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EMS to Trauma Care Transitions: An Investigation of Patient and Handoff Outcomes

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This dissertation was prepared under the direction of the candidate's Dissertation Committee Chair, Dr. Joseph R. Keebler and has been approved by the members of the dissertation committee. It was submitted to the College of Arts and Sciences and was accepted in partial fulfilment of the requirements for the Degree of Doctor of Philosophy in Human Factors.

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Abstract

The helicopter as a method of emergency medical service transportation of trauma patients has a long history of effective use-cases dating back to its inception during the Vietnam war. Compared to ground-based emergency medical transit, helicopters have been able to reach severely injured patients in environments with challenging terrain features that ground-based medical services cannot traverse. Additionally, the helicopter offers quicker and more direct-route transit options that result in both quicker response and shorter transportation times compared to their ground-based alternative. Further, research has indicated that helicopter ambulance teams utilize paramedics with more experience than ground ambulance paramedics. Prior research has provided evidence that these factors contribute to the higher survivability rates and lower length of stay times for patients. While evidence of the increased patient health-related outcomes of helicopter-transported patients remains consistent, there is controversy in the relationship between the studied factors and patient outcomes. Specifically, conflicting reports of transportation time on patient outcomes as well as the lack of observed data on paramedic experience on helicopter medical transports have resulted in an inconclusive understanding of why helicopter patients receive better health outcomes compared to ground ambulance patients. One aspect of patient care that has yet to be investigated but is previously hypothesized to be a factor in contributing to better patient health outcomes is that of the emergency medical service to emergency department trauma center handoff where information transfer between helicopter medical teams and trauma teams may be higher than ground team. Therefore, the purpose of this investigation is to advance the understanding of the relationship between patient health outcomes and patient transportation modality. This research utilized 223 transcripts of emergency medical service to trauma center handoffs. Information given as well as information questioned by the

EMS, trauma team, and patients during the handoff as well as the severity of the patient's injury, resources utilized by the trauma team, modality of transportation, and other identified control variables were used to investigate the relationship between helicopter and ground ambulance and patient care outcomes from a handoff-perspective. Additionally, the moderating factors of the modality of transportation on the information given and information questioned were investigated. Results indicated that more descriptive handoffs during emergency medical service to trauma team patient transfer contributed to lower patient mortality and longer emergency department lengths of stay when accounting for relevant control variables. Alternatively, more information questioned, when controlling for similar variables, led to higher rates of mortality. Results further indicated that the modality of transportation and its moderating effects on the information given and information questioned had no effects on either patient mortality or emergency department length of stay. The implications of this investigation as well as the considerations for future work are discussed.

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Chapter 1: Introduction

Background

The transfer of patient care, otherwise known as a handoff, can be a complex process that requires a significant amount of clinical and teamwork skills from the individuals performing the handoff (Young et al., 2016). Medical providers are expected to effectively communicate clinically relevant information in a succinct and digestible format to present to another medical provider. Additional challenges are presented when medical providers from two separate care domains are expected to provide contextually relevant patient information to one another. Emergency Medical Service (EMS) handoffs to emergency department trauma teams are prime examples of these challenging patient handoffs due to the trauma resuscitation process requiring providers from a wide array of care domains to attend to the patient's injuries within a short window of time. This diverse team may include but is not limited to depending on the policies of the care facility, radiologists, nurses, medical students, interns, residents, fellows, physicians, and surgeons (Williams et al., 2016).

Emergency Medical Services in Trauma Handoffs

During this transitionary period of patient care, EMS providers are expected to provide relevant information to the trauma team staff to ensure the patient receives the most optimal care possible. Additionally, EMS providers may be required to perform handoffs via differing standards depending on the hospital in which they are delivering the patient. Subsequently, strong teamwork competencies are required to control the handoff environment via the trauma resuscitation team to assure that the information being given is relevant, correct, and appropriately received (Fernandez et al., 2020; Spooner et al., 2016). Hence, understanding the competencies of teamwork elicited by medical teams during handoff has been a significant area of study (Alfes & Reimer, 2016; Dietz et al., 2014; Ernst et al., 2018; Fernandez et al., 2020; Jalilian & Antongiorgi, 2019; Parush et al., 2014; Symons et al., 2012; Upadhyay et al., 2019).

Helicopter emergency medical services (HEMS) is a mode of transportation that provides expedited transportation of a patient from the scene of an injury to a care facility or from one care facility to another. Much like traditional ground emergency medical services (GEMS), HEMS utilizes some type of emergency response care team that serves to provide a patient limited treatment or care while in transit. HEMS, however, differs from GEMS in that most HEMS medical crews may tend to have more clinical training and more experience than their ground-based counterparts (Andruszkow et al., 2016; Michaels et al., 2019; Weninger et al., 2006). Additionally, research indicates that HEMS transported patients reap more benefits from expedited care and more experienced care teams.

Problem Statement

The use of HEMS as a modality of expedited patient care and transport has steadily increased in the United States since its adoption in the early 1970s (*Maryland State Police Aviation Command*, n.d.). Since then, multiple outlets have reported HEMS yearly flight hours approaching and surpassing 600,000 hours (Blumen, 2009; Federal Aviation Administration, 2017). This increase in HEMS flights has been hypothesized to be sourced to the increased number of traumatic injuries in the United States as well as the availability of more HEMS programs. The allure in the use of HEMS is clear: helicopters can provide faster transport of severely injured patients to care facilities. This reason is believed to be an advantage due to the coveted golden hour of medicine where severely injured patients who receive emergency care quickly are more likely to survive and experience fewer adverse medical outcomes (Pham et al., 2017).

Handoff efficacy via information exchange has been associated with patient care outcomes in all stages of care including EMS to trauma ED. The Joint Commission (2012, 2017) attributes 80% of all severe medical errors and 30% of all malpractice claims to poor communication. Additionally, a multitude of handoff investigations (e.g., Denson et al., 2015; Hudson et al., 2015) has linked patient handovers to increased adverse patient outcomes such as mortality and patient length of stay. Prior investigations have found that significant levels of communication errors may be present during the EMS to trauma team handoff process (Goldberg et al., 2017; Jenkin et al, 2007), with one assessment finding 87% of handoffs included communication errors (Sumner et al., 2019).

Statement of Purposes

The varying effects found in better patient health outcomes from HEMS transported patients as compared to GEMS patients despite overall increased injury severities may be attributed to the handoff of the patient from EMS to trauma teams. Thus, the purpose of this research is to empirically assess how the varying inputs, as well as the moderator variables within a HEMS handoff process, differ from those in GEMS and the resulting patient outcomes associated with them.

Prior evidence indicates that EMS handoffs of critically injured patients significantly suffer from poor practices leaving out chief concerns, important patient status information, and prior patient factors (Goldberg et al., 2017; Jenkin et al, 2007). HEMS and GEMS patient transportation services are the most common method of transporting a patient to a hospital (HEMS M = 35%, GEMS M = 40%) (Cheung et al., 2014). The EMS to ED handoff is a critical point in patient care. This investigation sought to determine if HEMS and GEMS handoffs differ from one another in terms of communication practices and how these differences may affect patient mortality and length of stay. This research will assist healthcare organizations and providers to determine how to best implement handoff protocols and training practices to achieve better handoff outcomes during the EMS to trauma team handoff. Figures 1 and 2 present my hypothesized models regarding patient mortality and emergency department length of stay.

Figure 1.
Model for Patient Mortality.

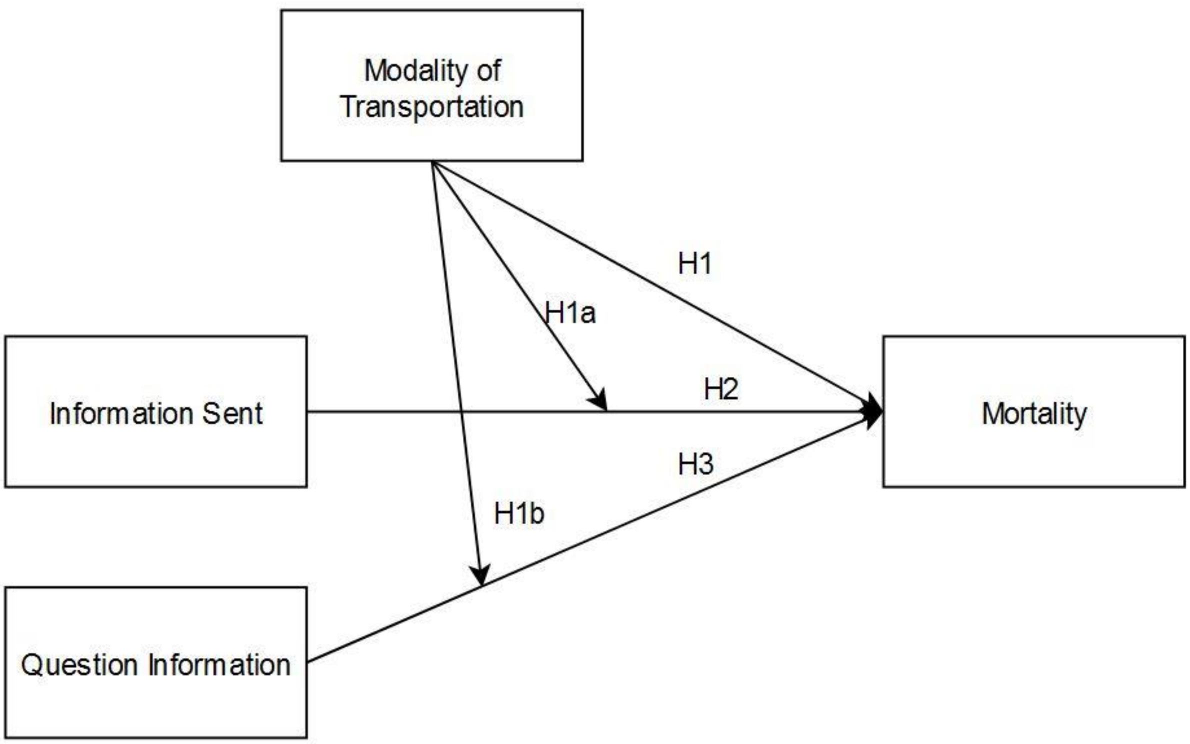
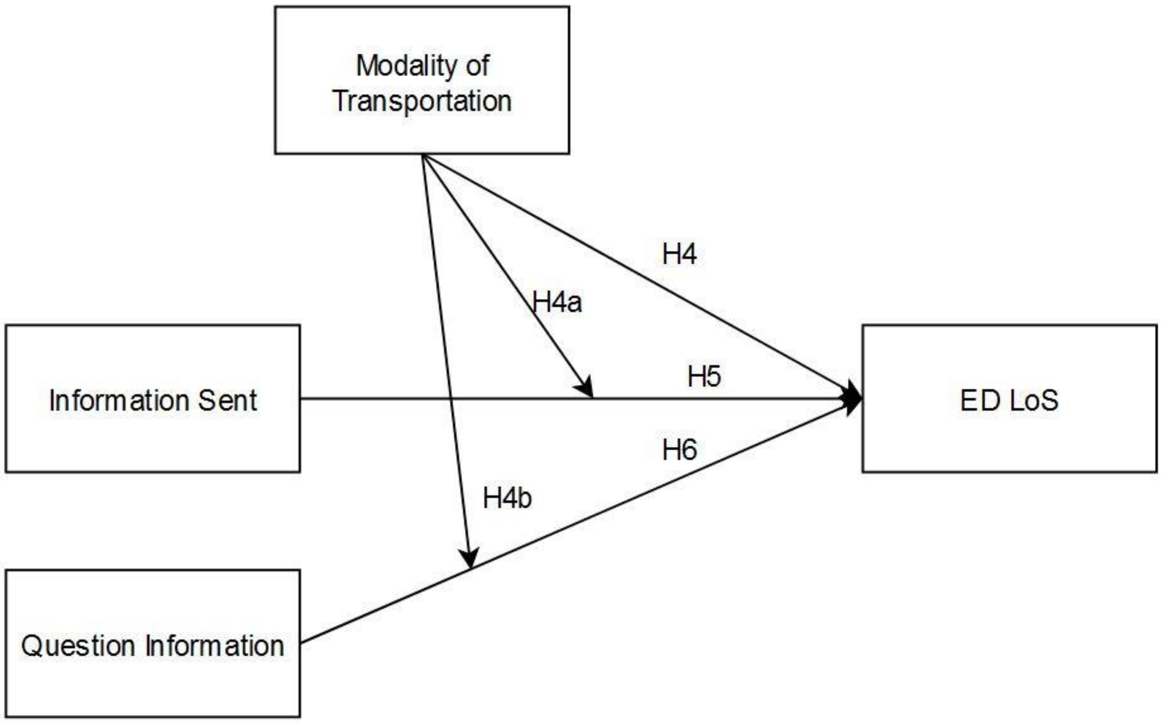


Figure 2

Model for Emergency Department Length of Stay



Chapter Two: Review of Literature

Introduction

This chapter provides a review of the literature regarding EMS to ED trauma resuscitation handoffs, GEMS and HEMS patient transportation services, as well as important control variables related to patient resuscitation and injury as well as other pre-investigation confounds. The processes that occur during the transfer of patient care from the EMS team to the trauma team are heavily reliant on teamwork. To capture these processes and to build a framework conducive to observable and measurable constructs regarding these processes, I utilize the Input Mediator/Moderator, Output, and Input (IMOI) model.

Input

Under the IMOI model, the first input acts as factors that begin at the development cycle or a team's performance and can include individual team member inputs, aggregated team inputs, and organizational level inputs (Hackman, 2002). Inputs are believed to be the base causal functions that influence teamwork outcomes. However, the path between various team inputs and their various outputs is non-linear via the effects of mediator and moderator variables. Finally, the last input section of the IMOI serves to describe how resulting outcomes can influence future team inputs.

Mediator and Moderator

Mediator variables are factors that influence the direct relationship between an input and an output variable (Agler & De Boeck, 2017). Mediation variables act as explanatory variables between input variables and output variables that are either not directly or indirectly related but describe some causal influence between the independent and dependent variables. As stated in the description of input variables, the inputs are believed to be the base function of outputs;

however, the complexity of teamwork means many actions must take place to cause or, in some cases, prevent an output.

Moderation variables, on the other hand, are factors that may influence the strength and directions of an input and output variable (Tabachnick et al., 2007). Many instances of patient care and subsequent outcomes are affected by the levels of variables that either increase or decrease patient outcomes. For example, a patient may present with a certain type of injury which will lead to mortality of patient survival. The likelihood that the patient will experience one of these outcomes may be moderated by the severity of the patient's injury. More severe injuries are more likely to lead to patient mortality as compared to less severe injuries. Therefore, the injury severity moderated the strength of (likelihood) and direction (mortality or survivability) of the patient's outcome. Moderator and mediator variables can be used concurrently in models. As in the above example, the patient's injury severity may influence the relationship between injury type and survivability, but the patient care team can still implement an intervention to influence the outcome of the said patient (mediator).

Output

Output variables are those that are identified as important to the task or team's ability to perform a task. Output variables are the primary interest of an investigation as they are the variables in which an investigator is attempting to either modify (e.g., increase or decrease its presence or quantity) or to understand the parameters that influence its data's generation. Thus, the IMOI model states that inputs are moderated or mediated by certain parameters that lead to the generation of output data. In the context of this manuscript, output variables are operationalized as those related to patient care and include patient mortality and patient emergency department length of stay.

Modeling Patient Outcomes and Modality of Transportation

The following literature review and hypotheses are based on prior hypothesized relationships between the factors that are believed to lead to causal relationships between any factors and patient mortality as well as emergency department length of stay. The model in Figures 1 and 2 can be read from left to right such that lines extending from and pointing into a factor hypothesize a direct relationship between those two factors, and moderators are visualized as variables that point into the line of a direct relationship (e.g., hypothesis 1a).

My proposed hypotheses visualized in Figures 1 and 2 seek to identify if there are any significant differences between the transition of patient care between helicopter and ground EMS to ED trauma teams and if these differences affect patient outcomes. Prior research investigating the outcomes of patients transported by GEMS compared to those transported by HEMS indicates a potential benefit of HEMS, reinforcing the belief that faster transportation equates to better outcomes. Specifically, multiple studies have found links between the HEMS transportation modality of traumatically injured patients and shorter lengths of stay as well as lower mortality rates (Elkbuli et al., 2021; Michaels et al., 2019; Pham et al., 2017; Weninger et al., 2006). The most challenging factor to understand in these relationships is that while HEMS patients may receive better health outcomes as compared to GEMS patients, they are more severely injured. Weninger et al. (2006) posited that the reason for this effect is due to HEMS crew having more clinical training than their GEMS counterparts, ultimately leading to better and more effective pre-hospital treatment of traumatically injured patients.

Other investigations comparing HEMS to GEMS transported patients have, on the other hand, found little to no differences in trauma patient outcomes (Stewart, 2015). While the heterogeneity of pre-hospital care to distal patient outcomes such as post-emergency department mortality and length of stay is expected due to the multitude of factors that confound these outcomes, contention regarding the comparability between HEMS and GEMS pre-hospital treatment and transportation time is argued. Abernethy (2021) suggests that multiple confounding factors can be attributed to biased assessments of pre-hospital care comparisons between HEMS and GEMS units. Specifically, they argue that the for-profit umbrella of HEMS dictates that Helicopter units get to select patients based on financial incentives, which may provide biased decision-making regarding what type of patients are transported. Further, Abernathy (2021) claims that due to the lack of standardized pre-hospital care provider composition, training, and quantitative knowledge of provider experience determining if this is the effect is not possible, rather, they further suggest that there is no effect in HEMS vs GEMS pre-hospital treatment. Therefore, this model focuses on the actions that take place after prehospital transportation care during the advanced trauma life support handoff that leads to treating injured trauma patients.

Model Outputs

Mortality

Patient mortality is a primary outcome utilized in the extant medical literature due to both its outcome importance (English et al., 2018; Stewart et al., 2016; Tourangeau et al., 2006) and as a gauge of resuscitation success (English et al., 2018; Kocasaban, 2019; Seethala et al., 2010). The primary goal of trauma resuscitation of severely injured patients is to increase the likelihood of patient survivability by restoring patient physiology to normality (Connelly & Schreiber, 2015). Due to the direct link of mortality as well as the severity of patient mortality as an outcome of medical intervention, research has utilized it as the outcome to measure a multitude of care indicators including intervention success and quality of care. For this investigation, I am operationalizing mortality to be whether the patient died before their release from the hospital.

Length of Stay

Patient length of stay is the total amount of time a patient occupies a bed at a care facility. Historically, length of stay has primarily been used as a measurement of hospital health from a financial perspective due to the increased cost of care for each day a patient occupies a bed. This becomes exasperating when a patient occupies a bed and subsequent resources unnecessarily. Thomas et al. (1997) posited that length of stay is not only reflective of organizational health but also the quality of care a patient receives from providers. Unfortunately, prior research provides evidence that extended patient length of stay is correlated with decreased patient health outcomes such as higher mortality rates (Lingsma et al., 2018). With these proposed ideas, the length of stay literature investigated how various stages of care may affect the amount of time a patient of various injury mechanisms and severities should occupy resources at the care facility compared to how long they do occupy resources.

Length of stay has been identified as an important predictor in various patient-related processes such as quality of care including the accuracy and timing of patient care interventions (Baek et al., 2018; Bueno et al., 2010; Rotter et al., 2010). While patient stay has been used as a patient outcome in a multitude of prior studies, evidence shows that under matched comparison of injury severity and injury types patients may experience vastly different lengths of stay (Kashkooe et al., 2020). This alludes to the possibility that complex processes are involved outside common patient inputs (e.g., patient injury severity or type) which may affect a patient's length of stay.

Emergency department length of stay is the amount of time a patient spends in the emergency department between registration or triage to emergency department discharge (Driesen et al., 2018). A variety of factors are shown to increase emergency department length of stay; however, the most saliently studied are based on the resources required to treat a patient and the injury severity of the patient (van der Linden et al., 2013; Vegting et al., 2015). Subsequently, emergency department length of stay may be a more proximal outcome to the EMS to emergency department handoff than other lengths of stay measurements (e.g., ICU or total hospital) which are further confounded by the care provided that is not directly related to resuscitation.

Model Inputs

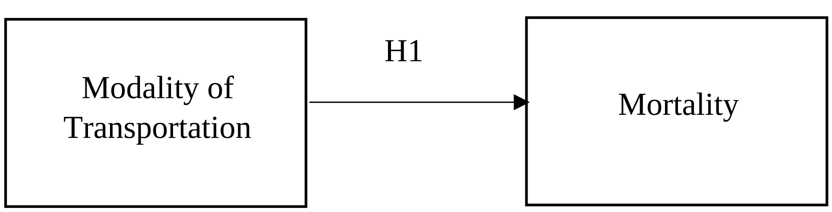
Modality of Transportation

Resuscitation success is an operationalization of whether some action taken by medical care providers successfully increased patient survivability. This paradigm has been applied to EMS literature to gauge if the expedited transport time of a helicopter over GEMS was necessary. The consensus, however, regarding patient mortality and the modality of EMS transportation has yet to be established. While some literature provides evidence that HEMS patients receive lower mortality rates as compared to GEMS patients (Michaels et al., 2019; Galvagno, 2013; Elkbuli et al., 2021; Andruszkow et al., 2016), other literature indicates insignificant effects (Beaumont et al., 2020; Chen et al., 2018; Enomoto et al., 2020). Abernathy (2021) posits the reason for this discrepancy in outcomes is that HEMS and GEMS are not directly comparable due to the lack of standardized training present for either EMS modality. However, the outcomes between the two EMS modalities may still have serious consequences for patients and, overall, show that HEMS results in lower mortality rates. Additionally, no direct observations of pre-hospital treatment between HEMS and GEMS have been conducted. Thus, other than the untested hypotheses that unmeasurable training results in better outcomes, no data have been proposed to suggest this relationship.

One potential reason for the many opposing results regarding patient mortality and the modality in which the patient was transported in the hospital-specific policies and guidelines for transporting patients and pre-hospital communication with the EMS crew. The heterogeneity of the prior reported results suggests that more data is needed to form a more cohesive understanding of the effects of HEMS vs GEMS transportation as compared to organization-specific policies. However, in alignment with prior arguments, the greater experience and expertise of the HEMS crew may lead to better patient outcomes due to their pre-hospital treatment provided to the patient en route as well as their quicker transit times as compared to GEMS transported patients.

Hypothesis 1: Modality of transportation will affect patient mortality such that patients who are transported via Helicopter EMS will result in lower mortality rates as compared to patients transported by ground EMS.

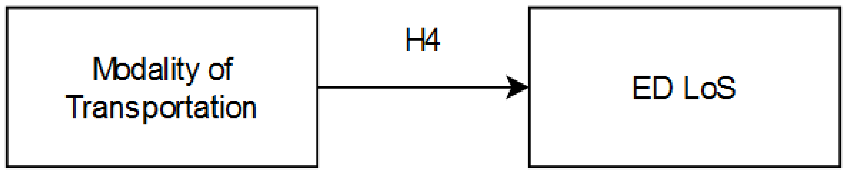
Figure 3.
Hypothesis 1.



Prior EMS research investigating the link between the length of stay and EMS transportation of patients has for the most part found null effects such that EMS transport vs selftransport have few identifiable differences (Aldelaijan et al., 2020; Cornwell et al., 2000; Rosenthal, et al., 2017; Usher et al., 2016). One of the main challenges in the identification of EMS modality and length of stay is that length of stay is a guaranteed yet distal outcome. In other words, every patient will receive a length of stay measurement whose data will vary greatly depending on various factors related to, possibly, EMS transportation modality as well as the quality of patient care, injury mechanism, and other patient-related factors (van der Linden et al., 2013; Vegting et al., 2015). Prior evidence does suggest that HEMS results in a lower emergency department length of stay compared to a ground ambulance (Ayer et al., 2019). A potential mechanism for this is the perception of patient injury and resuscitation needs as compared to their GEMS transported counterparts. In other words, prior work indicates that trauma teams heavily rely on a patient's perceived injury severity to determine care-related decisions, and HEMS patients are known to have significantly higher injury severity than their GEMS counterparts. Therefore, patients transported via HEMS may receive more resources and quicker care-related factors that decrease the amount of time they spend in the emergency department compared to GEMS patients.

Hypothesis 4 - Modality of transportation will affect patient emergency department length of stay times such that patients transported via Helicopter EMS will result in shorter emergency department length of stay times as compared to patients transported via Ground EMS.

Figure 4.
Hypothesis 4.



Model Mediator and Moderators

Team Communication

Patient trauma resuscitation is by nature a team activity. Teaming, defined as “a set of two or more individuals that adaptively and dynamically interact through specified roles as they work toward shared and valued goals” (Salas et al., 2008, pp. 40), necessitates team members work together through processes that derive teamwork.

Trauma resuscitation teams are formed on an as-needed basis, and the included EMS members of the team are dependent on the EMS members on shift and those that responded to the trauma call. This type of team is called ad-hoc. Ad-hoc teams are the most common type of team in hospitals, comprising 72% of all teams, and are described as teams that vary in membership (White et al., 2018). Thus, it is unexpected that EMS team members and trauma team members are consistent.

Ad-hoc EMS to ED trauma handoff teams holds the primary objective of transferring information about the patient's status, injury, and other care-related factors that are necessary to resuscitate the patient. During this initial communication stage called the handoff, or the transfer of responsibility of a patient on a temporary or permanent basis (Joint Commission, 2012), EMS providers exchange information about the patient to the receiving trauma team. The key teaming process that facilitates this transfer of information is team communication. Team communication is defined as the exchange of information between two or more parties (Cannon-Bowers et al., 1995).

Prior team communication research has identified eight communication types. These include unique information sharing, general information sharing, openness of communication, content communication, perceptions of information sharing, knowledge sharing, information elaboration, and overall information sharing (Marlow et al., 2018). Each of these communication types is defined and exemplified in Table 1.

Table 1

Communication Types – Adapted from Marlow et al. (2018) Table 1.

Communication Type	Description
Unique Information Sharing	The number of unique categories that are shared during a teams communication
General Information Sharing	The extent to which teams share relevant information to be kept in the loop and up to date on the teams' goals
Openness of Communication	The extent to which team members feel they can freely communicate with their teammates
Content Communication	An extension of Unique Information. The extent to which team members thoroughly communicate the appropriate amount of information in each unique category
Perceptions of Information Sharing	The perception of individual teammates on the extent to which team members thoroughly communicate the appropriate amount of information in each unique category
Knowledge Sharing	The extent to which goal-specific knowledge, rather than content, is shared with the team
Information Elaboration	The thoroughness of the information exchanged
Overall Information Sharing	The summation of how much information is shared regardless of context

However, not all of these communication measurements are relevant to the specific communications that occur during the handoff between EMS and ED trauma teams for patient resuscitation. Specifically, due to the fast-paced and quick reaction environment necessary for patient resuscitation, the objective of the handoff is to exchange resuscitation-relevant information with the trauma team as quickly and efficiently as possible. For example, it would be rare for EMS providers to share their unique and special knowledge regarding patient care with the EMS trauma team. In response, various investigations have identified the information exchange of relevant information during an EMS to ED handoff.

Prior research investigating the mechanisms behind HEMS and GEMS transported patients and their outcomes has sought to identify why and how HEMS patients receive generally better outcomes as compared to their GEMS counterparts. These prior works include investigations of pre-hospital communication and treatment as well as post-resuscitation care. All these included investigations have not found any evidence that these stages of patient care regarding HEMS and GEMS modality of transportation have any correlation to these differing outcomes. One stage, however, that has yet to be investigated that has a direct relationship to both EMS and the trauma team is the handoff of the patient between these teams. Thus, this investigation posits that a primary, and previously unstudied, a mechanism that may explain these better patient outcomes from HEMS transportation is the handoff that occurs between these EMS and trauma teams. These hypotheses stem from the previously identified evidence that handoffs are a key aspect that can dictate the outcome of a patient, and, if HEMS teams provide better handoffs as compared to their GEMS counterparts then HEMS patients would then receive better outcomes.

Handoff Content

Some literature has provided an overview of the content that should be handed off to ED personnel. The most common themes from this literature include current medical information, medical history, demographics, social factors, injury causal factors, environmental factors related to the injury, and current mental state. The individual items reported in this literature are available in Table 2 (Carter et al., (2009); Evans et al., (2010); Goldberg et al., (2017); Talbot & Bleetman, (2007); Yong et al., (2008)).

Table 2.

Overview of Literature-based EMS to ED Handoff Content

Medical Info	Medical History	Demographics	Social Factors	Injury Causal Factors	Environmental Factors	Mental State
Allergies, Ambulance Chart, Analgesia Given, Anatomic Location of Injury, Blood Length of stays, Current Medications, End Tidal CO2 Value, GCS Score, Intrusion, Oxygen Saturation, pain, Prehospital Intubation, Prehospital Treatment, Problems needing Immediate Treatment, Pulse Rate, Respiratory Rate, Signs, Symptoms, Vitals	Normal Vitals, Pre-existing Disease, Prior Level of Function	Age	Living Arrangements, Social Support, Who Called the Ambulance, Source of Information	Mechanism of Injury, History of Events	Patient Pickup Environment, Other Deaths/Injuries of Same Accident, Extrication Time, Estimated Force	Current Mental State, Past Mental History, Altered State of Consciousness

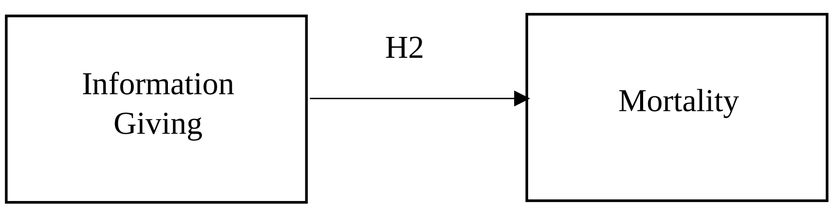
Prior handoff literature has identified key phases of the handoff in which measurable communication-related behaviors link to the effectiveness of a handoff. Specifically, seven handoff communication behaviors are specified and include information giving, information questioned, acknowledgment assessment, planning and decision making, handover management, use of documentation, social communication, and clinical tasks (Manser et al., 2013). Manser et al., (2013) operationally define each of these seven handoff behaviors. However, similar to the eight communication types identified in Marlow et al. (2018), only a subset relate directly to the information exchange portion of the EMS to ED trauma team handoff process. In particular, the handoff-specific processes of information exchange and clarification may be the most proximal handoff communication processes that influence patient outcomes.

Information Giving

Within the medical handoff domain, information giving (i.e., the transfer of information from one team or member to another) is the process of providing an individual with information regarding a specific case or scenario. Information exchange is at the core of a handoff as handoffs necessitate that the sender(s) exchange relevant information regarding the patient's care and status with the receiving care provider(s). One of the most important key aspects of handoffs, however, is passing the relevant information regarding the patient's care, status, and health-related challenges. Primarily, the Joint Commission (2012) attributes 80% of all severe medical errors to miscommunication. Additionally, an EMS to ED-specific quantitative study on 90 handoffs found that much of the key handoff information was not included during the handoff. Specifically, 22% (n = 20) handoffs did not include a chief concern, 53% (n = 48) did not include certain physical exam results, 42% (n = 38) did not include a description of the scene, and 69% (n = 62) did not provide a complete and holistic description of the patient’s clinical status (Goldberg et al., 2017). A qualitative review of the same topic found that ED nurses reflected similar themes in their experiences of EMS to ED handoffs. More specifically, the disorganization of the handoff process limited the receiving parties’ ability to perform medical care while receiving the handoff. Some more common themes identified were that the receiving party lacked the time and focus on the handoff as well as lacked some respect for the EMS handoff team, which may have contributed to lower levels of focus on the handoff during the transition (Jenkin et al, 2007). Other common themes within the EMS to ED handover include poor performance in listening to a handoff and performing their medical care simultaneously (Owen et al., 2009) and EMS personal needing to repeat information (Jenkin et al., 2007; Owen et al., 2009). The evidence linking lower rates is if the information given between the EMS receiving teams and patient outcomes is clear. Additionally, prior research regarding handoffs and patient outcomes indicates a clear link between better patient outcomes and information exchanged. Therefore, more information given should lead to lower rates of patient mortality.

Hypothesis 2: Higher frequencies of information-giving will result in lower rates of patient mortality.

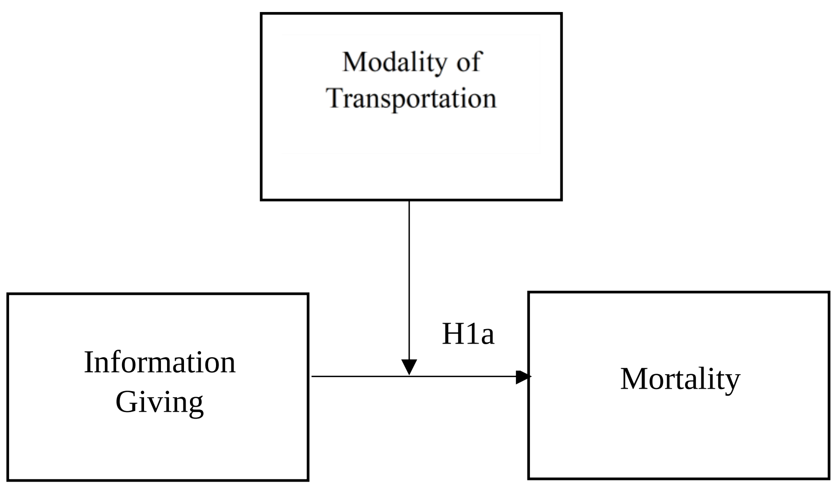
Figure 5.
Hypothesis 2.



Few investigations on the relationship between EMS to ED trauma team information sharing effectiveness or accuracy are available. More explicitly, no research has investigated any differences between HEMS and GEMS handoff information sharing with trauma teams. However, the potentially greater levels of expertise and experience of HEMS teams as compared to GEMS teams may lead to HEMS teams greater level of information giving and subsequently lead to lower rates of mortality as previously reviewed. Additionally, HEMS teams tend to service larger areas and transfer to more hospitals than GEMS teams, which may lead to these HEMS teams purposefully transferring greater detail to the trauma providers due to their unfamiliarity with their organization's handoff policies and protocols. Subsequently, the potentially greater information given on part of the HEMS teams may lead to lower rates of mortality.

Hypothesis 1a: Modality of transportation will moderate the relationship between information giving and patient mortality such that helicopter EMS providers will exhibit higher frequencies of information-giving as compared to ground EMS providers which will result in lower patient mortality rates.

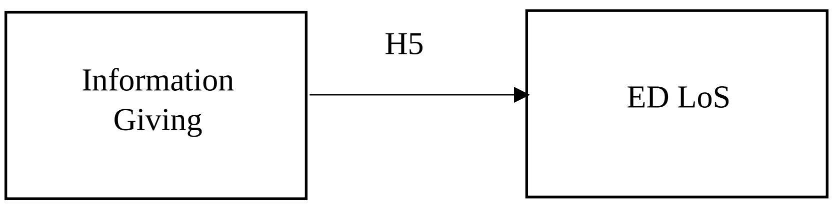
Figure 6.
Hypothesis 1a.



Few investigations provide an association between information sharing and patient length of stay (Foster & Manser, 2012; Keebler et al., 2016). However, there has been an identified relationship between these factors by Ryan et al., (2011) who found that the implementation of a standardized handover tool that increased information exchange also significantly reduced patient length of stay in the emergency department. Less direct relationships have also been identified in the implementation of standardized handoffs that have improved information exchange but have found no changes in patient length of stay (Keebler et al., 2016). One mechanism behind this relationship is the exploration trauma teams need to conduct to identify patient injuries and successfully resuscitate the patient. Therefore, if an EMS team provides more information on the patients, then, the trauma team should be able to identify injuries quicker leading to lower emergency department lengths of stay.

Hypothesis 5: Higher frequencies of information-giving will result in shorter patient ED Length of stay.

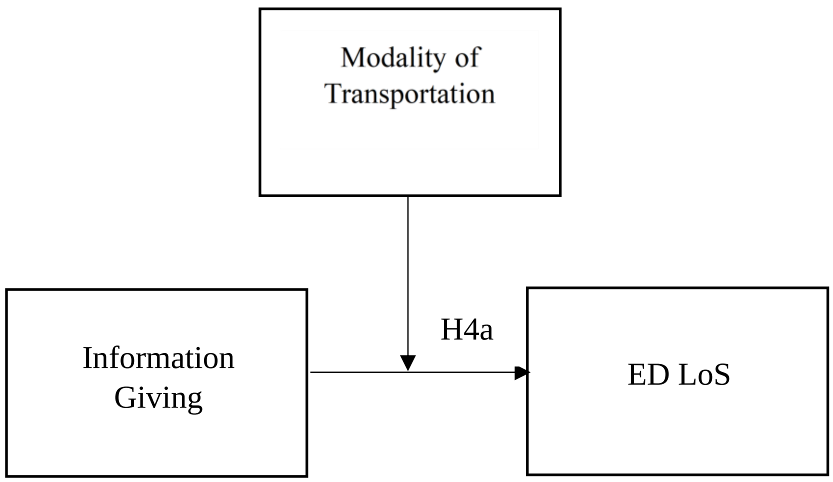
Figure 7.
Hypothesis 5.



The lack of direct evidence regarding the association between information exchange and length of stay also indicates that no investigations regarding the moderation of modality of EMS transportation on this relationship. However, as research has indicated that HEMS patients receive better length of stay outcomes (Ayer, 2019), the possibility remains that this could be caused by HEMS to ED trauma team handoffs having higher rates of information exchanged, which as previously shown, would contribute to longer emergency department lengths of stay as compared to their GEMS counterparts.

Hypothesis 4a: Modality of transportation will moderate the relationship between information giving and patient mortality such that helicopter EMS providers will exhibit higher frequencies of information giving as compared to ground EMS providers which will result in shorter patient ED Length of stay.

Figure 8.
Hypothesis 4a.



Information Questioned

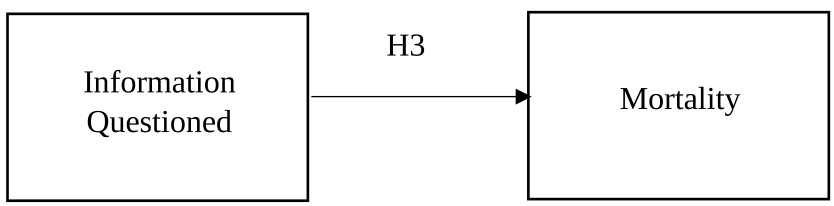
Information questioned is the aspect of communication that seeks to gain either information that was not given or information that was given and the receiver wishes to clarify it. Questions are a crucial part of team communication and, specifically, the handoffs that occur during the transfer of a patient. Prior research indicates that information loss as a result of miscommunication during these EMS to trauma team handoffs may approach nearly 30%, meaning 30% of the information sent by the EMS team is not received by the trauma team (Carter et al., 2009).

Regulatory bodies and researchers have identified this challenge and have invested numerous resources into solving them. One such proposed solution to ensuring increased information exchange is that of handoff standardizations, proposed by the Joint Commission (Joint Commission, 2012). Meta-analytic evidence has found that handoff standardization is an effective method of increasing rates of information exchange (Keebler et al., 2016), and EMS to ED investigations propose similar implementations. However, standardization requires interventions that are challenging to implement as all parties during the handoff protocol may require some aspect of training to successfully utilize the standardization protocol. Additionally, the effects of standardization cannot be observed retrospectively when no standardization was implemented. Currently, few investigations have explored the exact relationships between information exchange and standardization in the EMS to ED or trauma ED handoff. Those that have either find null or non-compliance-related results (Fahim Yegane et al., 2017; Talbot & Bleetman, 2007). Due to the lack of standardized communication protocols present during the EMS to trauma ED handoff, comparison of information exchange is difficult. However, one aspect that is consistent across many investigations of EMS to ED handoffs is the disorganized transfer of information from EMS to ED providers, resulting in ED providers potentially ignoring or seeking alternative means to gather information (Jenkin et al., 2007; Owen et al., 2009; Thakore & Morrison, 2001; Yong et al., 2008). An important feature that standardized handoff protocols have targeted to mitigate such information-loss-related events is via implementing specific handoff points that encourage or explicitly require the asking of questions to occur.

Information questioned can be elicited by both senders and receivers that seek to clarify portions of the information that were handed over in which the member is confused about or to fill in gaps of information that were otherwise missed. Prior literature has posited that for a handoff of pertinent information to successfully occur, the opportunity for and subsequent asking of handoff-related and patient care questions must exist (Arora et al., 2008; Haig et al., 2006; Patterson, 2004; Streitenberger et al., 2006). While prior literature is limited or non-existent in the relationship between frequency of questioned information and patient outcomes like mortality, there is a clear link between team-shared mental models and reduced morality (Wilson, 2019). Subsequently, higher frequencies of questions may lead to an increased shared mental model of the patient between the EMS and trauma team, reducing mortality rates.

Hypothesis 3: Higher frequencies of information questioned will result in lower patient mortality rates.

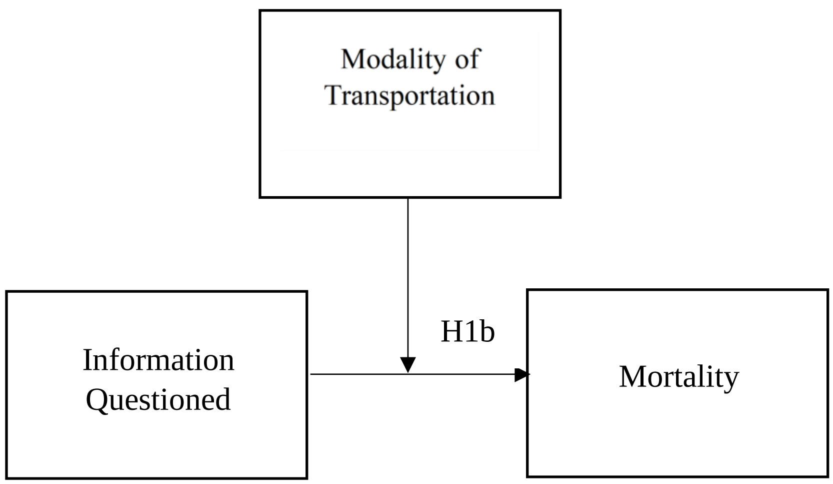
Figure 9.
Hypothesis 3.



The association between patient outcomes and information questioned is an important aspect identified by previous research, but no prior evidence is available regarding the moderating effect of the modality of transportation on information questioned and patient mortality. Prior discussions on the potential effects of the modality of transportation and patient outcomes such as mortality show that HEMS patients tend to be more severely injured, and, ED teams significantly rely on perceived injury severities to make relevant care-related decisions. Subsequently, these potential perceptions of injury severity due to the HEMS transportation modality may encourage trauma teams to ask more questions about the patient and their injury to gain a stronger understanding of the patient and to build a stronger shared mental model with the HEMS team regarding the patient's injury severity. This increased information questioning may lead to lower mortality rates by garnering more relevant patient information and building a better mental model of the patient's injuries.

Hypothesis 1b: Modality of transportation will moderate the relationship between information questioned and patient mortality such that handoffs with helicopter EMS providers will exhibit higher frequencies of information questioning as compared to ground EMS providers which will result in lower patient mortality rates.

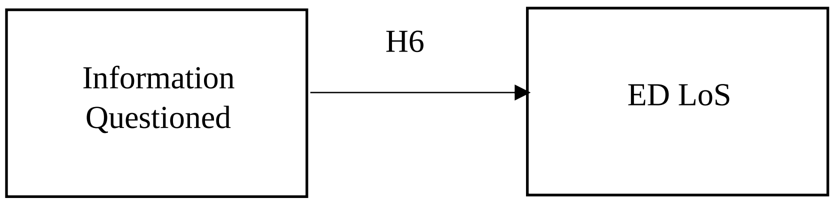
Figure 10.
Hypothesis 1b.



Mitigating increased length of stay of patients via information questioning is a key process in increasing patient quality of care and outcomes (Abraham et al., 2012). The relationship between information questioned and emergency department length of stay may be two-fold. First, as previously described, information questioning is a mechanism that may increase shared mental models between EMS and trauma teams, which, have been shown to decrease adverse patient outcomes. Second, trauma resuscitation after a patient’s transfer serves to 1) identify patient injuries that need to be addressed, and 2) address said injuries. Questioning information about the patient, their injuries, and the information given by the EMS team may also provide trauma teams with additional information regarding what injuries to look for and where therefore reducing the amount of time the trauma team needs to spend in identifying injuries.

Hypothesis 6: Higher frequencies of information questioning will result in shorter patient emergency department length of stay.

Figure 11.
Hypothesis 6.

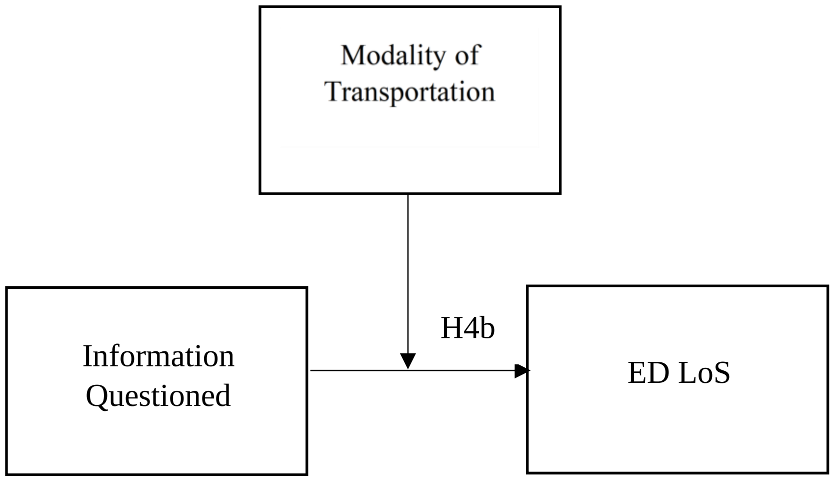


Further, the limited literature on information questioned offers little insight into the moderating effect of the modality of transportation on patient length of stay. However, as research has indicated that helicopter EMS patients receive shorter length of stay outcomes (Ayer, 2019), the possibility remains that this could be caused by helicopter EMS to ED trauma team handoffs having higher rates of information questioning that lead to shorter patient length of stay outcomes. Specifically, as previously discussed, HEMS transported patients tend to be perceived as more severely injured than their GEMS counterparts, and, receiving trauma teams heavily rely on perceived injury severity to make care-related decisions for their resuscitation plans. Subsequently, this previously identified higher perceived injury of HEMS transported patients may result in increased frequencies of information questioning, which as identified in hypothesis 6, may lead to shorter emergency department lengths of stay.

Hypothesis 4b: Modality of transportation will moderate the relationship between information questioning and patient emergency department length of stay such that helicopter EMS

handoff teams will exhibit higher frequencies of information questioning as compared to ground EMS teams which will result in shorter patient emergency department length of stay.

Figure 12.
Hypothesis 4b.



Controls

Several control variables were identified in the a priori collected dataset in this retrospective investigation. The following section provides a review of these control variables and why they were selected to be controlled for in this research.

Injury Severity

Injury severity is the measurement of how injured a patient is. Injury severity is assessed in a multitude of manners at various points of the patient's treatment including during the pre-hospital examination and stabilization, emergency department resuscitation, and finally during the post-treatment patient assessment. Various assessments, including the subject matter expertise of providers as well as the assessments of the Glasgow Colma Score (GCS), the Emergency Severity Index (ESI), and the number of resources needed for patient resuscitation are utilized to determine the severity of a patient injury. Pre-hospital injury severity determination is generally a fast-paced method of determining if the patient’s injury severity and health status constitute the transport to a trauma center, and if so, the decision of which level of trauma response the patient should receive.

The Center for Disease Control and Prevention (CDC) (Sasser et al., 2012) recommends a triage flow chart to determine where a patient should be transported (e.g., level of trauma center). Similar to pre-hospital triage injury, severity during patient triage and assessment during resuscitation is a process that relies on a multitude of information that is in direct observation of the current status of the patient's health and stabilization rather than a quantification of their specific injury severity level. Similar to the recommended CDC guidelines for EMS trauma patient triage, trauma resuscitation teams in the emergency department have access to such guides as the Washington State Department of Health trauma triage guidelines (Washington State Department of Health Office of Community Health Systems, 2016). Direct measurement of patient injury severity is only capturable at the end of trauma patient resuscitation and is calculated via the injury severity score metric. An injury severity score is a standardized measurement device medical providers use after a trauma patient’s resuscitation treatment to assess the severity of a patient’s injuries systematically with all available information to consider (Linn, 1995).

The ISS form is designed such that a provider can enter the most severe injury for each of either six or nine, depending on the version used (Innovation, 2014), and possible anatomical locations including the head, face, neck, thorax, abdomen, and pelvis, spine, upper extremities, lower extremities, and external injuries. The medical provider assigns each of these nine anatomical regions using the abbreviated injury score (AIS) that acts as a Likert-type scale to classify the severity of a particular injury. The AIS scale ranges from one (minor injury) to six (unsurvivable injury) (Innovation, 2014). Minor injuries are described as injuries that do not require medical intervention, and unsurvivable injuries are described as those that are not survivable and, therefore, cannot be treated (International Mission for Prognosis and Analysis of Clinical Trials in TBI, n.d.). The ISS is calculated such that three of the most severely injured anatomical regions' AIS values are imputed into a sum of squares calculation (Eq. 1) (Javali et al., 2019). If any of the nine anatomical regions of the body described receiving a score of six (i.e., not survivable), then the patient automatically received the maximal ISS of 75 (Javali et al., 2019). Eq 1.

$$ISS = AIS_1^2 + AIS_2^2 + AIS_3^2 \qquad \text{Eq 1.}$$

Injury severity score is highly correlated to various patient outcomes such as patient mortality. Lower values of the injury severity score are associated with lower rates of patient mortality while higher scores are associated with higher rates of patient mortality (Deng et al., 2016).

Evidence also indicates that patient length of stay is logarithmically correlated with their respective injury severity scores such that higher levels of injury severity lead to a significantly higher length of stay (Lavoie et al., 2005). The importance of the injury severity score as a control variable lies in the comparison of patients with similar injury levels. Due to the significant relationship between injury severity and the patient outcomes described in this investigation, comparing the communication frequencies of moderately injured patients and severely injured patients would lead to incomparable analyses. Therefore, the ISS will be used as a control to ensure that patients of similar severity levels are compared against each other.

Trauma Team Activation

Trauma team activation, or the act of calling on various medical providers to assess and resuscitate trauma patients, is a primary step in trauma patient resuscitation. Team activations are conducted in a variety of ways depending on the activation system in place at the care facility and the criteria set forth by the standard team activation practices. One method of trauma team activation and activation criteria was proposed by the Washington State Department of Health Office of Community Systems (2016) specifies two levels of team activation which include 1) modified trauma team activation and 2) full trauma team activation.

Modified Trauma Team Activation

Modified trauma teams under this criterion include the ED physician, ED registered nurse, respiratory therapist, radiology team member, and laboratory team member. Modified activation minimum criteria require that patients received an injury to an extremity, had pulse irregularity between the extremity and the heart, possessed an injury to the abdomen, had an altered mental state, received burns as a result of the traumatic injury, fractures to 1) two or more proximal long bones, 2) the pelvis or instability of the pelvis with a possible fracture, 3) three or more rib fractures, proximal amputation to an ankle or wrist, and all pediatric non-accidental trauma. Additionally, patients involved in a motor vehicle crash (MVC) that resulted in an ejection of the patient, death of a passenger, object injected more than 12 inches into the patients seating area or 18 or more inches into any seating area, any falls from greater than 20 feet (10 feet for pediatric patients), bicycle accidents involved in a significant impact, any motorcycle accident greater than 20 miles per hours or that resulted in the patient ejected from the motorcycle.

Full Trauma Team Activation

Full trauma team members include all those included in the modified team activation with the addition of the general surgeon and anesthesiologist certified registered nurse (CRNA). Full trauma team activation should be considered for patients who present with hemodynamic instability, low systolic blood pressure (e.g., 90 mmHg or lower) depending on the patient's age for greater than five years, pediatric patients with less than a 60 beat per minute heart rate, a Glascow Coma Scale (GCS) less than 9 or are not alert or verbally responsive with trauma to the torso or extremity, any penetrating injuries to the neck, chest, abdomen, pelvis or groin, unsecured airway or any blocked airway requiring surgical intervention, major vascular injuries, pediatric patients requiring intubation, any mass casualty (e.g., three or more trauma events) incident. Additionally, patients who do not meet these above-stated requirements can receive a full activation trauma team if the ED physician believes additional resources are required.

Trauma team activation is shown to provide myriad benefits to patients and the hospital providing care. Prior research has found that patient treatment time, resuscitation time, and intubation time all significantly decreased (Cherry et al., 2007; Khetarpal et al., 1999; Yoo & Mun, 2014. Further, there is evidence that inappropriate levels of activation (e.g., fewer providers present than necessary) result in higher patient mortality rates (Rogers et al., 2013). Due to the additional resources provided to full trauma team activations as compared to modified activations, including this variable as control is paramount to ensure that communication practices are comparable within the same activation levels.

Trauma Team Upgrade

Trauma team activation is a decision that is made by a trauma team upon information gained from EMS during pre-hospital care and pre-hospital communication. As such, these activations are dependent on extraneous information to the EMS handoff and the examination of the patient by the trauma team. Upon receipt of the handoff, after pre-hospital communication, and during resuscitation of the patient, a trauma team can decide as to whether the patient in question requires a higher activation than they initially received. These instances, called upgrades, occur for a variety of reasons. The most common occurrences are due to the deterioration of the patient after a handoff or during care. However, patients who were under-triaged are also eligible for an activation upgrade. This variable was chosen to be a control to limit the confounding effect of increased resource allocation for upgraded patients.

Mechanism of Injury

The mechanism of a patient injury within trauma literature is typically dissected into two categories, including blunt force trauma and penetrating trauma. While the medical literature is extant, the primary relation to patient outcomes lies in the trauma mechanisms influence on patient survivability. Specifically, prior work has indicated that blunt force trauma injuries tend to result in more significantly severe injuries than penetrating trauma, extending to longer lengths of stay and increased mortality risks (American College of Surgeons, 2014).

Patient Discharge Disposition

Patient discharge disposition is another variable extant in prior medical literature. Discharge disposition represents where the patient was discharged to after their hospital stay (e.g., home, psych ward, jail, etc.). However, in this investigation, discharge disposition may be an important control variable as identified in previous work. Specifically, O'Lynnger et al., (2016) found that standardizing care was a significant predictor in patient discharge, which, may represent patient injury severities do not capture in the injury severity score.

Prior Study Controls

Three additional variables were identified as important control variables that were the result of the investigation which collected this retrospective data. The prior investigation sought to identify if trauma team leadership training can improve the trauma team leadership capabilities during patient resuscitation. The previous investigation (Fernandez et al., 2020) noted significant effects of the training, which, may in turn affect communication between EMS and trauma team during the handoff. To account for the potential, confound of increased leadership abilities by the team leader on these handoffs, the experimental group, amount of time since training, and whether this handoff occurred before or after training were included.

Chapter Three: Materials and Methods

Introduction

In this chapter, materials and methods, I will describe the materials and methodologies I employed to conduct my research. Specifically, I will detail the research design of this investigation, the metrics and measurement tools utilized to capture the required constructs and data, the population, and sampled participants to be examined, the data inclusion and exclusion criteria, the legal and ethical considerations regarding the sampled data and methods of collecting said data, and the statistical methods used to assess the data.

Research Design

I used a retrospective quasi-experimental between-subjects design for this investigation. The between-subject groups were employed as the EMS and ED trauma teams involved in the patient handoff differed from one another. While it may be possible that certain providers within a team are measured more than once (e.g., the same provider on different teams), I posit that the mechanisms which make up the total team's ability to complete the handoff are developed from the interactions between members and not dependent wholly on the members themselves. The levels of my hypothesized variables (e.g., modality of transportation, injury severity score, team trauma activation and upgrade, questions during the handoff, team coordination, and information sharing score) were compared between each EMS-ED trauma team group and assessed to determine if they affected the patients' outcomes (e.g., mortality and emergency department length of stay).

Population and Sample

Population

Emergency medical service teams and emergency department trauma teams consist of a specific group of individuals specifically trained to act in providing care to trauma patients. Thus, the population for this investigation was HEMS, GEMS, trauma patients transported from the scene of an injury to an emergency department trauma center via helicopter or ground ambulance, and emergency department trauma staff within the Harborview Medical Center serviceable area in Seattle Washington, USA.

Sample

The collected sample for this investigation includes ground and helicopter emergency medical service providers and their patients who transported said patients from the scene of an injury to the Harborview Emergency Department trauma center as well as the trauma team medical providers who received the patients. Each sample consisted of an EMS team, patient, and trauma team.

Research Methodology

Data Collection

This study utilized archival audiovisual data of EMS to ED trauma team patient handoffs at the University of Washington Harborview Medical Center, from March 12, 2015, to March 11, 2016. Trauma teams were formed ad-hoc but included a second or third-year resident acting as the trauma team leader who received introductory onboarding or leadership training related to the trauma team leader role. Patient demographics and outcomes were coded at the time of audiovisual collection during each EMS to ED trauma handoff. Thus, the archival data provides pre-coded data of the initial trauma team activation and subsequent decision to upgrade as well as patient demographics including their mortality outcome, length of stay in the emergency department, modality in which they were transported to the hospital, and injury severity scores, as well as other noted control variables described in chapter two. No data regarding the handoff between the EMS and trauma teams were coded a priori. Thus, the information given and questioned was coded and analyzed from these archival videos.

Participant's Protection

No identifying information of patients or providers, except for likeness by way of the audiovisual recordings, is available within the archival data. Additionally, the audiovisual recordings and data were not available to anyone outside the research team. Audiovisual recordings were downloaded to the principal investigator's computer from the password-protected server in which they are stored as per their previous IRB guidelines one at a time for data coding. After which, the recording were permanently deleted from the researcher's computer.

Legal and Ethical Considerations

Provider participants voluntarily participated in the University of Washington IRB audiovisual recording of these EMS to ED trauma handoffs. Patients were not required to sign an informed consent and special consideration for this was employed by prior IRB researchers blurring the patient's likeness (e.g., faces) in the archival audiovisual recordings.

Materials

Trauma Center

Between March 12, 2015, and March 11, 2016, 223 helicopters and ground EMS to ED trauma center handoffs were conducted and recorded at the University of Washington Harborview Emergency Department trauma center. Four cameras and two microphones were visibly installed in two trauma center rooms (two cameras and one microphone each) to capture a side and top view of the patient and subsequent verbal and behavioral interactions of the EMS and trauma teams during the handoff.

Metrics

Modality of Transportation

Patients were transported to the Harborview Medical Center via either self-transportation or by using some professional emergency transportation service including ground ambulance, helicopter ambulance, or fixed-wing ambulance. For each EMS to ED trauma team handoff the modality in which the patient was transported was recorded as a patient demographic. Three-hundred forty-two trauma resuscitations were recorded. However, 119 utilized a transportation method other than ground or helicopter ambulance or were transferred from another healthcare facility. This investigation only studied the difference between patients transported via helicopter or ground ambulance from the scene of an injury, thus, these 119 videos were automatically excluded. Subsequently, this will be coded as a binary categorical variable with helicopter EMS transport marked as zero and ground EMS transports marked as one.

Trauma Team Activation & Upgrades

Trauma teams were activated based on pre-defined activation procedures set forth by the University of Washington Harborview Medical Center. These initial activations were recorded by the provider team and were coded in a binary format such that 0 indicated a modified team and 1 indicated a full team. Trauma team upgrades, on the other hand, could occur at any time between initial trauma team activation and the end of the trauma patient resuscitation. Trauma team upgrades will be coded into an observational codebook via a binary format (0 = no upgrade, 1 = upgrade).

Injury Severity Score

The injury severity score of each patient was calculated after the resuscitation of said included patient. This score was derived as per Baker et al's. (1974) guidance utilizing the three most severe injuries summing their squares (Eq 1). Following Baker et al's (1974) calculation, this score will be coded as a scalar continuous variable that ranges from zero (least severe injury) to seventy-five (most severe injury).

Information giving

Information giving serves to objectively identify and calculate the amount of information that is exchanged during a transfer of information from one party to another. In the case of handoffs, information giving has played a central role in measuring how handoff interventions have affected the amount of information transferred between providers. A typical handoff is conducted to transfer information that one party is aware of to another party that is not aware of said information. However, during the EMS to ED trauma handoff, this may not always be the case, as some information may have been previously transferred during the pre-hospital communication in the preparation for the patient's arrival. To account for this, any information about the patient that is communicated from the EMS team to the ED trauma team about the patient and their related injury will be considered as information exchanged during the handoff. However, information can also be exchanged between team members. Subsequently, in these cases, if the information is not a distinct coordinating or team-building statement (e.g., a joke or unrelated patient care comment), then it will also be included as information giving. Information giving will be measured via bits of information. A bit of information represents the smallest meaningful piece of information that can be extrapolated from a statement. The smallest meaningful piece of information for these handoffs was identified during the pilot coding of replicated EMS to trauma team transcription for reliability testing and coding training. Based on this testing, bits were broken down into two groups. First, if a word provided a meaningful addition that described the patient, environment, injury, or other factors included during a handoff then a rater individually coded that word as a bit. Alternatively, if a bit fell into one of the categories displayed in the following list:

- Noun
- Adjective
- Interrogative
- Pronouns/Names
- Unit of Measurement
- Verbs
- Auxiliary Verbs
- Prepositions
- Demonstratives

then the rater coded it as an individual bit. Appendix C contains the coding guidelines each coder used.

Additionally, all raters were provided a list of words that should not be separated, these included pleasantries, demonstratives, some prepositions, pause fillers, and any instance information given or questioned specifically referenced the patient. These rules were decided based on testing and the lack of meaning they added or inconsistencies between how they were utilized. For example, some transcriptions would include lists of information such as *the patient had a fever and dilated eyes and decorticate posturing* where as other transcriptions would not include the word *and* such as *the patient had a fever dilated eyes decorticate posturing*.

Information Questioned

Information questioned was measured in the same way as information given, but, was categorized via two additional groups including information requested and information verified. Information requested was defined as a bit of information contained within a question that was not previously explicitly given by the EMS team. Alternatively, information verified was defined as a bit of information contained within a question that was explicitly given by the EMS team. Questions are an inherent process that occurs during any information exchange between two parties and are a segment of the information exchange that many care facilities promote to increase the efficacy of handoffs. A member that is a part of a handoff may ask questions for a variety of reasons including but not limited to making attempts to clarify information that was confusing, complete information that was transferred incompletely, or request information to be repeated that was missed. The occurrence of a question was denoted via a question mark in the question. The determination of a question was made by myself, the principle investigator, during the transcription of the handoffs. A question was considered to be asked if an interrogative preceded it, and it was identified that the individual was expecting a response about the questioned topic.

Mortality

Patient mortality was recorded throughout the patient's admittance to the hospital. Any patient who died in the hospital before official hospital discharge received a "*D*" on the pre-coded records. Patients who were successfully discharged from the hospital subsequently received the total hospital length of stay. For this investigation, a new variable called *mortality* was created wherein patients who died before hospital discharge received a zero, and those who were successfully discharged received a one.

Emergency Department Length of Stay

Emergency department length of stay was recorded by the ED trauma team and after patient resuscitation. Emergency department length of stay was recorded in minutes and represents the amount of time a patient spent in the emergency department receiving emergency care after their resuscitation.

Chapter Four: Analyses

Introduction

This chapter will provide a discussion of the analyses I utilized for this investigation as well as the procedures for handling missing data, and the assumptions of the statistical models.

Missing and Excluded Data

All data was entered into the SPSS version 27 statistical software for analysis. Missing data were excluded listwise due to the assumptions of both planned models.

Data Analysis

Data was coded into an Excel .csv file and was imported into SPSS Version 27 for statistical analysis. Before data organization, each latent construct was assessed for reliability with inter-class correlation. Data was then segmented into their respective data frames.

Planned Statistical Tests

Input and Moderator Factors on Mortality

Main Effects

A moderated logistic regression analysis was conducted to determine the effects of team input and process factors on patient mortality. The team input factors that were considered are the modality of transportation (H1: Modality of Transportation will effect patient mortality such that HEMS transported patients will receive lower mortality rates than GEMS transported patients.). The team process factors included the frequency of information given (H2: Higher frequencies of information-giving will result in lower rates of patient mortality) and the frequency of information questioned (H3: Higher frequencies of information questioned will result in lower patient mortality rates).

Moderating Effects

The modality of transportation variable moderated the relationships between the frequency of information given (H1a: Modality of transportation will moderate the relationship between information giving and patient mortality such that helicopter EMS providers will exhibit higher frequencies of information giving as compared to ground EMS providers which will result in lower patient mortality rates), the frequency of information questioned (H1b: Modality of transportation will moderate the relationship between information questioned and patient mortality such that helicopter EMS providers will exhibit higher frequencies of information questioned as compared to ground EMS providers which will result in lower patient mortality rates).

Input and Moderator Factors on Patient Emergency Department Length of Stay

Main Effects

A moderated linear regression analysis was conducted to determine the effects of team input and process factors on patient emergency department length of stay. The team input factors are the modality of transportation (H4: Modality of Transportation will affect patient emergency department length of stay such that patients transported via HEMS will result in shorter ED length of stay as compared to their ground counterparts). The team process factors include the frequency of information given (H5: Higher frequencies of information-giving will result in shorter patient ED Length of stay), the frequency of information questioned (H6: Higher frequencies of information questioned will result in shorter patient emergency department length of stay).

Moderating Effects

The modality of transportation variable moderated the relationships between the frequency of information given (H4a: Modality of transportation will moderate the relationship between information giving and patient mortality such that helicopter EMS providers will exhibit higher frequencies of information giving as compared to ground EMS providers which will result in shorter patient ED Length of stay), the frequency of information questioned (H4b: Modality of transportation will moderate the relationship between information questioned and patient emergency department length of stay such that helicopter EMS handoff teams will exhibit higher frequencies of information questioned as compared to ground EMS teams which will result in shorter patient emergency department length of stay).

Chapter 5: Results

Introduction

The following chapter will detail the results of the work that sought to understand the relationship between various identified communication-based handoff factors as well as the pre-recorded patient demographic factors and their respective health outcomes. I will first discuss the management of data and any subsequent missing data, descriptive analyses, results of statistical analyses, and the further exploration of data discovered during collection.

Missing and Excluded Data

Two types of missing data are present and include missing from the a priori collected data and the a posterior transcriptions of the recorded EMS to trauma team handoffs. Data from the a priori data included non-identifiable and non-personal health information data regarding the patients at the center of the EMS to Trauma team handoffs. This data additionally contained information regarding the origin of the EMS modality of transportation (e.g., helicopter vs ground ambulance) as well as the activation and upgrade status of the trauma team. Data in this category was missing before this investigation's access to it. Alternatively, data regarding the types of communication during the handoff between the EMS and trauma teams were a posteriori transcribed via me, the principal investigator, and contained missing data due to difficulties in hearing what was said during the handoffs among other various handoff recordings related challenges. In these cases, when a word or suspected word was unintelligible a placeholder of (Unintelligible: suspected word) where the word after the colon in the parentheses represent the word I believed I heard was inserted. If a multitude of words were unintelligible, a placeholder of *unintelligible* was inserted in its place. These were later deleted listwise due to the challenge of determining the number of bits transmitted or the relevancy of the bits in the handoff. Further, a placeholder of #unintelligible: term# was inserted when a specific word was heard clearly and determined to be medical terminology not immediately identifiable by the transcriber. The term was phonetically spelled out and kept in for later identification. These cases were not removed as they were not confounded by the uncertainty of the bit of information.

Data Analysis

Descriptive Statistics Two-hundred twenty-three emergency medical service to trauma team handoffs were transcribed. 10.7% (*n* = 24) transcriptions were excluded for the following reasons: 1) challenges in hearing the handoff, due to either no handoff occurring (*n* = 2), 2) inability to differentiate between extraneous conversations and the handoff (*n* = 1), 3) excessive sounds that made the handoff difficult to hear (e.g., patient yelling, machine/equipment sound; *n* = 18), or the inability to identify who was speaking (e.g., entire handoff occurring off-screen; *n* = 3). These exclusions resulted in 199 transcriptions that additionally contained descriptive non-PHI and other non-identifiable information of the patient, emergency medical service team, and trauma team. Table 3 contains descriptive statistics on each of these variables.

Table 3. Descriptive Statistics of Archival Data

Variable	Mean (SD)	Description
Patient LoS in ED (Minutes)	20.42 (15.87)	Amount of time in minutes a patient spends in the emergency department
Patient LoS in ICU (Hours)	12.11 (19.35)	Amount of time in hours a patients spends in the intensive care unit
Patient LoS in Hospital (Hours)	113.19 (219.57)	Amount of time in hours a patient spends in the hospital
	239.73 (169)	
Mortality		Whether a patient died or not at the hospital
Alive	175 (87.9%)	
Dead	24 (12.1%)	
Transport Modality		The medium (ground ambulance or HEMS) of how the patient was transported
Ground Ambulance	157 (78.9%)	
Helicopter	39 (19.6%)	

Initial Trauma Team Activation		The initial activation level (modified or full) of a patient. Typically established prior to patient arrival
Modified	86 (43.2%)	
Full	110 (55.3%)	
Trauma Team Upgraded		Whether a patients activation was upgraded from modified to full
Not Upgraded	182 (91.5%)	
Upgraded	15 (7.5%)	
Patient Discharge Disposition		Where a patient was discharged to after their stay at the hospital
Home from ED	27 (13.6%)	
Shelter	7 (3.5%)	
Morgue	19 (9.5%)	
Sent Home from Other Department	91 (45.7%)	
Rehab	14 (7.0%)	
Psych	6 (3.0%)	
AMA	5 (2.5%)	
SNF	15 (7.5%)	
Jail	3 (1.5%)	
Died in ED	6 (3.0%)	
LTCH	2 (1.0%)	
HH	1 (.5%)	
NA	1 (.5%)	

Reliability of Recorded Data

The transcribed data including information given and information questioned as well as questions that were difficult to hear all received an inter-rater reliability score. Pre-study inter-rater reliability training and testing indicated that a high level of reliability was established before the beginning of the study with reliability scores ranging between 80 and 90 percent. The selected sample size for reliability testing was extracted from Bujang & Baharum (2017) who found with pre-established inter-rater reliability ratings of 70% to 90%, and with 4 raters, each rater should receive 12 observations to rate. Of the 223 original videos transcribed, 32 videos were randomly selected before their coding and then assigned to each rater. The number of transcriptions to rate per rater was substantially higher than the recommended number to account for the potential exclusion of chosen transcriptions as well as the multiple variables the raters coded. After exclusion, each rater coded 24 videos, twice as many as recommended, suggesting appropriate power for the inter-rater reliability calculation. In total, 36,694 pieces of information were extracted and coded, of which 34,484 were coded as information giving, 2,087 were coded as either information requested or verified, and 123 were coded as challenging to hear. All raters except for the principal investigator were blinded to the fact that these transcriptions were to be used for IRR metrics. Once all transcription coding was complete their respective variables (e.g., information giving, questioned, and challenging to hear questions) were individually aggregated and used in a two-factor ANOVA without replication to calculate the intra-class correlation coefficient. The intra-class correlation coefficients for the two identified categories of information requested and information verified yielded low-reliability rates (44% and 50% respectively). After further investigation via group discussion between all raters, it was identified that the reason for these low rates was due to each rater's ability to identify where questions began and ended when clarifying and verifying questions were asked consecutively. The solution to this low reliability was to remove any sub-categorization of a question, and instead, just identify that information was questioned. This calculation indicated that, between four judges, information giving categorization yielded 94% ICC, the aggregated information questioned yielded a 96% ICC, and challenging to hear categorizations yielded a 55% ICC. Based on standard practices of ICC, these results show that both information giving and information questioned have excellent reliability, while challenging to hear results in moderate reliability (Bobak et al., 2018). Additionally, due to the low reliability of challenging to hear coding, this variable was left out of the communication-based hypothesis tests in the following tested models. Finally, all hypotheses were directional in nature, therefore, the *p*-values reported in all significance testing, except for any omnibus models, were reported as in the model but were halved for interpretation for significance.

Moderated Regression Models

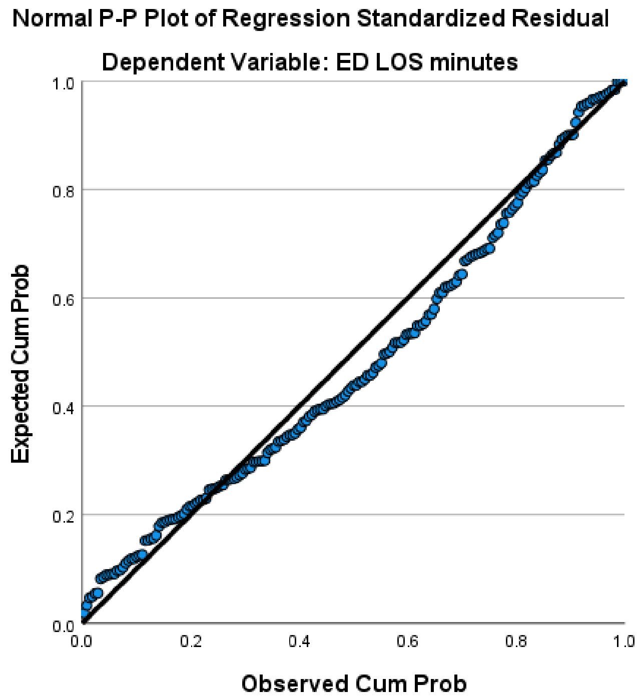
Two models are presented in this dissertation to identify relationships that predict two relevant patient outcomes based on prior literature including patient mortality and patient emergency department length of stay. Each hypothesis presented below was tested via a multiple moderated logistic regression (mortality) and a multiple moderated linear regression (emergency department length of stay).

Assumption Testing

Multiple Moderated Logistic Regression. First, the logistic regression model was developed to understand the relationships that exist between multiple explanatory variables that are both categorical and continuous in nature on the outcome of mortality. These variables, including the binary outcome of mortality, are all deemed appropriate for a multiple moderated binary logistic regression. Second, the assumption for the independence of observations was found to be automatically met as each team composition and patient record in this data set is unique such that no two outcomes contain repeated information in their tested independent variables. Third, multicollinearity was assessed via collinearity diagnostics through multiple linear regression. This assumption failed, and high multicollinearity was found between the modality of transportation and the moderation between the modality of transportation and information sent. Fourth, outliers were assessed via the Mahalanobis distance and its subsequent chi-square test. 4 outliers were identified but not removed to preserve the maximum power possible for the logistic regression also due to an ocular inspection revealing that none of the recorded values were identified to be outside the realm of their possible values. Finally, no formal power analysis was conducted for this test, rather, Bujang et al. (2018) guidelines for sample size were utilized in which they suggest the algorithm for calculating should be 100 samples plus 50 samples times the number of variables. The optimal sample size for this model would be 500, indicating an underpowered analysis.

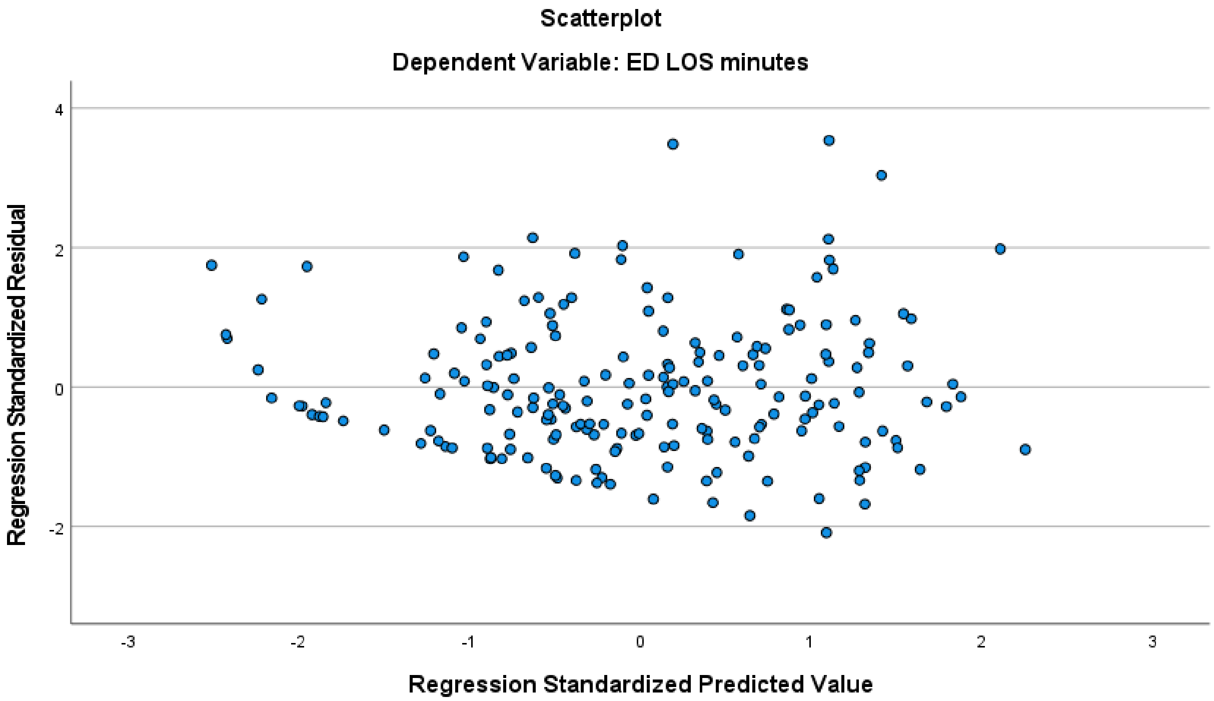
Multiple moderated linear regression. The linear regression model was developed to understand the relationships that exist between multiple explanatory variables that are both categorical and continuous in nature on the continuous outcome of emergency department length of stay. Therefore, the first assumption of variable appropriateness is met. Second, the independence of observations was found to be automatically met as to each team composition and patient record in this data set is unique such that no two outcomes contain repeated information in their tested independent variables. Third, multicollinearity was assessed via collinearity diagnostics. This assumption failed, and high multicollinearity was found between the modality of transportation and the moderation between the modality of transportation and information sent. Fourth, outliers were assessed via the Mahalanobis distance and its subsequent chi-square test. 4 outliers were identified but not removed to preserve both the maximum power possible for the linear regression also due to an ocular inspection revealing that none of the recorded values were identified to be outside the realm of their possible values. Fifth, the assumption of normally distributed residuals was tested via ocular inspection of a residual P-P plot, which indicated that the residuals are normally distributed (Figure 13).

Figure 13. Normal P-P Plot: Multiple Moderated Linear Regression on ED LoS



Sixth, linearity was also assessed ocularly via a scatter plot of standardized residuals and standardized predicted values (Figure 14).

Figure 14. Scatter Plot: Multiple Moderated Linear Regression on ED LoS



This test indicated a slight inconsistency for very low values of emergency department length of stay, however, was otherwise normally distributed. Finally, an a priori power analysis was conducted in gpower, version 3.1, with medium effect size, alpha of .05, power of .8, and 8 predictors. The result indicated that a total sample of 109 records needed indicating this analysis to be appropriately powered.

Mortality. Hypotheses 1 through 3 (Appendix B) were assessed via a multiple moderated logistic regression analysis with mortality as the output variable. In addition to the proposed hypotheses in this model, the patient's injury severity score, initial trauma team activation, subsequent trauma team upgrade, patient discharge disposition, and any recorded team training variables were included as a control variable due to prior literature's identification of its relationship to patient mortality and to control for training intervention effects. Any insignificant control variables were removed. The final logistic regression model was calculated with a sample size of 195, where 4 cases were excluded due to missing relevant data. Of the 195 cases, 79.5% (*n* = 155) were transported via a ground ambulance and 20.5% (*n* = 40) were transported via HEMS. Additionally, 87.6% (*n* = 171) of the patients lived while 12.3% (*n* = 24) died. The base model of this logistic regression model without any included variables was able to correctly classify 100% of the patients who survived and 0% of the patients who died, with an overall accuracy rate of 87.8%. The second block of the logistic regression model that contained all explanatory variables (Hypotheses 1 through 3) and the three included control variables (injury severity score, pre or post-training, and how many days since the training occurred) was found to be significant with a chi-square statistic ($\chi^2 = 49.96, p < .001$) with a Nagelkerke R^2 of .430 indicating that 43% of the variance in the model was predicted by the explanatory and control variables. Further, the Hosmer and Lemeshow model fit test indicated a good model fit ($\chi(8)^2 = 10.47, p = .234$). Table 4. provides a summary of the explanatory variable results on mortality via their unstandardized B and its subsequent standard error, Wald statistic, and significance.

Information given on mortality (**H2**) was found to significantly influence mortality (*B* = -.025, *S.E* = .008, *p* = .001) such that for every one piece of information given multiplies the odds of a death occurring by -.025 times suggesting that there is evidence to fail to reject this hypothesis. Similarly, the amount of information questioned (**H3**) significantly predicted patient mortality (*B* = .055, *S.E* = .032, *p* = .088) indicating that for every one-unit increase in information questioned multiply the odds of a death occurring by .055, thus this evidence shows support and is failed to be rejected. Next, the model of patient transportation was found to have an insignificant effect on patient mortality (**H1**) suggesting that there is no difference in mortality between ground ambulance and HEMS, therefore the hypothesis is rejected.

Hypotheses 1a and 1b were related to moderating effects of the patient modality of transportation on patient mortality. These moderating variables were calculated by multiplying the modality of transportation by each respective variable. The moderation of modality of transportation on the amount of information given (**H1a**; *B* = .016, *S.E* = .014, *p* = .243) and the amount of information questioned (**H1b**; *B* = -.049, *S.E* = .072, *p* = .492) were both found to be insignificant in predicting mortality.

Table 4. Results of Multiple Moderated Logistic Regression on Mortality

Variable	Unstandardized *B* (*S.E*)	Wald Statistic (df)	Significance	Odds Ratio	Hypothesis Support
Modality of Transportation	1.445 (2.350)	.378 (1)	.539	4.24	Not Supported
Information Given Moderated by Modality of Transportation	.016 (.014)	1.37 (1)	.243	1.017	Not Supported
Information Questioned Moderated by Modality of Transportation	-.049 (.072)	.472 (1)	.429	.952	Not Supported
Information Given	-.025 (.008)	10.98 (1)	.001	.975	Supported
Information Questioned	.055 (.032)	2.90 (1)	.088	1.056	Not Supported In Original Direction

The classification ability of this model improved by 4.1% overall, with a small reduction in the classification of non-fatal patients (97.7%) and a large increase in the classification of fatal patients (50%). The sensitivity of the logistic regression is 97.7% while the specificity is 50%. Additionally, the positively predicted value is 75% and the negatively predicted values are 93.3%.

Length of Stay. Hypotheses 4 through 6 (Appendix B) were assessed via a multiple moderated linear regression analysis with emergency department length of stay as the output variable. The linear regression model was calculated with a sample size of 194, where 5 cases were excluded due to missing relevant data. Of the 194 cases, the average emergency department length of stay was 241.26 (*SD* = 169.08) minutes. Additionally, 80% (*n* = 156) were transported via a ground ambulance and 20% (*n* = 39) were transported via HEMS. An initial model containing all a priori planned hypotheses were implemented and assumption testing was conducted.

This linear regression model was significant (F(7, 187) = 9.35, p < .001) with an R^2 of .232, indicating that 23.2% of the variance in emergency department length of stay could be predicted by this model. Hypotheses 4 through 6 were tested in this model with the addition of two control variables (trauma team activation level and injury severity score). Table 5. provides a summary of the explanatory results.

Information given on emergency department length of stay (**H5**) was found to have a significant influence mortality (*B* = .429, *S.E* = .215, *p* = .047). The amount of information questioned (**H6**) was an insignificant predictor of patient emergency department length of stay (*B* = .823, *S.E* = 1.26, *p* = .655). Finally, the mode of patient transportation was found to have an insignificant effect on emergency department length of stay (**H4**) (*B* = 111.82, *S.E* = 104.94, *p* = .288).

Hypotheses 4a and 4b were related to moderating effects of the patient modality of transportation and information given as well as information questioned. The moderation of modality of transportation on information given was found to be an insignificant predictor of emergency department length of stay (*B* = -.873, *S.E* = .588, *p* = .139) with similar results from the moderation of modality of transportation and information questioned on predicting patient emergency department length of stay (*B* = 1.547, *S.E* = 2.654, *p* = .561).

Table 5. Results of Multiple Moderated Linear Regression on ED Length of Stay

Variable	Unstandardized *B* (*S.E*)	Standardized *B*	t-statistic	significance	Hypothesis Support
Modality of Transportation	111.82 (104.94)	.268	1.066	.288	Not Supported
Information Given Moderated by Modality of Transportation	-.873 (.588)	-.394	-1.485	.139	Not Supported
Information Questioned Moderated by Modality of Transportation	1.547 (2.65)	.062	.583	.561	Not Supported
Information Given	.429 (.215)	.147	7.435	.047	Not Supported In Original Direction
Information Questioned	.823 (1.257)	.05	.655	.514	Not Supported

Exploratory Analyses

Multiple exploratory analyses were conducted to explore additional potential relationships identified in the hypothesis testing presented previously. Specifically, the relationship between the modality of transportation and various previously identified control variables (e.g., injury severity score, trauma team activation, trauma team upgrades, and discharge disposition) were analyzed.

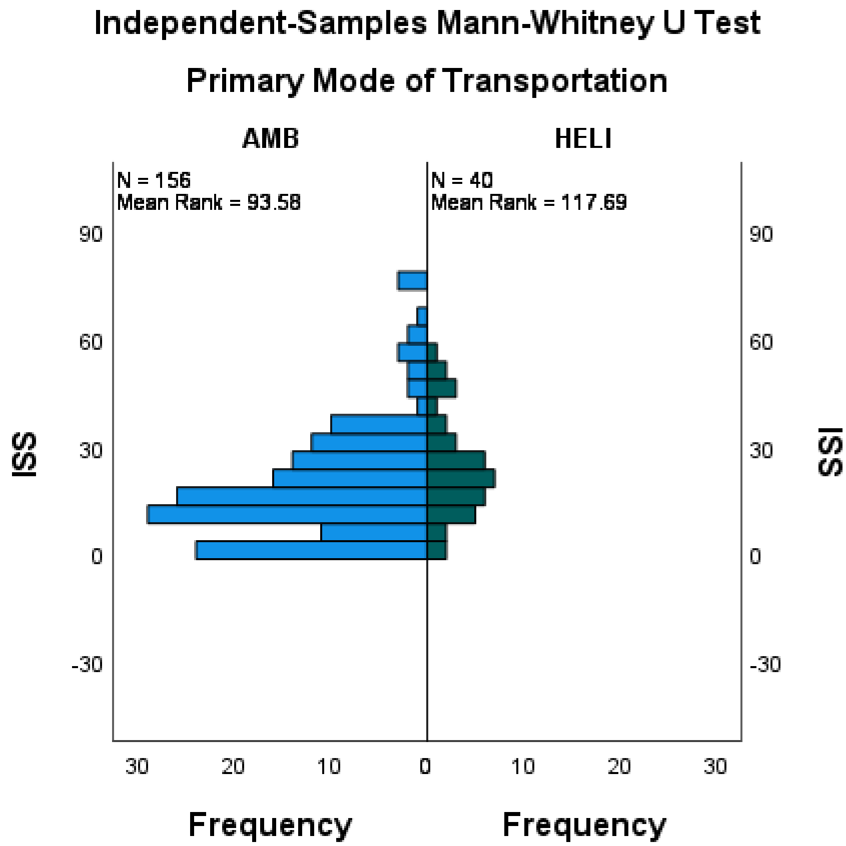
Modality of Transportation and Injury Severity Score

Prior research investigating the differences in pre-hospital care between ground and helicopter EMS transported patients to emergency department trauma centers has found varying differences in the injury severities of these patients. Specifically, (Michaels et al., 2019; Galvagno, 2013; Elkbuli et al., 2021; Andruszkow et al., 2016) have found relationships between lower rates of mortality and the increased levels of injury severities in HEMS transported patients. Alternatively, (Beaumont et al., 2020; Chen et al., 2018; Enomoto et al., 2020) found that, while HEMS patients were more injured, the relationship between that and mortality was null. While the purpose of this investigation is not to contribute to the opposing evidence of demographic and injury differences between ambulance- and helicopter-based patient transportation mediums, the data does serve to further elucidate these said differences.

The a priori recorded data provided information on each trauma patient's injury severity score and their modality of transportation. To test for a difference in injury severity score between modalities of transportation I conducted the non-parametric independent samples Mann-Whitney U test, which was chosen due to the non-normally distrusted nature of the ISS verified by both ocular inspection of a histogram of the data (Figure 15) as well as the 1-sample Kolmogorov-Smirnov test ($p < .001$).

The results of the Mann-Whitney U test suggest that helicopter transported patient's injury severity scores (Mean Rank = 117.69) are significantly higher than patients transported via ground ambulance (Mean Rank = 93.58) with a Mann-Whitney U test score of 2352.50 ($p = .016$).

Figure 15. Mann-Whitney U Visualization of Transportation on ISS



Modality of Transportation and Over triage

Patient over triage has been a significant point of interest in recent work due to the increased and inappropriate work and resource load it places on emergency departments. The American College of Surgeons (2014) reports that as much as 35% of trauma team activations are over-triaged, defined as a patient receiving a higher team activation than needed based on injury severity. Additionally, evidence indicates that HEMS patients may be twice as over-triaged as compared to their ground EMS counterparts. (Committee on Trauma American College of Surgeons, 2014; Bledsoe et al., 2006). Patients who experience higher levels of trauma team activation with injuries that do not necessitate them will be subjected to additional resuscitation resources that will decrease the likelihood of mortality. This investigation yielded data on injury severity scores as well as trauma team activation levels between ambulance and helicopter transported patients. While contested, most published work suggests that trauma patients who receive higher activations of recourses with injury severity scores below 16 are considered over-triaged (American College of Surgeons, 2014). While not the primary purpose of this investigation, the contribution to determining if there are differences in over-triage levels between these two transportation modalities may be impactful. To test this relationship, I calculated an over-triage variable that consisted of two groups of patients. Patients who received an injury severity score of 15 or below and received a high level of resource activation were categorized as over-triaged, whereas all other patients were not. I then conducted Fisher's exact test to assess if the levels of over triage between ambulance and helicopter transported patients are independent of one another. The results of the test show that of the 156 ground ambulances that transported patients, 23.1% (n = 36) were over triaged whereas of the 40 helicopter ambulances that transported patients only 7.5% (n = 3) were over triaged. Fisher's exact test was significant (p = .027) which suggests that the mode of transportation does affect triage rate, and, ground ambulance patients are more likely to be over-triaged than helicopter transported patients.

Table 6. Primary Mode of Transportation and Over-Triage

		Not Over-Triaged		Over-Triaged		Total	
		N	%	*N*	%	*N*	%
Modality	Amb	120	76.4	36	92.3	156	79.6
	Heli	37	23.6	3	7.7	40	20.4
Total		157	100	39	100	196	100

Under Triage

A similar analysis was taken for under triage, which is described as an instance in which a patient received an injury severity score of 16 or above, but was subsequently provided fewer resources than estimated for their injury severity. The results indicate that of the 196 patients transported with available data, 30% (n = 12) of helicopter patients were under triaged whereas 21.7% of ground transported patients were under triaged. This led to an insignificant chi-square test (p = .298) suggesting there are no differences in under triage between the two tested modalities of transportation.

Table 7. Primary Mode of Transportation and Under-Triage

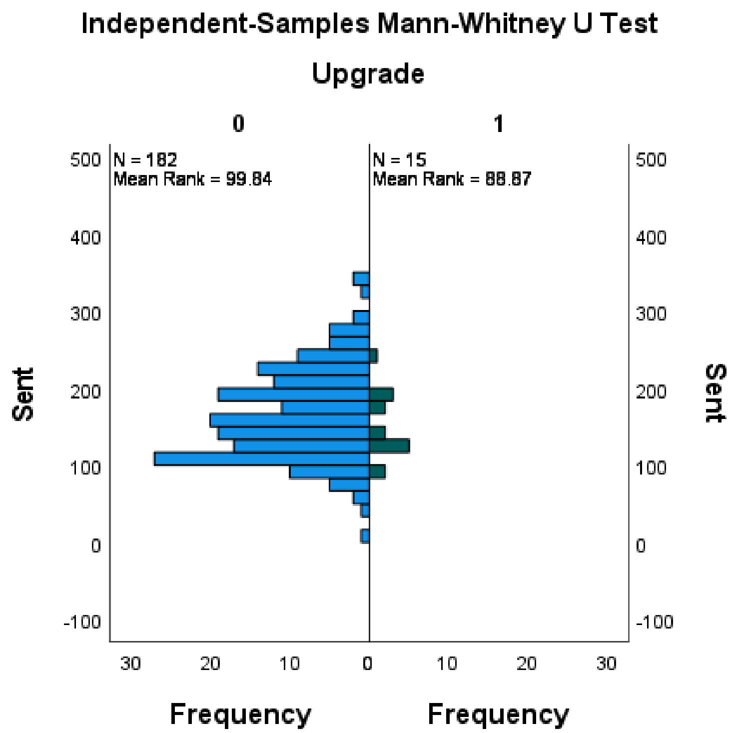
		Not Under-Triaged		Under-Triaged		Total	
		N	%	*N*	%	*N*	%
Modality	Amb	122	81.3	34	73.9	156	79.6
	Heli	28	18.7	12	26.1	40	20.4
Total		150	100	46	100	196	100

Information Given and Trauma Team Upgrades

Trauma team interventions occur at multiple points in the patient transfer process including during the pre- and concurrent-hospital stages. As identified previously, pre-hospital communication not only assists EMS in care-related decision-making but, also provides trauma teams guidance in determining what resources are required of them to increase the likelihood of successful resuscitation. Subsequently, the vast majority of initial levels of resource activations are made at the pre-hospital stage. However, after a patient arrives, if deemed necessary, the trauma team can activate additional resources if not done so during the pre-hospital stage and deemed necessary. These resource activation upgrades may, therefore, be influenced by a more detailed handoff that occurs during patient transfer. To test for this relationship, I conducted an independent sample Mann-Whitney U test of information given between upgraded and non-upgraded patients due to the non-normal distribution of information given verified via ocular inspection (Figure 16) and the 1-sample Kolmogorov-Smirnov test ($p < .013$).

The test suggested that there was no significant difference in information given between upgraded and non-upgraded patients (Mann-Whitney = 1213, $p = .474$).

Figure 16. Mann-Whitney U Visualization of Trauma Team Upgrade and Information Sent

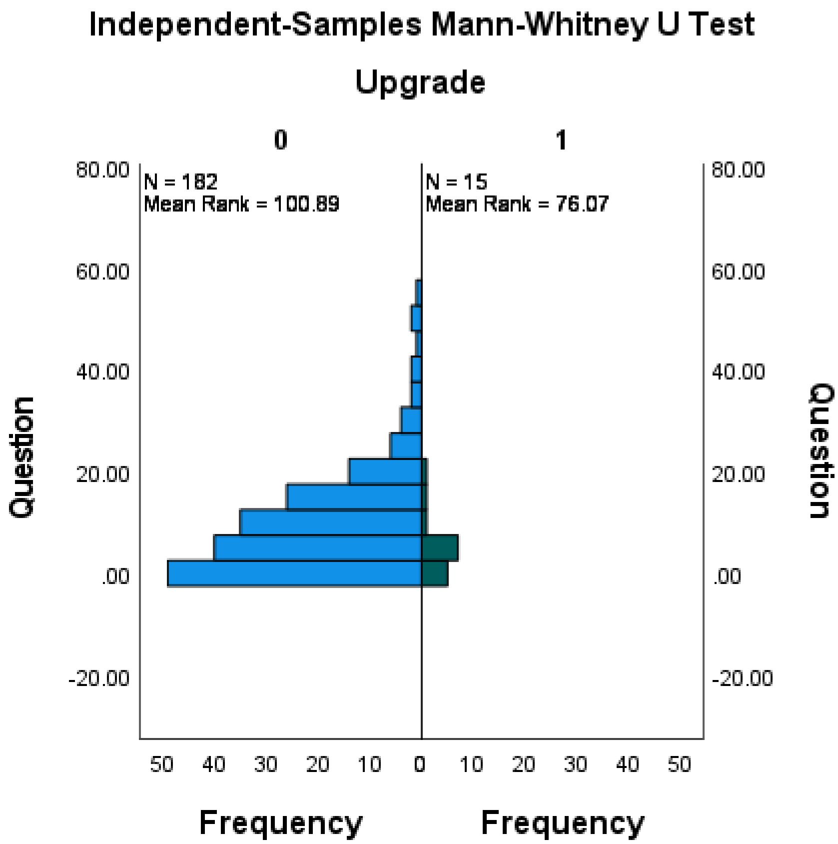


Information Questioned and Trauma Team Upgrades

Similarly, the amount of information questioned may also contribute to the upgrade of resources activated for patients. To test for this relationship, I conducted an independent sample Mann-Whitney U test of information questioned between upgraded and non-upgraded patients due to the non-normal distribution of information questioned confirmed via ocular inspection (Figure 17.) and a 1-sample Kolmogorov-Smirnov test ($p < .001$).

The test suggested that there was no significant difference in information questioned between upgraded and non-upgraded patients (Mann-Whitney = 1021, $p = .103$).

Figure 17. Mann-Whitney U Visualization of Trauma Team Upgrade and Information Questioned



Information Source and Patient Outcomes

The a priori formed hypotheses in this investigation sought to understand the relationship between information given during an EMS to trauma team handoff and the pre-identified patient outcomes. The communication-based variable of interest, however, was broken down into three separate categories including information given by EMS, the information given by the trauma team, and information given by the patient in addition to these separate categorizations for the variable of information questioned. To conserve power and to mitigate the challenge of perfect linearity, and due to the inter-rater reliability challenges identified in information verification and requests, these categories were simply summed into the information given and information questioned variable. However, to determine if one group's communication took precedent over others in its contribution to the identified patient outcomes, I tested each source of information set in the previously presented moderated regression models.

Mortality. In replacing the aggregated information given variable for each source (e.g., EMS, trauma, and patient) I found that the information given by the EMS team was a significant predictor in the model (B = -.025, SE = .008, p = .001) whereas the information given by the trauma team (B = -.005, SE = .045, p = .917) or patient (B = -12.93, SE = 3850.86, p = .997) were insignificant.

In replacing the aggregated information questioned variable for each source (e.g., EMS, trauma, and patient) I found that other than the aggregate information questioned variable, information questioned by the trauma team was also significant (B = .055, SE = .032, p = .090).

ED LoS. In replacing the aggregated information giving and questioned variables for the multiple moderated linear regression analysis I found that the information given by EMS teams was significant (p = .056), whereas the information given by trauma teams and patients was not.

Further testing was also conducted on information questioned by the EMS team, trauma team, and the patient. The results indicated that none of these subcategories were significant.

Emergency Department Length of Stay and Mortality

Opposing relationships between information given were identified in predicting patient emergency department length of stay and mortality. Specifically, the evidence indicated that higher rates of information given leads to a decrease in the likelihood of mortality, but, also leads to increased emergency department length of stay. Subsequently, I posited that there is an opposite relationship between these two outcomes. I tested this relationship via a Pearson's correlation test which indicated that longer emergency department lengths of stay are moderately correlated to lower likelihood of mortality (r = -.300, p < .001).

Chapter 6: Discussion

Summary of Results

Table 8 presents a summary of the tested hypotheses regarding patient mortality (hypotheses 1 through 3) and emergency department length of stay (hypotheses 4 through 6). This investigation found that primarily, the information given, was the most predictive hypothesized relationship between both tested outcomes, subsequently, only 3 out of the 10 hypothesized relationships were supported.

Table 8. Results of Tested Hypotheses for Mortality and ED Length of Stay

Patient Mortality			
Hypotheses	**Analysis Performed**	**Result**	**Outcome**
Modality of Transportation	Multiple Moderated Logistic Regression	Not a significant predictor of mortality	Hypothesis Not Supported
Information given Moderated by Modality of Transportation	Multiple Moderated Logistic Regression	Not a significant predictor of mortality	Hypothesis Not Supported
Information questioned Moderated by Modality of Transportation	Multiple Moderated Logistic Regression	Not a significant predictor of mortality	Hypothesis Not Supported
Information Given	Multiple Moderated Logistic Regression	Significantly reduced mortality	Hypothesis Supported
Information Questioned	Multiple Moderated Logistic Regression	Significantly increased mortality	Hypothesis Not Supported In Original Direction
Patient Emergency Department Length of Stay			
Modality of Transportation	Multiple moderated linear regression	Not a significant predictor of emergency department length of stay	Hypothesis Not Supported
Information given Moderated by Modality of Transportation	Multiple moderated linear regression	Not a significant predictor of emergency department length of stay	Hypothesis Not Supported
Information Questioned Moderated by Modality of Transportation	Multiple moderated linear regression	Not a significant predictor of emergency department length of stay	Hypothesis Not Supported
Information Given	Multiple moderated linear regression	Significantly increased ED LoS	Hypothesis Not Supported

			In Original Direction
Information Questioned	Multiple moderated linear regression	Not a significant predictor of emergency department length of stay	Hypothesis Not Supported

Additionally, table 9 contains a summary of the results of the exploratory analyses conducted.

Table 9. Results of Exploratory Analyses

Explored Variables	Analysis Performed	Result	Outcome
Modality of Transportation and Injury Severity	Mann-Whitney U Test	HEMS Patients are Significantly More Injured than GEMS	Significant Effect
Modality of Transportation and Over-Triage	Fisher's Exact Test	GEMS Patients Significantly More Over-Triaged than HEMS	Significant Effect
Modality of Transportation and Under-Triage	Fisher's Exact Test	No Significant Difference	No Effect
Information Given and Trauma Team Upgrades	Mann-Whitney U Test	No Significant Difference	No Effect
Information Questioned and Trauma Team Upgrades	Mann-Whitney U Test	No Significant Difference	No Effect
Information Source and Mortality	Multiple Moderated Logistic Regression		
EMS_Given		Significantly Predicts Mortality	Significant Effect
EMS_Questioned		No Significant Effect	No Effect
Trauma_Given		No Significant Effect	No Effect
Trauma_Questioned		Significantly Predicts Mortality	Significant Effect
Patient_Given		No Significant Effect	No Effect
Patient_Questioned		No Significant Effect	No Effect
Information Source and ED LoS	Multiple Moderated Linear Regression		
EMS_Given		No Significant Effect	No Effect
EMS_Questioned		No Significant Effect	No Effect

Trauma_Sent		No Significant Effect	No Effect
Trauma_Given		No Significant Effect	No Effect
Patient_Sent		No Significant Effect	No Effect
Patient_Given		No Significant Effect	No Effect
ED LoS and Mortality	Pearson's Correlation	ED LoS Significantly Negatively Correlated to Mortality	Significant Effect

Team Communication

Team communication during patient handoffs has been an area of significant study during the previous two decades of socio-technical healthcare research due to the significance of communication-related medical errors. Prior research has placed a significant value on the information transfer of relevant patient-related information (e.g., injury, history, demographics, social factors, environmental factors) and various patient outcomes. While these included factors have been deemed as relevant and important to patient care, prior work has also indicated that many EMS to ED handoffs are consistently missing many of these key factors. One potential mechanism behind these missing data points could be the high level of the knowledge gap that exists between EMS and ED personnel. Some prior work investigating the qualitative aspect in the identified challenges of EMS to ED handoffs indicates that EMS does not always know precisely what information is relevant or not in complex patient injury cases and, subsequently, tend to provide as much description of the patient and injury as possible in the form of a report. A result of these stories is that ED providers often find large portions of these stories to be irrelevant and overwhelming. What prior work has largely missed in their investigations of communication during the handoff of a patient between EMS and ED teams is the effect that these descriptive stories have on patient outcomes. This investigation sought to fill this gap and to extend said gap into understanding if communication measured by information transfer, an important patient outcome predictor identified in prior work, can explain the differences previously identified in patient outcomes between HEMS and GEMS transported patients. Overall, results show that descriptive information given between EMS and trauma teams is predictive of both patient mortality and emergency department length of stay, whereas information questioned only had an effect on mortality and the moderating effect modality of transportation on these communication-based variables had little predictive value in either outcome.

Mortality. Hypotheses 1 through 3 were related to team communication via information given and information questioned and its effects on patient mortality. These relationships were tested with a multiple moderated logistic regression with mortality as the outcome.

Results of these hypotheses show that hypothesis 2, the information given, was a significant predictor for patient mortality such that for every 1 piece of information given by either the EMS team, trauma team, or patient reduced the odds of mortality occurring by .025. The impact of this result provides evidence that shows when EMS provides more descriptive stories of the patient's injury mechanism and background leads to positive mortality outcomes. Specifically, prior literature (e.g., Zhang, 2016), as well as the handoffs observed in this investigation indicate that emergency medical service professionals often transfer what providers consider to be excessive information to build a comprehensive picture of the patient (Zhang, 2016). While some EMS cite they purposefully attempt to provide as much information regarding the injury and its mechanisms as well as the patient as possible due to their lack of medical background compared to ED physicians, those ED physicians and nurses claim they are often overwhelmed by said transfers. Although this investigation is not able to provide insights into whether or not the receiving providers listened to or retained the information given by the EMS teams, the results are clear in the benefit that descriptiveness of a patient and their injuries has during the complex handoffs between two teams with potentially massive gaps in medical expertise and knowledge.

Information questioned, hypothesis 3, was found to be a significant predictor of patient mortality such that for every bit of information posited via questioning by either the EMS team, trauma team, or patient, the risk of mortality increased by .056. This result was in the opposite direction initially hypothesized and is in contrast to suggestions that prior evidence. Specifically, prior research and theoretically based investigations suggest that asking questions leads to better handoffs and better patient outcomes. Originally, I hypothesized that a potential mechanism for the reduction of mortality risk as a result of increased information questioned would be due to the development of a shared mental model. However, upon re-evaluation, I believe that this same mechanism may be contributing to the increase in poor patient outcomes such as higher mortality rates. Rather than increased information questioned being a pathway for mental model development, increased information questioned during these handoffs may be indicative of low shared mental models between the teams. In other words, critically ill patients require quick-acting trauma teams to identify and resuscitate their injuries to reduce the patients' chance of mortality. However, these complex handoffs that occur between EMS and ED trauma teams, particularly with the previously identified EMS handoff challenges, a lacking shared mental model of the patient can lead to reduced resuscitation success.

Emergency Department Length of Stay. Hypotheses 5 and 6 were regarding the relationship between information given as well as information questioned and a patient’s length of stay in the emergency department. Prior literature is limited on how handoffs between EMS and trauma teams affect distal outcomes such as length of stay. Evidence that does link this relationship has been primarily focused on the effects of standardized handoffs on emergency department length of stay. However, this investigation included no standardized protocols in any of the handoffs observed. Hypothesis 5, the information given on emergency department length of stay, was significant with a standardized beta of .147 indicating the descriptiveness of a patient and their injury during an EMS to trauma team handoff increases a patient’s length of stay in the emergency department by .147 minutes for every 1 bit if information transferred. This hypothesis was supported, but, in the opposite direction it was previously hypothesized. Specifically, it was believed that giving more information during a handoff would lead to lower emergency department lengths of stay due to the knowledge gained of injury type, location, and severity. After investigating the data and the relationships found, I posit the mechanism behind this relationship holds the same, except, that the increase in length of stay is related to the additional work conducted by the trauma team. Explained another way, EMS to trauma team handoffs that yield more information provide more details about the patient for the trauma team during resuscitation, therefore, increasing their length of stay. Hypothesis 6 tested whether or not information questioned affected emergency department length of stay. There is a limited amount of research that indicates any relationship between asking questions and emergency department length of stay. Of those that do posit a relationship, minimal empirical evidence is provided, rather, prior researchers have suggested that good handoffs are those that promote team members to ask questions. The result of this hypothesis suggests that there is no significant relationship between information questioned and emergency department length of stay. One possible reason for this lacking relationship despite prior suggestions is that the information required by the trauma team to implement interventions that do effect emergency department length of stay are primarily captured when EMS initially provides relevant information regarding the patient.

Modality of Transportation

Mortality. Hypotheses 1, as well as 1a and 1b, were concerning the effects of the modality of transportation on mortality as well as its moderating effects on the information given as well as information questioned. The primary mode of transportation was found to be insignificant in predicting patient mortality. The literature base suggests continuously countering evidence regarding this effect on patient outcomes. While some literature shows that helicopter transported patients result in lower mortality rates, other studies indicate that there is a null difference in mortality rates as compared to a ground ambulance. This investigation is in alignment with the latter evidence showing that hypothesis 1 found no significant difference in mortality between HEMS and GEMS transported patients. One potential limiting factor in finding an effect between ground and helicopter ambulances in this investigation was the number of deaths that occurred in each category. Specifically, three times as many patients who were transported via ground ambulance (n = 18) died as compared to those who died and were transported via helicopter ambulance (n = 6). These low-case numbers may lead to challenges in the identification of any differences. Another possible explanation is that this lack of predictive significance, and the lack of significant difference in mortality found in exploratory analyses, is indicative of the effectiveness of the HEMS transportation modality. Exploratory testing found that HEMS transported patients had a significantly higher injury severity score than GEMS transported patients, yet, HEMS transported patients had no higher mortality rates than their GEMS transported counterparts. This result may show that, while not significantly predictive of mortality, HEMS transported patients received better outcomes due to their high injury severity and no higher mortality rate.

I further posited in hypothesis 1a that the modality of transportation will significantly moderate the effects between information given and patient mortality, such that HEMS teams will transfer more information and result in lower patient mortality. The results of this hypothesis were not supported as there was an insignificant relationship between this moderator and mortality. The results, however, do indicate that there was significantly more information given during handoffs for patients who were transported via helicopter compared to those who were transported via ground ambulance. This result serves as an additional explanation for the lack of difference in patient mortality rates between HEMS and GEMS transported patients despite higher injury severity levels for HEMS transported patients. As previously identified, higher rates of information given resulted in significantly decreased mortality rates, therefore, since HEMS teams transmitted significantly more information regarding their patients than GEMS teams then the lack of increased mortality rates given higher injury severity scores would follow logic. A caveat in interpreting this specific result is the high level of multicollinearity between the modality of transportation variable and its moderating effect on information sent. While this multicollinearity does not affect other variables or the model's performance itself, the beta estimate and p-value of this moderator should be interpreted such that its value may be inflated. However, further testing via removing each variable to mitigate multicollinearity indicated that the moderation of modality of transportation and information given is insignificant in predicting mortality regardless of multicollinearity Additionally, hypothesis 1b, higher levels of information questioned moderated by the modality of transportation will lead to lower patient mortality, was also found to have an insignificant effect. The increase in patient mortality when more information is questioned contributes to a challenging relationship between this moderation and mortality. Further research should be conducted to examine this relationship, and further, understand the relationship between shared mental models and information questioned as well as the modality of transportation.

Emergency Department Length of Stay. Hypotheses 4, as well as 4a and 4b, were concerning the effects of the modality of transportation on emergency department length of stay as well as its moderating effects on the information given as well as information questioned. The primary mode of transportation was found to be insignificant in predicting patient emergency department length of stay. Little research was identified during this investigation that studied, let alone identified a relationship, between modality of transportation and any forms of length of stay. The literature that has studied this relationship has either found null results or decrease in patient length of stay (Ayer et al., 2019). The length of stay in this investigation, the emergency department, was chosen specifically over other lengths of stay (i.e., ICU and hospital total) due to the more proximal timing of resuscitation and immediate treatment in the emergency department. Therefore, any effect a handoff has should become more salient as opposed to the more distal outcomes of other lengths of stay metrics that are subject to confounding factors that were not measured in this investigation. However, similar to prior research this linear regression found there was no significant difference between helicopter and ground ambulances as a medium of patient transportation and emergency department length of stay. As with the prior discussion on the modality of transportation and mortality, this lack of significant difference despite the higher injury severities identified in HEMS transported patients may indicate a positive finding, rather than a null finding.

Additionally, hypotheses 4a and 4b were the moderation of modality of the patient's transportation and the amount of information given as well as questioned during the patient handoff to the trauma team. As with the logistic regression model previously discussed there was a high level of multicollinearity between the modality of transportation variable and its moderating effect on information sent, therefore these variables' beta estimates and p-values should be interpreted such that their values may be inflated. However, further testing via removing each variable to mitigate multicollinearity indicated that the moderation of modality of transportation and information set is insignificant in predicting emergency department length of stay regardless of multicollinearity. This proposed hypothesis was new to the literature base as the differences in handoffs between helicopter and ground ambulance teams have not yet been investigated. However, prior literature did indicate that helicopter-transported patients received longer emergency department length of stay and better health outcomes (i.e., lower mortality rates) while being more injured. The results of the linear regression model suggest that there is no predictive difference between HEMS and GEMS transported patients regarding their emergency department length of stay, detracting from prior work. However, following the same logic from hypothesis 1a, HEMS teams transmitted more information. In fact, on average, helicopter patients spent 29 minutes less in the emergency department compared to their ground ambulance counterparts. Similar results were found with hypothesis 4b, which posited that more information questioning would occur with HEMS patients compared to their GEMS counterparts leading to higher emergency department lengths of stay. As previously posited, this lack of significance may suggest positive results rather than negative. If helicopter emergency medical service patients are on average more severely injured and their ED lengths of stay are not significantly different then these patients may have received better handoffs regardless of these insignificant results. This logic is extended by the fact that HEMS were significantly more descriptive of their patients than GEMS when conducting their handoffs.

Finally, multiple exploratory analyses were conducted to aid in the understanding and interpretation of hypothesized results in this study. The primary findings in these exploratory analyses yielded that the differing relationships found between information given and mortality (positive) and emergency department length of stay (negative) may be in someway related. Specifically, a pearsons correlation analysis indicated that longer emergency departments lengths of stay are associated with lower mortality rates. Therefore, the higher frequency of information given and lower mortality, and subsequently, higher emergency department length of stay seem to be related. One potential mechanism behind this may be in the resulting resuscitation processes as a result of more information given. If higher frequencies of information provide more opportunities for trauma teams to identify and resuscitate patients and their various injuries, then, they should also be provided more opportunities to decrease patient mortality. Next, it was identified that the information given from EMS teams, and questioned by trauma teams, were the actual mechanisms behind hypotheses 2 and 3 in their relationships with mortality and length of stay. This finding correlates with other handoff research, and, provides further evidence towards the presented hypothesis that increased information giving and questioning may be related to the development of shared mental models, which, in turn may be the mechanism influencing patient outcomes.

Implications

The results of this investigation provide evidence both in support of and opposing hypotheses identified in prior literature. This investigation provides multiple implications for both future research and practice for EMS and trauma resuscitation teams.

Research Implications

Prior investigations into EMS to trauma team handoffs have identified significant gaps in the information shared as well as the mental model of the patient being transferred. One of the predominant reasons for these discrepancies is the unique quality of these handoffs in a wide variety of patients and injuries that need to be shared with a trauma team from an EMS team with less medical training and knowledge. This discrepancy motivates the *report-style* aspect of these handoffs where EMS provide as much descriptive information about the patient and their injury as possible to ensure the trauma team understands the severity and mechanism of the injury as well as the demographic of the patient. Prior work investigating these types of handoffs has predominantly focused on, specifically, what information was transferred. However, multiple quantitative and qualitative works, now including this research, have identified similar methods of information transfer by EMS teams regardless of the training received or cognitive tools utilized (i.e., handoff tool, memory tool).

This investigation identified that this method of handing off information, concerning EMS to trauma teams, may be beneficial when controlling for injury severity and trauma team intervention. Specifically, this investigation found that the more descriptive an EMS team is in their handoff, the lower the mortality rate is for patients. The method of which the information given and questioned between the EMS and trauma team detracted from traditional handoff literature. Prior handoff work in the medical domains has primarily measured the amount of specifically identified information transmitted and asked for during a handoff. Such information has included medically relevant information (e.g., allergies, treatment, symptoms), patient medical history (e.g., normal vitals, pre-existing disease), patient demographics (e.g., age, gender), patient social factors (e.g., living arrangements, social support), injury mechanisms (e.g., history of events, mechanism of injury), environmental factors (e.g., extraction time, patient pickup environment), and patient psychological factors (e.g., mental state, mental history). While prior work has elucidated the importance of this medically important information, it has largely ignored how these handoffs occur and the limitations behind these low to high knowledge information transfer environments. Evidence of this appears in a multitude of investigations that have identified large quantities of previously identified information that has been left out of these handoffs. In response to these information-sharing gaps, researchers have posited that providing tools (i.e., handoff aides) and standardization strategies may improve EMS to trauma team information transfer. Challenges, however, identified with these approaches suggest that the heterogeneity of patients as well as the vast array of hospitals EMS transfer patients to may reduce the effectiveness of standardized protocols and tools, particularly when each team (i.e., EMS and trauma) are trained on different handoff methodologies.

Additionally, this work identified that the initial shared mental model and development of said mental model may be a crucial step in conducting handoffs in this environment. This work indicated that potentially low mental models may be a key predictor of poor trauma patient outcomes. Research may be able to pivot the measurement of shared mental models in these handoff scenarios to garner a further understanding of how these shared mental models develop, they affect patient outcomes, and what information is considered important to both teams during a handoff. Specifically, it has been shown in prior work that EMS and trauma team members have potentially different objectives during handoffs, and beliefs regarding what is and is not important to communicate. However, few works have experimentally measured or assessed these factors limited the scientific and medical communities' ability to identify why these discrepancies exist, and how they may be improved.

In-Practice Implications

The results of this investigation also posit multiple implications for medical practitioners. First, prior investigations into the handoffs between EMS and trauma teams have indicated differing mental models on the importance of information being transferred. Prior work shows that EMS team members are often unsure of the specific information that should be transferred and, subsequently, tend to share as much information as possible. Providers, on the other hand, often indicate that they are overwhelmed by excessive information during these transitions of patient care. While the results of this investigation show that more descriptive handoffs result in, generally, better patient outcomes (e.g., mortality) prior work also shows that significant gaps are often present in these handoffs. One potential implication may be that increased descriptiveness may account for the lack of structure and expertise that EMS has, such that some missing information may be extrapolated from trauma providers. However, the main implication for providers lies in the development and practice of leadership skills. Prior work via Fernandez (2021) shows that leadership training significantly improves a trauma team's ability to produce positive patient outcomes in improving trauma resuscitation teaming. Handoff-based leadership training research has also shown that similar leadership-based training interventions lead to improved handoff outcomes. Therefore, providing trauma team leaders with the skill and knowledge to effectively guide a handoff and garner relevant, structured information from EMS teams based on the descriptiveness of their current knowledge of the patient. In addition to leadership-based interventions, there is a need for healthcare organizations to measure and conceptualize the information deemed important to both EMS and trauma team providers during these handoffs. Without this understanding, any interventions (c.f., leadership, teamwork, etc.) may result in low efficiency when applied in real-world settings. Fundamental work is required to give both EMS and trauma team providers the tools and processes required to increase trauma resuscitation success.

This research also provides implications for healthcare organizations. Specifically, this work identified that the policies and procedures that healthcare facilities utilize regarding trauma triage and other trauma-related decision-making suffer from significant heterogeneity. Additionally, prior research regarding handoffs, in general, shows a significant variety in the methods and protocols utilized as well as the organization's modification of said protocols that guide the use of handoffs. While not confirmed in this investigation specifically, it is also generally known that HEMS and GEMS teams transport patients to a wide variety of hospitals, with HEMS potentially transporting to a larger area. This mechanism prevents the development and implementation of a systematized handoff protocol that, when applied, has been shown to significantly improve information transfer in EMS to ED handoffs. Therefore, a goal for hospitals and other healthcare facilities that receive critically injured trauma patients should strive to standardize the information expected from EMS to create a more homogenous handoff structure.

Limitations

This investigation suffered from multiple limitations including the measurements of team communication, observation and transcription of audio-visual data, and the use of a retrospective dataset.

First, team communication was originally intended to be measured concerning other investigation methods utilized in this same domain of work. Primarily via the use of categorizing handoff information. An example of this method is present in Carter et al., (2009); Evans et al., (2010); Goldberg et al., (2017); Talbot & Bleetman, (2007); Yong et al., (2008). However, it was later determined that the knowledge gap between the raters who would be coding the data transcribed in this investigation, including myself, and the medical expertise required to accomplish this task was too great. Consequently, the measurement of information transfer utilized in this investigation (bits of information) is incongruent with much of the previous handoff literature, specifical handoffs between EMS and ED trauma teams. Additionally, the systemized manner in which raters identified important bits via the categorization of descriptive words was subjective to an extent, regardless of the high inter-rater reliability scoring.

Second, the transcriptions of the audio-visual data into de-identified codebooks were conducted by only myself, the principal investigator. This lack of inter-rater transcription that would be possible with multiple transcribers reduces the validity of any outcomes associated with this investigation. Additionally, 213 phrases, words, or bits were marked as unintelligible and removed from the analysis of this data. Had multiple reviewers been able to view these videos for transcription, it may be possible that these data would have been included. Additionally, this lack of inter-rater reliability reduced to validity of the information questioned bits coded by the coding team. Due to the lack of context the coding team had in only viewing transcribed words, their ability to determine if a question was asked was significantly reduced. Therefore, I, the principal investigator, included question marks at the end of identified questions to assist the coding team in determining, contextually, if a question had been asked. This limitation also affected the coding team's ability to differentiate between the prior chosen categories of information requested and verified, as coding team members indicated they could not tell explicitly where one question category began, and one question category ended when multiple requests and verifications were made consecutively.

Third, this research utilized retrospective data from a trauma team leadership training investigation. Two primary limitations were identified from the usage of this data. First, trauma centers tend to be occupationally particularly in noise environments due to the nature of the work done in them. Machines, patients, team members, and other trauma bays within the center produce a quite significant amount of noise in varying frequencies that are not conducive to an audio recording with even modern microphones. Subsequently, portions of many of the handoffs, and in some handoffs the entire information transfer event, were unintelligible. Additionally, the visual recording aspect of the retrospective data collection also introduced significant challenges. While two cameras were included in each trauma bay to gain different perspectives of the handoff and resuscitation, often the individual giving the handoff walked around the room and out of the viewing range of the cameras to reach other team members. In these instances, it was often difficult, or impossible, to determine if the voice heard was still the originally identified team member, or, if someone else had begun speaking. While I did attempt to code for these instances, tracking individuals while listening to the handoff was found to be too difficult of a vigilance task. Additionally, in many handoffs, the speaker would step in and out of the camera so often that tracking it became a futile effort. Had this investigation been conducted prospectively, mitigating solutions may have been able to be implemented.

Recommendations for Future Work

Future work should aim to further study the effect that modality of transportation has on perceived injury severity, as well as the effects of handoff descriptiveness on the development of shared mental models in relation to patient outcomes.

The results of this investigation sought to identify if the modality of transportation of a trauma patient has any effect on the handoff that occurs between EMS and trauma teams. The results, at least for the sample studied, show that there is no identified relationship. However, it is still clear that HEMS patients are significantly more injured than GEMS patients, yet, have no different mortality rates than their GEMS counterparts. Prior work that contributed to this literature has also identified that the pre-hospital triaging and care of a patient also had null effects. Other than replication of this work, future research should focus not only on the quantified injury severity has a variable of interest, but, also the trauma teams perceived injury severity of the patient. Specifically, prior research, along with this work, has shown that HEMS patients are more injured, but, little is known about how trauma teams react and perform in resuscitation knowing their patients are transported via helicopter.

Future research should also investigate how information sharing between HEMS and GEMS teams with trauma teams assists in forming or breaking shared mental models of the patient. Evidence in this work identified that increased frequencies of information questioning resulted in generally poorer patient outcomes. This engagement in asking questions may be the result of team members, and in this case trauma team members, attempting to either build or rebuild a shared mental model with themselves and their EMS teammates regarding the patient injuries.

Chapter 7: Conclusion

The varying effects on patient outcomes, such as patient mortality and emergency department length of stay, that are found in the literature have yet to identify the mechanisms behind the overall higher rates of positive patient outcomes from HEMS transported patients as compared to GEMS transported patients. Prior work has attempted to quantify these effects and determine their cause by studying pre-hospital care and the time to care facility arrival difference between the two modes of transportation. However, thus far, no effects have been identified.

One aspect of a potential cause that has yet to be investigated is during the transition of the patient between the HEMS or GEMS team and the receiving trauma team in the emergency department. This investigation sought to close this knowledge gap and determine, regarding the population of trauma and EMS providers within the serviceable area of the Harborview Medical Center in Seattle, Washington, United States of America, if the information transfer between EMS and trauma staff effect pre-identified and relevant patient outcomes such as mortality and emergency department length of stay. Additionally, if this information transference does matter, is it in any way related to the modality in which the patient was transferred to the care facility (e.g., HEMS vs GEMS).

The literature review that preceded this investigation found that HEMS crews often are more highly trained, have more experience, and service more areas than their GEMS counterparts. These factors were hypothesized to influence the relationship between each crew's ability to effectively and efficiently transfer information about the patient to trauma teams via providing more information about the patient. The results of this investigation found that higher rates of information given during a handoff significantly reduce the likelihood of patient mortality, but, also increase the amount of time the patient stays in the emergency department.

Later exploratory work found that this relationship may be beneficial as longer emergency department lengths of stay were correlated with lower mortality rates. Further, it was identified that an increased rate of information questioned significantly increased the likelihood of mortality. I hypothesized that this relationship is motivated by the development, or the need to develop stronger, mental models of the patient and their care needs. In other words, increased frequencies of information questioned may be related to the trauma team and EMS team members attempting to build a poorly developed shared mental model of the patient, leading to lower patient outcomes. Finally, further exploratory testing found that the information given by the EMS teams, and information questioned by the trauma teams, were the primary contributors to these models, providing greater evidence that the handoffs (i.e., transferring information and requesting further information) were a key aspect of predicting patient outcomes.

The lack of significance found in the modality of transportation, as well as its moderating effects on information given and information, questioned, however, led to a more obfuscated interpretation of the results. Primarily, through this investigation, I found that the primary modality of transportation (e.g., HEMS vs GEMS) did not affect predicting patient mortality when controlling for important study and medically relevant confounding factors. However, further exploratory testing indicated that HEMS transported patients were significantly more injured than their GEMS counterparts, but, did not receive significantly different outcomes. While the injury severity score was controlled for in these analyses, this measurement only captures a post-hoc metric of injury severity, rather than the perceived injury severity of the patient at the time of transfer. The result indicating that HEMS transported patients received fewer adverse outcomes may provide evidence that HEMS is a more effective modality of transportation than GEMS for critically injured patients. This is further identified during exploratory analyses which indicate that HEMS teams communicated significantly more information than their GEMS counterparts.

The results of this investigation may assist both researchers and practitioners in employing research that more closely aligns with how EMS to trauma team handoffs occur as well as speaking on how to garner information from EMS teams effectively. First, concerning future research, prior work has primarily focused on the type of information transferred between EMS and ED teams via pre-identified categories of information. While such information is identified by subject matter experts, the coders of said information during these studies may miss some information implicitly transferred via the descriptiveness of the patient and their injury by the EMS team. Therefore, future research should seek to identify how it can pivot the measurement of handoff descriptiveness with the chunking of desired information from the EMS team. Additionally, this research may assist providers and organizations alike identify how to best implement policies that assist EMS teams in providing the most relevant information possible to handoff training practices. These EMS to emergency department trauma team handoffs are subject to the complex patient presentation which require EMS members to describe highly complex accident scenes in a very short period. These low contextual knowledge (EMS) to high contextual knowledge (trauma team) transfers may necessitate that trauma team leaders guide EMS in what information should be shared and how detailed the information should be.

While this investigation suffered from multiple limitations due to reliability and challenges due to employing retrospective data, it provides significant findings that, while similar to previous findings, posit alternative measurement techniques that may assist in advancing the handoff research domain. Additionally, this work further provides evidence that shows HEMS and GEMS patient outcomes do not differ when controlling for various medically relevant confounds. However, the significantly higher injury severity of HEMS patients may elucidate the effectiveness of HEMS transportation. A significant amount of future work is needed to identify the communication-based and transportation-based factors regarding the relationship between identified patient outcomes and their differences in HEMS and GEMS transported patients.

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Appendices

Appendix A

Operational Definitions of Constructs

Term	Definition	Citation
Modality of Transportation	Helicopter and Ground Emergency Medical Service	-
Information-Giving	Statements about patient demographics and medical information	Manser et al., 2013
Information Questioned	Any instance in which a question is asked during the handoff.	
Trauma Team Upgrade	Increase in the level of an activated trauma team	Washington State Department of Health Office of Community Health Systems. (2016)
Trauma Team Activation	Activation or necessary trauma team members and resources	Washington State Department of Health Office of Community Health Systems. (2016)
Injury Severity Score	Systemized assessment of a patient's injury severity level	Baker et al., 1974
Patient Mortality	Patient death in the responsible care facility	-
Patient Emergency Department Length of Stay	Time between patient triage of registration and their exit of the emergency department	Driesen et al., 2018)

Appendix B

Hypotheses and Related Analyses

Hypothesis	Analysis and Assumptions
H1 H1a H1b H2 H3	Multiple Moderated Logistic Regression on Mortality Assumptions: • Dichotomous Dependent Variable • Independence of Observations in Dependent Variable • Linear Relationship between Dependent and Independent Variables • Consistent Residual Variance Across Levels of Moderator
H4 H4a H4b H5 H6	Multiple Moderated Linear Regression on ED Length of Stay Assumptions: • Continuous Dependent Variable • Linear Relationship between Dependent and Independent Variables • No Significant Outliers • Independence of Observations • Homoscedasticity • Normally Distributed Residual Errors • Consistent Residual Variance Across Levels of Moderator

Appendix C
Coding Guidelines

Codebook Structure

The following variables correspond to columns in the codebook read from left to right, top to bottom.

	Row 1
Sender (EMS)	The EMS individual who is sending the information about the patient to the receiving provider
Receiver (Provider)	The provider who is receiving information from the EMS sender (Typically a nurse). However, may consist of multiple individuals throughout the handoff process.
Patient	Individual being treated on hospital bed
	Row 2
Description	Place to provide a high-level description of individual who is sending/receiving handoff. If multiple individuals speak, differentiate between them
	Row 3
Interruption	Whether or not the speaker was interrupted by the receiver/sender **NOT RELEVANT TO CODERS**
Transcript Time Stamp	Time stamp of the video player (Not of the video-embedded time). Each Interruption of continuous speaking will result in a new time stamp.
Transcript	Exact transcript of the speaker. See data dictionary on unintelligible categorization when you cannot understand/hear the speaker.
Quote	The direct quote from the transcript from which you are extracting the single bit of information. The quote should contain additional text for context regarding which part of the transcript was coded but should NOT contain additional bits of information. This should allow us to read the exact

	transcript line by line
Bit category	A logical category for which the bit of information is related. This may be subjective and should indicate why the bit was extracted.
Category of communication	Category of communication for the bit extracted. Three possible choices including information sent, information requested, and information verified. See the data dictionary for more info.

Data Dictionary

Category of Information	
Information Sent	Either unsolicited or solicited information provided during a handoff. May be new, repeated, and similar to previous information handed off.
Information Requested	Information an individual requests that was not explicitly previously sent.
Information Verified	Information an individual requests that was explicitly previously provided. OR, information that was unheard and is requested to repeat.
Unintelligible Categorization	
Unintelligible included in Question	When an unintelligible is included in a question you can categorize the question in 1 of 3 ways: If you can 100% point out the subject that was requested, the question gets marked as requested. If you can 100% point out the subject that was verified, the question gets marked as verified. If you can cannot point out the subject that was requested or verified, the question gets marked as challenging to hear Leave the unintelligible bit categorization

	empty. See last page for example.
Completely Unintelligible	Marked when the information cannot be heard or deciphered. Marked via: *unintelligible*
Partially unintelligible	Marked when the information can sort of be heard, but cannot be transcribed with full confidence Alternatively, information is difficult to hear but may be clarified depending on the context of information being shared. Marked via: (unintelligible)
Medical Terminology	Suspected medical terminology that you are unfamiliar with and may need clarification from an SME. Marked via: #unintelligible or word/phrase#

Coding Rules

- When dissecting a transcript into bits it is imperative to break down the bits into the most atomic form of meaning and information possible.
- Use the following tables as a guide to know when and when not to separate.
- If a cell is unintelligible leave the category of information empty
- If He/She His/Her etc is NOT about patient it gets seperated

Noun Rules

A noun is a word (other than a pronoun) used to identify any of a class of people, places, or things (common noun), or to name a particular one of these (proper noun). Separate all nouns. Examples:
Car Truck Van Semi Truck Man Woman House

Adjective Rules

Adjectives are words or phrases naming an attribute, added to or grammatically related to a noun to modify or describe it. Separate all adjectives. Examples:
Colors (red, blue, green) Size (large, big, small, tiny, wide, thin) Measurement (slow, fast) State of matter (dry, wet, thick, runny)

Interrogative Rules

Interrogatives are used when having or conveying the force of a question. Separate these words regardless of their use (interrogative or not).

Separate	Don't Separate
Who What When Where Why How	

Name Rules

Separate	Don't Separate
First Middle Last Mr. Ms. Dr.	

Pronoun Rules

A pronoun is a word that can function by itself as a noun phrase and that refers either to the participants in the discourse. **Separate all pronouns EXCEPT WHEN REFERRING TO PATIENT.**

Separate	Don't Separate
We Us I You (Also if they refer to trauma team member by name) They them **Any reference to other first responders from injury scene	Any instance referring to patient

Unit Rules

Separate	Don't Separate
Units are quantities used as a standard of measurement. These are usually communicated as acronyms (MPH). **Separate these acronyms into their full versions. Pay special attention to the Don't Separate column**.	
Separate	Don't Separate
Any unit Acronym	
MPH	
Miles	
Per	
Hour	

A & AN RULES

DO NOT SEPARATE "A" OR "AN"

Was Rules

SEPARATE WAS

Auxiliary Verbs

Auxiliary verbs are verbs used in forming the tenses, moods, and voices of other verbs. Auxiliary verbs may also be used to indicate uncertainty.

Separate	Don't Separate
Was	
Wasn't	
Am	
Am not	
Is/Isn't	
Being	
Been	
Be	
Have/Havn't	
Has/Hasn't	
Had/Hadn't	
Do/Don't	
Does/Doesn't	
Did/Didn't	
Will/Won't	
Would/Wouldn't	
Shall/Shan't	
Should/Shouldn't	
May/May not	
Might/Might not	
Must/Mustn't	
Can/Can't	
Could/Couldn't	

Common Prepositions

Prepositions are words governing, and usually preceding, a noun or pronoun and expressing a relation to another word or element in the clause. Separate all prepositions.

Separate	Don't Separate
about	And
above	Or
across	as
after	
against	
along	
among	
around	
at	
before	
behind	
between	
beyond	
but	
by	
concerning	
despite	
down	
during	
except	
following	
for	
from	
in	
including	
into	
like	
near	
of	
off	
on	
onto	
out	
over	
past	
plus	
since	

throughout
to
towards
under
until
up
upon
up to
with
within
without

Demonstrative Rules

Demonstratives are words used to point out to specific things. **Separate all demonstratives except for "the".**	
Separate	Don't Separate
This That There Those These	The

Pleasentry Rules

Pleasetires should be rare, but, when they occur do not separate them.	
Separate	Don't Separate
	Thank you You're Welcome

Semantic Pleonasm Rules

Semantic pleonasm occurs from redundancy, or unnecessary repetition of an idea or description of it. See below for a list of examples. Do not separate Semantic Pleonasms.	
Separate	Don't Separate
	Up North Down South Out East/West Stand up Kneel Down Join Together Enter in So

Additional Rules

- Red text indicates stumbling that should be combined into one cell
- Green text indicates an acronym that should NOT BE SEPARATED