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UNIVERSITY OF SAN DIEGO
Hahn School of Nursing and Health Science
DOCTOR OF PHILOSOPHY IN NURSING

THE USE OF CLINICAL DECISION SUPPORT TO
IMPROVE NURSING PRACTICE

by

Kathleen J. Klimpel, MSN, RN, CNS, RN-BC

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A dissertation presented to the
FACULTY OF THE HAHN SCHOOL OF NURSING AND HEALTH SCIENCE
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requirements for the degree
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May 2019

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Abstract

Healthcare information technology is solidly entrenched in most acute care hospitals but the need to demonstrate its positive impact on patient outcomes persists. Clinical decision support (CDS) is an informatics tool that is highly customizable to promote patient improvement activities. Despite its high potential, studies have had mixed results regarding the impact of CDS and it has not been widely studied in the realm of nursing practice. One aim of this dissertation was to analyze the concept of CDS in order to inform the examination of the relationships between CDS implementation and nursing interventions. The determining factors of nurses use and acceptance of CDS was also described within the context of the CDS concept schematic developed. Data from 4718 pediatric hospital admissions were analyzed to examine if there was a relationship between the implementation of CDS and the implementation of sequential compression devices (SCD) for the purpose of preventing VTE and the placement of chart notifications of VTE risk. Admissions with patients who were identified as at risk for VTE had SCDs placed almost two and one-half times more often after the CDS was implemented ($RR = 2.32$; 95% CI (1.9 – 2.83)) and 33 times more likely to have chart notifications placed. In order to describe the determining factors of use, the unified theory of acceptance and use of technology (UTAUT) was adapted to create an electronic survey. Two multivariate regression models were built to describe the UTAUT model from previous literature. Results demonstrated that the model as described explains the majority of the data but also highlighted some weaknesses in the realm of the construct voluntary use. The results of this dissertation contribute to the limited literature regarding CDS use in nursing practice.

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Dedication

This dissertation is dedicated to the numerous nurses that work tirelessly at the bedside of hospitalized children. My hope is that this work may be the start of many studies that can demonstrate how technology can assist nurses to provide the best care possible. By understanding how that can happen, we as a nursing profession can continue to make progress in providing quality care leading to quality outcomes.

In addition to the nurses at the bedside, I want to also dedicate this work to my colleagues in health IT. The work you do directly impacts both clinicians and patients alike despite that not always being understood by all. Your tireless efforts to create systems that are both efficient for clinicians and safe for patients are remarkable.

Of course, this journey would not have been possible without the loving support of my husband for which I am forever grateful. You were always there to provide appropriate distractions when I needed to take a break or you were taking over dinners, cleaning, gardening or whatever else needed to be done when I needed to work. Thank you Kurt for believing in me when I was hitting the abyss and bringing me out into the sunlight. Finally, Kerry and Tim, I am so proud of the adults you have both become. I hope my journey has shown you both that you never stop learning and growing.

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I also would like to thank the VTE Task Force at the study site. They welcomed my ideas to create a CDS to enhance their goals of preventing pediatric VTE. Dr. Thornburg was always supportive of nursing input and nurses' part to play in identifying at risk children. Dr. Billman cleared any operational roadblocks for the task force to accomplish their goals. Tracy Fulkerson and her PICU nursing colleagues helped blaze the trail with their work to educate nurses in the PICU. There were many other participants and I thank them all for they were the ones to provide insight into the development of the CDS to support the nursing practice.

Finally, I want to thank my colleagues in the CIS department at the study site especially Tracy Elmer (former director) and Dorothy O'Hagan (current director) for their flexibility in scheduling as well as their support for this journey. And to my two “monkeys” that have been on this informatics journey as long as I have been, Kelly and Brian. You two are the epitome of not only supportive colleagues but also the highest work ethic that I have ever known. You have always had my back and I yours, and because of that, we have done great work in the field of informatics. I look forward to continuing that history for years to come.

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Chapter 1

Despite increasing growth in the adoption of electronic health records (EHRs) within hospitals, there remains a lack of consistent improvement in patient outcomes and workflow efficiencies across the US healthcare system (Office of the National Coordinator for Health Information Technology (ONC), 2014; Riskin, Koppel, & Riskin, 2015). The increase in the adoption of EHRs can be attributed primarily to the enactment of the Health Information Technology for Economic and Clinical Health (HITECH) Act as part (Title XIII) of the *American Recovery and Reinvestment Act of 2009* (ARRA). This Act provided authority to the Centers for Medicare and Medicaid Services (CMS) to offer financial incentives to hospitals and others that demonstrated meaningful use of an EHR. These incentives have come to be known as Meaningful Use (MU) incentives (Centers for Medicare and Medicaid Services (CMS), 2018). The goal of MU incentives is to encourage structures be put in place for data in the EHR to be used to drive quality improvement. Demonstrating the adoption of an EHR was the initial level, Stage 1, of MU incentives and has been very successful. Subsequent stages of MU include an increased requirement of utilizing the data in an EHR in a meaningful way that ultimately improves patient outcomes but the success of these stages have not been shown to be as successful as the mere adoption of EHR's has been (Riskin et al., 2015).

Patient outcomes are improved when clinicians know what best practices to initiate and when to initiate them. Best practice guidelines provide that information but Clinical Decision Support (CDS) is the technical tool that presents those guidelines to clinicians at the correct time in their workflow to provide optimal clinical care (Centers for Medicare and Medicaid Services (CMS), 2017). Utilization of CDS has been

addressed in the literature but the operational definition of what constitutes CDS has been inconsistent. Also, the preponderance of the literature centers on the use of CDS to support medical practice of providers (those who independently direct care such as physicians or nurse practitioners) and less so with other clinicians who implement care such as registered or direct care nurses (Lopez et al., 2016).

This research examined the use of CDS within the context of screening for risk and preventive treatment of venous thromboembolism (VTE) in hospitalized children. This study described the impact of CDS on nursing practice for this population by comparing the frequency of the application of sequential compression devices (SCDs) to children identified to be at risk for VTE prior to the implementation of a targeted CDS tool to the frequency of SCD application to this same population after the implementation of the CDS tool. This study expanded on the limited research that investigated whether CDS improved the use of necessary nursing interventions.

Background and Significance

Health Information Technology and Clinical Decision Support

In *To Err Is Human: Building a Safer Health System* (Kohn, Corrigan, & Donaldson, 2000), the authors recommended utilizing information technology in healthcare, now known as health information technology (HIT), based upon the belief that its use would enhance healthcare quality and result in improved patient care. Specific examples of improved patient care resulting from the use of HIT have included early, standardized diagnosis (Goldberg et al., 2016), improved access to care (Jacobsen, 2009), improved patient safety (Kutney-Lee & Kelly, 2011), increased patient engagement (Gephart & Effken, 2013), and provision of behavioral health interventions

in nontraditional settings (Luxton, McCann, Bush, Mishkind, & Reger, 2011). The HITECH Act ("*American Recovery and Reinvestment Act of 2009*") provided the impetus and support for the rise of HIT. In 2015, the number of non-Federal acute care hospitals that had adopted a basic Electronic Health Record (EHR) was 83% (Henry, Pylypchuk, Searcy, & Patel, 2016; ONC, 2014) and this percentage continues to grow. Given that technology is available in a large number of acute care hospitals, the next challenge was to use the technology to improve patient outcomes.

As mentioned above, some evidence has demonstrated perceived improvements in the quality of patient care resulting from the use of HIT but other studies have indicated that there are not always improvements (Riskin et al., 2015). The later stages of MU Initiatives were structured to require that hospital participants in the program demonstrated an increase in the quality of care provided in order to ensure that the use of technology was meaningful. Stage 3 of the MU objectives and measures included the areas of protection of electronic protected health information, clinical decision support, computerized provider order entry, generation and transmission of prescriptions electronically, Health Information Exchange, patient-specific education resources, medication reconciliation, patient electronic access, and public health reporting. The focus of the MU CDS objective was to improve performance on high priority health conditions. (Centers for Medicare & Medicaid Services (CMS), 2018). Even with the more recent passing of the Medicare Access and CHIP Reauthorization Act (MACRA) (Centers for Medicare & Medicaid Services (CMS), 2016) which altered some aspects of the MU program, demonstrated the use of HIT for quality improvement remains an integral facet of financial incentives. Medicare eligible clinicians now need to follow the

new regulations under MACRA, which has rebranded MU as Advancing Care Information (ACI) and consolidated it under the Merit-Based Incentive Payment System (MIPS) (Clough & McClellan, 2016; Ferenz, 2016; Williams, Casale, & Oetgen, 2015). Therefore, the landscape remains unchanged such that HIT with innovations and optimizations of tools like CDS remain an integral component of the health care system and its success in providing quality care.

Clinical decision support has been defined as a software tool that uses patient specific information in conjunction with current clinical knowledge to augment the decision making of clinicians (HealthIT.gov). This definition has been used throughout the literature for investigating the impact of such systems upon patient outcomes as well as clinician efficiency despite its lack of specific detail. Specific characteristics used to define CDS systems are described in various studies (Gard & Wessel, 2014; Garg et al., 2005; Kawamoto, Houlihan, Balas, & Lobach, 2005; Lytle, Short, Richesson, & Horvath, 2015; McDowell, Newell, & Rosser, 1986) but those characteristics have not been consistent throughout all studies, which makes drawing conclusions about its impact on patient outcomes challenging. With a clearer characterization of what CDS is, additional research will be able to definitively examine the relationship between the implementation of CDS and subsequent quality improvement.

In addition to the lack of a clear characterization of CDS, there has been a gap in the nursing research literature related to CDS. The preponderance of literature related to CDS has reflected the practice of medicine with limited studies investigating CDS' impact on nursing practice (Lopez et al., 2016). This can lead to poorly designed CDS or even unintended effects on patient outcomes (Piscotty & Kalisch, (2014). The use of

CDS may be particularly useful in directing nursing practice within the context of screening patients for identified risk factors and implementing intervention. This study focused on the use of CDS within the context of screening for risk and preventive treatment of venous thromboembolism (VTE) in hospitalized children.

Venous Thromboembolism

General overview. It has been almost ten years since the Surgeon General made the occurrence of VTE a subject of one of his published “Call to Actions” (Office of the Surgeon General, 2008). Since then, The Joint Commission (2014) has identified the failure to prevent VTE in hospitalized patients as an important quality metric in the adult population (>18 years of age). Heit (2015) published an epidemiological review that reported the incidence of VTE to be similar to that of other diagnoses like stroke. Using data from a population-based study of adult patients, Heit identified the adjusted mean predicted costs of VTE related to current or recent hospitalizations as exceeding sixty thousand dollars per occurrence and reported hospital costs to be 2.5-fold higher than case matched patients without VTE. He noted that while there are prophylaxis options and that risk factors have been identified, the occurrence of VTE has not decreased and possibly has even increased slightly. He concluded that more study is needed to identify how to stratify at risk patients and provide appropriate prophylaxis. Unfortunately, in his review he does not mention the use of sequential compression devices (SCDs).

The use of SCDs has been examined through individual studies (Dennis et al., 2013) and a least one meta-analysis (Ho & Tan, 2013). The evidence supporting the use of SCDs in adults was so strong that the American Association of Critical-Care Nurses issued a practice alert for VTE that advocates the use of SCDs in adults (Stacy, 2016).

Dunn and Ramos (2017) published a clinical evidence review that both summarized the supporting evidence of the use of SCDs but also reviewed the role of nursing in ensuring that SCDs are used appropriately. After reviewing the current evidence regarding adherence to the use of SCDs, they recommended further study related to not only the barriers to the use of SCDs but also what standards are needed for the application, maintenance, and patient education for their use.

Review of the pediatric literature. The literature above focused on adult patients (>18 years old) and less is known regarding SCD use for hospitalized pediatric patients. Studies that identify the incidence of VTE in pediatrics have been rare but one paper reported that the incidence in pediatrics has increased by seventy percent from 2001 to 2007 noting that the incidence of pediatric VTE was 58 per 10,000 (Raffini, Huang, Witmer, & Feudtner, 2009). It was not until 2014 however, that the *Journal of Pediatrics* published an editorial call to action for pediatric VTE (Mahajerin & Thornburg, 2014). Accordingly, additional studies have focused on VTE in pediatrics. For example, a retrospective study examining the risk factors for pediatric hospital-associated VTE in non-critically ill children proposed that children should be assessed for risk and receive preventive treatment accordingly (Atchison et al., 2014). More recently, Petty (2017) looked at the incidence of VTE in hospitalized pediatric trauma patients and reviewed multiple studies of various size and design. The incidence found in those studies varied widely and ranged from 0.1-6.2%.

Other studies, such as those by Ishola et al (2016), provided insight into risk factors and co-morbidities in pediatric patients. This study was a retrospective look at 12-21 year-old patients that were documented to have had a VTE. Analysis was done to

characterize and draw comparisons among risk factors and co-morbidities. Once characterized, risk factors and co-morbidities can contribute to establishing a standardized protocol for the prevention and treatment of VTE in pediatrics. This evidence is necessary as an antecedent for development of CDS. Additional evidence can be found in the aforementioned paper by Petty (2017), which focused on the sub-population of pediatric trauma and reported on the incidence of VTE and the increased cost incurred when VTE does occur. Petty's (2017) paper presented an algorithm for prevention treatment that has been adopted for use by at least one regional children's hospital (C. Thornburg, personal communication, March, 2017). The algorithm included the use of SCDs for low risk patients, which is not always clearly delineated in other studies, especially in pediatrics. Yet, like many other studies regarding CDS, the emphasis of the algorithm's uses to support medical practice improvement by recommending pharmacologic prophylaxis rather than nursing interventions like SCD use.

Conceptual Frameworks

Matney, Brewster, Sward, Cloyes, & Staggers (2011) discussed a model that provided a "basis for linking theory and practice" (p. 6) not only for nursing informatics but also for the broader nursing community. This model was the Data, Information, Knowledge, and Wisdom (DIKW) Framework that has been under development by R. Nelson (personal communication, October 29, 2017) since 1989. More recently, a schematic representation of how the concepts of the model interacted with automated systems including decision support has been published (Englehardt & Nelson, 2018). This schematic (Figure 1) provided justification for the development of CDS to support

nursing practice as it highlighted the increasing interactions of nurses with data and information within an EHR which creates an environment of increasing complexity. In utilizing this framework, moving information into knowledge is how CDS supports nursing practice as environments become more and more complex with more and more data at clinician fingertips (Clancy et al., 2014).

Although the DIKW Framework provided a theoretical foundation for CDS development, that literature did not provide information regarding user acceptance of such tools. If nurses do not utilize CDS, it will not matter if it has strong theoretical underpinnings. There needed to be a basis for defining nurses' acceptance and use of this technology.

The Unified Theory of Acceptance and Use of Technology (UTAUT) first provided a framework to understand the acceptance and use of technology by end users in 2003 (Venkatesh). Since then, the UTAUT has been used in a number of other studies to validate nurse use and satisfaction with an EHR (Maillet, Mathieu, & Sicotte, 2015) and solicit providers perceptions of structured data entry (Bush, Kuelbs, Ryu, Jiang, & Chiang, 2017). The health IT community is still struggling with truly identifying the key constructs of user acceptance and so this model is evolving (Oshlyansky, Cairns, & Thimbleby, 2007). Recent evolution included integration of behavioral expectations (Maruping, Bala, Venkatesh, & Brown, 2017).

DIKW Framework. The DIKW framework for nursing was first published in 2002 (Englehardt & Nelson) although Ramona Nelson defined the concepts in an earlier article (personal communication, October 29, 2017). This framework was a second-generation evolution of the first conceptual framework used by the field of nursing

informatics which was published by Graves and Corcoran (1989). That first description included data, information and knowledge but not wisdom. Despite the wide acceptance of Graves and Corcoran's (1989) framework internationally, the DIKW framework with the addition of wisdom has since become the definitive framework for nursing informatics practice as well as for delineating informatics as a core competency of nursing (Staggers & Thompson, 2002). Even so, the framework was often criticized in the literature in regard to its perceived linearity (Ronquillo, Currie, & Rodney, 2016). There are also ongoing studies especially outside of the field of nursing regarding developing models that better represent the relationships of the four main constructs of the DIKW framework (Boell, 2017).

The four main constructs of this framework are data, information, knowledge, and wisdom. Data has been described as a single piece of information that, standing alone, has little if any meaning (Ackoff, 1989; Frické, 2009; Graves & Corcoran, 1989). Information is data put into a structure and context that creates meaning as described by Matney (2013). Knowledge has been described by Graves and Corcoran (1989) as information that is combined to demonstrate relationships. This knowledge can often answer questions of how or why. Anderson and Willson (2009) have also reviewed the concept of knowledge management and recognized its importance in many areas of nursing practice including development of CDS. The final construct is wisdom. The American Nursing Association defined wisdom as "the appropriate use of knowledge to manage and solve human problems" (p. 3) (2015). Precursors to wisdom include knowledge, information and data (Matney, Avant, & Staggers, 2016). Knowing when and how to apply knowledge in complex situations in healthcare is how nursing wisdom is

demonstrated (Englehardt & Nelson, 2002).

Unified Theory of Acceptance and Use of Technology (UTAUT). Just because the DIKW framework provided support for the development of CDS for nurses, it did not provide any indication if nurses would actually use it. As discussed earlier, HIT continued to evolve with increasing use of EHRs (ONC, 2014) yet improvement in patient outcomes has not met expectations. This unanticipated result has been thought to be related, at least in part, to the inefficient use of HIT (Riskin et al., 2015). In an attempt to understand why technology has not been utilized to its fullest, theoretical frameworks have been developed to describe the phenomena of technology utilization in the hopes of being able to identify where to make improvements (Khong, Holroyd, & Wang, 2015; Kulhanek & Kulhanek, 2013; Maillet et al., 2015). These models were generally developed within information science and not necessarily HIT although they have been the basis for HIT related studies looking at technology use and acceptance (Bush et al., 2017; Merrill, Deegan, Wilson, Kaushal, & Fredericks, 2013; Strudwick, Booth, & Mistry, 2016; Zhang, Cocosila, & Archer, 2010). The UTAUT model was first developed in 2003 (Venkatesh, 2003) but has been repeatedly evaluated and revised with the most recent revision published in 2017 (Maruping et al., 2017). This model was initially developed based on the review of eight other models. Those models individually accounted for between 17 to 53 percent of the variance of users' intention to use IT. When the best determinates from each model were combined to form the UTAUT, it outperformed all of the other models by being able to account for 69 percent of the variance (Venkatesh, 2003).

The most recent revision of the UTAUT (Figure 2) has added behavioral

expectation (BE) as a determinate of technology use in addition to behavioral intention (BI). Previous studies have demonstrated that performance expectancy (PE), effort expectancy (EE), and social influence (SI) to positively influence BI (Kim, Lee, Hwang, & Yoo, 2016; Maruping et al., 2017) while facilitating conditions (FC) directly influenced BE. In addition, the voluntary use (VOL) construct was considered a moderating factor along with gender, age, and experience. The UTAUT constructs have been assessed with various versions of a survey instrument that has been used across studies (Kim et al., 2016; Maruping et al., 2017; Sharifian, Askarian, Nematolahi, & Farhadi, 2014). This model of the use and acceptance of technology provided guidance in answering questions regarding the usability of this study's CDS.

Application

Hospitalized pediatric patients are now known to be at risk for developing VTE and ongoing research efforts are investigating both the risk factors as well as preventative interventions for at risk children. Notably, risk factors for pediatric patients can differ from those identified for adults, where risk is often related to increasing age or cancer diagnosis. In children, known risk factors include an altered level of activity and the presence of a central venous catheter (Atchison et al., 2014; Petty, 2017). Clinical decision support has been identified as one method to improve care for this population now that consensus is building toward best practices for screening for VTE risk and implementation of prevention strategies. This study examined the utility of using CDS, supported by the DIKW theoretical framework, to guide nursing practice in this context.

In addition to examining whether a theoretically based CDS can be used to improve nursing practice related to VTE risk identification and prevention, the

determinates of the use of the CDS by nurses was needed as CDS can only be effective when it is accepted and used. The UTAUT proved useful in identifying user acceptance issues (Bawack & Kala Kamdjoug, 2018; Maillet et al., 2015; Sharifian et al., 2014).

Study Purpose and Aims

The purpose of this study was to examine the relationships between the implementation of a CDS system and the nursing practice of screening for risk and initiating preventative treatment of VTE in admitted pediatric patients (10 years old and greater) at a large tertiary pediatric acute care hospital in southern California.

Specifically, the aims of this dissertation were:

1. Analyze and characterize the concept of Clinical Decision Support (CDS).
2. Examine the relationship between the implementation of a CDS for the screening for risk and the subsequent initiation of preventative treatment of VTE, as measured by use of SCDs, in admitted pediatric patients by clinical nursing staff.
 - a. Hypothesis: Pediatric patients 10 years old and greater that are identified as at moderate or high risk for the development of VTE and do not have a contraindication to the use of SCDs will have an increased use of SCDs after the implementation of a CDS system that will recommend best practice interventions for at risk patients.
3. Describe the determining factors of the acceptance and use of CDS technology by nurses in an acute care hospital in southern California.

Overview of the Manuscripts

Each manuscript is described along with its relationship to this dissertation's study aims.

Manuscript I - Clinical Decision Support in Nursing Practice: A Concept Analysis. This manuscript analyzed the concept of clinical decision support resulting in a framework presented as a schematic in order to meet study aim one. This framework can be used to guide nurses, other clinicians and informaticists in the development of CDS based on clearly articulated key attributes of the concept. The paper begins with a review of the known impact of CDS on nursing practice, the historical development of CDS, and the need for a current concept analysis of CDS is summarized to provide background for the analysis. Following this background, the methodology utilized for the analysis is summarized. Next, the results of the analysis are presented and, in the summary section, future implications for nursing practice and research based upon this concept analysis are explored.

Manuscript II – Clinical Decision Support Increases the Identification and Treatment of Pediatric Patients At Risk for Venous Thromboembolism. This manuscript examined the relationship between the implementation of CDS and nursing staff initiating the use of SCDs as preventative treatment of VTE.

Manuscript III – Determining Factors of Nurses' Acceptance and Use of Clinical Decision Support Using the Unified Theory of Acceptance and Use of Technology Model. This manuscript described the determining factors of the acceptance and use of CDS technology. The UTAUT was the model used for this study.

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Figures

Figure 1. Moving Data to Expert Systems - DIKW Framework aligning with automated systems (© 2013 Ramona Nelson, Ramona Nelson Consulting. All rights reserved.

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Figure 2. UTAUT Determinates of System Use (Maruping et al., 2017)

Chapter 2

Clinical Decision Support in Nursing Practice: A Concept Analysis

Abstract

The concept clinical decision support is inconsistently utilized and primarily found within the realm of medical practice in the literature. This paper analyzes the concept in order to develop a schematic representation for nursing practice improvement processes.

Keywords: Decision Support Systems, Clinical; Nursing Informatics; Informatics; Nursing Practice; Electronic Health Records; Health Information Technology

Clinical Decision Support in Nursing Practice: A Concept Analysis

Despite the increasing adoption of electronic health records (EHRs) within hospitals, there is a lack of consistent improvement in patient outcomes and workflow efficiencies in the US healthcare system (ONC, 2014; Riskin, Koppel, & Riskin, 2015). The increase in the adoption of EHRs can be primarily attributed to the enactment of the Health Information Technology for Economic and Clinical Health (HITECH) Act in 2009. This Act provided authority to the Centers for Medicare and Medicaid Services (CMS) to offer financial incentives to hospitals and others that demonstrated meaningful use of an EHR. These incentives have come to be known as Meaningful Use (MU) incentives. The goal of MU incentives is to encourage structures be put in place for data in the EHR to be used to drive quality improvement (Kohn, Corrigan, & Donaldson, 2000). Merely demonstrating the adoption of an EHR was the initial level, Stage 1, of MU incentives and has been very successful as previously stated. Subsequent stages of MU include an increased requirement of utilizing the data in an EHR in a meaningful way. One such meaningful way is to utilize the EHR data to build clinical decision support (CDS). A CDS is technology that uses patient specific information in an EHR in conjunction with current knowledge to augment decision making of clinicians at the point and time that clinical decisions are necessary.

The definition of CDS is used inconsistently in the literature. This inconsistency is evidenced by the many different ways CDS is used and at varying levels of complexity. The levels of complexity of CDS range from simply highlighting existing information in the form of various alerts to more complex uses that present intervention recommendations to clinicians (Gross, 2000; Richardson et al., 2016). The goal of all of

these types of CDS is to improve patient care and to meet MU requirements. But, despite the same goal, such inconsistent use of CDS makes it difficult to evaluate how CDS impacts clinical practice and patient care. These inconsistent uses of CDS have evolved because the field of Health Information Technology (HIT) has developed and matured as technological advances have been made. The attributes, or differentiating characteristics, of CDS need to be clarified in order to identify when CDS is in use. When it is known that CDS is in use, it can be studied to determine how this clinical tool impacts decision-making, clinical practice and patient outcomes. An analysis of the concept of CDS is necessary to develop clear attributes of CDS. Such an analysis is particularly important for nursing because nurses can utilize CDS to improve the quality of the clinical care they provide but the current literature contains very few studies that have investigated the utilization of CDS in nursing practice (Lopez et al., 2016). This concept analysis will direct future developers of CDS by providing a framework to guide clinical decision support development for the purpose of improving nursing practice.

This paper provides a concept analysis of CDS resulting in a framework presented as a schematic that will guide nurses, other clinicians and informaticists in the development of CDS based on clearly articulated key attributes of the concept. The paper will begin with a review of the known impact of CDS on nursing practice, the historical development of CDS, and the need for a current concept analysis of CDS will be summarized to provide background for the analysis. Following this background, the methodology utilized for the analysis will be summarized. Next, the results of the analysis will be presented. In the summary section, future implications for nursing practice and research based upon this concept analysis will be explored.

Background

Clinical decision support has been discussed in the literature since the 1950's (Miller, 1994). Since that time, HIT has evolved and so has the concept of CDS. In this section of the paper, the impact to date of CDS on nursing practice in particular and clinical practice in general will be presented, the historical development of CDS will be discussed, and the need for a current concept analysis of CDS will be summarized.

There have been a number of systematic reviews published regarding CDS (Garg et al., 2005; Hunt, Haynes, Hanna, & Smith, 1998; Kawamoto, Houlihan, Balas, & Lobach, 2005; Lopez et al., 2016; Piscotty & Kalisch, 2014). In these reviews, it was difficult to compare the impact of CDS across studies because the outcomes analyzed related to CDS differed. Most studies did include compliance of clinicians to following some type of protocol/algorithm as an outcome measure. The actual CDSs that were reviewed in these analyses varied and included systems for providing patient information for printing at discharge (provision of information alone) to recommending influenza vaccination (recommendation of a specific clinical action) within a clinician's workflow (Kawamoto et al., 2005). Very few studies examined patient care outcomes as a result of implementing CDS and, if they did, they did not have a clear method of measuring any improvement in patient care outcomes. When measuring the compliance of the clinicians to the CDS recommendations, there is an assumption that patient outcomes improved. Those assumptions need to be validated in future studies and included as findings in systematic reviews. For example, the rate of actual patient influenza vaccination as a result of implementing a CDS was measured in one study (McDowell, Newell, & Rosser, 1986) but that was not reported as an outcome in a systematic review (Hunt et al., 1998).

Since MU incentives were created to encourage the use of HIT to improve patient care, measuring improved patient care outcomes needs to be the standard when analyzing any particular CDS. Also, in these reviews it was evident that CDSs are commonly associated with impacting medical practice rather than nursing practice, both of which impact patients care outcomes. A subsequent integrative review of the literature validated those same findings, that CDS is more frequently associated with medical practice rather than nursing practice (Lopez et al., 2016). This gap in the literature regarding the use of CDS in nursing practice indicates the need for future studies in this area in order to guide the development of CDS specific to nursing practice with a goal of improving patient care outcomes.

Since the 1980's, CDS was discussed in the literature as only clinical decision support, with no mention of system in the term. The use of CDS became more common in the 1990s when a systematic review was published examining its effects (Hunt et al., 1998). With the enactment of the HITECH act in 2009, the term "CDS" is now a mainstay in HIT with patient safety and improved patient care outcomes being the focus of national HIT strategic plans (ONC, 2013).

Purpose of Analysis

The purpose of this paper is to analyze the concept of CDS to identify key attributes in the context of nursing practice. A schematic representation of these attributes will clearly communicate the relationships with the antecedents and outcomes of the concept all within the context of nursing practice. This schematic will provide a framework to guide development of clinical decision support for the purpose of

improving nursing practice. The schematic will also inform future nursing research related to the use of clinical decision support in nursing practice.

Methods

Rodgers' seven phases of a concept analysis was the framework for this analysis (Rodgers, 1989). This approach includes (1) the identification of the concept; (2) identification of surrogate terms and relevant uses; (3) identification of an appropriate realm; (4) identification of attributes; (5) identification of references, antecedents, and consequences; (6) identification of related concepts; and (7) identification of a model case. Rodgers' was chosen due to her view of concept development. Her description of the three influences on concept development (significance, use and application) is very applicable to CDS and its development over time in alignment to the technological advancements of computers. The concept of CDS was analyzed by conducting a search of the literature. The search of the literature used the databases CINAHL, PubMed, Medline, and Google Scholar and included the years 1980-2016 using the keywords clinical, decision support, and informatics. This search yielded a large number of articles so purposive sampling was used to obtain a broad range of articles related to CDS. The two systematic literature reviews identified in the search were utilized in the analysis. Study references prior to 1980 were also included to provide appropriate context to the evolution of the concept, an important point when utilizing Rogers' methodology. Abstracts were reviewed for applicability until a broad range of use cases were reviewed and saturation was met. Use cases were modeled after those in an integrated literature review (Lopez et al., 2016). Each of Rodgers' phases is presented as the results of the analysis.

Concept Identification

Clinical decision support system was identified as a concept that was not utilized consistently in the literature. This lack of clarity indicated the need for a concept analysis to be completed.

Surrogate Terms and Relevant Uses

Once the concept of CDS is chosen, the next step of the analysis is the identification of surrogate terms and relevant uses. Surrogate terms are important in identifying whether the terms are used for different concepts or unrelated uses of the same terms. Throughout the review of the literature, any use of the terms was noted and any variants from the main concept was noted to identify a surrogate term. No surrogate terms were evident in this search with the exception of a shortened version of the concept: clinical decision support.

Appropriate Realm

The appropriate realm helps narrow the intent of the concept and establish a context. This concept (CDS) is only applicable within the realm of an electronic health record (EHR). Here there is the ability to collect both patient data and best practice algorithms to determine recommendations for action through the use of computer software.

Attributes

Attributes are the building blocks of a conceptual definition of the concept. They are the characteristics most frequently associated with the concept. While reviewing each study, attributes are recorded as they are seen in relation to the concept. Reviewing and categorizing the studies to analyze this concept achieved this phase of concept analysis.

The studies were categorized by the intent of the CDS. The categories used were mimicked from those in an integrated literature review and included diagnostic support, medication management, providing situational awareness, supporting guideline adherence, triage care needs, non-medication based interventions (Lopez et al., 2016). By categorizing the studies reviewed, the integrity of the analysis is aided by ensuring that a wide range of uses of CDS is included in the analysis. Each of these categories included studies that used data from the EHR to support clinicians providing patient care.

In addition to studies in the literature, governmental documents were also reviewed to identify any key attributes. The Agency for Healthcare Research and Quality (AHRQ) produced a document that summarizes two ongoing demonstration projects that took place since 2007 that focused on CDS (AHRQ, 2014). The purpose of this report was to share lessons learned in these demonstration projects and to inform future research related to CDS. The objective of the projects is to improve healthcare decision-making by utilizing evidence-based knowledge that exists in current clinical guidelines to improve patient outcomes. Also, HealthIT.gov has compiled a document reviewing the positive possibilities for the use of CDS. The definition of CDS on the organization's website continues to be very broad but can be summarized as bringing patient specific knowledge to providers, clinicians, patients, and families at the right time to make healthcare better for all patients.

In the literature, it is evident that key attributes of CDS have emerged and evolved as the technical functionality of the EHR has developed. Current key attributes for the concept of CDS in the EHR are (1) assistance or support provided to clinicians to make

decisions; (2) computer assisted; (3) timing; and (4) format of the assistance or support as recommendations.

References, Antecedents and Consequences

Antecedents are the pre-requisites for the concept. During the review of the literature, in all cases there were phenomena present in order for CDS to be utilized across all the categories of CDS identified. These antecedents for CDS include (1) patient data elements recorded in an EHR; (2) a defined evidence-based algorithm or guideline; and (3) an identified clinical decision opportunity.

Consequences are the result of the occurrence of the concept. There are multiple consequences and any of them could be a change that is either an improvement, neutral, or a decline while another consequence may have the reverse effect. Consequences include (1) individualized care; (2) guideline compliance; (3) clinician efficiency; (4) patient satisfaction; (5) patient clinical outcome; and (6) clinician satisfaction. Figure 1 is a visual depiction of the relationships between CDS key defining attributes, antecedents and consequences.

Related Concepts

Alerts in the context of an EHR are a concept that is closely related to CDS. Alerts utilize patient information in the EHR to provide information to clinicians but there is one key difference from CDS. Alerts typically provide information but do not provide recommendations for action. The clinician determines any actions that need to be carried out following an alert without the guidance of a technologically imbedded evidence-based practice guideline.

Model Case

In a concept analysis, a model case is used to present an example of the everyday use of the concept. This model case describes the use of CDS with the implementation of the Pediatric Early Warning Score (PEWS) in a pediatric hospital (Duncan, Hutchison, & Parshuram, 2006). The PEWS instrument is utilized to identify pediatric hospitalized patients that are at risk for physiologic deterioration. The instrument is evidence-based and is supported in the literature as a valid instrument for non-critical care patients. It uses three categories (respiratory, cardiovascular, and behavior) with a defined scoring system per each category that are totaled together so that a total score can identify patients with an increased risk of deterioration. Interventions can be initiated that otherwise would have not been known to be indicated without the increased risk of deterioration identified by use of the PEWS. The use of this CDS is intended to direct the nursing staff in following the required guidelines of completing the assessment as well as assist in determining the appropriate, evidence-based interventions as a result of the assessment. The algorithms were built within the EHR so that a triggering score on the instrument would be identified once the nurse assigns a score in each category. The nurse would do that score assignment as part of the normal workflow when assessing routine vital signs. Once the instrument is completed and documentation entered into the EHR, the EHR will then calculate the total score and recommend nursing care interventions. The total score determines the recommended intervention based on the published escalation algorithms. If triggered by a total score, pop-up message appears within the EHR to the nurse while she or he is still completing his/her documentation. The pop-up message covers most of the screen and provides recommended next actions

for the nurse. The recommended actions are different based on the total score but may include to continue to monitor the patient but at an increased frequency, to consult with a nursing colleague to re-score together, a hyperlink to provide an electronic notification to the physician, and possibly call the rapid response team. The pop-up message only displays if the score dictates a specific nursing action. There is no disruption to the workflow if the total score is not at a level that would indicate the patient is at increased risk of deterioration as per the algorithm and no further action is required. This scenario represents a model case because it includes the key defining attributes including (1) assistance or support provided – the total score was calculated by the EHR and recommended interventions were provided to the nurse as appropriate; (2) computer assisted – the EHR provided the assistance; (3) timing – the recommended interventions were provided to the nurse immediately upon the documentation being entered; and (4) format – the message was displayed within the EHR in a manner that facilitated the nurse in seeing the message.

Contrary Case

Although Rodgers' methodology (Rodgers, 1989) does not call for the description of a contrary case, a description of a currently inappropriate use of CDS will highlight why this concept analysis is valuable. A contrary case can be found in the study by Lytle, Short, Richesson & Horvath (2015) on the effect of CDS on fall risk and prevention documentation. They identify three features that comprise their CDS intervention as “(1) an “admission documentation incomplete” fall risk assessment indicator, (2) a “shift documentation incomplete” fall risk assessment indicator, and (3) a “rules-based alert” for patients at high risk of falls and not on a fall prevention plan of

care.” The first two examples are only alerts (Centers for Medicare and Medicaid Services (CMS), 2017) and do not offer the clinician a recommendation regarding a decision-making opportunity. These alerts only point out what documentation has not yet been done. The last feature does seem to make the recommendation of adding a specific plan of care in the case of identified high risk patients, but it is not clear how specifically that plan of care is intended to guide and/or direct nursing practice. There is no description of any nursing actions that were initiated to prevent falls due to this EHR tool.

Summary

Understanding the concept of CDS is important for the appropriate development of future CDS as well as the foundation to analyzing the impact of CDS on nursing practice. As noted by Kelley, Brandon, and Docherty (2011), EHRs are expected to improve the quality of care but that has only been studied in a limited fashion. Lopez, et al reports that studies related to nursing practice and CDS are “lagging behind studies of CDS targeting medical decision-making in both volume and level of evidence” (2016, p. 1). This paper has outlined key attributes of CDS. Those attributes along with the identified antecedents and consequence have led to a schematic of this concept (figure 1). In order to highlight these key attributes, a contrary case was also presented from an example found in the literature. The addition of the example from Lytle et al (2015) has increased clarity in describing what the concept of CDS is not beyond using only Rodgers’ (1989) methodology.

The development of this schematic has important implications for both nursing practice and research. It provides a framework to guide development of clinical decision

support for the purpose of improving nursing practice. The schematic also informs future nursing research related to the use of clinical decision support in nursing practice.

An evidence-based guideline is one of the antecedents for the concept of CDS. Nursing practice is guided by evidence-based guidelines developed by researchers throughout the many specialties of nursing. Being able to integrate these guidelines into the EHR is crucial in the development of CDS as represented in the concept of CDS described in this paper. As discussed earlier, the AHRQ has already funded demonstration projects to investigate how to best design and implement CDS and they identified the need for integrating such evidence-based guidelines into the EHR (AHRQ, 2014).

The many studies related to CDS referenced in this paper can now be analyzed in the context of this concept schematic. How the CDS being studied addresses each of the key attributes can inform future development of CDS. There are many studies (Cortez, Dietrich, & Wells, 2016; Lopez et al., 2016; Lytle et al., 2015) looking at the implementation of various guidelines or other evidence-based practices with the use of CDS. Those studies are primarily measuring the effect of the evidence-based practice but not always identifying how the CDS is implemented. The attributes of timing and recommendation formatting are important concepts to be included in any future research about CDS. With further development on the key attributes of CDS, there can be future investigation about what practices are either effective or not effective in implementing CDS that improves nursing practice and patient outcomes. This can be analyzed in relation to the effect of new CDS on the consequences identified in this schematic such as

level of individualized care, guideline compliance, clinician efficiency, patient satisfaction, patient clinical outcome, and clinician satisfaction.

A limitation of this analysis is the inability to review all the literature due to the large volume. This creates the possibility that there may be other uses of this concept that were not reviewed, and some attributes not discovered.

In summary, the literature presented here supports a schematic of CDS as depicted in Figure 2.1. Utilizing this schematic for CDS will lead to more clarity and provide appropriate guidance for the creation of future CDS instruments in the EHR. Clarifying the key attributes of CDS will better enable researchers to measure the constructs of CDS and what are the interventions that lead to improved nursing practice that in turn will lead to improved patient care outcomes.

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Figures

Figure 2.1. Clinical Decision Support – representation of antecedents and consequences related to key defining attributes.

Chapter 3

Clinical Decision Support Increases the Identification and Treatment of Pediatric Patients
At Risk for Venous Thromboembolism

Abstract

Healthcare information technology is solidly entrenched in most acute care hospitals but the need to demonstrate its positive impact on patient outcomes persists. Clinical decision support (CDS) is an informatics tool that is highly customizable to promote patient improvement activities. Despite its high potential, studies have had mixed results regarding the impact of CDS and it has not been widely studied in the realm of nursing practice. The aim of this study was to demonstrate that CDS can be utilized to support nursing best practices. Improving the nursing practice for pediatric patients at risk for venous thromboembolism (VTE) was the focus of an implementation of CDS since best practices for prevention of pediatric VTE is evolving. Data from 4718 pediatric hospital admissions were analyzed to examine if there was a relationship between the implementation of CDS and the implementation of sequential compression devices (SCD) for the purpose of preventing VTE and the placement of chart notifications of VTE risk. Admissions with patients who were identified as at risk for VTE had SCDs placed almost two and one half times more often after the CDS was implemented ($RR = 2.32 [1.9 - 2.83]$) and 33 times more likely to have chart notifications placed. This study adds to the body of literature that demonstrates how CDS can support improvement of nursing practice by increasing the use of appropriate interventions. There continues to be the need for literature that goes beyond measuring only process measures of documentation and intervention implementation but will draw a direct association with improved patient outcomes.

Keywords: Electronic Health Records; Health information technology; Clinical decision support; Nurses; Venous Thromboembolism

Clinical Decision Support Increases the Identification and Treatment of Pediatric Patients At Risk for Venous Thromboembolism

Despite the increasing growth in the adoption of electronic health records (EHRs) within hospitals, evidence of consistent improvement in patient outcomes and workflow efficiencies in the US healthcare system is lacking (Office of the National Coordinator for Health Information Technology (ONC), 2014; Riskin, Koppel, & Riskin, 2015). The increase in the adoption of EHRs can be primarily attributed to the enactment of the Health Information Technology for Economic and Clinical Health (HITECH) Act as part (Title XIII) of the *American Recovery and Reinvestment Act of 2009* (ARRA). This Act provided authority to the Centers for Medicare & Medicaid Services (CMS) to offer financial incentives to hospitals and others that demonstrated meaningful use of an EHR. These incentives have come to be known as Meaningful Use (MU) incentives (Centers for Medicare & Medicaid Services (CMS), 2017). The goal of MU incentives is to encourage structures be put in place for data in the EHR to be used to drive quality improvement. Merely demonstrating the adoption of an EHR was the initial level, Stage 1, of MU incentives and has been very successful (Henry, Pylypchuk, Searcy, & Patel, 2016). Subsequent stages of MU include an increased requirement of utilizing EHR data in a meaningful way that will ultimately improve patient outcomes.

To meet improved patient outcome benchmarks, clinicians need to know best practices and when to initiate them. The literature and published best practice guidelines provide that information but Clinical Decision Support (CDS) systems are the informatics tools that present those guidelines to clinicians at the correct time in their workflow to provide optimal clinical care (Centers for Medicare & Medicaid Services (CMS), 2017).

Clinical Decision Support can be utilized by all clinicians to guide best practice but the preponderance of the CDS literature centers on its use to support medical practice of providers and less so with other clinicians including nurses (Lopez et al., 2016). All clinicians contribute to improved patient outcomes and so all clinicians need the literature to guide the use of CDS in their specific practices. Sensmeier (2018) identifies how HIT and CDS can improve nurses' ability to provide safe and effective care "if used appropriately and implemented effectively" (p. 11). She reports also on the conflicting studies about the success of CDS and calls for further study to determine the key factors contributing to the impact of CDS.

Health Information Technology (HIT) and CDS

In *To Err Is Human: Building a Safer Health System* (Kohn, Corrigan, & Donaldson, 2000), the authors recommend utilizing information technology in healthcare to prevent errors in healthcare. This recommendation is due to the positive effects can have on healthcare quality ultimately resulting in improved patient care. Some specific examples of improved patient care due to the use of HIT are early, standardized diagnosis (Goldberg et al., 2016), improved access to care (Jacobsen, 2009), improved patient safety (Kutney-Lee & Kelly, 2011), increased patient engagement (Gephart & Effken, 2013), and provision of behavioral health interventions in nontraditional settings (Luxton, McCann, Bush, Mishkind, & Reger, 2011). The ARRA with the HITECH Act (Title XIII) ("*American Recovery and Reinvestment Act of 2009*") provided an early impetus and financial support for the rise of HIT. In 2015, the number of non-federal acute care hospitals that had adopted a basic Electronic Health Record (EHR) was 83.8% (Henry et al., 2016) and continues to grow. Now that technology is available in a large number of

acute care hospitals, the next challenge is to use the technology in a meaningful way and improve patient outcomes.

There are studies demonstrating some perceived improvements in the quality of patient care as mentioned above but there are also others indicating that there are not always improvements (Downing et al., 2019; Riskin et al., 2015). The later stages of MU incentives are structured to require healthcare providers demonstrate an increase in the quality of care provided in order to ensure that the use of technology is meaningful. One focus of the MU quality items is the use of CDS to drive improvements in the care provided and to standardize best practices (CMS, 2018). With the more recent passing of the MACRA (CMS, 2016) and changing of the MU program, demonstrating the use of HIT for quality improvement remains an integral facet of financial incentives. For Medicare eligible clinicians, they will need to follow the new regulations under MACRA where MU has been rebranded and consolidated with other programs as Advancing Care Information (ACI) and included under Merit-Based Incentive Payment System (MIPS) (Clough & McClellan, 2016; Ferenz, 2016; Williams, Casale, & Oetgen, 2015). Despite restructuring of regulations, the landscape is unchanged for HIT and its role supporting quality healthcare. Innovations and optimizations of tools like CDS remain an integral component of the health care system and its success in providing quality care.

The preponderance of literature related to CDS reflects the practice of medicine with limited studies investigating CDS systems' impact on nursing practice (Lopez et al., 2016). This lack of information can lead to poorly designed CDS systems or even unintended effects on patient outcomes according to Piscotty & Kalisch (2014). They recommend more studies to answer not only the "how, when, and why" (p. 568) nurses

use CDS but also the efficacy of nursing CDS. One specific area where CDS may prove efficacious is in directing nursing practice in the context of screening for risk and preventive treatment of venous thromboembolism (VTE) in hospitalized children.

Venous Thromboembolism

Venous thromboembolism (VTE) is a disease the incidence of which may actually be increasing according to an epidemiological review completed by Heit (2015). The incidence of VTE is similar to other better-known diseases such as stroke with an incidence rate of up to 183 per 100,000 person-years. Heit also noted that patients with VTE had reported hospital costs to be 2.5 fold higher than case matched patients without VTE. Although Heit reports VTE to be found only rarely in patients younger than late adolescents, The *Journal of Pediatrics* printed an editorial asking for a “Call-to-Action” (Mahajerin & Thornburg, 2014) regarding pediatric VTE occurrence. In that same issue, a retrospective study was published proposing that children should be assessed for risk and receive preventive treatment accordingly (Atchison et al., 2014). In addition to pharmacologic prophylaxis (usually reserved for high risk patients due to the inherent risk for bleeding), there are low risk interventions that can be used to prevent VTE successfully (Dunn & Ramos, 2017) such as sequential compression devices (SCDs).

This study examined the use of CDS within the context of screening for risk and preventive treatment of VTE in hospitalized children. By comparing the frequency of both the recognition of children at risk for VTE and the application of sequential compression devices (SCDs) to at risk children prior to and then after the implementation of a targeted CDS tool, this study describes the impact of CDS on nursing practice for this population. This study expands the limited research regarding whether CDS fosters

the use of best practice nursing interventions and improves nursing practice. The population under study (VTE at-risk children) is a population of convenience due to a recent initiative at the location of the study that introduced CDS to support emerging nursing best practices for this population.

Methodology

We employed a quasi-experimental, time series design via secondary analysis of prospectively collected data from the EHR. Relationships between the implementation of a CDS system and the nursing practice of screening for risk and initiation of preventative treatments of VTE were examined. Local institutional review boards utilizing an expedited review process approved the study.

Intervention

The intervention included an EHR screening tool developed by an interdisciplinary task force at the study site and included screening for altered levels of activity, presence of a central venous catheter, and presence of specific co-morbidities (Table 1). This tool was based on a pre-existing nursing protocol that had not been integrated into the EHR. Due to that lack of EHR integration, there was no standardized screening process nor any nursing documentation of items of co-morbidities prior to the implementation of the CDS. Also, nursing education was done as part of the CDS implementation that clarified the documentation of altered activity levels for patients. The documentation standards did not change during the CDS implementation. Based on the data entered into the EHR for these items, patients would be identified as at risk for VTE. If a patient were identified as at risk for VTE, nurses would receive an alert when entering the chart to place notification of VTE risk on the patient's chart and to place

SCDs (if not otherwise contraindicated). The alert contained a mechanism to bypass it in case of other more urgent patient care priorities. The recommended actions for patients at risk for VTE were not new with the implementation of the CDS but pre-existed in the nursing protocol mentioned above. If neither the SCDs nor the chart notification were placed, nurses would continue to receive the alert until either they were placed or, on subsequent screening, the patient was no longer identified as at risk for VTE.

Participants, Setting and Data Collection

The population sample includes two groups of patient admissions at a southern California hospital with admission and discharge dates occurring within two distinct timeframes. The pre-CDS implementation group included hospitalizations between February 25 and June 27, 2017 and the post-CDS implementation group included hospitalizations between June 28 and December 31, 2017. All patients were between the ages of 10-25 years of age. Data was collected from previously entered information in the EHR. It included (1) demographic information (patient age, gender, admit and discharge dates), (2) physiologic data identifying patients defined as at risk for VTE (level of activity, presence of central venous catheters, SCD contraindications, co-morbidities, discharge diagnoses), (3) data of VTE-related nursing interventions (risk screening documented, SCDs initiated, risk precautions initiated) and (4) evidence of CDS being initiated by the EHR.

Analysis

We exported the data from the EHR into a Microsoft Excel file for coding, de-identification and review. Standard statistical principles were utilized for this process (Knapp, 2014; Polit & Beck, 2012). After de-identification of the data, we removed all

admissions that did not meet the inclusion criteria and then identified and coded the two groups of hospitalizations based on pre or post-implementation of the CDS tool. We calculated time units including length of stay (LOS) and time to SCD placement and CDS initiation. Once all time units were calculated, we eliminated actual dates from the data set. We then entered the data into SPSS v24 (IBM, 2016) for statistical analysis. We used descriptive statistics to identify demographics, VTE risk and treatments in the population. We used independent t-tests to compare continuous variables and calculated relative risk and 95% confidence intervals of altered activity, VTE risk, placement of SCDs and placement of chart notifications.

Results

The two groups were similar on baseline characteristics (Table 2). There were equal numbers of males and females in each group and the mean age was the same (pre = 14.01; post = 14.12). Although the LOS was statistically shorter for the pre-implementation group ($M = 3.6$, $SD = 5.44$) compared to the post-implementation group ($M = 4.02$, $SD = 2.1$; $t(4433) = -2.401$, $p = .016$, two-tailed), the effect size for this less than half-day difference (mean difference = -0.4167 , 95% CI: -0.757 to -0.0764) was very small (Eta squared = $.001$).

The placement of SCDs and chart notifications both increased (2.3 and 33 times respectively) after the implementation of CDS (Table 3). The identification of patients with altered activity decreased by 26% while patients at risk for VTE in the EHR decreased approximately 15%.

Discussion, Limitations and Recommendations

This study examined if the implementation of CDS to identify pediatric patients at risk for VTE increased the use of nursing interventions for these patients. The results of this study demonstrated an association between implementation of CDS and several variables including reported levels of altered activity, VTE risk, SCDs placed, and placement of chart notifications of VTE risk. It adds to the body of literature that demonstrates how CDS can support improvement of nursing practice by increasing the use of appropriate interventions. Unlike Downing, et al (2019), this study reveals an association between the use of CDS and implementation of appropriate interventions.

The structure of this CDS was important for supporting the best practices of nurses. Since VTE only became integral to inpatient pediatric care since the call to action that was written in 2014 (Mahajerin & Thornburg), nurses not only needed assistance in determining what interventions to use, but they also needed guidance in how and what to complete as part of the screening process. Recognition of the need for a standardized screening process was key to the design of this CDS and its effectiveness was demonstrated by the 94.8% screening completion rate (Table 1).

If the support to complete the screening had not been effective, we would not have seen the increase in the nursing interventions of SCDs and chart notifications placed. After implementing a standardized screening process with the CDS, there was about a 25% decrease in patients identified with altered activity and a 15% decrease in patients identified as at risk for VTE. The primary reason for this change can be attributed to the nursing education that occurred with the implementation of the CDS. The education emphasized the importance of assessing patients' level of activity

objectively and the definition of altered activity was clarified. A decrease in identified VTE at risk patients was also seen since altered activity was the primary driver in identifying patients at risk for VTE with the screening tool used. The CDS also included documentation of the co-morbidities identified in the literature as potential risk factors of VTE. This documentation not only provided the information to create the alerts for nurses but also was an active reminder to nurses to assess for the presence of those risk factors.

The result of completing the screening process enabled the CDS to create alerts for the nurse when appropriate. These alerts available after the implementation of the CDS were associated with an increase in the nursing interventions examined in this study. The placements of SCDs were almost two and one-half times more likely to occur and patients were nearly 35 times more likely to have chart notifications placed.

Although this study demonstrated the increase use of SCDs and chart notifications in the post-CDS implementation period, these are only process measures related to the final goal of improved patient outcomes. There continues to be the need for evidence that goes beyond measuring process measures of documentation and intervention implementation and draws a direct association with improved patient outcomes. Aspects of the implemented CDS also warrant further investigation. Some studies (Cortez, Dietrich, & Wells, 2016) look at CDS to improve evidence-based practice in nursing by measuring nursing knowledge but this does not evaluate CDS' impact to improve patient outcomes which is the ultimate goal of HIT.

Future studies related to pediatric VTE in particular are also needed to identify which interventions actually lead to improved outcomes. Evidence continues to emerge

that guides the design of CDS for this potential hospital morbidity (Dunn & Ramos, 2017; Petty, 2017; Tran et al., 2017) but no gold standard as to what constitutes VTE risk in pediatrics exists at this time. Now that proposed risk factors are being documented on a routine basis, future studies can evaluate their associations with VTE as an outcome or not.

Conclusions

Completion of VTE screening, applications of SCDs and the placement of chart notifications was associated with the implementation of CDS. Further research is needed to investigate what components of the CDS most influenced these significant associations as well as studies that demonstrate CDS impact on patient outcomes. Lastly, there continues to be the need to define both definitive risk factors for pediatric VTE as well as effective prevention strategies.

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Tables

Table 1

Occurrence of VTE screening and VTE risk factors (documentation initiated with CDS implementation)

	Post- implementation (n=2838)
Initial VTE screening completed within 24hours of admission	2691 (94.8)
Central Line	330 (11.6)
Obesity (BMI > 95%)	217 (7.6)
Major surgery of spine, abdomen, or lower extremity	149 (5.3)
Cancer, not in remission	97 (3.4)
Diabetic ketoacidosis (hyperosmolar state)	39 (1.4)
Mechanical ventilation	36 (1.3)
Inflammatory conditions (e.g. inflammatory bowel disease, rheumatologic disease)	29 (1.0)
History of venous thrombosis or pulmonary embolism	24 (.8)
Documented invasive infection requiring IV antibiotics	22 (.8)
Estrogen containing oral contraceptives	14 (.5)
Complex fracture of pelvis or lower extremity	12 (.4)
Nephrotic syndrome	11 (.4)
Single ventricle physiology	11 (.4)
Cardiomyopathy	10 (.4)
Acute spinal cord injury	9 (.3)
Traumatic brain injury	9 (.3)
Thrombophilia	1 (.04)
Pregnancy/recent post-partum	1 (.04)

Table 2
Descriptive Characteristics

	Pre- implementation (n=1880)	Post- implementation (n=2838)
Patient demographics		
Age, y		
Mean (SD)	14.01 (2.74)	14.12 (2.74)
Min-max	10-25	10-25
Sex, n (%)		
Male	932 (49.6)	1431 (50.4)
Female	948 (50.4)	1407 (49.6)
Hospitalization data		
Length of Stay, days		
Mean (SD)*	3.6 (5.44)	4.02 (2.1)
Min-max	0.1 - 73.1	0.1 - 86.1
VTE Diagnosis, n (%)	19 (1)	40 (1.4)
Central line on admission, n (%)	166 (8.8)	123 (4.3)

* $p < .05$

Table 3

Occurrence of altered activity and VTE risk in all admissions and SCDs and chart notifications placed in admissions with VTE risk.

	All Admissions		
	Pre- implementation (n=1880)	Post- implementation (n=2838)	Relative risk (95% CI)
Altered activity documented, n (%)	644 (34.3)	723 (25.5)	.74 (.68 - .81)
VTE risk identified, n (%)	644 (34.3)	825 (29.1)	.85 (.78 - .92)
	Admissions with patients at risk for VTE		
	Pre- implementation (n=644)	Post- implementation (n=825)	Relative risk (95% CI)
SCD placed, n (%)	103 (16)	306 (37.1)	2.32 (1.9 - 2.83)
Chart notification placed, n (%)	12 (1.9)	516 (62.6)	33.57 (19.11 - 58.94)

Chapter 4

Determining Factors of Nurses' Acceptance and Use of Clinical Decision Support Using
the Unified Theory of Acceptance and Use of Technology Model

Abstract

The aim of this study was to examine factors affecting the acceptance and use of clinical decision support technology for pediatric nurses at an acute care hospital. There are several models of information technology use. For this study, the unified theory of acceptance and use of technology was adapted to create an electronic survey. The theory uses seven constructs that are scored using twenty-six items. The items were scored on a 7-point Likert scale, ranging from “Complete Agreement (1)” to “Complete Disagreement (7)”. The sample population was all registered nurses that had completed orientation in the study hospital. Bivariate analyses were conducted using Pearson’s r on the survey data. Two multivariate regression models were built to describe the UTAUT model from previous literature. Results demonstrated that the model as described explains the majority of the data but also highlighted some weaknesses in the realm of the construct voluntary use. Such differences may be explained by the work paradigm of the bedside nursing role and the limited control over what information technology tools are to be used.

Keywords: UTAUT; Electronic Health Records; Health information technology; Acceptance; System Use; Clinical decision support; Survey; Nurses

Determining Factors of Nurses' Acceptance and Use of Clinical Decision Support Using the Unified Theory of Acceptance and Use of Technology Model

Despite the increasing growth in the adoption of electronic health records (EHRs) within hospitals, the ultimate goal of improving patient outcomes has not been shown to be as successful as the mere adoption of EHRs has been (Riskin, Koppel, & Riskin, 2015). Clinical decision support (CDS) capability is a common health information technology (HIT) tool in use in most acute care hospitals with an EHR (Office of the National Coordinator for Health Information Technology). The purpose of this technological tool, CDS, is to provide clinicians with actionable recommendations that will improve patient outcomes. This tool should be presented to clinicians at the time in their clinical workflow when they can most likely take the action recommended (Centers for Medicare & Medicaid Services (CMS), 2017). Despite the use of CDS by a wide range of clinicians, there is minimal information in the literature related to its use in nursing practice (Lopez et al., 2016). More recently, there has been some attention to the usability of CDS for nurses (Johansson-Pajala, Martin, & Jorsäter Blomgren, 2018; Stifter et al., 2018). Although these studies have assessed the usability of CDS, they offer minimal information regarding determining factors contributing to those nurses' acceptance and use of such technological tools. This study aims to fill that gap and seeks to describe those determining factors.

Understanding End User Acceptance

Piscotty and Kalisch (2014) reviewed the literature related to nursing and CDS systems and found it lacking, especially in two areas: (1) CDS design to support nursing practice and (2) whether CDS is having its intended effect on nursing practice. To

address the gap in the literature related to CDS design, understanding what elements are necessary for the design to support use in practice is paramount. Identifying the explanatory factors of nurses' acceptance of EHRs, perceived usefulness to doing their job and whether it is compatible to the nurses' work style are important factors in determining the design of the EHR (Maillet, Mathieu, & Sicotte, 2015), as well as other HIT including CDS. Some authors have attempted to identify determining factors of various HIT tools including physicians' use of electronic documentation (Bush, Kuelbs, Ryu, Jiang, & Chiang, 2017), nurses' and other clinicians' use of the EHR (Bawack & Kala Kamdjoug, 2018; Strudwick, Booth, & Mistry, 2016), and therapists use of technology for rehabilitation (Liu et al., 2015). Nevertheless, a greater understanding of the determining factors for nurses' acceptance and use of CDS remains needed in order to design CDS that will actually result in improving patient outcomes.

Multiple models and theories have been developed to explain the factors regarding the acceptance and use of information technology. These include the technology acceptance model (TAM) developed by Davis (1985) as an adaptation of the theory of reasoned action (TRA), as well as the unified theory of acceptance and use of technology (UTAUT) (Venkatesh, Morris, Davis & Davis, 2003). To develop the UTAUT, Venkatesh used eight models (TRA, TAM, the motivational model, the theory of planned behavior, the model of PC utilization, the innovation diffusion theory, the social cognitive, and a model that combined TAM and the theory of planned behavior) and integrated their identified elements into one unified theory. With the growth of HIT, these information technology theories have been used throughout the literature to explain and predict the acceptance and use of HIT.

Since its inception, the UTAUT has been used in a number of studies including to validate nurse use and satisfaction with an EHR (Maillet et al., 2015), solicit providers perceptions of structured data entry (Bush et al., 2017) and clinician adoption of health information systems (Bawack & Kala Kamdjoug, 2018). Health IT continues to struggle with identifying the key constructs of user acceptance as evidenced by this model's evolution overtime, including an investigation of cross-culture validity (Oshlyansky, Cairns, & Thimbleby, 2007) and, most recently, integration of behavioral expectations as a construct (Maruping, Bala, Venkatesh, & Brown, 2017). This latest modification of the theory (Figure 1) provides the constructs to describe determining factors of nurses' acceptance and usage of CDS.

Clinical Decision Support

According to the Agency for Healthcare Research and Quality (2018), CDS “provides timely information, usually at the point of care, to help inform decisions about a patient's care”. There are ten different types of CDS interventions that are found in one of four categories as identified by HIMSS (Healthcare Information and Management Systems Society (HIMSS), 2019). In the specific EHR in use at the site of the survey conducted for this study, the predominate CDS interventions used in nursing practice are referred to as BPAs (best practice alerts). Best practice alerts are designed to appear at the time the nurse is expected to take some sort of action as recommended by the BPA. The BPA is typically triggered by data that are either being entered or already exist in the EHR. These represent two of the four categories identified above by HIMSS.

The paucity of evidence regarding factors of acceptance and use of CDS technology by nurses limits our understanding of this issue and stifles efforts to maximize

use of CDS. The aim of this study is to describe the determining factors of the acceptance and use of CDS technology using a questionnaire modeled on the modified UTAUT in a sample of pediatric nurses working in an acute care hospital.

Methodology

We employed a descriptive, cross-sectional design using convenience sampling and a validated survey instrument to explore the determining factors of nurses' acceptance and use of CDS technology. Local Institutional Review Boards utilizing an expedited review process approved the study.

Participants, Setting and Data Collection

All registered nurses (RNs) currently employed and who had completed hospital orientation at an acute care hospital site in southern California were invited to participate in the anonymous external web-based survey (SurveyGizmo, LLC; 2005-2019), which was based upon a modified UTAUT. The survey was distributed via existing staff email distribution groups to 715 RNs over a six-week time period. The invitation email contained information regarding the study along with a uniform resource locator (URL), or web address, to the survey. Completion of the survey constituted consent. No personal identifiers were collected and no monetary nor gift incentives were provided for participation.

Instrument

A modified-UTAUT was used with a 7-point Likert scale anchored by "complete agreement" and "complete disagreement." The instrument was modified only to identify the technology in question that are best practice alerts or BPAs. Demographic information including age, primary work department, certifications, role as a travel nurse,

and years of experience as a registered nurse was also collected. Gender was not included due to the low numbers of individuals identifying as male employed as RNs on some units, which may have created the possibility of identifying a participant based on survey responses.

The survey consisted of the seven constructs adapted from the recent work done by Maruping et al. (2017) which included (1) Performance expectancy (PE), (2) Effort expectancy (EE), (3) Social influence (SI), (4) Facilitating conditions (FC), (5) Behavioral intention (BI), (6) Behavioral expectations (BE), (7) Voluntariness (VOL) (Table 1).

Analysis

The web-based survey results were retrieved and exported into MS Excel (Microsoft, 2011) inspected and coded for analysis. Of the 715 RNs invited to complete the survey, 310 (43.36%) participated in whole or part. Some participants were removed from the data prior to analysis due to lack of completion of hospital orientation (11), failure to complete any questions post the initial consent (76), or lack of response to any UTAUT questions (56). This resulted in 167 responses for analysis. Missing data for specific items from these 167 responses was minimal, are noted in the results tables, and were removed using the pairwise method during analysis as appropriate. No extreme outliers were identified. Data was then entered into SPSS v24 (IBM, 2016). Survey subscales were calculated for the UTAUT questionnaire. Preliminary analysis ensured there was no violation of the assumptions of normality nor outliers identified. Primary departments were collapsed into two groups, ICU (intensive care units) and non-ICUs to create comparable groups.

Data were first examined using descriptive analysis. This was followed by bivariate analysis of RN age and experience, travel assignment, certification, primary department and the UTAUT constructs. Variables with statistically significant correlations were entered into the multi-regression model.

Results

Cronbach's α for the UTAUT indicated good reliability and internal consistency (.849 – .992) except for two constructs that fell below the .7 threshold for an adequate result (Polit, 2010). The constructs with lower Cronbach's α were facilitating conditions (.699) and voluntary use (.542) (Table 2).

Responses of 167 (23.36%) participants that had completed the majority of the UTAUT items were used in this analysis. Participants ranged in age from 20 through 67 years of age ($M = 38.64$, $SD = 10.338$) with 12.47 years of experience on average ($SD = 10.0$). A majority of the participants reported holding a professional certification (76.1%). All inpatient care areas of the study site were represented in the responses. For analysis, inpatient units were grouped as intensive care units or non-intensive care units due to the small number from some units. Table 3 summarizes the demographic characteristics of the participants.

After completing preliminary analyses to determine no violation of the assumptions of normality, linearity and homoscedascity existed, the Pearson product-moment correlation coefficient (r) with a two-tailed probability test with a standard .05 level of significance was used to determine correlations and the substantive size of the relationships between RN age, RN experience and the UTAUT constructs (Table 4). There were strong positive correlations amongst all the UTAUT constructs with the

exception of voluntary use. Voluntary use only showed a statistically significant association with performance expectancy, behavioral intention and behavioral expectation. Not unexpectedly, participants' age and years of experience were found to significantly correlate ($r = .874$, $n = 154$, $p < 0.01$).

Independent sample t-tests were conducted to compare the survey scores between groups. Gender was not analyzed due to the small number of self-identified males in the sample. No statistically significant difference in mean construct scores was found between travel nurse and non-travel nurse; ICU and non-ICU department; or certified nurse and non-certified nurse (Table 5). All groups agreed with the constructs of effort expectancy, social influence, facilitating conditions, behavioral intention, and behavioral expectation with mean scores ranging from 2.33 to 3.84. The only two constructs with which the participants showed disagreement were performance expectancy and voluntary use ($M = 4.78$ to 4.92).

Multiple linear regressions were then performed to test the relationships in the models. Since that UTAUT model utilizes actual technology use as the final dependent variable, which we did not measure in this study, we examined the two constructs that the model identifies as precursors to technology use, behavioral intention and behavioral expectation. The first construct tested was behavioral intention (Figure 1). The model was successful in predicting that performance expectancy, effort expectancy, social influence, voluntary use, and years of experience would make contributions in predicting behavioral intention (adjusted $R^2 = .609$) (Table 6). We also included our unique variables of traveler status, certification status, and primary department type. Both certification status and primary department type made statistically significant

contributions to the model. Age was not used due to its extremely high correlation with experience. This model was shown to explain 60.9% of the variance in behavioral intention.

The second model (Figure 2) was also successful in predicting that social influence, facilitating conditions, voluntary use, behavioral intentions and years of experience would make contributions in predicting behavioral expectation (adjusted $R^2 = .820$) (Table 7). Again, we included our unique variables of traveler status, certification status, and primary department type. Only certification status made statistically significant contributions to this model. Once more, age was not used due to its extremely high correlation with experience. This model was shown to explain 82% of the variance in behavioral expectation.

Discussion and Conclusions

The analysis of the survey data provided a basis for describing the determining factors contributing to nurses' acceptance and use of CDS in this study setting. The model developed based on the latest modified UTAUT (Maruping et al., 2017) held true for this study population. Some items did not contribute as much as others to the model including the "voluntary use" construct which had a low Cronbach α (0.542) as did "facilitating conditions" (0.699). Specifically, "voluntary use" contributed marginally to the models and "facilitating conditions" was not a contributing factor in either model. Bedside nursing personnel have less choice in the tools they use during the workday which may explain these scores. Best practice alerts (the CDS at this site) are not tools that an individual nurse can turn on or off and use voluntarily. They are on and appear when triggered regardless of if the nurse intends to follow the recommendations or not.

Other researchers (Johansson-Pajala et al., 2018; Stifter et al., 2018) have suggested incorporating more data points about the clinician's perception of ease of use and the satisfaction with use. This would give information about actual use but it would leave it to the researcher to determine what led to any such positive use results. The difficulty is in finding an instrument that has been validated and that can be compared across studies. Development of such tools is in process but not yet completed so most studies use their own homegrown instruments (Kim & Park, 2012; Zhang, Cocosila, & Archer, 2010). Without understanding the precursor determinates of use, the development of guidelines to guide the design of future CDS for nurses remains challenging. Some researchers are now attempting to look at UTAUT results and tie them to actual usage of systems through various data logs (Kim & Park, 2012; Piscotty & Kalisch, 2014).

There were no differences in the responses of the groups surveyed but several of those groups were quite small, traveling assignment nurses and the nurses on each unit for example. Demographic data was limited due to the small sample size despite an elongated survey data collection time of approximately six weeks. The setting was a union environment and there was no incentive for participation in the survey. The highest correlations found were between the actual UTAUT constructs and not with the demographic make-up of the study population.

In this study of bedside nurses, both social influence and behavioral intention were strong constructs in the models tested. The mean of the responses for voluntary use was the closest to complete disagreement as any other construct ($M = 4.92$) and social influence was just shy of being neutral at ($M = 3.84$). This just highlights the need to consider the relevance of the voluntary use construct in the setting of a bedside nurse and

possibly other settings where there is not individual control over the technology to be used.

Limitations of this study include the lack of any direct construct of actual use of CDS rather than using behavioral intention as a marker for that actual use. A study design that directly ties the determining factors to the actual use and acceptance would greatly add to this body of knowledge. This study has shown that the UTAUT model is still a good fit in describing acute care bedside nurses' acceptance and use of CDS but it falls short of making the direct link to actual use. As discussed by Sensmeier (2018), those developing CDS must understand the need for careful design and integration into workflow so as not to introduce disruption but to improve patient outcomes.

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Figures

Figure 1 - Relationships to BI (behavioral intention) as tested in this study. Model adapted from UTAUT Determinates of System Use (Maruping et al., 2017)

Figure 2 - Relationships to BE (behavioral expectation) as tested in this study. Model adapted from UTAUT Determinates of System Use (Maruping et al., 2017)

Tables

Table 1

Items of UTAUT-modeled questionnaire

Performance expectancy
PE1: I find the Best Practice Alert (BPA) useful in my job
PE2: Using the BPA enables me to accomplish tasks more quickly
PE3: Using the BPA increases my productivity
PE4: If I use the BPA, I will increase my chances of getting a raise
Effort expectancy
EE1: My interaction with the BPA is clear and understandable
EE2: It is easy for me to become skillful at using the BPA
EE3: I find the BPA easy to use
EE4: Learning to use the BPA is easy for me
Social influence
SI1: People who influence my behavior think that I should use the BPA
SI2: People who are important to me think that I should use the BPA
SI3: The senior management of this hospital is helpful in the use of the BPA
SI4: In general, the hospital has supported the use of the BPA
Facilitating conditions
FC1: I have the resources necessary to use the BPA
FC2: I have the knowledge necessary to use the BPA
FC3: The BPA is not compatible with other systems I use (reverse scored)
FC4: A specific person (or group) is available for assistance with BPA difficulties
Behavioral intention
BI1: I intend to use the BPA in the next four months
BI2: I predict I would use the BPA in the next four months
BI3: I plan to use the BPA in the next four months.
Behavioral expectation
BE1: I expect to use the BPA in the next four months
BE2: I will use the BPA in the next 4 months
BE3: I am likely to use the BPA in the next 4 months
Voluntary use
VOL1: Although it might be helpful, using BPA is certainly not compulsory in my job
VOL2: My boss does not require me to use the BPA
VOL3: My superiors expect me to use the BPA (reverse scored)
VOL4: My use of the BPA is voluntary (as opposed to required by my superiors/job)

Table 2
Reliability Analysis

Construct	No. of Items	Cronbach's alpha
Performance expectancy	4	0.918
Effort expectancy	4	0.956
Social influence	4	0.849
Facilitating conditions	4	0.676
Behavioral intention	3	0.985
Behavioral expectation	3	0.992
Voluntary use	4	0.558

Table 3

Demographics	n = 167
Age, y	
Mean (SD)	38.64 (10.338)
Min-max	20-67
Missing	8
Experience, y	
Mean (SD)	12.47 (10.0)
Min-max	20-67
Missing	4
Current travel assignment, n (%)	
Yes	8 (4.8)
No	155 (92.8)
Missing	4 (2.4)
Professional Certification, n (%)	
Yes	123 (73.7)
No	40 (24)
Missing	4 (2.4)
Primary Department, n (%)	
Pediatric Intensive Care Unit**	49 (29.3)
2Rose Medical*	33 (19.8)
3East Surgical*	29 (17.4)
Cardiovascular Intensive Care Unit**	25 (15)
Hematology/Oncology Inpatient*	10 (6)
4East Medical*	10 (6)
Other*	3 (1.8)
4East MBU*	2 (1.2)
Missing	6 (3.6)
Departments grouped by acuity, n (%)	
ICU (** from above)	74 (44.31)
non-ICU (* from above)	87 (52.1)
missing	6 (3.6)

*Units that are grouped as non-ICU

**Units that are grouped as ICU.

Table 4

Pearson Product-moment Correlations Between UTAUT Constructs, Age, and Years of Experience

	1	2	3	4	5	6	7	8
1. Performance expectancy	-							
2. Effort expectancy	.645**	-						
3. Social influence	.688**	.616**	-					
4. Facilitating conditions	.585**	.765**	.623**	-				
5. Behavioral intention	.420**	.611**	.651**	.538**	-			
6. Behavioral expectation	.392**	.550**	.559**	.506**	.896**	-		
7. Voluntary use	.160*	-0.114	-0.088	-0.06	-.288**	-.381**	-	
8. Experience (y)	0.076	-0.001	-0.052	-0.03	-0.048	0.002	0.146	-
9. Age (y)	-0.057	-0.081	-0.156	-0.059	-0.105	-0.07	.185*	.874**

** p < 0.01 (2-tailed)

* p < 0.05 (2-tailed)

Table 5
Independent t Test Comparisons of UTAUT Constructs between Groups

	<i>Mean (SD)</i>	<i>Mean (SD)</i>	<i>t</i>	<i>df</i>	<i>p</i>	<i>Eta squared</i>
	ICU	Non-ICU				
Performance expectancy	4.60 (1.68)	5.01 (1.84)	-1.45	159	0.148	0.013
Effort expectancy	3.81 (1.73)	3.94 (2.06)	-0.42	158.99	0.674	0.001
Social influence	3.58 (1.47)	3.72 (1.82)	-0.521	156.05	0.603	0.002
Facilitating conditions	3.93 (1.39)	3.73 (1.34)	0.892	153	0.374	0.005
Behavioral intention	2.49 (1.55)	2.67 (1.8)	-0.653	151	0.515	0.003
Behavioral expectation	2.28 (1.5)	2.43 (1.72)	-0.58	157	0.563	0.002
Voluntary use	4.97 (.92)	4.83 (1.41)	0.75	149.54	0.455	0.004
	Traveler	Non-traveler				
Performance expectancy	3.88 (1.98)	4.85 (1.76)	-1.51	161	0.132	0.014
Effort expectancy	4.13 (.58)	3.85 (1.95)	1.05	17.13	0.311	0.007
Social influence	3.63 (1.03)	3.63 (1.7)	-0.02	9.14	0.99	0.000
Facilitating conditions	3.81 (.51)	3.81 (1.39)	0.02	13.52	0.97	0.000
Behavioral intention	3 (.76)	2.55 (1.73)	1.5	11.51	0.161	0.014
Behavioral expectation	2.75 (.46)	2.32 (1.65)	2.03	19.06	0.056	0.025
Voluntary use	4.13 (.13)	4.96 (1.24)	-7.57	109.67	0	0.262
	Certified	Non-certified				
Performance expectancy	4.86 (1.69)	4.61 (2.04)	0.69	57.38	0.491	0.003
Effort expectancy	3.9 (1.92)	3.76 (1.88)	0.4	161	0.687	0.001
Social influence	3.7 (1.7)	3.42 (1.59)	0.88	159	0.378	0.005
Facilitating conditions	3.88 (1.37)	3.58 (1.33)	1.2	155	0.232	0.009
Behavioral intention	2.48 (1.66)	2.86 (1.78)	-1.22	153	0.226	0.010
Behavioral expectation	2.21 (1.56)	2.74 (1.77)	-1.74	159	0.085	0.018
Voluntary use	4.89 (1.26)	5.03 (1.11)	-0.6	159	0.551	0.002

Table 6

Behavioral Intention construct regressed on Eight Predictors (N = 167)

	<i>b</i>	<i>SE</i>	<i>Beta</i>	<i>t</i>	<i>p</i>
(Constant)	-1.254	1.052		-1.192	0.235
Voluntary use	-0.108	0.051	-0.122	-2.118	0.036
Social influence	0.603	0.078	0.581	7.724	0
Performance expectancy	-0.192	0.084	-0.194	-2.294	0.023
Effort expectancy	0.375	0.065	0.418	5.738	0
Experience	0.008	0.009	0.051	0.934	0.352
Primary department type	0.386	0.193	0.112	2	0.047
Traveler status	0.13	0.482	0.015	0.27	0.788
Certification status	0.587	0.231	0.139	2.537	0.012
Overall $R^2 = .794$, Adjusted $R^2 = .609$, $F(8, 136) = 29.089$, $p < .0005$					

Table 7

Behavioral Expectation construct regressed on Eight Predictors (N = 167)

	<i>b</i>	<i>SE</i>	<i>Beta</i>	<i>t</i>	<i>p</i>
(Constant)	-0.834	0.729		-1.145	0.254
Voluntary use	-0.112	0.035	-0.129	-3.236	0.002
Behavioral intention	0.803	0.056	0.829	14.4	0
Facilitating conditions	0.098	0.061	0.08	1.623	0.107
Social influence	-0.03	0.056	-0.03	-0.532	0.596
Experience	0.008	0.006	0.05	1.31	0.193
Primary department type	0.045	0.135	0.014	0.335	0.738
Traveler status	0.339	0.328	0.041	1.032	0.304
Certification status	0.511	0.161	0.126	3.181	0.002

Overall $R^2 = .906$, Adjusted $R^2 = .820$, $F(8, 132) = 75.889$, $p < .0005$

Chapter 5

Discussion of Findings

The purpose of this study was to examine the relationships between the implementation of a CDS system and the nursing practice of screening for risk and initiating preventative treatment of VTE in admitted pediatric patients and to describe the determining factors of the acceptance and use of CDS technology by pediatric nurses in an acute care hospital in southern California. This final chapter presents a summation of the main findings related to the aims of this dissertation as presented in the three manuscripts found in Chapters Two, Three, and Four. Finally, implications for nursing practice, education, health policy, and future research are also presented.

Dissertation Aims

The aims of this dissertation were addressed in three separate manuscripts prepared for submission for publication. The aims were to:

1. Analyze and characterize the concept of Clinical Decision Support (CDS).
2. Examine the relationship between the implementation of a CDS for the screening for risk and the subsequent initiation of preventative treatment of VTE in admitted pediatric patients by clinical nursing staff.
3. Describe the determining factors of the acceptance and use of CDS technology by nurses in an acute care hospital in southern California.

Summary of the Manuscripts

Each manuscript was a description of the process and results of addressing each of the aims stated above. Chapter two laid the foundation for the subsequent aims by characterizing CDS through a concept analysis. The antecedents, attributes and

consequences identified in this chapter were investigated further to examine the impact of CDS on nursing practice (chapter three) and to determine the factors of the use and acceptance of CDS (chapter four).

Concept of Clinical Decision Support

The literature presented in chapter two was an analysis of the concept of CDS. This analysis supported the development of the schematic to characterize the antecedents, key defining attributes and consequences of CDS. The need for performing the concept analysis was related to the evolution of CDS due to technological advancements. With this evolution, incongruence in the characterization of the concept of CDS was found in the literature. The schematic in chapter two provides clarity for those both developing CDS for nursing practice as well as those studying this concept's impact upon nursing practice.

This analysis was done utilizing Rodgers' methodology (Rodgers, 1989) because that methodology aligns with how CDS has developed over time and the importance of context, nursing in this case, to a concept. Utilizing the resulting schematic for CDS will provide appropriate guidance for the creation of future CDS instruments in the EHR. Clarifying the key attributes of CDS will better enable researchers to measure the constructs of CDS and the interventions that lead to improved nursing practice that in turn will lead to improved patient care outcomes. This analysis helped develop such constructs that were explored through this study in particular.

A limitation of this analysis was the inability to review all the literature due to the large volume. This created a possibility that there may be other uses of this concept that were not reviewed, and some attributes not discovered.

Impact of Clinical Decision Support on Nursing Practice

Chapter three investigated the relationship of a novel CDS for pediatric patients and its consequences. In particular, individualized care and guideline compliance were the consequences studied. Patients' clinical outcomes were reported but the study was not adequately powered to be able to describe an effect. Informed by chapter two's concept analysis, the CDS under study incorporated all three antecedents (patient data in the EHR, defined evidence-based guideline, and a CDS opportunity). The implementation of the CDS included all four attributes as well (provision of CDS, appropriate timing of CDS, clear recommendations, computer assisted). The CDS under study was novel due to the more recent recognition of the risk of VTE in hospitalized children. Evidence from the literature had been used to develop a nursing guideline at facility where the study took place. This guideline was then used to develop the novel CDS to promote VTE risk screening of the appropriate patients (age 10 years or older) and recommend interventions (placement of notifications in the chart regarding VTE risk and SCDs) based on the data entered during the screening process.

Patients at risk for VTE were almost two and one-half times more likely to have SCDs placed as well as thirty-three times more likely to have notifications of that risk placed in their charts in the post-CDS period. This suggests the positive impact of using CDS in this circumstance of supporting pediatric nursing practice in the utilization of a newly identified best practice intervention (placing SCDs). Due to the low incidence of VTE in children, this study was not expected to show an association with decreased diagnosis of VTE and it did not.

Further research is needed to investigate what components of the CDS most influenced these significant associations as well as studies that can have the power to demonstrate CDS impact on patient outcomes. This study only looked at the outcomes of screening at admission and the initiation of nursing interventions. Future studies need to also look at the effects of CDS over time both in regard to patient outcomes as well as clinician satisfaction. Lastly, there continues to be the need to define both definitive risk factors for pediatric VTE as well as effective prevention strategies.

Determining Factors of Clinical Decision Support Use and Acceptance

Chapter four surveyed pediatric acute care nurses to determine the factors that influenced their use and acceptance of technology. Identifying the factors of nurses' acceptance of EHRs is important in determining the design of the EHR (Maillet, Mathieu, & Sicotte, 2015) and CDS is important in any EHR design. The UTAUT model (Maruping, Bala, Venkatesh, & Brown, 2017) was utilized for the constructs to structure the survey. Both social influence and effort expectancy were identified as strong constructs for the behavioral intention outcome while behavioral intention was the most significant for behavioral expectation as the outcome. Facilitating conditions and social influence were not significant in this study population for the outcome of behavioral expectancy. This just highlights the need to consider the relevance each construct in the setting of a bedside nurse and possibly other settings where there is not individual control over the technology to be used.

Limitations of this study included the lack of any direct construct of actual use of CDS rather than using behavioral intention and expectation as a marker for that actual use. A study design that directly ties the determining factors to the actual use and

acceptance would greatly add to this body of knowledge. This study shows that the UTAUT model is still a good fit in describing acute care bedside nurses acceptance and use of CDS but it falls short of making the direct link to actual use if there is not also a measurement of that at the same time. As discussed by Sensmeier (2018), those developing CDS must understand the need for careful design and integration into workflow so as not to introduce disruption but still to improve patient outcomes.

Implications

The results of this study have implications across the areas of nursing practice, education, health policy and research.

Nursing Practice

Passage of the HITECH Act (*American Recovery and Reinvestment Act of 2009 (Public Law 111-5)*, 2009) incited a technological revolution in all of healthcare.

Nursing practice must stay current with these technological changes in order to make full use of them. Nevertheless, discussion of use of CDS for nurses remains sorely under-represented in the literature (Lopez et al., 2016).

The work in this dissertation adds to the small body of work regarding CDS's relationship to nursing practice. By adding to this knowledge base, CDS can be developed to better support the unique scope of nursing practice and target specific nursing workflows. But in order to have targeted nursing CDS, the need for evidenced based guidelines are necessary, as described in chapter two's analysis of the CDS concept. The work in chapter three uses the evolving best practices for nurses regarding identifying and preventing pediatric, hospital acquired VTE to provide data both to support pediatric VTE clinical guideline development as well the impact of CDS. This is

important because literature is just emerging that can guide the design of CDS for this potential hospital morbidity (Dunn & Ramos, 2017; Petty, 2017; Tran et al., 2017). The data in this study supported the association of the use of CDS with risk identification and use of VTE preventative treatment.

Finally, chapter four describes the determining factors for nurses to accept and use CDS. As mentioned previously, there is a lack of literature regarding nurses use of CDS so understanding and clarifying those determining factors are important in the ongoing development of CDS for nurses. If CDS is bypassed or not presented when most needed by nurses, then its ability to influence and improve practice would likely be insignificant. The work here is meant to build on the limited literature for a profession that has been underrepresented to date. Since nurses have unique work environments, social influences and spheres of control that are different than the independent health providers most commonly represented in the CDS literature, understanding those differences is crucial in developing effective CDS for nurses. Chapter four's results add to that knowledge to provide impactful CDS in nursing practice.

Education

This study identified that there was more than a two-fold increase in nursing interventions after the implementation of CDS that followed an evidenced-based nursing guideline. Since an evidence-based guideline is key to CDS, nurses need to be involved in CDS development to identify the correct evidence and guidelines to use. Studies such as this can frame the narrative to encourage the involvement of practicing nurses who often see CDS as an annoyance. Understanding the potential impact of implementing effective CDS can be the first step in recruiting the bedside nurse to be involved in CDS

development as a content expert. Being knowledgeable about how to develop and utilize CDS is the next step since the majority of acute care hospitals have EHRs.

In addition to education of the currently practicing nurse, informatics as a discipline has been introduced into the basic nursing curriculum. This type of education prepares the new nurse for current practice where clinicians have access to tremendous amounts of data. Also, integrating the CDS schematic developed in chapter two into course curriculums will also create an environment of understanding of how technology should support nursing practice and not be a hindrance.

Another venue for education is the field of nursing informatics. The use of data and information to support the acquisition of knowledge and development of wisdom is integral to that curriculum. Nursing informaticists are in pivotal roles to promote nursing practice by bringing an understanding of both clinical needs to identify the data needed along with how to navigate the technology in a way to support nursing practice. Nursing informaticists need to stay aware of the emerging literature like this study and transform this research into their practice as informaticists.

Health Policy

In the landmark report, *Crossing the Quality Chasm: A New Health System for the 21st Century* (IOM, 2001), the Institute of Medicine (now the Academy of Medicine) made several recommendations to improve the quality of care that are relevant to the topic of this dissertation. Using computer-based CDS, implementing health information technology, aligning payment with quality improvement, and preparing the workforce through education are just a few examples. Legislation and regulation consistent with these recommendations, such as the MU incentives of the HITECH Act (*American*

Recovery and Reinvestment Act of 2009 (Public Law 111-5), 2009) and MACRA's incorporation of quality improvement reporting into its payment programs (*Medicare Access and CHIP Reauthorization Act of 2015 (Public Law 114-10)*, 2015) have incentivized the use of CDS and HIT infrastructure to facilitate the integration of delivery systems to promote patient centered outcomes, which also align with the objectives of the ACA (*Patient Protection and Affordable Care Act. (Public Law 111–148)*, 2010). While political influences and fiscal priorities will continue to impact legislative and regulatory activity, support for HIT will only continue if data supports the effectiveness of these initiatives in improving the quality of patient care.

Research

The work done in this dissertation begins to highlight how CDS can impact the quality of nursing practice. Investigation of nursing CDS for all facets of bedside nursing workflows is needed in order to support the time and effort in developing CDS for nurses. Since the literature is replete with studies of CDS supporting other professionals (physicians, nurse practitioners for example), the possibilities of creating both efficiencies and increased quality of bedside nursing practice could be overlooked.

The determining factors of nurses' use of CDS needs to be more clearly identified. The study described in chapter four began looking at this with the UTAUT model. The model showed some promise although there needs to be further investigation that uses that model with a final outcome variable that actual measure the use of the technology to quantify that impact. Other models might also need to be investigated given the role of the construct of voluntary use and the issue of its relevance for a population of bedside nurses that may not have a choice in using HIT.

Future studies related to pediatric VTE are also needed to identify the key risk factors of and the preventative interventions that will lead to improved outcomes.

Chapter three's results support the proposed risk factors created by this study's site and they are now being documented on a routine basis which makes future studies possible that can evaluate their associations with VTE as an outcome or not. Pediatric incidence of VTE is relatively low so there needs to be studies that can obtain enough power to indicate a significant change in that outcome.

Scholarly Trajectory

Nursing informatics is a discipline that I found later in my career, but it is one that is very much aligned with what my role has been for the last thirty plus years, a clinical nurse specialist (CNS). As a CNS, in addition to being an advanced practice nurse providing evidence based care to the patient populations that I served, I always saw my role as a primary support system for the nurse at the bedside. I was the one to provide education and bring research to nursing staff related to new or complicated patient clinical conditions. I was the one to work with the nurses to develop plans of care to meet the needs of patients with complex needs. I was the one to learn about, create procedures for and then educate others about new technologies coming into the patient care environment. This is how I became involved in nursing informatics. As I became involved, I saw the great benefit of the collection of data but I then became aware of how that great benefit can easily become a great burden as well. Just having more data does not create more quality. Discovering how the data can improve quality then became my quest.

This dissertation has started me on my path of how HIT can benefit the nurse at

the bedside to be the best that he or she can be. I believe that enabling the nurse at the bedside to be the best is what will create the environment of always improving patient care outcomes. My research will focus on the best way to use HIT, CDS in particular, to support bedside nursing staff in this era of more data and more technology to provide the best, patient centered, quality care possible.

Conclusion

This dissertation and collection of three manuscripts provides new knowledge for bedside nursing staff about the impact of CDS on nursing practice related to the screening and prevention of VTE in a pediatric patient population. Also, a schematic representation of the concept of CDS was developed to guide the creation of CDS in the context of nursing practice. Lastly, the determining factors for the acceptance and use of CDS in this study population were described.

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Appendix A

USD IRB Approval

University of San Diego

Kathleen Klimpel <kklimpel@san Diego.edu>

IRB-2018-459 - Modification: Modification

1 message

irb@san Diego.edu <irb@san Diego.edu>

Tue, Jul 31, 2018 at 9:53 AM

To: efrybwers@san Diego.edu, kklimpel@san Diego.edu

Jul 31, 2018 9:53 AM PDT

Kathleen Klimpel
Hahn School of Nursing & Health Science

Re: Modification - IRB-2018-459 The Use of Clinical Decision Support to Improve Nursing Practice

Dear Kathleen Klimpel:

The Institutional Review Board has rendered the decision below for IRB-2018-459, The Use of Clinical Decision Support to Improve Nursing Practice.

Decision: Approved

Findings: None

Research Notes:

Internal Notes:

Note: We send IRB correspondence regarding student research to the faculty advisor, who bears the ultimate responsibility for the conduct of the research. We request that the faculty advisor share this correspondence with the student researcher.

The next deadline for submitting project proposals to the Provost's Office for full review is N/A. You may submit a project proposal for expedited or exempt review at any time.

Sincerely,

Dr. Thomas R. Herrinton
Administrator, Institutional Review Board

Office of the Vice President and Provost
Hughes Administration Center, Room 214
5998 Alcalá Park, San Diego, CA 92110-2492
Phone (619) 260-4553 • Fax (619) 260-2210 • www.sandiego.edu

Appendix B

Modified-UTAUT Questionnaire

Years experience as an RN:	Age:	Gender:
Are you on a traveling assignment?		Yes/No
Have you completed your RCHSD orientation?		Yes/No
Do you currently hold a professional certification?		Yes/No
Primary department: Cardiovascular Intensive Care Unit		2Rose Medical
Pediatric Intensive Care Unit		4East Medical
Hematology/Oncology Inpatient		4East MBU
Neonatal Intensive Care Unit		3East Surgical
Other		

PE: Performance expectancy	Complete Agreement				Complete Disagreement			
PE1: I find the Best Practice Alert (BPA) useful in my job	1	2	3	4	5	6	7	
PE2: Using the BPA enables me to accomplish tasks more quickly	1	2	3	4	5	6	7	
PE3: Using the BPA increases my productivity	1	2	3	4	5	6	7	
PE4: If I use the BPA, I will increase my chances of getting a raise	1	2	3	4	5	6	7	
EE: Effort expectancy	Complete Agreement				Complete Disagreement			
EE1: My interaction with the BPA is clear and understandable	1	2	3	4	5	6	7	
EE2: It is easy for me to become skillful at using the BPA	1	2	3	4	5	6	7	
EE3: I find the BPA easy to use	1	2	3	4	5	6	7	
EE4: Learning to use the BPA is easy for me	1	2	3	4	5	6	7	
SI: Social influence	Complete Agreement				Complete Disagreement			
SI1: People who influence my behavior think that I should use the BPA	1	2	3	4	5	6	7	
SI2: People who are important to me think that I should use the BPA	1	2	3	4	5	6	7	
SI3: The senior management of this hospital is helpful in the use of the BPA	1	2	3	4	5	6	7	
SI4: In general, the hospital has supported the use of the BPA	1	2	3	4	5	6	7	

FC: Facilitating conditions	Complete Agreement				Complete Disagreement			
FC1: I have the resources necessary to use the BPA	1	2	3	4	5	6	7	
FC2: I have the knowledge necessary to use the BPA	1	2	3	4	5	6	7	
FC3: The BPA is not compatible with other systems I use	1	2	3	4	5	6	7	
FC4: A specific person (or group) is available for assistance with BPA difficulties	1	2	3	4	5	6	7	
BI: Behavioral intention	Complete Agreement				Complete Disagreement			
BI1: I intend to use the BPA in the next four months	1	2	3	4	5	6	7	
BI2: I predict I would use the BPA in the next four months	1	2	3	4	5	6	7	
BI3: I plan to use the BPA in the next four months.	1	2	3	4	5	6	7	
BE: Behavioral expectation	Complete Agreement				Complete Disagreement			
BE1: I expect to use the BPA in the next four months	1	2	3	4	5	6	7	
BE2: I will use the BPA in the next 4 months	1	2	3	4	5	6	7	
BE3: I am likely to use the BPA in the next 4 months	1	2	3	4	5	6	7	
VOL: Voluntary use	Complete Agreement				Complete Disagreement			
VOL1: Although it might be helpful, using the BPA is certainly not compulsory in my job	1	2	3	4	5	6	7	
VOL2: My boss does not require me to use the BPA	1	2	3	4	5	6	7	
VOL3: My superiors expect me to use the BPA	1	2	3	4	5	6	7	
VOL4: My use of the BPA is voluntary (as opposed to required by my superiors/job)	1	2	3	4	5	6	7	

Appendix C

Permission for Use of “Moving Data to Expert Systems” figure

Kathleen Klimpel <kklimpel@san Diego.edu>

Permission to use The figure Moving from Data to Expert Systems

1 message

Ramona Nelson <ramonanelson@verizon.net>
 To: Kathleen Klimpel <kklimpel@san Diego.edu>
 Cc: Ramona Nelson <ramonanelson@verizon.net>

Thu, Nov 9, 2017 at 3:18 PM

Kathleen

As requested, with this email I am giving you permission to use the figure titled *Moving from Data to Expert Systems* in your dissertation. This figure is printed on page 24 in Nelson R. & Staggers N. (Eds.) (2018) *Health Informatics: An Interprofessional Approach*. 2nd ed. St Louis: Elsevier/Mosby. This same figure 4 is also printed on page 6 of the 2nd edition of the ANA Scope and Standards of Practice (2015).

Please use the following acknowledgement:

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Please let me know if you have any additional questions.

Ramona

Ramona Nelson, PhD, RN-BC, ANEF, FAAN

Professor Emerita, Slippery Rock University

President, Ramona Nelson Consulting

ramonanelson@verizon.net

Appendix D

License to use UTAUT Determinates of System Use figure

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Apr 21, 2018

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