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Risk Reduction for Adverse Drug Events Through Sequential Implementation of Patient Safety Initiatives in a Children's Hospital

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ABSTRACT

BACKGROUND. Medication management is a complex, multifaceted system. Prescribing errors occur upstream in the process, and as such, their effects can be perpetuated, and sometimes even exacerbated, in subsequent steps. These errors place patients at risk of adverse drug events. Children, especially young infants, are at particular risk because of their size, unique physiology, and immature ability to metabolize drugs.

OBJECTIVE. The purpose of this study was to reduce the risk of harm to children resulting from prescribing errors.

METHODS. We sequentially implemented patient safety initiatives over a 1-year time frame at a pediatric tertiary care academic facility. The initiatives included an educational Web site with competency examination, distribution of a personal digital assistant-based standardized dosing reference, a zero-tolerance policy for incomplete or incorrect medication orders, prescriber performance feedback, and presentation of outcome data at citywide grand rounds. A total of 8718 orders were collected and analyzed to assess the impact of these initiatives.

RESULTS. The absolute risk reduction from prescribing errors was 38 per 100 orders, with a relative risk reduction of 49%. Web-based education with point-of-care drug references and a zero-tolerance policy for incomplete or incorrect orders were most effective in decreasing potential adverse drug events. Documentation of appropriate weight-based dosing and indication for therapy increased by 24% and 42%, respectively.

CONCLUSIONS. Process-improvement initiatives focusing on prescriber education and behavior modification can reduce the risk of harm to pediatric patients from prescribing errors.

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Key Words

patient safety, medication errors, adverse events, risk reduction, pediatric

Abbreviations

ADE—adverse drug event

CPOE—computerized physician order entry

FFF—forced-format form

WCHOB—Women and Children's Hospital of Buffalo

pADE—potential adverse drug event

CHECKS—Children's Hospital Ensuring Comfort and Kids Safety

PDA—personal digital assistant

ICD-9—*International Classification of Diseases, Ninth Revision*

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MEDICATION MANAGEMENT IS a complex, multifaceted system, which is prone to error during any one of the steps within the process. The act of prescribing medications has been shown to be a significant source of such error. Prescribing errors occur far upstream in the process, and as such, their effects can be perpetuated, and sometimes even exacerbated, in subsequent steps. Some errors result in adverse drug events (ADEs), which cause harm to patients and increase health care costs.¹⁻¹⁴

Prescribing errors are of particular concern in the pediatric population for which dosing based on weight or body surface area must be precise.¹⁴⁻²³ Children, particularly young infants, have unique physiology and an immature ability to metabolize drugs. These factors place them at greater risk for ADEs.

Medication prescribing involves both cognitive and technical components. Process-improvement initiatives must, therefore, focus on education in the safe and correct use of medications, as well as behavior modification to ensure clear communication of the prescription itself. Computerized physician order entry (CPOE) has been offered as a tool to help effectuate safe and correct prescribing practices. Studies have shown that CPOE can reduce prescribing errors, potential ADEs, and actual ADEs.²⁴⁻²⁶ However, there is also literature to suggest that implementation of CPOE may increase harm to patients in some settings.^{27,28}

Less than 10% of hospitals in the United States have CPOE systems completely available.²⁹ CPOE systems are expensive, and successful implementation requires changes in the culture and processes of a hospital, a task requiring enormous investments in time, labor, and resources. For many institutions, these factors are prohibitive for adopting such systems in the near future. Alternative methodologies to promote safe prescribing practices must, therefore, be sought and investigated.

The purpose of this study was to assess the impact of a series of process-improvement and educational initiatives aimed at reducing prescribing errors. These initiatives were built on the foundation of a previously established forced-format form (FFF) for medication orders, a precursor to CPOE.³⁰ The FFF promotes good prescribing habits by requiring documentation of the cognitive aspects of therapeutic decision-making, including indication for therapy, and standardizing prescribing mechan-

ics. Impact was assessed in terms of reduction of risk for ADEs from prescribing over a 1-year time period.

METHODS

Setting

The Women and Children's Hospital of Buffalo (WCHOB) is a 264-bed, tertiary care, regional referral center and a teaching facility affiliated with the State University of New York at Buffalo. The inpatient pharmacy processes >100 000 medication orders on an annual basis, representing ~12 000 admissions.

Operational Definitions

An "original order" was defined as a medication order written de novo by a prescriber, to be differentiated from an order rewritten by the prescriber after having been returned by the pharmacy. A "start order" refers to an order to initiate therapy, as opposed to an order to renew or discontinue therapy. All of the medication orders described in this article refer to original start orders unless otherwise specified.

A "complete order" was defined as containing all of the following elements appropriate for that order: medication name, weight-based dosing (eg, milligrams per kilogram per day), dose, route, interval, and indication for therapy. An order was considered correct if all of the components were consistent with standard pediatric dosing guidelines. Prescribers were required to document "max dose" or "adult dose" for weight-based dosing that reached or exceeded maximum or adult recommendations.

A "potential ADE" (pADE) was defined as any medication order that was not wholly complete and correct. In other words, any medication order with missing or incorrect information was considered a pADE.

Process-Improvement Initiatives

Sequential patient safety initiatives were implemented at WCHOB over the course of a 1-year period from June 2003 through June 2004 (Table 1). After each initiative, pediatric medication orders were collected from the medical and surgical units, the PICU, and the NICU and then analyzed to assess the effect. The 6 initiatives (and the

TABLE 1 Medication Orders Evaluated After Each Initiative

Time Frame	Initiative	No. of Days Sampled	No. of Orders
June 2003	Baseline	7	771
July 2003	New housestaff orientation	7	976
October 2003	Clinical staff education and PDA-based drug reference	14	1536
November/December 2003	Zero-tolerance policy	14	1524
February 2004	Prescriber feedback	14	1908
April 2004	Academic presentation	7	1007
June 2004	New housestaff orientation	7	996

baseline) are described below, including the number of orders analyzed for each.

Baseline

In mid-June 2003, a 1-week sample of medication orders was collected as a baseline ($n = 771$). This sample was taken at the end of the academic year before the arrival of new housestaff, presumably when housestaff skills were at their best.

New Housestaff Orientation

Through a collaboration with the State University of New York at Buffalo Graduate Medical Dental Consortium, a Web-based pediatric patient safety educational program called the Children's Hospital Ensuring Comfort and Kids Safety (CHECKS) Web site was incorporated into new housestaff orientation. The CHECKS Web site contains a tutorial designed to teach clinicians general principles of patient safety with specific attention to pediatrics. A case scenario is then used to test the user's skills in writing 4 pediatric medication orders. The Web site directs the user to correct any mistakes made until all 4 of the orders are complete and correct. Once this is accomplished, the user, as well as the hospital patient safety officer, receives notification that he/she has successfully completed the program and is certified to write pediatric medication orders at our facility. An electronic record was kept of all of the users who successfully complete the Web site. All of the incoming residents, regardless of specialty or level of training, were required to complete this training as a prerequisite for beginning their clinical duties. The inclusion of all of the housestaff presumed that most would rotate through the WCHOB at some point in their training, and all might potentially care for a child in an emergent setting. After the new housestaff completed the Web site and were credentialed to write orders, another 1-week sample of medication orders was collected in early July 2003 ($n = 976$).

Clinical Staff Education and Implementation of Standardized Electronic Dosing Reference

In October 2003, an institution-wide campaign was launched to have all of the clinical staff, including physicians, registered nurses, and pharmacists, complete the Web-based educational program. During this same time frame, a handheld electronic pediatric dosing reference (Pediatric Lexi-Drugs) was provided to all of the prescribers. For those prescribers who did not already possess a personal digital assistant (PDA), one was provided to them. Completion of the Web site was a requirement for the dosing reference and supplied PDAs. A 2-week sample of medication orders was collected after implementation ($n = 1536$).

Zero-Tolerance Policy

In November 2003, a zero-tolerance policy was implemented for incomplete or incorrect orders. Any medica-

tion order deemed by the nursing or pharmacy staff to be incomplete or incorrect was returned to the prescriber to be rewritten. Stickers with the phrase "please clarify and rewrite" were used to highlight these orders. A 2-week sample of medication orders was collected after this initiative ($n = 1524$).

Prescriber Feedback

In February 2004, all of the prescribers at our institution were provided with feedback. The 50 highest-volume prescribers were provided with individualized reports. All of the prescribers were given institution-wide performance averages. After the prescribers received the feedback, another 1-week sample of medication orders was collected and analyzed ($n = 1908$).

Academic Presentation

Institutional data were presented at citywide pediatric grand rounds in April 2004, after which a 1-week sample of medication orders was collected and analyzed ($n = 1007$).

Final Sample

In June 2004, a 1-week sample of medication orders was collected and analyzed ($n = 996$). This sample established the baseline for the new academic year, analogous to the July 2003 sample, with the departure of senior housestaff and the influx of new housestaff who completed the CHECKS Web site during their orientation.

Data Analysis

A relational database, referred to as Safe Prescriber Order Tracking (SPOT CHECKS), was designed to track order completeness and correctness. Data entry was performed by a registered nurse stationed within the inpatient pharmacy and supervised by a clinical pharmacist. Thirty-eight variables were assessed and evaluated per order reflecting both the cognitive aspects (ie, correctness) and the mechanics (ie, completeness). Questions regarding evaluation of an order were referred to a registered pharmacist. Data were analyzed, and statistics were computed using Microsoft Excel (Microsoft, Redmond, WA), SAS (SAS Institute, Cary, NC), and SPSS (SPSS Inc, Chicago, IL) software packages. Only original start orders for pediatric patients were included in the data sets for analysis.

Absolute risk reduction was calculated as the difference between the baseline and postintervention risks. Relative risk reduction was calculated as the absolute risk reduction divided by the baseline risk, converted to a percentage:

$$\text{absolute risk reduction} = \text{baseline risk} - \text{postintervention risk}$$

$$\text{relative risk reduction} = (\text{absolute risk reduction}/\text{baseline risk}) \times 100\%$$

Changes in pADE rates were evaluated by using *t* tests.

Changes in documentation of weight-based dosing and indication for therapy were compared by using χ^2 tests.

RESULTS

A total of 22 659 medication orders were entered into the Safe Prescriber Order Tracking database. Original medication orders comprised 14 155 (62.5%), and, of these, 8718 (38.5%) were start orders. Table 1 shows the number of original start orders in each data set.

As new patient safety initiatives were sequentially implemented, the number of pADEs trended downward. Table 2 shows the pADE rate and change in pADE rate after each intervention. Figure 1 depicts these results graphically.

Statistically significant reductions in pADEs were seen after 2 initiatives. First, a reduction in pADEs of 7.1% was documented versus the previous measurement period after hospital-wide clinical staff education and distribution of the PDA-based drug reference ($t = 6.296$; $P = .001$). Second, a dramatic reduction of 37.7% in pADEs was documented versus the previous measurement period after implementation of the zero-tolerance policy ($t = 30.753$; $P = .001$). A statistically significant increase was seen after the June 2004 new housestaff orientation. The absolute risk reduction achieved over the course of the study from June 2003 to June 2004 was 38 per 100 orders written ($t = 25.735$; $P = .001$). This yielded an overall relative risk reduction from prescribing errors of 49% ($P < .001$). The absolute risk reduction achieved comparing pADE rates at the start of each academic year (July 2003 versus June 2004) was 40 per 100 orders with a relative risk reduction of 50% ($t = 25.991$; $P = .001$).

Subanalysis was performed for the 2 components not traditionally included in a medication order: weight-based dosing and the indication for therapy. At baseline, 50% of the medication orders for which weight-based dosing was appropriate contained the correct information. At the end of the study, 74% had the correct information documented ($\chi^2 = 85.95$; $P < .001$). Indication for therapy was documented on 40% of the medication orders at baseline. By the end of the study period, 82% of orders contained this information ($\chi^2 = 229.66$; $P < .001$).

DISCUSSION

The results of this study support the use of multiple, interrelated educational and behavioral modification strategies to instill prescribing practices that reduce the rate of pADEs in a children's hospital. Specifically, intense Web-based clinical education with point-of-care drug references and a zero-tolerance policy for incomplete or incorrect orders were most effective in decreasing pADEs. These methodologies can be adapted for use in various settings. They do not require large investments in technology or personnel but do require the commitment of an institution to promote a culture of safe practices.

pADEs are, in effect, a measure of risk. An incomplete medication order requires assumptions to be made on the part of the nurse and/or pharmacist. These assumptions can be erroneous, thereby putting the patient at risk of harm. An order written without units could result in 5 mg being administered instead of 5 mcg. An order written without route of delivery could result in an oral solution being administered intravenously. Perhaps more alarming is incorrect information, which, if not detected and corrected, undoubtedly places the patient at risk of harm. By reducing the number of pADEs, the risk of actual ADEs may be reduced.

Years of attention have been invested in the issue of patient safety, yet accurate measurement of the prevalence of medical errors and incidence of actual adverse events remains elusive. Even the Institute of Medicine report *To Err is Human*¹ described the scope of harm inflicted by medical errors using broad margins. Incident reporting, the traditional method of quantifying this data, is affected by too many factors to be reliable. Time constraints, cumbersome reporting tools, severity and visibility of the event, blameful versus blameless environments of reporting, fear of retribution by colleagues or sanctions by regulatory agencies, and the awareness of surveillance itself influencing the reporting behavior are just some examples of these factors. Without the ability to reliably measure ADEs, it will remain difficult to discern whether variations in ADE rates are true changes or merely artifact resulting from the influences described above.

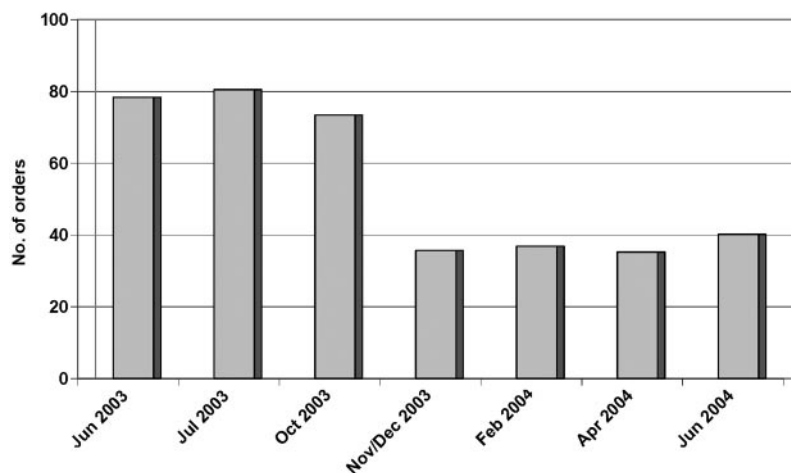
Our group focused on risk reduction using a consis-

TABLE 2 pADE Rate and Change in pADE Rate After Implementation of Each Initiative

Time Frame	Initiative	pADE Rate per 100 Orders	Δ pADE Rate per 100 Orders	P^a
June 2003	Baseline	78.3		
July 2003	New housestaff orientation	80.5	+2.2	NS
October 2003	Clinical staff education and PDA-based drug reference	73.4	-7.1	.001
November/December 2003	Zero-tolerance policy	35.7	-37.7	.001
February 2004	Prescriber feedback	36.8	+1.1	NS
April 2004	Academic presentation	35.3	-1.5	NS
June 2004	New housestaff orientation	40.2	+4.9	.01

^aStatistical significance as compared to previous measurement. NS indicates not significant.

FIGURE 1
pADEs per 100 orders.



tent, objective methodology independent of incident reports. Because pADEs would be expected to increase the risk of an error reaching the patient, reduction in the number of such potential events should result in the reduction of actual events. Quantifying the correlation between pADEs and actual ADEs is currently under study.

The statistically significant increase in pADEs seen after new housestaff orientation in 2004 would, at first glance, seem to suggest ineffectiveness of the initiative. However, this time frame represents data after an influx of new trainees and an egress of the senior housestaff, that is, a significant change in the prescriber population. A more relevant comparison is that between the baseline pADEs rates at the beginning of each academic year, which did show significant improvement.

Weight-based dosing is a key concept in safe pediatric prescribing. Therefore, we require its documentation on all of the medication orders at our institution and include it as a requisite part of a complete order. This safety practice is even more crucial in an academic institution where rotating housestaff with minimal to no pediatric experience may not know that, in children, “one dose does not fit all.” Documenting the weight-based dose, as well as the actual dose, allows both nurses and pharmacists to more efficiently and effectively double-check safe dosing and intercept pADEs.

Indication for therapy is rapidly being recognized as essential for improving medication safety in the hospital setting. This information ensures that appropriate therapy is being provided for the appropriate clinical condition and serves as a safety-check mechanism for nurses and pharmacists. The following anecdote illustrates this point:

In the NICU, a physician wrote an order for aminophylline, citing “sepsis” as the indication for therapy. The order was transcribed and sent to the inpatient pharmacy. The pharmacist noted the apparent discrepancy

between the medication ordered and its intended use and called the physician. The physician immediately recognized her error: she meant to write an order for amphotericin. The mistake was immediately corrected, and the patient received the proper therapy.

This patient clearly would have suffered significant morbidity, if not mortality, from the delay in necessary therapy. There was also the potential for the adverse effects from unnecessary therapy had the indication not been included in the order.

Although indication for therapy has not been routinely required on medication orders, the concept is already embedded in other clinical arenas. Diagnostic laboratories request indication in the form of an *International Classification of Diseases, Ninth Revision (ICD-9)* code before testing is performed. Imaging centers request an ICD-9 code before proceeding with radiologic studies. Ironically, indication has become mainstream for these processes, neither of which generally put patients at risk of harm, but has been only recently recognized for drug therapy that can and does put patients at risk every day.

Indication has benefits beyond those described for patient safety and appropriateness of therapy. We have linked the most common indications for therapy at our institution to the corresponding ICD-9 code. This will allow for tracking and assessment of drug use by clinical indication, providing outcomes data that can be used to establish best practices.

Finally, our organization learned a great deal from this series of initiatives about influencing physician behavior. As was shown in our “Results” section, the greatest single improvement, 37.7%, was experienced with the zero-tolerance policy. This underscores that neither technology nor education alone can produce as great a change in behavior as can the simple establishment of a legitimate safety-related policy of zero tolerance. Implementation, dissemination, and enforcement by a vigilant

clinical team of practicing physicians, nurses, and pharmacists were paramount to the success of this initiative.

Our results should be interpreted cautiously. Selection bias was unlikely to have caused the apparent difference in pADE rates, because all of the medication orders from the medical, surgical, and intensive care units were collected over a minimum of 7 days for each time period. In addition, time frames were specifically selected to represent the effect of each initiative. Evaluator bias was addressed by having only 1 nurse clinician evaluate all of the orders using an objective set of criteria, optimizing internal validity. Orders in question were adjudicated by a registered pharmacist. Prescribers were not aware of the data collection, thereby eliminating surveillance bias.

Reducing the risk of ADEs requires a change in the culture of medication management. This daunting but surmountable task can be facilitated by sequential implementation of patient safety initiatives aimed at multiple operant factors. This ongoing process requires strong leadership in implementation, as well as vigilance in clinical education, dissemination of safer practices, and surveillance of outcomes.

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REFERENCES

1. Kohn LT, Corrigan JM, Donaldson MS, eds. *To Err is Human: Building a Safer Health System*. Washington, DC: National Academy Press; 2000
2. Bates DW, Boyle DL, Vander Vliet MB, Schneider J, Leape L. Relationship between medication errors and adverse drug events. *J Gen Intern Med*. 1995;10:199–205
3. Bates DW, Cullen DJ, Laird N, et al. Incidence of adverse drug events and potential adverse drug events. Implications for prevention. ADE Prevention Study Group. *JAMA*. 1995;274:29–34
4. Cullen DJ, Sweitzer BJ, Bates DW, Burdick E, Edmondson A, Leape LL. Preventable adverse drug events in hospitalized patients: a comparative study of intensive care and general care units. *Crit Care Med*. 1997;25:1289–1297
5. Lesar TS, Briceland L, Stein DS. Factors related to errors in medication prescribing. *JAMA*. 1997;277:312–317
6. Lesar TS, Lomaestro BM, Pohl H. Medication-prescribing errors in a teaching hospital: a 9-year experience. *Arch Intern Med*. 1997;157:1569–1576
7. Hunt ML Jr, Rapp RP. Intravenous medication errors. *J Intraven Nurs*. 1996;19(3 suppl):S9–S15
8. Leape LL, Bates DW, Cullen DJ, et al. Systems analysis of adverse drug events. ADE Prevention Study Group. *JAMA*. 1995;274:35–43
9. Leape LL, Brennan TA, Laird N, et al. The nature of adverse events in hospitalized patients. Results of the Harvard Medical Practice Study II. *N Engl J Med*. 1991;324:377–384
10. Johnson JA, Bootman JL. Drug-related morbidity and mortality: a cost-of-illness model. *Arch Intern Med*. 1995;155:1949–1956
11. Bates DW, Spell N, Cullen DJ, et al. The costs of adverse drug events in hospitalized patients. Adverse Drug Events Prevention Study Group. *JAMA*. 1997;277:307–311
12. Classen DC, Pestotnik SL, Evans RS, Lloyd JF, Burke JP. Adverse drug events in hospitalized patients: excess length of stay, extra costs, and attributable mortality. *JAMA*. 1997;277:301–306
13. Leape LL, Cullen DJ, Clapp MD, et al. Pharmacist participation on physician rounds and adverse drug events in the intensive care unit. *JAMA*. 1999;282:267–270
14. Cimino MA, Kirschbaum MS, Brodsky L, Shaha SH. Assessing medication prescribing errors in pediatric intensive care units. *Pediatr Crit Care Med*. 2004;5:124–132
15. American Academy of Pediatrics, Committee on Drugs and Committee on Hospital Care. Prevention of medication errors in the pediatric inpatient setting. *Pediatrics*. 1998;102:428–430
16. Koren G, Haslam RH. Pediatric medication errors: predicting and preventing tenfold disasters. *J Clin Pharmacol*. 1994;34:1043–1045
17. Anderson BJ, Ellis JF. Common errors of drug administration in infants: causes and avoidance. *Paediatr Drugs*. 1999;1:93–107
18. Folli HL, Poole RL, Benitz WE, Russo JC. Medication error prevention by clinical pharmacists in two children's hospitals. *Pediatrics*. 1987;79:718–722
19. Meyer GE, Novielli KA, Smith JE. Use of refractive index measurement for quality assurance of pediatric parenteral nutrient solutions. *Am J Hosp Pharm*. 1987;44:1617–1620
20. Kaushal R, Bates DW, Landrigan C, et al. Medication errors and adverse drug events in pediatric inpatients. *JAMA*. 2001;285:2114–2120
21. Trinkle R, Wu JK. Errors involving pediatric patients receiving chemotherapy: a literature review. *Med Pediatr Oncol*. 1996;26:344–351
22. Tisdale JE. Justifying a pediatric critical-care satellite pharmacy by medication-error reporting. *Am J Hosp Pharm*. 1986;43:368–471
23. Levine S. Guidelines for preventing medication errors in pediatrics. *J Pediatr Pharmacol Ther*. 2001;6:426–442
24. Potts AL, Barr FE, Gregory DF, Wright L, Patel NR. Computerized physician order entry and medication errors in a pediatric critical care unit. *Pediatrics*. 2004;113:59–63
25. Upperman JS, Staley P, Friend K, et al. The introduction of computerized physician order entry and change management in a tertiary pediatric hospital. *Pediatrics*. 2005;116(5). Available at: www.pediatrics.org/cgi/content/full/116/5/e634
26. Fortescue EB, Kaushal R, Landrigan CP, et al. Prioritizing strategies for preventing medication errors and adverse drug events in pediatric inpatients. *Pediatrics*. 2003;111:722–729
27. Berger RG, Kichak JP. Computerized physician order entry: helpful or harmful? *J Am Med Inform Assoc*. 2004;11:100–103
28. Han YY, Carcillo JA, Venkataraman ST, et al. Unexpected increased mortality after implementation of a commercially sold computerized physician order entry system. *Pediatrics*. 2005;116:1506–1512
29. Ash JS, Gorman PN, Seshadri V, Hersh WR. Computerized physician order entry in U.S. hospitals: results of a 2002 survey. *J Am Med Inform Assoc*. 2004;11:95–99
30. Shaha SH, Brodsky L, Leonard MS, et al. Establishing a culture of patient safety through a low-tech approach to reducing medication errors. In: *Advances in Patient Safety: From Research to Implementation*. Rockville, MD: Agency for Healthcare Research and Quality; 2005

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