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Original Contribution

Anesthesiologists' ability in calculating weight-based concentrations for pediatric drug infusions: an observational study☆

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Abstract

Study Objectives: To assess the ability of anesthesiologists to calculate weight-specific drug concentrations for continuous drug administration in children, and to evaluate the acceptance of an inhouse-developed, computer-based application for calculating drug infusions for pediatric cardiac surgery.

Design: Observational study.

Setting: Anesthesiology department of a tertiary-care medical center in Israel.

Participants: 45 anesthesiology department staff members (attendings and residents).

Measurements: Anesthesiologists were asked to calculate the weight-based amount of drug and the corresponding amount in mL to be drawn from a standard vial and added to a 50-mL syringe in order to reach an infusion rate, where 1 mL/hr corresponds to 1 $\mu g \times kg^{-1} \times min^{-1}$. The time it took to reach the result was measured. Staff members were also asked to rate the user-friendliness and usability of the program.

Main Results: 41 of the original 42 participants returned the completed questionnaire. Only 6 (15%) of 41 anesthesiologists provided all the correct answers. The mean calculation time required was 205 (±53) seconds. There was no difference in success rate between attendings and residents. Incorrect calculations ranged from a drug concentration 50 times too low up to 56 times too high. Most staff members believed that the computer-based application to perform these calculations reduced errors (65%) and workload (81%), and improved patient treatment (71%). This application was rated as very user-friendly.

Conclusions: Anesthesiologists have difficulty calculating pediatric drug concentrations for continuous drug infusions. The correct calculations are time-consuming. Incorrect calculations may lead to dangerously high or low doses. A computer-based application to calculate drug concentrations was rated as very useful and user-friendly.

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1. Introduction

Iatrogenic events occur frequently in hospitalized patients and may result in serious adverse outcomes [1]. Medication errors are among the major causes of such events [2] with intravenous (IV) drug administration at greatest risk for errors [3]. There is almost a 50% error rate in IV drug administration, with 1% of these errors being potentially severe [4].

Children are at especially high risk for medication errors [5,6]. As pediatric doses are strictly weight or surface area-based and the therapeutic ranges are much narrower, erroneous calculations have more serious side effects than in adults [7]. Most drugs administered intravenously to children have to be diluted from vials with adult doses [7], which easily leads to tenfold [8] or hundredfold (if drug is not diluted correctly) drug dosing errors.

Anesthesiologists are among the only physicians who themselves prescribe, prepare and administer potent drugs to patients in critical situations without double checking with another medical practitioner [2,9]. Drug error administration is reported to occur in up to one of every 133 anesthetics [10], and may be even more frequent for anesthesiologists who are not familiar with pediatric dosing.

The goal of the present study was 1) to evaluate the accuracy and time required for anesthesiologists to calculate pediatric weight-specific concentrations for continuous drug infusions of dopamine, and 2) to perform a survey to assess the user-friendliness and general acceptance of a computer-based application we developed to calculate the amount of drug and the volume to be withdrawn from the drug vial to prepare weight-based infusions for various drugs for pediatric anesthesia.

2. Materials and methods

The study was approved by the Institutional Review Board of the Hadassah Medical Organization. Staff members could refuse to participate in the study. All data were processed anonymously.

2.1. Calculations to prepare syringe for weight-based infusion

Anesthesiologists were asked to calculate the milligram dose of dopamine that should be added to normal saline for a final volume of 50 mL such that a 1 mL/hr infusion rate corresponds to a dose of 1 μg x kg^{-1} x min^{-1}. Anesthesiologists were also asked to calculate the number of milliliters to be withdrawn from a standard dopamine vial (40 mg/mL) to obtain the correct concentration. A record was made of whether the results were correct (mg of dopamine and mL of dopamine solution). The time (measured in seconds using a stopwatch) needed to perform the calculations also was recorded. Study participants were allowed to use pen and paper (provided) and calculators (available in cellular phones carried by all staff members) to perform the calculations.

2.2. User-friendliness and general acceptance of a computer-based calculation application

We developed a Microsoft Excel 2003 (Microsoft, Redmond, WA, USA) spreadsheet application (Fig. 1) that performs the calculations of how many mg of drug have to be added to normal saline to fill a 50 mL syringe to reach a specific weight-based infusion rate (eg, 1 mL/hr corresponds to 1 μg x kg^{-1} x min^{-1}, 20 μg x kg^{-1} x min^{-1}, or 0.05 μg x kg^{-1} x min^{-1}). In addition, the exact amount (mL) of solution to be drawn from the specific drug vial is calculated. These calculations are made instantaneously and simultaneously for 14 different drugs.

This Microsoft Excel spreadsheet was installed on the computers in the operating rooms and was also made available on the hospital Intranet[1]. The webpage was also made accessible directly through the hospital's anesthesia information management system (Metavision; iMDsoft, Tel-Aviv, Israel).

A questionnaire on user-friendliness and usability of the computer program was distributed to all anesthesiologists. The questionnaire included questions with yes/no answers and Likert scales (5=excellent/very much, 1=bad/not at all) (Appendix 1).

2.3. Statistical analysis

The proportion of correct answers for the dose calculation was compared for residents and attendings, as was the mean time taken to complete the calculation. Data were calculated as means (SD). Proportions were compared using chi-squared tests and continuous data using the two-tailed Student's t-test. Statistical calculations were performed with Microsoft Excel 2003 (Microsoft, Redmond, WA). A P-value of < 0.05 was defined as statistically significant.

3. Results

3.1. Dose calculations

For the dose calculation quiz, 47 anesthesiologists (19 (40%) attendings and 28 (60%) residents) were approached. All of the residents initially agreed to participate; one (3%) did not complete the questionnaire and one (3%) refused to

[1] http://www.dripomat.info/version1. Functional only on a computer with Microsoft Office software installed and Microsoft Internet Explorer. To overcome this drawback, a purely web-based version of the program (based on Microsoft.NET technology, functional in all browsers and on smartphones and tablets also) was introduced later. (http://www.dripomat.info). This version also allows changing of syringe sizes, infusion rates, doses, and drug vial concentrations. Both versions are available online for demonstration purposes only and are noncommercial.