Preventing pediatric medication errors: Testing the iDoseCheck

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Abstract

Objective: Dosing errors are the most common type of pediatric medication errors, with morphine being the high alert drug most commonly given in error. The independent double-check is used to avoid dosing errors but fails to detect between 5% and 20% of errors. The iDoseCheck, a graphic computer application, was created to aid nurses in the calculation and verification tasks of the independent double check. The purpose of this study was to test the iDoseCheck in a pediatric emergency department and post-surgical care unit, by comparing nurses’ perceptions on the use of the application before and after its deployment.

Methods: The study used a mixed-methods pre and post design and employed both qualitative and quantitative measures.

Results: Pre and post system usability scores were 88.4 and 88.1 respectively, corresponding to an A+ grade for usability. Pre and post scores regarding dose calculation confidence, preference and helpfulness of the iDoseCheck showed significantly higher scores for the application than for the conventional method. Focus groups participants noted that the iDoseCheck was easy to use, visually appealing, and conveyed an appropriate amount of information. Nurses endorsed iDoseCheck as essential for doing calculations in time sensitive and stressful situations such as resuscitation.

Conclusions: This proof of concept research indicated that iDoseCheck is easy to learn, simple to use and provides nurses with sound technologic support for the independent double check. This support has the potential to decrease wrong dose medication errors and save lives.
Introduction

Medication errors are the most frequent type of errors in hospital settings and are potentially more harmful and have a higher incidence rate in pediatric than in adult populations\(^1\). Combined adverse events and medication errors can be three times higher in pediatric than in adult populations\(^2,3\). The American Pediatric Association has identified incorrect dosing as the most commonly reported medication error in pediatrics\(^4\). Calculation errors represent between 6% and 15% of reported pediatric drug errors, including 5 to 10 fold over-doses\(^5\), with over-dose errors being more pervasive than under-dose errors. A recent review of the nursing literature on factors contributing to medication errors\(^6\) identified deviations from procedures, including distractions during administration, excessive workloads and limited knowledge of medications. More specifically, a fast-paced health care environment can be the source of numerous distractions and interruptions, demanding from nurses constant multitasking, both in action and thought, during the process of medication preparation and administration\(^7\).

Although some reject the notion of a relationship between medication calculation errors and nurses’ deficits in their mathematical skills arguing that research has focused on nursing students rather than on practicing nurses in real life settings\(^8\), there is some evidence indicating that such a relationship does exist\(^9,10\). As described by Shanks and Enlow\(^11\), in a study of Finish nurses testing their mathematical and dosage calculation skills only 17% were able to make the calculations without error\(^12\). Similarly, results from research analyzing the relationship between nurses’ scores from a calculations test during their initial orientation and their later record of medication errors over a three year period, identified that two-thirds of nurses who failed the test made at least one medication error during the study period, compared to half of the nurses with passing grades\(^13\).
Medication type, especially in pediatric settings, can be an additional factor contributing to medication errors. Drugs acting on the nervous system, opioids and sedatives in particular, are those most frequently associated with medication errors in children\textsuperscript{14}, with morphine being the high alert drug most commonly related to pediatric drug errors\textsuperscript{15,16}. Drug dosing for children is weight-based and can be complex due to the calculations involved and the weight variability which can range from 0.5 kg for a premature newborn to over 100 kg for an obese adolescent\textsuperscript{4}. The accuracy of the dose calculations are essential, particularly in the case of high alert drugs, since they carry elevated error risk for causing significant harm\textsuperscript{17}.

The independent double check has been used as a method that can effectively identify and avoid medication errors at the point of care\textsuperscript{18}. It is a process whereby two nurses independently verify the patient, medication, drug concentration, drug, dose, time and route\textsuperscript{19}. However, it has limitations. Research indicates that it fails to detect between 5\% to 10\% of errors under ideal conditions\textsuperscript{20}, up to 20\% under moderate stress circumstances\textsuperscript{21,22}, in addition to being subject to process variations and not always being carried out independently\textsuperscript{23,24}. In light of such limitations, iDoseCheck, a graphic computer application developed by an interprofessional collaboration, was created to aid nurses in the calculation and verification tasks of the independent double check for the administration of intravenous morphine to children\textsuperscript{25}. When tested in a simulation study by comparing it against the traditional paper/pencil and calculator (PPC) dose calculation method, the iDoseCheck proved to be safe and effective. Its usability score was significantly higher (91.1) than the comparison benchmark value (68) and participants preferred it over and felt more confident with it than with the PPC procedure\textsuperscript{25}. The purpose of this study was to test the iDoseCheck in a pediatric emergency department and post-surgical care
unit, by comparing nurses’ perceptions on the use of the application before and after its deployment.

Methods

Design

The study used a mixed-methods pre and post design and employed both qualitative and quantitative measures.

Measures and Procedures

System Usability Scale (SUS)

The SUS is a 10-item scale that assesses subjective perception of usability\textsuperscript{26}. Questions address two key components: Usability and Learnability. Items are scored on a 5 point Likert scale with descriptors strongly disagree and strongly agree. The scores for each question are multiplied by 2.5 and final SUS score can range from 0 to 100, where higher scores indicate better usability. The SUS has good face validity and correlates highly (Cronbach’s alpha 0.91) with longer usability scales\textsuperscript{27,28}.

Perceived helpfulness of iDoseCheck features

A subjective measure of perceived helpfulness of the visual aids, features and functions of iDoseCheck was developed by the study authors. The questions addressed specific features and functions of iDoseCheck on 5-point Likert scale that ranged from 1 (not helpful) to 5 (very helpful). Participants were asked to respond to 5 questions about the helpfulness of visual aids such as the height of the patient, standard dose scale, written calculation, error warnings, and images of the vial(s) and syringe. Two questions about ease of error recovery and iDoseCheck as an accurate method to prepare IV bolus morphine were also scored on a 1 to 5 scale.

Confidence
Participants’ confidence in the accuracy of drug dose calculations and preparation was measured with a 6-item questionnaire. Responses were on a 5-point Likert scale and ranged from strongly disagree to strongly agree.

Preference

Preference for iDoseCheck or paper and pencil/calculator were ascertained with a 5 item questionnaire that focused on support for dose calculations specifically and support for the double check generally, speed, accuracy, and error detection. The response scale was coded 1 (preference for PPC), to 5 (preference for iDoseCheck).

Procedures

The study protocol received ethics approval from both the study hospital and the associated university. During the baseline period nurses were introduced to the study aims and trained to use iDoseCheck during group or individual sessions. Training for iDoseCheck consisted of a series of hands-on demonstrations calculating simulated drug doses. Immediately after the training session each nurse completed the evaluation questionnaires. When 80% of nurses were trained to use iDoseCheck the intervention period began. iDoseCheck was strategically placed on a desktop or laptop computer such that it was readily available to nurses doing an independent double check prior to administering a dose of IV bolus morphine. During the intervention period, the nurse checking the morphine dose used iDoseCheck and the nurse administering the dose used the standard paper and pencil/calculator method (PPC). This ensured that the conventional PPC method was available for each double check thus mitigating any risks associated with iDoseCheck, which is considered to be a practice change. There was no change to the other components of the double check and nurses worked independently as per usual routine and policy. The study was stopped after 100 doses of morphine were administered on
each patient care unit (emergency department and post-surgical care unit) and nurses completed the same questionnaires that were administered pre-intervention.

Five focus groups with nurses from both units where iDoseCheck was used took place once the intervention had finished. They explored nurses’ views on what they perceived as challenges and opportunities when using the application, on further refinements and developments for iDoseCheck, and on whether it could potentially contribute towards risk reduction in morphine administration in nursing practice.

Setting

The study took place in a 165-bed tertiary care pediatric hospital in eastern Ontario. Data collection occurred on a 27-bed post-surgical care unit and a 40-bed Emergency Department, reporting around 66,000 visits per year.

Results

Demographics. Ninety-three nurses answered the pre-questionnaire, 59 (63%) were full time and 29 (31%) were part time employees. Twelve (13%) nurses were in their first year of practice, 41 (44%) nurses had between two and 10 years of experience and 39 (42%) nurses had more than 11 years of experience in pediatric nursing. Fifty nurses answered the post questionnaire, 28 (56%) were full time and 21 (41%) were part-time employees. Seven (14%) nurses were in their first year of practice, 25 (50%) nurses had between two and ten years of experience, 17 (34%) nurses had more than 11 years of experience in pediatric nursing.

System Usability Scale (SUS). The pre-intervention mean SUS score was 88.4 (n = 93, SD = 11.8) with a corresponding 95% confidence interval (CI) [86.0, 90.8]. This places the usability score firmly in the A+ letter grade range designated by Sauro. Furthermore, it means
the application has a higher SUS score than 98% to 99% of other applications. The post-intervention SUS scores were similar. The mean was 88.1 (n = 49, SD = 11.4) with a corresponding 95% CI [84.8, 91.4].

**Confidence.** Each question for the confidence rating was analyzed independently using a one-sample t-test against a neutral value of 3. Both pre and post intervention, the questions scored significantly higher than the neutral value of 3, p = < .01 (Table 1.). As such, participants were confident (1) using the iDoseCheck to calculate the dose, (2) that the calculations obtained were accurate given the patient weight, (3) that the correct morphine volume was calculated, (4) that they were able to perform the double check with a colleague using the conventional method, (5) that the dose was within a standard range for the patient, and (6) that they were able to perform each calculation without hesitation.

When iDoseCheck was compared post-intervention to the paper/pencil/calculator method, there was no significant difference for four out of the six confidence items (Table 2.). For items on dose accuracy and on the dose being within range (not an over or under dose) iDoseCheck had significantly higher confidence ratings than the conventional method, p = < .05.

**Preference.** For both the pre and post intervention there was a significant preference for using iDoseCheck, p = < .01. (Table 3.) In each case, participants preferred iDoseCheck for (1) the general support in dosage calculations, (2) the speed at which the calculations could be performed, (3) the accuracy of the dose calculations, (4) the support in detecting dose errors, and (5) for support while performing the double check.

**Helpfulness Evaluation of Interface Components.** Interface component evaluation questions were analyzed against a benchmark value of 1 (not helpful). Pre and post intervention,
all questions scored significantly higher than the benchmark, \( p = < .01 \) (Table 4.) As such, participants found all interface components helpful including the (1) patient image, (2) standard dose scale, (3) dose calculation presented, (4) vial and syringe image, and (5) the under-dosing/over-dosing warning messages. In addition, it was also found that the application (6) was easy to recover from errors, and (7) it was perceived as an accurate method to prepare IV bolus morphine.

**Focus Groups.** Focus group participants examined reactions to iDoseCheck, specifically, the facilitators, barriers, and potential improvements to the tool. Focus groups were audio-recorded and transcribed verbatim. An inductive-deductive approach\(^30\) was used to analyse the data.

**Facilitators.** Nurses indicated that iDoseCheck was easy to use, visually appealing, and conveyed an appropriate amount of information. Nurses appreciated that the interface and navigation was intuitive and all necessary information was on one screen. As one participant indicated “It is not busy. It is very clean and easy to read, you are not bombarded with a thousand extra things that you are trying to read through.” Participants expressed appreciation for the graphics and visual elements of iDoseCheck user interface. Many indicated that the interface visuals such as the image of the ampoule, syringe, the size image, the calculation range and the actual calculation served as important cues for them in their practice. “I find the ampule is a very good image because you can see how many to take out in order to decrease errors.” “I like having the picture of the syringe and how much to pull up, it is like an extra set of eyes to show it is right.”

**Barriers.** Frequently, nurses mentioned the location of iDoseCheck as a primary barrier to consistent and efficient uptake. It was located in the medication room which was described as a
busy enclosed space and computers with iDoseCheck installed were hard to come by. Some nurses indicated that there were many practice changes being implemented in their departments, leaving the iDoseCheck to fight for staff attention and location. “Honestly, I think it is an excellent program but with everything in that med room right now, the med dispensing cabinets and everyone in line for that and people would have to be in line for iDoseCheck, I think there is just too much going on in that one area.”

A small number of nurses indicated concern about relying on a computer to do calculations, thus losing the ability to perform this skill without the computer. “For junior staff, a nurse with little experience may rely on it too much,…and they would not gain the experience of doing their own checks—that could be happening.” To a lesser extent, some nurses saw the potential for technical failures on the computer equipment.

*Improvements.* Though nurses generally valued the iDoseCheck interface they did offer suggestions that would improve the utility and efficiency of the tool. The ‘clear’ button was not well used and could be deleted or moved to a more prominent location. Nurses indicated they would like information about how to dilute the drug and how fast to push it. They did not want to access the drug manual for this information and felt it could be a ‘pop-up’ message at the bottom of the screen.

Accessibility was consistently cited by nurses as a factor that would improve the use of iDoseCheck in their departments. This included improved access to computers, more computers, better location of computers, and greater integration with other electronic devices and software. The ideal solution for many nurses was to create iDoseCheck for mobile devices or integrate iDoseCheck into the medication dispensing cabinet or into the electronic health record for
comprehensive functionality. Specifically in terms of awareness, one nurse suggested prompts in their new medication cabinet to instruct users not to forget about iDoseCheck.

Nurses highly endorsed the usefulness of iDoseCheck and suggested many other drugs which they felt should be included. High alert drugs such as opioids were first and foremost, however, antibiotics, and resuscitation drugs were also suggested. “Antibiotics, we give so many that we do not necessarily know the parameters for all of them and we do not have the time, to be honest, to go look up everything.” Regarding potential use in a pediatric resuscitation, one nurse stated “Yes, trying to do all of the math and everyone is basically yelling at you for the meds. Having the iDoseCheck and knowing that you have that double check as you are drawing up five or six meds at the same time would be so much easier.”

Conclusion

This proof of concept research indicated that iDoseCheck is easy to learn, simple to use and provides nurses with sound technologic support for the independent double check. This support has the potential to decrease wrong dose medication errors and save lives. Currently iDoseCheck-Morphine is accessed via a web link (www.idosecheck.com), however, nurses indicated that it is critical to have flexible access and the tool should be available at the point-of-care. For example, during resuscitation drugs are typically prepared and double-checked at the patient’s bedside. Depending on hospital context, there may not be easy access to a computer or to the web. Having iDoseCheck on a mobile device would enable nurses refer to the double-check information at the time of drug administration.

Next Steps. Consultation with nurses, pharmacists and physicians is currently underway to determine the drugs, features and platforms that will best serve the needs of healthcare
professionals that provide pediatric care. Of particular concern and interest are the needs of healthcare professionals in community hospitals that provide substantial pediatric care but do not have the same comfort with and knowledge of pediatric medications.
Reference List


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