OPTIMIZING PERFORMANCE in the CARDIOVASCULAR OPERATING ROOM

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1. Statement of the Problem

1.1. Introduction

Delivering optimum patient care in today's complex healthcare system can be an enormously daunting task. Challenges include mitigation of vulnerabilities intrinsic to multiple domains, such as the various stages of patient-provider interaction, the different theaters in which services are delivered, the integration of increasingly elaborate types of technology, and the coordination and communication of efforts among the myriad of personnel delivering patient service.

Since the 1999 Institute of Medicine Report[i] detailing the relationship between morbidity/mortality and medical error, the healthcare industry as a whole has come under increasing pressure to emphasize safety standards and reduce adverse patient outcomes. In response, the industry is focusing efforts on the development and application of rigorous scientific protocols to analyze deficiencies in healthcare delivery. The challenge facing the industry today, however, is not simply the reduction in human error as has been espoused in other fields. After all, medical professionals are among the most highly trained and skilled individuals within the modern workforce. Rather, the challenge is how to optimize performance among notably high achievers in a field where sentinel events are arguably rare.

1.2. The Cardiac Operating Room

Perhaps one of the most complex and characteristically demanding environments of clinical medicine is the cardiovascular operating room (CVOR). Cardiac surgery is a high-risk procedure performed by a multidisciplinary team functioning at a sophisticated level in a dynamic environment. It has been noted that cardiac surgery is particularly predisposed to pitfalls because it features multiple specialties, close coupling of concurrent tasks, changing plans, and high workload.[ii] In addition to managing their constant interaction with numerous technologically advanced systems, team members must continuously communicate effectively in order to efficiently coordinate patient care throughout the entirety of the surgical procedure. To further complicate matters, the acuity level of the patient places additional pressure on professionals in terms of necessitating prolonged optimal levels of performance among all players involved. Not to mention there are inherent organizational challenges facing the caregivers as well, such as stress, fatigue, the drawbacks associated with shiftwork, and increased production pressure coupled with the push to conserve revenue. Suffice it to say, the potential for hazards in this environment is considerable.

1.3. Human Factors Engineering

In the healthcare industry, the operational definition of a hazard can be expanded to include anything that poses a potential or real risk to the patient, including errors, near misses, and adverse events.[iii] Ventures to improve patient safety and reduce hazards in healthcare have been ongoing for more than a decade. Nevertheless, the literature provides little guidance regarding best practices for hazard identification and related intervention recommendations.

In an effort to enhance patient safety and increase efficiency in the CVOR, the industry recently turned to the field of Human Factors (HF) for solutions. Human Factors Engineering (HFE) is an interdisciplinary approach to evaluating and improving the design of environments and processes to optimize safety, efficiency, operator well-being, and overall system performance.

Stated another way, HFE is the study of designing and optimizing systems that fit the human body and its cognitive abilities.[iv] HF scientists are specifically concerned with studying multiple aspects of work systems, including task analysis and design; training; device evaluation and usability; communication, collaboration, and teamwork; and system resilience, adaptation, and failure. By utilizing qualitative and practical observational methods that focus on real-world experience and pressures - such as accidents, sentinel events, and "near miss" incidents - HF scientists can improve operational policies and technology design to make workplace systems more adaptive and resilient in the face of shifting demands.[v]

1.4. Human Factors in Medicine

Direct observation analysis in cardiac surgery has provided convincing evidence that small errors can influence outcome.[vi] However, HF scientists understand that an accident or near miss is caused by the culmination of a series of hazardous events, rather than a single, isolated error. Error investigation using human factors analysis examines not only the nature of the error itself, but also tries to determine why the hazardous event happened in the first place. As a consolidated effort, HF analysis investigates human-to-human interactions, human-to-machine interfaces, and what circumstances set up a well-meaning and well-trained individual to make an error. Towards that end, analysis of error using human factors methods focuses on the processes that permitted the error, rather than on the individual who committed the error.

The healthcare industry has increasingly turned to aviation models in order to optimize delivery of clinical services and reduce human error in the process of delivering these services. John Nance, an Alaska Airlines Senior Pilot and commercial aviation consultant for ABC News is quoted as saying, "Individuals can and will forever commit errors, but teams have the ability to be flawless." The aviation and nuclear power industry are held up as examples of high-risk industries in which human error has been dramatically reduced if not virtually eliminated. These industries applied HF methods to determine how human errors occur and put policies and processes into place to prevent simple errors from becoming catastrophes. Currently, there are no universal protocols in place that weave the collective efforts of specialized surgical teams into an integrated whole.[vii]

1.5. In Summary

It is well known in medicine that providing a prescription without diagnosis is malpractice. The same can be said about human factors and healthcare optimization. To offer up solutions without understanding the underlying disease state (i.e. where impediments to performance exist) makes no sense. Likewise, to base one's diagnosis on anecdotes and intuition rather than data is a prescription for the status quo at best and failure at worst.

Improvements in safety must be driven by research and data. It is paramount to understand *why* hazardous events occur and *how* other events lined up to create the circumstances surrounding the hazard. If factors (human) failed the individual and allowed such an event to occur, then a true culture of safety would examine not just the hazardous event, but also the particular circumstances surrounding that event. Using this perspective, the healthcare industry can build systems to overcome these deficiencies.[viii] In other words, having that in-depth understanding of the human factors that led to the hazard can ultimately help us create systems to prevent it.

To date, the application of human factors methods in the clinical setting has focused mainly on problem identification and training based on models from aviation. Yet, as Catchpole (2013) points out, it is glaringly incongruent to superimpose training on systems that are already deficient in design and therefore continue to be predisposing to error.[ix] While there is a great deal of literature aimed at understanding hazards in the cardiovascular operating room, little of this work has been singularly focused on flow disruptions and their correlation to human error. It stands to reason that any approach that will prove successful in this endeavor will address not just hazardous events in the CVOR, but also the preconditions that set the stage for the occurrence of such hazards.

The current proposal seeks to develop an integrative “toolkit” that will equip cardiothoracic surgical teams and healthcare administrators with the necessary metrics to strategically identify and categorize flow disruptions and potential hazards impeding optimum performance in the cardiac operating room. This undertaking is nested within a greater initiative to optimize patient safety through the comprehensive assessment of hazards in the cardiovascular operating room. A multidisciplinary approach will include multiple sites and a team of scientists and clinical practitioners capable of diagnosing the relevant issues using validated human factors tools. Once identified, these hazards can be prevented and/or mitigated using data-driven interventions that are developed using established human factors principles.

2. Recent Work

2.1. FOCUS Project

In 2008, the Society of Cardiovascular Anesthesiologists (SCA) Foundation launched the Flawless Operative Cardiovascular Unified Systems (FOCUS) project. FOCUS is a progressive national research effort to improve patient safety cardiac operating rooms. The goal of the FOCUS initiative is to substantially decrease the incidence and severity of human error in the cardiac operating room through scientific analysis leading to culture change. Central to this theme of cultural change is overall improvements in safety and quality. The near-term goal of FOCUS is to identify gaps in patient safety during cardiac surgery; in the long-term, the researchers and workgroups will use this knowledge to facilitate improvements in the quality of care delivered.[x]

The SCA recognizes an excellent opportunity for a cross-disciplinary approach using aviation protocols to aid in the development of evidence-based CVOR protocols that can yield improvements in patient safety. Specifically, FOCUS looks to the commercial aviation field and its high rate of success in managing human error through crew resource management (CRM). In the aviation industry, CRM represents a culture of safety within the entire team responsible for preparing, maintaining, and flying the aircraft. Central tenets of CRM training focus on communication, leadership, and decision making in the cockpit, each of which place emphasis on teamwork in order to achieve the underlying goal: safety. Generally speaking, CRM can be defined as a management system which makes optimum use of all available resources, including equipment, procedures, and people, to promote safety and enhance the efficiency of operations. It is concerned more so with the cognitive and interpersonal skills needed to manage resources within an organized system, rather than the technical knowledge and skills required to operate equipment.[xi]

The aviation industry has learned to manage crew resources for maximum effectiveness and error prevention through accident investigation, sentinel event review, and behavioral analysis. Likewise, FOCUS intends to achieve the same by conducting ethnographic research rooted in human factors principles to study the current processes, cultures, and systems at play in the CVOR. FOCUS is a complementary and cooperative effort designed to raise the bar for patient safety through human factors engineering.[xii]

2.2. LENS Study

Following the launch of the FOCUS initiative, the SCA Foundation contracted a research team from the Johns Hopkins University (JHU) Hospital's Quality and Safety Research Group (QSRG) to develop and test research methods to achieve the goal of creating harm-free cardiac surgery. Out of this collaboration came the LENS, or Locating Errors Through Networked Surveillance, project vision. The LENS study specifically sought to integrate the insight of diverse disciplines, including industrial psychology, organizational sociology, human factors engineering, and cardiovascular clinical care, in order to identify patient safety hazards in cardiac surgery.[xiii]

In 2009, the QSRG research group completed an extensive focused review of the cardiac patient safety literature and the National Health Service (United Kingdom) error reporting database. Using this information as background, the group developed an in-depth, two-day

observational process to identify characteristics of the CVOR contributing to hazards in patient safety. Prospective methods of data collection - including direct observations, contextual inquiry, and photographs - were used to collect data pertaining to the cardiac surgery perioperative period. This data was collected between February and September of 2008 in cardiac operating rooms at five separate hospitals. At each of the five sites, participants included surgeons, anesthesiologists, nurses, perfusionists, surgical technicians, and hospital executive management personnel. Individual staff members completed extensive surveys on motivation and patient safety culture and observations were conducted over several days at each site.

Results of the surveys and observations were collected in a database. Analysis of this data was ultimately intended to reveal preliminary recommendations for intervention strategies. These interventions would then be tested at newly selected cardiac surgical sites. In-depth details of the LENS study design have been described in prior publications.[xiv]

2.3. CORE OPS Research

As professionals in the aviation industry learned, the application of human factors principles in a complex system is not without its challenges. Preventable hazards in complex systems such as the CVOR are often not due to failure of technical skill, training, or knowledge. Rather, they typically represent “non-technical skills,” such as communication failures, simple interruptions, or even more mundane memory failures that often combine to complicate an already extensively complex procedure.

One of the difficulties associated with addressing systemic hazards is the objective classification of the data required to identify those areas that may benefit from interventions. Analyses of this sort have historically utilized post hoc methods for determining the number, type, and severity of adverse events. This is typically accomplished using questionnaires, interviews, surveys, or participant/witness reports. While the information gleaned from these types of data collection methods cannot be discounted, they share common limitations; these include hindsight bias, memory failures, and subjective interpretation of the events themselves.

In order to address these issues, the FOCUS Steering Committee, in collaboration with CORE OPS (Creating Operating Room Efficiency to Optimize Patient Safety), has adopted two separate human factors frameworks that can be used to collect and analyze flow disruptions and potential hazards in the CVOR in real time:

- **RIPCHORD** (Realizing Improved Patient Care through Human-centered Operating Room Design): a framework for identifying and classifying flow disruptions in the operating room.

- **HFACS** (Human Factors Analysis and Classification System): a framework for identifying and classifying both latent and active causal and contributory factors of human error in complex systems.

2.3.1. RIPCHORD

The impact of flow disruptions on patient outcomes is well recognized in the cardiac operating room. However, there are few standardized tools for the measurement of flow disruptions in the operating room and none have been developed for use by untrained

professionals. A self-assessment tool that allows cardiac teams to understand the nature and frequency of flow disruptions in the OR is vital to recognizing where performance is impacted and how management and healthcare providers can eliminate sticking points that disrupt the orderly and efficient flow of surgery.

For example, a recent study conducted by Palmer, et. al. (2013) demonstrated that operating room design is complicit in creating flow disruptions.[xv] Indeed, perfectly laid out operating rooms are few and far between. Instead, "design by committee," versus the "design by data" approach to operating room layout has left many a surgical team cursing at the designers and developing workarounds to overcome simple architectural flaws. By incorporating traditional healthcare architectural principles and link analysis in the study of flow disruptions, it is possible to geographically anchor and visually document those areas of the operating room that are ripe for interruptions in workflow (i.e. choke points), and, more importantly, identify where simple architectural changes may greatly reduce the potential for hazardous events.

Realizing Improved Patient Care through Human Centered Operating Room Design (RIPCHORD) is a taxonomy which classifies flow disruptions or events occurring during surgery that impede the "flow" or progression of the surgical procedure. Appendix A describes the types of flow disruptions identified by the RIPCHORD taxonomy. Whether as seemingly trivial as tripping over a cord on the floor or spilling saline to much more disrupting events, such as not having the needed equipment for a valve replacement, these "flow disruptions" introduce unwanted distractions and open the door for inefficiencies and errors to occur.[xvi]

2.3.2. HFACS

Not only does the untimely nature of flow disruptions in the CVOR sabotage procedural efficiency, these interruptions also set the stage for hazards downstream.[xvii] Serious hazards are often triggered by multiple preconditions that, in and of themselves, also pose a potential or real risk to the patient.[xviii] Such latent failures predispose the system to error and may result in adverse events if numerous deficiencies are present within the various levels of a system.[xix]

According to James Reason, accidents and adverse events occur when there are breakdowns in the interactions among components involved in a production process. These failures degrade the integrity of the system, making it more vulnerable to operational hazards, and thereby more susceptible to catastrophic failures.[xx] Reason's approach to accident causation is based on the assumption that there are fundamental elements of all complex productive systems that must work together harmoniously if safe and efficient operations are to occur. This approach takes into consideration the cascading nature of human error, asking accident investigators to contemplate the role organizational factors play in the genesis and management of human error.

Reason theorized that active failures of the operators that occur at the "sharp end" of the system can potentially be linked to latent failures or weaknesses at the "blunt end" of the system. These failures can be depicted as "holes" within the different layers of the system; given the image of Swiss cheese that this illustration conjures up, this theory is often referred to as the "Swiss cheese" model of accident causation. Appendix B

illustrates Reason's "Swiss cheese" model of accident causation as adapted by Wiegmann and Shappell (2003)[xxi] and as adapted by Carthey, et. al. (2001) for healthcare/hospital organizations.[xxii]

The Human Factors Analysis and Classification System (HFACS) is based on James Reasons' (1990) "Swiss Cheese" model of accident causation and provides a theoretical framework for dissecting the potential etiology of errors in complex systems.[xxiii] The framework was specifically developed to define the latent and active failures implicated in Reason's "Swiss cheese" model so it could be used as an accident investigation and analysis tool. For the model to be systematically and effectively utilized as an analytical tool, the "holes in the cheese" needed to be clearly defined. While Reason envisioned the holes in the cheese as representing systemic weaknesses existing at each level, HFACS filled in the holes by providing categories for each level. Appendix C illustrates the causal categories associated with each level of failure in a complex system, corresponding to the same layers contained within Reason's model. Accident investigation with HFACS uses these individual causal categories to aid in detecting systemic failures; thus, "holes" can ideally be filled before future accidents occur.

2.4. Results of CORE OPS Research

Both RIPCHORD and HFACS are tools used to classify and analyze hazards in form of flow disruptions and human error in the CVOR. The frameworks provide a systematic means of going beyond a "root cause analysis" approach that oftentimes results in the collection of data that is equivocal in nature, which makes it difficult to establish causal links to the events under investigation. Interventions based on data-driven techniques such as RIPCHORD and HFACS provide for effective and verifiable mitigation of those events that pose the greatest stumbling blocks to optimized procedures. CORE OPS utilized RIPCHORD and HFACS to reanalyze the observational data collected during the LENS study, allowing FOCUS to formulate a clearly prioritized list of CVOR hazards.

The LENS observational database includes event narratives labeled as "good practices," "hazards," "preferences or variations," and "time." CORE OPS culled all events labeled as "hazards" and eliminated duplicates, leaving 1,334 observations for analysis using RIPCHORD and HFACS. A team of six human factors scientist consisting of two senior scientists and four trained graduate students coded the data. Two medical doctors were consulted throughout data analysis and offered their opinions as subject-matter experts (SMEs). Coding was accomplished in pairs (minimum) via consensus and discussion continued until a unanimous agreement was reached. Where disagreements existed, the coders analyzed the narratives in more depth until reconciliation was achieved. In those instances which further discussion did not yield an uncontested decision, coding was temporarily suspended pending further discussion with an expert HFACS coder. Group discussions were also used to develop exemplars (i.e. nanocodes) within causal categories associated with the HFACS framework. Because HFACS focuses on the interrelationship among latent and active failures associated with incidents, compound coding was possible: as many causal and/or contributing factors as were applicable to the event were coded.

The three categories of flow disruptions most heavily populated in RIPCHORD were "Coordination," "Communication," and "Interruptions (Other)" (Figure 1).

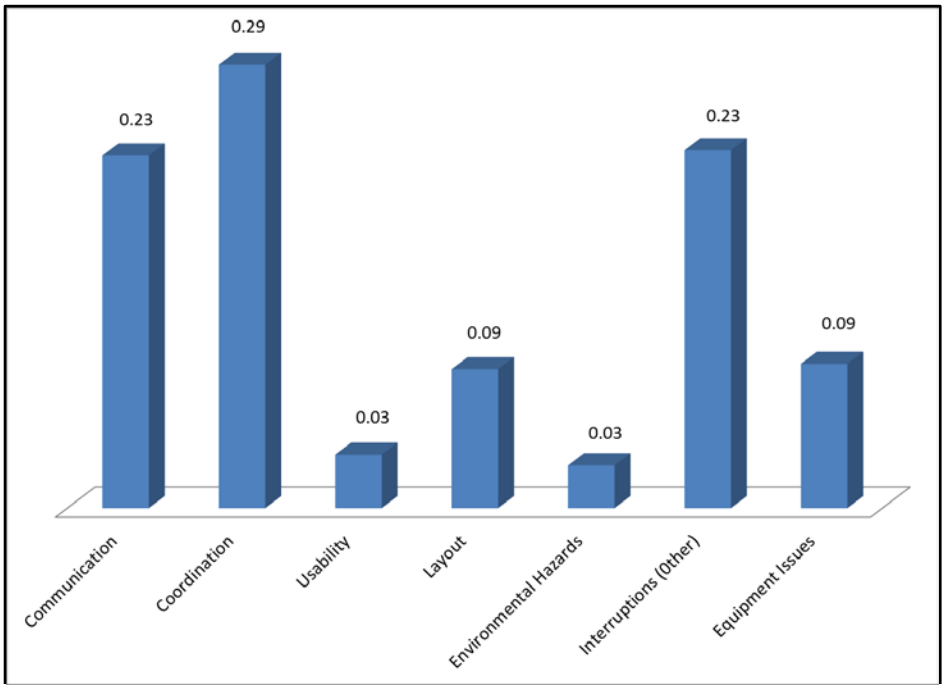


***Figure 1**: Frequency of RIPCHORD Major Category Flow Disruptions*

Within the "Coordination" major/sub category, "Planning/Preparation" accounted for 48 percent of flow disruptions (Figure 2).

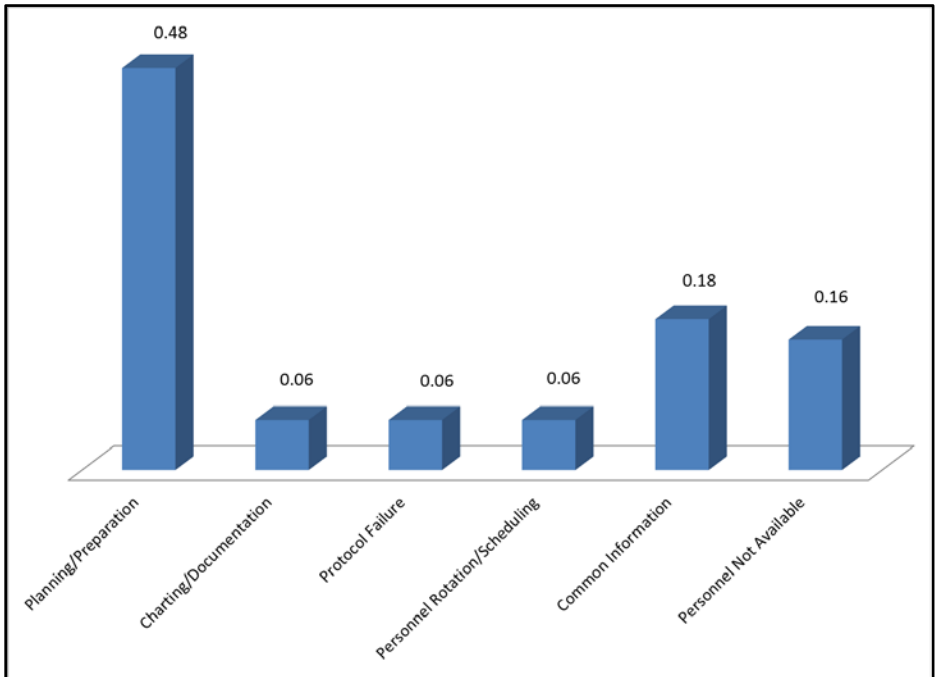


***Figure 2**: Frequency of RIPCHORD Flow Disruptions Within Coordination Subcategory*

Within the "Communication" major category, "Lack of Sharing" and "Lack of Response" accounted for 50 percent of flow disruptions (Figure 3).

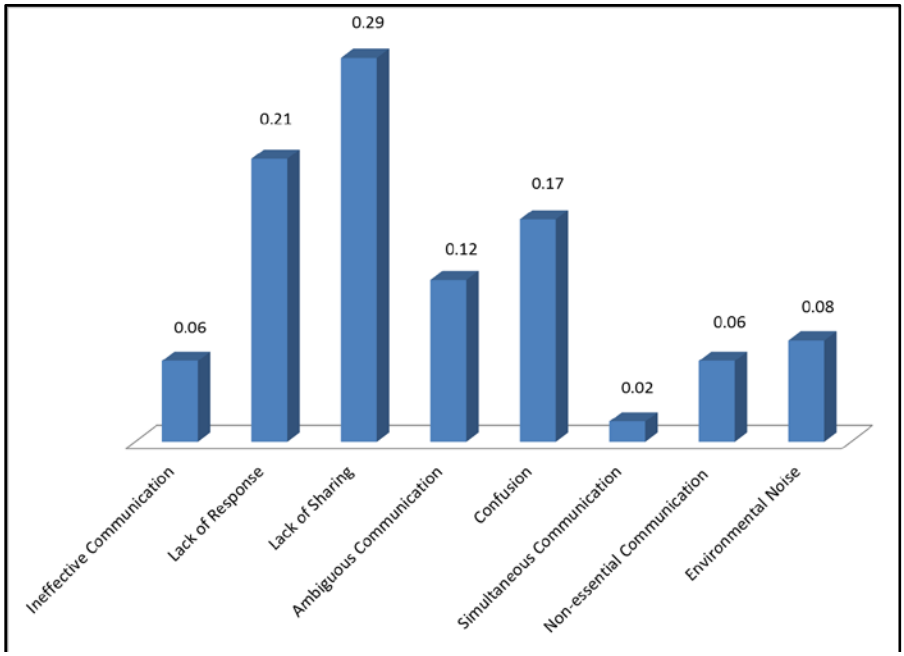


***Figure 3**: Frequency of RIPCHORD Flow Disruptions Within Communication Subcategory*

Issues involving interruptions comprised the third largest major category of flow disruptions. "Equipment/Supplies" and "Spilling/Dropping Items" accounted for 72 percent of interruption-related flow disruptions (Figure 4).

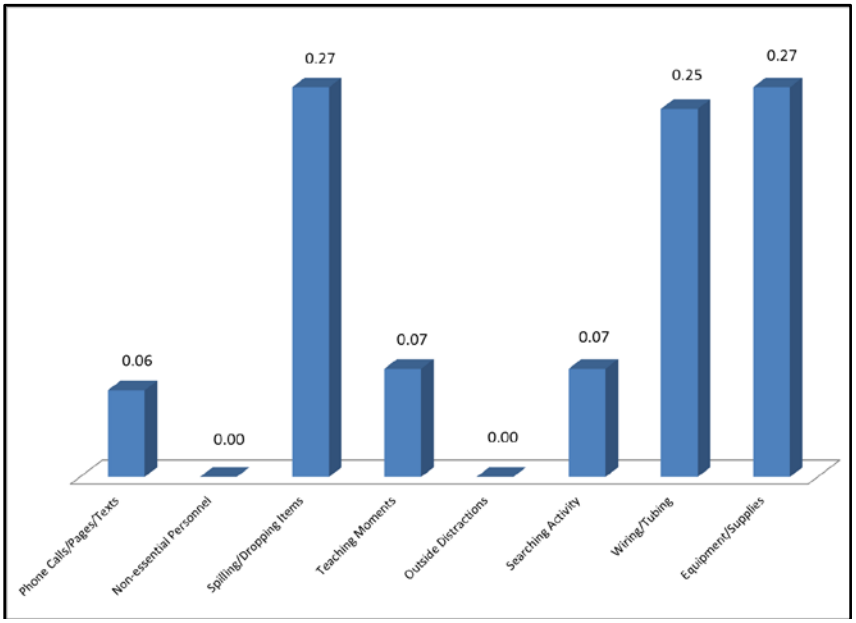


***Figure 4**: Frequency of RIPCHORD Flow Disruptions Within Interruption Subcategory*

The three major categories of errors identified using HFACS were “Communication, Coordination, and Planning”, “Violations,” and “Skill-based Errors,” collectively accounting for 93 percent of the failures noted in the cardiac OR (Figure 5).

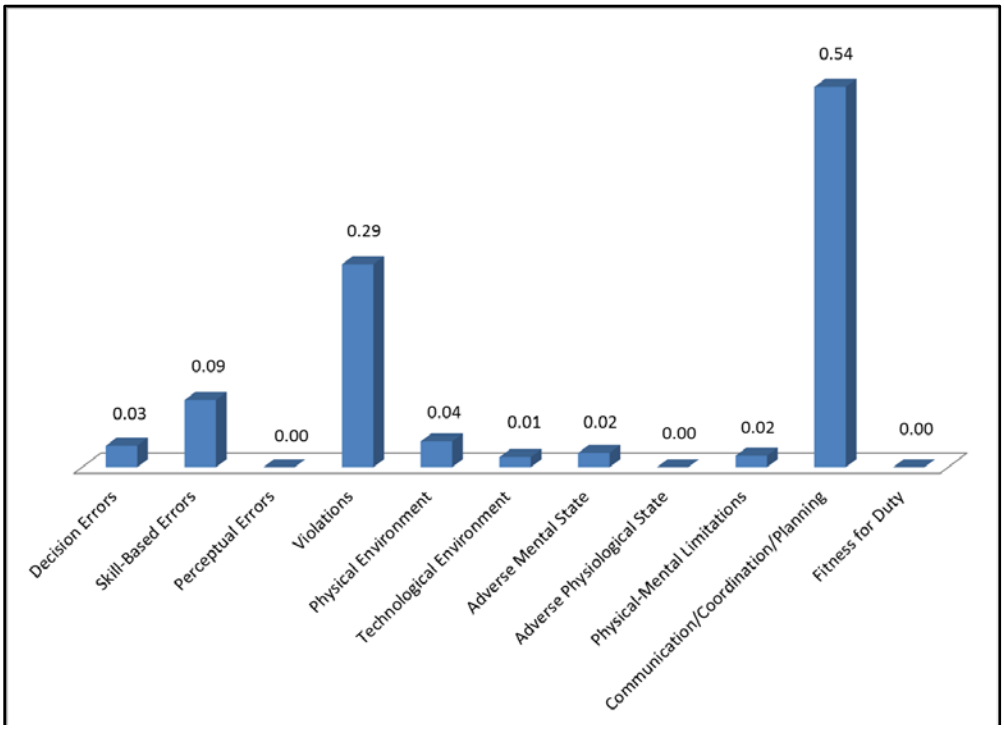


***Figure 5**: Frequency of HFACS Unsafe Acts and Preconditions*

The results of this analysis revealed some noteworthy commonalities. Hazardous events involving breakdowns in communication were disproportionately represented in both RIPCHORD and HFACS. Additionally, coordination and planning failures are heavily represented in both taxonomies. From an intervention standpoint, training (both initial and recurrent) have been shown to be effective in addressing these issues in complex systems.

Flow disruptions that are procedural in nature (e.g. “Equipment/Supplies” and “Spilling/Dropping Items”) and “Skill-based Errors” also overlap between the two taxonomies. These types of failures often represent failures in technique or attention. Given the “procedure rich” environment in the OR, this is not surprising and also provides a good place for cost-effective interventions.

The HFACS analysis of the LENS data highlighted “Violations” as a consistent systemic failure in the CVOR. Violations, which represent direct departures from standardized, accepted, or published protocol, accounted for essentially one-third of the overall hazards identified in the LENS study observations. These violations, which made up the second most populated category of HFACS, were comprised largely of breaks in sterile protocol. Note, however, that while incidents of this nature are certainly considered adverse and hazardous, they do not represent flow disruptions. This underlines the importance of utilizing the two different taxonomies in order to better capture adverse events and potential hazards in the OR.

3. Moving Forward

3.1. Rationale for the Current Investigation

While analysis of the data collected during the LENS study using RIPCHORD and HFACS provided insight into general areas of flow disruption and potential hazards in the CVOR, a greater level of resolution is necessary if improvements are to continue. Rather than use human factors principles to analyze global statements that characterize the overall status of the CVOR, the CORE OPS team is interested in studying flow disruptions and potential hazards threatening optimal performance of the cardiothoracic surgical team and ultimately patient outcomes.

3.2. Proposed Research Method

3.2.1. Proposed Research Sites

The initial stages of data collection will tentatively take place in selected CVORs located throughout the continental U.S. (e.g. Medical University of South Carolina (MUSC) in Charleston, Florida Hospital in Orlando, and Northwestern University Memorial Hospital in Chicago, IL). Additional observational sites are being solicited by the FOCUS initiative within the Society of Cardiovascular Anesthesiology.

3.2.2. Research Team

The CORE OPS research team consists of two senior human factors professors with doctorates in neuroscience and physiological psychology and four human factors doctoral students. During data collection, three CORE OPS team members will be assigned to observe a variety of cardiac surgical procedures. At each site, direct observation and contextual inquiry will be used to collect flow disruption and potential hazard data during the operative period of cardiac surgery. For the purpose of this study, the operative period is defined as starting when the patient enters the OR and ending upon patient transfer to the intensive care unit.

Each individual team member will be embedded in one of three clinical specialties (perfusion, anesthesia, circulating). During the procedure, the researchers will “shadow” staff from each clinical specialty in an effort to focus their investigation on flow disruptions and potential hazards unique to that clinical specialty. To reduce observer bias, the researchers will rotate among specialties between, but not within, surgical cases. For example, a human factors researcher observing anesthesia in one case will observe either perfusion or circulating in the next.

Note that no HF researcher will be embedded with the surgeon(s) or surgical nurse for logistical (i.e., space) reasons. Moreover, the objective of the study is to identify those potential threats to surgical performance, NOT medical error *per se*, so embedded observations of the surgical staff (i.e., surgeon, surgical fellows, surgical residents, and surgical nurse) are not required.

3.2.3. Data Collection

Digital data will be collected in real time using a customized application (Access-based software platform) installed on hand-held tablets (Microsoft SurfacePro's). The application, known as the Observation Precision Tool to Improve Communication and Safety (OPTICS) was specifically developed to capture demographics, RIPCHORD, and HFACS data. OPTICS enables the researcher to capture the description of the event, the type of disruption, the staff involved, and the duration of the event. Event location can also be saved by marking an architectural rendering of the surgical suite. The application enables both real time and *post hoc* classification of flow disruptions and potential hazards using drop down menus tailored to each framework (i.e., HFACS and RIPCHORD). A snapshot of the OPTICS data collection form is shown in Appendix D.

Digital data collected during the surgery will be stored in databases on the hard drive of the MS SurfacePro tablets and downloaded to a password protected and secure desktop computer for offline analysis.

3.2.4. Debriefing

Provider-workload permitting, the observers will complete a short debrief with each of the respective specialists following each surgery. Topics covered in the debrief interview will include general impressions of how the surgery progressed; notable interruptions, hazards, or failures; periods of higher than normal workload; and possible remedies for future surgeries. Information obtained throughout the procedure and during the debrief session will remain anonymous. Once data collection is complete for all sites involved in the study, comments from the debriefing interviews will be categorized and scored based upon the major constructs that make up the interviews.

3.2.5. Data Management and Analysis

All observational events will be downloaded into an Excel spreadsheet for *post-hoc* analysis. Data analysis will be accomplished in two phases. In the first "quality" phase, specific events (i.e., hazards and flow disruptions) coded during surgery will be checked for accuracy by all members of the HF data collection team. In addition, it is likely that there will be instances where the hazards/flow disruptions are so prevalent that complete coding of events may not be possible; however, the details of the event were captured. In those rare events, the HF team will code the data using HFACS and RIPCHORD to ensure the database is complete and accurate.

3.2.6. Confidentiality

All observations will be strictly anonymous (i.e., individual staff will not be identified) and all events will be assigned a unique identifier that cannot be traced to any individual patient or surgical team. Moreover, the principle investigators are not particularly interested in any specific case. Rather, it is the aggregate data that will be reported and from which any recommendations will be derived.

4. Future Directions

The CORE OPS research team is currently collaborating with FOCUS on three manuscripts relevant to the analysis of the LENS study data: the first manuscript examines the results of the RIPCHORD analysis, the second manuscript examines the results of the HFACS analysis, and the third manuscript examines communication and coordination breakdowns in the CVOR that were identified using both taxonomies. It is expected that the following three manuscripts will be submitted for publication to the respective journals listed below during the fall of 2013:

- Providing Another LENS on Cardiovascular Surgery Using RIPCHORD
  - Anesthesia, Annals of Thoracic Surgery, Anesthesia and Analgesia
- Using Human Factors to Identify System Failures in the Cardiovascular Operating Room
  - Anesthesia, Annals of Thoracic Surgery, Anesthesia and Analgesia
- Communication (or lack thereof) in the Cardiovascular Operating Room: A Survey
  - potential journals: New England Journal of Medicine, JAMA

Deliverables from both the current and proposed research will form the basis for a number of ERAU/SCAF-FOCUS “patient safety and healthcare quality” grant applications to federal funding agencies. These grants will seek to develop data-driven human factors engineering interventions that will enable cardiothoracic surgical teams and healthcare administrators to optimize patient safety in the CVOR.

Appendix A: Description of disruptions for the Realizing Improved Patient Care through Human Centered Operating Room Design (RIPCHORD) Observational Taxonomy

Communication (verbal and non-verbal)

Ineffective Communication – Communication between two or more individuals that does not achieve its desired goal.

Lack of Response – The failure of an individual to answer communication requiring a reply or confirmation.

Ambiguous Communication – Communication between two or more individuals which, by its nature, may result in multiple interpretations.

Confusion – A lack of understanding associated with communication.

Simultaneous Communication – Two or more individuals communicating at the same time necessitating the repetition of information and/or resulting in miscommunication.

Non-essential Communication – Non-essential communication (e.g., sports-talk, jokes, personal inquiries) during periods of time where attention should be focused on the task at hand.

Environmental Noise – The increasing sound level in the OR may disrupt communication and/or adversely affect concentration on the current task.

Lack of Sharing – Relevant information is withheld or not shared with other personnel**.**

Usability

Computer – Design issues associated with operating software, programs, and utilities; usability issues associated with pointing devices, monitors, and other hardware are also included in this category.

Equipment – Design issues associated with equipment other than computers and software-related devices.

Surfaces – Textures, colors, and other design-controlled attributes that inhibit optimal use.

Barriers – Issues associated with donning protective equipment (e.g., gloves, gowns, etc.) and/or erecting barriers for maintaining sterile fields.

Packaging – Issues associated with unwrapping, untying, or opening packaging containing supplies and instruments.

Data Entry (non-computer) – Design issues associated with hard-copy data entry devices (e.g., forms, checklists, etc.).

Layout

Connector Positioning – Lack of outlet connections and/or the inefficient use of existing outlet connections which can hinder movement of staff and/or equipment.

Equipment Positioning – Machines and tools may restrict or prevent the movement and actions of the staff.

Furniture Positioning – Room furnishings (e.g., chairs, the patient bed, desks) can cause OR staff to deviate from their original movement.

Permanent Structures Positioning – The inefficient layout of permanent structures; for example, doorways are frequently used in the OR during surgical procedures, which may prevent continuous movement and possible injury.

Inadequate Use of Space – Surface and floor space is used inappropriately through clutter, untidiness, congestion, and blockage.

Impeded Visibility – Objects which obstruct the ability of personnel to see at important junctions during the procedure.

Environmental Hazards

Slipping/Falling – OR staff have the potential of slipping on liquids and materials on the floor while not being cognizant of surroundings.

Sharps – Incidents which involve the interaction of OR staff with sharp objects that could cause a potential hazard.

Crushing – Objects that are forced and wedged between unintentional spaces.

Fluids – Incidents which involve the interaction of OR staff with bodily or other fluids that pose a potential health hazard.

Contaminated Equipment – Incidents which involve the necessary replacement of equipment due to contamination.

Interruptions (Other)

Phone Calls/Pages/Texts – Incoming or outgoing calls, texts, or pages may occur which draw attention away from the surgical procedure.

Non-essential Personnel – Staff that are not essential to the surgical procedure are labeled as a distraction.

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

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

Outside Distractions – Disruptions external to the operating room that interfere with normal activity (e.g., noises in the passageway, fire alarms, etc.).

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

Wires/Tubing – The entanglement or misplacement of wires and tubes, which can hinder movement and/or continuation of a task.

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

Coordination

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). This category may include a variety of coordination, and teamwork issues that impact performance.

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

Personnel Rotation/Scheduling – A break or disruption in the procedure caused by the planned or unplanned relief of personnel which unduly impacts the flow of the surgery; includes issues surrounding scheduling of patients and personnel for a given medical procedure.

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

Protocol Failure – Break or breach in protocol.

Personnel Not Available – Team members not present or otherwise accounted for at critical points.

Equipment Issues

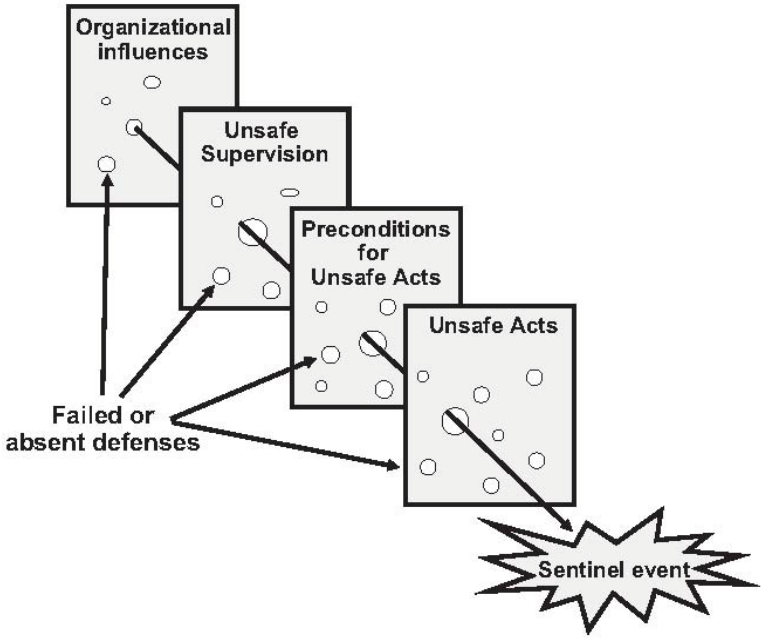
Surgeons Equipment – Equipment which malfunctions during surgery used by surgeons.

Anesthesia Equipment – Equipment which malfunctions during surgery used by anesthesiologists.

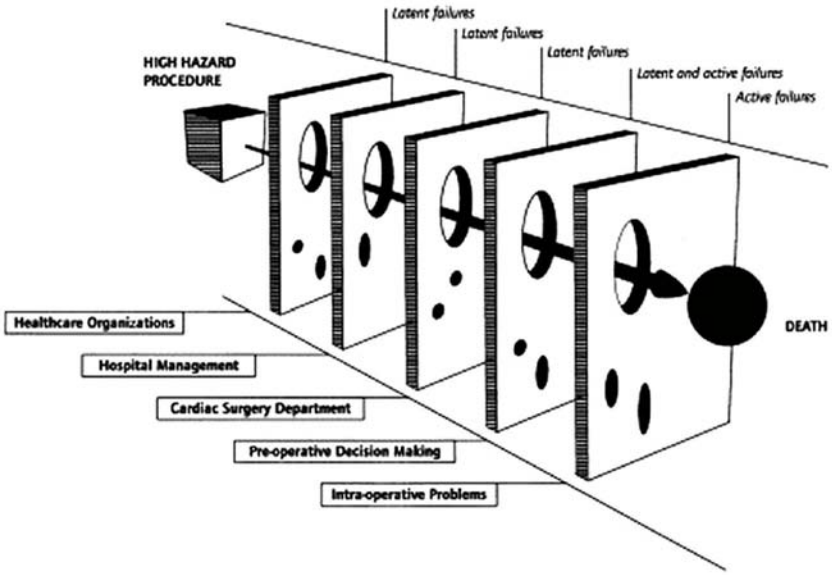
Perfusion Equipment – Equipment which malfunctions during surgery used by perfusionists.

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

Appendix B: Reason's "Swiss Cheese" model of accident causation

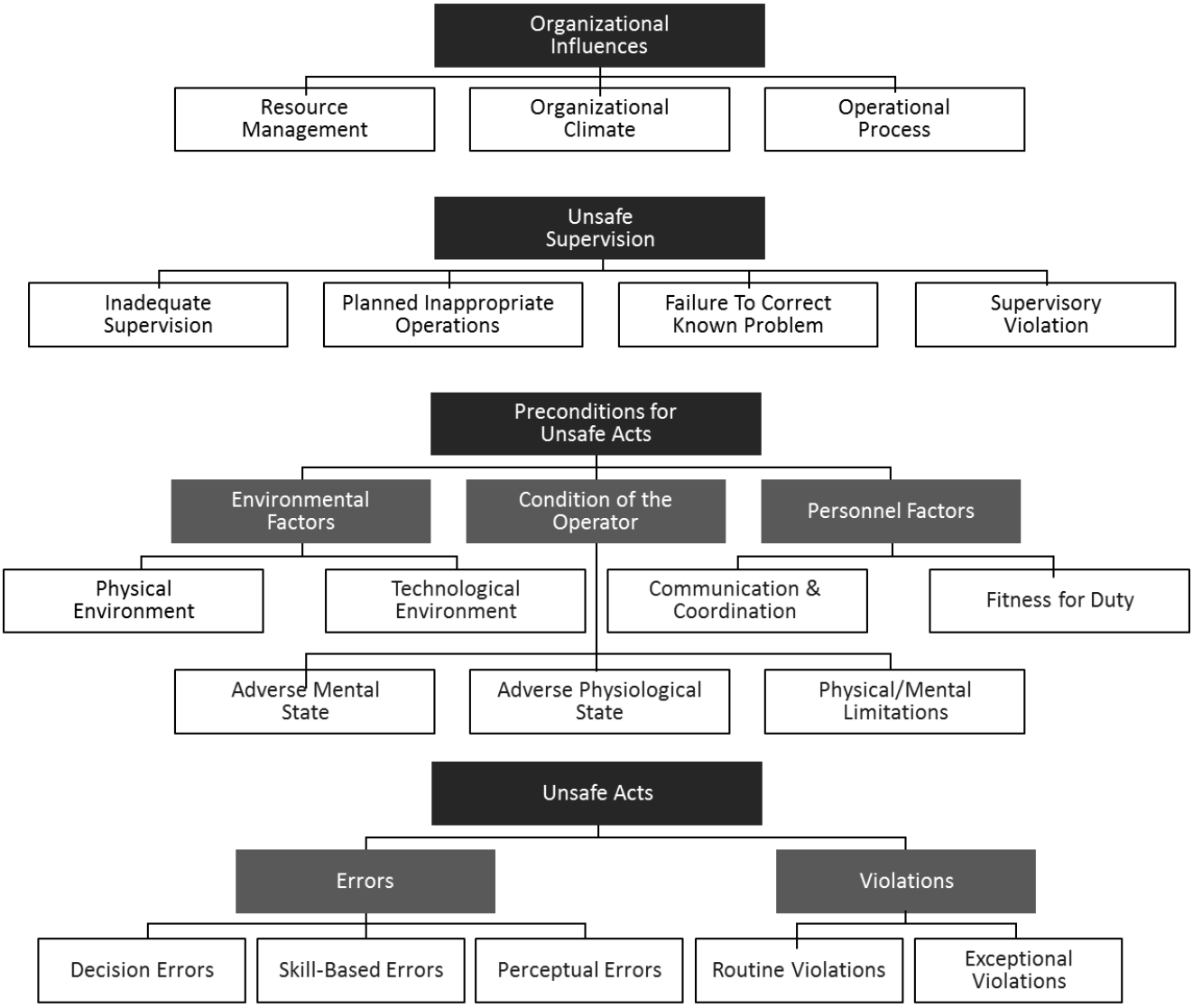


a). as adapted by Wiegmann & Shappell (2003) for HFACS

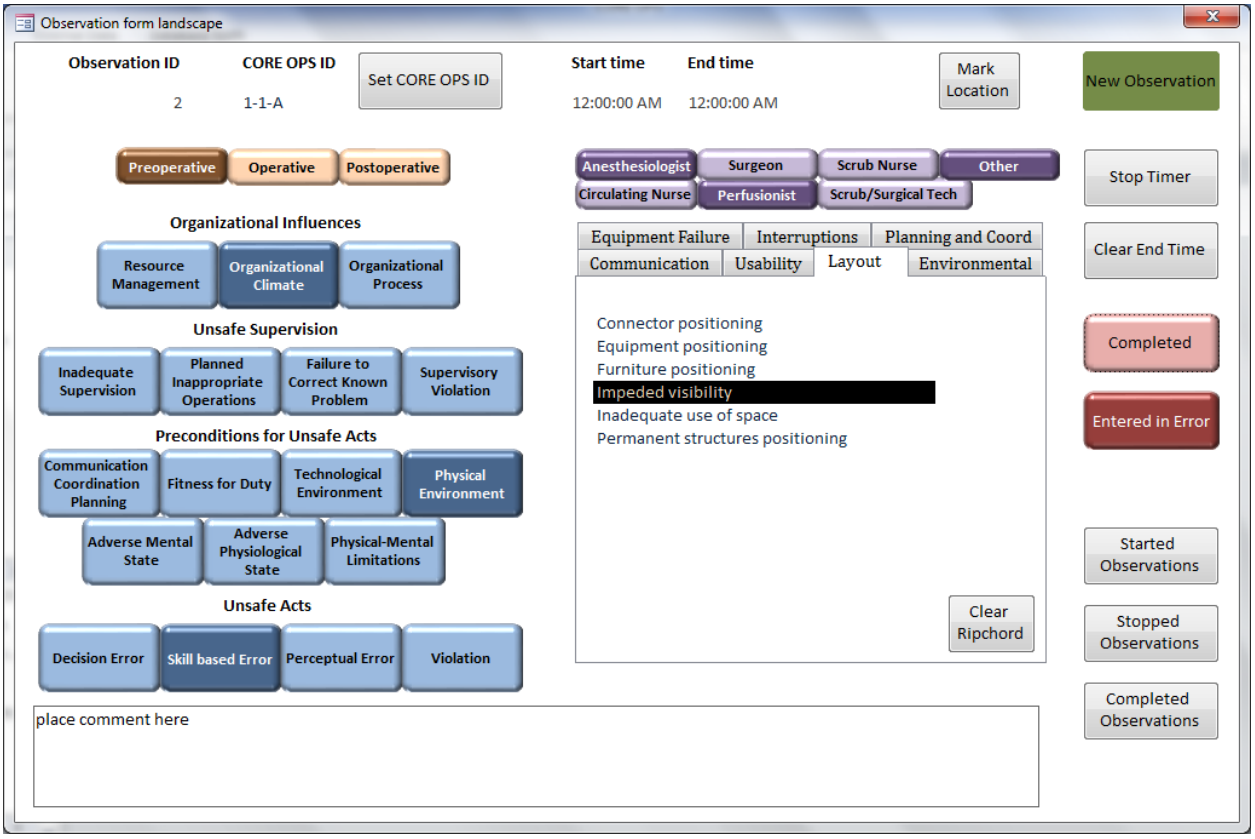


b). as adapted by Carthey, et. al. (2001) to healthcare/hospital organizations

Appendix C: The Human Factors Analysis and Classification System (HFACS)



Appendix D: Observation Precision Tool to Improve Communication and Safety (OPTICS) data collection form



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