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Exploring how nurses make sense of the safety features of smart infusion pump technology

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EXPLORING HOW NURSES MAKE SENSE OF THE SAFETY FEATURES OF SMART INFUSION PUMP TECHNOLOGY

by

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PH.D. THESIS

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God has blessed me.
This work is dedicated to my family.
To my husband Tom, your unwavering support and love sustains me.
To my beautiful sons (TK & David) - you have taught me so much about life.
You each have inspired me as travel this journey. I love you.

TK- you are now flying on eagle's wings, but I feel you with us always.

~Faith~
Adapt- Overcome-Survive

TK Kirkbride, 2013

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ABSTRACT

Smart infusion pump technology (SIPT) was designed to enhance safety with intravenous medication administration, but has introduced new patient safety risks and harm when nurses initiate workarounds that bypass SIPT safety features. This study sought to develop a grounded theory explaining nurses' experiences with SIPT, their perceptions of safety features, the rules and resources used in response to safety features, the actions taken in response to SIPT workflow blocks, and conditions contributing to nurse-initiated workarounds. Corbin and Strauss's (2008) grounded theory approach guided this study. Semi-structured interviews were conducted with 28 nurses who used SIPT across 13 adult patient care areas in a single Midwest teaching hospital.

The grounded theory *Nurse-Technology Interplay* was developed through constant comparison analysis of transcribed interview data. The four categories of interacting with SIPT, making meaning, taking action, and consequences, were linked through relational statements and theoretically integrated to develop the grounded theory. The grounded theory explicates the continual interplay that occurs as nurses interact with SIPT, and the cognitive and physical processes used to resolve workflow blocks in the context of care delivery. Interacting with SIPT reflected the learning curves faced by nurses, the context of patient-care unit characteristics, and encountered workflow blocks. Making meaning reflected the cognitive processes used by nurses as they encountered workflow blocks with SIPT, and was influenced by individual perspectives, as well as shared learning. Taking action often occurred simultaneously with making meaning, and represented processes of *doing*, such as rechecking programming activities, seeking assistance, or engaging in workarounds. Consequences of using SIPT included patient outcomes with medication administration and the impact on practice as nurses experienced disruptions in care delivery, dependency on SIPT, a loss of calculation skills, and alarm overload.

The grounded theory of Nurse-Technology Interplay provides an understanding of how nurses make sense of, and respond to, workflow blocks with SIPT safety features. The study yielded valuable insights into the complexity of SIPT implementation and the challenges nurses face while providing safe, effective, patient-centered care in the midst of juggling competing priorities. The findings have implications for nursing practice and nurse leaders. Critical to moving forward is a more purposeful approach to SIPT education and training within a patient safety framework, a systematic evaluation of organizational processes that impact SIPT, optimization the SIPT drug library to facilitate nurses' work, and promotion of a learning organization that capitalizes on the lessons that can be learned from workarounds.

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CHAPTER ONE

INTRODUCTION

Medication safety is a national priority. An *adverse drug event* (ADE) occurs when a medications cause an injury (Aspden, Wolcott, Bootman & Cronenwett, 2006). ADEs are the most common non-surgical adverse events in hospitals (de Vries, Ramrattan, Smorenburg, Gouma, Boermeester, 2008). ADEs may occur as an unforeseen reaction to a correctly administered medication, but when they are associated with a medication error they are considered preventable. Accurate measurements of how often preventable ADEs occur are difficult to obtain, but studies have estimated that 450,000 occur each year in hospitals (Aspden et al., 2006). Nearly 14% of Medicare patients hospitalized during 2008 experienced some type of adverse event with costs estimated at 3.8 billion dollars. Nearly one-third of the adverse events were associated with ADEs (Levinson, 2010).

While preventable ADEs occur at many points on the complex medication administration process (Vogelsmeier, Halbesleben, & Scott-Cawiezell, 2008), seminal research indicated that 32% of preventable errors occur when the medication is administered to the patient (Bates, Boyle, Vander Vliet, Schneider, & Leape, 1995). Nurses' play an integral role in preventing errors as they perform the final safety checks to intercept errors before medications are administered to patients (Flanders & Clark, 2010). Over half of medication errors are associated with the almost 90% of inpatients receiving intravenous (IV) infusion therapy (Ross, Wallace, & Patton, 2000). Infusion errors can result in serious consequences because they often involve potent medications that are rapidly absorbed into the bloodstream (Maddox, Danello,Williams & Fields, 2008). While most ADE-related harm is temporary, it accounts for nearly 7,000 deaths annually (Schneider, Nichols, Stevens, & Hook, 2010). ADEs also compromise patient trust, demoralize staff, and generate negative publicity (Forni, Chu & Fanikos, 2010).

To address costly patient safety challenge related to ADEs, the widespread implementation of medication safety technologies such as Smart Infusion Pump Technology (SIPT) has begun with the goal of intravenous (IV) medication error reduction (IOM, 2004; 2007). As a result, utilization of Smart Infusion Pump Technology (SIPT) has grown from 32% in 2005 to nearly 60% in 2008, (Pedersen, Schneider & Scheckelhoff, 2009). Despite SIPT introduction, errors related to IV medication administration have not been mitigated. Between 2005 and 2009 approximately 56,000 infusion-related ADEs were reported to the Food and Drug Administration (2010). Studies have illuminated the risks and unforeseen dangers of implementing new technology (Leape, 2005; Halbesleben, Wakefield & Wakefield, 2008; Mytton et al., 2010; Rothschild & Keohane, 2008; Scott-Cawiezell et al., 2009). Further highlighting these concerns, between 2012 and 2013 the Emergency Care Research Institute's (ECRI, 2012) moved infusion pumps from third to the second rank among top ten health technology hazards, with clinical alarms remaining first. Nurses, the primary users of SIPT, are critical to maximizing their positive impact; thus, it is important to understand their experiences with this medication safety technology (Kirkbride & Vermace, 2011).

Background and Significance

Administering medications is a common process in hospitals, a routine nursing practice, and a significant cause of preventable ADEs (Forni et al., 2010). However, medication administration is much more than a simple psychomotor skill (Wakefield, Wakefield, Uden-Holman & Blegan, 1998). The process involves coordination between multiple providers to order, transcribe, prepare, dispense, and deliver the medication (Bates et al., 1995; Leape et al., 1995).

Medication Safety Technology

The introduction of medication safety technology has changed administration processes, and it is recognized that clinicians serve as the critical interface to keeping

patients safe from their unintended consequences (Vogelsmeier et al., 2008). Safety concerns introduced by medication safety technology led to a 2008 Joint Commission *Sentinel Event Alert* recommended that hospitals examine workflow processes and safety-risks before, during, and after any implementation. The complexity of medication administration, the necessary elements of safety practices, and the many potential points of failure have been explored (Barker, Flynn, Pepper, Bates & Mikeal, 2002; Scott-Cawiezell et al., 2009; Westbrook, Woods, Rob, Dunsmuir, & Day, 2010). These failures are reflected in reports that nearly one of five administered inpatient medications ends in an error, with some resulting in preventable ADEs (Schneider et al., 2010).

Smart Infusion Pump Technology

The impact of IV infusion errors upon patients' safety continues to challenge the healthcare system. Basic infusion pumps were introduced in the 1970s to improve practices by allowing users to program rate and volume to be infused; however, programming errors accounted for approximately 60% of ADEs (Adachi & Ladolce, 2005; Kaushal et al., 2001; Murdoch & Cameron, 2008). In response to these programming errors SIPT was introduced in 2001, bringing computer decision support to the bedside (Vanderveen, 2007). SIPT creates intentional workflow blocks by alerting nurses to programmed dosing that exceeds organizational guidelines (Kaushal & Bates, 2002; Rothschild et al., 2005). However, the risks and potential causes of SIPT related errors were exemplified as two lethal heparin overdoses have resulted from nurses bypassing SIPT safety features, (ISMP, 2007; 2010). Actions such as bypassing technology safety features are commonly referred to as *workarounds*.

Workarounds

Workarounds are informal work procedures taken to accomplish a task by circumventing a real or perceived workflow block (Kobayashi, Fussell, Xiao, & Seagull, 2005). Workarounds are extremely common in healthcare environments (Halbesleben et

al., 2010; Vogelsmeier et al., 2008), and contribute to errors by creating disruptions and distracting staff from patient care (Beaudoin & Edgar, 2003; Tucker & Edmondson, 2002). As nurses attempt to resolve disruptions and efficiently resume care, they may engage in workarounds that involve bypassing technology features (Ash, Berg & Coiera, 2004; Halbesleben et al., 2008; 2010; Hassan, Badawi, Weber & Cohen, 2010). Nurse-initiated workarounds with SIPT safety features have been frequently reported (Husch et al., 2005; Nuckols et al., 2008; Rothschild et al., 2005). Insights about why nurses may initiate SIPT workarounds include time pressures, clinical emergencies, non-standardized drug concentrations, perceived extra work of technology, underestimation of related risk, and a culture that inadvertently supports risky behavior (ISMP, 2010; Keohane et al., 2005; McAlearney et al., 2007). However, few studies have directly examined how nurses work with or around SIPT safety features (Hertzel & Sousa, 2009).

Sensemaking

Sensemaking, a cognitive process triggered in response to an unexpected situation, literally means the making of sense, where *sense* refers to meaning and *making* refers to actively constructing it (Weick, 1995). Individuals engage in ongoing sensemaking by trying to fit situations into something familiar, based on personal knowledge, beliefs and experiences, or organizational standards; however, it intensifies in new or uncertain situations when people are unsure how to act (Weick, 1995; Weick, Sutcliffe & Obstfield, 2005). Sensemaking activities can fill information gaps, as individuals seek to understand: "What's the story here?" "What does it mean?" "What do I do next?", while looking for additional cues, taking action, or seeking help (Hoffman, Lei & Grant, 2009, p. 1261). These activities change the situation or generate new information, linking sensemaking with decision-making (Rudolph, Morrison & Carroll, 2009).

Organizations can use sensemaking events to discover gaps in what is believed to be in place and reality (Weick et al., 2005). As organizations strive to learn from events,

nurses are well positioned to detect risks and protect patients from harm (IOM, 2004). Nurses work in complex work environment and face unavoidable challenges as they manage changing patient conditions, marginal clinical resources and ever-changing technology (Tucker & Edmondson, 2002). Technology introduces workflow blocks designed to enhance safety (Halbesleben et al., 2008), which creates further complexity as nurses address urgent patient needs. Although the literature clearly demonstrates that nurses work around SIPT safety features, it is not understood how they make sense of these workflow blocks before taking action. Sensemaking provides an ideal lens for exploring nurses' interactions with SIPT safety features.

Problem Statement

Healthcare organizations are adopting SIPT which is designed to create intentional workflow blocks that alert nurses to potential errors and prevent administration until the issue is addressed (Carayon et al., 2008; Forni et al., 2010). However, nurse-initiated workarounds with SIPT are well documented (Elias & Moss, 2011; Hertzel & Sousa, 2009), and have resulted in patient harm and even death (ISMP, 2007; 2010). A comprehensive literature review failed to illuminate the phenomenon of nurse-initiated workarounds with SIPT, no research studies related to nurses' perspectives of SIPT safety features and related workflow blocks was found. To address this literature gap, the current research study was proposed.

Purpose of the Study

The purpose of this study was to develop a grounded theory (GT) explaining nurses' experiences with SIPT safety features and encountered workflow blocks. To accomplish this, a GT study was designed with primary data collected from interviews with staff nurses who used SIPT devices in a single hospital. Consistent with the purpose, initial research questions were developed to understand nurses' perceptions of SIPT

safety features, and the processes that they use to make sense of and take action in response to encountered SIPT workflow blocks.

Initial Research Questions

RQ 1. What are nurses' perceptions of the SIPT safety features?

RQ 2. What rules and resources do nurses consider when responding to SIPT safety features?

RQ 3. What actions do nurses take in response to workflow blocks with SIPT safety features?

RQ 4. Under what conditions do nurses initiate workarounds with SIPT safety features?

Conceptual Definitions and Key Terms

To provide clarity going forth, conceptual definitions are provided here. An additional list of key terms and definitions are found in Appendix A.

> Sensemaking is a complex process of comprehending, constructing meaning, searching *for* patterns, and interacting to pursue a common understanding (Weick, 1995).
>
> Smart Infusion Pump Technology refers to a computerized infusion device with *dose error reduction software* to detect programming errors (Vanderveen, 2007).
>
> Workarounds are alternative work procedures that bypass a real or perceived block to workflow and represent variations from intended procedures and processes (Halbesleben et al., 2008).
>
> Workflow blocks are disruptions to work processes that occur as an intentionally designed safety mechanisms of technology or as an unintentional result of poorly designed workflow processes (Halbesleben et al., 2008).

Chapter One Summary

Medication safety technologies which were designed to enhance medication safety have introduced new sources of error. Hospitals have rapidly adopted SIPT to improve the IV medication safety, but nurse-initiated workarounds bypassing the safety software have created new patient safety risks. Nurse-initiated workarounds are well-documented, but little is known about how nurses make sense of and take action in response to related workflow blocks. Given the increased adoption of SIPT and the

potential consequences of workarounds with safety features, it is critical to explore nurses' experiences with SIPT safety features.

Building on the presented problem, an overview of the remainder of the dissertation is provided. Chapter 2 illuminates the need for the study by synthesizing literature pertaining to SIPT, workarounds, and sensemaking. Chapter 3 describes the methods used in this grounded theory study. The findings and emerging theory that arose from the data are presented in Chapter 4. This dissertation concludes with Chapter 5, where the findings and implications for practice are discussed, and recommendations for future research are presented.

CHAPTER TWO

LITERATURE REVIEW

This chapter presents existing literature pertaining to medication safety and related intravenous (IV) medication errors, SIPT, workarounds, and sensemaking. The intended design and safety features, the impact on nurses' work, related workarounds, and the unintended consequences of SIPT are examined. An overview of sensemaking theory is also presented.

Medication Safety

Medication safety is a national priority, as discussed in Chapter One. A brief overview of medication ordering and administration processes was previously presented, demonstrating the multiple points of breakdown that could result in a medication error. Errors in the early stages of the process, prior to administration, are more likely to be detected and intercepted because pharmacists and nurses review orders, and check dispensed drugs before they reach the patient (Bates et al., 1995; Leape et al., 1995). During the later stage, when the medication is administered to the patient, the nurse performs the final safety checks intended to identify and prevent errors (Flanders & Clark, 2010). However, because there are few built-in safeguards and redundancies, errors at the point of administration are difficult to detect, and more likely to lead to serious injury (Bates et al., 1995; Leape et al., 1995).

Infusion Related Medication Errors

Infusion-related errors are well documented. Researchers found that up to 66% of potential ADEs were associated with IV medications (Bates, Vanderveen, Seger, Yamaga & Rothschild, 2005; Husch et al., 2005; Kaushal et al., 2001; Taxis & Barber, 2003). Administration of IV medications, by either direct bolus or via infusion, can be one of the most dangerous practices in hospitals due to their rapid onset and the frequency of "high-risk-of-harm" drugs (Forni et al., 2010; Hicks & Becker, 2006). Medications such as

heparin, insulin, vasopressors, norepinephrine, potassium chloride, and chemotherapy regimens are associated with potent side effects and can lead to egregious preventable ADEs (Maddox et al., 2008).

An increased risk of error is also related to the large variability in drug names, multiple concentrations, and weight-based dosing limits (Maddox et al., 2008). The complexity of administering IV medications has been discussed. It would be unlikely that a nurse would give 100 tablets to a single patient, yet the same clinician could inadvertently give a 100-fold overdose of an IV medication by not recognizing a miscalculated dose (Thurman, Sullivan, Williams & Gaffney, 2004). A missing decimal point or an accidental double key press could lead to 10 to 100 fold overdose (Williams & Maddox, 2005). To manage these risks, IV drug administration via infusion pumps is now considered the standard of care (Vanderveen, 2007).

Smart Infusion Pump Technology

The first standard infusion pumps lacked the capability of detecting programming errors, so incorporating electronic safeguards with SIPT were viewed as necessary to help nurses avoid administration errors (Williams & Maddox, 2005). SIPT provides a second check for the end user, creating an important opportunity to improve safety at the bedside (McAlearney et al., 2007). SIPT safety features, which will be discussed in detail later, are designed to address risks related to the human-technology interface, reducing the likelihood of error by structuring actions, guiding decisions, alerting providers to risk, and averting errors (Forni et al., 2010). Although SIPT adoption has increased, the technology's value has been questioned because IV medication error rates have not significantly decreased to a level where the benefit outweighs the cost (Nuchols et al., 2008; Rothschild et al., 2005). The complexity of SIPT is best appreciated by understanding its intended use, the impact on nurses' workload, and error-prone aspects of IV administration with the technology. Thus, SIPT safety features are described next.

Safety Features

While SIPT pump designs vary by manufacturer, key safety features are common across all models. These safety features are listed and further, described in Table 1.

Table 1. SIPT Safety Features

Drug Library (DL)	Computerized software containing customizable data sets that support hospital's practice with IV medications. Rules containing pre-defined parameters for the type, strength, and dosing limits of specific drugs (Vanderveen, 2007) and can be set for continuous infusions, boluses, and intermittent infusions (ISMP, 2009).
Care Area Profiles	Reflect specific patient care area, such as ICU, neonatal ICU, and pediatrics. They are designed to simplify programming and heighten safety by pulling commonly used drugs and appropriate dosages from the Drug Library (DL), for a specific patient population. Clinicians must confirm the appropriate care area profile when they power on the device. (Vanderveen, 2007).
Dosing Alerts	Safety alert that notifies the user that the programmed dose is out of the anticipated range (as established by each hospital); alerts are set as *soft* or *hard* stops (Vanderveen, 2007).Soft limit alerts that can be overridden by the user and the medication can still be infused without changing SIPT settings. Hard limit alerts indicate the dose is outside of the institution-determined safe range. Infusion cannot be administered unless the pump is reprogrammed within the acceptable range (Vanderveen, 2007).
Clinical Advisories	Safety feature alerting clinicians of specific actions needed with a specific to a medication, such as using a filter (ISMP, 2009).
Pump Logs Continuous Quality Improvement (CQI)	Software collecting quality improvement data about alerts, such as medication involved, initial programmed doses, and subsequent actions. Data can be used to measure the impact of SIPT, evaluate orders completion, and identify best practice and compliance (Longshore, Smith & Weist, 2010; Vanderveen, 2007).

Descriptions of SIPT features and their intended use in IV medication safety are provided, and pictures are included in Appendix B. Nurses participating in the current study used the *Sigma Spectrum C* (Appendix B1), manufactured by Baxter Healthcare Corporation (2012). After turning on the device, the user must select a Care Area Profile (Appendix B2) to match the Drug Library (DL) with a specific patient population. The

SIPT safety software checks to make sure that the programmed dose is within an acceptable limit (Appendix B3). Limits can be set to allow overrides (S*oft Limit* Alerts) or not (H*ard Limit* Alerts). After the Soft Limit Alert is confirmed, SIPT provides a red visual display (Appendix B4) and records it in an event log (Vanderveen, 2007). Hard Limit alerts (Appendix B5) prevent the infusion from running until it is reprogrammed within the predetermined safe limits (Vanderveen, 2007). SIPT also offers Basic Mode, a generic programming feature that bypasses the safety software and disengages alert capability (Appendix B6); infusions are also displayed with red lettering.

A unique feature of SIPT software is the ability to capture and record all medications, programming, alerts, and subsequent actions taken by the clinician in a *Continuous Quality Improvement* (CQI) log (Vanderveen, 2007). These logs provide programming data to assist with evaluating how orders are carried out, identifying best practices, determining the impact of the pumps on medication error reduction, and providing quality improvement data (Longshore et al., 2010; Vanderveen, 2007). These data can also be used to evaluate the impact on nurses' workflow.

Impact on Nurses' Workflow

Compared to traditional pumps, SIPT increases nurses' cognitive workload (Carayon et al., 2005). Nurses are required to take additional programming steps, such as selecting an appropriate Care Area Profile, choosing the correct medication and concentration from the DL, and correctly responding to pump alerts (Carayon et al., 2010). Manufacturers' variations in device and software design may influence how nurses use SIPT. Birk (2008) attributed initial compliance rates of less than 15% to the SIPT design which required nurses to take extra steps to opt into the safety software. In time-pressured situations, these additional demands may lead to nurses' bypassing SIPT safety features, which makes it function as a traditional pump (Eckel, Anderson,

Zimmerman, Szandzik, & McAllister, 2006; ISMP, 2007, 2010; Keohane et al., 2005; Rothschild et al., 2005; McAlearney et al., 2007; Siv-lee & Morgan, 2007).

Software alerts introduce new complexities and risks to nurses' work as they respond to intentional workflow blocks alerting them to potentially unsafe process (Kaushel & Bates, 2007). The nurse is key in keeping patients safe, as they critically analyze SIPT alerts in context, to determine appropriate patient's specific response. However, these alerts can contribute to alert *fatigue*, a phenomenon attributed to frequent alerts where users start to ignore or override alerts without considering their importance (van der Sijs, Aarts, Vulto, & Berg, 2006). Excessive alerting also reduces the credibility of the alarms, and frequent false alerts create the potential to miss positive alerts (van der Sijs et al., 2008). However, these alerts have not eliminated programming errors.

Impact on Programming Errors

Despite the introduction of safety features designed to enhance programming safety, errors have been documented. The most common SIPT programming errors are listed in Table 2. The errors are then discussed in more detail and examples are provided.

Table 2: Programming Errors

Programming Error	**Description**
Multiple-of-10 error	Infusion programmed 10x higher or lower than intended value.
Transposition errors	User enters the rate into the dose-rate field, or vice-versa.
Unit errors	Mix-ups between units of weight, dose-rate, rate or duration.
Keystroke errors	User pushes a wrong button on the pump during programming.
Key bounce errors	User presses number key and repeats same number.
Incorrect parameters.	User required changing pump parameters after infusion started.

Multiple-of-Ten Errors

Infusion errors programmed with a dose, rate, or duration value that is a multiple of 10 higher or lower than the intended value have been reported. The ISMP (2007) cited

one example where a nurse bypassed the Drug Library and programmed the patient's parental nutrition to run at 625 ml/hr instead of 62.5 ml/hr, resulting in a 10-fold overdose. Similar multiple of ten errors have been reported by researchers (Fanikos et al., 2007; Hahn & Whitbeck, 2007; Husch et al., 2005; Keohane et al., 2005; Peterson et al., 2008; Pratt, 2004; Rothschild et al., 2005).

Transposition Errors

Data transposition, such as entering the rate into the dose-rate field, can lead to errors. An example was reported when nitroglycerin was inadvertently programmed at a rate of 80 ml/hr instead of a dose-rate of 80 mcg/minute (Keohane et al., 2005). In another incident, heparin was programmed at a rate of 650 ml/hr instead of a dose-rate 650 units/hour (ISMP, 2007). Similar reported errors were believed to be preventable if programming was done through the safety software (ISMP, 2010; Malashock, Shull, & Gould, 2004).

Unit errors

Errors between units of weight, dose-rate, rate or duration have been reported (Cohen, 2007; Peterson et al., 2008). Examples include an event where a weight of 140 lbs. was entered as 140 kg, resulting in over 2 fold dosing error (Rothschild et al., 2005). Propofol, a hypnotic agent, was programmed at 80 mcg/kg/min instead of the ordered dose of 80 mcg/kg/hr (ISMP, 2007).

Keystroke errors

Errors can occur when the wrong button is pushed during SIPT programming. One such example was reported when a neuromuscular blocking agent was programmed at 105 mcg/kg/min instead of 1.5 mcg/kg/min because a zero was pressed instead of the decimal point. The dose was corrected after the nurse received a programming alert (Malashock et al., 2004); similar examples have been cited (Husch et al., 2005; Hahn & Whitbeck, 2007; ISMP, 2008).

Key bounce errors

Key bounce errors occur when the user presses a number key and receives a repeat of the same number. The ISMP (2007) cited one incident where a nurse delivered propofol at a rate of 225mL/hr instead of 25mL/hr. The nurse realized the mistake and corrected the error.

Incorrect parameters

Errors can occur when SIPT parameters are changed after the infusion has started. An error involving insulin occurred when the concentration of the replacement bag was different from the original bag, and the administered dose was significantly less than intended (Hicks & Becker, 2006). A similar error was observed when a nurse adjusted the infusion rate to administer a bolus, but failed to correctly reset the rate once the bolus was completed (Peterson et al., 2008). Other conditions are also error-prone.

Error-prone Conditions

In addition to the previously discussed situations with SIPT, certain error-prone conditions have been identified. These include secondary infusions, boluses, multiple infusions, and generic programming in crisis situations.

Secondary Infusions

Secondary infusions are commonly used to deliver intermittent medications, and need to be hung above the primary bag in order to flow when the secondary clamp is opened. After the infusion is completed, hydrostatic pressure allows the primary infusion to resume. During clinical simulation, 53% of nurses could not successfully complete a secondary infusion task due to programming errors and difficulty navigating SIPT software, and 38% forgot to open the secondary clamps and/or adjust the height of the bag (Nunnally & Bitan, 2006). The ISMP (2004) reported a case where a nurse forgot to open the roller clamp of a secondary bag containing potassium and the pump drew from the primary solution of insulin.

Medication Boluses

Administering a medication bolus can be a high-risk activity because a concentrated dose is delivered over a limited time. With traditional pumps, nurses would typically increase the infusion rate to administer a bolus and then return it to the original value. With SIPT, issues have been reported where boluses were administered by bypassing SIPT safety features (Peterson et al., 2008; Pratt, 2004).

Multiple Medications

Medications are often administered simultaneously, so manufacturers introduced multi-channel SIPT devices, allowing multiple IV infusions to be administered on a single pump. Although they save space, new opportunities for errors occur when users program two or more infusions on the same screen. One such error occurred when heparin and normal saline were reversed during an IV tubing change (ISMP, 2007). Other errors with multi-channel pumps resulted from staff having difficulties reading screens, and navigating programming pathways (Burdeu, Crawford, van der Vreede & McCann, 2006).

Generic Programming

SIPT permits medications to be programmed generically, bypassing the safety software, which is a risky, but necessary feature that may be indicated in clinical emergencies or in situations where it is clinically appropriate to over-ride a Hard Limit alert (Vanderveen, 2007). When evaluating the risk of error with urgent patient needs, nurses may need to make critical decisions about bypassing SIPT safety features. The inadvertent introduction of errors involving SIPT and the overall impact on medication safety is concerning. An overview of studies related to medication safety impact follows.

Impact on Medication Safety

To examine the impact of SIPT on medication safety, Hertzel and Sousa (2009) systematically reviewed the literature published between 2003 and 2008. They found

limited studies (n=9) specifically designed to evaluate the SIPT effectiveness with preventing medication errors. The authors concluded that there was a lack of well-designed research in respect to the effectiveness of SIPT in preventing medication errors (Hertzel & Sousa, 2009). One study evaluated the effectiveness of an education program on users' knowledge of SIPT to prevent medication errors (Dennison, 2007) and the remaining studies focused on compliance with SIPT features. The review yielded mixed findings as to SIPTs' impact on medication safety. Five studies reported a positive impact (Eckel et al., 2006; Fields & Peterman, 2005; Keohane, Hayes, Saniuk, Rothschild, & Bates, 2005; Larsen, Parker, Cash, O'Connell & Grant, 2005; Wilson & Sullivan, 2004), while the others reported no benefit (Husch et al., 2005; Nuckols et al., 2008; Rothschild et al., 2005). Relevant study findings are reported next.

A study done by Wilson and Sullivan (2004) reviewed heparin infusions (n=80) on twenty patients. Data were obtained from SIPT logs, computerized provider order entry, pharmacy orders, laboratory test data, and automated dispensing systems. They reported a 93% compliance with safety software and found that 95% of the orders matched downloaded transaction data. Their data showed that the proper use of smart pumps averted 100-fold dosage errors. These researchers concluded that SIPT could increase patient safety, was easy to implement, and had an immediate positive impact when used as intended.

Adachi and Lodolce (2005) conducted a retrospective pre-post study to determine the impact of an intervention on IV dosing and administration errors. The intervention involved implementing standardized order sets and SIPT with soft alerts. Standardizing concentrations eliminated wrong concentration errors. Although a small reduction in overall dosing errors (59 to 46) was seen, there was a larger reduction in pump-related dosing errors (24 to 10, or from 41% to 22%); nine of the 10 dosing errors resulted from noncompliance with SIPT safety features.

A retrospective study analyzed data from infusions (N=426) to evaluate whether SIPT without interface capability could prevent medication errors, Findings revealed that 285 (66.9%) had at least one error associated with administration and that 37 (13%) of these were programming errors. Researchers concluded that, without an interface with medication orders, SIPT is limited to detecting errors that exceed routine dosing and, therefore, is still vulnerable to prescribing errors that could occur with traditional infusion pumps (Husch et al., 2005).

Researchers examining the impact of SIPT implementation on preventing serious medication errors identified effectively averted errors early in their study (Keohane et al., 2005). Staff satisfaction with SIPT was positively associated with nurses' inclusion with SIPT implementation, involvement in evaluating causes of errors, supportive workload changes, and adequate training on SIPT use and new potential sources of error. These researchers emphasized the importance of creating a culture of competence and safety among SIPT users, as well developing unit-specific drug libraries (Keohane et al., 2005).

Rothschild and colleagues (2005) conducted a prospective study of SIPT with intervention (decision support on) and control (decision support off) periods to determine if decision support impacted the incidence of medication errors and ADEs in cardiac surgery patients (n=735). Preventable ADEs and non-intercepted potential ADEs did not differ significantly between groups. Users bypassed the DL 25% of the time (571 infusions) during the intervention period. Researchers concluded that the poor compliance with the DL contributed to SIPTs insignificant impact on medication safety. However, in this study, SIPT design required nurses to opt-in to the safety software, making it easier for users to skip the DL.

A retrospective study compared pediatric infusion errors 12 months before and after adopting a medication safety protocol combining SIPT, standardized drug concentrations, and redesigned medication labels. After implementing the protocol,

infusion related error rates were significantly decreased from 3.1 to 0.8 per 1000 doses, a risk reduction of 2.3 (95% CI 1.1-3.4, P <0.001). Because the protocol combined interventions, it was unclear how SIPT alone impacted error reduction. The researchers noted that the reported pre- and post-intervention error rates should be representative of the relative number of errors. However, it was noted that incident reports collected during the same timeframe, which rely on self-reporting, did not reflect the findings from the research study (Larsen et al., 2005).

User non-compliance with SIPT safety software was also reported across two uncontrolled studies. Fields and Peterman (2005) reported a high number of medication errors (n=506) due to users overriding Soft Limit alerts. Eckel and colleagues (2006) also reported that a high frequency of programming errors resulted from users bypassing the DL for drug selection (44%) and overriding Soft Limit alerts (88%).

A single pre-post intervention study evaluated the effectiveness of computerized educational modules designed to increase nurses (N=20) knowledge of medication errors prevention with SIPT. Although the findings of this study suggested that nurses' safety knowledge increased, there was no statistical difference in nurses' behaviors with SIPT safety features. Recognized study limitations included a lack of full consideration for factors that influence safety practice, such as readiness for change, multiple and conflicting practice changes, and leadership commitment (Dennison, 2007).

A retrospective record review of ICU patients (n=4,604) at two hospitals was completed to determine how often preventable ADEs could be intercepted by SIPT safety features. Researchers identified 100 preventable medication errors, 50% involved continuous infusions and 40% with bolus doses. Researchers concluded that SIPT could have intercepted only 4% of the total errors, primarily due to the poorly configured DL which included wide dosing ranges and no bolus parameters (Nuckols et al., 2008).

Summary of Smart Pump Literature

Current study findings illuminate the impact of SIPT on nurses' work as well as their unintended consequences. Nurses' actions, such as bypassing the safety software, increase the risk of medication errors reaching the patient and causing harm. The majority of the studies designed to assess SIPT efficacy implicated user noncompliance with SIPT safety features with the modest impact on preventing infusion-related ADEs (Hertzel & Sousa, 2009). Consequently, researchers are interested in understanding the conditions that promote SIPT workarounds.

Workarounds

Workarounds are a frequently documented phenomenon in healthcare, yet they remain poorly understood. The following section discusses workarounds, their consequences, and the workflow blocks that lead to them. Finally, workarounds are explored in the context of SIPT.

Definition

Simply defined, workarounds are alternative work procedures that bypass a real or perceived block to workflow and represent variations from intended procedures and processes (Halbesleben et al., 2010). A definition, based on analysis of healthcare practices, defines workaround as "a creative, redesigned process that facilitates care to patients by providing opportunities for nurses, designers, regulators, and administrators to interact and produce novel patterns or knowledge" (Lalley & Malloch 2010, p. 31). Despite the emphasis by the IOM that standardization is essential for reducing medical errors (Kohn, Corrigan, & Donaldson, 2000), healthcare professionals engage in workarounds so frequently that they have been classified as *masters of workarounds* (Morath & Turnbull, 2005). The literature indicates that clinicians find it necessary to engage in workarounds under several conditions.

Conditions and Workarounds

As noted, for a workaround to occur, a worker must perceive some disruption or block that prevents them from completing a task. In healthcare, the high workload already encountered by professionals is believed to contribute to workarounds (Halbesleben et al., 2008). Healthcare professionals may see a greater need to improvise or work around intended work practices as they balance the need to provide patient-centered care with the simultaneous demands of technology, regulation, time pressures, cost-effectiveness, and uncertainty (Halbesleben et al., 2008 & Halbesleben et al., 2010; Kobayashi et al., 2005). Workarounds tend to be temporary informal mechanisms that allow an employee to complete a task (Kobayashi et al., 2005). However, while it is unclear how workarounds proliferate, they can become routine practices that are widely accepted practice within a work group (Halbesleben et al., 2008). Unfortunately, the process of working around a workflow block can create a vicious cycle of workarounds (Kobayashi et al., 2005; Tucker & Edmondson, 2003).

Workflow Blocks

To understand why healthcare professionals engage in workarounds, the concept of workflow block must be explored. Researchers have discerned that workflow blocks vary by their source, and intention and typically fall into five categories, including (1) policies/laws/regulations, (2) protocols, (3) process/design/flow, (4) people, and (5) technology (Halbesleben et al., 2008).

Policies, laws and regulations, may serve as workflow blocks when they are perceived as not applicable to a specific patient's situation. *Protocols and clinical guidelines,* intended to improve patient care, may not be followed if they are perceived as a block to providing timely care. *Work process design* and processes can become fragmented and lead to workarounds as they are modified in response to errors, new regulations, or institutional preferences. *People* may be perceived as an unnecessary

workflow block when they add demands to care coordination and restrict individuals' choices, such as policies requiring employees to run an idea by a supervisor. These types of workflow blocks may add demands to coordinating care. *Technology* is recognized as a key source of workarounds because it introduces intentional and unintentional workflow blocks (Halbesleben et al., 2008). Workflow blocks can also take on a different forms based on intention. Many systems designed to reduce error function by introducing intentional work flow blocks which force function to ensure that correct actions are taken. For example, requiring nurses to confirm medication dosage settings prior to administration serves as an important workflow block intended to prevent patients from receiving lethal doses of medication (Halbesleben at al., 2008). Other intentional blocks include regulations that limit the hospital drug formulary or require a higher level authorization to ensure that certain high risk drugs are dispensed appropriately (Halbesleben et al., 2008).

However, the SIPT safety features can introduce unintended workflow blocks when processes are not effectively reengineered to accommodate workflow (Halbesleben et al., 2010 & 2008; Zuzelo, Gettis, Hansell, & Thomas, 2008). As healthcare organizations rely on technology, nurses must factor technology demands into their workflow. This human-technology interface has been addressed in the context of patient safety (Battles & Keyes, 2002; Vogelsmeier et al., 2008). While technology is an important innovation, understanding how nurses use (or do not use) the technology is more important (Vogelsmeier et al., 2008). Nurses may see workflow blocks encountered during care delivery as unnecessary, inconvenient, or inefficient, choosing to engage in workarounds (Beaudoin & Edgar, 2003; Halbesleben et al., 2008). These workarounds can have significant consequences.

Consequences of Workarounds

Researchers have begun to explore the consequences of workarounds in the context of patient safety. Successful workarounds can provide organizational solutions, but unsuccessful workarounds can threaten patient safety (Halbesleben et al., 2008; Kobayashi et al., 2005). New technology that introduces unanticipated consequences with desirable results may be thought of as happy surprises, but undesirable consequences can cause harm (Ash et al., 2004). When workarounds are viewed as innovation, they can be analyzed and learned from, in order to create more effective processes (Lalley & Malloch, 2010). Therefore, developing mechanisms to identify workarounds may improve organizational patient safety efforts. (Halbesleben et al., 2008; Kobayashi et al., 2005). Researchers assert that accepting and appropriately planning for workarounds can lead to positive results (Tucker & Edmondson, 2002).

Although workarounds are prevalent in healthcare, the extent of the phenomenon is unknown (Halbesleben et al., 2008). Workarounds bypassing technology safety features reduce the reliability of the technology and introduce new sources of error and patient safety risks (Halbesleben et al., 2008; Halbesleben et al., 2010; Koppel et al., 2005; 2008). Recent reports involving SIPT have linked workarounds to lethal outcomes (ISMP, 2007; 2010).

Workarounds with SIPT

Medication administration has been the focus of new technology designed to improve patient safety. The addition of SIPT and other medication safety technology has exposed nurses to new devices and processes that must be integrated into existing care delivery systems (Bates, 2007; Halbesleben et al., 2010; Scott-Cawiezell et al., 2009; Wilson & Sullivan, 2004; Zuzelo et al., 2008). However, as previously discussed, the impact of implementation and redesigned work processes have added complexity to nurses' work and contributed to workarounds (Halbesleben et al., 2010; Zuzelo et al.,

2008). Many documented workarounds involve bypassing the very safety features designed to avert errors (Halbesleben et al., 2008; Koppel et al., 2005; 2008; Vogelsmeier et al., 2008). Similar workarounds have been documented with SIPT.

Possible reasons why users may choose to bypass SIPT safety software include a false low perception of risk, extra work required to use the technology, time pressure, clinical emergencies, and a culture that inadvertently supports at-risk behavior, including not using the technology features properly (ISMP, 2009; 2010). The Joint Commission (2008) has cautioned that users need the knowledge and skills to operate technology properly in order to comply with all their safety features and significantly reduce medication errors. Behaviors of administering a medication outside of the safety software clearly reduce the ability to avert programming errors, yet these occurrences are well documented.

Focus groups interviews were used to explore registered nurses' (RNs') (n=24) experiences with SIPT, specifically looking at user interactions, challenges, training, and leadership support (McAlearney et al., 2007). While nurses viewed SIPT positively, they also described obstacles. Challenges were encountered with the weight of the pumps, variations in the volume of infusions, calculations and timing of infusions, false alarms, incomplete drug libraries, and patients tampering with lockout features of the pump. Other issues discussed were the strategies to overcome SIPT workflow blocks, as nurses improvised and engaged in workarounds to overcome system level issues (Table 3).

Table 3. Workarounds with SIPT

Workaround	System level Issue
Programming extra fluid volumes	Variability of fluid in secondary bags
Infused as different concentration	Needed concentration not in Drug Library
Exceeding dose limits	Hits hard limit and not authorized to change
Secondary run as primary	Need to run infusion faster than secondary allows
Manual calculations	System does not calculate heparin doses

Source: (McAlearney et al., 2007)

A post-implementation survey that exploring nurses' (n=512) perceptions of SIPT revealed that participants felt SIPT enhanced safety with medication administration, but they also reported overriding safety alerts (Rosenkoetter, Bowcutt, Khasanshina, Chernecky & Wall, 2008). Another interesting finding was related to problem solving behaviors. When resolving SIPT issues, only 28.8% of nurses' reported seeking out a pharmacist or a nurse colleague for advice (Rosenkoetter et al., 2008).

Focus group interviews with RNs (n=31) from medical-surgical nursing units across two institutions were used to explore their experiences with 21 different technologies used in daily practice, such as facsimile machines, cardiac monitors, and SIPT (Zuzelo et al., 2008). The study elicited barriers and facilitators of various technologies as well as problem-solving and decision-making strategies. Nurses described workarounds as they circumvented technology safety systems in an effort to save time. They also described selectivity about safety breaches which were based upon intuition, feelings, or selective sensemaking. As one nurse reported: ''we only work around some things… You feel it in yourself that it is safe'' (Zuzelo et al., 2008, p. 137). This study demonstrates that while nurses are aware of the potential consequences of workarounds, they sometimes perceive it necessary to engage in them.

Summary of Workaround Literature

Although limited in number, these studies provide insights to advance understanding about workarounds with SIPT safety features. Workflow blocks vary by their source and intentionality and can lead to workarounds. Workarounds are a temporary response to resolve a workflow block, but can become widely accepted within groups. Workarounds with SIPT have been linked to multiple organizational issues. The consequences of workarounds with SIPT are directly linked to patient safety as patient deaths have been reported. Halbesleben and colleagues (2008) suggested that future research concerning workarounds explore how clinicians problem solve and make

decisions in response to workflow blocks. To better understand how individuals make sense of and take actions in response to workflow blocks, a review of Sensemaking Theory and related studies are presented.

Sensemaking

Sensemaking provides an ideal lens to explore nurses' perceptions of encountered blocks with SIPT during the course of providing patient care, specifically the meaning that is constructed and action taken. A brief review of the theoretical underpinnings of sensemaking is presented, followed by a discussion of methods, and findings from selected healthcare studies.

Theoretical Underpinnings

Sensemaking is an organizational communication theory with its roots in social psychology. It literally means the making of sense, where *sense* refers to meaning and *making* refers to actively constructing it (Weick, 1995). Sensemaking focuses attention on *human agency, ambiguity, and relationships* (Weick, 1995; Weick et al., 2005). Human agency focuses on the action that people take based on their interpretation of an ambiguous situation that triggers sensemaking (Weick, 1995; Weick et al., 2005). Relationships refer to the social process of sensemaking, and consider the action people take based on their interpretation of an event, the social mechanisms for dealing with the event, and the resulting sense made of the event (Blatt, Christianson, Sutcliff & Rosenthal, 2006; Weick, 1995; Weick et al., 2005).

Although sensemaking is viewed as an ongoing process, it intensifies in situations where organizational members face new situations and are unsure how to act (Weick et al., 2005). Sensemaking focuses on the relationship between cognition and action, particularly addressing cognitive and social mechanisms for managing unexpected events (Weick, 1995). Sensemaking occurs retrospectively and serves to reduce the ambiguity from an unexpected event, allowing an individual to carry out daily tasks within a highly

complex system (Battles, Dixon, Borotkanics, Rabin-Fastmen, & Kaplan, 2006). Weick emphasizes that sensemaking is an active process and that "action is a precondition for understanding" (1995, p. 30). To sharpen the concept, sensemaking is contrasted with interpretation, as they are often used synonymously. Interpretation focuses on understanding or "reading" some kind of "text." On the other hand, sensemaking deals with how the text is read, and also how it is created. Therefore, sensemaking is about *authoring* as well as *reading* (Weick, 1995). Sensemaking gives meaning to experiences.

Sensemaking is a complex process that unfolds as individuals engage in comprehending, constructing meaning, searching for patterns and frameworks, and interacting, all in an effort to pursue a common understanding in organizations (Weick, 1995). Sensemaking by organizational members is grounded in both individual and social activity (Weick, 1995). Sensemaking can be used as a lens to examine how individuals make sense of a situation or as a central activity in organizations, to construct both the organization and the environment it confronts (Weick et al., 2005). Understanding how sensemaking occurs within organizations can help to identify how shared collective knowledge structures arise and further shape the actions of members (Jensen & Aanestad, 2007: Weber & Glenn, 2006). These aspects of sensemaking are further explored.

Sensemaking in Organizations

Sensemaking perspectives may be analyzed from organizational, shared, and individual levels. Sensemaking offers a useful way for organizations to learn from unusual or unexpected events by exploring the underlying factors that influenced the employees' decision making and actions at a particular moment in time (Blatt et al., 2006; Weick, 1995). Seven sensemaking properties described by Weick (1995), which interact as organizational members interpret events, are presented in Table 4.

Table 4. Sensemaking Properties

Property	Description
Grounded in identity construction	Who people think they are in their context shapes what they enact and how they interpret events
Retrospective	Retrospection in time affects what people notice; sensemaking of the present is grounded in past experience
Enactive of sensible environment	As people speak, it helps them understand what they think, organize their experiences, and predict events (Weick, 1995)
Social	Sensemaking is a social activity in that plausible stories are preserved and shared
Ongoing	Individuals simultaneously shape and react to their environments
Focused on and by extracted cues	Extracted cues provide a point of reference for linking ideas to meaning, and are simple structures from which people develop a larger sense of what may be occurring
Driven by plausibility rather than accuracy	Sensemaking is driven by the need for a workable level of understanding to guide action. People favor *plausibility over accuracy* in accounts of events and contexts

Source: Weick, 1995

Organizations continually need to make sense of their environment, learn from events, and identify risks and hazards that may be embedded in processes and systems at all levels (Battles et al., 2006). Sensemaking allows individuals within the organization to tie together separate processes to develop a greater understanding of risks and hazards in quality improvement. Data from workflow process maps and quality improvement findings can support sensemaking efforts when they are combined with end user expertise and knowledge. As organizations seek to make sense of their environment, they actively engage individual employees to develop shared sensemaking.

Shared sensemaking describes organizational social behaviors that lead to shared situational awareness (Weick, 1995). When an unexpected event occurs, individuals must first notice it, make sense of it, and then do something about it (Weick, 2001). Shared sensemaking allows participants to understand the nature of problems and opportunities, and to actively propose innovative solutions (Jordan et al., 2009). The process is strengthened as diverse perspectives are presented, assumptions are tested and challenged, and solutions are pursued (Weick et al., 2005). Sensemaking is highly

interdependent and it is uncertain whether shared and individual sensemaking can even be separated (Weick, 1995). Although shared sensemaking is a collective process, it is only possible when individuals seek out others while attempting to make sense of something unexpected (Hoffman et al., 2009; Jordan et al., 2009). Clearly, sensemaking starts with individuals.

Individual sensemaking is a human cognitive process which has been linked to both problem detection and decision making (Hoffman et al., 2009; Klein, Moon & Hoffman, 2006). In order for sensemaking to occur, an individual must be aware of an abnormality. Jeong and Brower (2008) identified three stages in the individual sensemaking process: noticing, interpretation, and action. Initially an individual notices something puzzling or troubling in a routine situation. Noticing triggers sensemaking and moves the individual from *automatic thinking* to *active thinking*, as they interpret the situation, form a plausible meaning of the underlying causes, and formulate possible appropriate actions (Weick, 1995). Finally, the individual takes action, which may create a change in the situation that provokes further noticing and interpretation (Weick, 1995).

Dimensions of Sensemaking

Unexpected events and workflow disruptions trigger sensemaking. In order to resolve the issue and continue work, the individual attempts to fit the situation into something familiar based on their personal knowledge, beliefs and experiences, as well as the organizational standards and rules for perceiving, interpreting, and acting (Weick, 1995). When the situation is not familiar, an information gap exists. In order to fill these gaps and discover new information, individuals may look for additional cues and triggers, take action, or seek out others for help (Hoffman et al., 2009; Weick, 1995).

Asking others for help is a dimension of sensemaking (Hoffman et al., 2009). The decision to seek assistance facilitates the communication that may add perspective to the situation. The resulting communication frequently occurs informally, allowing members

to collectively interpret and construct shared meaning in situational context (Battles et al., 2006; Weick, et al., 2005). These shared collective knowledge structures shape organizational members' future action, returning sensemaking from the individual to the organization (Orlikowski & Gash, 1994).

Sensemaking occurs informally in organizations, but the possibility of discovering new information and generating effective actions is greatly increased through the use of facilitated sensemaking conversations (Battles et al., 2006; Dixon, 2003; Jordan et al., 2009). Sensemaking conversations contain several critical elements: (1) they are about a particular event; 2) the subject involves an unexpected, or ambiguous event; (3) the purpose is literally to *make sense*; (4) sense is created as individuals share their unique knowledge and experience; (5) sensemaking is facilitated; (6) they allow the development of shared representations; and, (7) the shared representation allows participants to develop and implement potential actions (Dixon, 2003).

Sensemaking of Technology within Healthcare

Sensemaking is useful for investigating how and why organizational members act and make sense of technology at the local level. In the context of sensemaking, technologies are referred to as *equivoques* which indicate that they imply "several possible or plausible interpretations" (Weick, 1990, p. 2). Technologies require continuous sensemaking. As individuals interact with a technology, they determine which possible actions and constraints the technology offers, and then adapt them to meet the specific work context needs (Bansler & Havn, 2004). In order for people to interact and make sense of technology they develop particular assumptions, expectations, and knowledge about the technology, which then shapes their future actions (Jensen & Aanestad, 2007; Orliwiski & Gash, 2004). Sensemaking has served as the framework for studies involving technologies in various healthcare settings.

Jensen and Aanestad (2007) used interviews, observations, focus groups, and written materials and documentation to evaluate nurses' and physicians' sensemaking of an electronic patient record (EPR) in a Danish hospital. They identified three sensemaking themes: (1) c*onceptions of technology* referred to professionals' perceptions of the functionality and capability of the EPR; (2) *conceptions of work practices and role as professionals* referenced intended and actual use in clinical practice, as well as its relation to their roles; and (3) *conceptions of implementation issues* referred to professionals' understanding of adoption aspects of the EPR. Compared to more traditional perspectives of technology adoption and acceptance, understanding sensemaking mechanisms among users was determined to be crucial to healthcare technology management (Jensen & Aanestad, 2007).

Jensen, Kjaergaard, and Svgajvig (2009) combined sensemaking with institutional theory to investigate the impact of social and historical roles during implementation of an EPR among Dutch hospital physicians. An interpretive case study design used observation, interviews, and document reviews to develop an understanding of physician perceptions of the EPR. Using a sensemaking framework, researchers were able to address the phenomenon of EPR implementation at three levels, the organization, the organization/group, and the individual/socio-cognitive. The study showed how a myth about EPR efficiency had travelled throughout the organization and onto individual physicians. Their findings demonstrated strong human agency by showing how physicians enact their work practice and shape the use of the EPR (Jensen et al., 2009). The study suggested that the macro-level structures and individual interpretations must be addressed in order to identify how and why systems are adopted.

Riesenmy (2010) explored physician sensemaking and implementation readiness for electronic medical records (EMR) by interviewing physicians (n=4) in a single hospital. The findings revealed key factors in physician sensemaking, such as

expectations, outside influences, emotion, trust, forced implementation, controlled influence, and clarification of identity. Collectively, these factors described *meaning* through innovation. Study findings revealed that physicians were autonomous learners who used innovative thought processes to prepare for EMR implementation, clarifying their identity as efficient, competent professionals who demand performance excellence (Riesenmy, 2010).

Summary of Sensemaking Literature

The presented studies support sensemaking as an appropriate theoretically sensitive lens for the proposed study. When integrating technology into clinical practice, it is important to understand users' sensemaking processes and how they integrate information to provide safe patient care. As nurses integrate SIPT into clinical practice, they often face workflow blocks that trigger sensemaking. Interview methods provide an opportunity for nurses to describe their experiences with SIPT thus facilitating an understanding of their sensemaking processes.

Chapter Two Summary

Chapter Two provided a review of pertinent literature related to SIPT in medication safety, workarounds, and sensemaking. SIPT has changed medication administration processes and inadvertently introduced new threats to patient safety. Workarounds with SIPT safety features are well documented, but little is known about the conditions under which nurse-initiated workarounds occur in practice. The limited available studies examining workarounds can advance our understanding about SIPT workarounds, but no prior studies were found that explored how nurses make sense of SIPT workflow blocks and when they initiate workarounds. Halbesleben and colleagues (2008) suggested that future research with workarounds might include clinicians who make decisions to initiate them. Bansler and Havn (2004, p. 79) called for future studies to "complement more traditional technology studies with analyses of how sensemaking

processes of organizational members influence the adoption and use of technology in organizations". The current study addresses these gaps in the literature. Chapter Three describes the methods and procedures used in the current study.

CHAPTER THREE

METHODS

This chapter presents the methods used in this grounded theory study. A brief overview of the study purpose and the initial research questions from Chapter One are brought forth. The final study sample is described. GT methodology is then discussed in detail, describing how the initial research questions generated data that informed theoretical sampling, and refined the research questions needed to develop the concepts and categories. Theoretical integration and the processes used to develop the emerging grounded theory are then presented. The chapter concludes with a discussion of the processes used to ensure the quality and rigor of the methods.

Design

A qualitative research design using GT methods was chosen to illuminate the phenomenon of nurse-initiated workarounds in the context of SIPT safety features. Primary data collection used key informant interviews with staff involved with SIPT in a single hospital setting. This design enabled the investigator to address the study purpose, which was to develop a grounded theory explaining nurses' experiences with SIPT safety features and encountered workflow blocks. Initial research questions were developed to understand the processes that nurses use to make sense of and take action in response to SIPT safety features and encountered workflow blocks. These questions sought to understand nurses' perceptions of the SIPT safety features; the rules and resources used when responding to SIPT safety features; actions taken in response to SIPT workflow blocks; and, the conditions contributing to nurse-initiated workarounds with SIPT safety features.

Setting and Study Population

The study was conducted in a 500-bed Midwest academic medical center during 2012. The hospital converted to SIPT in January of 2009 and owns 575 devices. Due to

upgrades and manufacturer recalls, as of December, 2011 the hospital was using the third version of these pumps. The 1100 (915 full-time equivalents) registered nurses (RNs) employed by the hospital serve as the study population, as they are responsible for most IV medication infusions. It is the responsibility of a registered nurse (RN) to place the IV medication in an infusion pump and program the infusion to run over a specified time (Memorial Medical Center, 2011). Approval from the local Institutional Review Board (IRB), which includes a deferment agreement through University of Iowa, was obtained prior to initiating the study and is included in Appendix C.

Sampling and Recruitment

The sampling strategy for this study followed published recommendations and was inspired by grounded theory study completed by Groves' (2011). In qualitative studies, the sample size is determined by the concept of saturation (Charmaz, 2002; Corbin & Strauss, 2008; Morse et al., 2009). A purposive sampling strategy was used for initial data gathering and then subsequent theoretical sampling was guided by data analysis. To ensure diverse experiences RNs were recruited from various adult inpatient units and from different shifts. Recruitment occurred by various methods: e-mail invitations through the hospital's secure intranet (Appendix D), flyers in staff break rooms (Appendix E), and informational sessions at unit meetings. Inclusion criteria were English-speaking nurses employed by the study site, who used SIPT during care delivery. Nurses who did not use SIPT were excluded from the study. Interested participants contacted the investigator and were provided with a *Research Information Sheet* and a *Letter of Informed Verbal Consent* (Appendices E; F). Nurses who volunteered to participate were scheduled for an interview at a time convenient for them

Limitations of the Methods

The current study utilized grounded theory methods, which is used to guide inquiry into a phenomenon when little is known- with the purpose of generating a theory

(Corbin & Strauss, 2008). The generalizabilty of these research findings are limited because they were generated in an exploratory qualitative inquiry. The study design utilized interview data that relied on retrospective accounts of nurses' with SIPT, and the potential for participant recall bias was anticipated. Additionally, it was recognized that nurses may have used SIPT devices in other organizations and may have had experiences different than those in the current organization. To minimize these issues, nurses were specifically asked to reflect on their experiences with SIPT within the current organization. During the study design, it was recognized that nurses with negative experiences or errors involving SIPT may be hesitant to participate. To address this concern, measures to protect anonymity and confidentiality were addressed and are discussed in the human subject's protection section. The potential for volunteer bias, due to voluntary participation and data collection being limited to interviews, was minimized by following GT methods using theoretical sampling. Several nurses who volunteered were not used initially, but after data saturation was confirmed, those nurses were offered an interview as it was felt that their stories may enrich the data.

While conducting the research study, the investigator served as a research nurse within the hospital, had worked with many staff nurses on different projects, and thus routine participant at various nurse-led meetings throughout the organization. While this relationship was felt to be strength in terms of established trusting relationships with the nursing staff, the potential for researcher bias was recognized. This was addressed by maintaining a reflective journal, field notes, and memos throughout the data collection and analysis, to capture biases and assumptions. In addition, the committee methods expert provided oversight and feedback during the study.

Procedures

Consent to participate was indicated by scheduling an interview session with the investigator. Before the interview began, the study purpose and anticipated length of the

interviews was reviewed. Participants were made aware that the interviews would be recorded with their permission and that they could end the interview at any time. No one declined participation or recording of interview data.

Data Collection

Interviews were conducted in private office located away from the nurses' work area. To enhance confidentiality, a unique participant code was assigned prior to beginning the interview. Participants first reviewed the Letter of Informed Consent (Appendix G), and then completed a demographic data collection sheet (Appendix H). Verbal consent was digitally recorded prior to starting the interview. In GT, the researcher attempts to derive an abstract theory of the process, action, or interaction which is grounded in the views of the study participants (Creswell, 2007; Corbin & Strauss, 2008; Morse et al., 2009). Interviews are an effective technique to elicit participant experiences (Creswell, 2007) and have been utilized by researchers exploring individual's experiences with healthcare technology (Jensen & Aanestad, 2007; Jensen et al., 2009; Riesenmy, 2010).

To address the study purpose, an interview protocol was designed. Open-ended interview questions (Appendix I) were developed to elicit rich descriptions of participants' specific experiences or events involving workarounds with SIPT safety features. The interview protocol was piloted with two staff nurses prior to beginning the study; no revisions were needed. Study participants were instructed to consider their experiences with SIPT in the current organization. Following principles of GT methods, interview questions were refined and revised during data collection in response to theoretical sampling needs. Interviews were semi-structured, lasting from 15 to 45 minutes. Consistent with GT methods, data collection was expanded to include interviews with other organizational key informants, policies and procedures, historical training procedures, and organizational communications (Corbin & Strauss, 2008). Also,

consistent with qualitative research methods, participants were asked to consider completing a follow-up interview in order clarifies existing categories and research findings (Morse et al., 2009).

Human Subjects Protection

The risks to study participants were believed to be minimal. It was thought that participants might experience some stress at recalling specific events involving workarounds, particularly if the situation resulted in patient harm. Information for free support counseling was available during the interviews and offered to participants. There were no such occurrences, but nurses were advised of the service if they should have a delayed reaction. Participation in the study was voluntary and confidential, and there were no consequences if they declined or withdrew. To promote confidentiality, interviews were held in a private setting, unique participant codes were used, and verbal informed consent eliminated participant signatures.

Data Management

All data were secured on a password-protected computer with a firewall-protected server. Interviews were digitally recorded and uploaded to the computer immediately after the interviews were completed, and erased immediately after successful uploading was confirmed. Additionally, written field notes were transcribed by the investigator immediately after each interview, allowing for reflection within the context of each interview. Copies of demographic information, which included the date, time, location, and participant ID associated with each interview, were also scanned into the computer.

Interviews were transcribed verbatim by a professional transcriptionist who had completed IRB training and confidentiality issues of the narratives and stories were respected. Transcription accuracy was confirmed by the investigator reading the text while listening to the digital recording. Data were initially loaded into NVivo 10 (2012) data analysis software but as coding involved higher levels of abstraction, Microsoft

Excel (2010) and Microsoft Word (2010) were helpful analytical tools. A reflective journal was maintained, as well as handwritten notes and drawings; these were all dated and filed. Data will be retained for a minimum of three years or until the research process is complete, including dissemination of findings.

Data Analysis: Grounded Theory

Grounded theory methodology relies on the assumption that people strive to make sense of their world and attempt to put some order to it; therefore, the perceptions, thoughts, and behaviors of individuals sharing experiences are the essence of GT (Strauss & Corbin, 1990). Research is a continuous process of collecting and analyzing data, writing memos, and developing further questions- which leads to further data collection (Corbin & Strauss, 2008). During analysis, data are broken down, reorganized, and put back together in order to construct a description of the phenomenon of interest. This section provides an overview of the processes used to discover nurses' experiences with SIPT and follows procedures outlined by Corbin and Strauss (2008), including: open coding, theoretical sampling, comparative analysis, axial coding, theoretical sensitivity, and conceptual saturation.

Open Coding

Open coding is a brainstorming approach to analysis, where the researcher breaks down the data and considers all possible and potential meanings (Corbin & Strauss, 2008). Data analysis began after completing the first interview. Brief field notes were written during each interview, and recordings were reviewed immediately following completion of the interview. During this time detailed notes were taken to capture thoughts about codes, concepts, emerging categories, as well as questions and sampling that would guide subsequent interviews. These notes were used to develop *memos,* which are mini-analyses that capture themes, differences, and thoughts of what is being learned from the data. To illustrate the process, interview one is used to provide examples of

open coding (Appendix J), tentative category development (Appendix K), and a corresponding coding memo (Appendix L).

Theoretical Sampling

Theoretical sampling means that data collection is based on concepts that appear to be relevant to the evolving story, thus questions and concepts developed during analysis guide data collection and sampling (Corbin & Strauss, 2008). Data collection and analysis followed principles of theoretical sampling. While data were being collected, different coding tasks began. As codes were identified and examined for patterns and relationships, data sources were constantly reviewed, including nursing unit, shift, and years of experience, and then considered for theoretical sampling. Interviews 19 through 22 included nurses who entered the organization within the previous two years and routinely administered heparin during care delivery. Data were saturated with the 22nd interview. At this point six additional nurses had already volunteered to participate in the study. Because nurses were eager to participate, and the researcher felt that further interviews might yield additional stories to enrich the data, a total of 28 interviews with nurse end-users of SIPT were completed. Notes and memos were recorded throughout the study. An example of a summative memo related to theoretical sampling is provided in Appendix M.

Final Study Sample

The final study sample of 28 nurses reflected experiences from 13 different adult patient care areas, with one participant serving in a float nurse capacity. The units reflected care of adult patients in medical and surgical units, intermediate care areas, intensive care units, behavioral health, emergency and post-anesthesia. Participants' work assignments crossed all three shifts. Three males participated. Participant ages averaged 36.5 years, ranging from 22 to over 60; 11 participants were under age 30. Most participants held a Bachelor of Science in Nursing (n=26), most others held an Associate

Degree (n=5). Experience as an RN averaged 10 years, with a range of less than one to over 40. Some participants (n=6) held other roles in the organization prior to becoming an RN. Twelve participants were already working as RNs in the organization when SIPT were implemented, the remaining 16 started following implementation. Participant roles included staff nurse (n= 16), charge nurse (n=3), or both (n= 9).

Comparative Analysis

Comparative analysis a key strategy to discover theory in the data, and involves testing tentative ideas and concepts against existing and ongoing data (Corbin & Strauss, 2008). Comparative analysis was used to identify similarities and differences between interviews, thus adding to the properties and dimensions of coded data. Interview data were entered into NVivo 10 (2012) software to facilitate data organization and analysis. Provisional categories from the first interview were used to re-code the data. As subsequent interviews were completed, descriptive codes were placed into broader concepts and similar codes were collapsed together. Codes were then grouped into categories, comparing codes and phrases within and across categories. An example of early category development in NVivo10 is provided in Appendix N.

Axial Coding

Axial coding is a critical step in theory development and refers to the act of relating concepts and categories to each other through a combination of inductive and deductive reasoning. Although often viewed as a second step during data analysis, Corbin and Strauss stress that "open coding and axial coding go hand in hand" (2008, p. 198). While open coding relates to breaking data apart and identifying concepts to stand for data, axial coding is about putting data back together by relating those concepts. As concepts moved toward greater abstraction, they became broader and more explanatory but began to lose specificity. During axial coding supporting categories were developed using a table format to link related sub-categories, supporting concepts, and

representative text. An example of a final category development is provided in Appendix O. “It is the details included under each category and concept, through the specifications of properties and dimensions that bring out the differences and variations in each case” (Corbin & Strauss, 2008, p. 103). The ability to perceive variables and their relationships is accomplished by developing theoretical sensitivity.

Theoretical Sensitivity

“Theoretical sensitivity, or insight into data, is derived through what the researcher brings to the study as well as immersion in the data during data collection and analysis” (Corbin & Strauss, 2008, p. 41). Theoretical sensitivity enables the researcher to grasp the meaning of and respond to what is being said in the data, to arrive at concepts that are grounded in the data, and to present participant’s stories with an equal mix of abstraction, detailed description, and feeling (Corbin & Strauss, 2008). The use of literature and theoretical frameworks has been a controversial topic in qualitative research, although their usefulness has been acknowledged for providing insight, direction, and initial concepts (Corbin & Strauss, 2008). Corbin and Strauss also stress the importance of “remaining open to new ideas and concepts and the willingness to let go if certain imported concepts do not fit the data” (2008, p. 40). With that in mind, the use of literature in this study is addressed.

Sensemaking provided theoretical sensitivity for this study, where sense refers to meaning and making refers to actively constructing it (Weick, 1995). During data analysis, the researcher was mindful of the need to let the story unfold from the interviews, using *sensemaking* to guide theoretical sensitivity. The committee member guiding the research methods also provided feedback that helped the investigator, such as using participant words to guide coding and category development. As more abstract categories were developed, the researcher continually returned to the text to keep the analysis grounded. Interviews continued until conceptual saturation was achieved.

Conceptual Saturation

Data are gathered until reaching *conceptual saturation*, which is described as the point "where no new categories or relevant themes are emerging" and also where these categories are "developed in terms of their properties and dimensions, including variation, and possible relationships to other concepts" (Corbin & Strauss 2008, p. 148). After completing 18 interviews no new data were emerging, but the reasons for varied descriptions remained puzzling. Nurses described wide variations in: (a) education and training, (b) understanding of fundamental SIPT safety features, (c) and approaches to using protocols and finding medications the DL.

To further understand these phenomena, key informant interviews were conducted with organizational members from employee education, pharmacy, and a nursing administrator who were involved in the initial implementation and continued to support SIPT use in practice. Data from these interviews illuminated reasons for the varied responses between nurses and guided further theoretical sampling. Data were saturated with the 22nd interview but six additional nurses had already volunteered to participate in the study. Because nurses were eager to participate and the researcher felt that further interviews might yield additional stories to further enrich the data, a total of 28 interviews with nurse end-users of SIPT were completed. Data analysis allowed for theory development.

Grounded Theory Development

Developing grounded theory (GT) is complex and although creating categories is an important first step, but more work is required. Theory evolves over time as the analyst is immersed in the data, attempting to make sense of multiple concepts that exist in complex relationships and sorting through the range of conditions and consequences in which events are located and responded to (Corbin & Strauss, 2008). The connections between contextual factors and actions are often difficult to sort through, since one event

often leads to another, “like links in a chain” (Corbin & Strauss, 2008, p. 91). Research findings should not oversimplify the phenomenon, but rather capture some of the complexity of life. Another metaphor used to describe the consequences of conditions and subsequent actions was that they are likely to bounce off each another like “billiard balls, leading to consequences that one cannot always predict in advance” (p. 91). That was found to be true with this research. During the writing process the data seemed to be clear and then would muddy again, with categories often overlapping and almost becoming circular at times. With the guidance of the committee methods member and further analysis, these contextual factors and actions were further refined and integrated.

Theoretical Integration

Theoretical integration is considered a final analytical step for theory development. Theoretical integration starts with identifying a central category to serve as a conceptual umbrella, under which all other categories can be subsumed (Corbin & Strauss, 2008). An overview of the theoretical components of the emerging theory of Nurse-Technology Interplay, which serves to explain the complex and dynamic nature of nurses co-existing with SIPT, is provided in Appendix P. The central category may arise from an existing category or it may be determined that another more abstract term is needed. Corbin and Strauss recommend using Strauss’s criteria (1987, p.36):

1. *It must be abstract: that all other major categories can relate to it and be placed under it.*
2. *It must appear frequently in the data. This means that within all, or almost all, cases there are indicators pointing to that concept.*
3. *It must be logical and consistent with the data. There should be no forcing of data.*
4. *It should be sufficiently abstract so that it can be used to do research in other substantive areas, leading to the development of a more general theory.*
5. *It should grow in depth and explanatory power as each of the other categories is related to it through statements of relationship.* (cited in Corbin & Strauss, 2008, p. 105).

Several techniques are recommended for identifying the central theme, such as writing a story line, using diagrams, and reviewing and sorting memos (Corbin & Strauss, 2008). Following a review of initial data analysis, the committee member guiding methods suggested the development of a story line and also a review of the category labels which mirrored sensemaking literature, as it was important that the study findings remain grounded in the data.

Because of the potential for readers to misunderstand how sensemaking was used to provide theoretical sensitivity, a conscious decision was made to avoid the use of sensemaking terminology in the development of the final categories. To ensure that the findings were grounded in the data, coded data that reflected sensemaking terms were noted and memos developed throughout analysis. The investigator then reviewed the memos and then returned to the data to identify alternative codes that equally captured the essence of participants' experiences. For example, when participants talked about making "sense" of a situation, transcripts were reviewed and it was determined that making "meaning" accurately captured participants experiences. Thus "making meaning" was chosen as a category. Creating the storyline served to further confirm the findings.

The storyline serves to describe the research in a few words. Writing the storyline proved to be a helpful technique. As the original transcripts were reviewed a sense of what was going on came through the data. "Often, returning to the raw data and rereading several interviews or observations helps to stimulate thinking" (Corbin & Strauss, 2008, p. 107). As the interviews and memos were reviewed, category labels were further refined, and the story line emerged. This iterative process resulted in a concise description of the research as well as the identification of the central category and supporting categories of the emerging GT. Because this process served as a crucial component of the methods, and supports the rigor of the study, it is included here.

The Story Line

Below is the story line which led to the discovery of the central category and the theoretical memo that followed.

> **The story line.** Nurses interact with SIPT during care delivery while administering IV fluids/ medication. SIPT features include alerts which are designed to signal the nurse to a possible safety problem. When nurses encounter workflow blocks with SIPT, they engage in cognitive (meaning making) and physical (taking action) processes to resolve them. The way nurses interact with SIPT is influenced by various factors, but the way they use the technology is situational to meet the patient's specific needs and desired outcome, whether it be treating a life-threatening condition or creating an environment to support rest. So, using SIPT goes beyond medication administration and requires continual interplay between the nurse and technology to achieve desired patient outcome.
>
> **Memo: Theoretical Integration.** I am struggling with identifying a core/central theme. And, as I review my memos and identified categories, I am not totally satisfied with my first theme heading named "Nurses use of SIPT". As I re-read interviews, that term did not seem to truly reflect the story that was unfolding. So, I started to play with some of the words in the text to see if anything would emerge "NVivo". I really did not see anything – but I was really drawn to one of the categories that I had developed- "human-technology" interface. I was leaning toward interface, but that seemed too technical-and did not reflect the dynamic aspect of how nurses interact with SIPT- the situational aspects of care delivery. So, I changed that theme to "Interacting with SIPT". Could "interacting with SIPT" serve as a central theme? I played with that but as I tested it with Strauss's (1987) criteria- it did not really seem to serve as a "best fit" for all of the other categories. Then I was re-reading my notes and came across one of my possible choices for theme 1: "interplay". That seemed like a strong possibility for a central theme. Interplay: the ways in which two or more things, groups, etc., affect each other when they happen or exist together, often + between or of (Merriam-Webster online dictionary, n.d.). Interplay seems like a better fit for a central theme. It reflects the story that emerges from interviews- more of the dynamic nature of how nurses co-exist with SIPT, and how it influences care delivery by nurses. As the number of technology's increase, become more integrated and tightly coupled, nurses must adapt their practice- but the care and concern for the patient remains their central focus. I am also realizing how true it is that the experiences of the researcher will be reflected in data analysis (per Corbin & Strauss). As I reread some of the interviews and thinking about the story line, I found myself recalling experiences and observations made during my son's hospitalizations in 2013- many months after the last interviews were completed. (August 11th, 2013).

Quality and Rigor of the Research

"Quality in qualitative research is something that we recognize when we see it; however, explaining what it is or how it is done is much more difficult" (Corbin &

Strauss, 2008, p. 297). Rigor is built into GT methods through the inductive-deductive cycle of theory generation, thus applying the methodology correctly is the single most important factor in ensuring rigor (Cooney, 2011). Multiple methods were used to ensure the quality of the research findings. GT principles as outlined by Corbin and Strauss (2008) were followed and previously described. Data interpretation and analytic techniques were reviewed periodically with a committee member who has expertise in GT methods. Examples of notes and memos about sampling and analysis decisions were provided, and a reflective journal were maintained during the study; providing an audit trail (Corbin & Strauss, 2008; Morse et al., 2009).

Corbin and Strauss (2008) provide evaluative criteria which are addressed within this study. *Logic* describes whether the findings make sense to the reader; the current study findings reflected experiences with SIPT *Fit,* or whether the findings resonate with the intended professionals, was tested by sharing the storyline and overview of study findings with five nurse participants, who all confirmed the logic and fit criteria. *Applicability* refers to the usefulness of the findings; the emerging theory provides new insights for practice. *Concept*s reflect c*ontext and depth of* properties and dimensions, which are supported in the findings and discussion.

Chapter Three Summary

This chapter presented the methods employed in this GT study which explored nurses' experiences with SIPT safety features. Interview data were used to generate a GT that explains nurses' experiences with SIPT safety features and encountered workflow blocks. The emerging theory is presented in chapter four.

CHAPTER FOUR

RESEARCH FINDINGS

In this chapter, the results of the interviews and the evolving GT are shared. The purpose of this study was to develop a grounded theory that explains nurses' experiences with SIPT safety features and encountered workflow blocks while caring for patients. Data were obtained through staff nurse interviews. Interviews were limited to staff nurses who work directly with SIPT in a single hospital. The initial research questions were developed using sensemaking and workaround literature to elicit nurses' an understanding of how nurses make sense of and take action in response to SIPT workflow blocks. The inquiry became more focused using GT methodology to analyze data, refine research questions, and guide theoretical sampling. Three additional key informant interviews with members from employee education, pharmacy, and nursing administration provided organizational context that clarified variations in some participant responses. Finally, where present, context is provided within brackets to differentiate context from participant data.

Final Sample Description

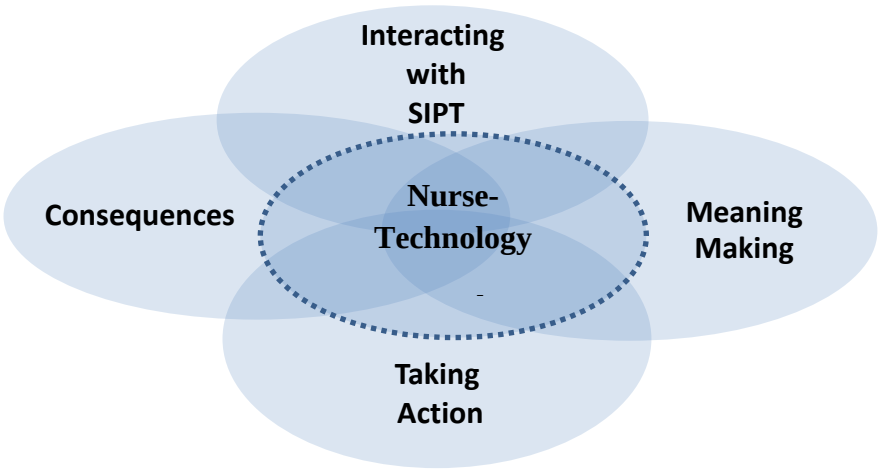
The final study sample of 28 nurses reflected experiences from 13 different adult patient care areas in a single organization. Participants' work assignments crossed all three shifts and reflected a diverse range of work experience and ages. Analysis of interview data resulted in an emerging grounded theory of Nurse-Technology Interplay.

The Emerging Theory of Nurse-Technology Interplay

This study sought to understand nurses experiences with SIPT in practice, particularly how they make sense of and respond to workflow blocks with SIPT safety features. The interview process provided data which were broken examined for similarities and differences in regards to nurses' experiences with SIPT. Sensemaking provided theoretical sensitivity for data analysis. From this analysis emerged the

grounded theory of *Nurse –Technology Interplay, which* explains the dynamic interrelationships that occur as nurses use SIPT in practice. The presented findings provide a synthesis of connections among the data and emerging categories. The four categories, (1) interacting with SIPT, (2) making meaning, (3) taking action, and (4) consequences, support the central category of Nurse -Technology Interplay (Figure 1).

Figure 1. The GT of Nurse-Technology Interplay



The supporting categories, sub-categories, and concepts of the grounded theory of Nurse-Technology Interplay are provided in Table 5. Although the presentation of the central and supporting categories may appear linear, they are complex, dynamic, and interrelated. An in-depth discussion of each category follows, using direct quotes to illustrate connections from interview data to abstract concepts (Corbin & Strauss, 2008).

Table 5. Categories of the GT of Nurse-Technology Interplay

Supporting Categories	Sub-categories	Concepts
Interacting with SIPT	Learning curve	SIPT Training Human-technology interface Complexity of the Drug Library Basic device knowledge gaps
	Patient-care unit characteristics	Patient population Unit level troubleshooting approaches
	Workflow blocks	Organizational blocks SIPT blocks
Making Meaning	Working through the clinical situation	Vigilance Rethinking Situational context
	Individual perspectives	Safety perceptions Personal experience
	Shared learning	Captured events Missed opportunities
Taking Action	Rechecking	Medication checks Reprogramming
	Workarounds	Fooling the pump Working outside safety software
	Seeking assistance	Unit level resources External resources
Consequences	Medication administration patient outcomes	No problems detected Problems detected
	Impact on nursing practice	Disruptions to care delivery Dependence on technology Loss of calculation skills Alert overload
	Impact on nursing practice	Disruptions to care delivery Dependence on technology Loss of calculation skills Alert overload

The Central Category: Nurse-Technology Interplay

Nurse-Technology Interplay describes nurses' experiences with SIPT, and how the technology impacts care delivery and nursing practice beyond IV medication administration. Merriam-Webster online dictionary (2013) defines interplay as*: the ways in which two or more things affect each other when they happen or exist together*. As

technologies become increasingly integrated into patient care delivery, they require nurses' attention to manage them, and influence all aspects of care delivery. As nurses described their experiences with SIPT, it was clear that their primary focus was supporting the patients' needs.

Interacting with SIPT

Interacting with SIPT is the first category supporting the grounded theory of Nurse-Technology Interplay. Interacting begins as nurses first encounter SIPT and continues throughout care delivery. Interacting reflects the diverse ways in which nurses encounter SIPT, and thus reflects many concepts. The categories of interacting include: learning curve, patient-care unit characteristics, and workflow blocks.

As nurses are trained on using SIPT, they experience a learning curve in understanding how the computer thinks, or the human-technology interface. Learning curves continue in practice when encountering unexpected situations, and are overcome through informal learning. Patient-care unit characteristics, reflecting the patient population and unit-level trouble-shooting approaches, strongly influence SIPT interactions. During SIPT interactions routinely encountered workflow blocks emerge from organizational factors and directly with SIPT. Workflow blocks are perceived as helpful or unhelpful, with a single block often falling into both categories, depending on the nurse's perception and situational context. Nurse-Technology Interplay is influenced by nurses' interactions with SIPT. For example, a knowledge gap of SIPT features may lead to inappropriate use, and potentially negatively impact patient care.

Making Meaning

This supporting category describes the cognitive and intangible aspects of Nurse-Technology Interplay. Nurse-Technology Interplay is dependent on the situational meaning involving SIPT and the desired patient care outcomes. Making meaning involves working through the clinical situation by attempting to make some sense of the

workflow block and determining what it means in context. Nurses engage in increased vigilance, rethinking their actions while considering the clinical situation and the potential impact on care delivery. Making meaning is influenced by individual perspectives, as well as shared learning. For example, future meaning-making may be influenced if organizational members collectively learn from events, make improvements, and share information. Thus, Nurse-Technology Interplay is influenced by the meaning that nurses make of the situation at hand.

Taking Action

This supporting category reflects the state or process of *doing*, representing the visible and tangible aspects of Nurse-Technology Interplay. Actions may occur simultaneously with, or as a result of, situational making meaning. When nurses encounter a workflow block they begin physically rechecking previous actions such looking at medication labels and programmed settings. Rechecking may lead to reprogramming, either through or around SIPT safety software. Working through SIPT safety software reflects programming by selecting the correct medication and concentration. Working around SIPT safety software represents alternative unapproved approaches to using the pump. Workarounds are actions that involved administering medications contrary to SIPT safety software, such as using the Basic mode feature. Nurses also take actions to avoid SIPT alerts by *fooling the pump* to run as medication other than was actually being delivered. When SIPT is not available, nurses resort to administering medications by alternative methods, such as syringe pumps. Other actions include seeking assistance of colleagues on unit or external to the unit.

Consequences

Consequences of Nurse-Technology Interplay reflect the influence of nurses co-existing with SIPT in care delivery. As nurses use SIPT to administer medications, they reported consequences impacting both patient outcomes and nursing practice. Most

nurses reported no problems detected with medication administration patient outcomes. However, others reported problems resulting in near misses and actual errors. Nurses described the impact of Nurse-Technology Interplay on practice, as they experience disruptions in care delivery, dependency on SIPT, a loss of calculation skills, and alarm overload.

A brief description of supporting categories and their relationship to Nurse-Technology Interplay was presented. The development and detailed findings of each category are presented.

Category Development and Findings

The categories supporting the grounded theory of Nurse-Technology Interplay are presented here. Each category includes discussion of related categories and concepts. Participant quotes, coded by case number, are used to illustrate the emergent theory. Within the findings key informant interview data are bracketed, further illuminating participant responses.

Interacting with SIPT

Interacting with SIPT reflects the first supporting category of Nurse-Technology Interaction, and is envisioned as the many ways nurses "experience" SIPT in practice. Interacting begins as nurses start as a "novice" learning the technology rules, and continues as nurses become an "expert*"* who masters the technology, learns to adapt to encountered obstacles, and teaches others. A more formal definition of interacting, from the *Merriam-Webster* online dictionary (2013) is "*to* act upon one another; to come together and have an effect on each other." In the study of the SIPT and nurse interactions, the categories of interacting include: learning curves, patient-care unit characteristics, and workflow blocks.

Learning Curve

Nurses interacting with SIPT face *learning curves*. A learning curve represents a common sense principle: as people gain experience in doing a task they become better at it. The phrase learning curve came up several times during interviews as nurses discussed initially using SIPT and as new interfaces with the SIPT occurred. Learning curves are associated with and influenced by nurses' initial training about SIPT, human-technology interface, the complexity of the Drug Library, and basic device knowledge gaps.

SIPT Training

SIPT training reflects both the education and training that nurses receive about SIPT, both initially and throughout care delivery. Initial training about SIPT includes training nurses about the basic skills needed to use the device, as well as educating them about the organizational processes and procedures that impact SIPT use. Findings revealed wide variations in how nurses initially learn about SIPT, reflecting both formal and informal approaches. Participants who were employed when SIPT was implemented described formal classes and structures to support ongoing clinical challenges such as nurses were trained and available as super-users. Alternatively, nurses employed following the initial SIPT implementation described a wide array of approaches to training including structured classes, unit level training with a preceptor, or very informal training. Additionally, nurses serving as unit level preceptors had different understandings of how new employees learn about SIPT during orientation, and none described a structured process at the unit level. As nurses described SIPT interactions in practice, they engaged in troubleshooting infrequent or unexpected situations. As one nurse described, "They might need to learn that on the fly" (Case 25). The following excerpt describes an experience with the initial training:

> I can't say I had any organized training I just kind of went to whoever I needed. It was a lot of piecemeal, when I needed to learn something I just asked somebody. I can't say I was ever like formerly trained on them (Case 12).

Human-Technology Interface

The human-technology interface reflects nurses' experiences with learning how SIPT is supposed to work, and how to use it in practice. Nurses discussed ongoing learning curves as they became familiar with SIPT, understanding how to think like the computer and determining the technology's limitations, trustworthiness, and efficiency. SIPT is designed to alert nurses to areas of potential safety risk by asking them to confirm specific information, such as the medication, rate, and concentration, or the patient's weight for correct dosing. Nurses must also acknowledge alerts, such as medication incompatibilities or rates nearing or exceeding pre-determined safe limit range. Most nurses felt SIPT adds a level of medication administration safety by forcing double-checks. However, nurses also discussed SIPT limitations, recognizing that machines do not replace good judgment. Nurses were more likely to trust SIPT if they had experienced an averted error. Nurses had mixed perceptions about SIPT efficiency, yet even those who felt programming took longer than traditional pumps believed the added safety was worth it. These excerpts exemplify the learning curve related to the human-technology interface:

> "It just takes a matter of remembering you've got to do all of that…I put it all in one day and hadn't even primed the tubing so "Error"-it's like oops! Take it all out and prime it. So it lets you know. And that's ok. It calls me back." (Case 3).
> The smart pump is just a computer so you have to think like a computer… It doesn't affect the care it just takes a little longer maybe… using it and answering those questions: are there drips? Is it dripping in the chamber? …or are you sure this is the correct medication? This is what you want even though it's not compatible with Heparin... So you're not used to those questions coming from a machine. You usually do that in your head, so that's the extras. I think the only learning curve was understanding how to communicate with it and understand its steps…Machines aren't always right- they're not fool-proof. (Case 9).

Complexity of the Drug Library

Complexity of the Drug Library reflects nurses' experiences with locating needed medications in SIPT, learning basic programming rules and exceptions. During interviews, participants described learning curves with finding medication and fluids in

SIPT. Nurses described selecting the appropriate care area profile which contains population specific dosages, such as critical care or oncology. Ideally, nurses would work from a single care area profile. Nurses discussed the need to work between multiple care area profiles during a shift, and sometimes in caring for a single patient. As one participant (Case 3) described: "So, you could be working out of 3 different drug libraries potentially." Once the care area profile has been selected the drug has to be selected.

Nurses described varied approaches to finding drugs. The pump uses a standard alphanumeric keypad. Thus, each number on the keypad corresponds to a set of alphabetical letters which are labeled on the key. So, to find the letter "D" for dextrose, the number key 2 would be selected. Most medications can be found by programming the first two letters of the drug name. Many nurses were unsure whether the drugs were programmed by generic or trade name, or whether information on the bag labels would facilitate programming. After the medication is found, the appropriate dosage or concentration would be selected. Participants often described difficulty in finding specific IV fluids and blood products. Dextrose solutions come in varied concentrations, such as 25 or 50 percent. Because numbers cannot be programmed on the keypad, nurses described programming a single letter "D" and then scrolling through a list of options. Nurses also described that blood products found by programming the device differently than they expected. Nurses expected to program blood products as they are ordered and executed, such as "PRBC" for packed red blood cells. Instead, blood products can be found under the letter "B." Below are some examples of nurses' descriptions of finding drugs:

> Learning all the different libraries [care area profiles] and what is in them takes a bit of time. At first it was hard to figure out- I think it's a learning curve- now everybody can usually find what they need, or at least help each other. (Case 23).

> Some medications still don't have a default rate, such as Vancomycin does not default to the rate should be. If you're going to do it for one I think it should be done for all. There can also be improvements made to the Drug Library like heparin; there are three different protocols for heparin. (Case 25).

Basic Device Knowledge Gaps

Participants also described learning curves in clinical situations that require them to use unfamiliar SIPT features. Many nurses were unaware of SIPT safety features (Basic Mode, Limit Alerts, DL updates). Basic Mode is a feature that allows the SIPT safety software to be bypassed during medication administration. Basic Mode presents an increased safety risk because it negates SIPT safety features and reduces it to function as a standard pump; however, it may be a necessary feature when a medication is not in the Drug Library. Nurses described being advised by pharmacists to run medications through Basic Mode, but they were unaware of the feature and had to learn it while managing the patient's care. Gaps in knowledge about the Basic Mode feature were apparent in nurses who started after initial SIPT implementation. A nurse described such an experience:

> I guess now that you explain that I know that you are talking about but it was never explained to me as Hard Limits and Soft Limits. (Case 4).

> I had to speak to the pharmacy manager and he was able to tell me how to get into Basic mode-because the person [pharmacist] I was talking to just didn't know how… Once you know it is pretty self- explanatory. I didn't know that was available before that. (Case 1).

Another gap was related to the meaning of the flashing red visual display that alerts users a programmed dose is out of the pre-determined safe range. These alerts are set as S*oft Limits* which can be over-ridden, or *Hard Limits* which prevent further programming. Several nurses were unclear about the differences between the two alerts, and described that they would call pharmacy when they saw the flashing red display just to make sure the dosage was acceptable.

> I had a nurse come to me and giving IV Potassium, they put the rate and everything in the machine, and it was red and they wanted to know why it was red. (Case 25).

Patient-care Unit Characteristics

Patient-care unit characteristics provide context for nurses' SIPT interactions. Concepts include typical patient population and unit level practices. Nurses' interactions

are influenced by the nurses' familiarity with the unique needs and challenges of a patient population, also reflecting the type and frequency of medications administered. In addition, unit level norms for troubleshooting influence interactions.

Patient Population

The patient-care unit type reflects the typical patient population cared for on each unit, such as medical cardiac, oncology, or surgical intensive care. Nurses describe that within these patient populations, medications delivered are typically within a standard range. Depending upon this patient population, nurses described using SIPT from only a few times a month to routinely managing multiple SIPT on a single patient. Intensive Care Unit nurses described the likelihood for each patient to have multiple SIPT infusions requiring frequent titration and adjustment. Nurses working in units that provide care for both inpatients and outpatients, such as the emergency department or post-operative recovery, discussed routinely managing a variety of infusion devices other than SIPT. These devices included a syringe type pumps, dial-a-flow tubing that regulates flow rates without using a pump, or simply running fluids to gravity. Nurses described challenges with needing to remain proficient with varied infusion approaches. These descriptions reflect differences in patient populations:

> Typically we have two to three ICU patients per shift administering vasopressors or pretty much anything you can put on a pump. All of our patients have smart pumps, and our patients have multiple pumps so there's a lot to keep track of (Case 22).

> I work in the emergency department so not all of my patients would have a smart pump in place but some of them do…. We start heparin infusions frequently in the ER and we start insulin drips but that's not a daily thing. (Case 25).

Unit-level Troubleshooting Approaches

Nurses described unit specific SIPT practices. Nurses develop an understanding of their available resources as they enter the organization. During orientation, new nurses learn who their troubleshooting resources are. As nurses learn what troubleshooting

resources are most dependable, they make choices accordingly. For example, night shift nurses discussed limited pharmacy staff and thus they did not typically seek them out as a resource. One unit had developed SIPT support materials to assist new nurses and as a reference for experienced nurses. Nurses who float to different units also described unit specific troubleshooting approaches.

> We have a pretty good unit orientation packet. It's in our smart book of the individual machines that we use and how to use them…for the unit, for new nurses and more experienced nurses that need a refresher. (Case 9).

> Since I float, I will typically go to the charge nurse first for a problem with a certain medication and find out how they handle it. The charge nurses are pretty good… and then that determines if I call pharmacy or not. (Case 27).

Workflow Blocks

Workflow blocks are the result of obstacles or barriers forcing the nurse to stop their work. The concepts of this category include organizational blocks and SIPT blocks.

Organizational Blocks

Organizational blocks reflect issues not directly related to SIPT-nurse interaction. Types of organizational blocks include pump availability, organizational policies, and an incomplete Drug Library.

Pump Availability: Nurses describe difficulties obtaining pumps in a timely fashion, more so in units that care for both inpatients and outpatients, where SIPT is not used for each patient. Nurses in the emergency department described how new programs, focused on reducing time to treatment, had increased the frequency and number of SIPT used. However, nurses working on inpatient units also described situations where SIPT was needed, and delays in obtaining devices. Nurses describe time spent looking for and waiting on SIPT, and then making decisions on how to infuse medications when SIPT was not available. These decisions include delaying medication delivery, or administering medications or fluids through syringe pumps, dial-a-flow tubing, or by gravity.

> Sometimes you send a patient to Cath Lab on Nitro, Heparin and fluids, so you know you sent them 3 pumps and they come back with fluids on gravity. You're going, "where's my pumps?" Sometimes, like if it's just a fluid thing they come back on the Dial-A-Flows so you know it's kind of regulated so you can at least... But if they have to get started up on a Nitro drip for a pressure problem or you are waiting to start up some critical drips on somebody else it can cause a delay in treatment. Number one problem we run into is somebody goes into rapid A Fib and we're trying to start Amiodarone or Diltizem and we can't find a pump and you can't start the bolus or the drip without a pump. I think the longest I've had is 45 minutes to an hour. And in between time you've used all your resources to go around the whole floor and make sure there aren't any hidden anywhere and you are still like looking. (Case 6).

> Try as we may, we don't always get the pumps when we request them and when the hospital is full we can't get smart pumps….If I don't have pumps available and it's just a regular fluid we hang it to gravity…. If we don't have the pump available, and we need to manage a certain drip like neosynephrine, we use micro drip tubing and titrate the medication accordingly per blood pressure. Now, if they are on a neosynephrine drip more than 30 minutes it must be run on the smart pump…. The only time we run a medication outside the safety software is when we don't have enough pumps. (Case 15).

Organizational Policies: Organizational policies can create unintended blocks to care delivery. Nurses described mixed feelings about the value of the 30 Minute Bag Near Empty Alert. [A nursing director who oversaw SIPT implementation confirmed that this feature is the default on all pumps and cannot be turned off. This decision was made with input of nursing staff prior to implementation and has not been re-evaluated.] Not having the ability to individualize this alarm frustrates nurses, creates disruptions to workflow, excessive alarming, and workarounds. Nurses discussed an overwhelming preference to have control over this feature, as exemplified by this excerpt:

> I like the 30 Minute Bag Near Empty Alert on vasopressor agents but I hate the 30 min. to bag empty alarm on things like normal saline or different antibiotics. I feel like those types of things I would like to have control over. It gets kind of frustrating when you're titrating medications and it keeps saying bags near empty, and I've been in this room six times in 15 min. just to address that. … you push okay that you know that the bags near empty the alarm has gone off, but then you go back and you're titrating it, so it keeps alarming every time you change the dose and titrate. So, if there are 17 min. left, it's going to alarm again to tell you that the bags near empty because you adjusted the dose. And if you titrate higher, it still tells you that the bags can be out in less than 30 min. so you push okay. (Case 14).

Incomplete Drug Library*:* Nurses described unexpected situations when the medication or needed concentration was not in the Drug Library. Nurses described various actions when encountering this situation, such as infusing the medication under another name, or seeking assistance from the pharmacist. Nurses described that sometimes the medication could be added immediately and at other times they were instructed to use Basic Mode until the medication could be entered into the Drug Library. [The pharmacist revealed that the Drug Library is maintained by one pharmacist, which may delay updates. Additionally, SIPT is incapable of running infusion volumes below 0.5 ml/hour.] Below are excerpts of nurses' interviews:

> I have once gone into Basic Mode. That was a specific situation that was for, it's when they have heparin allergies, I have only had two patients that have had it… we had to change the concentration in the bag and that wasn't programmed into the pump. It had to be manually changed from a 250 to a 500 bag for the same medication that was half as concentrated because the pumps can't deliver accurately less than half a milliliter an hour. (Case 1).

> Or sometimes I would just run it as normal saline, you know as long as you have the right rate and amount. Sometimes I have not been able to find other drugs but then it seems like after a while the pharmacy adds them. (Case 20).

SIPT Blocks

SIPT blocks reflect blocks originating from the technology, including alerts, problematic medications, and pump malfunctions.

Alerts*:* Alerts are intentional workflow blocks created to alert nurses to potential errors. As previously described, when a medication is programmed into SIPT the safety software assures the programmed dose is within an acceptable limit. Limits can be set to allow overrides (Soft Limit) or not (Hard Limit). If the user chooses to override the alert the display remains red. Nurses frequently reported that programming of certain medications according to the label, such as potassium, resulted in an unwarranted Soft Limit alert. The alert creates ambiguity as nurses expect the dose on the label to be within the safe range, as described:

> There are times when what is on the label is faster than what the pump says it should run at. So for example the label will say to run this over four hours at 120, and I think the pump Soft Limit is set at 100, so I just run it to what the pump says and not what's on the bag. Some of the vancomycin runs like that too, so I just run it at the Soft Limit and not what the bag says, unless if it's one of those antibiotics it is only stable for so long. So if it's a stability issue, it's written on the bag, and I will go ahead above the Soft Limit and run it at with the bag says not just with the pump it's telling you to run it at. (Case 20).

Other features discussed were the optional Call-Back Alert, the 30 Minute Bag Near Empty Alert, and Clinical Advisory Alerts. Clinical Advisory Alerts are designed to support nurses' workflow by warning nurses that infusions are nearly finished or advising of incompatible drugs, or additional needed precautions such as using a filter. Nurses reported that they frequently call the pharmacy to check about drug interactions and they wished more alerts were available. [The pharmacist advised that SIPT software limits Clinical Advisory Alerts to 200, otherwise he would expand to all drugs]. As described by one nurse: "Vancomycin comes up and has a big warning that it is incompatible with heparin. So, not a lot of them but the big ones are there." (Case 18).

Problematic medications*:* Nurses found specific drugs more difficult to administer. They found it puzzling that all drugs did not have default rates; frequent examples were heparin, vancomycin, and vasopressors. There were many frustrations and concerns related to these medications, primarily due to multiple doses and concentrations. Transitions in care were frequently the point of detecting problems with these types of medications. Below is an excerpt that illustrates problematic medications:

> Vasopressor agents are a little bit difficult because you can get several concentrations, so you have to make sure your eyes are open that we have several types of medications and several concentrations. Yes, one time I had a patient come up from the emergency department and they have the wrong concentration set up in the pump, so it was running totally wrong. Luckily, we got it quickly…the patient was not harmed. (Case 28).

Heparin, a potent blood thinner, was another problematic medication that nurses discussed and was also involved in medication errors. Nurses described complexity with choosing between different heparin concentrations and multiple protocols to manage specific illnesses, such as pulmonary embolus versus acute coronary issues. Nurses

discussed difficulty using protocols which are not in the Drug Library but available through an electronic resource. Nurses suggested that adding the protocols to the Drug Library might help avert errors. Below is an interview excerpt that illustrates concerns with administering heparin protocols:

> There can also be improvements made to the Drug Library for heparin; there are three different protocols [deep vein thrombosis, pulmonary embolus, and cardiac]…the pumps only have weight-based heparin. If you had those three, with the doses per kilogram, you could put those in weight-based and the pump would make that calculation. If they're smart make them really smart, and then you would get a warning: "oh, you can't do that, you can't run a cardiac over 1000 ml an hour, are you sure you want this rate?" There could be further default systems that help you. Mainly the heparin because we run it so much and it's so hard for the nurses to give because it's pretty much left out in the open and not explained very well to be honest with you. (Case 25).

Pump Malfunction*:* Pump malfunctions reflect unexpected events where the technology fails to work. The organization replaced the SIPT pumps about a year prior to these interviews due to a manufacturer's recall. Nurses discussed how a manufacturer's recall, related to a possible faulty mechanism that could cause SIPT to free-flow, changed practice. While SIPT devices were being replaced, a back-check valve was used to prevent free-flow during infusions. These back-check valves could not be used with blood, so blood products were run to gravity. This was a new experience for many nurses, as described below:

> Of course right after I started working here they had the recall on the pumps, and we had to start using the back check valves on everything except blood. And blood we had to go back to hanging by gravity. You really had to plan spending some extra time fiddling with drip rate and make sure you have that right…. and check them frequently… But that's when I really miss the recall feature of the pump. The back-check valves themselves added problems because they would cause some false downstream occlusions. And, if you did need to run fluids wide open you had to take the back check valve off so that delayed time. (Case 12).

Since the manufacturer recall, nurses described recent issues with pump malfunctions. Some malfunctions were easily detectable and accompanied by continuous alarming, these were taken out of service and sent to biomedical engineering. Other reported malfunctions were related to SIPT appearing to run but medications not

infusing. Similar stories were reported across inpatient units. This type of malfunction was not easily detected by nurses. These incidents were reported to biomedical engineering and devices were checked. The excerpt below reflects such a situation:

> I think our unit just had one error with the smart pump and I think that was a malfunction. The pump was reading like it was giving the medication-it was a heparin drip, so that was a pretty big medication error. That happened a few months back. It was a big deal, it went through two shifts and the second shift caught it. They noticed that the bag was still full and it should've been emptied by the end of the shift. (Case 16).

Helpful and unhelpful block*:* Nurses encountered many workflow blocks while using SIPT. Nurses valued blocks which are perceived to be helpful and support workflow or enhance safety. However, blocks that were ambiguous or that were not perceived to be value added were perceived as unhelpful. While limited in number, Clinical Advisory Alerts were highly valued. Soft and Hard Limits alerts were perceived as a safety enhancement. Staff stated they rarely encountered Hard Limits [the pharmacist clarified that very few medications have Hard Limits alerts programmed]. The Downstream Occlusion Alert was perceived as helpful, particularly since it self-terminates if the patient straightens their arm. Nurses liked features that could be controlled, such as the Callback Alert for secondary infusions. The low battery signal sounds different from other alerts, which was helpful because a technician could be sent to plug in the device.

Unhelpful signals included the Air-in-Line and Upstream Occlusion alerts. Both of these alerts were felt to be unreliable and perceived as nuisances. In many cases, depending on the perception of the nurse and the context of the clinical situation, the same block might be viewed as both helpful and unhelpful. The 30 Minute Bag Near Empty Alert was perceived as both helpful and unhelpful, with most nurses wanting control over when to use it. The following interview excerpts describe nurses' perceptions of SIPT alarms:

> There was this rare drug I had, I think it popped up and said: "Incompatible with Normal Saline and D5." So you had to use sterile water when you were flushing. So like that's not very common, so that was nice that it popped up. And I already knew that, but it was still nice, a little reminder that says: "don't do that!" (Case 8).

> The 30 Minute Bag Near Empty Alert would be something that could be programmed at the nurse's discretion using critical thinking to determine which drugs are which situations that would be appropriate for…your pressor agent is very critical.(Case 23).

Making Meaning

Making meaning reflects the cognitive processes which influence the Nurse-Technology Interplay. Categories of making meaning include: working through the clinical situation, individual perspectives, and shared learning.

Working through Clinical Situation

Nurses described encountering workflow blocks, such as SIPT alerts, amidst a variety of clinical situations. As nurses encountered workflow blocks, three distinct but often simultaneous activities were described: vigilance, rethinking actions, and developing situational context.

Vigilance

SIPT alerts signal the nurse to notice something is different. Nurses described *vigilance* as noticing, paying attention, and even scanning for additional signals. For example, an upstream occlusion alarm may simply indicate that a clamp had not been opened. However, a Soft Limit alert requires scanning for different things, such paying attention to specific aspects of the medication, such as the correct medication, dosage, or programmed rate. In the excerpt below, a nurse describes encountering a Soft Limit alert:

> I have hit Soft Limits I think with some antibiotics. It's like saying: Hey, pay attention! I have to check: is this the right dosage? Are we giving the right thing? Because it will ask you, is this too much? (Case 9).

Rethinking

As nurses become more vigilant, they also describe starting to *rethink* their previous actions. Rethinking was often triggered by questions asked by SIPT. As nurses

reflected on their actions, they affirmed they were correct or started to consider appropriate future actions, such as reprogramming the medication. SIPT software is also sensitive to extreme rate changes, such as increasing infusions from 100 ml/hour to 999 ml/hour. These excerpts reflect rethinking:

> When I had an alarm it makes me think: "what the heck's going on here?" It really makes me rethink what I've done, and I may find that I misprogrammed the medication, usually entry error on my part. (Case 27).

> Actually it will notify you if you try to make a drastic change. For example I had a patient vagal and I didn't have a pressure bag in the room so I hit the 999 on the pump and it did stop, and asked me if I was sure I wanted to increase the by such a large percent. So it will question you have you seize a drastic change even though it may not be something that hit a limit per se. (Case 12).

Situational context

Situational context involved considering the clinical situation in light of desired patient outcomes. While considering the type of alert encountered, nurses described anticipating their next steps in the context of the patient's clinical situation, the desired outcomes, and the potential impact upon patients. For example, nurses encountering a Soft Limit alert with an antibiotic would react very differently than an ICU nurse caring for an unstable patient who encounters a Hard Limit alert with a medication used to control blood pressure. Hard Limit alerts signal that the medication was programmed at a pre-determined unsafe range and SIPT will not allow administration. Although few nurses had encountered Hard Limit alerts, depending on situation context, some chose to administer medications outside of the safety software through Basic Mode. These excerpts describe situational context:

> Depends on whether it's a high limit or a low limit. If it's a low limit, it doesn't bother me because if I'm going less on the drug it can't hurt the patient. If it's a higher limit, then depending on the drug, I either notify the physician and say "this isn't working I need something different" or you know, I just try to not go any higher usually. (Case 5).

> The Hard Limits, depending on what is happening, typically when we hit the Hard Limit were at the point where the doctor just wants to add another pressor agent or we may be to the point where we just start taking things off the pump and

> dripping them in. So yes, I guess that is outside the safety software. The patient is really not responding, so you just do the best you can. The only other time that we may not use the pump is in a situation where we are giving a lot of blood, like we have a patient tanking and where just slamming everything that we can. In we're using the gravity bulb to infuse it fast like a pressure bag. (Case 14).

Individual Perspectives

Individual perspectives of SIPT technology influence the meaning that nurses make of the situation. Perspectives reflect safety perceptions and personal experiences.

Safety Perceptions

Safety perceptions refer to nurses' descriptions of valued SIPT features that support medication safety. SIPT safety features require nurses to verify programmed information, alerting them to potential errors. Nurses viewed SIPT as a safety net, providing safe parameters and requiring double-checks. Parameters are especially valued by newly graduated nurses, but also when nurses are working with medications unfamiliar to them, such as when orienting to a new patient-care unit or floating to a different unit. These excerpts describe nurses' perceptions of safety:

> So it offers an additional safety feature whereas the old ones were not smart like that. And I like how it double-checks you; if you're doing something weight-based it makes you enter the weight twice. Or if you're putting something in them it might be above the limits and asked you to check and make sure that that's the right dose. (Case 11).

> I like the smart pumps, because they give you an idea of how high according to the pump you can go, on the medication. Even if you can go higher, it just gives you an idea of how fast you might be able to run the drug. And that's very helpful when you're a new nurse. Here, the expectation is that every medication is run through the smart pump, so I feel that it has enhanced our ability to run the right medication and prevent medication errors. It is a little more work, but not an outrageous amount. So, I feel like it has made practice overall, seem safer. You know, med errors happen because we are all human, and humans make errors. So, I feel like it's made here practice a lot better. (Case 14).

Personal Experience

Some nurses described *personal experiences*, related previous events that influenced their perceptions of SIPT, both positively and negatively. One nurse shared a personal experience with a standard infusion pump, stating that although SIPT might

create more alerts, it was worth the enhanced safety features. Other nurses had experienced intermittent problems that could not be verified by biomedical engineering, so were less trusting of SIPT. These excerpts reflect personal experiences:

> I would rather have the smart pumps, and deal with the alarms, because there's less chance of error when you use them. And, I have a personal story, and that's how I know that. My husband was almost killed when he was a patient, but that was on the old pumps. (Case 15).

> Sometimes it seems like you can't quite trust it to have the right amount I have really figured out. We've told biomed about that but it seems like maybe it's falling on deaf ears. One of the nurses will call me in to check on this and say "look at this -this is so not right." (Case 23).

Shared Learning

Shared learning reflects experiences where members are aware of previous SIPT workflow blocks within the organization, and have the knowledge to resolve them in manner consistent with expected organizational practice. Captured events are experiences within the organization that may lead to shared learning, and missed opportunities reflect events that are not discovered. Nurses described varied problem solving approaches when encountering workflow blocks, such as medications not being in the Drug Library. Findings suggest that knowledge gaps exist about organizational processes related to SIPT. These experiences are described below as captured events and missed opportunities.

Captured Events

Some nurses described a formal process to notify pharmacy when a medication needed to be added to the Drug Library. [The pharmacist revealed that because only one pharmacist updates the Drug Library, when SIPT was implemented, formal processes were put into place to capture medications needing to be added. The process included contacting the pharmacist, completing a form, and notifying the unit manager. E-mail updates were sent to pharmacy staff, the educational coordinator, and the nursing director providing SIPT oversight. E-mails were to be distributed to staff. This process was

designed to capture events, correct the situation, and share the information with other staff]. The following excerpt reflects a nurse capturing an event and sharing the information:

> If I run it under Basic I always make sure another nurse checks it. I work nights so then I notify Pharmacy and then the house supervisor. And then sometimes if they tell me to, depending on the drug, I'll shoot an e-mail to my boss. So that's usually what happens. During the day I think they go straight to the boss and Pharmacy. (Case 5).

Missed Opportunities

Nurses described recent issues where needed medications or concentrations were not in Drug Library, but these nurses were unaware of formal processes to correct the situation. Nurses described running infusions under a different medication in the DL, a practice carried from shift to shift. Several nurses stated that they typically only contact the pharmacist to check drug compatibilities, not for other SIPT issues. [The pharmacist reported that immediately following implementation there were several requests for additional medications, but for the past several months he had very few requests coming from nurses and none through the formal processes. Most requests came from other pharmacist after being called by nurses. The nurse educator stated that no e-mails had been sent recently and was unaware of formal communications to nursing staff regarding updates.] The excerpt below exemplifies a missed opportunity for shared learning:

> I just had a situation last night where I could not find the medication in the pump… Even though we were infusing the right medication and the right rate, it did not match what was on the pump. … And we've had that happen with a few medications. I said something to my charge nurse about it, and I had told the patient too. And the patient said yeah that's how they been running it, but I know it doesn't have the calcium in it. And I'm thinking that that could be a safety problem. I'm not really sure if there's a process for reporting those kinds of things. (Case 17).

Taking Action

Taking action is the third supporting category of Nurse-Technology Interplay. When nurses encounter workflow blocks they take steps to remedy the situation. Taking

action is a state or process of doing, representing the observable aspect of Nurse-Technology Interplay. Actions may occur simultaneously with, or as a consequence of, making meaning. As nurses engage in meaning-making, they may also simultaneously engage in actions to resolve the situation. Taking action has three categories: rechecking, workarounds, and seeking assistance.

Rechecking

Nurses described actions involving rechecking themselves. In addition to the rethinking described above, nurses also described actively rechecking themselves on previous activities, such reviewing medication orders, looking at bag labels, and performing calculations. They also described rechecking programmed settings, which often led to reprogramming SIPT.

Medication Check

As they were involved in rechecking activities, nurses would check the medication order and the medication labels, looking for discrepancies between them as well as what had been programmed. Many nurses used the medication label during programming but others were unsure if it would accurately guide programming. [The pharmacist reported that the labels are printed to guide programming, the generic drug name will appear first and the trade name will follow]. Many nurses discussed encountering Soft Limit alerts when they programmed SIPT according to the medication label, they expected that pharmacy would not enter label information that would trigger an alert. [The pharmacist agreed that the Drug Library could be updated to prevent these types of alerts]. Interview excerpts are provided below:

> Yes, you still have to think about it because there have been times where I've had a bag that was labeled incorrectly before, with the correct rate that I had to call about it and it just didn't make sense. Once I was putting it in it didn't make sense so I went back and did the math and figured out it was wrong after I had someone else look at it. (Case 1).

> I hit the Soft Limits yesterday with potassium. There are times when what is on the label is faster than what the pump says it should run at. So for example the label will say to run this over four hours at 120, and I think the pump Soft Limit is set at 100, so I just run it to what the pump says and not what's on the bag. Some of the vancomycin runs like that too, so I just run it at the Soft Limit and not what the bag says, unless if it's one of those antibiotics it is only stable for so long. (Case 20).

Reprogramming

Nurses reprogrammed SIPT either through or around SIPT safety software. To enhance safe medication administration and allow the software to recognize the medication, nurses must select the appropriate medication and concentration. Nurses frequently described reprogramming actions through SIPT safety software as it was designed to ensure patient safety. Nurses also described working around SIPT safety software by using the Basic mode feature. The excerpt below represents reprogramming

> The only time I've ever run into a Hard Limit is when I programmed something wrong, and you just double check it and realized it, so I just re-program it correctly. So you just end up changing it. (Case 19).

Workarounds

Workarounds describe actions that deviate from intended SIPT processes, thus creating potential medication safety risks. Workarounds occurred both when nurses programmed medications through SIPT safety software and outside of SIPT safety software. One nurse described programming the device to fool the pump while still working through the safety software.

Fooling the Pump

The term *fooling the pump*, well-represented three types of workarounds described by multiple nurses, where nurses programmed medications through SIPT safety software yet contrary to SIPT design. The first practice involved administering multiple secondary infusions, where nurses simply changed the rate on the pump without programming the correct medication, as described below.

> A lot of other nurses on my unit do that just to save time, they just change the rate and not the actual antibiotic, but I feel like it's important to do it the right way. So

> it just pulls from the primary, the pump thinks that the right thing is infusing, it doesn't have any way to tell that it's not the secondary. That seems to happen a lot and we have missed doses. That's probably one of my biggest gripes is finding full bags. So then you're making the clinical decision okay, do I just infuse it? But you also don't really know if it didn't back prime from the primary into the secondary. (Case 20).

The second practice involved situations where a medication, concentration, or bolus was not in the DL; the situation was resolved by programming a different medication or fluid:

> So there again, you know how long it's supposed to go so you just program it in there…so you can just put LR or something else you know that it would accept at that rate. It kind of makes you nervous when you're like that because it's like OK, this isn't what I've got hanging and this isn't what I'm programming so, I guess being the Smart Pumps it gives you that uneasiness when it doesn't match up. And then another time that you may have to go out or kind of work around that is if the drug is not in there but you can pick something similar**...** to fool the pump. (Case 7).

> So we were trying to play around on the pump to see if we could increase the rate is to give a bolus and the limits showed up, so we knew we didn't want to push it not with insulin, so we went another route. So on the insulin we ended up running it at the rate it was supposed to run, but we just timed it to give nine units that we needed to for the bolus, so we nurses both set our watches and the patient was alert, and we said if we are not back by 9:42 then call us. I'm trying to think of another medication where we hit the limits but you know you can work around it, as long as you justify yes I know it's on the limits, you can do some more programming. (Case 13).

The third practice involved the 30 Minute Bag Near Empty Alert, which requires nurses to program the total volume to be infused in order to alert the nurse 30 minutes before the bag empties, allowing time to obtain a replacement bag. Nurses described programming in less volume than the bag contained, and there were variations between units and between nurses within units. Many nurses described not trusting the 30 Minute Bag Near Empty Alert feature and some believed that it was a practice left over from using standard pumps. Some nurses described uneasiness when fooling the pump; they were concerned that physicians and patients might think that the wrong medication was actually infusing. Nurses recognized that administering medications under a different

name would not allow SIPT software to apply specific rules such as incompatible medication. This excerpt reflects workarounds while working through SIPT:

> In a Critical Care setting we don't put the entire volume in, like if you are hanging a 100cc bag of Insulin, we don't put a 100ccs in the bag when we program it to begin with, we put 95, for it to ring a half an hour before it's empty at 95 we really have more time. That's just the way we, as Critical Care nurses think and we were used to the pumps before. (Case 14).

Working Outside Safety Software

Nurses described situations where medications were administered outside of SIPT safety software. When SIPT devices were not available, medications may be delivered via an alternative route. In situations where SIPT devices were available, the most common reasons for working outside the safety software involved medications or concentrations not available in the DL, or encountering Hard Limits. The potential negative consequences of using Basic Mode were previously discussed. However, nurses described being directed to use Basic Mode when medications were not in the DL. [The pharmacist confirmed that nurses may be directed to use Basic mode until the DL could be updated.] Examples of working outside SIPT safety software are provided below:

> If we have the smart pumps available, I will go ahead and start their fluids on the smart pump. If I don't have pumps available, that if it's just a regular fluid, we just hang it to gravity. Most of our drips run at about hundred cc an hour. If the floor fluids are running, we just usually let them put those to the smart pump we get there. If we don't have the pump available, and we need to manage a certain drip like neosynephrine, we use micro drip tubing and titrate the medication accordingly per blood pressure. (Case 14).

> Then the other day there was something else that wasn't in there so I had to call Pharmacy to tell them so they can profile it or whatever they do to get it in there, and he said just go ahead and just put the rate in and run it under Basic Mode because it wasn't in the Drug Library. (Case 7).

<u>Seeking Assistance</u>

When nurses engage in troubleshooting they either use unit-level resources or they contact resources outside of their unit for assistance.

Unit Level Resources

Most nurses describe using unit level resources as a first line strategy during troubleshooting. When encountering issues with SIPT blocks, most nurses sought out colleagues or the charge nurse, and occasionally, or the nurse manager. As previously discussed, troubleshooting responses are often developed during orientation, reflect unit level practices, and consider available resources.

External Resources

Nurses also discussed seeking the assistance of pharmacists, physicians, and biomedical engineering for specific needs. Some nurses did call a pharmacist for medications not available in the Drug Library, but many only called to check medication compatibility. Physicians were contacted when a medication needed to be changed, typically when Hard Limits were encountered. Biomedical engineering staff was contacted when pumps seemed to be malfunctioning. Below are examples of nurses' seeking assistance:

> I would just go the other nurses on the floor. The only thing I've called pharmacy for was drug compatibilities. I don't usually call pharmacy for anything for smart pumps and I'm really not aware if there's a process for getting different medications in them- I don't know what that would be. It really doesn't come up that often. (Case 24).

> So for troubles shooting when I was orienting I go to my preceptor and I had developed a good sense of my resources were. I usually call the pharmacist for questions of IV compatibility but not necessarily for the operation of the pump. I work night shift so there are not too many pharmacist on duty. (Case 12).

Consequences

Consequences, the fourth category of Nurse-Technology Interplay, reflect the intended and unintended outcomes of nurses' experiences with SIPT during medication administration. While outcomes typically represent the endpoint of a phenomenon, with SIPT these outcomes often trigger additional aspects of Nurse-Technology Interplay. For example, when nurses detect an error with SIPT, it is an unexpected event that triggers

increased vigilance as nurses strive to make meaning of the situation and take additional actions to resolve the situation. Even when nurses do not detect errors with SIPT, they described continual interaction with SIPT as they deal with alerts to prepare for continued medication administrations. Nurses also described how SIPT implementation has impacted nursing practice. Frequent SIPT alerts overload nurse and disrupt care delivery. Nurses also described their dependency on SIPT and the impact on their ability to perform calculations. These consequences are further discussed.

Medication Administration Patient Outcomes

SIPT is designed to assist nurses to safely administer medications. Patient-level consequences of Nurse-Technology Interplay are reflected by medication administration outcomes. As nurses described these outcomes, they frequently found no problems detected, but some had experienced near misses and errors.

No Problems Detected

The intended outcome of using SIPT is that medications are administered safely and as prescribed. Throughout the interviews, several participants described administering medications using SIPT without any problems detected. Many also could not recall encountering any surprising situations with SIPT: “I really can't remember too much with the pumps that I have not been able to do what I needed to do for the patient working through the smart pump.”(Case11); and “I honestly don't think I've ever used Basic Mode for anything. I know that there's a Basic Mode in there but I hate the thought of using it. So, everything goes to the Drug Library.” (Case 14).

Problems Detected

Nurses also described detecting problems while administering medications with SIPT. Nurses shared examples where medication errors may not be detected for several shifts. The types of problems detected included near misses and actual medication errors.

Near Misses**:** Near misses represent averted errors, those that are detected and acted upon before they reach the patient. Nurses described several near miss situations. SIPT is designed to alert nurses to potential errors. While programming medications into SIPT, nurses are asked to confirm a series of questions to ensure accurate delivery. As a result of this process, nurses reported detecting wrong patient, wrong medications, the wrong drug, and the wrong concentration. Nurses described the challenges of keeping up with new orders in response to changing patients' conditions, and sometimes the double checks required by SIPT allowed them to detect these changes. In the scenario below, a nurse describes how SIPT helps avert medication errors and is helpful in detecting order changes.

> Once I was putting it in it didn't make sense so I went back and did the math and figured out it was wrong after I had someone else look at it. I can't remember the exact situation but something wasn't right so I went back and it was a near miss not a med error. Yes, we just got the right thing sent down. I think the label itself was just wrong, it wasn't the medication. (Case 1).

Medication errors*:* Although infrequent, nurses did recall situations where actual errors were identified. Heparin, a previously discussed problematic medication, was frequently mentioned among SIPT-related medication errors. For other medications, errors typically occurred when the needed medication or concentration was not in the Drug Library, the wrong concentration was selected, or where pumps apparently malfunctioned. Medication errors were detected during care transitions, during rechecking activities, and during the SIPT double-checks, alerting the nurse to recognize the wrong medication was about to be infused.

> Yes, there have been several times that you hang something, and after going through your double checks you realize that's not the right medication, so you go take care that. So, I like the fact that it ask you to go ahead and verify that this is this the right drug! … And sometimes you like go into the room, and you're busy and you realize that this is the wrong patient. So, I think that helps. Another situation may be where a medication is changed but you didn't have time to check your orders yet, so you know that it is a different concentration or dose than you were previously running. … you may have had Vancomycin 1.5 ordered and now you're giving 1.7, so you have to change the pump for the new dose. And that is

> very helpful in this setting, because as patients conditions change rapidly so do their medication orders. (Case 14).

> I think our unit just had one error with the smart pump, and I think that was a malfunction. The pump was reading like it was giving the medication that it was sent it was a heparin drip, so that was a pretty big medication error. That happened a few months back, it was a big deal, it went through to shifts in the second shipment it up catching it. They noticed that the bag was still full and it should've been emptied by the end of the shift. (Case 16).

Impact on Nursing Practice

While overall nurses favored SIPT, they also described unexpected and unintended consequences on nursing practice. These include disruption to the care environment, dependence on technology, loss of calculation skills, and alarm overload.

Disruption to Care Delivery

SIPT has many audible alerts. Nurses were concerned about the impact of alerts upon the patient care environment, disrupting patients' rest, and also creating dissatisfaction with noise. Additionally, several nurses described that patients would silence the alerts, which prevented the nurse from getting the alert to order subsequent infusions, causing further disruptions. Nurses described managing SIPT alerts to prevent disruptions to patients' sleep, and they sometimes chose not to enable call back features so patients could rest. Nurses envisioned SIPT improvements that would better support nursing workflow and without disrupting patients, such alerts being delivered through a pager or computer. Ideally, the notification would also tell the source of the alarm, such as upstream or downstream occlusion.

> There are times when I've thought about using it [call back alert for secondary infusions] and but then I'm like "oh, I'll just try to remember, like in a half hour that one will be done I can hang the next one". It would be a good idea to use it but sometimes I'm like "oh, it's going to wake the patient up". I work nights so when I'm hang antibiotics at like two or three o'clock I try not to use it. I'd rather not interrupt their sleep any more than I already do. (Case 8).

> The 30 Minute Bag Near Empty Alert sometimes a patient pushes it, they push okay and then it will be completely run through so we didn't know that we needed order of bag. So we tell the patients not to do that. Sometimes it's beeping somewhere you can't figure out where it is and the patients just get tired..... Since I work nights I don't like for the alarm to be while the patient sleeping. (Case 17).

Dependence on Technology

Dependence on technology reflects nurses' awareness of their own apprehensions when medications were not infused via SIPT. Nurses discussed depending on SIPT beyond the added safety benefits, but because they were unsure of their ability to manage calculations and recognize standard dosages. Some nurses stated they would not feel safe using other pumps as they depend on SIPT to perform calculations and for the computerized programming features to alert them to errors. Recently graduated nurses may only have used SIPT in school and practice. Some nurses believed that nurse monitoring was unnecessary when SIPT devices were used. These quotes capture nurses' dependence on SIPT:

> They are really all that I have used, but I'm really not sure I would remember how to calculate drip rates for all of the drugs if I had to without the [smart] pump. I would really be struggling have to do that. But I think they really help because you double check everything and it takes a little pressure off of you with your math. I know we rely on them a lot, and we don't really check all the drips to make sure that there running accurately, we just trust the pump. (Case 18).

> I don't know, maybe like patients that come back from surgery and they have just the dial pump. I always switch it over because I feel like "oh my gosh, they're not on a pump!" I'm very reliant on pumps; everything has to be on a pump. I guess it helps me – it's a good way to double check when you are putting stuff in like you said its' got the limits so if you put something in, even if you just mistype something, it's going to be like "1000, you want the rate to be 1000 or 100?" (Case 10).

Loss of Calculation Skills

As nurses began to rely on SIPT there was an impact on performing calculations. Perceptions ranged from relief at having calculations done automatically through SIPT to concern with losing a valued skill. Nurses discussed trusting the pump and feeling a sense of relief from not having to perform calculations when using SIPT. Additionally, nurses also recognized a loss of calculation skills among colleagues and themselves. This included losing the ability to recognize standard doses, because the pump automatically

completes the calculations. This excerpt exemplifies nurses concerns with losing calculation skills:

> I think it's really important the nurses don't forget how to do calculations. Because what if we have a disaster or something and you need to figure out how to run the IV? I think it totally wipes out of your brain because one day I got dopamine and I just went and sat in figured it out because I wanted and now it, and it was there, so I thought I have still got it. But it makes me wonder if I will lose that? (Case 26).

Alert Overload

In addition to nurses expressing concern that alerts create excessive noise and negatively impact patients, they also acknowledged personal impacts. Nurses' discussed difficulty distinguishing between alerts. With the exception of the low battery signal, SIPT alerts sound similar, making them more difficult to troubleshoot. For example, the 30 Minute Bag Near Empty Alert requires the nurse to intervene, but the lower occlusion alarm may be resolved with directing the patient to straighten their arm, something that could be delegated to support staff. Nurses expressed challenges with managing alerts, chasing beeping pumps, and possibly becoming immune to them. As one nurse described: "I guess all of the alarms are helpful if you don't get immune to them." (Case 21). The 30 Minute Bag Near Empty Alarm created particular frustrations during with medications requiring frequent titration, as each adjustment creates another alert. The excerpt below describes a situation with alarm overload:

> It gets kind of frustrating when you're titrating medications and it keeps saying bags near empty, and I've been in this room six times in 15 min. just to address that. You just get so frustrated; you end up wasting 20 or 30 cc. of this medication and just hang in a new bag, because it's easier than addressing the alarm each time. You just get tired of being in there every 3 seconds because it says bags near empty… you go back and you're titrating it, so it keeps alarming every time you change the dose and titrate. And if you titrate higher, it still tells you that the bags can be out in less than 30 min. so you push okay. (Case 14).

Chapter Four Summary

The purpose of this study was to understand nurses' experiences with SIPT devices and safety software during medication administration, with a focus on related

workarounds. SIPT implementation has impacted nurses' workflow with patient care delivery. Findings show that nurses interact with SIPT in a variety of ways. During these interactions, nurses encounter workflow blocks either directly with SIPT or related to organizational issues and processes. The main activities used by nurses to resolve workflow blocks, which often occurred simultaneously, are making meaning of and taking action to resolve the situation. Nurses also described consequences of working with SIPT, which often lead to further interactions, related to medication administration, patient outcomes, and the impact on nursing practice.

This chapter presented the emergent grounded theory of Nurse-Technology Interplay, the relationships between categories, and the findings supporting category development. The next chapter will discuss the study findings, in the context of existing research; identify implications for practice, and present areas for future research.

CHAPTER FIVE

DISCUSSION AND IMPLICATIONS

Nurses' SIPT experiences are of interest to nurse leaders as medication safety technologies become more widely integrated into practice. There is a growing body of work related to SIPT workarounds, but the perspective of nurses working with complex patient safety technologies has been overlooked. Because nurses are directly accountable for SIPT's impact upon keeping patients safe, their insights are critical to moving patient safety forward.

The purpose of this study was to generate a grounded theory which emerged from nurses' experiences with SIPT safety features and encountered workflow blocks. GT is useful for understanding how people resolve problems, and data can be used to generate theory (Corbin & Strauss, 2008). Understanding problem resolution from both an individual's and group's perspective is critical to identify essential elements required for improving practice. To address the study purpose, as interview data were analyzed, the iterative interactions of each nurse's SIPT experience emerged. The final analysis resulted in the emergence of the grounded theory of Nurse-*Technology Interplay Theory,* which illuminates participating nurses' experiences with encountered workflow blocks and related consequences of interacting with SIPT safety features.

This chapter begins with a brief discussion of the grounded theory of Nurse-Technology Interplay in the context of individual and organizational factors. Next, a discussion of study findings in the context of the current literature is provided, followed by practice implications, limitations, recommendations, and conclusions. The discussion will address nurses' perceptions of SIPT safety features, responses to encountered workflow SIPT blocks, organizational conditions influencing SIPT workarounds, and consequences of SIPT implementation.

Individual and Organizational Interrelationships

The impact of medication safety technologies must be understood. The emergence and discussion of the grounded theory of Nurse-Technology Interplay has been presented in previous chapters. The core category represented the common goal of nurses as they responded to SIPT workflow blocks while attempting to address medication administration within the context of the patient's overall care needs. The theory focuses on the salient SIPT dimensions and the dynamic interrelationships of nurses interacting with SIPT during care delivery. Yet, the theory also illuminates the strong interdependence between individual and organizational factors that influence *Nurse-Technology Interplay*. This interdependence was reflected in the dimensions and properties of the supporting categories and is examined from a sensemaking perspective.

Sensemaking provided theoretical sensitivity during data analysis, and can be analyzed from individual, shared, and organizational levels. Individual sensemaking has been linked to both problem detection and decision making (Hoffman et al., 2009; Klein, Moon & Hoffman, 2006), often moving them from *automatic thinking* to *active thinking* (Weick, 1995). As individuals seek others out to make sense of something unexpected (Hoffman et al., 2009; Jordan et al., 2009) they develop situational awareness, are able to tie together separate processes, and create shared sensemaking (Weick, 1995). Shared sensemaking can help organizations learn from events and identify risks and hazards that may be embedded in processes and systems at all levels (Battles et al., 2006). However, organizational sensemaking is highly interdependent and it is uncertain whether shared and individual sensemaking can even be separated (Weick, 1995).

This interdependence is important because it demonstrates how individual behaviors can influence organizations and how organizations can influence individuals. Also, it highlights how individual problem solving behaviors are shared, and may eventually become normalized organizational behavior. In addition, based on observation

alone it makes it difficult to determine if individual problem-solving actions are reflective of real or perceived organizational expectations for problem-solving. To highlight this interdependence, each category, sub-category, and related concepts are introduced in a separate table, and the individual dimensions are represented by the shaded boxes. The interdependence of individual and organizational dimensions of each category is briefly discussed.

Interacting with SIPT

Interacting with SIPT reflects the many ways that nurses' encounter SIPT, from learning to operationalizing. The individual dimension of this category reflects the learning curve that nurses' face as they move from a "novice" learning basic rules to an "expert*"* who masters the technology, adapts to obstacles, and teaches others. Organizational dimensions that influence interactions with SIPT include the context of patient-care unit characteristics, and routinely encountered SIPT workflow blocks, arising from safety features or organizational factors.

Table 6. Interacting with SIPT

Category	Sub-categories	Concepts
Interacting with SIPT	Learning curve	• SIPT Training • Human-technology interface • Complexity of the Drug Library • Basic device knowledge gaps
	Patient-care unit characteristics	• Patient population • Unit level troubleshooting approaches
	Workflow blocks	• Organizational blocks • SIPT blocks

Making Meaning

Making meaning, the intangible aspect of Nurse-Technology Interplay, reflects nurses' consideration of the patient' condition and desired outcomes. While working through the clinical situation, nurses try to make sense of the workflow block in the

context of care, by becoming vigilant, rethinking actions, and considering the impact of future actions. Making meaning is influenced by individual perspectives and shared learning. Shared learning reflects organizational learning as members collectively learning from events, make improvements, and share information.

Table 7. Making Meaning

Category	Sub-categories	Concepts
Making Meaning	Working through the clinical situation	• Vigilance • Rethinking • Situational context
	Individual perspectives	• Safety perceptions • Personal experience
	Shared learning	• Captured events • Missed opportunities

Taking Action

Taking Action represents the observable aspect of Nurse-Technology Interplay including physically rechecking work, seeking assistance, and [re]programming activities that may be completed as workarounds. Workarounds are completed by programming either through or around SIPT safety software. Interestingly, many of the conditions that led to workarounds involved underlying organizational issues that created barriers to care delivery.

Table 8. Taking Action

Category	Sub-categories	Concepts
Taking Action	Rechecking	• Medication checks • Reprogramming
	Workarounds	• Fooling the pump • Working outside safety software
	Seeking assistance	• Unit level resources • External resources

Consequences

Consequences of Nurse-Technology Interplay reflect the results of nurses co-existing with SIPT during care delivery, and often required further interplay between nurses and SIPT. Individual dimensions in this category reflect care disruptions, dependency on SIPT, loss of calculation skills, and alert overload. However, the same factors that impact nurses have broader organizational implications such as alarm fatigue, as will be discussed later in this section.

Table 9. Consequences

Category	Sub-categories	Concepts
Consequences	Medication administration patient outcomes	• No problems detected • Problems detected
	Impact on nursing practice	• Disruptions to care delivery • Dependence on technology • Loss of calculation skills • Alert overload

As previously discussed, while the central and supporting categories initially appear to be linear, they are complex, dynamic, and interrelated. Likewise, the dimensions of the grounded theory of Nurse-Technology Interplay represent the complex and interrelated aspects of individuals within the organizational context. This is important because nurse-initiated workarounds are often viewed as an individual behavior issue, and the contributing organizational issues are not always apparent -nor easily observed. The next section discusses the study findings within the context of the current literature.

Nurses' Perceptions of SIPT Safety Features

Initial discussion with respondents explored nurses' perceptions of SIPT safety features. Nurses' perceptions of SIPT safety features are important because they have been shown to have a direct relationship between the primary users and how the features are maximized (Carayon et al., 2010). The current study findings suggest that (1)

perceptions of SIPT safety features are developed as nurses interact with the technology, (2) nurses viewed SIPT safety features as both helpful and problematic, and (3) nurses develop a level of trust with SIPT safety features that further influences their use of the technology.

Perceptions Develop During Interactions

Nurses' perceptions of SIPT safety features developed during their interactions with SIPT at this site. Researchers suggest that standardized training approaches for SIPT users improve compliance with SIPT safety features (Fan, Pinkney, & Easty, 2010; Trbovich, Cafazzo, & Easty, 2011). The negative impact of variable training approaches has been discussed. McAlearney and colleagues (2007) reported the challenges described by nurses following inconsistent training following SIPT implementation, which resulted in the emergence of an informal hierarchy of user expertise. To counter this hierarchy, nurses desired formal training and support, particularly focused on overcoming challenges with using SIPT in clinical practice.

In the current study, respondents present during initial implementation described extensive and structured training. However, nurses who started after initial implementation reported unstructured unit-level training that was dependent upon a variety of preceptors. All nurses experienced a learning curve to become familiar with SIPT. However, the more inconsistent training approach often seemed to encourage nurses *learning on the fly* while resolving a problem. *Learning on the fly*, resulted in decisions based upon limited awareness of SIPT safety features and distracted nurses from patient care. Training variations seemed to be related to nurses' entry into the organization and appeared to impact nurse level "competence and confidence" with SIPT, reflecting their preparedness to engage with the full array of safety features and troubleshooting.

These findings expand the limited literature on nurses' perceptions of SIPT training and illuminate the possible impact of training variations on nurse level capabilities. These findings have implications for nurse leaders and represent an area for future research. Nurses' ability to explore new SIPT features by trial has been shown to predict lower satisfaction with the quality of care provided (Wetterneck, Carayon, Hundt, & Kraus, 2006). This was supported in the current study as nurses described frustrating experiences with *learning on the fly*. The findings indicate that training matters.

SIPT Safety Features: Helpful and Problematic

SIPT safety features helped the participating nurses protect patients from medication errors, but they were also problematic. Due to the newness of the SIPT technology, there is limited research on nurses' perceptions of SIPT. Studies show that nurses believe SIPT enhances care delivery by promoting medication safety and potentially preventing errors (Bowcutt et al., 2008; McAlearney et al., 2007; Rosenkoetter et al., 2008). However, perceptions of efficiency are mixed when compared to traditional pumps. Rosenkoetter and colleagues (2008) reported that SIPT did not increase nurse's workload and made routines easier. In contrast, other studies found that SIPT changes users' work flow, requires additional learning, and may increase cognitive workload (Carayon et al., 2005; Carayon et al., 2010; Kaushel & Bates, 2007). Challenges previously identified with SIPT include DL issues, false alarms, device weight, the need to perform calculations, and patients tampering with features (McAlearney et al., 2007).

Respondents in the current study also had mixed perceptions of SIPT safety features. Nurses viewed SIPT as an organizational commitment to enhancing patient safety. The required double-checks added a layer of protection and dosing parameters provided a safety net that was highly valued by nurses administering unfamiliar medications. Although highly valued, the additional programming features were

perceived as taking more time than traditional pumps and workload was increased when a medication was not in the DL or when responding to false alarms. Other challenges were similar to those previously reported, except nurses in the current study liked the small size and portability of the newer devices, finding them easy to transport.

The current study supports previous findings that nurses have mixed perceptions of SIPT. Addressing issues with the DL and false alarms may improve perceived helpfulness. Although manufacturer's attention to specific device features can help to facilitate other aspects of nurses' work, it appears that there are abundant opportunities to improve aspects of alarms and other problematic SIPT safety features.

SIPT Safety Features: Trust and Mistrust

Nurses' trust of SIPT safety features influenced their use of the technology in the current study. Trust has been found to be an important aspect of patient safety and maintaining a safety culture (Blouin & McDonagh, 2011a).The impact of users trust with technology is of interest to patient safety experts. Parasuraman (1997) examined the effect of trust and mistrust on technology use, finding that overreliance led to misuse, whereas distrust of technology could lead to disuse (as cited in Montague, Asan, & Chiou, 2013). Montague and colleagues found that nurses' trust of SIPT influenced their use of the technology and was associated with characteristics of the user, organization, and technology. In their study, younger nurses and those with less experience trusted SIPT more that older nurses. Additionally, working environment and quality of work life were related to nurses' perceptions of trust. Additionally, nurses were more trusting if SIPT safety features facilitated efficiency, were easily learned, and if programming mistakes were easily detected.

The appreciation of detecting programming mistakes was further developed in the current study when nurses described the value of SIPT safety features as a deterrent to error. For example, a nurse described a "near miss" when the software averted detected a

programming mistake. Conversely, other nurses described examples that diminished their trust in the technology, such as false alarms or errors and device malfunction directly associated with SIPT safety features. Additionally recently graduated nurses expressed that they had only used SIPT, heavily relying on the technology for providing dosing parameters and completing calculations, with some even indicating an overtrust.

The current study adds a dimension to what is currently known about trust of SIPT safety features. Findings may also illuminate previous reports that younger nurses and those with less experience in the organization have increased trust of SIPT (Montague et al., 2013). These findings are important because it may help to better understand nurses' response to SIPT workflow blocks and gives insights into generational differences.

Nurses Responses to Workflow Blocks

Responses to encountered SIPT workflow blocks and nurses' help-seeking behaviors were another dimension of the study. The current study findings suggest that nurses engage in specific workarounds when responding to workflow blocks. Nurses' perceptions of SIPT are important because there has been shown to be a direct relationship between the primary user and how the SIPT safety features are maximized (Carayon et al., 2010). Activities described in response to workflow blocks illustrated the sensemaking process nurses use when confronted with SIPT safety features.

Making Sense of SIPT Workflow Blocks

As participating nurses interacted with SIPT safety features, they attempted to make sense of encountered workflow blocks in an effort to resolve them. Technologies often trigger sensemaking because as people interact with them in rapid and iterative processes, encountered workflow blocks can create several possible interpretations of the workflow block (Jensen & Aanestad, 2007; Orliwiski & Gash, 2004). Sensemaking involves *acting thinkingly* in order to make decisions in uncertain situations (Weick et al.,

2005). Sensemaking responses to technology workflow blocks have been described as rethinking and rechecking previous actions, and possibly seeking assistance of others (Hoffman et al., 2009; Weick, 1995). Seeking assistance facilitates communications so members can construct shared meaning and propose solutions in context (Battles et al., 2006; Weick, et al., 2005). Capturing and sharing this collective knowledge moves learning from the individual to the organizational level, shaping members' future actions (Jensen & Aanestad, 2007; Orliwiski & Gash, 2004).

In the current study, nurses described attempts to resolve SIPT workflow blocks through their stories of *making meaning* and *taking action*, which often occurred simultaneously. When initial troubleshooting activities were unsuccessful, nurses often described seeking assistance from colleagues or pharmacists. If the collaborator knew how to resolve the issue in a manner consistent with organizational expectations for troubleshooting, the collective problem solving moved to the organizational level. Otherwise, problem solving behaviors reflected unit level norms and available resources, remained local, and were often enacted as workarounds.

These activities are similar to those reported by sensemaking researchers. Individuals will resolve workflow blocks independently, but if they are unable to make sense of them they will seek assistance in resolving them (Hoffman et al., 2009; Weick, 1995). In relation to workarounds with SIPT safety features, it is important that nurses understand organizational expectations for troubleshooting and seek collaboration appropriately.

Selective Workarounds with SIPT

Participants described engaging in selective workarounds that involved working through SIPT safety features, without seeming to recognize them as risky behaviors. Nurse-initiated workarounds with SIPT safety features are well-documented and described by many researchers (Keohane et al., 2005; McAlearney et al., 2007;

Rothschild et al., 2005). Research suggests that nurses may use intuition or selective sensemaking when choosing to engage in workarounds (Zuzelo et al., 2008). Bypassing SIPT safety features through workarounds has been attributed to nurses not recognizing potential safety risks and organizational culture that inadvertently supports risky behavior (ISMP, 2009). Research suggests that workarounds are influenced by group norms, local and organizational culture, competencies, and collegiality (Debono et al., 2013). Workarounds tend to be temporary and informal but they can become a widely accepted local practice (Halbesleben et al, 2008), often becoming a vicious cycle (Kobayashi et al., 2005; Tucker & Edmondson, 2003).

In the current study, nurse's stories revealed workarounds enacted through SIPT safety features. A respondent talked about *fooling the pump* while describing numerous nurse-initiated workarounds using SIPT safety features to avoid potential alerts, such as infusing medications as plain fluids. Although the participants recognized that these actions prevented the application of medication specific rules, the nurses did not seem to associate their actions with patient risk. It seemed that workarounds that utilized SIPT safety features were viewed as less risky than those that bypassed safety features. Nurses floating to different units deferred to troubleshooting guidance from charge nurses, and unit-level workarounds were often passed through shifts. Vicious cycle workarounds were described with the 30 Minute Bag Near Empty Alert.

The examples presented by respondents, reflecting group norms but a lack of awareness or mindfulness of inherent risks, align with previous research describing similar workarounds. Nurses must be educated about risks of using SIPT in ways other they were designed to be used.

Workarounds in Clinical Context

In contrast, nurses also sometimes found it necessary to knowingly engage in risky workarounds that bypassed SIPT safety features that appear to be related to clinical

context. Context is defined as "local care settings, their processes, habits, and traditions" (Stevens & Shojania, 2011, p. 557). As they become aware of an abnormality, individuals attempt to make sense of the situation and determine actions to alleviate the risk (Hoffman et al., 2009, Jeong & Brower, 2008). In response to detected abnormalities, research indicates that healthcare professionals may engage in workarounds to balance contextual factors, such as the need to provide patient-centered care with the simultaneous demands of technology, time pressures, and uncertainty (Halbesleben et al., 2008; 2010; Kobayashi et al., 2005).

In the current study, the influence of clinical context was evident as ICU nurses described varied actions for resolving workflow blocks, after considering the type of alert, the patient's immediate clinical situation, and desired outcomes. For example, very different actions were used to resolve medication-specific Hard Limits, depending on whether the patient was stable or unstable. Nurses' occasionally bypassed SIPT safety features in situations with clinically unstable patients, after considering the risks and benefits in collaboration with the physician.

The findings enhance current literature documenting workarounds bypassing SIPT safety features by providing insights into nurses' sensemaking and problem solving approaches in the clinical context of an ICU setting. The findings reflect the unique role that nurses play in keeping patients safe as they consider the impact of their decisions on patient outcomes, in context.

Organizational Conditions Influencing Workarounds

Understanding the importance of context is critical to explicating what influences nurse-initiated workarounds of SIPT safety features. Nurses in this study described the influence of the many dimensions of context involving training approaches, policies and equipment, and the DL, and the impact of these contexts upon nurse-initiated

workarounds. The discussion will also address organizational factors that participants indicated contributed to workarounds.

Organizational Approaches to Training

Nurses described wide variations in initial training approaches, which seemed to impact their individual capabilities with SIPT safety features. Training is an important component of the SIPT implementation process (Fan, et al., 2010; Trbovich et al., 2011). Organizations routinely engage front-line users in training to introduce SIPT, facilitate optimization of the safety features, and communicate troubleshooting expectations. Variable training approaches create challenges in clinical practice when users lack the expertise to use SIPT safety features effectively (McAlearney et al., 2007). Researchers suggest that training move from historical technical-focused approaches used with traditional pumps, to training that addresses the complex technology and optimization in practice (Trbovich et al., 2011).

In the current study, the structured training sessions provided during SIPT implementation included hands-on experience, use of safety features, tips to prevent excessive alarming, and organizational expectations for troubleshooting SIPT. Troubleshooting approaches guided nurses' actions and triggered organizational mechanisms to capture unexpected events. Structures and processes were designed to facilitate shared learning by capturing and correcting events and sharing changes with front-line staff. Over time, training moved to the unit level, and the mechanisms to capture events and support shared learning appear to have eroded. Consequently, shared learning failures were described as nurses engaged in workarounds with concentrated medications, unaware they had been previously added to the DL.

These findings support previously described complexities that result from varied training approaches, but add valuable insights into the consequences of these changes from the nurse's perspective. The evolution of SIPT training as described by the

participating nurses and other key informants is contrary to recommendations of human factors experts (Fan et al., 2010). The current study further punctuates the urgency for the development of a patient safety curriculum that addresses complex healthcare technologies and assures that nurses properly use, assess, and analyze technology used on their patients' behalf (Van Geest & Cummins, 2003).

Policies and Processes

Nurses described frequent workarounds in response to organizational expectations for managing alerts and issues related to SIPT device availability. Policies, protocols, processes, people, and technology can create workflow blocks when they are perceived as a barrier to completing a task (Halbesleben et al., 2008). Within their complex work environment, nurses face unavoidable challenges, such as changing patient conditions, marginal resources, fragmented data, uncoordinated multidisciplinary agendas, operational failures, and ever-changing technology (Tucker & Edmondson, 2002). Workarounds with SIPT safety features have been linked to system level issues (McAlearney et al., 2007); often resulting from an inadequate analysis of nurse and pharmacist medication delivery processes (Blouin & McDonagh, 2011b). As organizational changes are strategized, researchers recommend proactively considering the impact on SIPT devices needs (Adachi & Lodolce, 2005).

In this study, nurses described frequent and cyclic workarounds involving the required 30 Minute Bag Near Empty Alert, particularly in the ICU nurses where frequent titrations triggered repeated alerts. Nurses also described workarounds related to SIPT device availability, recalling times when devices were not available, even for high-alert medications. Availability issues seemed to occur more often since implementing new protocols for treating clinical emergencies, which increased the frequency and number of SIPT devices needed. Nurses described searching for equipment or using individual

judgment regarding whether to use alternative infusion approaches or delay treatment until SIPT was available.

The findings of this study support those previously published and validate the importance of continued organizational scanning for potential points of failure. The findings offer important insights for nurse leaders focusing on SIPT as a single medication safety technology. However, as technologies are integrated and the infrastructure of medication safety evolves, the implications become critical to patient safety. Technology experts caution that vendors install systems in hospitals without a complete view of their associations with other systems; therefore, assessing the inherent risks and avoiding the negative unintended consequences increasingly falls on hospital staff (Cooper & Fuchs, 2013). Nurse leaders will need to ensure that nurses have the knowledge and skills to detect technology-related risks.

Complex Drug Library

Nurses experienced difficulty locating needed medication/infusion within the complex DL. Researchers have previously discussed issues with the human-technology interface in the context of patient safety (Battles & Keyes, 2002; Vogelsmeier et al., 2008). In order to maximize SIPT safety benefits, the ISMP (2009) recommends that organizations consider the resources needed to develop, maintain, and update DLs, alerts, and advisories. Optimization of the DL has been shown to be an important factor in supporting nurses' use of SIPT (Mansfield & Jarrett, 2013; Pedersen et al., 2009).

In the current study, nurses found the DL to be incomplete and complex to use. Nurses described difficulty finding medications in the complex DL because selections were not always found in a way that made sense to nurses. Also, most nurses were unaware that the fluid labels were designed to guide SIPT programming, a recommended practice of the ISMP (2009). Responsibility for updating the DL lay with a single

pharmacist, so other pharmacists had to advise nurses to work around the SIPT safety software until a medication could be added.

These findings support other published findings about the complexities of the DL and reinforce recommendations from the ISMP (2009) that organizations maximize SIPT safety features by optimizing the DL. Medication safety technologies offer data that was previously unavailable, such as frequency of over-ride alerts. This data should be incorporated into quality improvement strategies used to refine SIPT related processes.

Consequences of Working with SIPT Safety Features

When working with SIPT, nurses expect to deliver medications safely and efficiently. In this study, the consequences of nurses' experience with SIPT safety features revealed medication errors and near-misses, and barriers to safe nursing practice.

Medication Safety Outcomes

As these nurses used SIPT safety features, they experienced intended and unintended medication safety outcomes. Although using SIPT typically results in the safe medication administration, studies evaluating SIPT effectiveness found that a lack of compliance with SIPT safety features contributed to failures to eliminate infusion-related ADEs (Hertzel & Sousa, 2009; Trbovich et al., 2011). Workarounds often result from fragmented and poorly designed processes (Halbesleben et al., 2008). High-alert medications are of particular concern due to the risk of significant harm and even death (ISMP, 2007; 2010).

Although infrequent, and reported as not resulting in long-term harm, nurses experienced unintended outcomes when using SIPT safety features in this study. Issues involving near misses and errors were primarily related to an incomplete DL, selecting the wrong concentration, or a pump malfunction. Errors were also conveyed through stories involving heparin, which nurses found problematic to administer, primarily due to protocol issues.

These findings are similar to those previously reported. Continued detected errors reflect concerns that the full patient safety benefits of SIPT are yet to be realized, and are unlikely as long as it is not fully integrated with other medication safety technologies (Trbovich et al., 2011). Heparin errors are concerning because it may indicate that despite the widely publicized issues with associated fatalities (ISMP, 2007; 2010), organizations are not fully optimizing SIPT and processes to prevent heparin errors.

Barriers to Safe Nursing Practice

When nurses in this study used SIPT safety features with IV medication administration, they struggled to minimize the negative impact of accompanying alerts. Medication safety technologies are intended to reduce errors; however, many unintended consequences resulting from the uptake of patient safety technologies could not be anticipated (Elias & Moss, 2011). For example, the number of different medical-device alarms has increased from six in 1983 to 40 in 2011, bringing with them multiple false or non-actionable alarms (Purbaugh, 2014). This change has contributed to alarm fatigue, a phenomenon with patient safety implications because nurses lose trust in safety features, become desensitized, and may ignore or over-ride alerts (Mitka, 2013; Sendelbach & Funk, 2013; van der Sijs et al., 2008). Factors commonly contributing to alarm fatigue include settings not customized to the patient, inadequate staff education, and inadequate staff to respond to alarms (Sendelbach & Funk, 2013). Alarms more visibly impact patient satisfaction (Purbaugh, 2014). Satisfaction is measured through the *consumer assessment of healthcare providers and systems* (HCAHPS), which focuses on patient-driven expectations for an optimal experience, including a quiet hospital environment (Mazer, 2012). Environmental noise negatively impacts patients, leading to sleep deprivation, delirium, increased medication and restraint use, with this impacts extending to families, and staff (Mazer, 2012).

Participants described the impact of dealing with frequent and multiple SIPT alerts and their concern that they might become desensitized. Nurses described using alerts discriminately with attention to maintaining a healing environment, particularly at night or if they had just gotten a patient comfortable. Concern about the impact of noise and disruptions created by alarms, particularly false ones, and the consequential impact on patient satisfaction scores was raised by many participants.

These findings expand on what is already known about technology and alarm fatigue by illuminating the complexity of nurses' work while using SIPT safety features, keeping patients safe, and providing patient-centered care. The phenomenon of balancing these different values supports the idea that a safety culture may exist in competition with other cultures (Groves, Meisenbach & Scott-Cawiezell, 2011).

Implications for Practice and Nurse Leaders

The current study findings have implications for nursing practice and nurse leaders. These implications address SIPT education and training, evaluating SIPT processes, optimizing the SIPT DL, and promoting a culture that learns from workarounds.

Education and Training

An important implication for nursing practice lies in identifying effective approaches to SIPT education and training and determining appropriate competencies. Organizations need to design training programs that reflect the complexity of the technology and consider interdisciplinary approaches that focus on supporting patient safety outcomes with SIPT. These training standards need to be maintained following implementation. Training needs should consider a safety culture perspective. Groves and colleagues (2011) have brought this issue to the forefront and developed a Structuration Theory of Safety Culture that may guide future research studies in exploring the

processes by which safety culture produces safe patient outcomes as a result of nursing behavior.

Change leaders need to plan for training that considers the interdependence of nurses and pharmacists in troubleshooting approaches. Nurses and pharmacists are in critical areas to detect the risks and unintended consequences of SIPT, they need the education and training to recognize these risks as well as mechanisms to evaluate the technology. As healthcare organizations integrate medication safety technologies in a rapidly changing and complex environment, there is a need to ensure that real-time problems are addressed in a manner consistent with organizational expectations while staff are learning on the fly. Mechanisms that capture and share these lessons will need to be developed to ensure that organizational learning occurs and move toward highly reliable medication safety practices.

Evaluating SIPT Processes

As organizations focus on implementing SIPT to achieve and sustain improvements in medication safety, outcomes must be evaluated in terms of patent safety and nursing practice. Nurse leaders must routinely review and evaluate SIPT policies and processes to ensure they are achieving their intended outcomes. Intentional workflow blocks designed to support safe practices may be perceived as unhelpful by the nurses that use them. Because they have been linked to patient and staff outcomes, it is imperative that nurse leaders routinely evaluate nurses' perceptions of SIPT safety features and make appropriate improvements. Current attention to the impact of alarm fatigue provides opportunities for nurses to evaluate unnecessary and false alarms related to SIPT. Nurses in the current study envisioned SIPT improvements that support nursing workflow without disrupting patients, such as specific alert information being delivered through a pager, phone, or computer. Providing such feedback and recommendations to manufacturers can facilitate enhancements to SIPT device and software features. Nurse

leaders should use organizational structures and processes to provocatively assess the impact of changes in care delivery on resources such as SIPT devices. Such proactive risk assessments are critical to identifying risks as medication safety technologies are integrated.

Optimizing the SIPT Drug Library

Adopting SIPT requires leadership to make a long-term commitment to ensuring that resources are devoted to optimizing the technology in practice. Organizational resources need to be evaluated to determine whether they optimize practice or create unintended consequences. For example, a model using a single pharmacist to developing and maintain the DL creates a single point of failure. This model also requires other pharmacists to direct nurses to use the Basic Mode feature, which inadvertently supports workarounds. Optimization of the DL should include input from nurses in designing the DL and ongoing evaluation of medications frequently associated with alert over-rides. Nurse leaders should ensure that nurses have SIPT devices readily available to meet patient care needs. Additionally, because medication safety technologies are most effective when they are integrated, nurse leaders must strategically plan for this integration.

Learning from Workarounds

Nurse leaders set priorities and have the opportunity to elevate patient safety as the highest organizational priority. Nurse leaders can also influence how workarounds are viewed and framed as either patient safety opportunities or unsafe practices. Nurse-initiated workarounds are not simply the result of a nurse interacting with SIPT; they often result from organizational conditions. Sustaining a safety culture and supporting the human aspects of care delivery requires organizational structures and processes designed to prevent error and enable resilience (Blouin & McDonagh, 2011a). Nurse leaders are in key positions to address organizational barriers, thus influencing how nurses look for

patient safety opportunities and threats. Workarounds may not be recognized because they occur frequently and become normalized in practice; nurses need to be trained to identify them. Once workarounds are identified they need to be communicated, thus structures and processes must be put into place to capture these events.

Leaders need to engage front-line staff to learn from workarounds, which may require education and assistance from quality improvement and human factors experts. Once learning occurs, solutions must be determined and tested in context. Developed solutions need to be communicated across the organization. Leaders need to close the learning loop and ensure that new practices are evaluated for unintended consequences. Leadership, teamwork, communication, and staff empowerment can help organizations learn from workarounds to improve safety.

Study Limitations and Future Research

The current study yielded valuable insights into the complexity of SIPT implementation and the challenges faced by nurses while providing safe, effective, patient-centered care in the midst of juggling competing priorities. However, the study limitations should be noted. The findings rely on retrospective interview data. Although approaches to minimize this potential limitation were previously addressed, Future studies should consider other data collection methods, such as direct observations and the triangulation of any root cause analyses from SIPT-related error data. Additionally, although study findings may be of interest to nurses wishing to examine their own practices with SIPT, the emerging grounded theory of Nurse-Technology Interplay will need further explication since the theory was developed using the experiences of nurses across a single organization and with a single device type. While there were many findings that aligned with the literature, further theory testing may confirm if the themes and implications translate to other patient safety technologies and organizations. The emerging theory reflects complex work processes that would benefit from further inquiry

and analysis to better understand how nursing practice interfaces with patient safety technologies. The research design limits were previously discussed. However, because generated grounded theory can be applied to practical experiences, it would be feasible to design a survey study to support and expand this grounded theory. Such a study might produce more generalizable findings.

Research recommendations are made to support full achievement of SIPT safety benefits. The minimal competencies needed to support nurses' capabilities with SIPT should be explored, with a focus upon what facilitates keeping the patient safe. As patient safety competencies are identified they need to be tested in different training environments to determine the dose and timing of training interventions to patient safety-oriented behavior change. Additionally, to effectively achieve and sustain medication safety with SIPT, the organizational structures and processes necessary to support nurses' use of SIPT need to be better understood. Because care delivery occurs in such a dynamic and quickly-changing environment, it is of interest to explore how organizations support nurses' troubleshooting needs in real-time. A critical next step from the current study includes testing the emerging theory of Nurse-Technology Interplay to understand its usefulness for nurses to keep patients safe by providing the structure and language to identify and communicate relevant factors involving SIPT processes.

Conclusion

This study provided valuable insights into how nurses think through, act, and interact with SIPT safety features. The complexity of SIPT implementation and the important role that nurse leaders play in optimizing and sustaining effective practices is elucidated. The emerging grounded theory of Nurse-Technology Interplay represents the complexity of nurses co-existing with SIPT, and provides a structure that may help nurses identify and communicate SIPT safety issues. Clearly, when appropriate SIPT training

occurs and organizational mechanisms to support shared learning are robust, nurses can use "smart" technologies to effectively keep patients safe.

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APPENDIX A

DEFINITION OF KEY TERMS

Basic Mode reflects use of SIPT with the safety software disengaged. Users are alerted to the pump running in basic mode by the dosing information being displayed in red.

Care area profiles simplify programming by defaulting to appropriate population specific dosages such as Critical Care, Oncology, or Pediatrics (Vanderveen, 2007).

Clinical advisories are safety prompts that display information about a selected medication, such as the need to utilize a filter; these signal that further action may be needed (ISMP, 2009).

Continuous Quality Improvement (CQI) data logs are a function of the safety software, automatically collecting data about pump alerts and subsequent actions by the caregiver. These logs provide a source to measure the impact of the device on patient safety (Vanderveen, 2007).

Dosing limits are alerts that notify the user that the dose selected is out of the anticipated range for the specific medication; these alerts are set as soft or hard limits (Vanderveen, 2007).

Drug libraries are large data sets containing institution specific, pre-defined parameters for specific drugs and rates [continuous, intermittent & boluses (Vanderveen, 2007)].

Hard limits are dosing alerts that signal that a programmed dose is unsafe; the infusion cannot be administered without reprogramming to a safe range (Vanderveen, 2007).

Medication Administration is a complex process that involves coordination and communication between multiple providers through is a series of steps, including: prescribing, transcribing, dispensing, administering, and monitoring outcomes (Bates, 2007).

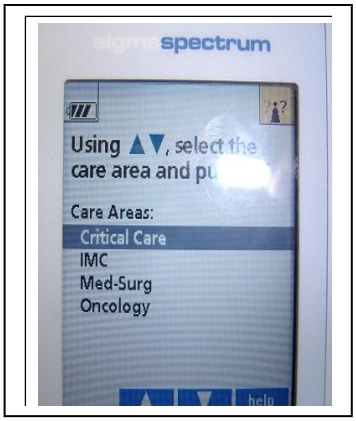
Soft limits are alerts indicating that a programmed dose is near a safety limit; they may be overridden without changing settings, allowing the medication to be infused (Vanderveen, 2007).

APPENDIX B

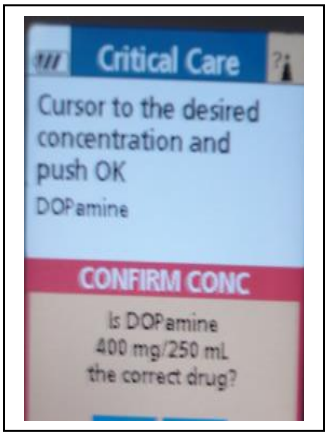
SIPT FEATURES

B1. Smart Pump

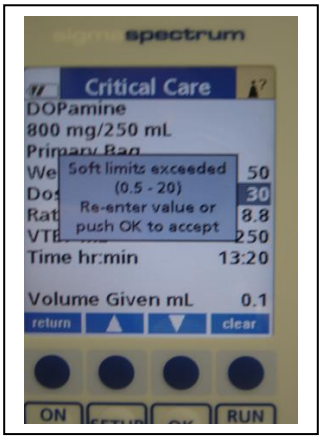
B 2. Care Area Profile



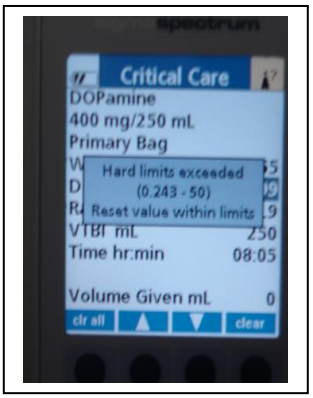
B 3. Confirm Concentration



B 4. Soft Limit Alert



B 5. Hard Limit Alert



B 6. Generic Mode

APPENDIX C

IRB APPROVAL LETTER

Springfield Committee for Research Involving Human Subjects (SCRIHS)
Notification of Final Approval

Dear Geri L Kirkbride, RN, MSN, PhD (c):

The SCRIHS Expedited Review Panel reviewed your submission entitled: Exploring how Nurses Make Sense of the Safety Features of Smart Infusion Pump Technology (12-184), Reference #:000457.

Study Number: Smart Pumps

Conditional approval was granted pending revisions and/or clarifications. Those revisions and/or clarifications have been submitted, reviewed and found to be acceptable. This letter is to confirm your final approval.

Approved Documents:

Submission Components			
Study Document			
Title	Version Number	Version Date	Outcome
Research	Version 1.1	02/24/2012	Approved
Research Information Sheet	Version 1.0	02/24/2012	
Research Protocol: Exploring how Nurses Make Sense of the Safety Features of Smart Infusion Pump	Version 1.0	03/01/2012	Approved
Letter for Verbal Consent	Version 1.0	02/24/2012	Approved
Initial Interview	Version 1.0	02/24/2012	Approved
Demographic Sheet	Version 1.0	02/24/2012	Approved
Recruitment Flyer	Version 1.0	02/24/2012	Approved
Recruitment E-	Version 1.0	02/24/2012	Approved

Continuing review for this study must be conducted no later than 04/03/2013.

IRB approval indicates that this project meets the regulatory requirements for the protection of human subjects. IRB approval does not absolve the principal investigator from complying with other institutional, departmental, or hospital policies or procedures.
It is a violation of DHHS and FDA regulations on Protection of Human Subjects to implement this study without final Institutional Review Board approval.
Federal regulations require all subjects to be provided with a signed copy of the informed consent form, unless a waiver of documented consent has been justified per 45 CFR 46.117(c).
Any changes to approved human subjects research require SCRIHS approval prior to initiating.
Immediately report to SCRIHS any unexpected or untoward results from this research.
Thank you for your cooperation with the committee's deliberations. It is greatly appreciated.

_____

From: Countryman, Michele L

Sent: Thursday, May 03, 2012 7:05 AM

To: Kirkbride, Geri I

Subject: Re: Reference Number (000457) Submission Letter: SCRIHS Expedited Final Approval

Geri,

No further actions are required of you. You have fulfilled your requirements.

Thank you. Michele

On Apr 10, 2012, at 11:30 AM, "Kirkbride, Geri I" <geri-kirkbride@uiowa.edu> wrote:

> Hi Michele - I understand that the approval process may take some time; I just want to make sure that you have all the documents that you need.

> Thanks in advance/ Geri

> Geri Kirkbride, RN, PhD(c), CENP, CPPS

> > _____

> From: SIU@imedris.com [SIU@imedris.com]

> Sent: Tuesday, April 03, 2012 3:21 PM

> To: Kirkbride, Geri; Research Administration

> Subject: Reference Number(000457) Submission Letter: SCRIHS Expedited Final Approval

> Outcome Letter Notification

>To: Selected users (when outcome letter is sent within the submission)

> Regarding:12-184 - "Exploring how Nurses Make Sense of the Safety Features of Smart Infusion Pump Technology "

> Submission Type: Submission Response for Initial Review Submission Packet

> Reference Number: 000457 > Attached is the outcome letter for this submission.

APPENDIX D

RECRUITMENT E-MAIL

Hello,

I am a nursing research facilitator at Memorial Medical Center and a doctoral student at the University of Iowa, College of Nursing. As part of my dissertation, I am conducting research on how hospital nurses interact with smart infusion pump technology (SIPT). Specifically, I want to explore nurses' perceptions of the SIPT safety features, how they are used in clinical practice, and any barriers encountered when using them. You are receiving this email because I am interested in talking to bedside nurses on the inpatient units about their experience with SIPT. If you are a registered nurse, speak English, and use SIPT in any of the inpatient units at Memorial Medical Center, you may be eligible to participate.

If you take part in this study, you will participate in a private and confidential interview about your experiences with SIPT in this hospital during the past three years. You may also be asked to participate in a follow-up interview or to provide feedback on study findings. The initial interview should last approximately 60 minutes and will be arranged at a time that is convenient for you. Your participation is strictly voluntary and you may choose to stop at any time. Any personal information you might provide as a participant will be kept confidential. Your participation will help further understanding about how nurses work with and make sense of the safety features of smart pumps. The ultimate goal of this research is to support medication safety practices and provide guidance for improving SIPT, thereby improving patient safety. Please contact me at Kirkbride.geri@mhsil.com or (217) XXX-XXXX if you are interested in participating.

Thank you,
Geri Kirkbride, RN, MSN, PhD(c)
Nursing Research Facilitator, Memorial Medical Center
Doctoral Candidate, University of Iowa College of Nursing

APPENDIX E

RECRUITMENT FLYER

Research Study: Nursing and Smart Pumps

You may be eligible to participate in a study to learn more how hospital nurses work with smart pumps if you are:

- A bedside RN working on an inpatient unit at Memorial Medical Center
- Use smart pumps in your daily work
- English-speaking

In this study you would participate in an interview about your experiences with smart pump safety features. The interviews will last for approximately 60 minutes and will be conducted by a nurse researcher. You may also choose to participate in follow-up interview to validate the study findings.

Participation is completely voluntary and confidential. The nurse researcher has received permission to conduct this study at Memorial Medical Center. The nurse researcher will work with you to complete the interview at a time that's convenient for you.

If you'd like to know more or are interested in participating, please contact Geri Kirkbride at (217) XXX-XXXX or Kirkbride.geri@mhsil.com

APPENDIX F

RESEARCH INFORMATION SHEET

STUDY TITLE:
Exploring how Nurses Make Sense of the Safety Features of Smart Infusion Pump Technology

You are being asked to take part in this study because you work with smart infusion pumps in your role as a registered nurse, employed at Memorial Medical Center. You are eligible if you work on an inpatient unit at MMC and you are English speaking.

WHO IS THE PRINCIPAL INVESTIGATOR FOR THIS STUDY?

Geri Kirkbride, RN, MSN, PhD(c), CCRN
Doctoral Candidate, University of Iowa College of Nursing
Nursing Research Facilitator, Memorial Medical Center
701 N. First Street. Springfield, Illinois 62781
Phone: 217-825-8295

WHY IS THIS STUDY BEING DONE?

You are being asked to participate in a research study being conducted at Memorial Medical Center. You should read the information below, and ask questions about anything you do not understand, before deciding whether or not to participate.

The main goal of the study is to gain knowledge that may help with improvements in clinical processes and patient safety. If you agree to be in the study, you will be asked to give verbal consent at the time the data is being collected. I will not ask for your signature or collect your full name as a possible participant in this study. This information sheet will tell about the purpose, risk and benefits of the study and how you can volunteer to participate or decide that you do not want to be a part of the study. The research is planned to start in the next 30 days.

The purpose of this study is to explore nurses' experiences with smart pumps. Specifically, I am interested in how nurses interact with the smart pump safety features and the workflow blocks that smart pumps create. This study is being completed to fulfill requirements for completion of my PhD in Nursing Administration.

HOW MANY PEOPLE WILL TAKE PART IN THIS STUDY?

Nurses from inpatients units who work with smart pumps are eligible to participate in this study. This study will use key informant interviews to have nurses describe their experiences with smart pumps. It is estimated that between 15 and 30 people may participate.

WHAT WILL HAPPEN IF I TAKE PART IN THIS RESEARCH STUDY?

If you agree to be in this study, I will contact you to arrange for an interview at a time that is mutually convenient. The interviews will be help in a private office away from the nursing units. After reading this Research Information Sheet and clarifying any questions, you will be asked for your verbal consent to participate in a recorded interview. You may choose not to participate at any time during the interview. You will be assigned a participant number and a pseudonym, and will be asked to complete a demographic sheet. Minimal information will be asked of you and your full name will not be used recorded. All information is confidential and will not be shared with anyone outside of the research team.

After you have given verbal consent, the interview will start, the interview will last approximately 60 minutes. During the interview you will be asked questions about your general experiences with smart pumps and then more specific questions about working with smart pump safety features, and any areas that may be troublesome. I am interested in how you handle these situations. The interviews will be audio recorded and transcribed, but your identity will be protected.

CAN I STOP BEING IN THIS STUDY?

Yes. You can decide to stop at any time. There are no consequences if you decide not to be in the study or stop your participation during the study.

WHAT SIDE EFFECTS OR RISKS CAN I EXPECT FROM BEING IN THIS STUDY?

There are no known risks from participating in this study. Participants may experience some stress at recalling specific events involving workarounds or interactions with smart pumps, especially if the situation involved a risk or harm to a patient. Your truthful response will help me to understand the challenges that nurses face in clinical practice.

ARE THERE BENEFITS TO TAKING PART IN THIS STUDY?

If you agree to take part in this study, there is no direct personal benefit. We hope to learn information that will improve patient safety and clinical practice.

WHAT OTHER OPTIONS ARE THERE?

You may choose not to participate in this study and may withdraw at any time.

WILL MY MEDICAL INFORMATION BE KEPT PRIVATE?

Since I am interested in aggregated information, no individual information will be reported about you and your name will not be used in the data analysis. Organizations that may look at/ or copy research records for quality assurance or data analysis include:

- Memorial Medical Center
- University of Iowa College of Nursing
- Southern Illinois University School of Medicine

I am a student at University of Iowa College of Nursing and will be working with my dissertation committee. They are authorized to review research records as part of their responsibility to protect human subject volunteers. Research records will be stored in a secure, confidential manner, so as to protect your identity. If information from this study

is published or presented at scientific meetings, your name and other personal information will not be used.

WHAT ARE THE COSTS?

There are no direct costs to you for participating. There is no compensation for your time or travel spent for the interview. Your participation is greatly appreciated.

WHAT HAPPENS IF I AM INJURED BECAUSE I TOOK PART IN THIS STUDY?

In the event of any injury resulting from study procedures, immediate medical treatment for injuries is available at usual and customary fees at Memorial Medical Center or St. John's Hospital, Springfield, Illinois. Check with your health care plan or insurance company to find out what coverage they will provide. If you suffer any physical injury as a result of participation in this study, you should contact the Chairperson of the Springfield Committee for Research Involving Human Subjects at:
Southern Illinois University School of Medicine
801 N. Rutledge Street
Springfield, IL 62702
Telephone number: (217) 545-7602

WHAT ARE MY RIGHTS AS A PARTICIPANT?

Taking part in this study is voluntary. You may choose not to take part or may leave this study at any time. Leaving this study will not result in any penalty.

WHOM DO I CALL IF I HAVE QUESTIONS OR PROBLEMS?

For questions about this study, contact the principle investigator:
Geri Kirkbride, RN, MSN, PhD (c) at 217-825-XXXX.
For questions about your rights as a study participant, contact the Springfield Committee for Research Involving Human Subjects (which is a group of people who review the study to protect your rights) at:
Southern Illinois University School of Medicine
801 North Rutledge
Springfield, IL 62702
Telephone number: 217-545-7602
The Chairperson of this committee will review the matter with you.

HOW DO I CONSENT TO PARTICIPATE?

Written consent is not being used in this project. This approach protects your identity because there is no written record of consent or participation. If you agree to participate, I will contact you and enroll you in a convenient interview. You will be asked to give verbal consent before the interview and this will be digitally recorded. If you change your mind, simply state that you do not wish to be part of this study.

APPENDIX G

LETTER OF INFORMED CONSENT

Exploring how Nurses Make Sense of the Safety Features of Smart Infusion Pump Technology

I am conducting a research study to explore nurses' perceptions of and experiences with the safety features of Smart IV Pumps. This study is an institutional review board approved study. This study will use interviews, lasting approximately 60 minutes, to explore RNs experiences with smart pumps. As part of this study, we are asking you to share your experiences with Smart IV Pumps, the safety software, and any problems you may have encountered. I am particularly interested in conditions that may require nurses to bypass, or workaround, these safety features.

The attached information sheet includes complete information about this study and your rights to be part of the study or decide not to participate. It is not necessary for you to sign this form. To protect your identity and keep your decision to participate anonymous, you are not required to sign an informed consent document. There is very little risk to you for your participation and using this type of verbal consent helps ensure that your decision to participate (or not) is protected information.

If you agree to participate, no compensation is offered. However, participation in this research project is an activity eligible for clinical ladder advancement. I am available to answer questions that you may have about participating in the study. Please feel free to contact me at 217-825-XXXX if you have any questions.

Thank you for your consideration of participating in the study,

Sincerely,

Geri Kirkbride, RN, MSN, PhD(c), CCRN
Principle Investigator
Nursing Research Facilitator, Memorial Medical Center
Doctoral Candidate, University of Iowa College of Nursing

APPENDIX H

DEMOGRAPHIC DATA COLLECTION SHEET

Participant ID#: _____Name _____

Date: _____

Time began: _____ Time ended: _____ Duration: _____

Demographics:

Age: _____ Gender: _____

Type of nursing education received: _____

Years of experience as a Registered Nurse: _____

Years of experience in the Organization: _____

Years of experience in the unit: _____

Unit type/location: _____

Shift most frequently worked: _____

Charge Nurse / Supervisor? _____

Please consider events that have occurred with smart infusion pump technology while working at the current organization within the past three years.

APPENDIX I

INITIAL INTERVIEW QUESTIONS

RQ 1. What are nurses' perceptions of the SIPT safety features?
RQ 2. What rules and resources do nurses consider when responding to SIPT safety features?
RQ 3. What actions do nurses take in response to workflow blocks with SIPT safety features?
RQ 4. Under what conditions do nurses initiate workarounds with SIPT safety features?

Definition: Workarounds are alternative work procedures that bypass a real or perceived block to workflow and represent variations from intended procedures and processes (Halbesleben et al., 2010).

Initial Interview Questions

1. Tell me about how you use the smart pump in your practice. (RQ 1)

2. Has anything unexpected or surprising happened while you were operating SIPT? (RQ1) Probe: Tell me more about it- What action did you take? (RQ 4)

3. What aspects or qualities of SIPT make it difficult to use? (RQ 1)
   Probe: What could be done to improve this? (looking for sources of WA)

4. After reviewing the definition of a work block and a workaround- can you recall a workaround situation with smart pumps that you have encountered in practice in the last year? Probe:(looking for actual experiences- tell me more about conditions and circumstances) (RQ 4)

5. What do you do when you encounter a problem or workflow block with SIPT? (RQ 3)
   Probe: What resources do you rely on (policies/process/flow/people/technology). (RQ2)

6. Under what circumstances would the Drug Library be by-passed? (RQ 4)
   Probe: How is this decision made? Does this impact patient care?

7. Please think of a time when a workaround was taken- what was the outcome? (RQ 4)
   Probe: Was it successful/unsuccessful? What happened next? How did this impact you?

8. What resources are most helpful when you encounter a block or problem? (RQ 2,3)
   Probe: Which are commonly used? How do you decide which resource to use?
   People (pharmacist, peers, formal, informal)/ Policies/ Other

9. Is there anything that you might not have thought about before that occurred to you during the interview?

10. Is there anything that you would like to tell me?

APPENDIX J

OPEN CODING INTERVIEW ONE

Text	Concepts	Tentative Categories
"We use Smart Pumps-that's one that our health system chose, but I think some type of pump is very important, especially for the more detrimental medications that you need to be at specific rates or problems could happen."	Pump is important Detrimental meds @ specific rates…or problems could happen.	**Perceptions of the Pump /Safety**
"Each medication is broken down into multiple lists because…so many concentrations… Vancomycin has several pages… have to click the right concentration and then go to it from there….that one is big- you have to look at kidney function … how much they can get."	Multiple lists/ different concentrations Vancomycin/ kidney function	Programming the Pump/ Meds complex to program Consider clinical situation- Vigilance
"Yes, you still have to think about it [administering medications] because there have been times where I've had a bag that was labeled incorrectly. I went to put in what the bag said, it [pump] came up with something different, one that gave it a much shorter period of time than I knew this was supposed to go It just didn't fit … so I went back and did the math and figured out it was wrong after I had someone else look at it. I had to call [pharmacist] about it and it just didn't make sense. So I went back and programmed it correctly - a near miss not a med error."	have to think about it something different…It just didn't fit-didn't make sense did math/ had someone else look/ call [pharmacist] (re) programmed bag labeled incorrectly/ near miss	Mindfulness Programming using label Surprising situation-(sensemaking trigger) Actions: calculation; contact nurse colleague; contact pharmacist; reprogramming. Outcome: Near Miss
"I have only once gone into Basic mode-(medication) for heparin allergies…only had two patients that have had it… patient was very sensitive… had to change the concentration from a 250 to a 500cc bag - wasn't in the pump...because the pumps can't accurately deliver less than half a milliliter an hour We had to put in Basic mode . Basic mode is a pretty powerful setting… That was the only time I have gone outside of the safety software. The patient really needed the low dose medication because their PTT was too high. I was actually asked [by pharmacy] how I was going to give it because there were no settings for it I had to get a specific order from the doctor to do this concentration. I had to speak to the pharmacy manager…to tell me how to get into Basic mode, because the person I was talking to [pharmacist] knew there was some way to do it, they just didn't know how. Once you know…Basic mode is pretty self-explanatory… didn't know that was available at all before that. That was a situation where I thought there would be an easier fix- I was on the phone for about an hour while I got everything	Basic Mode once Only 2 patients w meds. Concentration not in pump .really needed med Pump can't deliver less than .5 ml/hr. asked how I was going to give it/got order Pharmacist did not know how to get to Basic mode Didn't know available Thought there would be an easier fix (Emotion: frustration). can help somebody else.	Workaround safety software. / Infrequently used meds. Work block-concentration not in pump. Situational Awareness: safety /clinical situation. SIPT Limitations Basic mode: running Infusion outside the safety software. Frequency: rare use Basic Action: contacting Pharmacist/ Physician Unaware of pump features: pharmacist-how to direct nurse-Basic mode. Workblocks-

figured out. … if somebody else comes into a similar situation I'll be able to help them".		inefficiency). Teaching/Learning on the fly.
"The training… pretty much on the job… handed a bag and told what buttons to hit... as you need it you look up your medication and then just pick… antibiotic(s) have several different dosages. The only time it's not been that simple was when I had to change a concentration to something not normally carried…a limitation of the technology."	OJT: handed a bag & told buttons to hit. Look up med & pick. Simple except when concentration not carried/ SIPT limitations	Education & Training-unstructured/on the job Programming the Pump Complexity w limitation of SIPT

APPENDIX K

TENTATIVE CATEGORY DEVELOPMENT

Tentative Category	Concepts/Codes	Description	Field Notes
Using SIPT	Programming Pump	Situations encountered	
	Meds with multiple dosing/concentrations		Requires vigilance
	Meds not used frequently		Vigilance?
	First time using Basic mode		May reflect dimension use.
Perceptions	SIPT adds Safety	How nurses view SIPT	Safety culture?
	Basic mode is powerful		
Actions	Performing Calculations	Describes actions taken in response to situation	
	Contacting nurse colleague, pharmacist, physician		
	Reprogramming SIPT		
Consequence	Med given outside the safety software	Outcomes	Workaround-safety software
	Near Miss		
	Nurse frustration with resolving situation		
Workflow block	Med label did not program as expected /Labeling error	Unexpected situations	Creates work block & Triggers sensemaking-
	Concentration not in pump	Interrupt giving meds	? composition of DL
	Unaware of (Basic mode)		Related to education?
	SIPT Limitations: can't deliver < 0.5 ml./ hr.	Technology limitations	Other limitations?

Thinking through a situation	Consider clinical situation	Mindfulness	Part of Sensemaking?
	Contacting resources (colleague, pharmacist)		
Education/Training	Unstructured/ on the job	Approaches/Implications	
	Learning on the fly		
	Teaching from experiences.		Is learning captured and shared through organization?
	Unaware of pump features (pharm/nurse)		

APPENDIX L

MEMO FROM INTERVIEW ONE

From the analysis of interview one, I developed my initial my codes/ concepts and began to develop tentative categories and began to consider the dimensions and possible relationships of the concepts. I also began to identify *potential relationships.* Under *conditions,* usual medications and situations are easily programmed. However, programming specific medications or unexpected situations introduce additional complexity and make medication administration with SIPT more difficult. Medications that have multiple dosing/concentration options for or those not frequently used require heightened vigilance to ensure the correct dose is selected. Unexpected situations, such as medication label settings not matching Drug Library (DL) settings, or when needed concentrations are not found in the DL, create workflow blocks with programming. Something "**doesn't make sense."** As the nurse is thinking through and trying to make sense of these unexpected situations, additional information is sought. This information may be sought by taking action such as re-checking labels and performing calculations to recheck dosing, or by seeking assistance of nurse colleagues, pharmacy staff, and physicians. To continue with medication administration, nurses may need to reprogram the pump and even run it outside the safety software in Basic Mode.

In the situation where the concentration was not in the DL, the pharmacist instructed the nurse to run the infusion in *Basic mode,* which involves bypassing the safety software. In the latter situation, the nurse was unaware of Basic Mode which created an additional block; requiring additional time spent managing this particular situation. Interestingly, one of the pharmacists contacted did not know how to instruct the nurse to use Basic mode, thus the pharmacy manager was contacted to do this. This is an example where the *consequences/* outcome of this situation resulted in the administering the medication outside of the SIPT safety software. In subsequent interviews, I will try to identify similar or additional experiences, as well as outcomes resulting in delivering medications through or around SIPT safety software. I am surprised about the lack of structured training described and the unfamiliarity with Basic Mode. This was not one of my original interview questions but I think it is important to identify the type of training nurses are getting- I am wondering if it makes a difference in how the pumps are used. [BRACKET: As an RN in the organization- I attended the initial training and recall the fairly detailed education which required return demonstration- policy to call nursing supervisor if running medications outside of DL & an overview of Basic mode & risks of using].

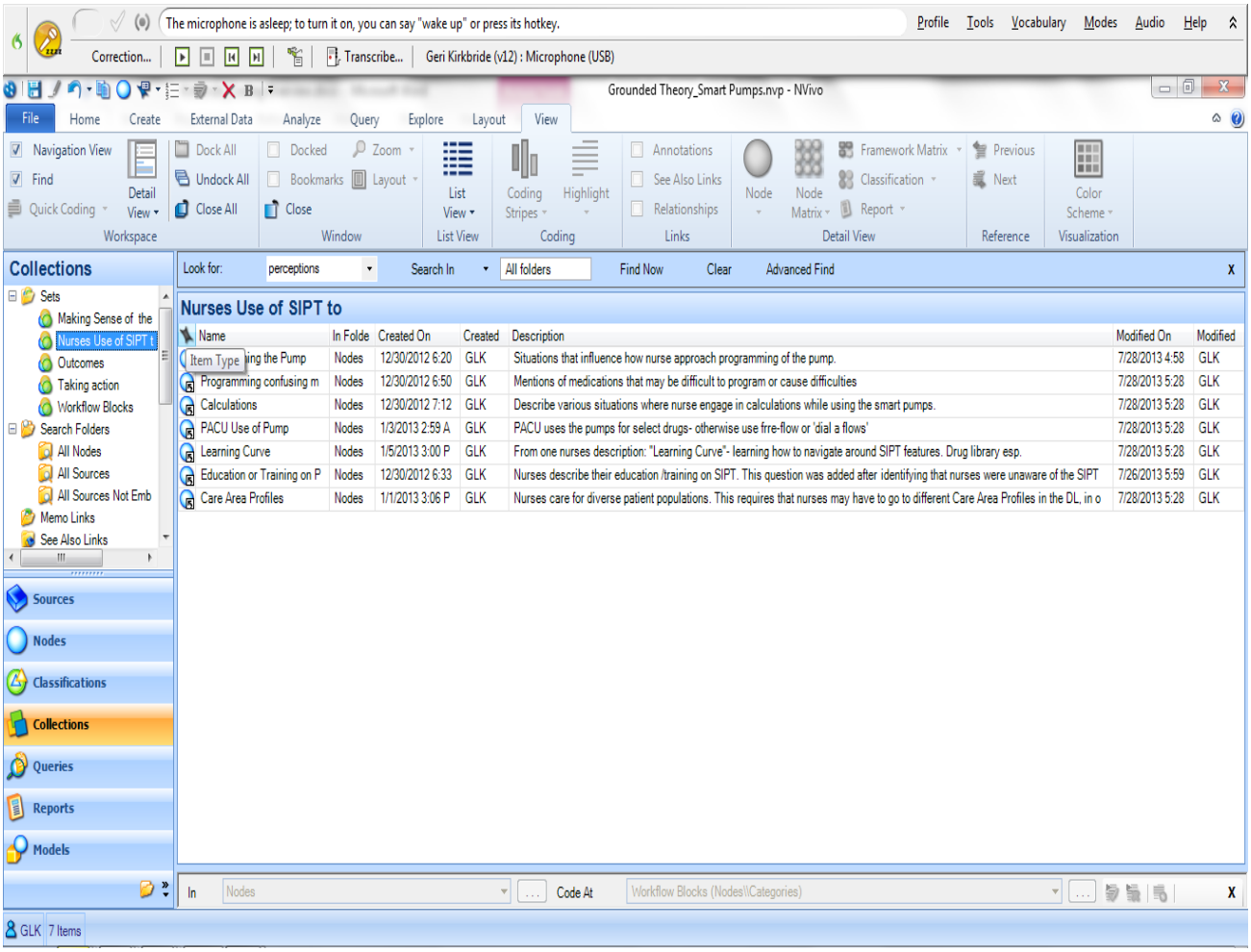
APPENDIX M

SUMMATIVE NOTE: THEORETICAL SAMPLING MEMO

"Name: Memos\\Theoretical Sampling Memos\\Theoretical Sampling Interviews 1-5
Description: Describes what was learned & where to direct the sampling and questions.
A purposive sampling strategy was used for initial data gathering- seeking information from nurses who use smart pump technology. During the first interview- a bit of a surprising finding for me was that the nurse was unaware of the Basic mode feature. Although knowledge & skills are a key component of successful technology implementation, I had not considered that staff may be totally unaware of the safety features. During a story about a surprising situation where the drug was not in the Drug Library- pharmacy was contacted and advised to run the drug in Basic mode until it could be added to the DL. The nurse was unaware of the Basic mode feature so the pharmacist instructed on how to set up. I probed a bit into how the nurse was educated on the pumps, added the education question to subsequent interviews- and made a note to include a diverse group of nurses in my sample (already a planned strategy but driven more from the perspective of nursing experience). I found much variation in how nurses are educated about the smart pumps. [BRACKET: As an RN in the organization- I attended the initial training on smart pumps and recall the fairly detailed education which required return demonstration- policy to call nursing supervisor if running medications outside of DL & an overview of Basic mode & risks of using]. Nurses describe setting up the pump in similar ways- yet they recall having difficulty finding some medications in the pump, common medications like normal saline and also IVs that are not given so frequently- such as banana bags and Dextran. I wonder if the method that the medication gets to the nurse (carried from pharmacy- sent from pharmacy- removed from dispensing machine) and/or urgency (routine or new order) and/or shift (one pharmacist at night) influence how nurses assimilate and coordinate medication administration with SIPT (getting it from Pyxis does not require waiting on pharmacist). Also-may make a difference on how the pump is used for the "*30 Minute Bag Near Empty Alert*" to end of bag. Similar patient types on units tend to have similar medications order- so staff eventually learns how to find these medications. The DL requires nurses to select the one most appropriate for the patient. Units that cohort different patient types (IMC & general floor) have to select the appropriate DLs but working on a nursing unit not designated as IMC describe that they find their medications in the IMC DL. - possibly reflecting the increased acuity of patients I started to ask if there were specific medications that were more difficult to give as well as use of protocols- heparin came up in several of the initial interviews. Very few instances of running into the "Hard Limits" and some staff seemed unclear on the difference between hard & Soft Limits. Proceeding with interviews across different units & shifts - as well as the experience within the organization."

APPENDIX N

EARLY CATEGORY DEVELOPMENT IN NVIVO



APPENDIX O

CATEGORY DEVELOPMENT

Theme	Categories	Concepts	Text
Interacting with SIPT	Learning Curve	Learning about SIPT User-Technology Interface Usability of drug libraries Device knowledge gaps	On the job training (1); We had an in-service and shown troubleshooting features (11); on the unit with my preceptor - hands on, you know, this is how you do it, so learn be seeing, learn by doing. (10) The smart pump is just a computer so you have to think like a computer… (9) Learning all the different libraries and what is in them takes a bit of time (23). At first it was hard [finding the drug] - it's a learning curve, (23)…the learning curve, how to communicate with it and understand it (9).
Interacting with SIPT	Patient Care Unit Characteristics	Patient populations Unit level troubleshooting approaches	I usually go in under Med-Surg… if I can't find something I'll go under Critical Care…like a dilaudid drip is under Critical Care… (8)If there are a 100ccs in the bag, we put 95 so it rings before its empty and we have more time...that's just the way we think as Critical Care nurses-and we were used to the pumps before (12).
Interacting with SIPT	Workflow Blocks	Organizational Factors SIPT Factors	If there was a way that instead of it beeping in the patient's room like we had some way that it beeped with something we had, even if we had to carry around a pager…it doesn't need to beep for the patients; it needs to beep for the nurses. (Case 10).

APPENDIX P

COMPONENTS OF NURSE-TECHNOLOGY INTERPLAY

Categories	Sub-categories	Concepts	Properties
Interacting with SIPT	Learning curve	SIPT Training	Initial Learning on the Fly
	Learning curve	Human-technology interface	Becoming Familiar with SIPT Thinking like a computer Understanding limitations
	Learning curve	Complexity of the Drug Library	Basic programming rules Exceptions to basic rules
	Learning curve	Basic device knowledge gaps	SIPT safety software Visual cues
	Patient-care unit characteristics	Patient population	Patient types Typical medications
	Patient-care unit characteristics	Unit level troubleshooting approaches	Available resources Unit level practices
	Workflow blocks	Organizational blocks	Pump availability Organizational policy Incomplete Drug Library
	Workflow blocks	SIPT blocks	Alerts Problematic medications Pump malfunctions Helpful/Unhelpful blocks
Making Meaning	Working through the clinical situation	Vigilance	Noticing Paying attention Scanning for additional cues
	Working through the clinical situation	Rethinking	Previous actions Considering future actions
	Working through the clinical situation	Situational context	Clinical situation Desired outcomes Potential patient impact
	Individual perspectives	Safety perceptions	Provides parameters Double-checks
	Individual perspectives	Personal experience	Positive perception of SIPT Negative perceptions of SIPT
	Shared learning	Captured events	Detected Events Communicating learning
	Shared learning	Missed opportunities	Undetected events
Taking Action	Rechecking	Medication checks	Medications order Medication labels

	Rechecking	Reprogramming	Working through SIPT software Working around SIPT software
	Workarounds	Fooling the pump	Secondary infusions Medication not in Drug Library 30 Minute Bag Near Empty
	Workarounds	Working outside safety software	SIPT availability Medication not in Drug Library Hard Limits
	Seeking assistance	Unit level resources	First line strategy Charge nurse Nurse colleagues
	Seeking assistance	External resources	Consider availability Pharmacist Physician Biomedical Engineering
Consequences	Medication administration patient outcomes	No problems detected	No unexpected events Working through SIPT
	Medication administration patient outcomes	Problems detected	Near Misses Medications Error
	Impact on nursing practice	Disruptions to care delivery	Disruptions to patient's rest Patient dissatisfaction with noise Patients silencing alarms
	Impact on nursing practice	Dependency on technology	Have only used SIPT devices Believe monitoring unnecessary
	Impact on nursing practice	Loss of calculation skills	Relieved SIPT does calculations Losing a valued skill
	Impact on nursing practice	Alert overload	Unable to distinguish types Excessive alerts