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Use of the Pediatric Trauma Score to Triage Severity of Childhood Injury

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by

Jennifer Fieber

2014

USE OF THE PEDIATRIC TRAUMA SCORE TO TRIAGE SEVERITY OF CHILDHOOD INJURY

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Abstract:

Trauma is the leading cause of pediatric mortality and morbidity in the United States, but there is no widely accepted trauma scoring criteria for the rapid triage of acute injuries in children. The objective of this study was to evaluate the association of the Pediatric Trauma Score (PTS) with central nervous system injury (CNS) and solid organ injury (SOI), subspecialist operative management, and emergency department (ED) disposition in pediatric trauma patients. Our hypothesis was that PTS would be adequately asssociated with these outcomes. We performed a retrospective review of the medical records of all patients less than 16 years of age evaluated for acute injuries in our Level I Pediatric Trauma Center from 1/2005-12/2011, excluding patients transferred from referring hospitals. Demographics, PTS criteria, and outcomes were abstracted. Receiver Operating Curve characteristics were performed to determine the predictive ability (AUC-Area under the Curve) of the PTS at detecting outcomes.

Our results included 3,817 patients, the average age was 7.25 years; 66.1% were male; and 98.4% sustained blunt trauma. Mean PTS value was 10.0. PTS had an outstanding association with mortality (AUC: 0.996; SE: 0.001). PTS had an acceptable association with CNS injury (AUC: 0.750; SE: 0.029) and operative management including neurosurgery (AUC: 0.788; SE: 0.041), reconstructive surgery (AUC: 0.750; SE: 0.051), and pediatric surgery (AUC: 0.746; SE: 0.027). PTS had a poor association with solid organ injury (AUC: 0.572, SE: 0.038); operative management by orthopedic surgery (AUC: 0.565, SE: 0.014); and ED disposition including discharge to home (AUC: 0.641, SE: 0.009), admission to the intensive care unit (AUC: 0.689, SE: 0.017), and admission to the surgical ward (AUC: 0.667, SE: 0.018). In conclusion, PTS may be a useful means to triage acute injury in children and to predict likelihood of mortality, presence of CNS injury, and need for subspecialist surgical management.

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<u>Introduction</u>:

Trauma is the leading cause of morbidity and mortality in children.[1] More children die from trauma than the following nine other causes of death combined.[2] One in five children are injured a year, leading to 9 million Emergency Department (ED) visits and 7,500 deaths.[2,3] Up to 25% of all trauma patients in the United States are children.[4] Despite this fact, the initial triage of pediatric trauma patients has remained a difficult issue. Pediatric patients have a unique physiology and also are prone to different injury patterns than adult trauma patients. As a result, many challenges can undermine efforts to identify ideal triage strategies for pediatric trauma patients, the goals of which are to provide the most efficient care in the most appropriate institution while decreasing rates of overtriage that can lead to unnecessary costs and radiation exposure. This introduction will review the types of traumatic injuries commonly diagnosed in pediatric patients, the inherent challenges in evaluating and managing these injuries, and the existing triage methods for pediatric patients.

Types of Traumatic Injuries:

The majority of pediatric injuries are due to unintentional blunt trauma. The most common MOIs are falls followed by motor vehicle accidents (MVA).[1,2] Penetrating trauma is the MOI in less than 10% of childhood traumas.[5,6] The vast majority of childhood trauma leads to minor injuries of only a single system.[5] Guice's retrospective analysis of over 7 million pediatric trauma admissions found that over 50% of patients had an isolated injury with fractures being the most common, contributing to 58% of trauma presentations.[2] In Bayreuther's analysis of 24,218 pediatric trauma cases, limb

injuries were most common and isolated limb injuries accounted for almost 85% of all injuries.[7]

Trauma is responsible for 50% of all childhood deaths.[5,8] Cooper's analysis of pediatric trauma in New York City from the Pediatric Injury database showed that injured children die at a rate of 20% of that of adult trauma patients but that they have a 56% higher rate of requiring hospitalization for treatment of their injuries.[8] Motor vehicle accidents are the leading cause of pediatric traumatic mortality, accounting for more than half of pediatric deaths, followed by homicide and suicide.[1,9] The most deadly mechanisms were self-inflicted trauma, firearm injuries, pedestrian accidents, suffocation, motorcycle crashes, and child abuse.[6] Mortality in children follows a bimodal distribution consisting of up to 70% unsalvageable injuries at the scene of injury followed by a second peak less than 24 hours into admission.[1,4] Younger children, higher Injury Severity Scores (ISS), and low Glasgow Coma Scores (GCS) had good correlation with mortality in Do's analysis of 331 pediatric trauma patients.[1]

Males are more likely to be injured than females at all age ranges.[2] Mortality from traumatic injury is twice as likely in males compared to females.[9] Risk of pediatric injury peaks during infancy and again in teenagers.[2] Black and other minority children also have much higher injury rates and mortality than White children.[9]

Head injuries have the highest mortality rate in children regardless of whether they occur in isolation or in association with other traumatic injuries.[7] Infants and young children have anatomic differences including larger heads, which may be the reason they have twice the rates of head injuries compared to older children.[1,7] Interestingly, in Bayreuther's study in London of 24,218 pediatric trauma cases recorded over a 15-year

period from the Trauma Audit and Research Network database the head injuries in infants occurred in isolation over 80% of the time, but in school-age children head injuries occurred in association with other injuries almost 50% of the time.[7] The most common serious injury in Walker's analysis of 598 injured children was central nervous system (CNS) injury followed by abdominal injury.[5] Children less than 5 years old also have higher rates of mortality for abdominal trauma because of their immature bone structures and musculature that limit the protection to their abdominal organs.[1]

Triage Challenges:

Pediatric trauma patients also present a challenge in the acute ED setting. One must balance the possibility of undertriage, which leads to not recognizing the seriousness of an injury, causing delayed involvement of specialized surgical care, and overtriage which leads to incorrectly believing a child is more seriously injured than the child really is, causing inappropriate resource utilization and potentially unnecessary procedures such as diagnostic imaging and its attendant radiation exposure. [10-12] Overtriage often impacts other clinical activities; as the trauma team is also involved in patient care elsewhere, such as on the wards, clinics, and operating room (OR).[13] Perhaps the best example of the significance of overtriage in pediatric trauma patients was shown in Knofsky's study of pediatric patients requiring helicopter transportation to a trauma center, as 23% of these patients were discharged from the ED.[14] The rate of overtriage has been estimated at 55% in Falcone's analysis of 650 pediatric patients. Up to 50% is considered an acceptable rate of overtriage as long as injuries are not missed.[5,15] The overall cost of childhood injuries in the United States has been estimated to be $375

billion annually, which is 3.8% of the gross domestic product, but millions of dollars at each institution is estimated to be spent on overtriage.[15,16]

Appropriate triage does improve patient care, efficiency, and resource utilization.[15] There is limited data on undertriage in the pediatric population, but Furnival's small study on pediatric trauma patients estimated the rate of delayed diagnoses at approximately 5%, and Falcone's study of pediatric trauma patients estimated the rate of undertriage at 9%.[17,18] The majority of these injuries (73%) were fractures that did not require operative management. While undertriage of these orthopedic injuries did not result in a longer hospitalization, a very small percent of critical head injuries and intra-abdominal injuries were missed.[17]

Another challenge in pediatric trauma triage is determining when to transfer children to specialized pediatric trauma centers. It is well accepted that pediatric trauma patients have improved survival and functional outcomes if they are treated at centers with designated pediatric trauma teams and specialized definitive care although there are a limited number of trauma centers.[3,19] Hospitals that are considered highly experienced with pediatric patients are often defined as having >8,400 pediatric trauma discharges/year compared to hospitals with low experience that have <1,800 pediatric trauma discharges/year.[2] In children with traumatic injuries who are treated at a specialized pediatric trauma center, mortality decreased by 25 to 30%.[18] Although only 5 to 15% of pediatric trauma patients will require the specialized resources of a pediatric trauma center, early identification of these patients is extremely important.[6,18]

Pediatric trauma centers have multiple advantages, including the accessibility to comprehensive pediatric subspecialty care.[4] For example, the rate of operative

management for solid organ injuries (SOI), transfusion requirements, and overall costs were higher for children managed by general surgeons in trauma centers without dedicated pediatric services.[3] For children with CNS injury, there are higher rates of surgical intervention at specialized pediatric trauma centers but lower mortality rates.[3] Specialized pediatric trauma centers also had differing management of femoral shaft fractures, with much higher rates of internal fixation and decreased length of hospital stays.[3] Despite the evidence of improved survival and outcomes, only 2 to 13% of all pediatric injuries are actually managed at these dedicated pediatric trauma centers.[3,4] Forty to 70% of children with serious traumatic injuries die before they are transported to a specialized pediatric center.[12] As there are a limited number of pediatric trauma centers, this presents a challenge for the prehospital care provider when making transport decisions for pediatric trauma patients.[11,12,19,20]

Additional challenges unique to the pediatric population include difficult application of the GCS and other assessments of mental status in the triage of the pediatric trauma patient. Pediatric patients have the additional variable of age-specific development in addition to the trauma challenges of sedatives, paralytics, and intubation that may be performed on presentation to the ED.[5] Young children also have limited communication abilities, which may lead to delayed detection of injuries.[21] Physiologic responses to injury also vary based on age as young children have the ability to maintain vital sign stability with larger percentages of blood loss but they also have tendency to deteriorate extremely quickly.[5,10] Children have a different response to SOI than adults and as a result, tend to have less hemorrhage and more minor injuries with similar MOI compared to adults.[5] Some MOI that appears harmless in adults have been shown to

increase mortality in children, such as blunt localized abdominal trauma from bike handlebars or improper use of lap-only seatbelts.[5]

Triage Systems:

An ideal trauma triage system rapidly identifies the severity of injury and leads to stabilization and transport to the best center for definitive evaluation and management.[12] Appropriate triage is important when determining the level of subspecialty care that a pediatric trauma patient will likely need. A perfect triage scale would have a sensitivity of 100% for severe injuries but would also not lead to unacceptable rates of overtriage, including unnecessary resource allocation and diagnostic imaging in children that are unlikely to have severe injuries.

Triage criteria can be broken down by physiologic, anatomic and mechanistic characteristics, as well as other special considerations.[22] Physiologic parameters most commonly include the Glasgow Coma Scale (GCS) or another measure of mental status, and vital signs, including some combination of respiratory rate, heart rate, and blood pressure. Anatomic parameters may consist of penetrating injuries, fractures, dislocations, lacerations, or paralysis. Mechanism of injury (MOI) consists of the type of incident and the overall severity of the damage at the scene of the incident. Special criteria may include co-morbid medical conditions or extremes of age such as infancy.

Mechanism of injury is often considered the simplest way to triage trauma patients. In adults, it has been shown to correlate with injury severity and to be a helpful tool for quickly establishing the potential for serious injuries. This leads to more rapid identification and stabilization of patients in the prehospital setting and more rapid involvement of definitive surgical care in the acute ED setting, improving survival in

adults. The usefulness of MOI alone, however, without considering physiologic or anatomic derangements, has been questioned.[23,24] Mechanism of injury alone has been thought to lead to high rates of overtriage and to have a limited association with the ISS and mortality in the adult population.[22]

Although MOI as a triage tool has been applied to pediatric trauma patients, it has not become a widely accepted triage aid for the pediatric population in the prehospital or acute ED setting.[21,25-27] Mechanism of injury has been linked with overtriage rates in pediatric patients of up to 200%. This has significantly contributed to the extensive economic impact that is estimated to be $347 billion per year to care for childhood injuries.[3,5]

In the pediatric population, MOI has been studied to determine potential mortality and functional disability, but not in the context of the acute ED setting.[6] Burd's large retrospective study using the National Trauma Registry found that the type, intent, and mechanism of injury provided valuable insight in future resource utilization, mortality, and disability although also concludes that the focus on the types of injury may need to be more targeted for common injuries in the pediatric population, additional safety measures in children, and unique anatomical and physiological differences which may alter outcomes from the adult population.[6] Haider did a similar retrospective review analyzing MOI predictions of fatality but took into account disability outcomes in pediatric trauma patients.[28] He identified MOI with extremely high mortality and morbidity in children but also found that some MOI that high mortality in adults had much lower mortality in children.[28] Haider emphasized the difference in the MOI in adults compared to children including restraint devices and back seat passengers in

MVAs. Demetriades further emphasized the differences in pediatric patient outcomes in injuries with falls based on age because of varying anatomical development with spinal injuries, pelvic fractures and lower extremity fractures being much more prevalent in older children.[29] The above studies suggest that MOI may be used in the future as an adjunctive in initial trauma assessment but that there needs to be more research that considers the unique clinical, anatomic, and physiologic features of injury in the pediatric population.

Multiple triage skills have been developed or applied to the pediatric population. General trauma scales include the Pediatric Trauma Score (PTS), Pediatric-GCS, Abbreviated Injury Scale (ASI), ISS, Revised Trauma Score (RTS), Pediatric Risk Index (PRI), American College of Surgeons-6 (ACS-6), Trauma Score-Injury Severity Score (TRISS), and the military Pediatric Trauma "BIG" Score. There have also been multiple organ specific injury scales.[30]

In pediatrics, the ISS, which emphasizes anatomic criteria, is considered the gold standard for predicting mortality. The ISS ranges from 0 to 75 with higher numbers indicative of more severe injury. The ISS has been validated in the pediatric population to predict outcomes.[5] The ISS is used to predict mortality with scores greater than or equal to 16 having death rates of 10 to 20%.[5] In Guice's study, 85% of patients had an ISS < 15.[2] The ISS has been criticized for underestimating injury severity since only one injury per body part can be included in the calculation.[31] Challenges for the ISS include that it requires trained medical personnel evaluation of both the medical record and detected injury to accurately calculate a score, so it is used for research purposes and trauma

database collection more than for direct patient care. Rutledge found that the principal diagnosis was a better measure to predict outcomes than the ISS.[9]

The Revised Trauma Score (RTS) is a physiologic system, which only requires the GCS, systolic blood pressure, and respiratory rate, was not developed specifically for pediatrics.[6] The score is often difficult to calculate because of age specific challenges with GCS and blood pressure as well as the confounding changes to respiratory rate if children require mechanical ventilation.[9] The TRISS combines RTS and the ISS with the addition of age to determine survival although it requires complex calculations and has many criteria. The PRI is a formula that includes ISS, GCS, and the PTS but has some limitations including not taking negative PTS values into account.[32] The ACS-6 includes a collection of 6 criteria including: hypotension, respiratory compromise, transfer from a referring hospital after receiving blood, gun shot wound, GCS score and if there was a change in any clinical parameter after the initial assessment.[18] The score tends to have only a 34% rate of overtriage but the undertriage rate of 16% is considered unacceptable; in addition, it is difficult for clinicians to remember or apply these criteria in direct patient care.[18] The BIG criteria requires laboratory values including base deficit and INR as well as GCS to calculate the score at admission and predict mortality although the necessity for laboratory results limits the usefulness in the triage setting.[26] Many of the required complex calculations and lab values that these triage criteria require are not initially feasible in the prehospital or acute ED setting.

The Pediatric Trauma Score:

The PTS is a unique pediatric trauma scale that was initially developed for prehospital triage and takes into account both anatomic and physiologic variables. [32,33]

The PTS criteria include patient size (> 20 kg, 10 - 20 kg, < 10 kg), airway (normal, maintainable, unmaintainable), systolic blood pressure, (> 90 mmHg, 50 - 90 mmHg, < 50mmHg), open wounds (none, minor, major, penetrating), skeletal trauma, (none, closed, open, multiple fractures) and CNS status (awake, obtunded, coma). Each criterion is assigned a score of 2,1, or -1 with lower scores for more severe findings. A total score for a patient may range from 12 to -6.

Table 1: The Pediatric Trauma Score

	2	1	-1
Weight (kg)	>20	10 - 20	<10
Airway	Patent	Maintainable	Intubated
SBP[A]	>90	50-90	<50
CNS[B]	Awake	Loss of Consciousness	Unresponsive
Wounds	None	Minor	Major/Penetrating
Fractures	None	Closed	Multiple/Open

[A] Systolic Blood Pressure
[B] Central Nervous System

These criteria take into account pediatric physiology with weight, critical illness with airway and systolic blood pressure criteria, common pediatric trauma with fractures and open wounds, and the most common cause of pediatric mortality, CNS trauma, by specifically addressing mental status.[33] The lower values for patient size was an attempt to incorporate a young child's risk of decompensating even if they are stable on presentation. It is also important to note that the PTS also does not consider MOI in the calculation of a patient's score. A major advantage of the PTS is the ease of use as it does

not require lab values and can be easily calculated by the triage ED nurse or by prehospital medical providers. The PTS can be calculated quickly, which makes it ideal for use in the setting of pediatric trauma.

The PTS has been found to be predictive of resource use, need for rehabilitation after hospital admission, and mortality.[34] Kauffman evaluated the PTS for triage accuracy, survival predictions, and correlation with predictors of severity and physiologic derangement. Kauffman found that patients with a PTS < 9 were at much higher risk of mortality and that use of the PTS criteria lowered the rate of undertriage but increased overtriage so therefore may not have been advantageous over previous scales. [35] Ramenofsy found that there were no deaths in children that had a PTS > 8.[36] Eichelberger evaluated the PTS and found that lower scores reliably correlated with increasing ISS and that the overtriage rate was 15%. [37] Jubelirer's analysis of 1307 patients less than 14 years old found that all deaths had a PTS < 9, with a mortality rate of 30% in these children. This analysis also found a close correlation with the ISS and strong validity of the PTS. [38] Aprahamian's results showed that patients with a PTS < 8 had higher resource utilization as the were more likely to require airway intervention, surgery, long hospitalizations, and intensive care unit (ICU) level care.[39] The PTS has been criticized because of the subjectivity when scoring open wounds and airway criteria, an overemphasis on soft tissue injury, and missing isolated SOI.[30,40]

Statement of Purpose:

We performed a retrospective analysis of the medical records of those patients who met criteria for activation of the pediatric trauma team of the Yale-New Haven

Children's Hospital ED from January 2005 through January 2011. We choose to use the PTS because of the simplicity of the calculations of the score, its specificity to the pediatric population, and the fact that the collection of the PTS data has been a part of the pediatric trauma triage form at our institution for the past seven years, although was not being used as a tool to determine the level of trauma service triage for children.

We sought to determine if the calculated PTS has an association with mortality, pediatric ED disposition, subspecialist operative management, CNS injury, and SOI. We assessed ED disposition to determine if there was a difference in the PTS in patients discharged home from the ED compared to patients that were admitted since the patients that were admitted required more intense care and resource usage than those that were discharged. We evaluated the association of the PTS to operative management based on subspecialists in orthopedic surgery, neurologic surgery, pediatric surgery and reconstructive surgery to assess if there was a difference in the PTS for patients that required surgery, with the potential to tailor the subspecialist surgical response based on scores so the appropriate surgeon would be available quickly if needed but also to improve resource management if a specific surgical subspecialty was not needed at a specific score threshold. We also evaluated the relationship of the PTS with CNS and SOI, as these are the leading cause of mortality and morbidity in pediatric trauma patients and often require resources that are optimal at a specialized pediatric trauma center. These outcomes were selected because they account for the majority of resource utilization in pediatric trauma and because an understanding of these associations may aid in improving the current pediatric triage protocol at Yale-New Haven Children's hospital.

We hypothesized that the PTS would predict these outcomes. The results of our study can inform future efforts to develop valid, reliable, and easy to use triage criteria based on our analysis of this data to predict pediatric trauma injury severity and the need for specialized care for use in the acute ED setting.

Research Design and Methods:

Database and Medical Record Review

We performed a retrospective review of the medical records of children < 16 years old who presented to the ED of Yale New Haven Children's Hospital over a 6-year period (2005 to 2011) who were evaluated by the pediatric trauma service and who were recorded in the hospital trauma service database. Patients were excluded if the information necessary to calculate the PTS was not available in the database or medical record, or if the patient was a transfer from a referring hospital and was not initially assessed at our institution after injury. We received Yale University Institutional Review Board approval for the use of the pediatric trauma database (Protocol number: 1205010198) and for additional data collection for this study. The data was collected through the trauma database and any missing data was accessed through the electronic medical records. The database contains initial ED vital signs, mechanism of injury, GCS, age, location of hospitalization, and weight. The medical records provided the data relating to open wounds, fractures, CNS status, airways, and systolic blood pressures when they were missing from the database.

Calculation of PTS

The PTS consists of six criteria, with each being assigned a score of -1, 1, 2 with additive scores ranging from 12 to -6. We calculated the PTS for each patient based on the information from the database and medical records. The first criterion, patient weight, was extrapolated, as the actual weights were not listed for the majority of patients. Patients less than one year of age were assumed to weight less than 10 kg and assigned a score of -1, patients one to five years of age were assumed to weight 10 to 20 kg and were assigned a score of 1, and patients greater than five years of age were assumed to weigh more than 20 kg and were assigned a score of 2.

For the calculation of an airway score, if the patient was intubated in the scene, on ED arrival or before hospital admission, the airway was labeled as unmanageable (score of -1), if the patient was not intubated but had a GCS < 9 or supplemental oxygen was referenced in the medical record, the airway was labeled as maintainable (score of 1), and the airway was assumed to be patent (score of 2) in patients with a GCS > 8 with no mention of difficulty maintaining the airway, no reference to supplemental oxygen in the medical records, and with respiration rates within normal limits. Central nervous system status was assigned as unresponsive (score -1) if GCS < 9 or the patient received a Pain or Unresponsive on the Alert-Verbal-Pain-Unresponsive (AVPU) Response scale, a score of 1 was assigned if there was any confirmed or questionable loss of consciousness with or without GCS score available or if the patient had any indication of altered mental status including GCS 9 to 14, being described as confused on the medical records, or being assigned an AVPU score of Verbal. A score of 2 was assigned if the GCS was 15 with no documented loss of consciousness (LOC) or if there was no recorded GCS but the patient was described as appropriate, alert and oriented with no LOC. Systolic blood

pressure score was determined from the first ED set of vital signs. Wounds were labeled as major (score 2) if they were labeled as complicated, open intracranial wounds, burns, amputations, penetrating injuries, tendon involvement, or tissue evisceration. Wounds were labeled as minor (score 1) if there were abrasions, lacerations, or an open fracture without suggestion of complications; if there was no reference to an open wound, a score of 2 was assigned. Fractures were assigned a score of 2 if they were open or there were multiple fractures. Closed single fractures and dislocations were assigned a score of 1. When there were fractures of the tibia and fibula, radius and ulna, maxillary and malar bones or skull base and vault they were also assigned a score of 1. Traumatic pneumothorax without a penetrating chest wound with no recorded rib fractures were also assigned a score of 1 as this was most likely from a fractured rib. Outcomes that were included in the database included ED discharge, the necessity and type of operative procedure performed, and the ICD 9 codes for CNS injury or SOI.

For example, a 7-year-old girl that was a restrained passenger a high speed MVA that presented to the ED crying, without any supplemental oxygen, alert but confused with an unknown loss of consciousness at the scene. Her weight was 25 kg and vital signs on arrival to the ED were blood pressure: 105/60, heart rate: 100 beats/minute, respiratory rate: 14 breaths/minute, temperature: 37 Celsius, and capillary refill is < 2 second. On physical exam, she is not able to move her left femur because of pain and has an abrasion where her seat belt crossed her pelvis. The PTS on this child would be calculated as: weight: + 2 as her weight is > 20 kg, airway: + 2 as she has a patent airway without requiring supplemental oxygen or other intervention, SBP: + 2 as her SBP > 90, CNS: + 1 as she is both confused and has an unknown LOC, wounds: +1 as she has a

minor abrasion, and fractures: +1 as she has a suspected fracture. The PTS score would thus be calculated to be 9.

Data Analysis

The dataset was de-identified before statistical analysis by eliminating the patients' names, date of birth, address, social security number, medical record number, and exact dates of admissions or discharge. The SPSS statistical package was used for all statistical procedures. The student t test was used to compare groups of patients with respect to the outcomes of interest (e.g. PTS, mortality, MOI). To evaluate the differences in proportions between the groups of patients with respect to the demographic outcomes of interest (e.g. race, gender), Chi Square analysis or Fisher exact test was used. Receiver operating characteristics-area under the curve (AUC) analysis was performed to assess for predictive accuracy. AUC was characterized based on the parameters: No association: <0.59, Poor: 0.6 to 0.69, Acceptable: 0.7 to 0.79, Good: 0.8 to 0.89, and Excellent: 0.9 to 1.0.

Table 2: Area Under the Curve Results Interpretation

Interpretation	Area Under the Curve Value
Excellent	0.9 - 1.0
Good	0.8 - 0.89
Acceptable	0.7 - 0.79
Poor	0.6 - 0.69
No relationship	<0.59

The AUC value, standard error (SE), asymptotic standard error, confidence interval (CI), sensitivity, and specificity were determined through this analysis. Significant findings were considered for $p < 0.05$. Sensitivity and specificity were determined for a PTS < 9.5 for all outcomes as this maximized the significance of each value, except for mortality, where a PTS < 8.5 was used to be consistent with previous studies. Positive predictive value (PPV) and negative predictive value (NPV) were calculated based on the prevalence, sensitivity, and specificity at the defined set point. Inter-observer validity for the abstraction of the PTS from the database and medical record was also calculated.

<u>Statement of my Participation:</u>

I independently performed much of the project design including designing data sets in collaboration with Dr. Bechtel. I wrote the HIC application and research funding applications. I independently reviewed the medical records and the database to extrapolate the data for the study and calculated the PTS for each patient. Dr. Bechtel performed the SPSS statistical processing. We discussed the ROC-AUC results together. I performed the student t tests independently as well as calculating the means and standard deviation in the outcomes we choose to compare. I also designed the tables and charts independently. I performed the literature review and discussion independently.

<u>Results:</u>

A total of 3,816 children met our inclusion criteria. The mean age was 7.06 ± 5.18 years old. Thirty-percent of patients were 13 to 15 years old, 25% of patients were less

than 3 years old, and only 45% of patients were 3 to 12 years old. Males consisted of 66.1% and females 33.9% of the total patients. Patient race consisted of 52.2% White, 23% Black, 18.8% Hispanic, 3% other, 0.8% Asian, and 2.1% Unknown. Trauma was categorized as blunt in 98.4% of patients and penetrating in 1.6% of patients.

The most common MOI was falls (45.5%) followed by MVA (11.5%). Sports injuries (7.9%), bike trauma (7.6%) and pedestrian injuries (6.2%) were the next most common mechanisms. Only 1.6% of the injuries were penetrating, consisting of gunshot and stab wounds. Nine and one-half percent of the trauma activations were categorized as full trauma responses, 72% as modified trauma responses, and 18.1% as a trauma service consults. The criteria for a full and modified trauma changed multiple times throughout the collection period of this data. The ISS was calculated in 1,532 patients (40.1%) with a mean score of 6.99 ± 6.64, range from 1 to 75, mode of 4, median of 5 (Fig. 1) The PTS ranged from 12 to -4 with a median score of 10, mode of 11, and mean score of 9.99 ± 1.72 (Fig. 2).

Fifty random medical records were selected to assess inter-observer validity for the abstraction of the PTS from the medical records and database. The inter-observer validity for the abstraction of the PTS from the database and medical record between the two investigators (myself and Dr. Bechtel) had a kappa of 0.775 (SE: 115) . This suggests substantial agreement (kappa: 0.61-0.90) between investigators with respect to calculating the PTS from abstraction of the variables from the medical record.
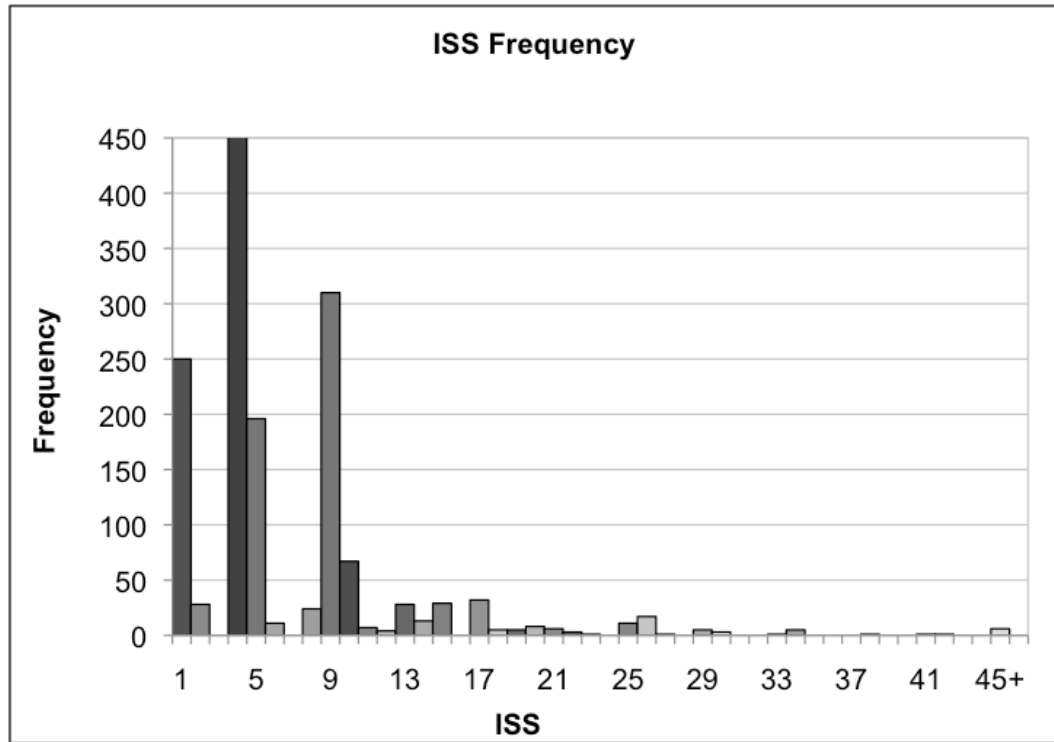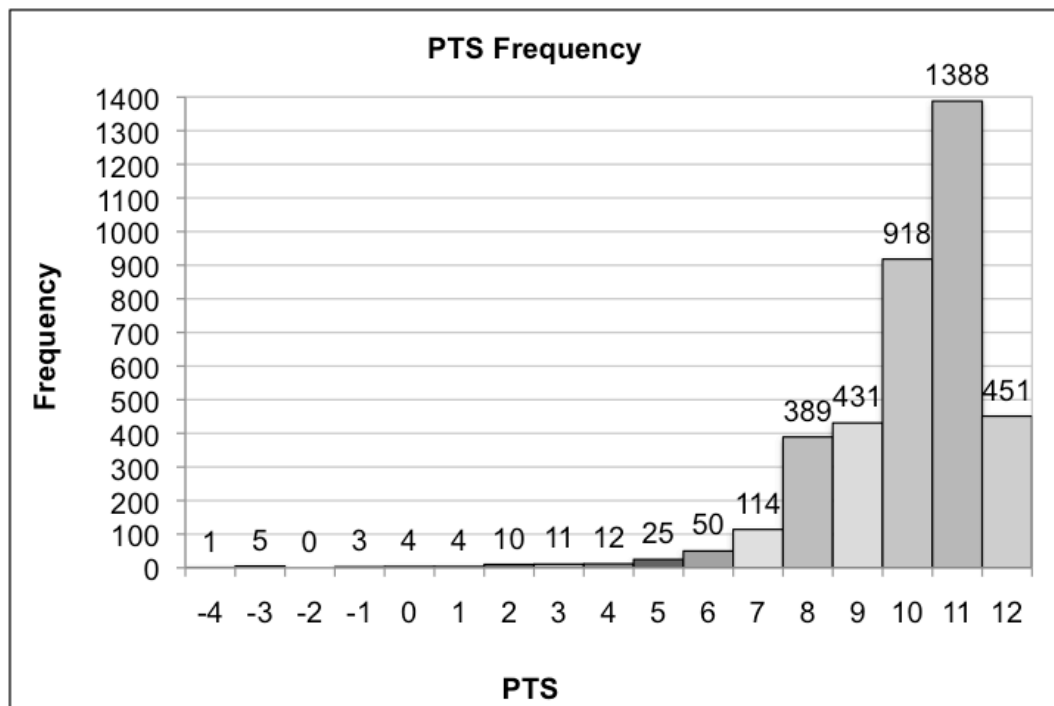
Figure 1:

Figure 2:

Table 3: Demographics

	Frequency	Percent
n	3816	
Sex (male)	1292	66
Race		
White	1993	52.2
Black	878	23.0
Hispanic	718	18.8
Other	116	3.0
Asian	30	0.8
Native American	1	0.0
Unknown	80	2.1
Age Categories (years-old)		
13-15	955	25.1
10-12	558	14.6
6-9	561	14.7
3-5	584	15.3
0-2	1153	30.3
Mechanism of Injury (%)		
Fall	1736	45.5
Motor Vehicle Accident	439	11.5
Sport Injury	301	7.9
Bike Acident	290	7.6
Pedestrian struck	236	6.2
Assault	88	2.3
Stab/Gun Shot Wound	61	1.6
Burn	53	1.4
Self inflicted injury	34	0.9
Unknown	353	9.3
Other	225	5.9
PTS		
10-12	2757	72.3
7-9	934	24.5
5-7	189	5
2-4	33	0.9
1- -1	11	0.3
-2 - -6	6	0.1

Mortality:

There were 22 deaths (0.60%) with 12 (54.4%) occurring immediately in the ED and the other 10 (47.8%) occurring after admission to the ICU (6 patients, 60.0%) or OR (4 patients, 40.0%). Of the patients that died, 15 were male (68.2%), 13 were Black (65%), and the average age was 7.22 ± 5.8 years old, which was not significantly different than the age of children who survived (p = 0.97). Children younger than 3 years of age accounted for 10 deaths (45.4%) and children 13 to 15 years old accounted for 7 deaths (31.8%), with only 5 deaths (22.7%) in children 3 to 12 years old. The ISS ranged 1 to 75 with a mean of 34.6 ± 20.8, mode of 26, and median of 30. The ISS of patients that died were significantly different than patients that survived (p < 0.0001, CI: 24.90 - 30.76, SE: 1.49). The PTS scores ranged from 4 to -4 with a mean score of 0.68 ± 2.67, mode of 2, and median of 1.5. Mortality was 40% in patients with a PTS < 5 and 8.4% in patients with a PTS < 8. The PTS for patients that died were significantly different than the PTS for patients that survived (p < 0.0001, CI: 8.69 - 10.05, SE: 0.345). For patients that died in the ED, the PTS ranged from 3 to -4 with a mean score of 0.58 ± 2.81 compared to patients that died after admission, with a PTS range of 4 to -3 and a mean score of 0.8 ± 2.65. There was no statistical difference in the PTS (p = 0.85) or age (p = 0.93) of the patients that died in the ED compared to the patients that died after admission. Patients that died after admission had a significantly higher ISS than patients that died in the ED (p = 0.002, CI: 10.1 - 38.7, SE: 7.126). The 12 deaths in the ED had an excellent association with the PTS (AUC: 0.996, SE: 0.001, CI: 0.994 - 0.999). The sensitivity was 1.000, specificity was 0.940, PPV was 4.78% and NPV was 100.00 for a PTS < 9.

Table 4: Outcomes

	Frequency	%	AUC[A]	SE[B]	95% CI[C]	Sensitivity	Specificity	PPV (%)[D]	NPV (%)[E]
Surgical Management									
Reconstructive	16	0.4	0.750	0.051	0.650 – 0.850	0.750	0.741	1.15	99.86
Pediatric	72	1.9	0.746	0.027	0.694 – 0.798	0.722	0.731	4.94	99.27
Neurological	42	1.1	0.788	0.041	0.709 – 0.868	0.667	0.724	2.62	99.49
Orthopedic	415	10.9	0.565	0.014	0.538 – 0.591	0.280	0.723	11.01	89.14
Occult Injury									
Central Nervous System	110	2.9	0.750	0.027	0.696 – 0.803	0.664	0.734	6.94	98.65
Solid Organ	102	2.7	0.572	0.038	0.497 – 0.647	0.500	0.729	4.87	98.13
ED Disposition									
Home	2217	58.1	0.641	0.009	0.623 – 0.659	0.805	0.280	60.70	50.80
Floor	985	25.8	0.530	0.011	0.510 – 0.551	0.296	0.729	27.52	74.86
Intensive Care Unit	359	9.4	0.689	0.017	0.656 – 0.721	0.557	0.752	18.90	94.20
Operating Room	224	5.9	0.667	0.018	0.632 – 0.702	0.464	0.735	9.89	95.63
Mortality	12	0.3	0.996	0.001	0.994 – 0.999	1.000	0.940	4.78	100.00

[A] Area Under the Curve
[B] Standard Error
[C] Confidence Interval
[D] Positive predictive value
[E] Negative predictive value

Table 5: Comparison of Survivors to Deaths

	n	Death	n	Survived	p value	95% CI[B]
Mean Age[A]	22	7.22 ± 5.84	2794	7.26 ± 5.21	p = 0.97	NA
Mean PTS	22	0.68 ± 2.68	2794	10.05 ± 1.60	p < 0.0001	8.69 - 10.05
ISS	20	34.60 ± 20.80	1510[C]	6.77 ± 6.24	p < 0.0001	24.90 - 30.76

[A] Age in years
[B] Confidence Interval
[C] ISS score not available for patients discharged home

Disposition:

Pediatric ED disposition outcomes were available in 3,813 of 3,816 patients. The

PTS was not adequately associated with any of the ED outcomes. Two thousand two

hundred seventeen patients (58.1%) were discharged to home from the ED. The

association of the PTS with discharge home was poor with AUC: 0.641 (SE: 0.009, CI:

0.623- 0.659). The sensitivity was 0.805, specificity was 0.280, PPV was 60.70%, and

NPV was 50.80% for a PTS < 10. Nine hundred eighty-five patients (25.8%) were

discharged to the regular pediatrics floor. The association of PTS with discharge to the

floor was poor with AUC: 0.530 (SE: 0.011, CI: 0.510 - 0.551). The sensitivity was

0.296, specificity was 0.729, PPV was 27.52%, and NPV was 74.86% for a PTS < 10.

Two hundred twenty-four patients (5.9%) were discharged to the OR. The association of

the PTS with transfer directly to the OR was poor with AUC: 0.667 (SE:0. 018, CI: 0.632

- 0.702). The sensitivity was 0.464, specificity was 0.735, PPV was 9.89% and NPV was

95.63% for a PTS < 10.

Operative Management:

Five hundred forty-five patients (14.3%) required operative management during their admission. The PTS had an acceptable association (AUC > 0.70) for reconstructive, pediatric, and neurological surgery. While orthopedic subspecialist management was most common with 415 patients (10.9%) requiring a procedure, it did not have an acceptable association with the PTS, as the AUC was 0.565 (SE: 0.565, CI: 0.538 - 0.591). For a PTS < 10, the sensitivity was 0.280, specificity was 0.723, PPV was 11.01%, and NPV was 89.14%. Pediatric surgery was second most common with 72 patients (1.9%) requiring a procedure. The AUC for the PTS and pediatric surgical intervention was 0.746 (SE: 0.027, CI: 0.694 - 0.798). Sensitivity was 0.722, specificity was 0.731, PPV was 4.94%, and NPV was 99.27% for a PTS < 10. Neurosurgical procedures were third most common with 42 patients (1.1%) requiring a procedure. The AUC for the PTS and neurosurgical intervention was 0.788 (SE: 0.041, CI: 0.709 - 0.868). The sensitivity was 0.667, specificity was 0.724, PPV was 2.62% and NPV was 99.49 for a PTS < 10. Plastic reconstructive surgery was least common, with only 16 patients (0.4%) requiring a reconstructive procedure. The AUC for the PTS and plastic reconstructive surgical intervention was 750 (SE: 0.051, CI: 0.650 - 0.850). The sensitivity was 0.750, specificity was, 0.741, PPV was 1.15%, and NPV was 99.86% for a PTS < 10.

Central Nervous System Injury

Central nervous system injuries were the most common serious injuries in our patients. They occurred in 110 patients (2.9%). Intensive care unit management was required in 71.80% of patients, 12.72% were admitted to the floor, 14.54% were taken directly to the OR, and one patient died while still in the ED. The mean age for CNS

injury was 6.46 ± 5.96 years old. The patients that required an operation were significantly (p = 0.003, CI: 1.65 – 7.81) older (10.51 ± 4.92 years old) than the patients that were admitted for medical management. Patients that required an operation also had significantly lower (p = 0.0007, CI: 1.30 – 4.70) mean PTS (5.06 ± 3.96). Patients that required surgery also had significantly (p = 0.0001, CI: 5.95 – 17.71) higher ISS (29.44 ± 17.40) compared to patients that did not require an operation (17.61 ± 9.38). The overall mortality for CNS injuries was 5.45%, but the patients that required an operation had a mortality of 12.5% compared to the patients that were treated medically with a mortality of 3.3%. CNS injuries did have an acceptable association with the PTS as the AUC: 0.750 (SE: 0.027, CI: 0.696 - 0.803). Sensitivity was 0.664, specificity was 0.734, PPV was 6.94%, and NPV was 98.65 for a PTS < 10.

Table 6: CNS Injury

	Total	**Non-Operative**[A]	**Operative**[A]	**p value**	**95% CI**
Frequency	110	93 (85.3)	16 (14.70)		
Gender (% male)	64.2	62.4	75		
Mean Age (years)	6.46 ± 5.96	5.78 ± 5.87	10.51 ± 4.92	0.003	1.65 - 7.81
Mortality (n (%))	6 (5.45)	3 (3.33)	2 (12.50)		

PED Disposition (n (%))
  ICU
  Floor
  OR
  Morgue
	79 (71.80)
	14 (12.72)
	16 (14.54)
	1 (0.91)				

Mean PTS	7.62 ± 3.32	8.06 ± 3.01	5.06 ± 3.96	0.0007	1.30 - 4.70
ISS	19.43 ± 11.69[B]	17.61 ± 9.38[C]	29.44 ± 17.40	0.0001	5.95 - 17.71

[A] Did not include patients that died in ED
[B] ISS calculated on 104/110 patients
[C] ISS calculated for 89/93 patients

Solid Organ Injury

The second most common serious injury in our pediatric trauma population was SOI to the spleen, liver, and kidney. Solid organ injury occurred in 102 patients (2.7%) with a mean age of 10.20 ± 4.59 years old. Non-operative management was successful in 90.2% of patients. Ten-percent of patients went directly to the OR. Of the patients treated conservatively, 66.7 % of patients were admitted to the ICU, 32.1 % of patients were admitted to the pediatric floor, and 4.9 % of patients died in the ED.

Table 7: SOI

	Total	Non-Operative[A]	Operative[A]	p value	95% CI
Frequency	102	87	10		
Gender (% male)	72.54	59	80		
Mean Age (years)	10.20 ± 4.59	10.22 ± 4.52	11.94 ± 4.24	0.254	NA
Mortality (n (%))	7 (6.86)	2 (2.30)	0 (0)		
ED Disposition (n (%))					
ICU	58 (56.86)				
Floor	28 (27.45)				
OR	10 (9.80)				
Morgue	5 (4.90)				
Mean PTS	8.48 ± 3.94	9.26 ± 3.20	5.70 ± 4.30	0.0018	1.35 - 5.76
ISS	15.63 ± 11.84[B]	13.66 ± 9.69[C]	24.30 ± 18.00	0.0039	3.51 – 17.77

[A] Did not include patients that died in the ED
[B] ISS for 98/102 patients
[C] ISS for 85/87 patients

When the need for surgical management was compared to nonoperative management, the patients that required operative management had significantly lower PTS (5.70 vs. 9.26; p = 0.0018, CI: 1.35 - 5.76) and higher ISS (24.30 vs. 13.66; p = 0.0039, CI: 3.51 - 17.77). Solid organ injury had a poor association with the PTS (AUC: 0.572, SE: 0.038, CI:

0.497 - 0.647) for all patients with SOI. Sensitivity was 0.500, specificity was 0.729, PPV was 4.87% and NPV was 98.13% for a PTS < 10.

Discussion:

While trauma continues to be the leading cause of mortality and morbidity in the pediatric population, there is not a currently accepted, rapid triage protocol to identify children with traumatic injuries who are in most need of surgical intervention. Trauma triage has been plagued by overtriage in the pediatric population and the frequent question of when it is best to transport a patient to a specialized pediatric trauma center. Within pediatric trauma centers, questions remain as to what resources will improve outcomes without leading to unnecessary procedures and taking surgical providers away from their other responsibilities when these injured children arrive in the ED.

To the best of our knowledge, we have conducted the largest retrospective review on the use of the PTS as a triage tool for injured children when they initially present to the ED. A total of 3,816 children were included in our study. The demographics of our study population were similar to previous studies, with two thirds of our patients being male, the majority of patients experiencing blunt trauma, and falls being the leading MOI.[35,39,41] Our population was slightly younger than the other populations studied, with a mean age of 7 years old, likely because the trauma protocol at Yale-New Haven Children's Hospital has an upper limit of 16 years of age for evaluation of traumatic injuries in the pediatric ED.[35,39,41] Our population also had a larger Black population. This may have had an impact on the severity on injuries in our study as Wan et al previously found that children of African American ethnicity had higher mortality and morbidity than other ethnicities.[9,35] The overall severity of injuries, as calculated by the ISS, was

similar to previous studies with 91.0% of scores < 15. This is consistent with Guice's study of almost 150,000 pediatric trauma patients that showed 85% of patients had ISS scores < 15.[2] Our ISS is likely skewed to more severe injuries as 96.7% of the patients that did not have an ISS calculated were discharged home from the ED.

Mortality:

Trauma remains the leading cause of death in children accounting for more than 50% of pediatric deaths annually in the United States.[2,5,7] Our cohort had a lower than expected mortality of 1.1% as estimated by Guice's large analysis.[2] Our patient population did have much higher rates of mortality in young children, infants, and teenagers than the school age population. We also had a disproportionate number of deaths in the Black population as only 23% of pediatric trauma patients were identified as Black but 65% of the deaths were in Black patients. The ISS was significantly higher and the PTS was significantly lower in patients that died.

Our results showed an outstanding association of the PTS with mortality. Our patient population did not have any deaths with a PTS > 4, but for patients that presented with a PTS ≤ 4, the mortality was 40%. Previously, the critical triage point for severe injury was thought to be a PTS ≤ 8 but our results suggest it may be lower.[35] For patients with a PTS ≤ 8, our study had a mortality of 8.4%, sensitivity of 1.00, and specificity of 0.94 while Ramenofsky's study had a mortality of 24%, Jubilier's study had a mortality of 30%, and Kaufmann's study had a mortality of 13%. [35,36,38] Our lower mortality may have been because of advances in the field of trauma as these are older studies, a difference in study population, or just by chance as the mortality in all of these studies is very low. The PTS does seem to be a useful tool in predicting mortality for use in

outcomes research and to possibly gauge severity of injuries through developing a critical
point for triage.

Operative Management:

Despite the movement of trauma management towards conservative, nonoperative
treatment, 14.3% of our population required operative management. Burd's large analysis
found that 0 to 5% of children required an immediate operative intervention but
throughout all hospitalizations, the percent of children requiring interventions ranged
from 4 to 69%.[6] Tepas analysis of the National Pediatric Trauma Registry found that
55.6% of children had injuries that required subspecialty surgical assessment and 11.4%
required operative management, which may underestimate the true proportion of children
requiring surgical intervention, as this study did not include neurologic or orthopedic
procedures. [42] We did not include patients that may have benefitted from nonoperative
management by surgeons and therefore our results may have underestimated the PTS
threshold for requiring subspecialty surgical evaluation. Unlike some previous studies,
we did find an acceptable association between the PTS and the need for operation for
pediatric surgery, neurological surgery, and plastic reconstructive surgical procedures.[30]

Over 75% of the children that required an operation required an orthopedic
procedure. Since the majority of pediatric trauma patients present with a single system
injury, with fractures being the most common injury, it is logical that these fractures are
also the most likely indication for surgical management.[2,5,7] Unfortunately, the PTS had a
poor association with requiring orthopedic surgery. This is likely because the majority of
patients had an isolated injury, so these patients had overall high PTS. The great majority
of isolated limb injuries do not require emergent surgical management, so orthopedic

surgeons should likely remain as a trauma consultation instead of requiring the presence immediately on trauma activations.

Our results showed that the PTS had an acceptable association with requiring a procedure performed by a pediatric surgeon. Less than 1% of patients with a PTS > 9 required pediatric surgical management, which suggests a potential threshold for determining when to have a pediatric surgeon attend a trauma activation. Only 13% of patients requiring an operation needed the expertise of a pediatric surgeon, but these patients tended to be some of the sickest and most severely injured. Interventions included exploratory laparotomies, bowel resections, splenectomies, and control of intra-abdominal hemorrhage. In some cases, the presence of a pediatric trauma surgeon clearly benefits the patient. The presence of a trauma surgeon at trauma activations does decrease the time it takes to reach the OR in penetrating injuries but has less of an effect in blunt trauma.[13] Doolin's study found that the presence of a trauma surgeon decreased mortality in severely injured pediatric trauma patients because of the speed of intervention, as hemorrhage is the second cause of death in children after CNS injury.[43] It is unclear how much the presence of a pediatric surgeon impacts care if no surgical intervention is necessary. Most institutions, including specialized pediatric trauma centers, have a very limited number of pediatric surgeons available to respond to traumas in addition to their other responsibilities. In addition, in some cases, a pediatric surgeon may not improve outcomes and may actually have a negative impact on care. Groner's study evaluating the necessity of pediatric surgeon presence in trauma activations found that when pediatric emergency medicine physicians instead of senior surgery residents or fellows were responsible for Level 2 trauma alerts, there was a higher rate of discharge

from the ED but also a much higher percent of traumas were upgraded for Level I traumas.[44] It would be optimal to have a pediatric surgeon immediately available only in cases that would benefit the patient.

Reconstructive surgery by a plastic reconstructive surgeon was rarely needed in our pediatric population. The association with the PTS for these procedures was acceptable and only 0.04% of patients with a PTS > 8 required a procedure, but the positive predictive value was extremely low. Overall, plastic reconstructive surgery had a very limited role in our trauma activations and probably should be used more as a consulting service in the rare cases that a pediatric trauma patient will benefit from their expertise.

Neurological Surgery and Central Nervous System Injury

Head injuries often lead to the most devastating outcomes in pediatric trauma patients. Almost 500,000 traumatic brain injuries occur in pediatric patients a year leading to over 42,000 hospitalizations and 2,000 deaths.[45] Only about 3% of our patients had CNS injuries but of those, 14.5% required neurosurgical management. In Pickering's analysis, 6.5% of patients presenting with a head injury had evidence of intracranial hemorrhage on imaging studies and 1.2% of pediatric head injuries required surgical management.[46] Our higher rate of surgical management in patients with CNS injuries is likely because our definition for CNS injury required an ICD-9 code diagnosis and minor head injuries were not accounted for in our study. Over 70% of our patients with CNS injuries required ICU management and all of the patients except for one patient, who died in the ED, required hospital admission.

The patients that required a surgical intervention for CNS injury had a significantly higher mean age than the patients that were admitted for non-operative management. This is likely because younger children have a higher rate of non-accidental trauma and the history is often difficult to ascertain, so they are more likely to be admitted for observation. [47,48] Patients that required operative management also had higher mortality, lower PTS, and higher ISS suggesting that they had more severe injuries at presentation.

The PTS had an acceptable association with both CNS injury and requiring neurosurgical procedures. Only 0.51% of patients with a PTS > 9 required neurosurgery and 1.35% of patients with a PTS > 9 had a diagnosis of CNS injury. This suggests that the PTS may be an acceptable triage tool for determining when to have a neurosurgeon attend a trauma activation and also when to suspect an underlying CNS injury. Rapid neurosurgical management in the case of most severe head injuries may have a major impact on outcomes and our results suggest that the PTS is an adequate tool for detecting these injuries. [47]

The PTS has a unique emphasis on multiple criteria that likely led to the association with CNS injury and requiring neurosurgical management. Patients receive a lower score based on weight, which usually correlates with age. Young children are twice as likely as older children to suffer from head trauma and more likely to die from their head injuries because of their physiology, propensity towards falling, and the prevalence of non-accidental trauma in this population.[1,7,49] The CNS criteria within the PTS are very simple with any minor change in mental status or even questionable loss of consciousness receiving a lower PTS. In more severe head injuries, a patient will often lose the ability to

maintain his airway because of severely altered mental status and therefore also receive a lower PTS.

Solid Organ Injury:

Abdominal SOI are the second most common serious injuries in children.[5] About 2% of our patients were diagnosed with a SOI, but these injuries did not have correlation with the PTS. The PTS criteria is not really weighted towards SOI as children tend to maintain their systolic blood pressure with SOI for longer periods of time than adults before suffering from acute decompensation. Most SOI will not have visible bruising, open wounds, or altered mental status. Almost 90% of splenic injuries and 90 to 100% of liver injuries are treated conservatively in children, which is consistent with our results, as 10% of children with SOI required operative management.[50] The management of SOI in children tends to emphasize conservative, nonoperative management of splenic lacerations more so than in the adult population.[50]

Although SOI was not adequately associated with the PTS, pediatric surgery procedures had an acceptable association, and many of these procedures were for SOI. This may be because patients unstable enough to actually require operative management instead of conservative management for their SOI had physiologic and anatomic derangements that detected by the PTS. This was evidenced in our results as the PTS was significantly lower and the ISS was significantly higher in children that required operative management for SOI. This is helpful to know because the ED can activate other services (OR, ICU, blood bank, IR) knowing this number and the fact that the child has a SOI. Our sample size was small for SOI but a larger study would provide more insight into this association.

Disposition:

The majority of our patients were able to go home after presenting to the ED with a trauma. This is similar to Guice and Bayreuther's findings that the majority of pediatric trauma consists of minor injuries to one organ system, especially limb injuries that often do not require a hospital admission.[2,7] Almost half of our patients were admitted to the hospital from the ED with almost 10% requiring ICU care, 6% needing an urgent operation, and about 25% being admitted to the general medicine ward. Mortality was very low in the ED with only 0.3% of patient's dying before admission. Our findings were consistent with Cooper's study that showed that children were more likely than adults to require hospital admission after a trauma but were much less likely to die from their injuries.[8] Unfortunately, the PTS was poorly associated with requiring hospital admission and with which level of care that patients require. Our finding that the PTS was not associated with ICU admission was consistent with Narci's study that the PTS was not associated with ICU management. [30]

Limitations:

There were multiple limitations of our study including that it was a single institution study of one urban Level one pediatric trauma center. Further study is needed to determine if these results are reproducible. This was also a retrospective analysis and a prospective analysis would strengthen our results.

Possible limitations with the way the PTS was calculated include the challenges of chart review and extrapolating information. Since there were limited weights recorded in the trauma reports, we used age as a proxy for weight and may not have accurately categorized all of the children accurately. For the airway criterion, we considered any

intubation as a -2, although it is common in the pediatric ED to intubate children for imaging studies and not necessarily because of respiratory failure or inability to protect one's airway. Another limitation with the PTS is that it requires an accurate systolic blood pressure, which can be difficult to obtain in young children or if a child is scared, angry, or in pain. For CNS injury determination, we used GCS as a proxy for level of consciousness if the score was available but one of the advantages of the PTS is that it does not require a numerical calculation. The PTS from the described wounds and fractures are also subjective criteria although the inter-observer for the PTS was kappa 0.775 which suggests that there was not a significant amount of variability on which scores were assigned for these criteria based on the medical record data.

Future Directions

Our immediate goals in the future include further analysis of the correlation of the PTS with MOI to evaluate if there is a role for mechanistic information in improving the triage of pediatric patients when combined with the PTS. We also plan to perform a study to evaluate the rates of overtriage and undertriage in our institution and the relationship with the PTS. We also hope to look further into various anatomic and physiologic criteria to evaluate if it is possible to improve the association of the PTS with outcomes so that the PTS would be a more effective triage tool. Possible other directions include applying the PTS in the prehospital setting to further assess the benefit in determining when to transport to a specialized pediatric trauma center and performing a prospective study so that the PTS can be evaluated in real time instead of extrapolated from previous records.

Conclusion:

Our study had promising results regarding the use of the PTS in the pediatric trauma triage setting, especially when evaluating the need for emergent surgical subspecialist management and detection of CNS injuries, which is a leading cause of traumatic morbidity and mortality in children. Potential implications of these results include modifying the surgical subspecialist response to improve resource utilization without sacrificing optimal care based on the PTS since pediatric trauma patients with a calculated PTS > 9 very rarely suffered from serious CNS injuries or required pediatric surgery or neurosurgery. Further prospective evaluation is needed to confirm the utility of the PTS in the triage of acutely injured children so as to further improve pediatric trauma triage. [29]

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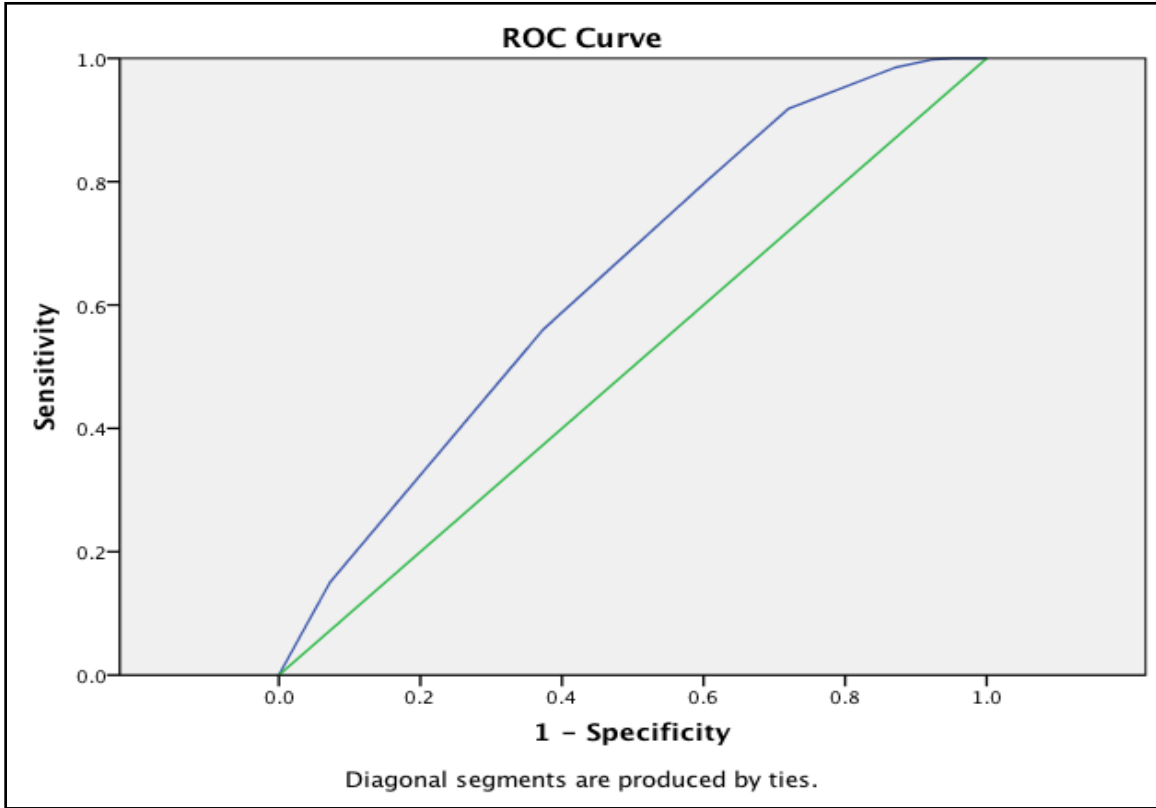
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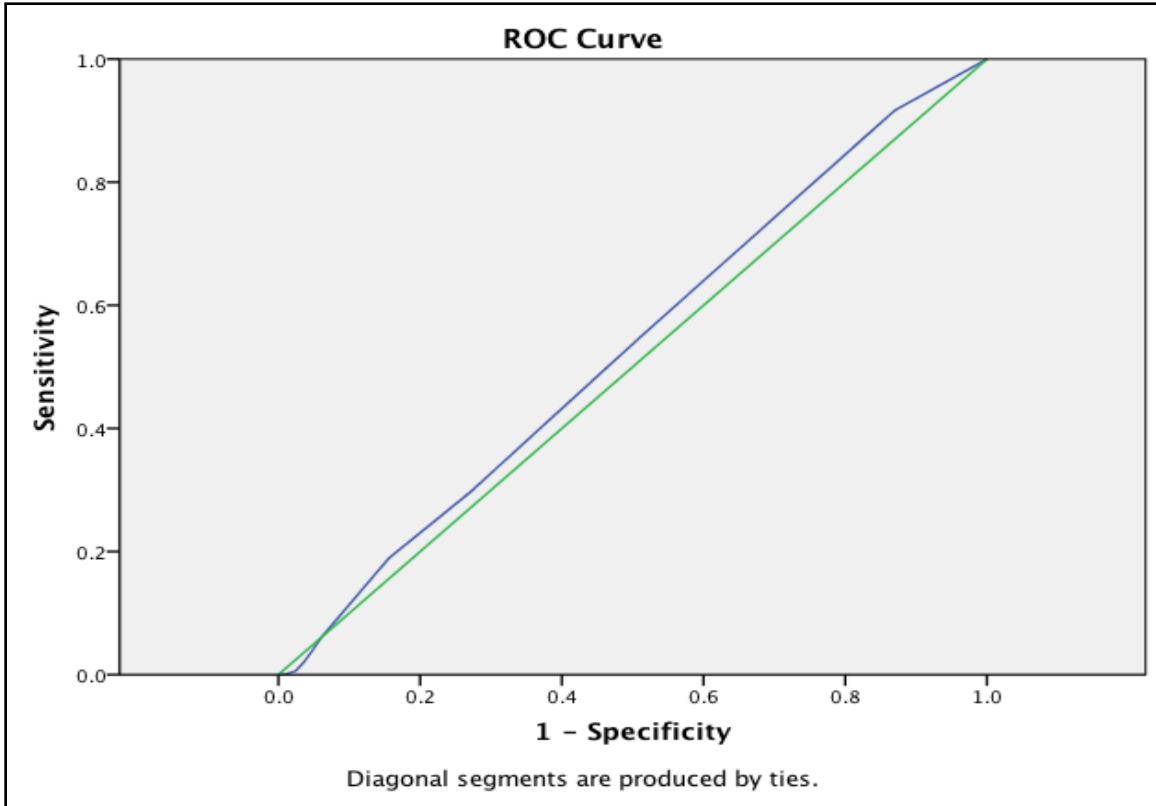
Appendix:
Mortality:

ROC Curve

Diagonal segments are produced by ties.
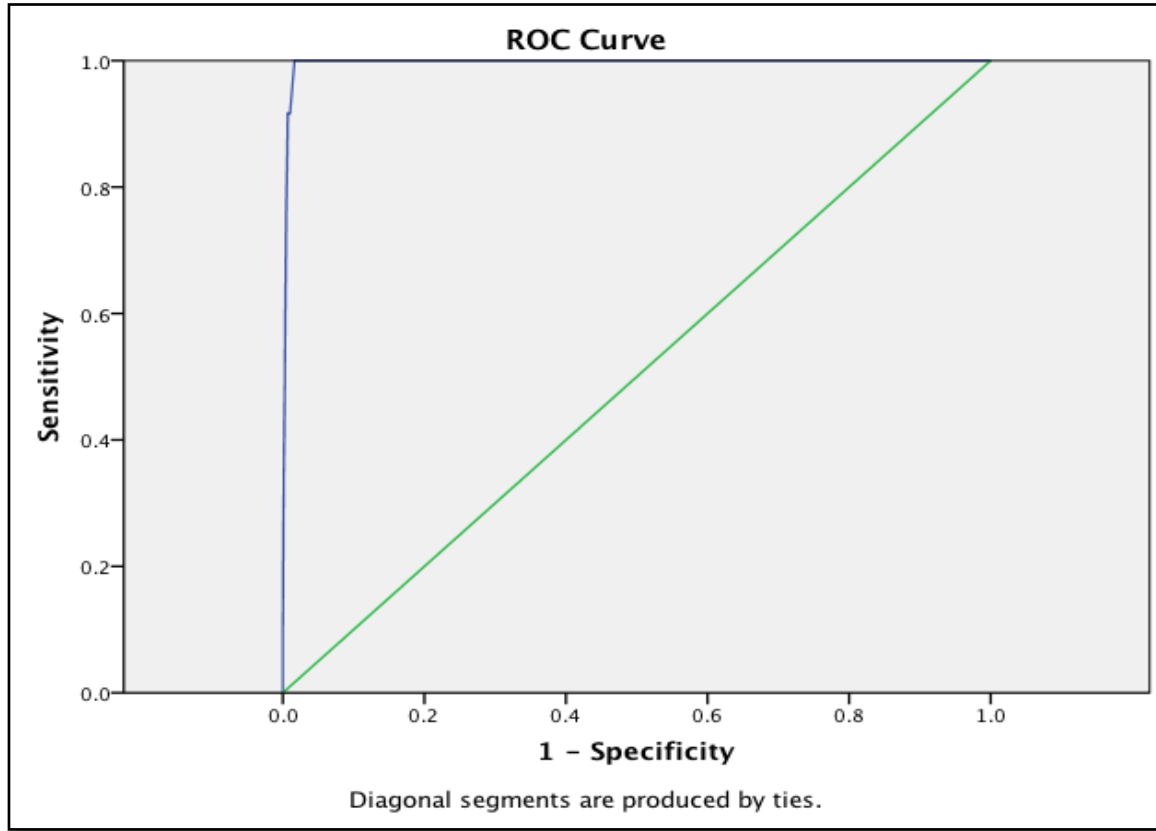
Pediatric Emergency Department Disposition:

Home:

ROC Curve

Diagonal segments are produced by ties.

Floor:

ROC Curve

Diagonal segments are produced by ties.

Operating Room:

ROC Curve

Diagonal segments are produced by ties.

Intensive Care Unit:

ROC Curve

Diagonal segments are produced by ties.
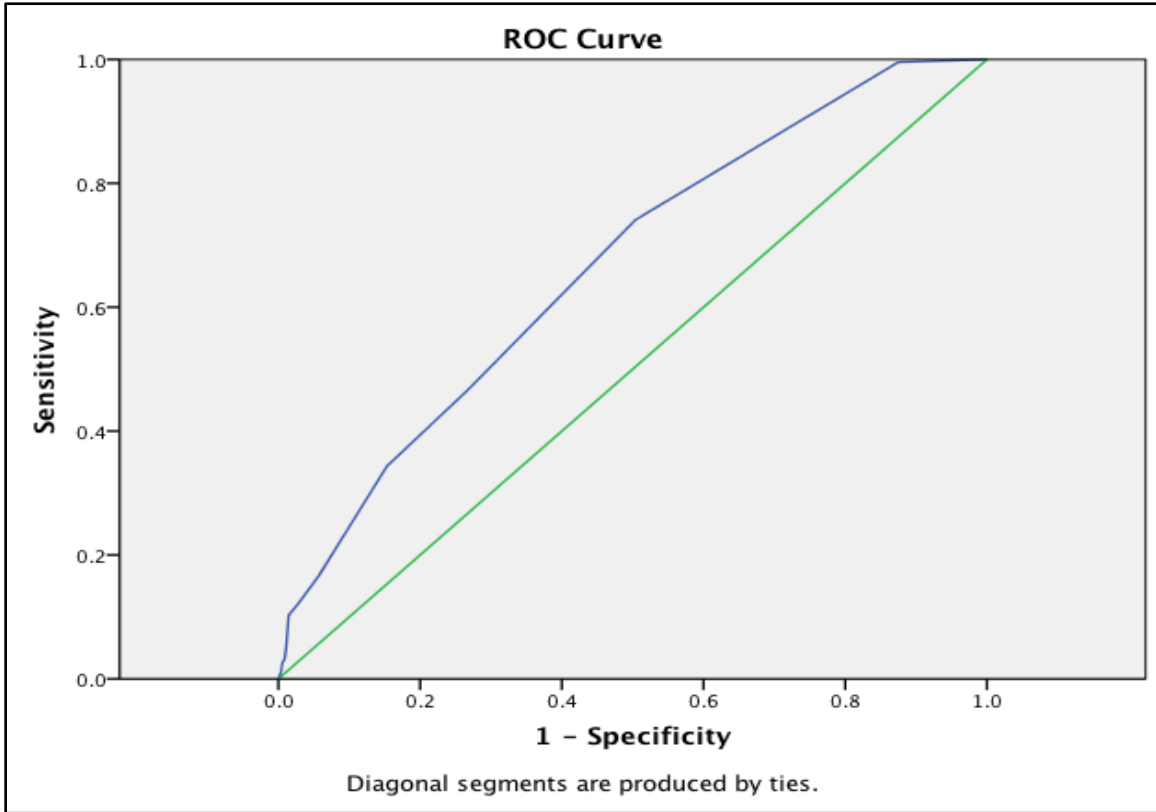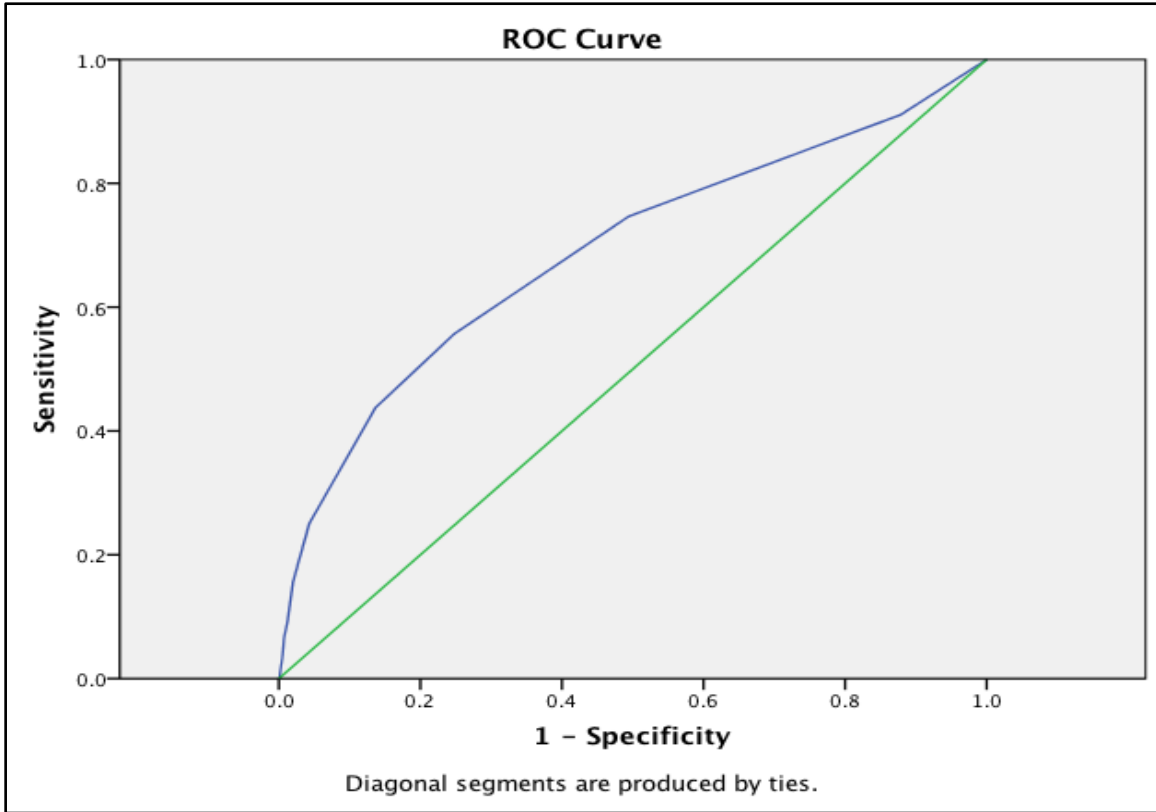
Operative Subspecialist Management:

Reconstructive Surgery:

Pediatric Surgery:

Diagonal segments are produced by ties.

Neurologic Surgery:

ROC Curve

Diagonal segments are produced by ties.

Orthopedic Surgery:

ROC Curve

Diagonal segments are produced by ties.
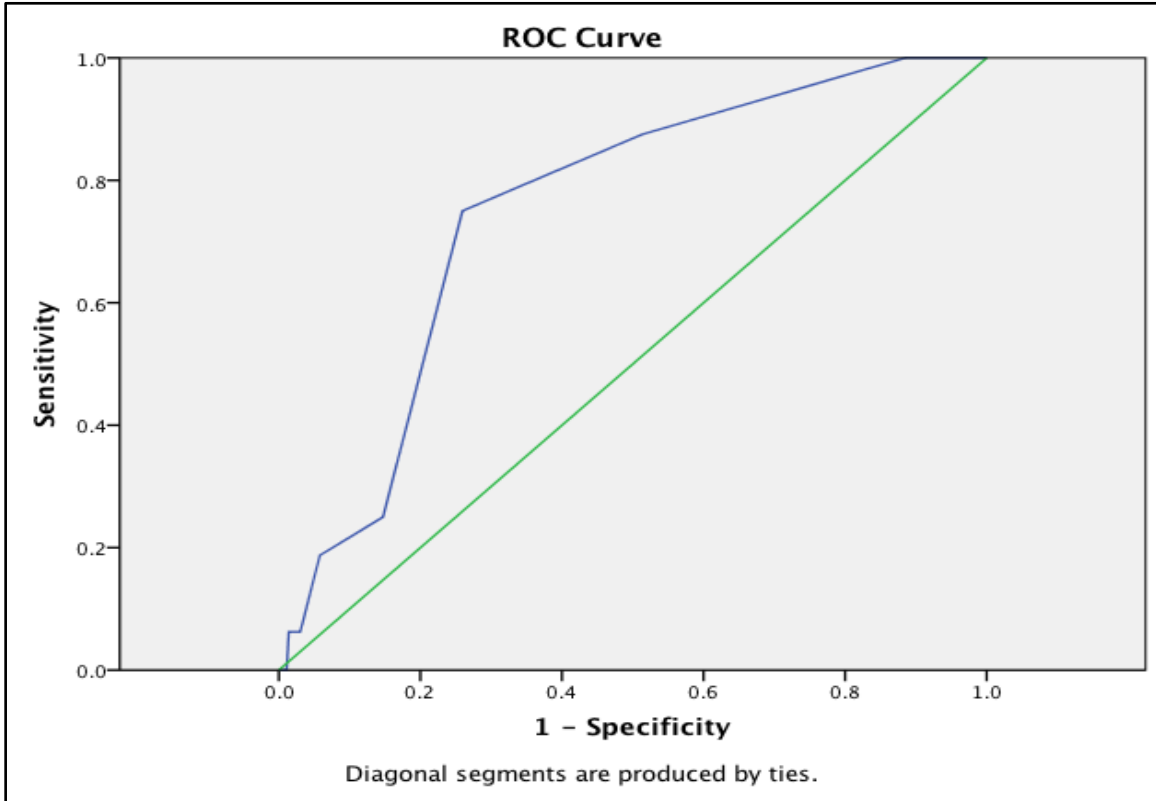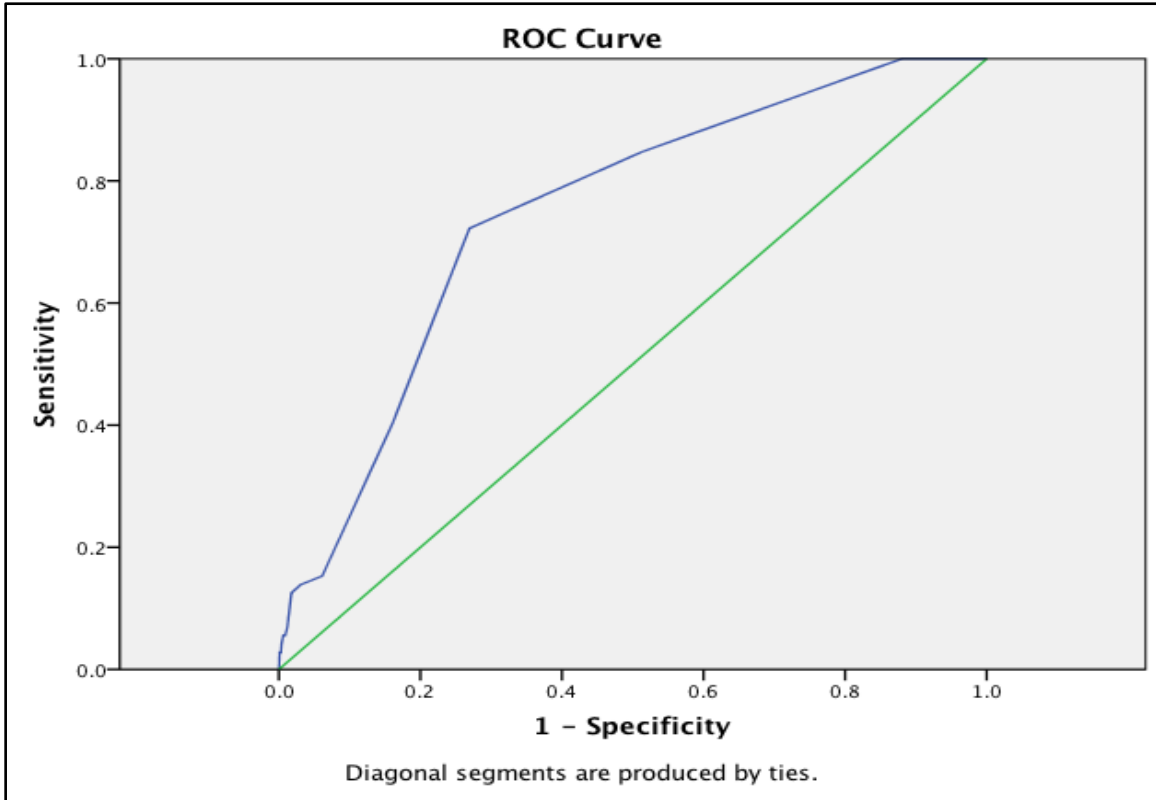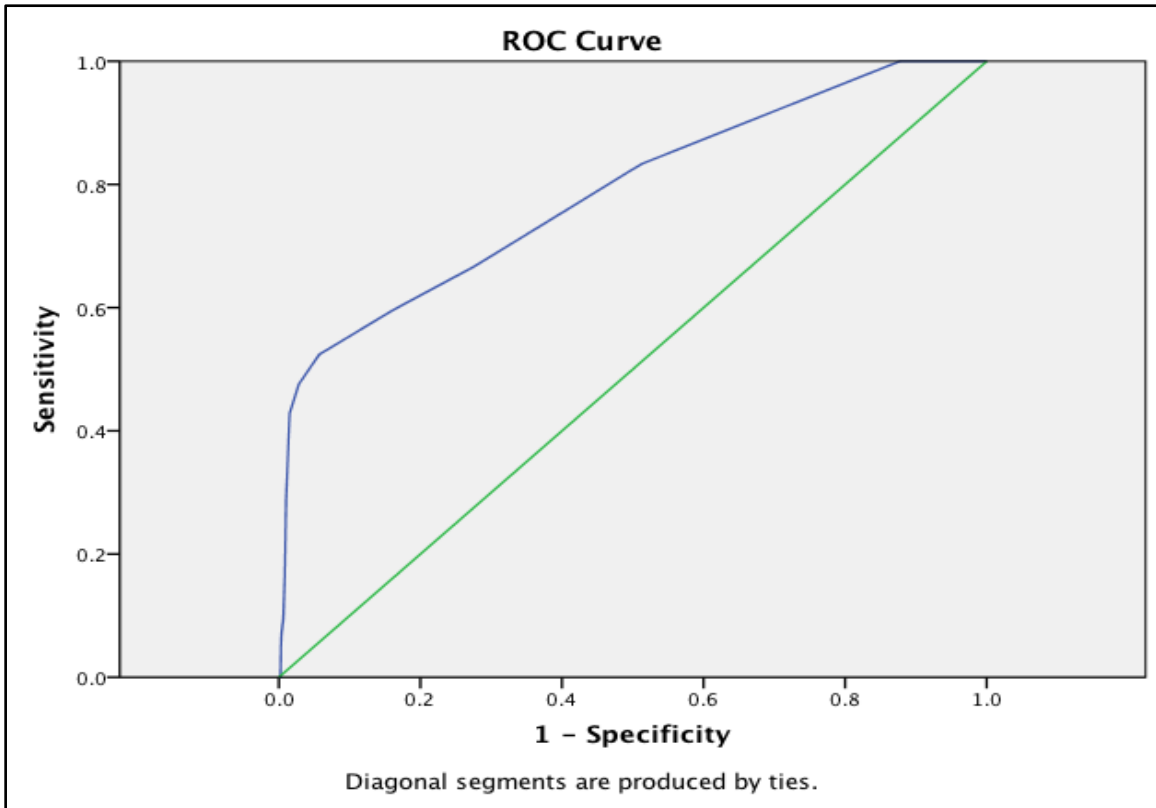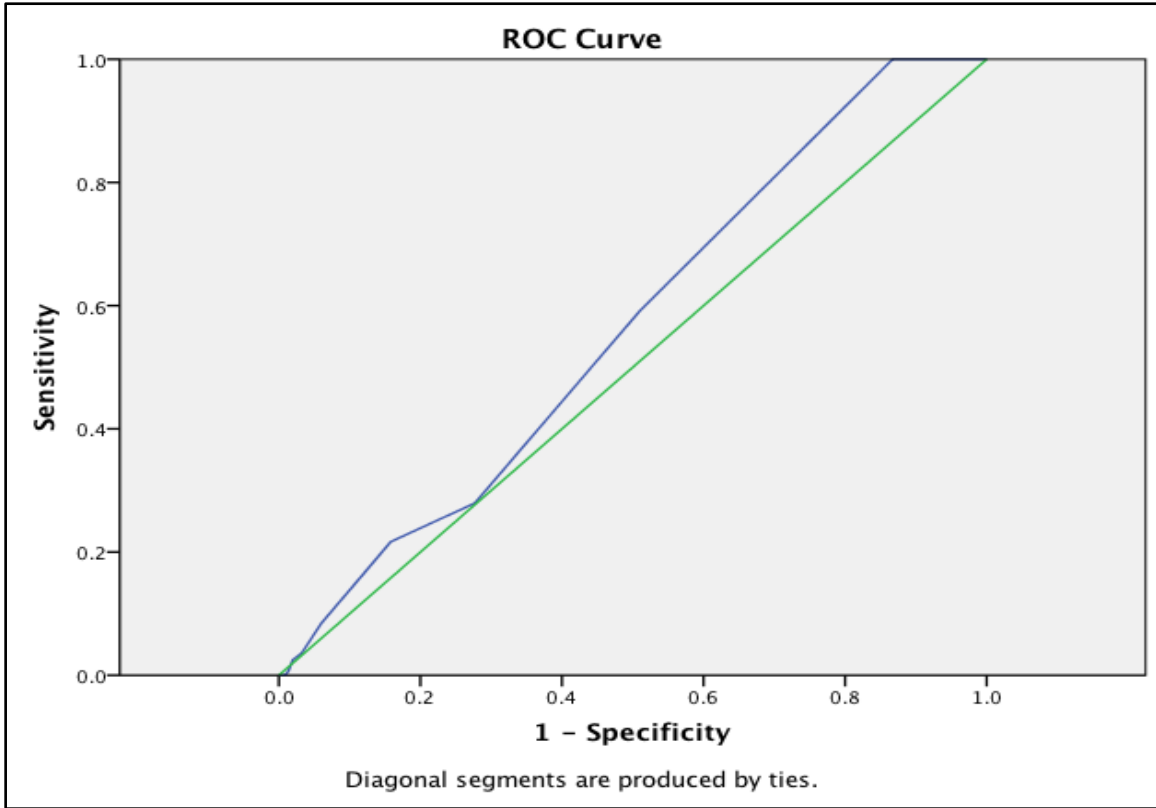
<u>Serious Injury:</u>

Central Nervous System Injury:

Solid Organ Injury:

ROC Curve

Diagonal segments are produced by ties.