The medication use process is one of the most complex and risky in the hospital. It involves a large number of caregivers in widely diverse areas: physicians, nurses, pharmacists and respiratory therapists. Studies performed over the past several years have shown a high incidence of patient harm caused by medication errors and adverse drug events in all parts of the medication use process (e.g., ordering, transcribing, dispensing and administration). Hospitals have attempted to remedy this situation through significant investments in technology, however, the incidence of preventable medication errors and adverse drug events remains unacceptably high. Oftentimes, the technology implemented is driven by a department or in response to a serious event, with little understanding of the overall impact and complexity introduced when the solution is not envisioned as part of a whole system. Also, there must be an understanding that technology will not be effective unless there is a culture that embraces reduced variation and a multidisciplinary approach to the medication use process.

**MEDICATION USE WITH SUPPORTING TECHNOLOGIES**

The medication use process is widely recognized to include the key steps and activities outlined below, all of which must work in concert to ensure efficient and effective medication therapy. Each of these steps is beset with challenges that organizations must address through policy changes, process redesign and technology implementations. The opportunities for preventable adverse drug events (ADE) within each of the steps of the medication use
process are well understood, with those percentages highlighted below. Technologies are available in all parts of the medication use process which have been shown to significantly reduce patient harm associated with medication errors. Many organizations have implemented some or all of them with varying degrees of success.

HISTORY TAKING

Obtaining and documenting medication history: Challenge—Inability to completely identify home medications and separate true allergies from other sensitivities.

Reconciling medications at admission: Challenge—Medications are often not completely reconciled for hours or even days after a patient is admitted and admitting orders have been written. The reconciliation process is time consuming enough to demotivate prescribers from performing it, especially specialists who have limited experience with range of medications a patient may be taking.

The following technologies have proved effective at addressing the challenges in the history-taking process, when coupled with an organizational focus on multidisciplinary clinical workflow redesign, a drive toward reduction in care variation and change management.

Electronic home medication prescription inquiry: Provides complete home prescription information from insurance companies, PBMs and exchanges electronically.

Electronic medication reconciliation: Electronic mechanism to support the review of home medications and facilitate ordering/reordering at admit, discharge and change of level of care. This technology also may provide the benefit of incorporating the medication reconciliation process into the ordering process, which makes the performance of the task more palatable and less time consuming for providers.

ORDERING AND TRANSCRIBING

Fifty-nine percent of preventable ADE’s occur in prescribing, and 11 percent occur in transcribing.

Therapeutic decision making: Challenge—Providers have incomplete patient information on which to make therapeutic decisions.

Medication ordering: Challenge—Provider orders are illegible and do not contain all of the information needed by departments to perform ordered therapies and diagnostics. Providers do not always promptly order all related orders (e.g., drug levels when a drug with a narrow therapeutic range is ordered.)

Submission of paper orders and transcription into a dispensing system: Challenge—Distribution of paper orders is slow; and orders are easily misplaced and must be re-entered into the pharmacy system.

The following technologies have proved effective at addressing the issues with the ordering and transcribing processes, when coupled with an organizational focus on multidisciplinary clinical workflow redesign, a drive toward reduction in care variation and change management.

CPOE with clinical decision support: Provider entry of orders with decision support facilitated by robust electronic order sets. Decision support includes drug interaction checking (drug-drug, drug-allergy, etc.); screen and field checking of values for appropriateness; and alerts which suggest additions or changes to therapy based upon patient parameters, lab values and other orders. Within the context of a complete electronic health record which provides more complete information to the physician, CPOE results in more complete and therapeutically appropriate orders which are transmitted electronically into departmental systems (e.g., radiology, laboratory, pharmacy) rapidly and with the elimination of transcription or re-entry of orders.

Research has shown that up to 50 percent of ADE’s are eliminated from the prescribing process and up to 72 percent are eliminated from the transcribing process through the appropriate use of CPOE.

MEDICATION PROCUREMENT

Selection/management of formulary: Challenge—Agreement of medical staff to a formulary and enforcement of limited use of non-formulary items.

Purchasing: Challenge—Substitutions of one manufacturer’s product for another due to availability from the wholesaler or savings opportunities means that a variety of brands is stocked for many items.

Management of medication inventory: Challenge—Difficulty maintaining appropriate levels of medication stock in the multitude of areas where medications are stocked. Incorrect stocking of automated dispensing devices or other storage locations.

The following technologies have proved effective at addressing the issues with the medication procurement process, when coupled with a drive toward reduction in care variation and change management.

Electronic supply chain tools. Maintenance of perpetual inventories within dispensing areas including automated dispensing machines, which facilitate electronic medication purchasing. The use of bar codes for inventory management facilitates the maintenance of the perpetual inventory and provides safeguard at all steps of the stocking process.

PHARMACY MANAGEMENT

Fourteen percent of preventable ADEs occur in dispensing.

Evaluate and verify order: Challenge—Significant lag time between order and availability of medications.

Select medication for dispensing: Challenge—Not all medications are labeled with readable bar codes from the manufacturer.

Prepare medication: Challenge—Errors in preparation of IVs and lack of unit dose for odd doses(e.g., ½ tabs).

Dispense/distribute medication: Challenge—Errors in dispensing related to; wrong medication, wrong dose, incorrect labeling.

The following technologies have proved effective at addressing the issues with the pharmacy management process, when coupled a focus on multidisciplinary process improvement with a drive toward reduction in care variation and change management.

Automated dispensing systems. There are two basic categories of dispensing devices: those that support centralized (from the pharmacy department) dispensing and those that support decentralized (at or near the point of care) dispensing. These sys-
tems are typically integrated with the pharmacy departmental system to receive orders and exchange cart fill lists. Typically, carousels and robotics are used within a centralized area and automated dispensing machines (ADM) or locked cabinets in patient rooms are used in decentralized dispensing. ADMs can use bar codes on medications to ensure that the medications are placed in the proper location within the devices. All systems can reduce the manpower required for dispensing activities.

**Medication repackaging and labeling with barcodes.** Devices that are used to re-label and repackage medications with bar codes in either standard or patient specific packages. In some cases these devices are used to repackage all medications, even those which can be purchased with bar codes, in others just those which cannot be purchased with readable bar codes. This technology also allows for medications to be re-packaged into patient specific doses which are not commercially available (e.g. ½ tab) reducing the complexity during medication administration. There are two types of devices to help with this; simple standalone tabletop re-packaging/re-labeling devices that are used to periodically repackage batches of medications, and sophisticated real-time dispensing/re-packaging/re-labeling devices that store 100 to 500 medications and repackage them in patient-specific packages as needed for first dose and ongoing dispensing.

Research has shown that up to 97 percent³ of ADEs not addressed by BCMA, are eliminated in the dispensing process through the appropriate implementation of bar code dispensing technologies.

**ADMINISTRATION MANAGEMENT**

Twenty-six percent of preventable ADEs occur in Administration.¹

**Educate and engage patient/family:** Challenge—Varying English language proficiency and educational levels make education difficult.

**Select medication and transport to the point of care:** Challenge—Current order information and medications are often not readily available at or near the point of care.

**Administer medication:** Challenge—Dosing calculations can be made in error whether simple (e.g. ½ tab=150mg) or complex infusion rates calculations.

**Document administration and related information:** Challenge—Documentation of administrations is often incomplete and/or not completed in a timely manner. Documentation of administrations is done on different records in different systems so a comprehensive record is not ready available to all caregivers.

**Assess and monitor response:** Challenge—Documentation of assessment and patient response is done on different records in different systems so a comprehensive record is not ready available to all caregivers. Follow-up monitoring of medication effectiveness (e.g., pain score) is often delayed or overlooked entirely.

The following technologies have proved effective at addressing the challenges with the medication administration process, when coupled with an organizational focus on multi disciplinary clinical workflow redesign, a drive toward reduction in care variation and clinical change management:

**Electronic medication administration record with bar code medication administration.** eMAR provides an up to date electronic record of medication orders and administrations and other relevant information (e.g., lab values) that can be used at the point of care. BCMA provides checking of doses and timing of administrations at the point of care supported by bar codes to ensure all of the “rights” are accurate and facilitates the documentation of medication administrations.

**The medication use process is one of the most complex and risky clinical processes in the hospital.**

**Smart pumps.** Advanced infusion pumps which provide safeguards for IV administration including bar code readers and limits to infusion rate range entries. The most sophisticated are integrated with the medication orders for checking purposes and to receive order information, and eMAR and I&O to eliminate duplicate documentation tasks in these systems.

Research has shown that up to 70 percent⁴ of ADEs are eliminated from the dispensing process and up to 13 percent⁴ are eliminated from the administration process through the appropriate use of BCMA. Likewise, smart pumps have been shown to reduce up to 37 percent⁴ of preventable administration ADEs.

**QUALITY ASSURANCE**

**Self-reporting of medication incidents:** Challenges—Lack of automated information requires time consuming manual data collection. Less than 10 percent of all medication incidents are reported by self-reporting systems. Incidents are gathered from multiple sources (e.g., self-reporting, retrospective review, coded errors) and are not easily compared or analyzed together to identify trends. Often the reported incidents are not researched in a timely manner after the occurrence and it is difficult to gather information when time has passed.

**Surveillance for ADEs (Concurrent and Retrospective):** Challenges—Lack of automated information requires time consuming manual data collection and analysis.

The following technologies have proved effective at addressing the challenges with the medication quality assurance process when combined with a focus on driving a culture of quality and change.

**Automated ADE surveillance.** These systems provide a concurrent and retrospective review of orders, lab values and other clinical data which can identify potential adverse drug events. Review by a trained clinician is required to positively identify whether an ADE has occurred. They often identify ADEs that are not reported by self-reporting systems.

**Med event self-reporting and analysis systems.** Electronic self-reporting systems can ensure that critical information is collected when the report is made and can facilitate analysis of medication events.

**COMPREHENSIVE MEDICATION SAFETY APPROACH**

Implementation of the technologies outlined in the previous section can be expensive, intrusive and complex. In order to gain the benefits from them, the implementation requires organizational commitment with extensive user input to change work processes as well as the wise use of a range of supporting tools (e.g., scan-
The purpose of this activity is to conduct an effort. The current state definition requires an understanding the following:

- What steps are performed and by whom?
- What are the connection points and handoffs?
- What parts of the process work well and what parts do not?
- What technologies are used and how does information flow?

Leadership alignment also is important to gauge as processes cross organizational boundaries. It is important to assess risks, communicate the strategy and receive commitment early on from key leaders. A change readiness assessment tool can be used to evaluate current practices and help the organization plan for and manage the change effort.

Visioning. Establishing a vision for the future medication use process will help to clearly define what the future state environment will look like for all stakeholders. This is a critical step that is often overlooked by organizations as they begin process improvement initiatives. The operational changes are significant and often times difficult for the stakeholders to fully understand prior to the actual implementation. Creating a vision not only forms the highest level road map, it also generates a shared direction and momentum amongst the participating stakeholders and organizational leaders. This shared vision of the future enterprise focuses the organization on achieving the desired future state rather than just correcting what is wrong with the present state.

The enterprise vision should be a brief but compelling document depicting what the enterprise will be like in the future once the process improvements have been accomplished. It is most effective and will be best understood by a broad range of constituents when it includes a narrative description, pictures and scenarios, expected benefits and success measures. The identification and clarification of goals, objectives and expected value/benefits is essential to the success of any project. The organizational future state exists to support the achievement of clinical change goals, objectives and priorities.

A set of guiding principles will need to be agreed upon, documented and validated in order to provide the proper executive guidance to those involved in the initiatives as they prepare to make decisions about process, workflow, and system configurations. Guiding principles are the ideals and business rules established by the organization to help meet strategic goals and objectives.

Unified design. The purpose of this activity is to conduct an integrated, multidisciplinary redesign of current processes and to identify required changes to system set-up, technologies, policies and current practices that will drive the implementation of medication safety enhancements.

The results from the current state assessment are evaluated with recommendations for the future state vision during a series of design sessions this phase to determine the future state in the design sessions. We generally suggest bringing future state recommendations/best practice to the group for discussion, rather than attempting to organically develop future state from a blank slate in the design sessions.

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**Fig. 1: Activities performed following the development of a comprehensive medication safety strategy.**

- **Current State Definition:** Development of a deep understanding of the current medication processes.
- **Future State Vision:** Development of high level understanding of what the future of the medication use will be like for the participants.
- **Unified Design:** Design of the future state processes leveraging technologies with a clear understanding of the various roles and responsibilities.
- **Planning:** Development of a comprehensive plan to implement the technologies and process changes necessary to reach the desired future state.
This unified design process looks at process, practice, technology concurrently and is multidisciplinary. We recommend the use of a combination of process maps, prototypes for potential improvements, discussion regarding the impacts of current deficiencies or areas for improvement and a drive toward consensus on changes to the process, technology and staff roles.

**Planning.** The purpose of this activity is to do preliminary planning for the technology implementations. The Implementation Plan should include sequencing and conversion requirements and project scope; project staffing/resource requirements; project governance and structure; risk mitigation/contingency model; change management plan; technology requirements; timeline; budget; and benefits realization plan.

**IMPLEMENTATION APPROACH**

Implementation of these technologies will result in a closed loop medication management process (CLMM). This CLMM process when designed and implemented properly is the safest approach to medication use which is currently available. It will likely take several years and tens of millions of dollars to implement in a typical hospital. It is critical that a plan be developed, around the phasing of the technology implementations, which ensures that technology supports how clinicians work and does not dictate processes that lead to dangerous workarounds. The planning should also take into account:

- Implementation and maintenance staffing.
- Impact of interim states on staff workload.
- Capital and operating budgets.
- Impact of competing initiatives.
- Medication safety risks of the interim states.
- Ease of implementation of the technologies.
- Time needed to implement each of the technologies.
- Current state of technology implementation and technology infrastructure required to support the future state.
- Maturity of software from selected technology vendors(core HIS vendor).

The table below contains a listing of general information on implementation: time, level of difficulty, cost and any predecessors of the major technologies used to improve medication safety for a typical medium-sized hospital with the required level of focus and commitment:

While there is no industry best practice around the sequencing of the implementation of IT in the medication use process, the suggested sequence outlined below is the result of our experience in assessing and assisting hospitals to reduce errors and harm associated with the medication use process. Each hospital must examine its own medication system, culture and available resources when deciding on technology implementation roll out approach. The suggested sequencing outlined is for an ideal hospital in a clean-slate position, which is a hospital with none of these technologies, whose sole focus is medication safety.

The technology sequencing depicted in Figure 1 would enable an organization to take advantage of the optimal medi-

<table>
<thead>
<tr>
<th>Technology</th>
<th>Time to Implement</th>
<th>Level of Difficulty to Implement &amp; Support</th>
<th>Cost Range to Implement</th>
<th>Mandatory Predecessors</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPOE</td>
<td>&gt; 1 yr</td>
<td>High</td>
<td>$1 million</td>
<td>Integrated Pharmacy system, wireless network, mobile devices</td>
<td>Includes order set development</td>
</tr>
<tr>
<td>Medication Reconciliation</td>
<td>&lt; 1 yr</td>
<td>High</td>
<td>$250,000</td>
<td>EHR</td>
<td>Best acceptance when used with CPOE</td>
</tr>
<tr>
<td>Automated Supply Chain Tools</td>
<td>&lt;3 months</td>
<td>Low</td>
<td>$50,000</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Medication Repackaging &amp; Relabeling with bar Codes</td>
<td>&lt;3 months</td>
<td>Low</td>
<td>$75,000</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>ADM (decentralized)</td>
<td>&lt;6 months</td>
<td>Medium</td>
<td>$750,000</td>
<td>Integrated Pharmacy system</td>
<td>Needs Bar Code Labeling &amp; repackaging done for automated checking during loading</td>
</tr>
<tr>
<td>Dispensing Robotics (centralized)</td>
<td>&lt;3 months</td>
<td>Low</td>
<td>$1 million</td>
<td>Integrated Pharmacy system, Bar Code Labeling/repackaging</td>
<td></td>
</tr>
<tr>
<td>Dispensing Carousel (centralized)</td>
<td>&lt;3 months</td>
<td>Low</td>
<td>$500,000</td>
<td>Integrated Pharmacy system, Bar Code Labeling/repackaging</td>
<td></td>
</tr>
<tr>
<td>eMAR</td>
<td>&lt;6 months</td>
<td>Medium</td>
<td>$250,000</td>
<td>Integrated Pharmacy system</td>
<td>Often done with pharmacy system implementation, most of the costs are training related</td>
</tr>
<tr>
<td>BCMA</td>
<td>6 months</td>
<td>High</td>
<td>$1 million</td>
<td>Integrated Pharmacy system, Bar Code Labeling/repackaging, mobile med carts, wireless network</td>
<td>Often done with eMAR, automation of other nursing documentation increases acceptance of this technology</td>
</tr>
<tr>
<td>Smart Pumps</td>
<td>&lt;6 months</td>
<td>Medium</td>
<td>$500,000</td>
<td>wireless network</td>
<td>Needs orders interface to maximize medication safety</td>
</tr>
<tr>
<td>Automated Adverse Drug Event (ADE) Surveillance</td>
<td>&lt;3 months</td>
<td>Low</td>
<td>$100,000</td>
<td>Automated medication order, lab value and related clinical data</td>
<td></td>
</tr>
<tr>
<td>Med Event Self-Reporting and Analysis Systems</td>
<td>&lt;6 months</td>
<td>Medium</td>
<td>$200,000</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Pharmacy Departmental Information System</td>
<td>9 months</td>
<td>Medium</td>
<td>$500,000</td>
<td>None</td>
<td>Needs interfaces from other clinical systems (e.g. lab, EMR) and EMR for orders</td>
</tr>
</tbody>
</table>
cation safety benefits that these technology implementations can provide.

The technology implementation sequence discussed below with a brief explanation of its place in the sequence.

**Pharmacy departmental IS.** This is the fundamental system which links the disparate systems and technologies together in the medication use process. It is used as the hub with interfaces to them, even in the presence of a CPOE system. The pharmacy system is much more product based than the CPOE system so it more easily links to the various dispensing devices and other systems.

**Smart pumps.** The significant impact in reducing IV ADEs puts this high on the list of med safety technologies. In its simplest form the libraries in the pumps reduce the likelihood that harmful infusion rates will be set. The more advanced functionality—orders and documentation interfaces—are just beginning to come available and will lead to an increase in medication safety.

**eMAR.** This has the potential to have a dramatic impact on the administration process by providing up to date order and administration information to all providers. It is a natural by-product of the order entry and management in the pharmacy system so can be transitioned to from a paper MAR without great difficulty either when a pharmacy system is implemented or at any time after.

**Automated supply chain tools.** These tools for purchasing and inventory management will not have much direct impact on medication safety, except when bar coding is used to stock the ADMS and other storage locations.

**Med re-packaging and re-labeling with bar codes.** At a minimum this is a necessary batch function to ensure that all medications have readable bar codes on them to support bar code based dispensing and administration. More sophisticated versions provide a combination of repackaging and dispensing functions.

**Medication event self-reporting and analysis systems.** This is usually a stand-alone system which provides information on med incidents which can provide valuable insights and lead to changes which can improve med safety. It is a fundamental technology.

**Automated ADE surveillance.** This more sophisticated approach to identifying adverse drug events works in tandem with self-reporting and is a very simple, low-cost way to expand the knowledge of medication issues. It does require that a significant amount of clinical data be available online.

**ADM (decentralized).** These are used by most hospitals to dis-
pense between 20 percent and 90 percent or more of medications (excluding large-volume IVs). There is not a lot of evidence that this technology has a significant impact on medication errors, but it does make medications, especially first doses more rapidly and readily available. When coupled with bar code technology for stocking and removing medications from these devices some improvement of medication safety can be achieved.

**Dispensing carousel (centralized)/dispensing robotics (centralized).** The appropriate combination of centralized and decentralized dispensing technologies is a difficult balance to achieve. In general, med safety is enhanced through increased centralized dispensing rather than high volume of decentralized dispensing. These technologies provide the tools for pharmacy to take on the load of centralized dispensing while holding staffing and service (e.g., delivery times) levels constant.

**BCMA with positive patient ID.** This technology is extremely effective in eliminating administration errors. It is extremely complex and expensive to implement, requiring significant changes in the dispensing, storage and administration processes, as well as a significant investment in supporting technologies such as mobile medication carts, PCs, scanners and bar-code labeling. It is most successfully implemented after a high degree of centralized dispensing is implemented.

**CPOE.** Despite being a highly effective mechanism for reducing ordering and transcribing errors, CPOE is near the end of this list due to its high degree of difficulty. It requires that a robust EMR is in place so that the vast majority of clinical information is available online. It is especially difficult for hospitals with an independent medical staff to achieve a high degree of CPOE use otherwise. When a lower level of CPOE use is present, a complex and dangerous hybrid ordering/transcribing system is necessary. It is this risk of ineffective or partial implementations that moves this technology to this point on the list. A general rule of thumb is that the more information that is online, the more likely it is that physicians will get online and use the system, including for CPOE. It has become increasingly clear, from a safety perspective, that implementing CPOE before a pharmacy system, BCMA and eMAR are in place creates high-risk workflows that have been shown to ultimately increase the risk to patients.

**Med reconciliation.** This technology is highly effective in reducing the risk of medication errors, when done consistently and carefully. It is ideally implemented with or slightly after CPOE so that it can be integrated into the ordering workflow. In that situation the physician workflow is minimally disrupted and so the likelihood of a successful implementation is increased.

We recommend that any technology selected should be tested to determine if it achieves the desired functionality. If the technology is not well designed and implemented, users will develop workarounds that can lead to new errors.

**OTHER CONSIDERATIONS**

The American Recovery and Reinvestment Act (ARRA) of 2009 provides a commanding $30 billion for the adoption and use of health IT by Medicare and Medicaid providers over the next 10 years. To receive the financial incentives, eligible hospitals must make “Meaningful Use” of the HIT. It is expected that the federal incentive programs, driving healthcare provider organizations will increase the push for CPOE. The definition of meaningful use will likely impact that push toward CPOE to be a part of a larger health IT strategy, including the medication-use process to address anticipated requirements for key medication safety components such as: medication reconciliation, CPOE, a robust CDS tool set, integrated eMAR with bar coding and a pharmacy system integrated with CPOE and eMAR.

Factors coming out of the finalization of ARRA may create other incentives that play into the ultimate establishment of an implementation plan for provider organizations. **JHIM**

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2. Assumes that 80 percent of physicians will adopt CPOE; for adopting physicians 90 percent of orders will be placed electronically and 70 percent of recommendations will be followed equals 50 percent impact on prescribing-related ADEs. Since CPOE virtually eliminates transcription errors for those orders placed by physicians the impact would be 80 percent x 90 percent = 72 percent.


4. Product value analysis: smart infusion systems. Thompson and Classen; FCG 2005