areas where it may not be possible to limit traffic directly (Anthony et al., 2010). It is also important during medication administration for critical verbal information to be heard. At the same time, it is not feasible or desirable to eliminate noise entirely. The acoustical design criteria in the FGI *Guidelines* provides information for layout, selection of materials, and HVAC/building systems design to support well-designed acoustical environments. White noise may sometimes help to mask undesirable sounds.

Interior design and selection of materials can be used to create visual cues of a medication safety zone, as well as to reduce noise.

Furnishings

It is important that the medication safety zone is ergonomic and well-organized to enable staff to easily and accurately perform tasks related to medication preparation. This might include paying attention to drawer and storage location and design, lighting design, counter height, use of adjustable fixtures, and



workspace design to support workflow and minimize surface clutter. A pressing concern related to medication errors is the clutter associated with the storage of different medications/drugs. Research shows that more dispensing errors occurred when medication storage containers were placed in a cluttered fashion with less than an inch of separation between distinct drugs, making it difficult to differentiate between each item (E. Flynn, Dorris, Holman, Carnahan, & Barker, 2002).

Lighting

Critical visual tasks related to medication administration include reading small print on labels and handwritten prescriptions and inspecting medication dosage forms. Inadequate lighting during such tasks can lead to errors (Buchanan, Barker, Gibson, Jiang, & Pearson, 1991; Grissinger, 2012; United States Pharmacopeia (USP), 2010). The United States Pharmacopeia and The National Formulary (USP–NF) General Chapter (1066) list the lighting levels needed for specific critical visual tasks, which can serve as a guide for required lighting levels. Inadequate lighting during such tasks can lead to errors. Focused task lighting (with appropriate illumination levels) on mobile medication dispensing carts can minimize the risk of errors due to compromised vision. This is particularly important at the point of care (where the medication is administered to the patient) to allow for visual confirmation of the correct patient (e.g., reading arm band) and medication.

The ability to read information from a computer screen is a key component of medication administration. Although there is no empirical research linking glare on the computer screen to error, it follows the fundamental principle of enabling critical visual tasks. For lighting fixtures to provide required illumination levels, it is important that they are maintained at recommended levels. The selection of the appropriate light fixture type and quantity should take into account the effects of light loss from lamp lumen depreciation (LLD) and luminaire dirt depreciation (LDD).

Reducing clutter to provide clear visualization of tasks being performed can be improved through the careful selection of storage, lighting, and adjustable fixtures.

LIGHTING

Medication administration is dependent on proper lighting:

- 1 Provide focused task lighting (with appropriate illumination levels).
- 2 Provide focused lighting at both the point of medication dispensing and the point of distribution.
- 3 Avoid sudden contrast between dark and bright areas, as this affects visual acuity. Use transitional lighting if needed.



TECHNOLOGY INTEGRATION

It is important for designers to be aware of the impact of technology with respect to the spatial and electrical needs of the building. Workflow may also change, so designers need to consider how this might impact spatial needs as well. Technology has the potential to decrease medication errors substantially.

Lastly, a narrow focus on adequate illumination and task lighting in areas identified for critical visual tasks may inadvertently result in extremely dark adjacent areas. This sudden contrast between dark and bright areas can cause issues while pupils are adjusting, impacting visual acuity. Best practice recommendations suggest the use of transitional lighting to avoid this situation.

Technology Integration

In addition to understanding all the work tasks that will be performed in the space, it is important for the designer to have a sense of all the equipment and safety technology linked to the work tasks.

Studies show that automated dispensing systems improved the efficiency of drug distribution over the traditional unit dose cassette-exchange system. While not directly related to the physical environment, considerations for an automated dispensing system could impact workflows and, subsequently, the design of the medication safety zone (Schwarz & Brodowy, 1995). Research shows appropriate increases in the use of information technology in healthcare (i.e., the introduction of clinical decision support and better linkages in/among systems, resulting in process simplification) could result in substantial improvement in patient safety (Bates et al., 2001; Chaudhury et al., 2009; Poon et al., 2006). IT has specific implications for design relating to electrical outlets, cables, and provision of equipment required for medication safety.

Use of the electronic medication administration system (i.e., bar code eMAR) substantially reduced the rate of errors in order transcription and in medication administration, as well as potential adverse drug events (Poon et al., 2010). Point-of-care bar code verification, and an integrated electronic medication record, can also decrease or avert medication errors. The physical environment can enable this verification process at the point of care, such as the patient bed, gurney, or exam table. Considerations should include wiring buildings to accommodate technology, such as point-of-care bar code verification, at varied locations. Additionally, ready access to relevant information (lab results, drug info, vital signs, and pertinent patient information) is a critical component of staff efficiency. The workspace organization has to address the information technology component relevant to the tasks performed in a particular medication safety zone.



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Conclusion

Medication safety is linked to five key areas influenced by the design of environments: workspace organization, lighting, interruptions and distractions, sound and noise, and medication safety zones. It is crucial to understand workflows, work tasks, and technology that will be used to support the organization's intended model of care.

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References

- Anthony, K., Wiencek, C., Bauer, C., Daly, B., & Anthony, M. K. (2010). No interruptions please: Impact of a no interruption zone on medication safety in intensive care units. *Critical Care Nurse*, 30(3), 21–29. <http://doi.org/10.4037/ccn2010473>
- Bates, D. W., Cohen, M., Leape, L. L., Overhage, J. M., Shabot, M. M., & Sheridan, T. (2001). Reducing the frequency of errors in medicine using information technology. *Journal of the American Medical Informatics Association: JAMIA*, 8(4), 299–308.
- Buchanan, T. L., Barker, K. N., Gibson, J. T., Jiang, B. C., & Pearson, R. E. (1991). Illumination and errors in dispensing. *American Journal of Hospital Pharmacy*, 48(10), 2137–45.



- Chaudhury, H., Mahmood, A., & Valente, M. (2009). The effect of environmental design on reducing nursing errors and increasing efficiency in acute care settings: A review and analysis of the literature. *Environment and Behavior*, 41(6), 755–786. <http://doi.org/10.1177/0013916508330392>
- Flynn, E. A., Barker, K. N., Gibson, J. T., Pearson, R. E., Berger, B. A., & Smith, L. A. (1999). Impact of interruptions and distractions on dispensing errors in an ambulatory care pharmacy. *American Journal of Health Systems Pharmacy*, 56(13), 1319–25.
- Flynn, E., Dorris, N., Holman, G., Carnahan, B., & Barker, K. (2002). Medication dispensing errors in community pharmacies: A nationwide study. Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 46(16), 1448–1451.
- Flynn, L., Liang, Y., Dickson, G. L., Xie, M., & Suh, D.-C. (2012). Nurses' practice environments, error interception practices, and inpatient medication errors. *Journal of Nursing Scholarship: An Official Publication of Sigma Theta Tau International Honor Society of Nursing/Sigma Theta Tau*, 44(2), 180–186. <http://doi.org/10.1111/j.1547-5069.2012.01443.x>
- Grissinger, M. (2012). Physical environments that promote safe medication use. *Pharmacy and Therapeutics*, 37(7), 377–378.
- Mahmood, A., Chaudhury, H., & Valente, M. (2011). Nurses' perceptions of how physical environment affects medication errors in acute care settings. *Applied Nursing Research: ANR*, 24(4), 229–237.
- Pluyter, J. R., Buzink, S. N., Rutkowski, A. F., & Jakimowicz, J. J. (2010). Do absorption and realistic distraction influence performance of component task surgical procedure? *Surgical Endoscopy*, 24(4), 902–907.
- Poon, E. G., Cina, J. L., Churchill, W., Patel, N., Featherstone, E., Rothschild, J. M., . . . Gandhi, T. K. (2006). Medication dispensing errors and potential adverse drug events before and after implementing bar code technology in the pharmacy. *Annals of Internal Medicine*, 145(6), 426–434. <http://doi.org/10.7326/0003-4819-145-6-200609190-00006>
- Poon, E. G., Keohane, C. A., Yoon, C. S., Dittmore, M., Bane, A., Levzion-Korach, O., . . . Gandhi, T. K. (2010). Effect of bar-code technology on the safety of medication administration. *New England Journal of Medicine*, 362(18), 1698–1707. <http://doi.org/10.1056/NEJMsa0907115>
- Schwarz, H. O., & Brodowy, B. A. (1995). Implementation and evaluation of an automated dispensing system. *American Journal of Health-System Pharmacy*, 52(8), 823–828.
- United States Pharmacopeia (USP). (2010). General Chapter (1066) physical environments that promote safe medication use. *United States Pharmacopeia, National Formulary, USP 34-NF 29*. Retrieved from http://www.usp.org/sites/default/files/usp_pdf/EN/USPNF/c1066.pdf