DEVELOPMENT OF AN OPTIMAL PATIENT TRANSFER TASK SET AND SIMULATION-BASED INTERVENTION TO REDUCE MUSCULOSKELETAL INJURY IN HEALTHCARE WORKERS

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Introduction:

Occupational injury is recognized as a key attrition factor in nursing with musculoskeletal injury the most common cause. Nurses, nurse aides and orderly injury rates are consistently listed in the top ten US occupations in terms of total numbers of injuries with patient transfer a primary etiologic factor. Patient transfer education for trainees as well as employees remains inconsistent and non-standardized. Legislative and policy efforts have not been effective.

Methods:

Two methods are combined in this paper to approach the problem: hierarchical task analysis and a simulation educational intervention. Hierarchical task analysis has been used to solve industrial process problems for more than three decades and simulation education methods have been used in aviation since the 1920's. The hierarchical task analysis process is used to develop an optimal task set which was the used to frame and implement a healthcare simulation training intervention.

Results:

Performance evaluation tools for patient transfer were developed based on the optimum task set. Transfer of simulation training outcomes to the clinical setting was demonstrated on pilot study intervention and control units. The program was implemented in a community hospital with sustained improvement in transfer skill and reduction of injury rates and lost work days.

Conclusion:

Because patient safety and improved outcomes are linked to adequate levels of nurse staffing, the public health implications of this project are significant. If nursing injury can be avoided using these methods then true progress can be made in arresting the injury epidemic with resultant reduction of nursing workforce losses with consequent healthcare system benefits.

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PREFACE

Completing a doctoral dissertation and conducting a major study while concurrently holding multiple roles within the University of Pittsburgh has been the greatest challenge of my career. I would like to acknowledge the individuals who have helped to make this possible. I wish to thank my wife Melinda and my children Conor, Maeve and Liam. I have spent many hours in study and preparation and they have been incredibly patient, supportive and understanding. Next I wish to acknowledge Mr. Joseph S. Goode. As a friend and co-investigator he contributed both intellectually and personally. Long-lasting thanks to Tom Thomas who has been a friend, confidante, mentor and guide on this vision-quest. I wish to acknowledge my committee Chair Dr. Kim Sutton-Tyrell. I think I was a bit of an anomaly as a student and I very much appreciated her support and flexibility. Fourth, I wish to acknowledge the committee members Dr. Nick Bircher, Dr. Richard Henker, Dr. Sheryl Kelsey and Dr. Pamela Peele who all have offered support and positive suggestions along the way. I also wish to acknowledge my Department Chair and mentor Dr. Leslie Hoffman. Dr. Hoffman has encouraged, supported and most importantly-motivated- in her usual straightforward fashion. Thanks as always to my other supports: Dr. Paul Phrampus (WISER Director) who is a champion of nursing education and research, Mr. John Lutz who helped with data and IT support and the members of the fabulous team at WISER. Dr. Gail Wolf and Ms. Tami Minnier of UPMC provided superb administrative support of the project. Mr. John Close of the School of Dental Medicine, Dr. Manny Vallejo and my other academic colleagues have given much needed help and words of encouragement along the way. Last but certainly not least, I wish to acknowledge my students and professional colleagues in the Nurse Anesthesia Program. Your hard work and dedication is inspiring and provided additional motivation for me to move toward completion.

1.0 INTRODUCTION TO THE PROJECT

1.1 PATIENT SAFETY AND THE NURSING SHORTAGE

1.1.1 Patient Safety

While patient safety and reduction of errors is becoming an integral part of the fabric of healthcare education, the challenge remains to determine how embedded systems, care cultures and historical practices can be changed rapidly and effectively to the benefit of patients and providers alike. In 1999 the Institute of Medicine (IOM) published 'To Err is Human' a landmark patient safety report which identified key problems within the US healthcare delivery system. The most startling aspect was the number of adverse and mortal events attributed to medical negligence and error with the authors estimating that 44,000-98,000 deaths occur every year because of medical error(1). Of interest for this dissertation is that the report suggested the use of human patient simulation education as a mechanism for error reduction and thus prevention of patient injury. The outcome of the report was to provide impetus for the transformation of healthcare delivery and education as it helped to catalyze the national patient safety and simulation education movements.

The Institute for Healthcare Improvement (IHI) founded by Dr. Don Berwick in 1991 had been a leading national safety advocacy group for many years prior to the IOM report. The report stimulated this safety leadership group to initiate the 100,000 lives campaign- obviously a direct correlate to the 98,000 figure highlighted in the 'To Err is Human' report (2). In July of 2006, the IHI reported saving 127,000 lives over a period of a little more than a year after recruiting more than 3,000 hospitals to adopt a series of six safety initiatives with standardized reporting. Unfortunately, this data while indicating a higher number of patient safety related deaths also appears to be an underestimation. This is emphasized by findings of the American Health Qualities Annual Report 2004 which reported 241,280 deaths attributable to patient safety incidents (PSIs) among the Medicare population alone (3). The 100,000 lives campaign can be directly linked to developments in simulation as the core concepts behind the six IHI measures have been incorporated within simulation training curricula as a mechanism to enhance patient safety and/or demonstrate provider competence (4-22).

1.1.2 Nursing Shortage

One factor which has been demonstrated to improve patient safety is adequate levels of nurse staffing (23-28). In a 2006 meta-analysis, Kane reported that "higher registered nurse staffing was associated with less hospital-related mortality, failure to rescue, cardiac arrest, hospital acquired pneumonia, and other adverse events. The effect of increased registered nurse staffing on patients safety was strong and consistent in intensive care units and in surgical patients" (29). Nurse shortages have been associated by several authors with increased risk of medical error (30), burnout (24, 27) and injury (31, 32). Multiple indices of patient comfort, satisfaction and even patient survival may be impacted by nurse staffing levels (23-28, 33). In a series of studies, Aiken demonstrated that higher RN staffing levels resulted in improved patient safety and better outcomes (25, 28, 34). Unfortunately, achieving optimal nurse staffing is jeopardized by the emerging nurse shortage. Shortages of nurses are typically related to an imbalance of supply with demand. In 2006 the American Hospital Association reported a national RN vacancy rate of 8.5% based on a shortage of approximately 118,000 RNs (35). This shortage is expected to accelerate with nurse deficit projections ranging from 340,000 to 1,000,000 by the year 2020(36, 37).

In meeting this challenge, interventions have been proposed to support the nursing workforce through increased use of assistive personnel, increased enrollment and graduation from nursing programs and to decrease loss of existing nurses. Factors which lead to ongoing losses of nurses and assistive personnel from the workforce due to non-retirement causes oppose these efforts. Examples include burnout, moral distress, change of career, change of life status, professional disillusionment and occupational injury (24, 27, 38-40).

1.1.3 Occupational Injury

Injury epidemiology is the systematic study of preventable injuries within the population (41). The term 'accidental' injury is often broadly used to describe injuries, however true 'accidents' must be differentiated from injuries with predictable causal patterns and potential for preventive intervention(41-43) More than 140,000 Americans die every year from injuries. Overall, injury remains among the leading causes of death in the United States ranking 4th in 2004 and 5th in 2006 (42, 44). Injury is the leading cause of death for Americans in the age ranges of 1-44(45).

A nonfatal injury is defined by the Centers for Disease Control and Prevention Web-based Injury Statistics Query and Reporting System (WISQARS™) as "bodily harm resulting from severe exposure to an external force or substance (mechanical, thermal, electrical, chemical, or radiant) or a submersion" (45). The category of non-fatal injury is highly significant and involves substantial financial, physical, psychological and emotional costs (42). It is estimated there are as many as 18 hospital discharges and 250 injury-related emergency room visits for every injury death (43).

A sub-set of non-fatal injuries is the non-fatal *occupational* injury. The US Bureau of Health Labor Statistics maintains a public database of all non-fatal occupational injuries and the National institute for Occupational Health and Safety (NIOSH) provides oversight for occupation related injury (46, 47). Musculoskeletal injury is the leading cause of non-fatal occupational injuries with the category 'sprains and strains' representing the largest group requiring days away from work (46, 48) For the overall workforce, musculoskeletal injury rates are affected by multiple variables including training (increased amount and quality= decreased injury), employee turnover rates (higher rate = increased injury), experience of the worker (less experience = increased injury), extent of mechanization and automation (greater mechanization = decreased injury), industry division and occupation (service industry and nurse = greater injury), source (increased lifting = greater injury), exposure (increased repetitive motion = increased injury), age (older worker = increased cumulative injury), gender (men are injured more than women), obesity (increased obesity = increased injury), physical conditioning (increased physical conditioning = decreased injury) (49-51). From 1992-2002 the absolute numbers of occupational injuries and illnesses declined but the basic trends associated with different factors remained almost unchanged (49). Data from 2006-2007 demonstrate a decrease in musculoskeletal injury rates (52). The reasons cited for this decline are US workforce-wide changes in working conditions, focus on injury prevention and potentially the outsourcing of many physically challenging jobs to other countries (49). Factors which predict disability from musculoskeletal injury include delay in seeking treatment, construction and logging industry workers, older age, delay in claim filing post treatment, small firm size, female gender, higher unemployment rates, having dependents and back injury (53). The most common musculoskeletal injuries are to the shoulders and back which represent 33% of all musculoskeletal injuries, of which many are associated with lifting activities (52).

1.1.4 Patient Transfer and Provider Injury

Nursing injury in the workplace is of concern across the healthcare industry due to direct cost, indirect cost with impact on non-injured providers and because of the ongoing nursing shortage (50, 54-56). This issue remains a healthcare policy focus with efforts aimed at establishing consistent and achievable goals through policy initiatives, professional practice standards and legislation. One important national effort is the American Nurses Association (ANA) ‘handle with care’ program which has suggested a limit of 35 pounds maximum per provider in any patient transfer or lift as opposed to the Revised National Institute for Occupational Safety and Health (NIOSH) lifting equation which calculates the maximal weight to be lifted per person in a manual task at 51 pounds (47, 56, 57). The ANA initiative began in 2003 and takes into account the difference between a patient and a static load such as a box (47). This campaign has been widely publicized to both the public and to regulatory groups. Despite the national trend toward reduction in non-fatal occupational injury and these administrative efforts, in 2007 nurse aides, orderlies and attendants and nurses (registered nurses and licensed practical nurses) remain in the top ten of all occupations relative to absolute numbers of non-fatal occupational injuries requiring days away from work **(Table 1)** (58, 59). Patient transfer is the most frequently cited cause of injury and thus is a viable target for development of an injury prevention intervention.

1.2 METHODS IN DEVELOPMENT OF AN INTERVENTION: HIERARCHICAL TASK ANALYSIS AND HUMAN SIMULATION EDUCATION

1.2.1 Hierarchical Task Analysis

A unique aspect of this project was in use of hierarchical task analysis or HTA. As the name implies, this method breaks processes down into component parts and puts them in an order or hierarchy as appropriate (60). This task analysis approach involves repetitive description, analysis and then re-description of a process in terms of its goals and sub-goals. Widely used in industry and considered central to the science of ergonomics, hierarchical task analysis has been used successfully for more than 40 years to analyze simple to complex tasks involving both individuals and teams (60-63).

Hierarchical task analysis methods were chosen for this dissertation because they are highly flexible and can be used to analyze anything from an isolated procedure to team performance to the function of an entire system (60). To an outside observer, the task of transferring a patient is deceptively simple. Closer examination reveals patient transfer to be quite complex with pre-move planning involving patient assessment and equipment selection, a move process combining cognitive and psychomotor aspects of coordinating and performing the transfer and then reassessment of the patient and environment with return of equipment to storage areas. When using hierarchical task analysis to describe the process of patient transfer, it is necessary to deconstruct this seemingly continuous event into discrete and measurable components in order to develop an optimal task set. Developing evidence-based rationale for each component of the task set establishes a clear theoretical and practice based foundation for teaching and evaluation. When applied in this manner HTA methodology provides a flexible and robust approach for description of the complex task of patient transfer as well as a clear template for evaluation of each step required to complete the task(60-63).

Several authors have used the hierarchical task analysis method in reduction of medication administration error in the clinical setting. In 2003, Chung et. al used hierarchical task analysis as a method to predict errors when using volumetric infusion pumps. This safety-based study compared various pump-user interfaces to predict points at which error in programming and use would be likely to occur. The outcomes of the study demonstrated that the substantial variability between devices was a source of usage error (64). In 2006, Brannon used the hierarchical task analysis method to look at the cognitive tasks and errors associated with use of standardized drug infusions versus mixing the infusions at the bedside (ad hoc) in the neonatal ICU setting. The ad hoc mixtures had the benefit of being tailored for the individual weight of the patient such that dosing required minimal adjustment of the infusion pump but carried the risk of an admixture error. The premixed infusion concentrations required less provider medication interaction but more programming of the volumetric pump devices. The outcome of this study demonstrated that use of the premixed infusions may lead to increased programming errors (65). Also in 2006, Lane and Stanton used the hierarchical task analysis method to analyze the steps of the medication administration process which include prescribing, documenting, dispensing or preparation, administering and monitoring. This project illustrated how task analysis can be used to break down a process into component parts with isolation of underlying causal factors for error. Systematic error reduction and prediction processes were used to demonstrate how the task analysis method can be used to substantially reduce medication administration error (66).

Other authors have used hierarchical task analysis methods in analysis of surgery and anesthesia processes. In a series of studies in 2008, Sarker et. al. initially developed a surgical hierarchical task analysis that would allow evaluation of technical and decision making behaviors in a variety of operations including laparoscopic cholecystectomy, open inguinal hernia repair, saphenofemoral junction ligations, upper GI endoscopy and lower GI endoscopy.

The primary outcome was to construct a valid and reliable method for developing a surgical task analysis which could be used to evaluate the skills of novices to experts for a wide variety of surgical procedures (67). In the follow-up study, they used hierarchical task analysis as a tool to create an 'operative decision map' exclusively for laparoscopic surgery. Both surgeons in training and expert surgeon performances and actions were analyzed. The hierarchical task analysis process resulted in a checklist for evaluation and also was used in mapping surgeon decision-making processes (68). Also in 2008, Phipps et. al. used the hierarchical task analysis method to identify the task sets involved in preparing medications and administering anesthesia. The method used to identify points in the task sets where human error could occur was called the systematic human error reduction and prediction approach or SHERPA. SHERPA was not only used to identify the points for error evolution, but also to suggest methods by which the errors could be prevented. The authors concluded by reporting that induction of anesthesia was the point in anesthesia administration where errors were most likely to occur and made suggestions for development of error reduction strategies (69).

As demonstrated in the literature, hierarchical task analysis has been used in the healthcare industry to describe key processes in medication safety, error evolution, technical skills and decision making. Despite its origin as an industrial ergonomic tool, this method has not previously been used to describe processes implicated in occupational injury in healthcare. Further, while the hierarchical task analysis process has been used to analyze and suggest changes to clinical processes; it has not been used to build a targeted educational intervention. Borrowing from lessons learned in the aviation industry, the in-depth analysis of processes offered by task analysis combined with concentrated simulation training has the potential to improve performance, safety and outcomes (70-74).

1.2.2 Healthcare Simulation and the Aviation Industry Connection

The aviation industry initiated formal simulation training in 1929 when Edwin Link developed the first aircraft simulator known as the 'Link Trainer'. This device although crude in some respects, was a valuable tool for rapid development of basic flying skills and represented a key component in preparation of pilots before and during World War II (75, 76). Since this humble beginning, simulation in the aviation industry has undergone tremendous advancement with crew-based simulation training now a requirement within the industry (77-79).

Parallels between current healthcare simulation and aviation industry simulation are substantial. The work environment in both industries exists in a state of constant and dynamic change. Other parallels include: high risk, multiple variables affecting decisions, complex machines, and dependence on multiple interactions between (fallible) humans. In managing acute events, the healthcare provider must master the techniques of multi-tasking, hyper-vigilance, serial monitoring and quick decision-making which are also necessary in aviation (80). One final commonality is that aviators and healthcare providers only rarely encounter events that are critical or life-threatening. For example, in the practice of anesthesia, data suggest that unplanned incidents occur during approximately 1 out of 20 anesthetics administered and that for the vast majority, the providers quickly identify and address the issue (80, 81). A percentage of these events are not effectively addressed and progress to become more acute threats to patient safety (critical incidents) (82-84).

Human error is often implicated in critical incident development with the Australian Incident Monitoring Study revealing human error as a contributor in up to 83% of volunteered reports describing critical incidents (81). Because of the rarity of critical events, most providers are unlikely to gain sufficient experience in clinical practice and must depend on previous classroom based learning or work-based learning to inform their response to a problem (85). In 2006, Bligh suggested that if used appropriately, simulation (conceptualized as the third 'learning place' for training after the classroom and clinical environments) can be a valuable learning supplement (85). Because simulation education and technology allow the healthcare provider (or the pilot) to encounter events in a controlled setting, deliberate and realistic practice and skill refinement are made possible (86). By extension, this experiential learning should result in reduction of the likelihood of harm if the situation should be encountered in the clinical environment (1, 75). Further, the simulation setting provides a safe environment with opportunity for deliberate practice of cognitive and psychomotor skills in patient care (87-103).

1.2.3 Historical Context of Simulation Education in Healthcare

Static mannequins such as 'Mrs. Chase' in 1911 foreshadowed by almost six decades the development of Sim-1, the first high fidelity simulator (104-106). Mrs. Chase was used for classroom demonstration and skill development with new editions of the mannequin available until the 1970's (107). The use of simulation in healthcare education is neither new nor entirely unfamiliar to most educators. Simulation methodology is penetrating all areas of healthcare education and is being adopted across disciplines. Ranging from static rubber IV insertion arms (part-task trainer) to screen-based interactions with representations of patients (avatars) to live events including full clinical context with high technology mannequins, use in this area is rapidly growing. As simulation science and definitions of what constitute 'simulation' have evolved, many activities which perhaps had not been credited such as role play, use of standardized patients and blending of part-task trainers with full body simulators are emerging as key components to achieve integration of simulation within a program of study. The introduction of technologically advanced yet affordable patient simulators has encouraged more widespread use and further pushed healthcare educators to consider this educational approach. Also, studies are emerging which demonstrate that this educational approach shows promise in increasing retention of skills (108-111).

In 1968, Dr. Michael Gordon presented the first high technology cardio-pulmonary simulator at a meeting of the American Heart Association. This simulator remains in production, has been extensively validated and is widely considered to be the most realistic cardiopulmonary simulator available (112-114). In 1969, Denson and Abrahamson developed the first anesthesia simulator, known as SIM1. It consisted of an upper torso with arms that could be utilized to practice both intubation and induction of general anesthesia. Sim-1 was potentially a ground-breaking advancement in the field of anesthesia (and healthcare) education. Unfortunately, financial and technologic constraints limited its use and resulted in the abandonment of further development (115). In the mid 1980s, computer-based simulators re-emerged in the anesthesia community in the form of screen-based simulators such as the SLEEPER and BODY systems. These devices displayed a realistic patient presentation, including clinical data and the work environment on the screen. They tested an anesthesia provider's ability to manage cases and incorporated both pharmacological and physiological models. In 1986 a Stanford team led by Gaba and DeAnda developed a full-scale simulator called CASE (Comprehensive Anesthesia Simulation Environment) to study decision-making during critical events (116). Since the development of the CASE simulator, the progression toward development of more realistic, self contained and fully functional human simulators has accelerated with concurrent integration into both medical and nursing curricula.

1.2.4 Simulation in Development of Competence

In the nursing profession, there is no universally accepted definition of competence nor is there consensus as to who is responsible for nurses remaining competent. Merriam-Webster defines competence as “the quality or state of being functionally adequate or of having sufficient knowledge, judgment, skill, or strength” (117). In 2002 Epstein provided a more comprehensive, healthcare oriented definition: “the habitual and judicious use of communication, knowledge, technical skills, clinical reasoning, emotions, values, and reflection in daily practice for the benefit of the individual and the community being served”(118). In 2004, the Joint Commission established requirements for competency assessment for nurses (HR 2.30 and 3.10) (119). These requirements address the need for institutions to identify the competencies required for practice, develop assessment tools, establish evaluation timeframes and in delineation of the mechanisms for assuring ongoing competence (120).

Traditional entry into nursing practice has involved demonstration of competence through completion of a program of study and then passing a multiple choice licensure examination. Some of the other methods that have been used in competence validation include completion of continuing education coursework, self-assessment models, oral or essay examinations, performance based systems using videotaped clinical vignettes and certification including practice exams using patient simulations (121, 122). The limitation of using the current didactic threshold examinations for entry to practice is that this method measures only the knowledge, and to some degree judgment, aspects of competence. Skill, communication, teamwork, values, critical thinking and the ability to handle ambiguity are not addressed. Given the heterogeneity available in entry-level preparation for professional nursing practice, these other areas may not be adequately addressed in educational programs. Simulation offers the potential to evaluate multiple competence domains in a controlled setting. Several authors have described their approaches to this problem.

In 2007, Ackermann described use of a simulation program to assist the transition of new nurses into practice. This is an important opportunity for simulation training as this transitional period represents the window of time when new nurses develop their competency foundation. Patient safety and outcomes are impacted by new nurses who must cope with the stressors associated with entering a new profession, lack of self-efficacy and issues of competence. These authors reported that simulator training programs can support development of critical thinking, decision making, and clinical confidence and describe the process of course development (123).

DeVita et al have published several papers demonstrating use of an on-line curriculum integrating didactic content with simulation training and a novel debriefing tool to improve multidisciplinary rapid response team performance. These authors report substantial increase in team task completion and simulator survival (124, 125). The program has been offered to improve competency of nurses in management of patient emergencies within the University of Pittsburgh Medical Center (UPMC) system (Pittsburgh, PA and surrounding region). Stringer described use of simulation training with 'smart sim labs' to improve rapid response team performance among practicing nurses in Southern California (126).

In 2006, Landry described a competency training and evaluation program for professional nurses. A total of 75 medical-surgical nurses completed the two-day program. The program blended use of a variety of part task, full task and virtual reality simulators. Competencies evaluated included hand washing, restraint use, transfer training, urinary catheter insertion and care, virtual IV insertion, code protocols and procedures, chest tube management, blood administration, injections; nasogastric tube insertion and care, PEG tube care, care of central venous access devices, care of dialysis catheters, suctioning and tracheostomy care(127). Trained instructors evaluated each participant and written feedback was given at each station. Findings from the program were used to refine this program and a corresponding on-line learning management platform which provided supplemental information for each topic (127).

Beyea et al described a simulation based residency program for 42 new nurse graduates who were accepted as residents. The program incorporated high-risk, low-frequency clinical events, as well as lower-risk high-frequency events. Didactic lectures, simulation sessions and clinical practice were coordinated throughout the program. Both mannequin and computer based simulations were used. Three primary outcomes were analyzed: participant perceptions (clinical competence, confidence, and readiness for independent practice), performance (both clinical and simulated environments) and length of orientation. The authors reported that the program improved competence, confidence and readiness for practice. The variability in orientation length was reduced and overall participant satisfaction was high (128).

Professional nurses are required to update core patient safety and institutional safety skills on an annual basis. These requirements are established at the facility level as well as through regulatory bodies and accreditation agencies. How facilities meet these competencies vary widely with simulation educational approaches representing the cutting edge of these efforts. Kuzminsky et al reported development of a series of professional nursing courses. These authors described use of simulation for professional nursing training and measurement in orientation to critical care and the OR. Participants had improvement in satisfaction, knowledge and skill (129). In a 2008 review, Decker acknowledges the existing pressures associated with documentation of employee competencies. She points out that valid and reliable tools for evaluating competency in the clinical area through simulation methodology are needed but have not yet been fully refined. Further she asserts that simulation has value in evaluating nursing judgment and competence in the professional nursing domain (130).

1.2.5 Purpose of the Study

This dissertation focuses on use of hierarchical task analysis and emerging simulation science to develop a simulation-based injury prevention intervention. The educational intervention was designed to reduce occupational injury among nurses, nurse aides and orderlies. In order to reduce injury rates, a hospital based training program was developed to teach proper techniques and to monitor compliance. The specific aims are: 1) Develop a valid, measurable and standardized patient transfer protocol based on an optimum task set; 2) Evaluate patient transfer performance in a simulation lab; 3) Develop methods to score patient transfer in real time, including a mobile data collection system; 4) Evaluate the effect of a simulation intervention on patient transfer success in a clinical setting.

Importantly, this approach has potential for benefit to public health in that patient transfers are common, nursing personnel are frequently injured, loss of the nursing workforce is a national concern and evidence suggests that inadequate nurse staffing is linked to adverse patient outcome (23, 25, 30). The information gained from the study can be used to further develop and refine a hospital based program for nurse, nurse aide and orderly injury prevention.

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2.0 METHODS PAPER

2.1 TITLE PAGE

AN ERGONOMIC PROTOCOL FOR PATIENT TRANSFER THAT CAN BE SUCCESSFULLY TAUGHT USING SIMULATION METHODS

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2.2 ABSTRACT

Introduction: Nursing personnel injury related to patient transfer is epidemic and reduction of injury rates is a national priority. Hierarchical task analysis (HTA) was chosen to address this issue.

Methods: HTA methods were used to create an optimum task set and protocol which consisted of internet-based education, simulation practice, and debriefing. Subjects (n= 71) were randomly assigned to teams to perform simulated transfers. Pre to post-intervention transfer success was evaluated by ergonomic experts.

Results: Each team improved significantly from pre- to post-intervention (n =19) with every protocol step demonstrating improvement (n =10). Inter-rater reliability of the evaluation instrument was calculated (0.43-0.83).

Conclusion: Simulation was used successfully to improve transfer success. This approach shows promise in reduction of transfer-related nursing injury.

2.3 INTRODUCTION

Bernardo Ramazinni (1633-1714), the father of modern occupational medicine, first identified and studied workplace related disease in the late 1600's (1, 2). The striking fact is that in the over three centuries since Ramazinni first identified the problem of workplace related injury, it remains persistent with an epidemic now seen in nurses and nurse aides. Nurse aides and nurses have the highest rate of workers' compensation claims within the healthcare industry and are consistently among the top ten of non-fatal work -related injury groups among all US workers. When combined these two groups are second in total injuries compared to all other US occupations exceeding groups including laborers and dock workers (3-7). This high incidence of musculoskeletal injury (MSI) in the nursing profession has been widely reported and analyzed (8-11). The National Institute of Occupational Safety and Health (NIOSH) reports an annual prevalence rate of back pain among nurses of 40% to 50% with up to 52% of nurses report having had chronic back pain of 14 or more days within the last six months. NIOSH also reports a lifetime prevalence rate of back pain or injury among nursing personnel of 35%-80% (12). These statistics are highly significant because there is an emerging national and international nursing shortage. Currently there are 2.9 million nurses in the U.S. workforce with an average age of 48. Up to 40% of practicing nurses are projected to retire in the next 5 years with experts predicting a deficit of at least 1 million nurses by the year 2020 (13-16). As many as 38% of nurses suffer from back pain severe enough to require time off from work during their careers with up to 12% leaving the profession annually due to this issue. Prevention of nursing injury would therefore have a significant impact on the emerging nursing shortage (8, 9).

In order to reduce injury rates, a hospital based training program is necessary to teach proper techniques and to monitor compliance. Development of a comprehensive, ergonomically sound program would require development of 1) a protocol which includes the optimum task set for moving patients; 2) an effective, standardized and scalable training process; and 3) the ability to monitor program compliance in the clinical setting.

Before an effective simulation training program for patient transfer can be implemented, the ergonomic issues that constitute the transfer task must be clearly defined. The task analysis process used in ergonomic science fits well with this approach. Task analysis entails defining and describing either a job or the particular task or set of tasks within a job(17). A sub-type, hierarchical task analysis, has been used extensively in ergonomics research and field work for over 30 years(17). As the name implies, hierarchical task analysis not only lists each step of a particular task but also analyzes and attempts to place each step in the order in which it should or could be performed (17-19). The power of hierarchical task analysis results from its ability to facilitate description of individual or team behaviors by acknowledging that most tasks are "are comprised of subgoals linked by plans"(17). Because this approach deconstructs tasks into discrete components, it can be used not only to measure overall task completion, but also to improve task performance by identifying problematic steps in the system or process.

While nurses experience many different types of musculoskeletal loads in their work, the task of transferring patients is particularly implicated in causing injury(12). Currently, no standardized, universally accepted method accomplishes the overall outcome of 'a safe patient transfer' while adhering to all ergonomic principles in prevention of caregiver injury. Partly, this deficiency exists because patient transfers require complex coordination of personnel and equipment, and must be tailored to meet individual patient and facility needs. Additionally, moving a patient with heavy non-fixed limbs and a shifting center of gravity is not comparable to moving a static, gravity centered load, such as a box or other solid object. Regulatory standards from the National Institute for Occupational Safety and Health tend to emphasize the 'static' situation and are not specifically designed to address patient transfers. This makes the problem of preventing healthcare worker injury more difficult to remedy (12).

Didactic educational programs and single-focus interventions such as back belts have been demonstrated to be ineffective in reducing long term injury rates (3, 20-30). An emerging educational approach, which shows promise in increasing retention of skills, is hands-on, scenario-based simulation training using a mannequin (31-34). Simulation educational approaches have been reported for training a wide range of simple to complex healthcare tasks (35-51). Notably, the Institute of Medicine (IOM) has recommended the use of simulation educational methods to improve safety within the healthcare system (52).

The purpose of this report is to describe: 1) development of a valid, measurable and standardized patient transfer protocol based on an optimum task set;; 2) evaluation of patient transfer performance in a simulation lab; 3) methodology used in determining if raters could reliably score patient transfer in 'real time'; and 4) development of a mobile data collection system. This information can be used to develop a hospital based program for nurse and nurse aide injury prevention. Further, this approach has potential for benefit to public health in that patient transfers are common, nursing personnel are frequently injured, loss of the nursing workforce is a national concern and evidence suggests that inadequate nurse staffing is linked to adverse patient outcome (53-55).

2.4 METHODS

2.4.1 Patient Transfer Protocol Development

In order to develop a broadly applicable patient transfer protocol, the optimum task set for performing a patient transfer was needed. The method for deriving this task set was as follows: a panel of healthcare experts was recruited including physical therapists, occupational therapists, professional nurses, hospital administrators, ergonomic experts and an occupational medicine physician. The expert panel followed a nine step hierarchical task analysis process (**Table 1**)(17-19).

Table 1: **Nine Step HTA Process in Developing the Transfer Protocol**

Hierarchical Task Analysis Process Step	Patient Transfer Protocol Development Steps
1. Define the purpose of the analysis	We defined our purpose as 'development of a flexible and broadly applicable protocol for patient transfers using optimal ergonomic principles and best evidence from the literature'.
2. Define the boundaries of the system description	Defined as all procedures or tasks that healthcare providers would need to complete in order to safely transfer a patient.
3. Access a variety of information sources about the system to confirm reliability and validity of the analysis	Sources of information included baseline clinical observations, interviews with nurses, occupational therapists, physical therapists, physicians and experts in patient safety and simulation and extensive review of nursing and occupational health literature.
4. Describe the system goals and sub-goals; define a sub-goal hierarchy for the task at hand.	The system (super-ordinate) goal was framed as "transfer a patient according to ergonomic and patient safety principles". Through an iterative process based on ongoing expert input and best-evidence from literature, the sub-goals or steps of a patient transfer protocol were identified and then arranged in a logical order. The protocol steps were then clinically validated through observation of actual patient transfers.
5. Try to keep the number of immediate sub-goals under any super-ordinate goal to a small number (between 3 and 10).	The hierarchical task analysis literature supports limiting sub-goals to a maximum of 10. In our process, the final set of sub-goals (patient transfer protocol steps) was reduced to 10 through actual clinical observation with feedback to the expert panel.
6. Link goals to sub-goals and describe the conditions under which sub-goals are triggered (Tables 3 and 4)	Operational definitions for each patient transfer protocol step were derived from patient care standards or best evidence from the literature. These established definitive end points in evaluation of each sub-goal step, and provided a trigger for evaluation of the subsequent step.
7. Stop re-describing the sub-goals when you judge the analysis is fit-for-purpose	The re-description process stopped when the level of description was deemed adequate in measurement of the super-ordinate goal of patient transfer. This was confirmed by again observing actual patient transfers after which the patient transfer protocol was judged as fit for purpose.
8. Verify the analysis with subject-matter experts	A panel of subject matter experts (ergonomists and other clinicians and non-clinicians) was engaged in final review of both the patient transfer protocol and the operational definitions.
9. Be prepared to revise the analysis based on feedback	Expert feedback, patient care standards and final observations were used to finalize the patient transfer protocol prior to development of the patient transfer training materials and generation of data collection instruments based on the patient transfer protocol.

Using this process, a comprehensive list of all activities during a patient transfer was compiled by the panel. Equipment used and policies and procedures referring to patient transfer were considered. While the expert panel was clear with respect to the overall goal of an optimum patient transfer; the order and operational definitions for the overall task set required multiple revisions. In hierarchical task analysis methods, the overall goal is defined as the 'superordinate' goal. The comprehensive task list was refined through review of the literature and clinical observation of actual patient transfers with ongoing feedback to the panel. A process map was developed and transfer activities were grouped and condensed in order to develop the optimum task set. Each main task was broken down into its component sub-tasks to ensure that each main task could be operationally defined.

2.4.2 Development of On-line Support Materials

The patient transfer protocol was then used as a process map in development of an internet based training curriculum which supported the scenario based simulation training program. The program was designed to be appropriate for all categories of healthcare professionals including registered nurses, licensed practical nurses, nurse assistants and any other direct care personnel (Figure 1). All course materials were designed to reinforce the patient transfer protocol steps and were posted to a proprietary learning management system website at the University of Pittsburgh's Winter Institute for Simulation, Education and Research (WISER). . The project was approved by the University of Pittsburgh Biomedical IRB and subjects required a password for access to this website. Subjects received the password after providing consent.

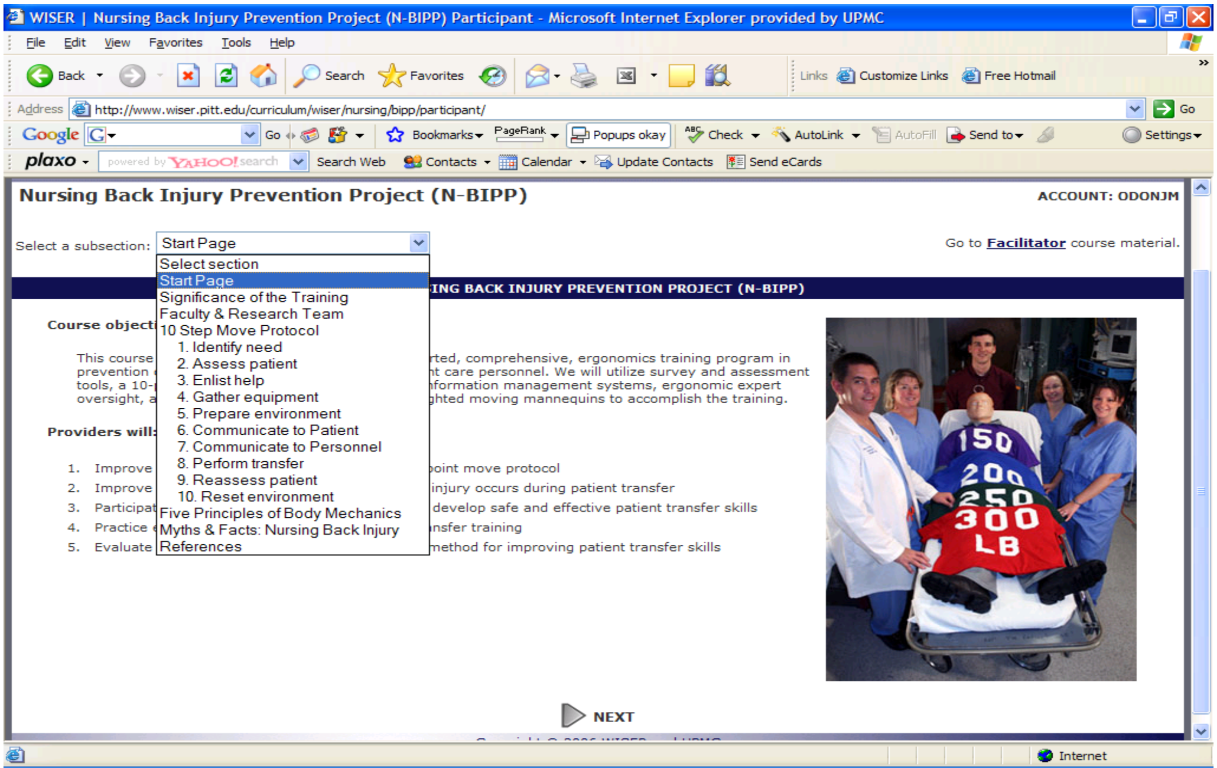


Figure 1: **Screenshot of On-Line Course Materials**

2.4.3 Development of Data Collection Tools

The investigators developed and evaluated two data collection tools which were programmed with the patient transfer protocol. The first tool was the protocol in the form of a checklist programmed into the Laerdal SimMan™ software system (version 2.3) (**Figure 2**). Ergonomic experts rated transfers in the simulation lab using this system. In addition, evidence based rationale for each main task step was programmed into the SimMan™ Debriefing Viewer Program which facilitated a structured and best-evidence supported post-transfer debriefing.

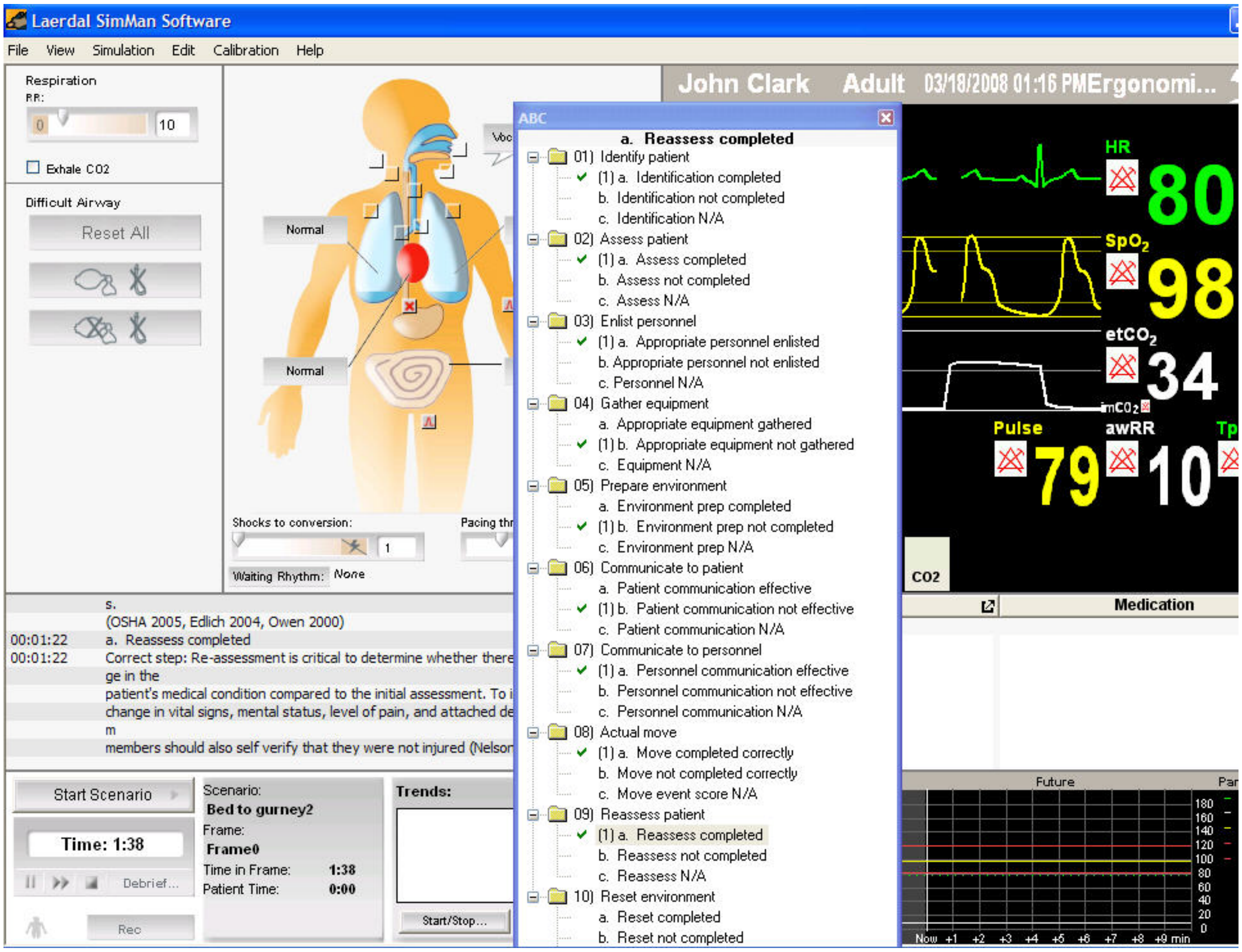


Figure 2: Patient Transfer Protocol Programming of the Laerdal SimMan™ Universal Patient Simulator interface (version 3.2).

The second data collection tool was the HP IPAQ™ handheld computer (Figure 3) running the Windows Mobile™ 5.0 operating system. The handheld computers were programmed with the patient transfer protocol as a checklist. The programming used embedded visual BASIC to create a graphic user interface (GUI). This handheld tool was used by non-expert raters during the study.

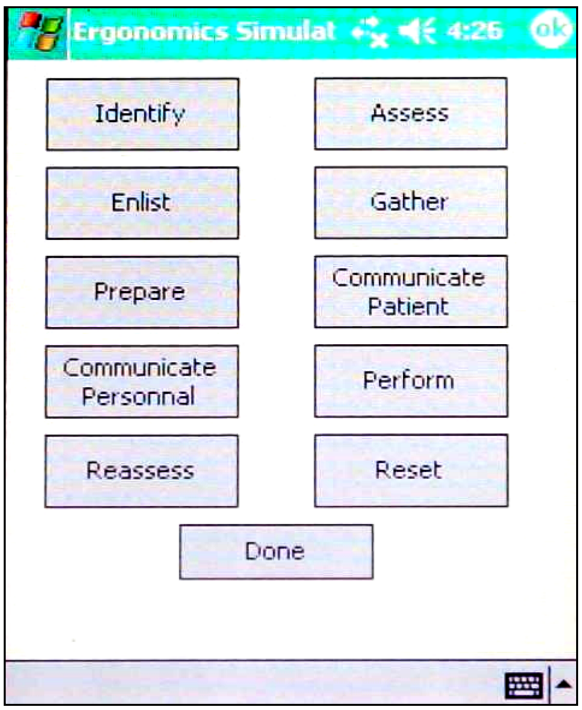


Figure 3: Patient Transfer Protocol Programming of the HP IPAQ Graphic User Interface (GUI).

2.4.4 Simulation Intervention

Nurses (n=48) and nursing assistants (n=23) were recruited to participate in a four hour simulation intervention at the WISER Center.   After consent was obtained, baseline transfer skill was determined by having teams (3-4 participants per team) perform two simulated transfers using the Tuff Kelly Transfer Mannequin™ (Laerdal Inc., Stavanger Norway).   This mannequin is specifically designed to simulate patient transfers across a variety of settings. After the second transfer was performed, a structured video debriefing was conducted for each transfer event. The SimMan™ Debriefing Viewer Program was used to provide in-room debriefing. The SimMan™ log file display included evidence-based statements providing rationale for each transfer step as well as the rating of the expert. An embedded video link facilitated review of each transfer event and allowed expert commentary as part of the structured debriefing method. On-line patient transfer protocol materials were reviewed with each team. The debriefings and on-line material review constituted the intervention which lasted for 1.5 hrs. Following this intervention, transfer skill was reassessed by having the same participant teams perform two different simulated patient transfers. The entire protocol took place over a 3 hour period.

2.4.5 Rater Training

Non-expert raters (n = 7) used the hand-held tools to rate pre- and post-intervention transfer events concurrently with the expert raters in the simulation lab. These non-experts had varied backgrounds including nurse anesthesia, critical care nursing, healthcare finance and healthcare administration. None had a background in ergonomics or body mechanics. The non-expert raters were trained by ergonomic experts before the simulation intervention in how to use the transfer protocol which had been programmed into the HP IPAQ™ handheld computers. The training included a 1 hour review of the patient transfer protocol and operational definitions for each protocol step (**Table 2**). Non-experts then went to clinical units and were supervised for 4 hours of observing and rating actual patient transfers- again under the supervision of the ergonomic experts. The operational definitions were laminated on 4 X 6 cards and given to each rater for reference during patient transfer observation and rating.

Table 2: **Patient Transfer Protocol Steps with Operational Definitions**

Patient Transfer Protocol Step	Operational Definitions
1. Identify Patient & Need for Move	**Completed**: ID the need for a specific move. ID the patient by name and verify 2 discrete patient identifiers per NPSGs **Did not complete:** Did not ID need for a specific move. Patient ID is not completed using 2 discrete identifiers.
2. Assess Patient	**Complete**: Patient condition, assist level and pain level are assessed (0-10) **Did not complete:** Condition, assist level and pain level are NOT assessed
3. Enlist Help	**Completed** Enlists appropriate number of personnel given patient weight, ability to assist and transfer device being used. **Did not complete:** Number of personnel recruited is not appropriate given patient weight, ability to assist or device used.
4. Gather Equipment	**Completed** Appropriate equipment is obtained (friction reducing device, chair, gurney or lift device) **Did not complete** If required transfer equipment or devices are not assembled and positioned for impending move
5. Prepare the Environment	**Completed** Prepares environment by setting bed to appropriate height, lowering handrails, locking bed, gurney, or wheelchair wheels, moving room furnishings out of way, securing lines, removal of arm and leg supports **Did not complete**: Any of the following factors are not completed: setting bed to appropriate height, lowering handrails, locking bed, gurney, or wheelchair wheels, moving room furnishings out of way, securing lines, removing arm and leg supports
6. Communicate with the Patient	**Completed** Must communicate with patient and inform of move and enlist patient assistance if possible. Must communicate the need for the move and all events that are about to occur. **Did not complete** Patient is not fully informed of move requirement and timing. Patient help is not enlisted.
7. Communicate with Personnel	**Completed**: Inform personnel assisting with transfer of type and need for move. Give appropriate instructions in coordinating the transfer ("Transfer on 3- 1, 2, 3") **Did not complete**: Personnel are not informed of transfer type or instructions given are unclear/sketchy
8. Perform Move	**Completed:** Correctly transfer patient abiding by 5 principles of body mechanics and correct use of lift devices **Did not complete** Failed to adhere to correct body mechanics, correct use of lift device
9. Reassess Patient	**Completed** Assesses patient comfort/pain levels (0-10) after transfer – evaluates for changes **Did not complete** Any element of patient re-assessment is not completed post-transfer
10. Reset the Environment	**Completed** Returns all equipment (tray table, call bell, etc.), reposition equipment and lines in room, and reset room to condition prior to transfer, return lift device to designated storage area, arm rests/leg holders are returned to position **Did not complete**: Patient equipment is left out of position, room condition is not reset, lift device is not returned to designated storage area, arm and leg support devices are not returned to position

2.4.6 Statistical Methods

The transfer team was the unit of analysis. Each group performed four scenario based simulated transfers, two pre-intervention and two post-intervention. Ergonomic expert raters scored each transfer according to the patient transfer protocol. Each task step of the protocol was rated either correct or incorrect for each group transfer. The operational definitions were used to determine whether a step was performed correctly or incorrectly (**Table 2**). The two pre-intervention transfer ratings and the two post intervention transfer ratings were averaged for analysis. The pre to post intervention average score for each team was compared using a paired samples t-test (SPSS 15.0™). The level of statistical significance was set *a priori* at $\alpha \leq 0.05$.

Inter-rater reliability was calculated as follows: expert ratings were compared with non-expert ratings during simulated transfer events. The expert data was entered into the SimMan platform and the non-expert data was entered into the HP IPAQ handheld units. Each move was named according to a specific naming protocol to eliminate mis-identification. Expert and non-expert ratings were compared for agreement. All patient transfer protocol steps were rated as either correct or incorrect according to the operational guidelines. The Cohen's kappa statistic which assesses agreement of categorical data was calculated for each patient transfer protocol step.

2.5 RESULTS

2.5.1 Patient Transfer Protocol

As described, an optimum task set or protocol for doing patient transfers was developed using the hierarchical task analysis method (**Table 2**). This protocol was then used for programming the Laerdal SimMan™ software platform as well as the handheld HP IPAQ™ data collection units. The iterative process of expert panel analysis, live clinical observation and ongoing redescription of transfer steps facilitated final description of a detailed patient transfer protocol map with operational definitions for each step (**Table 3**).

Table 3: **HTA Table with Detailed Description of a Patient Transfer**

Super-Ordinate	Task Component – operation or plan	Notes
0.	*Transfer a patient according to ergonomic and patient safety principles.* Plan 0: Task initiated by need for patient transfer as outlined by patient-specific plan of care. Linear plan: 1 > 2 > 3 > 4 > 5 > 6 > 7 > 8 > 9 > 10	
	1. Identify patient and confirm need for patient transfer	
	2. Assess patient's baseline physical and mental status	Physical status, mental status, pain level, medical devices
	3. Enlist appropriate number of personnel	
	4. Gather necessary equipment	
	5. Prepare the environment to optimize performance	
	6. Communicate with the patient	Communicate the 'why', 'what' and 'how' of the transfer
	7. Communicate with personnel	Communicate roles, expectations and timing
	8. Perform the transfer	
	9. Reassess the patient versus baseline status	Physical status, mental status, pain level, medical devices
	10. Reset the patient and unit environment	
1.	Identify patient and confirm need for patient transfer Plan 1: Do 1.1 then 1.2 Then exit	
1.1	Identify patient using ≥ 2 approved identifiers	Use at least two approved identifiers per JCAHO 2006 National Patient Safety Goals
1.2	Confirm need for patient transfer	Confirm that the transfer fits with the patient-specific plan of care
2.	Assess the patient's baseline physical and mental status Plan 2: Do 2.1 through 2.5 in any order, but 2.2 must precede 2.3 Then exit	
2.1	Assess physical condition markers	Basic vital signs, height, weight, invasive monitoring data, other indicators of physical status
2.2	Assess mental status	Level of Consciousness (LOC) or other markers; will determine how 2.3 is assessed
2.3	Assess pain level	If able, have patient rate pain on 0-10 scale; otherwise non-cognitive markers (heart rate, blood pressure, etc)
2.4	Assess need to transport essential medical devices or other patient need	IV's, central lines, drains, pumps, ventilators, etc.
2.5	Assess patient's ability to participate	Determine if and how much patient can participate in the move process; will affect 3.1 and 6.2

Table 3 (continued)

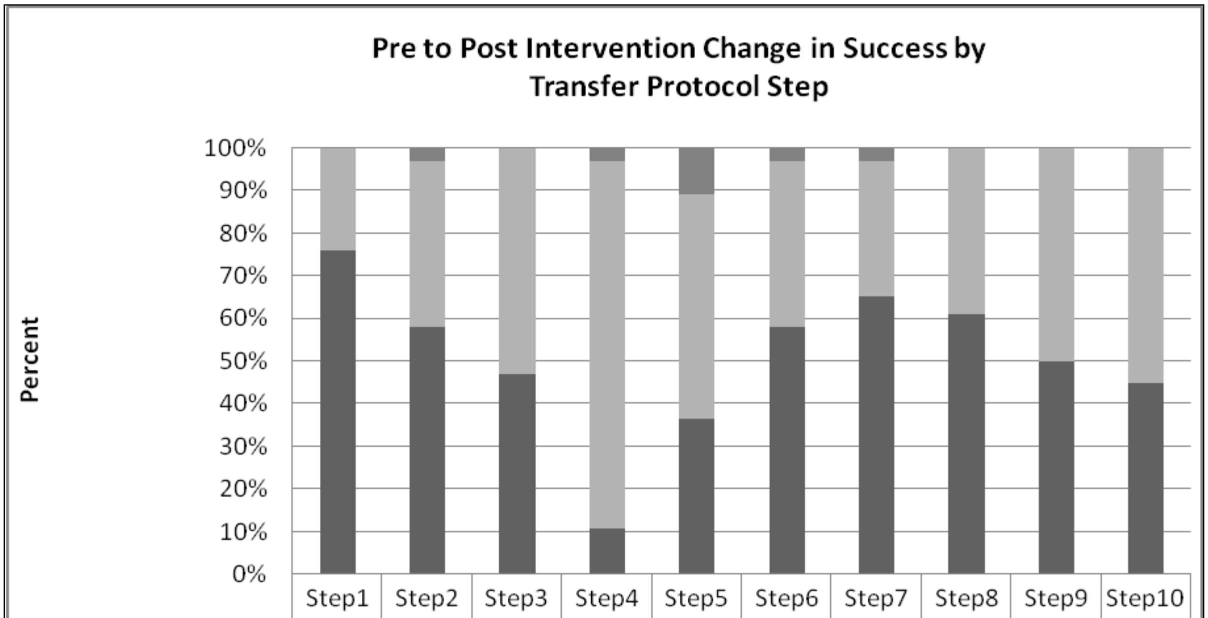
Super-Ordinate	Task Component – operation or plan	Notes
3.	Enlist appropriate number of personnel Plan 3: Do 3.1 Then exit	
3.1	Consider weight, ability to assist, transfer type, equipment	General guideline: Max weight for 1 person ≤ 50 lb of patient weight (e.g. 200lb patient = at least 4 move personnel if assuming full patient weight under ideal conditions)
4.	Gather the necessary equipment Plan 4: Do 4.1 Then exit	
4.1	Choose best equipment	Consider equipment availability, patient need, available space, training of providers
5.	Prepare the environment to optimize transfer Plan5: Do 5.1 through 5.3 in any order Then exit	
5.1	Match surface heights	Match heights (i.e. bed and stretcher height) with overall height of both adjusted for shortest provider
5.2	Free attached devices	Attached devices should be disconnected if appropriate or free to move with patient
5.3	Move obstructions	Move objects (i.e. furniture) that could impede the move or transport or cause sub-optimal ergonomics
6.	Communicate with the patient Plan 6: Do 6.1 through 6.2 in any order Then exit	
6.1	Inform patient as to why the move is necessary, how it will performed and when it will occur	
6.2	Instruct patient to assist as able	Determination made in 2.5
7.	Communicate with personnel Plan 7: Do 7.1, 7.2 then 7.3 Then exit	
7.1	One provider will assume a leadership role	Leader will define roles, expectations and timing
7.2	Communication is clear and specific between providers	
7.3	A ‘move count’ will be done prior to the move	Important to assure that the transfer is done in a smooth manner (i.e. “Move on three. 1…2…3”)

Table 3 (continued)

Super-Ordinate	Task Component – operation or plan	Notes
8.	Perform the transfer Plan 8: Do 8.1.1 through 8.1.5 concurrently Then exit	
8.1	Avoid awkward/dangerous positions; use 5 main principles of correct body mechanics 8.1.1 Posture with chin tucked and level, chest up, stomach in, knees slightly flexed 8.1.2 Keep patient at correct height, close to the body 8.1.3 Be square to the patient; hips, shoulders in alignment 8.1.4 Symmetrical use of both sides of body when pulling, lifting or pushing 8.1.5 Maintain wide base of support; feet at least shoulder width apart	
9.	Reassess the patient versus baseline status Plan 9: Do 9.1 then 9.2 then 9.3 Then exit	
9.1	Reassess patient versus baseline all parameters [2.1-2.5]	
9.2	Report or intervene with regard to any changes from baseline assessment	
9.3	Survey transfer team for any injury incurred during transfer; intervene as necessary	
10.	Reset the patient and unit environment Plan 10: Do 10.1 then 10.2 Then exit	
10.1	Reset patient environment	Includes furniture, call bell, telephone, restraints, etc.
10.2	Replace and reset equipment	Enhances team and unit efficiency

2.5.2 Improvement in Patient Transfer

A total of 71 nurses and nurse aide providers were divided into 19 teams of 3-4. The members of each transfer team remained consistent for all four moves. Ergonomic experts performed the rating of the transfer events. The overall rating or 'score' for each team transfer event was calculated as the number of steps rated 'correct'/total number of steps. Patient transfer protocol success increased significantly from pre- to post-intervention for every team (n =19) and for every protocol step (n =10). Mean pre- to post-intervention improvement by team was 52% ± 15 (range 10-75%) with mean improvement by protocol step increasing an average of 51% ± 18 (range 11-76%). The greatest pre- to post-intervention positive change occurred in step 1' Identifying the Patient and Move Requirement' (76% positive change). The smallest pre- to post-intervention positive change occurred in step 4 'Gather Equipment' (11% positive change) (**Figure 4**).



	Step1	Step2	Step3	Step4	Step5	Step6	Step7	Step8	Step9	Step10
% Negative Change	0%	3%	0%	3%	11%	3%	3%	0%	0%	0%
% No Change	24%	39%	53%	89%	53%	39%	32%	39%	50%	55%
% Positive Change	76%	58%	47%	11%	37%	58%	66%	61%	50%	45%

Figure 4: Pre to Post-Intervention Change in Success by Transfer Protocol Step

Percent change in pre to post-intervention transfer success was measured by expert ratings for each protocol step. Data was evaluated for all 74 transfer events (n = 38 Pre-Intervention, n = 38 Post-Intervention).

Each of the 19 teams completed 2 moves pre-intervention (Pre1, Pre2, n =38) and each team completed 2 moves post-intervention (Post1, Post2, n = 36). Two post-intervention expert patient transfer observations were lost due to computer data storage error. As stated, pre-intervention and post-intervention ratings were averaged for each team (Table 4). The average for the ratings of the two pre-intervention transfers across all 19 teams was 34% ± 12. The average for the ratings of the two post-intervention transfers for the 19 teams was 86% ± 10. The improvement from pre- to post-intervention was highly significant ($t_{18} = 14.76$, $p < 0.0004$) (**Table 4, Figure 5**)

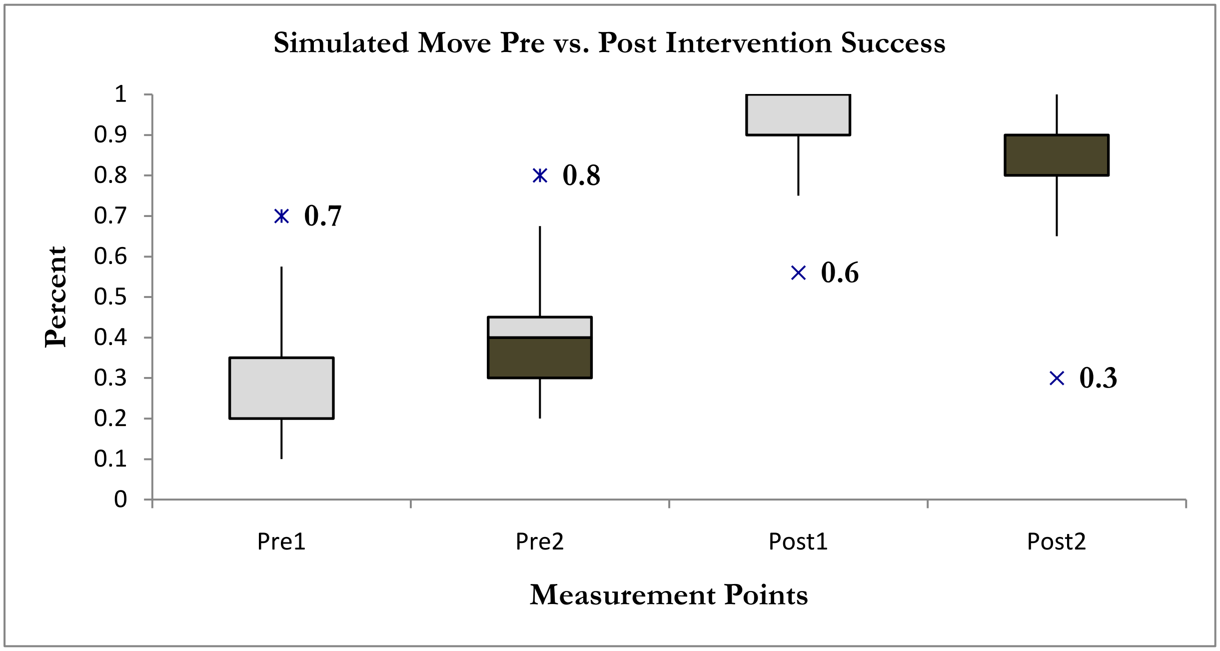


Figure 5: Transfer Success by Measurement Point

Box and Whisker plots for distribution of the averaged pre and post intervention transfer ratings at 4 measurement points (Pre-Intervention 1 and 2, Post-Intervention 1 and 2) demonstrating the impact of the simulation intervention on team success.

Table 4: Ergonomic Expert Rating of Pre vs. Post- Intervention Team Success

Team	Pre1 Rating	Pre2 Rating	Post1 Rating	Post2 Rating	Mean Pre Rating	Mean Post Rating	Δ
1	20%	80%	90%	80%	50%	85%	35%
2	60%	63%	90%	100%	61%	95%	34%
3	20%	20%	100%	30%	20%	65%	45%
4	20%	30%	70%	90%	25%	80%	55%
5	20%	40%	.	100%	30%	100%	70%
6	60%	40%	.	60%	50%	60%	10%
7	70%	20%	80%	90%	45%	85%	40%
8	30%	30%	90%	90%	30%	90%	60%
9	30%	40%	100%	80%	35%	90%	55%
10	10%	50%	89%	60%	30%	75%	45%
11	10%	50%	90%	90%	30%	90%	60%
12	40%	40%	100%	90%	40%	95%	55%
13	20%	40%	56%	100%	30%	78%	48%
14	20%	50%	100%	80%	35%	90%	55%
15	50%	40%	100%	90%	45%	95%	50%
16	10%	20%	90%	90%	15%	90%	75%
17	10%	30%	90%	80%	20%	85%	65%
18	20%	20%	100%	80%	20%	90%	70%
19	30%	40%	90%	100%	35%	95%	60%
Mean	29%	39%	90%	83%	**34%**	**86%**	52%
Median	20%	40%	90%	90%	30%	90%	55%
SD	19%	15%	12%	17%	**12%**	**10%**	15%
Max	70%	80%	100%	100%	61%	100%	75%
Min	10%	20%	56%	30%	15%	60%	10%

A total of 71 nurses and nurse aides were divided into teams of 3-4. The transfer teams remained the same for all moves. Two simulated transfers were conducted prior to the intervention (Pre1, Pre2) and two transfers after the intervention (Post1, Post2). The score for each transfer (n =74) represents the number of moves rated 'correct'/total number of moves. The success of all 19 teams improved from pre to post-intervention with the two pre-intervention transfers and two post intervention transfers averaged for each team. (Pre-intervention mean ± SD = 34% ±12 (range 15-61%), post-intervention mean ± SD = 86% ± 10 (range 60-100%). The mean difference pre- to post-intervention of 52% was highly significant (t_{18}, $p < 0.0004$)

2.5.3 Inter-Rater Reliability

The rating of simulated patient transfers was completed concurrently by experts and non-experts. Each transfer step within the protocol was rated as correct or not-correct according to a set of operational definitions. For 24 of the 74 recorded transfers, two non-experts were rating the event at the same time as the expert rater. This resulted in 98 matched transfer event ratings (expert vs. non- expert). The measure of agreement used was the Cohen's Kappa statistic. Kappa values were calculated for each step of the protocol and ranged from 0.43-0.83 (**Table 5**) (56). The lowest kappa scores were seen with step 5 'Prepare the Environment' and step 6 'Communicate to the Patient' indicating a moderate level of agreement between experts and non-experts for these steps. The highest kappa scores were seen with step 3 'Enlist Appropriate Number of Personnel' and step 1 'Identify the Patient and Move Requirement' indicating substantial to near perfect agreement between experts and non-experts for these steps

Table 5: Inter-rater Reliability for Each Step of the Transfer Protocol

Patient Transfer Protocol Step		**Kappa Value***	**Interpretation** [56]
1	Identify the patient and move requirement	0.83	Almost perfect
2	Assess patient condition & pain level	0.58	Moderate
3	Enlist appropriate number of personnel	0.78	Substantial
4	Gather appropriate equipment	0.59	Moderate
5	Prepare environment	0.45	Moderate
6	Communicate with patient	0.43	Moderate
7	Communicate with personnel	0.59	Moderate
8	Perform the patient transfer	0.67	Substantial
9	Reassess patient pain level & condition	0.62	Substantial
10	Reset the environment	0.63	Substantial

The rating of simulated patient transfers was completed concurrently by experts and non-experts. Each transfer step within the protocol was rated as correct or not-correct according to a set of operational definitions. For 24 of 74 transfers, two non-experts were rating the event at the same time as the expert rater. This resulted in 98 matched transfer event ratings.

* All kappa values statistically significant, $p < 0.0004$

2.5.4 Development of Data Collection Tools

The patient transfer protocol programmed into the Laerdal SimMan software system facilitated scoring of each team's performance. This system also supported ergonomic experts in conducting a structured and evidence supported debriefing through use of the SimMan™ Debriefing Viewer Program. This program generated an accurate record of events or 'log file'. The SimMan™ log file display included the ergonomic experts rating (correct or incorrect) of each transfer step and displayed the evidence-based rationale for each transfer step. Concurrently, the HP IPAQ handheld computers programmed with the patient transfer protocol were used by non-experts to rate team performance during the transfer events. These programmed handheld devices provided a consistent, mobile assessment tool designed for 'live', unobtrusive scoring of transfer events.

2.6 DISCUSSION

The simulation intervention resulted in improvement in patient transfer skill for each team of providers and for each step of the patient transfer protocol (Figure 4 and 5). Core components of the intervention included pre-intervention transfer practice, transfer event debriefing, internet-supported didactic content and post-intervention evaluations of transfer success. During debriefing, correct as well as incorrect performance of patient transfer protocol steps was reviewed with participants. The debriefing materials incorporated evidence-based rationale for each patient transfer protocol step. Ergonomic experts then encouraged correct performance through facilitated discussion and demonstration.

The project required development and parallel testing of the patient transfer protocol instrument programmed as a checklist into two unique data collection tools. The first tool was the Laerdal SimMan™ software which was used by the experts in rating transfers. This tool was used to both gather data and to provide immediate participant reinforcement of correct versus incorrect patient transfer skills during debriefing. This approach allowed simultaneous use of input from three sources: expert rating, the event video and the pre-programmed evidence-based rationale for each patient transfer protocol step. The second data collection tool was the HP IPAQ™ hand-held computer that was used by non-experts. Because of its mobility, it can be used to rate subject performance in a variety of settings including both simulation laboratory and clinical arena.

When the ratings from the two tools were matched, Cohen's kappa statistics were calculated for each protocol step. The range of kappa values was 0.43- 0.83 indicating moderate to near perfect agreement between expert raters (ergonomists) and non-expert raters (healthcare workers with a wide variety of clinical experiences). The terms moderate, substantial and near-perfect agreement in interpretation of the kappa statistics are based on the classic interpretation by Landis and Koch (1977) (56)

A unique aspect of this project was in use of hierarchical task analysis. Hierarchical task analysis was chosen because it is highly flexible and can be used to analyze anything from an isolated procedure to team performance to the overall function of an entire system(17). In finalizing the protocol, we adhered to guidelines as outlined by Annett (1971, 2000), Shepard (2001) and Stanton (2006). They described important principles which govern use of the hierarchical task analysis process, which can be summarized as follows (17-19):

- Each task is an operation which is defined as a part of the overall system level goal (super ordinate goal) and is measured in terms of production units, quality or other criteria.
- Each operation or task can be broken down into sub-operations or task steps.
- Each task step can then be defined by a sub-task measured in terms of its contribution to the overall system goal. This allows the sub-task to be measured and increases relevance in terms of overall performance standards and criteria.

The important relationship between tasks and sub-tasks is that sub-tasks are included within the overall task (a hierarchical relationship). Sub-tasks of main tasks are typically included in the task definition, but do not have to be accomplished in a specific sequence in order to be listed as performed correctly (17, 19). When using hierarchical task analysis, guidelines should also be developed which describe temporal and order relationship between levels of description (e.g. x followed by y, followed by z *or* x and y *in any order* followed by z)(17). Because hierarchical task analysis involves description and then re-description of a system or process in terms of its goals and sub-goals, the procedure can go on for any number of iterations. One of the more difficult aspects is in establishing the detail level at which to stop the analysis as there are no specific formulas or guidelines to determine a definitive endpoint (17, 57).

Hierarchical task analysis methods have a number of advantages when applied in this manner as they allow a flexible, robust approach for description of a complex task and provide a clear template for evaluation of each step required to complete the task. In the case of patient transfer, deconstructing a seemingly continuous event into discrete, measurable parts allowed analysis and evaluation of a common, yet complex, healthcare task. It was then possible to rate performance of the optimal task set by teams in the simulation environment. Another advantage of hierarchical task analysis was the emphasis that this rigorous method places on incorporating evidence-based practice into the development of each protocol step, thereby providing a clear theoretical or practice based foundation for evaluation of performance and process. Measuring events in a clinical setting can be both difficult and labor intensive. Evaluation of measurement reliability was important in determining if personnel with little experience in ergonomics could be trained to accurately code transfer events in real time by comparing their scores with those of experts. Because the hierarchical task analysis process and resultant operational guidelines identified and clearly defined steps for all raters in evaluation, they were able to accurately score transfer events. The development and programming of the handheld HP IPAQ™ data collection tool with a user friendly software interface resulted in a data collection platform that was flexible, portable and unobtrusive.

A valid hierarchical task analysis process is dependent on accurate descriptions of goals and sub-goals. Inadequate description can lead to measurement errors with false interpretation of results. As might be expected, there was not always complete concurrence among the development team in defining transfer steps. Ultimately, the patient transfer protocol steps were selected and operationally defined based on published evidence, clinical observations and expert opinion. Analysis of the success rate for each patient transfer protocol step was valuable in two respects. First, an increase in overall success from pre- to post-intervention was an indicator of the overall effectiveness of the hierarchical task analysis derived simulation training protocol. Second, a consistent increase in success rate across *every* step of the patient transfer protocol served to validate that the overall hierarchical task analysis descriptive process was done correctly, otherwise failure rates would be likely to remain high at one or more individual steps post-training. The step which showed only an 11% improvement (Gather Equipment) demonstrated the imperfection of a simulation setting in duplicating clinical care because the patient transfer equipment was too readily accessible in the simulation lab. This is not the case in the clinical setting and this step will be carefully analyzed during collection of patient transfer data in the clinical environment.

Our findings are the first to report systematic use of hierarchical task analysis methods combined with simulation to train providers in patient transfer, a task which is commonly perceived as requiring little skill. Simulation programs in healthcare education have traditionally been used in training of complex tasks required in the care of critically ill patients, e.g., airway management skills, cardiopulmonary resuscitation. Its value in these settings has led to widespread application in other settings by nurses (39, 51, 58-61), respiratory therapists (35, 62, 63), nurse anesthetists (64-68) and students training in these fields.

Viewed through the lens of hierarchical task analysis, the task of transferring a patient is quite complex and, if not performed properly, has been directly implicated in both patient and provider injury (9). By weaving hierarchical task analysis principles into the development of this training program, we were able to build an evidence-based patient transfer protocol and demonstrate an immediate post-intervention improvement in simulated transfer performance. As such, this methodology would appear to have great value in teaching and evaluating other skills used in patient care.

2.6.1 Limitations

Several limitations were identified within the study. A convenience sample was used with subjects recruited from patient care units specializing in care of head and spinal cord injuries.

Subjects were randomized to date of training and to group assignment. Because subjects were not familiar with the simulation setting, an orientation to the environment and to the mannequin was conducted to minimize this impact. Despite this, subjects appeared to initially be reluctant to interact with the mannequin as they would with a human. This may have contributed to the low pre-intervention ratings on the steps 'Patient Identification' and 'Communicate to the Patient'. It must be noted however, that failure to identify patients correctly remains a national priority as evidenced by annual inclusion as a Joint Commission National Patient Safety Goal (69). Finally, not all conditions in the clinical setting could be duplicated in the simulation lab (e.g. storage area for patient transfer equipment) although subjects reported that the simulation scenarios were realistic and similar to their daily practice.

2.7 CONCLUSION

The use of hierarchical task analysis methodology supported achievement of study aims. Hierarchical task analysis can be used as a means of analyzing a specific healthcare intervention (patient transfer) with deconstruction of the process into distinct components. Through a multi-step process based on methods described by Annett, Stanton and Shepard, a patient transfer protocol was derived and validated [17-19, 57]. The validation process included achieving expert consensus, referencing steps to evidence-based rationale and performing structured clinical observations with ongoing feedback to the expert development panel for final refinement of the protocol. The patient transfer protocol was then used to formulate a simulation intervention incorporating on-line curricular support materials, simulated mannequin transfers and structured debriefing. Every subject team demonstrated pre- to post-intervention improvement in transfer skill. In addition, improvement occurred in every patient transfer protocol step.

The patient transfer protocol rating checklist was programmed into two data collection tools: the Laerdal SimMan™ software and the HP IPAQ PC™. The use of two separate data collection tools proved valuable and efficient in generating inter-rater reliability statistics.

Inter-rater reliability indicated substantial agreement between ratings of experts and non-experts. Further, it was important to evaluate the utility of the HP IPAQ PC™ tool during the simulation intervention as a mobile and unobtrusive data collection tool will be necessary for collecting patient transfer data in the clinical setting for future evaluation of transference of skills.

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3.0 DATA PAPER

3.1 TITLE PAGE

EFFECT OF A SIMULATION EDUCATIONAL INTERVENTION ON KNOWLEDGE, ATTITUDE AND TRANSFERENCE OF PATIENT TRANSFER SKILLS FROM THE SIMULATION LAB TO THE CLINICAL SETTING

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Key Words: Simulation, Hierarchical task analysis, Back Injury Prevention

3.2 ABSTRACT

Introduction

Musculoskeletal Injury is the single biggest factor in workforce loss of nurses. Current simulation educational methods have not been studied in this area, but may have advantages over traditional approaches. Specific aims were to: 1) Evaluate the effect of a simulation intervention on patient transfer success in a clinical setting and 2) Measure change in participant knowledge and attitude as a result of the intervention.

Methods

A prospective, longitudinal, repeated measures design was used. Baseline patient transfer observations were conducted on control and intervention units. An optimum task set was developed using hierarchical task analysis methods. Subjects ($N=71$) completed pre and post-intervention knowledge and attitude assessments. The protocol consisted of simulated transfers, education and training followed by repeated simulated transfers with debriefing. Observations of patient transfers in patient care areas were repeated at 4 and 12 weeks.

Results

Patient transfer success improved from 66% at baseline to 88% at the 4 week measurement point ($t = 7.447$, $p \leq 0.0004$). At 12 weeks, transfer success had regressed to 71% with addition of new employees between weeks 4 and 12 confounding the 12 week measurement. Knowledge improved from a baseline of 65% to 95% post simulation intervention ($z = -6.634$, $p \leq 0.0004$). Attitude change was also evaluated with significance seen with 12/15 items ($p \leq 0.05$).

Conclusions

A simulation intervention was successful in significantly improving knowledge and changing subject perceptions. Skills acquired through simulation successfully transferred to the clinical setting. Improvement in success for transfers *not* trained in the simulation lab suggests that acquired skills were generalizable and supports application to different settings.

3.3 INTRODUCTION

Nurses and nurse aides represent the bulk of healthcare providers with nurses alone comprising approximately 55% of the total healthcare workforce (1). Back and other musculoskeletal injury has been cited as *the* single largest contributor to the ongoing nursing workforce shortage (2). The US Department of Labor's annual reporting of non-fatal injuries within private industry consistently lists nurses and nurse aides among injury leaders in the US workplace. In 2006, nurse aides, orderlies and attendants had the second highest number of reported injuries within the US workforce; with only manual laborers having a greater absolute number of injuries (3). Additionally, registered nurses ranked number five in injury among all workers. Incidence rate (defined as injuries per 10,000 workers) among nurse aides and orderlies was 293.3/10,000 which is nearly twice the rate of manual laborers (157.9/10,000)(3). Nurse injury rates were 59/10,000 but due to the large number of nurses in the workforce, the overall number of injuries maintained a top five position. The issue of nurse and nurse aide injury is a national priority due to both a national and international shortage of nurses with projections indicating a shortfall of as many as a million nurses by 2020 (4).

Nursing training in patient transfer combines information on proper body mechanics with discussion of injury mechanisms. Back belts and other lift-support devices have been evaluated but have not been demonstrated to consistently reduce injury (5-7). Lifting teams and comprehensive ergonomic assessment of work spaces combined with lift equipment purchase and 'no-lift' or 'minimal lift' policies have been advocated and form the core of a national campaign sponsored by the American Nurses Association(8-10). Despite these admirable efforts, nurse and nurse aide injury rates remain high with manual patient transfer identified as the most important risk factor (2, 11) . Relatively new to healthcare education, hands on simulation may represent an exciting new approach to the problem of transfer related injury. Simulation has been used to evaluate the spinal loading effect of manual patient transfer vs. use of mechanical devices. Daynard et. al. found that spinal loading was less with mechanical devices, but that lifts took a significantly longer period of time to perform (12). Simulations have been used frequently in industry to model mechanisms of musculoskeletal injury and identify prevention strategies (13).

Patient simulation as an educational methodolology has grown dramatically in popularity over the last decade. While the discipline of healthcare simulation can be defined in several ways, Tekian et. al (1999) defined simulation as "a person, device or set of conditions which attempts to present evaluation problems authentically"(14). While the spectrum of applications within the healthcare setting is impressive, evaluation of the effect of simulation training on improved patient care processes is complicated by several obstacles. These include the infrequency of some clinical events, shortage of resources required for structured study in a clinical setting and a lack of validated methodology and tools for collection of clinical data. Patient transfer is a viable simulation training target for several reasons. First, patient transfer is <u>not</u> a rare event, occurring hundreds of times per day in most hospitals. Second, patient transfer is a task which can be broken into component elements. Third, the high level of nursing and nurse aide injury related to this task make it a priority target (3).

In approaching this issue, O'Donnell et. al identified the lack of a universally accepted approach to performing patient transfer while minimizing provider risk. Using the ergonomic method of hierarchical task analysis, these authors identified an optimum task set for patient transfer, created a patient transfer protocol **(Table 6)**, wrote a corresponding simulation training program and developed mobile data collection tools for observation of patient transfers in the clinical setting (15, 16). The protocol was based on best evidence from the literature, reviewed by an expert panel and refined through an iterative process of description, clinical observation, evaluation and re-evaluation. Significant improvement in caregiver team transfer success was demonstrated in the simulation lab. Interrater reliability in use of the protocol was established (16).

Table 6: Patient Transfer Protocol Steps with Descriptions

Step Number	Step Description
1	Identify the patient and the need for the patient transfer
2	Assess the patient's baseline physical and mental status prior to transfer
3	Enlist appropriate number and type of personnel needed to perform the transfer
4	Gather the necessary equipment to perform the transfer
5	Prepare the environment to optimize performance of the transfer
6	Communicate with the patient the why, what and how of the transfer
7	Communicate with personnel to define roles, expectations and timing of the transfer
8	Perform the transfer according to ergonomic and patient safety principles
9	Reassess the patient for change in physical or mental status post transfer event
10	Reset the patient and unit environment

The protocol was derived through Hierarchical Task Analysis Methodology through an ongoing, iterative process based on observation, best evidence from the literature and standards of care.

The purpose of this study was to determine the impact of a simulation training program emphasizing a patient transfer protocol on successful clinical adoption of the protocol. Specific aims were to: 1) Evaluate the effect of a simulation intervention on patient transfer success in a clinical setting and 2) Measure change in participant knowledge and attitude as a result of the intervention.

3.4 METHODS

3.4.1 Setting and Sample

The setting was a University-affiliated rehabilitation institute including four clinical units divided between 2 hospitals. The three intervention units were physically connected at one hospital and employed 81 providers. The control unit was at a separate facility and employed 14 providers. Key demographic factors were compared between control and intervention unit personnel at baseline to assure equivalence. The intervention group was a convenience sample of nurses and nurse aides who were randomized to teams of 3-4 for the simulation intervention. Inclusion criteria for the intervention group included employment as a nurse or nurse aide on the intervention units and participation in direct patient care. Exclusion criteria included age < 18 or inability to perform a patient transfer due to a physical limitation.

A total of 71 employees on the intervention units agreed to participate in the simulation intervention representing 88% of the total employee group (71/81). All participants were either nurses (n = 48) or nurse aides (n = 23). Participants were consented prior to receiving the simulation intervention and completing the knowledge and attitude tools. Control unit employees conducted patient transfers according to their normal practice and did not receive an intervention. The simulation intervention was conducted at the Peter M. Winter Institute for Simulation, Education and Research (WISER) of the University of Pittsburgh.

3.4.2 Simulation Intervention Design and Measurement

A prospective, longitudinal, repeated measures design **(Figure 6)** was used. Following IRB approval, structured pre-intervention observation of patient transfers was conducted on control and intervention units. The unit of analysis was the *team* as patient transfers are typically a 'team' activity. Transfers were observed at baseline and again at 4 and 12 weeks. At each observation point, transfer events were rated by trained observers supervised by ergonomic experts. Each unique transfer event was rated with a score which represented the number of steps rated 'correct'/the total number of steps rated using the patient transfer protocol.

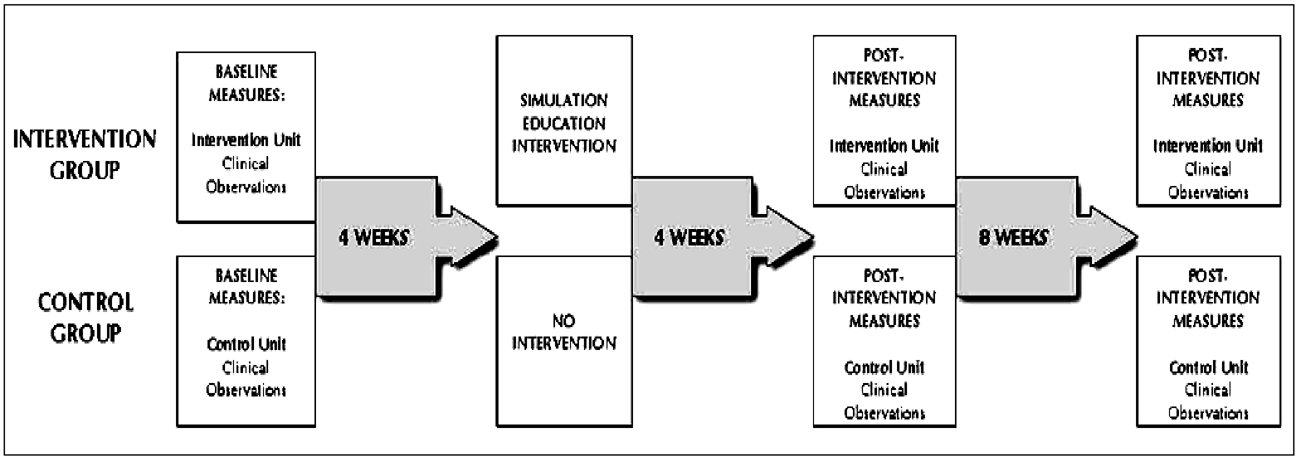


Figure 6: Patient Transfer Training Using a Simulation Intervention: Study Design

A 10 item knowledge and 15 item attitude assessment were completed pre- and post-intervention by participants via wireless computer consoles with responses automatically uploaded into the WISER Simulation Information Management System (SIMS). These tools were specifically referenced to the optimal transfer steps described through the task analysis. The SIMS system allowed assessment data to be entered in a secure, password protected manner. Using an ‘honest-broker’ system, all subject data was de-identified prior to analysis

Knowledge and attitude assessments were submitted by participants via wireless computer consoles with responses automatically uploaded into the WISER Simulation Information Management System (SIMS). This system allowed assessment data to be entered in a secure, password protected manner. Using an ‘honest-broker’ system, all subject data was de-identified prior to analysis.

3.4.3 Instruments

The primary measurement tool for evaluating team performance of patient transfer was the ‘patient transfer protocol’. The construct validity of the patient transfer protocol tool can be evaluated in light of evidence of the five sources of validity defined by Downing which include *content evidence, response process, internal structure, relationship to other variables and consequences* (17, 18).

Content evidence in support of the validity of the patient transfer protocol is established by two methods. First, as described in a related methods paper, the transfer protocol defined the optimal task steps for patient transfer and was developed using hierarchical task analysis methods (19, 20). Use of hierarchical task analysis resulted in development of a patient transfer protocol that accurately represented the clinical process. This task analysis development process was iterative and included observation, description and testing in order to establish the optimum set of task steps **(Table 6).** Each step was cross-referenced to best evidence from the literature and accepted standards of care and then operationally defined by sub-steps. Second, a 10 item multiple choice knowledge tool was given pre and post simulation intervention. Each item was associated with a transfer protocol step and referenced to best evidence or standards of care. All items were cross referenced to content within the web-supported course material or to specific debriefing feedback programmed within the SimMan™ programming.

Response process evidence in support of the validity of the transfer protocol included use of a standardized instructor manual to ensure that the simulation intervention and all assessments were conducted in the same manner for all participants. A test map was developed for multiple choice items with reference to each protocol step. All researcher activities in the simulation setting were followed according to a checklist including reading of introduction and consent forms, obtaining consents, administering pre-intervention knowledge and attitude assessments, randomizing participants to transfer teams, conducting two initial transfers, transfer debriefing and review of course material, conducting two final transfers and administering post-intervention knowledge and attitude assessments. Deidentified knowledge and attitude measure scores were reported via the WISER SIMS system. Analysis of the knowledge test items was conducted by a panel of healthcare experts. All trainee responses were deidentified by the WISER SIMS system and aggregate item analysis included measures of item difficulty.

Internal structure evidence in support of validity of the tool included evaluation of inter-rater reliability during use of the tool. Ergonomic expert scores were compared with trained raters during simulated transfer events. Step scoring options included 'correct' indicating successful completion of *all* sub-steps or 'incorrect' indicating failure on *any* single sub-step. The interrater reliability scores from the simulated moves can be characterized as substantial to near perfect (κ = 0.43-0.83) (19). The terms moderate, substantial and near-perfect agreement in interpretation of the kappa statistics are based on the classic interpretation by Landis et. al. (21).

Relationship to other variables was demonstrated in two areas. First, a 15 item attitude instrument separated into cognitive, affective, psychomotor, communication and safety perceptions. These areas directly relate to domain areas needed to perform a patient transfer. Items were adapted with permission from attitudinal items used by the Office for Measurement and Evaluation (OMET) at the University of Pittsburgh or the Winter Institute for Simulation Education and Research (WISER) of the University of Pittsburgh. Secondly, the percent of intervention unit participants trained in the protocol was correlated with their performance in transferring patients on the clinical units.

Consequences of the intervention in support of validity were evaluated as follows. Participants (71/81 or 88% of intervention unit personnel) entered the intervention arm voluntarily. Table 2 demonstrates that participants had a very high level of anticipation that the intervention would be valuable across multiple domain areas including improved understanding of how to prevent provider injuries. A second important consequence of the protocol was the recognition of employee value by the UPMC Health Plan™ which adopted the protocol for use in mandatory employee training across two community hospitals with subsequent plans to support implementation across the entire UPMC Health System.

3.4.4 Statistical Methods

SPSS 15.0™ was used for all data analysis. Level of significance for all statistical tests was established *a priori* as 0.05. Observations of patient transfer were conducted at three measurement points; baseline, 4 weeks, 12 weeks. The unit of analysis was the transfer team with success measured by adherence to the patient transfer protocol as previously described. A distribution of patient transfer ratings was developed for each measurement point. The data collection site and the location (intervention vs. control unit), the type of move performed and a score for each step of the transfer were recorded. A 2 X 2 X 3 univariate analysis of variance (ANOVA) was conducted with three main effect variables entered into the model. These included: Group (control vs. intervention units), Move-type (chair moves vs. bed moves) and Time (patient transfer performance pre-intervention, 4 weeks post-intervention and 12 weeks post-intervention).

Pre and post intervention knowledge level was measured using a 10 item multiple choice exam. Mean ± SD scores were calculated for both the pre and post intervention scores. Improvement in performance was evaluated using a Wilcoxon signed ranks test. Pre and post-intervention attitude data was also obtained. Attitude items were rated with a five point likert scale (strongly disagree = 1, strongly agree = 5). MANOVA was used to evaluate within subject effects. Post-hoc univariate analysis of the pre and post attitudinal items was conducted.

Descriptive statistics were used to summarize and compare baseline demographic variables of employees on both intervention and control units. Mean ± SD and median values were calculated for age. The Mann Whitney U test was used to evaluate for differences in age between the control and intervention groups. Differences between gender, job class and categories representing years of clinical experience were evaluated using chi square (X^2).

3.5 RESULTS

3.5.1 Clinical Transfer Skill Improvement

The study was conducted from May 2005 to August 2005. The total number of transfer observations in the study was 306. At baseline, a total of 103 transfers were observed on the intervention units and 34 events were observed on the control unit. Four weeks post intervention, a total of 53 transfers were observed on the intervention units and 30 transfers were observed on the control unit. At 12 weeks a total of 54 transfers were observed on the intervention units and 32 transfers on the control unit. HP IPAQ™ handheld personal computers programmed with the patient transfer protocol checklist were used for data collection.

All three main effect variables (Group, MoveClass and Time) in the 2 X 2 X 3 ANOVA model demonstrated significance ($p \leq 0.0004$). Interaction effects were then analyzed with the Group*Time interaction significant ($p \leq 0.0004$). The three interactions which had non-significant results were Group*MoveClass, MoveClass*Time and Group*MoveClass*Time. These interactions had an observed power (computed using $\alpha < 0.05$) of 0.057, 0.395, 0.176 respectively. These values for observed power must be considered with respect to the estimated effect size (partial eta on the ANOVA table). The partial eta values for the non-significant interactions were 0.0004, 0.013 and 0.005 respectively. Because the low observed power is combined with a low estimated effect size, a very large sample size would be needed to detect a statistically significant difference. Even should there be a statistical significance, it would be unlikely to be clinically relevant. In summary, if the p value is NS and the observed power is low, the eta must be evaluated. If the eta is large, it is likely that the test is truly underpowered. In this case, the eta values are small. Post-hoc pair-wise comparison revealed that the change in transfer success (66% to 88%) at the 4 week post--intervention measurement point was highly significant ($t = 7.447$, $p \leq 0.0004$) **(Figure 7)**. No other pair-wise comparison of Group*Time was statistically significant indicating that patient transfer success at the 12 week post-intervention point had regressed toward baseline.

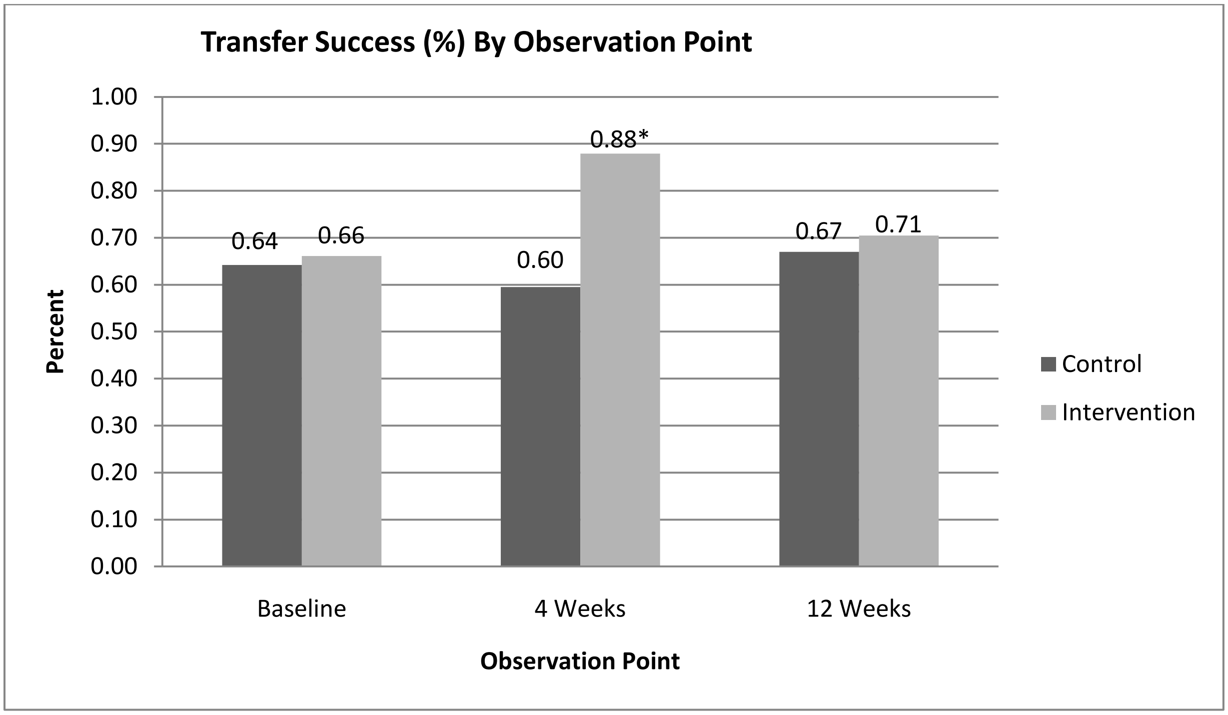


Figure 7: Patient Transfer Protocol Success: Control v. Intervention Units

A variety of transfers were observed on the clinical units. They were stratified into bed-based transfers vs. chair based transfers (MoveType). The 'type of transfer' performed was statistically significant as a main effect within the model as there were almost twice the amount of chair-based transfers (202) vs. bed based transfers (104) observed. All transfer events during the simulation intervention were conducted as 'bed' events due to mobility limitations of the Laerdal Tough Kelly™ mannequin. Improvements in chair-based transfer success in the clinical setting at 4 weeks post-intervention were equal to improvements in bed-based transfer success. As noted, overall patient transfer success at 12 weeks regressed toward baseline (88% to 71%). Interestingly, the chair-based transfer success regressed from 86% to 54% while the bed-based patient transfer success regression was smaller (89% to 77%) **(Figure 8).**

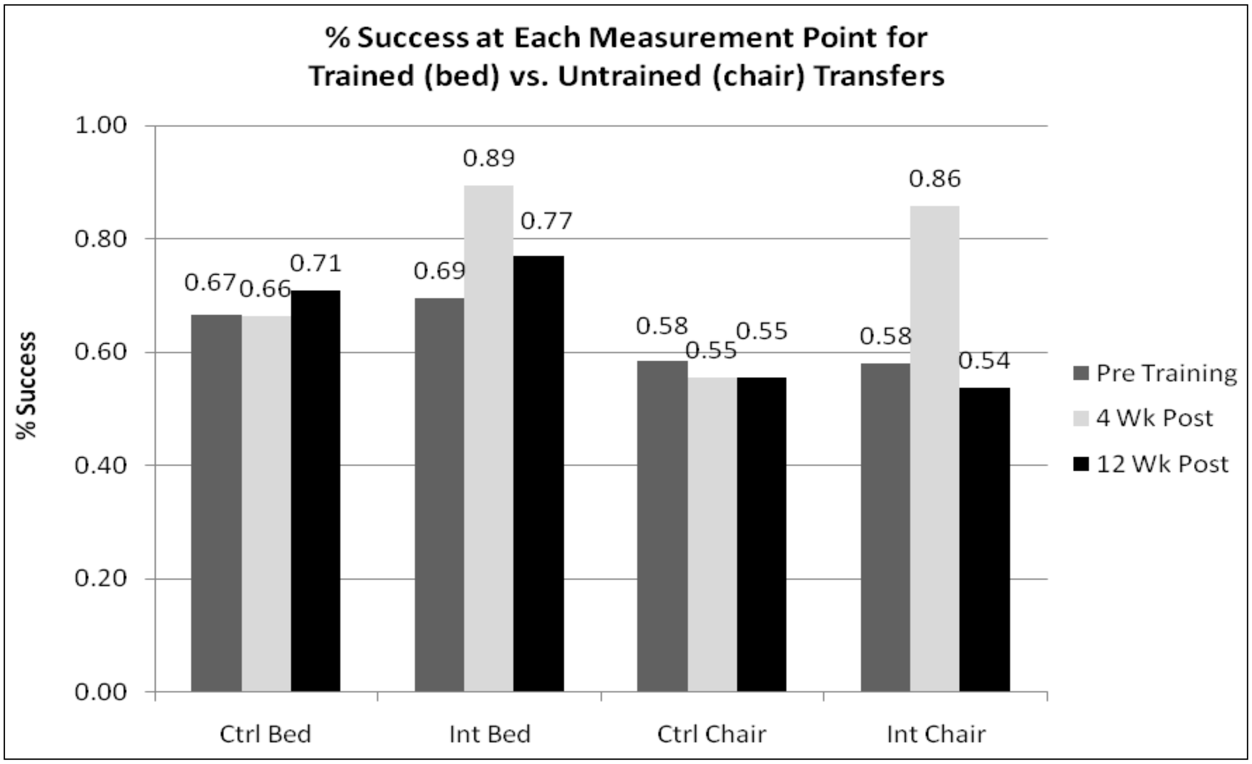
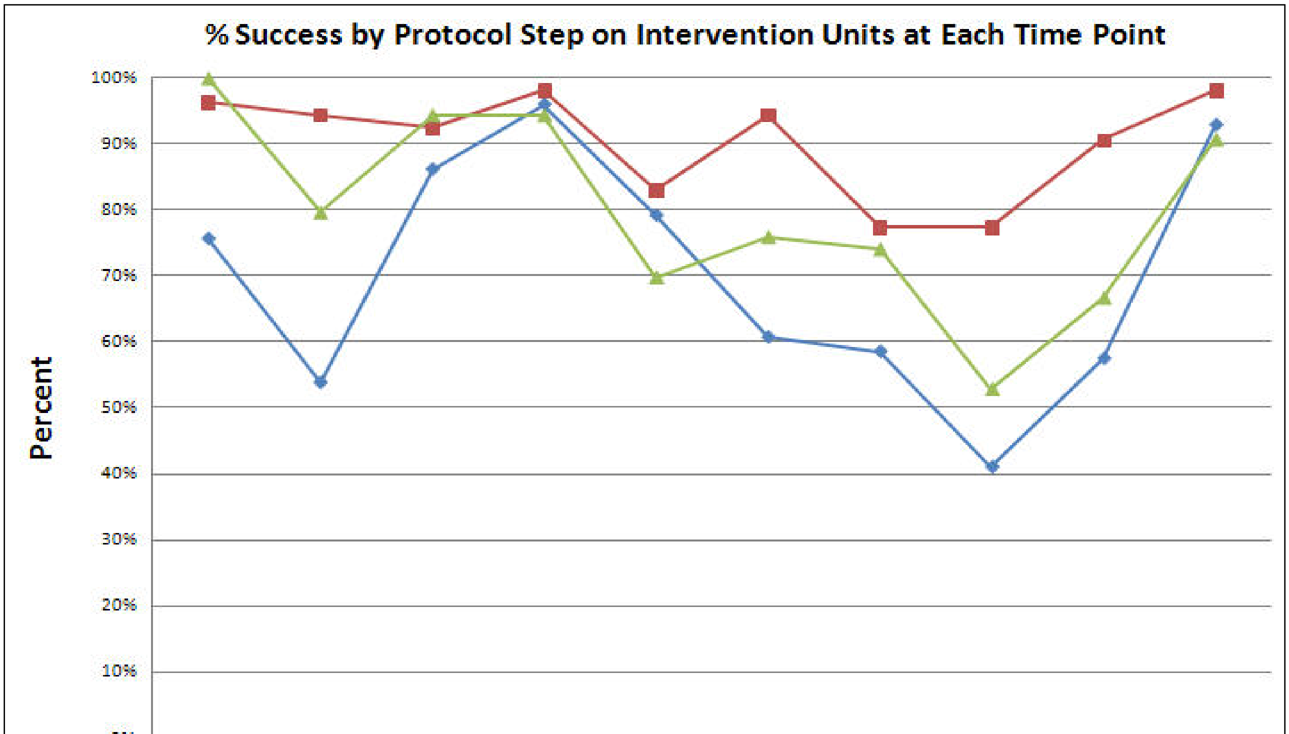


Figure 8: Comparison of Patient Transfer Protocol Success by Type of Move, Observation Point and Unit. Key: Ctrl Bed = Bed based transfer on the control unit, Int Bed = Bed based transfer on the intervention unit, Ctrl Chair = Chair based transfer on the control unit, Int Chair = Chair based transfer on the intervention units.

Success on each transfer protocol step on the intervention units was analyzed for each measurement point. The protocol steps with the highest baseline success rates were Gather Equipment and Resetting the Environment. Steps with the lowest pre-intervention success were Perform the Move followed by Assess the Patient, Reassess the Patient and Communicate to Personnel **(Figure 9).**



	Identify	Assess	Enlist	Gather	Prepare	Comm. Patient	Comm. Personnel	Perform	Reassess	Reset
Baseline	76%	54%	86%	96%	79%	61%	59%	41%	58%	93%
4 weeks	96%	94%	92%	98%	83%	94%	77%	77%	91%	98%
12 weeks	100%	80%	94%	94%	70%	76%	74%	53%	67%	91%

Figure 9: % Success by Protocol Step on Intervention Units at Each Time Point

Percent success at baseline indicates that the Gather Equipment and Resetting the Environment steps had the highest % success. Post- intervention, all individual steps were above the 80% success level with the exception of Communicate to the Patient and Perform the Move. At 12 weeks, Perform the Move success had dropped to 53% with Reassess the Patient also below 70% success.

At 4 weeks post-intervention every protocol step demonstrated improvement which paralleled the simulation lab findings. All individual protocol steps were above the 80% success level with the exception of Communicate to the Patient and Perform the Move. At 12 weeks the overall success percentage had regressed to 71%. When broken into individual protocol steps, 8/10 of the steps had regressed (**Figure 10**). Perform the Move, Reassess, Communicate to the Patient and Assessment were the steps which showed the greatest regression.

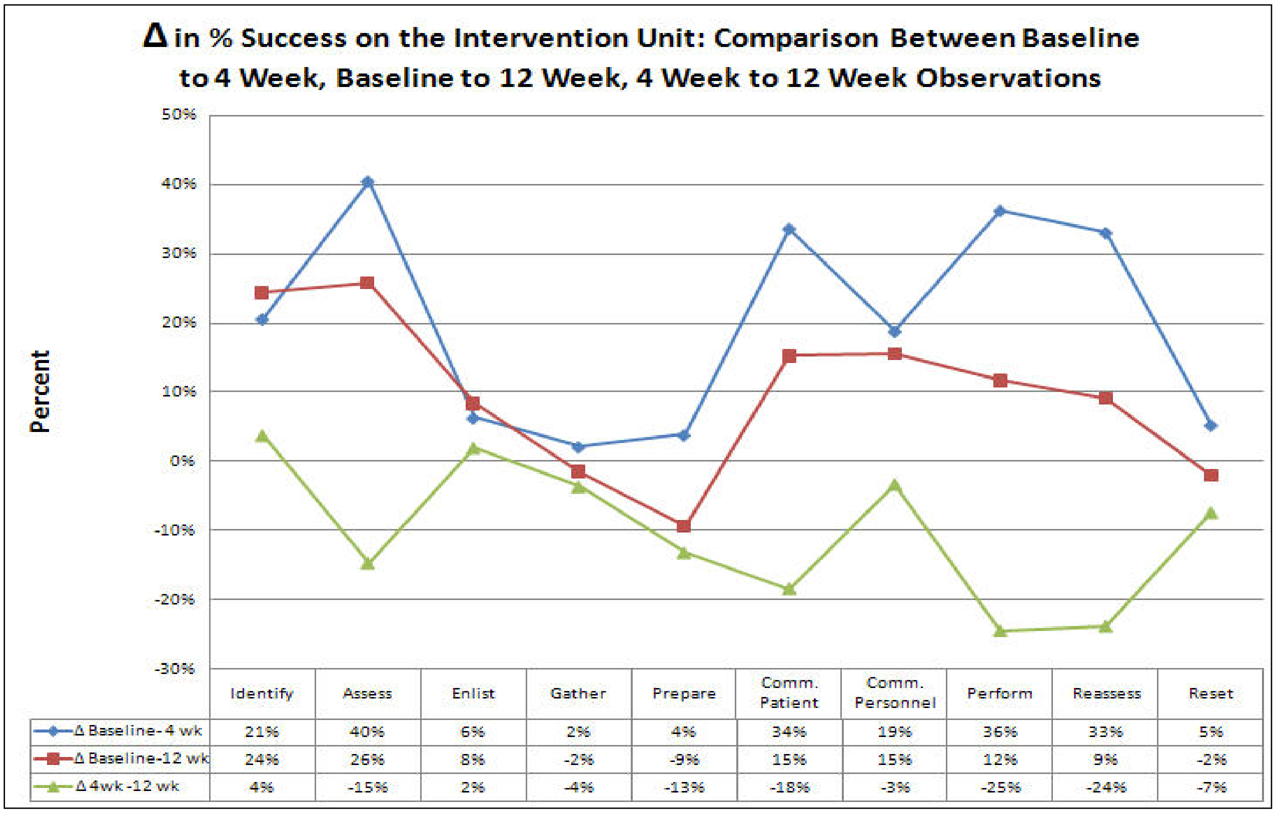


Figure 10: Change in % Success Broken Down by Protocol Steps and Observation Point

Greatest improvement at 4 weeks was noted on Assessment, Communicate to Patient, Performing the Move and Reassessment Steps. At 12 weeks, 8/10 of the steps had regressed toward baseline. Perform the Move, Reassess, Communicate to the Patient and Assessment were the steps which showed the greatest regression. The overall regression of transfer success from 4 to 12 weeks was 10.3% which corresponded to a 12.3% (10 providers) increase in untrained staff.

3.5.2 Knowledge Improvement

The 10 item multiple choice knowledge instrument was administered pre and post-intervention to all subjects in the intervention arm of the study. Knowledge improvement was significant with mean knowledge scores improving from 65% (± 18%) to 90% (± 12%) ($z = -6.634$, $p \leq 0.0004$).

3.5.3 Attitude Change

Pre and post-intervention attitude evaluation was conducted. Subjects responded on a five point Likert scale to a total of 15 items. Mean scores for both pre and post attitude measures were calculated. MANOVA was used to evaluate within subject effects; Wilk's Lambda was highly significant ($F=2.94$, $p = 0.003$). Post hoc univariate analysis demonstrated statistically significant change in 12/15 items ($p \leq 0.05$) **(Table 8)**.

Table 7: Pre vs. Post-Intervention Attitude Assessment

Items: Health Professional Simulation Education Assessment Tools (HtSEAT v.1 and v.2)*	Δ in mean scores pre to post	p value
Met course objectives	0.48	0.000
Knowledge base on back injury and prevention	0.27	0.011
Number of personnel need by patient weight	0.33	0.001
Realism of simulation scenarios	0.24	0.048
Similar to actual clinical transfer events	0.42	0.003
Gain in injury prevention skills	0.37	0.001
Gain in patient transfer skills	0.38	0.000
Confidence in instructor evaluation of skill	0.26	0.017
Anxiety related to observation of performance	-0.31	0.124
Gain in confidence during patient transfer	0.25	0.008
More effective patient communication	0.40	0.001
More effective provider communication	0.45	0.000
More effective team member during transfer	0.34	0.000
Improve patient safety during transfer	0.30	0.001

This assessment titled the 'Health Professional Simulation Education Assessment Tool (HtSEAT v1 and v2)' was used to evaluate subject perceptions of curriculum, realism, gain in skill, confidence, anxiety, safety skills and communication ability. A paired samples t-test was used to evaluate change in means scores with 13/15 items demonstrating significant change ($p \leq 0.05$). * Scale 1 strongly disagree to 5 strongly agree

3.5.4 Control and Intervention Unit Demographics

Deidentified demographic data were obtained for respondents on both control (n = 74) and intervention (n =14) units. Mean age of personnel in the intervention unit was 44.6 ± 11.9 and on the control unit 44.4 ± 13.8. These age differences were not statistically significant ($z = -0.097$, $p = 0.953$). Gender, years of experience and job title classifications were compared using the chi-square statistic (X^2). Control and intervention unit personnel were <u>not</u> significantly different with respect to these variables ($p > 0.05$) **(Table 9)**.

Table 8: Demographic Variables- Control v. Intervention Unit

Baseline Demographics	Control Unit (n =14)	Intervention Unit (n =74)	Statistic	p value
Gender (%)				
Male	14.3	16.4	χ^2*	0.846
Female	85.7	83.6		
Experience Category (%)				
< 1 year	14.3	4.3	χ^2	0.563
1-3 years	0	0		
3-5 years	14.3	15.9		
> 5 years	71.4	71.7		
Job Title (%)				
Nurse (RN and LPN)	71.4	66.1	χ^2	0.211
Nurse Aide	28.6	33.9		
Age				
Mean	44.4	44.6	t-test**	0.953
SD	13.8	11.9		
Median	48.5	45		

Control unit personnel (n =14 respondents) were compared with intervention unit personnel (n =74 respondents, 7 employees did not submit data) on four demographic variables: Gender, # years of work experience, job title, and age. No significant differences were identified.

Key: χ^2 = Pearsons Chi Square, t-test = independent samples t test

3.6 DISCUSSION

In this report, we demonstrate that a simulation intervention can be used to improve success for a common clinical event- the patient transfer. Improvement in patient transfer success was measured using an optimal task set for patient transfer. Participants on the intervention units demonstrated significant improvement in transfer skill at the 4 week measurement point demonstrating that the protocol was effective in changing clinical behavior among teams of nurses and nurse aides. This clinical improvement paralleled improvement in simulation lab transfers reported by O'Donnell (16). In that report, 19 teams of nurses and nurse aides completed 76 transfer events or 4 per team. The success of all 19 teams improved from pre to post-intervention (mean score pre-intervention was 34% and improved to 86% post-intervention, $p < 0.0004$). These results demonstrate that skills acquired in a simulation lab can directly transfer to patient care.

In addition to improved patient transfer skill, participants in this study demonstrated improvement in knowledge and change in attitude. The knowledge improvement was 25% and participants indicated that items were relevant and that the assessment should be used again in future courses. Participants also demonstrated change in multiple attitudinal areas. Importantly they felt that they had improved in identifying: personnel needed for moves; knowledge of injury prevention; skill in injury prevention; overall skill in patient transfer; improved communication; and safety in patient transfer. Additionally participants reported: that training program objective were met; scenarios were realistic; scenarios were realistic; scenarios were similar to clinical transfer events; injury prevention skills had improved; overall patient transfer skills had improved; confidence had increased; and effectiveness as team members had improved.

Three items which did not demonstrate statistically significant change in rating were 'improved knowledge of equipment needed for transfer' and 'anxiety related to being observed' and 'realism of simulation scenarios' during the transfer events. Equipment selection is not a focus of the curriculum although the on-line material does review this topic. Anxiety scores pre- to post intervention decreased perhaps reflecting efforts to provide a non-threatening and comfortable environment for subjects within the context of the research protocol. This decrease was not statistically significant. Participants anticipated that the simulation scenarios would be realistic prior to the event (mean score 4.17/5) with no significant change in this perception.

Finally, post- intervention improvement in success on untrained (chair) moves was similar to improvement on the trained (bed) moves at 4 weeks **(Figure 8)**. This finding indicates that participants applied the patient transfer protocol to moves they did *not* practice during the intervention. The improvement in untrained moves suggests that use of the protocol was generalized to the chair moves by participants. This is relevant in use of the protocol in training at institutions which use different equipment or perform other types of patient transfers.

Further, this has broader implication for use of simulation approaches in developing future training and evaluation protocols for other healthcare tasks. This is an important finding as a number of other reports have described a broadened scope and diversity in the application of simulation methods including alteration of attitude, skill attainment, diagnosis of system problems, enhanced knowledge and evaluation of competence.

3.6.1 Attitude

O'Donnell described the development of a course designed to teach Anesthesia Crisis Resource Management (ACRM) skills to Nurse Anesthesia Students. This paper described the development of key logistical and operational elements. Student course evaluations were positive in the areas of scenario fidelity, practice variation and the utility of debriefing (22).

Liu et al used a simulated operating room setting to demonstrate how simulation could be used to prevent blood transfusion errors through changing attitudes of the impact of distraction. A total of 12 anesthesiologists administered blood in an OR setting complete with a planned distraction. Those anesthesiologists who were able to avoid the distraction were able to safely manage the transfusion and expressed the need for skill and attitude alteration in order to promote safety (23).

DeCarlo et al surveyed nursing attitudes regarding barriers in use of simulation. In a sample of 523 full and part-time pediatric nurses, these authors reported 'being videotaped', 'unfamiliar equipment' and 'stressful environment' as the most frequently cited barriers. Responses were stratified according to participant simulation experience, clinical experience and care environment (acute vs. non-acute). Non-acute care nurses perceived stressful environment as an important barrier. Nurses with simulation experience and those with < 5 years of clinical experience found 'not the real thing' to be a barrier (24).

3.6.2 Skill Development

Several authors have described using simulation methods to improve skills in code and CPR management. Spunt et. al described use of a 'mock code' within a blended curricular model to improve undergraduate nursing student management of code events (25). Ackerman demonstrated that traditional training plus a simulation scenario resulted in significantly increased CPR knowledge and skill as compared to traditional training alone. Further, knowledge and skill retention was improved (26).

In a review, Tsang identified seven surgical simulation studies. Three of the studies focused on carotid stenting and four studies focused on training for peripheral vascular angioplasty. Tsang summarized the findings of the studies and concluded that simulator training is a valid, feasible and acceptable training tool for surgical training. Also noted was that one of the randomized studies which looked at carotid stenting had demonstrated transfer of skills to the operating room (27).

In the obstetric domain, Draycott et. al. and Crofts et.al. demonstrated that multidisciplinary simulation training in specific areas of care (shoulder dystocia) demonstrated significant improvement in performance in the simulation center. Further, these authors demonstrated subsequent transfer of skills to the clinical setting with significant improvement in management of the problem (28, 29).

3.6.3 Diagnosis of Clinical Problems

Cardiac arrest outcomes remain problematic in the hospital setting. Timing of first responder arrival and their subsequent actions have a significant impact on survival. Marsch et. al. used simulation techniques to evaluate the ability of first responders to adhere to algorithms of cardiopulmonary resuscitation using a simulated cardiac arrest in an intensive care environment. Every team demonstrated communication errors and multiple therapeutic errors and treatment delays were documented. This 'diagnostic' use of simulation highlighted the need for deliberate practice of these types of rare but critical healthcare events (30).

In a parallel investigation, Hunt et. al used 'in situ' simulated arrests in the pediatric setting to measure elapsed times and also to identify the types and frequencies of errors in pediatric medical emergencies. Outcomes included identification of significant treatment delays and deviations from recommended care algorithms. The authors concluded that simulation of pediatric events is effective in identifying targets for education and system remediation (31)

DeVita et. al. have reported the use of a unique simulation curriculum to improve team task performance in codes. In these reports, the development of medical emergency teams (MET) or rapid response teams is highlighted with focus on flattening the care team hierarchy and completing all critical code tasks within a compressed time window. Overall task completion was associated with simulator 'survival' in this model(32). Further, in a retrospective analysis, these authors reported a reduction in code-related mortality in the affiliated health system (33)

The rapid response team concept combined with simulation training has also been extended to the obstetric setting. Thompson et. al. (2004) reported implementation of 'preeclampsia drills' in a large obstetric unit. Simulation scenarios focused on pre-eclampsia were used as a diagnostic tool to identify unit deficiencies. The primary outcome was improvement in subsequent simulated eclampsia events (34).

3.6.4 Increased Knowledge

Hoffman et. al describes the integration of human simulation educational modules within an undergraduate critical care course. Students (n=29) were exposed to 6 simulation events across a 14 week term divided into 7 weeks of clinical and 7 weeks of simulation   Basic Critical Care Knowledge Assessment Test, Version 6 (BKAT-6) was administered in a pre-test, post-test design. Student knowledge gain was significant in 6/8 BKAT subscales. The two BKAT domains that failed to show improvement, also did not have a corresponding simulation training component (35).

3.6.5 Evaluation of Clinical Competency

Ability to perform a wide variety of clinical tasks or processes is essential for all levels of providers. Further, it should be possible to use simulation to differentiate between skill levels of novice to expert practitioners. Girzadas developed a simulation-based assessment of patient care competency which evaluated varying levels of medical residents and their performance of a variety of simple to complex tasks. An anaphylaxis model was used to evaluate ability to problem solve, administer medications, administer IV fluids and perform airway management. The study demonstrated that simulation could be used to differentiate between novice and experienced provider competency across tasks (36).

Simulation has also been used to develop a training program and subsequently demonstrate competency for a specific procedure. Tuttle et. al. describe use of simulation to conduct training and evaluate competency of respiratory therapists in the area of the mini bronchoalveolar lavage (mini-BAL) procedure. Substantial gains in competency to perform the procedure (73 +/- 10 to 92 +/- 8%) were demonstrated (37).

As these reports demonstrate, simulation educational methods hold promise for use in a broad spectrum of education and research applications across simple to complex healthcare tasks. Learners recognize the value of practicing skills outside of the demands of the clinical environment; especially for skills that are difficult to obtain, rare, or expose patients/providers to risk (38).

3.7 LIMITATIONS

3.7.1 Regression of Transfer Success

Regression of patient transfer success at 12 weeks represents the most significant limitation. Two main explanations were considered for this effect: 1) dilution of group skill by the addition of untrained personnel or 2) a fading of the intervention effect.

3.7.2 Dilution of Group Skill

To determine if there was a dilution effect, we analyzed personnel turnover on both control and intervention units. The control unit experienced the following changes in their staff. Five providers left the unit and 6 were hired bringing the total staffing to 15. None of the new employees had worked on the intervention units or received training in the protocol. The overall success rate on the control units did not substantially change between the three observation points.

Success on the protocol related to change in staff on the intervention units was then analyzed. At the 4 week measurement point, 89% of the staff on the intervention unit had received the training and transfer success was 88%. Between the 4 week and 12 week measurement points, a total of 3 employees left the unit and 13 employees were hired. The 3 employees who left had not received the training. The addition of the 13 new personnel therefore represented the addition of a net 10 untrained providers (12.3%) and a new personnel total of 91 (81 + 10). The new staff were not trained before the 12 week measurement point. The 10.3% regression in transfer success between 4 and 12 weeks must therefore be considered in light of this 12.3% increase in untrained personnel.

3.7.3 Fading of the Intervention Effect

We next evaluated the possibility of a fading of the intervention effect. As noted in Methods, the UPMC Health Plan™ evaluated and decided to adopt the protocol for use in transfer training as part of an overall musculoskeletal injury prevention and fitness program ('We've Got Your Back™). Nurses and nurses aides in the community hospital (n = 293) received the training. Baseline transfer success rate was 56% which was similar to the baseline on both the control and intervention units during the study. A 16 week post training observation was conducted and an 83% success rate was demonstrated. The overall improvement in success from baseline was 27% **(Table 9).** Importantly, all new employees received the simulation training during orientation which eliminated any potential dilution effect.

Table 9: Pre- and Post-Intervention Success Rate by Protocol Step in a Community Hospital

Step	Title	Pre- Intervention (%) (n =13)	16 week Post Intervention (%) (n=112)	Improvement (%)
1	Identify	69%	75%	6%
2	Assess	25%	68%	43%
3	Enlist	69%	88%	19%
4	Gather	80%	94%	14%
5	Prepare	69%	92%	23%
6	Communicate Patient	69%	85%	16%
7	Communicate Personnel	39%	88%	49%
8	Perform	46%	85%	39%
9	Reassess	15%	67%	52%
10	Reset	77%	91%	14%
Mean		**56%**	**83%**	**27%**

All nurses and nurse aides (n =293) received the simulation transfer training. Results at baseline (56% success) were similar to baseline in the pilot study (63%) and results at 16 weeks (83%) were similar to 4 week results (88%) in the pilot.

3.7.4 Technology Challenges

A second limitation to the study was the level of technology expertise required to participate. While 71 nurses or nurse aides participated in the simulation intervention, only 67 participants were able to complete both the pre and post-test knowledge tool. Participant lack of familiarity with use of technology in general and the wireless laptop system in particular despite orientation and available information technology support was identified as the probable cause. Several participants reported that they 'lost' responses during use of the computers and did not wish to repeat the assessment. As a result, two pre-intervention and two post-intervention knowledge exams were not recorded involving 4 different participants. In addition only 67 of the 71 nurses or nurse aides completed both the pre and post-test attitude tools. This represented a total of 3 different participants with one subject failing to submit both tools.

3.8 CONCLUSION

As described, over the past three decades a variety of patient transfer and injury prevention programs have been published in the literature. However, none have combined an ergonomically derived patient transfer protocol with current simulation educational approaches. The purpose of this study was to determine the impact of a simulation training program emphasizing a set of optimum transfer task steps on transfer success in the clinical setting. The 4 week post-intervention observation point demonstrated significant improvement in transfer success; however the regression at 12 weeks was confounded by the addition of new staff on the intervention unit. In a follow-up program in which all nurses in one community hospital were trained, we conducted a 16 week (4 month) observation which indicated a sustained impact on patient transfer success. Further study must be conducted to determine the optimum time interval between training cycles to ensure ongoing adherence with the protocol.

The development of the handheld computer data collection system was crucial to the success of this project. The graphic user interface is reprogrammable and will be adapted for future healthcare simulation projects requiring acquisition of clinical data. Other important characteristics of the system included simplicity of data entry, streamlined data uploading, ability to change or add to answers during rating of transfers and the use of removable storage chips which support portability and data protection. Finally the system is unobtrusive allowing the observer to enter data without alarming providers, families or patients in the clinical setting.

Improvement in provider success in transfer-types (chair-based transfers) that were not part of the intervention indicates that the patient transfer protocol is generalizable to events other than those which were specifically trained during the intervention. This finding is particularly intriguing as it holds potential for deploying this move protocol across a variety of settings and transfer types. In addition these results suggest that, with modification, the approach could be adapted to transfer situations outside of the health care setting (i.e. industry or the military) or for improving performance of other healthcare processes.

The public health implication of the ongoing loss of qualified nurses from our health care system due to injury is evident. In this report we have combined a proven ergonomic approach with a human simulation intervention. Use of simulation methods grounded in established ergonomic methodology provides a new approach to developing training and assessment protocols in nursing back injury prevention as well as for other healthcare processes. The patient transfer protocol guided development of the simulation educational intervention and the corresponding development of measurement instruments. These instruments allowed measurement of both simulation lab and patient care area skills.

Ideally, follow-up investigation will focus on training an entire healthcare system with concurrent tracking of protocol adherence, provider injury rates and costs. It is important that an economic analysis be conducted to characterize 'return on investment (ROI) for the program. Additional follow-up goals include several long term measurements. These include transfer skill retention, reduction of provider injury rates and decreased attrition of providers due to injury during a time of significant nursing personnel fluctuations.

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4.0 CONCLUSION/POLICY PAPER

4.1 TITLE PAGE

IS A SIMULATION EDUCATION INTERVENTION ANOTHER PIECE IN SOLVING THE COMPLEX PUZZLE OF HEALTHCARE RELATED OCCUPATIONAL INJURY?

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4.2 ABSTRACT

Introduction

Healthcare industry occupational injury rates remain high among nurses (registered nurses and licensed practical nurses) and nurse aides (nurse aides, orderlies and attendants) despite legislative efforts, 'comprehensive' educational programs and targeted injury reduction interventions. A variety of organizations and regulatory agencies have advocated programs including ergonomic evaluation, wholesale equipment replacement and environmental re-engineering. Simulation educational methods have become more broadly accepted within healthcare education and show promise for bridging the gap between the classroom and clinical environments.

Methods

In this paper we describe an approach using hierarchical task analysis as the framework for development of a simulation based intervention and resultant hospital wide training program.

Results

Improvement in team transfer skills in the simulation lab successfully transferred to the clinical environment. Improvement in knowledge and change in attitude was demonstrated. The program was adopted as a mandatory hospital training program with reduction of reportable injuries, injury rates and total lost work days. Participants were matched with controls and one year follow-up demonstrated reductions in overall and targeted musculoskeletal injury rates.

Conclusion

Simulation educational methods constructed according to a framework of hierarchical task analysis were demonstrated to be an effective method allowing transference of skill to the clinical area. Improvement in patient transfer in the simulation setting was transferred to the clinical setting with resultant reduction in provider injury rates. This new approach shows promise in solving the complex puzzle of healthcare related occupational injury.

4.3 THE PROBLEM OF MUSCULOSKELETAL INJURY IN NURSING PERSONNEL

4.3.1 The Injury Epidemic

The risk and reality of occupational injury to healthcare workers remains a significant concern to employers, insurers, health care providers, the public and perhaps most importantly to the individuals and their families whose lives are changed dramatically and often permanently by an injury. Non-fatal occupational injury remains one of the largest causes of lost workdays across the US workforce (1). In healthcare, nurse (registered nurses and licensed practical nurses) and nurse aide (nurse aides, attendants and orderlies) musculoskeletal injury has been described as an epidemic in the United States as well as across the world (2-12) . As many as 38% of nurses suffer from back pain severe enough to require time off from work during their careers and up to 12% leave the profession due to back pain(13). The National Institute of Occupational Safety and Health (NIOSH) reports an annual prevalence of back pain among nurses of 40% to 50%. NIOSH further reports a lifetime prevalence of back pain and injury as high as 80% (14). In 2007 nurses and nurse aides were both in the top ten of all occupations relative to absolute numbers of non-fatal occupational injuries requiring days away from work **(Table 10)** with no other healthcare occupations in the top ten (15). Finally, these injury statistics while alarming may not represent the full scope of the problem. In a 2008 report, Menzel indicates that the number of workplace injuries is substantially under-reported in private industry including healthcare (16).

Table 10: Number of nonfatal occupational injuries and illnesses involving days away from work by selected worker occupation and major industry sector. Top 10 occupations, 2007 (1). (Adapted from US Bureau of Labor Statistics)

Occupation	**Private industry** (Total cases = 1,158,870)
1. Labor and freight, stock, and material movers, hand	79,000
2. Truck drivers, heavy and tractor-trailer	57,050
3. Nursing aides, orderlies, and attendants	**44,930**
4. Construction laborers	34,180
5. Truck drivers, light or delivery services	32,930
6. Retail salespersons	32,920
7. Janitors and cleaners, except maids and housekeeping cleaners	30,060
8. Carpenters	23,800
9. Maintenance and repair workers, general	23,460
10. Registered nurses	**20,020**

4.3.2 Cost and Impact of Nursing Injury

In the US the total direct and indirect costs of back pain in the US workforce have been estimated to exceed 50 billion dollars per year (17). These costs include but are not limited to, replacement costs, accomodation and return to work modification costs, administrative costs, legal costs, financial losses from workers compensation claims, stresses to staffing levels from loss of personnel and lost wages for the injured party. Direct costs are typically defined as medical expenditures, workman's compensation and temporary to permanent disability payments. Indirect costs include loss of productivity, increased insurance costs, legal costs and expenses associated with hiring and orientation of replacement staff (18). Estimates specific to the healthcare industry indicate $20 billion annual total cost with an estimated $10 billion in indirect costs for the industry (2, 19). In a 2005 study by Waehrer, nurse related injury costs were 940 million dollars and nurse aides incurred 2.4 billion in costs related to injury (20)

While the financial burden on the healthcare system alone is staggering, the impact of ongoing nursing injury rates during periods of nursing shortage cannot be underestimated (4). In 2006 the American Hospital Association reported a national RN vacancy rate of 8.5% based on a shortage of approximately 118,000 RNs (21). This shortage is projected to accelerate despite the current economic downturn as the average age of nurses is now 48 (21, 22). Nurse deficit projections range from 340,000 to 1,000,000 by the year 2020 **(Figure 1)** (23, 24).

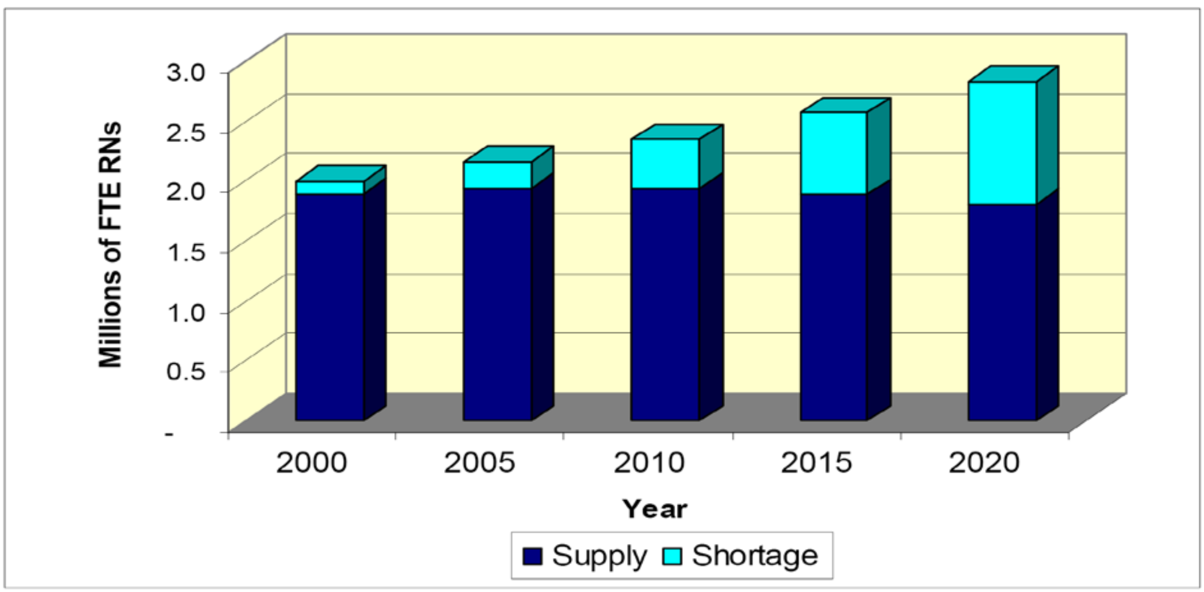

Exhibit 24. Projected U.S. FTE RN Supply, Demand, and Shortages

	2000	2005	2010	2015	2020
Supply	1,890,700	1,942,500	1,941,200	1,886,100	1,808,000
Demand	2,001,500	2,161,300	2,347,000	2,569,800	2,824,900
Shortage	(110,800)	(218,800)	(405,800)	(683,700)	(1,016,900)
Supply ÷ Demand	94%	90%	83%	73%	64%
Demand Shortfall	6%	10%	17%	27%	36%

Figure 11: Projected US Full Time Equivalent (FTE) RN Supply, Demand, and Shortages 2000-2020 (Bureau of Health Professions 2004) (24).

Shortages of nurses are typically related to an imbalance of supply with demand and are often compensated for by increasing the work burden and length of hours worked by the remaining workers. Multiple indices of patient comfort, satisfaction and even patient survival may be impacted by nurse staffing levels (25-30). Shortages have been associated with increased risk of medical error(31), burnout (26, 29) and injury (3, 5). The shortage of nurses combined with an aging workforce and an already high rate of injury raises concern about future healthcare system capacity. Loss of direct care personnel results in increased pressure on the remaining workers, and elevates their risk profile (2).

4.3.3 Historical Context and Injury Risk Factors

The prevalence of occupational injuries reported in the 1960's through the 1970s sparked more intense review of the back injury problem (32, 33). In 1978, Snook et al reported on back injury prevention in industry. At that time the standard approaches were 1) careful worker screening and selection, 2) training in safe lifting (body mechanics) and 3) job redesign to fit workers (environmental redesign approach)(34). The authors concluded that these approaches were not effective (34). In parallel development, teaching in nursing focused on prevention, back health, overall fitness, explanation of proper lifting techniques and body mechanics with instructor demonstration of technique (35-37). Again, it has been concluded that these techniques are not effective although they continue to be taught in schools of nursing and hospital training programs (38-41).

Worker shortages are only one factor contributing to occupational injury among nurses and nurse aides. Patient transfer has been identified as the leading source of musculoskeletal injury among these providers (3, 5-8, 11, 42, 43). Manual lifting during transfer is the most frequently cited causative factor although other patient care situations have been implicated as contributors (2, 4, 5, 11, 44-48). Some studies link injury to particular types of patient units or populations (e.g. bariatric and orthopedic patients) and to frequency of patient transfers per shift (5, 49). The theory is that increased frequency and intensity of patient transfers is associated with a cumulative loading effect on the musculoskeletal system with consequent risk of injury. Additional risk factors contributing to development of injury include improper body mechanics, prior injury history, weight, age, fitness, obesity, genetics, and reduced muscular strength (5, 6, 50, 51).

4.4 TRADITIONAL APPROACHES TO SOLVING THE PROBLEM

4.4.1 Legislative Efforts

Both Australia and the United Kingdom saw the emergence of educational and legislative initiatives in the 1990's which focused on the issue of prevention of nursing back injury. 'No lift' policies were instituted in these countries in 1996 and 1998 respectively (4). Perhaps a better term for these policies would be 'safe-lift' or 'minimal-lift' instead of 'no-lift' as the latter description implies that nurses will not be involved in any patient transfer events or situations- an impractical absolute. These policies call for greatly reduced nursing exertion during lift maneuvers and the use of lift devices whenever possible. Funded by centralized national health systems, all facilities in these countries were outfitted with lifting devices to promote use of mechanical lifts. The result of these regulatory initiatives has been a reduction but not complete elimination of injury among nursing personnel (52).

Following these efforts in Australia and the United Kingdom, advocates in the United States pushed for similar legislation. In 2000, officials of the Occupational Safety and Health

Administration (OSHA) were poised to publish a final ergonomics rule (29 CFR Part 1910 Ergonomics Program; Final Rule) that would have set parameters for all US hospital-based patient transfers. As many as 6 million employers and 93 million employees would have been affected. Despite widespread support from individual nursing advocates and professional associations, healthcare industry lobbyists garnered congressional support for a counter measure (S-J Res. 6) which repealed the rule (53). In the repeal the following directive severely limited follow-up action: "A condition of this repeal is that OSHA is barred from pursuing development of another ergonomics standard unless ordered so by Congress with agreement of the Executive Branch" (43). In 2005, the ongoing 'healthcare crisis' as a result of disabling back injuries among the US healthcare workforce was used as rationale to again call for national legislation to institute a mandatory 'no-lift' policy similar to those enacted abroad (4). No Federal policy or standard has yet been promulgated, although the Occupational Safety and Health Administration (OSHA) has published ergonomic guidelines for patient transfers in nursing homes and the Health Resources and Services Agency (HRSA) has published an annual update on the state of the nursing workforce for the past six years (54, 55). Additionally, the National Institute for Occupational Safety and Health has established a research program and the American Association of Orthopedic Surgeons has made the issue of occupational musculoskeletal injury an action priority(56). At the state level, eight states have now passed safe patient handling legislation. Outcomes relative to injury rate reductions in these states have not been determined (57).

4.4.2 Preventive Approaches

Three modes of prevention concerned with reduction of risk factors for injury have been identified. They include primary prevention (the injury is not allowed to occur), secondary prevention (the injury is rapidly identified and treated) and tertiary prevention (environmental modification to allow the injured to work and to prevent recurrence) (58). Legislation would be considered a 'primary' approach as the goal would be to avoid occurrence of injury. However, it is safe to assume that legislation alone may not be sufficient as a prevention measure. This is demonstrated by the United Kingdom experience as well as by US construction industry findings. The construction industry has strong parallels to healthcare as injury rates are high and this job classification is a leader in work days lost due to occupational injury (1, 59, 60).

A 2008 systematic review of the literature for preventive interventions in the construction industry evaluated a total of 7522 articles and identified only *five* with methodology and outcome data sufficient to meet study inclusion criteria (60). Four of the studies were interrupted time series (ITS) studies and the fifth was a controlled ITS. One study intervention was a 'safety campaign' (public relations combined with instructions on safe lifting), a second focused on a multifaceted drug free workplace program (impaired workers are more likely to be injured) and the remaining three focused on the impact of legislation on injury rates. The safety campaign and drug free workplace interventions had a small effect on injury rates while legislative initiatives demonstrated no effect (60).

Most initiatives described in addressing the injury problem in healthcare generally and with nurses, nurse aides and orderlies have been of a primary or secondary prevention nature. The following section reviews interventions which are focused on the lift itself (back belts and lift teams) as well as those which claim to be 'comprehensive' in nature and include the lift as well as aspects of education and surveillance.

4.4.3 Back-Belts

Back belts are devices which have enjoyed significant popularity in isolated segments of industry (retail stores) and are designed to address both primary and secondary prevention. These devices theoretically support back and abdominal muscles during lifting in order to avoid initial injury or to avoid re-injury. The first significant study on back belt use in 1994 by Mitchell et. al. was a retrospective study of 1316 workers. These authors reported that back-belts were <u>not</u> effective in reducing injury risk. In this study, two primary risk factors were isolated as strong predictors of injury: 1) the amount of time performing lifts and 2) prior injury history (61). In 2000, Wassell et. al. conducted a prospective study of retail employees (n=13,873) that evaluated a spectrum of back-belt usages (optional, frequent or employer mandated). This author demonstrated that there was no injury reduction associated with use of back-belts under any of these conditions (62). Finally, a 2003 review by Gatty et. al. looked at back-belts, educational interventions with task modification and educational interventions with task modification plus workplace redesign and found the value of back-belts to be minimal (63).

4.4.4 Lift Teams

A 'lift team' is comprised of 2-3 individuals who receive specialized training in patient transfer and in lift devices which are used in the facility. Typically these individuals are available 'on-call' and respond to provider requests for patient transfer with the intent that primary care givers will not lift patients. Typically these individuals are classified as orderlies or patient care technicians hired as nursing support personnel. Use of the lift team model was first described by Charney in 1991. This report speculated that use of this approach could avoid up to 95% of provider injuries(64). In 2003, Trinkoff and Brady conducted a survey of 1163 registered nurses and concluded that lift teams reduced odds of musculoskeletal injury(11). Several authors have speculated as to why this concept has not gained widespread support and have concluded that the expense in hiring adequate numbers of specialized lift team members available on a 24 hour as-needed basis was an important inhibiting factor (46, 65, 66).

In a promising 2009 report, a six year lift team initiative was described. This intervention was the main component of a safe patient handling program. These authors report on a variety of positive outcomes that include a 62% overall reduction in patient handling-related injury rate, an 82% reduction in RN injury rate, a 97% reduction in workers compensation costs for patient handling injuries and a 91% reduction in lost workdays (67). Lessons learned included need for a culture change (eg physicians initially resisted the new approach), turnover of lift team members due to status (most were students) and inadequate compensation (job classification is nursing support personnel, rate $12-17/hr). These authors do not report on the rate of lift team member injury, the overall cost-benefit analysis of the lift team implementation and whether lift team members were included in the injury reduction data (67).

4.4.5 'Comprehensive' Prevention Approaches

Ideally, a comprehensive approach would support primary, secondary and tertiary modes of prevention. There have been many reports which have claimed that their approach to injury reduction is 'comprehensive' however it is clear that the definition of this term is not generally agreed upon within the community. Examples of papers claiming use of a 'comprehensive' strategy include interventions such as didactic education on the principles of patient lifting (Melton, 1983), development of continuous 'educational feedback loops' to assist provider skill acquisition (Wood 1987) and targeted environmental re-engineering initiatives (Feldstein, 1993) (36, 68-71).

In 1999, funded by a grant from the National Institute for Occupational Safety and Health (NIOSH), Garg et. al. described a study of the long term effectiveness of a 'comprehensive' zero-lift program implemented in seven nursing homes and one hospital. These authors reported that injuries from patient transfer, lost work days, restricted work days and workers compensation costs were reduced although there was substantial variability between study sites with some showing little improvement and others demonstrating worsening rates (72).

Another 'comprehensive' program was described in 2001. This approach incorporated instruction in lifting and lift device use. The authors hypothesized that emphasis on use of lift devices would be effective in reducing the overall number of lifts by workers. The study compared two interventions (training + mechanical lift vs. training + manual lift) with the arm using mechanical lift showing significant reduction in overall number of lifts performed by workers. Despite this reduction in lifts, the researchers were unable to demonstrate change in musculoskeletal injury rates (73). In attempting to explain these phenomena, Edlich pointed out that some tasks in nursing place repetitive and insidious exertional loads on individuals that have a cumulative effect and that will result in injury regardless of technique (2).

The first study to clearly link injury reduction to cost savings was by Nelson et.al. in 2003. These authors described a more robust 'comprehensive and ergonomically derived process' which used assessment protocols, patient assessment criteria, multiple move-specific algorithms, redesign of work areas, equipment evaluation and purchase combined with post-intervention review tools. Training and redesign expenditures were $750,000 with a first year reduction in workman's compensation claims of $804,786. This appears to be a significant reduction, however the year in which the intervention was implemented represented the highest workers compensation payout year in the six reported ($9, 560,391) and was reduced to $8,755,605 in the year after the intervention. However, this number still represents the 2nd highest of the six reporting years, is $572,000 above the average workman's compensation payout for the six year window (average 8183630), is less than a 1 standard deviation reduction(SD ± 853182). Additionally, no follow-up data have been reported although the authors speculated that the equipment purchased would last at least 10 years and that these workman's compensation rates would continue to fall.

These authors concluded that a truly comprehensive program can be self-sustaining through reduction in injury cost outlay (51). The study which originated in the VA Healthcare system, has now been adopted by the American Nurses Association into their national 'Handle with Care' program (57) and has also been incorporated within nursing home lift guidelines published by the Occupational Safety and Health Administration (OSHA)(55). Further, these authors advocate that 'no-lift' policies be developed within institutions analogous to those which have been adopted in the United Kingdom (51).

In 2004, Collins et.al. reported use of a 'comprehensive' best practices musculoskeletal injury prevention program conducted in six nursing homes. A pre-post intervention evaluation and cost-benefit analysis was conducted from January 1995-December 2000. The program consisted of mechanical lifts and repositioning aids purchases, a zero lift policy, and employee training on lift usage. Significant reductions in resident handling injury incidence, workers' compensation costs and lost workday injuries were realized. Cost-benefit analysis demonstrated that the equipment and training expenditures of $159, 556 and resultant reduction in workman's compensation claims allowed cost recovery in three years (74).

Finally, in 2007, Ouellette described yet another 'comprehensive' prevention approach. This program was implemented in one Canadian hospital with focus on primary and secondary prevention. Despite the availability of these services, a high percentage of injured employees

(60%) did not seek access. Perception that the injury was 'minor' was the most common reason for failure to engage (45%) and employees also indicated that it was important to directly interact with knowledgeable providers who understood the needs of their individual work setting (75). This point illustrates the psychosocial component as frustration with the injury as well as with the healthcare system is common (58, 76, 77). Importantly, if providers do not report injury then the national statistics on injury rates will represent an underestimate of the true incidence.

In attempting to develop a 'comprehensive' program to identify best scientific practices in the area of musculoskeletal injury prevention, the National Institute for Occupational Safety and Health (NIOSH) financially supported the work of Garg et. al (72), Nelson et al (51) and Collins et. al. (19, 56). In addition to the aforementioned studies, NIOSH has also supported the development of an evidence-based curriculum for training nurses and nursing students. In a 2007 report, this curricular model was tested in 26 schools of nursing. Using pre and post intervention survey methods, the authors collected data on knowledge, attitudes, and beliefs in the area of safe patient handling. Data was collected from both instructors and students with significant improvement noted in student knowledge post intervention. Participants also reported readiness to use mechanical lift devices in the future. This curriculum did not include a hands-on simulation component (78) and the authors made no attempt to define cost-benefit when compared to traditional education.

4.5 SIMULATION EDUCATIONAL METHODS

Despite these efforts to develop a comprehensive educational and training model for musculoskeletal injury prevention, nurses and nurse aides continue to experience some of the top non-fatal injury rates in the US workforce (15, 68, 69). What is required is an approach which will help to bridge the gap between classroom and clinical environments in order to truly impact work-culture and processes of care. Simulation educational methods hold promise for just such a bridging. They have been applied successfully in training for a broad spectrum of simple to complex healthcare tasks (79-100). These methods provide the opportunity for deliberate practice, active engagement, reflective learning, hands on skill attainment combined with an immersive learning experience and are now being embraced across both educational and service sectors in the healthcare industry (101-104). These methods have been effective in improving technical skills on specific tasks, enhancing non-technical skills such as communication, are superior in head to head comparison with other educational approaches and can be even be used to replace traditional training preparation for clinical trials research in humans (105-111).

4.5.1 Task Analysis and Simulation Education: Pilot Testing in the Sim Lab

In 2009, O'Donnell et. al. reported combining the use of the ergonomic methods of hierarchical task analysis with a corresponding simulation training intervention (112, 113). Hierarchical task analysis, a well established ergonomic technique, was used as a means of analyzing the process of patient transfer. This process was then deconstructed into distinct and measureable components. Through a multi-step process based on methods described by Annett, Stanton and Shepard, an optimum task set for patient transfer was then derived and validated (114-117). The validation process included achieving expert consensus, referencing steps to evidence-based rationale and performing structured clinical observations with ongoing feedback to an expert development panel for final refinement of the protocol. The protocol was then used to develop a simulation intervention incorporating on-line curricular support materials, simulated patient transfers and a structured debriefing session. In the pilot, a total of 19 teams of direct care providers were studied. Every team demonstrated pre- to post-simulation intervention improvement in transfer skill with an overall mean improvement of 52% (34% to 86%). The patient transfer protocol was programmed into two data collection tools: the Laerdal SimMan™ software system and the HP IPAQ PC™. Overall interrater reliability across the task steps indicated moderate to near perfect agreement (k = 0.43-0.85). Development of a reliable measurement of transfer events combined with an unobtrusive mobile platform was critical for extending the study to the clinical environment (112)

4.5.2 Pilot Testing on Head and Spinal Cord Injury Clinical Units

In follow-up to the simulation pilot, O'Donnell et. al. (2009) evaluated the impact of the simulation education intervention on knowledge, attitude and skill of the teams of patient care providers who participated in the simulation pilot. Using a prospective, longitudinal, repeated measures design, baseline clinical observations of patient transfers by teams working on head and spinal cord injury units were conducted. Clinical observations of team patient transfers were repeated at 4 and 12 weeks post simulation training. A patient transfer was treated as a team event while individual participants completed knowledge and attitude assessments. Actual patient transfer skill according to adherence to an optimum task set improved from 66% at baseline to 88% at the 4 week measurement point ($t = 7.447$, $p \leq 0.0004$) but regressed to 71% at 12 weeks. The addition of 10 untrained employees between 4 and 12 weeks (12.3% increase in untrained personnel) confounded the 12 week results. Further, the difference between baseline performance in the clinical environment (66%) and simulation environment (34%) can be explained by lack of familiarity of subjects with the simulation setting and in interacting with a simulation mannequin. Knowledge improvement was 25% (65-90%, $z = -6.634$, $p \leq 0.0004$) and attitudes relative to patient safety, communic ation and confidence improved.

4.5.3 Hospital-Based Implementation of the Training

Based on these two pilot projects, the simulation intervention was developed as a mandatory hospital-based training program in musculoskeletal injury reduction. A total of 327 nurses, nursing aides and orderlies were trained at one suburban hospital with 297 trained within 3 months. This represented more than 95% of all direct care employees. Interventions in addition to the simulation education training in patient transfer using the optimal task set program included educational materials and assessment of core muscle strength. Teams of providers were evaluated during patient transfers in the clinical setting at baseline (56%

success) and at 16 weeks (83% success rate - a 27% improvement in success) **(Table 10)** demonstrating that training of *all* personnel resulted in sustained skill retention.

The total training intervention was completed in 4 months and at the end of 1 year, comparison with historical data from the previous two years was conducted. Reductions of more than 50% were noted in OSHA reportable injury rates, % of employees injured annually, injury rate during transfer and days away restricted transfer **(Table 11)** (118). Given this reduction in injury rates, the total cost of the program ($28,908 including materials, instructor training, employee training and computer programming) was rapidly recovered.

Table 11: Results. of the UPMC Health Plan 'We've got your Back!" Program

	2005	2006	2007	% reduction; 2005-2007
OSHA recordable injury rates (per 10,000)	13.7	11.6	6.85	50%
% of employees injured (annually)	10.6	9.1	5.0	53%
Injury rate during transfer (per 1000)	1.6	1.5	0.8	50%
Days away restricted transfer (DART)	1200	1300	500	58%

This mandatory, hospital-based program consisted of an interactive, web supported simulation training program. All direct care employees at one suburban facility were required to complete the training (n = 327) (118).

Individual participants in the study were followed for 1 year post intervention with 101 participants who completed the patient transfer course matched with a non-participant cohort within the parent healthcare system (119). Matching was based on sex, age (within two years), job type (care manager, nurse, nurse assistant or patient care technician), job status (full vs. part time), length of job tenure (within six months), Charlson comorbidity index, and the presence of obesity (BMI >=30). A Cox proportional hazards frailty model (which accounts for the correlation between recurrent events associated with one subject and the correlation introduced by the matching process) was used to evaluate the treatment effect on post-program injury rates. Outcomes included injury reduction of 28% (p=0.016) for all musculoskeletal injuries among course participants; neck musculoskeletal injury was reduced by 77% (p<0.01) and back musculoskeletal injury was reduced by 65% (p<0.01). This program demonstrated that the simulation intervention developed through use of the ergonomic method of hierarchical task analysis could be successfully deployed on a large scale as a hospital training program with long term benefit (119).

4.6 CONCLUSION

Substantial issues remain surrounding occupationally induced musculoskeletal injury in nurses and nurse aides. Healthcare industry occupational injury rates remain high despite legislative efforts, targeted injury reduction interventions and 'comprehensive' educational programs. A variety of organizations and regulatory agencies have advocated programs including ergonomic evaluation, wholesale equipment replacement, hiring of lift teams and environmental re-engineering. The impact of some of these efforts appears to be positive; however a dramatic reduction or elimination of the burden of injury within the community of direct patient care providers has not yet occurred. In this era of economic uncertainty in the healthcare industry combined with shrinking resources within individual hospitals and systems, an alternative which combines injury reduction at a reasonable cost is highly attractive.

Simulation educational methods for healthcare education have become broadly accepted and show promise for bridging the gap between the classroom and clinical environments. In this paper we describe an approach using hierarchical task analysis methods to develop an optimal task set for patient transfer, a simulation based training protocol, a robust data collection system and ongoing evaluation of effect relative to provider skills and injury rates. Improvement in team transfer skills in the simulation lab was mirrored in the clinical environment where we were able to measure improved team transfer success. Individual subjects demonstrated knowledge improvement and attitude change relative to patient safety, confidence and ability to communicate more effectively during the transfer. Finally, the results of the pilot study led to creation of a mandatory, hospital-based patient transfer training program for reduction of musculoskeletal injury. A dramatic reduction was seen in the participant group OSHA reportable injury rates, % of employees injured, injury rate during transfer and restricted duty days when compared with historical data. Individual participants were matched with a cohort from within the parent healthcare system and followed for one year. Significant reductions in musculoskeletal injury rates were realized generally and in neck and back injury specifically. The improvement in patient transfer success and the substantial reductions in overall and targeted musculoskeletal injury rates demonstrated through this approach argue for the value of a simulation approach grounded in accepted ergonomic methodology. We believe that this simulation educational intervention is indeed an important piece in solving the complex puzzle of healthcare related occupational injury and further represents an effective, high return on investment and thus low cost alternative in an austere economic landscape.

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APPENDIX

REVIEW PAPER: HUMAN SIMULATION TRAINING IN THE ICU:

APPLICABILITY, VALUE, AND DISADVANTAGES

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Introduction

Simulation training has a long history with examples ranging from “modeling” in the animal kingdom (eg, a lion teaching hunting skills to a cub), to “war games” designed to better prepare soldiers for battle (1-2). In health care, simulation can be used in a broad range of situations, ranging from simple part-task trainers, such as IV arms, to computer-driven mannequins that emulate adult, pediatric, and obstetric events (3-13). In its most complex form, high fidelity human simulation provides a mechanism to provide safe, realistic training for a wide range of common, emergent and/or rarely encountered situations across multiple practice domains. The introduction of advanced yet affordable simulators has encouraged clinical critical care educators to learn more about this form of education. Simulation training is not a panacea or replacement for traditional clinical education. In our experience, this approach is a valuable adjunct to traditional education that allows educators to enhance cognitive and psychomotor skills in a safe environment and thereby improve practice. This essay will review advantages and disadvantages of simulation training and describe lessons that we have learned in our work in this area.

Advantages

ETHICAL ISSUES

Traditionally, health care professional education has extensively relied on the apprenticeship model. Typically, clinical experience begins with a lecture, followed by demonstration and, when the time is right, performing a procedure or managing a case with faculty supervision. This approach has several notable disadvantages. First, clinical settings are designed to provide care, not educational experiences. Second, expertise in critical care practice is acquired over time. There is no guarantee that appropriate exposure will occur before a novice practitioner must make critical decisions (4,6-9,12). Prior to the development of lower-cost, high fidelity simulators, no reasonable alternative existed. With simulation, it is possible to train critical care practitioners to manage common and rarely occurring events before encountering them in clinical practice. Third, simulation provides a forgiving environment. Trainees can respond to scenarios designed to mimic critical care practice and observe consequences of their actions, effective or ineffective (4,6-9). Using computer feedback logs and integrated audio-visual capability, faculty can review actions taken during these scenarios in a debriefing session. Together, faculty and trainees can collaboratively critique decision-making and identify more appropriate actions. Trainee errors can be used to learn from one's mistakes—a powerful teaching tool(2,4).

This training can be very realistic because scenarios can be designed to branch in several directions, dependent on participant actions. Also, presenting conditions can be designed to be ambiguous to better mimic critical care events, since most real life critical care situations do not have clear decision points. With simulation, learning occurs during and after the event. Lighthall and colleagues6 evaluated the performance of medicine, anesthesia and surgery residents who participated in scenarios designed to replicate medical crises, or observed while others performed the scenarios. A number of common errors were noted that were categorized as technical (improper drug selection or dosage), vigilance related (failure to notice dysrhythmias, ventilator alarms), judgment related (inappropriate delay of therapy, uncorrected abnormality) or communication related (ineffective use of personnel). The residents easily recognized many of these errors and, in debriefings, agreed they were everyday occurrences in medical emergencies (6). Using such observations, it is possible to refine teaching and reduce the likelihood of such events.

RARE EVENT TRAINING

One particular benefit of simulation is that all trainees can experience rare events and receive immediate feedback with an opportunity for expert modeling and correction. Barsuk et al13 assessed the performance of 36 physicians who completed Advanced Trauma Life Support (ATLS) training using simulation scenarios and noted practice errors. They modified the training to include an additional 45 minutes of simulation that incorporated skills involved in ATLS training and repeated testing in a second group of 36 physicians. The addition of simulation produced a significant decrease in the number of individuals not performing critical actions or taking appropriate steps in the recognition and management of tension pneumothorax, hypovolemic shock, and cervical spine mobilization.

COMMON EVENT TRAINING

With simulation, it is possible to train large groups of providers in patient scenarios that are common, but which pose a threat if performed incorrectly. Examples include: 1. procedures such as endotracheal intubation, difficult airway management, central line insertion, and fiberoptic bronchoscopy; 2. management of acute pathophysiologic conditions, such as shock, arrhythmia, hypotension, or hemorrhage; and 3. team response during cardiac arrest, trauma resuscitation, or out-of-hospital rescue. The ability to teach crisis management skills is a particular advantage (6).

When the apprenticeship model is used, students may be pushed to the background or asked to leave the room in the interest of patient safety. In a simulated environment, trainees are forced to assume a lead position and direct care. Marsch and colleagues (12) tested ability of first responders to adhere to algorithms of cardiopulmonary resuscitation using a simulated cardiac arrest in an intensive care environment. The physician nurse teams functioned well in areas such as recognizing the arrest and calling for help, but there were significant delays in the initiation of basic life support and defibrillation. Such observations called attention to the need to provide additional training in crisis team management.

TRAINING EFFICIENCY

Training efficiency is an often overlooked advantage of simulation training. Abrahamson and colleagues8 compared outcomes following usual training of anesthesiology residents to usual training plus simulation. The residents were able to attain proficiency in a smaller number of elapsed days, thus effecting a time saving of personnel, and achieved proficiency in a smaller number of trials in the operating room, thereby posing a significant lower burden of supervision and threat to patient safety. Our experience has been similar. Since introduction of simulation training, we have reduced the amount of time nurse anesthesia students require before assuming responsibility for intubation from 3 months to less than one day. Concurrently, the role of the faculty has changed from performing skills while students observe or directing student performance to coaching, cuing, and prompting. Simulation also appears to promote learning retention (12).

RECRUITMENT

An additional unique advantage of simulation education relates to recruitment and retention of personnel. We routinely schedule visits of applicants to our simulation training center as part of recruitment efforts. Students, prospective house staff and fellows immediately perceive the value of hands on practice and training and seek out these experiences when available.

CRITICAL THINKING

One of the most important critical care competencies involves the ability to apply critical decision-making skills in routine, as well as emergent situations. Simulation training can facilitate learning to manage such situations independently or with support analogous to that available in the critical care setting. Such training provides an ideal opportunity to evaluate and refine communication skills required for effective clinical practice (10). Simulation training can also be used to explore common communication errors within professions and across multidisciplinary teams (10). Findings from qualitative studies suggest that this approach helps students work through problems, acquire skills and build confidence that can be transferred to the clinical setting. Faculty also benefit from simulation education by refining their clinical knowledge base and learning to develop innovative educational strategies.

TRAINEE FEEDBACK

When formal evaluation is incorporated into simulation training, evaluations are almost unanimously positive. In anecdotal reports, trainees have expressed gratitude for being adequately prepared through the simulation experience. A recent nursing graduate recounted being present in a cardiac arrest situation during the night shift. She was able to function effectively until the cardiac arrest team arrived because she had prior simulation experience managing a code in the role of a critical care nurse. In our training, we use two facilities, a single high-fidelity human simulator (Laerdal SimMan™) located in the School of Nursing and the WISER Center (www.wiser.pitt.edu) which houses 16 high-fidelity simulators and conducts training for approximately 6,000 practitioners yearly from within and outside the University.

SUMMARY OF ADVANTAGES

In summary, simulation education offers the ability to provide a customized educational experience and, if administered as a component of an educational program that includes objectives, pre-course didactic preparation, well designed simulator programming, and effective evaluation tools, can be reliable and valid with development of true performance benchmarks. Reported benefits of simulation education include improved appreciation of team work, the ability to recognize and handle anxiety provoking situations, improved communication skills, and a potential for incorporation of skills developed through simulation into improving patient outcomes.

Disadvantages

ARTIFICIAL ENVIRONMENT

Although students state that they find the simulation training realistic and valuable, simulation is not reality. Manikins can provide realistic physical responses which mimic various pathologies. Many manikins have accurate airways which can be manipulated to demonstrate a range of easy to difficult airway scenarios. Few manikins have realistic eyes. Some allow for line placement or chest tube insertion. Many mimic bowel, lung, and heart sounds. At least one can talk, but none have the ability to mimic conversation with a patient, limiting patient provider interaction manipulated to demonstrate a range of easy to difficult.

PAUCITY OF SUPPORTING EVIDENCE

An important challenge facing those who advocate this training relates to the need to objectively validate benefits of this training through methodologically sound studies. To date, few validation studies have been performed. Studies are needed to demonstrate the ability to improve knowledge and skills and transfer this knowledge to actual patient situations.

EQUIPMENT AND PERSONNEL COSTS

Developing and maintaining a simulation program is costly. Computer based high-fidelity human simulation will cost more than $50,000 for the manikin and support equipment. The environment necessary for full utilization of the experience, cameras and recording equipment, a dedicated area in which to establish the equipment, additional manikins of varied ages and physical conditions, adds significantly to this cost. Time is also a consideration. Simulation training involves a substantial amount of time in set up and evaluation. Although the scenarios or experiences may take a relatively short period of time, analysis of the student's actions, mistakes and options can be time consuming. Lectures can be provided to a large number of students, but the number that can participate in a simulation activity is dependent on the number of manikins and faculty. Others may observe and add to their learning experience, but it is not hands-on experience.

Perhaps the most costly aspect is the expense of providers being away from the clinical setting for training. In undergraduate nursing programs, this problem can be solved by having the faculty who would be supervising students in the clinical setting involved in simulation training. Other programs do not have the same access to faculty who can leave the bedside. An additional problem involves finding and training a cadre of faculty to run simulation courses. Despite the standardized, open-ended programming capability of the Laerdal SimMan™ and SimBaby™ products, many clinicians have little interest in creating their own programming for scenarios or do not feel they have time to do this writing. This represents a substantial burden for technical staff associated with simulation facilities, but will likely be minimized in the near future with the emergence of commercial simulation educational products.

Summary

Despite challenges, affordable high fidelity simulator devices (such as the Laerdal SimMan™, among others) are becoming increasingly integrated into the education of critical care professionals. Although simulation education cannot replace all aspects of traditional clinical training, it is clearly a valuable supplement. The key to a successful simulation program includes several important considerations. These include: 1. at least one dedicated advocate within the clinical faculty who is willing to catalyze the effort; 2. strong administrative support for the effort; and 3. the ability and dedication conduct studies that quantify the value of training in regard to translation to the clinical setting and thereby data that can be used to evaluate training and modify this as needed. As research in this area continues, we believe that simulation training will become essential for evaluation and benchmarking of key cognitive and psychomotor skills. This benchmarking will provide assurance that all personnel have the requisite skill and ability to safely practice in an increasingly complex clinical environment.

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