Impact of an Interactive Online Nursing Educational Module on Insulin Errors in Hospitalized Pediatric Patients

Short Title: Impact of Online Education on Insulin Errors

Mary M. Sullivan, RN, DNP, ANP-BC, CDE (1); Colette R. O’Brien, RN, MS, C-PNP, CDE (2); Stephen E. Gitelman, MD (2); Susan E. Shapiro, RN, PhD (1); Robert J. Rushakoff, MD (3)

1. Department of Nursing, University of California, San Francisco
2. Division of Pediatric Endocrinology, University of California, San Francisco
3. Division of Endocrinology and Metabolism, University of California, San Francisco

Corresponding Author:
Mary M. Sullivan, RN, DNP, ANP-BC, CDE
Email: mary.sullivan@ucsfmedctr.org

Additional information for this article can be found in an online appendix at http://care.diabetesjournals.org

Submitted 7 January 2010 and accepted 13 May 2010.

This is an uncopyedited electronic version of an article accepted for publication in Diabetes Care. The American Diabetes Association, publisher of Diabetes Care, is not responsible for any errors or omissions in this version of the manuscript or any version derived from it by third parties. The definitive publisher-authenticated version will be available in a future issue of Diabetes Care in print and online at http://care.diabetesjournals.org.
**Objective** - To determine effectiveness of an online module for reducing insulin administration errors by nurses caring for hospitalized pediatric patients.

**Methods** - Pediatric nursing staff completed a mandatory online training module teaching insulin pharmacokinetics; the insulin order form; using diluted insulin; and finishing with 15 interactive cases. A chart audit to determine all possible insulin errors of patients receiving insulin was done before and 2-6 months after the educational module.

**Results** - All of the medical center’s 283 pediatric nurses successfully completed the educational module. 24 charts were audited in the pre-intervention phase and 22 in the post-intervention phase. The pre-intervention insulin error rate was 14.8%, reduced to 1.7% (p < .001) post-intervention. Improvement occurred in correct insulin dosing and type, timing of administration, and timely blood glucose monitoring and documentation.

**Conclusions** - An interactive, online, nursing module can be an effective strategy for reducing pediatric nurses’ insulin administration errors.
Insulin administration errors pose a serious problem for hospitalized patients, specifically for children (1,2), and are responsible for 39% of the serious medication errors causing harm to patients (3). Insulin has a narrow therapeutic window and incorrect dosing of insulin can cause hypoglycemia, hyperglycemia, and fatalities (4-6). Children, with their developing renal and hepatic systems, limited ability to communicate, and potential needs for diluted insulin, are particularly vulnerable to medication errors (7). In response, The Joint Commission (8) has mandated that health care organizations develop strategies to manage high risk medications.

At our academic children’s hospital, a failure modes effect analysis of reported insulin errors identified knowledge deficits among nurses regarding care of the child with diabetes mellitus or hyperglycemia. A root cause analysis identified problems with insulin dosing, insulin omission, and calculating and administering a diluted dose of insulin, all due to a lack of a standardized educational process and infrequent treatment of children with diabetes. This study was conducted to evaluate the effectiveness of an educational module on reducing pediatric nurses’ insulin administration errors.

**RESEARCH DESIGN AND METHODS**

This performance improvement study used a one-group, pre- and post-intervention design at an academic 150 bed children’s hospital from February 2006 to January 2008. Institutional review board approval was obtained.

**Learning Module:** The pediatric nursing staff (see Online Appendix Table 1 for demographics) was required to complete a three part module (viewed at: http://rushakoff.com/rushakoff/rushakoff2). Section 1 provides information regarding types of diabetes; insulin pharmacokinetics; physiological insulin dosing; calculating and administering a diluted insulin dose; recognition and management of hypoglycemia; insulin pump therapy; and explains our institution’s 2-RN independent check process for high-alert medications (2 RNs independently determine insulin dose from physician order).

Section 2 provides information regarding use of the pediatric subcutaneous insulin order set, including timing of injections and glucose monitoring.

Section 3 consists of 15-questions related to interpreting insulin orders, determining the correct insulin dose, and identifying nursing actions based upon the blood glucose and carbohydrate amount. Nurses had to discern the correct answer from other plausible, but incorrect answers. For each question, if answered incorrectly, the nurse was instructed why the selected answer was incorrect and was required to try again.

**Chart Review:** This analytic sample consisted of all pediatric patients during the study periods with a diagnosis of diabetes or hyperglycemia. Patient charts were identified for audit by a pharmacy generated insulin list. All eligible charts were reviewed by two members of the study team (MMS and CRO) to identify the number of possible and actual insulin related medication errors. Using a comprehensive audit tool (Online Appendix Table 2, which is available at http://care.diabetesjournals.org) created by the research team, retrospective chart audits were conducted for a period of six months prior to implementing the module and two to six months post implementation. Inter-rater agreement was achieved through consensus. Opportunity for error was defined as each time the blood glucose should have been checked per physician order or the hypoglycemia protocol. An error was defined as any dose of insulin given or omitted that deviated from the physician order (omission...
Impact of Online Education on Insulin Errors

of an insulin dose, wrong insulin dose or type, wrong administration time, blood glucose not checked per order or hypoglycemia protocol, and blood glucose not documented in the record).

Statistical Methods: Differences in error rates were compared using a 2-tailed t-test. All analyses were done using SPSS version 16.0.

RESULTS
Patient demographics and details of insulin errors are in Table 1. One hundred percent of the children’s hospital’s registered nursing staff (n = 283) completed the educational module. Pre-intervention, 131 errors were identified out of 882 opportunities for errors. The mean number of errors per patient in this sample was 5.20. In the post-intervention sample, 19 errors were identified out of 1,119 opportunities for error. The mean number of errors per patient in this sample was 0.86 (p = .003). The number of patients experiencing insulin-related errors during their hospitalization decreased from 21 out of 24 (87.5%) in the pre-intervention phase to 5 out of 22 (22.7%) post-intervention. The overall error rate decreased from 14.8% in the pre-intervention phase to 1.7% in the post-intervention phase (p < .001). These effects were sustained over 6 months.

DISCUSSION
These findings demonstrate that an interactive, online, nursing educational module can be an effective strategy for reducing insulin administration errors in hospitalized pediatric patients. Multiple studies have found deficits in nurses’ knowledge regarding diabetes mellitus (9-11), suggesting that additional education about diabetes mellitus is needed in order for nurses to provide safe and effective care to these patients. Consistent with Philip’s (12) recommendation that educational modules provide frequent feedback to learners, our module used a self-paced technological medium that provided active learning, problem solving, and immediate feedback to the nurses. Strategies that enhanced implementation included engaging hospital administration support from the beginning of the study; recruiting nursing unit champions who took ownership of the performance improvement initiative at the unit level and acted as an educational resource for the nursing staff; and requiring that all nurses view the module.

Study limitations include limited generalizability due to a small convenience sample of pediatric nurses at a single academic medical center’s children’s hospital. Second, although the chart reviewers were not involved in the care of these patients, and so were blinded to the medication administration process and documentation, the analysis was done by the same team that collected the data, leaving the possibility of investigator bias. However, the magnitude of the difference between the pre-and post-intervention findings makes it likely that a real reduction in errors did, in fact, occur. Finally, using a retrospective chart audit to detect errors was also a limitation as it relies upon the accuracy and adequacy of nursing documentation.

In conclusion, this study presents a first attempt to evaluate an effective and feasible method of educating a large number of nurses on the correct implementation of physiologic insulin dosing for hospitalized pediatric patients. More research is needed to validate these findings, as well as to determine how to sustain and disseminate successful educational programs.

Author Contributions: M.S. designed study, collected and analyzed data, wrote edited manuscript. C.O. collected data, analyzed data and reviewed/edited manuscript. S.G. designed study, reviewed and analyzed data and reviewed/edited manuscript. S.S. assisted with study design, performed statistical analysis, and reviewed/edited
manuscript. R.R. wrote/programmed education module, designed study, reviewed/analyzed data and reviewed/edited manuscript.

ACKNOWLEDGEMENTS
This study was partially funded by a McKesson sponsored American Organization of Nurse Executives (AONE) Institute research grant for improving patient safety. This study was presented as an abstract 334-OR at the American Diabetes Association 69th Scientific Sessions.

Disclosure. Robert Rushakoff has served as a speaker for Merck, Lilly and Novo.

REFERENCES
1. Amori RE, Pittas AG, Siegel RD, Kumar S, Chen JS, Karnam S, Golden SH, Salem DM. Inpatient medical errors involving glucose-lowering medications and their impact on patients: Review of 2,598 incidents from a voluntary electronic error-reporting database. Endocr Pract. 2008;14:535-42.
2. Hicks RW, Becker SC, Cousins DD. Harmful medication errors in children: A 5-year analysis of data from the USP's MEDMARX program. J Pediatr Nurs. 2006;21:290-8.
3. Rashidee A, Hart J, Chen J, Kumar S. High-Alert Medications: Error Prevalence and Severity. Patient Safety & Quality Healthcare. 2009:July/August. Available from: http://www.psqh.com/julyaugust-2009/164-data-trends-july-august-2009.html.
4. Hellman R. A systems approach to reducing errors in insulin therapy in the inpatient setting. Endocr Pract. 2004;10 Suppl 2:100-8.
5. Hellman R, Hellman J, Rosen H. Provider error is an important cause of poor outcomes in diabetes care. Diabetes. 1999;48 (Suppl 1):A-67.
6. Bates DW. Unexpected hypoglycemia in a critically ill patient. Ann Intern Med. 2002;137:110-6.
7. Kaushal R, Jaggi T, Walsh K, Fortescue EB, Bates DW. Pediatric medication errors: What do we know? What gaps remain? Ambul Pediatr. 2004;4:73-81.
8. National patient safety | joint commission. [cited 12/30/2009]. Available from: http://www.jointcommission.org/PatientSafety/NationalPatientSafetyGoals.
9. el-Deirawi KM, Zuraikat N. Registered nurses' actual and perceived knowledge of diabetes mellitus. J Nurses Staff Dev. 2001; 17:5-11.
10. Rubin DJ, Moshang J, Jabbour SA. Diabetes knowledge: Are resident physicians and nurses adequately prepared to manage diabetes? Endocr Pract. 2007;13:17-21.
11. Thomas D. Survey reveals shortfall in paediatric nurses' knowledge of diabetes. Journal of Diabetes Nursing. 2004;8:217-21.
12. Phillips JM. Strategies for active learning in online continuing education. J Cont& Educ Nurs. 2005;36:77-83.
Table 1. Study Demographics and Insulin Errors per Patient

|                              | Pre intervention (N=24 patients) | Post Intervention (N=22 patients) |
|------------------------------|----------------------------------|-----------------------------------|
| **Mean Age year (SD)**       | 14.96 (4.4)                      | 13.68 (6.5)                       |
| **Female N (%)**             | 17 (70.8)                        | 16 (72.7)                         |
| **Mean Length of Stay in days (SD)** | 9.25 (8.7)                      | 7.0 (5.3)                         |
| **Type of Diabetes (N (%))** |                                  |                                   |
| Type 1                       | 12 (50)                          | 16 (72.7)                         |
| Type 2                       | 4 (16.6)                         | 2 (9.1)                           |
| Glucocorticoid-induced       | 5 (20.8)                         | 2 (9.1)                           |
| Cystic fibrosis related diabetes mellitus | 3 (12.5)                     | 2 (9.1)                           |
| **Used Insulin Pump in Hospital (N (%))** | 1 (4.2)                  | 5 (22.7)                          |
| **Total Possible Errors**    | 882                              | 1,119                             |
| **Total Number of Errors**   | 131                              | 19                                |
| **Mean Number of Errors/Patient (SD)** | 5.20 (6.8)                  | 0.86 (2.01)*                      |
| **Number who experienced errors (%)** | 21 (87.5)                | 5 (22.7)                          |
| **Error Rate**               | .148                             | .017 **                           |
| Missed Injection             | 32 (24.4)                        | 6 (31.5)                          |
| Wrong Dose                   | 11 (8.3)                         | 1 (5.2)                           |
| Wrong Insulin Type           | 1 (0.7)                          | 0                                 |
| Wrong Time                   | 1 (0.7)                          | 0                                 |
| **Glucose Not Tested ***     | 43 (32.8)                        | 6 (31.5)                          |
| **Glucose Not Documented *** | 43 (32.8)                        | 6 (31.5)                          |

* *p = .003  (pre to postintervention)
** *p < .001 (pre to postintervention)
*** These are not duplicates. Glucose may have been found in laboratory data, but not documented as mandated per nursing policy.