Safe Drug Use in Critically Ill Patients

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Learning Objectives

1. Assess the relationship between medication errors (MEs) and adverse drug events (ADEs).
2. Produce a safe drug use surveillance system.
3. Evaluate causes of MEs and ADEs.
4. Devise ME and ADE prevention strategies.
5. Analyze the use of technology for safe medication practices.

Introduction

Overview of Medication Errors and Adverse Drug Events

Medication errors (MEs) are the most common type of medical error occurring in the intensive care unit (ICU). The definitions and incidence rates for MEs and types of adverse drug events (ADEs) are listed in Table 1-1. Medication errors may result in patient injury, but this is not a requirement to be considered an error. Clinicians strive to reduce MEs to avoid the possibility of injury, referred to as a *preventable ADE*. Data from a study performed in a medical and coronary ICU indicate that about one-fourth of MEs result in an ADE. This proportion varies with the definition of injury, which is not clearly described in many ADE investigations. An injury could be as benign as a transient abnormal laboratory value or a rash; conversely, it could be as significant as end-organ damage. This definition of injury associated with a drug requires clarification in the literature.

Potential ADEs (or near misses) are MEs that *could* result in injury but that do not. The most common example of a potential ADE involves the patient who, despite a documented allergy to penicillin, receives a dose of this drug but does not have an anaphylactic reaction. Several MEs may occur without producing an ADE. The converse is also true: ADEs are not always the result of an ME. Such an event is referred to as a *nonpreventable ADE*. This chapter discusses safe drug use in both ICU and emergency department (ED) patients.

Epidemiology: Incidence in Each Process Node

Critically ill patients spend a substantial amount of time in the ED before being transferred to the ICU. It has been estimated that ED physicians provide at least 15% of the total critical care a patient receives. More information is available on ADEs and MEs in the ICU.

A prospective, direct observation study of MEs and ADEs was performed in a mixed medical/surgical, adult ICU at a university hospital. Clinically important MEs were assessed for each node of the drug use process. Preventable ADEs were most common at the prescribing node (77%)

Baseline Review Resources

The goal of PSAP is to provide only the most recent (past 3–5 years) information or topics. Chapters do not provide an overall review. Suggested resources for background information on this topic include:

- Institute for Healthcare Improvement. Trigger tool for measuring adverse drug events (IHI tool). Available at *www.ihi.org/IHI/Topics/PatientSafety/MedicationSystems/Tools/Trigger+Tool+for+Measuring+Adverse+Drug+Events+%28IHI+Tool%29.htm*. Accessed February 8, 2010.
- Cullen DJ, Sweitzer BJ, Bates DW, Burdick E, Edmondson A, Leape LL. Preventable adverse drug events in hospitalized patients: a comparative study of intensive care and general care units. Crit Care Med 1997;25:1289–97.
- Morimoto T, Gandhi TK, Seger AC, Hsieh TC, Bates DW. Adverse drug events and medication errors: detection and classification methods. Qual Saf Health Care 2004;13:306–14.
- Leape LL, Cullen DJ, Clapp MD, Burdick E, Demonaco HJ, Erickson JI, et al. Pharmacist participation on physician rounds and adverse drug events in the intensive care unit. JAMA 1999;282:267–70.

Abbreviation List

ADE	Adverse drug event
CMS	Centers for Medicare and Medicaid Services
CPOE	Computerized prescriber order entry
ED	Emergency department
JC	Joint Commission
ME	Medication error

and less common at the administration node (23%). Potential ADEs, also classified by drug use process node, were related to administration, dispensing, prescribing, and transcription (34%, 34%, 28%, and 5%, respectively). Most nonintercepted potential ADEs occurred during administration. The dispensing node was more likely to have a potential ADE intercepted before reaching the patient compared with other nodes in the drug use process.

Medication errors and ADEs for each drug use process node were also categorized according to severity using a 5-point Likert scale (i.e., fatal, life threatening, serious, significant, or nonsignificant). Overall, most errors were determined to be serious or significant. More than 50% of all life-threatening errors identified were attributed to prescribing, followed by equal incidences in the dispensing (22.2%) and administration (22.2%) nodes. Most potential and actual ADEs classified as serious errors occurred during prescribing. Most significant errors were identified during the administration phase.

A prospective, multicenter study by the United Kingdom Intensive Care Society in 24 ICUs investigated the incidence of prescribing errors by reviewing drug orders daily for 4 weeks. During the study period, 21,589 new drug orders were written, of which 15% had at least one error (i.e., 2.2 errors per patient). Although most errors were classified either as not having an adverse effect or minor, 19.6% were considered potentially significant, serious, or life threatening.

One prospective observational study, involving 205 ICUs in 29 countries, evaluated unintended events that compromised patient safety during a 24-hour period. The authors determined that 23% of events were drug related; these occurred at a rate of 10.5 per 100 patient-days. The process node event rates were 5.7 per 100 patient-days for prescribing and 4.8 per 100 patient-days for administration. The same investigators used a similar study design in a follow-up investigation that focused on MEs at the administration node; this investigation included self-reported

Table 1-1. Definitions and Incidence of Medication Administration Events

Term	Definition	Incidence	Comment
Medication error	Error occurring at any stage in the drug use process. The drug use process nodes consist of prescribing/ordering, transcribing/documenting, dispensing, administration, and monitoring	Median 106 per 1000 patient-days (range 1.2–947 patient-days)	Rate is for adult ICUs; varies with the method of detection[a] and the process node being evaluated
ADE	Injuries caused by drugs	See combination of preventable and nonpreventable	Rate is usually reported separately as preventable and nonpreventable ADEs
Preventable ADE	Injuries caused by drugs that are associated with medication errors	5.2 and 12.8 per 1000 patient-days	Rate varies with detection method and drug use process node being evaluated
Nonpreventable ADE	Injuries caused by drugs that are not the result of a medication error	24.8 per 1000 patient-days	Rate varies with method of detection and drug use process node being evaluated
Potential ADE	A medication error with the potential for drug-related injury but injury did not occur	13.8 and 116.8 per 1000 patient-days	Rate varies with method of detection and drug use process node being evaluated Can be further classified as intercepted and non-intercepted potential ADEs
Injury	Definitions not consistently provided End-organ damage is a possible end point	N/A	Definitions vary or are not provided in ADE studies, creating some inconsistency in interpretation of rates

[a]For a description, see text section on method of detection.
ADE = adverse drug event; ICU = intensive care unit; N/A = not applicable.

errors from nonstudy ICU staff. A total of 861 MEs were found involving the care of 1328 patients (i.e., 74.5 errors per 100 patient-days). Unfortunately, 15 MEs in 12 patients resulted in either permanent harm (n=7) or death (n=5). Errors attributed to the wrong administration time were the most common, but errors of omission and wrong dose were also common.

In the ED, the prescribing and administration stages can be highly vulnerable for MEs. Because fewer drugs are dispensed from the pharmacy, an inherent increase in the chances of error is associated with this node. Transcription errors could be higher in the ED than in the ICU; verbal orders, which form a crucial communication step between the physician and the nurse in emergency situations, carry the potential for miscommunication and create a considerable risk of MEs. High-risk medications (e.g., "soundalike" drugs) may cause errors during transcription. For example, a verbal order for "Cardizem CD 240 mg by mouth daily" may be mistaken as "Cardizem 240 mg by mouth daily." MEDMARX, a national de-identified database of voluntarily reported MEs, has data showing that administration, prescribing, documenting/transcription, and dispensing errors occur at incidences of 49%, 29%, 12%, and 8%, respectively, in the ED. Although this supports the notion that the prescribing and administration nodes are vulnerable, the ED remains an important area for future research into the nature and causes of MEs.

Severity of MEs and ADEs in the ICU Compared with General Care Units

Factors placing critically ill patients at risk of MEs and ADEs include the stressful environment, distractions in the ICU, complex drug administration requirements, and altered pharmacokinetics. Data from an older study (more than 10 years ago) showed that preventable and potential ADEs in the ICU were more common than in general care units; however, this higher incidence was a reflection of ICU patients receiving twice the number of drugs. An increased severity of events was also shown. A more recent study compared the MEs obtained from an institution's MEDMARX voluntary reporting system for process node involvement, causes, drug classes, and outcomes. The incidence of MEs by process nodes did not differ between settings, with prescribing and administration having the most errors. Of interest, the human and technical causes of MEs were "procedure not followed" and "knowledge deficit" in the ICU, whereas they were "work-flow disruption" and "human deficit" in the general care unit.

As may be expected, the drugs associated with the MEs differed as well. Opioid analgesics were the primary drug class related to MEs in the ICU, and antiasthma/bronchodilators were the most common in the general care unit. Finally, the MEs in the ICU were more commonly associated with patient harm. The differences described between patient care environments are important because they support the rationale for evaluating patient safety data separately so that systematic prevention strategies can be implemented accordingly. In addition, because ICU events have greater potential for harm, increased pharmacovigilance in this environment is essential.

Patient Safety Standards Influencing Surveillance

The Institute for Safe Medication Practices, National Quality Forum, Leapfrog, Agency for Healthcare Research and Quality, and the World Health Organization continue to suggest actions to promote patient safety; the Joint Commission (JC) and the Centers for Medicare and Medicaid Services (CMS) are already enforcing some of these advisements. Several of these organizations, referred to as a *Quality Choir*, are working together to develop recommendations. The Safe Practices for Healthcare developed by the Quality Choir were originally published in 2006 and were updated in 2009. This document contains 34 practices organized into seven functional categories.

Safe practice 11 addresses the ICU workforce; it recommends that skilled caregivers with critical care medicine training work in the ICU, further supporting the need for a critical care pharmacist. Other safe practices in the recent Quality Choir recommendations are related to the critical care pharmacist's activities; these include medication reconciliation through the continuum of care (consistent with the JC National Patient Safety Goals), prevention of complications in ventilated patients, guidance for prevention of surgical site infections, and performance measures for venous thromboembolism prevention, glycemic control, monitoring anticoagulation therapy, and fall prevention.

Never events, which are also referred to as preventable health care–acquired conditions, are events that are considered inexcusable and that should never happen in patient care, according to the National Quality Forum. The National Quality Forum had identified 28 never events by 2006. The CMS is enforcing penalties for some of the never events by not reimbursing hospitals when an event occurs. By October 2008, eight never events were associated with penalties, and an additional nine events were proposed. The occurrence of venous thromboembolisms related to knee and hip replacements, certain manifestations of poor glycemic control, and falls are no longer provided a higher diagnosis-related group payment, causing hospitals to lose money when these occur. Pharmacists have an opportunity to play a role in preventing thromboembolisms, glucose derangements, and falls by recommending prophylaxis drug therapies, assisting with insulin management, or limiting drugs that cause altered mental status function, respectively.

Several never events proposed for the future also have pharmaceutical implications. For example, the never event of delirium can be an adverse complication of benzodiazepine use. If these and other conditions become never events not reimbursable by the CMS, the pharmacist's involvement in preventing them or in optimizing drug therapy will be essential and will have substantial cost ramifications for a

Table 1-2. Relative Incidence of Drug-Induced End-Organ Damage and Causative Agents[a]

End-Organ Damage	Incidence of Events	Common Drug Causes
Acute kidney injury	Drugs are contributing factors in 19% to 25% of acute renal failure cases	Acute tubular necrosis: aminoglycosides Osmotic nephrosis: hypertonic solutions Allergic interstitial nephritis: penicillin Papillary necrosis: nonsteroidal anti-inflammatory drugs Glomerulonephritis: angiotensin-converting enzyme inhibitors
Myocardial infarction	1.1% of adverse drug reactions reported in the Netherlands Center for Monitoring Adverse Reactions to Drugs were related to chest pain or myocardial infarction	Cardiovascular drugs, central nervous system drugs, respiratory system drugs, hormonal drugs, anti-infective drugs, and analgesic drugs
Delirium and acute brain dysfunction	12% to 39% of delirium cases are caused by drugs	Opioids, anxiolytics, antidepressants, and corticosteroids
Hepatoxicity	58% of acute liver failure cases in the United States are drug-induced	Acetaminophen
Respiratory failure	Not reported	Impaired central drive: opiates, benzodiazepines, barbiturates, alcohol Neuromuscular weakness: paralytic agents, aminoglycosides, corticosteroids Pulmonary fibrosis: amiodarone

[a]Data are from aggregate sources; they provide an overview and are not intensive care unit–specific.

hospital. Regardless of the clinician's opinion or agreement whether there should be zero tolerance for never events, the CMS is proceeding to impose these penalties.

Clinical and Economic Outcomes

By definition, ADEs are associated with injury. The most significant injury is end-organ damage, and clinicians should monitor antecedents to this injury. Table 1-2 lists the incidence of ADEs leading to end-organ damage and the causal drugs. According to 5 years of MEDMARX data, MEs potentially related to death occur at a rate of less than 0.4% in the ICU and 0.3% in the ED. Because these data are based on voluntary reporting (which underestimates actual occurrence), the number of fatalities caused by MEs may be much higher.

Adverse drug events also have a substantial impact on costs. Patients in the surgical ICU experiencing an ADE incurred an additional stay of 2.3–3.4 days compared with patients not having an ADE, suggesting substantial increases in resource use. The increased length of stay and cost for the ICU patient with ADE were 0.6 days and $5691, respectively, compared with the general care unit. The pharmacist's active participation in patient care could help reduce these costs. A more recent evaluation found that the cost avoided for potential and preventable ADEs from 129 interventions in a 4.5-month period was between $205,919 and $280,421. Pharmacist interventions most often occurred during chart review and patient care rounds and occurred less often during order entry. This information provides support for incorporating these activities into the pharmacist's patient care responsibilities.

Risk Factors

Patient and Environmental Characteristics

Studies of risk factors for ADEs, to date, have not addressed risk factors specific to the critically ill population. One may expect that the risk factors differ between ICU and non-ICU environments because critically ill patients have increased severity of illness, require an increased number of drugs, and more often need the intravenous route of drug administration.

In a recent evaluation, investigators compiled a list of risk factors for ADEs using voluntarily reported ICU data occurring over 7.5 years. The evaluated sample contained 367 cases with 507 ADEs. The risk factors included patient and drug characteristics such as age, sex, severity of illness, type of insurance, various morbidities, high-risk drugs, highly protein-bound drugs, route of administration, and laboratory values. About half of the risk factors identified were statistically significant in the ICU. The most prominent findings were that patients with acute renal failure, longer ICU length of stay, thrombocytopenia, or drug allergy had 2–10 times greater likelihood of an ADE than patients without these risk factors. Other potential risk factors evaluated in the literature include lack of a medication

reconciliation process, patients receiving more drugs, and type of ICU. This information highlights patients who may require additional monitoring for the prevention of ADEs.

Route of Drug Administration

One risk factor deserving attention is the route of administration because patients in the ICU receive more intravenous drugs than non-ICU patients. Intravenously administered drugs enter the bloodstream directly, so there is an inability to prevent absorption and an immediate concern for patient harm. One of every five drugs administered intravenously to critically ill patients is done so in error. More broadly, 44% of potential ADEs and 61% of all ADEs considered serious or life threatening are associated with intravenous drugs. A prospective, multinational study using self-reporting as the vehicle for identifying parenteral drug-related events found that patients with failing organs, a higher severity of illness score, a higher patient-to-nurse ratio, and a higher number of parenteral drug administrations were more likely to experience at least one ME.

Drugs administered by continuous infusion pose the added complication of potential drug incompatibilities. A cross-sectional survey of 434 patients in 13 mixed medical/surgical ICUs in Canada showed that about 25% of patients receive three or more drugs by continuous infusion. Incompatible Y-site drug combinations were administered in 8.5% of all ICU patients, increasing to 18.7% for patients administered more than one continuously infused drug. The rate described in the Canadian hospitals was consistent with the 7.2% rate of incompatible drug pairs observed in a German 12-bed gastroenterologic ICU.

High-Alert Drugs

Additional risks for critically ill patients may be posed by treatment with high-alert drugs. These are drugs that, when used in error, have a higher chance of causing patient harm, according to the Institute for Safe Medication Practices. Drug categories considered high alert include adrenergic agonists, adrenergic antagonists, antiarrhythmics, antithrombotics, and inotropics. Examples of specific drugs are epoprostenol, insulin, nitroprusside, and potassium chloride. Evaluation of voluntarily reported ADEs in the ICU indicates that patients are at slightly greater risk of an ADE if they receive a high-risk drug. The relative risk of ADE in patients with a bleeding event was higher for antiulcer (3.7%) and anticoagulant drugs (4.2%) compared with patients without a bleeding event. In addition, patients receiving several vasoactive drugs were more likely to have an ME of comission or an ME requiring an intervention.

Drugs and Causes Commonly Associated with MEs and ADEs

National MEDMARX data evaluated for 5 years indicate that several drugs have a unique association with MEs in the ICU. These drugs include piperacillin/tazobactam, pantoprazole, total parenteral nutrition, amiodarone, digoxin, diltiazem, methylprednisolone, and midazolam. Table 1-3 lists the agents and causes commonly associated with MEs and ADEs according to published literature for the ICU and ED. These data are from various countries and from single health care institutions; however, similarity exists in drugs or drug-related classes associated with the events. It is not surprising that the drugs highlighted in Table 1-3 are similar to the high-alert drugs reported by the Institute for Safe Medication Practices. Most of the drugs reported in Table 1-3 are ME related and not necessarily the drugs associated with harm, but they clearly have the potential to cause harm. This information provides clinicians a subset of drugs with which to begin surveillance and prevention.

An understanding of the causes of MEs and ADEs listed in Table 1-3 is important in addressing systematic changes as part of a future prevention strategy. The common themes among causes are not as obvious as the drug classes related to these events. Causes vary by drug use process node, institution, and type of ICU. In addition, data show that causes vary for ICUs compared with general wards. Active patient safety surveillance systems are recommended by the Institute of Medicine and should include analyzing causal data separately for the ICU and general care units.

Active ME and ADE Surveillance

Proximal Causes and System Failures

A recent study evaluated proximal causes and system failures throughout the entire drug use process in the ICU. Overall, lack of drug knowledge was the most common proximal cause. Slips/memory lapses, error in drug identification, rules violations, inadequate monitoring, and drug stocking/delivery problems were other underlying causes contributing to clinically important MEs. Most of these causes apply to the entire drug use process. However, the causes at the transcription node were associated with transferring prescribed orders to handwritten drug administration records, as well as with faulty interactions among services (e.g., poor interdepartmental communication of time-sensitive laboratory results, potentially affecting medication administration).

Identifying the proximal causes associated with MEs is important in understanding the source of failed systems and facilitating the steps necessary to improve processes. The previously mentioned ICU study attributed drug knowledge dissemination as the system failure associated with almost half of all MEs. Drug dose and verification, standardization of procedures, and medication order tracking were other principal system failures, accounting for more than 90% of all MEs identified. Table 1-4 illustrates various proximal causes, providing definitions and examples for each.

Although the study took place in an ICU setting, these system failures may also be applicable to the ED. However,

Table 1-3. Drugs and Causes Associated with MEs and ADEs in the ICU

Data Source	Event	Drug or Drug Class (Top Five)	Causes (Top Five)
Multinational Evaluation of Parenteral Drugs – data for ICUs	ME	Sedation and analgesic agents Antimicrobial agents Vasopressor and catecholamines Coagulation related Electrolytes and insulin	Wrong time Missed drug Wrong dose Wrong drug Wrong route
UK National Patient Safety Agency – data for ICUs	ME	Morphine Gentamicin Insulin Noradrenaline Vancomycin	Administration node • Incorrect checking of drug • Rate of infusion/administration • Omitted drug • Wrong dose given • Delay in initiation Prescribing node • Dose, dosage interval, or rate incorrect • Ambiguous prescription • Drug not prescribed when indicated • Confusion because of complexity of chart • Unit policy noncompliant
U.S. National MEDMARX data for ICUs	ME	Insulin Heparin Albuterol Morphine Potassium chloride	Omission error Improper dose/quantity Prescribing error Unauthorized/wrong drug Wrong time
MEDMARX data for code situations	ME	Antiasthma/bronchodilators[a] Autonomic drugs Sedative/hypnotics	Performance (human) deficit Communication Verbal order Procedure/protocol not followed Knowledge deficit
U.S. National MEDMARX data for EDs	ME	Heparin Insulin Ceftriaxone Morphine Acetaminophen	Performance deficit Procedure/protocol not followed Documentation Communication Knowledge deficit
Single-center prospective evaluation of MICU/SICU	Potential and preventable ADEs	Sedation and analgesic agents Antimicrobial agents Chemotherapy Cardiovascular drugs Hematologic drugs	Omission Wrong dose Wrong drug Wrong form Extra dose
Single-center prospective evaluation of CCU and MICU	ME including potential/preventable ADEs	Cardiovascular drugs[a] Anticoagulants Anti-infective agents	Wrong dosage Duplicate medication orders Wrong drug Failure to discontinue an order Wrong route

[a]Only three drug classes provided in reference.

ADE = adverse drug event; CCU = cardiac care unit; ED = emergency department; ICU = intensive care unit; ME = medication error; MICU = medical intensive care unit; SICU = surgical intensive care unit; UK = United Kingdom.

Table 1-4. Proximal Causes of Medication Errors

Proximal Cause	Definition	Examples
Lack of drug knowledge	Inadequate drug information leading to the inappropriate indication, dose, monitoring, or route of administration	Prescriber orders fondaparinux 10 mg subcutaneously q24h for patient receiving hemodialysis
Lack of patient information	Missing facts or clinician unaware of pertinent patient information contributing to inappropriate drug therapy	Prescriber reloads patient with fosphenytoin 20 mg/kg IV on admission unaware of previous load at outside hospital
		Patient unable to communicate penicillin allergy and is prescribed penicillin-derivative antibiotic
Rule violations	Noncompliance with established procedures, policies, or protocols	Prescriber writes drug order without route of administration
		Prescriber does not use sedation order form for mechanically ventilated patient with dosing parameters and goal sedation (e.g., orders "propofol - titrate to sedation")
Slips and memory lapses	The individual who contributes to the error "knew better" or forgets pertinent information/actions necessary for safe and effective drug therapy	Prescriber forgets to discontinue antihypertensives in a patient now requiring vasopressor support
		Nurse omits patient's drug after distractions
Transcription errors	Errors associated with manual medication order transcription and/or verification process	Unit secretary writes down wrong dose on paper medication administration record from prescription
		Pharmacist fails to enter drug from prescribing orders in the chart (i.e., overlooked order)
Faulty drug identity and dose checking	Pharmacist or nurse fails to accurately check correct drug or dose	Pharmacist dispenses cefuroxime instead of ordered cefepime
		Nurse draws up incorrect dose of drug
Faulty interaction with other services	Miscommunication or lack of communication among services, departments, and/or units in the admission, transfer, or discharge of patients	Patient's antibiotics not reordered after surgery when returning to the ICU
Infusion pump and parenteral delivery problems	Error in pump programming, pump delivery failure, central vs. peripheral line confusion	Norepinephrine administered through peripheral instead of central line
Inadequate monitoring	Necessary monitoring (e.g., drug concentrations, vital signs) not appropriately performed or failure to adjust drugs based on monitoring parameters	Digoxin dose not reduced despite a supratherapeutic drug concentration
Drug stocking/delivery problems	Late or missing drugs because of delivery issues	Antibiotic administration about 8 hours late because of delay in transition from pharmacy
Preparation errors	Pharmacist or nurse contributes to error in the calculation or reconstitution of drugs, leading to incorrect dose	Nurse prepares amiodarone infusion bag in wrong diluent
Lack of standardization	Administration errors result in inappropriate concentrations, dosing regimens, and/or infusion rates	Enoxaparin administered within an hour to epidural needle placement

ICU = intensive care unit; IV = intravenous; q24h = every 24 hours.

lack of familiarity with the patient is a primary system failure in the ED; this has not been reported as problematic in the ICU. Critical information including the patient's medical history, drug list, and known allergies may not be available during emergency situations. Patients, even those normally without communication problems, may not provide accurate information about their medications in the ED. This system failure causes a considerable challenge for safe and effective medication management in the ED.

Methods of Detection

Reporting of MEs and ADEs plays a pivotal role in the quality improvement process to provide safe medication practices. Most MEs and ADEs go undetected because they have not been reported. It is imperative that a reliable method of detection and reporting be established within health care institutions. This will allow institutions to recognize system failures and implement necessary changes to prevent errors from recurring. Several methods of detection and reporting have been used, with varying degrees of success; however, each approach has advantages and disadvantages.

Incident Reports

Incident reports encompass the following: (1) voluntarily reported events; (2) existing reports such as medical emergency information and autopsy reports; and (3) stimulated reports such as those generated by computer from administrative data or from automated dispensing machines, bar-coded technology, smart pumps, and computerized prescriber order entry (CPOE) decision support.

Voluntary reporting drastically underestimates the incidence and circumstances contributing to MEs. Various theories attempt to explain the low compliance with error reporting. Voluntary incident reporting requires an individual to take the initiative to actively report the ME or ADE; however, individuals may perceive their actions as not making a difference, or they fear retribution. More realistically, reporting takes time. Whether the voluntary reporting process is viewed as tedious or easy, the ICU and ED are demanding settings that may pose inherent barriers to clinicians who need to report these events.

Administrative data can be used as an existing incident report to evaluate E-codes, which are International Disease Codes associated with ADEs. Coders are responsible for generating these E-codes, which may have limitations because the coders are not likely to have clinical experience and must base their interpretation on explicit documentation in the clinician's notes. In addition, E-codes are not based on a financial incentive. Despite these limitations, a subset of E-codes had a positive predictive value of 63% in one study.

Automated dispensing machines can provide institutions a simplified way of identifying ADEs. Some of these machines can be programmed with a list of specific drugs (*tracer drugs*) commonly used for treating certain ADEs (e.g., phytonadione, diphenhydramine, naloxone, dextrose 50%, flumazenil, sodium polystyrene). When these drugs are removed from the automated dispensing machines, a report is generated that can serve as a notice that further investigation may be needed to determine whether a drug-induced event has occurred. In addition, some machines have the capacity to prompt the nurse before tracer drugs are removed. A pop-up screen inquires whether the tracer drug is being used for an ADE or an allergy. The nurse is then compelled to report whether an ADE has transpired. Although this technology could potentially increase ADE reporting, pop-up screen prompts are also unreliable. Emergency situations in the ICU or ED usually require immediate medication administration; this may lead the nurse to bypass the prompting screen to gain access to the drugs. It may be preferable to rely on another individual (e.g., quality management officer, health care professional) to investigate tracer drug removal in the ICU and ED. The disadvantage is the daunting task of screening all tracer drugs, because some may be frequently used for reasons other than ADEs (e.g., diphenhydramine for allergies). Barcode technology, smart pumps, and CPOE can be used to create reports for overrides and indicate which alerts or recommendations from these support devices were unheeded.

Medical Record Review

Medical record review is another method of discovering MEs and ADEs. Scanning the medical chart may be a reliable means of identifying these events; however, missing or incomplete documentation will hinder the reviewer's ability to properly identify the event or associated system failures contributing to the error. The review of a voluminous medical chart is a daunting task. Rather than arbitrarily scanning the entire chart, a structured approach can use text word searches, signals, or tracking of high-alert drugs. This kind of targeted medical record review may save time while more efficiently identifying ADEs.

Signals or triggers are clues that suggest the presence of an ADE. Signals are typically referred to using three categories: (1) antidotes, (2) abnormal laboratory values, and (3) drug concentrations. A medical record review for signals or high-alert drugs can be performed while the patient is hospitalized or after discharge. Text word searching is more commonly performed retrospectively. The accuracy of detection using signals will vary based on the timing of the review and the information available during the assessment. Pharmacist involvement in medical record reviews can be advantageous, having been shown to identify more ADEs than when other health care professionals perform reviews.

Direct Observation

Although it is the most laborious method, direct observation is a comprehensive way of collecting ME data. This technique uses a trained individual who systematically observes real-time medication administration in an

unobtrusive manner. The main advantage of this method is the ability to detect MEs that may otherwise not be voluntarily reported or identified during a chart review. Direct observation is especially advantageous in the administration phase when errors such as lack of sterile technique, wrong infusion rates, and incompatible coadministered intravenous drugs would otherwise go undetected.

One recent study used direct observation to determine the incidence and nature of MEs in an adult ICU. The investigators directly observed the nursing staff for the entire study as well as evaluated the entire drug use process. This study found a higher incidence of MEs and adverse events than did reports using voluntary reporting or chart reviews in an ICU setting. Furthermore, because each error was captured in real time, the investigators were able to classify the events into degrees of severity and preventability. This technique also provided insight into the proximal causes and system failures leading up to each event. Although this method has not been reportedly used in the adult ED patient population, it could provide invaluable information and insight about MEs specific to emergency medicine.

Despite its obvious advantages over chart review and voluntary reporting, direct observation has limitations. Data collectors require substantial training before using this method. This assessment is resource-intensive, requiring personnel to perform the observations and clinical evaluators to identify MEs in the data. Another concern regarding this technique is the Hawthorne effect – the phenomenon of study subjects altering otherwise normal behavior or performance while under observation. However, one study has shown that this effect does not appear to influence results.

Patient and Family Interviews

Patient and family interviews may also help identify MEs and ADEs. In these interviews, health care professionals solicit clinical information about the patient (e.g., diagnosis, laboratory values, symptoms) and check for associations with drug-induced events. This technique has been shown to be valuable in the outpatient setting. However, its use in the acute care setting, especially the ICU, may not be feasible because these patients are often unstable with acute, complex medical issues. Therefore, establishing a robust correlation between the patient's condition and a specific drug may be difficult.

Each of these methods of ME and ADE detection has advantages and limitations in the ICU and ED. The ideal approach would include more than one method to increase detection. In addition, different detection methods reveal different types of events. Automated dispensing machines and voluntary reporting – which are not as labor-intensive – could be used simultaneously. Direct observation and chart review may compliment the other detection methods by providing more detailed information; however, because they are time-consuming, it may be best to use them periodically and as part of a targeted approach. For example, automated dispensing machines and voluntary reporting within an institution may suggest unacceptably high incidences of hydromorphone-related ADEs requiring intervention with naloxone. Therefore, a focused chart review of all hydromorphone orders for a given period may determine the associated proximal causes and faulty systems that should be targeted for improved processes.

Analysis of Data: Sentinel Events and Root-Cause Analysis

Medication error data analyses form a vital component of process improvement. Root-cause analysis is useful in determining the proximal causes of MEs. Although root-cause analyses were originally developed to investigate major industrial accidents, in 1997, the JC mandated root-cause analysis for accredited hospitals to investigate all sentinel events. The JC defines a sentinel event as an unexpected occurrence involving serious injury or death. Therefore, drug-related sentinel events resulting in death, coma, paralysis, or major permanent loss of function require the use of root-cause analysis. Institutions may have multidisciplinary teams including medicine, surgery, risk management, nursing, and pharmacy personnel involved in the root-cause analysis process.

The first step in performing a root-cause analysis is to gather all facts of the event such as the exact time the incident occurred, the location, a timeline of procedures or actions leading up to the event, and a description of the deleterious outcome. Next, causality between the suspected drug and the adverse event is determined. It is imperative to establish all known causal associations including faulty systems or processes contributing to the error. Finally, an action plan is developed to implement process improvement changes as well as a plan to measure the impact of these changes. Root-cause analysis is retrospective, but its purpose and importance is to develop plans that can prevent a recurrence of major or fatal adverse outcomes.

Strategies for Safe Medication Use

An ideal world would have zero tolerance for MEs and ADEs; however, this is not realistic because nonpreventable ADEs exist, and some MEs are inevitable. Realistically, we hope to minimize the number of MEs; minimize the number of preventable ADEs; increase the number of intercepted events; and detect drug-related hazardous conditions before injury occurs, thereby reducing the incidence of preventable and nonpreventable ADEs. There are many prevention strategies that could be implemented; some require more resource allocation, and others may be more effective at reducing events. A combination of mechanisms would be best. Many prevention strategies exist, such as standardization of medication infusions, protocol implementation, double signature requirements for drug administration, frequent intravenous line changes, and requirements for pharmacists to admix drugs instead

of other health care professionals. The focus of the following section is on the use of prevention strategies that have recently received a lot of attention – technology, education, interdisciplinary teams, signals/triggers, and medication reconciliation – to improve patient safety.

Technology

Computerized Prescriber Order Entry

Institutional system changes are necessary to reduce or avoid preventable MEs. Several technologic strategies offer potential mechanisms for safe medication practices throughout the entire drug use process. Computerized prescriber order entry can be incorporated with clinical decision support software. These integrated strategies focus on the prescribing as well as the transcription phase of the drug use process, when significant, preventable MEs have been shown to occur.

Studies evaluating the impact of these technologies exclusively in the ICU or ED are limited. An investigation comparing the rates and types of MEs in ICUs before and after CPOE implementation reported ME rates were substantially reduced with CPOE. Medication error rates began to decrease shortly after CPOE implementation and continued to decline for several months, suggesting a learning curve with the new technology and process. Although CPOE reduced, if not eliminated, some types of MEs in an ICU, it also increased other types of errors not identified with handwritten orders. For example, CPOE significantly reduced incomplete orders such as omissions in dose, units, frequency, or route but increased the rate of dosing errors such as selecting the wrong drug or dose. Although CPOE can ensure a complete order, without clinical decision support, it cannot ensure the most effective and safest dosing regimen. The CPOE systems lacking clinical decision support do not address proximal causes (e.g., insufficient knowledge of drug therapy) substantially associated with MEs in the ICU.

Another evaluation of CPOE showed a considerable reduction in intercepted and serious MEs. Although prescribing errors increase proportionally with increases in the number of physician orders in paper-based systems, CPOE systems have not shown this trend in the ICU. Prescribing errors can still occur with CPOE (e.g., selecting the wrong drug or dose for a patient based on the location of the drug in the electronic list), but CPOE can help minimize the incidence of MEs. Clinical decision support software, used in conjunction with CPOE, can further reduce the risk of error. For example, CPOE can prevent the prescriber from ordering levofloxacin 500 g instead of 500 mg intravenously daily, whereas paper-based systems cannot. However, the CPOE order for 500 mg could be erroneous if the patient had compromised renal function. Clinical decision support could guide the prescriber to select 250 mg intravenously daily as more appropriate given the patient's renal function.

Administration Technology

Bar-coded medication administration technology provides a method of electronically verifying accurate drug documentation and administration. This technology has shown a 36% decrease in dispensing errors after implementation. Clinically significant and serious potential ADEs were also dramatically reduced after implementation. The bar-coded system not only targets dispensing errors but also has been shown to reduce administration errors. Another evaluation found a 54% reduction in medication administration errors with this technology. Although this technology has not been exclusively evaluated in an ICU or ED setting, it should undoubtedly improve drug safety in these settings. As with other technologies, it is imperative for pharmacists to be intimately involved in the planning and implementation process.

Intravenous infusion pump technology is another mechanism targeting the administration phase of the drug use process. Also known as *smart pumps*, these devices are programmable infusion systems with drug libraries containing standardized concentrations, predefined dose ranges, and automatic calculations for weight-based dosages. More advanced infusion pump systems may contain sophisticated point-of-care, real-time clinical decision support capabilities integrated with CPOE, monitoring systems for real-time vital sign evaluation, and laboratory data to alert clinicians of abnormal data. One study compared serious MEs in critically ill patients who received drugs by smart infusion pumps, either with or without clinical decision support software. Surprisingly, clinical decision support on the infusion pump technology did not reduce the rate of serious MEs, and MEs and ADEs were common in both groups. This is possibly explained by the nursing staff's ability to circumvent the drug library and override alert systems. Evading these safety features eliminates the capacity to reduce potential and preventable ADEs.

New technology may bring with it opportunities of errors if these new systems are not used as intended or vigilantly monitored for optimal effect. Unfortunately, smart pump technology has not been evaluated in adult patients presenting to the ED. However, such infusion systems with clinical decision support software would likely be beneficial in this setting. The wide range of disease states and patient characteristics seen in the ED presents a challenge to the provision of safe intravenous drugs. Infusion technology integrated with decision support could prevent potential ADEs in these patients by ensuring that clinicians are provided with laboratory values and vital signs before administration of drugs that may complicate care.

Automated Dispensing Machines

Another mechanism to improve safe medication practices is automated dispensing machines. This technology minimizes potential MEs by limiting access to drugs until pharmacist verification occurs. In addition, automated dispensing machines reduce wrong-time errors because most

common drugs used in the ICU and ED are already stored and available immediately after the order verification. Unfortunately, the impact of this technology is only maximized when proper procedures are in place. In emergency situations, the override feature poses a potential breakdown in the process for minimizing MEs. This may be a more common occurrence in the ED, an environment requiring prompt medication administration.

The JC has mandated that all drug orders be reviewed by pharmacists. Although these standards are ideal in concept, the reality is that most institutions lack a dedicated ED pharmacist. Time is of the essence in emergency situations, and this could limit the pharmacist's ability to review the drug order to ensure the agent dispensed from the automated dispensing machine is appropriate. Unfortunately, the ED remains a highly susceptible environment for dispensing and administration errors from automated dispensing machines.

Education

Although several public health organizations recommend the use of CPOE to reduce prescribing errors, implementation in U.S. hospitals is limited. Institutions that still rely on manual order writing could provide educational programs as a mechanism to decrease prescribing errors. One study, conducted in an ICU, examined intervention with an education module focused toward physician trainees. The module consisted of real-life examples of prescribing problems, a review of standards for prescribing, guidance on obtaining appropriate drug information, educational patient care rounds, and an audit of their work including feedback divided in three cycles. Prescribing errors, which were evaluated in a pre-intervention period, postintervention period, and 6 weeks after the intervention, decreased from around 22% to 5% because of this educational effort.

Multidisciplinary Patient Care Team

Evidence supports the effectiveness of team training. A meta-analysis that correlated team training in organizations with outcomes such as performance, cognitive skills, and processes found a moderate positive relationship. Many clinicians believe that teamwork promotes better patient care and patient outcomes, and that incorporating team training into the ICU patient care team could further improve outcomes and efficiencies. At minimum, a multidisciplinary patient care team in the ICU has shown improvements in patient care.

Ideally, a structured approach to rounds improves communication and potentially reduces harm. Team training may provide added benefits, and implementation of a multidisciplinary team can decrease the number of adverse events. More than simply a matter of two or more individuals working together for a common goal, there is a science to team performance and team training. One recommendation, based on the literature, is for teams to undergo Crew Resource Management Training. This training module was named after the aviation industry and aims to develop a high-reliability team. Crew Resource Management Training requires initial preparation such as a needs assessment. Other steps include identifying a targeted outcome, developing training content, determining training delivery, and applying evaluation techniques. Crew Resource Management Training can be an important part of a health care organization's strategy to improve patient safety and quality of care. Team training may improve behaviors, cognitive skills, and attitudes to provide optimal care and reduce errors. The success of a team is not solely dependent on its ability to function but also on the commitment of the organization to provide recognition and resources.

Monitoring Signals/Triggers

Signals/triggers are clues that suggest the occurrence of an ADE. Monitoring triggers such as abnormal laboratory values or physiologic changes may be antecedents to patient harm and can be used for prevention. Triggers can be used for surveillance, then analyzed for root causes. They may be used to develop systematic changes to prevent future events or for real-time intervention, depending on the trigger. Performance characteristic data, described as the ability of a trigger to detect an ADE, are beneficial before implementing signals so institutions could select signals with high positive predictive values.

Ideally, a signal would detect an ADE 100% of the time, enabling resources to be used efficiently. However, this is not realistic because of false-positive events. As an example, abnormal laboratory values are not drug related in every case. Determining the positive predictive value, sensitivity, and specificity of an abnormal laboratory value enables an understanding of how often it is associated with an ADE. This allows an appropriate resource allocation and reduces the clinician's alert burden in an automated signal detection system. Recently, five antidote signals in the ICU were retrospectively evaluated and were determined to have an overall positive predictive value of 0.30. The same performance evaluation could be applied to text word searches and to the tracking of high-alert drugs. The ability of a signal to predict an ADE is expected to differ for ICUs versus non-ICUs and between types of ICUs. More research is needed on the use of signals to optimize an ADE surveillance system.

Medication Reconciliation

It is estimated that 50% of all MEs occur when new orders are written for a patient on admission to or discharge from the hospital. Critically ill patients are at risk of MEs during ICU admission and discharge because about 60% of regularly scheduled drugs are discontinued on admission. In fact, 33% of patients discharged from an ICU have at least one chronic drug unintentionally omitted at hospital discharge. The MEs are not limited to omitted drugs because medication reconciliation of ICU discharge orders results in changes for 94% of orders.

The first randomized, controlled trial of information technology–based reconciliation intervention in the ICU showed a 28% relative risk reduction in unintentional medication discrepancies that had the potential for harm. The number needed to treat was 2.6 patients to prevent one unintentional medication discrepancy with the potential for harm. The data supporting medication reconciliation as an approach for ADE prevention are mounting. However, the amount of evidence necessary for implementation seems sufficient because the need for medication reconciliation appears to be intuitively obvious.

Conclusion

Clinicians are becoming more aware of the incidence and importance of MEs and ADEs in the ICU and ED. The data addressing the drugs that are most often related to ADEs – and the MEs that led to these events – are available to aid clinicians in identifying patients at risk so that preventive monitoring can be provided. Active patient safety surveillance is recommended by the Institute of Medicine. Many methods exist for detecting MEs and ADEs; however, most require additional resources and a financial commitment from hospital administrators. An active patient safety surveillance system should be constructed specific to the ICU. It has been shown through voluntary reporting that ADEs should be analyzed for ICU and ED environments separately from general care units so that systematic changes can be implemented. Several prevention strategies are available to help in the reduction of patient harm, and these should be used whenever possible.

Annotated Bibliography

1. Bertsche T, Mayer Y, Stahl R, Hoppe-Tichy T, Encke J, Haefeli WE. Prevention of intravenous drug incompatibilities in an intensive care unit. Am J Health Syst Pharm 2008;65:1834–40.

   The study design for this investigation was a combination of retrospective and prospective evaluations to identify drug incompatibilities. Of the drug pairs potentially given concomitantly in the retrospective medical record review, 7.2% were considered incompatible. This information was the basis for developing the new standard operating procedures mandating that certain drugs be separated before administration. The prospective portion of this study was completed to ensure the drugs were being prescribed at the same time; this is an obvious limitation of the initial retrospective analysis. The prospective portion of the study was designed as a before and after evaluation of the implementation of the new standard operating procedures. The drug incompatibility rate was reduced from 5.8% to 2.4% after standard operating procedures were implemented. However, the drug incompatibilities dictated by the new standard operating procedures were reduced from 1.9% to 0.5%. Therefore, a substantial reduction in incompatibilities was not explained by the intervention. These results would be difficult to generalize because the data are limited to one ICU.

2. Camire E, Moyen E, Stelfox HT. Medication errors in critical care: risk factors, prevention and disclosure. CMAJ 2009;180:936–43.

   This review article attempts to complete the gap in the literature regarding the risk factors for MEs. The authors identified 49 articles pertaining to risk factors, but only 6 met the inclusion criteria. It appears that all 49 articles were used to develop the list of potential risk factors. In addition, the studies evaluated did not focus on risk factors. Five of the 17 articles described in the appendix assess causal factors rather than risk factors. Evaluating risk factors requires a comparator group of patients not experiencing an ADE, and many of the studies did not have such a comparator. In addition, the authors selected 31 articles to develop a list of potential ME prevention strategies; however, only 11 of these met the inclusion criteria. Therefore, the list of risk factors and prevention strategies proposed in this review should be considered potential and not confirmed based on evidence. Although this article claims to be an evaluation of risk factors for MEs, several of the references refer to ADEs. The risk factors for MEs and ADEs may differ, and the differences were not considered in this comparison. Nevertheless, this article provides a useful review of ME data in the ICU and offers possible prevention strategies.

3. Denham CR. A growing national chorus: the 2009 safe practices for better healthcare. J Patient Saf 2008;4:253–60.

   This review article highlights the changes and additions to the Safe Practices for Healthcare, which were created by a consensus of organizations. Several guidelines and requirements for patient care are proposed by different organizations; these proposals emphasize patient safety. Insight is provided into the relationship between the Safe Practices for Healthcare and compliance with the National Quality Forum's Voluntary Consensus Standards for Prevention and Care of Venous Thromboembolism, the JC's National Patient Safety Goals, published guidelines, and the CMS. This article provides an overview of practices the pharmacist should manage as part of an interdisciplinary team. Patients receiving drugs that cause mental status changes are at risk of falls, and pharmacists should be active in discontinuing these drugs when possible. Thromboembolism prophylaxis is a central focus of the JC and the CMS, so pharmacists should be vigilant in ensuring the compliance of their institution.

4. Kane-Gill SL, Kowiatek JG, Weber RJ. A comparison of voluntarily reported medication errors in intensive care and general care units. Qual Saf Health Care 2010; 19:55–9.

   A national survey indicated that few institutions track ICU-specific patient safety data. Compiling voluntarily reported data for an institution without delineating the ICU data could result in proposed systematic changes for general care units that may be skewed or may not apply to critically ill patients. This retrospective evaluation of voluntarily reported data was intended to answer the question, Are there differences in type, cause, contributing factors, type of staff initiating an error, drug use process node, drug classes, and patient outcomes between ICUs and general care units? Data were obtained from a large academic medical center's

MEDMARX database for 4.5 years. There were 541 MEs identified for the ICUs and 2711 MEs in the general care units. The type of error, contributing factors, drug classes, and patient outcomes varied for the ICU compared with the general care unit, suggesting that institutions should track ICU-specific data separately. The main limitation of this study is the use of voluntarily reported data, which is typically what most institutions rely on. In addition, the study institution has a large transplant population, making it difficult to generalize the contributing drugs.

5. Kopp BJ, Erstad BL, Allen ME, Theodorou AA, Priestley G. Medication errors and adverse drug events in an intensive care unit: Direct observation approach for detection. Crit Care Med 2006;34:415–25.

These investigators conducted a prospective observational study in a medical/surgical ICU in a university medical center to determine clinically important ADEs and MEs. Unlike other ME studies using direct observational methods, this study was unique because it was specifically focused in an ICU setting. Most potential ADEs were considered serious or significant (29.1% and 61.8%, respectively). Most MEs occurred during prescribing, dispensing, and administration (28%, 34%, and 34%, respectively), whereas 77% of actual preventable ADEs were attributable to prescribing. It should be emphasized that these rates for prescribing and transcription errors represent an institution without CPOE and are likely overestimated for institutions with CPOE. In addition, the errors identified at the dispensing node were not intercepted by the dispensing pharmacist, highlighting the potential for further process improvement to reduce the error rate at this particular node. A valuable area of future research would be a similar study at this institution after the implementation of CPOE, bar coding, and electronic medication administration.

6. Lipshutz AKM, Morlock LL, Shore AD, Hicks RW, Dy SM, Pronovost PJ, et al. Medication errors associated with code situations in U.S. hospitals: direct and collateral damage. Jt Comm J Qual Patient Saf 2008;34:46–56.

These authors reviewed MEs associated with code situations from 2000 to 2005 using information from 834 health care facilities in the National MEDMARX voluntarily reported database. Only 0.22% (2288/1,043,939) of the MEs were related to code situations; of these, 6.5% and 0.59% resulted in patient harm and death, respectively. Comparing these data with non–code-related errors, patients having an ME during code situations were 39 times more likely to have harm and 51 times more likely to die. Of note, most MEs in this study were reported in general patient care wards, with fewer occurring in the ED and ICU. It is uncertain whether the lower ME rate in the ED and ICU is a reflection of the staff skill and specialized training or the lack of voluntary reporting. A prospective evaluation of MEs during code situations is needed to answer this question. This evaluation provides insight into when the errors occurred by categorizing the ME as (1) error to the patient involved in the code, (2) error to a patient other than the one involved in the code, (3) error preceding the code, or (4) error after the code. Of interest, most errors reported were to patients other than the one involved in the code. This could be considered collateral damage from the code situation caused by workflow disruption and missed medication administration (specifically, antiasthma drugs and bronchodilators). These voluntarily reported data resulted in action in 29% of cases, and errors associated with harm were 3.7 times more likely to result in a policy-level action. Because these data were voluntarily reported, it is likely that the number of MEs was underestimated.

7. Rothschild J, Keohane CA, Cook EF, Orav J, Burdick E, Thompson S, et al. A controlled trial of smart infusion pumps to improve medication safety in critically ill patients. Crit Care Med 2005;33:533–40.

This study investigated the impact of smart infusion pumps on intravenous MEs and ADES in critically ill patients. The study was not exclusive to the ICU: it included two cardiac surgery ICUs and two cardiac surgery stepdown units. Although the purpose of this study was to determine the smart infusion pump's effect on serious ME rates, the findings showed no substantial reduction in these rates. Nonetheless, this research brought to light some very important findings. The lack of impact with smart pumps in this study may have been attributable to pump design and programming. These pumps allowed nursing staff the option to bypass the medication library software (e.g., infusion rate calculations, standardized concentrations); in fact, 94% of nonintercepted potential ADEs were associated with nursing staff not using the medication library. In addition, the nurses could override alerts, which enabled inappropriate medication administration practices. These findings emphasize the importance of proper implementation as well as appropriate use of technology. The investigators did not anticipate these systematic failures before study initiation because data collection began only 2 weeks after the smart pumps were implemented.

8. Phansalkar S, Hoffman JM, Nebeker JR, Hurdle JF. Pharmacists versus nonpharmacists in adverse drug event detection: a meta-analysis and systematic review. Am J Health Syst Pharm 2007;64:842–9.

This meta-analysis included 13 studies in which medical records were reviewed for the detection of ADEs; 9 of these reviews were by a pharmacist, and 4 involved physicians or nurses. The record review approach varied among the studies, which included both retrospective and prospective designs. The number of ADEs detected accounting for the total number of patient admissions led to a variable effect size with 0.13–0.94 and 0.01–0.60 incidence rates for the pharmacist and nonpharmacist reviewers, respectively. Overall, the mean weighted ADE detection rate was 0.33 per admission for pharmacists and 0.16 for nonpharmacists. This study continues to support the role of the pharmacist as a member of a pharmacovigilance team and as a key participant in the identification and reduction of ADEs. The studies assessed in the meta-analysis were of inpatients but were not ICU-specific; however, the results would likely be beneficial in the ICU setting as well. In addition, the rate of ADE detection for medical record reviews completed prospectively and retrospectively may differ because a prospective evaluation allows communication with the patient care team.

9. Salas E, DiazGranados D, Klein C, Burke CS, Stagl KC, Goodwin GF, et al. Does team training improve team performance? A meta-analysis. Hum Factors 2008;50:903–33.

The proposition that team training can improve team outcomes is reviewed in this meta-analysis of studies mainly performed using college students in simulated laboratory settings for the aviation industry and military. Team training was identified as more effective at improving team process outcomes than other types of outcomes. In fact, team training explained 12% to 19% of the variance in team performance. A trained intact team (i.e., consistent team members) had better outcomes than a trained ad hoc team. Intact teams showed benefit from training for performance outcomes but were similar to ad hoc teams for process outcomes. Finally, large teams (in most cases, more than five team members) had a greater performance benefit from team training than did medium and small teams. However, training provided better correlation with cognitive outcomes in medium teams and process outcomes with small teams compared with large teams. For the ICU, this could mean that a medium team with some consistency in members (i.e., intact team) is beneficial, but this structure requires further testing.

10. Schnipper JL, Hamann C, Ndumele CD, Liang CL, Carty MG, Karson AS, et al. Effect of an electronic medication reconciliation application and process redesign on potential adverse drug events. Arch Intern Med 2009;169:771–80.

The primary objective of this cluster-randomized, controlled trial was to compare unintentional discrepancies between preadmission drugs and admission or discharge drugs with the potential for patient harm. The intervention applied the use of a computerized medication reconciliation tool. A pharmacist obtained a gold standard preadmission drug history with which the admission and discharge reconciliations were compared. The control group received care as usual, with medical residents taking the drug histories; pharmacists reviewing orders for appropriateness; physicians writing discharge orders; and nurses educating patients on their drugs. Patient harm was evaluated by a team of physicians blinded to the group assignments. The results showed significantly more potential ADEs in the control arm, particularly for ADEs occurring during the discharge reconciliation. It seems intuitively obvious that structuring the medication reconciliation process would lead to a reduction in discrepancies, so these findings may not be surprising; however, it is a useful validation that the effort dedicated to medication reconciliation results in a reduction of potential ADEs. In addition, this study shows the value of formalizing the medication reconciliation process to ensure better accuracy. Medication reconciliation is a requirement of the JC, and using a computer to assist in this process could help show compliance. Ideally, medication reconciliation documentation on admission could be synchronized with CPOE to streamline the process.

11. Shulman R, Singer M, Goldstone J, Bellingan G. Medication errors: a prospective cohort study of hand-written and computerized physician order entry in the intensive care unit. Crit Care 2005;9:R516–21.

This prospective study evaluated MEs in an ICU by comparing handwritten orders and CPOE without decision support. The focus of the study was only on the prescribing phase of the drug use process. The results suggest that CPOE is associated with higher dosing errors than the handwritten cohort, at least when decision support capabilities are not involved, as in this study. The most noticeable trend in handwritten errors was missing information (e.g., route, units). Looking at all MEs, CPOE reduced the total incidence of errors. However, dosing errors were more common in the CPOE cohort. The overall ME rate continued to decline throughout the study, suggesting a learning curve with the implementation of a new CPOE system. Although this study shows a reduction in the overall rate of prescription errors, it is important to recognize that CPOE does not completely eliminate all prescribing errors.

12. Valentin A, Capuzzo M, Guidet B, Moreno R, Mentintz B, Bauer P, et al. Errors in administration of parenteral drugs in intensive care units: multinational prospective study. BMJ 2009;338:b814.

This prospective, observational, multinational study investigated the incidence and proximal causes of MEs associated with parenteral drugs in the ICU. All nurses and physicians on duty were asked to complete a bedside structured questionnaire to assist in the reporting of MEs. This type of voluntary reporting may underestimate the true incidence of errors compared with other detection methods. The large number of enrolled ICUs included clinical staff with a wide variation in experience and training for error observation/reporting, institutional differences with respect to technology, and differing practices that could bias the results of ME detection. This report offers insight into contributing factors surrounding these events, which may be extrapolated to other institutions for process improvement. This study reported an incidence of 74.5 MEs per 100 patient-days. The most common type of error was wrong time of administration; this was followed by drug omission, wrong dose, wrong drug, and wrong route. Seventy-one percent of MEs resulted in no significant impact on the patient's clinical status; however, 0.9% of the patients experienced permanent harm or death.