Adaptive Behaviors of Experts in Following Standard Protocol in Trauma Management: Implications for Developing Flexible Guidelines

Mithra Vankipuram MS[1], Vafa Ghaemmaghami MD, FACS[2], Vimla L. Patel PhD, DSc[3]
[1]Arizona State University, Scottsdale, AZ; [2]Banner Good Samaritan Medical Center, Phoenix, AZ; [3]New York Academy of Medicine, New York, NY

Abstract

Critical care environments are complex and dynamic. To adapt to such environments, clinicians may be required to make alterations to their workflows resulting in deviations from standard procedures. In this work, deviations from standards in trauma critical care are studied. Thirty trauma cases were observed in a Level-1 trauma center. Activities tracked were compared to the Advance Trauma Life Support standard to determine (i) if deviations had occurred, (ii) type of deviations and (iii) whether deviations were initiated by individuals or collaboratively by the team. Results show that expert clinicians deviated to innovate, while deviations of novices result mostly in error. Experts' well-developed knowledge allows for flexibility and adaptiveness in dealing with standards, resulting in innovative deviations while minimizing errors made. Providing informatics solution, in such a setting, would mean that standard protocols would have be flexible enough to "learn" from new knowledge, yet provide strong support for the trainees.

Introduction

Protocols and standards are important for ensuring process consistency and patient safety in health care. It has been shown that linear systems and processes are aided by protocol and checklist deployment. For example, Pronovost and colleagues showed that implementation of a checklist for central line placement decreased the rate of catheter related blood infections from 2.7% to zero in the first three months of deployment[1]. Such protocols limit errors by reducing the workload on human memory and automating the care process[2]. Most critical care environments, however, are characterized by non-linear interactions and dynamic emergent behavior[3]. In such environments, clinicians need to make dynamic adjustments to protocols and guidelines, in order to adapt to the operational conditions and to achieve high accuracy and efficiency.

Researchers often equate error to any deviation from some known standard[4-6]. The Institute of Medicine (IOM), in a report released in 2000, defined error as *"…a deviation from that (protocol, procedure) which is generally held to be acceptable"*[7]. While equating errors to deviations may be generally accurate, the converse need not necessarily be true. Deviations are made for a variety of reasons and not all deviations result in errors. In fact, deviations from protocol may be innovations designed to maximize patient safety and increase throughput[8]. The identification and analysis of such cases is important for the evaluation and improvement of existing protocols.

In a previous study[9], we explored deviations from the Advance Trauma Life Support (ATLS) guideline. Field observations of ten trauma cases were conducted in a Level-1 trauma unit. Errors and innovations were defined as deviations that may be linked to negative and positive outcomes, respectively. The results from this study show that expertise of the caregivers and criticality of a patient's condition influence the number and type of deviations from standard practice. While this research was reported as a novel approach for assessing protocols and guidelines, the sample size was small. In addition, errors and innovations were defined in terms of patient outcome. The causal effect between deviations and specific patient outcomes may be difficult to track in critical care environments. For this reason, there is a necessity to define deviations in relation to protocols and guidelines instead. This will also enable definitions to be more generalizable to other critical care environments.

In this paper, we explore the relationship between errors, innovations and standards as a function of expertise in complex critical care environment and discuss implications for generating informatics solution such as developing and updating electronic guidelines that cater for both experts and trainees.

Background

In critical care settings, teams of professionals care for patients. These teams typically involve clinicians with varying backgrounds and expertise, working in a collaborative manner. These teams operate in environments with dynamic social structures[10] and are required to adapt to varying task demands and coordinate their efforts to complete activities necessary for task completion[11]. Team decision-making is a key factor that impacts co-ordination between individuals involved in the patient care process.

Cannon-Bowers, Salas and Converse[12] define team decision making as a "team process that involves gathering, processing, integrating and communicating information in support of arriving at task-relevant decisions". It is a process that requires individuals to apply their expertise to filter data and communicate relevant information and recommendations to other team members. This can be affected by a number of environmental factors such as situation complexity, time pressures, multi-component decisions and evolving (at times ambiguous) information[13]. Effective decision making under these circumstances relies on the emergence of shared mental models and related thinking (cognition) among all the providers involved in the care process[14]. Experts' ability to quickly filter relevant from less relevant information makes them more flexible and adaptive to environmental changes.

Shared mental models reduce the communication required to co-ordinate decisions as well as activities required to complete a particular task. Members of a "good team" perceive and interpret situations in a similar manner. This enables the team to make decisions and take action effectively. Providing teams with the tools to promote the development of shared mental models is critical to the development of coordinated healthcare delivery. Protocols, standards and guidelines are one such set of tools. In addition to providing a systematic way to treat patients, protocols and guidelines serve to establish shared goals and a common vocabulary for multi-disciplinary teams, thereby enabling individuals to function and make decisions as a team.

In trauma situations, clinicians follow the Advance Trauma Life Support (ATLS) guideline[15]. The tasks and goals for "Initial Survey and Management" in trauma are common to both physicians and the nurses. In this way, the immediate goals of the guideline are shared among individuals with varying backgrounds and levels of education.

The guideline can be roughly divided into three sections (i) Primary survey and resuscitation, (ii) Secondary survey and examination, and (iii) Definitive care and transfer. In the primary survey, all immediate, life-threatening conditions are mitigated. Once the patient's vital signs stabilize, a thorough head-to-toe examination can be performed. Information obtained from examinations (and diagnostic tests) allow the trauma team leader to make decisions relating to the care of the patient. The following section describes the guideline in detail, placing it within the context of the environment, tasks and goals.

Trauma Domain Description

Trauma Team Structure

The core team typically includes the attending surgeon, residents, an anesthesiologist, and nurses. Supporting members include a respiratory therapist, pharmacist and an X-ray technician. Roles and responsibilities are well defined for team members. The trauma *team leader* supervises the trauma, making major decisions and delegating work to other members of the team. The trauma lead may be assisted by a resident physician. The *assisting physician* performs hands-on evaluation and suggests treatment. The *primary trauma nurse* is responsible for immediate care of the patient. A nurse recorder who documents events in workflow sheets may assist the primary trauma nurse. The structure of the team is often dynamic. Roles of team-leader and assisting physician may shift between residents and attending surgeons. In teaching hospitals, attending surgeons mostly play the role of a mentor overseeing residents serving as the trauma leaders.

Trauma Information Sources

Trauma teams receive information from a variety of sources including pre-arrival patient information, trauma workflow sheets, patient vital signs monitor, x-ray and computerized tomography (CT) scans, diagnostic tools to analyze blood and urine samples, and information shared by other care providers[16]. In such conditions, one of the main challenges faced by teams is decision making with evolving information. Trauma teams may be required to adapt they decision making as more information emerges.

Trauma Scenario Walkthrough

Irrespective of the type of trauma, certain key steps are performed (*in quasi-sequential order*), to evaluate the patient. In this section, we will walkthrough a typical trauma case scenario encountered at a trauma facility (workflow depicted in Figure 1). This scenario is based on workflow observed on site at the Level-1 Trauma center as well as on the existing literature on ATLS guideline implementation[15].

Trauma Preparation: A trauma scenario typically begins with an announcement of trauma arrival with an acuity or case type indicator. Based on the trauma severity, provider teams assemble in the Trauma unit. Once the required team members assemble, the clinicians have a brief window (ranging from 2 to 10 minutes), in which they perform various activities to prepare for the case at hand. For example, members may exchange information about the case, or scrub and wear appropriate protective garments. When the patient arrives, emergency medical technicians transfer the patient to the trauma bay and provide a brief overview of patient history. At this point the trauma leader takes charge of the trauma and initiates the primary survey.

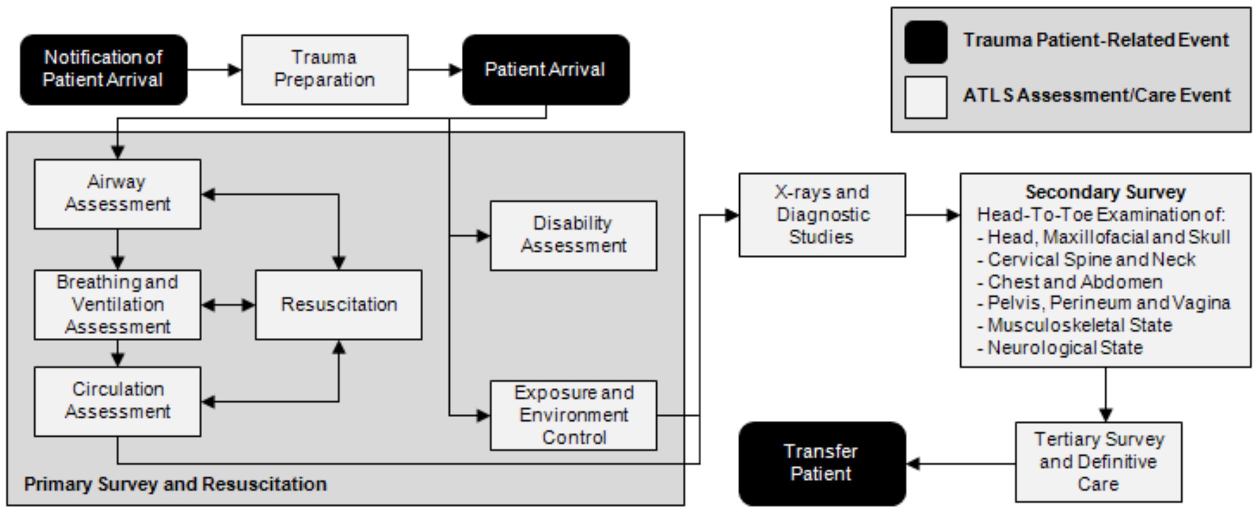

Figure 1. Trauma scenario walkthrough: typical workflow observed in trauma

Primary Survey and Resuscitation: In the primary survey, the leader evaluates patient airway, breathing, circulation and neurological state. This survey is usually quick and performed within the first two minutes of patient's arrival. Resuscitative efforts (orders given by the leader) and patient exposure are typically performed in parallel by other team members (primary nurse and assisting physician). When all life threatening conditions have been managed, the team proceeds to use tests available to diagnose patient trauma and follow appropriate treatment.

Secondary Survey and Definitive Care: The secondary survey may be performed while waiting for the results of diagnostic tests and involves a detailed head-to-toe examination of the patient. The trauma leader then proceeds with formulating a treatment plan. Physicians may consult with the mentor (attending surgeon) or a specific specialty (for example, orthopedic or plastics consult), if needed, at this stage. The team may then proceed with providing definitive care (management of conditions not treated at the end of the primary survey) and performing tertiary surveys. When the patient is ready to be transferred out of trauma, they may be discharged or moved to a room for monitoring and extended treatment through a consult.

The ATLS standard, described above is a *guideline* as opposed to being a fixed protocol. A guideline is defined as "a statement or other indication of policy or procedure by which to determine a course of action"[17]. In contrast, a protocol is "a precise and detailed plan … for a regimen or therapy"[18]. Trauma is a complex system that is inherently dynamic and unpredictable. Gawande[19] states that when confronted with complex and non-routine problems individuals working in teams need to be given the room to adapt based on their experience and expertise. Providing clinicians with a rigid protocol may limit their ability to adjust to the situations at hand. A guideline, on the other hand, does not inherently penalize individuals for not performing a particular step in order. This allows clinicians to adapt the guideline to suit the dynamic needs and requirements of the team.

For the purpose of this research, we consider the ATLS guideline to be a set of minimum specifications. The guideline provides general direction for the team and describes role boundaries, resources and constraints[20, 21]. The implementation of such a guideline, as opposed to detailed protocols, can result in the emergence of innovative and complex behaviors[22]. The key challenge here is to ensure that the deviations or novel adaptations made by the team members do not contradict the purpose of the guideline and consequently compromise patient safety. The objective of this research is to identify and classify the various deviations (from this guideline) that occur, in order to understand how expertise of the team may affect the types of deviations made and the overall team performance.

Conceptual Framework for Classification of Deviations from Standard Practice

In our previous research[9], we classified deviations as (i) Errors, (ii) Innovations, (iii) Proactive deviations, and (iv) Reactive deviations. In this section, we will revisit the classification of deviations from the perspective of their impact on workflows (as suggested in Kahol et al.[9]). In addition, in this study we examine the deviations to assess whether they were initiated by individuals or collaboratively by members in the trauma team.

Deviations as Errors: An error is defined as a deviation from the standard, if, it (i) violated a prescribed order of activities with a negative impact on workflow, (ii) resulted (directly or indirectly) in compromising patient care or (iii) resulted in an activity being repeated due to failure in execution or a loss of information. Examples of errors encountered in the trauma cases observed in our study include,

- A resident completed the secondary survey prior to ordering chest/abdomen/pelvis x-rays. Consequently, obtaining these x-rays for diagnosis was delayed. In this case, sequence in which the tasks were performed violated the order prescribed in the ATLS standard. As this deviation caused a delay in receiving information critical to treating the patient in a timely manner (and thereby negatively impacting workflow), it was classified as an error.
- A junior resident attempted to remove the spine board before the patient's spine was cleared (confirmed not be injured). This deviation directly compromised patient care and consequently was classified as an error.
- The lab technician needed to redraw a sample for blood work as additional tests were ordered. The previous sample had been discarded. A lack of communication within the team resulted in this deviation. While not as severe as the previous error, the repetition of a task by a team member due to a failure in communication was classified as an error.

Deviations as Innovations: Innovations are defined as deviations that potentially benefit the individual, team or patient by bringing a novel perspective to the situation at hand[23]. Some examples of innovations identified in this study are given below:

- A patient required a translator in order to communicate with the resident. The team was unable to find a translator. The attending asked the trauma nurse to see if the patient's family could help. The patient's sibling was able to come into trauma and act as a translator. This allowed the resident to continue with his examination, leading to successful assessment and treatment of the patient. The standard protocol of seeking an in-house translator was violated. A novel step (that resulted in a positive outcome) was introduced in the workflow, which qualifies as an innovative deviation.
- A patient was nervous about the damage done to his face due to an accident. In order to calm the patient, the nurse provided him with a small mirror so that he could assess the damage for himself. The patient then relaxed. For such a case, the guideline provides no instruction on how to deal with a difficult patient. The clinician deviated by introducing an action outside the scope defined by the guideline to successfully care for the patient.
- The resident examined a patient's leg injury (in fewer than 15 seconds), and ordered an x-ray of the extremity along with chest and abdomen x-rays. By introducing a brief examination of the injury site, the resident was able to anticipate a future need and advance a step in the standard. The results were relayed back to the team more promptly than if the prescribed order of steps had been followed. The introduction of a novel step that resulted in a positive outcome on the workflow was considered to be an innovation.

Proactive Deviations: A proactive deviation occurs when (i) an activity is performed (without compromising patient care) in anticipation of a future requirement (or lack thereof) when treating a patient or (ii) an activity (which may be out of the bounds of an individual's role in the trauma team) is performed in order to correct or prevent error occurrence. Some examples of proactive deviations encountered in the trauma cases observed include,

- A radiology technician set up the x-ray sensor board for a chest x-ray prior to the trauma arrival as the trauma team had been notified about the nature of the trauma.
- A trauma nurse called the radiology unit to let them know that the technician would not be required as the scans are already taken in the previous facility.
- The trauma nurse reminds a junior resident that c-spine results have to be received prior to removal of the spine board.

Reactive Deviation: Reactive deviations occur when an activity is performed in reaction to an unanticipated event or change in patient condition, diagnosis process or treatment plans. Examples of reactive deviations found in this study include,

- A patient was violently reacting to pain and needed to be held down by the trauma team in order to complete primary survey and intubate patient (if necessary).
- The results of the x-ray ordered were inconclusive. As a result, the resident ordered an angiogram.
- A patient concerned about his facial injuries requested a plastics consult. The treatment plan had to be altered to accommodate the patient's request.

Table 1 summarizes the terminology involved in classifying deviations. In addition to classifying deviations by the impact they may have on workflow, deviations may also be classified based on whether they occur at the individual or team level. At the individual level, deviations may be related to how the guideline is implemented (*process* related deviations), or how a specific medical intervention is performed (*procedure* related deviations) or how care related interventions are provided to the patient *(care delivery* related deviations).

Table 1. Summary of Deviation Terminology

1. Type of Deviation	
A. Error	Related to standard practice: ▪ Task order violation ▪ Task omission ▪ Task repetition due to communication or execution failure Impact on workflow: **Negative** ▪ Causes delays ▪ Compromises patient care
B. Innovation	Related to standard practice: ▪ Novel task addition Impact on Workflow: **Positive** ▪ Improves workflow efficiency ▪ Improves quality of patient care
C. Proactive	Related to standard practice: ▪ Task advancement ▪ Error prevention Impact on Workflow: **Neutral** ▪ No observable effect on workflow or patient care.
D. Reactive	Related to standard practice: ▪ Common task addition in response to random event Impact on Workflow: **Neutral** ▪ No observable effect on workflow or patient care.
2. Initiated By	
A. Individual: Process related	Initiated by single clinician in the team. Related to standard practice: ▪ Deviations (including task order change, omission and addition) that relate to how the standard is implemented.
B. Individual: Procedure related	Initiated by single clinician in the team. Related to standard practice: ▪ Deviations (including tasks repeated due to execution failure) that relate to medical interventions provided to the patient.
C. Individual: Care-delivery related	Initiated by single clinician in the team. Related to standard practice: ▪ Deviations related to care interventions provided to the patients.
D. Team	Initiated collaboratively by two or more clinicians in team.

Examples of process related deviations include log roll not being performed correctly or an x-ray being ordered after the secondary survey. In both examples, clinicians deviated from the recommended method for guideline implementation. In contrast, procedure related deviations, such as a clinician making an error in stapling a wound, deal with how a specific step of the guideline is performed. Any deviation dealing with the care provided to the patient (not specified in guidelines) including providing a mirror to a patient concerned by facial injuries or providing medications for a patient in pain, is classified as deviations in care delivery.

While an individual may initiate many of these deviations, some deviations occur at the team level. Such deviations involve more than one clinician participating in the event. For example, a resident may decide on an alternate course of treatment based on a discussion with his attending or the team, may fail to perform a critical step in the guideline. Such deviations were classified as *team level* deviations. Understanding where and at what level deviations take place can enable us to understand various factors contributing to the deviations. In this research we explore (i) various types of deviations that occur in trauma, (ii) how they relate to expertise, and, (iii) the whether they were initiated by an individual or by a team.

Methods

One researcher, from September 2010 to December 2010 at Banner Good Samaritan's Level-1 trauma unit, conducted field observations for this work. A total of 30 Trauma cases were observed with 15 cases being led by 4th or 5th year residents (PGY 4/5) and 15 cases led by 2nd or 3rd year residents (PGY 2/3). The trauma cases were observed by the researcher using the A(x4) model[24]. This model requires contextual observations (snapshots) to be captured by highlighting 4 key parameters, namely, actors, activities, atmosphere and artifacts. Observations captured in this manner provide rich contextual descriptions of the situation, which is required for analysis of deviations. Each time-stamped observation was compared to the corresponding step in the ATLS guideline[15] in order determine (i) if a deviation had occurred and (ii) the type of the deviation. The data were analyzed iteratively until the number and type of deviations stabilized. The analysis methodology is similar to the methods described in our previous preliminary study[9]. It should be noted that the number of raters classifying the deviations limits the study described in this work. Further experimentation to assess inter-rater reliability of the classification schema is a part of our future work.

The Institutional Review Boards of Arizona State University and Banner Good Samaritan Medical Center approved this study and the informed consents were obtained from the participants on each encounter.

Results

A total of 153 deviations from the standard protocol were identified based on 30 Trauma cases observed. These deviations are described categorically using the variables (i) experience level of the resident leading the trauma, (ii) role played by clinician initiating the deviation in the trauma team, and (iii) phase of the trauma standard where the deviation took place. In addition to summative statistics described in the figures, the results are textually presented as mean deviations per case (μ) ± standard deviation (σ).

Deviations and Trauma Leader

While no significant difference was found in the frequency of deviations, the types of deviations made were found to be related to the experience level of the clinician leading the trauma. Chi-square analysis between team leader and classification of deviation by impact on workflow showed significant relationship between these variables (Chi-sq = 9.93, df = 3, p = 0.0192). In figure 2 (left) depicts the relationship between the experience level of the trauma leader and errors, innovations, proactive and reactive deviations. The number of proactive deviations was similar (PGY2/3: 1.13±0.56, PGY4/5: 1.20±0.63) for the two groups. Errors (PGY2/3: 1.53±0.82, PGY4/5: 0.80±0.57) and reactive deviations (PGY2/3: 1.87±1.16, PGY4/5: 1.20±0.57) were found to be greater in cases led by PGY2/3 residents when compared to cases led by PGY4/5 residents. On the other hand, the total number of innovations (PGY2/3: 0.80±0.34, PGY4/5: 1.67±0.88) was found to be greater in cases led by a senior resident. These finding suggests that (i) trauma leaders with more experience are able to adapt (making innovations) to the dynamic environment while minimizing errors, and (ii) experience enables leaders to guide a more proactive trauma team. Thus, it can be hypothesized that the proactive nature of expert trauma leaders enables them to anticipate future needs and possible errors, thereby minimizing resource wastage and unnecessary negative impact on patient outcomes.

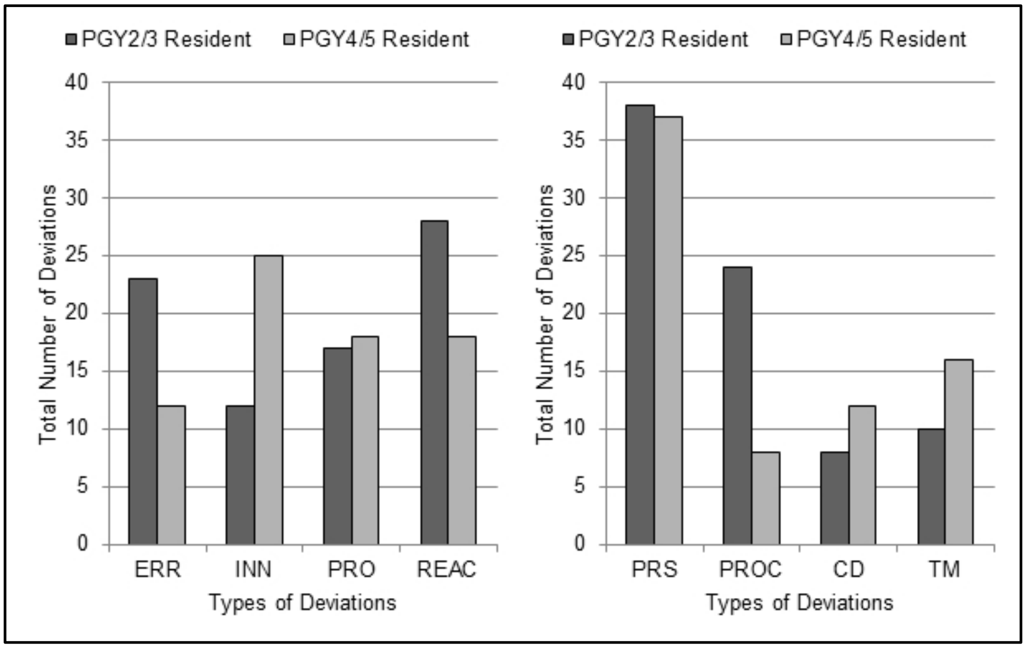

Figure 2. Frequency and Types of Deviations and Expertise of Trauma Leader – Types of deviations (left) based on consequence to workflow and (right) level of occurrence are compared against leader expertise. (ERR: Error, INN: Innovation, PRO: Proactive deviations, REAC: Reactive deviations, PRS: Process, PROC: Procedure, CD: Care delivery, TM: Team)

We also found significant relationship between the experience level of the team leader and the type of deviation by level of occurrence (Chi-sq = 9.89, df = 3, p=0.0194). Figure 2 (right) depicts the relationship between leader expertise and individual and team level deviations. Cases led by junior residents had fewer (in total) care delivery (PGY2/3: 0.53±0.50, PGY4/5: 0.80±0.54) and team related deviations (PGY2/3: 0.67±0.62, PGY4/5: 1.07±0.77). The lack of experience at the helm could be affecting communication channels critical to efficient and adaptive team performance in trauma. Junior residents were also found to focus more on specific procedures. Deviations in their cases were biased toward procedure related deviations (PGY2/3: 1.60±1.08, PGY4/5: 0.53±0.53). This is indicative of their level of training. Senior residents have mastered procedures, and can focus on developing other skills, such as communication. While there were differences in procedure-related deviations, the number of process related deviations (PGY2/3: 2.53±0.84, PGY4/5:2.47±0.56) were found to be similar for the two groups.

Deviations and Phases of Trauma Care

Figure 3 (left and right) shows the total number of deviations identified at each key stage in the trauma management standard. We found that greater number of deviations occur in the phases following trauma preparation and primary survey and resuscitation (Percentage of deviations in Phase 1: 12.42%, Phases 2-4: 87.58%). Using chi-square analysis we found a significant relationship between the phase in the standard and the deviation type (Chi-sq = 63.09, df = 12, p<0.0001).

As seen in figure 3 (left), errors occur throughout the various stages of the trauma (across Phases 1-4: 7.0±1.94), while innovations only occur once the primary survey is completed. This is indicative of the level of adaptability the guideline allows for in the earlier stages of trauma treatment. The primary survey is protocol driven, while the secondary survey and definitive care are more flexible allowing the trauma team to deviate and adapt to the case at hand. The key difference between an expert clinician and a novice is that expert clinicians deviate with the flexible portions of the guidelines, resulting in innovations. Novices, on the other hand, do not possess the necessary knowledge to understand the boarder implications of their actions. Deviations made in critical steps, such as the primary survey, would result in error. In addition to errors and innovations, it can be seen that more proactive deviations occur in the earlier stages of the trauma standard, while reactive deviations occur in the tertiary survey and definitive care stages. This is expected. As more information becomes available to the team, decisions about care of the patient may be altered in a reactionary manner.

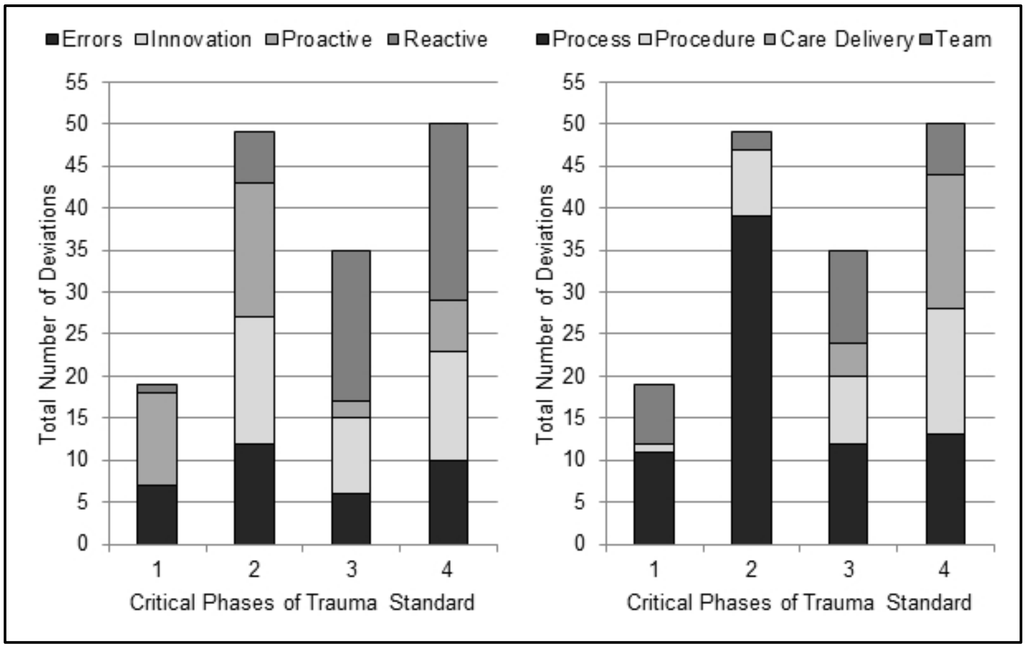

Figure 3. Frequency and Types of Deviations and Phases of Trauma Standard – Key phases in trauma standard are compared to (left) deviations classified by impact on workflow and (right) deviations classified by level of occurrence. Phases compared include 1: Trauma Preparation, Primary Survey and Resuscitation, 2: X-ray and Diagnostic Studies, 3: Secondary Survey, 4: Tertiary Survey and Definitive Care

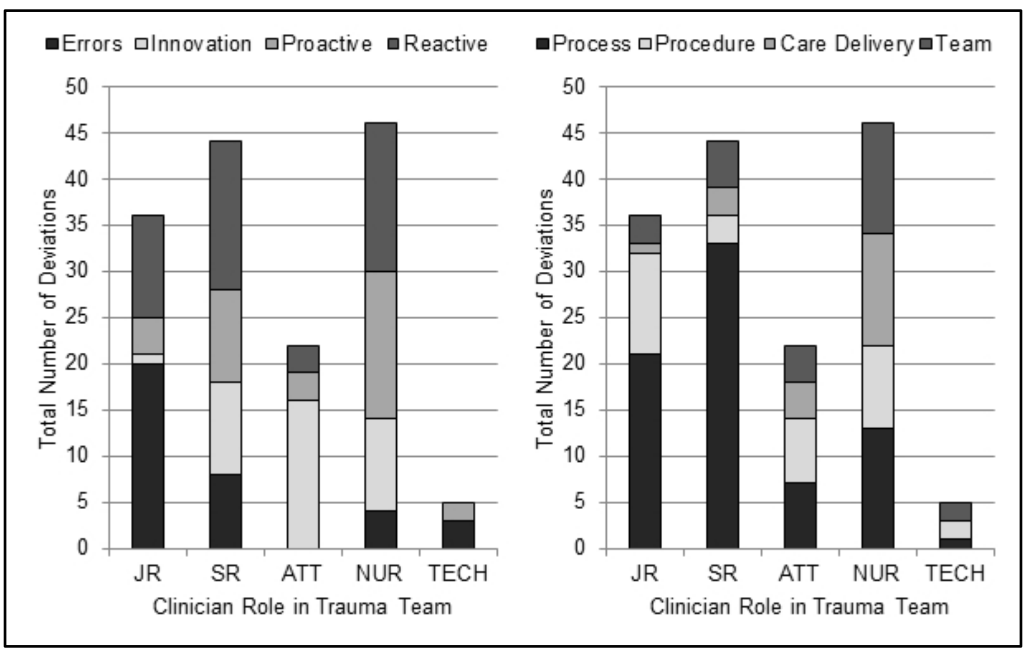

Figure 4. Frequency and Types of Deviations and Role in Trauma Team – Types of deviations (left) based on impact on workflow and (right) level of occurrence are compared role of clinician in trauma team. Roles include JR: Junior Resident (PGY1/2), SR: Senior Resident (PGY4/5), ATT: Attending, NUR: Trauma Nurses, TECH: Technicians

Figure 3 (right) shows that the total number of process-related deviations is higher when x-ray and diagnostic tests are ordered (52% in Phase 2). This indicates that certain steps in trauma treatment may be more adaptable than others. Identifying such critical steps and monitoring the deviations that occur could provide more information that will help direct guideline updates. In addition to the differences in process related deviations, it is interesting to note that procedural deviations linearly increase as trauma care proceeds through the various phases. This is expected, because the initial phases of the trauma care are more focused on examination of the patient. Once a diagnosis is made and results from x-rays and diagnostic tests are obtained, interventions to treat the patient trauma are performed. It should also be noted that supportive care delivery deviations occur largely in Phase 4. In Phases 1-3, the focus of the team is in examining the patient. Supportive care is usually provided after these phases are completed.

Deviations and Clinician Role in Trauma Team

Figure 4 shows the total number of deviations made by the individual members of the trauma team. We found a statistically significant relationship between types of deviations and the role played clinician in the trauma team (Chi-sq = 69.83, df = 12, p<0.0001). Figure 4 (left) shows that expert clinicians made more innovations (attendings: 43.24%, PGY4/5 residents: 6.54%, trauma nurses: 6.54%) when compared to PGY 2/3 residents (0.65%) and technicians. PGY 2/3 residents on the other hand made more errors than any other group (57.14%). These findings support the results reported in our previous study[9]. Comparing individual-level and team level deviations to clinician role in the team (Figure 4: right), we found that while resident's deviations are mostly process related (72%), trauma nurses lead the group in number of deviations in care delivery (60%) and at the team level (46.15%). It is not unusual that deviations made by nurses are predominately care delivery-related. Trauma teams have well-defined role boundaries and trauma nurses often act as an information hub, connecting technicians and patients to residents and attending surgeons. This enables teams to function effectively in chaotic situations and may be a reason for the large number of team related deviations made by this group. The results indicate that deviations are closely related to the level of domain expertise and the nature of the task.

Conclusions

Expertise is critical to formation of adaptive teams in trauma critical care. Our results show that trauma leaders with more experience are able to adapt to the dynamic environment will minimizing errors. Novices, on the other hand, are preoccupied by procedural aspects of trauma and fail to achieve the necessary levels of communication needed to facilitate team innovations. Another key difference between experts and novices lies in their ability to recover from errors and unexpected events. Patel and colleagues[25] showed that experts' knowledge is adapted to recognize familiar patterns of stimuli. However, their heuristic reasoning from the pattern recognition strategy may not be effective in some complex situations[26]. Experts may make errors, but are adept at correcting them before negative consequences occur. Novices on the other hand fail to perceive the consequences of their decisions until it's too late[27, 28].

There is a strong need for informatics tools that will enable novices to adapt to the trauma environment in following certain standards and allowing for fewer errors. In protocol driven environments, checklists have been found to be a valuable tool in minimizing error rates. However, since experts' deviations are important for education and practice, these checklists would have to be flexible enough to be automatically updated. For a dynamic environment like trauma, these checklists when implemented would need to be adaptable as well. In order to develop such a tool, one would need to know the general decision process in trauma and the various types of deviations that may occur. Using the classification of deviations presented in this work, it may be possible to create such a checklist; one that is customizable to the expertise and the role played by the individual in a trauma team. The next steps for this research include assessing the inter-rater reliability if the classification schema and further exploring the causal relationships between errors and innovations.

Acknowledgements

This research project was supported by Grant No. 220020152 by *James S McDonnell Foundation (JSMF)* for *Cognitive Complexity and Error in Critical Care* to Vimla L. Patel. Additionally, we would like to acknowledge Kanav Kahol (Public Health Foundation of India) for his mentorship during the formative phase of this work and clinicians from Banner Good Samaritan Medical Center's Trauma center for their help during the study. We thank Thomas Kannampallil for providing valuable comments on the earlier draft of the manuscript.

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