Journal of Clinical Anesthesia 49 (2018) 107–111

Contents lists available at ScienceDirect

Journal of Clinical Anesthesia

journal homepage: www.elsevier.com/locate/jclinane

Original Contribution

Medication errors in a pediatric anesthesia setting: Incidence, etiologies, and error reduction strategies

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ARTICLE INFO

Keywords:
Medication errors
Medication safety
Quality improvement

ABSTRACT

Study objective: The objective of the study was to: a) characterize the frequency, type, and outcome of anesthetic medication errors spanning an 8.5-year period, b) describe the targeted error reduction strategies and c) measure the effects, if any, of a focused, continuous, multifaceted Medication Safety Program.
Design: Retrospective analysis.
Setting: All anesthetizing locations (57).
Patients: All anesthesia patients at all Boston Children's Hospital anesthetizing locations from January 2008 to June 2016 were included.
Interventions: Medication libraries, zero-tolerance philosophy, independent verification, trainee education, standardized dosing; retrospective study.
Measurements: Number and type of medication errors.
Main results: 105 medication errors were identified among the 287,908 cases evaluated during the study period. Incorrect dose (55%) and incorrect medication (28%) were the most frequently observed errors. Beginning within 3 years of the implementation of the 2009 Medication Safety Program, the incidence declined to an average of 3.0 per 10,000 cases in the years from 2010 to 2016 (57% reduction) and declined to an average of only 2.2 per 10,000 cases since 2012 (69% reduction). Logistic regression indicated a 13% reduction per year in the odds of a medication error over the time period (odds ratio = 0.87, 95% CI: 0.79–0.95, $P = 0.004$).
Conclusions: Although medication errors persisted, there was a statistically significant reduction in errors during the study period. Formalized Medication Safety Programs should be adopted by other departments and institutions; these Programs could help prevent medication errors and decrease their overall incidence.

1. Introduction

Medical errors constitute the third leading cause of mortality in the United States [1] and medication complications are implicated most commonly in adverse medical events (19.4% of all events) [2]. Combatting anesthetic medication errors poses distinct challenges; especially in the pediatric population; generally accepted anesthesia practice is devoid of many of the checks and balances present in other parts of the hospital. Anesthesia providers are the only health care team members that are routinely responsible for the entire medication administration process, potentially associated with 40 component steps [3]: diagnosing the problem; deciding on the appropriate therapy; selecting the drug, dose, time, and route of administration; procuring the medication and ultimately administering the medication. These decisions need to be made rapidly by clinicians that are often multi-tasking, stressed and sometimes fatigued [4,5].

Pediatric patients compound the risks for, and consequences of, anesthesia medication errors. Pediatric doses are weight-based and require careful calculation. Additionally, patient maturity may affect medication clearance and, thus, amplify the effect of inappropriate dosing [6]. Despite considerable advances in technology and patient safety initiatives, accurately assessing the frequency of medication errors remains difficult [7–17]. Reported anesthesia-related medication errors persist at rates ranging widely from 0.0075% to 4.17% [7–17]. The Department of Anesthesiology, Critical Care and Pain Medicine, like WakeUp Safe, identified prevention of medication errors as a high priority patient safety initiative. The WakeUp Safe Quality Improvement Initiative recently published an analysis of six years of data concerning medication errors reported to their database. This report was able to examine the patterns of medication errors during the

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https://doi.org/10.1016/j.jclinane.2018.05.011
Received 15 March 2018; Received in revised form 3 May 2018; Accepted 18 May 2018

perioperative period and to suggest targeted interventions that might address the identified patterns of medication errors. During this same time period the Department of Anesthesiology, Critical Care and Pain Medicine at Boston Children's Hospital was a contributing member to this database and actually incorporated many of the suggested interventions [18].

The objective of this study is to: (1) identify the type, severity and frequency of medication errors from 2008 to 2016 (2) assess the etiologies of medication errors and describe the execution of error reduction strategies (3) observe trends related to the focused, multifaceted Medication Safety Program that occurred during the study period. While this is not designed to determine which, and to what extent, the initiatives and policies implemented under the Medication Safety Program impact the rate of medication errors, it is hypothesized that a decrease in the frequency of errors will be observed.

2. Methods

2.1. Study population

After obtaining approval by the Institutional Review Board (IRB), all medication errors that occurred in all anesthetizing locations by the Department of Anesthesiology, Critical Care and Pain Medicine between January 2008 and June 2016 were analyzed. The data from January 2008 through June 2012 was acquired from manual chart reviews conducted by a Registered Nurse, who is also the Department's Quality Improvement Manager and the Boston Children's Hospital's Safety Event Reporting System (SERS), which can be used by any employee to report any event. The charts were reviewed to identify all possible anesthesia complications including medication errors. The criteria for determining the presence of a medication error was as follows: the incorrect dose, medication and/or route, and possible medication related adverse events. From July 2012 through June 2016, medication errors were self-reported via an electronic quality improvement dashboard and SERS reports (N = 287,908 cases).

2.2. Study design

In 2008, the Department implemented a systematic data collection database to capture reported medication errors: self-reported, SERS reports, or discovered via manual chart review of every anesthesia record. The questionnaire utilized by the WakeUpSafe (WUS) national registry was used as a basis for the root cause analysis conducted for every medication error. Medication route, outcome (Table 1), intervention, time of error, and rank of the staff responsible for the error were also recorded.

In addition to data collection, all medication errors were reviewed and categorized by the Department's Perioperative Systems Improvement (PSI) Committee based on error type, severity, preventability, accountability, and potential systems-level issues. PSI is composed of Department attending physicians, CRNAs, fellows, and the Department's Executive Director and QI Manager. Using the WUS root cause analysis tool, each incident was independently reviewed by three clinical committee members. These members then presented the case for discussion and final categorization. Recommendations for process changes, if any, were made at this time. Event ratings were then averaged and input into the Department's clinical adverse events tracking database. These entries were the basis of this analysis.

Table 1
Medication error outcomes: definitions.

Term	Definition
Outcome 1	Recovered without intervention or sequelae
Outcome 2	Recovered with intervention, without sequelae
Outcome 3	Recovered with transient sequelae
Outcome 4	Recovered with permanent sequelae
Outcome 5	Not recovered

The data were analyzed based on the personnel involved in the errors, classified as either “primary anesthesia provider” or “trainee”. Primary anesthesia providers were defined as attending anesthesiologists and CRNAs. Trainees included fellows, residents, Student Nurse Anesthetists (SRNAs), and non-anesthesia rotators.

During the study timeframe, a number of specific interventions were devised and implemented by the Department, and consequently, reviewed and analyzed in this study. These interventions include:

- 2009: Implementation of the Medication Safety Program to promote reporting and reduction of medication errors with an emphasis of medication errors at Morbidity and Mortality conferences, staff meetings and Grand Rounds.
- 2010: Installation of a custom built pediatric anesthesia drug library for medication infusion pumps. These pumps include extensive libraries with suggested dose ranges and forcing functions to double check the patient's weight and appropriate dosages. When an out-of-range dose is programmed into the pump, the anesthesiologist needs to confirm that the dosage is as intended.
- 2010: Increased pharmacy support with standardization of drug dilutions, premixed antibiotics, and prefilled syringes of commonly used medications introduced successively during the study period.
- 2011: Initiation of Medical Administration for Anesthesia Providers Policy, which requires anesthesia providers drawing up or administering medications to have a second clinical provider, an MD, CRNA, RN, or NP, perform an independent confirmation of the patient, medication, dose, time and route. Table 2 includes the frequently used anesthesia medications that are *exempt* from this policy to preserve anesthesia workflow. Only medications listed in the table, as well as prefilled pharmacy syringes, are exempt from this policy, although exceptions are made for medications used in clinical emergencies.
- 2013: Implementation of Zero-tolerance philosophy for all medication errors; this was deemed necessary to help enforce the Department's philosophy that “production pressure” will not be tolerated as an excuse for not taking the time to “do it right”. If after a Root Cause Analysis it is determined that the Department's Medication Administration for Anesthesia Providers Policy was deliberately disregarded, the practitioners involved in the incident would meet with the Anesthesiologist-in-Chief to review the circumstances of the incident.

2.3. Statistical analysis

Analysis of findings included a descriptive summary of all medication error types with cross-sectional and longitudinal analysis of patient outcome variables, where the investigation team assessed whether the incidence of medication errors has changed over the time period from 2009 through 2016. A logistic regression-based strategy was applied to assess the event frequency throughout the study period and to compare the incidence (per 10,000 cases) before and after initiation of the protocol in 2009 (reference year) [19]. In addition, a bivariate logit model with year as a continuous independent covariate was performed to estimate the year-to-year reduction in the odds of a medication error over the time period. The Wald test was used to assess significance of changes in the incidence of medication errors over time and 95% confidence intervals for incidence of medication errors were derived using Wilson's method [20]. Two-tailed $P < 0.05$ was considered statistically significant. Statistical analysis was performed using IBM SPSS Statistics (version 23.0, IBM Corporation, Armonk, NY).

3. Results

After the elimination of nine events in which a patient experienced