The Journal of Pain, Vol 10, No 2 (February), 2009: pp 160-166
Available online at www.sciencedirect.com

ELSEVIER

Original Reports

Assessing Controlled Substance Prescribing Errors in a Pediatric Teaching Hospital: An Analysis of the Safety of Analgesic Prescription Practice in the Transition From the Hospital to Home

Benjamin H. Lee,[*,§] Christoph U. Lehmann,[†,‡] Eric V. Jackson,[*,§] Sabine Kost-Byerly,[*,†,§] Sharon Rothman,[§] Lori Kozlowski,[§] Marlene R. Miller,[†,‖] Peter J. Pronovost,[*,‖] and Myron Yaster[*,†,§]

**Department of Anesthesiology/Critical Care Medicine and [†]Department of Pediatrics, Johns Hopkins Medical Institutions, Baltimore, Maryland; [‡]Division of Health Sciences Informatics, Johns Hopkins University School of Medicine, Baltimore, Maryland; [§]Pediatric Pain Treatment Service, Department of Anesthesiology/Critical Care Medicine, Johns Hopkins Medical Institutions, Baltimore, Maryland; and [‖]Department of Health Policy and Management, Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland.*

Abstract: **Iatrogenic errors producing serious and often preventable injury occur frequently in hospitalized patients, particularly in children. Little is known about the epidemiology of analgesic medication errors in patients being discharged from the hospital. The goal of this study was to describe the epidemiology of controlled substance prescription errors by physicians-in-training for children being discharged from the hospital. We conducted a prospective, observational study of the analgesic prescriptions and discharge forms of 241 pediatric patients discharged from a Children's Center of a major urban teaching hospital from November 2003 to April 2004. All patients who were actively followed by the Pediatric Pain Service at the time of their discharge and were discharged with an analgesic prescription were included in the study. Primary outcome variables were the percentage of prescriptions that contained at least 1 medication error or potential adverse drug event. Errors were defined using the Institute for Safe Medication Practices' (ISMP) List of Error-Prone Abbreviations, Symbols, and Dose Designations, literature review, expert panel consensus, and the Johns Hopkins Department of Pharmacy hospital formulary. Two hundred forty-one patients who received 314 prescriptions were included in this study. Prescription errors were common; 257 of 314 (82%) of the prescriptions examined contained 1 or more errors. The most common errors were missing or wrong patient weight (n = 127, 77%), incomplete dispensing information (n = 167, 53%), and no or wrong date on prescription (n = 19, 6%). Nine prescriptions (2.9%) had the potential for significant medical injury and were considered potential adverse drug events. Discharge prescription errors for children requiring potent, opioid analgesic drugs in the management of pain are common, and nearly 3% could cause significant harm. The high rate of prescribing errors highlights the importance of developing, testing and implementing effective error-prevention strategies, especially in high-risk medications such as narcotics.**

Perspective: ***Narcotic prescriptions written by trainees at discharge from a pediatric hospital are error prone and nearly 3% have the potential to cause significant harm. With a low therapeutic profile, the hospital may consider a review/verification process to reduce the risk of patient harm.***

Key words: *Patient safety, narcotics, medical error, prescribing, children.*

Received May 22, 2008; Revised August 1, 2008; Accepted August 9, 2008.
Address reprint requests to Dr Christoph U. Lehmann, The Johns Hopkins Hospital, Nelson 2-133, 600 N Wolfe Street, Baltimore, MD 21287. E-mail: clehmann@jhmi.edu

1526-5900/$36.00

doi:10.1016/j.jpain.2008.08.004

Iatrogenic errors producing serious and often preventable injury occur frequently in hospitalized patients.[3] The landmark 1999 report by the Institute of Medicine "To Err is Human," estimated that iatrogenic injury results in 44,000 to 98,000 preventable deaths in the United States each year.[9] Although there has been some controversy about the accuracy of these estimates, many studies have found that hospitalized patients commonly have adverse events related to medical therapy and that many of these injuries are preventable.[1-3,12] Medication errors are the most common type of iatrogenic errors.[12] Children have a 3-fold greater risk of having a potentially harmful medication error than adults and are more likely to be harmed.[7] In children, drug doses are usually calculated individually on the basis of age, weight, and clinical condition, and the difference between therapeutic and toxic drug levels is smaller than for adults. Additionally, young children, and newborn infants in particular, often have less reserves than most adults to buffer errors, and young children have less developed communication skills with which to recognize or communicate potential mistakes or to describe signs of adverse effects.[7,16,28]

Medication errors can occur during drug ordering, transcribing, dispensing, administering, and monitoring. Some studies estimate that most adverse drug events (ADEs) occur at the stage of prescription writing or drug ordering (68% to 75%).[23,27] These mistakes involve incorrect dosing or dose calculation, incorrect medication, failure to use "best prescription writing practice" (eg, decimal points, units, and abbreviations), handwriting legibility, and dosage forms.[6,27] Errors involving opioid analgesics are among the most pernicious. However, little is known about the epidemiology of analgesic medication errors in patients being discharged from the hospital. In a recent study of the prevalence of potential outpatient medication dosing errors in children from 3 health maintenance organizations, analgesic medications were the most likely to involve prescription overdosage errors.[18] The specific aim of this study was to describe the epidemiology of controlled substance prescription errors and deviation from hospital "best practice" guidelines by physicians-in-training (who write all the outpatient prescriptions in our institution) for children being discharged from the hospital.

Methods

Study Design and Patient Population

This prospective study was conducted by the Pediatric Pain Service at the Children's Medical and Surgical Center of the Johns Hopkins Hospital, a major urban teaching hospital with a socioeconomically diverse patient population. The Johns Hopkins Hospital treats both adult and pediatric patients but has a geographically and administratively distinct children's hospital within the hospital. This study was approved by the institutional review board and a waiver of informed consent was provided. Patients who were admitted to the Children's Medical and Surgical Center of the Johns Hopkins Hospital and who received a consultation by the Pediatric Pain Service were studied on discharge from the hospital if they received a narcotic prescription written by their primary service. Narcotic prescriptions were defined as United States Drug Enforcement Agency Class 2-5 drugs and included opioids and benzodiazepines.

Outcome Variables

Our primary outcome variables were the percentage of prescriptions that contained at least 1 prescribing medication error or potential adverse drug event. Prescribing medication errors and "best practice" guidelines were defined a priori, based on the Institute for Safe Medication Practices' (ISMP) List of Error-Prone Abbreviations, Symbols, and Dose Designations, a combination of literature review and expert panel consensus, and the Johns Hopkins Medicine Department of Pharmacy hospital formulary.[6,22] Deviations from "best practice" guidelines were categorized as missing/omitted information, dosing errors, incomplete information, and patient identification errors (Table 1). The prescriptions were also reviewed to determine the severity of the deviations from the a priori consensus-based guidelines (Table 2).[17,25] The severity of the deviations was rated by the researchers (BHL) on a scale from 1 to 5 (with 1 = insignificant to 5 = severe), based on previously published guidelines, which were slightly modified for analysis of prescriptions. Prescriptions containing multiple deviations were assigned a single severity score, determined by the most significant deviation present. Prescriptions with severity scores of 3 or greater were considered prescribing errors. Potential ADEs were defined as prescription orders that have the potential to result in significant medical injury if the prescription were filled and the drug administered as ordered by the health care provider.

A prescription that met "best practice" or safe prescription writing guidelines contained no prescribing medication errors and no error-prone abbreviations, symbols, or dose designations as defined by the Institute

Table 1. Type of Prescription Errors

Wrong formulation is written.
Wrong dose of medication is written.
No weight or age (or birth date) recorded on the prescription (or incorrect weight) in patients weighing <40 kg.
No information on dose/kg body weight (ie, mg of drug/kg of body weight) for patients weighing <40 kg.
Frequency of the medication is significantly out of the range commonly accepted without overdosing or underdosing (potential lack of efficacy).
No date listed on the prescription.
Medication is prescribed when there is likely the potential for an allergic reaction.
Illegible prescription.
Illegible signature or printed name.
Medication is prescribed to the wrong person or is in the wrong chart.
Wrong instructions are given for a medication (eg, crush OxyContin tablet).
Wrong medication is written.

Table 2. Severity Categories of Prescribing Medication Errors*

5 = Severe:	Medication with low therapeutic index written for >10 times the normal dose, or the potential result of a pharmacological effect associated with severe or fatal reactions. The dose has the potential for a severe life-threatening reaction in the patient.
4 = Serious:	Medication with a low therapeutic index 4 to 10 times the normal dose, or potential for serious toxic reaction. Wrong medication or route prescribed with potential for serious reaction. Prescription illegible such that an error in filling could produce a serious reaction.
3 = Significant:	Medication with a low therapeutic index 1.5 to 4 times the normal dose. Dose of any medication more than 5 times normal with potential for an adverse effect related to the dose. Dose or duration inadequate for therapeutic effect. Illegible such that error could result in adverse effects or treatment failure.
2 = Problem:	Lacks specific drug, dose, strength, formulation, route, or frequency. Dose 5 times normal without the potential for toxic reaction. Prescription unlikely to be filled due to nature of or missing information.
1 = Insignificant:	Prescriptions assigned an error that is likely to be filled without the potential for significant side effects or treatment failure.
0 = No medication error detected.	

*Adapted from "Prescription Writing Errors in the Pediatric Emergency Department," with minor changes focusing on applicability for narcotic prescriptions only.[14]

for Safe Medication Practices. Rule violations (faulty medication orders with little potential for harm or extra work as pharmacy and nursing staff can typically interpret them correctly without additional clarification) were not considered medication errors. An example of a rule violation is a pro re nata (PRN) order without a designation of the purpose of the medication. Medication errors and potential ADEs were reported as the percentage of total prescriptions.

Methods of Data Collection and Analysis

The investigators photographed and photocopied the analgesic prescriptions and discharge forms of medical and surgical pediatric patients at the time of their hospital discharge. The prescriptions were written by the patient's primary medical or surgical service. All analgesic prescriptions in our institution are written by trainees. Data were collected from November 2003 to April 2004. The data obtained represent a convenience sample of patients and prescriptions that were discharged during routine daytime hours when a member of the Pediatric Pain Treatment Service was available to collect prescription and discharge information. Discharge analgesic prescriptions are routinely written by the patient's primary medical or surgical service and not by the pediatric pain service. All discharge analgesic prescriptions selected for analysis were written by trainees from the patient's primary service.

Neither the patient nor the physicians writing the prescriptions knew that discharge prescriptions were being studied. To minimize bias, clinicians writing the prescriptions were not informed of the study. To remain compliant with the Health Insurance Portability and Accountability Act of 1996 (HIPAA), only patients who had previously been consulted by the Pediatric Pain Service were studied. The Pediatric Pain Service rewrote any prescriptions that contained errors that would be considered potential ADEs.

The unit of analysis for this study was the analgesic prescription written by the health care provider. We present descriptive statistics for the percent of prescriptions that contained at least 1 prescribing error and/or potential adverse drug event. There were some patients who were discharged with multiple analgesic prescriptions, and these prescriptions were analyzed independently. In the descriptive analysis of error type, categorical variables were summarized as frequencies.

Results

Population

There were 453 inpatients at the Children's Medical and Surgical Center with a Pediatric Pain Service consultation during the study period, and data were obtained for analysis in 241 (53%) of these patients. Prescriptions for analysis were not available in 212 patients because these patients were discharged from the hospital at a time that the study investigators were unavailable. Demographic data are seen in Table 3. Nineteen percent of patients were younger than 4 years and 56% were 12 years of age or younger. All of the patients were discharged home on opioid therapy and 5% were given nonsteroidal anti-inflammatory drugs (NSAIDs). Sixty-two patients (26%) were discharged on 2 or more analgesic prescriptions.

Prescriptions

There were 314 analgesic prescriptions analyzed during the study period. The median number of prescrip-

Table 3. Demographic Data (Patients, n = 241)

No. of prescriptions by age (n = 314)	
0–3 y	60 (19%)
4–12 y	115 (37%)
>12 y	139 (44%)
Weight (kg)*	37 ± 22 (range, 4–116)
Sex, M:F	M = 135 (56%): F = 106 (44%)
Length of admission (d)*	4.6 ± 4 (range, 1–44)
No. of rule violations/prescription†	2 (range, 0–7)
No. of deviations from Best Practice Prescribing Guidelines/Prescription†	1 (range, 0–9)

*Values are mean ± SD.

†Values are median.

tions written per patient was 1 (range, 1 to 5), and 95% of the prescriptions were written by surgical services. The majority of prescriptions were written by the Pediatric Orthopedic service (n = 171, 55%), followed by the Pediatric Urology service (n = 48, 15%), Plastic Surgery service (n = 33, 11%), and the General Pediatric Surgery service (n = 32, 10%). The vast majority of the prescriptions written were for Schedule II opioid analgesics or combination drugs containing opioid analgesics (91%). The most common drug prescribed for use at discharge was oxycodone (n = 236, 75%).

Deviations From Best Practice

Prescriptions that deviated from "best practice" guidelines were very common; 257 of 314 (82%) of the prescriptions contained 1 or more such deviations. The most common issues were missing or wrong patient weight (n = 127, 77% of 166 patients with <40 kg body weight had no weight or an incorrect weight noted on prescription), incomplete dispensing information (n = 167, 53%), and no or wrong date on prescription (n = 19, 6%) (Table 4). The median number of deviations from "best practice" guidelines/prescription was 1 (range, 0 to 9), and many prescriptions (n = 120, 38%) contained 2 or more deviations (Table 5). Most of the deviations were insignificant or minor (77%) (Fig 1); however, 16 prescriptions (5%) contained severity scores of 3 or greater.

Severe Errors

Nine prescriptions (2.9%) contained prescribing errors with the potential for significant medical injury and were considered potential ADEs. These included the following: inappropriate administration instructions of a sustained-release opioid formulation (n = 1), inappropriate dosing frequency (n = 7), and a 10-fold dosing error of opioid for the patient's weight (n = 1). In the case of the sustained-release opioid prescription, the prescribing administration instructions involved crushing the sustained-release product, which may have led to an inappropriately high concentration of the drug leading to respiratory depression and potential injury. In 7 of the prescriptions, an inappropriate administration frequency of a combined product of acetaminophen/opioid would have resulted in exceeding the recommended daily intake of acetaminophen and potential liver toxicity. One prescription contained a dosing error in which 10-fold the recommended dose/age was prescribed (in

Table 4. Types of Prescribing Medication Errors*

Error Type	Medication Errors (n = 374)
Dose	16 (4.3%)
Frequency	12 (3.2%)
Route of administration	13 (3.5%)
Missing or wrong weight (n = 166)†	127 (77%)
No or wrong date	19 (5%)
Illegible script	7 (1.9%)
Incomplete dispensing information	167 (45%)
Incomplete patient identification	10 (2.7%)
Incorrect administration instructions	3 (0.8%)

*Values are expressed as number (percentage).

†n = 166, which is the number of prescriptions for patients <40 kg body weight requiring weight-based dosing to be noted on prescription.

Table 5. Rule Violations, Prescribing Medication Errors, and Potential Adverse Drug Events (n = 314)

Rule Violations

No. of Rule Violations per Prescription	No. of Prescriptions
0	19 (6.1%)
1	136 (43%)
2	135 (43%)
3	24 (7.6%)

Prescribing Medication Errors

No. of Prescribing Medication Errors per Prescription	No. of Prescriptions
0	58 (19%)
1	136 (43%)
2	78 (25%)
3	39 (12%)
4	3 (1%)

Potential Adverse Drug Events

No. of Potential Adverse Drug Events per Prescription	No. of Prescriptions
0	305 (97%)
1	9 (2.9%)

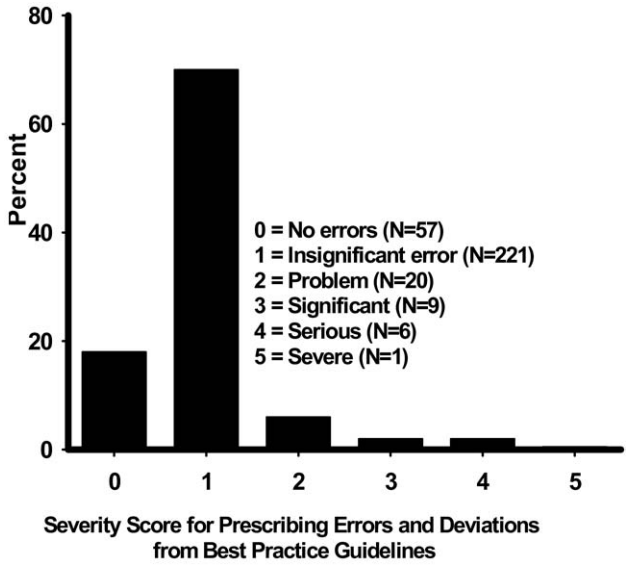

Figure 1. Severity scores for prescribing errors and deviations from Best Practice Guidelines for Controlled Substances Prescriptions (n = 314).

an opioid-naive patient) that could have potentially led to significant respiratory compromise and patient injury. In the case of this prescription, the weight and age of the patient were not recorded by the prescriber.

No weight or weight-based dosing was documented in 77% of prescriptions for patients weighing less than 40 kg. In the vast majority of cases, the dose of the prescription was appropriate for the patient's age and weight, and there was no potential clinical significance. In prescriptions for patients requiring weight-based dosing (weight <40 kg) in which the patient's weight was recorded (n = 50), the weight written on the prescription was incorrect (compared with weight listed in the patient's daily medication record administration nursing flow sheet) in 6% of prescriptions (n = 3). In the case of the prescription with a 10-fold dosing error, the patient's weight was not recorded on the prescription. An incorrect name or patient identifier was seen in 3.2% of prescriptions and discrepancies were seen between the drug that was written for the prescription and the drug listed in the discharge form in 4.6% of patients. The quantity of drug to be dispensed was not properly noted in 53% of prescriptions analyzed.

Discussion

Our study demonstrated that analgesic discharge prescription errors in children are common, and, in some cases, could lead to harm. Many of the prescribing medication errors resulted from incomplete information regarding weight-based dosing in infants and small children. Other common errors involved lack of clear instructions regarding the quantity of drug to be dispensed. There was also a disagreement between analgesic prescriptions that were given to families and those noted on the discharge form in almost 5% of patients. Whereas most of the deviations from "best practice" prescription writing principles were insignificant, of most concern, we discovered a small number of prescriptions (2.9%) with the potential to cause significant injury. These prescriptions contained errors that involved dosing miscalculations, the potential for overdose of analgesic medications and toxic side effects, and inappropriate administration of a sustained-released form of an analgesic.

Our findings are similar to the results of Kaushal et al,[7] which showed a high rate of medication errors in pediatric inpatients but low rates of serious adverse events. As with previous in-patient studies, medication errors occur commonly at the stage of drug ordering and some of these may be preventable with a computerized order entry program with clinical decision support.[7,29] All of the prescriptions analyzed in this study were written by residents and fellows in training and probably lacked an independent review by an attending physician or pharmacist who may have intercepted the error. Prescriptions written by house staff have a high incidence of error and prescription writing skills are often overlooked in resident education.[4,18,19,26] In pediatric emergency medicine, the prescription writing by a trainee has been associated significantly with a higher risk for error.[11] In adult in-patient studies, the review of medication orders by clinical pharmacists has been shown to substantially reduce medication error.[13] Whether the use of this resource could reduce the risk of prescription writing errors for outpatient pharmacy prescriptions was not assessed in this study.

Mistakes in pediatric prescriptions are predictable, given the current method of prescribing, and these errors are particularly common and pernicious for analgesics.[7,18] Accurate prescribing requires an accurate weight, proper conversion of pounds to kilograms, and the choice of an appropriate medication preparation and concentration. Drug dosing in pediatrics is calculated individually based on age, weight, and clinical condition. Their small size limits the therapeutic window and makes children more vulnerable to dosing errors. In addition, when errors occur, young children have less developed communication skills with which to recognize or communicate potential mistakes or to describe signs of adverse effects. Dosing errors for opioid analgesics is of particular concern because these drugs have very narrow therapeutic indexes and increasingly patients are discharged home even when they are still experiencing moderate to severe pain. Indeed, overdosage can have serious and even fatal consequences. Young children and medically compromised children are at greatest risk. Underdosage is also of concern. The failure to provide adequate analgesia can have serious consequences and result in unnecessary suffering.

For each error, there are generally multiple underlying latent or system factors (ie, organizational vulnerabilities) that allow for the mistake.[24] Our study demonstrated this principle. For example, if the error is the prescription of the wrong dose of a medication, underlying system vulnerabilities might include conventions for identifying weight or age, a protocol for writing the dose per kilogram, and a protocol for printing the prescriber's name as well as his/her signature. Significant improvements in patient safety will not come from blaming clinicians but by mitigating system vulnerabilities, many of which will be invisible in the absence of a thorough investigation.[21]

The high rate of medication errors highlights the importance of developing, testing, and implementing effective error-prevention strategies. The Institute of Medicine has identified computerization of medication prescribing as an important patient safety strategy.[9] Many of the commercially available computerized provider order entry (CPOE) programs do not currently provide weight- and age-based dosage decision support and do not contain mechanisms to alert physicians to potential overdosing and underdosing. Even if they do, the impact of CPOE on medication errors is uncertain.[5,10] Nevertheless, principles from safety sciences should guide the development of safety systems. These include standardizing the prescription process, creating independent checks for key steps in the process, and learning from mistakes when they occur.[20] Based on our experience with error reduction through CPOE in total paren-

teral nutrition, chemotherapy, and continuous medication infusions, we have developed a computer-based controlled substances prescription writing program that is linked to the hospital's patient demographic database and contains weight-based dosing and decision management to reduce the potential for errors.[8,14,15] Extensive β-testing is currently underway.

Our study has several potential limitations. We do not have data for patients followed by the Pediatric Pain Service who were discharged home at nights and on weekends and in whom prescriptions were not obtained for analysis. Because these times are usually associated with less supervision, our results may underestimate the actual error rate that occurs. Additionally, we only included patients who received a pain consultation, and these patients may represent more complex patients and may potentially be at a higher risk for error. Second, we do not know what, if any, level of supervision occurred during house staff discharge prescription writing and how many errors were detected before placing prescriptions on patient charts. Third, our definition of "best practice" guidelines and errors may have misclassified prescriptions as error-prone prone that may seldom if ever result in true errors, potentially introducing bias. Study investigators analyzed prescriptions for errors and deviations from "best practice" guidelines using predefined criteria; however, there is no consensus in the literature as to the definition of an error. For example, is the failure to write a patient's weight and/or age an error? Because our institutional policy on inpatient medication orders requires a patient's weight and/or date of birth as well as weight-based dosing (mg/kg) of medications on all medication orders for pediatric patients, we included the omission of weight and or age as a deviation from "best practice" guidelines for pediatric patients.[4] It is the authors' opinion that the widespread violation of "best practice" guidelines creates the environment in which potentially fatal prescribing errors may occur. Characteristics of high reliability organizations are the following: safety as the highest priority, a preoccupation with failure and its consequences, an open environment for discussing/disclosing error, and an emphasis (obsession) with creating an error-free environment. This study emphasizes not only the potential ADEs but stresses the high number of error-prone deviations that occur in prescription writing. Finally, our study is limited to house staff prescribing practices at a teaching hospital and may not be generalizable to hospitals without postgraduate medical trainees.

In conclusion, discharge prescription errors for children requiring potent narcotic drugs in the management of pain are common and some were potentially life-threatening. Efforts to reduce these errors are an important research priority. Until the development of computerized prescription writing with weight-based dosing to reduce errors is available, health care providers and parents need to be vigilant about medications prescribed, particularly in the youngest and smallest patients.

Acknowledgments

The authors acknowledge the support of the nurses of the Children's Center of the Johns Hopkins Hospital and the faculty of the Divisions of Pediatric General Surgery, Orthopaedics, Urology, Plastic Surgery, Neurosurgery, and Pediatric Medicine of the Johns Hopkins University School of Medicine. Additionally, the authors acknowledge the support of Lisa C. Phifer, RN, MN, Director of Pediatric Nursing, George J. Dover, MD, Professor and Chairman Department of Pediatrics, John A. Ulatowski, MD, PhD, MBA, Professor and Chairman Department of Anesthesiology and Critical Care Medicine, and the Pediatric Pain Nurse Practitioners of the Department of Anesthesiology and Critical Care Medicine of the Johns Hopkins University School of Medicine for their support in making this project possible.

References

1. Bates DW, Boyle DL, Vander Vliet MB, Schneider J, Leape L: Relationship between medication errors and adverse drug events. J Gen Intern Med 10:199-205, 1995

2. Bates DW, Cullen DJ, Laird N, Petersen LA, Small SD, Servi D, Laffel G, Sweitzer BJ, Shea BF, Hallisey R: Incidence of adverse drug events and potential adverse drug events: Implications for prevention: ADE Prevention Study Group. JAMA 274:29-34, 1995

3. Brennan TA, Leape LL, Laird NM, Hebert L, Localio AR, Lawthers AG, Newhouse JP, Weiler PC, Hiatt HH; Harvard Medical Practice Study I: Incidence of adverse events and negligence in hospitalized patients: Results of the Harvard Medical Practice Study I. N Engl J Med 324:370-376, 1991

4. Ghaleb MA, Barber N, Dean FB, Wong IC: What constitutes a prescribing error in paediatrics? Qual Saf Health Care 14:352-357, 2005

5. Han YY, Carcillo JA, Venkataraman ST, Clark RS, Watson RS, Nguyen TC, Bayir H, Orr RA: Unexpected increased mortality after implementation of a commercially sold computerized physician order entry system. Pediatrics 116:1506-1512, 2005

6. ISMP, Institute of Safe Medicine Practice. Available at: www.ismp.org. 2006

7. Kaushal R, Bates DW, Landrigan C, McKenna KJ, Clapp MD, Federico F, Goldmann DA: Medication errors and adverse drug events in pediatric inpatients. 285:2114-2120, 2001

8. Kim GR, Chen AR, Arceci RJ, Mitchell SH, Kokoszka KM, Daniel D, Lehmann CU: Error reduction in pediatric chemotherapy: Computerized order entry and failure modes and effects analysis. Arch Pediatr Adolesc Med 160:495-498, 2006

9. Kohn LT, Corrigan JM, Donaldson M: Institute of Medicine (IOM) Report: To Err is Human: Building a Safer Health System. Washington, DC, National Academy of Sciences, 1999.

10. Koppel R, Metlay JP, Cohen A, Abaluck B, Localio AR, Kimmel SE, Strom BL: Role of computerized physician order

entry systems in facilitating medication errors. JAMA 293:1197-1203, 2005

11. Kozer E, Scolnik D, Macpherson A, Keays T, Shi K, Luk T, Koren G: Variables associated with medication errors in pediatric emergency medicine. Pediatrics 110:737-742, 2002

12. Leape LL, Brennan TA, Laird N, Lawthers AG, Localio AR, Barnes BA, Hebert L, Newhouse JP, Weiler PC, Hiatt H: The nature of adverse events in hospitalized patients: Results of the Harvard Medical Practice Study II. N Engl J Med 324:377-384, 1991

13. Leape LL, Cullen DJ, Clapp MD, Burdick E, Demonaco HJ, Erickson JI, Bates DW: Pharmacist participation on physician rounds and adverse drug events in the intensive care unit. JAMA 282:267-270, 1999

14. Lehmann CU, Conner KG, Cox JM: Preventing provider errors: Online total parenteral nutrition calculator. Pediatrics 113:748-753, 2004

15. Lehmann CU, Kim GR, Gujral R, Veltri MA, Clark JS, Miller MR: Decreasing errors in pediatric continuous intravenous infusions. Pediatr Crit Care Med 7:225-230, 2006

16. Lehmann CU, Kim GR: Prevention of medication errors. Clin Perinatol 32:107-123, 2005

17. Lesar TS, Briceland L, Stein DS: Factors related to errors in medication prescribing. JAMA 277:312-317, 1997

18. McPhillips HA, Stille CJ, Smith D, Hecht J, Pearson J, Stull J, Debellis K, Andrade S, Miller M, Kaushal R, Gurwitz J, Davis RL: Potential medication dosing errors in outpatient pediatrics. J Pediatr 147:761-767, 2005

19. Meyer TA: Improving the quality of the order-writing process for inpatient orders and outpatient prescriptions. Am J Health Syst Pharm 57(Suppl 4):S18-S22, 2000

20. Pronovost PJ, Berenholtz SM, Goeschel CA, Needham DM, Sexton JB, Thompson DA, Lubomski LH, Marsteller JA, Makary MA, Hunt E: Creating high reliability in health care organizations. Health Serv Res 41(4 Pt 2):1599-1617, 2006

21. Pronovost PJ, Holzmueller CG, Martinez E, Cafeo CL, Hunt D, Dickson C, Awad M, Makary MA: A practical tool to learn from defects in patient care. Jt Comm J Qual Patient Saf 32:102-108, 2006

22. Proulx S, Wilfinger R, Cohen MR: Medication error prevention: Profiling one of pharmacy's foremost advocacy efforts for advice on error prevention. Pharm Pract Manag Q 17:1-9, 1997

23. Raju TN, Kecskes S, Thornton JP, Perry M, Feldman S: Medication errors in neonatal and paediatric intensive-care units. Lancet 2:374-376, 1989

24. Reason J: Human error: Models and management. BMJ 320:768-770, 2000

25. Taylor BL, Selbst SM, Shah AE: Prescription writing errors in the pediatric emergency department. Pediatr Emerg Care 21:822-827, 2005

26. Walson PD, Hammel M, Martin R: Prescription-writing by pediatric house officers. J Med Educ 56:423-428, 1981

27. Wilson DG, McArtney RG, Newcombe RG, McArtney RJ, Gracie J, Kirk CR, Stuart AG: Medication errors in paediatric practice: Insights from a continuous quality improvement approach. Eur J Pediatr 157:769-774, 1998

28. Wong IC, Ghaleb MA, Franklin BD, Barber N: Incidence and nature of dosing errors in paediatric medications: A systematic review. Drug Saf 27:661-670, 2004

29. Woods D, Thomas E, Holl J, Altman S, Brennan T: Adverse events and preventable adverse events in children. Pediatrics 115:155-160, 2005