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Improving Medication Safety Across Clinical Settings

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Abstract
Purpose: We planned to address the following specific aims among the six studies in the Improving Medication Safety Across the Clinical Settings Project:

1) Evaluation of a uniform reporting system across an integrated delivery system and evaluation of the yield and methodology of learning from errors/adverse events.
2) Assessment of the epidemiology of medication errors and adverse drug events in the outpatient pediatric setting followed by the development, implementation, and evaluation of an intervention to decrease serious medication errors in this setting.
3) Assessment of the epidemiology of medication errors and adverse drug events in the inpatient psychiatric setting followed by the development, implementation, and evaluation of an intervention to decrease serious medication errors in this setting.
4) Evaluation of the impact of a novel approach to reduce the frequency of inpatient intravenous errors.
5) Evaluation of the frequency of errors in warfarin use in nursing home patients.
6) Development and validation of a tool to assess institutional safety and organizational culture.

Scope: Medications are the most commonly used form of medical therapy and continue to be one of the most frequent causes of adverse events. The Improving Medication Safety Across Clinical Settings project sought to broaden the scientific knowledge about medication safety.

The goals of this Center were to fill some of these gaps and to create models of error reduction that may be generalized to other safety domains. The main focus for this Center of Excellence was to improve medication safety across a variety of clinical settings, including inpatient, outpatient, and nursing home settings, and a variety of populations, including pediatric, psychiatric, and elderly patients. The work of the Center remained synergistic in a number of ways, benefiting from the strengths of well-known patient safety researchers. The group met monthly to share its expertise and review each project's study as it related to medical errors in general and medication errors and

adverse drug events in particular. We sought to create and optimize learning from novel, progressive reporting systems, and we have increased our understanding of the organizational and leadership contexts required for changing core processes to accelerate change in patient safety. We believe the work of the Center was strengthened by input from investigators in our group from content domains, including clinical epidemiology, human factors theory, infection control, biostatistics, culture change, and healthcare policy. The Center also brought together experts from a variety of clinical specialties, including physicians, nurses, and pharmacists. The Center also included leadership from the Partners and Fallon Healthcare Systems, two large integrated delivery systems, and from Children's Hospital, a freestanding pediatric institution with an ambulatory care network, all of whom remain committed to improving patient safety. The Center has also maintained and strengthened its connections at both the regional and national levels. Recently, the Center formed an Executive Council comprised of leading patient safety and industry experts to continue and expand upon the work begun under the P01 grant.

Background: Although iatrogenic injury has been a major problem for years, the Institute of Medicine report "To Err Is Human" brought it to the forefront of public attention.[1] The IOM report estimated that more than a million injuries and nearly 100,000 deaths are attributable to medical errors annually. The IOM report made four key points: 1) the extent of harm that results from medical errors is great; 2) errors result from failures of systems, not people; 3) achieving acceptable levels of patient safety will require major systems changes; and 4) a concerted national effort is needed to improve patient safety.

Although medications are clearly beneficial in the aggregate, accumulating information suggests that many patients annually are injured as a result of medications.[3;4] Furthermore, many of these injuries, or adverse drug events (ADEs), appear to be preventable. However, much of the epidemiological data about medication errors and ADEs has come from the inpatient adult setting. At the time of this grant submission, it was determined that more data were needed regarding the frequency of medication errors and ADEs in the ambulatory setting; in alternative care settings, such as nursing homes; and in specific populations, such as children, the elderly, and psychiatric patients. Though data suggest that a number of interventions can improve the safety of drug use, most also come from the inpatient setting. Specifically, our group has demonstrated the effectiveness of a computerized physician order entry system[5;6] and a ward-based clinical pharmacist[7] in decreasing serious medication errors. Others have also found that computerized decision support offers substantial benefits.[8;9]

Results: The results for each of the six projects within the PO1 are described below.

Key Words: Surveillance and reporting of adverse events; adverse drug events in ambulatory pediatrics, psychiatric inpatients, and nursing homes; smart pump technology; organizational culture, medication safety

I. Project 1: Evaluating Tools that Facilitate Reporting, Surveillance, and Analysis of Medical Errors and Adverse Drug Events

Purpose:

- To assess the impact of a web-based error/adverse event reporting system on the ease and rate of reporting, particularly among physicians.
- To evaluate tools that classify adverse events and contributing factors for their usefulness in assisting local safety officers and hospital administrators to effectively prioritize their activities.

- To develop tools to track whether reports of errors/adverse events lead to better systems improvements and to assess, qualitatively, if stratifying the reports according to priority assists those charged with implementing prevention strategies and tactics.
- To assess the impact of stimulated reporting on reported error/adverse event rates.
- To learn what triggers, drawn from embedded hospital data, are predictive of medical error/adverse events and can form the basis for automated detection.

Scope: Background: Error Reporting Systems, and Learning from Error

Although iatrogenic injury causes substantial harm,[10] comparatively few data are available regarding how best to foster environments in which individuals can learn from their mistakes or regarding how hospital systems can implement systematic error prevention strategies. To advance our collective knowledge about developing systems that prevent and buffer errors, we gathered information about the types and causes of injuries associated with them. Lack of this information is a serious impediment to hospitals committed to improving patient safety.

Incident and error-reporting systems are not widely used, especially by physicians, due to cultural barriers, time constraints, shame, and fear of legal action or retribution.[11] Tools to collect and analyze confidential data on incidents and errors, and then provide actionable feedback, will foster learning and have a substantial impact on patient safety. Factors essential to an effective reporting system are 1) safety and empowerment for individuals with 'domain expertise'— those with intimate knowledge of the daily work environment and direct experience with a medical error; 2) nonthreatening investigation and analysis, performed by individuals skilled at finding contributing factors; 3) pooling of reported data to facilitate trend analyses and prioritization; and 4) leadership backing of nonpunitive reporting, investigative analysis, and implementation of improvement strategies.

For a reporting system to be successful, it is essential that busy healthcare workers be able to report quickly and easily. Another key success factor is that they must perceive that it produces visible impact. Human factors and systems perspectives are not an intrinsic part of healthcare education, and clinicians are often remarkably ignorant about other parts of the healthcare environment. As a result, the information supplied by a reporter often requires further investigation by experienced analysts. A key challenge is to structure the reporting component to facilitate this process.

A web-based reporting system offers several potential advantages. A computer-accessible web-based system offers the potential of access to a reporting mechanism that is immediate, quick, and convenient.

Another key issue is efficiently translating data into action. Compiling errors is only useful if the results can be used to improve system safety. At one extreme, organizations could make changes based on single, isolated events that would have little positive impact or even a negative impact on overall system performance. At the other extreme, they could have little information and make few changes of any type. The goals will be to refine error detection and classification schemes so that reports can be used by analysts efficiently and translated by leadership into improved system performance.

Context: Review of incident reports entered into the new web-based incident reporting system at Brigham and Women's Hospital and comparative review of incidents identified through spontaneous reporting through Executive WalkRounds and events reported to the hospitals Risk Management Department were done. We sought to review these data

and also compare them to hospital claims data to identify what information is gleaned from each system and if similar contributing factors exist.

Settings: We performed this evaluation at Brigham and Women's Hospital, a 735-bed, tertiary academic medical center where approximately 45,000 inpatients are treated annually and 2800 nurses are employed.

Participants: This study involved a retrospective review of hospital reported incidents.

Incidence: Not applicable

Prevalence: Not applicable

Methods/Study Design: We compared various reporting methods across different Partners HealthCare System institutions and then evaluated the impact of a systemwide, web-based reporting system with short-term call back but long-term confidentiality. As the RMF develops analytical tools to classify and understand errors/adverse events, we sought to institute and evaluate feedback among our institutions and evaluate the impact of this feedback on the actions taken to make systems improvements. Knowledge gained was pooled and compared to create a sharable information base of prevention strategies and best practices. We employed definitions of errors and adverse events that have been standardized across the Center of Excellence.

Limitations: Review of incident reporting data was limited to one institution.

Results: The manuscript outlining the principal findings of this project has been submitted and is currently under review at the Journal of Patient Safety. A manuscript entitled Assessing Patient Safety at the Organizational Level: Visualizing the Elephant, by Dr. Osnat Levtzion-Korach, is in preparation and will examine benefits of various reporting systems available to hospital executives to aid in prioritizing safety initiatives. The Center will inform the Project Officer of the determination of this review once received. If accepted, a copy of the findings and anticipated publication date will be sent to AHRQ for dissemination purposes.

Principal Findings/Outcomes/Discussion: During the study period, 14,179 reports were submitted. The leading incident categories were labs (30%), followed by medication issues (17%), falls (11%), and blood bank (10%). Physicians submitted 2.9% of the reports; the rest of the reports were submitted by nurses, pharmacists, and technicians. Physicians tended to report on more severe cases and focused on different topics than other professionals. Overall, 84% of the reports came from the inpatient setting.

Conclusions: This application effectively captured incidents, actions, and follow-up of certain areas. The areas reported are driven by the reporter's profession, mainly nurses. Ease of data manipulation facilitated descriptive statistical analysis, and the ability to use branching algorithms may have helped in decision making and follow up.

Discussion: This study evaluated a commercial web-based reporting application. The rate of incidents reported was relatively similar to other reports. Approximately 30% of eligible employees submitted at least one incident report, with the severity ranging among incidents. Submission of incident reports by physicians remained small but did increase with the

new systems. The application was more robust, capturing relevant information that facilitated follow up by appropriate personnel.

Significance: This project makes a significant contribution to the body of knowledge concerning the impact the value of a confidential web-based incident reporting tool in facilitating reporting, surveillance, and analysis of medical errors. Our study addresses key issues through the evaluation of this technology in a large academic setting.

Implications: Web-based reporting systems show promise in improving the efficiency of incident reporting. A comprehensive and robust reporting tool can assist in identifying safety issues in hospital institutions and aid in developing strategies to address and mitigate errors thus improving patient safety overall.

II. Project 2: Pediatric Outpatient Prescribing Study

Purpose: This was an epidemiological study of pediatric medication errors and adverse drug events (ADEs) in the ambulatory setting with the following goals:

- To determine the rates, types, and predictors of medication errors and ADEs.
- To perform a randomized, controlled trial assessing the effectiveness of an intervention in reducing serious medication errors.

Background: Drugs are commonly used in the pediatric ambulatory setting; 72% of pediatric office visits are associated with the continuation or initiation of a drug.[12] However, few pediatric studies have focused on iatrogenic injury. These studies are important, because pediatric drug ordering, dispensing, administering, and monitoring are particularly complex and error prone. Because weight-based dosing is needed for virtually all drugs in pediatrics, ordering medications typically involves many calculations. In addition, medical providers must often choose between several different preparations of even commonly used medications, such as acetaminophen, which comes in infant drops, an elixir, chewable tablets, and capsules. Increased emphasis on provider productivity coupled with an expanding range of routine healthcare responsibilities leave healthcare providers with less time to make critical prescribing decisions, tell parents how to administer medications, or explain potential side effects. Dispensing drugs in pediatrics is also error prone, because pharmacists often must dilute stock solutions and split or crush tablets to prepare small dosages. At the administration stage, young children cannot reliably self-administer medications, requiring an effective caregiver-child interaction for administration. Special arrangements are often necessary to ensure timely administration of drugs to children in daycare or schools. Young children do not have the communication skills to warn medical providers about potential mistakes in administering medications or to inform them about side effects they may experience. Cultural attitudes and beliefs or linguistic, socioeconomic, or educational barriers may adversely affect the pivotal role of parents as intermediaries between the prescribing physician and dispensing pharmacist on one hand and the pediatric patient on the other. Finally, all children, especially neonates, may have more limited internal reserves than adults with which to buffer errors. Due to these unique challenges to the medication use system, it is important to study the epidemiology of medication errors and ADEs as well as develop prevention strategies in ambulatory pediatrics.

Context: The study involved a retrospective review of prescriptions generated during pediatric ambulatory visits to assess for the presence of any medication errors. A follow-up survey was performed to elicit information from parents to determine if an adverse drug event or potential adverse drug event was associated with the prescription.

Settings: For phase I of the Pediatric Outpatient Prescribing Project, patients were recruited from six participating clinics in the Boston area. Two of the clinics that participated in phase I were unable to participate in phase II, as neither clinic has access to an electronic prescribing module, which was the primary intervention associated with this study. An electronic prescribing module was needed by one of these clinics to enable them to serve as an intervention site, which would then allow the corresponding clinic to act as a control site. Therefore, phase II was conducted in only four ambulatory clinics.

Participants: This study involved patients younger than 18 years of age.

Incidence: N/A

Prevalence: N/A

Methods/Study Design: To define the epidemiology of medication errors and Adverse Drug Events (ADEs) for the first aim of the study, a prospective cohort study was performed at six pediatric ambulatory primary care sites affiliated with Partners HealthCare System and Children's Hospital in Boston. Data collection occurred for 8 to 10 weeks at each site. In total, 3680 patients were recruited. Any patient who had a prescription written was eligible for inclusion, with one exception. Anyone receiving a prescription for birth control or sexually transmitted diseases was excluded from participation in the study. If there was any question as to the reason for antibiotic prescription, the patient was not called. However, this is an important area for potential medication errors. Therefore, those prescriptions were reviewed for errors, and chart review was conducted for potential adverse events. Based on the analysis of data from phase I of this study, a practical intervention, an electronic prescribing module with decision support software, was designed to reduce serious medication errors and to test the efficacy and cost-effectiveness of this intervention in a randomized controlled trial.

We collected data at each of the participating clinics for a 2-month period. The two original urban neighborhood health centers and two academic teaching clinics participated in this second phase. Two clinics served as control sites, and two served as intervention sites. The clinics that served as intervention sites used the electronic prescribing module described above in writing prescriptions for patients. Our methodology for data collection remained the same as previously outlined in phase I. Staff (including residents) participated in the study by using duplicate prescription pads (at the control sites) or by using the computerized prescribing system in place (intervention sites). The duplicates and electronic files were collected daily and reviewed by research nurses. Patients/families who received a prescription were mailed a letter with an attached opt-out card. Eligible patients were contacted via telephone by a research assistant 10 days following the visit for an interview. At the time of the interview, parents were once again given the opportunity to opt out of participating in the study. The survey included an assessment of the medications that the patient was taking at home, where the medications were being obtained, and any symptoms or adverse events that may have occurred. A follow-up interview was conducted 6 weeks later. Chart review was done 2 months following the initial visit. Patients who were over the age of 12 and received medications that may be used to treat sexually transmitted diseases, or any patient who received prescriptions for birth control, prenatal vitamins, and equipment or lab tests, were excluded. Additionally, providers were emailed daily regarding each patient for whom a prescription was received to ensure that the patient

could be contacted. The participation of the patients, families, and providers in this study was voluntary and confidential. Data were not linked to individual patients or physicians.

Data collection: Prior to the initiation of the study, each clinical site was visited by study personnel to engage the site staff in a collaborative, multidisciplinary planning process. In previous studies, such meetings have been essential to ensure full cooperation with data collection and error detection. A paper survey was administered at each site to document important potential predictors of errors, such as training of healthcare providers, staffing, workload, and the prescription refill system. For data collection, the methods developed for the Improving Medication Prescribing (IMP) Study were adapted for ambulatory pediatrics.[13] Each step in the system for prescribing, dispensing, administering, and monitoring medications was evaluated by reviewing all prescriptions, conducting surveys of families 10 days and 6 weeks following the clinic visit, and reviewing clinic charts 4 months after the visit.

Limitations: We obtained data from six office practices in Massachusetts. Although the practices served socioeconomically, racially, and ethnically diverse populations, the generalizability of the study may be limited by the number of practices. In addition, physicians were not blinded to the purpose of the study, and physician awareness could have affected the incidence and detection of errors.

Results: We identified 57 preventable ADEs (rate, 3%; 95% confidence intervals [CI], 3%-4%) and 226 nonpreventable ADEs (rate, 13%; 95% CI, 11%-15%) in the medical care of 1788 patients. Of the ADEs, 152 (54%) were able to be ameliorated. None of the preventable ADEs were life threatening, although eight (14%) were serious. Forty (70%) of the preventable ADEs were related to parent drug administration. Improved communication between healthcare providers and parents and improved communication between pharmacists and parents, whether in the office or in the pharmacy, were judged to be the prevention strategies with the greatest potential

We identified 1205 medication errors with minimal potential for harm (rate, 68% of patients [95% CI, 64%-72%]; 53% of Rxs [95% CI, 50%-56%]) and 464 potentially harmful medication errors (i.e., near misses) (rate, 26% of patients [95% CI 24%-28%]; 21% of Rxs [95% CI, 19%-22%]); 94% of the 1205 medication errors with minimal potential for harm (rate, 50% of Rxs; 95% CI, 47%-53%) and 60% of the 464 near misses (rate, 12% of Rxs; 95% CI, 11%-14%) occurred at the ordering stage. The most common types of errors were inappropriate abbreviations, followed by dosing errors. The most frequent cause of errors was illegibility.

Principal Findings/Outcomes/Discussion: Patient harm from medication use was common in the pediatric ambulatory setting. Errors in home medication administration resulted in the majority of preventable ADEs. Approximately one fifth of ADEs were potentially preventable, and many more could potentially be ameliorated. Rates of ADEs due to errors are comparable in children and adults despite less medication utilization in children. Medication errors with minimal potential for harm and near misses are very common in the pediatric ambulatory setting. Interventions targeted at the ordering and administration stages may be most beneficial.

Significance and Implications: Many of the errors identified may have been detected through appropriate decision support capabilities integrated into electronic prescribing systems. This study can assist in providing criteria for the development of standards.

III. Project 3: Epidemiology and Prevention of Medical Errors in Psychiatric Inpatients

Purpose: We proposed to study the epidemiology of serious MEs (including preventable ADEs and nonintercepted potential ADEs) in hospitalized psychiatry patients and then use these data to develop an intervention, which we would then test prospectively.

- To study the incidence and nature of serious MEs in hospitalized psychiatric patients.
- To design a multimodal intervention to prevent serious MEs in this patient population. Strategies will incorporate previous successfully demonstrated approaches, including those developed by our group (e.g., information technologies) and information gained from Aim 1 to develop an intervention to prevent serious MEs in this population.
- To conduct a randomized, controlled trial of the effectiveness of an intervention to prevent serious MEs in psychiatric inpatients.

Scope of Work: Background: The pharmacologic treatment of psychiatric disorders has improved tremendously in recent years. Specifically, many new psychopharmacologic compounds have been developed. A number of acute and chronic psychiatric illnesses can now be treated much more effectively than even a decade ago. However, though these new agents have better side effect profiles than many of the older drugs, the potential for medication error and adverse drug events continues to be an important problem.

Although substantial information is available regarding the frequency and prevention of medication errors (MEs) and adverse drug events (ADEs) in inpatients, most of these studies have not included psychiatric patients.[14] Some of the limited available data suggest that the psychiatric inpatients represent another unique, high-risk population.[15] In this prospective study, we found that ADEs were disproportionately frequent on psychiatric units compared with medical and surgical units and, moreover, that this group was especially costly. Furthermore, though some prevention strategies have been found to be effective in inpatients, the most effective approaches may be different in psychiatry, especially because very high doses of some psychiatric drugs are sometimes used with good effect in the inpatient setting, so that simple dose checks might have little utility.

Context: Psychiatric pharmacotherapy represents a cornerstone of psychiatric care today but has important risks. Medication safety in psychiatric hospitals has received relatively little attention.

Setting: A 172-bed New England academic psychiatric hospital. Medication orders were paper based, and medication administration records (MARs) were rewritten every 7 days. Patients: Admissions to six study units between September 2004 and February 2005.

Results: We studied 1871 admissions with 19,180 patient-days. The most common diagnostic categories were mood/affective and schizophrenic disorders. The rate of ADEs was 10.2 per 100 admissions or 10 per 1000 patient-days. We found 203 medication errors, including 178 near misses and 25 preventable ADEs, and a rate of 6.3 serious medication errors per 1000 patient-days. Preventable ADEs accounted for 13% of all ADEs (25/191). The most common classes of drugs associated with ADEs were atypical antipsychotics (37%), mood stabilizers (20%), and antidepressants (19%). Nonpsychiatric drugs accounted for only 4% of nonpreventable ADEs but were associated with nearly 1/3 of all preventable ADEs and near misses. Medication errors were most frequently associated with physician orders (68%), but there was also a high rate of nursing transcription errors (20%).

Principal Findings/Outcomes/Discussion: We found that rates of ADEs and especially nonpreventable ADEs were common in an academic psychiatric hospital and comparable to rates previously found in similar studies in general hospitals.[1] However, in

contrast to findings in general hospitals, there were fewer life-threatening and no fatal ADEs, possibly due to the lower potential toxicity of commonly used psychiatric medications. The psychotropic medications most commonly associated with ADEs were atypical antipsychotics, and the central nervous system was the most frequently affected organ system. Although ADEs due to psychotropic medications were far more common than those due to nonpsychotropic medications, nonpsychotropic medication ADEs were more likely to be associated with an error and, therefore, to be preventable. We also found many near misses, both intercepted and nonintercepted.

Conclusions: Adverse drug events and serious medication errors were common among psychiatric inpatients and similar to rates in studies of general hospital inpatients. Rates of life-threatening and fatal ADEs were lower than in general hospitals, possibly because of the lower toxicity of commonly used psychiatric medications. Although strategies to improve medication safety have been studied in different settings, interventions targeting psychiatric care need further study.

Limitations: This study was conducted at a single institution in one city, so the results may not be generalizable to other organizations or settings. Our detection approach relied on finding events from the chart, and some ADEs may have not been recorded in the medical record. Assessing whether or not a specific set of symptoms represents ADEs provides particular challenges in psychiatry, especially in severely ill patients, in whom it may be acceptable to have certain symptoms if a regimen appears to be effective in treating the underlying disorder.

Significance and Implications: Although there has been a tremendous reduction in the number of hospitalized psychiatric patients, due in large part to advances in psychopharmacotherapy, these patients still represent a significant proportion of the national inpatient population. This study represents the largest of its type that has been carried out in this population, and it has provided valuable information about the potential impact of prevention strategies. This study is also important because previous studies of inpatient psychiatric medication safety have most commonly been retrospective and studied nonpreventable ADEs (also known as adverse drug reactions, ADRs), studied psychotropic medication use among general medical-surgical patients, or included psychiatric inpatients as part of general hospital medication safety studies.

IV. Project 4: Safe Intravenous Infusions Study

Purpose:

- To study the incidence and epidemiology of serious MEs associated with IV infusion pump delivery systems in critically ill patients.
- To evaluate the impact of a “smart” infusion system on the incidence of serious MEs in critically ill patients; secondary outcomes will include mortality, length of stay, and total costs.

Scope: Background: Intravenous medications are vital in the therapeutic management of hospitalized patients. Inpatients frequently receive several intravenous (IV) medications concurrently, and these are often delivered with infusion pump systems. In particular, critically ill patients frequently receive potent IV drugs that have narrow safety margins and require careful titration. Intravenous medications, especially continuous drips, are commonly managed with infusion pump systems. Although these medications can be life saving, errors in administering them have a high risk for severe adverse events and have caused many fatalities.

Newer infusion pumps incorporate significant technologic improvements. Important safety advances include mechanisms to nearly eliminate the risk of free-flow, which has caused many fatalities. Other features include enhanced functionality, convenience, and

portability but may also add complexity, resulting in potentially unsafe medication delivery. To attempt to "engineer out" errors, some of the newest infusion pumps have features that include drug/dose calculations, programmable volume and time calculations, improved alarms and indicators, and, most recently, inclusion of drug- or patient-specific decision support capabilities. To our knowledge, there have been no prospective studies of the incidence and nature of serious MEs associated with IV infusion pump delivery systems. It is important to note that, though such data are important, the FDA does not generally require them before approving devices, and such studies are thus rarely performed.

Context: Infusion-related errors associated with intravenous medications present a great risk of harm to patients. Computerized infusion systems with "smart technology" show promise in helping mitigate the potential for harm.

Setting: This study was conducted in Brigham and Women's Hospital, a 720-bed, tertiary care, academic medical center. Cardiac surgery (CS) patients admitted between March 2002 and December 2002 to two CS intensive care units (ICUs) and two CS stepdown monitored units (SDUs) were eligible for study enrollment. The four units have 51 beds located on a single floor staffed by the CS nursing service**.**

Research Design and Methods: We evaluated a new IV infusion pump system developed by the Alaris Corporation. The study will be confined to the cardiac surgical service consisting of cardiac anesthesia. Patients admitted or transferred to other areas of the hospital (e.g., overflow) will remain on current pump technologies used in those patient care areas. These "smart" infusion pumps have a modular patient care software system that provides point-of-care decision support to nursing personnel. Modules can be programmed to record data associated with IV drug infusion either with the feedback decision support in the "off" mode (baseline or control settings) or "on" mode (intervention setting).

This study evaluated the incidence and nature of MEs and ADEs using a "smart" multichannel infusion system, the Alaris MEDLEY Drug Manager (subsequently referred to as the Medley IV pump). We will employ the event monitoring technology currently embedded in the Medley's decision support software during our epidemiological study of serious MEs. During the control or "off" phases, the feedback mode providing real-time nursing decision support will be "turned off." The current Med System III drug library without guardrails will be incorporated into the Medley pumps during the "off" phases. During the intervention or "on" phases, the feedback mode with decision support (the Medley "Guardrails") will be fully operational. The intervention phases will evaluate the impact of the Medley IV pump's decision support and feedback on safe care delivery.

Results: There were 800 total CS admissions, including 393 during the control periods and 407 during the intervention periods. After excluding 29 control admissions (7.4%) and 27 intervention admissions (6.6%) with missing pump data logs, 744 admissions (735 patients) were analyzed. Pump log data were sometimes lost when untagged pumps were used for only a few hours or only on weekends, when logs were not downloaded. Patients admitted in both sets of periods were similar with regard to diagnoses, Charlson comorbidity index, preoperative risk stratification scores, and surgical procedures. None of the nine (1.2%) crossover patients had events in both the control and intervention periods. There were 4276 and 3869 patient-pump days in the control and intervention periods, respectively. In total, 5364 and 5295 IV medications were ordered in the control and intervention periods, respectively. Cardiac surgery patients on average used 10 different classes of medications during their hospitalization. Overall, the most common drugs infused through IV pumps were

electrolyte solutions, antibiotics, and colloids. The most commonly used drugs in the library were vasopressors, diuretics, and propofol.

Adverse Drug Events and Medication Errors:

In the intervention period, we found 22 ADEs, of which 11 were preventable (0.28/100 patient-pump days), and 82 were nonintercepted PADEs (2.12/100 patient-pump days). In the control period, the comparable numbers were 28 ADEs, 14 preventable ADEs (0.33/100 patient-pump days), and 73 nonintercepted PADEs (1.7/100 patient-pump days). There were no statistically significant differences in any of these rates between the intervention and control periods, including the control of phase of the study.

Drugs being given with no documented order were frequent and were not included as potential ADEs in our analysis. Among all 10,659 administered IV medications, there were 823 undocumented physician verbal orders (7.7%), including 427 in the control and 396 in the intervention groups.

Overall, we found a total of 219 IV medication errors. In this study, our detection strategy focused mainly on the administration stage, so it is not surprising that the administration stage was the most common stage for errors. The most common types of error were incorrect dosing of titratable drugs and incorrect IV drug rates. The most common medications resulting in ADEs were vasopressors (20%; 1.3% of vasopressor orders), electrolyte concentrations (18%; 1.3% electrolyte orders), and diuretics (14%; 0.4% of diuretic orders). The most common injuries resulting from ADEs were cardiovascular, especially hypotension, defined as a systolic blood pressure less than 90 mm Hg (40%), and metabolic derangements, such as severe hypoglycemia or hyperkalemia (24%). Most preventable ADEs were serious or life threatening (18/25, 72%). Additionally, most potential ADEs were rated as having the potential for serious or life-threatening injury (183/194, 94%). There was no difference in event severity between the control and intervention groups. The levels of interrater agreement for incident classification ($k = 0.89$), preventability ($k = 0.91$), and severity ($k = 0.66$) were good.

Principal Findings/Outcomes/Discussion: Two problematic IV administration practices, or violations, frequently occurred during the study: bypassing of the drug library and overriding alerts, including the use of inappropriate boluses. During the intervention period, we found that, among drugs preprogrammed in the drug library, a total of 573 infusions (24%) bypassed the library either accidentally or intentionally, especially propofol (68.3%) and insulin infusions (61.5%). Among the bypasses, three were associated with preventable ADEs and 44 were associated with nonintercepted potential ADEs. Overridden soft alerts resulted in one preventable ADE and 24 nonintercepted potential ADEs.

The findings in the intention-to-treat intervention period were analyzed to reassess smart pump use and assess if the safety features were correctly used during the intervention period. After correcting for both library bypassing and alert overrides, the rates of preventable ADEs and nonintercepted potential ADEs during the intervention would have decreased from 0.28 to 0.18 ($p = 0.27$) and from 2.12 to 0.36 ($p < 0.0001$) per 100 patient-pump days, respectively.

We found that medication errors and ADEs associated with IV infusion pumps in cardiac surgical patients were common and often potentially hazardous. Though smart IV pumps with decision support capabilities have the capacity to intercept many dangerous medication errors and allowed detection of many errors that would have been difficult to find through other mechanisms, smart pumps did not reduce the rate of serious medication errors in this study. This was probably the case, in part, because the pump

setup made it easy for nurses to bypass the drug library and because overrides were frequent. Thus, we believe that no benefit was found because of the pump design and unforeseen clinical practices that included many violations.

These study findings are in contrast to recent studies, in which we have demonstrated that decision support during CPOE significantly reduced serious ordering and transcription medication errors.[12] In the CPOE intervention, the old paper order system was entirely replaced, but, in this intervention, we did not achieve consistent use of the smart pumps' new technologic safety advances. On the other hand, we were able to uncover correctable unsafe practices, such as administering many potent medications without documentation of physician verbal orders and the use of very high rates for certain drugs, that we had not previously been aware of except on an anecdotal basis and which would have been difficult or impossible to quantify through other mechanisms.

Safe medication practice depends on institutional (systems) factors, such as standardization of medication concentrations and knowledgeable clinicians at the sharp end.[16] Intravenous medication and fluid administration in critically ill patients are complex, multistep processes that provide many opportunities for errors.[17] Infusion pumps, similar to other complex medical devices and tools designed to improve patient care, may not always be used as intended and may result in unforeseen and unintended consequences.[18]

In addition to improving safe drug delivery, human factors design is critical to speedy adoption and correct use of technologies such as infusion pumps.[26] This involves making it easy to "do the right thing." A surprising unintended consequence found in this study was the infrequent use of the drug library. The default at the beginning of the study was not to use the drug library, and, in fact, during the intervention periods, nurses only used the library 75% of the time and as infrequently as 31% for propofol, a high-risk medication. The extra programming for nurses to use the drug library proved to be an important barrier to library use compliance. As a result of these data, the drug library was subsequently made the default, and the library was expanded.

Conclusions: The use of smart pumps enabled the detection of many medication errors, which would have not otherwise been identified. However, there was no impact on the serious medication error rate or the preventable ADE rate.

Limitations: This study was conducted at a single institution in one city, so the results may not be generalizable to other organizations or settings. An early version of the pump was studied, and the software was designed in such a way that it was easy for nurses to avoid using the error prevention software.

Significance and Implications: The study described the frequency and potential consequences of serious intravenous errors and demonstrated that these errors are more frequent than many have believed. Although the pump did not reduce the serious error or adverse event rate, the findings of the study led the manufacturer to make a number of design changes, and subsequent studies have shown that it has been effective at reducing error rates in other settings.

V. Project 5: Improving Safety with Anticoagulation in the Nursing Home

Purpose:

1. To evaluate the quality of anticoagulation management in the nursing home setting utilizing two principal quality measures:

a) the proportion of time that nursing home residents receiving warfarin have their international normalized ratios (INRs) within the target therapeutic range; and
b) the time until the next INR measurement when an out-of-target range INR value occurs.

2. To determine the rates of bleeding complications and potential adverse warfarin-related events (PAWEs) among warfarin-treated residents of nursing homes. (PAWEs are defined as incidents that have the potential to cause serious, life-threatening, or fatal bleeding but in which bleeding does not occur. For the purpose of this study, a PAWE is defined as an INR level above 4.5.)
3. To assess the underlying causes and systems failures that lead to preventable warfarin-related bleeding events and PAWEs in nursing homes.
4. To appraise the process of anticoagulation management by means of total quality improvement techniques in each participating nursing home.
5. To lay the groundwork for a randomized trial, with randomization at the level of the nursing home, and to evaluate the efficacy of coordinated anticoagulation care by a centralized, dedicated anticoagulation management service versus nursing home-specific process improvements identified through total quality improvement methods.

Background: The decision to use anticoagulants in the elderly hinges on the balance between the decreased risk of thromboembolism and the increased risk of hemorrhage. It has been clearly shown that excessive anticoagulation can place patients at substantial risk of bleeding.[19] Hylek and Singer[20] reported that an intensity of anticoagulation expressed as a prothrombin time ratio above 2.0 (roughly corresponding to an International Normalized Ratio of 3.7-4.3) resulted in an increased risk of intracranial hemorrhage among outpatients taking warfarin. Although a number of studies have reported an age-related increase in the risk of bleeding with warfarin therapy[20] and an age-related increase in the anticoagulant response to warfarin has been observed,[21] the increased risk of bleeding with advancing age may be diminished with careful management through the auspices of an anticoagulation management service.[22-23]

The use of medications in the nursing home presents a complex blending of issues from several diverse realms of medical practice. A vortex of forces and relationships in this setting of care for 1.6 million Americans in the nation's 17,000 nursing homes combine to place the elderly nursing home resident at special risk for drug-related iatrogenic injury. At its foundation lies basic concepts from clinical geriatrics, such as the "homeostenosis" that marks the response of the elderly organism to stressors of various kinds. Built upon this are pharmacokinetic and pharmacodynamic changes that occur with aging[24]; for example, there are increases in the intrinsic sensitivity to a number of medications, including warfarin, with advancing age.

The quality of management of long-term oral anticoagulant therapy in the nursing home setting is highly variable; our early nursing home work, conducted during the years 1993-1995, showed that nursing home residents on warfarin were maintained outside the recommended therapeutic range on average 50%-60% of the time.[25] We have also found there to be a common practice of underdosing the nursing home resident to purposely maintain the INR (International Normalized Ratio) below the recommended therapeutic range,[26] substantially reducing the potential protective benefits of warfarin therapy against the occurrence of ischemic stroke.[27]

In a more recent study of the incidence and preventability of adverse drug events in 18 community-based Massachusetts nursing homes, 73% of adverse drug events associated with warfarin therapy were deemed preventable after independent review by two physicians.[30]

Furthermore, 80% of all potential adverse drug events, defined as medication errors with the capacity to cause injury but that failed to do so by chance or because they were intercepted ("near misses"), were associated with warfarin therapy. These potential adverse drug events were all considered preventable and primarily involved the development of excessively high INR values due to errors in anticoagulation management (the mean INR in these patients was 6.1; range: 4.0 to 15.6). Errors in ordering and monitoring of warfarin therapy were found to be common. Providers frequently made no modifications in the warfarin dosing scheme or the usual frequency of monitoring when drugs with well-established interactions with warfarin were prescribed. They also often failed to respond appropriately when a particular INR value warranted a change in warfarin dose or an increase in the frequency of monitoring. Consistently subtherapeutic INR levels (at least three consecutive values < 1.5 over several weeks of treatment) were also considered to be potential adverse drug events when the appropriate therapeutic range for the specified indication was 2 to 3. The mean INR value in these patients was 1.2 (range: 0.8 to 1.4), substantially below the level providing adequate protection against the occurrence of thromboembolic events.[27]

In considering systems-level approaches for reducing the risk of adverse drug events in nursing homes, it is necessary to recognize that the nursing home setting differs in fundamental ways from hospital and ambulatory care settings. In most healthcare settings, the providers are the central, ongoing components of the system of care. Approaches to quality improvement have focused appropriately on improving the skills of these providers through such modes as education, opinion leaders, team-based care that includes clinical pharmacists, and academic detailing. However, in the nursing home, it is the residents who are the consistent component over time, and there is often frequent turnover in nursing, physician, and pharmacy staff. Programs to improve the knowledge base and skills of these clinical staff in the nursing home setting often need to be re-applied continuously over the long term. In this situation, systems-based approaches to improving safety may offer a clear advantage.[1] More widespread use of centralized, dedicated anticoagulation management services in the nursing home setting, to provide coordinated anticoagulation care, may add to the effectiveness and safety of warfarin therapy in this particularly high-risk group of patients[28] and may be preferable to use of nursing home-specific total quality improvement-based approaches.

Context: The study was limited to warfarin-related incidents occurring in the nursing home setting. Incidents were detected through retrospective review of nursing home records in 3-month segments, performed by trained nurse abstractors for each eligible resident of the nursing home who was receiving warfarin at any time during that time period.

Setting: A major strength of the proposed study was that it would be performed in a sample of community nursing homes, so the investigation should be broadly generalizable to nursing homes across the United States. Twenty-six study nursing homes will be enrolled from among 40 nursing homes that have an ongoing relationship with Qualidigm, including nursing homes that are members of the Connecticut Alliance for Long-Term Care, a statewide network of JCAHO-accredited nursing homes. These 40 nursing homes have an average census of 123 long-stay (i.e., not subacute or rehabilitation) residents, with a range of 50-342.

Study Population: The study population was derived from all long-stay residents (i.e., not subacute or rehabilitation) of the study nursing homes. These 4920 residents of the 40 prospective study nursing homes were an average age of 84 years old, and the percentage of female residents was 73%. The race of the vast majority of residents of these facilities was White: 90% white; 8% African American; 2% other; these percentages essentially mirror the United States nursing home population.[29] All nursing home

residents who have been receiving warfarin for any indication for more than 30 days and who have been residents of the nursing home for more than 30 days were included in the study population. Based on our recent work relating to the incidence and preventability of adverse drug events in the nursing home setting, we estimated that prevalence of warfarin use among all nursing home residents for all indications was 12%.

Research Design and Methods: We performed a cohort study of all long-term care residents of 25 nursing homes (bed size range, 90-360) in Connecticut over an up-to-12-month observation period. The total number of residents in these facilities ranged from 2946 to 3212 per quarter. There were 490 who received warfarin therapy. Possible warfarin-related incidents were detected by quarterly retrospective review of nursing home records by trained nurse abstractors. Each incident was independently classified by two physician-reviewers to determine whether it constituted a warfarin-related event, its severity, and its preventability. The primary outcome was an adverse warfarin-related event, defined as an injury associated with the use of warfarin. Potential adverse warfarin-related events were defined as situations when the international normalized ratio (INR) was noted to be > 4.5 and an error in management was noted, but no injury occurred. We also assessed time in specified INR ranges per nursing home resident day on warfarin.

Results: Over the 12-month observation period, 720 adverse warfarin-related events and 253 potential adverse warfarin-related events were identified. Of the adverse warfarin-related events, 625 (87%) were characterized as minor, 82 (11%) were deemed serious, and 13 (2%) were life threatening or fatal. Overall, 29% of the adverse warfarin-related events were judged to be preventable. Serious, life-threatening, or fatal events occurred at a rate of 2.49 per 100 resident-months; 57% of these more severe events were considered preventable. Errors resulting in preventable events occurred most often at the prescribing and monitoring stages of warfarin management. The percentages of time in the < 2, 2-3, and > 3 INR ranges were 36.5%, 49.6%, and 13.9%, respectively.

Principal Findings/Outcomes/Discussion: The use of warfarin in the nursing home setting presents substantial safety concerns for patients. Adverse events associated with warfarin therapy are common and often preventable in the nursing home setting. Prevention strategies should target the prescribing and monitoring stages of warfarin management. Consistent with previous studies, this study demonstrates that nursing home residents on warfarin are frequently maintained outside the optimal therapeutic range.

The system of medication management in the nursing home includes the nursing staff within the facility and the physicians, laboratories, and pharmacy vendors external to the nursing home who interact to provide services to the residents. Although an adverse event in this setting may be directly linked to a “human error,” the root cause may be defined as the defect in the system that permitted such an error to occur. In the case of warfarin management for nursing home residents, an important root cause is poor information flow. For example, a frequent occurrence in the care of nursing home residents is a telephone call from the nursing home to a covering physician about a resident with a urinary tract infection without noting that the resident is taking warfarin.[1] The result may be an order for an antibiotic that interacts with warfarin, resulting in a supertherapeutic INR level and increased risk of bleeding. Leading-edge high-technology-based strategies to alleviate problems in prescribing and monitoring warfarin

are currently poorly amenable to incorporation into most nursing home settings. The information technology infrastructure required to support computerized physician order entry with decision support is almost nonexistent in the vast majority of US nursing homes. Few long-term care facilities have implemented such systems owing to cost, complexity, and logistical challenges as well as uncertainty about how effective the systems actually are for reducing drug-related injuries once implemented.

Limitations: Foremost among them was our reliance solely on information contained in nursing home records to assess the occurrence of warfarin-related incidents. In randomized controlled trials, comprehensive ascertainment and careful assessment of endpoints (i.e., thromboembolic events and bleeds) are the priority; systematic approaches are utilized to enhance detection (e.g., periodic administration of stroke-symptom questionnaires followed up by direct clinical assessment of the patient). Such approaches were obviously not possible in our study; in our study, we relied on information that could be ascertained solely through retrospective review of nursing home records. Our priority in this study was to assess the safety of warfarin therapy in the nursing home setting by describing how errors in warfarin management contribute to adverse events and "near misses." This observational study, employing retrospective review of nursing home records, was not designed to assess the effectiveness of warfarin therapy for the prevention of thromboembolic events. As our focus was on warfarin management in the nursing home setting, the fact that we did not include any hospital experience for the individuals in our study population also probably impacted on the rates of thromboembolism and hemorrhage reported in our study. In some instances, we may have missed some potential adverse warfarin-related events, because no INR measurement was ever obtained during the period when an interacting drug had the potential to impact on the INR. For this reason, our estimates of potential adverse warfarin-related event rates must be considered conservative.

Significance and Implications: We feel that the findings of this study provide very compelling evidence of serious safety concerns around the use of warfarin therapy in the nursing home setting. If our findings are generalized to residents on warfarin in all US nursing homes, there may be nearly 34,000 fatal, life-threatening, or serious adverse warfarin-related events per year, of which the majority may be preventable. Furthermore, "near misses" are common. Many residents of nursing homes on warfarin are subjected to a very high risk of bleeding due to high INR levels that are associated with an error in warfarin management. Nursing home residents on warfarin also spend considerable amounts of time in the subtherapeutic range, potentially reducing the benefits of therapy.[30]

VI. Project 6: The Role of Organizational Culture in Promoting Patient Safety

Purpose: To develop a survey instrument that characterizes staff attitudes about patient safety.

- To establish the psychometric properties of the survey instrument developed in Aim 1.
- To administer the survey to a stratified random sample of staff in two facilities.
- To assess the associations between staff attitudes about patient safety and organizational culture in four healthcare entities; (2) patient care units within four hospitals; and (3) the pharmacy services in the hospitals within these four facilities.
- To disseminate the results of these assessments to appropriate and constituents in the integrated delivery system as it promotes patient safety as well as in the academic literature.

Background: Organizational culture is defined as "the values, beliefs, and norms of an organization that shape its behavior."[31] Based on the underlying values of members of organizations, Quinn and Kimberly defined four paradigmatic types of organizational cultures: group, developmental, rational, and hierarchical.[32] Group cultures are based on norms and values associated with affiliation, teamwork, and participation. Developmental cultures are based on risk-taking innovation and change. Hierarchical cultures reflect the values and norms associated with bureaucracy. Rational cultures emphasize efficiency and achievement.

What is the role of organizational culture in promoting patient safety?

A critical question, therefore, is whether the promotion of staff attitudes conducive to promoting patient safety requires that management address more fundamental aspects of the values, norms, and beliefs within institutions. If true, this would suggest that, to optimize patient safety, healthcare leaders and policymakers must accomplish basic cultural change while they are also attempting to affect specific changes in attitudes that promote patient safety within their organizations. Another question is whether such basic cultural change must proceed at the level of the overall organization or whether it can be accomplished to some extent at the level of subunits (e.g., individual patient care units) of those organizations. This research is designed to address these and other issues that lie at the heart of initiatives to improve patient safety in healthcare organizations. Shortell's work in quality improvement implementation and limited data from other error-prone industries suggest that growth and development cultures may more readily make the necessary changes to reduce errors. We might also hypothesize that some patient care units are more likely to exhibit predominantly hierarchical or rational features (e.g., operating rooms) that may be more likely to support some features of progressive patient safety—for example, the use of checklists and protocols, but these units may be less likely to have an environment in which the most junior member of the care team feels as comfortable as the most senior in identifying an adverse event. One of the features of this research will be to explore in more depth the variation in dominant organizational culture among different patient care units. We also will study the organizational culture types in the pharmacy and the association between organization type and progressive staff attitudes about patient safety.

Research Design and Methods: We surveyed a sample of direct caregivers (physicians, nurses, and pharmacists) drawn from four hospitals in two states; our response rate was 59%. We used the AHRQ Hospital Survey of Patient Safety Culture (HSOPS) to assess caregiver attitudes about multiple dimensions of patient safety.

Context: The study evaluated the performance of a new instrument for assessing safety climate in a number of institutions.

Setting: We implemented this survey among staff in four institutions in two states.

Results: Problematic responses were common and varied by safety culture dimension. Most commonly problematic (32%) were responses concerning handoffs and transitions, whereas the least commonly problematic were those concerning teamwork (12%) and communication openness (10%). Problematic responses also varied by type of clinical work area, with the highest frequency of problematic responses (26%) from the emergency department and the lowest frequency (17%) from medicine. Hospital management support for safety, as assessed by the respondents, was the dimension most strongly associated with respondents' overall rating of safety in their work area. A multidimensional safety

culture score was more strongly correlated with the overall safety rating than any individual dimension.

Principal Findings/Outcomes/Discussion: Safety culture varies by type of clinical work area and predicts ratings of overall safety. A multidimensional assessment of culture is strongly correlated with respondents' rating of safety in their work area.

E. List of Publications and Products

The following publications and presentations are products of this grant. We plan to submit additional findings regarding the effects of a barcode technology on reducing medication errors once our final analysis is complete.

Publications:

Kaushal R, Goldmann DA, Keohane CA, Christino M, Honour M, Hale AS, Zigmont K, Lehmann LS, Perrin J, Bates DW. Adverse drug events in pediatric outpatients. Ambul Pediatr. 2007 Sep-Oct:7 (5) 383-9.

Stebbing C, Kaushal R, Bates DW. Pediatric medication safety and the media: what does the public see? Pediatrics, 2006 Jun;117(6):1907-14.

Stephanie O. Zandieh, MD, MS, Donald A. Goldmann, MD, Carol A. Keohane, RN BSN, Catherine Yoon, MS, David W. Bates, MD, MSc, Rainu Kaushal, MD MPH. Risk Factors in Preventable Adverse Drug Events in Pediatric Outpatients The Journal of Pediatrics, In Press, Journal of Pediatrics.

Claire Stebbing, MBBS MRCPCH ,David W. Bates, MD, MSc ,Catherine Yoon, Carol Keohane, RN,Garrett Fitzmaurice, Rainu Kaushal, MD, MPH. The Role of Advice in Medication Administration Errors in the Pediatric Ambulatory Setting; Manuscript submitted to Pediatrics.

Rainu Kaushal, MD MPH1, Donald A. Goldmann, MD, Carol A. Keohane, RN, BSN, Lauren Mercincavage, BA, Seth Wolf, BA, Catherine Yoon, MS, Katherine Zigmont, RN, David W. Bates, MD, MSc. Medication Errors in Pediatric Outpatients. Manuscript in final stages of preparation.

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Subramanian S. Hoover S. Gilman B. Field TS. Mutter R. Gurwitz JH. Computerized physician order entry with clinical decision support in long-term care facilities: costs and benefits to stakeholders. Journal of the American Geriatrics Society. 55(9):1451-7, 2007 Sep.

Aneesh K. Singla, MD, MPH, Barrett T. Kitch, MD, MPH, Joel S. Weissman, PhD, Eric G. Campbell, PhD. Assessing Patient Safety Culture: A Review and Synthesis of the Measurement Tools; currently in press.

Barrett T. Kitch, MD, MPH, Susan Regan, PhD, Joel S. Weissman, PhD, Georgianna Willis, PhD, Eric G. Campbell, PhD. Variation in the Culture of Patient Safety: Results of a Survey of Physicians, Nurses and Pharmacists. Manuscript in preparation.

Presentations:

Rothschild JM, Keohane CA, Thompson S, Bates DW. Intelligent intravenous infusion pumps to improve administration safety. Proc AMIA Symp 2003; Suppl 1: 992.

Bates, D.W., and Rothschild, J.M.**,** discuss the methodology, study findings and recommendations from their study, The Incidence and Nature of Adverse Events and Serious Medical Errors in Intensive Care, during an educational webcast on November 4, 2005, sponsored by the Center for Medication Safety and Clinical Improvement.

Rainu Kaushal, Donald A. Goldmann, Carol A. Keohane, Melissa Honour, David W. Bates. “Medication Errors in Ambulatory Pediatric Patients,” presented at Pediatric Academic Societies, Annual Meeting, 2005.

Bates, DW. “Medication Safety: How can Pharmacists Contribute Most?

Keynote presentation, Rho Chi Pharmaceutical Society Induction Ceremony, Massachusetts College of Pharmacy & Health Sciences, Boston, MA. April 2007.

Bates, DW. “A Global Agenda for Patient Safety Research: First Public Release from the Global Alliance for Patient Safety and WHO” Speaker, International Conference, The International Society for Quality in Health Care (ISQua): Transforming Healthcare in the Electronic Age, Boston, MA. October 2007.

Bates, DW. May 20, 2002 “Drugs and Information Technology: What’s Next?” Keynote speaker, AMIA 2002 Spring Congress “A Drug by any Other Name: The Role of Informatics from Drug Development Through the Point-of-Care.” American Medical Informatics Association, Scottsdale, AZ.

Bates, DW. “The Impact of Clinical Decision Support Tools on Patient Safety.” Medical Grand Rounds, University of Chicago, Chicago, IL June 4, 2002.

Bates, DW. “Critical Medication Administration Errors - Framing the Problem.” Moderator, ALARIS Center for Medication Safety and Clinical Improvement Conference, ALARIS Medical Systems, San Diego, CA. November 7, 2002.

Bates, DW. “Preliminary Findings from a Comprehensive IV Infusion Pump Study.” Speaker, Addressing Harm with High Risk Drug Administration conference, ALARIS Medical Systems, Inc., San Diego, CA. November 7, 2003

Bates, DW. “Variability in Intravenous Infusion Therapy.” Speaker, Consortia Medication Safety Symposium at ASHP, Cardinal Health, Orlando, FL. December 8, 2004.

Bates, DW. “The Future of Medication Safety: Implications.” Speaker, AACP Annual Meeting and Seminar, American Association of Colleges of Pharmacy, San Diego, CA. July 9, 2006.

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