Addressing Risk Factors in Morphine Administration: A Collaborative Prototyping Approach

Catherine Campbell1,2, Avi Parush2, Thomas Garvey2, Jacqueline Ellis1,3, Régis Vaillancourt1, Daniel Lebreux1
1Children’s Hospital of Eastern Ontario, 2Carleton University, 3University of Ottawa
Ottawa, Ontario, Canada

Morphine is a high alert medication that has the potential to cause harm particularly to young patients and has been associated with medication errors. A prospective study of intravenous morphine use on a pediatric surgical unit indicated that many of the top risk contributing factors were related to medication preparation and tools and equipment in the medication room. Cross-functional-collaborative-prototyping (CFCPing) was used to engage multiple disciplines and professions in the development of solutions to address identified risk factors and improve patient safety and nursing work life. Positive feedback from participants suggests this method could be used to address other interprofessional challenges faced by healthcare institutions.

INTRODUCTION

Medication error is a well-recognized problem. There is evidence that potentially harmful medication errors may be three times more common in the pediatric population than in adults (Kaushal et al., 2001; Ghaleb et al., 2006). Systematic review of the literature suggests that dosing errors are probably the most common type of error in the pediatric population and 10-fold overdoses caused by calculation errors have led to serious consequences (Wong et al., 2004). An analysis of more than 4000 pediatric incidents reported across 11 hospitals highlighted morphine as most frequently causing harm as a consequence of medication error (ISMP, 2009). In 2008, Parshuram and colleagues found that errors of the greatest magnitude were made when morphine infusions were prepared from small volumes of stock solutions.

Morphine is a high alert medication commonly prescribed for pain management in perioperative settings. As a high alert medication it bears a heightened risk of causing significant patient harm when used in error (ISMP, 2011). For pediatric patients, morphine dose calculation is based on a patient’s weight. Therefore doses are patient-specific and, when delivered intravenously, often prepared by extracting a specific amount from standard-volume stock solutions. Thus the opportunity for dosing error is arguably higher in a pediatric setting where patient ages and weights can vary greatly.

In an effort to ensure prescribed doses are appropriate for individual patients, pharmacists verify physician orders before they appear on a patient’s medication administration record (MAR). Nursing staff responsible for preparing and administering high-alert medication are also required to ask a colleague to perform a double check of the dose calculation and five rights (right patient, right medication, right dose, right time, right route) prior to medication administration (ISMP, 2005). Despite the implementation of these protocols and procedures medication errors continue to be reported.

BACKGROUND

In 2009, a prospective study of “as needed” or PRN (pro-re nata) intravenous morphine use on a pediatric surgical unit identified 68 different factors that could potentially contribute to medication error (Parush et al., 2010). Identified factors included environmental conditions, equipment and tools, operating characteristics and organization and social factors. Risk ranking by subject matter experts led to the assignment of a priority number (P) to each risk factor (Campbell et al., 2010). The top 18 risk factors are presented in Table 1.

Table 1: Top risk factors associated with PRN IV morphine

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<th>The Top Five Influencing Factors</th>
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<td>P1. Nurse does not take MAR/Order into the patient room</td>
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<td>P2. Multi-tasking, especially during drug preparation</td>
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<td>P3. Rushing (affects all phases of preparation, administration, follow-up)</td>
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<td>P4. Unrelated conversation during drug preparation</td>
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<td>P5. Fatigue related to lack of sleep or workload and missing regular breaks (affects all phases of preparation, administration, follow-up)</td>
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<td>P6. Interruptions by another staff member (mostly during drug preparation)</td>
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<td>P7. Unexpected events such as new admission or patient in pain leading to unplanned vs scheduled pain management</td>
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<td>P8. ID bracelet not on patient (affects verification of 5-rights at the bedside)</td>
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<td>P9. Discontinuity in the preparation process, such as one nurse leaving and another taking over during drug preparation or post-administration monitoring</td>
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<td>P10. Wall clock in PR not easy to see (from bedside)</td>
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<td>P11. Elevated (potentially distracting) noise in medication room</td>
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<td>P12. Information display design issues such as a requirement for double data entry or availability of information e.g. trouble finding information (MAR, White sheet, Black binder, etc.)</td>
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<td>P13. Nurse is asked to give morphine to another nurse’s patient (unexpected event #7)</td>
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<td>P14. Potential distractions due to shared workspace - e.g. multiple nurses preparing in the medication room/narcotic prep area</td>
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<td>P15. Choosing to double check vs. independent double check</td>
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<td>P16. Can’t find calculator in MR</td>
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<td>P17. Verbal miscommunication/misunderstanding</td>
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<td>P18. Asking other staff to help with patient care activities (too busy)</td>
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= Related to medication preparation in the medication room

Two thirds of the top-ranked risk factors are related to medication preparation and tools and equipment in the medication room (P2-P6, P9, P11, P12, P14-P17).

As medication delivery involves multiple disciplines within the hospital, the development of tangible solutions required involvement of professionals with a variety of
knowledge backgrounds, perspectives and expertise. A participatory approach was selected, engaging front line nurses, pharmacists, pharmacy technicians and industrial designers in collaborative design development.

While there are many advantages to bringing end users and professionals from different disciplines together in this type of activity, namely the joining of diverse pools of knowledge, there are also challenges generated by the inherent difference in perspectives and language used. As noted by Goldschmidt (2007, p43) developing shared mental models across team members in the early, conceptual phase of the design process is both difficult to achieve and critical to successful design development.

A significant amount of literature supports the use of prototyping as a means to support communication across disciplines during collaborative design activities (see Carlile, 2002; Hoonhout, 2007; Muller, 1992, Muller, 2003, Sanders & Stappers 2008, Schrange, 2000). Carlile (2002) recognizes prototypes as boundary objects that support the transfer, translation and transformation of knowledge that is required for innovation. As tangible visual representations of an idea or concept, prototypes can become a common language across disciplines that might otherwise experience debilitating misunderstandings stemming from differences in terminology and lack of shared understanding.

Cross-functional-collaborative-prototyping (CFCPing) (Chung, 2009) is a method of engaging professionals from different disciplines in collaborative design development. It uses prototyping as a tool to support communication, collaboration and innovation in an interdisciplinary setting and is intended for application in the early, conceptual phase of the design process. As such, it seemed an appropriate method to support development of new ways of storing and preparing medication on the surgical unit.

The following collaborative prototyping method is summarized from Campbell et al (in press), which reports on interdisciplinary interactions during the collaborative sessions and how prototyping was observed to support collaboration and concept development in this context. Additional details on the conduct of the sessions can be found in Campbell (2010). Here the use of CFCPing is explored as a means to develop solution concepts addressing morphine safety risk contributors by involving front-line staff very early in the design process. Analysis of solution concepts and feedback from participants is used to evaluate the utility of the sessions.

METHODS

Cross-Functional Collaborative Prototyping

Two 2.5 hour collaborative concept development sessions were conducted with surgical unit nurses, pediatric pharmacists, pharmacy technicians and professional product designers from industry. The stated objective was to develop concepts for new systems and tools that will improve narcotic storage and preparation on the surgical unit. Participants were asked to focus on addressing the top risk contributors identified as: interruptions and distractions during drug preparation, information display design, data entry design, and workflow.

At the beginning of each session, participants were introduced to the problem and method of CFCPing and then divided into small interdisciplinary teams. Each team of three to five participants was asked to brainstorm ideas, develop concepts and build rough mock-ups of their recommended solutions. Following Muller (1992) and Chung (2009), low-fidelity prototyping materials were provided, including cardboard sheets, Styrofoam, modeling clay, scissors, markers and masking tape, all of which are easy to manipulate so that non-designers would feel comfortable working with them.

The small interdisciplinary teams focused on brainstorming for approximately 20 minutes, after which they came back together to share ideas with the other groups. During the second breakout session small group work focused on concept development. This lasted approximately 40 minutes during which participants were asked to develop their solutions and test ideas using the prototyping materials provided. Participants were encouraged to generate visual representations of their ideas as they progressed from brainstorming to concept development and finished mock-ups. At the end of the session, each team presented their final concepts followed by a large group discussion of the presented solutions.

All sessions were video recorded and the sketches and mockups generated by each small group were collected for future reference and analysis.

Qualitative Analysis of Video

Qualitative analysis, including systematic observation of video recordings (Bakeman & Gottman, 1997), was used to extract solution ideas and concepts. This data was analyzed to identify themes across ideas and solutions generated by each small group. Solution ideas and concepts were then evaluated to determine the extent to which identified risk factors had been addressed.

For the purpose of this study, an idea was considered to be a specific design characteristic, for example: wall-mounted computer screens, or an isolated narcotic storage and preparation area. A concept represented a group of related ideas, such as “zoning”. During the collaborative sessions the term “zoning” was used explicitly by some groups and implicitly by others when articulating concepts related to the task-based organization, isolation, and workspace design ideas intended to support individual concentration and reduce opportunities for interruption and distraction during the preparation of IV bolus morphine. A theme was used to represent related concepts and ideas across groups.

Feedback Questionnaires

A feedback questionnaire was distributed at the end of each session to evaluate participant’s perception of the use of prototypes to develop solution concepts, and their overall impression and perceived value of the session. The questionnaire consisted of 19 questions. The majority were rated on a Likert scale of 1 to 5, where 1 was very negative
and 5 was very positive in relation to the question. The overall questionnaire response rate was 84% (n=22).

RESULTS

Six solution concepts designed to improve medication management on the surgical unit were developed during the collaborative sessions. Each included mock-ups of design concepts and explanations of new workflows. A total of 132 ideas were generated across the six groups with some overlap between groups. Analysis of identified solution ideas and concepts revealed that 16 of the top 18 risk-contributing factors had been addressed. Sorting and grouping of related ideas and concepts revealed three major themes in the solutions generated by participants: integration of technology, work space design, and workflow design. The relationship between solution concepts generated during the collaborative sessions and the previously identified top priority risk contributing factors is presented in Table 2.

Integration of Technology

Integration of technology was a major theme in both collaborative sessions. Design concepts including computer-supported work through integrated information systems, supported double-checking, unit dose dispensing and automated dispensing cabinets. These solutions were designed to mitigate top risk contributors by reducing cognitive load, supporting improved workflow and efficiency and ensuring the Five Rights of medication delivery.

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Information systems. Information systems solutions included:

- Computer access at all workstations for information retrieval and documentation, replacing existing paper based documentation systems.
- RFID/bar-code scanning to automate documentation and support assurance of the five rights while eliminating the need for staff to take the MAR (as a separate piece of paper) into the patient’s room (P1).
- Integrated electronic documentation replacing the narcotic binder and paper charts.
- Integrated computerized provider order entry (CPOE) and electronic MARs (eMAR), and
- Decision support for practitioners.
Participants believed that together these systems could improve information availability, portability, and reduce documentation time (P12). Reducing cognitive load was a key element calling for information systems with the following characteristics:

- Interfaces designed to highlight critical information
- Forcing functions that ‘walk the user through a process’ reducing the risk that steps would be forgotten or skipped
- Pull-down lists to speed up data entry and reduce the risk of incorrect entry
- Calculation support eliminating the need for a separate portable calculator (P16).

Information systems solutions were designed to address multi-tasking (P2), rushing (P3) and fatigue (P5) during medication preparation by reducing workload and forcing staff to focus on one task at a time. A number of the proposed solutions are aligned with published best practice, including unit dose and automated dispensing systems, not yet in place at the hospital. Other solutions directly supported guidance produced by the Institute of Safe Medication Practices (2008) on the ideal environmental conditions for safe medication storage and preparation areas.

Notification systems. The concept of computer-supported work also included electronic notification systems supporting communication between staff to increase capacity for group and individual planning. For example, use of PDAs to allow staff to request the presence of a cosigner, or notify coworkers of an emergency. However, it was noted that these notification systems would need to be carefully designed to avoid the addition of visual and auditory distractions to the environment.

Advanced monitoring. Advanced monitoring technologies, though currently technically feasible, were also conceptualized to support dose calculation and verification of Five Rights including:

- Smart beds that automatically input updated patient weight into the computer system to support the accuracy of dose calculations
- Fluid analyzers that verify the correct medication and dose concentration has been drawn up, serving as an automated double-check
- Automated post-administration monitoring via a computer hooked up to the patient monitor that can notify of respiratory depression

These solutions are illustrated by the prototype in Figure 1.

**Supported double-check.** A number of groups spent time conceptualizing automated double-check systems including remote monitoring video-based systems and computerized systems. These alternative/automated approaches were perceived as being more accurate and more efficient, and having the potential to reduce the incidence of interruptions for double-checkers, as compared to the current method. The computerized double-check, in particular was seen as a means to improve the accuracy and reduce the time commitment required for a verification task associated with multitasking (P2), rushing (P3) and interruption (P4, P6, P9).

One of the computerized-double-check concepts generated during the sessions included visual representation of patient (size) and syringe (fill-level) corresponding to the calculation entered. This concept was well received by participants. It also closely reflects an ongoing project at the hospital to develop a computerized-double-check (Ellis et al. 2011); though it was unclear whether the participants who generated this idea during the collaborative sessions were aware of this project at the time.

**Unit dose and automated dispensing technology.** There was unanimous support for unit dose dispensing and implementation of automated dispensing systems, again in an effort to reduce the cognitive load of tasks, to save time and to reduce the potential for selection or preparation of the wrong medication or dose (helps to address P5). Implementation of this technology would fulfill some of the electronic information systems requirements discussed above and support dose calculation and information availability, addressing factors P12, P13 and P16.

**Workflow Design**

The second major theme in the solutions generated by participants of the collaborative sessions related to workflow. This included concepts that focused on the sequence and steps required to prepare IV bolus morphine, the location of equipment, and current workspace layout.

Concepts generated by the interdisciplinary teams included: pharmacy prepared doses, decentralized medication preparation stations, creating functional zones within the medication room, and restricting traffic through medication...
preparation areas. Each of these solutions aimed to reduce the likelihood of multi-tasking (P2), interruptions (P6) and distraction (P4, P11, P14).

Pharmacy prepared doses. The idea of pharmacy-prepared doses eliminates the medication preparation task from nurses all together. There was a perception that though this may be safer from a dose preparation perspective, it might result in delayed pain management. While preparation of anticipated PRN doses based on physician orders may reduce the delay it is also likely to result in more waste.

Decentralized med storage & prep stations. Solution concepts fell into two major categories: a modular system with multiple workstations throughout the unit (Figure 1) and a centralized medication room with a protected narcotic preparation area (Figure 2). There is some literature suggesting the decentralized approach has advantages including reduction in walking distance for staff nurses (Guly, 2007; Hendrick & Chow, 2008). This is also the current trend in hospital design. However, the centralized approach also has distinct advantages, possibly making the best use of available space and providing better protection from interruptions (P6) and distractions (P4, P11, P14).

Zoned functions within med room. Zoning was manifested in a number of groups physically isolating narcotic preparation from other medication storage and preparation areas. Both semantic and physical barriers were suggested to achieve this goal. For example, Figure 3 shows a “no interruption zone” marked on the floor at the narcotic preparation area. These solution ideas were also augmented with signage directly addressing interruptions and distractions, e.g. A sign that says “calculations in progress” to discourage others from interrupting staff in the narcotic preparation area.

Restricted/redirected traffic. Participants identified a need to protect staff who are preparing narcotics from interruption/distraction. This was achieved by isolating the narcotic preparation area from other ward stock storage and preparation areas in an effort to eliminate unnecessary traffic, thereby supporting increased concentration during the preparation or high-risk medications.

Workspace Design

Physical design considerations were a focus of much of the small group activity and the requirement for groups to generate a physical model of their solution enabled more attention to detail in this area. Many of the workspace design elements represent tangible ways to support the desired workflow design changes. Based on the discussion and prototyping during collaborative sessions, participants recommended using physical barriers, increasing workspace, improving shelving and equipment organization and adding task lighting systems.

Physical barriers. Physical barriers were designed to separate the narcotic preparation area from the rest of the medication room. Participants recommended that the barriers be translucent, or have a window so that other staff can see when the workstation is occupied and who is occupying it in case they are looking for that staff member (Figure 4).

More workspace. To address equipment design issues, particularly a perceived requirement for added space, medication room design concepts included:

- Wall-mounted computers, supporting electronic documentation and regaining valuable counter space
- Pocket doors on non-fire rated entry/exits to maximize usable area in the medication room and provide more opportunities for added counter space
Improve shelving. Wall-mounted “hardware store” type shelving, was introduced by industrial designers as a means to increase storage space by up to 60%, allow supplies to be located at a more ergonomic height for the nursing population and support infection control by reducing dust accumulation experienced by the current open-bin system (Figure 4). Transparent drawers were also used to provide visual cues to the location of supplies and medications, reducing search time.

Improve task lighting. Installation of task lighting under wall-mounted shelving and in ceiling edges was recommended to eliminate shadows and distribute light, reducing glare and increasing speed of perception and psychological focus in the preparation space.

Feedback from Participants

Feedback from participants of the collaborative sessions was positive, with 84% of respondents scoring their overall impression of the workshop as valuable or extremely valuable (M=4.3). Healthcare workers were open and enthusiastic towards the CFCPing method and saw opportunities to use this type of concept development strategy to address other challenges faced by the healthcare system. Approximately 90% of respondents indicated they would encourage others to participate in a similar collaborative design activity in future (M=4.6). Health care workers specifically stated this was an “Excellent session to move this project to a positive outcome”, a “Fabulous idea - need to use this expertise for other workflow issues” and an “Excellent way to get people talking”.

Participants from all disciplines, nursing (N), design (D) and pharmacy (P/PT) indicated they were comfortable sketching (M=4.4) and prototyping (M=4.3) to share their ideas (Figure 5). There was also a strong indication (see Figure 6) that participants felt that sketching and prototyping activities supported communications and sharing of ideas within the group (M=4.4), the development of common understanding (M=4.3), and the development of solution concepts (M=4.3).
CONCLUSION

The success of the collaborative prototyping method is reflected not only in the scope and number of solution ideas and concepts generated by interdisciplinary teams, but also by the positive feedback received from health care workers who participated in this activity.

The medication room design concepts generated during the CFCPing sessions highlight the preferences and priorities of nursing and pharmacy staff. They represent innovative ideas for workflow and space redesign and suggest the kinds of new technologies that are perceived to be most useful to clinical staff responsible for medication preparation and management on the pediatric surgical unit. A number of the solution ideas and concepts generated by interdisciplinary teams during the collaborative sessions reflect published best practice, pre-existing products or soon-to-be available technologies. Specifically automated dispensing systems, which are currently available and implemented in many US and Canadian hospitals, recommendations for medication room design published by ISMP (2008) and the zoning concept that reflects the MedRite system developed and tested by Kaiser Permanente (2009). These design concepts can be used to support the selection and development of new technologies and workflow design elements that will have the greatest positive impact on medication safety at the hospital.

Since the completion of this study, the hospital has launched a program to select and implement unit dose and automated dispensing cabinets in inpatient units. The identified risk factors and design solutions developed for the surgical unit context are now being used to inform the analysis and redesign of medication rooms and workflows across the hospital. The success of the collaborative concept development sessions has also been a driver for the continued use of human factors methods and a participatory approach to design development as part of this program.

The positive feedback received from participating hospital staff suggests the CFCPing method could be used to engage front line staff and support current interprofessional teamwork initiatives. Engaging healthcare workers in this way may also facilitate a better understanding between disciplines and support development of a cooperative organizational culture. Interdisciplinary or interprofessional care has been identified as a means of addressing practice oriented and organizational challenges and as contributing to reducing the likelihood of patients experiencing adverse reactions (Canadian Health Services Research Foundation, 2006). Thus the positive response to CFCPing by nursing and pharmacy staff participating in this study suggests that CFCPing may be a useful tool that healthcare organizations can use to initiate employee involvement and support interprofessional teamwork.

TAKEAWAY

The CFCPing method can be implemented relatively quickly and cheaply to address interdisciplinary issues. It can be used to engage front-line healthcare workers in the development of practical solutions to interprofessional challenges in their work environment. CFCPing has the ability to facilitate dialogue between disciplines and can result in very practical outcomes that can be implemented by the institution.

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