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A Prospective Investigation to Develop Data-Driven Interventions and Improve Process Efficiency at a Level II Trauma Center

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A PROSPECTIVE INVESTIGATION TO DEVELOP DATA-DRIVEN INTERVENTIONS AND IMPROVE PROCESS EFFICIENCY AT A LEVEL II TRAUMA CENTER

By

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ABSTRACT

INTRODUCTION: The purpose of this investigation was to better understand process inefficiencies in a Level II trauma center through the identification and classification of flow disruptions. Data-driven interventions were systematically developed and introduced in an effort to reduce disruptions threatening the optimal delivery of trauma care.

METHOD: Medical human factors researchers observed disruptions during resuscitation and imaging in 117 trauma cases. Data was classified using the human factors taxonomy Realizing Improved Patient Care through Human-centered Operating Room Design for Threat Window Analysis (RIPCHORD-TWA). Interdisciplinary subject matter experts (SMEs) utilized a human factors intervention matrix (HFIX) to generate targeted interventions designed to address the most detrimental disruptions. A multiple-baseline interrupted time-series (ITS) design was used to gauge the effectiveness of the interventions introduced.

RESULTS: Significant differences were found in the frequency of disruptions between the pre-intervention (*n*=65 cases, 1137 disruptions) and post-intervention phases (*n*=52 cases, 939 disruptions). Results revealed significant improvements related to ineffective communication (x^2 (1, n=2076) = 24.412, p=0.00, x^2 (1, n=1031) = 9.504, p=0.002, x^2 (1, n=1045) = 12.197, p=0.000); however, similar levels of improvement were not observed in the other targeted areas.

CONCLUSION: This study provided a foundation for a data-driven approach to investigating precursor events and process inefficiencies in trauma care. Further, this approach allowed individuals on the front lines to generate specific interventions aimed at mitigating systemic weaknesses and inefficiencies frequently encountered in their work environment.

Keywords: trauma care, process efficiency, interventions, patient safety

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Dedicated to my mom (1942-1999), who I miss still to this day

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ACRONYMS

ACS – American College of Surgeons

ASC-COT – American College of Surgeons' Committee on Trauma

CVOR – Cardiovascular Operating Room

CDC – Centers for Disease Control and Prevention

CITI – Collaborative Institutional Training Initiative

CT – Computed Tomography

CEU – Continuing Education Unit

CRM – Crew Resource Management

CUS – Concerned, Uncomfortable, Safety

HHS – Department of Health and Human Services

DV – Dependent Variable

EMR – Electronic Medical Record

EPT – Embedded Performance Tool

ERAU – Embry-Riddle Aeronautical University

ED – Emergency Department

FACES – Feasibility, Acceptability, Cost, Effectiveness, and Sustainability

FAA – Federal Aviation Administration

FD – Flow Disruption

GCS – Glasgow Coma Scale

HIPAA – Health Insurance Portability and Accountability Act

HRO – High Reliability Organization

HFACS – Human Factors Analysis and Classification System

HFES – Human Factors and Ergonomics Society

HFIX – Human Factors Intervention Matrix

IV – Independent Variable

IOM – Institute of Medicine

IRB – Institutional Review Board

ICU – Intensive Care Unit

ITS – Interrupted Time Series

MOI – Mechanisms of Injury

MUSC – Medical University of South Carolina

MKE – Multidisciplinary Knowledge Elicitation

NTSB – National Transportation Safety Board

NLT – Nurse Leadership Training

OR – Operating Room

PPE – Personal Protective Equipment

PI – Principal Investigator

PHI – Protected Health Information

RFID – Radio-frequency Identification

RIPCHORD – Realizing Improved Patient Care through Human-centered Operating Room Design

RIPCHORD-TWA – Realizing Improved Patient Care through Human-centered Operating Room Design for Threat Window Analysis

SA – Situation Awareness

SMS – Safety Management System

SSMP – Safety Systems Management Process

SME – Subject Matter Expert

SFDT – Surgical Flow Disruption Tool

SEIPS – Systems Engineering Initiative for Patient Safety

PPMD – Trauma Program Medical Director

TSM – Trauma Services Manager

CHAPTER 1

Introduction and Literature Review

"If you don't understand what is causing the problem, you will continue, forever and forever, to have to solve the problem." – Robert Zinser, CEO, International Federation of Gynecology and Obstetrics

Traumatic injury is a major public health problem in the United States. Each year more than 192,000 people lose their lives to trauma (Centers for Disease Control and Prevention (CDC), 2015). In the last decade alone, the number of trauma deaths has increased by 22.8%, while the U.S. population increased by only 9.7%, making traumatic injury the leading cause of death for all Americans from birth to age 46 (Rhee et al., 2014). There is a great economic burden associated with fatal injuries as well. In 2013, injury-related deaths exceeded $214 billion in combined medical and work-lost costs, which is approximately one-third of the total direct and indirect costs associated with all injuries (Florence, Simon, Haegerich, Luo, & Zhou, 2015).

The alarming increase in death rates associated with traumatic injury as well as the considerable value of the services offered by the nation's trauma centers, compels researchers to gain a better understanding of the challenges facing providers in the effective and efficient delivery of trauma care. Studies have shown that providing treatment for the critically injured patient at an urban Level I trauma center reduces mortality by 25%, as compared to treatment at a non-trauma center (MacKenzie et al., 2006). Reports indicate significantly reduced mortality rates for patients properly triaged and treated at a regional acute care facility such as a Level II trauma center, in comparison to patient outcomes at a non-trauma center (Vickers et al., 2015). A substantial proportion of trauma patients are treated in trauma centers designated as Level II or lower. Therefore, expanding the research to include Level II trauma centers is paramount to gaining a more comprehensive understanding of the process inefficiencies threatening the delivery of care to the traumatically injured patient.

Medical Error

The Institute of Medicine's (IOM) *To Err Is Human* (Kohn, Corrigan, & Donaldson, 2000) report described an incidence of 44,000 to 98,000 preventable deaths annually. Since the release of the report 15 years ago patient safety has advanced in many ways. For instance, there has been demonstrated improvements in specific areas such as hospital-acquired infections. According to the U.S. Department of Health and Human Services (HHS), hospitals across the country have prevented 2.1 million hospital-acquired infections, saving 87,000 lives, and nearly $20 billion in healthcare costs from 2010 to 2014 (HHS, 2015).

Much of the work dedicated to improving the safety of patient care has focused attention on the study of medical error. However, efforts to reduce these errors have largely been unsuccessful. A recent review by James (2013) estimated the number of deaths resulting from preventable medical errors in hospitals range from 210,000 to more than 400,000 per year, which is more than four times the original IOM estimate. In fact, Makary and Daniel (2016), extrapolating from several different investigations, placed the total beyond 250,000 deaths per year, ranking medical errors as the third most common cause of death in the U.S. (Makary & Daniel, 2016).

Medical Human Factors

Given these alarming figures, it isn't surprising that healthcare professionals have turned to the field of human factors to improve the safety and efficiency in the delivery of care. In the last few years, human factors researchers have spent a great deal of time in healthcare settings addressing medical mistakes, human error, and work system factors using human factors engineering principles. The value of human factors and risk management concepts are widely recognized in complex organizations such as the military, nuclear power, and aviation. For decades, these high-risk industries have relied on the interdisciplinary science of human factors to ensure the effectiveness, safety, and ease of performance between humans and the elements of a system in the performance of precise tasks (Human Factors and Ergonomics Society (HFES), 2016).

In recent years, numerous comparisons have been made between cockpit operations and how it can translate to increased safety in medicine, particularly in the operating room (OR). One such comparison stems from a 2005 report by the Joint Commission that found communication failures (i.e., human factors) to be the root cause of over 60% of sentinel events. Similarly, in years past, communication breakdowns among crew members resulted in 70% of commercial aviation accidents. These commonalities suggest that valuable lessons can be learned from aviation and has prompted healthcare to attempt to mimic programs that have been credited with improving safety in commercial aviation. For instance, adopting crew resource management (CRM) and standardizing communications and tools may be an effective strategy to reduce medical errors (Karl, 2009; Leonard, Graham, & Bonacum, 2004; Lingard et al., 2004).

Traditionally, healthcare has focused on patient outcomes and sentinel event reporting to aid in understanding adverse events and improving patient safety. However, these data points lack detail concerning the specific nature of systemic issues (Blocker, Eggman, Zemple, Wu, & Wiegmann, 2010; Henrickson Parker, Laviana, Sundt, &

Wiegmann, 2009). Analysis of the system allows researchers to identify weaknesses and inefficiencies that open the window of opportunity for errors and adverse events to occur. This data serves as a much richer body of information on which to base the development of remedial interventions.

Latent conditions present in the system range from failures in organizational management to poor tool design to physiological performance limitations such as sleep deprivation. These factors are often subtle and seemingly minor in their effects and in isolation they may have little to no direct impact on the system overall. However, their accumulation, or multiplicative effect, has a strong relationship to negative outcomes and potentially threaten the delivery of patient care (Dankelman & Grimbergen, 2005; de Leval, Carthey, Wright, Farewell, & Reason, 2000; Reason, 1990; Wiegmann & Shappell, 2003). In this vein, it makes sense that healthcare would look for other metrics to better address patient and system safety.

Flow Disruptions

Process inefficiencies have come to be called flow disruptions (FDs). Wiegmann, ElBardissi, Dearani, Daly, and Sundt (2007) defined FDs as deviations from the natural progression of a task that potentially compromise the safety of the process and/or task. Research suggests that efficient care improves patient survival. Flow disruptions, on the other hand, threaten this efficiency, presenting distractions, impairments, lost time, and workarounds that divert attention from the task at hand. In essence, FDs are symptomatic of underlying latent failures somewhere in the system (Blocker et al., 2012).

Flow disruptions, in the present context, were first identified in the cardiovascular operating room (CVOR) and often consisted of communication failures, external interruptions, and equipment and technology issues. Results from these studies have been intriguing from a process efficiency standpoint, empirically linking an accumulation of FDs, even seemingly minor ones, to surgical errors down the line. Specifically, teamwork and communication failures were found to be the strongest predictors of surgical errors (Wiegmann et al., 2007).

This approach assumes that FDs, or a lack thereof, is indicative of an effectively performing system (Healy, Olsen, Davis, & Vincent, 2007). However, this approach suffers from a lack of clearly identifiable outcomes and may be misleading when drawing conclusions. For example, there could be multiple miscommunications occurring during a procedure that do not necessarily impact the patient. Furthermore, while multiple team members may experience numerous disruptive events while providing care to the patient, these events do not necessarily affect the procedure itself. Likewise, an anesthesiologist receiving multiple text messages over the course of a CVOR surgery, however, these disruptions do not necessarily interrupt the surgeon or the progress of the procedure. This reveals the difficulty faced in isolating those FDs that truly pose discernable threats to patient safety as well as the overall process of patient care. Flow disruptions are not necessarily major events that immediately or directly impact performance. Rather, they are often minor events that can accumulate over time. From a human factors perspective, any number of minor disruptive events that occur during the course of patient care may have a negative impact on the provider’s ability to counteract subsequent major events. Therefore, even the most trivial disruption matters (Palmer et al., 2013; Wong et al., 2007).

Given the potential relationship between FDs and errors, it may be better to conceptualize the accumulation of these FDs as *threat windows* (Boquet et al, 2017b; Cohen et al., 2016). *Threat windows* can be operationally defined as the aggregates of FDs and process inefficiencies that plague a system which may open the window for errors and adverse events to occur (Boquet et al., 2017b; Cohen et al., 2016).

By conceptualizing FDs and process inefficiencies as *threat windows*, researchers are better equipped to understand potential threats to patient safety by looking at the cumulative sum of disruptions experienced during the delivery of patient care and conceivably intervene before an error reaches the patient (Boquet et al., 2017b; Cohen et al., 2016).

Human Factors Taxonomies

There are a variety of approaches researching system threats that could potentially affect patient outcomes and safety. Researchers have used a data collection taxonomy known as the Systems Engineering Initiative for Patient Safety (SEIPS) to classify a multitude of hazards in the healthcare setting, most notably, during observations in cardiac surgical cases (Blocker et al., 2010; Blocker, 2012; Carayon, Hundt, Karsh, & Gurses, 2006; Wiegmann et al., 2007). The SEIPS model is comprised of five elements: 1) tools and technology, 2) organization, 3) person, 4) task, and 5) environment. Typically, the source of an FD exists when one or more of these interconnected components breaks down (Blocker et al., 2012).

Other researchers have utilized the Surgical Flow Disruption Tool (SFDT) to systematically categorize and measure surgical FDs, or latent factors that contribute to adverse events, and their impact on patient safety. The SFDT is an observational taxonomy derived from the SEIPS framework, which incorporates Reason's (1990) model of human error as well as the work of Wiegmann and Shappell (2003). The SFDT consists of: 1) environmental factors, 2) teamwork, 3) technology and instruments, 4) technical factors, 5) training and procedures, and 5) an "other" category. Although it was originally designed for observing cardiac surgical cases (Blocker et al., 2010; Henrickson Parker et al., 2009), it has been found to be a valid tool for use in other healthcare domains, including trauma care. Application of the SFDT in trauma allowed researchers to identify the clinical phases of treatment (resuscitation, imaging, or trauma OR) that had a high disruption frequency (Blocker et al., 2012; Blocker et al., 2013; Catchpole et al., 2013; Catchpole et al., 2014; Shouhed et al., 2014). Blocker et al. (2012) expanded the SFDT and further categorized the type of FDs according to: 1) equipment (malfunctions, improper use, unfamiliar equipment, maintenance); 2) communication (misunderstanding, communication unheard, case related communication, extraneous conversation); 3) external interruptions (extraneous people, phone calls, or intercom messages that did not relate directly to the procedure at hand); 4) coordination (personnel exchanges, improperly configured equipment, not adhering to surgeon or team preferences, and requesting or providing assistance to fellow team members); 5) environment (problems with noise, temperature, lighting); 6) patient factors (disruptions related to the patient's unique anatomy such as an excessive amount of unanticipated adhesions or scar tissue); 7) technical skills (including poorly executed tasks, misinterpretation of relevant information); and 8) training (teaching a new skill, correcting an improper action, posing questions to test the knowledge of the team, student, or trainee); and 9) other (not specified).

Another taxonomy used to identify interruptions in healthcare evolved from an analysis of studies found in the interruption literature from other high-risk industries. The authors also noted that only a small number of these types of taxonomies have been developed (Brixey, Walji, Shang, Johnson, & Turley, 2004). The tool they developed for describing instances of human interruption contained the following eight categories: 1) source of interruption; 2) individual characteristics of the person receiving interruption; 3) method of coordination; 4) meaning of interruption; 5) method of expression; 6) channel of conveyance; 7) human activity changed by interruption; and 8) effects of interruption. The researcher’s preliminary taxonomy focused on the introduction of technology, which contributes to new interruptions and the changing work of clinicians. It is currently being used to code interruptions observed in an emergency department and includes the following 11 categories: 1) signal, 2) technology, 3) initiator, 4) recipient, 5) reason to interrupt, 6) cognitive, 7) frequency, 8) context/location, 9) environment, 10) outcome, and 11) management techniques (Brixey et al., 2004).

Realizing Improved Patient Care through Human-centered Operating Room Design (RIPCHORD)

Realizing Improved Patient Care through Human-centered Operating Room Design (RIPCHORD) was originally developed by a team of collaborators consisting of industrial engineers and healthcare architects with human factors expertise from Clemson University as well as cardiothoracic anesthesiologists from the Medical University of South Carolina (MUSC). RIPCHORD was initially designed as an architectural framework for identifying and classifying workflow disruptions in the CVOR (Palmer et al., 2013). The researchers in this study were not interested in exploring medical errors but rather in documenting workflow as it related to human factors and potential threats to patient safety. They were specifically observing disruptions to the flow of operations. After observing the first surgery, they organized the observational data into human factors clusters or similar groupings. The aggregate analysis yielded six distinct clusters. These clusters became the RIPCHORD major categories: 1) communication, 2) usability, 3) physical layout, 4) environmental hazards, 5) general interruptions, and 6) equipment failures. The six clusters were then further differentiated into 33 subgroupings using affinity clustering, which ultimately became the RIPCHORD minor categories. The subgroups were validated and refined using an additional nine surgeries to develop the final taxonomic structure, known as RIPCHORD (version 1.0). Palmer et al. (2013) concluded that they had "developed a robust taxonomy to describe the quantity and location of flow disruptions encountered in a cardiac OR which can be used for future research and patient safety improvements" (p. 11).

Research Objectives

The purpose of this current study is to investigate FDs threatening the efficient delivery of patient care in a Level II trauma center. More specifically, this investigation seeks to answer four questions:

Q1: Can an FD taxonomy previously used only in the CVOR be successfully employed to identify and classify disruptions in trauma care?

Q2: Do differences in threats exist between different clinical phases of treatment in trauma care (resuscitation and imaging)?

Q3: Can this information be used to develop targeted, data-driven interventions in trauma care?

Q4: Do these implemented interventions address and potentially reduce the frequency of those disruptions threatening the optimal delivery of trauma care?

This current study employed a multiple-baseline interrupted time-series (ITS) design and was divided into four phases: 1) Baseline 1/pre-intervention, 2) Baseline 2/ pre-intervention, 3) Intervention, consisting of the introduction of targeted strategies, and 4) Post-intervention. In a multiple-baseline ITS design data is typically collected at multiple time points. Specifically, researchers collect several observations (O) over a period of time that spans before and after an intervention, or treatment (X), in order to determine if the intervention had an effect. To address threats of internal validity and increase the likelihood of more valid conclusions two waves of measurement were made prior to the implementation of interventions, thus, establishing a baseline. This method is called a double-pretest design, or a multiple-baseline design. This type of ITS design attempts to control for selection-maturity in that the groups may be different in some way before the interventions were introduced. If the intervention program (post-intervention phase) and the comparison group (pre-intervention phase) are maturing at different rates this could be noted as a change from baseline 1/pre-intervention to baseline 2/pre-intervention. This pre-test series allows researchers to directly examine the possibility of differences in maturation and potentially attribute post-intervention differences to the intervention program (Trochim, 2005). This type of experimental design is considered a strong quasi-experimental design as it resembles experimental designs but must use quasi-independent variables rather than true independent variables (IVs). In other words, subjects cannot be randomly assigned to either an experimental group or a control group. Moreover, researchers cannot control which group receives the treatment. One advantage of an ITS design is that it is considered the best quasi-experimental approach for evaluating longitudinal effects of interventions as it allows researchers to evaluate the impact of a quasi-independent variables under naturally occurring conditions (Bordens & Abbott, 2014).

Pre-intervention and post-intervention phases served as one IV and clinical phase of treatment (resuscitation and imaging) was the second IV. The targeted minor categories within the major categories of the expanded RIPCHORD taxonomy served as the dependent variables (DVs). In effect, disruption data served as an objectively measurable outcome and the basis for continuous improvement.

The strength of this current study was the ability to combine science and practice into a living, breathing document. This method allowed researchers to present data in real-time; tracking and monitoring results in a quantitative, data-driven manner. A comprehensive, systematic methodology such as this may prove more successful and lasting in deploying the right interventions to mitigate threats to the delivery of life-saving trauma care. A schematic of the ITS design is pictured below (see Figure 1.1).

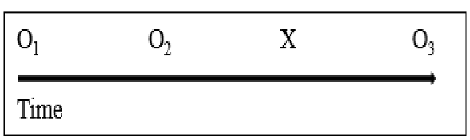

Figure 1.1. Multiple-Baseline Interrupted Time-Series (ITS) Design

CHAPTER 2

PRE-INTERVENTION PHASE

Introduction

Unlike the surgical setting, a limited number of investigations have evaluated FDs in trauma care. While surgery often follows a predictable and lengthy course, the same is not true for trauma care. Trauma resuscitation efforts are unpredictable and fast-paced, producing an environment where healthcare professionals must quickly and accurately evaluate and diagnose potentially life-threatening injuries in unstable patients with incomplete histories. This process is information laden, multi-disciplinary team dependent, and relies heavily on clinical skill and the efficiency of the system (Gruen, Jurkovich, McIntyre, Foy, & Maier, 2006; Sarcevic, 2009). The multi-disciplinary team that typically responds to a trauma alert includes: 1) a trauma surgeon, 2) an emergency physician, 3) specialty surgeons (e.g., neurology, orthopedic, ophthalmologic), 4) surgical and emergency residents, 5) emergency department nurses and technicians, 6) a laboratory technician, 7) a radiology technologist, 8) an orthopedic technician, 9) a critical care nurse, 10) an anesthesiologist or certified registered nurse anesthetist, 11) a respiratory technician, 12) an operating room nurse, 13) security officers, 14) a chaplain or social worker, and 15) a scribe, according to the American College of Surgeons' Committee on Trauma (ASC-COT) and as outlined in *Resources for Optimal Care of the Injured Patient* (2014). As defined by Kozlowski and Bell (2003), a team is composed of two or more individuals that exist to perform organizationally relevant tasks and share a common goal through their specific interdependent roles and tasks. Gruen et al. (2006) explains how trauma care also involves concurrent and competing tasks, long hours, and inexperienced medical residents who often work after hours in busy emergency departments, making it the “perfect storm” for the occurrence of medical error (p. 371).

Previous investigations of disruptions in trauma care found communication and coordination issues make up approximately half of all FDs in Level I trauma centers (Blocker et al., 2012; Blocker et al., 2013; Catchpole et al., 2013; Catchpole et al., 2014; Shouhed et al., 2014). There are few other occupations where effective communication and coordination is as crucial in saving lives, yet these findings are not surprising considering the inefficiencies and weaknesses of the systems within which trauma teams must work every day. An interdisciplinary team of researchers used prospective study methods to identify system issues throughout the entire trauma care process (multiple trauma resuscitation bays, imaging rooms, and ORs) at a Level I center, and then used FDs as a metric to develop evidence-based interventions. Their analysis of identified FDs suggested an implementation of targeted interventions related to coordination problems, communication failures, and equipment issues (Blocker et al., 2012; Blocker et al., 2013; Catchpole et al., 2013; Catchpole et al., 2014; Shouhed et al., 2014). Additionally, the researchers conducted process mapping, interviews, and safety culture questionnaires to define problematic areas and identify solutions. From these interactions, a short list of subsystem interventions was developed and deployed, which included equipment storage, medication packs, employing a whiteboard, pre-briefing, and teamwork training. Observational measures were re-initiated to gauge the effectiveness of the interventions. At the Level I trauma center where the study was carried out, researchers found that this type of human factors subsystem approach reduced FDs, treatment time, and length of patient stay (Catchpole et al., 2014).

Despite sustained efforts in safety and quality, preventable deaths in trauma care continue to occur at a rate of 2 to 22% (Pucher et al., 2013). However, some estimates of preventable trauma-related death rates may be as high as 50% (Cales & Trunkey, 1985; Chua, D'Amours, Sugrue, Caldwell, & Brown, 2009). Pucher et al. (2013) conducted a retrospective error analysis in order to identify not only the incidence of preventable error in trauma care but also the underlying causes of these types of errors. The majority of errors identified occurred during the initial phase of trauma patient assessment and care. Similar to the findings of numerous studies in healthcare, the largest proportions of errors were attributed to human error (Hoyt et al., 1994; Gruen et al., 2006; Chua et al., 2009). Furthermore, most of these errors were categorized as either a process or structural failure. While only 12.1% of errors were identified as structural failures (e.g., staffing issues, lack of equipment, or equipment malfunctions), process errors, or active failures accounted for 87.9%. Process errors were identified as the most common recurring error and included issues such as failure of assessment, diagnosis, or decision making, as well as technical or communication errors. The researchers also found a high prevalence of omission errors (62%), or latent failures, which typically are a result of cognitive lapses such as recognition or attention failures. They suggested that understanding the nature of the errors may be helpful in implementing measures to reduce them. Additionally, they cited Reason (1995; 2002), proposing that protocols and checklists are an effective means for preventing lapses and errors of omission (Pucher et al., 2013).

Trauma Center Designations

There are four levels of trauma care facilities in the U.S. The quality of care and clinical outcomes at various levels of trauma centers are expected to be similar.

Furthermore, all designated trauma centers must meet specific standards for the provision of clinical care to the injured patient as specified by the ongoing verification program sponsored by ASC-COT and outlined in *Resources for Optimal Care of the Injured Patient* (2014). The volume of patients and the severity of injury are the major criteria distinguishing Level I trauma centers from Level II trauma centers and lower. These differences warrant a separate set of ACS criteria (ASC-COT, 2014). Table 2.1 outlines the key trauma center requirements by level (see Table 2.1).

Table 2.1 Key Trauma Center Requirements by Level

Level I
Must admit at least 1200 patients annually or have 240 admissions with an Injury Severity Score (ISS), an established medical score to assess trauma severity, of more than 15, which is considered a major trauma (or polytrauma)
A surgically directed critical care service must be led by a surgeon boarded in surgical critical care and critically ill trauma patients should be cared for in a designated Intensive Care Unit (ICU) by an ICU physician team
24-hour in-house availability of the attending surgeon
A surgeon will be in the emergency department on patient arrival, with adequate notification from the field (the maximum acceptable response time is 15 minutes for the highest-level activation, tracked from patient arrival)
Trauma surgeon on call must be dedicated to a single trauma center while on duty as well as a published backup call schedule for trauma surgery must be available
Must participate in a residency training program and fellowships in trauma/surgical critical care/acute care surgery
Must publish 10 to 20 trauma-related, peer-reviewed journal articles within a three-year period and demonstrate trauma-related scholarly activities
Required to be a leader in education and outreach activities designed to help improve outcomes from trauma and prevent injury by publicly and professionally disseminating information
Must participate in regional disaster management plans and exercises
Level II
Same requirements as Level I trauma centers
Except that volume and severity requirements do not apply
Except that research and educational activities do not apply, but are strongly encouraged
Must participate in regional disaster management plans and exercises
Level III
Must have transfer agreements with Level I or Level II trauma centers
Must have continuous general surgical coverage
A surgeon must be in the emergency department on patient arrival, with adequate notification from the field (the maximum acceptable response time is 30 minutes for the

highest-level of activation, tracked from patient arrival)
Must participate in regional disaster management plans and exercises
Level IV
Must have transfer agreements with higher-level trauma centers in the region
Must have 24-hour emergency coverage by a physician or midlevel provider
A physician (if available) or midlevel provider will be in the emergency department on patient arrival, with adequate notification from the field (the maximum acceptable response time is 30 minutes for the highest-level of activation, tracked from patient arrival)
The emergency department must be continuously available for resuscitation, with coverage by a registered nurse and physician or midlevel provider, and it must have a physician director (providers must maintain current Advanced Trauma Life Support® certification and should attend trauma-related continuing medical education (CME) of at least 8 hours yearly)
Must participate in regional disaster management plans and exercises

According to the Florida Department of Health (2017), the state of Florida has 19 trauma service areas and a total of 33 trauma centers. Of these centers, 10 are Level I, 21 are Level II, and two are pediatric facilities. The majority of research has been concentrated in Level I trauma centers, mainly due to ACS criteria research requirements as well as the inherently large patient pool afforded by these institutions. Despite Level I trauma centers garnering the bulk of the attention in clinical and patient safety research, a significant number of trauma patients are treated in Level II trauma centers or lower. Some research has suggested there is improved survival for trauma patients treated at a Level I center versus a Level II or lower center (Cudnik, Newgard, Sayre, & Steinberg, 2008; Demetriades et al., 2005; Demetriades et al., 2006; Glance, Osler, Mukamel, & Dick, 2012; Nirula, Maier, Moore, Sperry, & Gentilello, 2010; Scarborough et al., 2008). Others research has found no significant difference in mortality between Level I and Level II trauma centers (Recinos et al., 2009; Rogers et al., 2011).

As previously mentioned, the literature describes one research study that focused exclusively on FDs and process inefficiencies in trauma care at a Level I trauma center

(Blocker et al., 2012; Blocker et al., 2013; Catchpole et al., 2013; Catchpole et al., 2014; Shouhed et al., 2014). This current study, on the other hand, investigated process inefficiencies observed in a Level II trauma center. Because of the unique differences between Level I and Level II trauma centers, it is reasonable to assume that process inefficiencies observed at a Level I trauma center may not reflect those seen in a Level II trauma center. Understanding the challenges unique to centers other than those designated as Level I is just as important in order to ensure quality of care at those respective facilities. The empirical study of FDs in a Level II facility broadens the scope of inquiry, increasing an understanding of potential interventions these types of facilities can employ to improve life-saving trauma services. Furthermore, utilizing a fine-grained taxonomy such as RIPCHORD, not previously used in any trauma domain, better describes the quantity, location, and variety of FDs encountered throughout trauma care.

Measuring and Identifying FDs

To enhance trauma systems in a manner that ensures lasting success in mitigating the process inefficiencies threatening optimal delivery of care, researchers must first understand the nature and frequency of FDs. A robust approach to the measurement of FDs and the threats they pose can identify problems unique to a particular clinical treatment area such as resuscitation or imaging (Boquet et al., 2017b), or to a specific surgical task, role, or position such as the anesthesiologist, perfusionist, or circulating nurse (Cohen et al., 2016). Furthermore, it may prove arduous to implement targeted interventions on a local level without using an appropriate and accurate method of measuring and identifying process inefficiencies in the first place (Healy et al., 2008).

Evaluating a socio-technological system such as trauma services requires researchers to use unique measurement methods to precisely detect a wide-range of objects, processes, and conditions of the system (Healy et al., 2008). This current study submits that the RIPCHORD taxonomy is best equipped to describe and categorize the FDs encountered in trauma care.

Since its inception, the RIPCHORD taxonomy has been used in the CVORs of multiple hospitals to identify FDs (Abernathy, 2015; Barbeito et al., 2014; Cohen et al., 2016; Palmer et al., 2013). Throughout its application, the RIPCHORD framework has undergone several iterations and further development by researchers at Embry-Riddle Aeronautical University (ERAU). The most current version of RIPCHORD has been expanded to accommodate *threat window analysis* and is now called Realizing Improved Patient Care through Human-centered Operating Room Design for Threat Window Analysis (RIPCHORD-TWA) (Boquet et al., 2017b; Cohen et al., 2016). RIPCHORD-TWA is comprised of six major categories for classifying human factors related disruptions: 1) communication, 2) coordination, 3) equipment issues, 4) interruptions, 5) layout, and 6) usability. Further classification of the data into subcategories (i.e., minor categories, nanocodes) enables fine-grained analysis and provides the researchers with a greater level of detail associated with the observed threats (see Tables 2.2 and 2.3).

Table 2.2 RIPCHORD-TWA Taxonomy

Communication (verbal and non-verbal)	**Interruptions (Other)**
Confusion	Alerts
Environmental Noise	Distractions
Ineffective Communication	Equipment/Supplies
Lack of Response	Interaction with Biohazards
Lack of Sharing	Searching Activity
Nonessential Communication	Spilling/Dropping
Simultaneous Communication	Task Deviation
	Teaching Moments
Coordination	**Layout**
Charting/Documentation	Connector Positioning
Personnel Not Available	Equipment Positioning
Personnel Rotation	Furniture Positioning
Planning/Preparation	Inadequate Space
Protocol Failure	Permanent Structure Positioning
Unknown Information	Wires/Tubing
Equipment Issues	**Usability**
Anesthesia Equipment	Barrier Design
General Equipment	Computer Design
Perfusion Equipment	Surface Design
Surgeon Equipment	Equipment Design
	Packaging Design
	Data Entry (non-computer) Design

Table 2.3 RIPCHORD-TWA Definitions of the Six Major Categories and the 37 Minor Categories

Communication (verbal and non-verbal)
Ineffective Communication – Communication between two or more individuals that does not achieve its desired goal (i.e. not covered by the other categories). o includes (example of when someone doesn't know the name of someone else and can't communicate efficiently with them)
Lack of Response – The failure of an individual to respond to communication resulting in delay. o receive no answer regardless of follow up; this includes "did not respond, had to repeat"
Confusion – Ambiguous or unclear communication resulting in a lack of understanding. o this category has to deal with comprehension not hearing
Simultaneous Communication – Two or more individuals communicating at the same time resulting in the repetition of information and/or miscommunication.
Nonessential Communication – Communication irrelevant to the procedure that is taking place during periods of time where attention should be focused on the task at hand. o this includes anything that is not professional in nature; also includes any non-essential communication in the room regardless of who is involved
Environmental Noise – The increasing sound level in the OR disrupts communication and/or adversely affects concentration on the current task.
Lack of Sharing – Relevant information is withheld or not shared with other personnel.
Usability
Computer Design – Design issues associated with computer software/hardware and peripheral devices (e.g., programs, pointing devices, monitors, etc.).
Equipment Design – Design issues associated with equipment other than computer systems.
Surface Design – Design issues associated with textures, colors, and other design-controlled attributes.
Barrier Design – Design issues associated with donning protective equipment (e.g., gloves, gowns, etc.) and/or erecting barriers for maintaining sterile fields.
Packaging Design – Design issues associated with unwrapping, untying, or opening/closing packaging containing supplies and instruments.
Data Entry (non-computer) Design – Design issues associated with hard-copy data entry devices (e.g., forms, checklists, etc.).
Layout
Connector Positioning – Lack of outlets, connections and/or the inefficient use of existing outlets or connections such that movement and/or continuation of a task is hindered. o about where an outlet is placed or inefficient use of outlet
Equipment Positioning – Medical devices, machines, and tools positioned such that movement and/or continuation of a task is hindered. o e.g. TEE machine, pump machine that is on the IV pole
Furniture Positioning – Room furnishings (e.g., chairs, the patient bed, desks, trash can) positioned such that movement and/or continuation of a task is hindered.

  - e.g. the ICU bed, trashcan, chairs, IV pole, Pyxis machine,

Permanent Structures Positioning – The layout of permanent structures (e.g., doorways, light switches, etc.) such that movement and/or continuation of a task is hindered.

  - this category is reserved for items that always exist in the room (i.e. the room always has these items in it and are in a fixed location)

Inadequate Space – Lack of sufficient space for personnel to operate effectively and/or the inefficient use of space through clutter, untidiness, congestion, and blockage.

  - this also includes not having a proper place to put particular equipment

Wires/Tubing – The entanglement or misplacement of wires and tubes which interferes with movement and/or continuation of a task.

Interruptions (Other)

Distractions – Non-essential personnel and other interruptions that draw attention away from the current task.

  - includes things that can be ignored or something that diverts the attention of the person

Teaching Moments – Staff may pause to deliver reprimands and/or corrective measures during the procedure.

  - at a teaching hospital, a teaching moment in and of itself is not a flow disruption unless the teacher elected an inopportune time to mentor

Searching Activity – Miscellaneous items become missing in the OR and are pursued when they are needed immediately (e.g., missing sponges).

Task Deviation – Personnel leaves the primary task to start another task.

  - includes texting, answering a phone call, when another personnel interrupts someone to do another task that is pertinent to the procedure

Alerts – Human or technological alert to a potential hazard (this category includes false alarms).

Equipment/Supplies- Equipment and/or supplies that must be retrieved due to an unforeseeable need (e.g., incorrect aortic valve size, supplementary equipment).

Spilling/Dropping – When materials are dropped or spilled on the floor, resulting in the staff member being diverted away from their current task.

Interaction with Biohazards – Incidents which involve the interaction of OR staff with sharps, cleaning up fluids (bodily or other), and contaminated equipment.

Coordination

Personnel Rotation – A break or disruption in the procedure caused by the planned or unplanned relief of personnel which unduly impacts the flow of the surgery.

Personnel Not Available – Team members not present or otherwise unavailable during the procedure

Unknown Information – Information which every staff member should be knowledgeable of yet forgets and interrupts others to obtain the information (e.g., lack of familiarity with equipment, procedures, or protocol).

Protocol Failure – Break or breach in protocol that affects the ability of the group to function as a cohesive/efficient team.

Charting/Documentation – Issues surrounding the documentation of patient care for a given medical procedure (e.g., medication dosing/labeling, lab values, etc.).

Planning/Preparation – The failure to establish a common set of goals and/or procedures to accomplish a given task (e.g., having the necessary equipment to complete the procedure).

Equipment Issues

Surgeon Equipment – Surgeon equipment which malfunctions during surgery.
Anesthesia Equipment – Anesthesia equipment which malfunctions during surgery.
Perfusion Equipment – Perfusion equipment which malfunctions during surgery.
General Equipment – General (hospital) equipment which malfunctions during surgery.

Taxonomies such as RIPCHORD-TWA are beneficial to healthcare research in that they offer the ability to conduct a fine-grained analysis, which provides an ideal level of resolution necessary to develop targeted interventions that address true problems in the system. Thus, it presents the opportunity to shift away from a reactive approach and towards a more proactive approach to aid in the understanding and reduction of potential threats impacting patient outcomes. Without a reliable method of measuring and identifying the threats that impair and interfere with a caregiver's performance, it would be a challenge to truly drive any "real" local improvements. In aviation, this is called managing safety, which has been promoted to an advanced level, known as Safety Management Systems (SMS). Being proactive is one characteristic of an SMS, as explained by Stolzer, Halford, and Goglia (2008), "SMS practitioner in charge of such a program does not have to wait for events to happen, but rather uses every technique available to discover the information necessary to anticipate areas of increased risk, before they happen" (p. 35).

Method

Population

Experienced medical human factors researchers prospectively observed a sample of trauma cases at a Level II trauma center. All observations were collected at an East

Central Florida community hospital with 678 licensed beds and three dedicated trauma resuscitation bays (expandable to six) located in the Emergency Department (ED). The ED has a total of 110 treatment rooms. The trauma center serves two counties and has a catchment area of over 1,300 square miles. On average, the hospital receives 500-600 trauma activation alerts annually. Below is a photograph of one of the trauma resuscitation bays (see Figure 2.1).

Figure 2.1. Trauma Resuscitation Bay

Given the critical condition of incoming trauma patients, it was not possible to obtain their consent to participate in the study. The study was approved by the hospital's Research Oversight Committee as a quality improvement project. It was considered exempt from Institutional Review Board (IRB) review as the focus was on disruptions involved in the trauma care process rather than clinical outcomes of the patient. In accordance with the Health Insurance Portability and Accountability Act (HIPAA) of 1996 and Protected Health Information (PHI) Privacy Rule, all health information pertaining to the patient was protected. There was no effort made on the part of the researchers to collect personal and/or identifying information specific to either the patients undergoing treatment or the hospital personnel providing care. Data extraction beyond that which was collected on-site was performed by the Principal Investigators (PIs) holding clinical privileges at the hospital. Furthermore, all data extracted was de-identified by the PIs in accordance with HIPAA guidelines and was concerned only with demographics and processes associated with the delivery of care. Hospital staff and trauma team members were aware of the presence and research goals of the observers. Specific demographics, including gender, age, mechanisms of injury (MOI), and Glasgow Coma Scale (GCS) scores, were recorded for each patient. GCS is the most accepted clinical method for assessing the initial level of consciousness in trauma patients as well as trends in responsiveness, which is useful for prognosis after acute brain injury. It uses three categories, eyes (E), verbal (V), and motor (M), to summarize the severity of the patient's condition using a scale from 3 to 15. A numerical sum of 15 on the scale indicates the highest response observed in a patient and lower scores are associated with deep unconsciousness (Teasdale et al., 2014).

Procedure

Data collection. Experienced medical human factors researchers observed and recorded FDs during a total of 65 complete (“wheels in” to “wheels out”) trauma cases. FDs are deviations from the natural progression of a task that potentially compromise the safety of the process and/or task (Wiegmann et al., 2007). FDs were operationally defined as those events that resulted in a disturbance in a team member's progress or any other delay. Researchers had either medical and/or human factors background and underwent a comprehensive educational training process to ensure they could properly identify and capture FDs. In addition, the hospital adheres to strict ethical standards for the use of human participants in conducting research; therefore, researchers were required to complete the IRB training, an online training module through the Collaborative Institutional Training Initiative (CITI) Program.

Beginning on April 29, 2014, researchers observed trauma cases during normal and peak operational times. This hospital's geographic location makes it subject to informally defined peak operational times, where the hospital experiences a potential influx of additional trauma patients as a result of an increase in the tourism population. Events that take place locally include Bike Week, Biketoberfest, various NASCAR racing events, and Spring Break. These special events can result in substantially higher trauma patient volume.

Prospective data collection began at the time the patient arrived in the trauma resuscitation bay. The resuscitation bay is the designated area for providing emergency resuscitative efforts in order to stabilize the injured patients. Immediately following successful resuscitation efforts, the majority of trauma patients are taken to imaging. The imaging suite consists of a Computed Tomography (CT) scan room and viewing hallway where healthcare personnel wait while a CT scan obtains in-depth images of the patient. These images help providers gain a better understanding of the patient's clinical status and injuries. Data collection continued throughout imaging and terminated upon disposition to surgery, the medical floor unit, or the ED. Below are photos of the imaging/CT scan room and the viewing hallway (see Figures 2.2 and 2.3).

Figure 2.2. Imaging/CT Scan Room

Figure 2.3. Imaging/CT Viewing Hallway

Observers recorded the time the patient was wheeled into the trauma resuscitation bay and the time they were wheeled out. Likewise, the time was noted when the patient was wheeled into and out of imaging. For recording purposes, the patient’s transport time between resuscitation and imaging was still considered under the auspices of resuscitation since an official handoff to imaging had not yet occurred.

FD observations were documented in real-time in a free-response format using paper and pencil or digitally recorded using an electronic tablet. Observations and time spent in resuscitation and imaging were then transferred to a Microsoft Excel Workbook for consensus coding and subsequent statistical analysis.

Data coding and classification. FDs were classified using the human factors taxonomy, RIPCHORD-TWA (Boquet et al., 2017b; Cohen et al., 2016). RIPCHORD-

TWA is comprised of six major categories for classifying human factors related disruptions: 1) communication, 2) coordination, 3) equipment issues, 4) interruptions, 5) layout, and 6) usability. There are multiple subcategories (i.e., minor categories, nanocodes) within each major category.

At least two or more medical human factors researchers consensus coded each observation into the RIPCHORD-TWA taxonomy. The coding process was iterative and was carried out in an independent fashion for each observation recorded. First, researchers determined if the individual observation was considered an FD. The decision as to whether or not to code the observation as an FD in the first place was made in consensus. In other words, the researchers had to reach a unanimous agreement. Next, a specific major and minor RIPCHORD-TWA category was assigned for each FD via consensus coding. During the coding process, researchers consulted a table which included definitions and examples of the six major categories and the multiple minor categories (see Table 2.3).

Data analysis. Descriptive statistics were calculated, including frequency of FDs and percentage of FDs by category and treatment area observed (resuscitation or imaging). Likewise, inferential statistics were calculated in regards to comparing frequency data between the clinical phases of care (resuscitation and imaging). The time elapsed during the case, whether in resuscitation or imaging, as well as the number of threats that occurred over an elapsed period of time were also calculated. In order to measure the potential impact of the observed threats, ratios were calculated to measure through-put: the cumulative number of disruptions observed overall as well as by phase (resuscitation and imaging), divided by the total elapsed time to treat a patient (patient contact minutes) also broken down by phase (resuscitation and imaging). Ratios provided an estimate of how often FDs occurred per minute, as a means to gauge the "window of opportunity" for potential adverse events to occur.

Results

Analysis of FD Data

Of the total sample of 65 trauma cases, the average age of the patient (male=50, female=15) was 41.2 (*s*=20.4). The mean GCS score of the sample cases was 12.78 (*s*=3.9). A total of 38 (58.5%) of the trauma cases occurred during the first shift (7:00a.m.-7:00p.m.) and 27 (41.5%) occurred during the second shift (7:00p.m.-7:00a.m.). A total of 32 (50%) of the trauma cases were observed during peak operational periods that correlated with special tourism events (i.e., Biketoberfest, Bike Week). Additionally, four (6%) of the observed cases were considered multiple traumas, meaning more than one trauma patient arrived at the same time and were treated simultaneously by multiple trauma teams. The breakdown for MOI was as follows: falls (15 or 23%), motor vehicle crashes (10 or 15%), motorcycle crashes (26 or 40%), stab wounds (1 or 1.5%), assaults (2 or 3%), gunshot wounds (3 or 5%), burns (1 or 1.5%), and other/unspecified (7 or 11%), which included cases such as a pedestrian struck by a motor vehicle, a suicide attempt, or a drug overdose, for example (see Table 2.4).

A total of 1,137 disruptions were identified during the 65 observed cases (2,468 patient contact minutes). This translated to nearly 17.5 disruptions per case (*s*=10.9), meaning approximately one disruption occurred every two minutes. The average total treatment time per patient was close to 38 minutes (*s*=17.6). A total of 545 disruptions were identified in resuscitation alone (1,068 patient contact minutes), with treatment time averaging just over 16 minutes (*s*=11.46), which translated to more than eight disruptions per case (*s*=6.6). In imaging, a total of 592 disruptions were identified (1,400 patient contact minutes), with treatment time averaging 21.5 minutes (*s*=9.8), which translated to nine disruptions per case (*s*=6.6). Furthermore, the overall ratio of the number of FDs per minute, or the through-put measures, was 0.46 per minute. More specifically, the ratios were 0.51 per minute in resuscitation and 0.42 per minute in imaging.

Table 2.4 Pre-Intervention Phase Patient Demographics

Pt	Age	Sex	Mechanism of Injury	GCS	E	V	M	Event	Multiple Trauma?	Shift
1	31	M	Fall	6	4	1	1			1st
2	16	M	Fall – sports	15	4	5	6			1st
3	40	M	Fall	14	4	5	6			1st
4	30	F	Motor vehicle crash	14	4	4	6			1st
5	48	F	Fall	15	4	5	6			2nd
6	8	F	Fall	15	4	5	6			1st
7	70	M	Fall	3	1	1	1			1st
8	58	M	Fall	15	4	5	6			1st
9	13	M	Fall	11	4	1	6			1st
10	28	M	Laceration – machine tool (other/unspecified)	15	4	5	6			1st
11	58	M	Motor vehicle crash	14	4	4	6			1st
12	69	F	Fall	15	4	5	6			1st
13	70	M	Fall	15	4	5	6			1st
14	62	M	Motor vehicle crash	15	4	5	6			1st
15	71	M	Other/Unspecified	15	4	5	6			1st
16	27	M	Motorcycle crash	15	4	5	6			1st
17	26	M	Scooter (motorized/ motorcycle crash)	15	4	5	6			1st
18	25	F	Motor vehicle crash	15	4	5	6			2nd
19	7	M	Fall	15	4	5	6			1st
20	65	M	Motorcycle crash	3	1	1	1			1st
21	44	M	Motorcycle crash	14	4	4	6	Biketoberfest		2nd
22	35	M	Motorcycle crash	9	2	3	4	Biketoberfest		2nd
23	1	F	Burn	15	4	5	6	Biketoberfest		2nd
24	24	F	Motor vehicle crash	15	4	5	6	Biketoberfest		2nd
25	63	M	Assault	14	4	4	6	Biketoberfest		2nd
26	28	F	Motor vehicle crash	14	4	4	6	Biketoberfest		2nd
27	26	M	Fall	6	4	1	1	Biketoberfest		2nd

28	21	M	Penetration (stab wound)	15	4	5	6	Biketoberfest		2nd
29	52	M	Motorcycle crash	14	4	4	6			2nd
30	32	M	Motorcycle crash	15	4	5	6	Bike Week		1st
31	60	M	Assault	15	4	5	6	Bike Week		2nd
32	1	F	Fall	15	4	5	6	Bike Week		2nd
33	49	M	Motorcycle crash	12	3	4	5	Bike Week	Yes	2nd
34	29	M	Motor vehicle crash	15	4	5	6	Bike Week	Yes	2nd
35	38	F	Vehicle vs. pedestrian (other/unspecified)	15	4	5	6			1st
36	72	M	Motorcycle crash	15	4	5	6			2nd
37	21	M	Self-harm; blunt (other/unspecified)	14	4	4	6			1st
38	21	M	Gunshot wound	14	4	4	6			1st
39	53	M	Hanging (other/unspecified)	3	1	1	1			1st
40	19	F	Gunshot wound	15	4	5	6			2nd
41	59	M	Fall	15	4	5	6			1st
42	16	M	Motor vehicle crash	3	1	1	1			1st
43	29	M	Motor vehicle crash	7	1	2	4			1st
44	58	M	Fall	15	4	5	6			1st
45	63	M	Gunshot wound	15	4	5	6			1st
46	37	M	Motorcycle crash	8	1	1	6			1st
47	31	M	Motorcycle crash	15	4	5	6	Biketoberfest		1st
48	77	M	Motorcycle crash	15	4	5	6	Biketoberfest		1st
49	55	M	Motorcycle crash	14	4	4	6	Biketoberfest		2nd
50	23	M	Motorcycle crash	15	4	5	6	Biketoberfest		2nd
51	69	M	Motorcycle crash	14	4	4	6	Biketoberfest		1st
52	54	M	Motorcycle crash	6	1	1	4	Biketoberfest		2nd
53	63	M	Motorcycle crash	15	4	5	6	Biketoberfest		2nd
54	27	M	Motorcycle crash	15	4	5	6	Bike Week		1st
55	39	F	Motorcycle crash	3	1	1	1	Bike Week	Yes	2nd
56	37	M	Motorcycle crash	15	4	5	6	Bike Week		2nd
57	82	M	Motorcycle crash	15	4	5	6	Bike Week		1st
58	48	M	Motorcycle crash	13	4	4	5	Bike Week		1st
59	44	M	Motorcycle crash	11	3	4	4	Bike Week		2nd
60	50	M	Motorcycle crash	14	4	4	6	Bike Week		2nd
61	21	M	Vehicle vs. pedestrian (other/unspecified)	15	4	5	6	Bike Week		2nd
62	30	M	Motorcycle crash	15	4	5	6	Bike Week		2nd
63	56	F	Motor vehicle crash	15	4	5	6	Bike Week		1st
64	30	F	Vehicle vs. pedestrian (other/unspecified)	3	1	1	1	Bike Week		1st
65	69	F	Motorcycle crash	15	4	5	6	Bike Week	Yes	1st

Of these 1,137 disruptions, communication issues represented 32% of the total, interruptions made up 26%, and coordination issues were third most frequent at 21%. Layout, usability, and equipment issues comprised 14%, 5%, and 2% of the disruptions, respectively (see Figure 2.4).

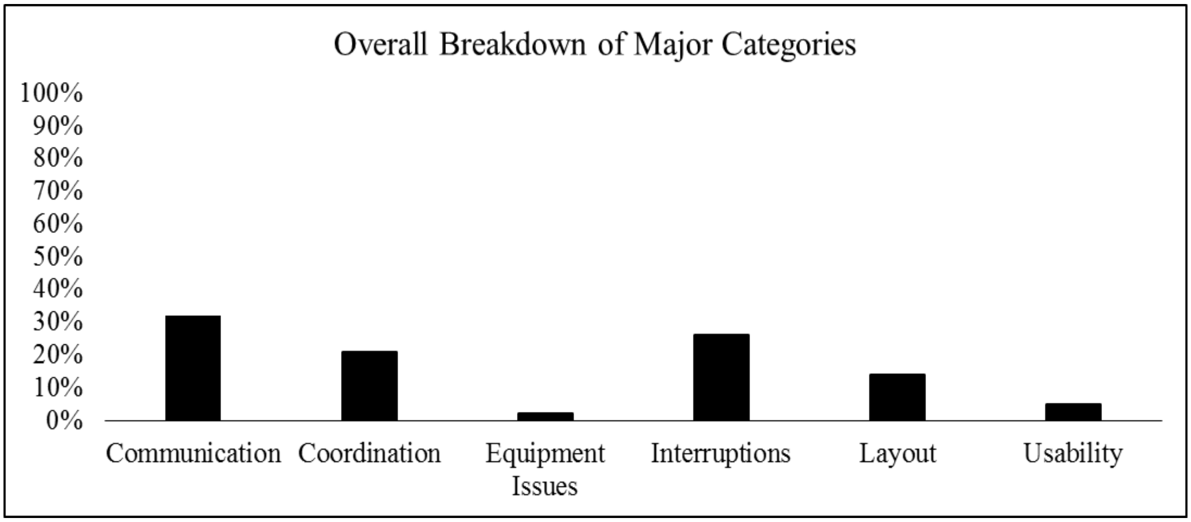

Figure 2.4. Overall Breakdown of Major Categories During the Pre-Intervention Phase

Further analysis examined the difference in disruptions between resuscitation and imaging. While the pattern of results was similar to that seen during the preliminary analysis, some differences were observed. Although communication disruptions occurred evenly in both phases of care (32%), interruptions were observed more frequently during resuscitation (28%), whereas disruptions resulting from coordination problems were more prevalent in imaging (26%) (see Figure 2.5).

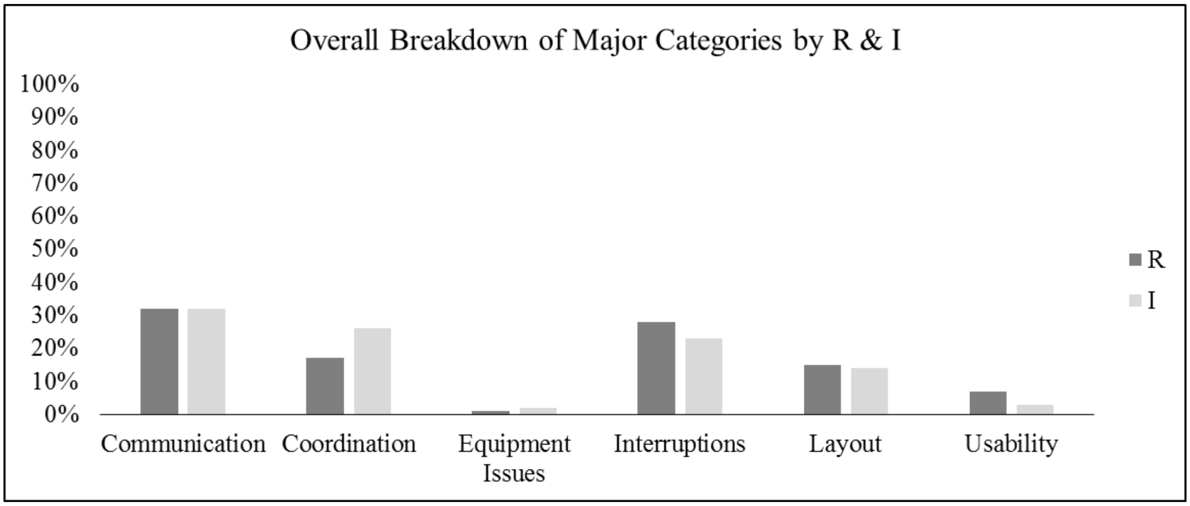

Figure 2.5. Overall Breakdown of Major Categories by Resuscitation and Imaging During the Pre-Intervention Phase

In order to obtain a more detailed understanding of the types of disruptions populating each major RIPCHORD-TWA category, fine-grained analysis of the data was conducted. Within the major category of communication, disruptions largely consisted of the following three minor categories: nonessential communication (37%), lack of response (25%), and ineffective communication (24%). The remainder of disruptions observed were divided among confusion (5%), simultaneous communication (4%), lack of sharing (3%), and environmental noise (2%) (see Figure 2.6).

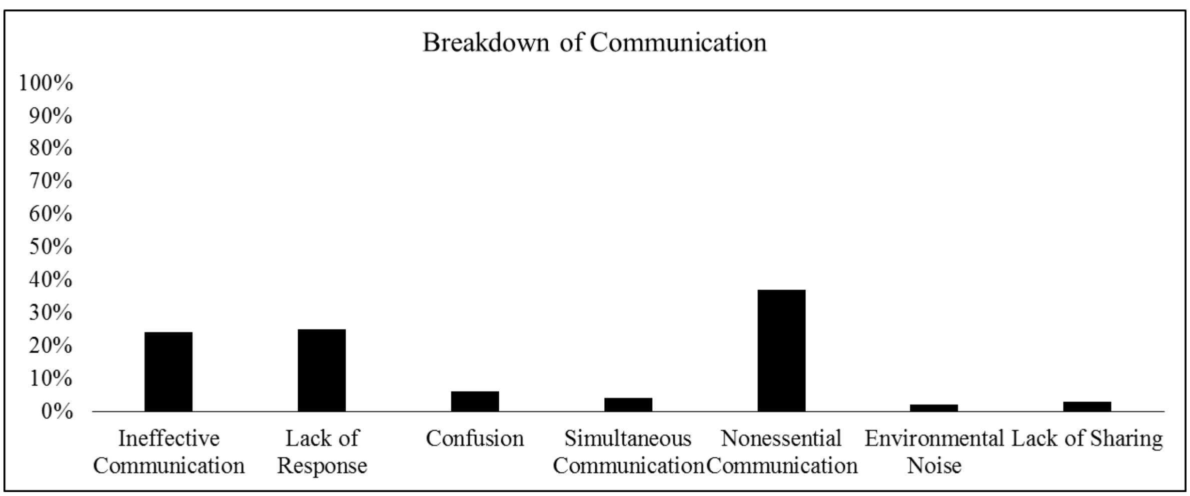

Figure 2.6. Communication Breakdown During the Pre-Intervention Phase

The two most heavily populated minor categories within interruptions were:

spilling/dropping (27%) and distractions (24%). These were followed by equipment/supplies (15%), teaching moments (11%), alerts (10%), searching activities (9%), task deviation (5%), and interaction with biohazards (0%) (see Figure 2.7).

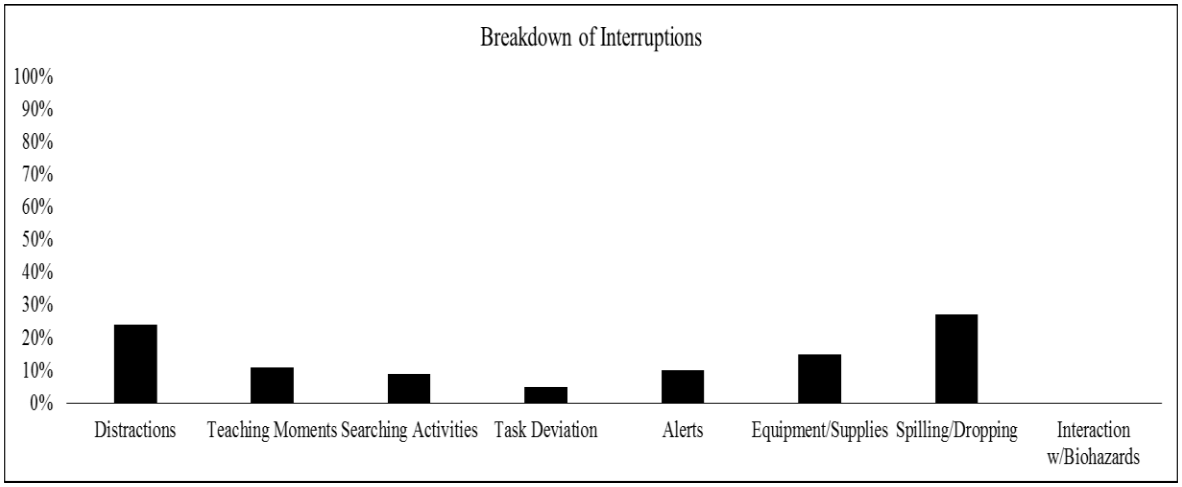

Figure 2.7. Interruptions Breakdown During the Pre-Intervention Phase

Minor categories making up the majority of coordination issues consisted of: planning/preparation (34%), charting/documentation (22%), unknown information (18%), and personnel not available (16%). These categories were followed by protocol failure (9%) and personnel rotation (0%) (see Figure 2.8).

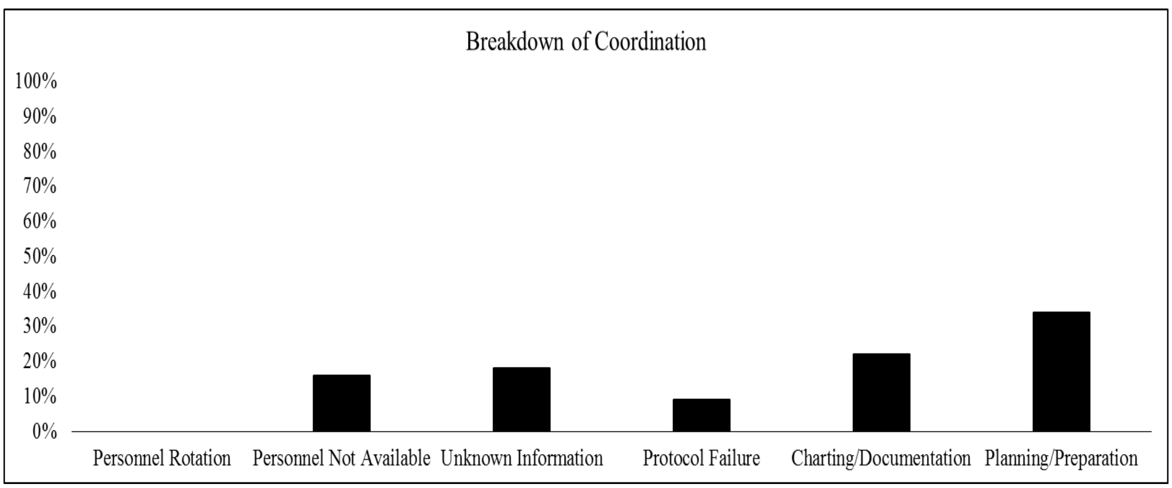

Figure 2.8. Coordination Breakdown During the Pre-Intervention Phase

Disruptions related to layout included wires and tubing (43%), inadequate space

(38%), equipment positioning (14%), connector positioning (2%), furniture positioning (2%), and permanent structures positioning (1%) (see Figure 2.9). The minor category distribution in the usability category was computer design (30%), data entry (non-computer) design (28%), equipment design (24%), barrier design (15%), packaging design (4%), and surface design (0%) (see Figure 2.10). The only minor category populated in the major category of equipment issues was general equipment (100%) (see Figure 2.11).

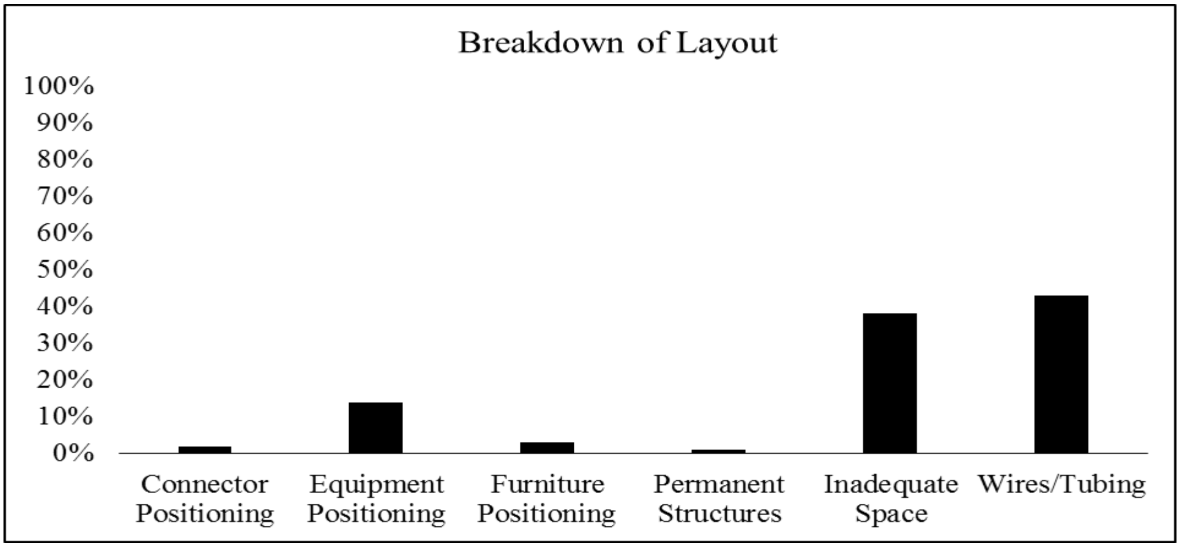

Figure 2.9. Layout Breakdown During the Pre-Intervention Phase

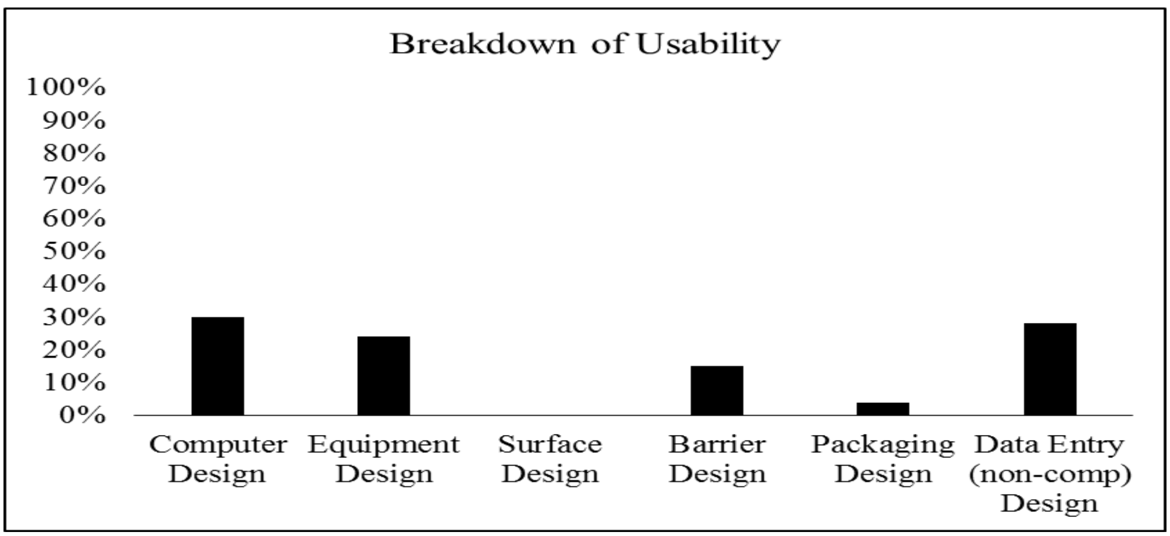

Figure 2.10. Usability Breakdown During the Pre-Intervention Phase

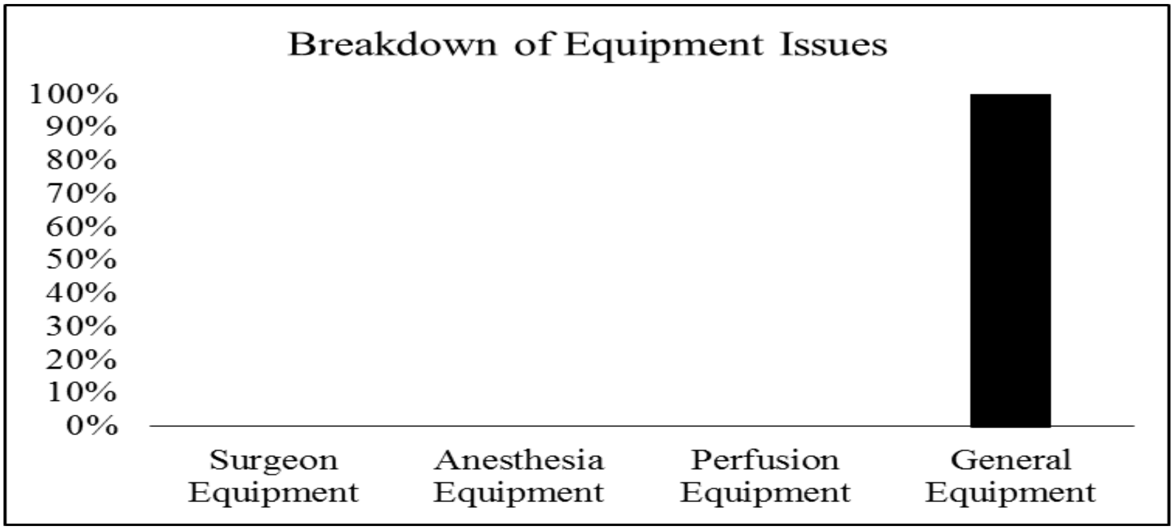

Figure 2.11. Equipment Issues Breakdown During the Pre-Intervention Phase

The table below provides specific examples of the types of observations coded in each respective RIPCHORD-TWA major/minor category (see Table 2.5).

Table 2.5 Examples of Specific FDs Observed and Coded in RIPCHORD-TWA

Major Category	Minor Category	Example
Communication (verbal and non-verbal)	Confusion	Trauma surgeon says "bilaterally". "What side?" says the scribe
	Environmental Noise	Trauma surgeon made a hand gesture to the charge nurse from across the room asking them to turn down the Vocera; charge nurse didn't understand; trauma surgeon said "turn down the extraneous noise in the room."
	Ineffective Communication	Needed an X-ray of the forearm/wrist; radiology tech said "I'm going to do …., You want me to do ….?"; physician responded, "I want you to do the right stuff."
	Lack of Response	Scribe yelled out to team, "Do we have a BP reading?"; no response
	Lack of Sharing	Scribe calls MRI on the unit phone that is directly across from CT scan only to find out that MRI is already aware of trauma patient on their way
	Nonessential Communication	Nurses discussing a test they were studying for
	Simultaneous Communication	Everyone trying to update the scribe with the medications they had given; scribe said "Hold on! Hold on! I am doing too many things!"
Coordination	Charting/ Documentation	Scribe was asking trauma surgeon about "missing" information on flow sheet while patient

		was in CT scan
	Personnel Not Available	Team was looking for the trauma surgeon; asking about his whereabouts
	Personnel Rotation	ED physician asked for radiologist to look at scans; operator went to look for radiologist; he returned to report that the radiologist was out to lunch
	Planning/ Preparation	Resident and team were locked out of CT room; resident walked around to the side entrance of the imaging suite to let patient and team into room from the inside
	Protocol Failure	Staff started to work on patient before report was done. Trauma surgeon asked them to “Wait, hear them out”
	Unknown Information	Nurse asks if blood stays with the patient; ED physician responds “yes please”
Equipment Issues	Anesthesia Equipment	[No specific events observed/recorded]
	General Equipment	Nurse said, “[ED tech], I need a new pump and I need a new pump quick! This one’s broken.”
	Perfusion Equipment	[No specific events observed/recorded]
	Surgeon Equipment	[No specific events observed/recorded]
Interruptions (Other)	Alerts	Trauma surgeon asked nurse to adjust the Foley; it was not in correctly
	Distractions	The nurse was called on the Vocera to assist with another situation; she asked if they could call someone else because she was still with a trauma patient
	Equipment/ Supplies	The runner (ED tech) was asked/told to go get more blood again
	Interaction with Biohazards	Radiology tech asked another tech to wipe down machine because it had blood on it
	Searching Activity	Team member asked radiology tech for a nasal cannula; radiology tech pointed out where they were in the CT hallway
	Spilling/ Dropping	The surgical attending was kicking trash/stuff on the floor out of the way so that he could brace himself properly
	Task Deviation	Scribe says "I need two units of blood now"; ED tech must stop blood draw to get blood from pharmacy
	Teaching Moments	One radiology tech explaining to another radiology tech how to operate the X-ray machine; had to provide direction

Layout	Connector Positioning	Team had to move one IV pole/ stylus to get to another one; however, when they tried to pull on it they realized it wouldn't move freely because it was connected to the outlet
	Equipment Positioning	Someone has to move a cart out of the way to allow radiology tech to move out with equipment
	Furniture Positioning	Difficulty opening Omnicell drawers all the way because a desk (not currently being used) was in the way
	Inadequate Space	7 team members are crowded around monitor in corner by trauma bay #1 door looking at X-rays
	Permanent Structures Positioning	As patient is leaving trauma bay to go to CT the bed gets snagged on door and has to be reversed
	Wires/Tubing	Staff adjusting lines prior to transferring to CT machine
Usability	Barrier Design	Team member is stuck in their Personal Protective Equipment (PPE) and needs someone to help her get it undone in the back
	Computer Design	Radiology techs looking at images and questions if "[the patient's] too low"; the other one says "No, I think you're fine"; then radiology tech tells the one operating the computer that it's not a touch screen; radiology tech says "Oh, that explains it"
	Data Entry (non-computer) Design	Scribe visibly frustrated with the layout of the trauma flow sheet (regarding the location of certain items in particular)
	Equipment Design	Belmont rapid infuser rate drops because it is running on battery
	Packaging Design	A team member walked over to help the ED physician open/pull out the chest tube kit (in general there was a lot of equipment used and it took a lot of time to open each of these kits/sets of equipment)
	Surface Design	[No specific events observed/recorded]

Similar to the analysis of the major categories, the fine-grained analysis revealed some differences between resuscitation and imaging that are notable. The most prevalent types of communication disruptions observed in resuscitation were lack of response (36%) and ineffective communication (31%), which occurred almost twice as often in resuscitation than in imaging (14% and 17%, respectively). On the other hand, nonessential communication (55%) represented the largest threat to communication in imaging, but was observed less frequently in resuscitation (28%) (see Figure 2.12).

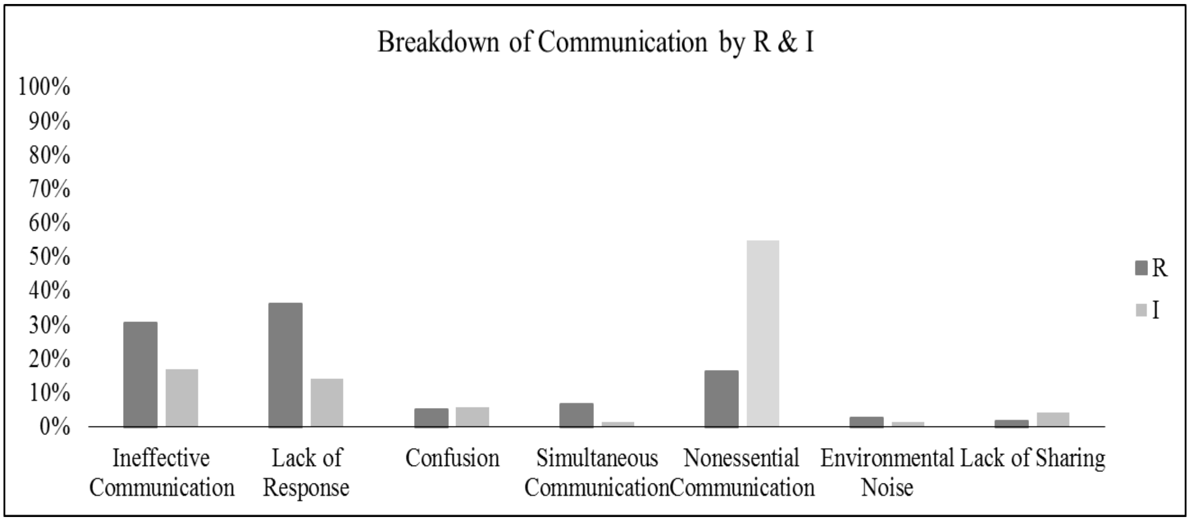

Figure 2.12. Communication Breakdown by Resuscitation and Imaging During the Pre-Intervention Phase

With respect to interruptions, the most frequently occurring disruption in resuscitation was spilling/dropping (40%) as compared to imaging (12%). Distractions posed the largest threat to the team in imaging (39%), but not during resuscitation (10%) (see Figure 2.13).

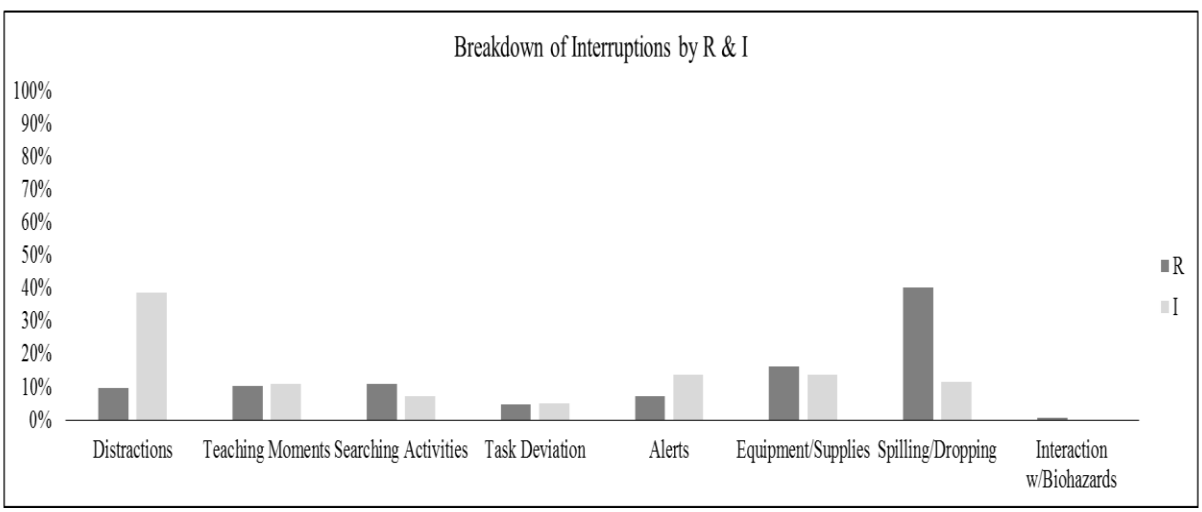

Figure 2.13. Interruptions Breakdown by Resuscitation and Imaging During the Pre-Intervention Phase

In both resuscitation and imaging, breakdowns in coordination most often took the form of issues related to planning/preparation (43% and 29%, respectively). However, issues with charting/documentation (29%) occurred just as often as those related to planning/preparation in imaging. Following planning/preparation issues, unknown information (22%) was the next largest coordination issue in resuscitation. In imaging, personnel not available (20%) was the next most frequently occurring disruption (see Figure 2.14).

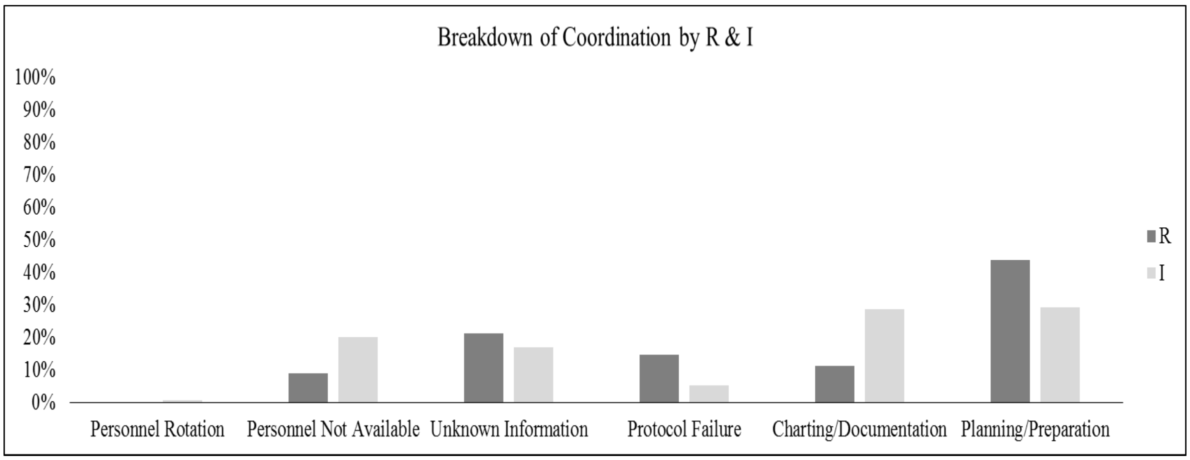

Figure 2.14. Coordination Breakdown by Resuscitation and Imaging During the Pre-Intervention Phase

There were several differences involving the specific types of layout issues involved in resuscitation and imaging. Inadequate space was the largest contributor to disruptions in resuscitation (48%) and it continued to be somewhat of a factor in imaging (28%) as well. On the other hand, wires and tubing issues comprised of 65% of the disruptions in imaging, whereas these issues were not as prevalent in resuscitation (20%) (see Figure 2.15).

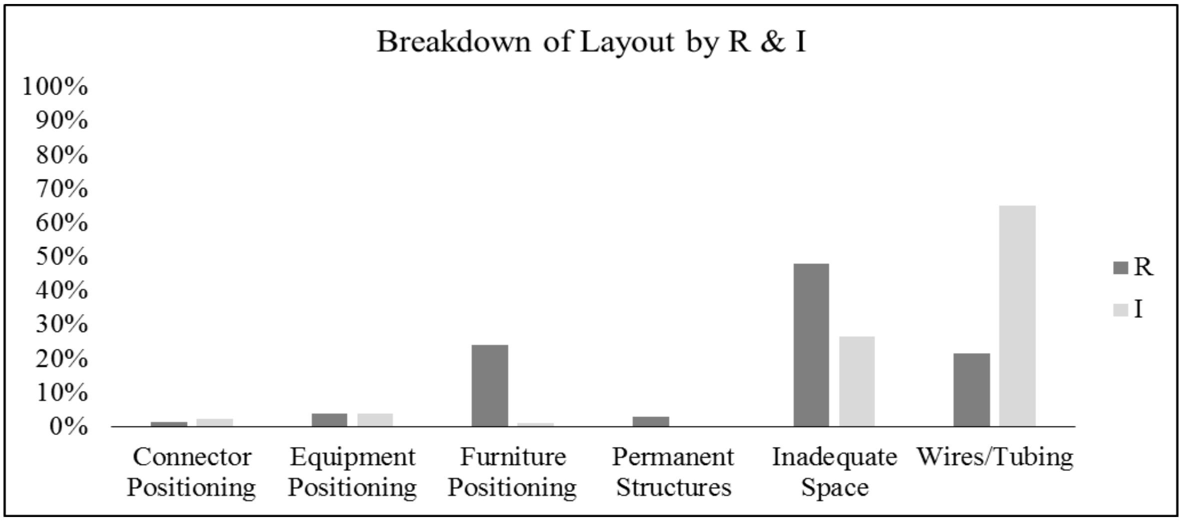

Figure 2.15. Layout Breakdown by Resuscitation and Imaging During the Pre-Intervention Phase

The final two major categories, usability and equipment issues were both lightly populated overall, representing only 5% and 2% of disruptions, respectively. With respect to usability, the most populated minor category was computer design (38%) in resuscitation, followed by equipment design (27%). However, the most prevalent disruptions in imaging were related to data entry (non-computer) design issues (71%) compared to only 8% in resuscitation (see Figure 2.16). Finally, equipment issues were made up entirely of general equipment issues for both resuscitation and imaging and occurred almost evenly in both treatment areas (see Figure 2.17).

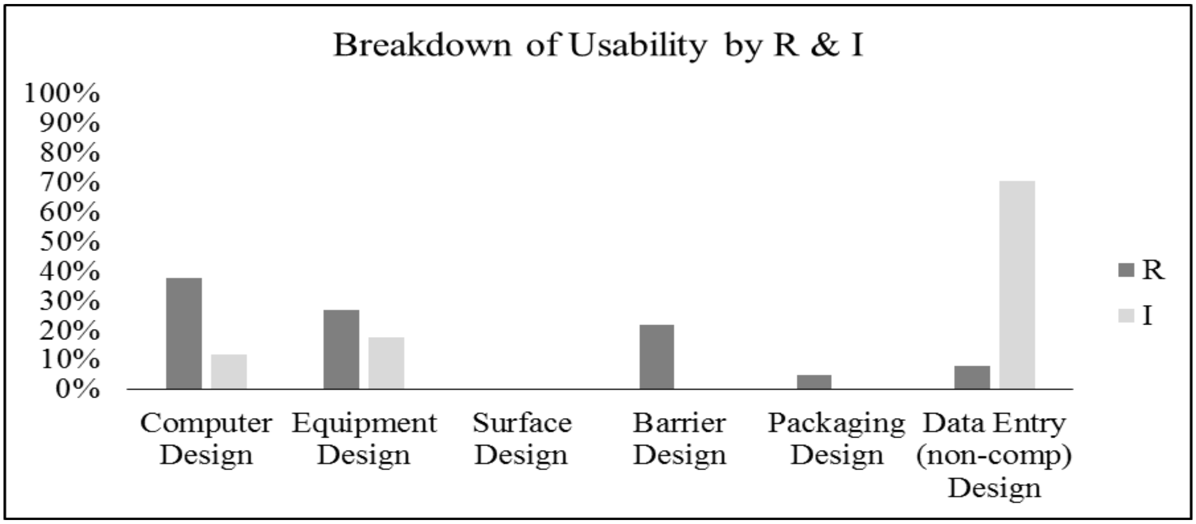

Figure 2.16. Usability Breakdown by Resuscitation and Imaging During the Pre-Intervention Phase

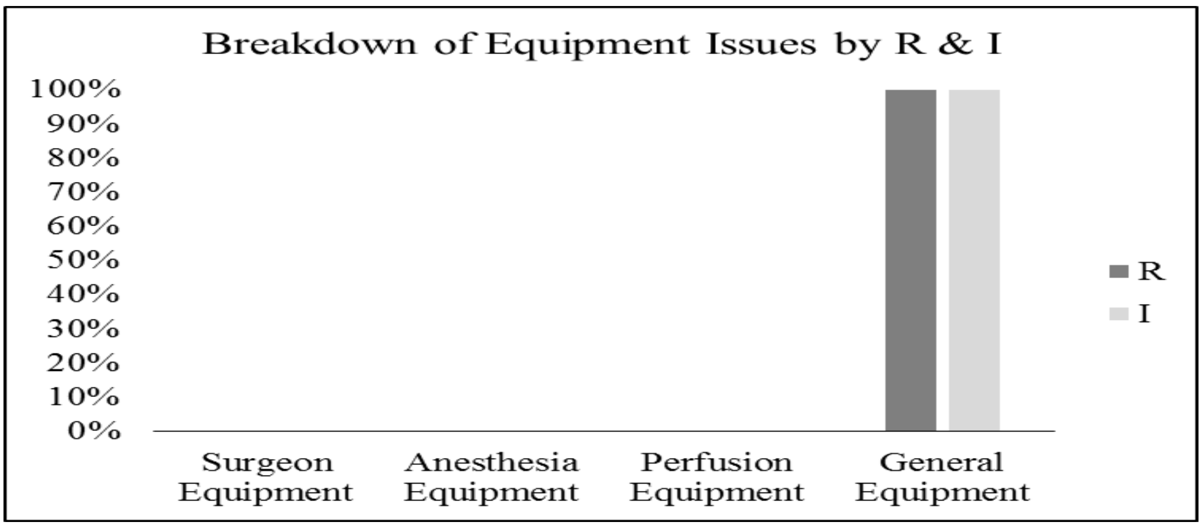

Figure 2.17. Equipment Issues Breakdown by Resuscitation and Imaging During the Pre-Intervention Phase

Frequency Comparisons

Frequency data was compared between the clinical phases of care (resuscitation and imaging) using chi-square statistic (x^2) goodness of fit tests. Alpha levels were adjusted accordingly to maintain the family-wise error rate at p<=.05. The chi-square statistic (x^2) refers to comparing the expected values (E_i) with the values that are collected (O_i) and is one way to show a relationship, or contingency, between two categorical variables. A significant chi-square indicates that the two variables are significantly related. A chi-square test (x^2) is the statistic of choice when the DV is a frequency count, however, it is sensitive to sample size in that no cell has an expected value less than one and no more than 20% of the cells can have an expected cell frequency less than five (Bordens & Abbott, 2014; Boslaugh & Watters, 2008). The formula for the chi-square statistic (x^2) is depicted below (see Figure 2.18).

$$\boxed{\chi_c^2 = \sum \frac{(O_i - E_i)^2}{E_i}}$$

Figure 2.18. Chi-square statistic (x^2)

Major categories by phases of care (resuscitation and imaging). For the major category communication, a chi-square goodness of fit test indicated there was not a significant difference in the frequency of communication disruptions identified in the resuscitation phase of clinical care (32%) as compared with the imaging phase (32%), x^2 (1, n=1137) =0.038, p=0.846.

For the major category coordination, a chi-square goodness of fit test indicated there was a significant difference in the frequency of coordination disruptions identified in the resuscitation phase of clinical care (17%) as compared with the imaging phase (26%), x^2 (1, n=1137) =14.087, p=0.000.

For the major category equipment issues, a chi-square goodness of fit test indicated there was not a significant difference in the frequency of equipment-related disruptions identified in the resuscitation phase of clinical care (2%) as compared with the imaging phase (2%), x^2 (1, n=1137) =0.513, p=0.474.

For the major category interruptions, a chi-square goodness of fit test indicated there was not a significant difference in the frequency of interruption disruptions identified in the resuscitation phase of clinical care (28%) as compared with the imaging phase (24%), x^2 (1, n=1137) =3.385, p=0.66.

For the major category layout, a chi-square goodness of fit test indicated there was not a significant difference in the frequency of layout disruptions identified in the resuscitation phase of clinical care (15%) as compared with the imaging phase (14%), x^2 (1, n=1137) =0.052, p=0.819.

For the major category usability, a chi-square goodness of fit test indicated there was a significant difference in the frequency of usability disruptions identified in the resuscitation phase of clinical care (7%) as compared with the imaging phase (3%), x^2 (1, n=1137) =9.626, p=0.002.

Minor categories by phases of care (resuscitation and imaging). Once 37 minor categories are broken down into treatment areas, the data sets become smaller or more sparsely distributed, therefore, in order to avoid skewing the data, the chi-square test included only those minor categories with an observed cell frequency of five or more. For the minor category ineffective communication, a chi-square goodness of fit test indicated there was a significant difference in the frequency of ineffective communication disruptions identified in the resuscitation phase of clinical care (31%) as compared with the imaging phase (17%), x^2 (1, n=1008) =10.890, p=0.001.

For the minor category lack of response, a chi-square goodness of fit test indicated there was a significant difference in the frequency of lack of response disruptions identified in the resuscitation phase of clinical care (36%) as compared with the imaging phase (14%), x^2 (1, n=1008) =24.178, p=0.000.

For the minor category confusion, a chi-square goodness of fit test indicated there was not a significant difference in the frequency of confusion disruptions identified in the resuscitation phase of clinical care (5%) as compared with the imaging phase (6%), x^2 (1, n=1008) =0.006, p=0.940.

For the minor category nonessential communication, a chi-square goodness of fit test indicated there was a significant difference in the frequency of nonessential communication disruptions identified in the resuscitation phase of clinical care (17%) as compared with the imaging phase (55%), x^2 (1, n=1008) =35.633, p=0.000.

For the minor category personnel not available, a chi-square goodness of fit test indicated there was a significant difference in the frequency of personnel not available disruptions identified in the resuscitation phase of clinical care (9%) as compared with the imaging phase (20%), x^2 (1, n=1008) =10.477, p=0.001.

For the minor category unknown information, a chi-square goodness of fit test indicated there was not a significant difference in the frequency of unknown information disruptions identified in the resuscitation phase of clinical care (22%) as compared with the imaging phase (16%), x^2 (1, n=1008) =0.037, p=0.848.

For the minor category protocol failure, a chi-square goodness of fit test indicated there was not a significant difference in the frequency of protocol failure disruptions identified in the resuscitation phase of clinical care (14%) as compared with the imaging phase (5%), x^2 (1, n=1008) =2.231, p=0.135.

For the minor category charting/documentation, a chi-square goodness of fit test indicated there was a significant difference in the frequency of charting/documentation disruptions identified in the resuscitation phase of clinical care (12%) as compared with the imaging phase (28%), x^2 (1, n=1008) =14.493, p=0.000.

For the minor category planning/preparation, a chi-square goodness of fit test indicated there was not a significant difference in the frequency of planning/preparation disruptions identified in the resuscitation phase of clinical care (43%) as compared with the imaging phase (29%), x^2 (1, n=1008) =.013, p=0.909.

For the minor category general equipment issues, a chi-square goodness of fit test indicated there was not a significant difference in the frequency of general equipment-related issues identified in the resuscitation phase of clinical care (100%) as compared with the imaging phase (100%), x^2 (1, n=1137) =0.280, p=0.597.

For the minor category distractions, a chi-square goodness of fit test indicated there was a significant difference in the frequency of distractions disruptions identified in the resuscitation phase of clinical care (10%) as compared with the imaging phase (39%), x^2 (1, n=1008) =17.320, p=0.000.

For the minor category teaching moment, a chi-square goodness of fit test indicated there was not a significant difference in the frequency of teaching moment disruptions identified in the resuscitation phase of clinical care (10%) as compared with the imaging phase (11%), x^2 (1, n=1008) =0.430, p=0.512.

For the minor category searching activity, a chi-square goodness of fit test indicated there was not a significant difference in the frequency of searching activity disruptions identified in the resuscitation phase of clinical care (11%) as compared with the imaging phase (7%), x^2 (1, n=1008) =3.279, p=0.070.

For the minor category task deviation, a chi-square goodness of fit test indicated there was not a significant difference in the frequency of task deviation disruptions identified in the resuscitation phase of clinical care (5%) as compared with the imaging phase (5%), x^2 (1, n=1008) =0.099, p=0.753.

For the minor category alerts, a chi-square goodness of fit test indicated there was not a significant difference in the frequency of alert-related disruptions identified in the resuscitation phase of clinical care (7%) as compared with the imaging phase (13%), x^2 (1, n=1008) =0.751, p=0.386.

For the minor category equipment/supplies, a chi-square goodness of fit test indicated there was not a significant difference in the frequency of equipment/supplies disruptions identified in the resuscitation phase of clinical care (16%) as compared with the imaging phase (14%), x^2 (1, n=1008) =2.236, p=0.135.

For the minor category spilling/dropping, a chi-square goodness of fit test indicated there was a significant difference in the frequency of spilling/dropping disruptions identified in the resuscitation phase of clinical care (40%) as compared with the imaging phase (12%), x^2 (1, n=1008) =38.568, p=0.000.

For the minor category inadequate space, a chi-square goodness of fit test indicated there was a significant difference in the frequency of inadequate space disruptions identified in the resuscitation phase of clinical care (48%) as compared with the imaging phase (28%), x^2 (1, n=1008) =7.087, p=0.008.

For the minor category wires/tubing, a chi-square goodness of fit test indicated there was a significant difference in the frequency of wires/tubing disruptions identified in the resuscitation phase of clinical care (20%) as compared with the imaging phase (65%), x^2 (1, n=1008) =15.996, p=0.000.

Discussion

Analysis of data collected during the pre-intervention phase revealed that the trauma team experienced an average of 17.5 disruptions per case, translating to one disruption every two minutes. Communication related disruptions were most prevalent, followed by interruptions and issues related to coordination. These results were similar to related research in various healthcare domains (Blocker et al., 2012; Blocker et al., 2013; Catchpole et al., 2013; Catchpole et al., 2014; Shouhed et al., 2014; Wiegmann, et al., 2007). Disruptions associated with layout, usability, and equipment comprised the remainder of disruptions.

While the identification of the major types of disruptions is important, this alone does not provide the detail necessary to generate targeted, data-driven interventions. To accomplish this, a fine-grained analysis was performed by classifying the data into minor RIPCHORD-TWA categories. Additionally, in order to move away from the "one size fits all" paradigm, the data analysis was further separated by treatment phase (resuscitation or imaging).

The fine-grained analysis revealed three categories that accounted for the majority of communication-related disruptions in resuscitation and imaging: nonessential communication, lack of response, and ineffective communication. Perhaps these issues are related to the inherent differences in training received by nurses and physicians. As explained by Thomas, Bertram, and Johnson (2009), nurses are generally taught to be descriptive in their thought and language while physicians are trained to be concise in thought and speak using shorter narratives. For instance, lack of response and ineffective communication posed a greater threat during resuscitation, whereas nonessential communication occurred more frequently during imaging. This is not surprising, given the nature of the treatment during those phases. In resuscitation, a multidisciplinary team comprised of a minimum of 8-10 team members is responsible for stabilization of a critically injured patient. This process occurs at a fast pace and demands that multiple interactions occur concurrently, heightening the propensity for dropped requests. On the other hand, once the patient is stable and situated in the CT scanner, there is more down time, relatively speaking. This provides an interim of reduced intensity, which fosters a relaxed environment that is more conducive to nonessential communication. Nevertheless, the importance of remaining alert to sudden changes in patient status during this time cannot be emphasized enough.

Within the major category of interruptions, the most populated minor categories were spilling/dropping and distractions. These categories not only accounted for the greatest number of disruptions, they were the most disparate between resuscitation and imaging. The spilling and dropping of items occurred much more often during resuscitation than imaging. The combination of fast-paced resuscitation efforts alongside team member's interaction with various equipment and supplies may explain the prevalence of issues related to spilling/dropping. On the other hand, distractions represented a greater threat during imaging. This is consistent with the high volume of nonessential communication during this time. Additionally, team members wear a portable communication device around their necks called a Vocera Communication Badge, which is tied to a communication software platform that is internal to the hospital.

Oftentimes, trauma team members, and more specifically, nurses, were interrupted by their Vocera device with questions unrelated to trauma that were regarding their primary patients in the ED. A major difference between the trauma teams working in a Level II and Level I facility is the non-intact nature of the team. It is comprised of multidisciplinary group of individuals that must quickly leave their principal duties to respond to the unscheduled arrival of a trauma patient. Interestingly, these findings are similar to those of studies conducted at a Level I trauma center, which found FDs to be most prevalent during the imaging phase of patient care (Shouhed et al., 2014).

Disruptions related to the retrieval of equipment and/or supplies due to an unforeseen need were the next most frequent issue in both treatment areas. It is difficult to stock or carry every imaginable item that may be necessary when caring for a dynamic and relatively unpredictable patient load. For example, in one trauma case, a pacifier was retrieved from another location for an infant who was crying during the CT scan.

The importance of effective coordination is vital to the safe and efficient care of trauma patients. Coordination is difficult to manage in a hectic trauma environment, where space restrictions, time constraints, and the number of personnel involved pose unique challenges to providing optimal patient care. Overall, the fine-grained analysis indicated that planning/preparation issues occurred most frequently, with a substantial number of these issues observed during resuscitation, however, they continued to be present fairly often in imaging as well. This observation may again be a manifestation of the unique team structure within a Level II center that does not have an intact, dedicated trauma team. Therefore, at the outset of a trauma patient's unscheduled arrival there may be no clear leader in the trauma suite until the trauma surgeon arrives, possibly up to 15 minutes later. Related research in aviation suggests that “rostered” teams (i.e., non-intact teams) are less effective than “fixed” teams. For instance, rostered teams, unlike fixed teams, do not call each other out on safety infractions (Barach & Weinger, 2007).

Charting/documentation and personnel not available followed planning/preparation in terms of frequency, however, both issues were more prevalent during imaging. Unknown information disruptions occurred at about the same rate in both phases of care. Charting/documentation functions rest largely on the shoulders of the primary nurse/scribe, or nurse recorder. Trauma resuscitation efforts are complex and time-pressured during the initial evaluation and treatment of severely injured patients. Yet, the system relies heavily on handwritten records and manual data entry for recording and time stamping events. All the while, most of the information is conveyed verbally in an unorganized fashion (Sarcevic, 2010). It makes sense that during the time when the patient is in the CT scanner the primary nurse/scribe would tend to play catch up and often recruit the help of other team members to ensure that the trauma flow sheet (the only record of patient care) is as error-free as possible.

Disruptions associated with personnel not available speak to one of the more significant differences between a Level I and a Level II trauma center. This may also account for the increase in disruptions related to personnel not available specifically in imaging. After the patient is stabilized in resuscitation, personnel enlisted from other departments may migrate back to their primary duty stations, rendering them unavailable should the need for their services arise again. This speaks to the previously discussed disruption related to equipment/supplies, which involves the need for personnel to temporarily leave to retrieve an item or a medication due to an unforeseeable need.

Disruptions related to wires and tubing issues posed the greatest threat to layout. There was a greater frequency of these types of disruptions in imaging as compared to resuscitation. This is consistent with the observation that medical personnel must not only physically move the patient into a confined space but also manage auxiliary clinical equipment. On the other hand, inadequate space and equipment positioning posed more of an issue during resuscitation than during imaging. This finding is understandable considering the large number of personnel operating in a limited space around the patient. This issue was exacerbated by the continuous need to reposition equipment (e.g., portable X-ray machines) so that medical personnel could accomplish their individual clinical tasks.

The last two major RIPCHORD-TWA categories, usability and equipment issues were substantially less populated than the other categories (54 and 20 total disruptions, respectively), which makes it difficult to draw definitive conclusions based on the results of the data analysis.

Minor Categories Selected for Data-driven Intervention

Systematic analysis of the data and guidance from experienced human factors researchers helped guide trauma administrators in deciding which types of disruptions would be selected for intervention development. Results were communicated to the Trauma Services Manager (TSM) and the Trauma Program Medical Director (TPMD) to help them make an informed decision.

Overall, considering the rank of communication failures as the most populated major category for FDs, it was deemed beneficial to identify one or two of its minor categories to target for intervention development. Nonessential communication disruptions (37%) occurred at the highest rates within communication. Therefore, it was recommended that nonessential communication be considered for future intervention development. Although lack of response was the next most frequently occurring minor category (25%), it was decided instead to explore interventions for ineffective communication disruptions (24%). It was postulated that targeting specific issues related to ineffective communication, which is formally defined in RIPCHORD-TWA as “communication between two or more individuals that does not achieve its desired goal (i.e., not covered by the other categories),” would most likely have a magnifying effect. Rather than focusing narrowly on a single, very specific type of communication issue, it was believed that efforts to improve communication in general would have a positive influence on other areas of communication, and therefore, deliver “bigger bang for the buck,” so to speak.

The next most populated major category was interruptions and within this category, disruptions related to spilling/dropping (27%) occurred the most often overall but to a much lesser degree in imaging. Whereas distraction-related disruptions (24%) occurred only slightly less than spilling/dropping in general, it posed a greater threat during imaging. As mentioned previously, resuscitation efforts tend to be hurried and fast-paced, which may explain the prevalence of issues related to spilling/dropping in this treatment area. Perhaps the introduction of a large mobile trash container to encourage a more convenient way to throw away packaging and other materials may be a simple solution. On the other hand, distractions can be more insidious. It is formally defined in RIPCHORD-TWA as “non-essential personnel and other interruptions that draw attention away from the current task." Therefore, it was recommended to include distractions as an area to explore in regards to intervention development.

Coordination was also a highly populated major category and the most prevalent disruption (37%) within coordination was planning/preparation. Planning/preparation is formally defined in RIPCHORD-TWA as "the failure to establish a common set of goals and/or procedures to accomplish a given task (e.g., having the necessary equipment to complete the procedure)." Therefore, it was recommended that planning/preparation be added to the list of minor categories that would be used to develop data-driven interventions.

In summary, based on results of the fine-grained analysis and input from the TSM and the TPMD, four minor categories were ultimately selected for data-driven intervention development: 1) ineffective communication, 2) nonessential communication, 3) distractions, and 4) planning/preparation. These four targeted areas were deemed to potentially have the greatest positive impact on quality and efficiency of patient care. It was determined that these categories were highest in priority and, due to time and practical limitations, should be the first and only four categories addressed in the initial stages of the iterative process.

CHAPTER 3

INTERVENTION DEVELOPMENT

Introduction

Implementing quality improvement interventions and ensuring their success has always posed a challenge in healthcare. Case in point, two recent studies reported that mandated surgical checklists in Ontario, Canada and in Intensive Care Units (ICUs) in Brazil had no beneficial effect in reducing in-hospital mortality (Authors/Writing Group for the CHCKLIST-ICU Investigators and the Brazilian Research in Intensive Care Network (BRICNet), 2016; Urbach, Govindarajan, Saskin, Wilton, & Baxter, 2014). Yet, beginning with Haynes et al. (2009), which included Gawande, general and endocrine surgeon and author of *The Checklist Manifesto*, and a number of other studies conducted since that time, researchers have demonstrated that checklists are remarkably successful and have been shown to reduce surgical complications and mortality by more than 30% (Leape, 2014). Even so, it is not surprising that some quality initiatives fail due to breakdowns in the implementation process and a lack of understanding that the “how” is just as important as the “what” (Sundt, 2011; Wiegmann, 2015). Too often, organizational decision makers, consultants, researchers, and the like create solutions and deploy intervention ideas utilizing a “throw spaghetti at the wall and see what sticks” approach, rather than seeking out an in-depth understanding of the intervention itself as well as the complex and dynamic forces at work in the implementation process.

Wiegmann (2015) proposed a sociotechnical systems approach, which involves dynamic interactions among system variables (i.e., people, tasks, technology, environment, workplace factors) and transitions through specific phases of development to achieve intervention success. To sum it up, Leape (2014) labels intervention failures as "a social problem of human behavior and interaction" and suggests "…successful system change requires demonstrating the need for change, engaging institutional leadership, collecting data, and most important, providing training in teamwork so that everyone feels respected and accountable. The WHO [World Health Organization] recommends adapting the surgical safety checklist to suit local needs, an approach that furthers team building and a sense of ownership" (p. 1063). Leape (2014) offers this insight based on his familiarity with a number of successful patient safety initiatives over the years. In particular, he points to successful endeavors by Pronovost and colleagues with the Keystone ICU project (Pronovost & Goeschel, 2005) and catheter-related bloodstream infections (Pronovost et al., 2006). Pronovost and Goeschel (2005) outlined a five-step approach for the introduction of safer care interventions in the ICU that reduced the risk of medical errors. They contend that their model and interventions could be replicated in any setting, with any advocates willing to embrace major change (Pronovost & Goeschel, 2005).

Previous studies in a Level I trauma center (Blocker et al., 2012; Blocker et al., 2013; Catchpole et al., 2013; Catchpole et al., 2014; Shouhed et al., 2014) studied FDs throughout the entire trauma care process (multiple trauma resuscitation bays, CT imaging rooms, and ORs) and attempted to apply a "total systems analysis" to deploy "complex subsystem interventions" (i.e., sociotechnical interventions), which included task-, team-, environment-, and equipment-related solutions (Catchpole et al., 2014, p. E2). Their analysis suggested targeted interventions related to coordination problems, communication failures, and equipment issues. In addition to using FD observations to define problematic areas marked for improvement and to identify solutions, the researchers conducted process mapping, interviews, and safety culture questionnaires. From these interactions, a short list of subsystem interventions was developed and deployed such as equipment storage, medication packs, employing a whiteboard, pre-briefing, and teamwork training. Observational measures were re-initiated to gauge their effectiveness. They found that this type of human factors subsystem approach reduced FDs, treatment time, and length of patient stay (Catchpole et al., 2014).

Similarly, Hildebrand (2014) investigated the relationship between non-routine events (NREs) which can be defined synonymously with FDs and team briefing characteristics, in addition to variations in their communications in gynecological surgery. The findings indicated that improving orientation briefings prior to surgical procedures as well as variations within the team briefing (i.e., who was present, who led the briefing, the timing of the briefing, the amount of communication), were associated with fewer FDs observed during subsequent surgical procedures (Hildebrand, 2014). However, it is unknown if either of these studies experienced long lasting clinical benefits utilizing their respective interventional approaches.

Another compelling framework for guiding the development of interventions is Haddon's Matrix. This framework originated over 40 years ago and was used to apply basic principles of public health to the problem of traffic safety. It is a conceptual model that can be used to generate a list of prevention strategies in order to address a variety of injuries or other public health problems (Runyan, 1998).

Just as this investigation has generated substantive data and empirical evidence, devising comprehensive interventions to mitigate identified inefficiencies should also follow suit. In order to best capitalize on the unique potential for successful patient safety initiatives, an evidence-based, system-wide collaboration approach was decidedly paramount. Rather than using a traditional interventional approach, which tends to fall flat in the real world, the researchers utilized an interventional technique that is driven by empirical findings and relies on input from multidisciplinary healthcare professionals. This method allowed practitioners on the front line to implement customized interventions to problems they face on a regular basis. The benefit of this method was that it allowed the "people in the trenches," or those individuals who have intimate knowledge of existing threats to safety, to weigh in with respect to improving performance in their own workplace. Fortunately, a more systematic methodology for generating intervention and prevention strategies in this manner already existed.

Human Factors Intervention Matrix (HFIX)

The Human Factors Intervention Matrix (HFIX) is a system based on human factor engineering principles that allows organizations to implement targeted, data-driven interventions with the ultimate goal of reducing human error. This concept was developed as an extension to the Human Factors Analysis and Classification System (HFACS) framework conceived by Wiegmann and Shappell (2003). HFACS analyses help identify underlying human factors issues that contribute to accident, incidents, and near-misses in aviation as well as a number of other complex systems. By using the HFACS framework to analyze aviation accidents one can identify areas in need of improvement, and then, begin to develop interventions to address those specific problems. This dynamic whole-systems approach to the safety management process, which includes generating interventions and prevention strategies, is portrayed in a flow diagram below (Wiegmann & Shappell, 2003) (see Figure 3.1).

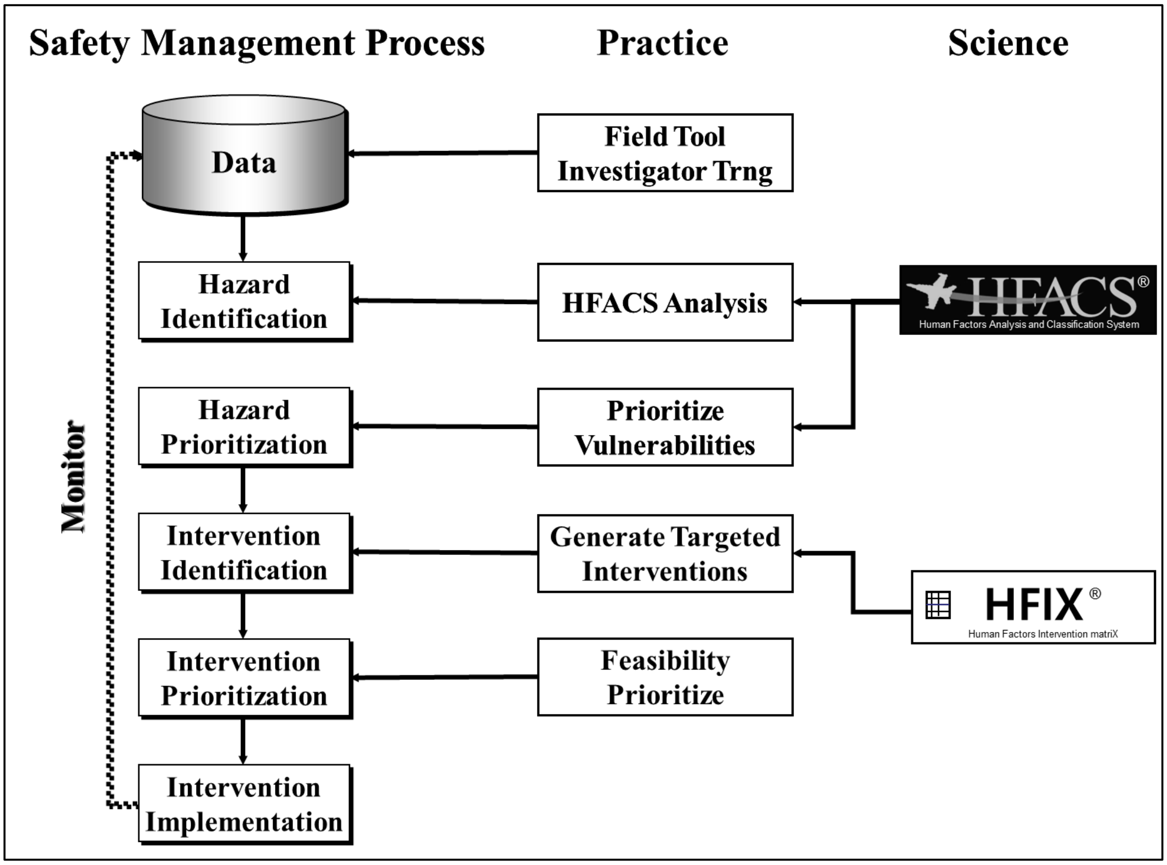

Figure 3.1. HFACS System Management Process

Shappell and Wiegmann (2006) also provided a comprehensive systematic methodology for identifying prospective interventions and ensuring the most expansive assortment of interventions were considered to address the weak areas being targeted. It is akin to the original Haddon Matrix method, which shows the host, agent, and environmental factors set against the time sequence of an incident (Haddon, 1972). Below is an illustration of the Haddon Matrix for a motor vehicle collision (Haddon, 1972) (see Figure 3.2).

	Host (person affected)	Agent or vehicle	Physical environment	Social environment
Pre-event (→ primary prevention)	Driving skill; Time pressures (in a rush to get home?); Inebriated?	Car design & handling; Anti-lock brakes, etc.; Maintenance of car	Road design; Speed limits	Reliance on private, rather than public transportation raises traffic load; Compliance with seatbelt laws
During the event (→ secondary prevention)	Wearing seatbelt?	Air bags working? Size of car & crash resistance	Weather conditions; ice on road?	Quality of emergency assistance; Assistance from bystanders
Post-event (→ tertiary prevention)	Ability to call for help (phone available?); Knows first aid?	Tendency of car to catch on fire	Emergency vehicle access to collision site	Continued funding for emergency services

Figure 3.2. Haddon Matrix for a Motor Vehicle Collision

The addition of a third dimension emphasized the multidisciplinary nature of potential interventions and provided value criteria (e.g., feasibility) in the decision-making process (Haddon, 1972; Runyan, 1998).

Along these same lines, the HFIX methodology ensures that factors affecting human performance are addressed at multiple levels from multiple directions, thereby promoting the development of effective interventions. This unique human factors engineering process of developing and implementing targeted, data-driven interventions utilizes SMEs. SMEs are those individuals on the front line of an organization as well as administrative personnel. Together, the SMEs generate (e.g., brainstorm) intervention strategies aimed at addressing specific human factors and accident causal issues. In other words, this tool provides a systematic way of forcing individuals and groups to think outside of the box (S. Shappell, personal communication, August 10, 2016). The HFIX framework pits identified threats against five different intervention approaches, also known as traditional intervention approaches. These capture the underlying causal mechanisms of human error and serve as fundamental ways to address the root causes of errors and inefficiencies in systems design (Shappell & Wiegmann, 2006). The five intervention approaches, or dimensions, are as follows (Shappell & Wiegmann, 2006):

1. Human/Crew-Centered: focuses on how the human can be improved or changes to affect performance and reduce errors
2. Technology/Engineering-Centered: focuses on the use of tools/technology to replace or augment human performance
3. Technical/Physical Environment-Centered: focuses on the threat to operational or personal safety posed by a situation, event, or hazard
4. Task/Procedure-Centered: focuses on ways to change the nature of a task to reduce errors
5. Organizational/Supervisory-Centered: focuses on how the organization can be changed to improve performance and reduce errors

While generating specific interventions participants are encouraged to be as specific, open, and free-thinking as possible and to not concern themselves with the "how's," cost, feasibility, or effectiveness of implementing the intervention ideas. According to Haddon (as cited in Runyan, 1998), "intervention feasibility" is an important consideration, but it should not be contemplated until all other elements have been thought out (p. 305). Haddon (as cited in Runyan, 1998) explained, "…by considering feasibility too early, creativity may be stifled and options excluded that may, in fact, be judged highly desirable by other criteria" (p. 305).

While HFIX may prove useful in generating a number of comprehensive intervention strategies, organizations cannot implement every single recommendation conceived. Consequently, evaluation of each individual suggested intervention is conducted during the next stage in the process. Participants in groups are asked to rank the intervention ideas using the following five criteria: 1) Feasibility, 2) Acceptability, 3) Cost, 4) Effectiveness, and 5) Sustainability (FACES). Each of these assessment criteria are rated on a 5-point Likert scale, where 1 indicates "worst" and 5 indicates "best". FACES rankings can then be used to determine which interventions should be selected for implementation (Shappell & Wiegmann, 2006). The criteria used to assess the interventions is as follows (Shappell & Wiegmann, 2006):

1. Feasibility refers to raters considering the question "Can it be done?"
2. Acceptability refers to raters considering the question "Will operators accept it?"
3. Cost refers to raters considering the question "Can we afford it?"
4. Effectiveness refers to raters considering the question "Will it work?"
5. Sustainability refers to raters considering the question "Will it last?"

This process is designed to operate similarly to that of a matrix, which is why it is so named. The final product is represented in a cubed structure such as the one presented here (see Figure 3.3). This figure represents the threats identified against the intervention approaches and evaluation criteria. Although this process may appear complex, in reality, organizational decision makers utilize this third dimension all the time. Applying this HFIX framework to map specific interventions onto a matrix can provide a broader perspective while also enabling a more structured approach to intervention development (Shappell & Wiegmann, 2006).

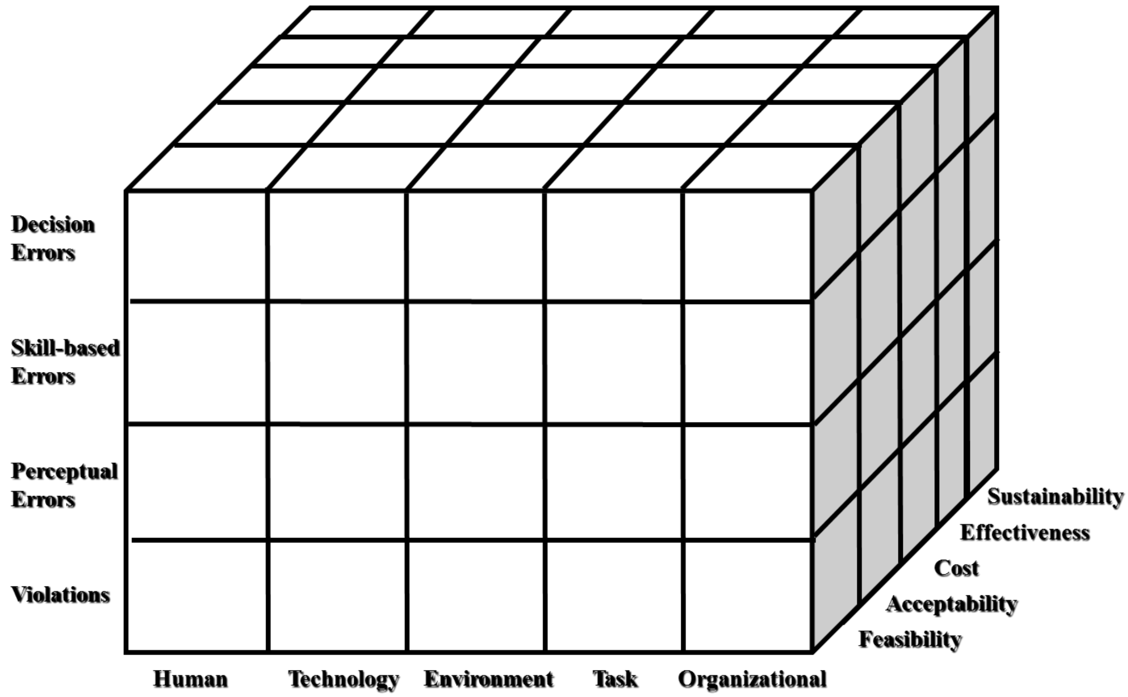

Figure 3.3. Example of an HFIX Cube ($HFIX^3$)

A key feature of the HFIX approach is to engender a feeling of investment and accountability, ultimately, promoting a sense of ownership of the intervention tool by all stakeholders in the process. The inability to include those at the "sharp end of spear," or worse yet, intentionally excluding their input, is one of the reasons why quality initiatives often fail (Leape, 2014). For example, Leape (2014) responded to the Urbach et al. (2014) study with strong criticism—98% of the Ontario hospitals self-reported using a checklist, and of those who provided a copy of their checklist (92 out of 101 hospitals), 90% used an unmodified checklist. Leape (2014) insists that one cannot just "tick" off items on a checklist instead it is more than that; it's a tool for making sure teams communicate. He goes on to suggest that more needs to be done to support "local" efforts to implement checklists, including allowing those at the "sharp end" to make it their own (Leape, 2014). This represents a fundamental belief in a commitment to empowerment and accountability for front line personnel (Stolzer, Halford, & Goglia, 2008). It is imperative that researchers and developers design and apply the right tools and cultivate the right environment to help caregivers attain their full potential. To that end, it is evident that RIPCHORD-TWA is the “right” tool to employ to investigate FDs threatening the efficient delivery of patient care in a Level II trauma center. It has delivered on its promise to identify and classify disruptions in trauma care. With the application of HFIX, another “right” tool for the job, it is expected that the information gained from RIPCHORD-TWA can be used to develop targeted, data-driven interventions to address and potentially mitigate those disruptions. Rather than using HFIX to focus on accident investigation and error data, which was its original purpose, this framework could be used proactively to study the rates of precursor events, a much richer source of data, and ensure that organizations have sufficiently filled the gaps in their safety, quality, and efficiency programs.

Method

Multidisciplinary Knowledge Elicitation (MKE)/HFIX Activity

A multidisciplinary knowledge elicitation (MKE) exercise was conducted on June 19, 2015 involving 19 SMEs and interdisciplinary personnel that included seven ED nurses, four trauma surgeons, four ED technicians, three administrative personnel, and a chaplain. Four human factors researchers facilitated the brainstorming exercise during which intervention strategies were developed aimed at reducing the occurrence of the four selected minor category threats to the trauma system: 1) ineffective communication, 2) nonessential communication, 3) distractions, and 4) planning/preparation. On May 29, 2015, an email was sent to ED staff inviting those interested in participating to attend the upcoming brainstorming session (see Appendix A). Participants were required to notify the TSM if they were planning to attend. Participants were compensated with non-productive pay by the hospital for their time. In advance of the meeting, respondents were assigned to five groups in an effort to ensure that each group was representative of a robust grouping of various hospital personnel and disciplines within trauma services. Table 3.1 shows the group assignments and their roles (see Table 3.1).

Table 3.1 MKE Group Assignment and Roles

Group 1	Group 4
Trauma Surgeon (M.D.)	ED Nurse (R.N.)
ED Charge Nurse (R.N.)	Patient Access Manager
Chaplain	Trauma Services Manager (R.N)
ED Educator	
Group 2	Group 5
Trauma Medical Director (M.D.)	ED Nurse (R.N.)
ED Nurse (R.N.)	ED Technician
Orthopedic Tech Manager (R.O.T.)	Radiology Technician
Trauma Registrar (R.N., Retired)	
Group 3	
Trauma Surgeon (M.D.)	
ED Nurse (R.N.)	
ED Educator	
ED Technician	

HFIX forms were created for each of the four specific areas targeted: 1) ineffective communication, 2) nonessential communication, 3) distractions, and 4) planning/preparation. Each process inefficiency form included its RIPCHORD-TWA taxonomy definition, a description of the HFIX dimension on which to focus on (Human, Technology, Task, Environmental, or Organization), space to write up to 15 intervention ideas, and columns to rank each intervention using the FACES criteria (see Appendix B). A Microsoft PowerPoint presentation was delivered to provide a brief overview of the research objectives as well as analyses and results of pre-intervention FD data observed. Also, the purpose of the MKE and the HFIX model was explained and instructions were given that included a detailed description of the five HFIX dimensions and FACES criteria. Examples of specific FDs observed were also provided for each specific area targeted and remained on the projector screen for reference throughout the exercise. Copies of a detailed description of the five HFIX dimensions were available for reference throughout the exercise (see Appendix C). Individual groups were asked to generate various types of remedial approaches that centered around a specific process inefficiency and were based on one of the five HFIX dimensions. Each group was given approximately 15 minutes to write down as many ideas as possible. The forms were rotated from one table to the next so that each group could repeat the process for a different minor category process inefficiency and dimension. After all groups had the opportunity to generate interventions for each specific process inefficiency and HFIX dimension, forms were rotated again and the groups were asked to rank the generated interventions on a 5-point Likert scale, from 1 being “worst” to 5 being “best” using FACES. They were given approximately five minutes to discuss their rankings of each intervention listed for a specific process inefficiency and dimension. The forms were then rotated to another table so that the next group could repeat the process on a different process inefficiency and dimension. After all groups had the opportunity to rank all of the intervention ideas the meeting was adjourned. The entire process took approximately two hours to complete.

A schematic was developed based on the HFACS and HFIX intervention generation model to illustrate the unique process undertaken at this hospital. It was aptly called the Safety Systems Management Process (SSMP). It borrows from the insights of an effective SMS, which was grounded in quality management principles as well as quality tools and methods aimed at reducing accident rates. An SMS must be a closed-loop system that requires constant monitoring, evaluation, and feedback into the system (Stolzer, Halford, & Goglia, 2008) (see Figure 3.4).

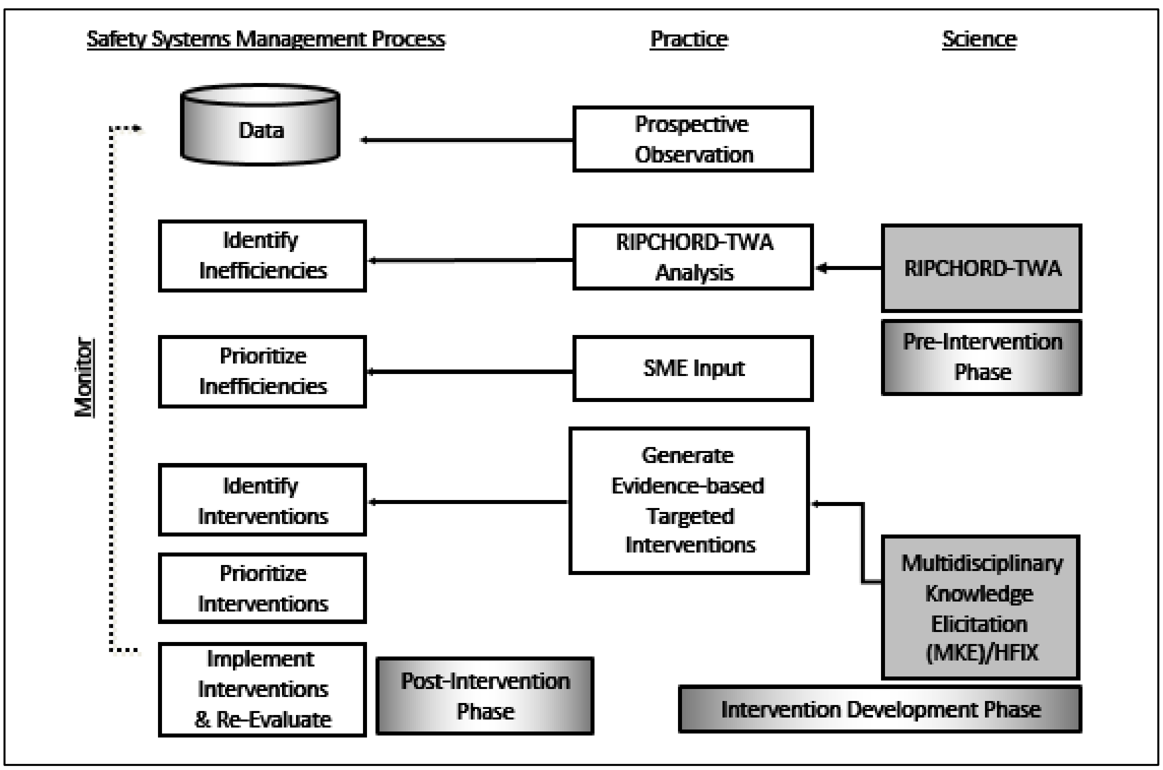

Figure 3.4. Safety Systems Management Process (SSMP)

The specific task of those participating in the MKE is represented in the HFIX Cube (HFIX^3) as shown (see Figure 3.5).

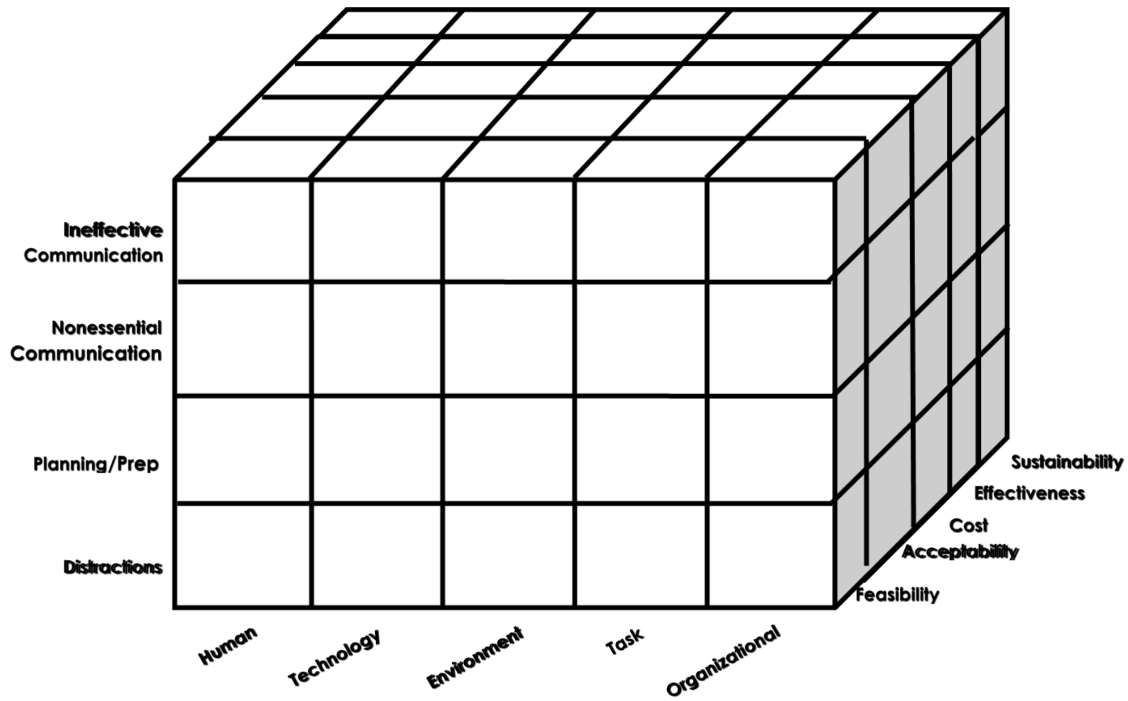

Figure 3.5. Intervention Generation Task Represented in the HFIX Cube (HFIX^3)

Intervention ideas and rankings from FACES were transferred to a Microsoft Excel Workbook in rank order from highest to lowest. The highest-ranking qualitative data was analyzed by the human factors researchers to derive themes, or patterned responses, by comparing theme frequencies, identifying theme co-occurrences, and organizing relationships between the differing themes. Researchers also provided commentary regarding whether an idea represented a clear intervention targeted at the intended process inefficiency or if it was not specific enough. Finally, the file was reviewed with the TSM and the TPMD for intervention selection.

Results

MKE/HFIX Activity Results

A total of 97 interventions were generated during the brainstorming portion of the exercise. Based on results from the FACES ranking task, 34 potential interventions were considered for implementation. Table 3.2 lists the highest ranked intervention ideas targeting each specific minor category threat (see Table 3.2).

Table 3.2 Highest Ranked Interventions Generated as a Result of the MKE

Targeted Threat	Group Submitting	High Ranking Intervention
Ineffective Communication	Task	EVAC report-charge nurse to give the latest report to trauma team prior to arrival; updates from the field
	Task	Clear role identification-will be helped with role sticker; in cases increased staff to help with additional tasks
	Technical	Scribe tablet Bluetooth to a large computer screen at patient's head of bed on wall for all individuals to see documented info
	Technical	Mobile work space with tablet and printer for unit clerk in trauma bay and dump into Meditech
	Human	Clear chain of command/leadership of physicians or nurses. Hierarchy of priorities/team captains
	Human	Standard response to acknowledge communication
	Human	Communication improvement of the organization to the Trauma staff.
Nonessential Communication	Task	Leadership in the trauma room that addresses nonessential communication and refocuses task. Hold people accountable. Semi-sterile environment in terms of conversation.
	Task	Pre-arrival checklist includes a point about giving a secondary contact for nurses involved in the trauma to prevent Vocera calls mid-trauma. "DO NOT DISTURB" button.
	Task	After action review that includes assessment of nonessential communication (even in the absence of audio visual ability)
	Technical	Calling center-to hold all non-emergency call or all other calls until a "All clear trauma"-avoid non-essential communications
	Technical	CT contact person to walk in trauma room to get the essential info: what CT, essential lab values
	Technical	I-stat results-to be given to CT staff by phlebotomist
	Human	Roles of each team member defined
	Human	Transition care-nurses stay for overlap with change of shift
	Organizational	When MDs, lab, RAD, RN swipe badge a "clock in time", individuals name, and credentials show up on scribe’s tablet and on the large screen at patient’s head of bed wall

		(reduces the scribes need to ask names)
Planning/ Preparation	Task	Planning-pre arrival huddle/briefing. Charge nurse query for as many details as possible from EVAC prior to arrival
	Task	Preparation-checklist for charge/triage nurse to get as much info as possible prior to arrival
	Task	Coordination-letting scribe and staff know who was called AND were they summoned, time AND plan; T.S. role/requirement; Staff/team prompt T.S. if info missing
	Task	Coordination-call list in CT; board or list
	Task	Immediate debrief in ISC/nurses station-time permitting after a trauma for correctly and incorrectly done, opportunities for improvement
	Technology	Large digital clock that talks and says, "5 min in", "10 min in", etc. to keep track of time
	Technical	Circulating nurse to grant or deny entry
	Technical	Physical barrier that prohibits unnecessary/unauthorized entry to the area
	Organizational	Make sure OR room is <u>Always</u> open for TA until "TA all clear"
	Organizational	Needle-less system-to give tetanus, instead of drawing up meds
	Organizational	Thyroid covers-increase number
Distractions	Technical	Distractions-nonessential communication in CT-not allowed
	Technical	Nonessential conversation in trauma bay-observers are silent; no conversation <u>not</u> related to patient-all team members to enforce
	Technical	Charge nurse selects any nonessential personnel to remain
	Technical	Garbage thrown in bin
	Organizational	Charge nurse or foreman/circulator to manage capacity of the room
	Organizational	Physician policy of refraining [from] usage of cell phones for non-trauma related purposes
	Organizational	Vocera group for only trauma group. Pre-arrival you are removed from POD groups and have only trauma. Post-departure you add yourself back to your POD groups. Vocera can do NOT DISTURB.

For practical reasons, all 34 highest ranked interventions could not be introduced simultaneously. For robust evaluation purposes and at the request of the TPMD, it was established that no more than five interventions were to be implemented at one time. A thorough review of the 34 highest ranked interventions was undertaken to identify recurring intervention ideas suggested by the MKE participants and to develop possible themes.

A review of the highest ranked interventions included comparing theme frequencies, identifying repeated and recurrent themes, and organizing relationships between different themes. This thematic analysis revealed that 19 out of 34 interventions followed a pattern and revolved around four central themes. Table 3.3 depicts the clustering of individual highest ranked interventions that revolved around co-occurring themes (see Table 3.3).

Table 3.3 Clustered Interventions Revolving Around Repeated and Recurrent Central Themes

Targeted FD	Group Submitting	Intervention
Theme 1: Identifying roles and clarifying duties of trauma team members; introducing a role identification system		
Ineffective Communication	Task	Clear role identification-will be helped with role sticker; in cases increased staff to help with additional tasks
Nonessential Communication	Human	Roles of each team member defined
Theme 2: Importance of leadership and leadership effectiveness within the trauma team		
Ineffective Communication	Human	Clear chain of command/leadership of physicians or nurses. Hierarchy of priorities/team captains
Nonessential Communication	Task	Leadership in the trauma room that addresses nonessential communication and refocuses task. Hold people accountable. Semi-sterile environment in terms of conversation
Distractions	Technical	Charge nurse selects any nonessential personnel to remain
Distractions	Organizational	Charge nurse or foreman/circulator to manage capacity of the room
Theme 3: Integrating a checklist to structure pre-arrival trauma patient information, including plan of action and expectations as well as the initiation of an after action review or debrief		
Ineffective Communication	Task	EVAC report-charge nurse to give the latest report to trauma team prior to arrival; updates from the field
Nonessential Communication	Task	Pre-arrival checklist includes a point about giving a secondary contact for nurses involved in

		the trauma to prevent Vocera calls mid-trauma. "DO NOT DISTURB" button
Nonessential Communication	Task	After action review that includes assessment of nonessential communication (even in the absence of audio visual ability)
Planning/Preparation	Task	Planning-pre arrival huddle/briefing. Charge nurse query for as many details as possible from EVAC prior to arrival
Planning/Preparation	Task	Preparation-checklist for charge/triage nurse to get as much info as possible prior to arrival
Planning/Preparation	Task	Immediate debrief in ISC/nurses station-time permitting after a trauma for correctly and incorrectly done, opportunities for improvement
Theme 4: Utilizing specific and standard communication practices during trauma care		
Ineffective Communication	Human	Standard response to acknowledge communication
Ineffective Communication	Human	Communication improvement of the organization to the Trauma staff
Nonessential Communication	Task	Leadership in the trauma room that addresses nonessential communication and refocuses task. Hold people accountable. Semi-sterile environment in terms of conversation *This suggestion also overlapped with the theme surrounding leadership
Nonessential Communication	Technical	Calling center-to hold all non-emergency call or all other calls until a "All clear trauma"-avoid non-essential communications
Distractions	Technical	Distractions-nonessential communication in CT-not allowed
Distractions	Technical	Nonessential conversation in trauma bay-observers are silent; no conversation not related to patient-all team members to enforce
Distractions	Organizational	Physician policy of refraining [from] usage of cell phones for non-trauma related purposes

This review was presented to the TSM and TPMD, who selected the following four highest ranking interventions for implementation: 1) introduction of a role identification system utilizing stickers to identify team member roles and names; 2) a formal leadership and teamwork training; 3) a pre-arrival checklist/brief and debrief; and 4) establishment of standardized communication protocols.

Intervention Development

This phase of the study focused on the careful implementation of those specific interventions that received the highest rankings and underwent systematic evaluation. The data-driven interventions were: 1) introduction of a role identification system utilizing stickers to identify team member roles and names; 2) a formal leadership and teamwork training; 3) a pre-arrival checklist/brief and debrief; and 4) establishment of standardized communication protocols.

Role identification and sticker system. The role identification system utilizing stickers to identify team member roles and names was implemented shortly after the MKE took place. The TSM created a .pdf. Microsoft PowerPoint file that explained the sticker system and provided background information and directions. It was distributed via email to all trauma team members on August 18, 2015. This was a common method for the TSM to distribute information to the entire trauma team. Indeed, there were also a number of other issues also discussed in the same distribution material. The Microsoft PowerPoint file included the following updates: 1) how to use the elevators properly when going to the Helipad; 2) backboard removal procedure; and 3) adoption of a more common role identification congruent with many trauma centers verified by the ACS, movement from Nurse A, B, and C to Primary Nurse, Fluids Nurse, and Procedures Nurse including a diagram identifying each member's role and duties. Efforts to improve communication were also incorporated into this bulletin. Suggestions included addressing team members by name to improve the teams' communication as well as the physicians' ability to know who is on the team and to better identify the intended recipient of a request. In his book, *The Checklist Manifesto*, Gawande (2009) discusses the importance of making sure that everyone on the team knows one another's names. Teams who know members' names work better together. Researchers found that when teams orientated themselves in this manner, the communication ratings went up significantly. This method of introducing themselves by name and role, especially with teams that are consistently adding new people who may have never worked together (i.e., non-intact teams), enabled team members to better assign roles and responsibility to avoid the tendency to work as isolated units and diffusion of responsibility, meaning no one tends to help because the responsibility is spread throughout the group (Darley & Latané, 1968). They also report that when nurses had the opportunity to say their names and mention concerns at the beginning of a surgical case, they were more willing to verbalize problems and offer solutions (Gawande, 2009). In summary, the implementation of a role identification and sticker system is a simple strategy that was put into practice to address those threats related to communication and coordination disruptions, specifically, ineffective communication and planning/preparation.

Pre-printed label stickers that had designated roles printed on them and a line to write individual names were placed in the trauma resuscitation bay. A Sharpie pen was attached to the label dispenser for writing team members' names on the stickers. The TSM discussed the sticker concept and reviewed the process and location of the stickers in the pre-shift huddles on multiple occasions. Time constraints prohibited staff from practicing the new procedure. Trauma surgeons were also given the same in-person overview. Since the implementation of the sticker system was somewhat limited and informal, the TSM decided the process needed to be covered more in-depth during the leadership and teamwork training, which was planned for a later date and became known as the Nurse Leadership Training (NLT).

Nurse Leadership Training (NLT), pre-arrival checklist/brief and debrief, standardized communication protocols. Following the MKE process and recommendations, researcher efforts focused on creating an evidence-based leadership and teamwork training. This training would be mandatory for all ED nurses since many of them also serve in the role of trauma nurse. The objective of the comprehensive two-hour training was to improve communication and collaboration and to highlight the importance of enhancing nontechnical performance aspects of trauma care. Multiple studies suggest that effective leadership is associated with better processes of care in resuscitation and trauma care in general. For instance, studies have shown a correlation between strong leadership and improvements in basic ventilation, chest compressions, and more successful cardiopulmonary resuscitations. Trauma teams with a leader demonstrated higher rates of task completion of their primary and secondary surveys (i.e., standards of care for the initial assessment of trauma patients) and reduced transit time to CT (Ford et al., 2016). Additionally, teams with leaders who spend more time performing procedures rather than prioritizing and delegating tasks to other team members are less effective (Barach & Weinger, 2007). Moreover, since communication and coordination disruptions were so prevalent in imaging, it was hypothesized that proceeding to imaging with as much preparation and resources as possible such as a pre-arrival checklist/brief, would help to reduce the frequency of these types of disruptions.

Most training programs do not address this broad spectrum of skills, and instead tend to focus on advancing a medical professional’s technical skills (Arora et al., 2012). These “soft skills” (communications, loss of situational awareness, problem solving, decision making, and teamwork) became known collectively as CRM and were techniques embraced by aviation in the 1970s following a series of deadly accidents that were found to be caused by pilot/crew error (Flin, O'Connor, & Crichton, 2008; Helmreich, Merritt, & Wilhelm, 1999). Leadership and communication are essential nontechnical skills that can directly affect the function and success of teams (Awad et al., 2005; Xiao, Seagull, Mackenzie, & Klein, 2004). Failures in teamwork and communication have been correlated with increased surgical errors and FDs in both the OR and trauma care (Blocker et al., 2012; Blocker et al., 2013; Catchpole et al., 2013; Catchpole et al., 2014; Shouhed et al., 2014; Wiegmann, et al., 2007). Strong leadership, teamwork, and communication skills have been identified as key components in high performing teams and improving patient outcomes (Leonard, Graham, & Bonacum, 2004; Lingard et al., 2004). Furthermore, a meta-analysis conducted by Salas et al. (2008) maintained that team training is a relevant intervention for affecting team processes and performance. A more recent meta-analysis by Hughes, et al. (2016) indicated that team training is not only effective but also surpasses employees' pre-training utility and enjoyment expectations, induces learning, transfers learned material to the job, and leads to improved organizational and patient results. Hughes et al. (2016) asserts, "Although team training may receive less attention from healthcare managers because it is perceived to be "soft skills" training, our results suggest that team training improves objective criteria such as patient mortality, and surprisingly, stronger transfer of team training to task performance than teamwork performance" (p. 25).

The customized training curriculum for the NLT included elements from a variety of well-respected resources, including the Agency for Healthcare Research and Quality's

(AHRQs) TeamSTEPPS® (AHRQ, 2016), Trauma Team Dynamics (Gillman, Brindley, Blaivas, Widder, & Karakitsos, 2016), and Values Coach, Inc. (Tye, n.d.), all of which are composed of teachable, learnable skills. The course outlined the roles and expectations of the trauma nurses, introduced clearly defined tools to communicate and plan, and included illustrative videos and simulation-based scenarios for practice. Simulation-based training is a useful practice exercise to incorporate task and teamwork skills. Core concepts of leadership, teamwork, and communication were integrated with the science of human factors and its principles. Throughout the course, patient safety, organizational culture, and culture change were emphasized. The NLT covered the strengths and weaknesses of individual leaders in the trauma suite and how the trauma process lends itself to the interchangeable assignment of a leader (Flin, O’Connor, & Crichton, 2008; Sakran et al., 2012). This provided the opportunity to introduce a new concept, namely that the primary trauma nurse would now be expected to fill the role of team leader in the absence of the trauma surgeon. This designation was considered the most logical one, because they already serve as the scribe, or nurse recorder, considered the “coordinator” of the trauma suite, and is always present at the beginning of the case.

Another essential component of the leadership training was establishing effective leadership goals, team expectations, and rules of engagement. Along those same lines, nursing roles and responsibilities were revisited with a key focus on what characterizes high-performing teams. This included the interplay between an individual’s positive attitude, exceptional behavior, and enhanced cognition, also known as the ABCs of teamwork (Salas, Rosen, Burke, & Goodwin, 2009; Weaver, Rosen, Salas, Baum, & King, 2010).

The training introduced specific communication protocols, information exchange strategies, and embedded performance tools (EPTs). These EPTs included: 1) a team readiness check-in checklist, 2) pre-arrival checklist brief/debrief, 3) call outs, 4) closed-loop communication and read backs, 5) Concerned, Uncomfortable, Safety (CUS) technique, 6) two-challenge rule, 7) redundancy and choice vocabulary, and 8) sterile cockpit rule (i.e., elimination of nonessential communication) (see Appendices D-J). These are tactics used regularly in high reliability organizations (HROs) such as aviation. Research background as well as full descriptions, how-tos, examples, and practice guidelines are available on AHRQs TeamSTEPPS® website. TeamSTEPPS® is comprised of five core principles: 1) team structure, 2) leadership, 3) situation monitoring, 4) mutual support, and 5) communication. Within these principles a variety of skills, competencies, and tools are readily available to incorporate into training and practice (AHRQ, 2016). Gawande (2009) explained how checklists, a classic tool borrowed from aviation, can provide protection against such failures as faulty memory and distraction. Checklists ensure that a procedure is performed the same way every time. Recognizing the importance of adapting the checklist and pre-arrival brief to suit local needs, the TSM worked in collaboration with medical human factors researchers to customize the tasks on the checklist and verify that it was in line with human factors checklist guidelines. Supplemental information regarding the proper way to utilize a checklist, conduct an after action review, also known as a debrief, and avoiding debriefing pitfalls were provided (Tannenbaum & Cerasoli, 2013). A recent meta-analysis by Tannenbaum and Cerasoli (2013) revealed effective debriefs boosted team performance by an average of 25%.

A key principle of the training was to address team dynamics and flatten the hierarchy among team members through the use of unique communication tools. These information exchange strategies were designed to empower individuals to speak up when a concern arose and offer solutions. These new skills were simulated and practiced during the training, using case scenarios, role-play, and prepared examples. Demonstrations were integrated into the NLT that recognized the need for teams to compensate for one another's bias and weakness specifically in terms of how it relates to the concept of inattentional blindness (Chabris & Simons, 2010). Other high-risk industries (e.g., aviation, military, maritime, nuclear power, auto racing) were also brought in as exemplars and related to similar circumstances in trauma care (Catchpole et al., 2007; FAA, 2016; NOVA, 2007; NTSB, 1996). In summary, the development of a formal training program for trauma nurses, known as the NLT, that focused on the principles of leadership, communication, and teamwork, and included such interventions as a pre-arrival checklist/brief and debrief and standardized communication protocols, was a strategic measure aimed at minimizing the frequency of threats in all four specific problem areas: 1) ineffective communication, 2) nonessential communication, 3) distractions, and 4) planning/preparation.

NLT attendance was required for all ED nurses since many of them also serve in the role of trauma nurse. Training sessions were taught by the TSM and scheduled at various times to best accommodate the majority of employee schedules. Upon completion of the training, nurses received a unique Trauma/Acute Care Team recognition pin that communicated to others in the trauma suite that "I have taken the same leadership training as you and we speak the same language." Nurses were compensated with non-productive pay for attending and earned Continuing Education Units (CEUs).

Assessment of the NLT

After five training sessions were taught and 20 participants had completed the training, the course contents and participants were assessed using a multi-method approach. Immediate assessments were administered both before and after the training. Participants completed a 12 question pre- and post-test to evaluate knowledge acquired (see Appendices K and L). The test included several questions obtained directly from the TeamSTEPPS® training curriculum (AHRQ, 2016). The TSM and medical human factors researchers created the remaining questions to reflect the content offered in the training. Responses to the pre- and post-tests were graded and recorded in a Microsoft Excel Workbook by the medical human factors researchers including the participant's name and the date they attended the training. The average score for both the pre- and the post-test was calculated as well as the average improvement from pre-test scores to the post-test scores.

At the end of the training, participants completed an anonymous evaluation of the training program (see Appendix M). Their responses and comments were sent directly to the hospital's CME Coordinator for processing. Overall results were compiled in order to provide an overview regarding participants' reactions to the training program in terms of its content, delivery, and satisfaction on a 5-point Likert scale, in which 5 was "strongly agree" and 1 was "strongly disagree". Evaluators were asked to check specific items related to what they learned from the presentation that would enhance patient care or change practices. The assessment also included a question regarding commercial bias as well as a free response section.

Additional Interventions Introduced

Dating back to February 2015, a collection of system-wide interventions had been steadily introduced to the delivery of trauma care as part of a "trauma optimization project", or TOP, as it was termed by the TSM. The presence of the ERAU researchers was a catalyst for many of these changes, and as a direct result, a series of these interventions were specifically identified during the MKE phase of the study and subsequently enacted mostly due to their ease of implementation. However, others evolved as a result of the ongoing review and discussion of FD observations and analyses as well as the trauma center's continued progress towards national ACS accreditation. Table 3.4 includes a listing and description of the additional interventions introduced, when they were implemented, and if they were directly related to the MKE (see Table 3.4).

Table 3.4 List of Additional Interventions Introduced

Count	Date of Implementation	Intervention	Comments
1	1/1/2014	EMS handoff	This is the expectation that all team members should not move the patient until EMS has completed their report; this is not an official policy but is regularly emphasized; it was a previous complaint by EMS; has been "in place" since approximately 1/1/14
2	2/1/2015	Required scribe to be an RN	Smith stated on 11/6/15 that since putting an RN at the scribe position flow sheet documentation has improved significantly
3	2/1/2015	3 RNs & 1 ED Technician	

4	2/5/2015	Trauma Update I	PPT sent out by Smith; included the following updates: minor changes to the flow sheet, difference between trauma activation levels 1 and 2 and to check box on flow sheet indicating which activation level, introduced new badge reader to assist with flow sheet documentation of team member arrival times, reminder to dispose of sharps properly, suggested good preparation and being well-familiarized with equipment, difference between massive transfusion protocol (MTP) and "Emergency Release" blood as well as processing procedures, and a reminder to wear PPE
5	2/5/2015	Revised Flow Sheet I	Per Smith: "the trauma flow sheet's been revised but the changes are very few and not significant in terms of flow"
6	2/5/2015	Badge reader	Timestamps time of entry
7	2/19/2015	Lighted scribe bedside table in CT	A small adjustable spotlight was permanently attached to the bedside table used by scribe in CT, which is dimly lit for monitoring viewing purposes
8	3/6/2015	Large mobile trash can in resuscitation room	
9	5/1/2015	Clinical Coordinating Team	Positioned in the ED to assist clinical staff with clinical skills, procedures, and equipment
10	6/19/2015	Multidisciplinary Knowledge Elicitation (MKE) Meeting	
11	7/18/2015 MKE-related	Boostrix prefilled syringe	This was the date we were notified via email Smith was ordering
12	8/1/2015	Vocera App	Mainly for physicians to share information with one another regarding patients; HIPAA protected; Smith stated he has the app installed on his phone

			but has not learned to use it; to his knowledge the physicians are not currently using this technology
13	8/12/2015 MKE-related	Trauma Update II	PPT sent out by Smith; included the following updates: how to use the elevators properly when going to the Helipad, backboard removal procedure, and adoption of the more common role identification congruent with many trauma centers verified by ACS: movement from Nurse A, B, and C to Primary Nurse, Fluids Nurse, and Procedures Nurse, which also displayed a diagram identifying each member's role and duties, efforts to improve communication, suggestions included addressing team members by their name to improve the teams', and in particular, the physicians' ability to know who is on the team and to better identify who to give an order to. This is where the role identification system utilizing stickers was first introduced. It was explained that pre-printed labels with every role in the room would be available with a spot to write individual names name on the sticker. A Sharpie pen would be tied to the label dispenser in order to easily add name as the team is gowning up with PPE. Since the information was distributed without direct guidance Smith decided to discuss the sticker concept and went over the process and location of the stickers in the shift huddles, however, they did

			not entail actual practice due to time constraints.
4	8/12/2015	Movement from trauma nurse A, B, & C to Primary Nurse, Procedures Nurse, and Fluids Nurse	
15	8/13/2015 MKE-related	Disposable pulse ox band aids	Rec'd an email from Smith on this date "FYI: we added disposable pulse ox band aids to the trauma room today"
16	8/18/2015 MKE-related	Sticker System & Role Identification	Per Smith: "I've been discussing the label concept in the morning huddles. They don't entail actual physical practice due to time constraints but we do go into the trauma room to show them where they are and then discuss the process. I'm meeting with the surgeons tonight to discuss with them also (or really to remind them!)." Covered in NLT
17	9/1/2015 MKE-related	Ordered more thyroid covers	There was a recommendation to order more thyroid covers, which Smith did and he thinks they were available in Sept. 2015. Update: we had a discussion about this item on 1/21/16 and it reminded him that he may need to order more because he hasn't seen team members wearing them lately
18	9/11/2015	Trauma Rounds (re-instituted)	1100 in ISC Unit on Mondays, Wednesday, and Fridays
19	11/11/2015	Helipad training safety items badge	Since 9/21/2015 we have assisted Smith and the Aviation Unit with creating the badge and safety items
20	11/20/2015	Revised Flow Sheet II	Sent an email out to trauma team on 11/20/15 since they were running low on previous flow sheets so it couldn't wait until Nurse Leadership Training (NLT); minor changes

21	11/24/2015 MKE-related	Digital Stopwatch/clock (installed but not instructed on how to use remote yet)	This device has a remote that someone has to be designated to start the clock; Smith states the instructions are not user-friendly so it is not regularly used; need to get this device working again. Update: On of 8/5/16 a PPT was sent out explaining its purpose, how to operate (instructions are in trauma bay) and designating the primary nurse to start
22	11/24/2015	Applied for ACS consultative visit	Which means the hospital has approximately 1 year to comply with ACS standards before ACS will schedule a visit and then within 6 to 12 months they will have a final review. Update: As of 2/7/17 Dr. James stated they are not ready for ACS verification
23	1/18/2016 MKE-related	Two Barrier Arms installed in J-Pod and imaging hallway	Update: As of 3/23/16 a 2nd Barrier Arm was installed in the South end of the hallway (the corridor leading to imaging)
24	2/23/2016 MKE-related	Nurse Leadership Training (1st one)	A total of 13 2-hour trainings offered; 88 nurses completed by 6/21/2016 (last one)
25	2/23/2016 MKE-related	Minimize nonessential communication in CT (initial email on 11/24/15)	Covered in NLT/Sent an initial email out to trauma team on 11/24/15 in response to a congestion issue in CT
26	2/23/2016 MKE-related	Communication Protocol	Covered in NLT
27	2/23/2016 MKE-related	Team Readiness Check-In (Shift Huddles)	Covered in NLT
28	2/23/2016 MKE-related	Pre-arrival brief	Covered in NLT
29	2/23/2016 MKE-related	Debrief	Covered in NLT
30	3/1/2016	New CT Scanner installed in first room nearest to trauma	Dr. Johnson explains it has better focus, clearer images, less CT time, better quality, less workstation work
31	3/4/2016	Helipad training safety items poster	Since 9/21/2015 we have assisted Smith and the Aviation

			Unit with creating the badge and safety items
32	5/16/2016	Helipad recurrent training	First one ever created and instituted; plan to offer on an on-going basis throughout the year along with helipad training for new trauma team members
33	6/7/16 & 7/5/16	Brief informal presentation of NLT at Trauma Committee Meetings	Not all trauma surgeons present, importance of new protocols also mentioned by ED representative at meeting on 8/2/16 and re-iterated by Smith and ERAU team; NLT Powerpoints have been sent multiple times to trauma surgeons

NLT Results

Beginning February 23, 2016, a total of 13 NLT training sessions were held at varying times to accommodate the majority of the nurses' schedules. A total of 88, or 99%, of trauma nurses completed the two-hour training. The number of participants attending each session ranged from one to 11 and participants had varying years of experience. Every course was taught by the TSM and was accompanied by at least one medical human factors researcher to help supplement the course information.

Pre- and post-tests/knowledge assessments of NLT. A total of 68 (out of 88) pre- and post-tests were collected and scored. Two participant's scores were excluded since they did not complete both tests. The average pre-test score was 74% (s=10.39) and the average post-test score was 94% (s=6.98), which resulted in an average improvement in the test scores of 20%.

A t-test for correlated samples was used to compare the two groups (pre-test and post-test). The scores from these two groups encompassed basically two observations of the same variable on the same participants. The two means being compared were not necessarily independent of one another, therefore, a dependent samples t-test took into account any correlation between the scores (Bordens & Abbott, 2014). A dependent samples t-test, was conducted to evaluate the difference between the pre- and post-test scores. The test indicated the post-test scores were significantly higher than pre-test scores, t (65)=-13.92, $p \leq .01$, thus supporting the effectiveness of the training with respect to knowledge acquisition.

On the post-test, Questions five and nine had a higher proportion of incorrect answers than the other 10 questions, which prompted a further review. Regarding Question five on the post-test, 21% answered the question incorrectly. Regarding Question nine on the post-test, 18% answered the question incorrectly. In other words, approximately 80% answered both questions correctly which does not justify eliminating the questions all together.

Evaluation of NLT. The evaluation ratings on the quality of the course content were calculated and submitted by the hospital's CME Coordinator based on the responses of individuals who attended the training program (see Appendix N). A total of 86 (out of 88) participants completed the evaluation form immediately following the training. The questionnaire addressed four points in particular using a 5-point Likert scale where 5 was "strongly agree" and 1 was "strongly disagree." The four points were as follows:

1. Did the course meet the stated objectives? 94% responded that they "strongly agreed."
2. Was the course information current? 95% responded that they "strongly agreed."
3. Was the educational level appropriate? 95% responded that they "strongly agreed."

4. Was the teaching method appropriate? 94% responded that they “strongly agreed.”

Given the data, it is evident that the overwhelming majority of nurses who took the training felt that the information was relevant and useful to them in the performance of their duties.

Discussion

MKE/HFIX Activity

New knowledge about how to precisely attempt to fix the obstacles these front line practitioners cope with in their day-to-day work, especially while performing safety critical tasks, was obtained by virtue of valuable SME input. The HFIX model proved to be a useful tool for the development of effective intervention strategies rather than a swift “knee jerk” reaction to fix a problem (Shappell & Wiegmann, 2006). This framework offers several unique strengths that may prove beneficial in directly targeting the problem areas. In comparison to other intervention strategies that have been publicized or touted in journals, there is no doubt that the total package put forth in this investigation that culminated with the application of the HFIX model stands out. First, HFIX offered a broader perspective and a more structured approach to thinking “outside the box” when it came to generating intervention ideas. It also ensured that a broad range of viable and effective intervention strategies were explored. Additionally, it provided the ability to map interventions onto five broad categories of interventions, which captures the underlying causal mechanisms of potential human error. Second, it is known that the prospective study identified the largest threats to safety within this trauma facility, which were: 1) ineffective communication, 2) nonessential communication, 3) distractions, and 4) planning/preparation. HFIX helped to determine if the proposed and future intervention strategies had the potential to address those problems as well as mapping exactly which types of human error might be affected by their implementation (Shappell & Wiegmann, 2006). Third, this approach allowed those on the front line, who have intimate knowledge of the existing threats to safety, to generate customized solutions to the problems they face on a regular basis on the "shop floor" (i.e., the trauma suite). Further, this approach fostered team building, a sense of ownership, and employee empowerment and accountability (Leape, 2014; Stolzer, Halford, & Goglia, 2008).

Over 90 intervention strategies were conceived during the MKE, all of which represented tailored solutions aimed at reducing the four specific types of threats identified as most detrimental to the delivery of trauma care. The FACES ranking task and the three-dimensional nature of the matrix, which are unique strengths of the HFIX model, helped narrow down the list to 34 potential interventions. In other words, these final 34 intervention strategies afforded stakeholders the best opportunity to fix their identified problem areas and were based on both empirical findings as well as the philosophical views of the "experts" involved. Obviously, not all 34 interventions could be introduced simultaneously. Therefore, this number was reduced to a more manageable collection of interventions by identifying co-occurring intervention ideas suggested by the MKE participants and then developing central themes. This thorough review led to the grouping of 19 out of 34 of the highest-ranking interventions into four central themes, which were ultimately selected by the TSM and TPMD for full implementation. These selected interventions were: 1) the introduction of a role identification system utilizing stickers to identify team member roles and names; 2) a formal leadership and teamwork training; 3) a pre-arrival checklist/brief and debrief; and 4) the establishment of standardized communication protocols.

All of the intervention strategies generated in the MKE and the final four interventions selected for implementation revolved around a common theme. They are about changing patterns of behavior rather than attempting to modify the individual's core personality. It is unacceptable for personality to be used as an excuse for unsafe behavior at work. Instead, the chatty extrovert may have to learn to talk less and listen more and the shy introvert may need to start sharing their thoughts about team goals and planned actions. Equally, the insecure millennial may have to gain the confidence and practice speaking up when they think the team leader is making an error (Flin, O'Connor, & Crichton, 2008).

A comprehensive account of the development of these four highly specialized interventions slated for implementation are described next in detail. A multitude of resources were surveyed from psychological and human factors material as well as a vast amount of healthcare literature and guidebooks from a wide range of HROs (e.g., aviation, military, maritime, mining, nuclear power, auto racing), which are organizations who achieve exceptionally high levels of reliability (Hines, Luna, Lofthus, Marquardt, & Stelmokas, 2008). Most importantly, in order to achieve success, an in-depth understanding of the interventions as well as the complex interactions and dynamics involved in the process is essential (Wiegmann, 2015).

By introducing these four data-driven interventions, the prospective collection of disruption data in the post-intervention phase should reflect a change in practice particularly as it relates to: 1) ineffective communication, 2) nonessential communication, 3) distractions, 4) planning/preparation. Comparison of disruption frequencies between the pre-intervention and post-intervention phases allowed researchers to gauge the effectiveness of these interventions through real-time monitoring in a quantitative, data-driven manner. The thrust of this current study, and perhaps more important than the actual results themselves, is that this successful process may serve as a model for others to learn from and follow in their selection of appropriate intervention ideas and implementation strategies. The SSMP provides a reliable tool for organizations to measure their own risk so that they can begin thinking rationally and clearly while planning their implementation strategies (Stolzer, Halford, & Goglia, 2008).

Shappell and Wiegmann (2006) conclude their discussion of the HFIX model with a quote from Reason (2000) “[Human errors] are like mosquitos. They can be swatted one by one, but they still keep coming. The best remedies are to create defenses and to drain the swamps in which they breed” (p. 769). To take it a step further and drawing on an analogy from Shappell and Wiegmann (2006), the RIPCHORD-TWA taxonomy provides a view of the swamp and HFIX makes sure the right swamps are drained.

Intervention Development

First, it is important to note the “experimental laboratory” borrowed for this current study was a naturalistic setting where the researchers had little control over the setup, environment, and inner workings of the people’s behaviors observed, the specific tasks, or the future evolution of the project. The medical human factors researchers provided guidance to key decision makers/administrators where necessary and appropriate. For the most part, they were accommodating. However, ultimately, the project catered to their time schedule, needs, and final decisions.

The NLT course was created in an effort to improve communication and collaboration and incorporated important concepts such as strong leadership, teamwork, and communication. McCulloch, Rathbone, and Catchpole (2011) performed a systematic literature review on the beneficial effects of teamwork and communication training for healthcare staff and found weak evidence of improving safety or clinical care mainly due to disparate measurement techniques and design limitations. However, the researchers went on to suggest that those studies with a stronger intervention (i.e., high quality teamwork training) provided more positive results and lasting improvements in technical and clinical performance specifically in the reduction of errors. On the other end of the spectrum, teamwork training based on CRM principles, at the very least, seemed to improve cooperation and communication among team members over the long term (i.e., several months). There is no doubt that teamwork and communication training is a complex intervention, and at this time, there are no clear recommendations as to the type of training that should be provided and how (McCulloch, Rathbone, & Catchpole, 2011). Perhaps this current study provides the scientific evidence that data-driven interventions developed in a systematic manner will, in the end, produce real, trackable, and measurable benefits.

The two-hour comprehensive course was designed using several resources which included human factors principles and evidence-based fundamentals, including AHRQs TeamSTEPPS® (AHRQ, 2016), Trauma Team Dynamics (Gillman et al., 2016), and Values Coach, Inc. (Tye, n.d.), in addition to well-recognized research in the field. First and foremost, the course illustrated the strengths and weaknesses of individual leaders in the trauma suite, including the lack of leadership, which was previously identified in the pre-intervention phase of observation and data analyses as a possible source of observed coordination disruptions. The trauma surgeon is considered the discernible team "captain," however, due the structure of this particular trauma system (i.e., Level II), the trauma team is considered non-intact. Therefore, the trauma process lends itself better to the interchangeable assignment of a leader, which lends to nomination of the nursing staff, specifically the primary trauma nurse, who is assigned the task of scribe, or nurse recorder (Flin, O'Connor, & Crichton, 2008; Sakran et al., 2012). This individual is always present at the beginning of the case, whereas the trauma surgeon may not be.

Emphasis was placed on establishing rules of engagement, effective leadership goals, and team expectations, including re-visiting nursing roles and responsibilities, with a key focus on what comprises high-performing teams and the interplay between an individual's positive attitudes, exceptional behaviors, and enhanced cognitions, also known as the ABCs of teamwork, during the delivery of trauma care (Salas et al., 2009; Weaver et al., 2010). A plethora of demonstrations were presented to foster the recognition of compensating for team members' bias and weakness and how it relates to the concept of inattentional blindness (Chabris & Simons, 2010).

Communication protocols and information exchange strategies were simulated and practiced during the course, which integrated case scenarios, role play, and prepared examples. The need for a nurse to assert communicative authority with hierarchical figures such as trauma surgeons and ED physicians was rehearsed with an opportunity for healthy feedback from both the instructor and peers. Other high-risk industries (e.g., aviation, military, maritime, nuclear power, auto racing) were looked to as exemplars and compared and contrasted with trauma care. In particular, EPTs, which are used regularly to achieve high reliability and zero error rates, were introduced. These EPTs included: 1) a team readiness check-in, 2) pre-arrival brief/debrief, 3) call outs, 4) closed-loop communication and read backs, 5) CUS technique, 6) two-challenge rule, 7) redundancy and choice vocabulary, and 8) sterile cockpit rule (i.e., elimination of nonessential communication) (see Appendices D-J). Patient safety, organizational culture, and culture change were also themes that were emphasized throughout the course curriculum.

In summary, the multiple methods employed to assess the NLT, the pre- and post-tests and the evaluation questionnaire, provided supporting evidence regarding the effectiveness of the training. The difference between the pre-test scores and the post-test scores indicated that participants gained novel knowledge and learned new skills that will lead to enhanced patient care and/or changed practices. Furthermore, the high evaluation ratings and comments received indicated that attendees were very satisfied with the content and delivery of the training.

CHAPTER 4

POST-INTERVENTION PHASE AND COMPARATIVE ANALYSES

Introduction

To determine the effects of the four data-driven interventions the pre-intervention *threat windows* data analysis was compared to data collected post-intervention. The overarching question was: Have those areas regarded as high in disruption frequency and most detrimental been mitigated by the systematic introduction of the selected interventions? In other words, were the interventions effective in addressing and potentially reducing those disruptions threatening the optimal delivery of trauma care?

The post-intervention phase of the study focused on evaluating the effectiveness of the interventions put in place through prospective observation once again and conducting subsequent analyses of FD data to measure the overall changes post-intervention. If the results revealed that the interventions were not effective, the SSMP model developed as part of this current study is iterative in nature, thus, researchers can pinpoint exactly where the problems lie, then go back to the drawing board to generate a series of new potential solutions in order to “try, try, and try again”, as the old adage goes.

This prospective study previously identified several types of threats that are known contributors to patient harm, most notably communication failures, interruptions, and coordination breakdowns. Results of the pre-intervention phase indicated that these types of threats were occurring at unacceptable levels in a Level II trauma center. While the identification of the major types of FDs is clearly important, this alone does not provide the level of resolution necessary to generate data-driven interventions. The researchers conducted a fine-grained analysis of the data by classifying it into minor RIPCHORD-TWA categories, separating the data by phase of care (resuscitation and imaging). Thus, four specific types of threats were isolated and deemed to have the most detrimental impact on quality and efficiency: 1) ineffective communication, 2) nonessential communication, 3) distractions, and 4) planning/preparation. In response, four evidence-based interventions were generated and implemented, aimed at mitigating those particular process inefficiencies threatening the delivery of optimal care to the critical patient. After implementing carefully designed and developed, data-driven interventions in a systematic manner, researchers anticipated observing, a quantifiable reduction in those most prevalent and detrimental threats.

This current study emphasizes the utility of FD data in that it serves as an objectively measurable outcome as well as the basis for seeking continuous improvement. The FDs represented *threat windows*—left unchecked, these *threat windows* not only have the potential to become routine and commonplace in the system, but they may also negatively influence a caregiver's ability to counteract subsequent disruptions or major events (Boquet et al., 2017b; Cohen et al., 2016; Palmer et al., 2013; Wong et al., 2007). Ultimately, this approach afforded researchers the ability to address inefficiencies proactively. This technique serves to eliminate, or at the very least mitigate, the breeding grounds for these threats, which have been correlated with the genesis of adverse events and errors in the first place.

In recent years, the healthcare industry has placed great emphasis on analyzing adverse events and errors and their relationship to negative patient outcomes, focusing more on the outcomes than on processes. Despite enormous efforts, the medical community still struggles to reduce patient morbidity and mortality directly related to preventable medical mistakes (James, 2013; Makary & Daniel, 2016). In other words, concentrating the focus solely on outcomes and adverse events has failed to make medicine “safer.” Naturally, the next step would be to understand why this is the case.

First, while these measures are noteworthy, they focus on incidents after they have occurred and the patient has already been harmed (Hildebrand, 2014). This reactive course of managing errors and adverse events is no different than treating an already sick patient. It makes more sense to act proactively by identifying system weaknesses that precede errors, rather than waiting for errors to occur. Much like a true SMS, the most important role is not the analysis of a particular event, instead it is exposing the precursors of such an event (Stolzer, Halford, & Goglia, 2008). Second, these reactive measures often require large-scale studies and a high number of participants to see significant results. Third, in the general scheme of things, sentinel events and reportable medical errors are rare. In contrast, disruptions and threats occur much more frequently and are observable during daily practice. Fourth, the stigma associated with the capture of adverse events and errors has the potential to lead to blame, which may stifle exploratory efforts by limiting the focus of the investigation to the “sharp end of the spear.” Finally, outcome measures such as reductions in medical errors, adverse events, and mortality are remote outcomes that are lagging indicators. Thus, they do not reveal much about the real-time complications occurring on the ground and the effectiveness of the interventions implemented (Hildebrand, 2014).

If we are to overcome these limitations, and contribute lasting improvements to creating a safer healthcare system, the approach to solving the problem must change.

Improving the “communication culture,” remediating flawed coordination, and counteracting distractions are all imperative modifications because of their insidious nature and pervasiveness. Patients deserve a healthcare without the worry of being harmed by the system itself. Perhaps the approach taken in this current study, which is armed with both quantitative and qualitative results as well as an overall process for assessment, will inspire other healthcare domains to develop and support similar programs.

Method

Population

Experienced medical human factors researchers re-commenced observations at the same Level II trauma center, an East Central Florida community hospital. Due to the critical condition of incoming trauma patients, it was not possible to obtain their consent to participate in the study. The hospital’s Research Oversight Committee approved the study as a quality improvement project. It was exempt from IRB review as the focus was on disruptions involved in the trauma care process rather than clinical outcomes of the patient. In accordance with HIPAA and the PHI Privacy Rule, all health information pertaining to the patient was protected. There was no effort made on the part of the researchers to collect personal and/or identifying information specific to either the patients undergoing treatment or the hospital personnel providing care. Data extraction beyond that collected on-site was performed by the PIs holding clinical privileges at the hospital. Furthermore, all data extracted was de-identified by the PIs in accordance with HIPPA guidelines and was concerned only with demographics and processes associated with the delivery of care. Hospital staff and trauma team members were made aware of the presence and research goals of the observers (see Appendix O). Specific demographics such as gender and age, MOI, and GCS scores were recorded for each patient.

Procedure

Data collection. Beginning on July 8, 2016 and continuing through December 26, 2016 medical human factors researchers observed 52 complete ("wheels in" to "wheels out") trauma cases during normal and peak (i.e., Biketoberfest) operational times. The researchers recorded FDs in the same manner in the previous 65 trauma cases observed. FDs were operationally defined as those events that result in a disturbance in a team member's progress or any other delay. Researchers possessed medical or human factors background or both and underwent a comprehensive educational process to ensure they can properly identify disruptions and process inefficiencies. In addition, the hospital adheres to strict ethical standards for the use of human participants in conducting research, therefore, researchers were required to complete the IRB training, an online training module through CITI.

Prospective data collection began at the time the patient arrived in the trauma resuscitation bay. Data collection continued through imaging and terminated upon disposition to surgery, the medical floor unit, or the ED. Observers recorded the time the patient was wheeled into the trauma resuscitation bay and the time they were wheeled out. Likewise, the time was noted when the patient was wheeled into and out of imaging. For recording purposes, the patient's transport time between resuscitation and imaging was considered still under the auspices of resuscitation since an official handoff to imaging has not yet occurred. Lastly, observers were provided with an observational template to assist them in documenting whether the implemented interventions were carried out during the observed case, namely: 1) role identification system utilizing stickers to identify team member roles and names, 2) quality of the pre-arrival brief, and 3) communication protocols (see Appendix P).

FD observations were documented in real-time in a free-response format using paper and pencil or digitally recorded using an electronic tablet. Observations and time spent in resuscitation and imaging were transferred to a Microsoft Excel Workbook for consensus coding and subsequent statistical analysis.

Data coding and classification. Disruptions were classified once again using the human factors taxonomy RIPCHORD-TWA (Boquet et al., 2017b; Cohen et al., 2016) by at least two or more human factors researchers through consensus coding.

Data analysis. Descriptive statistics were calculated, including frequency of the threats observed and percentage of disruptions by category. Likewise, inferential statistics were calculated in regards to comparing frequency data between baseline1/pre-intervention and baseline 2/pre-intervention, pre-intervention and post-intervention phases, and clinical phases of care (resuscitation and imaging). The time elapsed during the case, whether in resuscitation or imaging, as well as the number of threats that occurred over an elapsed period of time were also calculated. These through-put measures provided an estimate of how often FDs occurred per minute, allowing researchers to gauge the “window of opportunity” for potential adverse events to occur. Additionally, observational data was reviewed to determine how often the role identification stickers with names were donned, if the pre-arrival brief was conducted, and the quality of the pre-arrival brief. The pre-arrival brief was considered effective if Steps 1, 2, and 3 were completed (see Appendix E).

Additional Interventions Introduced During the Post-Intervention Phase

Throughout the post-intervention phase, system-wide interventions continued to be introduced as part of the "trauma optimization project," or TOP. Table 4.1 includes a listing and description of the interventions introduced, when they were implemented, and if they were directly related to the MKE (see Table 4.1). One initiative that occurred during this phase of the study stands out because it involved a major change within the trauma program. Hospital administrators decided to end contractual services with the long-standing trauma surgeon group and contract with a new trauma surgeon group. This transition began on October 17, 2016, nearly halfway through the post-intervention phase observational period. It is important to note that two of the trauma surgeons from the original contracted group remained on staff, however, three new trauma surgeons joined the team.

Table 4.1 List of Additional Interventions Introduced During the Post-Intervention Phase

Count	Date of Implementation	Intervention	Comments
34	10/14/16	Emailed "Trauma at X: A Change in Practice and a Change in Culture"-a reminder of NLT practices	Smith emailed to trauma surgeons and staff
35	10/17/16	An administrative contractual review resulted in a transition from the long-standing trauma surgical team to a new trauma surgical team (2 original trauma surgeons remained on staff, however, 3 new trauma surgeons joined	

		the team)	
36	11/6/16	Created a “Welcome to X Trauma” standard email to introduce new trauma surgeons to trauma operating procedures and expectations	Included brief information regarding sticker system, pre-arrival brief and debrief, and communication protocols; described the trauma alert criteria, arrival time, and badge reader
37	11/16/16	Revised Shift Huddle-Readiness Check-In and an accompanying email to ED nursing staff explaining the new revisions to the Check-In and how to	In response to team members who had not completed helipad training that were assisting with air transports on the roof; additionally, team members were occasionally being assigned to a trauma team w/o being TNCC trained
38	1/12/2017	Transitioning outline created and sent to key administrators by Smith in anticipation of his resignation	Email outlined expectations for continuing the helipad trainings, on-going chart review by the trauma medical director, “incentive shift” explanation, routine review of administrative policies and clinical practice trauma guidelines, and maintaining the Multidisciplinary Trauma Conferences, Trauma Committee meetings, and Peer-Review meetings

Post-Intervention Phase Results

Analysis of FD Data

Of the total sample of 52 post-intervention trauma cases, the average age of the patient (male=38, female=14) was 52.5 (s=19.7). The mean GCS score of the sample cases was 12 (s=5.1). A total of 32, or 62% of the trauma cases occurred during the first shift (7:00a.m.-7:00p.m.), and 20, or 38% occurred during the second shift (7:00p.m.-7:00a.m.). Six of the trauma cases, or 12%, were observed during peak operational times (i.e., Biketoberfest). Additionally, five of the observed cases, or 10%, were considered multiple traumas, meaning more than one trauma patient arrived at the same time and were treated simultaneously by multiple trauma teams. The breakdown for MOI is as follows: falls (11 or 21%), motor vehicle crashes (15 or 29%), motorcycle crashes (7 or 13%), stab wounds (4 or 8%), gunshot wounds (1 or 2%), and other/unspecified (14 or 27%). Two cases labeled “other” MOIs involved two simultaneous cases of trauma patients who were in a small airplane crash, one patient being the pilot, and the other being the passenger. Nine of these “other” cases involved pedestrians or bicyclists that were struck by a motor vehicle. The post-intervention phase data sample contained no cases involving assault or burn patients (see Table 4.2).

A total of 939 disruptions were identified during the 52 observed cases (2,081 patient contact minutes). This translated to 18 disruptions per case (s=7.5), or approximately one disruption occurred every two minutes. The average total treatment time per case was 40 minutes (s=16). A total of 486 disruptions were identified in resuscitation alone (954 patient contact minutes), with treatment time averaging just over 18 minutes (s=12.5); this translated to more than nine disruptions per case (s=6.3). In imaging, there were a total of 453 identified disruptions (1,113 patient contact minutes), with treatment time averaging just over 21 minutes (s=9.89); this translated to almost nine disruptions per case (s=4.8). Furthermore, the overall ratio of the number of FDs per minute, or the through-put measure, was 0.47 per minute. More specifically, the through-put ratios were 0.53 per minute in resuscitation and 0.42 per minute in imaging.

Table 4.2 Post-Intervention Phase Patient Demographics

Pt	Age	Sex	Mechanism Of Injury	GCS	E	V	M	Event	Multiple Trauma?	Shift
66	32	F	Vehicle vs. pedestrian (other/unspecified)	8	1	3	4			1st
67	67	M	Motor vehicle crash	15	4	5	6			1st
68	25	M	Motor vehicle crash	3	1	1	1			2nd
69	68	M	Scooter (motorized/ motorcycle crash)	3	1	1	1			1st
70	61	F	Gunshot wound	3	1	1	1			2nd
71	58	M	Machine tool (other/unspecified)	15	4	5	6			1st
72	8	M	Motor vehicle crash	15	4	5	6		Yes	2nd
73	51	F	Fall	3	1	1	1		Yes	2nd
74	57	M	Vehicle vs. bicycle (other/unspecified)	15	4	5	6			2nd
75	58	M	Motor vehicle crash	3	1	1	1			1st
76	44	M	Motor vehicle crash	15	4	5	6			1st
77	49	F	Motor vehicle crash	3	1	1	1			1st
78	86	M	Penetration (stab wound)	11	4	1	6			1st
79	40	M	Motor vehicle crash	15	4	5	6			1st
80	57	M	Unknown (other/unspecified)	3	1	1	1			2nd
81	22	M	Motorcycle crash	3	1	1	1			2nd
82	58	M	Fall	15	4	5	6			2nd
83	18	M	Motor vehicle crash	15	4	5	6			2nd
84	90	F	Motor vehicle crash	15	4	5	6			1st
85	71	F	Motor vehicle crash	15	4	5	6			1st
86	43	F	Fall	13	4	4	5			1st
87	53	M	Fall	15	4	5	6			1st
88	81	F	Motor vehicle crash	15	4	5	6	Biketoberfest		1st
89	23	M	Vehicle vs. pedestrian (other/unspecified)	15	4	5	6	Biketoberfest		1st
90	16	M	Sports (other/unspecified)	15	4	5	6	Biketoberfest		2nd
91	84	M	Fall	15	4	5	6	Biketoberfest	Yes	1st
92	51	M	Motorcycle crash	15	4	5	6	Biketoberfest		2nd
93	45	F	Motorcycle crash	15	4	5	6	Biketoberfest		1st
New Contracted Trauma Surgeon Group Took Over										
94	65	M	Motorcycle crash	3	1	1	1			1st
95	63	M	Vehicle vs.	3	1	1	1			1st

			pedestrian (other/unspecified)							
96	52	M	Penetration (stab wound)	15	4	5	6			2nd
97	51	M	Pedestrian vs. vehicle (other/unspecified)	15	4	5	6			2nd
98	62	M	Penetration/blunt force (stab wound)	14	4	4	6			1st
99	35	M	Motorcycle crash	12	3	4	5			2nd
100	68	F	Fall	14	4	4	6			1st
101	32	M	Motorcycle crash	15	4	5	6			1st
102	65	M	Vehicle vs. pedestrian (other/unspecified)	11	1	4	6			2nd
103	74	M	Vehicle vs. pedestrian (other/unspecified)	15	4	5	6			1st
104	31	F	Vehicle vs. pedestrian (other/unspecified)	3	1	1	1			2nd
105	39	M	Aircraft accident (other/unspecified)	13	4	4	5		Yes	1st
106	50	M	Aircraft accident (other/unspecified)	15	4	5	6		Yes	1st
107	60	M	Fall	15	4	5	6			1st
108	23	F	Motor vehicle crash	15	4	5	6			1st
109	53	M	Fall	5	1	1	3			1st
110	61	F	Motor vehicle crash	15	4	5	6			1st
111	87	M	Fall	15	4	5	6			1st
112	63	M	Motor vehicle crash	15	4	5	6			2nd
113	59	M	Vehicle vs. bicycle (other/unspecified)	15	4	5	6			1st
114	66	M	Fall	13	4	3	6			2nd
115	25	M	Penetration (stab wound)	15	4	5	6			2nd
116	78	F	Motor vehicle crash	3	1	1	1			2nd
117	52	M	Fall	15	4	5	6			1st

Note. *n*=52 cases.

Of these 939 disruptions, post-intervention communication issues represented 32%, interruptions were comprised of 30%, and coordination issues were the third most prevalent at 18%. Layout, usability, and equipment issues included 15%, 2%, and 2% of the disruptions, respectively, in the post-intervention phase (see Figure 4.1).

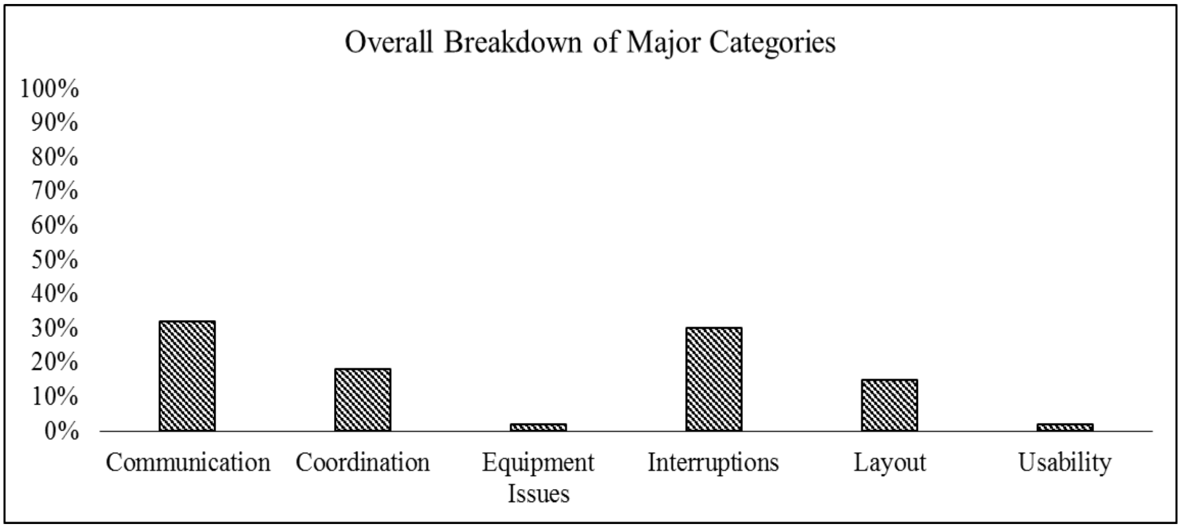

Figure 4.1. Overall Breakdown of Major Categories During the Post-Intervention Phase

Further analysis examined the difference in the post-intervention disruptions between resuscitation and imaging. First, communication disruptions occurred less often in resuscitation (27%) than in imaging (38%). Post-intervention coordination issues were also less frequent in resuscitation (16%) than in imaging (21%). In fact, layout issues (18%) rose slightly in the post-intervention phase surpassing coordination-related disruptions in resuscitation. On the other hand, interruptions during the post-intervention phase were more prevalent during resuscitation (34%) than in imaging (26%). Layout issues (see Figure 4.2).

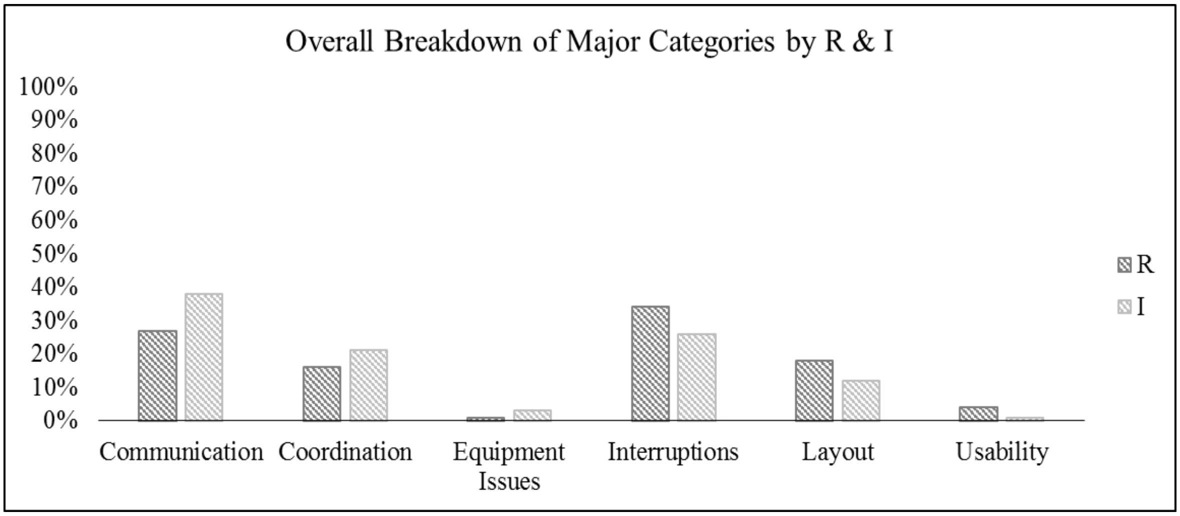

Figure 4.2. Overall Breakdown of Major Categories by Resuscitation and Imaging During the Post-Intervention Phase

In order to obtain a more detailed understanding of the types of disruptions populating each major RIPCHORD-TWA category, a fine-grained analysis of the post-intervention data was conducted. Within the major category of communication, disruptions largely consisted of the following two minor categories: nonessential communication (56%) and lack of response (25%). The remainder of the disruptions observed were distributed among ineffective communication (8%), simultaneous communication (5%), confusion (2%), lack of sharing (2%), and environmental noise (2%) (see Figure 4.3).

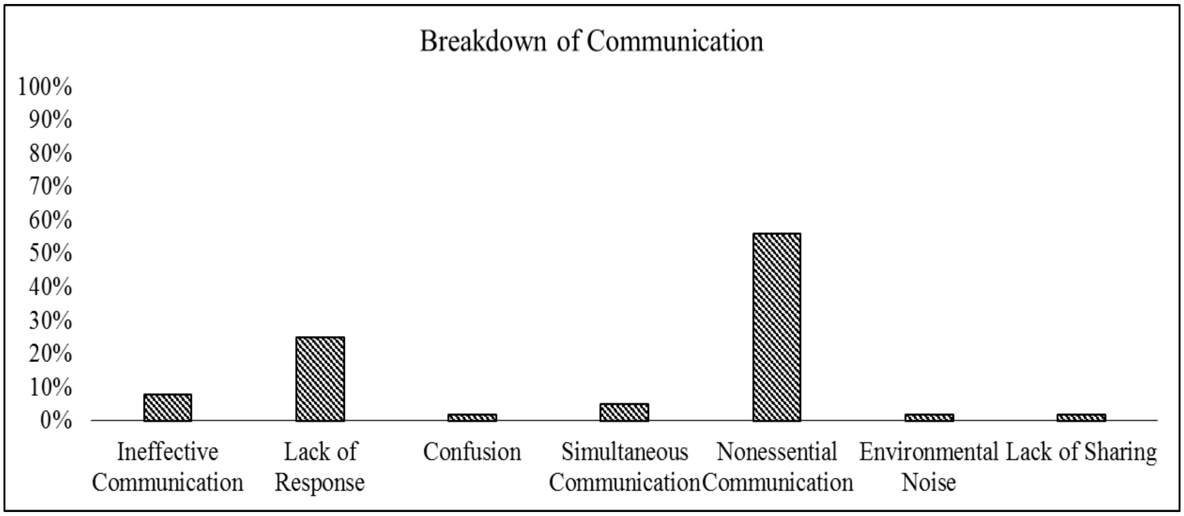

Figure 4.3. Communication Breakdown During the Post-Intervention Phase

The two most heavily populated minor categories within post-intervention interruptions were: distractions (29%) and spilling/dropping (22%). These were followed by teaching moments (15%), equipment/supplies (11%), alerts (11%), task deviation (7%), searching activities (3%), and interaction with biohazards (2%) (see Figure 4.4).

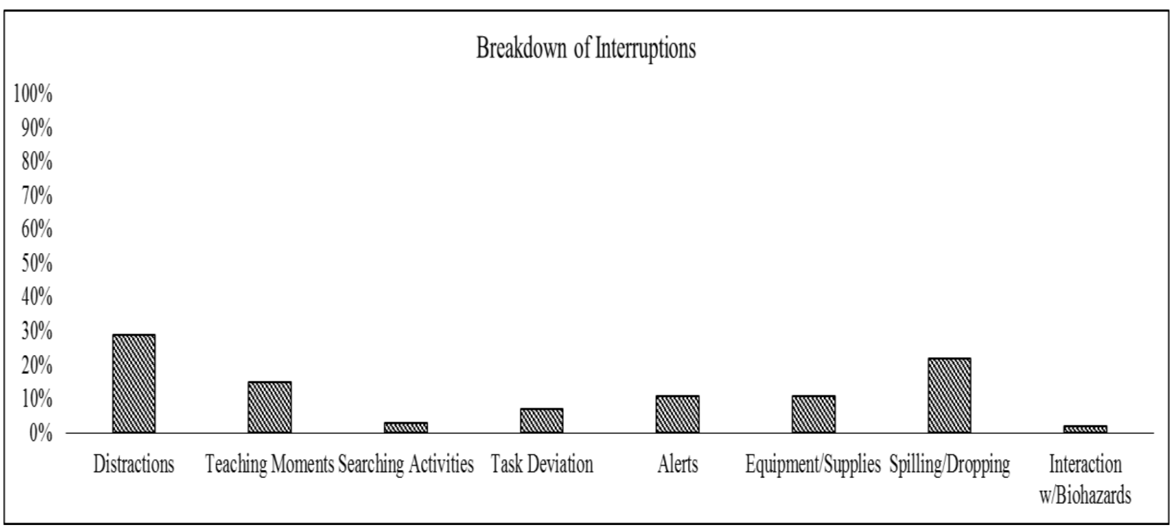

Figure 4.4. Interruptions Breakdown During the Post-Intervention Phase

The two minor categories making up the bulk of post-intervention coordination issues consisted of: planning/preparation (35%) and charting/documentation (35%). These categories were followed by unknown information (12%), personnel not available (11%), protocol failure (5%), and personnel rotation (1%) (see Figure 4.5).

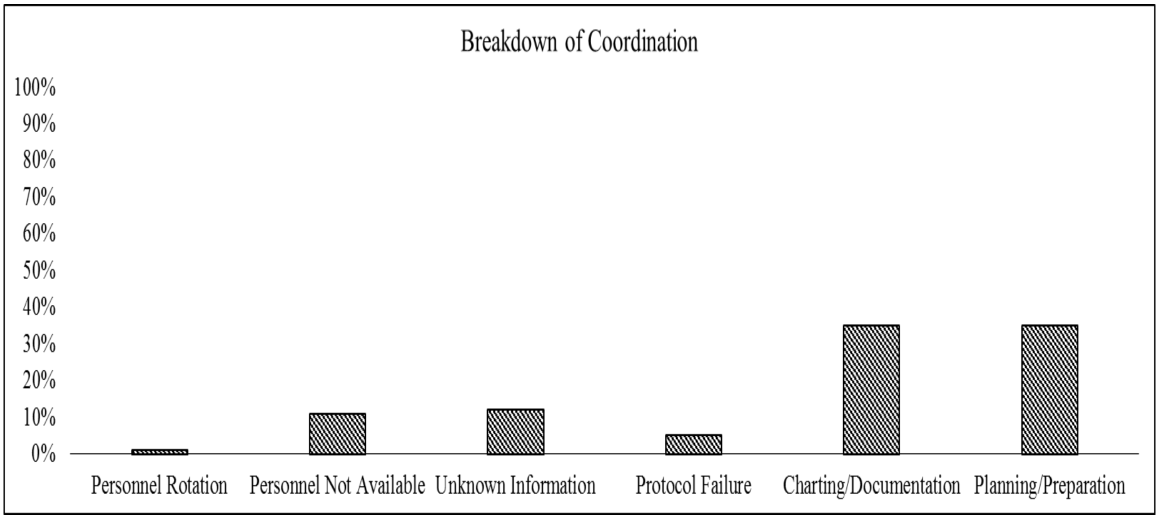

Figure 4.5. Coordination Breakdown During the Post-Intervention Phase

Post-intervention disruptions related to layout included inadequate space (40%), wires and tubing (37%), equipment positioning (13%), furniture positioning (6%), permanent structures positioning (5%), and connector positioning (0%) (see Figure 4.6). The minor category distribution in the usability category was computer design (55%), equipment design (20%), barrier design (15%), packaging design (10%), data entry (non-computer) design (0%), and surface design (0%) (see Figure 4.7). The only minor category populated in the major category of equipment issues was general equipment (100%) (see Figure 4.8).

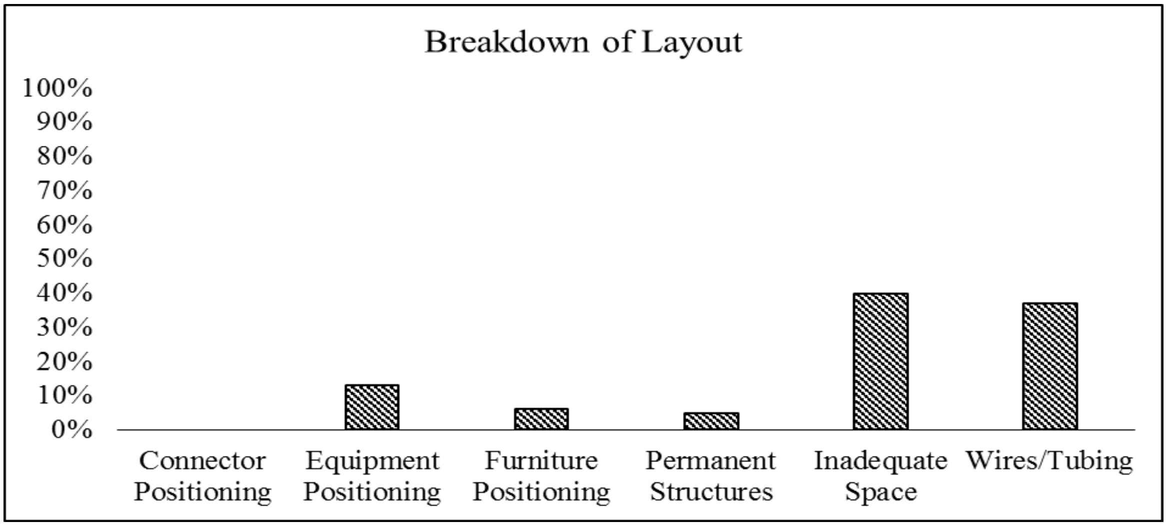

Figure 4.6. Layout Breakdown During the Post-Intervention Phase

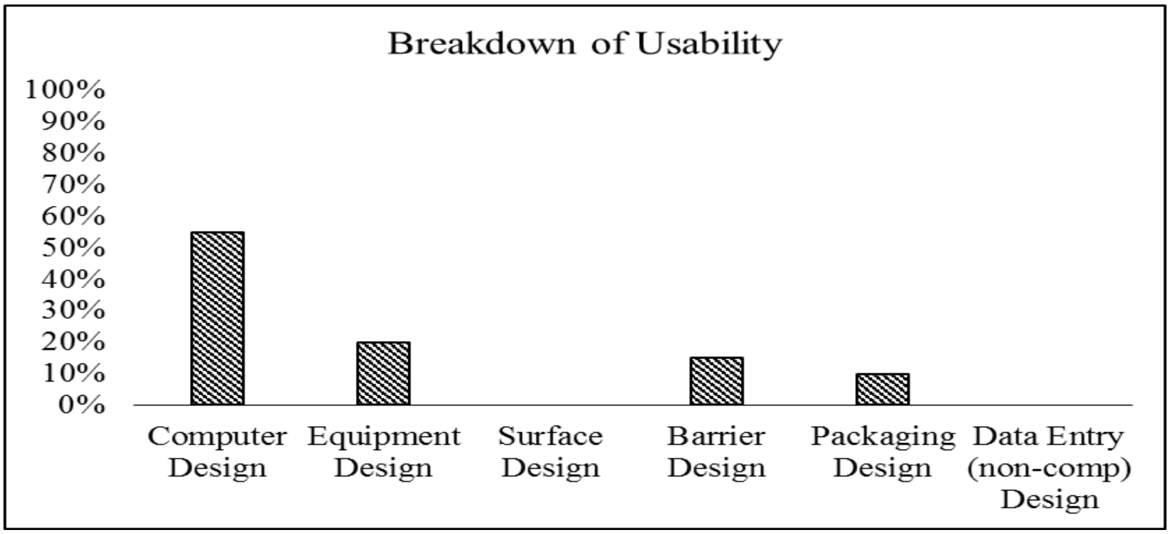

Figure 4.7. Usability Breakdown During the Post-Intervention Phase

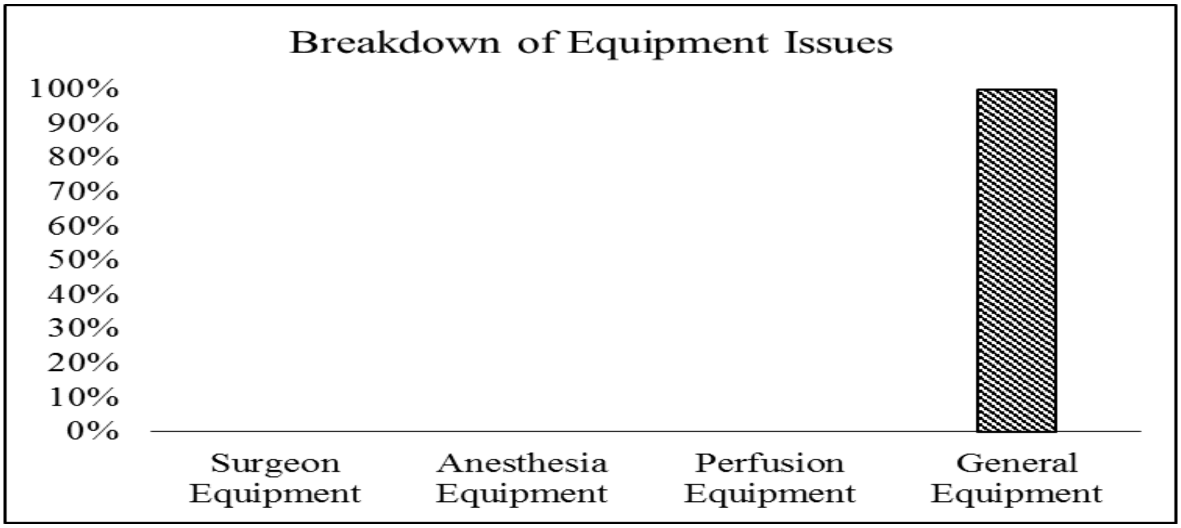

Figure 4.8. Equipment Issues Breakdown During the Post-Intervention Phase

Differences between FDs in resuscitation and imaging were also observed. The most prevalent type of post-intervention communication disruption observed in resuscitation was lack of response (41%), however, it was not observed as often in imaging (13%). However, in imaging, nonessential communication (76%) represented the largest threat to communication, but not nearly as much in resuscitation (28%). Finally, the next most prevalent communication issue was ineffective communication, but to a much lesser degree, occurring more in resuscitation (15%) than in imaging (3%) (see Figure 4.9).

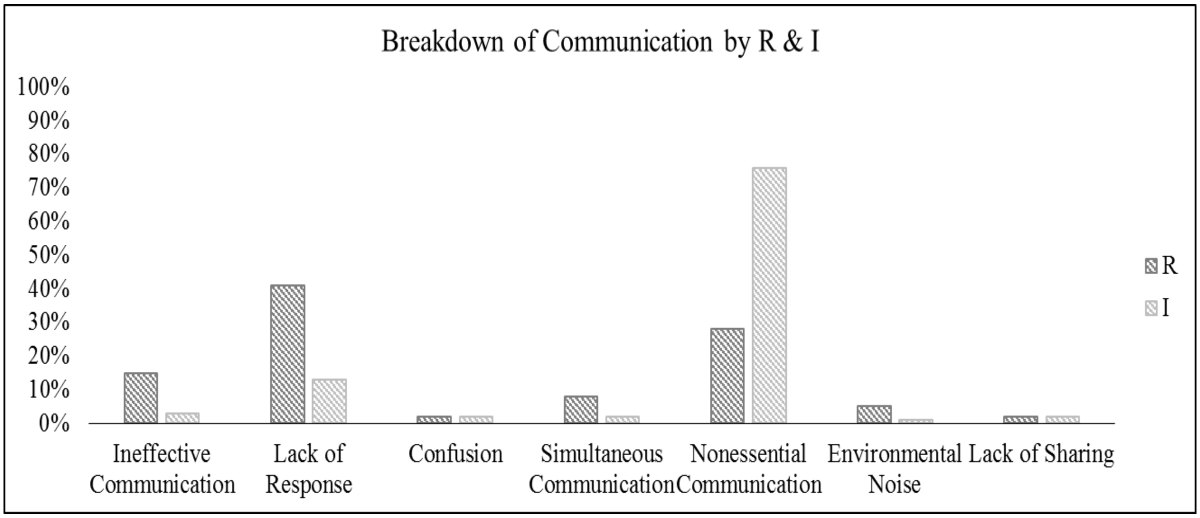

Figure 4.9. Communication Breakdown by Resuscitation and Imaging During the Post-Intervention Phase

With respect to interruptions, the most frequently occurring post-intervention disruption in resuscitation was spilling/dropping (29%), however, it occurred less frequently in imaging (11%). Next, distractions posed the largest threat in imaging (44%), but not quite as often in resuscitation (19%). Equipment/supplies (14%) and alerts (14%) were the next most prevalent issues in imaging, occurring equally as frequently (see Figure 4.10).

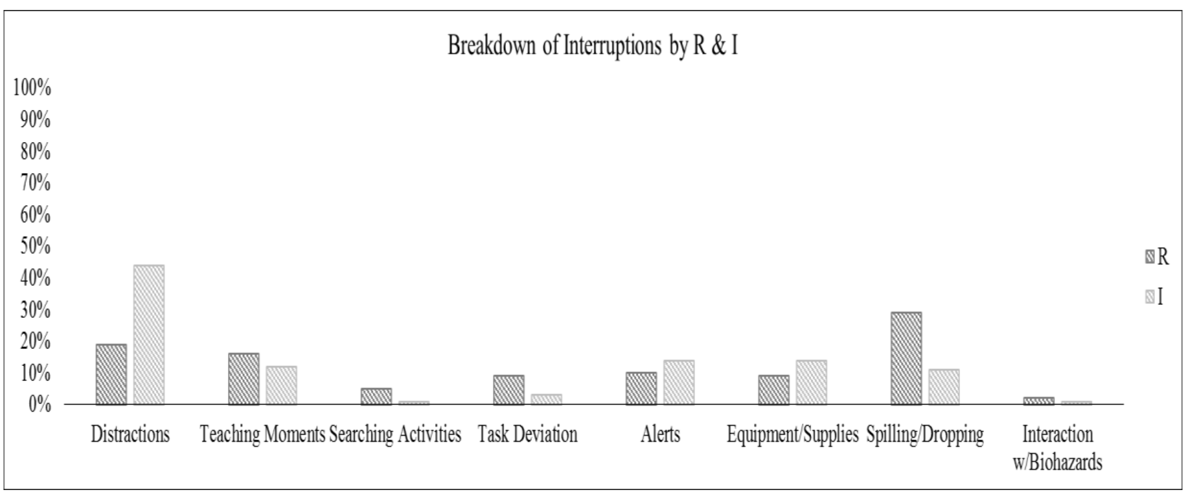

Figure 4.10. Interruptions Breakdown by Resuscitation and Imaging During the Post-Intervention Phase

In resuscitation, breakdowns in post-intervention coordination were mostly related to planning/preparation (46%) as compared to 27% in imaging. On the other hand, issues surrounding charting/documentation occurred most frequently in imaging (51%) as compared to resuscitation (16%). Following planning/preparation issues, personnel not available was the next largest coordination issue in resuscitation (13%), whereas it represented 10% of the disruptions in imaging. Similarly, unknown information was the next most prevalent disruption in imaging (13%), while it represented 11% of the disruptions in resuscitation (see Figure 4.11).

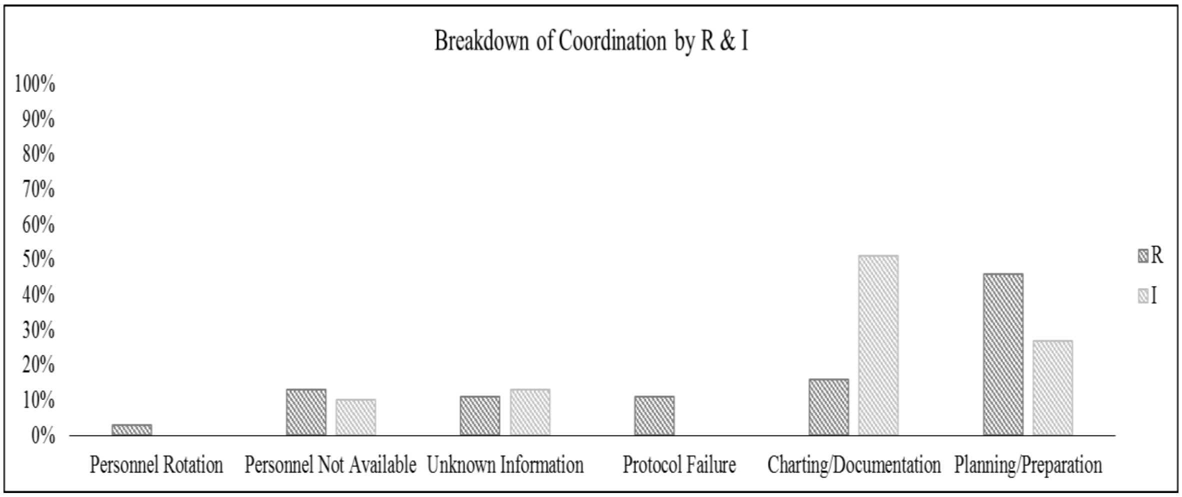

Figure 4.11. Coordination Breakdown by Resuscitation and Imaging During the Post-Intervention Phase

There were several differences involving the specific types of layout issues involved in post-intervention resuscitation and imaging. Inadequate space was the largest contributor to disruptions observed in resuscitation (57%), but was not necessarily a major factor in imaging (11%). On the other hand, wires and tubing issues made up 68% of the disruptions in imaging, whereas they were not as prevalent in resuscitation (18%). Equipment positioning disruptions occurred slightly more often in resuscitation (14%) than in imaging (11%). Finally, furniture positioning issues occurred evenly in both resuscitation and imaging (6% each) (see Figure 4.12).

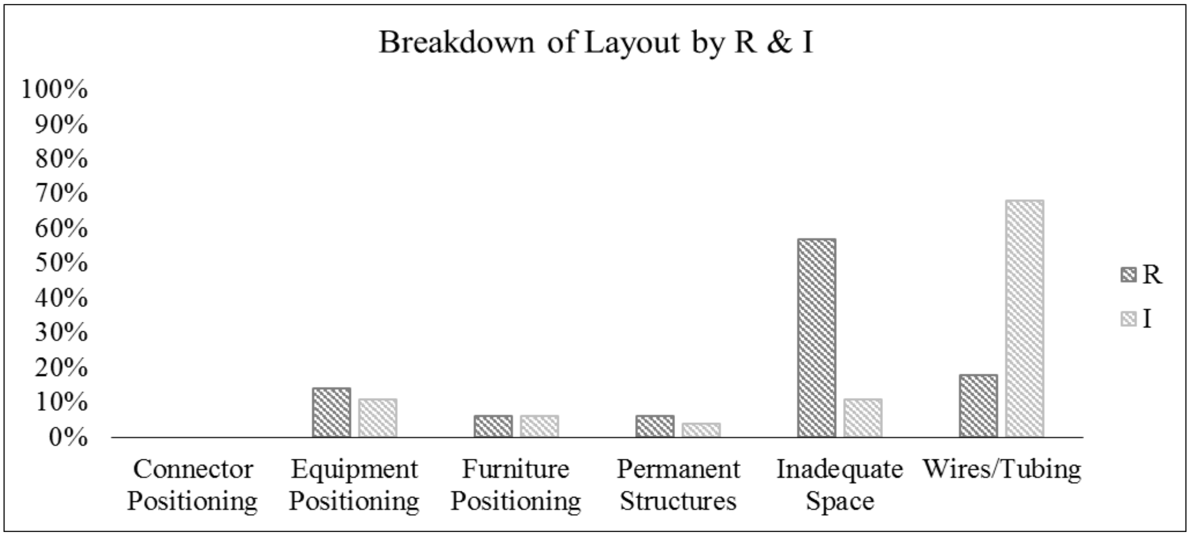

Figure 4.12. Layout Breakdown by Resuscitation and Imaging During the Post-Intervention Phase

The final two categories, usability and equipment issues were both lightly populated, each representing only 2% of post-intervention disruptions. With respect to usability, the most populated minor category was computer design (59%) in resuscitation, followed by equipment design (18%), barrier design (12%), and packaging design (12%). However, the most prevalent disruptions in imaging were equally distributed among computer design, equipment design, and barrier design (33% each) (see Figure 4.13). Finally, equipment issues were made up entirely of general equipment issues with slightly more disruptions occurring in imaging (3%) than in resuscitation (1%) (see Figure 4.14).

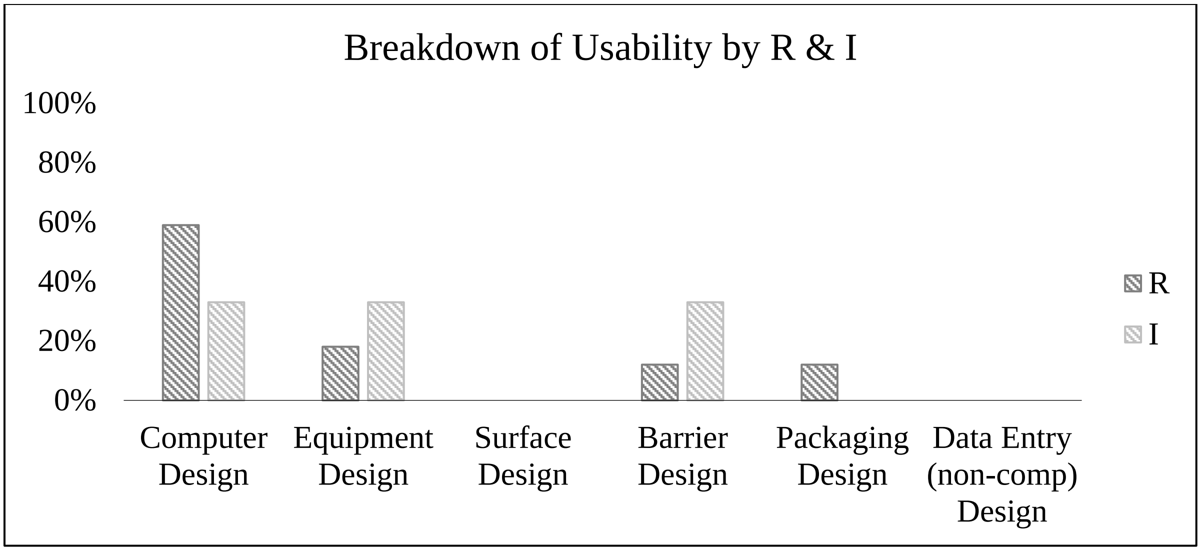

Figure 4.13. Usability Breakdown by Resuscitation and Imaging During the Post-Intervention Phase

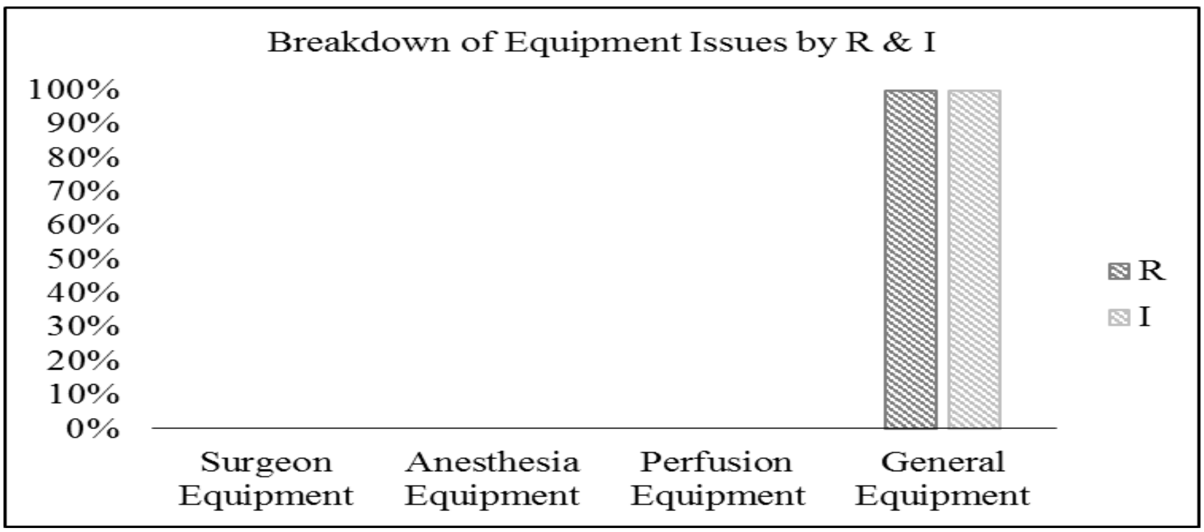

Figure 4.14. Equipment Issues Breakdown by Resuscitation and Imaging During the Post-Intervention Phase

Pre-Intervention and Post-Intervention Phases Comparative Analysis

Analysis of FD Data

The table below presents a side-by-side comparison of the patient demographic data collected during both the pre-intervention and post-intervention phases (see Table 4.3).

Table 4.3 Patient Demographics by Pre-Intervention and Post-Intervention Phases

Patient Demographic		Pre-Intervention	Post-Intervention
Gender	Male	50 (77%)	34 (73%)
	Female	15 (23%)	14 (27%)
Mean Age		41.2 (*s*=20.4)	52.5 (*s*=19.7)
Mechanisms of Injury (MOI)	Fall	15 (23%)	11 (21%)
	Motor Vehicle Crash	10 (15%)	15 (29%)
	Motorcycle Crash	26 (40%)	7 (13%)
	Stab Wound	1 (1.5%)	4 (8%)
	Assault	2 (3%)	0
	Gunshot Wound	3 (4%)	1 (2%)
	Burn	1 (1.5%)	0
	Other	7 (11%)	14 (27%)
Mean Glascow Coma Scale (GCS)		12.78 (*s*=3.9)	12 (*s*=5.1)
Multiple Traumas		4 (6%)	5 (10%)
Biker Events		32 (49%)	6 (12%)
Work Shift	1st (12 hr)	38 (58.5%)	32 (62%)
	2nd (12 hr)	27 (41.5%)	20 (38%)

Note. Pre-Intervention n=65 cases. *Post-Intervention n*=52 cases.

A total of 1,137 disruptions were identified during 65 observed cases (2,468 patient contact minutes) in the pre-intervention phase. A total of 939 disruptions were identified during 52 observed cases (2,081 patient contact minutes) in the post-intervention phase. This translated to nearly 18 disruptions per case, which was approximately one disruption every two minutes. This was slightly more than the average of 17.5 disruptions per case identified in the pre-intervention phase. The average total treatment time per case increased slightly between the pre-intervention and post-observation phases (38 minutes and 40 minutes, respectively). Likewise, the average time spent in resuscitation also increased by two minutes between the pre-intervention and post-intervention phases (16 minutes and 18 minutes, respectively). However, the average treatment time in imaging remained effectively the same between the pre-intervention and post-intervention phases (21.5 minutes and 21.4 minutes, respectively).

With respect to the overall ratio of the number of FDs per minute, or the through-put measures, there was a slight increase in the overall ratio post-intervention compared to pre-intervention phase (0.46 and 0.47, respectively). Similarly, the ratio in resuscitation also revealed an increase during the post-intervention phase compared to the pre-intervention phase (0.51 and 0.53, respectively). However, the ratios calculated for imaging remained stable throughout both observational phases (0.42 and 0.42, respectively).

The frequency of communication related disruptions during both the pre-intervention and post-intervention phases was 32%, therefore, overall, this threat was not reduced. In the post-intervention phase, interruptions comprised 30% of the disruptions, which represented a 4% increase compared to the pre-intervention phase. Coordination issues continued to be the third most frequent disruption at 18% in the post-intervention phase, a 3% decrease compared to the pre-intervention phase. Layout, usability, and equipment issues comprised 15%, 2%, and 2% of the disruptions, respectively, in the post-intervention phase. Compared to the pre-intervention phase, layout increased 1%, usability decreased 3%, and equipment issues did not change (see Figure 4.15).

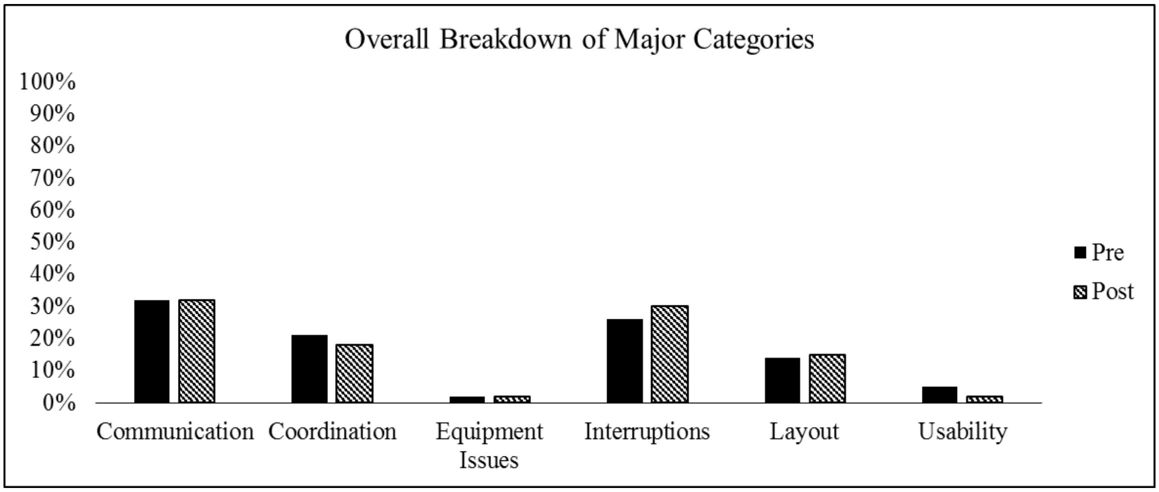

Figure 4.15. Overall Breakdown of Major Categories Comparing Pre-Intervention and Post-Intervention Phases

Further analysis examined the differences in disruptions between resuscitation and imaging during the pre-intervention and post-intervention phases. Disruptions related to the major category of communication occurred 5% less frequently in resuscitation during the post-intervention phase, while there was a 6% increase in imaging. Alternatively, post-intervention interruptions experienced a 6% increase in resuscitation, and a 3% increase in imaging. Coordination issues observed post-intervention did not differ notably in resuscitation, but occurred 5% less frequently in imaging (see Figure 4.16).

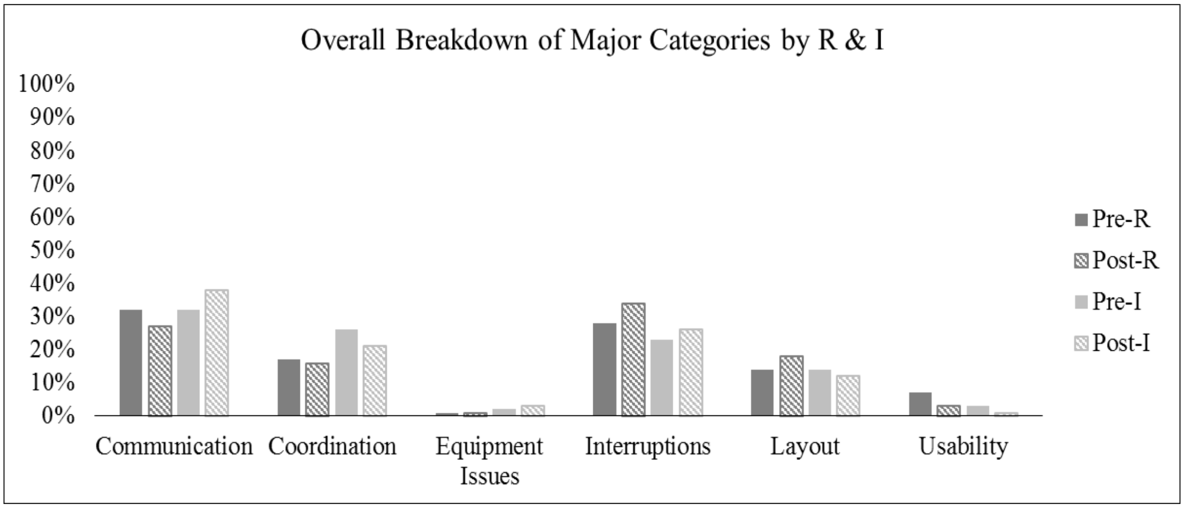

Figure 4.16. Overall Breakdown of Major Categories by Resuscitation and Imaging Comparing Pre-Intervention and Post-Intervention Phases

In order to gauge the effectiveness of the interventions introduced, the four minor categories selected for intervention were examined more closely. The data points of interest were isolated and a fine-grained analysis of the data was conducted for further comparisons.

Within the major category of communication, there was a stark difference between the data observed during the pre-intervention and post-intervention phases for the minor category, ineffective communication, resulting in a 16% reduction in disruptions. However, disruptions related to the minor category of nonessential communication increased by 19% in the post-intervention phase. Regarding the minor category of distractions within interruptions, there was an increase of 5% identified during the post-intervention phase. Within coordination, planning/preparation disruptions remained relatively unchanged as compared to pre-intervention data, only a minor increase of 1% (see Figure 4.17).

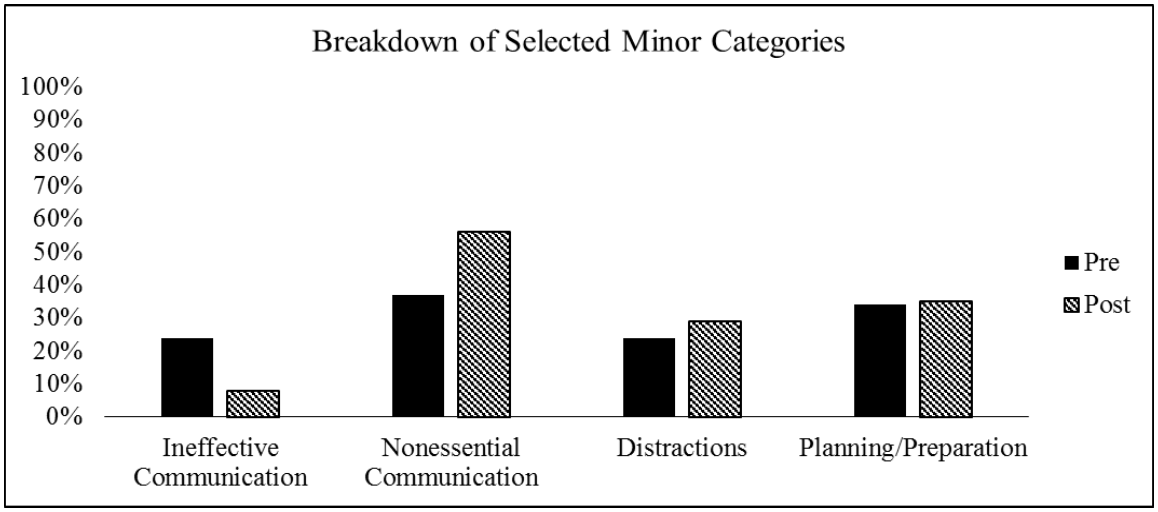

Figure 4.17. Breakdown of Selected Minor Categories Comparing Pre-Intervention and Post-Intervention Phases

The fine-grained analysis revealed differences between resuscitation and imaging during the pre-intervention and post-intervention phases. First, regarding ineffective communication issues, there was a 16% decrease in post-intervention disruptions occurring in resuscitation, and in imaging, a 14% decrease. However, there was a substantial increase in the distribution of disruptions related to nonessential communication. Researchers observed a 12% increase in resuscitation and a 21% increase in imaging post-intervention. In regards to distractions, there was a 9% increase in resuscitation and a 5% increase in imaging post-intervention. Coordination breakdowns in the data indicated there was little change in planning/preparation issues in both resuscitation and imaging (see Figure 4.18).

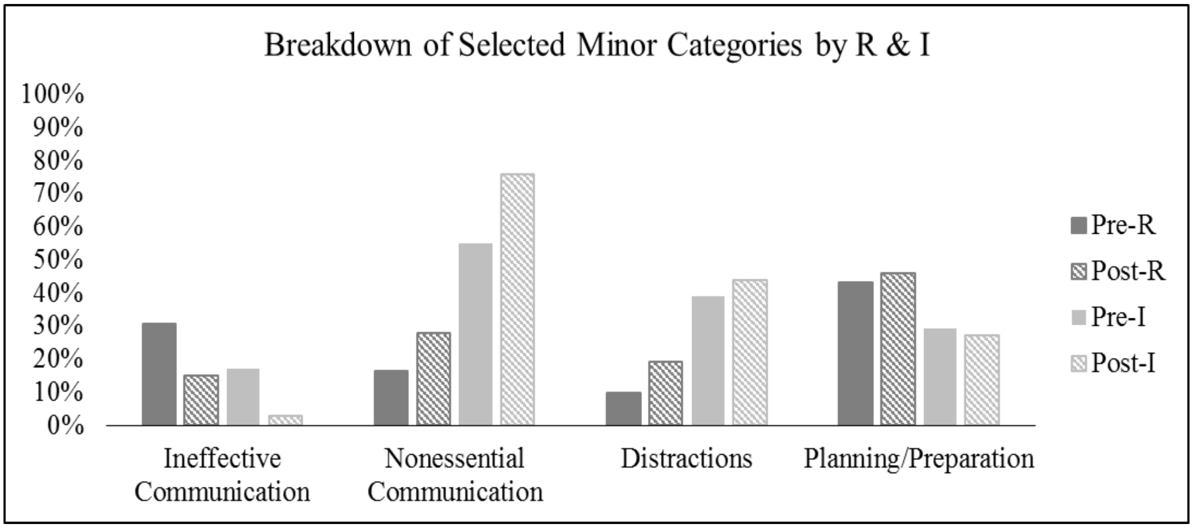

Figure 4.18. Breakdown of Selected Minor Categories by Resuscitation and Imaging Comparing Pre-Intervention and Post-Intervention Phases

Multiple-Baseline Comparative Analysis

Analysis of FD Data

Multiple measurements were made in an effort to establish a baseline and assess process changes. The baseline 1/pre-intervention consisted of an initial 34 cases (576 disruptions). The baseline 2/pre-intervention consisted of the next 31 cases (561 disruptions). Once again, the four minor categories selected for intervention were examined more closely. The data points of interest were isolated and a fine-grained analysis of the data was conducted for further comparisons.

For the minor category ineffective communication, a decrease of 15% in disruptions was observed in baseline 2/pre-intervention as compared to baseline 1/pre-intervention. However, disruptions related to the minor category of nonessential communication increased by 29% during the baseline 2/pre-intervention segment. Distraction-related disruptions increased 14% during the baseline 2/pre-intervention as compared to baseline 1/pre-intervention. Planning/preparation disruptions remained relatively unchanged between the baseline 1/pre-intervention and baseline 2/pre-intervention series, with a decrease of 2% (see Figure 4.19).

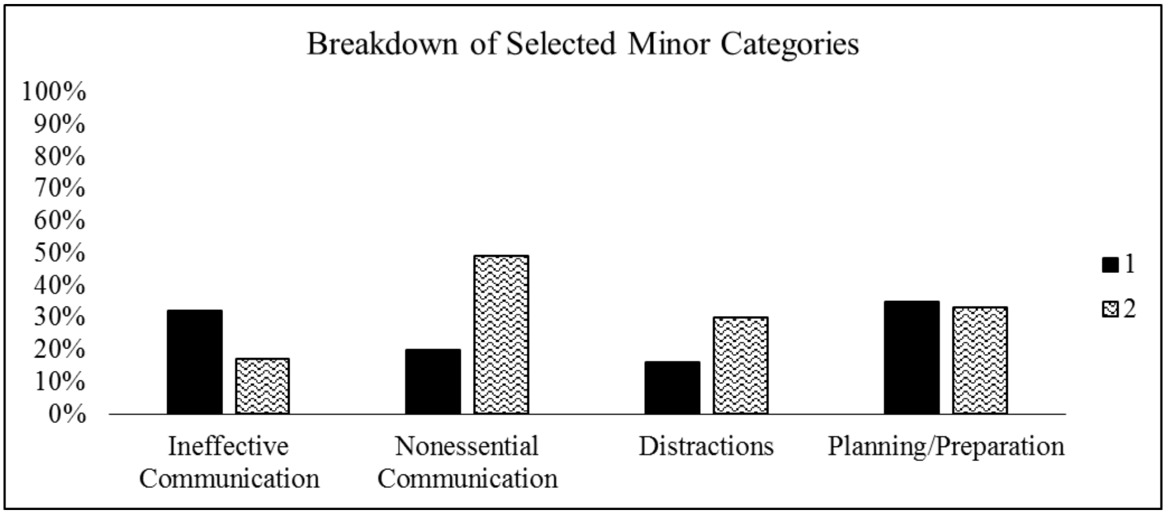

Figure 4.19. Breakdown of Selected Minor Categories Comparing Baseline 1/Pre-Intervention and Baseline 2/Pre-Intervention

The fine-grained analysis revealed differences between resuscitation and imaging during the baseline 1/pre-intervention and baseline 2/pre-intervention series. First, regarding ineffective communication issues, there was a decrease of 8% in baseline 1/pre-intervention disruptions occurring in resuscitation, and in imaging, a decrease of 18%. There was an increase of 8% in the distribution of disruptions related to nonessential communication in resuscitation and an increase of 35% in imaging during baseline 2/pre-intervention as compared to baseline 1/pre-intervention. There was little change in the disruptions related to distractions in resuscitation between baseline 1/pre-intervention and baseline 2/pre-intervention, a decrease of only 1%. However, a 25% increase in imaging occurred during the baseline 2/pre-intervention segment. Planning/preparation issues in resuscitation saw a decrease of 9% during baseline 2/pre-intervention as compared to baseline 1/pre-intervention, however, in imaging these disruptions remained about the same, only a minor decrease of 1% (see Figure 4.20).

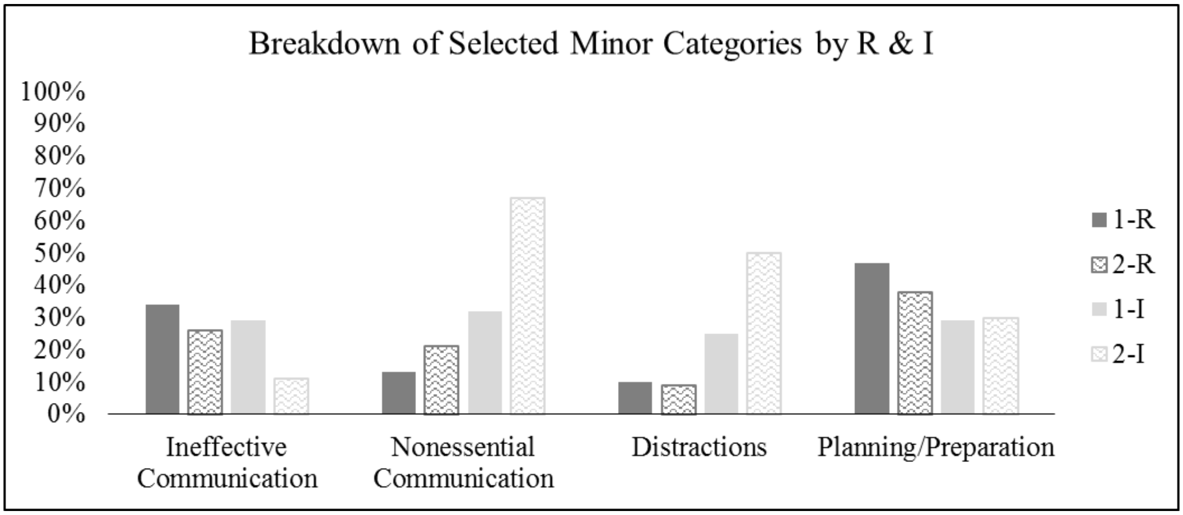

Figure 4.20. Breakdown of Selected Minor Categories Comparing Baseline 1/Pre-Intervention and Baseline 2/Pre-Intervention

Frequency Comparisons

Frequency data for the four minor categories selected for improvement was compared between the pre-intervention and post-intervention phases overall as well as in resuscitation and imaging using chi-square statistic (x^2) goodness of fit tests. Next, frequency data for the four specific areas targeted was compared between two waves of measurement prior to the implementation of interventions, known as baseline 1/pre-intervention and baseline 2/pre-intervention, both overall and during the clinical phases of care (resuscitation and imaging) using chi-square statistic (x^2) goodness of fit tests. Alpha levels were adjusted accordingly to maintain the family-wise error rate at $p<=.05$.

Pre-Intervention and Post-Intervention Phases Analysis

Overall. For the targeted minor category ineffective communication, a chi-square goodness of fit test indicated there was a significant decrease in the frequency of ineffective communication disruptions identified in the post-intervention phase (8%) as compared with the pre-intervention phase (24%), x^2 (1, n=2076) = 24.412, p=0.00.

For the targeted minor categories of nonessential communication and distractions, a chi-square goodness of fit test indicated there was a significant increase in the frequency of both nonessential communication and distraction-related disruptions occurring in the post-intervention phase as compared with the pre-intervention phase, x^2 $(1, n=2076) = 16.422$, $p=0.00$; Pre (37%) < Post (56%) and x^2 $(1, n=2076) = 5.412$, $p=0.02$; Pre (24%) < Post (29%), respectively.

Finally, for the targeted minor category planning/preparation, a chi-square goodness of fit test indicated that there was no significant difference between the frequency of planning/preparation disruptions identified in the post-intervention phase (35%) as compared with the pre-intervention phase (34%), x^2 $(1, n=2076) = 2.664$, $p=0.103$.

Phases of care (resuscitation and imaging). For the targeted minor category, ineffective communication, a chi-square goodness of fit test indicated that there was a significant decrease in the frequency of ineffective communication disruptions identified during the post-intervention phase for both the resuscitation and imaging phases (15% and 3%, respectively) as compared with the pre-intervention resuscitation and imaging phases (31% and 17%, respectively), x^2 $(1, n=1031) = 9.504$, $p=0.002$ and x^2 $(1, n=1045)$ $= 12.197$, $p=0.000$, respectively.

On the other hand, for the targeted minor category nonessential communication, a chi-square goodness of fit test indicated that there was a significant increase in the frequency of nonessential communication disruptions identified during the post-intervention phase for both the resuscitation and imaging phases (28% and 76%, respectively) as compared with the pre-intervention resuscitation and imaging phases

(16% and 56%, respectively), x^2 (1, n=1031) = 4.708, p=0.030 and x^2 (1, n=1045) = 19.654, p=0.000, respectively.

Regarding the targeted minor category distractions, a chi-square goodness of fit test indicated that there was a significant increase in the frequency of distraction disruptions during the post-intervention resuscitation phase (19%) as compared with the pre-intervention resuscitation phase (10%), x^2 (1, n=1031) =11.424, p=0.001. However, there was no significant difference between the frequency of distraction-related disruptions identified during the post-intervention imaging phase (44%) as compared with the pre-intervention imaging phase (39%), x^2 (1, n=1045) = 1.296, p=0.255.

Finally, for the target minor category, planning/preparation, a chi-square goodness of fit test indicated there was no significant difference between the frequency of planning/preparation disruptions identified during the post-intervention period for both the resuscitation and imaging phases (46% and 27%, respectively) as compared with the pre-intervention resuscitation and imaging phases (43% and 29%, respectively), x^2 (1, n=1031) = 0.741, p=0.389); Pre-intervention (43%) < Post-intervention (46%) and x^2 (1, n=1045) = 1.781, p=0.182); Pre-intervention (29%) > Post-intervention (27%), respectively.

Multiple-Baseline Analysis

Overall. For the targeted minor category ineffective communication, a chi-square goodness of fit test indicated there was not a significant difference in the frequency of ineffective communication disruptions identified in the baseline 1/pre-intervention (32%) as compared with baseline 2/pre-intervention (17%), x^2 (1, n=1137) = 3.579, p=0.059.

For the targeted minor category nonessential communication, a chi-square goodness of fit test indicated there was a significant increase in the frequency of nonessential communication disruptions occurring in the baseline 1/pre-intervention (20%) as compared with baseline 2/pre-intervention (49%), x^2 (1, n=1137) = 40.258, p=0.00.

For the targeted minor category distractions, a chi-square goodness of fit test indicated there was a significant increase in the frequency of distraction-related disruptions occurring in the baseline 1/pre-intervention (16%) as compared with baseline 2/pre-intervention (30%), x^2 (1, n=1137) = 8.822, p=0.03.

Finally, for the targeted minor category of planning/preparation, a chi-square goodness of fit test indicated there was not a significant difference between the frequency of planning/preparation disruptions identified in the baseline 1/pre-intervention (35%) as compared with baseline 2/pre-intervention (33%), x^2 (1, n=1137) = 2.851, p=0.091.

Phases of care (resuscitation and imaging). For the targeted minor category, ineffective communication, a chi-square goodness of fit test indicated there was not a significant difference in the frequency of ineffective communication disruptions identified during the baseline 1/pre-intervention as compared with baseline 2/pre-intervention for resuscitation (34% and 26%, respectively), x^2 (1, n=545) = 1.239, p=0.266, as well as for imaging (29% and 11%, respectively), x^2 (1, n=592) = 1.869, p=0.172.

For the targeted minor category nonessential communication, a chi-square goodness of fit test indicated there was not significant difference in the frequency of nonessential communication disruptions identified during the baseline 1/pre-intervention as compared with baseline 2/pre-intervention for resuscitation (13% and 21%, respectively), x^2 (1, n=545) = 1.947, p=0.163. However, a chi-square goodness of fit test indicated there was a significant increase in the frequency of these disruptions during the baseline 2/pre-intervention as compared with baseline 1/pre-intervention for imaging (32% and 67%, respectively), x^2 (1, n=592) = 38.091, p=0.000.

Regarding the targeted minor category distractions, a chi-square goodness of fit test indicated there was not a significant difference in the frequency of distraction disruptions identified during the baseline 1/pre-intervention as compared with baseline 2/pre-intervention for resuscitation (10% and 9%, respectively), x^2 (1, n=545) =.002, p=0.962. However, a chi-square goodness of fit test indicated there was a significant increase in the frequency of these disruptions during the baseline 2/pre-intervention as compared with baseline 1/pre-intervention for imaging (25% and 50%, respectively), x^2 (1, n=592) = 9.393, p=0.002.

Finally, for the target minor category planning/preparation, a chi-square goodness of fit test indicated there was not a significant difference between the frequency of planning/preparation disruptions identified during the baseline 1/pre-intervention as compared with baseline 2/pre-intervention for resuscitation (47% and 38%, respectively), x^2 (1, n=545) = 0.428, p=0.513), as well as for imaging (29% and 30%, respectively), x^2 (1, n=592) = 2.985, p=0.084).

Discussion

Analysis of data collected during the post-intervention phase revealed that the trauma team experienced an average of 18 disruptions per case, which translated to one disruption occurring every two minutes, roughly the same as the baseline phase. The patients observed during the post-intervention phase were, on average, 11 years older than the pre-intervention sample (41.2 and 52.5, respectively). As the population ages and lives longer, older individuals are more susceptible to trauma. From 2000 to 2010, the age group that experienced the highest frequency of death due to traumatic injury was 45 to 55 (Rhee et al., 2014). In fact, patients of advancing age have higher rates of complication and mortality than younger patients (Adams et al., 2012).

During the post-intervention phase, there were slightly more motor vehicle crashes than during the pre-intervention phase (15 versus 10, respectively), but there were fewer motorcycle crashes (7 versus 26, respectively). During the pre-intervention phase, researchers observed trauma cases during four different biker events: Biketoberfest 2014 and 2015 and Bike Week 2015 and 2016. In contrast, the post-intervention observation phase only encompassed one biker event: Biketoberfest 2016. Thus, not surprisingly, there were not nearly as many biker event-related cases observed as compared to the pre-intervention phase (32 versus 6, respectively).

The number of other/unspecified trauma cases doubled during the post-intervention phase as compared to the pre-intervention phase. Two of these “other” MOIs involved patients who were in a small airplane crash and arrived simultaneously. Nine of these “other” MOIs were motor vehicle-pedestrian/bicyclist crashes, which was six more than the number of cases observed during the pre-intervention phase. Factors related to these types of injuries and their severity could have contributed to the higher rate of disruptions experienced by the trauma team. Previous research has found that higher risk cases are potentially more affected by disruptions and generate a greater number of minor failures than lower risk cases (Blocker et al., 2012; Blocker et al., 2013; Catchpole et al., 2007). A report prepared by the Governors Highway Safety Association (as cited in Retting & Schwartz, 2017) found fatal pedestrian accidents increased by 11% in 2016, which was the largest increase in more than two decades. According to the same report, distracted driving and walking such as cellphone use and other electronic devices, was the main cause of pedestrian fatalities (Retting & Schwartz, 2017).

The reported GCS scores, which are an indication of injury severity and level of consciousness, remained relatively stable over both the pre-intervention and post-intervention phases. Gender, work shift distribution, and number of multiple traumas also remained fairly steady in comparison.

It is likely a sufficient level of stability in the pattern of disruptions was established overall especially considering the improved design of adding a multiple-baseline analysis. Any change in the DV (FDs) was able to be evaluated relative to the baseline values (baseline 1/pre-intervention and baseline 2/pre-intervention) and also relative to a change in the comparison series (post-intervention phase). Specifically, as it relates to ineffective communication there were no changes in the pre-intervention observation data series, therefore, a change in FDs following the intervention may indeed be due to the intervention introduced. Also, the sample of trauma cases captured during both the pre-intervention and post-intervention phase seemed to represent the typical “parent” trauma population with respect to patient demographics (e.g., age, gender, MOI, GCS, work shift, event).

The role identification sticker system was one of the targeted interventions developed in an effort to improve ineffective communication and help address planning/preparation issues. In the majority of post-intervention phase trauma cases, the trauma team members complied with the request to don a sticker that identified their role and included their name. In 43 out of 52 cases (83%), most, if not all, trauma team members wore a role identification sticker. In 40 cases out of 52 cases (77%), most, if not all, trauma team members also included their name on the sticker. An example of one of these observations states, “Dr. [X] reminded team to use the stickers (2-4 stickers were applied as a result of this reminder); ultimately 6 persons wearing stickers, all with names written down.” On the other hand, there were six cases, or 11.5%, where it was observed that team members were not wearing stickers at all or, at best, only one or two members, were wearing stickers. For example, it was observed and noted, “Most everyone was wearing their PPE, but no stickers; although noticed tech [A] and tech [B] had stickers on.” In three cases, or 6%, it was unknown (i.e., not recorded) if the team members donned a sticker.

Next, the implementation of conducting a pre-arrival brief and debrief was one of the targeted interventions developed in an effort to improve ineffective communication and help address planning/preparation issues. Out of 52 trauma cases, it was observed in 24 cases (46%), that a partial pre-arrival brief was completed or attempted, meaning only one or two of the three required steps were conducted (see Appendix E). An example of one of these observations stated, “Nurse [X] mentioned doing briefing. Briefing was completed a few minutes after nurse [X] mentioned that it would be a good idea; nurse [X] prepped the team by giving details of the injury including mechanism, locations, and severity of blood loss.” In six cases (11.5%), all three elements of a pre-arrival brief (Steps 1, 2, and 3) were completed (i.e., an effective pre-arrival brief was conducted by the team). For example, it was observed and noted, “Complete pre-arrival brief conducted w/ checklist in hand." In 17 cases (33%), there was no pre-arrival brief conducted at all. For instance, the observation simply stated, "Pre-arrival brief not conducted." It was unknown if a pre-arrival brief was conducted in five (10%) of the cases. This was due to observers accompanying the trauma team to the helipad or arriving just prior to the patient arrival, but not necessarily in time to witness whether a brief was conducted in the trauma resuscitation bay. In other words, in just over half of the observed cases, a pre-arrival brief was conducted effectively or at least attempted.

Since observations began from the time the patient arrived in the trauma resuscitation bay through imaging and ended upon disposition to surgery, the medical floor unit, or the ED, researchers were unable to observe the team's debriefing activities. However, on two separate occasions researchers observed the team initiate a debrief while awaiting the CT scan results. The debrief was conducted in the viewing hallway of the imaging suite. Additional debriefs may have theoretically been conducted at the conclusion of a trauma case post-surgery, or after the patient was transferred to the medical floor unit or the ED. However, because researchers did not continue to follow the patient beyond imaging, it is unknown how often a debrief occurred in these locations.

The rate of communication-related disruptions post-intervention continued to be the most frequent, followed by interruptions and issues related to coordination. These results were similar to those of others conducting related research in various healthcare domains (Blocker et al., 2012; Blocker et al., 2013; Catchpole et al., 2013; Catchpole et al., 2014; Shouhed et al., 2014; Wiegmann, et al., 2007).

Most notably, disruptions involving ineffective communication were relatively nonexistent in the post-intervention observations, which may speak directly to the information exchange strategies presented in the NLT such as the simulation-based practice scenarios, and the positive results of the training program (see Appendices G-J and N).

The fine-grained analyses revealed that the majority of communication-related disruptions in resuscitation and imaging continued to involve nonessential communication, which occurred much more frequently during imaging. This was not surprising, as previously discussed, given the distinct nature of trauma care during each of these phases. Within the major category of interruptions, distractions continued to represent more of a threat during imaging, which corresponds to the high frequency of nonessential communication that also occurred during this time frame. Although planning/preparation occurred equally as much during the post-intervention phase, planning/preparation issues still persisted more often in resuscitation.

There were several factors that contributed to the decision to complete observations by December 26, 2016. As previously mentioned, there was a major change that occurred within the trauma program two and a half months after post-intervention observations began. The long-standing contracted trauma surgeon group was replaced by a new contracted group that consisted of mostly new trauma surgeons (only two trauma surgeons from the original group remained on staff). By the end of the year, the number of cases observed were almost evenly distributed between the two groups: 28 cases with the previously contracted group and 24 with the new group.

Also, traditionally, there is a substantial amount of bedside nurse turnover in the beginning of each new year at most hospitals. Consequently, it was presumed that at least some out of the 88 ED/trauma nurses who participated in the NLT may either no longer be employed with the hospital or may have transferred to other units. The national nurse turnover rate continues to rise, exceeding the national hospital turnover rate, which leveled off in 2015. The nurse turnover rate increased to 17.2% in 2015, up from 16.4% in 2014. Nurses working in emergency care experience one of the highest turnover rates (NSI Nursing Solutions, Inc., 2016).

Additionally, the TSM submitted his resignation effective January 13, 2017. It was unknown if the hospital anticipated asking the new manager that would be filling the vacant position to present the NLT to new ED hires.

To capture a trauma activation from start to finish, researchers were scheduled to be “on call” at the hospital around the clock in an attempt to observe as many cases as possible. However, the sporadic nature of the trauma patient volume at this Level II trauma center and researchers’ school schedules contributed to a lengthy process. This, in addition to the overall time constraints and unforeseen circumstances specific to the naturalistic setting of this current study posed significant challenges to the observational research design and limited the overall sample size of the cases. Consequently, there were 13 fewer trauma cases observed post-intervention as compared to the pre-intervention phase.

In addition to the “changing of guard”, or the replacement of the long-standing contracted trauma surgeon group, another important factor to consider when comparing results is the recipients of the training intervention. First, the physicians (i.e., trauma surgeons, ED physicians, anesthesiologists, radiologists) did not receive the NLT content in the same format as the ED nurses. Instead, the trauma surgeons and ED physicians received the NLT content through Microsoft PowerPoints via email. Anesthesiologists and radiologists did not receive the training in any format. Also, at the request of the TPMD, medical human factors researchers presented an abridged version of the NLT on two separate occasions during the monthly Trauma Committee Meetings (June 7, 2016 and July 5, 2016). Unfortunately, not all the trauma surgeons were in attendance during those meetings. When evaluating the results of the interventions, an important factor to consider is that physicians need to be part of the whole process, from development to rollout and any training in between. As noted by Thomas and Galla (2013), if physicians do not “buy in” to the process, engage as champions, and believe in the value and importance of teamwork, any attempts at team training will suffer.

Furthermore, ED technicians, who serve a key role as fundamental members of the assembled trauma team, did not receive the NLT training at all. A number of other team members such as lab, orthopedic, respiratory, and radiology technicians also did not receive the NLT training as well. Thus, all technicians that were part of the trauma team were, for all intents and purpose, unaware of the expectations presented in the training concerning leadership, teamwork, and communication. This deficit in training may have been most disadvantageous from the standpoint of the imaging phase of patient care. Although trauma care requires multiple caregivers from varying disciplines to work together as an effective team with the goal of saving a life and preventing harm, the trauma team must enter and coordinate patient care while operating under the auspices of the radiology unit in nearly every trauma case. In a sense, organizationally, it is the radiology technicians and radiologists who “lead the charge,” so to speak, during this phase of care.

Providers from many different disciplines bring with them their own expectations, norms, attitudes, and cultures and, in order to achieve effective team communication, teams must overcome these barriers (Barach & Weinger, 2007). One way to achieve this goal is to participate in team training. As previously mentioned, Salas et al. (2008) found that team training was an effective intervention for influencing team processes and performance. The increase in disruptions related to nonessential communication and distractions observed in imaging may have been a direct result of the lack of team training for every member of the team. Also, the stability of team membership is an important aspect to consider since “team effect”, in a sense, may have indirectly influenced the results. Recall that a Level II trauma team is non-intact, meaning the makeup of the team is fluid, so it was not uncommon to observe, on average, only two to three core members present in a case.

The good news, however, was that despite the lack of an intact team and comprehensive team training, ineffective communication remained low throughout the post-intervention phase. As part of the NLT curriculum, trauma nurses practiced team communication and teamwork skills using low-fidelity simulation-based training as well as role-playing in a relevant context. Embedding simulation training into the didactic curriculum may explain why these desired team competencies, which included communication protocols and information exchange strategies, transferred so well to the floor of the trauma suite. Shapiro et al. (2004) found that simulation training improves teamwork skills and behavior in the clinical environment and offers the opportunity for participants to sustain the lessons they learned.

Although the overwhelming majority of nurses who participated in the NLT felt the information was relevant and useful to them in the performance of their duties and the pre-post-test scores supported the effectiveness of the training with respect to knowledge acquisition, the changes observed were not expected and not consistent with the proposed hypothesis in this current study. The data-driven interventions appeared to improve only one selected minor category, ineffective communication, however, similar levels of improvement were not observed in the other targeted areas.

Combining data-driven interventions and team training together led to marked improvement post-intervention in the ineffective communication typically relied on by the team members. These positive findings indicated a consistent pattern as far as the implemented interventions having an effect on team performance and their non-technical communication skills (i.e., ineffective communication). Yet, no significant difference was found in the planning/preparation process before and after intervention. Even worse, there was a trend towards increasing the process inefficiencies, or threats, experienced by the team as it related to nonessential communication and distractions in the post-intervention phase. The disruption data identified and classified suggested the NLT and the data-driven interventions actually increased the rates of nonessential communication and distractions substantially.

The initiatives introduced in the NLT were not “written in blood” by any means. In other words, there was no enforcement of these new protocols from an organizational standpoint. Case in point, the role identification stickers and names were worn during the majority of the cases post-intervention, however, a pre-arrival brief was conducted effectively or attempted in just over half of these cases. The pre-arrival brief was specifically implemented to address issues having to do with planning/preparation. Lack of follow-through regarding the pre-arrival briefing may explain why there was little change in the frequency of this threat.

By the same token, team members' cell phones were not confiscated, nor were the hospital communication devices (i.e., Voceras) turned off during the course of care for a trauma patient. These are essential tools, but also tools that were routinely involved in many of the distractions the trauma team experienced during any given case. To illustrate this point, a count of how often the words "phone" and "Vocera" were found in the Microsoft Excel Workbook yielded 200 entries, indicating healthcare professionals are clearly experiencing multiple potential threats related to their personal electronic devices in each case. The casual use of these personal communication devices introduces new distractions in an already complex, high-stakes environment. While it may be difficult to measure exactly how disruptive ringing phones, scrolling through Facebook, or Vocera pages are to highly trained healthcare providers, there is no question these events break their concentration and threaten situation awareness (SA). Smith and Hancock (1995) defined SA as an "adaptive, externally directed consciousness" (p. 138). It is a dynamic factor in an operator's task environment that has the capacity to externally direct consciousness and influence behavior. Within an operator's multi-dimensional "risk space" there are a number of elements that compromise safety (Smith & Hancock, 1995). This is where these distraction-related threats have their greatest impact. Boquet and colleagues (2017a) investigated a similar concept within surgical team performance called "error space." They proposed that these disruptions represented an aggregated space, which disconnects the team from the task at hand, thus, increasing the demands on the cognitive resources healthcare providers need to stay better focused on the patient status and the central task (Boquet, Cohen, Reeves, & Shappell, 2017a). One disruption in isolation may not pose a threat to the delivery of trauma care, however, when these disruptions accumulate, they create a window of opportunity for errors to occur (Boquet et al, 2017b; Cohen et al., 2016).

In reality, each of the implemented interventions fell short of obtaining full compliance to some extent. There is no ignoring the fact that this partial compliance likely had a direct effect on the final results of the study.

Treatment time was not specifically pursued as an outcome measure or DV in the study. However, results indicated that there was not a reduction in overall time elapsed per case following the implementation of interventions. Treatment time increased by two minutes on average in the post-intervention phase as compared to the pre-intervention phase. Since there was not an overall reduction in FDs, it is not necessarily surprising that length of case time followed suit. This provides further support for the assertion that an excessive number of minor disruptions may increase the duration time of treatment.

When teamwork, leadership, communication, and coordination are improved upon, it typically positively influences team outcomes in terms of their ability to communicate, plan, and make decisions. One would expect these improvements to result in more effective and timely patient care (Salas, Rosen, Burke, & Goodwin, 2009; Weaver, Rosen, Salas, Baum, & King, 2010). Results of this current study indicated the opposite effect in terms of duration of care. Although high performing teams may deliver better quality care and improved patient outcomes, perhaps this trauma team, in particular, took more time to do so in the form of “good practices,” information exchange strategies, correcting, informing, protocol compliance, clinical/technical proficiency, etc.

Nevertheless, results of this current study found that during the post-intervention phase there were notable improvements, team members made special efforts to communicate more clearly and unambiguously. This finding was related to the lower incidence of ineffective communication disruptions observed during the post-intervention phase. This improvement in the process inefficiency related to ineffective communication are encouraging, particularly from a training standpoint. The results suggested that RIPCHORD-TWA was able to detect improvements after team training. Considering the brevity, feasibility, and success of the training, this provides support for a more wide-scale implementation of an inter-professional team training program.

Previous studies utilizing FDs as an outcome measure as well as attempting to design distinct interventions to reduce their occurrence, reported promising results (Catchpole et al., 2014; Hildebrand, 2014). However, little is known of the long-term sustainability of these positive outcomes. The prospective study in trauma was conducted in a Level I trauma center. Because of their unique differences, it is reasonable to assume that process inefficiencies observed at a Level I trauma center may not generalize to reflect those observed in a Level II trauma center. Therefore, this empirical study in a Level II trauma facility broadens the scope of inquiry and increases the understanding of potential interventions that these types of facilities can employ to improve life-saving trauma services. Furthermore, these studies did not investigate multiple subcategories within major categories. In the study, the minor categories of RIPCHORD-TWA lend itself to a fine-grained analysis, allowing for greater resolution of the disruptions threatening the system. The robust, subcategory taxonomy recognizes the subtle differences between underlying causes, thereby provides a richer source of data with which to develop effective interventions.

What also makes this current study so unique lies not only in better delineating the "what" that is being fixed, but also the "how", and then, orchestrating the "who" that is directing the fix (i.e., those on the front lines). It is well known that many quality improvements do not succeed because program administrators, and the like, fail to realize that the "how" is just as important as the "what" (Sundt, 2011; Wiegmann, 2015). Routinely, they create solutions and preside over interventions by "simply closing their eyes and hoping to hit the bullseye." Instead, program administrators should have an in-depth understanding of the intervention itself, increasing buy-in, and involving those at the "sharp end of the spear" to better guide their focus and further guarantee hitting the target.

Furthermore, findings from this current study were informative and made a methodological contribution because they provided empirical evidence obtained from direct observations in order to generate potential interventions. Since it is known that errors are the consequences of systemic breakdowns, focusing on systemic factors may be more fruitful than approaches that focus solely on who committed the error, an individual's clinical skill, or on the error itself. For obvious reasons, the systems perspective is much more widely accepted by healthcare professionals especially when it concerns prospective observations. By referring to individual events as FDs and not errors, researchers are better equipped to study the real-time dynamics that threaten the optimal delivery of patient care.

Limitations

There were a number of limitations to this current study, most of which are related to an ITS design and the drawbacks that affect both internal and external validity.

First, it is possible that the mere presence of the observer(s) confounded the normal trauma team work flow. This is called the Hawthorne effect or observer effect, a phenomenon in which individuals modify an aspect of their behavior in response to being observed and are, therefore, less likely to behave naturally (Rice University, 2014). Some steps were taken to deliberately diminish this effect. For example, observers' uniforms consisted of medical scrubs in order to blend in as much as possible. They attempted to be as inconspicuous and unobtrusive as possible by observing the case and taking notes from a distance to reduce the awareness of their presence.

Second, this current study was not double-blinded, meaning the researchers who designed the study, also served as the observers, and were privy to the expected results. This lack of blinding, may have led to observer bias and a potential overestimation of the positive effects while ignoring the negative aspects during subsequent observations. Attempts were made to combat this type of bias by thoroughly training observers in terms of establishing clear criteria for what was to be recorded (Rice University, 2014).

Third, becoming more adept at recognizing FDs over time may have led to capturing more detail and disruptions during the baseline 2/pre-intervention and the post-intervention phase compared to the baseline 1/pre-intervention. Observers, especially those who have been observing the trauma care process since the beginning of the study, nearly three years in all, were able to "catch" a lot of disruptions at this point due to sheer expectation, knowing clinically how a case progresses, and where the "hang ups" tend to occur. For instance, two of the researchers had been observing for all three years, one had been observing for two and a half years, and one other had two years of observing experience.

It is worth noting that the prospective post-intervention observations demonstrated that the interventions were not employed all of the time. However, it could be that they were deployed in the cases that the researchers did not directly observe.

In addition to utilizing human observers, human coders, although well-trained, categorized the observations into a human factors taxonomy, RIPCHORD-TWA. Their idiosyncrasies, biases, and inconsistencies may have affected the results as well.

Attempts to sustain the changes introduced by the training involved multiple strategies aimed at reinforcing the core principles addressed during the training. For example, researchers intended to hang a large poster on the wall in the trauma resuscitation bay displaying the pre-arrival brief. This poster would have served as a continuous visual reminder to use the preparation tools and communication protocols introduced during the training. Unfortunately, the hospital’s marketing department made numerous mistakes during the drafting stage of the poster, which delayed production. Consequently, the poster was not completed or displayed in the trauma resuscitation bay.

On a related note, with the deployment of interventions targeting specific problem areas, there is always a concern that a fix in one area may lead to an unforeseen provocation somewhere else in the system. As specific FDs were targeted and possibly mitigated, other marginal threats may have begun to take their place and occur more frequently. Thus, the occurrence of threats may never be eliminated completely. Worse yet, they could be replaced by other more potentially vexing issues. Data collected during the study points to a good example of this dilemma. Post-intervention charting/documentation disruptions increased by 23% in imaging as compared to the pre-intervention phase. Perhaps efforts to improve team communication and ensure that everyone on the team knows one another's names meant they were also more willing to verbalize patient information directly to the primary nurse/scribe than ever before. Reciprocally, the team may have been more willing to support the tasks of the primary nurse/scribe and ensure that information was documented efficiently and accurately.

Lastly, regarding external validity, the prospective investigation was limited to a single medical facility. Thus, the ability to generalize the results to other hospitals housing Level II trauma centers might be restricted due to differences in emergency services systems. Also, this medical facility is located in an area with a unique population demographic and serves a considerable number of transient clientele. It resides in the "World's Most Famous Beach" in the South, where a number of elderly and homeless individuals live and bikers and tourists visit. Thus, patient population demographics may limit the ability to generalize the results to other hospitals and their Level II trauma centers.

Generally, a host of issues related to real-world conditions, non-compliance, and organizational apathy, jeopardized the sustainability of the changes introduced by the interventions. In and of themselves, these complications imparted their own set of limitations to the follow-through of interventional implementation. It is difficult to definitively say how much these types of limitations directly impacted the results. It is believed that having had more control over the environment during the study could have widened the gap in the distribution of the data between the pre-intervention and post-intervention phases.

Future Research and Direction

With the departure of the TSM, the hospital's proposed plan for continued training efforts is unknown at this time. It was planned for the future to include a mandatory leadership/team training and orientation for new ED nurse hires. Plans also included an annual mandatory refresher to support ongoing process improvement and aid in the retention of knowledge, skills, and attitudes. Additionally, future plans considered the development of a training program for all trauma team members (e.g., physicians, technicians) with the intent of clarifying specific performance expectations and presenting a clear message that patient safety is the highest priority. Also, it was recommended by the human factors researchers that the department consider executing unannounced mock drills for team members to practice their newly gained skills or to strengthen skills. The novel information exchange protocols and pre-arrival briefs/debriefs can be difficult and awkward at first because healthcare professionals have been trained using a variety of communication styles. Practice allows them to move from the awkward beginning stage of call outs and read backs to the point where effective communication becomes second nature.

The results of this current study support the importance of implementing policies and procedures restricting the use of cell phones and Voceras as well as imposing a sterile cockpit rule in any procedural area of the trauma suite. The ACS' Committee on Perioperative Care (2008) issued a statement on the use of cell phones and personal devices in the operating room and the distractions that can arise from this technology.

From a human factors perspective, adopting formal policies, enforcement, and reporting non-compliance are simple strategies to solving a pervasive problem.

Post-intervention phase observations indicated that the role identification sticker system had become almost as standard for the trauma team as “gowning up” in their PPE. However, many of the other interventions were far from being hard-wired into their operations. Ongoing promotion, positive reinforcement by administration, and buy-in and active participation on the part of the physicians will go a long way to help hard-wire the process. Identifying nurse “champions” and empowering trauma nurses to transfer their newly learned skills, potentially fostering cultural change to the entire ED, will also improve these system processes. As change takes hold and these initiatives are adopted consistently, all trauma team members will conduct operations in the same manner every time, “no matter what the weather.”

The researchers have successfully adapted a robust human factors taxonomy, previously used only in the CVOR, to identify and classify disruptions encountered in an entirely different healthcare domain. As it currently stands, the descriptions of the FDs, which may be applicable to other disciplines, cater to disruptions found in surgery specifically the CVOR. Nevertheless, the RIPCHORD-TWA framework provides a universal blueprint that concentrates on the human factors elements of a system. Future studies should focus on the generic modification of this methodology across all healthcare disciplines. Of special note, RIPCHORD-TWA does not distinguish between “good” and “bad” disruptions, yet one may consider some minor pauses (e.g., clarifying communication mix-ups, alerts, on-the-job training) as advantageous or “good practices”. In fact, skilled teams often use these temporary halts to prevent adverse events. An example of this is a "time out," which is performed in the OR just prior to the induction of a patient or an invasive procedure. It involves active communication among surgical teams using a standardized checklist. The "time out" checklist was part of an effort to eliminate sentinel events such as wrong site and wrong person surgeries and is essential for ensuring quality of care, reducing risk, and improving patient safety (Joint Commission, 2017).

To illustrate this point, an example of what could be considered a "good" disruption is an observation that was coded as a teaching moment under interruptions: "Nurse begins to insert a Foley, trauma surgeon stops her and explains that best practices require Foley to be inserted in ICU and why, trauma committee recommendation, etc." It was not documented how many of the disruptions observed in the study overall represented "good practices." Nor, were these types of disruptions singled out. Instead, per the operational definition of FDs, "good" and "bad" FDs were combined together as one and the same, although the argument could be made that not all FDs are created equally.

The role of the primary nurse/scribe is the most complex and challenging in the broader context of trauma teamwork. Perhaps future research should consider their work requirements and the designing of technologies (e.g., computer-based data entry, electronic medical records (EMRs)) that are better able to support the nurse recorder in the documentation process. Developing more functional, accurate, and effective work practices centered on the recorder's tasks are essential not only for the primary nurse/scribe, but also for the other team members who are busy with patient care.

Along these same lines, researchers may also be interested in examining the influence of a given FD on the trauma team by attempting to measure the length of disruptions (i.e., how long it took to resolve the disruption), the impact on surrounding team members, and relationship to a specific discipline type (e.g., trauma surgeon, ED physician, fluids nurse). They could also examine whether the FD can be directly linked to an overt error or patient outcome as well as the mental effort required by the provider to overcome the disruption (e.g., workload assessments, structured interviews, metacognition debriefs).

One future study already underway involves using isolated communication and coordination FD data to examine where the major threats lie. Based on this rich source of information, the critical skills that should be directly targeted can be clearly determined. The focus is on developing a more comprehensive and effective training program that is compatible with the measurement tool and assessment model presented in the study. Ultimately, this investigation will help engineer even more quality into the system and provide on-going feedback from the process about the system deficiencies to enhance team performance through improved training efforts.

Specified patient demographics were obtained for each case observed. Future studies may utilize regression analyses to explore the significance of relationships between FDs and various demographics collected, including patient age, gender, GCS score, MOI, biker-related events (annual Bike Week and Biketoberfest), work shift, physician providing care, air transport versus ground, multiple trauma patients received, etc. For instance, investigating whether cases with critical patients with a poor prognosis are correlated with a higher number of FDs would be a worthwhile analysis. Research indicates that case complexity requires a greater need for resources and higher pressures on the team, which may accompany more severely injured patients (Shouhed et al., 2014).

An abundance of qualitative data was collected in the format of unstructured, free-response observational notes. These comprehensive notes provide a more in-depth look at the problems facing the trauma teams during the continuum of patient care. The narrative provides additional insights into the nature of the interactions and also reveals numerous “good practices” among trauma team members. This data may provide the foundation for further exploratory research as well as generate ideas for future quantitative research.

A follow-up survey could be created and administered to gauge how well the interventions are working from the perspective of hospital personnel. The purpose of the survey would be to evaluate trauma team members’ perceptions, opinions, and awareness of the trauma optimization project and obtain a better idea of whether the interventions introduced are being sustained in practice. Survey questions may include the following: 1) Are the interventions improving your work? 2) Are they effective? 3) Do other staff members comply? 4) Is there a real and noticeable difference in the frequency of process inefficiencies occurring during care of a trauma patient? This survey would attempt to address the subjective nature of the effects of the interventions. Quantitative results, or the number of disruptions occurring per case, do not necessarily parallel the qualitative consequences of intervention implementation. This survey would attempt to capture the more abstract differences experienced by members of the trauma team. In other words, do team members “feel” the difference? Do they truly perceive that they are operating in a more efficient manner and as a well-coordinated team? Could there be improvements to the process? If so, what specifically would they suggest doing to mitigate process inefficiencies they are experiencing? Elements of patient safety and quality, culture change, leadership, communication, and teamwork could also be assessed using this questionnaire. The hospital may choose to re-administer the survey over different points in time to examine trends in patient safety initiatives and culture change.

In today's technological world, combining video recording and big data analytics is a viable data collection instrument that has significant advantages over prospective observation. Intelligent video analytics, 360-degree video cameras, and social sensing technology provide powerful tools for capturing workflow disruptions. Options include expanded analytic hardware and software for detection, movement, and tracking, repeated replays, and useful real-time feedback. Best of all, the video gathered can be used as an effective learning and training tool for quality improvement. Audio and video recording in the healthcare environment has its own set of challenges such as acceptance from clinicians, medico-legal issues, patient confidentiality, privacy, employee performance risks, and commiserating audiovisual capabilities. Some of these obstacles can be overcome by properly introducing the system and encouraging participation, especially by using clinician reviews, developing trust, reporting feedback, as well as involving multidisciplinary experts (Mackenzie & Xiao, 2003). This innovative technology has the potential for autonomous observation and coding, essentially removing the human element from the data collection, measurement, and analysis. The platform could also support additional technologies. For example, radio-frequency identification (RFID) can be simultaneously introduced to identify and track individuals, objects, and any relevant biometrics (physical and behavioral characteristics), which could deliver a wealth of information.

This prospective investigation has produced a promising model that may prove helpful for any healthcare organization wishing to embark on their own journey towards improvements in the process of patient care. The key to this current study was the development of a measurement tool and assessment model, both of which generated specific feedback that could be used to gauge and enhance team performance, based on the foundations of safety science. Whether they are a public, community hospital such as this one, a large-scale hospital system, or a small labor and delivery unit, front line staff and administrators alike could benefit from tailoring aspects of this trauma optimization project towards their own quality improvement projects to aid them in ensuring that they are deploying the right interventions.

Considering the healthcare industry is still struggling to reduce patient morbidity and mortality directly related to preventable errors and adverse events, it is evident that current problem solving approaches must change. Systematically identifying *threat windows* and presenting FDs as aggregates and multiplying the threats to safety and quality of care exposes process inefficiencies earlier in the chain of events, thereby affording researchers the opportunity to intervene well before a potential error or adverse event occurs. This approach provides data-derived evidence for motivating action and directing decision making regarding the “what” and the “how” to pursue improvement. The “who” comes from engaged participants acting locally and focusing on fixing the problems they encounter in the system where they must work. Improvements do not happen overnight or with one big fix, instead, it is a continuous, systematic cycle of "If at first you don't succeed, try, try, and try again."

The Safety Systems Management Process (SSMP) model provides a visual guide for others to use as they assess their own programs targeting process inefficiencies. SSMP ensures that they are deploying the right interventions while aiming for real local improvements (see Figure 4.21).

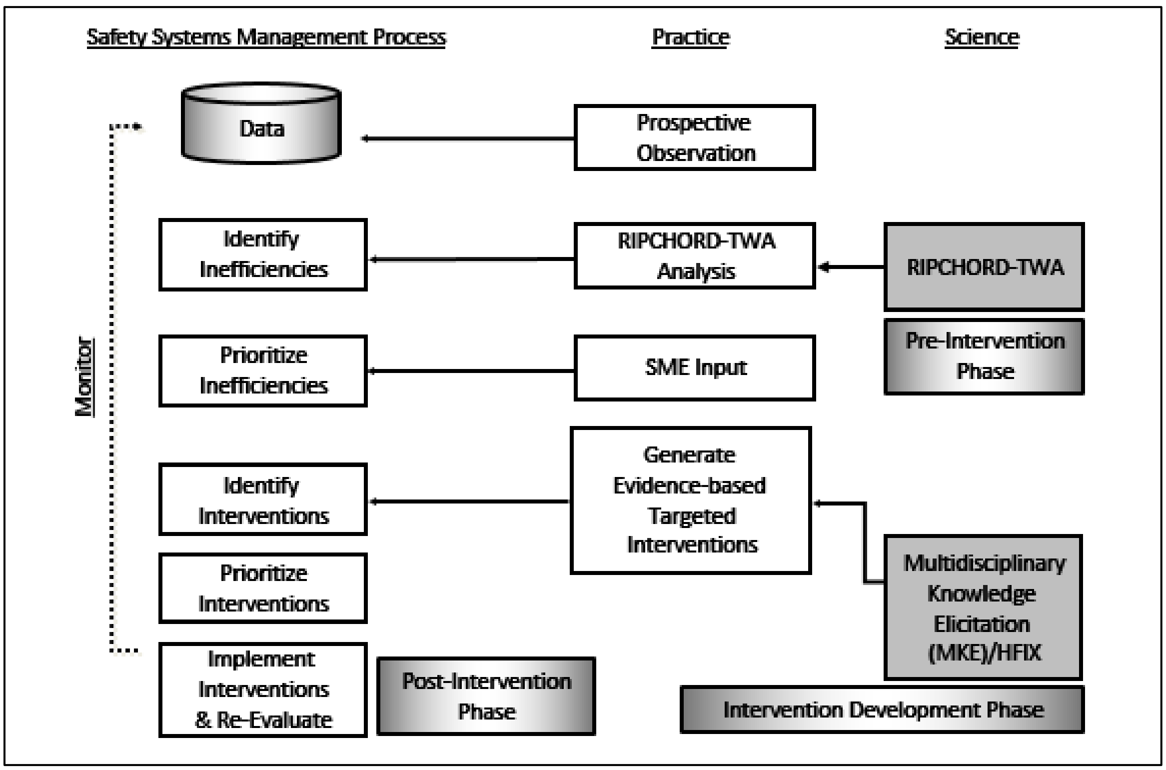

Figure 4.21. Safety Systems Management Process (SSMP)

CHAPTER 5

CONCLUSION

As threats accumulate, along with the absence of adverse events associated with them, these seemingly minor events begin to be perceived as unrelated to safety and efficiency. Healthcare professionals working day-to-day with these process inefficiencies may easily ignore their presence since they fail to blatantly exhibit any inherent potential for detrimental consequences. They become an accepted way of doing things. To borrow logic from Reason (1990) and Dekker (2006), at the end of the day this unknowing intransience increases the likelihood of “drift” towards disorder.

The most important role for risk managers, and the like, of the future will not be their retrospective analysis of a particular event and making a guess of how to prevent it from reoccurring, instead it will be uncovering the precursors of such an event, obtaining the information necessary to anticipate areas of increased risk, measuring the process, and engineering quality into the system to intervene before errors and adverse events occur (Stolzer, Halford, & Goglia, 2008).

This research has attempted to re-conceptualize FDs as potential threats to safety and efficiency in a healthcare system. This approach gives standalone merited weight to these events. By doing so, it reframes the problem in a manner that encourages healthcare providers to intervene before these disruptions manifest into catastrophic errors that reaches the patient.

However, this information has no value unless the organization learns from it. Although healthcare aspires to be an HRO, it clearly has not adopted a “highly reliable” systematic approach to accomplish this goal. To best drive prevention and reduce systematic medical errors, healthcare has to first move away from fear of retribution and its punitive nature. Rather than a retrospective review of patient safety events and reporting errors and near misses after the fact, or focusing on outcome-based initiatives, a new process should be implemented that looks at all the factors that may cause an event to happen in the first place. There is no question that healthcare providers are much more amenable to this process and more willing to use this information to drive prevention. The SSMP provides an audit trail for threats that have been discovered during the analyses process. This discovery should lead to a preventative/corrective action to reduce future threats. The SSMP offers a language for healthcare professionals to detect and discuss the everyday process inefficiencies threatening the system in which they work as well as a framework to generate their own ideas of how to mitigate them.

Compared to the pre-intervention data, the success was evident in regards to ineffective communication and deploying targeted, data-driven interventions in a systematic manner. Despite experiencing multiple real-world challenges that attempted to despoil any potential change for the better, ineffective communication remained low throughout. That is the beauty of the SSMP model. It is a living, breathing document that can present the data in real-time. This comprehensive, systematic methodology allows researchers, personnel, risk managers, quality regulators, and administrators to track and monitor results in a quantitative, data-driven manner. How can an organization (or individual, for that matter) truly improve if they do not know the baseline from which to grow? Ultimately, the principal strength of this current study, and perhaps more important than the actual results themselves, is combining science and practice by employing RIPCHORD-TWA, the HFIX framework, and including multidisciplinary

SME input, which may prove more successful and lasting in mitigating the real threats to the delivery of trauma care. The benefit of this method is that it allows practitioners on the front line to implement customized interventions to problems they face every day. Next generation improvement must persistently gather data on the problems and rely on tracking information and failures—for what can be measured can be managed.

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Appendix A

5/29/15

Dear Colleagues:

As many of you know, X Health has been engaged in a trauma optimization project with the Human Factors Doctoral Program of Embry-Riddle Aeronautical University (ERAU). To date, the ERAU team has collected large amounts of data surrounding the concept of flow disruptions in trauma care. And now, wait 'till you see these data!

Data collected from trauma observations has been sorted and we have arrived to the point at which we need team members in all the trauma-related disciplines to convene and come up with "interventions" that might better optimize our delivery of trauma care here at X. We're asking for trauma care volunteers to participate in a two-hour meeting on Friday, June 19th from 1:00pm - 3:00pm.

While we will indeed show you the data in this meeting, it won't end up being a lecture-type meeting; instead, it will be an active, collaborative, and working meeting to "brainstorm" on ideas/processes that we can implement to make trauma care better. How about we formally call this a "Multidisciplinary Knowledge Elicitation" trauma meeting! That sounds cool, doesn't it?

If you are interested, please reply to this email and we will add your name to the list of potential volunteers for selection. The deadline for submission is (preferably) June 15th. You will receive non-productive pay for participating in this meeting. To ensure we have a well-balanced group of disciplines, you will be notified via email if you are chosen to participate.

Thank you in advance for your participation.

Mr. Smith

Appendix B

TASK/PROCEDURE GROUP - *Focuses on ways of changing operators' task to reduce errors and improve safety (task characteristics, timing, work pressures, feedback, etc.). Please be open and free-thinking and as specific as possible when generating interventions.*

Process Inefficiency: **Communication** (Major Category)/ **Ineffective Communication** (Minor Category) Description: Communication between two or more individuals that does not achieve its desired goal (i.e., not covered by other categories); includes (example of when someone doesn't know the name of someone else and can't communicate efficiently with them)					
Intervention Ideas	F	A	C	E	S

Appendix C

TASK/PROCEDURE

Focuses on ways of changing operators' task to reduce errors and improve safety (task characteristics, timing, work pressures, feedback, etc.)

How can the task be restructured so that it requires less reliance on human memory (i.e., use checklists or technology that signals next step in task)?

If the task is done simultaneously with other tasks (divided attention), can it be done by itself? How can the mental workload/timesharing be reduced?

How could errors in performing the task be reduced by having another team member check/verify important steps in the procedure?

How could checklists be developed to guide the task or verify that the task has been performed properly?

How could immediate feedback be integrated into the task to allow operators to know when they have done things correctly or incorrectly?

How can procedures or checklist be redesigned to be clearer or more user-friendly?

If the task allows for easy short-cuts, how could it be redesigned to eliminate these shortcuts or reduce the likelihood that they are done?

How could procedures be re-written so that they are less ambiguous or inapplicable to the safety critical tasks operators perform?

How could procedures be developed that restrict the performance of safety critical tasks when there is time pressure to complete it?

When operators switch tasks, what procedures could be developed to reduce negative transfer?

If compliance with safe work practices goes unrewarded, how can a reward system be developed to ensure that compliance is reinforced?

If a task is repetitive, monotonous, or boring, how could it be made more interesting? How could "time on task" be changed to reduce vigilance decrements or mental lapses in attention?

Could operators be rotated off the tasks, checked for errors, or monitored more closely? Could the pacing or ordering of a particular task be modified to reduce opportunities for error? How could a task be modified to reduce the demands on the operator's physical or perceptual limitations?

How could the task be redesigned so that its requirements are within reasonable bounds/limits of all persons performing the job (e.g., force, speed, precision, requirements, etc.)?

Are the various tasks performed appropriately grouped into jobs? How could similar tasks be more effectively grouped/assigned to operators so that they are performed by operators with the same skills?

Appendix D

Trauma Team Readiness Check-In

To be Conducted by Primary Nurse during shift huddle
with Trauma Teams 1 & 2 in the Trauma Resuscitation Suite

- Who is the trauma team today?
- Who are the on-call trauma physicians today?
- Confirm the Daily Checklists: Trauma Suite (Primary Nurse); Helipad (ED Tech)
- "Does anyone have anything to add or any concerns? If so, speak up!?" *AND* "Is everyone in agreement?"

Introspective questions to consider:
Is your fellow trauma colleague…

- Punctual? Prepared?
- Does s/he contribute or just disengaged?
- Does s/he disagree?
- Is s/he committed to decisions?
- Does s/he support the team's decisions after the fact?
- Is s/he toxic to the mission, values, and vision of the trauma team?

Appendix E

Pre-Arrival Brief

1. **First statement:** Team member introductions (names/roles): *"I am NAME and my role is ROLE."*
2. Case Preparation
    - Mechanism of injury / predicted injury patterns
    - Anticipated treatment plan
    - Alert other areas (e.g. Blood Bank, CT)
3. **Last statement:** *"Does anyone have anything to add or any concerns? If so, speak up!?"* AND *"Is everyone in agreement?"*

Appendix F

Debrief

1. Set the stage

“This is a quick opportunity for learning and continuous improvement. Let’s take a look at how we handled the case.”

2. Ask the team for their observations

- *What happened?*
- *What did we do well?*
- *What challenges did we face?*
- *What should we do differently or focus on next time?*
- *What could help us be more effective?*

3. Add your observations/recommendations and confirm understanding

4. Summarize any agreed upon actions or focus for the future

Appendix G

Call Outs

- A strategy used to communicate to the entire team simultaneously (in the following example, used to communicate with one person, specifically the scribe)
- Helps team members anticipate next steps
- Helps create a shared mental model
- Receiver (with name) should either verbally or non-verbally acknowledge the transmission, such as with a nod of the head
- With eye contact!

Appendix H

Closed-loop Communication & Read Backs

- Require the sender to verify the information that is being received by the other team member

- Some communication takes place during times of escalating stress, such as in a rapid response event. In these sorts of situations, effective and efficient communication is crucial for successful patient outcomes.

- Receivers repeat back requests

- Senders request check backs and acknowledge the information is correct

- With eye contact!

Appendix I

CUS Technique

- Concerned, Uncomfortable, Safety
- Provides a framework
  - When used, everyone understands the issue and the magnitude.
- State your concern first. Then state why you are uncomfortable. If the conflict is not resolved, state that there is a safety issue. If the safety issue is not acknowledged, a supervisor should be notified.

Appendix J

Two Challenge Rule

- Invoked when an initial assertion is ignored.
- You are hereby empowered to question any potential breach of safety.
- It is your responsibility to assertively voice your concern at least two times to ensure that it has been heard.
- The member being challenged must acknowledge.
- If the outcome is still not acceptable
    - Take a stronger course of action
    - Use supervisor or chain of command.

Appendix K

HALIFAX HEALTH
TRAUMA CENTER

EMBRY-RIDDLE
AERONAUTICAL UNIVERSITY

TRAUMA NURSE LEADERSHIP COURSE
PRE TEST

1. In the concept of leadership, the assignment of a leader is not interchangeable under any circumstances?

True
False

2. Why is assertive authority an important skill to learn and demonstrate when appropriate during the resuscitation of the severely injured patient?

A. Because the physician doesn't really know what he or she is doing so the nurse has to tell them, especially if they aren't board certified.
B. Because a nurse might observe something unsafe which other hierarchical members of the team do not identify.
C. Because studies have shown the nurses are right more times than physicians so it's important to come down on the physicians with more authority.
D. Because the aerospace and aviation fields do it, so that really means we should. Everything in aviation works in medicine anyway.

3. In the interest of care, quality, and safety, it is expected and mandatory that:

A. Conflict is avoided at all cost.
B. People always do the right thing.
C. Members speak up if they are concerned.
D. Leaders not make mistakes.

4. Who is the leader in trauma teams?

A. Doctor
B. Nurse
C. Patient
D. It depends on circumstances

5. The best communication tool or method to get critical information to the whole team is:

A. Call Out
B. Read Back
C. Write it on the white board
D. Write it in the orders

6. After a trauma case, the most helpful pathway towards team performance improvement involves:

A. The leader telling everyone what they did wrong.
B. Meeting as a team to debrief the event.
C. Attending the autopsy.
D. Blaming the people who made the mistakes.

7. Why is it important to rely on the skills, knowledge, and abilities of the other team members?

A. Because it's less work with more people (aka social loafing).
B. Because you know who to go to later on when you need to borrow money.
C. Because others' contributions can compensate for your inattentional blindness.
D. It doesn't matter, good teamwork is not important at all.

8. Choose the best option below that best describes the communication strategy of CUS?

A. Communication, Unilateral decision making, Superiority.
B. Concerned, Utilitarian, Satisfactory
C. Communication, Understanding, Safety
D. Concerned, Uncomfortable, Safety

9. Which of the following statements regarding the use of checklists in the delivery of acute trauma care is FALSE?

A. A well-designed checklist can be completed by a trauma team in less than two minutes.
B. Checklists are designed for new procedures or practitioners with relatively low experience.
C. Checklists create standardization of quality but not technique.
D. Checklists help ensure that every item is completed every time.

10. The team is making great progress with the procedure until the nurse recognizes that the doctor is clearly making a dangerous mistake and asking for an unusually high dose of Gentamycin. Very concerned, the Procedures Nurse asks the doctor if he's sure if that is what's wanted. Giving her a nasty look, he growls "well, that's

what I asked for, isn't it?" Confident that the dose is way off base, her next action should be to:

A. Say, "I'm very concerned about the safety of that dose, doctor. It' much higher than I've ever seen given."
B. Walk away and indicate discouragement at being treated so rudely.
C. Say loudly, "That's a huge mistake, doctor. Nobody uses a dose like that!"
D. Not say anything out of fear in making the doctor more angry.

11. For the real life situation in the previous question, the doctor did not acknowledge the Procedure Nurse's concern and ignored her questioning. Now, the nurse should take the following course of action.

A. Say loudly, "You're off your rocker!"
B. Not say anything out of fear in making the doctor even more angry.
C. Prepare the medication and say to the doctor, "Here you push this med."
D. Challenge the doctor with assertive authority at least two times to ensure your concern has been heard.

12. During the acute care delivery of a Trauma Alert case, the doctor utters: "Let's go ahead and give 'em a little more Diprivan." Having heard this, the nurse should?

A. Prepare for immediate administration of propofol because the patient obviously needs it.
B. Ask the doctor to clarify the dose and then insist on a read back technique to verify the information.
C. Call pharmacy and give the phone to the doctor.
D. Pass the ambiguous order on to the oncoming procedures nurse because it's 0659 and you've got Happy Hour plans right after work.

Appendix L

HALIFAX HEALTH
TRAUMA CENTER

EMBRY-RIDDLE
AERONAUTICAL UNIVERSITY

TRAUMA NURSE LEADERSHIP COURSE
POST TEST

1. In the concept of leadership, the assignment of a leader is not interchangeable under any circumstances?

True
False

2. Why is assertive authority an important skill to learn and demonstrate when appropriate during the resuscitation of the severely injured patient?

A. Because the physician doesn't really know what he or she is doing so the nurse has to tell them, especially if they aren't board certified.
B. Because a nurse might observe something unsafe which other hierarchical members of the team do not identify.
C. Because studies have shown the nurses are right more times than physicians so it's important to come down on the physicians with more authority.
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B. Not say anything out of fear in making the doctor even more angry.
C. Prepare the medication and say to the doctor, "Here you push this med."
D. Challenge the doctor with assertive authority at least two times to ensure your concern has been heard.

12. During the acute care delivery of a Trauma Alert case, the doctor utters: "Let's go ahead and give 'em a little more Diprivan." Having heard this, the nurse should?

A. Prepare for immediate administration of propofol because the patient obviously needs it.
B. Ask the doctor to clarify the dose and then insist on a read back technique to verify the information.
C. Call pharmacy and give the phone to the doctor.
D. Pass the ambiguous order on to the oncoming procedures nurse because it's 0659 and you've got Happy Hour plans right after work.

Appendix M

Program Evaluation Form

You must stay for the entire length of the program as partial credit will not be given. You must sign-in at the front table before the start of the program and return this completed evaluation form to the same location to receive credit. The Educational Services Department reserves the right to deny credit to participants who do not meet these criteria.

Trauma Nurse Leadership Training

Mr. Smith

Feb-May 2016

ACTIVITY EVALUATION	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
The activity met the stated objectives	5	4	3	2	1
The information was current	5	4	3	2	1
The educational level was appropriate	5	4	3	2	1
The teaching method was appropriate	5	4	3	2	1
SPEAKER EVALUATION	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
The panel was knowledgeable	5	4	3	2	1
The panel was effective	5	4	3	2	1
I would recommend this class again	5	4	3	2	1

Did you notice any commercial bias in speaker or the presentation material? Yes No

What did you learn from the presentation that will enhance your patient care or change how you practice?
(Choose all that apply.)

_____ Improve patient safety
_____ Change practice related to diagnostic interpretation
_____ Update plan of care to evidence based standards
_____ Improved team coordination
_____ Knowledge to reduce medical errors
_____ Improve communication
_____ Enhanced coordination of care
_____ Regulatory process/changes
_____ Improved teamwork capabilities
_____ Other (please describe)

Other Comments:

What other topics would you like to see presented?

Appendix N

Program Evaluation Form

You must stay for the entire length of the program as partial credit will not be given. You must sign-in at the front table before the start of the program and return this completed evaluation form to the same location to receive credit. The Educational Services Department reserves the right to deny credit to participants who do not meet these criteria.

Trauma Nurse Leadership Training

Mr. Smith

Feb 23 to June 21, 2016

Activity Evaluation	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
The activity met the stated objectives	**81**	**5**			
The information was current	**82**	**4**			
The educational level was appropriate	**82**	**4**			
The teaching method was appropriate	**81**	**5**			
Speaker Evaluation	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
The speaker was knowledgeable	**82**	**4**			
The speaker was effective	**82**	**4**			
I would recommend this speaker again	**81**	**5**			

Did you notice any commercial bias in the presentation (verbal, print, or electronic)?
Yes **(No)**

What did you learn from the presentation that will enhance your patient care or change how you practice:

(72) Improve patient safety

(80) Improve communication

(41) Change practice related to diagnostic interpretation

(68) Enhanced coordination of care

(47) Update plan of care to evidence based standards **(51)** Regulatory process/changes

(77) Improved team coordination **(78)** Improved teamwork capabilities

(55) Knowledge to reduce medical errors **(9)** General topic overview / Other

Comments and/or what topics would you like to see in the future?

Excellent- love the team readiness checklist!
Great class- maybe do a mock-trauma in the room with Belmont, etc if possible!
Very helpful information!
The role of staffing lends to + versus – outcomes!
Very informative class!
This class was very informative and helpful!
I would like to see a presentation on skills used while in trauma (use of kits, chest tube tray, thoracotomy tray, etc.)
Tour of trauma room and procedure set up!
This class should be mandatory for surgeons and ED physicians!
Great forum to openly discuss leadership!
Keep track of time!
Very good presentation and evident of that by the way everyone felt they could speak up and be heard. I think the presentation gives everyone a breath of fresh air and helps remind us why we're here!
The program was excellent but also applicable to some everyday high stress situations (like codes, stroke alerts, etc.). Thank you again!
Good class- helpful information!
All members of the Trauma Team should take this course!
Good information!
Thank you! Very helpful!
Great presentation (as usual) by Mr. Smith!
Mr. Smith is the best instructor ever!
How a trauma is meant to be run!

Appendix O

7/8/16

Dear Colleagues,

Likely, you will begin to see the human factors staff from Embry-Riddle returning to prospectively observe trauma cases, and there may be some new faces as well. As usual, they will be out of the way on the far north end of the room and you probably won't even know they'll be there. Now that 99% of RNs working trauma have taken the trauma nurse leadership course, please employ what you've learned and practiced from the course.

Let me know if any questions.

Thank you for caring and for helping to optimize the care of the injured patient at X.

Mr. Smith

Appendix P

Items to Capture	✔
Trauma surgeon (name on whiteboard)	
~Number of people in trauma bay before pt arrives	
Is ED physician present? Is trauma surgeon present? (If not, note the time when they arrive)	
Number of people NOT wearing a sticker or no name on it. Number of people NOT wearing PPE	
Team activities before pt arrives. Pre-arrival brief completed? (If so, document who completed it & was it properly done, meaning Steps 1, 2, & 3)	
Is barrier arm (trauma in progress) in place?	
Exact time the pt is rolled into trauma bay	
As best you can, pt detail and mechanism of injury	
Was stopclock started?	
Team activities while EVAC is giving report	
~Number of people in the trauma bay/pt field at the time the pt arrives	
~Number of people in the trauma bay/pt field during course of treatment	
Location of large trashcan/Is trashcan being used?	
Exact time pt leaves the trauma bay	
Exact time pt enters the CT scan room	
~Number of people in the CT scan room at the time the pt arrives	
Is scribe using special spotlight attached to table?	
~Number of people in the CT scan room/during course of treatment	
Exact time the pt leaves the CT room	
Overall were standardized communication protocols used (call outs, read backs, etc.)?	
Ask the primary nurse/scribe & the Trauma Surgeon as pt is being wheeled out of CT: How would you rate the efficiency of this case on a scale from 1-10? Low, 1=very inefficient, High, 10=highly efficient (document rating and any comments)	