

# Technology Utilization to Prevent Medication Errors

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**Abstract:** Medication errors have been increasingly recognized as a major cause of iatrogenic illness and system-wide improvements have been the focus of prevention efforts. Critically ill patients are particularly vulnerable to injury resulting from medication errors because of the severity of illness, need for high risk medications with a narrow therapeutic index and frequent use of intravenous infusions. Health information technology has been identified as a method to reduce medication errors as well as improve the efficiency and quality of care; however, few studies regarding the impact of health information technology have focused on patients in the intensive care unit. Computerized physician order entry and clinical decision support systems can play a crucial role in decreasing errors in the ordering stage of the medication use process through improving the completeness and legibility of orders, alerting physicians to medication allergies and drug interactions and providing a means for standardization of practice. Electronic surveillance, reminders and alerts identify patients susceptible to an adverse event, communicate critical changes in a patient's condition, and facilitate timely and appropriate treatment. Bar code technology, intravenous infusion safety systems, and electronic medication administration records can target prevention of errors in medication dispensing and administration where other technologies would not be able to intercept a preventable adverse event. Systems integration and compliance are vital components in the implementation of health information technology and achievement of a safe medication use process.

**Keywords:** Technology, intensive care unit, patient safety, medication.

## INTRODUCTION

Adverse drug events (ADEs) represent an unwanted complication of hospital care and medication errors have been increasingly recognized as a major cause of iatrogenic injury [1]. While their frequency, severity, cost, and optimal prevention strategies remain a source of debate, a single event is capable of generating enormous negative publicity, compromising patient trust, and demoralizing hospital staff [1-4]. Past ADE reports have provided valuable information in hospitalized, long term care, and ambulatory care patients [5-7], but research in the intensive care unit (ICU) setting has been limited to observational studies in narrow patient populations [8-10]. While the best way to prevent medication errors has not been fully elucidated, systems improvement remains the focus of ADE prevention efforts [11]. Implementation of technologies such as computerized physician order entry (CPOE), clinical decision support systems, telemedicine, electronic reminders, computerized adverse event monitors, bar code medication verification, electronic medication administration record (eMAR), and intravenous infusion safety systems ("smart pumps") may help reduce ADEs.

## ADVERSE DRUG EVENTS IN THE ICU

An ADE is an injury resulting from the use of a drug, and includes both medication errors and adverse drug reactions [12]. Medication errors are errors that occur during prescribing, transcribing, dispensing, administering, adherence, or monitoring of medications. Not all medication errors lead to ADEs, although they have the potential to become ADEs. In contrast, an adverse drug reaction results in unexpected patient harm when a drug is administered at normal therapeutic doses, and is more commonly referred to as a medication side effect [12]. An observational study evaluated adverse events in the critical care setting, following 391 patients over 1,490 ICU patient days. The most serious medical errors occurred during the ordering or administration of medications, accounting for 61% of the errors. Of these, 34% were

deemed preventable. Incorrect medication dosing was the most common error, but administration errors of incorrect or duplicate medications also occurred frequently. Errors were most commonly attributed to memory slips and lapses rather than knowledge deficits. There were 80.5 adverse events per 1000 patient days. This study suggests that errors in the ICU setting are common, life-threatening, and often preventable. Interventions directed at ensuring treatment regimens are ordered and administered correctly are likely to enhance patient safety [10].

## COMPUTERIZED PHYSICIAN ORDER ENTRY

Errors in medication ordering have been the primary identified source of preventable ADEs [1]. Computerized physician order entry (CPOE) eliminates handwritten orders and reduces errors related to medication prescribing. Furthermore, CPOE enhances quality and efficiency by improving the completeness and legibility of orders. It offers clinical decision support and provides a means for standardizing practice [13]. An epidemiology study of prescribing errors found a rate of 62.4 errors per 1000 medication orders. Of these errors, 31% were considered clinically significant and 64% were determined preventable with CPOE. In addition, 43% of prescribing errors that were previously classified as potentially harmful to the patient were determined likely to be preventable with CPOE [14].

In a landmark trial evaluating the impact on serious medication errors, implementation of CPOE resulted in a 55% (10.7 vs 4.86 per 1000 patient days) reduction in the rate of serious medication errors across all stages of the medication use process [15]. Preventable ADEs were also reduced by 17%. The study included both medical and surgical ICUs. The results of this study were confirmed and extended in a time series analysis that evaluated adult inpatient medication prescribing [16]. CPOE was used to optimize prescribing practices through displaying medication use guidelines, typical doses and frequencies, as well as therapeutic alternatives.

While initial studies have reported benefits with CPOE, others have found an increase in errors post-implementation. The number of ordering errors in a neurosurgical ICU increased during the initial transition period following CPOE implementation. This increase, however, did not result in an increase in patients harmed from

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medication errors [17]. In 2005, a study characterized CPOE related factors that can increase the risk of prescribing errors [18]. Errors were classified as information errors (e.g., reliance on CPOE to display usual doses or frequencies), or human-machine interface flaws (e.g., incorrect patient or medication selection). These studies highlight the importance of education prior to, during, and after CPOE implementation, as well as continued re-evaluation and quality improvement to ensure optimum performance.

Only 17% of U.S. hospitals have implemented CPOE and even fewer have implemented comprehensive electronic based record systems [19]. A variety of barriers have been identified and include physician and organizational resistance, high cost, immaturity of the vendor market, and poorly defined interfaces [20].

### CLINICAL DECISION SUPPORT SYSTEMS

Clinical decision support systems (CDSS) can enhance patient safety. A time series study showed each successive CDSS addition reduced the rate of medication errors [16]. Baseline data with handwritten orders was compared to: 1. CPOE with minimal CDSS, 2. CDSS with drug allergy checking, and 3. CDSS with additional drug-drug interaction screening and pathways for potassium prescribing and administration. At study conclusion, medication errors were reduced by 81% and non-intercepted serious medication errors were reduced by 86%. When the data was separated based on level of care, the medication error rate was decreased to a greater extent in the ICUs versus the non-ICUs (ICU: 248 to 35.2 per 1000 patient days; non-ICU: 109 to 22.6 per 1000 patient days).

CDSS improves medication dosing accuracy in patients with renal dysfunction [17]. Prescribing of the correct dose and frequency increased significantly with the addition of guided medication dosing, from 54% to 67% and 35% to 59%, respectively. There was a significant reduction in the mean length of stay, 0.3 days, in patients with guided dosing [21].

### PATIENT MONITORING: ELECTRONIC SURVEILLANCE, REMINDERS, AND ALERTS

Information technology aimed at communicating critical changes in a patient's condition can improve quality of care. Computerized surveillance which utilizes pre-programmed rules, medical conditions, medication orders, and laboratory results can identify patients susceptible to an ADE. A study using a computer

based alerting system, for which a patient met the conditions of a pre-programmed rule set, identified 275 ADEs from 2,620 alerts. While this was less than the number detected with chart review, the system provided a more efficient detection strategy, requiring fewer labor hours [22].

Computerized clinician reminders can help to increase patient safety and decrease the cost of care. In one study, a computer application identified patients at risk for venous thromboembolism (VTE), alerted the responsible physician (Fig. 1), and offered an opportunity to prescribe prophylaxis [23]. They found that more patients were prescribed prophylaxis in the group of physicians who were alerted, and in these patients objectively confirmed VTE was reduced at 90 days by 41%.

System alerts can also assist in converting intravenous medications to less expensive oral route formulations. A computerized system was able to promote the conversion or discontinuation of 372 intravenous medications in 1,045 patients that were eligible for oral medications [24].

Automation of critical laboratory results can facilitate timely and appropriate treatment [25]. A prospective randomized controlled trial that utilized a system to detect and notify prescribers of critical conditions found a shorter time to medical intervention and a reduction in the time to resolution.

While interventions such as these can facilitate critical data transmission that is vital to patient safety, there is a risk of overwhelming practitioners with alerts. Practitioners can become desensitized to the alerts and eventually disregard or override them [26]. Optimal performance of CDSS requires continuous quality improvement and minimizing unnecessary alerts, so that users remain responsive and patients obtain the maximal benefit.

### TELEMEDICINE

Healthcare systems are frequently confronted with providing off-hour patient coverage. While ICU studies show a dedicated intensivist staffing model is associated with superior patient outcomes, the shortage of practitioners makes the implementation challenging. An ICU telemedicine program, using a physician-led care team in a centrally-located facility, can monitor patients and provide supplemental care in multiple ICUs, 24 hours a day [27].

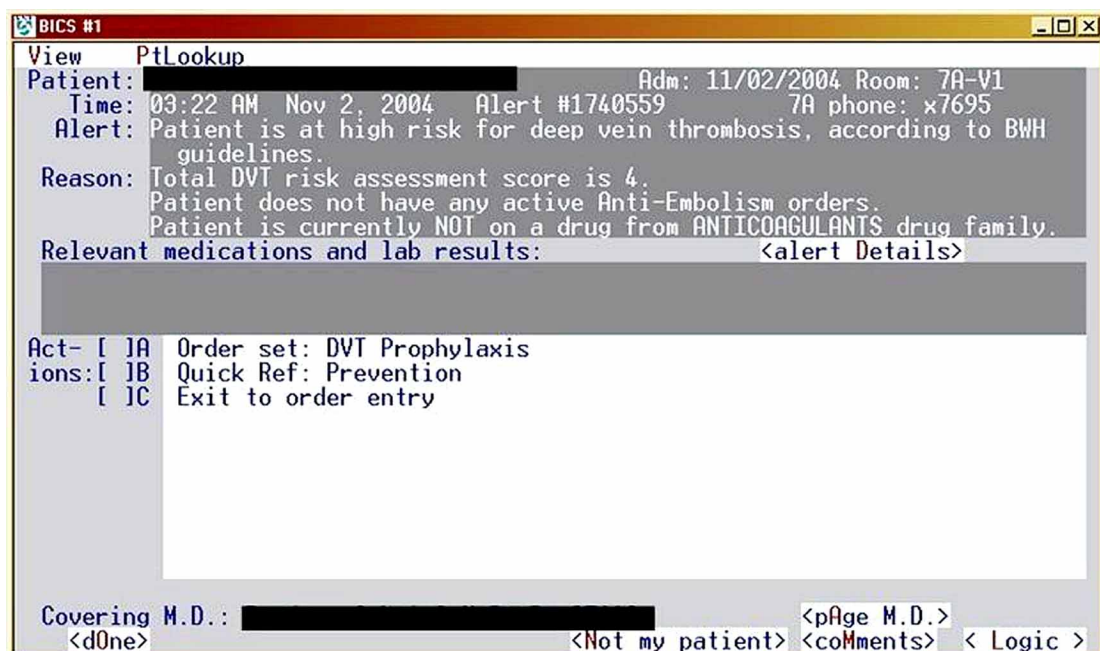


Fig. (1). Computer alert for venous thromboembolism risk.

Utilizing a remote intensivist program has been shown to decrease severity-adjusted hospital mortality (9.4% vs 12.9%), reduce ICU length of stay (3.63 days vs 4.35 days) and provide hospital cost savings.

**DISPENSING AND ADMINISTRATION ERRORS**

**Bar Code Medication Verification**

Recent efforts to reduce the occurrence of ADEs have focused on eliminating errors in medication dispensing and administration. Machine readable bar codes were developed in the late 1960s when the National Association of Food Chains (NAFC) searched for systems that would speed the checkout process. Bar code technology is a method to reduce medication errors that other systems, such as CPOE, cannot detect and intercept. In 2004, the Food and Drug Administration (FDA) required that all newly approved drugs be packaged with a linear bar code, containing the National Drug Code number, within 60 days of approval.

Despite the FDA mandate, the implementation of bar coding technology within healthcare systems has been slow. Inpatient hospital pharmacy operations are complex, requiring multiple steps, involving vital interactions of personnel and technology. Dispensing errors are common. Furthermore, few safety nets exist to stop these errors from reaching a patient. One hospital found an error rate of 3.6% during their pharmacy dispensing processes, or approximately 1 error for every 36 medications dispensed [28]. Of these errors, most of which were due to the dispensing of an incorrect medication, 22.8% had the potential to cause harm. Errors occurred in dispensing of medications to both the automated

medication cabinets and to nursing staff for direct patient administration. A before-after study evaluating the impact of bar code technology on medication dispensing errors demonstrated a reduction in dispensing errors by 36% and potential adverse drug events by 63% [29]. The event reduction occurred in multiple dispensing processes with many different types of errors, including, but not limited to, wrong medication selection.

A review of reported adverse drug events in cardiology and cardiac surgery inpatients found that 3.1 adverse drug events occurred per every 1000 patient days and 66% of these events were deemed preventable [30]. These errors occurred most commonly with drug administration (32.4%). Both bar code medication verification and smart pump technology are preventative strategies that can target this phase of the medication use process. Through a computer interface with our CPOE system, bar code scanning at the patient’s bedside identifies the medication being administered to assure it is in fact the prescribed medication and dose. By placing a bar code on a patient wrist bracelet and on an identification (ID) badge we can assure an identical match between patient and medication and capture the practitioner administering the medication (Fig. 2).

**SMART INFUSION PUMPS**

There are fewer opportunities to intercept ADEs as medication administration approaches the patient’s bedside. For example, when an error is made in prescribing, a pharmacist or nurse in their review process, may intercept the error. When an error is made at the bedside at the time of administration, there are fewer checks and limited processes in place to stop the error from reaching the



Fig. (2). Bar code medication scanning.

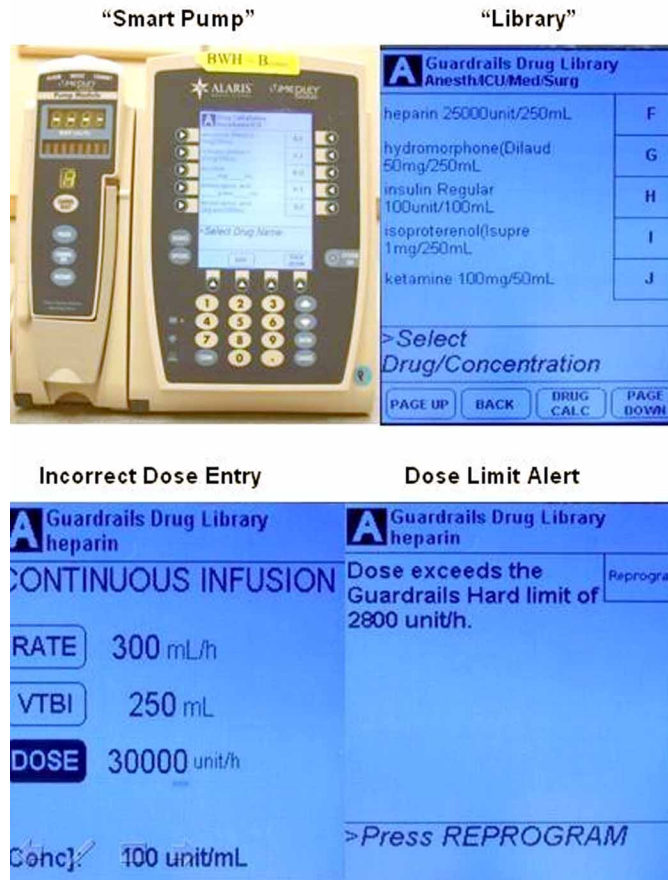


Fig. (3). “Smart pump” drug libraries.



Fig. (4). Electronic medication administration record.

patient. Although errors in the ordering stage of the medication use process have been identified as the most common type of error, Bates found that 48% of these errors were intercepted prior to reaching the patient [1]. This is in contrast to administration errors, of which none were intercepted prior to reaching the patient. Errors in the administration of intravenous medications can be particularly

dangerous. Technology may play an even more vital role in patient safety. New intravenous infusion safety systems, “smart pumps”, can help to prevent these errors from reaching the patient. Smart pumps have pre-programmed safeguards such as hospital-specific drug libraries and hard and soft dose limits to help prevent errors in intravenous administration (Fig. 3).

Critically ill patients frequently receive multiple intravenous medications. Often these medications have a narrow therapeutic index and are being administered to a patient population that is particularly vulnerable to errors. An analysis of adverted intravenous medication errors with the use of smart pumps reported that 78% of the devices were used in critically ill patients and 84% of the adverted errors occurred in this patient population [31]. In 2005, a study conducted in the cardiac surgery ICU and step down units evaluated smart pump log data during two periods, one with and one without smart pump decision support. The investigators found no significant difference between the two time periods, with 11 preventable ADEs (0.28 per 100 patient pump days) with the smart pump alerts turned on and 14 preventable adverse drug events (0.33 per 100 patient pump days) with the smart pump alerts turned off [32]. There were 82 non-intercepted potential ADEs in the intervention group and 73 non-intercepted potential ADEs in the control group (2.12 vs 1.7 per 100 patient pump days, respectively). The most common type of medication error was incorrect dose set in the infusion pumps. Unfortunately, in 25% of the alerts during the intervention period, nurses violated standard infusion practices. A follow up study over 16 months suggested "smart pump" alerts, triggered by anticoagulant therapy, intercepted dosing errors. Both 10 to 100 fold overdoses and sub-therapeutic doses were common, with errors frequently duplicated. Practitioners were forced to either reprogram the correct dose or cancel the anticoagulant infusion [33].

This study uncovered and highlighted two important compliance issues for the successful implementation of smart pumps, overriding alerts and not utilizing the drug library, which are inherent safety features of the smart pumps. Medication errors can be detected and avoided with smart pumps, but only if used properly. It is imperative that proper user training is performed and use is monitored to identify practices that are not ideal.

#### ELECTRONIC MEDICATION ADMINISTRATION RECORD

Few studies have evaluated the benefits of an electronic medication administration record (eMAR). eMAR has been proposed as part of an integrated system designed to improve nursing efficiency and reduce medication errors. eMAR systems are designed to organize medication administration schedules and prompt nurses to ensure timely medication administration (Fig. 4). Mekhjian compared medication administration processes using CPOE with and without eMAR [34]. There was a significant improvement in medication availability, turnaround time, medication ordering, medication dispensing, and laboratory result reporting time. Furthermore, there was a reduction in time to medication administration and a complete elimination of transcription errors. Combining CPOE and eMAR can have effects across all areas of the medication use process, but in particular, was associated with a decreased rate of transcription errors, from 11.3% to 0%, and an increased awareness of timely medication administration.

#### COST

The resources required for purchasing technology and the labor required for technology implementation are substantial. Costs analyses weigh these aspects, but also consider the stream of expenses avoided from ADEs. The benefits of health information technology have been well described, but the costs have been much less documented. Costs of implementing information technology can stem from redesigning processes, integrating systems, implementation, and technical support. It is also dependent on the size of the institution. The cost of implementing CPOE has been estimated at approximately \$8,000,000 for a 500 bed hospital, with additional ongoing annual maintenance expenses of \$1,350,000 [13]. Smart pumps and bar coding technologies have been associated with a lower cost than CPOE, \$1.2-1.5 million and

\$500,000 to 2 million, respectively [35]. Hospitals incur approximately \$2,200 per adverse drug event and approximately \$4,685 per preventable adverse drug event [36]. One study estimated a \$2.2 million dollar annual savings with the use of bar code technology. The authors were able to demonstrate a significant financial return on investment following the implementation of bar code technology [36].

#### CONCLUSION

The implementation of health information technology can result in a reduction in ADEs and can impact the quality of patient care. Systems integration and compliance are vital in achieving a safe medication use process. Hospitals that have extensive computerized technology and have greater automation tend to have better patient outcomes, including fewer complications, reduced inpatient mortality and lower hospital costs [37]. Regulatory agencies and payers are now using performance standards and financial incentives to force practice changes [38]. This may increase the speed and likelihood of technology implementation. While many providers may dismiss technology as being beyond their scope of practice or responsibility, both practitioners and patients should be prepared for these changes.

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