



eNeonatal Review

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Promoting the safety of our tiny patients and reducing adverse events in Neonatal Intensive Care Units by reducing medical errors is of utmost importance. Our focus this month is on the use of computers and medical informatics in pediatrics and neonatology to promote safety.

Long before the Institute of Medicine published its report "To Err is Human" in 2000, with its focus on how medical errors occur and its prescription for creating safety systems within health care, informatics research has investigated the problem, particularly in the domain of medication errors. Because of the variable dosing needs of pediatric and neonatal patients, these populations are at higher risk for medication errors and potential (and actual) adverse drug events. As a result, an increasing number of groups are investigating ways to model and minimize errors through applications of information technology.

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Guest Editors of the Month

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George Kim, MD, FAAP
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COMMENTARY

Biomedical Informatics and Patient Safety

An understanding of the importance of Biomedical Informatics - also known as Medical Informatics and/or Healthcare Informatics - to increased patient safety begins with a working definition, and one of the most cogent comes from the American Medical Informatics Association: "the rapidly developing scientific field that deals with the storage, retrieval, and optimal use of biomedical information, data, and knowledge for problem solving and decision making" (1).

The University of Washington (UW) Biomedical and Health Informatics Program has approached this field of study from a functional perspective by delineating three application domains: Biomedical Research (e.g. bio-informatics); Clinical Care (e.g. consumer informatics, clinical informatics, nursing informatics); and Public Health. In addition, they have developed four foundational areas: Biomedical Data and Knowledge Representation, Biomedical Information Access, Biomedical Decision Making, and Information & Technology Use in Biomedical Contexts.

Applied to patient safety, informatics research has focused in large part on the electronic medical record (EMR) and computerized physician order entry (CPOE) aspects to develop decision support systems for diagnostics and error prevention.

Why the recent push for EMRs and CPOE? Reducing human error and improving quality in healthcare have risen to the forefront as priorities in the business and academic community. While the driving force is a desire to improve safety, a definite secondary driver is to improve efficiency and thereby control spiraling health care costs.

In 2000, The Institute of Medicine (IOM) issued a seminal report (2) on medical errors that generated controversy in the lay and academic press, with extrapolations estimating that as many as 98,000 patient deaths annually were attributable to health care provider and pharmacist errors. While there is agreement that medical errors are a real problem, much debate has occurred in the scientific community regarding a) how accurate the reported numbers are, and b) what percentage of these errors are in fact preventable.

In 2001 the IOM published a follow-up report (3) focused on developing methods for improving healthcare. Meanwhile, the [Leapfrog Group](#), a business coalition of 145+ purchasers of healthcare benefits, has been investigating methods of improving patient safety while reducing health care costs. Information generated by both the IOM and the Leapfrog Group strongly indicates that increased computerization, and in particular increased use of EMRs and CPOEs, may provide at least part (though by no means all) of the solution.

As evidenced by the articles reviewed in this issue, biomedical informatics has great and documented potential to reduce errors - however, it is neither a panacea nor the total solution to achieving improved patient care at reduced costs. To illustrate:

- Though CPOE with decision support was found to prevent 72.7% of medication errors, the alternative method of monitoring by a clinical pharmacist was found to prevent 83.7% of errors. Importantly, the cost/benefit of these two alternatives has not yet been fully explored.
- Estimates of failure rates for EMR deployment range from 15-50%. Notably, system failures are not generally related to a failure of the system to work, but instead are related to a failure of users to adopt them. Lack of adoption is often related to lack of perceived personal

benefit - in fact, in fact, one study showed adoption of a first generation CPOE system added up to 90 minutes a day of additional work for the user. Unfortunately studying the causes of failures of EMR deployments is made very difficult by a publication bias against negative studies and by an enormous reluctance of healthcare organizations who have invested millions in such systems to publicize their failures.

Clinical informatics research today must - and in many respects already has - become better focused on understanding all the factors that lead to successful implementations of systems, including human factors research, change management, organizational behavior, and workflow and task analysis. Only by taking into consideration all these critical factors can biomedical informatics truly achieve its fullest potential in improving patient safety.

References

1. "[AMIA Frequently Asked Questions \(FAQs\)](#)" - "What is medical informatics"
2. "[To Err Is Human: Building a Safer Health System](#)". The National Academy Press. 2000.
3. "[Crossing the Quality Chasm: A New Health System for the 21st Century](#)". The National Academy Press. 2001.

ANALYSIS OF POSSIBLE PREVENTION STRATEGIES

Kaushal R, Bates DW, Landrigan C, McKenna KJ, Clapp MD, Federico F, Goldman DA. Medication errors and adverse drug events in pediatric inpatients. JAMA. 2001 Apr; 285(16): 2114-2120.

Fortescue EB, Kaushal R, Landrigan CP, McKenna KJ, Clapp MD, Federico F, Goldman DA, Bates DW. Prioritizing strategies for preventing medication errors and adverse drug events in pediatric inpatients. Pediatrics. 2003 Apr; 111(4):722-729.

A study of over 1,000 pediatric inpatients admitted to two Boston academic identifies medication errors and adverse drug events from a variety of sources.

These two articles report on a prospective cohort study of over 1,000 pediatric inpatients admitted to two Boston academic hospitals over a six-week period, where researchers identified medication errors and adverse drug events (ADEs), both potential and actual, from staff reports, medication order records (MORs), medication administration records (MARs) and patient charts. In 10,778 medication orders, they identified 616 errors (5.7%) with a potential ADE rate of 1.1% (actual ADE rate was 0.24%, of which 19% were judged as preventable). The pediatric medication error rate was similar to the rate found for adults, but the pediatric potential ADE rate was three times higher than that for adults with a significantly higher potential ADE rate for patients in a neonatal intensive care unit (NICU). Most potential ADEs occurred at the ordering stage (79%) and involved dosing errors (34%), antibiotics (28%) and intravenous medication (54%).

Of the 616 medication errors, the most frequent time of occurrence was at ordering (77.8%), followed by administration (12.8%), and then at transcription (5.8%). Dosage errors (failure to document, missed doses, overdosing) were the most common (28.4%), followed by drug route errors (17.7%), then by transcription errors (frequency) (12.5%). Potentially harmful errors involved dosages, allergies and frequency.

Analysis of ten prevention strategies applied to each medication order demonstrated that three strategies could have had the greatest potential clinical impact. First, direct monitoring by clinical pharmacists may have prevented significant errors in ordering (58.3%), transcription (19.6%) and administration (5.8%). Second, basic (without decision support) computerized physician order entry (CPOE) may have prevented 65.9% of all errors (with an additional 6.8% reduction with decision support). Third, improved communication between health care practitioners may have prevented errors (physician-pharmacist: 47.4%; physician-nurse: 17.4%). Altogether, these strategies could have prevented 98.5% of errors.

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Medication Errors And Adverse Drug Events In Pediatric Inpatients

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Prioritizing Strategies For Preventing Medication Errors And Adverse Drug Events In Pediatric Inpatients

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EVOLUTION OF A SUCCESSFUL SYSTEM

Horn W, Popow C, Miksch S, Kirchner L, Seyfang A. Development and evaluation of VIE-PNN, a knowledge-based system for calculating the parenteral nutrition of newborn infants. *Artif Intell Med.* 2002 Mar; 24(3):217-28.

The value of a rule-based expert system for aiding the planning and calculation of parenteral nutrition of neonates.

The authors describe the design and evolution of VIE-PNN, a rule-based expert system for aiding the planning and calculation of parenteral nutrition of neonates. The goals of the implementation of VIE-PNN were to provide a) rule-based support for daily calculation of parenteral nutritional solutions (PNS), b) decision support to encourage changes from parenteral to oral feedings, c) documentation support for creation and archiving of PNS records, and d) management support for facilitated rule updates by domain experts

The system's structure, its modules and its evolution from a stand-alone application to a server-client model, with expansion to the primary PNS calculation support for two NICUs are described. After two years of continuous system operation, the authors performed an evaluation of the system by comparing 50 routine PNS calculations in parallel to handheld calculations by physicians in charge, followed by a user survey.

In the evaluation, the authors noted a significant time saving of 4.7 minutes per PNS order (2.4 min VIE-PNN vs 7.1 min hand calculation). They noted no life-threatening errors in either group and fewer "major" and "minor" errors and omissions in the VIE-PNN group. Most errors in the hand calculation group were related to prescription of different components of PNS. The overall rating of the system for performance and usability of the system by users was "good", with the primary reasons for using the system given as "time-saving" and "accuracy improving". The authors add that a benefit is the intuitive Web-based user interface that facilitates input.

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SUCCESSFUL NICU STRATEGY & IMPLEMENTATION

Lehmann CU, Conner KG, Cox JM. Provider error prevention: online total parenteral nutrition calculator. *Proc AMIA Symp.* 2002;:435-9.

Lehmann CU, Conner KG, Cox JM. Preventing provider errors: online total parenteral nutrition calculator. *Pediatrics.* Accepted for publication 2003

Development of a low-cost online parenteral nutritional calculator designed to produce a reduction in total parenteral nutrition (TPN) ordering errors.

In the Johns Hopkins University neonatal intensive care unit (NICU) from Baltimore, Maryland, the authors developed a low-cost online parenteral nutritional calculator using a combination of a commercial rapid application development environment and agile methodology to produce a demonstrated reduction in total parenteral nutrition (TPN) ordering errors. Total software development time was three weeks.

A "before-after" study was implemented with two intervention periods to determine the effectiveness of the calculator in the ordering process. TPN orders prior to system introduction were evaluated for errors over a six-week control period with an average of 10.8 errors per 100 orders noted. Types of errors noted included calculation errors, osmolality outside of the allowed range, incomplete order forms, and other knowledge problems.

After the first six-week intervention period, the number of errors was reduced to 4.2 errors per 100

orders (61% reduction), with marked reductions in calculation errors (100%), osmolality (88%), knowledge problems (84%), and incomplete forms (35%). There was no difference in the percentage of orders reaching the pharmacy by the set deadline. An examination of errors in the first intervention period led to a redesign of the system with further reductions in errors in the second intervention to an overall error rate of 1.2 errors per 100 orders.

A survey of users after six months of operation showed overall satisfaction (partly due to time-saving) and trust of the system to prevent errors by all stakeholders. Use of the system has since been expanded to the whole Children's Center and to several other hospitals. Success of the system and its low-cost implementation are attributed to several factors: presence of an operational network infrastructure, use of an available rapid application development tool (ColdFusion) with a domain expert serving as programmer and user, and an intentional non-disruptive fit of the system into the existing workflow (i.e. a Web form similar to existing paper forms, engagement of all stakeholders, etc).

Provider Error Prevention: Online Total Parenteral Nutrition Calculator



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NICU PRACTICES SURVEY

Porcelli P. Neonatal nutrition information practices. Proc AMIA Symp 2002;:1133-1133.

Porcelli P. A survey of neonatal parenteral nutrition design practices in North Carolina. J Perinatol. 2003; 00:1-6.

A survey of eight NICUs in North Carolina to understand nutritional errors and how to reduce them

In a survey of eight medium-to-large regional neonatal intensive care units (NICUs) in North Carolina caring for very low birthweight (VLBW) infants, data was collected on demographics (NICU size, number of admissions by birth weight, race and gender), infant nutritional support staffing and workflow (timing and staff input into daily prescription of neonatal parenteral nutrition). Data was also collected on the calculation/order forms for parenteral nutrition (paper/computerized, number of calculations, decision support provided). Interviews with staff collected data on self-reported errors.

Data from forms were evaluated for the potential for the range of decision support provided, computation required, opportunities for (electronic) decision support and potentials for misinterpretation. Self-reported errors were characterized according to a described hierarchical schema of medical errors.

Of the eight centers, five had an experienced neonatal nutritionist on staff. Nutritional decision-making occurred in the morning with attending neonatologist, primary care provider, nutritionist and pharmacist in attendance. Six centers used internally developed paper order forms. The average number of values per paper form was 612 requiring an average of 107 calculations. Most errors were related to misinterpretation of orders (units), inaccurate transfer, or procedural inaccuracies. The author estimates that about half may have been eliminated with the use of an electronic parenteral nutrition design system.

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Neonatal Nutrition Information Practices.



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CPOE INTERVENTION RESULTS

King WJ, Paice N, Rangrej J, Forestell GJ, Swartz R. The effect of computerized physician order entry on medication errors and adverse drug events in pediatric inpatients. Pediatrics. 2003 Sep; 112(3): 506-509

A retrospective study from a Canadian tertiary care pediatric facility evaluating medication error rates over a three year period.

In a retrospective cohort study from a Canadian tertiary care pediatric teaching hospital,

medication error rates (MERs, a medication error being defined as any event involving prescription, dispensing, administration or monitoring of medications and resulting in an incident report) and their severity of harm to patients was recorded in 5 inpatient services (3 medical and 2 surgical wards, average patient ages 5.5-7 years) over a three year period (1993-1996). Severity was classified as an adverse drug event (ADE, defined as an event resulting in injury) or a potential ADE (where potential but no actual harm to a patient existed).

In 1996, a commercially available computerized physician order entry (CPOE) system without clinical decision support and interfaced with a laboratory (but not pharmacy) system was introduced into 2 medical wards with 1 medical and 2 surgical wards (where handwritten orders were used) serving as controls. After 6 months of use, the MER was measured on intervention and control wards for the subsequent 3 year period (1997-1999).

The MERs before the introduction of the CPOE system for were 4.48-4.80 per 1000 patient days, with a 40% reduction in MER in the intervention group after introduction of the CPOE system. There was no difference in the ADEs (although the number was small), however there was a larger decrease in potential ADEs in the control group in comparison to the intervention group.

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Recommended References for Further Information

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Napper C, Battles JB, Fargason C. Pediatrics and Patient Safety. *J. Pediatr* 2003 Apr 359-360.



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Holdsworth MT, Fichtl RE, Behta M, Raisch DW, Mendez-Rico E, Adams A, Greifer M, Bostwick S, Greenwald BM. Incidence and Impact of Adverse Drug Events in Pediatric Inpatients. *Arch Pediatr Adolesc Med.* 2003 Jan;157:60-65.



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Target Audience [back to top](#)

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Learning Objectives [back to top](#)

The Johns Hopkins University School of Medicine and The Institute for Johns Hopkins Nursing take responsibility for the content, quality, and scientific integrity of this CE activity. At the conclusion of this activity, participants should be able to:

- Develop an understanding of the impact computer technology can have on the reduction of medical errors.
- Evaluate the adequacy of your current error identification and prevention methodology.
- Determine which (if any) of the systems described would provide enough benefit to you and your patients to justify the time/money investment necessary to adopt.

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- Dr. Nogee has indicated a financial relationship of grant/research support with Forest Laboratories and has received an honorarium from Forest Laboratories.
- Dr. Lawson has indicated a financial relationship of grant/research support from the NIH. He also receives financial/material support from Nature Publishing Group as the Editor of the Journal of Perinatology.

All other faculty have indicated that they have not received financial support for consultation, research, or evaluation, nor have financial interests relevant to this e-Newsletter.

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