

COMPARISON OF THE EFFECTIVENESS OF TRADITIONAL NURSING
MEDICATION ADMINISTRATION WITH THE COLOR CODING KIDS SYSTEM
IN A SAMPLE OF UNDERGRADUATE NURSING STUDENTS

by

Colleen Coletta Burgess

A dissertation submitted to the faculty of The
University of North Carolina at Charlotte in
partial fulfillment of the requirements
for the degree of Doctor of Education in
Educational Leadership

Charlotte

2009

Approved by:

Dr. J. Allen Queen

Dr. Jacqueline Dienemann

Dr. Claudia Flowers

Dr. Corey Lock

©2009
Colleen Coletta Burgess
ALL RIGHTS RESERVED

ABSTRACT

COLLEEN COLETTA BURGESS. Comparison of the effectiveness of traditional nursing medication administration with the Color Coding Kids system in a sample of undergraduate nursing students. (Under the direction of Dr. J. ALLEN QUEEN)

The problem of medication errors in hospitals and the vulnerability of pediatric patients to adverse drug events (ADE) was investigated and well substantiated. The estimated additional cost of inpatient care for ADE's in the hospital setting alone was conservatively estimated at an annual rate per incident of 400,000 preventable events each incurring an extra cost of approximately \$5,857.

The purpose of the researcher was to compare the effectiveness of traditional nursing medication administration with the Color Coding Kids (CCK) system (developed by Broselow and Luten for standardizing dosages) to reduce pediatric medication errors. A simulated pediatric rapid response scenario was used in a randomized clinical study to measure the effects of the CCK system to the traditional method of treatment using last semester nursing students.

Safe medication administration, workflow turnaround time and hand-off communication were variables studied. A multivariate analysis of variance was used to reveal a significant difference between the groups on safe medication administration. No significant difference between the groups on time and communication was found.

The researcher provides substantial evidence that the CCK system of medication administration is a promising technological breakthrough in the prevention of pediatric medication errors.

ACKNOWLEDGEMENTS

Appreciation is given to my dissertation advisor, Dr. J. Allen Queen, and research advisor, Dr. Claudia Flowers, and committee members, Dr. Corey Lock and Dr. Jackie Dienemann for their expertise, time and willingness to support this research as committee members. A special thanks to my husband Bill, children Brian, Meghan, Ricky, and Danny for their continual encouragement. A very special thank you is extended to Drs. James Broselow and Robert Luten, for their consultation and willingness to share their years of pediatric expertise, and to LuAnn Martin, RN, MSN as a co-investigator.

Thank you to Catawba Valley Community College President, Dr. Garrett Hinshaw, without his support and encouragement this project would not have been possible. Thank you to Gregory B. Russell, M.S., for his willingness to provide biostatistical support. To the nursing faculty members at the college, appreciation and sincere gratitude to Eleanor Bloomfield, Sharon Jimison, Kim Roberts, Judy Flowers, and Joyce Estes for facilitating the simulations and participating in the scenarios. Thank you to Dr. Jane Neese and Dr. Lienne Edwards for the use of their simulation lab and support.

My sincere gratitude is given to the North Carolina Community College Nursing Department Chairs; Janet Arthurs, Dr. Camille Reese, and Kathy Freeman for their support of this research and Lenoir Rhyne University Nursing Department Chair, Dr. Linda Reese. Finally, to my dear friend Janet Arthurs, is my resolute gratitude, for helping to navigate me through a tremendous life storm.

TABLE OF CONTENTS

LIST OF TABLES	vii
LIST OF ABBREVIATIONS	viii
CHAPTER 1: INTRODUCTION	1
Statement of the Problem	8
Significance of the Research	9
Research Question	9
Definitions and Abbreviations	11
Organization of the Study	14
CHAPTER 2: LITERATURE REVIEW	16
Overview	16
Traditional Nursing Medication Administration	39
Technology to Prevent Medication Errors	40
Clinical Decision Support Systems	43
Broselow-Luten Color Coding Kids	51
CHAPTER 3: METHODOLOGY	53
Overview	53
Research Question, Hypotheses, and Procedures	54
Sample and Setting	55
Procedure for Data Collection	55
Research Design	62
Data Analysis and Procedures	66
Description of Participant	67

	vi
Summary	69
CHAPTER 4: RESULTS	70
Introduction	70
Research Question	70
Summary of the Findings	73
CHAPTER 5: DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS	74
Synopsis	74
Review of Findings	80
Conclusion	82
Recommendations for Further Study	84
REFERENCES	85
APPENDIX A: STUDIES OF CDSS IMPLEMENTATION	98
APPENDIX B: PEDIATRIC STUDIES OF COMPUTER DECISION COLOR CODING KIDS	113
APPENDIX C: LITERATURE PERTAINING TO THE BROSELOW-LUTEN COLOR CODING KIDS	132
APPENDIX D: PEDIATRIC RAPID RESPONSE MEDICATION SCENARIO CHECKLIST	135
APPENDIX E: SBAR RUBRIC	136
APPENDIX F: POSTED FLYER	138
APPENDIX G: LETTER TO DEPARTMENT HEADS	139
APPENDIX H: PARTICIPANT DEMOGRAPHICS	142

LIST OF TABLES

TABLE 1: Types of Medication Errors	26
TABLE 2: Comparison of Study Groups on Sociodemographic Variables	68
TABLE 3: Comparison of Study Groups on the Three Main Outcome Variables	71

LIST OF ABBREVIATIONS

ADE	adverse drug events
AND	associate degree nurse
AE	adverse event
AHRQ	Agency for Health Research Quality
BSN	bachelor degree nurse
CDSS	clinical decision support technology
CMP	case management program
EDs	emergency departments
HER	electronic health record
FDA	Food and Drug Administration
FME	fatal medication error
HIT	health information technology
IOM	Institute of Medicine
ISMP	The Institute for Safe Medication Practices
JCI	Commission and Joint Commission International
<i>M</i>	mean
MANOVA	multivariate analysis of variance MAR medication administration record
MEDCHECK	safe medication administration checklist
<i>Mdn</i>	median
MER	medication error rate
MEQI	The Medication Error Quality Initiative

MINUTE	measurement of turnaround time in minute
n	total number in a subgroup
N	Total number in a sample
NCC MERP	National Coordinating Council for Medication Error Reporting and Prevention
PDA	personal digital assistant
p	probability
S.B.A.R.	Situation Background Assessment Recommendation tool
SD	standard deviation
t	computed value of the t test
USP	United States Pharmacopeia
WHI	World Health International
WHO	World Health Organization
\tilde{f}^2	Cohen's estimate of effect size
λ	Wilk's Lambda

CHAPTER 1: INTRODUCTION

An overview of the magnitude of the problem of medication errors in the acute-care hospital setting in the United States is presented. System efforts to develop solutions to the problem of medication errors and healthcare reform to address errors are discussed. Solution seeking clinical decision support technology (CDSS) and specifically the *Broselow-Luten Color Coding Kids* system (CCK) provides promise of one of the solutions to medication administration errors. The CCK system is described.

In 2000, Members of the Institute of Medicine (IOM) Committee on Quality of Health Care in America, published a ground breaking report, *To Err is Human: Building a Safer Health System*. The authors of this report provided the first of a series exposing serious concerns about patient safety in the American health care system. As a subset of a larger report in 1998, the Committee members initiated projects to improve the quality of health care in the subsequent ten year period. Revealed in the first report was the fact that “tens of thousands of Americans die each year from errors in their care and hundreds of thousands suffer “(p. 2) due to such mistakes. Healthcare workers had been challenged to foster quality and accountability, and develop research for areas of concern identified in the healthcare system.

As an outspoken advocate for patient safety and champion of healthcare reform, Dr. Lucian Leape (1994) introduced a paradigm shift in the way in health care professionals think about patient safety, “Errors must be accepted as evidence of system

flaws, not character flaws. Until and unless that happens, it is unlikely that any substantial progress will be made in reducing medical errors” (p. 1851). Hopefully, removing the cloak of secrecy, blame and finger pointing, healthcare providers will work collectively to resolve system problems.

Prior to the IOM investigations, Dr. James Broselow, a nationally renowned emergency pediatric physician, distressed about the incidence of real life pediatric emergency errors through his clinical practice, developed a method of handling pediatric medication preparation and administration in highly stressful emergency situations in a systematic way. Children are particularly vulnerable to medication errors due to the necessity of calculating medication dosages based on body weight. In many emergency situations healthcare professionals find great difficulty weighing the child.

In 1986, encountering several critically ill children, Dr. Broselow discovered that a child’s ideal lean body weight corresponded accurately with body length and thereby created the Broselow tape. Professionals use the tape to measure the length of the child and provide an accurate estimation of weight. Given lengths correspondingly to color zones can be used to provide a guideline for treatment until the patient can be weighed (DeBoer, Seave, & Broselow, 2005). Dr. Broselow later teamed with Robert Luten, MD, to create a color-coded system for pediatric emergencies CCK SYSTEM. Currently, Dr. Robert Luten, nationally recognized for the development of the Pediatric Advanced Life Support (PALS) in concert with Dr. Broselow, developed this clinical decision support technology.

At a national level, members of the IOM (2000) reviewed hospital data and reported the frequent occurrence of medication errors. Initial studies were based on data

from the Harvard Medical Practice (Brennan, Leape, Laird, Herbert, & Localio et al., 1991) and the Utah and Colorado Medical Practice Study (Classen, Pestotnik, Evans, Lloyd, & Burke, 1997; Thomas, Studdert, Burstin, Orav, & Zeena, 2000) revealed medication errors as the most prevalent errors in hospitals. Estimates published from the IOM (2000) of the incidence of fatal medical errors were reported as high as 98, 000 annually.

Phillips et al. (1998) reviewed US death certificates and reported a two and a half fold increase in medication errors during a ten year period from 1983 to 1993. These researchers uncovered a rise in medication errors from 2,876 deaths per year in 1983 to 7391 in 1993. In a separate investigation by Bates et al. (1995), an analysis of 4,031 medication orders written by physicians at two teaching hospitals, identified 247 adverse drug events (ADEs) injuries related to medication and 194 potential ADEs were identified.

The second part of the (IOM) report, *Crossing the Quality Chasm: A New Health System for the 21st Century* was released in 2001, and viewed as an agenda for reforming the health care system. The Committee challenged all health care constituencies from policymakers, providers, administrators, purchasers, regulators, management and consumers, to commit to six aims for improving the quality of care to unparalleled levels: safety, effective, patient-centered, timely, efficient, and equitable care. In addition to the six aims, the IOM (2001) researchers outlined the following challenges for health care organizations: redesigning care processes; effective use of technology; managing clinical knowledge; developing effective teams, coordinating care; and developing outcome

measures for performance. The overarching intentions were aimed at providing exemplary healthcare practice.

By 2004, representatives from the Kaiser Family Foundation in collaboration with the Agency for Healthcare Research and Quality [AHRQ] and the Harvard School of Public Health conducted *The National Survey of Consumers' with Patient Safety and Quality Survey*. Representatives from the organizations worked together to develop the questionnaire and analyze the results. Representatives of this collaborative conducted a survey by telephone from July 7 to September 5, 2004. Using a randomly selected national sample of 2,012 adults 18 years or older, interviews were conducted in English and Spanish. The data analysis revealed 34-40% of the individuals surveyed reported having experienced medical errors, of which 28 percent were medication errors. The prevention of medication errors in the acute care settings was a key priority. *The Patient Safety and Quality Healthcare Publication* in (2008) details an estimated 1.5 million preventable medication errors that occur each year which result in adverse drug events (ADEs). Barker, Flynn, Pepper, Bates, & Mikeal (2002) reported one of every five doses administered by nurses was in error at a rate of 19% in a study of 36 facilities.

In response to the first IOM (2000) report, Congress enacted legislative action, *The Patient Safety and Quality Improvement Act of 2005*, passed by both the House of Representatives and the Senate due to the growing concerns about patient safety in the US AHRQ (2005). Congress intention in this act was to encourage health providers to report, and trend data and glean information to improve patient safety to reduce the incidence of events that adversely affect patients and development of Patient Safety

Organizations (PSOs) that can work with clinicians and health care organizations to reduce risks and hazards associated with patient care.

Steady progress has been made since the passage of the *Patient Safety and Quality Improvement Act of 2005*. In 2007, the (IOM) Committee released another report, *Preventing Medication Errors*, investigating adverse drug events (ADE) in US hospitals, not accounting for other health care settings. The estimated additional cost of inpatient care for these ADE's in the hospital setting alone was conservatively estimated at an annual rate per incident of 400,000 preventable events each incurring at an extra cost of approximately \$5,857. "In 1993 that amount yielded \$2.3 billion and a reported increase of, \$3.5 billion dollars by 2006." (IOM, 2007, p.5)

At best, the reported error rates in hospitals are conservative and are dependent upon the methods utilized to report the errors. Bates et al. (1995a) utilized the most comprehensive detection method and yielded the highest reported error rates. These scientists found 1,400 prescribing errors per 1000 patient admissions which suggest approximately 0.3 prescribing errors per patient per day. Narrowing the focus of ADE's to the pediatric population (Kaushal et al., 2001) using methods similar to Bates et al. (1995a) discovered 405 prescribing errors per 1000 patient admissions or 0.1 errors per patient per day occurring in the pediatric population alone. Kaushal et al. (2001) reported 19.5 % of the errors were deemed serious and preventable. According to Payne, Nichol, Hoey, & Savarino (2002) error reporting rates are as low as 5%. Knowledge of medication errors is vital to prevention.

According to AHRQ (2002) committee members, medical errors are one of the leading causes of death and injury in America. Pediatric patients are particularly

vulnerable to adverse events. The occurrence of ADE's for hospitalized children were comparable to rates for hospitalized adults but the rate for potential adverse drug events was three times higher in children, and substantially higher in the neonatal intensive care units.

The problem of medication errors in hospitals and the vulnerability of pediatric patients to ADEs has been well substantiated (Bates, et al. 1999; [AHRQ] ,2002; Cohen, 2000; Ferranti et al.2008; Fortescue et al, 2003; Fox, G. 1996; Han et al. 2005; Koren & Haslam,1994; Kaushal et al. 2001; Kozer et al. 2002; Le, Nguyen, Law, & Hodding, 2006; Miller, Elixhauser, & Zham, 2003; Leonard et al., 2006; Otero, Leyton, Mariani, & Cernadas 2008; Sharek et al. 2006; Slonim, LaFleur, Ahmed, & Joseph, 2003; The United States Pharmacopeia, 2004; Woods, Thomas, Holl, Altman, & Brennan, 2005). There is promising evidence that clinical decision support systems may prevent or reduce the incidence of human error in the process of nursing medication administration (Bergman, & Fors, 2008; Carter, 2002; Casalino et al., 2003; IOM, 2001; Davidhizer & Lonser, 2003; Del Beccaro, Jeffries, Eisenberg, & Harry, 2006; Ferranti, Horvath, Cozart, Whitehurst & Eckstrand, 2008; Hillsden & Fenton, 2006; Holdsworth et al., 2007; Johnston et al., 2004; Kawamoto, Houlihan, Balas, & Lobach, 2005; Killelea, Kaushal, Cooper, & Kuperman, 2007; King, Paice, Rangrej, Forestell, & Swartz, 2003; Kozer, Scolnik, MacPherson, Rauchwerger, & Koren, 2005; Mahoney, Berard-Collins, Coleman, Amaral, & Cotter, 2007; McMullin et al., 2004; O'Cathain, Munro, Armstrong, O'Donnell, & Heaney,2007; Potts, Barr, Gregory, Wright, & Patel, 2004; Rothschild et al.2006); Roukema, Steyerberg, Van der Lei, & Moll, 2008; Sard et al., 2008; Stevenson, Barbera, Moore, Samore, & Houck, 2005; Taylor, Loan, Kamara, Blackburn, & Whitney,

2008; Toth-Pal, Wardh, Strender, & Nilsson, 2008; Walsh et al., 2008; Wang et al., 2007; Weber, 2007).

Swenson (2007) in the article *Point-of-Care Medication Error Prevention: Best Practices in Action*, discussed solutions and expert recommendations to prevent adverse drug events in the hospital. Swenson (2007) further claimed patient safety technology at the point of care is the top priority in preventing medication errors. The next step for research for prevention strategies should focus on evaluating the use of technology and “How to make a business case for investment in error prevention strategies” ... (IOM, 2007, p. 318). The (IOM, 2007) report deemed research, recommending medication safety systems, and the study of the effectiveness of these tools, as a major initiative in healthcare practice. Since the first IOM (2000) report little progress in improving patient outcomes in relation to medication errors has occurred. The reported rate of errors remains one per patient admission.

Suggestions for future nursing research by AHRQ Committee members are published in *Patient Safety and Quality: An Evidence-Based Handbook for Nurses*. The authors, Staggers, Weir, & Phansalkar (2008) outlined future research themes that emerged during investigation of current best practice.

“Three major themes for future research emerged: (1) nursing impacts from computerized orders management, (2) human-computer interaction issues, and (3) implementation science” The authors further commented, from the nursing perspective, that any study of medication orders management with the impact on nursing would be novel. Also suggested was an interdisciplinary study of orders management was needed (Staggers, Weir, & Phansalkar, 2008).

Statement of the Problem

Leape (2004) pointed out some improvements have been made in the past 10 years but changes have not been adequate. Contributing factors to the lack of change include resistance to change by presenting barriers such as the punitive environment in hospitals, physicians' denial of the problem, lack of leadership and lack of systems thinking.

To address this problem, a new bedside technology was developed to reduce errors at the point of care. The CCK system was developed from the Broselow-Luten tape using length to standardize pediatric dosages (J. Broselow, personal communication, September 9, 2008). Although there is evidence of the positive effect of the Broselow-Luten tape in reducing weight error estimates, and improving work flow time (DeBoer, Seave, & Broselow, 2005; Lubitz et al., 1988; Lancaster, 2005; Kozer, Seto, Verjee, Parshuram, & Khattak, 2004; Rand, Conn, Crittenden, & Halterman, 2004; Frush, Luo, Hutchinson, & Higgins, 2004; Shah, Frush, Luo, & Wears, 2003; Hofer, Ganter, Klaghofer, & Zollinger, 2002; Kaushal, Jaggi, Walsh, Fortescue, & Bates, 2003), the need for a comprehensive assessment of the newly developed CCK clinical decision support system technology remains.

The purpose of the researcher was to compare the effectiveness of traditional nursing medication administration with the Color Coding Kids system in an effort to reduce pediatric medication errors using a sample of undergraduate nursing students.

The investigation was designed to clinically test in a simulated environment the implementation of the CCK system for the nursing administration of medication in a pediatric rapid response scenario. Simulation provided a safe means of examining the

effect of this web based application of the CCK system which standardizes medication dosages. Drs. James Broselow, and Robert Lutten, two nationally recognized experts in pediatric emergency care served as consultants in this study.

Significance of the Research

Safe administration of medication is the responsibility of the professional registered nurse. With knowledge of the data about medication errors in hospitals, research is needed to address medication obtain knowledge to prevent medication errors is crucial for the safety of all patients and particularly vulnerable children in an emergency situation. A simulated environment addressing the safety and efficacy of the CCK system during the implementation stage was important to prevent potential errors and risk to patients. The researcher examined the newly developed CCK system in a simulated pediatric real life scenario environment. The use of a simulated hospital, high – fidelity manikins, real life clinical scenarios, and merging new technological point of care programs, is a new and promising field in healthcare research.

Research Question

A simulated pediatric rapid response research scenario was designed and implemented with student nurses enrolled in the last semester of nursing education programs. Seeking solutions for adverse pediatric medication events, this study was developed to address the deficiency of research exploring this new CCK pediatric medication safety system. A simulated pediatric emergency scenario was selected for the first trial to eliminate the risk of harm to patients. The vulnerability of children and the potential three fold risk of adverse drug events guided the selection and design of the pediatric simulation scenario. The researcher's intent was to address the lack of empirical

evidence about the CCK system. The registered nurse is responsible for safe medication administration falls within the domain of the registered nurse. The effect of the CCK technology aimed at the reduction of pediatric medication errors in with emergency medication administration was explored.

Due to the need for further research exploring new technologies to reduce pediatric medication errors, an effort was made to compare the extent of the effect of the implementation of the CCK system on the safety of pediatric medication administration in a rapid response simulation scenario, compared to the traditional method of pediatric medication administration. Specifically, the researcher offers the following research question that guided the study.

Research Question

Will nursing students in the experimental group using the CCK method of medication administration perform more efficiently, present better workflow turnaround times and demonstrate better hand- off communication than the nursing students in the control group?

Delimitations

The delimitations were:

1. Sample: The study was conducted in a metropolitan area and the majority of participants were nursing students from a rural or small metropolitan area in NC.
2. Differential selection of participants: Although all participants are undergraduate student nurses, some attend associate degree nursing programs and others baccalaureate programs that utilize simulation.

The limitations were:

1. Simulation and “real world” situations may present a differing effect on performance however; participants were prepared and agreed to perform as if responding to a pediatric emergency.
2. Isolation of treatment: The result of a single treatment experience was difficult to isolate. Factors that may influence individual performance on a given day may not be predictive of their overall performance.
3. Reactive arrangements: Participant effects that may threaten validity are the feelings and attitudes of the participants. In order to assure anonymity and reassure students of confidentiality and anonymity as participants were coded by number without using names. The primary investigator met with participants and assured them their participation was anonymous.

Definitions and Abbreviations

The key terms used in the study were defined as follows:

1. *ADE* – Term used by the IOM (2007) to denote serious adverse drug events. A preventable ADE is associated with a medication error.
2. *AHRQ* -The Department of Health and Human Services' Agency for Healthcare Research and Quality.
3. *Cronbach's Coefficient Alpha* – estimate of internal consistency of how items on a test relate to all other items on the test (Gay, Mills, & Airasian (2006).
4. *Clinical Decision Support System (CDSS)* - are automated tools to support clinical decision making and improve the outcomes of the decisions. These tools are

capable of processing a tremendous amount of data contained in information systems.

5. *Color –Coding Kids (CCK)* – The CCK system is a web-based system of standardized medication dosing developed from the Broselow-Luten tape system. Children are sorted by color coded categories based on weight and height. In cases where the weight is unknown the height alone will sort the child into a standardized color category. The system contains a color-coded therapeutic pathways and information to increase efficiency and reduce medication and medical errors. Pathways are driven by key terms ordered by the physician yielding predetermined, standardized, color coded safe and rapid information access for therapeutic interventions. Color becomes the universal language of safety throughout the entire spectrum of acute pediatric emergency care (Broselow, 2008).
6. *Computer Physician Order Entry (CPOE)* – This term is used inconsistently in the literature. For the purpose of this study the description of a specific type of CPOE with orders with integrated alerts, reminders, and decision support for medications was used (Staggers, N., Weir, C., & Phansalkar, S.,2008).
7. *Electronic health record (EHR)* - is a real-time, point-of-care, patient-centric information resource for clinicians¹ that represents a major domain of health information technology (Staggers, N., Weir, C, & Phansalkar, S., 2008).
8. *Hand - off communication* - Completion of the SBAR tool for report of the patient's condition and treatment.
9. *HIT* – Health information technology.

10. *IOM* - Institute of Medicine.
11. *MANOVA* - Multivariate analysis of variance. A statistical procedure used where there is more than one dependent variable and the dependent variables cannot be combined (Gall, Gall, & Borg, 2007).
12. *Medication error* - medication error as "any preventable event that may cause or lead to inappropriate medication use or patient harm while the medication is in the control of the health care professional, patient, or consumer. Such events may be related to professional practice, health care products, procedures, and systems, including prescribing; order communication; product labeling, packaging, and nomenclature; compounding; dispensing; distribution; administration; education; monitoring; and use." [NCCMERP] (2000).
13. *Point-of-care (POC)* - decision-support applications and patient safety technology at the point of care or POC.
14. *Safe medication administration* – accurate and complete compliance with all ten steps of the traditional method of medication administration.
15. *SBAR*: The SBAR (Situation-Background-Assessment-Recommendation) technique is a framework for communication between members of the health care team about a patient's condition.
16. *Simulation* - Simulation in nursing education is defined by Billings and Halstead (2005) as a close representation of real life events presented by computer software, role play, case studies and games that actively involve the learner in the application of theory. The use of high fidelity computer human patient simulation manikins have been added to the repertoire of tools. Provides the opportunities for

nursing students to safely practice clinical skill development and critical thinking abilities.

17. *Status Epilepticus* - Status epilepticus is a medical emergency that requires hospital treatment to bring the seizures under control. Episodes of non-stop seizures need to be treated immediately.
18. *Turnaround time*: The amount of time in minutes the participant spends to complete the task of medication administration, assessment, and documentation.
19. *Traditional nursing medication administration* – Standard nursing procedure for the safe administration of medication. Traditional “*Five Plus Five Rights of Drug Administration*” – The traditional rights are (1) the right client, (2) the right drug, (3) the right dose, (4) the right time and (5) the right route. Plus the five essential rights (1) the right assessment, (2) the right documentation, (3) the client’s right to education, and (4) the right evaluation, (5) the client’s right to refuse.

Organization of the Study

In chapter 1, the researcher presented an overview of the importance of finding solutions to pediatric medication errors for the safety, and protection of this vulnerable population, thereby, establishing the purpose, relevance and research question for the study. Meeting the challenges posited by the IOM (2007), *Preventing Medication Errors*, future recommendations for nursing research includes implementation studies of current technological breakthroughs.

In chapter 2, a review of the current and related literature addressing medication errors in hospitals, pediatric medication issues, and studies related to healthcare

technology systems, CCK system and clinical decision support CDSS technology is presented. A review of prior research is also presented.

In chapter 3, the researcher delineated the method, design and protocols used to conduct the experimental trial of the CCK system. The research question and related hypotheses and procedures for data collection and analysis are included. Result of the trial study in relation to the research question and hypotheses and discussion of the findings are presented in chapter 4. Conclusions related to the findings, implications for nursing education and recommendations for future research are presented in chapter 5.

CHAPTER 2: LITERATURE REVIEW

The purpose of the researcher was to compare the effectiveness of traditional nursing medication administration with the Color Coding Kids system in an effort to reduce pediatric medication errors using a sample of undergraduate nursing students.

An overview of the role of the Institute of Medicine (IOM) to hospital medication errors is explained. The literature reviewed covers the following research areas: hospital medication errors, pediatric medication errors, solution seeking technology and the Broselow-Luten Color Coding Kids Hospital System. An overview of the traditional medication administration procedure for registered nurses is outlined.

Overview

In 1970, the (IOM) was established by Congress. As a branch of the National Academy of Sciences, Members of the IOM serve as advisors to the nation to improve health care in the United States. Recommendations from the (IOM) shape health policies to improve the quality of health for millions of people. A function of this branch of government is to assemble the world's top scholars, scientists and health experts to investigate critical health issues. The IOM is comprised of committees of scientists and scholars who serve without compensation. Committee reports are rigorously peer reviewed and reported publicly (IOM, 2008). The Committee on the Quality of Health Care in America, a subcommittee of the IOM was formed in 1998 to improve the quality of health care in the Unites States. Following extensive research, the IOM Committee members published a series of three reports detailing the results of their research on the quality and safety of healthcare in America.

A national spark was ignited by the first IOM report in 2000 calling for pressing reform of the health care system. The catalyst behind the reform was the release of the committee's safety report; *To Error is Human: Building a Safer Health Care System*. A national agenda for transforming the healthcare system was presented along with specific recommendations to reduce medical errors and improve patient safety at a system level. The intent of the IOM report was not to point the finger of blame on well intended healthcare providers but to honestly present the alarming reality of the latest research

As a result of the first IOM (2000) investigation, two dimensions of the environment that influence quality were identified, quality was depicted as; (1) patient safety, (2) provision of care and best practice, and (3) customer specific values and expectations. Secondly, the environmental forces that drive quality, the legislative/regulatory and economic dimensions. The domains of quality were redefined as follows; patient safety is considered freedom from accidental injury, best practice is the standard of care, and lastly care needs to be individualized and customized to patient values and preferences. The dimension of regulation and economics drive the healthcare system based on public values, policy, regulation and economics. Regulation can influence the quality of care by empowering chief executives and governance within the system. All healthcare organizations are then required to meet minimum standards of care. The Committee suggests that the market place, both public and private purchasers, directly motivate businesses, by rewarding beyond minimum standards (IOM, 2000).

The topic of the research was medication related errors in hospitals. The Institute of Medicine (2000) investigated and published their findings in the following documents; *To Err is Human: Building a Safer Health System (2000)*, *Crossing the Quality Chasm: A New Health System for the 21st Century (2001)*, and *Preventing Medication Errors: Quality Chasm Series (2007)*. Data summarized in the first report resulted in the following generalizations; based on two large studies one in Colorado and Utah (Thomas, Eric, Studdert, Burstin, & Helen et al., 1999) extrapolating results to the 33.6 million admissions to U.S. hospitals, an implied 44,000 patients die annually. In the New York study by Brennan, Troyen, Leape, Laird, et al. (1991) extrapolating their results, an estimated 98,000 individuals die annually. This translated into two of every 100 patient admissions to the hospital experienced adverse drug events (ADE) at a cost of \$ 4,700 per event. The annual cost projected for a large 700 bed hospital was conservatively estimated at \$2.8 million dollars annually and \$2 billion nationally for preventable adverse drug events (Leape et al. 1991).

The inconsistency of reporting systems and lack of standardization resulted in this very conservative number (IOM, 2000). It is difficult to accurately ascertain the true cost of errors, as several aspects of the cost cannot be measured. Most of the studies have focused on hospital reporting however; the magnitude of the problem was grossly underestimated and does not account for all treatment settings such as ambulatory clinics, long term care, and home care. Additional costs not considered in the reports include inflated insurance prices and co-pays to cover errors, and the cost as the patient treated outside of the hospital for injury incurred in the hospital. Some losses cannot be tallied

quantitatively such as diminished satisfaction by the patient, loss of trust, not to mention physical and psychological suffering and impairment (IOM, 2000).

Medication errors that resulted in death were reported separately in the (IOM, 2000) study. Death due to medication errors is infrequent but increasing due to the extensive use of drugs in our society. The IOM committee reviewing death certificates from 1983 to 1993 found 2,876 deaths due to medication errors in 1983 and an increase to 7,391 deaths in 1993 which was a 2.57-fold increase.

In earlier studies researchers summarized (IOM, 2000) convincing evidence of the extent of the medication error problem in America. More than fifty studies exploring the causality of ADEs suggested the unacceptable frequency of medication errors. A comparison chart of the available research studies, sample description, data source results, definitions and causes or types of errors, are contained in the IOM (2000) report.

Researchers in the second committee reported in *Crossing the Quality Chasm: A New Health System for the 21st Century* (2001) additional quality issues. This report was a call to improve the entire system of health care delivery as a whole. Although the development of technology in the health and medical sciences made tremendous strides, the (IOM, 2001) purported that healthcare systems are floundering and are unable to provide consistent high-quality care to Americans. One of the concerns expressed by this Committee was the absence of progress toward applying information technology to advance clinical processes.

Of particular interest to this investigation was the (IOM, 2001) call for designing systems to prevent errors, “avoiding reliance on memory and vigilance, and simplifying and standardizing key processes (such as using checklists and protocols).” (p.121)

Additional suggestions contained in the 2001 report; automating, simplifying, standardizing and color coding systems to avoid errors. As a means of improving patient safety is to design “procedures that can mitigate harm from errors such as up to date information available to clinicians” (p. 123). Mass customization of care was also recommended such as medical conditions by degree of severity or level of risk such as controlled or uncontrolled hypertension.

Information technology is the interconnecting mechanism to link evidence based knowledge into clinical practice. The (IOM, 2001) challenged the “healthcare system” as a whole to develop competencies; tracking and disseminating new information, manage clinical change incorporating new information into practice, and to make sure professionals have the competency and skills, and utilize simulation to enhance skills and manage crisis.

In addition, the second report (IOM, 2001) from the committee defined quality for the health system as “the degree to which health services for individuals and populations increase the likelihood of desired health outcomes and are consistent with current professional knowledge” (p.232). Quality was evaluated based on three criteria; (1) structural issues such as health care capacity, (2) process or interactions between patients and providers and, (3) outcomes or changes in patients health.

Steady progress has been made legislatively since the release of the first two IOM reports. The Senate Finance Committee prompted the United States Congress, through the Medicare Modernization Act of 2003, to solicit Medicare and Medicaid Services and contract with the IOM to formulate a national agenda for reducing medication errors.

Scientists were commissioned to estimate errors and determine the efficacy of prevention strategies (IOM, 2007).

The results of the investigation and an agenda for reform by The Committee on Preventing Medication Errors were published by the IOM (2007) and contained in the report, *Preventing Medication Errors*. Definitions accepted nationally by the committee were; a medication error is any error occurring during the medication use process, and adverse drug events (ADE) or any injury due to medication. The committee approximated that hospitalized patients experienced one medication error per day, with prescribing and administering medications accounting for three fourths of the errors.

The IOM was not the first organization in the United States to investigate or monitor (ADEs) in the United States. In fact since 1992, the Food and Drug Administration (FDA) began monitoring medication error reports from the *United States Pharmacopeia (USP)*, the *Institute for Safe Medication Practices (ISMP)*, and the direct contacts to the FDA through MedWatch. Citizens as well as manufacturers report (ADEs) directly to the FDA through MedWatch forms on their website. The USP in 1998, just prior to the release of the IOM report, launched MEDMARX, an internet reporting system for medication errors. Aggregated trends and patterns of medication errors are analyzed by the USP's, (Center for the Advancement of Patient Safety ([USP CAPS], 2004) on an ongoing basis. The Division of Medication Errors and Technical Support of the FDA included a medication error prevention program. Staff pharmacists and personnel reviewed medication error reports sent to the USP Medication Errors Reporting program and MedWatch, to evaluate and analyze the data to provide feedback to others at the FDA (USP, 2008).

In addition, the USP initiated in 1995 the development of the National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP). The NCC MERP is an independent body comprised of several national organizations. These national health care organizations meet to collaborate and address the interdisciplinary issues and causes of errors and to promote safety (NCCMERP, 2008).

Global initiatives are in progress to develop safer health practices. Although the IOM is concerned with safe practices in America, global committees have been formed to address safety and health care reform worldwide. For example, Members of the *World Health Organization* (WHO) initiated a *World Alliance for Patient Safety* in 2005. This initiative identified six global action areas. One of the action areas of particular interest to this study is the development of "Solutions for Patient Safety" (Collaborating Centre for Patient Safety Solutions, 2008) . In 2005, The (WHO) appointed the Joint Commission and Joint Commission International (JCI) as the world's first WHO Collaborating Centre dedicated solely to patient safety (Collaborating Centre for Patient Safety Solutions, 2008). The focus of the collaborative is to reduce the disconcerting numbers of serious medical injuries worldwide. As a result of the efforts between the Commonwealth Fund, the WHO World Alliance for Patient Safety, and the WHO Collaborating Centre for Patient Safety, The High 5s: World Alliance for Patient Safety initiative was started. This global joint effort provides a mechanism to implement innovative, standardized protocols for five patient safety solutions within five years (WHO Collaborating Centre for Patient Safety Solutions, 2008). <http://www.ccforspatientsafety.org/patient-safety-solutions>

The goal of the authors' of the High 5s was to implement solutions that would impact the prevention of avoidable catastrophic adverse events death or serious injury in

hospitals. The following five solution areas are the focus of these initiatives: (1) hand-over errors, (2) wrong site / wrong procedure / wrong person surgical errors, (3) continuity of medication errors, (4) high concentration drug errors, (5) hand hygiene practices (WHO Collaborating Centre for Patient Safety Solutions, 2008). Global members of The High-5s include the Commonwealth Fund with Australia, Canada, New Zealand, the United Kingdom, and the United States of America, Germany and more recently the Netherlands. Each country enrolled 10 hospitals to implement standardized protocols. From those hospitals, proposed solutions will be included in the High 5s project. These hospitals comprised an international solution learning laboratory for health care delivery and patient safety disseminating learning worldwide via the High 5s web site. The collaborative learning network fosters the sharing of knowledge and experience in implementing patient safety solutions (WHO, 2009).

In 2007, nine *Patient Safety Solutions* were announced by the WHO Collaborating Centre for Patient Safety Solutions. These additional *Patient Safety Solutions* addressed look-alike drugs, sound-alike names; patient identification; hand-over communications; correct procedure at the correct body site; control of concentrated electrolyte solutions; medication accuracy; catheter and tubing misconnections; needle reuse and injection device safety; and hand hygiene. The basic purpose was to prevent inevitable errors from reaching patients (JCI, 2008).

Due to the varying incidence of medication errors across patient care settings this literature review focuses more specifically on acute care in-hospital medication errors and adverse events and more specifically pediatric administration medication errors.

Medication Errors in the Hospital Setting

Ascertaining the exact number of medication errors in the acute care hospitals is difficult to obtain due to the varied reporting mechanisms. Data was reported in several studies indicating the magnitude of the problem in the United States. The first IOM report in 2000 estimated 7,000 Americans die each year due to errors in prescribing, transcribing, or administering medications. Mazur (2008) reviewed research on medication reporting systems and claims voluntary internal reporting systems are limited for evaluating the real frequency of medication errors and ADEs. Factors that contribute to omitting the reporting process were listed: lack of time, pressure, fear of punishment, and a lack of perceived benefits of reporting. However, improvements were made in internal reporting process when the reporting environments were non-punitive (Reich & Resar, 2001). Even then, the reported rates underestimate the true error rate. Mazur (2008) included in his research international studies of medication errors (excluding wrong time errors) and found 2.4 to 11.1% errors per dose were reported.

Commenting on the magnitude of the problem, Kaushal, Jaggi, Walsh, Fortescue, & Bates (2003) agreed patient safety was a public health problem. Even though there was controversy over the quoted 44,000–98,000 deaths annually from medical mistakes in hospitals, most agreed there was significant need for improvement (Kaushal et al., 2003).

According to the (United States Pharmacopeia [USP], 2004), *Advancing Patient Safety in U.S. Hospitals: Basic strategies for success* medication errors were reported back since 1962. Reports of hospital errors were published by Barker and McConnell (1962) in the *American Journal of Hospital Pharmacy* at a rate of 16 errors per one hundred doses. In a 1995, study (Bates, Boyle, & Valet, 1995) examined 10,070 medication orders, 530 errors were discovered at a rate of 5.3 per 100 orders. An

additional study published by Bates, Cullen, & Laird (1995), of two tertiary care hospitals reported, 6.5 ADEs and 5.5 per 100 nonobsterical admissions, of which 40% of the errors were life-threatening and preventable. Barker, Flynn, & Pepper et al, (2002) found errors occurred in 19% of all administrations and confirm the IOM (2000, 2001, and 2007) reports that the nation's hospitals have major system problems. Also in concert with the (IOM, 2000, 2001, and 2007) reports, the [USP], 2004 report concluded that the majority of errors are not due to individuals but more commonly faulty systems. The key is reporting as much as possible and to find systems issues that correct them.

Adding to the IOM (2000) study another less publicized significant report was conducted by the (USP) a private, not-for-profit organization to assure quality of therapeutic products. The study reviewed 6, 224 medication errors from 56 healthcare facilities. The results were published in 2000. Davidbizer & Lonser (2003) highlighted the results of this report. The complete medication process, from prescribing to monitoring, was examined. The results indicated the majority of errors occur in the administration mode 40%, compared to documenting 21%, dispensing 17%, prescribing 11%, and monitoring 1%. Some of the most common errors reported were omission 1,689, improper dose 1,323, unauthorized drug 751, and prescribing errors 475.

Further analyzing the USP data from 2000, Davidhizer & Lonser (2003) included a review of factors reported to have contributed to the medication errors. The most commonly reported factors were; distractions 798, workload increase 263, inexperienced staff 237, and shift change 103. The authors' note that of the 6,224 reported errors in the USP count, only one resulted in death of the patient. Of the errors reported 3% or (177 out of 6224 errors) resulted in harm. Table 1, Types of Medication Errors, contains the

reported medication errors from MEDMARX published by the USP (2004) reporting a 5-year data from 1999- 2003.

Table 1

Type of Medication Errors

Type of error	Percent
Omission	25.7
Improper dose/quantity	23.2
Prescribing error	18.9
Unauthorized drug	11.1
Wrong time	6.8
Extra dose	5.6
Wrong patient	4.9
Wrong drug preparation	4.5
Wrong dosage form	2.3
Wrong route	1.6
Wrong administration technique	1.3
Expired product	0.1
Deteriorated product	0.1

Source: United States Pharmacopeia (2004)
5-year data CY 1999-CY 2003

A distinctive investigation published in the *Annals of Internal Medicine* explored adverse events after the patient was discharged from the hospital. Weismann, Schneider, Weingart, Epstein, David-Kasdan, Feibelman, Annas, et al (2008), compared adverse events reported in post-discharge patient interviews with adverse events detected by the

medical record review. A random sample survey of 998 recently hospitalized adults in Massachusetts in 2003 was conducted. The purpose of the survey was to compare adverse events reported in post-discharge interviews with adverse events from the medical record.

Comparing the medical record to patient interviews, Weissman et al (2008) reported the following discrepancies; 23% had at least 1 (ADE) detected per interview, and 11% had at least 1 (ADE) identified by record review. The κ statistic demonstrated poor agreement between interviews and medical records for any type of adverse event ($\kappa = 0.20$ [95% CI, 0.03 to 0.27]) with better agreement between interviews and medical records when the event was life-threatening or serious events ($\kappa = 0.33$ [CI, 0.20 to 0.45]).

Contrasting record review with interviews, 11 serious, preventable events (1.1% of patients) were reported per record and an additional 21 serious and preventable events per interview that were not documented in the medical record. The patient interviews revealed an additional 12 pre-discharge events, and 9 post-discharge events, that occurred after the patient left the hospital. Limitations of this study noted that only patients well enough to be interviewed were included, and some interviews were delayed (6 to 12 months after discharge). Gleaning additional information about adverse events was prudent. The authors suggested the inclusion of adverse events on discharge patient surveys (Weismann et. al., 2008).

Pham (2008) recently investigated the incidence of (ADEs) and quality of healthcare in emergency departments (EDs) in the United States. Medication errors in (EDs) were included as one of the aspects of the quality of care explored in this study. This researcher analyzed medication errors reported to MEDMARX, a voluntary national reporting system, and evaluated the rate, type, cause and consequences. According to

Pham (2008) error rates nationally vary and are reportedly between (4% and 14%). An alarming statistic noted by this author was the incidence of pediatric medication errors as high as 39%.

Pham (2008) conducted a cross-sectional study of all ED errors reported to MEDMARX between 2000 and 2004. MEDMARX received 13, 932 medication error reports during that time span from 496 participating hospitals. The majority of the hospitals did not have CPOE systems. Errors analyzed in this study amounted to approximately 88 errors per 100,000 emergency department visits. The majority 42% of the mistakes were made on the 3:00 to 11:00 pm shift with the highest number reported on Mondays at 16.5%. Of the total errors, physicians were responsible for 24% of the errors and nurses 54%. The most frequent occurrence of errors was during the administration phase at (36%), due to inaccurate dose and quantity.

The following causes of medication errors were analyzed and listed by Pham (2008) in the order of frequency; (1) not following protocol 17%, (2) miscommunication 11%, (3) distractions 7.5%, (4) emergencies 4.1%, (5) workload increase 3.4%, (6) and computer order entry 2.5%. Additional findings included, 2.6% of the errors caused harm to the patient and there were three reported deaths due to the medication errors. This researcher recommends continued research, development, particularly at the administration process to reduce error, minimize distractions and implement simulations to encourage teamwork. Pham (2008) concluded his investigation citing the potential for 2,000- 2700 medication errors in the ED annually based on 110 million visits per year. Pham's research confirmed earlier data reported by the (USP, 2004) that the wrong administration technique continues to be the highest percent of harmful errors.

Data release by the (USP Convention Inc. , 2004) *MEDMARX 5th Anniversary Data Report: A Chartbook of 2003 Findings and Trends 1999-2003* provided trended data from 1999 to 2003 calculating and tallying types, causes, factors and reports of medication errors in hospitals reporting voluntarily to MEDMARX. Types of errors by volume and percent were calculated and reported to help target interventions. Six types of errors were selected as they exceeded the overall harm threshold. The highest percentage of harmful errors was the wrong administration technique and wrong route.

According to Barker, Flynn, Pepper, Bates, & Mikeal (2002) after reviewing reports of multiple facilities, asserted that medication errors were common. These investigators in an observational study one of every five doses administered by nurses was in error. The reported mean error rate detected at the 36 sites was 19% or (605 of 3216) doses. The error rates by category revealed that the most frequent errors were wrong time 8%, omission 6%, and wrong dose 3%; as a percentage of all errors, the results included wrong time 43%, omission 30%, wrong dose 17%, and unauthorized drug 4%. The distribution of error rates by category was similar between accredited and nonaccredited hospitals and skilled nursing facilities. When rate by site was compared substantial variation between sites was found, with error rates ranged from 0% at one site to 66.7% at another. Assuming 10 doses per patient day, this would mean the typical patient was subject to about 2 errors every day. This rate was higher than the previously reported one error per day.

Errors occur at all stages of the patient care process. The handoff process defined as the transfer of care from one provider or nurse to another, one shift to the next, and hospital to home or other facilities is a source of concern. Hughes (2008) in a review of

current literature pertaining to medication errors cites, interruptions, physical and/or emotional pressures at the time of patient transfer, communication or lack thereof, and translation as added contributing factors.

Hughes (2008) proposed using simulation as an educational strategy of medication administration and errors in a controlled setting to improve medication safety, duplicate the nurse-patient interaction and related cognitive thought. Suggesting further, simulation to prepare nurses to recognize and manage medication errors when and if they occur.

A more recent investigation conducted by *Phillips, Barker, & Eguchi (2008)* discovered the death rate resulting from medication errors increased from (1983 to 2004) by an astounding 360.5%. Fatal medication errors (FMEs) as defined in this study as accidental overdose or wrong drug given, amounted to 224,355 deaths. These alarming statistics surpassed by far the increase in death rates due to motor accidents. The percent from adverse effects of medications were reported at 33.2%, or alcohol and/ or street drugs 40.9%. The most prevalent (FMEs) were combined with alcohol and/or street drugs and demonstrated the largest increase 3196%. The escalation was most rampant in the 40 to 59 age group with a dramatic increase of 890.8%.

Some variations in reported medication errors existed across treatment settings such as in the home, acute care and long term care. The Medication Error Quality Initiative (MEQI) collected four years of data on medication errors reported in nursing homes in North Carolina. Nursing homes are required by law Senate Bill 1016 to report all actual and potential medication errors to (MEQI). According to the *MEQI-Annual Report (MEQI-AR)*, over 50% of the errors reported, basic human error was cited as one

of the primary causes. Additional sources of errors reported included medication name confusion, packaging design and product labeling, and shift report (Williams, Greene, Hansen R. et al., 2006)

The USP (2004) substantiated the original IOM (2000, 2001) reports of the scope of the problem of medication errors in the United States. In addition, a recent Associated Press release on October 22, 2008, the (Institute of Safe Medication Practice [ISMP] (2008) revealed nearly 21,000 incidents of serious drug reactions, and more than 4,800 deaths in the first three months of this year (2008) setting a new and alarming record. The errors reported to the FDA, from January through March was 38 percent higher than the average for the previous four calendar quarters, and the highest for any quarter, the report said. The number of deaths 4,824, was a reported threefold increase from the last calendar quarter of 2007. The FDA identified that heparin from China was tainted and the discovery unleashed an international scandal. The other drug was Chantix that demonstrated serious drug safety problems. In light of the current demonstrated threat to the health and well being of the public, and specifically to advocate for vulnerable populations, this experimental study focused on the implementation of a new technology intended to protect children from medication errors in rapid response and emergency settings. The focus of the next section of the report was on pediatric medication issues and errors.

Pediatric medication administration errors

Safe medication administration falls within the domain of the professional nurse. Medication errors pose a serious threat to the safety of the pediatric patient. Providing the proper drug therapy to a hospitalized patient involves a number of individuals and several steps in the process. Mistakes occur at all points in the process from prescribing, transcribing, ordering, dispensing, administration monitoring and tracking medications. Human error was established by the IOM (2000) and occurs at all points in the process. For multiple reasons, pediatric patients may be at greater risk for medication errors and more vulnerable to their effects. ADEs resulting from medication errors are threefold higher for children than for adult patients. (Kaushal, R., Bates, D. W., Landrigan, C., & et al., 2001).

Significant differences exist for the pediatric population. The size and body composition as well as organ maturity are factors that affect the pharmacokinetics such as absorption, distribution, metabolism, and excretion of drugs (Kee, Hayes & McCuistion, 2006). Further differences presented by Kee, Hayes, & McCuistion (2006) include the degree and rate of absorption are based on the child's age, health status, and route of administration. The maturity of the gastro-intestinal tract, gastric emptying, and pH, hydration, and nutrition are all factors that influence absorption. In addition, the distribution intravenously is dependent on the peripheral vascular perfusion. Concentration of water and fat soluble medications differ for children with changes in body fluid and fat composition. Additional concerns for clinicians are the differing rates of metabolism, excretion and actions of medications on children. (Kee, Hayes & McCuistion, 2006). Considering the number of special issues with pediatric medication

administration, the accuracy of dosing and monitoring is of paramount concern for all nurses working with the pediatric patient.

Dosing and calculating medications for the pediatric patient are subject to human error with every dose administered and calculated manually. Pediatric doses are available and based on the child's kg body weight. When pediatric dosages are not available for a medication, the correct dose is obtained through a mathematical process by extrapolating the adult dose. A nomogram is used which involves calculations using the height, weight, and body surface area in square meters (Kee, Hayes & McCuiston, 2006).

Summarizing data investigating pediatric medication errors, King, Naomi, Jagadish, Gregory, Forestell & Swartz (2003) compared the adult rate of ADEs, which occur at a rate of 5 per 100 medication orders, and report a similar error rate observed for children. They elucidated the special conditions of the pediatric population. King et al (2003) claim children are at risk for unique medication errors such as large, 10-fold errors in dosing. These researchers attributed the risk for medication errors to several variables; weight-based dosing, off-label drug usage and preparation, limited capacity to withstand a dosing error, limited or lack of ability to communicate with health care personnel to prevent an error or signal that an error has occurred. A review of prospective studies of ADEs in hospitalized children noted an overall incidence of 9.5%, with severe reactions accounting for 12% of the total. In 2 academic pediatric hospitals, the medication error rate (MER) was 6 per 100 medication orders, the majority of which occurred during physician medication ordering. Many ADEs are preventable (51% to 93%), as medication errors often occur during drug ordering and may be corrected, especially if the error is detected early in the order process.

Since the release of the IOM reports (2000, 2001, and 2007), Woods, Thomas, Holl, Altman, & Brennan (2005) conducted a study of adverse events in children. These researchers addressed the lack of research related to adverse events in children and claimed most of the focus of studies since the reports have been primarily on medical care for adults. They expressed concern that children are also vulnerable if not more so, to adverse events, and as such have been relatively unstudied.

Woods et al (2005) hypothesized that the epidemiology of adverse events and preventable adverse events in children were likely to differ significantly from that of adults. Their investigation used the Colorado and Utah Medical Practice Study data set with a focus on pediatric adverse events estimating the incidence and distribution of adverse event and preventable adverse event types in hospitalized children. The investigators used the same data base the IOM (2000) study. This was the first project to compare the rates of occurrence of these events between children and nonelderly adults. The sample included 67.7% newborns and infants (0–1 year of age), 9.6% toddler and school-aged children (2–12 years of age), and 22.7% adolescents (13–20 years of age). The high proportion of newborns and infants was anticipated as most children in the US are delivered in a hospital.

An adverse event rate of 1% and a preventable adverse event rate of 0.6% for hospitalized children were found by Woods et al (2005). A rate of 1% represents 1200 to 2100 children, in just 2 states, experienced a prolonged hospitalization or a disability as a result of an adverse event during a single year (1992) and, for 860 to 1500 of these children, the event was determined to be preventable. Nationally the rate for hospitalized children discharged from a hospital each year in the United experiencing an estimated 1%

annual adverse event rate would represent 70, 000 hospitalized children, with 60% possibly preventable. This study corroborates many of the results found in other studies about patient safety problems in children (Thomas et al. 2000; Kaushal, et al., 2001; Miller, et al. 2003; Slonim et al., 2003).

Woods et al (2005) supported previous research of (Kaushal et al., 2001; Fox, G, 1996; Koren & Haslam, 1994; Perlstein, Callison, White, Barnes, & Edwards, 1979) that adverse event risk differs for children than from that of adults and the processes, mechanisms, and systems that lead to an adverse event for children may differ significantly from adults. This study suggested due to the higher proportion of errors, research interventions should begin by focusing on adolescent hospitalized patients, birth-related medical care, and diagnostics in hospitalized children. The authors' further claimed future patient safety research needs to focus on pediatric-specific studies to explore the different processes, mechanisms, and systems.

Kaushal, et al. (2001) conducted a prospective, multicenter study of medication errors in two academic pediatric hospitals cite. A total of 10,778 medication orders were written for the 1020 patients in the study. Of these, 616 (5.7%) orders involved an error at one or more of the stages of the medication therapy process: ordering, transcribing, dispensing, administering, or monitoring. There were 5 (0.8%) preventable ADEs, 115 (18.6%) potential ADEs, and 496 (80.5%) errors with little potential for harm. A total of 320 (31%) patients experienced a medication error; 118 (12%) patients experienced two or more errors. The errors occurred at a rate of 5.7 errors per 100 orders. Most (79%) occurred during ordering. Several errors involved incorrect dosing 34%. This overall error rate was similar to that found in a previous study of adult inpatients using similar

methods, but the potential to cause harm was three times more likely to occur in the pediatric inpatients compared with adults. Reportedly, the neonatal ICU patients were particularly vulnerable.

Examining adverse events and means of prioritizing and preventing pediatric medication errors, researchers (Fortescue et al., 2003; and Kaushal et al., 2003) discovered factors contributing to compromised pediatric patient safety at similar or increased rates to adults. Factors placing hospitalized children at high risk were identified as patient-provider communication barriers, dependence on parents or guardians who cannot continuously manage their care. According to Fortescue, et al., (2003) Spanish-speaking patients whose families have a language barrier seem to be at increased risk for serious medical events compared those families that do not have a language barrier. In another study of medical errors in hospitalized children, Slonim et al. (2003) reported additional factors contributing to medical errors included children with special medical needs or who are dependent on technology.

A recent study by Otero, Leyton, Mariani, & Cernadas (2008) in Buenos Aires, Argentina assessed the prevalence and characteristics of medication errors in pediatric and neonatal inpatients. These researchers measured the impact of interventions to reduce medication errors. A pre-intervention and post-intervention cross-sectional study was conducted of a sample of prescriptions ordered and medications administered in the NICU, PICU, at the Hospital Italiano de Buenos Aires Department of Pediatrics from (2002 to 2004). The number, type of errors, time, occurred, and any kind of ADs were recorded. Several interventions, including incorporating a positive safety culture without

a punitive management of errors and specific prescribing and drug-administration recommendations were implemented.

The incidence of total errors reported was significantly lower post-intervention in 2004 compared with 2002: in the second phase was 7.3% (199 of 2732) and 11.4% (201 of 1764) in the first phase. The risk difference was minus 4.1% occurrence of errors.

Although somewhat conflicting data was obtained using an intensive surveillance methodology, McBride, Chiang, Goldmann, & Landrigan (2005) found relatively few medication errors occurring among 684 infant patients admitted for bronchiolitis. This research did support earlier findings by Kaushal et al. (2001) that the children that were critically ill were more at risk for AEs and experience longer hospital stays. Although McBride et al. (2005) were examining all AEs not just medication errors the results do shed knowledge on the severity of the errors and outcomes for patients with bronchiolitis suffering ADEs. Separating the medication errors from medical errors relatively few errors were detected. Three medication incidents were described. The first medication error classified as severe type was a tenfold overdose of a paralytic agent given to an intubated pediatric patient with bronchiolitis, another error involved an overdose of pancreatic enzymes intercepted before reaching the patient, and the last amoxicillin was ordered for the wrong patient and that also was intercepted by nursing. The physiologic vulnerability of ill infants and the magnitude of the overdoses cited contribute a sobering reality to the issue of pediatric dosing errors and miscalculations.

Some empirical evidence exploring the variables associated with medication errors in pediatric emergency medicine does exist (Leape, Brennan, Laird, & et al, 1991; Thomas, Studdert, Burst, et al., 2000). These scientists found that preventable errors are

significantly more common in emergency departments (EDs) with prescribing errors most common in pediatric emergency departments.

Kozer et al. (2002) explored the incidence and type of drug errors in pediatric medicine to determine the factors associated with the risk of errors. A retrospective cohort study of the charts of 1532 children treated in the pediatric tertiary care ED was performed in 2000. Two independent pediatricians decided whether a medication error occurred and ranked errors according to severity. These investigators found errors in prescribing in 10.1% of the charts. Variables associated with an increased proportion of errors in univariate analysis were: patients seen between 4 AM and 8 AM, patients with severe disease, and medication ordered by a trainee, and patients seen during weekends. Among trainees, there was a higher rate of errors at the beginning of the academic year. Logistic regression also revealed increased risk for errors when a medication was ordered by a trainee, and in seriously ill patients. Extrapolating, to a 1-year period, Kozer et al. (2002) approximated 50, 000 children are treated annually at the Hospital for Sick Children ED. An estimated 5000 children each year might be exposed with possibly 2500 subjected to significant errors.

Sharek et al. (2006) conducted an extensive project to develop and test a NICU-specific trigger tool to identify both ADEs, as well as AEs. Recognizing that NICU patients are at high risk for AEs and ADEs, these scientists aimed to (1) develop and test a NICU trigger tool for the detection of AEs, (2) determine rates of AEs in NICUs in North America, and (3) identify frequent AEs in NICUs to assist in the development of strategies to prevent harm in NICU patients. They selected trigger methodology, based on reports of superior performance to voluntary reports and conventional chart review to

identify AEs in hospitalized adult patients. Trigger was defined as the occurrence of or flag found on review of the medical record that ‘triggers’ further investigation about the presence or absence of an adverse event. Studies (Takata, Mason, Taketomo, Longsdon, & Sharek , 2008; Rozich, Haraden, & Resar, 2003; Resar, Rozich, & Classen, 2003; Rozich, Haraden, Smithson, Simmonds, & Resar, 2006) using the trigger methodology identified AE rates 50 times higher than hospital-based reporting strategies and identified ADEs in high-risk patients at a rate 20 per 100 patients.

Sharek et al. (2006) randomly selected 50 patients from each site with a minimum 2-day NICU stay. Adverse events identified were evaluated for severity, preventability, ability to mitigate, ability to identify the event earlier, and presence of associated occurrence report. Results reported (Sharek et al., 2006) reviewing 749 charts from 15 NICUs, 2218 triggers or 2.96 per patient, and 554 unique adverse events or 0.74 per patient were flagged. The positive predictive value of the trigger tool was 0.38. Adverse event rates were higher for patients <28 weeks’ gestation and <1500 g birth weight. Fifty-six percent of all adverse events were preventable. Only 8% of adverse events were identified by existing hospital reports. The most common adverse events identified were nosocomial infections, catheter infiltrates, and abnormal cranial imaging. Sharek et al. (2006) concluded using the trigger tool; adverse event rates in the NICU setting are substantially higher than previously detected.

Traditional Nursing Medication Administration

An integral part of the educational preparation of nursing students is instruction on the safe procedure for medication administration. Students are tested frequently on medication administration, supervised in the clinical setting, and must demonstrate competence safely administering medication. In practicality, a focal point for nurses in

practice is the safe administration of medication to the patient. The traditional method and standard of practice for professional nurses is the “Five plus Five Rights” of drug administration. The traditional five rights of safe administration are (1) the right client (2) the right drug (3) the right dosage (4) the right time, and (5) the right route. Additional steps were added to the original rights the “plus five” rights that are considered essential for safe administration. These rights include; (1) the right assessment (2) right documentation (3) client’s right to education (4) the right evaluation and (5) the client’s right to refuse (Kee, Hayes McCuiston, 2006).

Safe patient medication administration in a hospital system is a combined effort of healthcare professionals. There are multiple steps in the process before the medication is administered to the patient at the bedside. At any stage in the process from; prescribing, transcribing, dispensing, preparing, to administering medications to the patient at the bedside, and monitoring effects of medications, errors can occur. In order to address the problems with medication errors in hospitals, the entire medication administration process is a system within the hospital and proper interventions need to be implemented at a system level as well as at the individual performance level of professional such as physicians, nurses, and pharmacist. However, at any stage within the system of safe medication administration process interventions are warranted. A description of the current technological systems that exist to seek solutions to common medication errors is presented in the following section.

Technology to Prevent Medication Errors

Nurses play a crucial role in the implementation of change within the healthcare system. During an interview (L. Leape, personal communication, 2004) with Peter

Buerhaus, Professor of Nursing and Senior Associate Dean for Research, at Vanderbilt University, Dr. Leape commented on the profession of nursing and healthcare reform.

“When the idea of "needing to change the systems rather than just focus on individuals" was first brought forward, the group that understood this quickest was nurses. ... Nurses are on the front line and see their own mistakes as well as those of others. Patient safety is not an abstract problem to them. No nurse wants to hurt a patient, and no nurse wants to make a mistake nurses particularly, that understood the broad implications and the power of changing the approach to that of redesigning systems” (p. 368)

Research conducted by Casalino et al., (2003) confirms earlier reports by the IOM (2000, 2001, and 2007) that the quality of healthcare in the U.S. falls short of current biomedical knowledge and this chasm was more about organizations than practitioners. In an effort to investigate the actual implementation of computerized case management programs (CMPs), this research group discovered that in over 2000 practice groups employing independent practitioners, the utilization of organized healthcare management systems and processes were relatively uncommon. Strongly supporting the development of healthcare information technology Casalino et al. (2003) points out:

“Although information collection, processing, communication and management are at the heart of healthcare delivery, and considerable evidence links the use of clinical information technologies to improvements in the quality, safety, and patient-centeredness of care, the healthcare sector remains woefully underinvested in these technologies.” (p. 24)

An example of the chasm between knowledge and practice, relevant to this study was the apparent lack of research by engineering specifically targeting medication systems despite the empirical evidence documenting the scope of the problem medication errors. A recent study by Mazur (2008) investigated the medication delivery systems of a local 89 bed hospital. Utilizing a mixed method design, nurses and student nurses participated in this study. Mazur (2008) explored the efficiency, productivity of workflow and management sources of medication errors to help support decisions about investing in strategies to reduce medication errors. Mazur (2008) suggested using systems theory and nursing vigilance to resolve the current medication error rates. Implications for future research include healthcare organizations starting with frontline professionals and encouraging the expectation that it is everybody's job to improve the process. According to Mazur (2008) the role expectation with respect to medication error reporting, analysis and improvements should be well communicated, supported by managers and administrators to all frontline employees and continuously evaluated.

Research provides evidence that nurses feel pressured about productivity and this pressure exerted on nurses contributes to medication errors (Leape, 1995, Cohen, 2000; IOM, 2001, Buchanan et al., 1991; Flynn et al., 2003). The most common types of dispensing errors or near misses are attributed to workload and staffing, distractions during processing, inadequate packaging and labeling, poorly designed work areas, and outdated or incorrect drug reference information. In a structured questionnaire of medical-surgical nurses ($N = 784$), Pertinent research (Aiken and Patrician., 2000; Aiken et al., 2001; Aiken et al., 2002) related to medication administration revealed that a large proportion of nurse's time was spent on performing housekeeping duties, and ancillary

services such as transporting patients. An estimated 35% of the nurse's time, even during medication administration was interrupted (Hillsden & Fenton, 2006).

Leape (2004) asserted that information technologies could improve productivity, quality, patient safety and satisfaction, as technology has improved similar human service businesses. Information technology has a priority and fully acknowledged as an integral member of the healthcare system. Technology does not involve just computers and equipment but techniques and procedures used by healthcare professionals, and human-technology interactions should be incorporated into healthcare technology research.

A (2008) handbook published by ARHQ for nurses encouraging nurses to assume a leadership role. Despite information technologies being a relatively new field of inquiry, in patient safety and quality, the need to improve patient quality and safety is the responsibility of all clinicians, providers, leaders and managers (Hughes, April 2008). The following section is a review of the use of computer-based clinical decision support systems technology for health professionals.

Clinical Decision Support Systems

CDSS are automated tools to support clinical decision making and improve the outcomes of the decisions. These tools are capable of processing a tremendous amount of data contained in information systems (Saba & McCormick, 2006). Due to the complexity of the healthcare system there is an increasing need for accessible information systems that address best practice to promote clinical decisions, and facilitate effective and safe patient care. A basic definition offered by (Saba & McCormick, 2006, chap. 10) CDSSs as any computer program that helps healthcare providers access information and make clinical decisions. Holyroyd, Bullard, Graham, & Rowe (2007) simply defined CDSS as a system to aid directly in clinical decision making by using specific

characteristics of the individual patient which then generates patient specific recommendations.

Considering the information explosion in the last ten years, it was impossible for healthcare professionals to keep up with the latest advances in healthcare “in their heads”. According to Saba & McCormick (2006) the numbers of drugs alone have increased 500% in the last ten years and over 20,000 new articles are published in biomedical literature every year. Nurses have identified the need for a tool at the point of patient care that is accessible, reliable, evidenced based data information, rapid response, user friendly, and an integrated system. This need is yet to be realized. The three main purposes of a CDSS are: (1) assist problem solving, (2) support not replace clinical judgments, (3) and improve the effectiveness of decision-making. Saba & McCormick (2006) also point out that healthcare agencies more recently have learned that combination systems are of optimal value to the hospital. Key functions of the CDSS are outlined by Saba & McCormick (2006) as: (1) administrative, (2) management of clinical complexity, (3) cost of control, and (4) decision support. The knowledge based system was the focus of this study.

Further classifying CDSS, Saba, & McCormick (2006) divided the systems into data based: population-based, model-based (case based), knowledge-based (rule-based), and graphics-based systems. The authors define population based models as a fundamental input in an intelligent system that provides decision support from a population perspective using longitudinal data, cohort, cohort and cross-sectional databases. A model base DSS manipulates statistical, financial and or simulated models. The models may be pathophysiology, statistical or analytic. Knowledge based systems

rely on expert knowledge that was embedded or accessible from another source. It was used to capture the cognitive processes of healthcare providers and represents what was known as evidence-based practice or knowledge based decision support. Saba & McCormick (2006) also describe a new system called evidence adaptable CDSS that is maintained and constantly updated with the most recent information. The final classification as described by the authors was called a graphics-based system which uses cues for the user such as graphs, color or data visualization. The implementation of the CDSS was the focus of this research therefore the following review focuses on the knowledge-based CDSS.

Since the release of the IOM reports (2000, 2001, and 2007) there has been an increasing demand for access to “best practice” at the point of care. To address the deficiencies and errors in care, healthcare organizations turned to clinical decision support systems to provide access to patient-specific assessments or recommendations to support clinical decision making (Kawamoto, Houlihan, Balas, & Lobach (2005). CDSS systems have the capacity to respond to and critique or change orders, assist in “tasks” that are prone to human error, such as calculations, decision trees, diagnosis and management tools just to name a few. These systems have demonstrated an improvement in prescribing, and reducing serious medication errors and improving adherence to standards of care. Compared to other systems CDSS were more effective in clinical practice (Kawamoto, Houlihan, Balas, & Lobach, 2005; Mahoney, Berard-Collins, Coleman, Amaral, & Cotter 2007; Stevenson, Barbera, Moore, Samore, & Houck, 2005; Cobos et al., 2005; and Toth-Pal, Wardh, Strender, & Nilsson, 2008).

A review of current data-based empirical studies published from 1999 to 2008 is presented in Figure 1. Questions explored through this review and the 19 studies selected pertained to 1) implementation of CDSS technology to prevent medication errors, 2) the type of setting studied 3) the sample and data source 4) the results of the effectiveness or use of technology. Articles were selected based on the analysis of the stated content. In addition due to the limited empirical data on CDSS systems implementation, additional articles relevant to this study were selected from CPOE systems and point of care technology.

Of the 19 general population studies reviewed, one study conducted by Alexander (2008) investigated the use of CDSS system to track the frequency of alerts and triggers to signal patient distress or conditions. Important evaluative data was collected noting the most common trigger in the nursing home setting was dehydration (32.5% at one facility and 29.8%) at another clinical site included in the study. Additional information collected included the incidence of constipation occurring (21.1% of the time and (32% for skin integrity), alerts and improved condition were the second most commonly reported trigger (23% and 24% respectively). The ability of the CDSS system to collect patient condition data could provide valuable information useful to project patient care needs.

Investigating the use of CDSS on diagnostic outcomes, Bergman & Fors (2008) compared the CDSS to pencil paper diagnosis with a psychiatric patient population. No major differences were found and a significantly shorter time was found for paper verses pencil. The CDSS was not as accurate for Depression and yielded fewer correct diagnosis.

Recognizing the human-computer interaction involved in the implementation of technology, researchers have investigated the opinions and attitudes of the users. Toth-Pal et al. (2008) explored the influence of CDSS on general practitioners' management of congestive heart failure. Based on an internet questionnaire, physicians rated their confidence level in the CDSS for diagnosing, a change in prescription medication due to the CDSS, and support received. Reviewing 48 cases, 25% reported confidence in the diagnosis, information searching by CDSS was reported 31% of the time, 10% reported a change in prescribing, and 35% of the cases were reported as substantial confidence in CDSS. In another study exploring risk attitudes of nurses at a national telephone assessment service in Scotland using the CDSS, O'Cathain, Munro, Armstrong, O'Donnell & Heaney (2007) reported no evidence of a change in decision making from using the CDSS to refer patients to a service or recommend self care was noted. Wheeler (2007) interested in the use of point of care technology by practitioners, surveyed 119 physicians. Physicians were asked to rank their preference and list the top three choices of references to answer questions from the patient. Of the 199 physicians that responded to the survey, the most 28% preferred electronic references for clinical information with 13% preferring journals. The most preferred electronic references were UpToDate at 26% and PubMed at 16%.

Further investigation into the human-computer interactions using a qualitative approach, Weber (2007) explored the effects of CDSS on medication safety in a multi-hospital setting. Interviewing 23 advanced practice nurses, 13 clinical nurse specialists, and 10 nurse practitioners 5 core variables emerged; system learning, understanding the technology, creating inferences from the data, comparing system derived data, and levels

of trust in the system derived data. Practitioners were able to forecast client outcomes this was the main intent of implementing the system.

Safety was of paramount concern to practitioners during the entire process of medication administration, particularly with the implementation of new technologies. Cognizant of the potential problems a new system might pose, Mahoney et al. (2007) investigated the effects of an integrated clinical information system with both CPOE and CDSS on medication safety in a multi-hospital setting. Reviewing pre-implementation orders (1,452,346) and post-implementation (1,390,789) a significant effect reducing prescription error rates were demonstrated for three of the four indicators, allergy detection reduced from (833 to 109), and excessive dose from 1341 to 871). Unclear orders from 1976 to 663). The fourth indicator therapeutic duplication from (665 to 584) was not significant. The results are promising for the future to improve patient safety and medication administration. Ray et al. (2006) conducted an assessment of psychometric characteristics of a PDA with a sample of 82 internal medicine residents in an ambulatory care setting. The evaluation of the characteristics of the PDA demonstrated that the scale was both reliable and valid and can be used to guide future research using handheld DSS development.

Pertinent to patient safety, although not a CDSS the implementation of a CPOE system was investigated to determine errors. Koppel, Metlay, Cohen, Abaluck, & Localio (2005) surveyed 261 healthcare providers in a 750 bed hospital and identified 22 types of medication errors facilitated by the integration of CPOE. The relevance to this study was a caution to researcher to glean more than quantitative data in protecting the public when

it comes to large implementation projects. The use of multiple qualitative and survey methods identified error risks not previously mentioned in the literature.

More directly exploring the CDSS system, Stevenson et al. (2005) tested the practitioners' confidence level, and evaluated the usefulness of an antimicrobial trial prescribing support system. Compliance with the prescribed protocols varied from 0 to 71%, and statistical significance was demonstrated for 2 performance measures, the agreement with all CDSS recommendations and agreement with dosing. Adverse clinical outcomes were not statistically significant with the implementation of the CDSS. What was promising was the confidence level in the technology for future practitioners.

Three studies queried the cost effectiveness of CDSS (Cobos et al., 2005; McMullin et al., 2004; and Carter & Cox, 2000). Cobos et al. (2005) studied the management of hypercholesterolemia; patients in the intervention group with the CDSS were prescribed less medication than the control with no difference in impact on lipid levels thus inducing considerable savings. McMullin et al., (2004) demonstrated a significantly lower prescription costs with the CDSS intervention with a reported 6 month \$450.00 savings, and (Carter & Cox, 2000) reported similar results which resulted in a \$1, 030 saving per month for psychiatric patients.

Studies researching the effectiveness of the CDSS on patient outcomes and support for client care are (Kawamoto, Houlihan, Balas, & Lobach, 2005; Johnston et al., 2004; Hetlevik, Holmen & Kruger, 1999). Encouraging results were reported in all of these studies. Kawamoto, Houlihan, Balas, & Lobach (2005) found significant improvement in clinical practice in 68% of the trials. Johnston et al. (2004) in a study of medical students' use of personal digital assistant (PDA's) discovered although the

results were mixed, mean scores for usefulness of the PDA were given a (3.9 out of 6).

Utilization in the clinical setting was low, and perceived usefulness was associated with supportive faculty attitudes and greater knowledge of computers skills which resulted in increased use.

In a systematic review of the literature conducted by Bergman & Fors (2008) of the use of health information technology (HIT) to improve systems in hospitals, the authors concluded that the overall use of HIT had these benefits: increased adherence to guidelines for care, increased surveillance and monitoring of patients, yet had mixed effects for medication errors, and mixed effects on time utilization. The effect of HIT, CDSS or any electronic systems on nursing practice will have a tremendous impact.

The broad term electronic health record (EHR) was defined by AHRQ (2008) as a real-time, point-of-care, patient-centric information resource. In addition, EHR has been defined as a longitudinal electronic record, containing data from various care settings and encounters. The EHR contains patient information; orders, medications, past medical history, base line data, notes, laboratory results, and radiology reports, among other things. In essence the electronic record is an electronic individual medical historian. The electronic medical record and EHR are used interchangeably in the literature (Hughes, April 2008).

Understanding the electronic management of the many phases of the administration of patient medication, through the electronic medical record (EMR) is imperative because the effect on nursing practice promises to be substantial. In fact, according to Staggers, Weir, & Phansalkar (2008) a national agenda initiated by President Bush called for implementation in the next ten years of EHR systems to HIT. Also,

supporting this technology transition, AHRQ (2008) published an online handbook for Nurses, *Patient Safety and Quality: An Evidence-Based Handbook for Nurses*. A complete review of literature, future directions and recommendations for future research are presented in the handbook.

Broselow-Luten Color Coding Kids

A description of the Broselow – Luten Color Coding System is presented.

Traditional standards of education and nursing care for pediatric patients involved the memorization of countless medications, medication math calculations, determining the preparation of accurate dosages, side effects, modes of administration, and drug-drug interactions just to name a few. Is it any wonder that the most rampant errors in the acute care hospitals are medication errors? Adding to an already unmanageable task of gross quantities of data memorization, the acute care environment involves managing high anxiety states for the healthcare providers as many nurses see critically ill children or pediatric trauma patients only on a rare, if not very rare, basis. Seeking solutions as a practicing emergency department physician, Dr. Broselow developed a standardized system for the emergency treatment of pediatric patients. (Vital-signs Inc, 2008)

A historic, current and future review of the system was presented by DeBoer, Seaver, & Broselow (2005). The Broselow Color-Coded tape was introduced in 1986. The idea was based on a simple concept rather than the traditional method using weight and age to calculate dosages, the Broselow tape color-coded resuscitation packs and crash carts containing medications. The Broselow tape was initially designed to assist clinicians in the quick and accurate estimation of weight in cases of pediatric trauma. Recently it was used to guide clinical decisions by color coding for determining equipment sizes and

medications. Every pediatric chart was labeled, each piece of equipment from stretchers to arm bands and medication vials (Vital-signs Inc, 2008).

At a glance the nurse can ascertain the correct equipment, treatment decision, and dose and baseline normal values by color zone. The CCK system was designed to be integrated into pharmacy and hospital systems. Supporting national recommendations, the parents can also track the safety of their child by accurate color zones. According to DeBoer, Seaver, & Broselow (2005) with pharmacy services incorporated into the color-coding program, an order can be made, for a drug identifying the correct weight range of the patient without confusion between pounds and kilograms. Many common medications, from Tylenol (acetaminophen) and antibiotics to biological warfare antidotes are now being color-coded. Color coding was also used for information to support clinical decision making. All doses are pre-calculated not only in milligrams (mg), but also in terms of the milliliters (ml) of a standard concentration and infusion rates where applicable. Everything from syringes, resuscitation medication boxes, infusion bags have rainbow labels. The pre-calculation of medication dosages has allowed the development of simplified therapeutic algorithms which address a wide variety of pediatric emergencies (DeBoer, Seaver, & Broselow, 2005).

The researcher presented information about studies pertaining to medication errors in the appendices. The results are summarized in the following tables; Table 1 *Studies of CDSS implementation*, Table 2 *Pediatric studies of computer support systems* and, Table 3 *Literature pertaining to the Broselow Luten Color Coding Kids System*.

CHAPTER 3: METHODOLOGY

The purpose of the researcher was to compare the effectiveness of traditional nursing medication administration with the Color Coding Kids system in an effort to reduce pediatric medication errors using a sample of undergraduate nursing students. A simulated pediatric rapid response scenario was designed and implemented with student nurses in the last semester of their undergraduate nursing education program. In this chapter, the researcher presents the methods of this study. The research design and procedures for the protection of human subjects are presented. The research procedures, research participants, data collection procedures, the plan for data analysis and statistical testing are presented according to the research questions.

Overview

Seeking to obtain information about the effectiveness of the CCK system a simulated pediatric emergency scenario was selected for the trial to eliminate the risk of harm to patients. The simulated pediatric rapid response scenario was designed and implemented utilizing a high fidelity manikin in a simulated hospital room located at a community college simulation hospital and a university nursing skills lab. Student nurses in local programs in the Piedmont and Foothills areas of North Carolina enrolled in the last semester of their undergraduate nursing education program were recruited. In order to simulate an actual rapid response scenario, the selection of the case study scenario was in consultation with Dr. Robert Luten (Luten October, 10, 2008) was based on a recent

pediatric case in the emergency department. Dr. Luten provided the data for the case study used in the simulation. Identifying information was changed to ensure confidentiality of patient information.

Research Question and Hypotheses and Procedures

The analyses of the data are presented based on the researcher's interpretation of the hypotheses. The research question that guided this research and subsequent hypotheses are as follows:

Will nursing students in the experimental group using the CCK method of medication administration perform more efficiently, present better workflow turnaround times and demonstrate better hand- off communication than the nursing students in the control group?

Null Hypotheses

1. There is no significant difference between the mean scores on safe medication administration for the nursing students who received the CCK treatment and nursing students using the traditional method of safe medication administration.
2. There is no significant difference between the mean scores on handoff communication for the nursing students who received the CCK treatment and nursing students using the traditional method of medication administration.
3. There is no significant difference between the mean scores on workforce turnaround time for the nursing students who received the CCK treatment and nursing students using the traditional method of medication administration.

Sample and Setting

This study was conducted at a regional simulation hospital located in a metropolitan area in the foothills of North Carolina and an urban nursing school simulation lab in North Carolina. The criterion for inclusion in the convenience sample was: 18 years of age, volunteer undergraduate registered nursing student, currently enrolled in a nursing program and preparing to graduate in May 2008, in the last semester of the nursing program. Students that rotate through simulation as a part of clinical experiences were invited to participate. The primary investigator explained the study and obtained signed informed consent for inclusion in the study. All students were reassured of anonymity and participation or refusal to participate was anonymous and did not affect their grades or clinical progression.

Procedure for Data Collection

Volunteer nursing students, scheduled for simulation clinical, completing informed signed consent were randomly assigned to the experimental or control groups. Participants were selected from associate degree and baccalaureate students in North Carolina. A sample of 68 students, 34 participants in each group was selected for the study. The participants were informed and agreed to treat the simulation event as a real life rapid response scenario and keep the information in the scenario confidential to control for cross-contamination of information between groups. All equipment and materials necessary for the rapid response scenario were available and simulated as closely to the hospital environment as possible. All participants experienced the identical pediatric rapid response scenario. The dependent variables in this study were representative of three tasks inherent in the administration of medication; safe

administration, time to perform the task, and the accuracy of the completion of documentation as evidenced by the handoff communication. Safe medication administration was measured using the MEDCHECK sheet measuring the completion of the 5 plus 5 rights of medication administration. The dependent variable, workflow turnaround time, was the time spent from the minute the nurse accepts the care of the patient to the completion of the documentation and transfer of the patient. The dependent variable handoff communication was measured by the SBAR.

Procedure for Data Collection

Two expert nurse educators trained as observers collected the data while observing the student participant during the simulated medication administration scenario. Observers independently scored the MEDCHECK tool. Results were tallied individually per participant by the observers and compared to establish inter-rater reliability.

The results of the independent variable; experimental and control groups were tallied and the variances between the two groups on the dependent variables, medication administration, workflow turnaround time, and handoff communication were analyzed using multivariate analysis of variance (MANOVA).

Procedure for Scenario

A nurse educator read the initial shift report using the SBAR format for a new admission. The two observers began timing the participants upon completion of the patient assignment and report. The scenario ended upon completion of the participant's submission of the SBAR and handoff report the observers then stopped the clock. Each participant's time was recorded in minutes. During the simulation, the nurse educator observed and completed SBAR and MEDCHECK for each participant. The

MEDCHECK and SBAR were scored by the investigator observers using the instrument rubrics contained in the (APPENDICES D and E).

Experimental Group Implementation of the (Broselow-Luten CCK System)

Procedure:

1. Investigator obtained signed voluntary consent for participation. All participants were informed of confidentiality of information.
2. Each participant completed a sociodemographic questionnaire.
3. Each participant in the experimental group was given a screen shot of the Broselow –Luten Color Coding Kids Hospital System. The principle investigator instructed each participant on the use of the medication system and walked each participant through a sample 3 minute tutorial. All participants were informed that the scenario involved a pediatric patient.
4. All participants were informed that they could withdraw from the study at any point without any penalty.
5. All participants agreed to treat the simulation as a real life event.
6. The participants were informed by the physician actor when to transfer the patient and report off.
7. The scenario ended with submission of the SBAR, MAR and report to transfer care to the next nurse.
8. The following information was read to each participant with a patient room assignment. Each participant was informed they were to perform as the nurse.

9. Each participant was introduced to the observers and physician for assistance in the scenario. Each participant was oriented to the hospital room and location of the medication carts and nursing unit.
10. The following information was reported to each participant. A 12 month old Caucasian female weighing 10 kilograms was just admitted to the Pediatric unit directly from the physician's office. She is accompanied by her mother who is with her at the bedside. The admitting diagnosis is a fever of unknown origin. Her vitals on admission are (P = 166, R= 24, T 106.6, O2 saturation 100% on room air). The physician just arrived and is at the nursing station and has not seen the baby. The only order so far is an IV just started in her right antecubital space of D5 and 50% saline running at 43 milliliters per hour.

Simulation: A high fidelity infant simulator (Laerdal) was used in a private room and bed in a simulated nursing unit. A chair for the mother, a medication cart, stocked, reference material, calculator, pen, and paper, nursing station with a physician, located outside the private room. A simulated oxygen cannula and outlet was present in the room. The simulator was programmed to cry then began grunting with seesaw movements of the chest ... Mother calls for help.

Case Scenario:

A 12 month old Caucasian female was just admitted to the Pediatric unit from the physician's office. She is accompanied by her mother. The admitting diagnosis is a fever of unknown origin.

1. Timing of scenario began when the mother calls for help. Mother (actor) informs participant that the child stopped breathing and began jerking and

shaking and drooling. (The infant simulator is programmed to seizure activity and vital signs read on arrival the patient is intermittently seizing.

2. On exam the patient is pink and well perfused and intermittently having generalized tonic and clonic seizure activity. The child is unconscious.
3. The physician was seated at the nursing station writing orders.
4. Mother states: “Is my baby going to die? I thought she just had a bad cold?”
5. Observers recorded the amount of time in minutes that it took for the students to call for help.
6. Once the physician was notified the diagnosis was stated aloud “status epilepticus” and provided the following orders.
7. Give Lorazepam seizure dose (.1 milligram per kilogram IV).
8. Patient did not improve and physician ordered Dilantin (phenytoin) 15 mg per kilogram IV.
9. Physician orders a transfer to the intensive care unit (ICU). Participant was instructed to document on the SBAR and handoff report to ICU nurse.
10. Time clock was stopped after participant reports off and the submission of completed documentation.

Control Group (Traditional Medication Administration)

Procedure:

1. Investigator obtained signed voluntary consent for participation. All participants were informed of confidentiality of information.
2. Each participant completed a sociodemographic questionnaire.

3. Calculation books, formulas and pediatric textbooks will be available for review for traditional medication administration.
4. All participants were informed that they could withdraw from the study at any point without any penalty.
5. All participants agreed to treat the simulation as a real life event.
6. The participants were informed by the physician actor when to transfer the patient and report off.
7. The scenario ended with submission of the SBAR, MAR and report to transfer care to the next nurse.
8. The following information was read to each participant with a patient room assignment. Each participant was informed they were to perform as the nurse.
9. Each participant was introduced to the observers and physician for assistance in the scenario. Each participant was oriented to the hospital room and location of the medication carts and nursing unit.
10. The following information was reported to each participant. A 12 month old Caucasian female weighing 10 kilograms was just admitted to the Pediatric unit directly from the physician's office. She is accompanied by her mother who is with her at the bedside. The admitting diagnosis is a fever of unknown origin. Her vitals on admission are (P = 166, R = 24, T 106.6, O2 saturation 100% on room air). The physician just arrived and is at the nursing station and has not seen the baby. The only order so far is an IV started in her right antecubital space of D5 and 50% saline running at 43 milliliters per hour.

Simulation: A high fidelity infant simulator (Laerdal) was used in a private room and bed in a simulated nursing unit. A chair for the mother, a medication cart, stocked, reference material, calculator, pen, and paper, nursing station with a physician, located outside the private room. A simulated oxygen cannula and outlet was present in the room. The simulator was programmed to cry then began grunting with seesaw movements of the chest ... Mother calls for help.

Case Scenario:

A 12 month old Caucasian female was just admitted to the Pediatric unit from the physician's office. She is accompanied by her mother. The admitting diagnosis is a fever of unknown origin.

1. Timing of scenario began when the mother calls for help. Mother (actor) informs participant that the child stopped breathing and began jerking and shaking and drooling. (The infant simulator is programmed to seizure activity and vital signs read on arrival the patient is intermittently seizing.
2. On exam the patient is pink and well perfused and intermittently having generalized tonic and clonic seizure activity. The child is unconscious.
3. The physician was seated at the nursing station writing orders.
4. Mother states: "Is my baby going to die? I thought she just had a bad cold?"
5. Observers recorded the amount of time in minutes that it took for the students to call for help.
6. Once the physician was notified the diagnosis was stated aloud "status epilepticus" and provided the following orders.
7. Give Lorazepam seizure dose (.1 milligram per kilogram IV)

8. Patient did not improve and physician ordered Dilantin (Phenytoin) 15 mg per kilogram IV
9. Physician orders a transfer to the intensive care unit (ICU). Participant was instructed to document on the SBAR and handoff report to ICU.
10. Time clock was stopped after report off and submission of completed documentation.

Observer Training Worksheet

1. Researchers were introduced to participants during orientation. The participants were informed that observers would not respond to them during the scenario. (verbally or non-verbally)
2. Researchers complete IRB online tutorial at UNCC.
3. Researchers were supplied with: a 30 minute orientation by investigator, copy of study case scenario for review before the scenario, stop watch, *and* pencil.
4. MEDCHECK scoring sheet and rubric.
5. SBAR score sheet and rubric.

Research Design

A prospective randomized controlled experimental research study was designed to evaluate the effects of the implementation of a standardized pediatric medication hospital system, CCK to the traditional pediatric medication administration process, in a simulated pediatric rapid response scenario. Effectiveness was evaluated using observation, medication calculation, administration, work flow turnaround time, and hand-off assessment documentation and report. Efforts to employ a multidisciplinary team as suggested by the AHRQ (2008) were implemented through close consultation

with nationally renowned emergency pediatric physicians, Drs. James Broselow and Robert Luten.

Participants were randomly assigned to a treatment or control group. Each nursing student participated in one simulated rapid response stabilization event. Participants completed a demographic questionnaire including age, gender, ethnicity, years of education completed, and type of school of nursing attending. No identifying information was used and all participants were given a code number. Demographic survey data was coded and stored in a locked cabinet. The key outcome measures were the effectiveness of the medication administration process evaluated by performance on the following tasks; (1) proper identification of the patient, (2) accurate transcription, (3) the right drug selected, (4) the right dosage, (5) the right time, (6) the right route, (7) the right assessment, (8) the right documentation (MAR), (9) the right evaluation and (10) education of the family.

Instruments

A sociodemographic sheet was completed for each participant containing age, gender, ethnicity, years of education completed, and type of nursing school attending. The SBAR was used to gather data about handoff communication while observing participants administering medication and scoring the MEDCKECK list. The measure was prepared by the researcher according to the traditional steps of medication administration procedure called the 5 plus 5 rights as described previously. (Appendix D) Face validity of the tool was evaluated by two nurse educators for comprehensiveness and ease of documentation. The tool was developed and adapted from the skills check sheet pharmacology text (Kee, Hayes, & McCuiston, 2006).

The SBAR was used to determine the quality of hand off communication. The SBAR tool was developed by Michael Leonard, MD, at Kaiser Permanente of Colorado, and has been increasingly adopted by several hospitals through the United States and supported by JCAHO for accreditation of hospitals. Face validity has been substantiated by these authoritative bodies and inspection of the content, however there was a paucity of empirical research.

According to JCAHO (2006), medication errors reviewed from 1995 to 2005, of the 2537 sentinel events in general hospitals, the root cause analysis revealed an overwhelming majority, 70% of untoward events involved communication failure. The clinical environment has evolved beyond the limitations of individual performance, the SBAR tool was developed to reduce communication errors related to medication administration. The Institute for Healthcare Improvement ([IHI], 2007) supports the use of the SBAR in the 2007 Annual Report commenting that despite best intentions, miscommunication was the root cause of most medical errors. The SBAR was a relatively new tool in healthcare and a communication framework borrowed from the nuclear submarine service that was changing healthcare communication.

Although these two prominent healthcare authorities recommend the SBAR as the standard of practice, Rodgers (2007) addressed the lack of empirical evidence supporting the use of SBAR by conducting a pilot study using the SBAR to improve nurse-physician phone communication. The pilot was designed to implement and measure the effectiveness of the tool. Rodgers used a quasi-experimental design, convenience sample of nurses. The dependent variables were nurses' anxiety related to calling the physician and skill in communication using a survey tool. The tool was found to be internally

consistent. Total item analysis yielded p values of (0.00 and 0.002). Cronbach's Alpha scores were (0.73 and 0.73). The author cautions further testing was needed. ANOVA values showed significant differences in the nursing unit groups. Caution was noted that additional research was needed.

SBAR was used to define the components of communication necessary to hand off a patient, from one caregiver to another. Other uses for the SBAR include shift report, and frequently for quality improvement reports. An inexperienced, anxious, or fatigued nurse may omit specific important information. The primary goals of SBAR are to provide a structure for such communication. The communication model of the SBAR as described by Kaiser Permanente (2004) is:

1. *Situation*: The nurse reports a change in the patient's condition; the nurse identifies his or her name and unit, the name and room number of the patient, and the problem. The nurse describes what is happening at the present time that has warranted the SBAR communication.
2. *Background*: The nurse includes relevant background information specific to the situation. The patient's diagnosis, his mental status, current vital signs, complaints, pain level, and physical assessment findings.
3. *Assessment*: The nurse analyzes the problem. If the situation is unclear, the nurse tries to isolate the problem to the body system that might be involved and describes the problem. This assessment step is to convey more extensive data about the patient.

4. *Recommendation*: The nurse states what he or she thinks would help the situation and provides suggestions for patient care or what might be helpful to the situation.
5. The SBAR was scored by two nurse educator experts in agreement using a pre-determined rubric of correct documentation responses, to establish inter-rater reliability. Each component of the documentation, Situation, Background, Assessment and Recommendation, will be score from 0 = no documentation to 5 = complete assessment for a total of 20 possible points. Individual participant scores and experimental and groups scores will be tallied and analyzed using analysis of variance. A copy of the SBAR is contained in (APPENDIX E).

Hospital workflow is a process to accomplish, the set of people or other resources available to perform those processes, and the interactions among them (Hughes, 2008). Workflow turnaround time was measured in minutes, upon completion of the set of the medication administration tasks. In this scenario, the task was safe medication administration and accurate report and documentation during a pediatric rapid response scenario.

Data Analysis

For study variables measured at the interval level, descriptive statistics (mean, median, mode, and standard deviation) are reported. For variables measure at the nominal and ordinal level (frequencies and percentages) were reported. Preliminary data analysis included comparing the experimental and control groups on all sociodemographic characteristics. The Fisher's Exact Test which is a post hoc test for numerous means was

used to compare the groups for variables measured at the nominal and ordinal level. The *Mdn*, *M*, and *SDs* were computed for all demographic variables to describe the sample set. The data are presented in Table 2 below.

The independent variables included the experimental and control groups and the dependent variables in this study were medication administration, turnaround time, and handoff SBAR documentation. Due to more than one dependent variable and the need for corrective factors, a MANOVA was used to determine significance as related to the null hypotheses.

Description of Participants

The experimental and control groups were compared on all sociodemographic variables which included age, gender, ethnicity, and previous education. An independent *t*-test was used to assess differences between study groups. Study variables measured at the nominal level in categories were compared using the Fisher's Exact Test. A summary of the comparison of the experimental and control groups is presented in Table 2.

The sample included ($N = 68$) with ($n = 34$) participants in each group. As illustrated in Table 2, the average age for the experimental group (28 years) was not significantly different from the average age of the control (31 years) ($p = .22$). The total sample was predominately female (61) and included (7) males. There was no significant difference in the groups for gender composition with (2) males in the experimental and (5) in the control group ($p = .43$). Previous educational experience did not significantly differ between the groups with the highest education level a bachelor degree with (7) in the experimental and (5) in the control group ($p = .63$). The ethnic background in the experimental group consisted of two African-American and 31 Caucasians and one

Hispanic, participants in the and control group were two African–Americans, 32α Caucasians, and one Hispanic. The α level of $p < .01$ was used to lessen the possibility of committing s Type I error.

Table 2 *Comparison of Study Groups on Sociodemographic Variables*

Variable	Experimental (<i>n</i> = 34)	Control (<i>n</i> = 34)	Statistic (<i>p</i>)
Age in years			<i>p</i> = .22
<i>M</i>	28.76	31.21	
Median	26.50 (19	29.50 (20	
Range	- 50)	– 49)	
<i>SD</i>	8.24	8.15	
Gender			<i>p</i> = .43
Female (61)	32 (94.12%)	29 (85.29%)	
Male (7)	2 (5.88%)	5 (14.71%)	
Education			<i>p</i> = .63
GED	1 (2.94%)	3 (8.82%)	
High school	21 (61.76)	23 (67.65%)	
Associate degree	5 (14.71%)	3 (8.82%)	<i>p</i> = .99
Bachelor's degree	7 (20.59)	5 (14.71%)	
Ethnicity			
African-American	2 (5.88)	2 (5.88%)	
Caucasian	31 (91.18%)	32 (94.12%)	
Hispanic	1 (2.94%)		

Summary

The author described the purpose of this research and procedures used to compare the effectiveness of traditional nursing medication administration with the Color Coding Kids system in an effort to reduce pediatric medication errors using a sample of undergraduate nursing students. The research hypotheses and analysis of the hypotheses were explained. The sample and setting, procedure, instruments, case scenario, simulation and design were outlined. The procedure for the analysis of the data conducted was also presented.

CHAPTER 4: RESULTS

Introduction

The researcher used a randomized experimental design to examine mean differences in treatment and control conditions. Nursing students, as subjects, were recruited, interviewed and randomly assigned from local area nursing programs completing the final semester requirements for graduation and the completion of the NCLEX licensure exam in 2009. All student subjects had successfully completed the required pediatric nursing requirements and were at least 18 years of age.

Data collection processes were divided into three stages for conducting the required analyses: (a) a comparative description of the two study groups, the treatment group using the CCK system and the control group using the traditional method of medication administration; (b) preliminary data analyses; and (c) analyses used to answer the research hypotheses. Statistical findings are presented in each of these sections.

Research Question

Before conducting the major analyses, all data were screened for outliers and normality of the distribution and statistical assumptions were tested. There were no outliers detected for the MEDCHECK dependent variable. There were multiple outliers detected (5 in the treatment and 2 in the control conditions) for the SBAR and one detected for MINUTES. All the analyses were run with and without the outliers. Based on these results a decision was made to include outliers in the following analyses.

The distribution for MEDCHECK and SBAR appeared normality distributed but MINUTES was positively skewed. Because the sample sizes for each condition are equal the results should be robust for violating this assumption. Additional nonparametric statistics were calculated to verify all parametric statistics. The means, SD, and, skewness coefficients, and kurtosis coefficients for the three dependent variables are reported in Table 3.

Table 3: Comparison of Study Groups on the Three Main Outcome Variables

Variable (<i>N</i> = 68)	Experimental (<i>n</i> = 34)	Control (<i>n</i> = 34)	Statistic (<i>p</i>)
MINUTES			<i>p</i> = .72
<i>M</i>	17.18	17.65	
<i>SD</i>	6.66	5.95	
Mdn	16	16	
SBAR			
Mean	8.15	6.53	* <i>p</i> = .02
<i>SD</i>	2.31	3.26	
<i>Mdn</i>	8	7.5	
MEDCHECK			
<i>M</i>	6.35	4.38	** <i>p</i> = .0005
<i>SD</i>	2.04	2.41	
Mdn	6	4	

p* < .05, *p* < .01,

A MANOVA was conducted with the independent variable as the treatment and control conditions and the dependent variables were MINUTES, SBAR, and MEDCHECK. Using the Wilk's λ , the combined dependent variables were statistically affected by the treatment, Wilk's $\lambda = .81$, $F(3, 64) = 4.94$, $p = .004$. This indicated that there was a statistically significant difference between the conditions on a linear combination of the dependent variables. Following up using univariate F and applying Bonferroni's correction (adjusted alpha was .017), there were statistically significant difference in the means between the experimental and control groups on MEDCHECK, ($F(1, 67) = 13.21$, $p = .001$) but not ($F(1, 67) = .094$, $p = .76$) or SBAR, ($F(1, 67) = 5.57$, $p = .02$). The magnitude of differences between the groups on MEDCHECK was large ($d = .79$) indicating that the CCK condition had a much higher mean than the control condition. SBAR did not meet the stringent level of statistical significance ($p < .017$) but the magnitude of the difference was moderate ($d = .58$) and the post hoc power was .64. Using a one-tailed test, which would increase power, there was a statistical significant difference between the two groups for SBAR.

Additional nonparametric tests were used to examine the robustness of the MANOVA. Results from Mann-Whitney U tests agreed with the results of the univariate F tests, there was a significant difference between the groups on the analyses of the ranks for (MEDCHECK) (Mann-Whitney U = 318, $Z = 3.24$, $p = .001$) but not for (MINUTES) (Mann-Whitney U = 546, $Z = .39$, $p = .70$). Using a one tail test there was a statistically significant difference between the condition for (SBAR) (Mann-Whitney U = 423, $Z = 1.93$, $p = .03$).

Summary of the Findings

The purpose of the researcher was to compare the effectiveness of traditional nursing medication administration with the Color Coding Kids system in an effort to reduce pediatric medication errors using a sample of undergraduate nursing students. A simulated pediatric rapid response scenario was designed and implemented with student nurses in the last semester of their undergraduate nursing education program.

The independent variables included the experimental and control groups and the dependent variables in this study were medication administration, turnaround time, and handoff SBAR documentation. Due to more than one dependent variable and the need for corrective factors, a MANCOVA was used to determine significance as related to the null hypotheses.

It was hypothesized that the CCK condition would perform better on turnaround time, handoff communication, and safe medication administration. While the means for the CCK condition were higher on SBAR and MEDCHECK and lower on MINUTES, there were only statistically significant differences for MEDCHECK. The magnitude of difference between the conditions was large with the CCK condition having a much higher MEDCHECK mean than the control condition. SBAR did not meet the stringent level of statistical significance ($p < .017$) but the magnitude of the difference was moderate ($d = .58$) and the post hoc power was .64. Due to the moderate magnitude of the SBAR results and possibility of committing a Type II error a one-tailed test, was conducted which would increase power. Using the one-tailed test, there was a statistically

significant difference between the means of the two groups for SBAR, with the CCK condition having a higher mean than the control condition.

CHAPTER 5: DISCUSSION, CONCLUSION, AND RECOMMENDATIONS

A synopsis of the present investigation including the statement of the problem, the statement of the purpose, the research question, a description of the instruments, and the statistics used are presented by the researcher in this chapter. The conclusions are discussed; nursing implications and recommendations for future study are included.

Synopsis

Medical errors are one of the leading causes of death and injury in America. Pediatric patients are particularly vulnerable to adverse events. The problem of medication errors in hospitals and the vulnerability of pediatric patients to adverse drug events (ADEs) are well substantiated. Researchers reveal one of every five doses administered by nurses was in error. The rate for potential adverse drug events was reportedly three times higher in children, and substantially higher in the neonatal intensive care units.

Although some improvements have been made in the past 10 years, system changes are not adequate. Contributing factors to the lack of change include resistance to change by presenting barriers such as the punitive environment in hospitals, physicians' denial of the problem, lack of leadership and lack of systems thinking.

A new bedside technology the CCK system was developed to reduce errors at the point of care. The CCK system was developed from the Broselow-Luten tape using length to standardize pediatric dosages. Although there is evidence of the positive effect

of the Broselow-Luten tape in reducing weight error estimates, and improving work flow time, the need for a comprehensive assessment of the newly developed CCK clinical decision support system technology remained.

The intention of the researcher was to compare the effectiveness of traditional nursing medication administration with the Color Coding Kids system in an effort to reduce pediatric medication errors using a sample of undergraduate nursing students. This study was designed as a clinical trial to test in a simulated environment the implementation of CCK system for the nursing administration of medication in a pediatric rapid response scenario while providing a safe means of examining the effect of this hospital computer system based on the Broselow-Luten Color Coding Kids standardized medication dosages. This investigation was conducted in consultation with two nationally recognized experts in pediatric emergency care, Drs. James Broselow, and Robert Luten.

The underlying assumptions of the study were that the implementation of the CCK system may prevent or reduce the incidence of human error in the process of nursing medication administration, improve workflow time, and improve handoff communication.

Hughes (2008) proposed using simulation as an educational strategy of medication administration and errors in a controlled setting to improve medication safety, duplicate the nurse-patient interaction and related cognitive thought. Suggesting further, simulation to prepare nurses to recognize and manage medication errors when and if they occur.

Due to the need for further research exploring new technologies to reduce pediatric medication errors, an effort was made to compare the extent of the effect of the implementation of the CCK system on the safety of pediatric medication administration. In addition, the effect of the CCK system on workforce turnaround time, and improved handoff communication was measured in a rapid response simulation scenario, and compared to the traditional method of pediatric medication administration. The analyses of the data are presented according to the research hypotheses.

Research Question

The research question that guided this research and subsequent hypotheses were as follows:

Will nursing students in the experimental group using the CCK method of medication administration perform more efficiently, present better workflow turnaround times and demonstrate better hand-off communication than the nursing students in the control group?

The literature review covered the following research areas: medication errors in the acute-care hospital setting in the United States, pediatric medication errors, system efforts to develop solutions to the problem of medication errors and healthcare reform, clinical decision support technology (CDSS) and specifically the (CCK) system. The CCK system was described.

The dependent variables in this study represented three of the general tasks inherent in the administration of medication; safe administration, time to perform the task, and the accuracy of the completion of documentation as evidenced by the handoff communication. Safe medication administration was the completion of the 5 plus 5 rights

of medication administration measured by the MEDCHECK. For the purpose of this study, the dependent variable workflow turnaround time, was the time in spent from the minute the nurse accepts the care of the patient to the completion of the documentation and transfer of the patient.

The instruments used for this study were: a sociodemographic questionnaire, MEDCHECK, SBAR, and time recorded in MINUTES. A sociodemographic sheet was completed for each participant containing age, gender, ethnicity, years of education. The MEDCHECK was used to gather data for the first hypothesis while observing participants administering medication. The measure was prepared by the researcher according to the traditional steps of medication administration procedure called the 5 plus 5 rights as described previously. The SBAR was used to determine the quality of hand off communication. The SBAR tool was developed by Michael Leonard, MD, at Kaiser Permanente of Colorado, and has been increasingly adopted by several hospitals through the United States and supported by JCAHO for accreditation of hospitals. Face validity has been substantiated by these authoritative bodies and inspection by the researcher and research assistant of the content.

The SBAR tool was developed to reduce communication errors related to medication administration. The Institute for Healthcare Improvement ([IHI], 2007) supported the use of the SBAR in the 2007 Annual Report commenting that despite best intentions, miscommunication was the root cause of most medical errors. The SBAR was a relatively new tool in healthcare and a communication framework, borrowed from the nuclear submarine service, and was changing healthcare communication.

SBAR was used to define the components of communication necessary to hand-off a patient, from one caregiver to another. The primary goals of SBAR are to provide a structure for communication. The communication model of the SBAR as described by Kaiser Permanente (2004) is:

1. *Situation:* The nurse reports a change in the patient's condition; the nurse identifies his or her name and unit, the name and room number of the patient, and the problem. The nurse describes what is happening at the present time that has warranted the SBAR communication.
2. *Background:* The nurse includes relevant background information specific to the situation. The patient's diagnosis, his mental status, current vital signs, complaints, pain level, and physical assessment findings.
3. *Assessment:* The nurse analyzes the problem. If the situation is unclear, the nurse tries to isolate the problem to the body system that might be involved and describes the problem. This assessment step is to convey more extensive data about the patient.
4. *Recommendation:* The nurse states what he or she thinks would help the situation and provides suggestions for patient care or what might be helpful to the situation.
5. The SBAR was scored by two nurse educator experts in agreement using a pre-determined rubric of correct documentation responses, to establish inter-rater reliability.

Workflow turnaround time was measured by the completion of the set of tasks, grouped chronologically into processes, interacting with a set of people or resources needed to accomplish a given goal. In this scenario the task was safe medication administration in a pediatric rapid response scenario. Hospital workflow was the process to accomplish, the set of tasks during the simulation and the interactions among them.

Descriptive statistics were used to describe the experimental and control groups with regard to all sociodemographic variables. Measures of central tendency were computed on all variables measured at the interval or ratio level. With continuous measures, an independent t-test was used to assess group mean differences. Nominal and ordinal categorical data was analyzed using the Fisher's Exact Test, due to the small sample size and equal numbers in each group, to detect differences in the means of the groups.

The data were examined to determine whether they met the underlying assumptions. Before conducting the major analyses, all data were screened for outliers and normality of the distribution and statistical assumptions were tested. Because the sample sizes for each condition are equal the results should be robust for violating this assumption. Additional nonparametric statistics were calculated to verify all parametric statistics.

A MANOVA was conducted with the independent variable as the treatment and control conditions, and the dependent variables were the time in minutes of workflow turn around, handoff communication and safe administration of medication.

Review of Findings

Comparing sociodemographic variables between the experimental and control groups, the average age for the experimental group was (28) years and not significantly different from the average age for the control group. There were no significant differences between the groups on gender, ethnicity, and previous education level.

It was hypothesized that the CCK condition would perform better on turnaround time, handoff communication, and safe medication administration. While the means for the CCK condition were higher on MEDCHECK and lower on MINUTES, there were only statistically significant differences for the MEDCHECK. The magnitude of difference between the conditions was large with the CCK condition having a much higher MEDCHECK mean than the control condition. However, using a one tailed test and the related significance level, there was a statistically significant difference between the two conditions on SBAR, with the CCK condition having higher mean scores than the control condition.

The results indicated that there was a significant difference between the groups on safe administration of medication. Nursing students participating in the CCK treatment scored significantly better on safe medication administration. The magnitude of the difference was impressive with the treatment group performing significantly safer medication administration in a simulated environment. It was not surprising to find such a difference as the CCK system contains pre-calculated standardized pediatric dosages. These results support previous research by Hohenhaus, Caldwell, Stone-Griffith, Sears-Russell, Baxter, et al (2008) and Mahoney et al (2007) demonstrating improved accuracy by nurses in the administration of medication using the CCK system. However, the lack

of significance of the effect of CCK on workflow turnaround time did not support the results of a previous study by Hohenhaus, Caldwell, Stone-Griffith, Sears-Russell, Baxter, et al. (2008) reducing workflow time.

The lack of significance between the mean scores of the groups on the turnaround time variable may partially be attributed to the human computer interaction factor. This research supports a previous study by Roukema et al. (2008) that CDSS did not improve turnaround time.

An additional factor to consider was the previous student instruction about medication administration. Students were instructed in their nursing programs for several semesters on the traditional method of medication administration in nursing school. The two nurse educator investigators noted anecdotally that students often calculated the dosage in spite of the CCK system instructions. A mandatory curriculum requirement of nursing students was that they are instructed to calculate medications for pediatric patients per kilogram body weight and recheck orders before administration. An additional factor that may have contributed to the lack of statistic significance in reduced turnaround time was the lack of manual dexterity preparing medications for parenteral administration compared to the previous study using experienced nurses.

The participants' lack of familiarity with the new CCK system also led to student questions during the experimental simulated scenario such as "Is this OK to do? Aren't we supposed to calculate it and recheck?" The participants in the experimental group were all instructed to use only the CCK system during the scenario as the standard of care. Some participants were confused by the lack of difficulty with the CCK system and challenged the investigators. Three participants, cognizant of being observed, questioned,

“Is this a trick? We don’t have to calculate this?” Investigators did not respond to questioning. Another contributing factor was the urgency of the scenario. Individuals may respond differently to urgent situations based on personality factors which were not controlled for in this study.

The lack of significance between the mean scores of the groups on the handoff communication (SBAR) may partially be attributed to the position of “novice” or student nurse. Both group medians were below 50% of the items recommended in a handoff report. Participants lacked the experience and critical thinking ability of expert nurses using the tool in the acute care settings. The tool was relatively new and not standard to nursing education curriculum. All participants were familiar with the tool and lacked practice applying the instrument to clinical situations.

Conclusion

The researcher concluded that the treatment condition with the CCK system had a highly significant effect on the safe administration of medication in a simulated pediatric rapid response scenario compared to the traditional method of medication administration. No significant differences between the groups were evident on the handoff communication. Although SBAR did not meet the stringent level of statistical significance the magnitude of the difference was moderate. Using a one-tailed test, there was a statistically significant difference between the two groups for SBAR. No significant differences between the groups were evident on the workforce turnaround time. The mean scores of both groups on the SBAR suggest that another intervening variable, not measured in the present research, may be influencing these findings. For example, students verbalized uncertainty about trusting the new system CCK and

violating previous educational instructions. These findings may also reflect a limitation of the novice nurses' lack of experience using the SBAR instrument.

The results of this trial using the CCK system compared to the effectiveness of traditional nursing medication administration have important implications for nursing practice and nursing education. The safe administration of medication is the responsibility of the professional registered nurse. In light of current data presenting the many problems with medication errors, particularly with pediatric patients, the present study provides evidence of a promising technological breakthrough in the prevention of pediatric medication errors. Needlessly, precious time is often wasted in emergency, live threatening situations. Nurses are calculating medication dosages and looking for information about medications. The Broselow–Luten System provides accurate dosing and critical data for the nurse in a matter of seconds. It is not surprising that a significant improvement in safe dose administration was demonstrated in this study.

The lack of student clinical experience may have influenced the SBAR scores yielding lower total scores and influencing test results. Considering the stage of development in nursing science, measuring hospital handoff communication and the refinement of instruments measuring nursing report communication was indicated. Workforce turnaround time was not significantly impacted by the CCK treatment in this study. Evidence during data collection, was the students uncertainty related to veering from traditional medication administration. An additional consideration possibly impacting the time was the lack of manual dexterity demonstrated by students preparing medications. The impact of the human – computer interaction documented by Swenson (2008) was demonstrated during this study. The use of simulation for the education and

training of medication administration as suggested by Staggers, Weir, & Phansalkar (2008) provides a safe means of further investigation.

Recommendations for Further Study

Recommendations for further research include the continued examination of the factors that contribute to the incidence of medication errors in the acute care settings. In addition, the continued testing and use of technology and simulation to improve medication administration and nursing practice was indicated. Active participation of nurses in the research, development, transition and implementation of technology at the bedside is critical to ensure the safety of patients.

The safe administration of medications in emergency pediatric care, and the well being of children in emergent situations cannot be overstated. Given the highly significant results of this clinical research, the swift implementation of a CDSS system such as CCK should be prioritized as an industry best practice.

Research testing handoff communication tools such as the SBAR is necessary for the further development of reliable and valid communication tools to prevent medication errors and safeguard the care of patients. Developing accurate handoff communication tools and utilizing simulation as a safe testing environment provides promise for future resolutions. Replicating this study with experienced nurses in the clinical setting may provide additional information about the implementation of CCK system in the clinical setting to reduce pediatric medication errors. Best nursing practice is continual, unrelenting perseverance to eradicate preventable pediatric medication errors. The protection of vulnerable pediatric patients is the responsibility of parents, society, healthcare providers, researchers and practitioners, business and industry.

REFERENCES

- Agency for Health Care Research and Quality (2002). *Patient fact sheet: 20 tips to help prevent medical errors in children*. Retrieved online Oct 9, 2008 from ahrq.gov: <http://www.ahrq.gov/20tipkid.pdf>
- Agency for Health Care Research and Quality. Wheeler (2008). Child Health Research Findings Retrieved April 20, 2009 from www.ahrq.gov AHRQ Pub. No. 09PB001 December 2008 (Replaces AHRQ Pub. No. 07P007)
- Aiken, L. H., & Patrician, P. A. (2000). Measuring organizational traits of hospitals: The revised nursing work index. *Nursing Research*, 49(3), 146-153.
- Aiken, L. H., Clarke, S. P., & Sloane, D. M. (2001). An international perspective on hospital nurses' work environments: the case for reform. *Policy, Politics, and Nursing Practice*, 2(4), 255-263.
- Aiken, L. H., Clarke, S. P., Sloane, D. M., Sochalski, J., & Silbert, J. H. (2002). Hospital nurse staffing and patient mortality, nurse burnout, and job dissatisfaction. *JAMA*, 288(16), 1987-1993.
- Alexander, G. (2008). Analysis of an integrated clinical decision support system in nursing home clinical information systems. *Journal of Gerontological Nursing*, 34(2), 15-20.
- Barker, K. N., Flynn, E. A., Pepper, G. A., Bates, D. W., & Mikeal, R. L. (2002). Medication errors observed in 36 health care facilities. *Archives of Internal Medicine*, 162(16), 1897-1903.
- Barker, K., Flynn, E., & Pepper, G. (2002). *Archives of Internal Medicine*, 162(), 1897-1903.
- Bates, D. W., Boyle, D. L., & Vander Vilet, M. V. (1995). Relationship between medication errors and adverse drug events. *Journal of General Internal Medicine*, 10, 199-205.
- Bates, D. W., Cullen, D. J., & Laird, N. M. (1995). Incidence of adverse drug events and potential adverse drug events: Implications for prevention. *JAMA*, 274, 29-34.
- Bates, D., Miller, E., Cullen, D., Burdick, E., & Williams, L. et al. (1999). Patient risk factors for adverse events in hospitalized patients. *Archives of Internal Medicine*, 159, 2553-2559.

- Bergman, L., & Fors, U. (2008). Decision support in psychiatry - a comparison between the diagnostic outcomes using computerized decision support system versus manual diagnosis. *BMC Medical Informatics and Decision Making*, 8(9). Retrieved from <http://creativecommons.org/licenses/by/2.0>
- Brennan, T. A., Leape, L. L., Laird, N. M., Herbert, L., & Localio, A. R. et al. (1991). Incidence of adverse events and negligence in hospitalized patient. Results of the Harvard Medical Practice Study I. *New England Journal of Medicine*, 324(6), 370-376.
- Buchanan, T. L., Barker, K. L., Gibson, J. T., Jiang, J. C., & Pearson, R. E. (1991). Illumination and Errors in Dispensing. *American Journal of Hospital Pharmacy*, 48(10), 2137-2145.
- Buerhaus, P. I. (2007). Is hospital patient care becoming safer? A conversation with Lucian Leape. *Health Affairs*, 26(6), 687.
- Carroll, A., & Christakis, D. (2004). Pediatricians' use of and attitudes about personal digital assistants. *Pediatrics*, 113, 238-242. Retrieved October 10, 2008 from <http://www.pediatrics.org/cgi/content/full/113/2/238>
- Carroll, A., Tarczy-Hornoch, P., O'Reilly, E., & Christakis, D. (2004). The effect of point-of-care personal digital assistant use on resident documentation discrepancies. *Pediatrics*, 113, 450-454. Retrieved from <http://www.pediatrics.org/cgi/content/full/113/3/450>
- Carter, M. (2002). Rural nurse managers' use of a labor computer decision support system. *Nursing Economics*, 20(5), 237-243.
- Carter, M., & Cox, R. (2000). Nurse Managers' use of a computer decision support system: Differences in nursing labor costs per patient day. *Nursing Leadership Forum*, 5(2), 57-64.
- Casalino, L., Gillies, R., Shortell, S., Schmittiel, J., Bodenheimer, T., & Robinson, J. et al. (2003). External incentives, information technology and organized processes to improve healthcare quality for patients with chronic diseases. *JAMA*, 289(4), 22-29.
- Classen, D. C., Pestotnik, S. L., Evans, R. S., Lloyd, J. F., & Burke, J. P. (1997). Adverse drug events in hospitalized patients: Excess length of stay, extra costs, and attributable mortality. *JAMA*, 277(4), 301-306.
- Classen, D. C., Pestotnik, S. L., Evans, R. S., & Burke, J. P. (1991). Computerized surveillance of adverse drug events in hospital patients. *JAMA*, 266, 2847-2851.

- Cobos, A., Vilaseca, J., Asenjo, C., Pedro-Botet, J., S´anchez, E., & Val, A. et al. (2005). Cost effectiveness of a clinical decision support system based on the recommendations of the European Society of Cardiology and Other Societies for the Management of Hypercholesterolemia Report of a cluster-randomized trial. *Disease Management Health Outcomes*, 13(6), 421-432.
- Cohen, M. R. (2000). *Medication Errors: Causes, Preventions and Risk Management*, Mass: Jones and Bartlett.
- Committee on Quality Health Care in America, Institute of Medicine. (2000). *To Err is human: Building a safer health system*. (Institute of Medicine). Washington, DC: National Academy Press.
- Committee on Quality Health Care in America, Institute of Medicine. (2001). *Crossing the quality Chasm: A New Health System for the 21st Century* (Institute of Medicine). Washington, DC: National Academy Press.
- Committee on Quality Health Care in America, Institute of Medicine. (2007) *Preventing Medication Errors* (Institute of Medicine). Washington: The National Academies Press.
- Courtney, K., Alexander, G., & Demiris, G. (2008). Information technology from novice to expert: Implementation implications. *Journal of Nursing Management*, 16, 692-699.
- Davidhizer, R., & Lonser, G. (2003). Strategies to reduce medication errors. *Health Care Manager*, 22(3), 211-218.
- DeBoer, S., Seave, M., & Broselow, J. (2005). Color Coding to Reduce Errors: The Broselow–Luten System streamlines pediatric emergency treatment. *AJN*, 105(8), 68-71. Retrieved from <http://colorcodingkids.com/pdf/DeBoer-Broselow.pdf>
- Del Beccaro, M., Jeffries, H., Eisenberg, M., & Harry, E. (2006). Computerized provider order entry implementation: No association with increased mortality rates in an intensive care unit. *Pediatrics*, 118, 290-295.
- DuBois, D., Baldwin, S., & King, W. (2007). Accuracy of weight estimation methods for children. *Pediatric Emergency Care*, 22(4), 227-230.
- Ferranti, J., Horvath, M., Cozart, H., Whitehurst, J., & Eckstrand, J. (2008). Reevaluating the Safety Profile of *Pediatrics*: A Comparison of computerized adverse drug event surveillance and voluntary reporting in the pediatric environment. *Pediatrics*, 121, e1201-e1207. Retrieved from <http://www.pediatrics.org/cgi/content/full/121/5/e1201>

- Flynn, E. A., Barker, K. N., & Carnahan, B. J. (2003). National Observational Study of Prescription Dispensing Accuracy and Safety in 50 Pharmacies. *Journal of the American Pharmaceutical Association*, 43(2), 191-200.
- Flynn, E. A., Barker, K. N., Pepper, G. A., Bates, D. W., & Mikeal, R. L. (2002). Comparison of Methods for Detecting Medication Errors in 36 Hospitals and Skilled-nursing Facilities. *American Journal of Health-System Pharmacy*, 59(5), 436-446.
- Fortescue, E. B., Kaushal, R., Landrigan, C. P., & et al, (2003). Prioritizing strategies for preventing medication errors and adverse drug events in pediatric inpatients. *Pediatrics*, 111, 722-729.
- Fox, G. (1996). Minimizing prescribing errors in infants and children. *American Family Physician*, 54, 1319-1325.
- Frush, K., Hohenhaus, S., Luo, X., Gerardi, M., & Wiebe, R. (2006). Evaluation of a web-based education program on reducing medication dosing error. *Pediatric Emergency Care*, 22(1), 62-70.
- Frush, K., Luo, X., Hutchinson, P., & Higgins, J. (2004). Evaluation of a Method to Reduce Over-the-Counter Medication Dosing Error. *Arch Pediatric Adolesc Med.*, 158, 620-624.
- Gall, M., Gall, J., & Borg, W. (2007). *Educational research: An introduction* (8th ed.). (A. Burvikovs, Ed.). Boston: Allyn and Bacon.
- Gay, L.R., Mills, G., & Airasian, P. (2006). *Educational research: Competencies for analysis and application* (8th ed). Ohio: Pearson.
- Han, Y., Carcillo, J., Venkataraman, S., Clark, R., & Watson, S. et al. (2005). Unexpected increased mortality after implementation of a commercially sold computerized physician order entry system. *Pediatrics*, 116, 1506-1512. Retrieved from <http://www.pediatrics.org/cgi/content/full/116/6/1506>
- Hetlevik, I., Holmen, J., & Kruger, O. (1999). Implementing clinical guidelines in the treatment of hypertension in general practice: Evaluation of patient outcomes related to the implementation of a computer-based clinical decision support system. *Scandinavian Journal of Primary Health Care*, 17, 35-40.
- Hicks, R. W., Santell, J. P., Cousins, D. D., & Williams, R. L. (2004). *MEDMARXSM 5th Anniversary Data Report: A Chartbook of 2003 findings and trends 1999-2003* (USP Center for Advancement of Patient Safety). Rockville, MD: The United States Pharmacopeial Convention
- Hillsden, I., & Fenton, G. (2006). Improving practice and patient safety through a medication systems review. *Quality in Primary Care*, 14(1), 33-40.

- Hofer, C., Ganter, M., Klaghofer, A., & Zollinger, R. (2002). How reliable is length-based determination of body weight and tracheal tube size in the paediatric age group? The Broselow tape reconsidered. *Br J Anaesth*, *88*, 283–5.
- Hohenhaus, S. M., Caldwell, S. M., Stone-Griffith, S., Sears-Russell, N., Baxter, T., & Hicks, W. et al. (2008). Assessment of emergency nursing practice during critical pediatric medication administration in a simulated resuscitation using the “Color Coding Kids Hospital System”: A multi site trial. *Advanced Emergency Nursing Journal*, *30*(3), 233-241.
- Holdsworth, M. T., Fichtl, R. E., Raisch, D. W., Hewryk, A., & Behta, M. et al. (2007). Impact of computerized prescriber order entry on the incidence of adverse drug events in pediatric inpatients. *Pediatrics*, *120*, 1058-1066. Retrieved from <http://www.pediatrics.org/cgi/content/full/120/5/1058>
- Holroyd, B., Bullard, M., Graham, T., & Rowe, B. (2007). Decision support technology in knowledge translation. *Academic Emergency Medicine*, *14*, 942-948.
- Hughes, R. (April 2008). Patient Safety and Health Information Technology. In N. Staggars, C. Weir, & S. Phansalkar (Eds.), *Patient Safety and Quality: An Evidence-Based Handbook for Nurses*. Retrieved from <http://www.ahrq.gov/qual/nurseshdbk/nurseshdbk.pdf>
- Hughes, R. (April 2008). Patient Safety and Health Information Technology. In N. Swenson, B.R. (Eds.), *Point-of-care medication error prevention: Best practices in action*. Retrieved from <http://www.ahrq.gov/qual/nurseshdbk/nurseshdbk.pdf>
- Hunt, E. A., Hohenhaus, S. M., Luo, X., & Frush, K. (2006). Simulation of Pediatric Trauma Stabilization in 35 North Carolina Emergency Departments: Identification of Targets for Performance Improvement. *Pediatrics*, *117*, 641-648. Retrieved from <http://www.pediatrics.org/cgi/content/full/117/3/641>
- Institute for Healthcare Improvement. (2007). *OSF Healthcare System Reduces the Rate of Adverse Events from 98 to 35 per 1,000 Patient Days in Two Years*. Retrieved from <http://www.ihl.org/IHI/Topics/PatientSafety/SafetyGeneral/ImprovementStories/OSFReducestheRateofADEs.htm>
- Institute for Safe Medication Practices. (2008, October 22, 2008). *Reports of serious drug reactions set a record. FDA got 21,000 accounts, including 4,800 deaths in first 3 months of 2008* [Press release]. Retrieved from <http://www.msnbc.msn.com/id/27323056/>

- Institute of Medicine of The National Academies (2007, 2007). *Preventing Medication Errors: Quality Chasm Series* (Institute of Medicine of the National Academies). Washington: The National Academies Press.
- Johnston, J., Leung, G., Tin, K., Ho, L., Lam, W., & Fielding, R. (2004). Evaluation of a handheld clinical decision support tool for evidence- based learning and practice in medical undergraduates. *Medical Education*, 38, 628-637.
- Joint Commission on Accreditation of Hospitals. (2006). *SBAR* [PowerPoint slides]. Retrieved from http://74.125.45.104/search?q=cache:2T3fHDELfloJ:www.valleyhealth.com/pdf/preclinical/SBAR_Powerpoint.ppt+sbar&hl=en&ct=clnk&cd=2&gl=us
- Kaiser Family Foundation/Agency for Healthcare Research and Quality/Harvard School of Public Health. *National Survey on Consumers' with Patient Safety and Quality Information* (2004) (Retrieved from Kaiser Family Foundation's website: www.kff.org)
- Kaiser Foundation, (2004). *Off Unit Handoff/Report Tool* [Fact sheet]. Retrieved from http://www.medleague.com/Articles/medical_errors/sbar.htm
- Kaji, A., Gausche-Hill, M., Conrad, H., Young, K., & Koenig, W. et al. (2006). Emergency medical services system changes reduce pediatric epinephrine dosing errors in the pre-hospital setting. *Pediatrics*, 118(4), 1493-1500. Retrieved from <http://www.pediatrics.org/cgi/content/full/118/4/1493>
- Kaushal, R., Bates, D. W., & Landrigan, C. et al. (2001). Medication errors and adverse drug events in pediatric inpatients. *JAMA*, 285, 2114-2120.
- Kaushal, R., Bates, D. W., Abramson, E. L., Soukup, J. R., & Goldman, D. A. (2008). Unit-based clinical pharmacists' prevention of serious medication errors in pediatric inpatients. *American Journal of Health System Pharmacy*, Jul 1; 65(13), 1254-60.
- Kaushal, R., Jaggi, T., Walsh, K., Fortescue, E., & Bates, D. (2003). Pediatric medication errors: What do we know? What gaps remain? *Ambulatory Pediatrics*, 4(1), 73-81.
- Kawamoto, K., Houlihan, C., Balas, E. A., & Lobach, C. (2005). Improving clinical practice using clinical decision support systems: a systematic review of trials to identify features critical to success. *BMJ*. Retrieved November 4, 2008 from [PubMed]
- Kee, J., Hayes, E., & McCuiston, L. (2006). *Pharmacology: A nursing process approach*. (5th ed.). St Louis, MO: Mosby, Inc.

- Killelea, B. K., Kaushal, R., Cooper, M., & Kuperman, G. J. (2007). To what extent do pediatricians accept computer-based dosing suggestions? *Pediatrics*, *119*, e69-e75. Retrieved from <http://www.pediatrics.org/cgi/content/full/119/1/e69>
- King, J., Paice, N., Rangrej, J., Forestell, G., & Swartz, R. (2003). The effect of computerized physician order entry on medication errors and adverse drug events in pediatric inpatients. *Pediatrics*, *112*, 506-509.
- Koppel, R., Metlay, J., Cohen, A., Abaluck, & Localio, A. R. et al. (2005). Role of computerized physician order entry systems in facilitating medication errors. *JAMA*, *293*(10), 1197-1203.
- Koren, G., & Haslam, R. H. (1994). Pediatric medication errors: Predicting and preventing tenfold disaster. *Journal of Clinical Pharmacology*, *34*, 1043-1045.
- Kozer, E., Scolnik, D., Macpherson, A., Keays, T., Shi, K., & Luk, T. et al. (2002). Variables associated with medication errors in pediatric emergency. *Pediatrics*, *110*, 737-742.
- Kozer, E., Scolnik, D., MacPherson, A., Rauchwerger, D., & Koren, G. (2005). Using a preprinted order sheet to reduce prescription errors in a pediatric emergency department: A randomized, controlled trial. *Pediatrics*, *116*, 1299-1302.
- Kozer, E., Seto, W., Verjee, Z., Parshuram, G., & Khattak, S. et al. (2004). Prospective observational study on the incidence of medication errors during simulated resuscitation in a paediatric emergency department. British Medical.
- Kronman, M., Hall, M., Slonim, A., & Slonim, S. (2008). Charges and lengths of stay attributable to adverse patient-care events using pediatric-specific quality indicators: A multicenter study of free standing children's hospitals. *Pediatrics*, *121*, e1653-e1659. Retrieved from <http://www.pediatrics.org/cgi/content/full/121/6/e1653>
- Kuperman, G. J., Bobb, A., Payne, T. H., Avery, A. J., Gandi, T. K., & Et al., et al. (2007). Medication-related clinical decision support in computerized provider order entry systems: A Review. *Journal of the American Medical Informatics Association*, *14*(1), 29-40.
- Lancaster, L. (2005). Mission impossible: Minimising the terror of paediatric resuscitation for staff in the ED. *Accident and Emergency Nursing*, *13*, 24-28.
- Leape, L. (1994). Error in medicine. *JAMA*, *272*(23), 1851-1857.
- Leape, L. L. (2004). Human Factors Meets Health Care: the Ultimate Challenge, *Ergonomics in design*, *12*, 6-12.

- Leape, L. L., Bates, D. W., Cullen, D. J., Copper, J., & Demonaco, H. J. et al. (1995). Systems analysis of adverse drug events, *JAMA*, 274(1), 35-43.
- Leape, L. L., Brennan, T. A., Laird, N., & Et al, (1991). The nature of adverse events in hospitalized patients: Results of the Harvard practice study II. *New England Journal of Medicine*, 324, 377-384.
- Leonard, M. S., Cimino, M., Shaha, S., McDougal, S., Pilliod, J., & Et al., et al. (2006). Risk reduction for adverse drug events through sequential implementation of patient safety initiatives in a Children's Hospital. *Pediatrics*, 118, e1124-e1129. Retrieved from <http://www.pediatrics.org/cgi/content/full/118/4/e1124>
- Lubitz, D. S., Seidel, J. S., Chameides, L., Luten, R. C., Zaritsky, A. L., & Campbell, F. W. (1988). A rapid method for estimating weight and resuscitation drug dosages from length in the pediatric age group. *Ann Emerg Med.*, 17(6), 576-81.
- Luten, R., Wears, R., Broselow, J., Zaritsky, A., & Barnett, T. et al. (1992). Length-based endotracheal tube and emergency equipment in pediatrics. *Ann Emerg Med.*, 8, 900-904.
- MacDavitt, K. (2008). An examination of the relationship between nursing outcomes and patient outcomes. (Doctoral dissertation, Columbia University, 2008). *Dissertations Abstracts International*, 1-161-161.
- Mahoney, C., Berard-Collins, C., Coleman, R., Amaral, J., & Cotter, C. (2007). Effects of an integrated clinical information system on medication safety in a multi-hospital setting. *American Journal of Health-System Pharmacists*, 64, 1969- 1977.
- Mazur, L. M. (2008). The study of errors, expectations and skills for medication delivery systems improvement. *Dissertations Abstracts International*, 1-133. (UMI No. 3297148 AAT)
- McBride, S. C., Chiang, V., Goldmann, D., & Landrigan, C. P. (2005). Preventable adverse events in infants hospitalized with bronchiolitis. *Pediatrics*, 116, 603-608.
- McMullin, S., Lonergan, T., Rynearson, C., Doerr, T., Veregge, P., & Scanlan, E. (2004). Impact of an evidence-based computerized decision support system on primary care prescription costs. *Annals of Family Medicine*, 2(5), 494-498. Retrieved November 1, 2008 from www.annfann.org
- Miller, M. R., Elixhauser, A., & Zham, C. (2003). Patient safety events during pediatric hospitalization. *Pediatrics*, 111, 1358-1366.
- Mutsch, K. (2000). Factors contributing to medication errors. *Dissertations Abstracts International*, (EP25673), 1-57. (UMI No. EP25673)

- Nguyen, T., Law, A., & Hodding, J. (2006). Adverse drug reactions among children over a 10-year period. *Pediatrics*, *118*, 555-562. Retrieved from <http://www.pediatrics.org/cgi/content/full/118/2/555>
- O’Cathain, A., Munro, J., Armstrong, I., O’Donnell, C., & Heaney, D. (2007). The effect of attitude to risk on decisions made by nurses using computerized decision support software in telephone clinical assessment: an observational study. *BMC Medical Informatics and Decision Making*, *7*(39). Retrieved November 4, 2008 from <http://www.biomedcentral.com/1472-6947/7/39>
- Otero, P., Leyton, A., Mariani, G., & Cernadas, J. M. (2008). Medication errors in pediatric inpatients: Prevalence and results of a prevention program. *Pediatrics*, *122*, e737-743.
- Payne, C.H., Smith C.R., Newkirk L.E., Hicks R.W. (2007). Pediatric medication errors in the postanesthesia care unit: Analysis of MEDMARX data. *AORN J.*, *85*:731-740.
- Perlstein, P., Callison, C., White, M., Barnes, B., & Edwards, N. (1979). Errors in drug computation during newborn intensive care. *American Journal of Disabled Children*, *133*, 376-379.
- Pham, J.C. (2008). The state of healthcare quality in emergency medicine. *Dissertation Abstracts International*, (UMI No. 3309735).
- Phipps, L. M., Thomas, M. J., Gilmore, R. K., Raymond, J. A., & Bittner, T. R. et al. (2005). Prospective assessment of guidelines for determining appropriate depth of endotracheal tube placement in children. *Pediatric Critical Care Med*, *6*(5), 519-522.
- Potts, A., Barr, F., Gregory, D., Wright, L., & Patel, N. (2004). Computerized physician order entry and medication errors in a pediatric critical care unit. *Pediatrics*, *113*(1), 59-63. Retrieved from www.pediatrics.org
- Ramarajan, N., Krishnamoorthi, R., Strehlow, M., Quinn, J., & Mahadevan, S. (2008). Internalizing the Broselow-Tape: How reliable is weight estimation in Indian Children. *Academy of Emergency Medicine*, *15*(5), 431-436.
- Rand, C., Conn, K., Crittenden, C., & Halterman, J. (2004). Does a Color-Coded Method for Measuring Acetaminophen Doses Reduce the Likelihood of Dosing Error? *Arch Pediatric Adolesc Med.*, *158*, 625-627.
- Ray, M., Houston, T., Yu, F., Menachemi, N., & Maisiak, R. et al. (2006). Development and testing of a scale to assess physician attitudes about handheld computers with decision support. *Journal of the American Medical Informatics Association*, *13*(5), 567-572.

- Resar, R. K., Rozich, J. D., & Classen, D.C. (2003). Methodology and rationale for the measurement of harm with trigger tools. *Qual Saf Health Care, 12*, 39-45.
- Rodgers, K. (2007). Using the SBAR communication technique to improve nurse-physician phone communication. *AAACN Viewpoint, 29* (2), 7-9. Retrieved from [https://connect2.uncc.edu/ehost/,DanaInfo=web.ebscohost.com+results?vid=6&hid=6&sid=1bfa3a53-012d-4137-b5c3-a4b85fd6ef1b%40sessionmgr2&bquery=\(sbar+AND+research\)&bdata=JmRiPW M4aCZsb2dpbnBhZ2U9TG9naW4uYXNwJnR5cGU9MCZzaXRIPWVob3N0LWxpdmU%3d](https://connect2.uncc.edu/ehost/,DanaInfo=web.ebscohost.com+results?vid=6&hid=6&sid=1bfa3a53-012d-4137-b5c3-a4b85fd6ef1b%40sessionmgr2&bquery=(sbar+AND+research)&bdata=JmRiPW M4aCZsb2dpbnBhZ2U9TG9naW4uYXNwJnR5cGU9MCZzaXRIPWVob3N0LWxpdmU%3d)
- Rothschild, J., Fang, E., Liu, V., Litvak, I., Yoon, C., & Et al. (2006). Use and perceived benefits of handheld computer-based clinical references. *Journal of the American Medical Informatics Association, 13*(6), 619-626.
- Roukema, J., Steyerberg, E., Van der Lei, J., & Moll, H. (2008). Randomized trial of a clinical decision support system: impact on the management of children with fever without apparent source. *Journal of the American Medical Informatics Association, 15*(1), 107-113. Retrieved October 9, 2008 from [PubMed]
- Rozich, J. D., Resar, C. R., & Resar, R. K. (2003). Adverse drug event trigger tool: a practical methodology for measuring medication related harm. *Qual Saf Health Care, 12*, 194-200.
- Ryan, D. D. (2007). Measurement of Student Nurse Performance in the Safe Administration of Medication. *Dissertations Abstracts International*, -117. (UMI No. 3279892).
- Saba, V. K., & McCormick, K. A. (2006). *Essentials of Nursing Informatics* (4th ed.). New York: McGraw-Hill.
- Sard, B. E., Walsh, K. E., Doros, G., Hannon, M., & Moschett, W. et al. (2008). Retrospective evaluation of a computerized physician order entry adaptation to prevent prescribing errors in a pediatric emergency department. *Pediatrics, 122*, 782-787. Retrieved from <http://www.pediatrics.org/cgi/content/full/122/4/782>
- Shah, A., Frush, K., Luo, X., & Wears, R. (2003). Effect of an Intervention Standardization System on Pediatric Dosing and Equipment Size Determination: A Crossover Trial Involving Simulated Resuscitation Events. *Arch Pediatr Adolesc Med., 157*, 229-236.
- Sharek, P., Horbar, J., Mason, W., Bisarya, H., Thurm, C., & Et al. (2006). Adverse Events in the Neonatal Intensive Care Unit: Development, testing, and findings of an NICU focused trigger tool to identify harm in North American NICUs. *Pediatrics, 118*(1332-1340). Retrieved from <http://www.pediatrics.org/cgi/content/full/118/4/1332>

- Sharek, P., Horbar, J., Mason, W., Bisarya, H., Thurm, C., & Gautham, S. et al. (2006). Adverse events in the Neonatal Intensive Care Unit: Adverse events in the Neonatal Intensive Care Unit: Development, testing, and findings of an NICU-focused Trigger Tool to identify harm in North American NICUs. *Pediatrics*, *118*, 1332-1340.
- Slonim, A. D., LaFleur (Medicine, 2000)r, B. J., Ahmed, W., & Joseph, J. G. (2003). Hospital-reported medical errors in children. *Pediatrics*, *2003*, 617-62.
- Spooner, S., & Council on Clinical Information Technology, (2007). Special requirements of electronic health records systems in pediatrics. *Pediatrics*, *119*(3), 631-637. Retrieved from <http://www.pediatrics.org/cgi/content/full/119/3/631>
- Stebbing, C., Kaushal, R., & Bates, D. (2006). Pediatric medication safety and the media: What does the public see? *Pediatrics*, *117*, 1907-1914. Retrieved from <http://www.pediatrics.org/cgi/content/full/117/6/1907>
- Stevenson, K., Barbera, J., Moore, J., Samore, M., & Houck, P. (2005). Understanding keys to successful implementation of electronic decision support in rural hospitals: Analysis of a pilot study for antimicrobial prescribing. *American Journal of Medical Quality*, *20*(6), 313-318.
- Takata, G., Mason, W., Taketomo, C., Longsdon, T., & Sharek, P. (2008). Development, testing and findings of a pediatric-focused trigger tool to identify medication related harm in US children's hospitals. *Pediatrics*, *121*, e927-e935.
- Taylor, J., Loan, L., Kamara, J., Blackburn, S., & Whitney, D. (2008). Medication administration variances before and after implementation of computerized physician order entry in a neonatal intensive care unit. *Pediatrics*, *121*, 123-128. Retrieved November 1, 2008 from www.pediatrics.org/cgi/content/full/121/1/123
- The United States Pharmacopeia Convention Inc. (2004). *MEDMARX 5th Anniversary Data Report: A Chartbook of 2003 findings and trends 1999-2003*. (US Pharmacopeia). Rockville MD: The United States Pharmacopeia Convention Inc.
- The United States Pharmacopeia Convention Inc. (2004). The introduction of CPOE and change management in a tertiary pediatric hospital. *Pediatrics*, *116*, e634-e642. Retrieved from <http://www.pediatrics.org/cgi/content/full/116/5/e634>
- Thomas, E. J., Studdert, D. M., Burstin, H. R., & Et al, (2000). Incidence and types of adverse events and negligent care in Utah and Colorado. *Med Care*, *38*, 261-271.
- Thomas, E. J., Studdert, D. M., Burstin, H. R., Orav, E. J., & Zeena, T. et al. (2000). Incidence and types of adverse events and negligent care in Utah and Colorado. *Medical Care*, *38*(3), 261-271.

- Toth-Pal, E., Wardh, I., Strender, L., & Nilsson. (2008). A guideline-based computerized decision support system (CDSS) to influence general practitioners management of chronic heart failure. *Informatics in Primary Care*, 16, 29-39.
- United States Pharmacopeia. (2004). *Advancing Patient Safety in U.S. Hospitals: Basic Strategies for Success*. : Author.
- Upperman, J.S., Staley P., Friend K., Benes J., Dailey, J., Neches W., Wiener E.S. Nov. (2005). The Introduction of Computerized Physician Order Entry and Change Management in a Tertiary Pediatric Hospital. *Pediatrics*, 116(5), pp. e634-e642.
- Wiener, E. S. (2005). The Impact of Hospital-wide Computerized Physician Order Entry on Medical Errors in a Pediatric Hospital. *Journal of Pediatric Surgery*, 40(1): 57-9.
- Vital-signs Inc (2008). *Color Coding Kids: The Broselow-Luten System*. Retrieved November 17, 2008, from <http://colorcodingkids.com/index.html>
- Walsh, K. E., Landrigan, C. P., Adams, W. G., Vinci, R., & Chessare, J. et al. (2008). Effect of computer order entry on prevention of serious medication errors in hospitalized children. *Pediatrics*, 121, e421-e427. Retrieved from <http://www.pediatrics.org/cgi/content/full/121/3/e421>
- Walsh, K., Adams, W., Bauchner, H., Vinci, R., & Chessare, J. et al. (2006). Medication errors related to computerized order entry for children. *Pediatrics*, 118, 1872-1879. Retrieved from <http://www.pediatrics.org/cgi/content/full/118/5/1872>
- Wang, J., Herzog, N., Kaushal, R., Park, C., Mochizuki, C., & Et al, et al. (2007). Prevention of pediatric medication errors by hospital pharmacists and the potential benefit of computerized physician order entry. *Pediatrics*, 119, e77-e85. Retrieved from <http://www.pediatrics.org/cgi/content/full/119/1/e77>
- Weber, S. (2007). A qualitative analysis of how advanced practice nurses use clinical decision support systems. *Journal of the Academy of Nurse Practitioners*, 19, 652-667.
- Westbrook, J. I., Braithwaite, J., Georgeiou, A., Ampt, A., & Creswick, N. et al. (2007). Multimethod evaluation of information and communication technologies in Health in the context of wicked problems and socio-technical Theory. *Journal of the American Medical Informatics Association*, 14(6), 746 -755.
- Williams, C.E., Greene, S.B., Hansen R., et al. (Nursing Home Medication Error Quality Initiative (MEQI) Report: Year 3, October 1, 2005 to September 30, 2006. Chapel Hill, North Carolina. The Cecil G. Sheps Center for Health Services Research at the University of North Carolina at Chapel Hill. *Chapel Hill, NC 27599-7590*

Woods, D., Thomas, E., Holl, J., Altman, S., & Brennan, T. (2005). Adverse events and preventable adverse events in children. *Pediatrics*, *115*, 155-160.

WHO Collaborating Centre for Patient Safety Solutions (2008). Retrieved from <http://www.ccforspatientsafety.org/patient-safety-solutions>

APPENDIX A: STUDIES OF CDSS IMPLEMENTATION

Table 1: *Studies of CDSS Implementation*

Reference	Sample description	Data source	Results
Alexander, G. (2008) Analysis of an integrated clinical decision support system in nursing home clinical information systems.	Evaluated CDSS component of a clinical information system implemented in three nursing homes located in the Midwestern United States.	Descriptive study analysis included the frequencies of alerts and their triggers collected from two facilities during a period of 155 days.	The two most frequent patient condition alerts were for both facility A & B were dehydration (32.5%, 29.8%) and improved condition (23.3%, 24.8%) respectively. Constipation was the third most frequently occurring alert (21.2%) followed by skin integrity (16.1%) for facility B. The most frequent alert for both facilities were skin integrity. Facility A reported of the (5339 active alerts, 1148 were for skin integrity). Facility B (5276) total alerts, 1726 (32%) were for skin integrity. Evaluations from CDSS alert data might be useful for resident care. Limitation noted that staff interaction with the computer was not considered.

<p>Bergman & Fors (2008)</p> <p>Decision support in psychiatry - a comparison between the diagnostic outcomes using computerized decision support system versus manual diagnosis</p>	<p>63 clinicians of that 34 specialists 24 psychologists, 2 general practitioners, 1 specialist in neurophysiology, 1 physician, 2 psychiatric physicians in training, 3 clinical psychology training</p>	<p>Investigated the (CDSS) with regard to the feasibility of improving diagnostic procedures and save time.</p> <p>Compared traditional 'paper and pencil' diagnostic method with computer aided diagnostic system for processing time and accuracy of diagnosis using two paper based case studies.</p>	<p>No major difference was demonstrated between 'pencil and paper' and computer supported diagnosis. A significantly shorter time was found for 'paper' verses computer for the difficult case.</p> <p>A significant difference existed in accuracy of diagnosis with the pencil paper method for Depression. The majority of clinicians found supportive and easy to use it took a longer time and yielded fewer correct diagnosis.</p>
--	---	--	--

<p>Kronman, Hall, Slonim & Slonim (2008) Charges and Lengths of Stay Attributable to Adverse Patient-care events using pediatric-specific quality indicators: A multicenter study of free standing children's hospitals.</p>	<p>Adverse events in 431 524 discharges from 38 freestanding, academic, not-for-profit, tertiary care pediatric hospitals in the United States participating in the Pediatric Health Information System database in 2006.</p>	<p>Data were obtained from the Pediatric Health Information System (PHIS), an administrative database that, during the study period, contained inpatient data from 38 freestanding, academic, not-for-profit, tertiary care pediatric hospitals in the United States. All of the discharges from any of the 38 hospitals participating in the Pediatric Health Information System between January 1 and December 31, 2006, were eligible for inclusion. The primary outcomes were excess lengths of stay and charges were attributable to adverse patient-safety events as determined by 12 pediatric-specific quality indicators.</p>	<p>Statistically significant excess lengths of stay ranged from 2.8 days for accidental puncture and laceration to 23.5 days for postoperative sepsis, and statistically significant excess overall charges ranged from \$34 884 for accidental puncture and laceration to \$337 226 for in-hospital mortality after pediatric heart surgery. Each charge category had significant charge increases caused by pediatric-specific quality indicator events, with the largest being laboratory and other charges, ranging from \$7622 to \$78 048 and \$11 094 to \$97 805, respectively.</p>
--	---	--	---

<p>Otero et al. (2008) Medication Errors in Pediatric Inpatients: Prevalence and Results of a Prevention Program</p>	<p>A total of 590 prescriptions and 1174 drug administrations for 95 patients in the first phase of the study and 1144 prescriptions with 1588 drug administrations for 92 patients in the second phase were evaluated.</p>	<p>Reviewed prescriptions that were ordered by physicians and medications that were administered by nurses to patients at the NICU, PICU, and general pediatric settings at the Hospital Italiano de Buenos Aires Department of Pediatrics in 2002 and 2004. Number and type of errors, time shift on which they occurred, and whether they had any kind of adverse event on the patient were recorded. Medication errors were stratified according to physicians' and nurses' status.</p>	<p>Prevalence of medication error rate in the second phase was 7.3% (199 of 2732) and 11.4% (201 of 1764) in the first phase. The risk difference was 4.1%.</p>
--	---	--	---

<p>Roukema et al. (2008) The study assessed compliance with the system and to assess the effects of the CDSS on time spent in the ED, and diagnostic tests</p>	<p>Children who attended the ED at the Sophia's Children's Hospital in Rotterdam from 2003 to 2005, (1,744 children aged 1-36 months)</p>	<p>The CDSS was used by ED nurses to register children presenting with fever. The CDSS identified children who met the inclusion (Children presenting with fever of unknown sources without chronic comorbidity 1-36 months) Children at high risk for serious bacterial infection were "randomized" for the intervention (n = 74) or the control (n=90) In the intervention group the CDSS provided advice and in the control the physician assessed the children and ordered laboratory tests. The aim was to assess compliance with the system and to assess the effects of the CDSS on 1) time spent in the ED, 2) amount of performed diagnostic tests</p>	<p>Compliance with registration of febrile children into the CDSS was moderate at 49%. Adherence to the advice to order laboratory tests was good at 82%; however, the time spent in the ED for the children with fever was not significantly different. The study considering compliance and adherence to the CDSS was successful but the patient outcome was not as predicted as the length of time spent in the ED was not reduced significantly.</p>
--	---	---	--

<p>Toth-Pal et al. (2008) Explored the influence of CDSS on general practitioners' (GPs) management of chronic heart failure</p>	<p>Medical records of 48 cases of each practitioner using guideline based CDSS on the internet and completing a questionnaire for each case</p>	<p>Assess changes in the confidence of GPs diagnosis, and support they perceived from the CDSS. The outcome measure was the number of reports of a change in confidence and reported support.</p>	<p>The GPs change in confidence was reported in 25% of the cases. Further investigation was reported in 31% of the cases and a 10% change in prescribed medication. There was a wide range of values for perceived support but was described as substantial in 35% of the cases.</p>
<p>O'Cathain, Munro, Armstrong, O'Donnell, & Heaney (2007) Studied the effect of attitude to risk on decisions made by nurses using (CDSS) in telephone clinical assessment</p>	<p>A national telephone assessment service in Scotland (NHS 24) 265 nurse responses on a questionnaire about their background and attitudes to risk on referrals to service or self care. (231, 112 calls)</p>	<p>Assess the variation in the decisions made by telephone assessment nurses using (CDSS) to refer to services or self care. Explore the effects of risk attitudes and referrals.</p>	<p>Attitudes to risk varied greatly There was no evidence that the nurse's attitude about risk affected their decision to refer or not.</p>

<p>Wheeler (2007) Implementation of a medical resource in electronic record: Can more questions be answered at the point of care?</p>	<p>A survey of all Stars and Stripes Healthcare Network Primary Care Physicians was conducted to identify a baseline use of electronic medical knowledge. (119 responded)</p>	<p>Completion of a self administered questionnaire, physicians ranked references and listed top three choices.</p>	<p>Of the 119 respondents, 45% preferred textbooks, 13% journals and 28% electronic resources for clinical information. The most preferred electronic sources were UpToDate (26%), PubMed (16%), Micromedex, and OVID Medline (12%).</p>
<p>Mahoney et al.(2007) Effects of an integrated clinical information system on medication safety in a multi-hospital setting.</p>	<p>Multihospital Rhode Island Hospital (a private, 719- acute care hospital and academic medical center with a pediatric division, the Hasbro Children’s Hospital; and The Miriam Hospital (TMH), a 247-bed, acute care Both are teaching hospitals associated with the Warren Alpert Medical School of Brown University</p>	<p>The reduction in related medication errors. Total number of medication orders of 1,452,346 and 1,390,789 during the preimplementation and postimplementation Results were based on the total number of colchicine orders of 868 and 783 during</p>	<p>The indicators for CPOE with inherent CDSSs demonstrated a significant effect of this functionality on reducing prescribing error rates for three of the four indicators measured: drug allergy detection (reduced from 833 to 109),excessive dose (from 1341 to 871), and incomplete or unclear order (from 1976 to 663). The fourth indicator measured, therapeutic duplication (reduced from 665 to 584) was not statistically significant For the rules engine software CDSS, the colchicine indicator did not show a statistically significant effect on prescribing error rate, but a significant decrease in prescribing errors related to metformin use in renal insufficiency was observed (from 101 to 66) after implementation of the rules engine software and integration with CPOE</p>

<p>Weber (2007) Effects of an integrated clinical information system on medication safety in a multi-hospital setting.</p>	<p>A convenience sampling of 23 APN (13 CNS and 10 NPs) predominantly white females, from 16 critical care units in the Midwest</p>	<p>Qualitative study comprised of a single structured in-depth interview. Open ended audio taped questions were conducted with each participant.</p>	<p>Core variables that emerged from the data were, outcomes with five major categories 1) system learning 2) understanding the technology, 3) creating inferences from system data, 4) comparing system derived data 5) and levels of trust of subjects in system derived data. These variable lead to forecasting decision outcomes. The main reason for using the system was to have a scientific base to forecast client outcomes.</p>
<p>Westbrook et al. (2007)</p>	<p>Sydney, New South Wales, Australia A mayor academic center located in Sydney, Australia. A public medical-surgical hospital of (400) beds</p>	<p>Using prospective error surveillance measures, all patients' medication charts were reviewed daily by a hospital pharmacist across four general medical/surgical wards to record errors. Data were collected for eight months before system implementation to detect prescribing errors. Model measurements include the three dimensions of system impact: safety and quality, organizational culture, work and communication patterns.</p>	<p>Methods included medication error audits and social network analysis.</p>

<p>Ray et al. (2006) Development and Testing of a Scale to Assess Physician Attitudes about Handheld Computers with Decision Support</p>	<p>Participants were 82 Internal Medicine residents in post-graduate years one, two, and three at an urban medical center in the southeastern United States, who volunteered to participate in a study examining the use of handheld CDSS. The residents' inpatient experiences were at various urban acute care hospitals. The residents had ambulatory clinics that primarily serve lower income populations and are affiliated with a primary care residency program in an urban university</p>	<p>A prospective assessment of psychometric characteristics of the H-DSS including reliability, validity, and responsiveness. evaluated the scale using a sample of 82 Internal Medicine residents. Residents were recruited from a pool of 126 residents and all residents were offered the opportunity to participate in the study. Those agreeing to participate were given a PDA and completed a Likert scale survey.</p>	<p>The authors' evaluation demonstrated the H-DSS scale was reliable, valid, and responsive. The scale can be used to guide future handheld DSS development.</p>
--	--	---	--

Koppel, Metlay, Cohen, Abaluck, & Localio, 2005)
Role of Computerized Physician Order Entry Systems in Facilitating Medication Errors.

<p>Sample participants were from a major urban tertiary-care teaching hospital with 750 beds, 39000 annual discharges, and a widely used CPOE. (<i>N</i>=261; 88% of CPOE users)</p> <p>Participants included House staff, nurses, and hospital leaders.</p>	<p>Surveyed house staff (<i>N</i>=261; 88% of CPOE users); conducted 5 focus groups and 32 intensive one-on-one interviews with house staff, information Technology leaders, pharmacy leaders, attending physicians, and nurses; shadowed house staff and nurses; and observed them using CPOE.</p>	<p>Results revealed widely used CPOE system facilitated 22 types of medication error risks. Examples include fragmented CPOE displays that prevent a coherent view of patients' medications, pharmacy inventory displays mistaken for dosage guidelines, ignored antibiotic renewal notices placed on paper charts rather than in the CPOE system, separation of functions that facilitate double dosing and incompatible orders and inflexible ordering formats generating wrong orders. Three quarters of the house staff reported observing each of these error risks, indicating that they occur weekly or more often. Use of multiple qualitative and survey methods identified and quantified error risks not previously considered, offering many opportunities for error reduction.</p>
--	---	---

<p>Stevenson et al., (2005) Understanding keys to successful implementation of electronic decision support in rural hospitals: Analysis of a pilot study for antimicrobial prescribing.</p>	<p>5 rural hospitals in southwestern Idaho</p>	<p>Using a pretest/posttest design, an Internet-based CDSS designed to optimize antimicrobial prescribing was pilot tested for community- acquired pneumonia The baseline (January 1, 2001, to August 4, 2001) and intervention (January 1, 2002, to August 4, 2002)</p>	<p>As a group, statistical significance was demonstrated for 2 performance measures. Agreement with all recommendations had a pooled odds ratio of 1.88 (95% confidence intervals [CIs], 1.01 to 3.56, $P = .04$), and agreement with recommended dose had a pooled odds ratio of 1.97 (95% CI, 1.04 to 3.74, $P = .04$). Adverse clinical outcomes due to use of the Antibiotic Assistant, measured as overall mortality, 30-day readmission rates, and transfers to another facility, were not different between the baseline and intervention time periods in all hospitals and among all patients. Compliance with the complete study protocol by hospitals ranged from 0% to 71%.</p>
--	--	---	---

<p>Cobos et al. (2005) Cost effectiveness of a clinical decision support system based on the recommendations of the European Society of Cardiology and Other Societies for the Management of Hypercholesterolemia Report of a cluster-randomized trial.</p>	<p>Public health system general practices from a variety of areas in Spain 2221 patients were included in the study (1161 in usual care group and 1060 in the intervention group)</p>	<p>A cluster-randomized, unblinded, pragmatic trial was conducted to assess the cost effectiveness of a clinical decision support system (CDSS) for Hypercholesterolemia Management (ESCHM). The primary evaluation criteria were the total direct costs of hypercholesterolemia management and the effectiveness defined as success or failure</p>	<p>The intervention was as effective as usual care, both in an unadjusted analysis and after adjusting for absolute CVR and previous treatment with lipid-lowering drugs (LLDs) [odds ratio (OR) 1.02; 95% CI 0.58, 1.77]. The intervention had no impact on lipid profiles. Intervention patients were prescribed LLDs less frequently than usual care patients (OR = 0.37; 95% CI 0.26, 0.52; $p = 0.0001$), particularly when CVR was low. This induced important savings in treatments ($p = 0.0001$) and total costs ($p = 0.001$), which were estimated as 24.9% and 20.8%, respectively. The intervention increased the number of laboratory analyses. The recommendations issued by the CDSS were accepted in 71.3% of the visits. The CDSS based on the recommendations of the ESCHM did not modify the effectiveness of usual care but induced considerable savings.</p>
---	--	--	---

<p>Kawamoto, Houlihan, Balas, & Lobach (2005) Improving clinical practice using clinical decision support systems: a systematic review of trials to identify features critical to success</p>	<p>(70) studies that evaluated the ability of CDSS to improve practice.</p>	<p>Systematic review of randomized controlled trials. The purpose was to identify features of clinical decision support systems critical or improving clinical practice. Authors searched data sources Medline (1966-2003), CINAHL (1982-2003). And Cochran Controlled Trials Register (2003) for relevant studies pertaining to CDSS.</p>	<p>(CDSS) significantly improved clinical practice in 68% of trials. Univariate analysis revealed that 5 features of the CDSS significantly improved clinical practice. Multiple regression analysis identified 4 features that as independent predictors of improved clinical practice; automatic provision for CDSS as a part of clinical workflow($p = 0.0187$), provision of decision support at the time and location of decision making ($p = 0.0263$), provision of recommendations rather than just assessment ($p=0.018$), provision support at location ($p = 0.0263$), computer based decision support ($p = 0.0294$). Of the 32 systems providing all 4 features, 30 (94%) significantly improved practice.</p>
<p>Johnston et al. (2004) Evaluation of CDSS/PDA for evidence based learning and practice in medical undergraduates.</p>	<p>169 Year 4 undergraduate medical students at the University of Hong Kong</p>	<p>Post randomized controlled trial survey. Outcome measures were CDSS/PDA usefulness, satisfaction, functionality and utilization.</p>	<p>Student means score for usefulness 3.9 out of 6, (95% confidence level (CI = 3.78, 4.03) They reported less satisfaction with functional features of the CDSS (mean scores were 3.51) 95% CI = (3.32, 3.59) and the PDA (mean score 3.51) 95% CI = CI 3.40, 3.62) utilization was low with the average use less than once per week. CDSS was used infrequently in clinical. Multivariate regression showed that CDSS usefulness was associated with supportive faculty attitudes, greater knowledge of EBC, better computer skills, resulting in increased use in the clinical setting.</p>

<p>McMullin et al. (2004) Impact of an evidence-based computerized decision support system on primary care prescription costs.</p>	<p>Pharmacy claims database was used, matching clinicians using CDSS with a control group by pharmacy billed amount, number of patient treated, number of new prescriptions filled during a 6 month baseline period not using the system.</p>	<p>A retrospective cohort study was performed using the pharmacy claims database. The primary outcome measure was the difference in prescription costs between the two groups after implementing the CDSS in the intervention group.</p>	<p>Clinicians who received evidence based decisions support had significantly lower prescription costs than those in the control the average cost was \$4.99 lower ($P = 0.01$) The 6 month savings was estimated at \$, 450 (95% CI, \$1, 030-\$5, 863)</p>
<p>Carter & Cox (2000) Nurse Managers' use of a computer decision support system: Differences in nursing labor costs per patient day.</p>	<p>A convenience sample of 4 nurse managers from two hospitals, one psychiatric and one medical in a 466 state owned facility and the other a 526 bed hospital in a metropolitan area.</p>	<p>A descriptive design was used for an investigation of the labor costs on two different types of units. Hours per patient day were included for a three month baseline and three month study period. The study group used CDSS and the control used the traditional Model.</p>	<p>The psychiatric unit cost per patient day (PPD) compared to the control resulted in a decrease from \$44.77 to \$43.60 representing a 3% cost decrease per patient day which resulted in a \$1,030 per month decrease even with an increase in census.</p>

<p>Hetlevik, Holmen & Kruger (1999) Evaluated the implementation of CDSS guidelines for hypertension.</p>	<p>17 health centres in Norway with 24 doctors and 984 patients in the intervention group. 849 patients in the final analysis. In the control 12 health centres with 29 doctors and (1255) patients (1119) in the final analysis.</p>	<p>Randomized study with health centres as units, to evaluate the implementation of CDSS guidelines for hypertension. The intervention group used the CDSS. After an 18 month period group differences in the level of systolic and diastolic blood pressure, serum cholesterol, body mass index, and risk score for myocardial infarction were calculated and group differences in smokers.</p>	<p>Significant group differences with from the intervention group lowering the diastolic pressure blood 1mm Hg (95% CI -1.89, -1.17) and a significant difference in the systolic 2.7 mmHg (95% CI 1.0, 4.5) for the control. There were no significant differences in patient outcomes.</p>
--	---	--	--

APPENDIX B: PEDIATRIC STUDIES OF COMPUTER DECISION SUPPORT SYSTEMS

Table 2: *Pediatric Studies of Computer Decision Support Systems*

Reference	Sample description	Data source	Results
Sard, Walsh, Doros, & Hannan (2008) Retrospective Evaluation of a Computerized Physician Order Entry Adaptation to Prevent Prescribing Errors in a Pediatric Emergency Department	An academic, urban, pediatric ED. A level 1 trauma center, with a physically separate pediatric ED serving an annual volume of 30 000 patients. The staff consists of 7 attending physicians, 4 pediatric emergency medicine fellows, and 130 pediatric residents. Boston University Medical School.	A retrospective comparison of 75 orders from 420 randomly selected visits before and after quicklist introduction. Error rates were analyzed with respect to urgency level, physician training level, and patient age. The quicklist was examined for frequency of use and error rates.	840 patient visits (420 pre and 420 post intervention) a review of 724 medication orders, which contained 156 medication prescribing errors (21%). There were significant decreases in the rate of errors per 100 visits, from 24 to 13 errors per 100 visits, and in the rate of errors per 100 orders, from 31 to 14 errors per 100 orders. The quicklist was used in 30% of the orders in the postintervention group. In this group, the error rate was 1.9 errors per 100 orders when the quicklist was used, compared with 18.3 errors per 100 orders when the list was not used. Errors of wrong formulation, allergy, drug-drug interaction, and rule violations were eliminated.

<p>Taylor, Loan, Kamara, Blackburb, & Whitney (2008) Medication administration variances after CPOE entry in NICU</p>	<p>Data on 526 medication administrations, including 254 during the pre-(CPOE) period and 272 after. A prospective observational study was conducted</p>	<p>Nurses recorded details of medication administrations in a NICU during standardized observation periods. Variance was defined as a discrepancy between the order and the medication administration. Rates of variances before and after CPO entry in the NICU were compared. Specific types and reasons for variances were also compared.</p>	<p>Medication variances were detected for 19.8% of administrations during the pre-(CPOE) period, compared with 11.6% with (CPOE) (rate ratio: 0.53). There were no statistically significant differences in rates of errors before versus after (CPOE) Administration of a medication at the wrong time accounted for 53.1% of all variances. Variance rates related to giving a drug at the wrong time were significantly lower in the (CPOE) period than in the pre- (CPOE) (rates: 6.7% and 9.9%, respectively; rate ratio: 0.53). Even with (CPOE) variances were noted for 11% of all medication administrations, suggesting that additional methods may be needed to improve neonatal patient safety.</p>
---	--	--	---

<p>Ferranti, Horvath, Cozart, Whitehurs, & Eckstrand (2008) Reevaluating the Safety Profile of Pediatrics: A Comparison of Computerized Adverse Drug Event Surveillance and Voluntary Reporting in the Pediatric Environment</p>	<p>A total of 849 medication-related reports were entered into the safety reporting system, 1537 medication-related events detected by surveillance</p>	<p>Computerized surveillance and safety reporting systems over a 1-year period for Duke University Hospital pediatric inpatients</p>	<p>849 error reports were entered into the safety reporting system, 93 caused patient harm, resulting in an (ADE) rate of 1.8 events per 1000 pediatric patient-days. Seventy eight of the 1537 error events detected by surveillance resulted in patient harm, giving a rate of 1.6 events per 1000 patient-days. The most common events identified by reporting system were failures in the medication use process (26.9%), drug omissions (16.1%), and dose- or rate-related events (12.9%). The most frequent (ADE) by surveillance categories were nephrotoxins (20.7%), narcotics and benzodiazepines (19.3%), and hypoglycemia (11.5%). Most voluntarily reported events originated in ICUs (72.0%), surveillance events were split evenly across intensive and general care</p>
--	---	--	---

<p>Walsh, Landrigan, Adams, Vinci, & Chessare, et al. (2008) Effect of Computer Order Entry on Prevention of Serious Medication Errors in Hospitalized Children</p>	<p>627 pediatric admissions, with 12 672 medication orders written over 3234 patient-days</p>	<p>Charts orders reviewed and incident reports for 40 admissions per month to the NICU, PICU, and inpatient pediatric wards for 7 months before and 9 months after implementation of (CPOE) entry in a general hospital.</p>	<p>In 627 pediatric admissions, with 12 672 medication orders written over 3234 patient-days, 156 medication errors were detected, including 70 nonintercepted serious medication errors (22/1000 patient-days). Twenty-three errors resulted in patient injury (7/1000 patient-days). In time-series analysis, there was a 7% decrease in level of the rates of nonintercepted serious medication errors. There was no change in the rate of injuries as a result of error after computerized physician order entry implementation.</p>
--	---	--	--

<p>Holdsworth et al., 2007 Impact of Computerized Prescriber Order Entry on the Incidence of Adverse Drug Events in Pediatric Inpatients</p>	<p>All pediatric patients admitted to the PICU or pediatric unit at the New York Presbyterian Hospital, Weill Cornell Medical Center, Komansky Center for Children's Health consecutively between April 1, 2004, and October 5, 2004, were included. For comparison purposes, data from a previous published study on these same units during the pre-CPOE period from September 2000 to May 2001 were also included. The units are located in a large metropolitan tertiary care center and are composed of 20 and 30 beds, respectively.</p>	<p>A single clinical pharmacist, reviewer during each study period, prospectively identified events and potential events. The primary reviewer identified recordable events on a daily basis in a prospective review of physician and nursing notes, pharmacy records, medication administration records, and laboratory data. Nursing, medical, and pharmacy personnel were interviewed to resolve questions during medical chart review.</p>	<p>Data for 1197 admissions pre (CPOE) were compared with 1210 admissions collected after CPOE implementation. After CPOE implementation, it was observed that the number of preventable adverse drug events (46 vs. 26) and potential adverse drug events (94 vs. 35) was reduced. Reductions in overall errors, dispensing errors, and drug-choice errors were associated with the (CPOE). There were reductions in significant events, as well as those events rated as serious or life threatening, after the implementation of (CPOE) Adverse drug events continued to persist, specifically underdosing of analgesics. There were no differences in length of stay or patient disposition.</p>
--	--	--	--

Killelea, Kaushal, Cooper, & Kuperman, (2007)
 To What Extent Do Pediatricians Accept Computer-Based Dosing Suggestions?

Pediatric inpatients at a large, urban teaching hospital between April 15, 2004, and December 31, 2004.

A retrospective analysis of all orders entered into the CPOE system at a general urban teaching hospital with a socioeconomically diverse patient population between April 15, 2004, and December 31, 2004.

Rates of physician acceptance of computerized physician order entry system-generated dosing and frequency suggestions were determined.

Analysis of 54 413 orders in the CPOE, of which 27 313 orders had dosing or frequency decision support. Of the orders with decision support, approximately one third (8822) were accepted exactly by prescribers. Of the 18 491 remaining orders, 8708 were changed for dose, 2466 for frequency, and 7317 for both. Among the 18 491 orders that were changed, the majority 11 322 deviated by a substantial amount (50%) from the total daily dose initially suggested by the decision support feature. Overall, patient weight was missing 31.3% of the time, patient age alone sometimes was sufficient for the computer to make a dosing suggestion.

<p>Wang et al., (2007) Prevention of Pediatric Medication Errors by Hospital Pharmacists and the Potential Benefit of Computerized Physician Order Entry</p>	<p>This study included 16 938 medication orders for 678 admissions to the pediatric units of a large academic community hospital. During this period, the pediatric units contained a total of 84 beds, including a 31-bed pediatric ward, a 45-bed NICU, and an 8-bed PICU</p>	<p>The clinical and medication records of consecutive pediatric admissions at Cedars-Sinai Medical Center, an urban, tertiary care academic community hospital, were prospectively reviewed for a 3-month period from February through April 2002, before any implementation of CPOE.</p>	<p>865 medication errors occurred, corresponding with a rate of 5.2 per 100 medication orders. A near-miss rate of 0.96% and a preventable adverse drug event rate of 0.09% were observed. Overall, 78% of potentially harmful prescribing errors were intercepted. None of the potentially harmful errors at administration was intercepted and accounted for 50% of preventable adverse drug events. A CPOE could capture potentially harmful prescribing and transcription errors (54%–73%) but not administration errors (0% versus 6%).</p>
<p>Del Beccaro, Jeffries, Eisenberg, & Harry (2006). Explored changes in risk-adjusted mortality after the implementation of a (CPOE) in a PICU.</p>	<p>Study was undertaken in a tertiary care PICU with 20 beds and 1100 Admissions/year.</p>	<p>Retrospectively chart review of admissions from the PICUEs database for the period October 1, 2002, to December 31, 2004. The 13 months before and 13 months after (CPOE) implementation. Pediatric Risk of Mortality III mortality risk adjustment was used to determine standardized mortality ratios.</p>	<p>2533 patients were admitted to the PICU. The 13-month preimplementation mortality rate was 4.22%, and the 13-month postimplementation mortality rate was 3.46%, representing a nonsignificant reduction in the risk of mortality. The standardized mortality ratio was 1.10 preimplementation versus 0.70 postimplementation. Analysis of the 13-month preimplementation versus 5-month postimplementation periods showed a non-statistically significant trend in reduction of mortality for all PICU.</p>

<p>Hunt, Hohenhaus, Luo, & Frush, (2006) Simulation of Pediatric Trauma Stabilization in 35 North Carolina Emergency Departments: Identification of Targets for Performance Improvement.</p>	<p>Thirty-five hospitals and 5 alternates were chosen randomly from the list of all hospitals in North Carolina that has EDs. The number 35 served as a convenience sample for this study and represented more than one third of the EDs in North Carolina.</p>	<p>An evaluation tool was created to score each mock code on 44 stabilization tasks. Primary outcomes were (1) interrater reliability of tool, (2) overall performance by each ED, and (3) performance per stabilization task.</p>	<p>Evaluation-tool interrater reliability was excellent. The median number of stabilization tasks that needed improvement by the EDs was 25 (57%) of 44 tasks. Many EDs need improvement in tasks complicated in pediatric resuscitations, including (1) estimating a child's weight (17 of 35 EDs [49%]), (2) preparing for intraosseous needle placement (24 of 35 [69%]), (3) ordering intravenous fluid boluses (31 of 35 [89%]), (4) applying warming measures (34 of 35 [97%]), and (5) ordering dextrose for hypoglycemia (34 of 35 [97%]).</p>
---	---	--	--

Kaji, Gausche-Hill, Conrad, Young, & Koenig, (2006)
 Emergency Medical Services
 System changes reduce pediatric epinephrine dosing errors in the pre-hospital setting

A total of 104 children <12 years of age who were determined to be in pre-hospital cardiopulmonary arrest and who received pre-hospital epinephrine treatment by paramedics, in the periods of 1994 to 1997 and 2003 to 2004, were included in the study.

An observational analysis of a natural experiment was performed. Data collected from 2003 to 2004 were obtained from the LA County EMS Agency for a consecutive cohort of children 13 years of age who experienced pre-hospital cardiopulmonary arrest between January 1, 2003, and September 30, 2004.

For the 2003 to 2004 cohort, EMS data forms and the original paramedic run sheets were collected and reviewed.

Variables recorded for both study cohorts included age, patient weight determined with the Broselow tape, gender, arrest rhythm, and actual dose, concentration, and route of the first dose of epinephrine administered.

A total of 104 children in pre-hospital cardiopulmonary arrest who received epinephrine with a documented weight and route of administration. Only 29 of 104 subjects in the 1994 to 1997 cohort received the correct dose, whereas 46 of 104 subjects received a first dose within 20% of the correct dose. In the 2003 to 2004 cohort, we identified 41 children <12 years of age, who were in cardiopulmonary arrest and received pre-hospital epinephrine treatment, 4 children were excluded, leaving 37 subjects. Twenty-one of 37 subjects received the correct dose, whereas 24 of 37 subjects received a dose within 20%. The odds ratio for obtaining the correct epinephrine dose after the system changes versus before was 3.0, and that for obtaining a dose within 20% of the correct dose was 2.5.

<p>Rothschild et al. (2006) Use and perceived benefits of handheld computer-based clinical references</p>	<p>Sample consisted of 29,000 physicians with subscriptions to the complete set of clinical reference applications and who also had previously participated in previous Epocrates' surveys.</p>	<p>Data were collected from 2 sources; an online survey to assess physicians' experience with HC clinical references and downloaded tracking data from HCs to capture actual application usage patterns. The tracking data for HC usage behavior was collected during synchronization through a desktop computer to the Epocrates website. Researchers compared individual survey findings to the captured usage data for each participant.</p>	<p>The survey response rate was 42% ($n = 1501$). Physicians reported using the clinical reference software for a mean of 4 years and 39% reported using the software during more than half of patient encounters. Physicians who synchronized their HC during the data collection period ($n = 1249$; 83%) used the pharmacopeia for unique drug lookups a mean of 6.3 times per day (SD 12.4). The majority of users (61%) believed that in the prior 4 weeks, use of the clinical reference prevented adverse drug events or medication errors 3 or more times. Physicians also believed that alerts and other notifications improved patient care.</p>
---	---	---	--

<p>Sharek et al. (2006) Adverse Events in the Neonatal Intensive Care Unit: Development, testing, and findings of an NICU focused trigger tool to identify harm in North American NICUs</p>	<p>Fifty patients from each site with a minimum 2-day NICU stay were randomly selected between November 1, 2004, and January 31, 2005.</p>	<p>This study was a cross-sectional study, using retrospective chart review, in 15 NICUs (14 in United States, 1 in Canada</p>	<p>Review of 749 randomly selected charts from 15 NICUs revealed 2218 triggers or 2.96 per patient, and 554 unique adverse events or 0.74 per patient. The positive predictive value of the trigger tool was 0.38. Adverse event rates were higher for patients 28 weeks' gestation and 500 g birth weights. Fifty-six percent of all adverse events were preventable; 16% could have been identified earlier, and 6% could have been mitigated more effectively. Only 8% of adverse events were identified in existing hospital-based occurrence reports. The most common adverse events identified were nosocomial infections, catheter infiltrates, and abnormal cranial imaging.</p>
--	--	--	--

<p>Stebbing, Kaushal, & Bates (2006) Pediatric medication safety and the media: What does the public see?</p>	<p>Newspaper coverage of pediatric medication errors and adverse drug events from the United States, Canada, United Kingdom, Australia, and Ireland, during a 10-year period (1994–2004)</p>	<p>Searched Lexis Nexis for newspaper articles on pediatric medication safety using keywords. Main outcome measures were the number of articles (adjusted for population), the type of events covered, and article slant. Examined qualitatively the overall themes and the extent to which the articles portrayed a culture of safety to the public.</p>	<p>Across the world, there was a steady increase in articles on pediatric medication safety, peaking in 2003, with the highest per-capita rate in Canada. Approximately 65% of articles were about patient incidents, 20% mentioned policy, and 25% discussed research. Of the reported events judged to be negative for patient safety, 75% were covered in a neutral manner and 19% were covered in an unduly negative manner. These data suggest that the media may be helping to close the gap between the expert approach to reducing adverse events, through the culture of safety, and public opinion. These data suggest that the efforts to reduce adverse event rates should be publicized to the public through the media.</p>
---	--	--	---

Walsh, Adams, Bauchner, Vinci, & Chessare, et al. (2006)
 Medication errors related to computerized order entry for children.

A total of 352 randomly selected, inpatient, pediatric admissions were reviewed retrospectively for identification of medication errors, 3 to 12 months after implementation of a (CPOE)

Retrospective chart orders review for identification of medication errors, 3 to 12 months after implementation of a (CPOE)

Among 6916 medication orders in 1930 patient-days, there were 104 pediatric medication errors, 71 were serious (37 serious medication errors per 1000 patient-days). Computer related errors were 19% (7 serious and 13 with little potential for harm). The rate of computer-related pediatric errors was 10 errors per 1000 patient-days, and the rate of serious computer-related pediatric errors was 3.6 errors per 1000 patient-days. The following 4 types of computer-related errors were identified: duplicate medication orders (same medication ordered twice in different concentrations of syrup, to work around computer constraints; 2 errors), drop-down menu selection errors (wrong selection from a drop-down box; 9 errors), keypad entry error (5 typed instead of 50; 1 error), and order set errors (orders selected from a pediatric order set that were not appropriate for the patient; 8 errors). In addition, 4 preventable adverse drug events in drug ordering occurred that were not considered computer related but were not prevented by the computerized physician order entry system.

<p>Han, Carcillo, Venkataraman, Clark, Watson, et al. (2005) Unexpected increased mortality after implementation of a commercially sold CPOE</p>	<p>Demographic, clinical, and mortality data were collected of all children who were admitted via interfacility transport to our regional, academic, tertiary care level children's hospital during an 18-month period.</p>	<p>Retrospective analyses of pre-CPOE and post-CPOE implementation time periods (13 months before and 5 months after CPOE implementation) were subsequently performed.</p>	<p>Among 1942 children in the study period, 75 died, accounting for an overall mortality rate of 3.86%. Univariate analysis revealed that mortality rate significantly increased from 2.80% (39 of 1394) before CPOE implementation to 6.57% (36 of 548) after CPOE implementation. Multivariate analysis revealed that CPOE remained independently associated with increased odds of mortality (odds ratio: 3.28; 95% confidence interval: 1.94–5.55) after adjustment for other mortality co-variables.</p>
<p>Kozer, Scolnik, MacPherson, Rauchweger, & Koren (2005) Using a preprinted order sheet to reduce prescription errors in a Pediatric Emergency Department: A randomized, controlled trial</p>	<p>Children treated at the ED of the Hospital for Sick Children in Toronto, Canada All prescriptions written during the study period were used. The analysis was conducted by prescription, not by patient.</p>	<p>The study was a randomized, controlled trial that was conducted at the Hospital for Sick Children (Toronto, Ontario, Canada), a tertiary care pediatric facility. All available patient charts were reviewed for medication errors according to a method described previously (2002)</p>	<p>A total of 795 medications were ordered. Within the study period, there were 2157 visits. A total of 2058 (95.4%) charts were available for review. A total of 411 (52.2%) orders for drugs in the ED were ordered on the regular form, and 376 (47.8%) were given on the new form. Drug errors were identified in 68 (16.6%) orders when the regular form was used and in 37 (9.8%) of the orders on the new form. Using the new form was associated with a significant reduction in the risk for an error (odds ratio: 0.55; 95% confidence interval: 0.34–0.90).</p>

<p>Upperman et al. (2005) The introduction of (CPOE) and change management in a tertiary Pediatric Hospital</p>	<p>Related CPOE articles on Medline with a pediatric focus.</p>	<p>Systematic literature review of CPOE-related articles indexed on Medline, with particular emphasis on pediatric applications and the implementation process at a tertiary pediatric hospital.</p>	<p>Children’s Hospital of Pittsburgh (CHP) implemented a (CPOE) an organizational and cultural transformation. The complete transition to CPOE was little more than 1 year and CHP overcame the typical obstacles of implementation. The early success of CHP was achieved by creating a realistic, positive, work environment, which fostered hospital wide participation and integration. The article contained lessons learned.</p>
<p>Potts, Barr, Gregory, Wright, & Patel (2004) Evaluated the impact of CPOE on the frequency of errors in the medication ordering process in a pediatric critical care unit (PCCU).</p>	<p>514 pediatric patients admitted to a 20-bed PICCU in a tertiary-care child’s hospital pre and post (CPOE) implementation.</p>	<p>13 828 medication orders were reviewed. Errors were identified after review of all orders during the study period and classified as potential ADEs, medication prescribing errors (MPE), and rule violations (RV)</p>	<p>Before implementation, potential ADEs occurred 2.2 per 100 orders, MPEs at 30.1 per 100 orders, and RVs at a rate of 6.8 per 100 orders. After implementation, the rate of potential ADEs was reduced to 1.3 per 100 orders, MPEs to 0.2 per 100 orders, and RVs to 0.1 per 100 orders. The error reduction was 95.9%. Potential ADEs were reduced by 40.9%, and MPEs and RVs were reduced by 99.4% and 97.9%. CPOE resulted in almost a complete elimination of MPEs and RVs and a significant but less dramatic effect on potential ADEs.</p>

<p>Carroll & Christakis (2004) Pediatricians' Use of and Attitudes About Personal Digital Assistants</p>	<p>Pediatricians (2130) were selected randomly from the American Medical Association Physician Masterfile of US- licensed physicians</p>	<p>All participants were mailed a survey along with a prepaid return envelope and a \$1 incentive. Of eligible participants, 63.2% returned a survey.</p>	<p>35% of respondents currently use PDAs at work, and 40% for personal use. The most commonly used applications were for drug reference (80%), personal scheduling (67%), and medical calculations (61%). Few use PDAs for prescription writing (8%) or billing (4%). Users of PDAs were more likely to be male (adjusted odds ratio [AOR]: 2.29; 95% Confidence interval [CI]: 1.64–3.19), in an urban community (AOR: 1.81; 95% CI: 1.30–2.55), in training (AOR: 2.64; 95% CI: 1.58–4.42), not in private practice (AOR: 1.47; 95% CI: 1.03–2.11), and a more recent graduate of medical school (AOR: 1.04 per year; 95% CI: 1.02–1.06). When controlling for covariates, those using PDAs believe that PDAs can decrease medical errors (AOR: 2.22; 95% CI: 1.46–3.38) and increase efficiency (AOR: 2.40; 95% CI: 1.56–3.71). When compared with nonusers, users were less likely to view the small screen size (AOR: 0.53; 95% CI: 0.37–0.77) or system speed (AOR: 0.47; 95% CI: 0.26–0.84) as a problem but were significantly more likely to view memory as an issue (AOR: 3.48; 95% CI: 2.30–5.25).</p>
--	---	---	---

<p>Carroll, Tarczy-Hornoch, O'Reilly, & Christakis (2004)</p> <p>The Effect of Point-of-Care Personal Digital Assistant Use on Resident Documentation Discrepancies</p>	<p>Clinical trial in an academic NICU</p>	<p>Progress note review of 339 charts from the baseline period and 432 progress notes in the intervention period</p>	<p>Controlling for covariates in the regression, there were significantly fewer documentation discrepancies of patient weights in the PDA system (14.4%–4.4% of notes; odds ratio [OR]: 0.29; 95% confidence interval [CI]: 0.15–0.56). When using the PDA system, there were no significant changes in the numbers of notes with documentation discrepancies of medications (27.7%–17.1% of notes; OR: 0.63; 95% CI: 0.35–1.13) or vascular lines (33.6%–36.1% of notes; OR: 1.11; 95% CI: 0.66 –1.87).</p>
<p>Fortescue, Kaushal, Landrigan & et al. (2003)</p> <p>Prioritizing Strategies for Preventing Medication Errors and Adverse Drug Events in Pediatric Inpatients</p>	<p>1020 patients admitted to 2 academic medical centers during a 6-week period in April and May 1999.</p>	<p>A prospective cohort study was conducted 10 778 medication orders were reviewed.</p>	<p>Of 10, 778 medication orders reviewed 616 contained errors. Of these, 120 (19.5%) were classified as potentially harmful, including 115 potential adverse drug events (18.7%) and 5 preventable adverse drug events (0.8%). Most errors - ordering stage (74%) and involved errors in dosing (28%), route (18%), or frequency (9%). Three interventions might have prevented harmful errors: 1) (CPOE) with (CDSS) (76%); 2) ward-based clinical pharmacists (81%); and 3) improved communication among physicians, nurses, and pharmacists (86%). Interrater reliability of error prevention strategy assignment was good (agreement: 0.92; κ: 0.82).</p>

<p>King, Paice, Rangrej, Forestell & Swartz (2003)</p> <p>The Effect of Computerized Physician Order Entry on Medication Errors and Adverse Drug Events in Pediatric Inpatients</p>	<p>Tertiary care pediatric hospital. Pediatric inpatients on 3 medical and 2 surgical wards.</p>	<p>A retrospective cohort study assessed the impact of a CPOE system on medication errors and adverse drug events (ADEs) in pediatric inpatients. Rate of medication error and ADEs before and after CPOE implementation.</p>	<p>A total of 804 medication errors were identified with 18 ADEs, resulting in patient injury among 36 103 discharges and 179 183 patient days. The overall medication error rate (MER) was 4.49 per 1000 patient days. Before the introduction of CPOE, the MERs of the intervention versus control wards were indistinguishable (ratio _ 0.93; 95% confidence interval [CI] 0.76, 1.13). After the introduction of CPOE, the MER was 40% lower on the intervention than on the control wards (ratio _ 0.60; 95% CI _ 0.48, 0.74). On average, 490 patient days are required to see the benefit of one less medication error using CPOE. We did not demonstrate a similar effect of CPOE for ADEs (ratio of rate ratios _ 1.30; 95% CI 0.47, 3.52).</p>
---	--	---	--

Kozer et al. (2002)

Variables Associated With Medication Errors in Pediatric Emergency Medicine

Children treated at the ED of the Hospital for Sick Children in Toronto, Canada.

Retrospective cohort study was conducted of the charts of 1532 children who were treated in the ED of a pediatric tertiary care hospital during 12 randomly selected days from the summer of 2000.

Prescribing errors were identified in 10.1% of the charts. Variables associated in univariate analysis with an increased proportion of errors: patients seen between 4 AM and 8 AM (odds ratio [OR]: 2.45; 95% confidence interval [CI]: 1.10 –5.50), patients with severe disease (OR: 2.53; 95% CI: 1.18 –5.41), medication ordered by a trainee (OR: 1.48; 95% CI: 1.03–2.11), and patients seen during weekends (OR: 1.48; 95% CI: 1.04 –2.11). A higher rate of errors by trainees at the beginning of the academic year (OR: 1.67; 95% CI: 1.06 –2.64). Logistic regression revealed increased risk for errors when a medication was ordered by a Trainee (OR: 1.64; 95% CI: 1.06 –2.52) and in seriously ill patients (OR: 1.55; 95% CI: 1.06 –2.26).

APPENDIX C: LITERATURE PERTAINING TO THE BROSELOW-LUTEN COLOR CODING KIDS

Table 3: *Literature pertaining to the Broselow-Luten Color Coding Kids*

Reference	Sample description	Data source	Results
Hohenhaus, Cadwell, Stone-Griffith, Sears-Russell, Baxter, et al. (2008) Assessment of emergency nursing practice during critical pediatric medication administration	Nurses from 4 hospital emergency departments n = 53 pre-implementation and n = 32 post implementation	Emergency room nurses at two pediatric emergency medication for a pediatric scenario.	Most common errors during the simulation were the incorrect reconstitution of the drug, wrong medication chosen and the incorrect dose given. This study identified areas for improvement in medication dosing. The need for further study of the human interaction of the tool and improved education in regard to the use of the tool.
Ramarajan, Krishnamoorthi, Strhlow, Quinn & Mahadevan (2008) Internalizing the Broselow Tape: How reliable is weight estimation in Indian Children.	Cross-sectional study of 548 children	A government pediatric hospital in India. Researchers conducted a cross-sectional study of three weight groups compared to Broselow-predicted weight groups.	The Broselow weight prediction was 70.8% accurate in children weighing less than 10kg. but only 56.3% in the 10-18 kg. group and 33.5% for those over 18 kg. The author states the Broselow tape over-estimates the weight of Indian children by 10%.

<p>DuBois, Baldwin & King (2007) Accuracy of weight estimation methods for children.</p>	<p>400 children were recruited with 100 in each weight class.</p>	<p>Children presenting in the triage of an Alabama hospital ED.</p>	<p>The study investigated 4 different weight classes. The Broselow –Luten tape and the DWEM system were both statistically correlated with actual weigh. However, both systems underestimated body weight. Some of the accuracy of the Broselow-Luten is lost after 20-25 kg.</p>
<p>Payne, Smith, Newkirk, & Hicks (2007) Pediatric medication errors in the Post anesthesia Care Unit: Analysis of MEDMARX Data.</p>	<p>Pediatric patients in the post anesthesia care unit</p>	<p>Six years of records from the MEDMARX databases consecutive non-probability sampling</p>	<p>19 different causes of error involved 28 different products were isolated. Results indicate that organizations need to focus on causes of errors. Recommendations for safe medication use were also included in the analysis.</p>
<p>Frush, Hohenhaus, Luo, Gerardi & Wiebe (2006)</p>	<p>89 pediatric care providers Children’s Hospital with Advanced Life Support, a tertiary care with ALS air and ground support and a private health system. Random sample of pediatric care providers.</p>	<p>3 study sites consisting of physicians, advanced practice nurses, and paramedics The intervention was a web based-education system using the Broselow –Luten tape</p>	<p>Analysis of medication prescribed indicated the decrease in the dosing deviation and dosing time in the education group was obvious. The reduction in dosing time in the education group was dramatic.</p>

<p>Phipps, Thomas, Gilmore, Raymond, Bittner, Orr & Robertson (2005) Prospective assessment of guidelines for determining appropriate depth of endotracheal tube placement in children.</p>	<p>Orally intubated pediatric intensive care unit patients of ≤ 12 yrs of age</p>	<p>Penn State Children's Hospital, Department of Critical Care Medicine and Pediatrics, Children's Hospital of Pittsburgh and University of Pittsburgh Medical Center, Pittsburgh, PA (RAO); and the Pediatric Critical Care Medicine (CLR), Baltimore, MD.</p>	<p>Suggested ETT size based on the Pediatric Advanced Life Support (PALS) age-based formula and the Broselow tape-length-based guidelines were determined. A total of 174 of 226 ETTs (77%) were correctly positioned. If practitioners utilized the 3x ETT size for the actual tubes chosen, 170 of 226 (75%) would have been accurately placed. More accurate were the 3x PALS-based ETT size (81%) and 3x Broselow-suggested ETT size (85%). The use of the Broselow ETTs to determine the depth would have led to a significantly improved ETT position ($p = .009$) compared with the actual ETT. Practitioners can improve the reliability of this formula by utilizing the recommended ETT size as suggested by the Broselow tape.</p>
<p>Luten, Wears, Broselow, Zaritsky, Barnett, Lee, Bailey, Vally, Brown, & Rosenthal (1993) Length-based endotracheal tube and emergency equipment in pediatrics</p>	<p>Two hundred five children undergoing elective surgery.</p>	<p>Department of Surgery, University of Florida Health Science Center, Jacksonville. Criteria for acceptable fit in this group included leak pressure as above and the anesthesiologists' decision to accept the tube size or to reintubate.</p>	<p>The tape selected the appropriate ET tube size by leak pressure criterion in 77% of the cases and was within ± 0.5 mm of the "correct" size 99% of the time. This was significantly better (P less than .005) than two widely used age-based rules, which gave the correct initial size in only 47% and 9% of these cases, and were within ± 0.5 mm for 86% and 59%. The anesthesiologists chose to continue with the tape-sized tube rather than to reintubate in 89% of cases.</p>

APPENDIX D: PEDIATRIC RAPID RESPONSE MEDICATION SCENARIO
CHECKLIST

Date: _____

Total _____

Participant code number _____

PEDIATRIC RAPID RESPONSE MEDICATION SCENARIO CHECKLIST

(Scoring Rubric) Total possible 11 points

Safe Medication Administration Check Measure	Check column upon safe completion of task	Do <u>NOT</u> check square and <u>record error</u> in box
1. Proper identification of the patient (1 point)		
2. The right drug selected (1 point)		
3. The right dosage (1 point) Dilution (1)		
4. The right time (1 point)		
5. The right route (1 point)		
6. Right assessment (1 point) Did they check compatibility, allergies?		
7. The right documentation (MAR) time/dose/route/initials (1 point)		
8. The right evaluation (1 point)		
9. Education of family member (1 point)		
10. Right to refuse (Did they check or inform with the mother?) (1 point)		

Observer: _____

APPENDIX E: SBAR RUBRIC

Code number _____ Total points _____ Observer initials: _____
 HANDOFF/REPORT TOOL (Scoring Rubric) Total score ____

<p>S Situation (5)</p> <p>Total score: _____</p>	<p>Name Carol Long Age 12 months Diagnosis- FUIO, Status Epilepticus (1point)</p> <p>Situation: 5-10 second “punch line” – What is happening now? What are the chief complaints or acute changes?</p> <ol style="list-style-type: none"> Patient is sleeping (R 24) color pink P-130 T-105.6 (1point) 14:00 tonic and clonic seizures, absence of respirations and became cyanotic (1 point) <p>Meds (3 points): IV Lorazepam at _____(1) Phenytoin Loading IV _____ (1)</p> <ol style="list-style-type: none"> Pt responded color improved and vitals –no evidence of seizure activity presently(1 point)
<p>B Background (5)</p> <p>Total score: _____</p>	<p>Allergies/ any problems with contrast?</p> <p>What factors led up to this event? Pertinent history (eg, admitting diagnosis) & objective data (eg, vital signs, labs) that support how patient got here.</p> <p>The patient has Elevated temp <u>106.6 on admission</u> and sent from pediatrician’s office to be admitted. Began <u>seizuring</u> on admission, Mother reported <u>cold like symptoms</u>, <u>current vitals</u> (1 point for each underlined _____Did the student document allergies (1 point)</p>
<p>A Total score: _____ Assessment (5)</p>	<p>What do you see? What do you think is going on? A diagnosis is not necessary; include the severity of the problem.</p> <p><i>I think the problem is</i> _ Febrile (1), Respiratory congestion (1point), Respiratory infection or pneumonia (1 point) Responding to interventions (1 point) Color (1 point)</p>
<p>R Total score: _____ Recommendation (5)</p>	<p>What action do you propose? State what the patient needs (get a time frame).</p> <p><i>I request that you Continue to <u>monitor assess respiratory status & cough chest x-ray needed and order for O2, and LOC, vitals q15 minutes until stable, observation by RN and instruction to mother, IV of D 5 0.5 saline at 43 ml/hr rate microdrip.</u> (point for each underlined)</i> <u>Transfer to ICU for closer monitoring</u></p>

Scoring Instructions for Research Assistant Nurse Educators

SBAR Instrument

Two nurse educators will independently score the SBAR. Each section under the SBAR documentation is worth 5 points per section. In order to remain objective the raters are asked to score only the data presented on the key to the SBAR. If a student does not report the information on the SBAR form subtract one point for every missed item. For example if the participant does not report the current vital signs in the S (situation) section but included other items they would receive a score of 4. The total number of points obtainable for this instrument is 20 points. Please record the participant number and total score at the top right of the SBAR page.

Scoring for the PEDIATRIC RAPID RESPONSE SCENARIOMEDICATION CHECKLIST

Two nurse educators will independently score the checklist. Each section under the checklist is worth one point per section. In order to remain objective the raters are asked to score as one point if the participant did the action or 0 if the participant did not complete the action. Any attempt by the participant to inform the mother on # 9 or educate the mother is scored as one point. Please record the Code number for each subject and total score on the top right corner.

APPENDIX F: POSTED FLYER

Calling All Senior Nursing Students

Join Us in an Effort to Protect Vulnerable Children by
Participating in a Research Project

- Who is eligible: Enrollment in an entry level nursing program (BSN) or (ADN). Student must be in the last semester of their studies and ready to graduate in spring semester of 2009. Students must have taken pediatric nursing and must be at least 18 years old and a student at UNCC or CVCC or simulation clinical student at CVCC.
- What: Pediatric simulation participation. All information and participation confidential –not even your instructor will know!!! We use numbers not names
- Where: UNCC nursing lab or CVCC simulation hospital
- Why: Help us improve the safety of nursing care through research. Be eligible to enter a drawing for free NCLEX licensure fees. Receive a Certificate of Participation for your portfolio. Just contact: Colleen Burgess at 828-327-7000 ext 4592, or LuAnn Martin 828-327-7000 4224

APPENDIX G: Letter to Department Heads

January, 2009

Dear Department Head for Nursing,

My name is Colleen Burgess, a nurse educator and doctoral candidate at UNCC specializing in nursing educational leadership. I will be conducting a research project at the Catawba Valley Regional Simulation Hospital. The simulation will be a pediatric scenario intended for senior graduating nursing students that have completed their pediatric rotation. The scenario is based on a real case. Your students are invited to participate during their regularly scheduled simulation clinical or at their convenience during a scheduled research simulation time. No individual data will be identified. All participants will be coded and no names will be used. The scenario total time will be approximately 30 to 40 minutes which includes orientation to the project and the simulated nursing unit. We believe this experience will be not only informative but exciting to participate in a research project. We will be conducting the research in January and February 2009.

Attached please find fliers that can be posted in the nursing department. I hope that you will share this opportunity with your students. If I may, I would like to visit your nursing class for 5 minutes and inform them of the project. I can be contacted by e-mail at cburgess@cvcc.edu or 828-327-7000 extension 4592 to set a time to meet with students or answer questions. A schedule will be sent to you with the dates we will be conducting the research. Participants will be given a certificate of participation for their professional portfolios and a raffle ticket for a chance to win reimbursement for their NCLEX licensure fee.

Thank you for your attention.



Department of Educational Leadership

UNC Charlotte
 Educational Leadership
 266 College of Education Bldg.
 Charlotte, NC 28223-0001 t/ 704.687-8856

University of North Carolina-Charlotte

Study Title: A Comparison of Traditional Medication Administration and Color Coding Kids

Principle Investigator: Colleen Burgess

Telephone number of the researcher: 704-458-4099 and E mail ccburge2@uncc.edu

The information presented to you here is designed to inform you of the nature of the study and your rights about participating in the study. You are a volunteer. The decision to participate in this study is completely up to you. If you decide to be in the study, you may stop at any time. You will not be treated any differently if you decide not to participate.

What is the objective of the study?

The objective of the study is to gain knowledge about the current practice of nursing medication administration and the impact of computer technology.

How many people will participate in this study?

70 participants will be selected.

How much time will it take to participate in this study?

Approximately 30 minutes.

What will happen if you participate in the study?

You will be asked to provide nursing care and assessment documentation in a simulated environment to a child in distress. We will be using manikins for the study.

What might some of the benefits of participating in this study be?

Participants will receive a certificate of participation in a nursing research study for their career portfolio. Each participant completing the scenario will be given a raffle ticket toward reimbursement for their licensure fee for NCLEX.

What are some of the possible risks or annoyances that may occur from participating in this study?

You may feel uncomfortable or anxious in a simulated experience or embarrassed. It is like role playing.

How will your privacy be protected?

No names will be used and the performance is confidential. All forms for the simulation are numbered not named and the names are not recorded.

What if you have questions about this study?

You may contact Colleen Burgess at 704-458-4099 e-mail ccburge2@uncc.edu or Dr. J. Allen Queen 704-687- 8856 in writing to UNCC, 9201 University City Boulevard, Charlotte,28223.

What if you have questions about your rights about participating in this study?

UNC Charlotte wants to make sure that you are treated in a fair and respectful manner. Contact the University's Research Compliance Office (704-687-3309) if you have any questions about how you are treated as a study participant.

What are some general things you should know about research studies?

You are being asked to take part in a research study. To join the study is voluntary. You may refuse to join, or you may withdraw your consent to be in the study for any reason without penalty.

Research studies are designed to obtain knowledge. This new information may help people in the future. You may not receive any direct benefit from being in the research study. There also may be risks to being in research studies.

Details about this study were discussed above. It is important that you understand this information so that you can make an informed choice about being in this research study. You will be given a copy of this consent form. You should ask the researchers named above any questions you at any time.

Participant Consent:

I have read the information in this consent form. I have had the chance to ask questions about this study, and those questions have been answered to my satisfaction. I am at least 18 years of age, and I agree to participate in this research project. I understand that I will receive a copy of this form after it has been signed by me and the Principal Investigator.

Participant Name
(PRINT)

DATE

Participant Signature

DATE

Investigator Signature

DATE

This form was approved for use on *January, Day, 2009* for a period of one (1) year.

APPENDIX H: PARTICIPANT DEMOGRAPHICS

Code number: _____

Date: _____

Thank you for completing this survey. I appreciate your willingness to participate in this project. Your individual responses will be kept confidential. The data will be reported only in a summary format and will be available upon request.

Please complete the demographic information below.

1. Anticipated nursing graduation date. _____
2. Which program of study?
 - a. Associate degree nursing (ADN)
 - b. Baccalaureate nursing (BSN)
3. What is your gender?
 - a. Female
 - b. Male
4. What is your ethnicity?
 - a. Caucasian
 - b. African American
 - c. Asian
 - d. Other _____
5. Previous educational background? (Select only if you have completed)
 - a. GED
 - b. High school graduate
 - c. Associate degree
 - d. Baccalaureate degree
 - e. Master's degree
 - f. Other
6. Age _____

Thank you.

This certificate is presented to
[Name]
For participating in a nursing research project about
*Safe Pediatric Medication Administration Color
Coding Kids*

Dated this ____ day of _____, 20____.

Investigator