Epidemiology of Traumatic Esophageal Injury: An Analysis of the National Trauma Data Bank

A thesis submitted by

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In partial fulfillment of the requirements for the degree of

Master of Science

In

Clinical and Translational Science

Tufts University

Sackler School of Graduate Biomedical Sciences

May 2018

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ABSTRACT

Introduction: Traumatic injury of the esophagus (TIE) is rare, and the existing literature is limited. The aim of this descriptive study was to comprehensively describe the clinical characteristics and outcomes of TIE among trauma patients using the National Trauma Data Bank (NTDB).

Methods: Patients with TIE from 2010-2015 were identified in the NTDB by the Abbreviated Injury Scale. The prevalence of TIE among trauma patients was estimated. The demographic and clinical characteristics and hospital outcomes, including hospital length of stay, complications, and mortality, of these patients were further analyzed according to injury mechanism, injury severity score (ISS), and sex.

Results: 1,411 adult patients with TIE were identified. The prevalence of TIE among all trauma patients was 37 patients per 100,000 (95% CI: 35, 39). The prevalence of TIE was 257 cases per 100,000 (95% CI: 250, 270) among patients with penetrating trauma and 16 cases per 100,000 (95% CI: 15, 18) among patients with blunt trauma. Patients with ISS ≥ 25 were 34 times more likely to have TIE than those with ISS 0-9, and TIE was almost 3 times more likely in males as compared to females. Among cases of TIE, 523 (37%) were blunt and 888 (63%) were penetrating. Compared to those with blunt TIE, patients with penetrating TIE were significantly younger (34 vs 46 years), more likely to be male (85% vs 74%), and were more severely injured (ISS ≥ 25: 48% vs 40%) (all $p < 0.001$). Patients with blunt TIE were more likely to have associated spine injuries as compared to those with penetrating TIE (43% vs 27%, $p < 0.001$). Overall in-hospital mortality in patients with TIE was 19%, and patients with TIE had significantly higher mortality than those without after adjusting for age, sex, and ISS (OR = 1.4, 95% CI: 1.1, 1.7). There was no statistically significant difference in mortality between blunt and penetrating TIE in both crude analysis (20% vs 18%) and multivariable adjusted analyses.

Conclusion: TIE is associated with more severe injuries, male sex, and penetrating trauma. Mortality is markedly elevated in trauma patients with TIE but is not associated with mechanism of injury.

DEDICATION

This project is dedicated to my wife, Betty, who has been my greatest supporter and motivation. Thank you for encouraging me to always push further in pursuing my passions.

ACKNOWLEDGEMENTS

I would like to acknowledge and thank my program mentor, Dr. Jessica K. Paulus, my statistical mentor, Janis Breeze, and my project mentor, Dr. Nikolay Bugaev, whose mentorship and guidance made this project possible.

In addition, I would like to acknowledge the CTSI and Sackler faculty, particularly Dr. David Kent, Dr. Karen Freund. Dr. Angie Mae Rodday, Dr. Farzad Noubary, Dr. Robert Goldberg, Robin Ruthazer, and Benjamin Koethe, for their teaching and support.

To my classmates in the CTS Master's Program, thank you for your peer mentorship and support throughout the program.

Financial Support: 4TL1TR001062-04

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LIST OF ABBREVIATIONS

ACS	American College of Surgeons
ACSCOT	American College of Surgeons Committee on Trauma
AIS	Abbreviated Injury Scale
AMA	Against Medical Advice
CI	Confidence Interval
DOA	Dead on Arrival
ED	Emergency Department
GCS	Glasgow Coma Scale
GEE	Generalized Estimating Equations
GSW	Gunshot Wound
HR	Heart Rate
ICD	International Classification of Diseases
ICU	Intensive Care Unit
IQR	Interquartile Range
ISS	Injury Severity Score
MTOS	Major Trauma Outcome Study
MVC	Motor-vehicle Collision
NTDB	National Trauma Data Bank
NTDS	National Trauma Data Standard
PTOS	Pennsylvania Trauma Outcomes Study
RR	Respiratory Rate
SBP	Systolic Blood Pressure
TIE	Traumatic Injury of the Esophagus

CHAPTER 1: INTRODUCTION

The Centers for Disease Control reports that approximately 200,000 individuals die from trauma in the United States (U.S.) each year, with one death every three minutes. In 2015, unintentional injury was the leading cause of death for individuals aged 1-44, and there were nearly twice as many deaths from this cause as there were from non-communicable diseases such as cardiovascular disease and cancer. In 2013, medical costs and lost work from injury and violence totaled over $670 billion[1].

With such a high death toll and high associated costs, there is an important need for research to treat and prevent such injuries. Recognition of the need for trauma research was first highlighted in 1966 with the publication of "Accidental Death and Disability. The Neglected Disease of Modern Society" by the National Academy of Sciences. The report emphasized the need for prevention efforts to reduce this significant loss of life and noted that medical care providers can help identify health hazards that may lead to these injuries. The report further described the need for establishing registries to collect data on various traumatic injuries, and recommended the establishment of a central registry to consolidate such data[2]. The first U.S. trauma centers were developed in the 1970s along with early computerized trauma registries, and in 1982, the American College of Surgeons Committee on Trauma (ACSCOT) established the Major Trauma Outcome Study (MTOS), a database of United States trauma patients[3].

The American College of Surgeons (ACS) National Trauma Data Bank (NTDB), an aggregation of trauma registry data from registered United States trauma centers, was implemented in 1997, after the MTOS concluded in 1989, and contains more than six million records. Data in the NTDB is collected under the basis of the National Trauma

Data Standard (NTDS) for standardization of trauma injury information[3]. The NTDB is not a population-based dataset and may not be representative of all trauma hospitals in the U.S.; however, all ACS-accredited trauma centers in addition to other voluntarily-participating institutions are included. With more than 900 participating trauma centers, the NTDB represents a majority of trauma centers; a 2003 report identified 1,154 trauma centers in the U.S.[4] The NTDB is therefore the largest aggregation of trauma registry data available and the best available database for representing patients at trauma centers within the U.S.

The U.S. has a structured approach to the prevention, management, and rehabilitation of injured patients. Trauma centers represent the inpatient aspect of this approach. Trauma centers in the U.S. are categorized based on resources available at the facilities; higher level centers are generally capable of managing more severely-injured patients. Briefly, Level I centers provide the most comprehensive care for trauma patients and are required to have education and research programs, Level II centers are similar to Level I centers, but do not necessarily need to conduct research or provide education, Level III centers have the resources for diagnosis and resuscitation as well as general surgery, Level IV centers may evaluate and stabilize trauma patients, though not all provide surgery, and Level V centers are similar to Level IV centers, but may not be open 24 hours per day[5].

The accurate description of multiple injuries plays an important role in the prediction of trauma patient outcomes and evaluation of trauma centers and provider performance; the Injury Severity Score (ISS) was therefore created and validated. ISS is a score for summarizing overall anatomical injury severity in trauma patients[6]. ISS ranges from 0 to 75 and is calculated using the Abbreviated Injury Scale (AIS) as the sum of the square of the highest AIS severity in the three most severely injured body regions. AIS scores the severity of injury by anatomic body region, and identifies the specific injured body region (head, face, neck, thorax, abdomen, spine, upper extremity, lower extremity, external, or other) as well as severity of the injury from 1 to 6. For calculating ISS, body regions without injuries receive an AIS severity of 0, and patients with any injury of AIS severity 6 automatically receive an ISS of 75.

Traumatic injury of the esophagus (TIE) is extremely rare, though its occurrence is associated with significant morbidity and mortality[7,8]. Traumatic esophageal injury can be associated with both penetrating and blunt trauma; penetrating TIE is commonly due to gunshot wounds (GSW) and stabbings[4] and typically occur in the relatively small and exposed cervical region, while blunt TIE is most commonly due to motor vehicle collisions (MVC) and falls and may co-occur with cervical spinal fractures and hyperextension of the neck[10-18].

The morbidity and mortality associated with TIE is well-described in case-reports[10-18], yet relatively few large cohort studies have investigated clinical outcomes of patients with TIE or estimated the prevalence among the general trauma patient population[7-9,19-25] (Appendix 1). Most available cohort studies have focused on esophageal injury due to penetrating trauma; few studies have characterized the occurrences of blunt TIE, with blunt TIE being discussed primarily in case studies[19,20,22,22]. Among studies that have, mortality in blunt TIE has been found to be higher than in cases of penetrating TIE[24]. Blunt trauma in general is commonly associated with significant force, and previous studies have documented poorer outcomes including more complications and higher mortality in blunt trauma[19,23,26-28].

A recent study investigated non-iatrogenic esophageal injury in the NTDB (years 2007-2014), and specifically compared characteristics and outcomes of cervical and thoracic injuries. The authors found a 0.02% prevalence of TIE among trauma patients and significantly higher mortality in patients with blunt versus penetrating TIE (18.8% and 9.8%, respectively), though additional descriptions such as patient demographics or characteristics according to the mechanism of injury were not included[24]. Additionally, a retrospective multicenter study in Scotland found 30 cases of TIE (0.06% among trauma patients in the database) and found greater mortality in patients with blunt TIE (82.4% vs 53.8%), though statistical significance was not reached, with the very small sample size likely limiting statistical power[19].

A retrospective study conducted among Level I trauma centers within Pennsylvania compared patients with TIE to other trauma patients without and found a prevalence of 0.14% (0.3% within Philadelphia only), higher than other studies investigating TIE. In this study, patients with esophageal injury were younger and more severely injured. The authors of the study also explored the association between TIE and mortality, and found that after adjustment for age and injury severity, both sustaining a TIE and male sex were independently associated with increased risk of death[22].

Due to the anatomic location of the esophagus, evaluation and surgical treatment are challenging. The esophagus is located in three regions of the body (the neck, chest, and abdomen) and is surrounded by the heart and lungs as well as vital structures including great vessels, airways, and large nerves. The esophagus is protected by the spine, sternum, and the ribs, posteriorly, anteriorly, and laterally, respectively[29]. Operative treatment (e.g., primary repair, esophagectomy, drainage) is the traditional approach in managing esophageal perforations, but recent trends, likely due to advances in diagnostic capabilities such as computed tomography and endoscopy, as well as improved care in the intensive care unit (ICU), have shifted more toward non-operative management (including intravenous fluids, antibiotics, nothing by mouth), particularly in patients with contained leaks without significant extra-esophageal involvement[30-33].

It has been suggested that after 24 hours from the initial injury, there is little difference between operative and non-operative approaches in management of TIE[7,30-33], though some studies have found that the diagnostic workup and associated delay to surgical management are associated with a greater risk of complications in patients with TIE[20,21]. In an analysis of the NTDB for the years 2007 and 2008, time to first esophagus-related procedure did not affect outcomes[7], yet, in a different large multicenter study including 34 trauma centers in the U.S., patients with time delays in preoperative diagnostic evaluation (average 13 hours) had an over 3 times higher odds of developing esophagus-related complications[21].

Despite prior studies investigating TIE, the frequency of the injury and reported outcomes vary widely in the literature. To date no studies have comprehensively investigated the clinical epidemiology of TIE, by both blunt and penetrating mechanisms, and described its prevalence, risk factors, management, and outcomes in a large study population of trauma patients. Furthermore, differences in those factors, particularly clinical characteristics and outcomes, between blunt and penetrating TIE, have not been explored. Thoroughly understanding the descriptive epidemiology of TIE as well as differences in demographics, clinical characteristics, and outcomes between patients with blunt and penetrating TIE is important for recognizing patients who may be at risk for such injuries and improving the clinical management in cases of TIE to reduce the associated morbidity and mortality.

The objective of this study was to estimate the prevalence of traumatic injuries of the esophagus among patients who experienced a trauma during the period 2010-2015 using data from the NTDB. Our secondary study objective was to describe the demographic and clinical characteristics and clinical outcomes of these patients. We also aimed to compare those factors between patients with blunt and penetrating TIE.

Chapter 2

Epidemiology of Traumatic Esophageal Injury: An Analysis of the National Trauma Data Bank[1]

[1]Xu, AA., Breeze JL., Paulus JK., Bugaev N. To be submitted to *J. Trauma Acute Care Surg.*

2.1 INTRODUCTION

Traumatic injury of the esophagus (TIE) is rare, though its occurrence is associated with significant morbidity and mortality[7,8]. Traumatic esophageal injury can be due to either penetrating trauma, most commonly gunshot wounds (GSW) and stabbings[7], in the relatively small exposed cervical region, or blunt trauma, most commonly motor vehicle collisions (MVC) and falls, often co-occurring with cervical spinal fractures and hyperextension of the neck[10-18].

The morbidity and mortality associated with TIE is well-described in case-reports[10-18], yet few large cohort studies have investigated the clinical outcomes of patients with TIE or estimated the prevalence of TIE among the general trauma population[7-9,19-25]. Most available cohort studies have focused primarily on penetrating TIE, with few characterizing the occurrence of blunt TIE[19,20,22,23]. Blunt trauma in general is commonly associated with significant force, and previous studies have documented poorer outcomes including more complications and higher mortality in blunt trauma[19,23,26-28], and among studies that have investigated blunt TIE, mortality in blunt TIE has been found to be higher than in cases of penetrating TIE[24]. Additionally, the diagnostic workup for TIE and the associated delay to surgical management have been suggested to be associated with a greater risk of complications[20,21].

To date no studies have comprehensively investigated the clinical epidemiology (prevalence, risk factors, management, and outcomes) of both blunt and penetrating TIE in a large population of trauma patients. Understanding the descriptive epidemiology of TIE and the differences in demographics, clinical characteristics, and outcomes between patients with blunt and penetrating TIE is important for improving patient management and reducing their associated morbidity and mortality.

The objective of this study was to estimate the prevalence of traumatic injuries of the esophagus among trauma patients during the period 2010-2015 using data from the American College of Surgeons (ACS) National Trauma Data Bank (NTDB). Our secondary study objective was to describe the demographic and clinical characteristics and clinical outcomes of these patients. We also aimed to compare those factors between patients with blunt and penetrating TIE and hypothesized that patients sustaining blunt TIE would experience more complications and worse outcomes than patients with penetrating TIE.

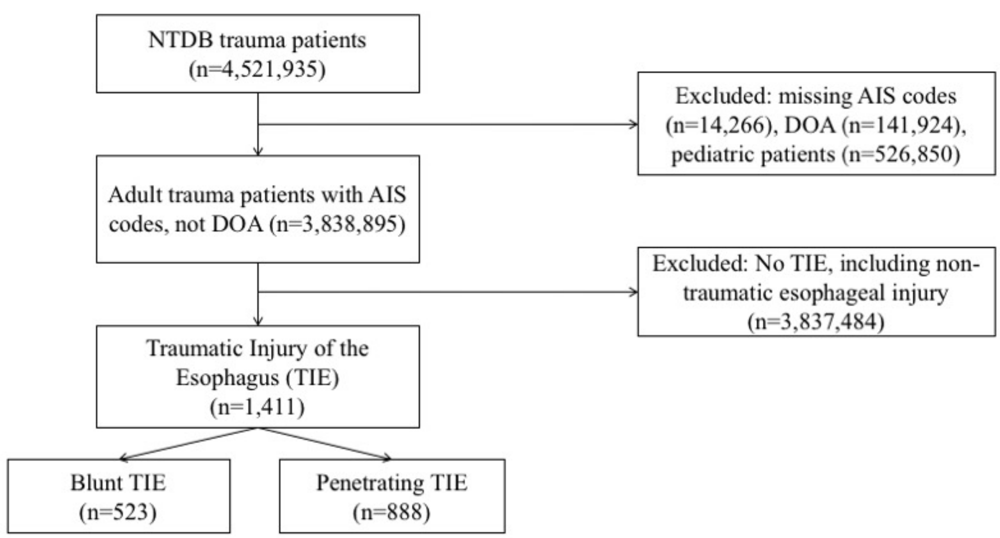
2.2 METHODS

2.2.1 Population and Study Design

This study included patients who experienced a trauma in the NTDB Research Data Sets (RDS) for the years 2010 through 2015 (inclusive). The NTDB is an aggregation of U.S. trauma registry data from participating trauma centers containing trauma information for more than six million cases from more than 900 registered U.S. trauma centers. Data is collected under the basis of the National Trauma Data Standard (NTDS) for standardization of trauma injury information. All patients presenting to participating trauma centers with International Classification of Diseases, Ninth Revision (ICD-9) codes 800.00-959.9 (injuries and poisoning) who were admitted or died, excluding patients with late effects of injury, blisters, contusions, abrasions, insect bites, or foreign bodies, were included in the NTDB dataset. The NTDB is not a population-based dataset and may not represent all trauma hospitals in the U.S., though all ACS-accredited trauma centers in addition to other voluntarily-participating institutions are included[3]. NTDB RDS for each of the years under study were included, and after checking for consistency in variables between years, such as changes to variable definitions and wording, the data sets were concatenated.

A cross-sectional study design was utilized to estimate the prevalence of TIE among adult (age ≥ 16 years) trauma patients in the NTDB. Entries in the NTDB are incident-based, and since it is not possible to identify patients who have presented for trauma multiple times in the same year[3], all incidents were treated as independent patients. Patients missing AIS-98 codes (n=14,266) and patients who were dead on arrival to the ED (DOA) (n=141,924) were excluded (Figure 2.1).

Figure 2.1: Flow Chart of Patients included in Analysis



Demographic factors, clinical characteristics, select procedures, and clinical outcomes were described and summarized for patients with TIE. These descriptive analyses were repeated after stratifying by overall mechanism of injury (blunt or penetrating), ISS, sex, and trauma center level. Variables included in the analysis dataset included demographics, comorbidities, geographic region, trauma center level (I-V), mechanism of injury, emergency department (ED) vital signs (heart rate (HR), systolic blood pressure (SBP), Glasgow Coma Scale (GCS), blood oxygen saturation, and respiratory rate (RR)), esophageal injury grade, injury severity score (ISS, categorized as mild (0-9), moderate (10-15), severe (16-24), and critical (≥25)), associated injuries, diagnostic and operative procedures, time to procedures, complications, length of stay (hospital and intensive care unit (ICU)) (LOS), ventilator days, hospital discharge disposition, and mortality (variables defined in detail below).

TIE was defined as injuries of the esophagus, identified using the Abbreviated Injury Scale (AIS) version 1998 (AIS-98 codes: 440899.2, 440802.2, 440804.3, 440806.3, 440808.4, and 440810.5), which identifies the specific injured body region (head, face, neck, thorax, abdomen, spine, upper extremity, lower extremity, external, or other) and severity of the injury from 1 to 6, in patients with blunt or penetrating mechanisms of injury. In the case of esophageal injury severity, grade 2 injuries include hematomas and contusions, grade 3 injuries include partial-thickness lacerations, grade 4 injuries include full-thickness perforations, and grade 5 injuries include avulsion, rupture, or transection. Patients with other mechanisms of injury (e.g., burn) were excluded. ISS ranges from 0 to 75 and is defined as the sum of the square of the highest AIS severity in the three most severely injured body regions. For calculating ISS, body regions without injuries receive an AIS severity of 0, and patients with any injuries with AIS severity of 6 automatically receive an ISS of 75[6].

2.2.2 Clinical Characteristics

Injury mechanisms were categorized as blunt (injuries due to falls, machinery, transportation-related collisions, strike (e.g. accidental, assault)) and penetrating (injuries due to cutting or piercing, firearms)[3].

Pre-existing comorbidities available in the NTDB from 2010 through 2015 were categorized into ten groups as follows: cardiopulmonary, hematologic, compromised immunity, endocrine and metabolic, hepatobiliary, neuropsychologic, renal, neonatal, health status, and other (Table 4.3).

Concurrent or associated injuries (excluding esophageal injuries) were categorized by body region using AIS-98 codes.

Trauma center levels are defined based on resources available at the facilities. Level I centers provide the most comprehensive care for trauma patients and are required to have education and research programs, Level II centers are similar to Level I centers, but do not necessarily need to conduct research or provide education, Level III centers have the resources for diagnosis and resuscitation as well as general surgery, Level IV centers may evaluate and stabilize trauma patients, though not all provide surgery, and Level V centers are similar to Level IV centers, but may not be open 24-hours per day[5].

2.2.3 Procedures

Procedures potentially associated with the diagnosis or management of TIE available in the NTDB were summarized (Appendix 3.1), but due to extensive missingness in the procedure data within the dataset, these descriptive analyses were considered hypothesis-generating in nature.

2.2.4 Clinical Outcomes

Complications available in the NTDB were categorized as either potentially esophagus or non-esophagus-related (Table 4.4).

Hospital LOS was reported and summarized both for all patients and for only those patients who survived their hospital stay; the ICU length of stay and number of days on a ventilator were also reported.

Discharge disposition in the NTDB is defined as the status of a patient at the time of hospital discharge. This endpoint was categorized as deceased (in-hospital mortality), discharged to another institution for rehabilitation/further care, discharged to home (with or without services), discharged to other institutions (e.g., hospice, law enforcement), and left against medical advice (AMA).

2.2.5 Statistical Analysis

The normality of continuous variables was assessed using histograms and descriptive statistics including means and medians. Statistical tests were used to examine differences in demographic factors, clinical characteristics, and clinical outcomes between the primary comparisons of interest, namely penetrating and blunt mechanisms of injury. Normally distributed continuous variables were described using means and standard deviations, and compared between groups using t-tests. Non-normally distributed variables were described as medians and interquartile ranges (IQR) and compared between groups using Mann-Whitney U tests. Categorical variables were described using counts and percentages and compared using chi-square tests. Prevalence was calculated as the number of trauma patients with TIE divided by the total number of trauma patients in the dataset, and 95% confidence intervals (CI) were reported for these estimates. Statistical tests were two-sided with alpha = 0.05.

Among all adult trauma patients, the association between the presence of TIE and in-hospital mortality was estimated in unadjusted and adjusted generalized estimating equations (GEE) logistic regression analyses to account for clustering of patients within trauma centers. The intraclass correlation coefficient (ICC) for the clustering of patients within centers was estimated based on the mortality outcome. The multivariable model adjusted for likely confounders of the association between TIE and mortality (ISS (continuous), age (continuous), and sex), which were selected *a priori* based on clinical knowledge and the prior literature[7,22,34]. Odds ratios and their 95% CIs were reported. All statistical analysis was performed using R (version 3.3.1, including the "tableone," "geepack," and "rptR" packages).

2.3 RESULTS

2.3.1 Adult Patients in the NTDB

During the six years under study from 2010 through 2015, a total of 3,838,895 adult trauma patients in the NTDB met inclusion criteria (Table 2.1). Patients who sustained a trauma were on average 51.5±22.8 years old and predominantly male (62%) and white (75%). Most patients presented to Level I trauma centers (55%), and blunt trauma was most common (84%). The most common mechanisms of injury were falls (42%) followed by motor-vehicle collisions (29%). Most trauma patients were mildly injured (66% ISS 0-9), and the median ISS was 9 (IQR: 4,12).

Table 2.1: Demographic and Clinical Characteristics of Adult Trauma Patients (n=3,838,895)	
Demographics	
Age (mean yrs) (SD)	51.5 (22.8)
Male (n (%)) (missing n=1,426 (0%))	2,362,296 (62%)
Race (n (%)) (missing n=159,987 (4%))	
White	2,756,393 (75%)
Black	515,815 (14%)
Other	406,700 (11%)
Hispanic Ethnicity (n (%)) (missing n=689,596 (18%))	371,996 (12%)
Trauma Center Level (n (%)) (missing n=108,936 (3%))	
I	2,038,901 (55%)
II	1,293,163 (35%)
III-V	397,895 (11%)
Overall Injury Mechanism (n (%)) (missing n=164 (0%))	
Penetrating	345,961 (9%)
Blunt	3,220,351 (84%)
Other	272,419 (7%)
Overall Injury Severity (median [IQR]) (missing n=82,599 (3%))	9 [4,12]
ISS (Categorical) (n (%)) (missing n=82,599 (3%))	
ISS 0-9 (mild)	2,494,191 (66%)
ISS 10-15 (moderate)	581,373 (15%)
ISS 16-24 (severe)	419,345 (11%)
ISS ≥25 (critical)	261,387 (7%)

2.3.2 Prevalence of TIE in the NTDB

1,411 cases of traumatic esophageal injury were identified, with an overall prevalence of 37 cases of TIE per 100,000 trauma patients (95% CI: 35, 39).

The prevalence of TIE among adult trauma patients, stratified by mechanism of injury, ISS, sex, and trauma center level, is presented in Table 2.2. Traumatic esophageal injury was 16 times more prevalent among adults with penetrating injuries (257 cases per 100,000, 95% CI: 240, 270) compared to those with blunt injuries (16 cases per 100,000, 95% CI: 15, 18). Males were almost 3 times more likely to sustain TIE than females, and TIE was 34 times more common among the patients in the highest as compared to the lowest ISS category.

Table 2.2: Prevalence of TIE among Different Subgroups of Adult Trauma Patients	
	Prevalence (n (#/100,000, [95% CI]))
All NTDB 2010-2015 Trauma Patients (n=3,838,895)	1,411 **(37, [35,39])**
By Mechanism of Injury	
Penetrating (n=345,961)	888 **(257, [240,270])**
Blunt (n=3,220,351)	523 **(16, [15,18])**
By Injury Severity	
Mild (ISS 0-9) (n=2,494,191)	183 **(7, [6,9])**
Moderate (ISS 10-15) (n=581,373)	172 **(30, [25,34])**
Severe (ISS 16-24) (n=419,345)	400 **(95, [86,105])**
Critical (ISS ≥ 25) (n=261,387)	621 **(238, [219,257])**
By Gender	
Male (n=2,362,296)	1,139 **(48, [45,51])**
Female (n=1,475,173)	272 **(18, [16,21])**
By Trauma Center Level	
I (n=2,038,901)	938 **(46, [43,49])**
II (n=1,293,163)	362 **(28, [25,31])**
III-IV (n=397,895)	66 **(17, [13,21])**

2.3.3 Demographic and Clinical Characteristics of Patients with TIE

Demographic and clinical characteristics of adult patients with TIE, stratified by penetrating versus blunt mechanism of injury, are summarized in Table 2.3. Penetrating TIE was more common; of the 1,411 cases of TIE, 888 (63%) were caused by a penetrating injury while 523 (37%) were caused by a blunt trauma. The most common cause of penetrating TIE was firearm (69%), while the most common cause of blunt TIE was motor vehicle trauma (57%). Patients with blunt TIE, as compared to patients with penetrating TIE, were significantly older (mean age 46.1 vs 33.5), less likely to be male (74% vs 85%), and more likely to be white (77% vs 35%) (all p <0.001).

Patients with penetrating TIE, compared to those with blunt TIE, were more likely to have evidence of circulatory shock with systolic blood pressure <80 mmHg (15% vs 10%, p=0.01) and a respiratory rate >20 bpm (34% vs 27%, p=0.005). Patients with penetrating TIE had higher median injury severity scores (median ISS 24 vs 21 p=0.001) and had a significantly greater proportion of patients with ISS ≥ 25 (48% vs 40%, p < 0.001). Additionally, the esophageal injuries in patients with penetrating trauma were also more severe than in the patients with blunt trauma (37% grade 3 and 4 injuries in penetrating TIE vs 21% in blunt TIE, $p < 0.001$).

Procedures in patients with TIE, stratified by mechanism of injury, are summarized in Appendix 3.2.

Associated injuries among penetrating and blunt TIE patients also differed. Penetrating TIE patients were more likely to have neck injuries (40% vs 15%) though blunt TIE patients had significantly more associated spine injuries (43% vs 27%) (all $p < 0.001$). All associated injuries as well as geographic region, and comorbidities, compared between adult blunt and penetrating TIE patients, are further summarized in Appendix 4.1.

Table 2.3: Demographic and Clinical Characteristics of Adult TIE patients according to Mechanism of Injury			
Injury Mechanism	Blunt (n=523)	Penetrating (n=888)	p-value
Demographics			
Age (mean yrs) (SD)	46.1 (20.5)	33.5 (14.3)	**<0.001**
Male (n (%))	388 (74)	751 (85)	**<0.001**
Race (n (%)) (missing n=59 (4%))			**<0.001**
White	386 (77)	300 (35)	
Black	59 (12)	417 (49)	
Other	54 (11)	136 (16)	
Hispanic Ethnicity (n (%)) (missing n=201 (14%))	51 (12)	129 (17)	**0.02**
Vital Signs (n (%))			
HR >100 bpm (missing n=33 (2%))	195 (38)	368 (43)	0.10
SBP <80 mmHg (missing n=43 (3%))	49 (10)	124 (15)	**0.01**
GCS <13 (missing n=53 (4%))	163 (32)	308 (36)	0.20
O_2 Saturation <90% (missing n=241 (17%))	39 (9)	87 (12)	0.12
RR >20 bpm (missing n=78 (6%))	133 (27)	287 (34)	**0.005**
Trauma Center Level (n (%)) (missing n=45 (3%))			**<0.001**
I	321 (64)	617 (71)	
II	137 (27)	225 (26)	
III-IV	41 (8)	25 (3)	
Injury Mechanism (n (%))			
Penetrating	N/A	888 (100)	
Cutting/piercing	N/A	277 (31)	
Firearm	N/A	611 (69)	
Blunt	523 (100)	N/A	
Fall	105 (20)	N/A	
Machinery	12 (2)	N/A	
MVT	300 (57)	N/A	
Pedal cyclist collision	5 (1)	N/A	
Pedestrian collision	3 (1)	N/A	
Strike	59 (11)	N/A	
Transport collision	39 (8)	N/A	
Overall Injury Severity (median [IQR]) (missing n=35 (2%))	21 [12,32]	24 [16,33]	**0.001**
ISS (Categorical) (n (%)) (missing n=35 (2%))			**<0.001**
ISS 0-9 (mild)	103 (20)	80 (9)	
ISS 10-15 (moderate)	63 (12)	109 (13)	
ISS 16-24 (severe)	147 (28)	253 (29)	
ISS ≥25 (critical)	205 (40)	416 (48)	
Esophageal Injury Grade (n (%))			**<0.001**
2	310 (59)	190 (21)	
3	103 (20)	366 (41)	
4	92 (18)	291 (33)	
5	18 (3)	41 (5)	
Associated Injuries (n (%))			
Thorax	374 (72)	655 (74)	0.39
Abdomen	183 (35)	272 (31)	0.10
Neck	77 (15)	352 (40)	**<0.001**
Spine	223 (43)	239 (27)	**<0.001**

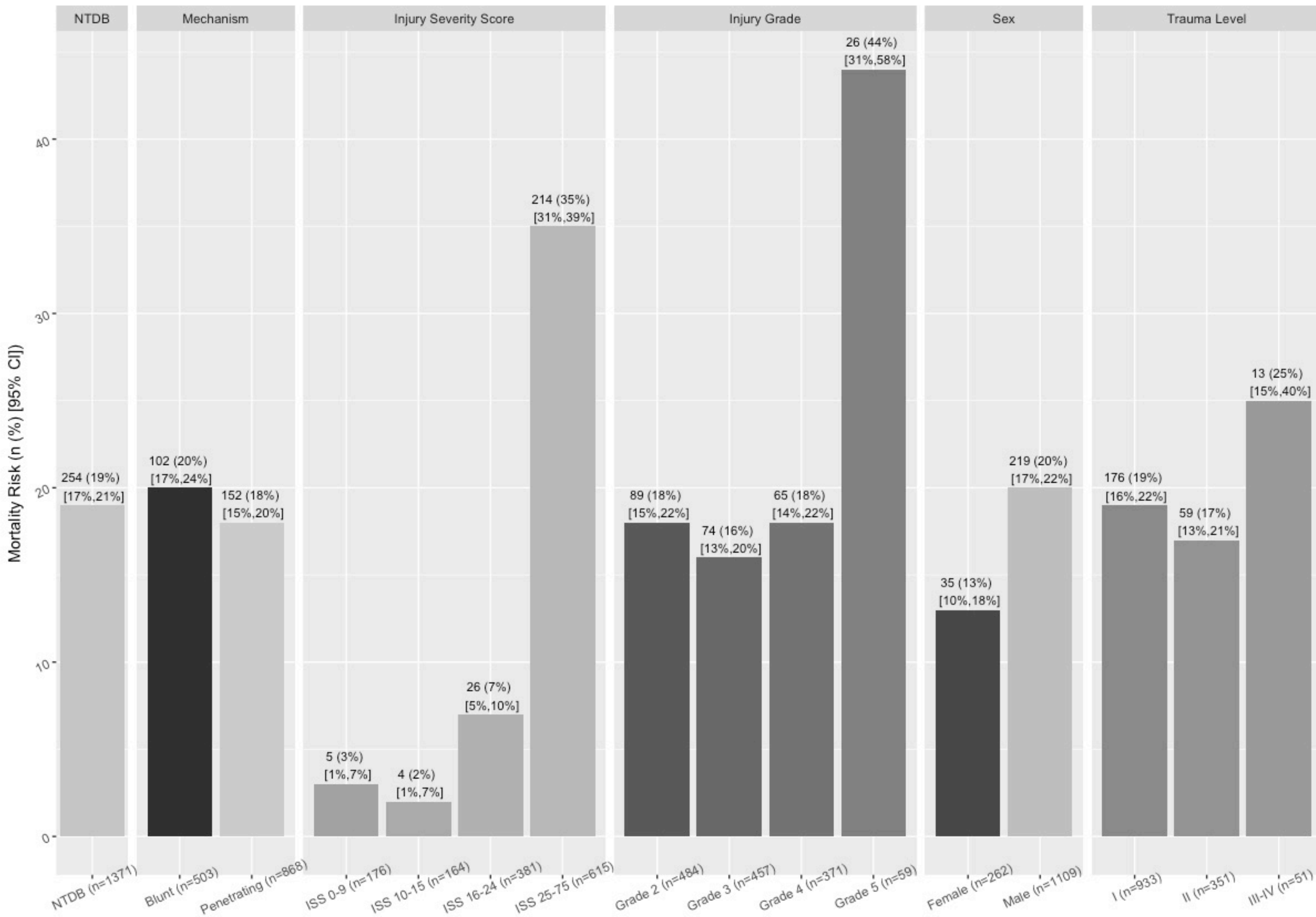
Data was complete for variables where no missing data are reported.

2.3.4 In-Hospital Mortality and Other Outcomes in Patients with TIE

Among the 1,411 patients with TIE, 254 (19%) died during their hospital stay. In-hospital mortality did not differ between patients with penetrating (18%) versus blunt TIE (20%) (p=0.22). The in-hospital mortality risk among other subgroups is presented in Figure 2.2. Patients with higher ISS and esophageal injury grade had greater in-hospital mortality. The in-hospital mortality of TIE patients was 19%, 17%, and 25% at Level I, II, and III-IV trauma centers, respectively.

Among patients with TIE, patients who died during their hospital stays had a significantly lower proportion of patients with pre-existing co-morbidities (48% vs 65%, $p < 0.001$).

Figure 2.2: Mortality Risk Among Subgroups of Adult NTDB Trauma Patients with TIE



Other clinical outcomes in patients with blunt or penetrating TIE are shown in Table 2.4. A greater proportion of patients with blunt TIE experienced no complications (50% vs 44%, *p*=0.05), but patients with penetrating TIE had significantly longer hospital stays (median length of stay 11 vs 6 days, $p < 0.001$). Discharge disposition was not statistically significantly different according to mechanism of injury.

Table 2.4: Clinical Outcomes of Adult TIE patients according to Mechanism of Injury

Injury Mechanism	Blunt (n=523)	Penetrating (n=888)	p-value
Complications (n (%)) (missing n=63 (4%))			
Esophageal-related	98 (19)	180 (20)	0.53
Non-esophageal-related	89 (17)	159 (18)	0.73
Other	169 (32)	301 (34)	0.58
None	261 (50)	393 (44)	**0.05**
Ventilator Days (median [IQR]) (missing n=54 (4%))	5 [1,14]	4 [2,11]	0.34
Length of Stay (all patients) (median days [IQR])			
Hospitalization (missing n=3 (0%))	6 [2,18]	11 [4,21]	**<0.001**
Intensive Care Unit (missing n=26 (2%))	6 [2,15]	6 [3,14]	0.17
Length of Stay (survived to discharge) (median days [IQR])	n=421	n=736	
Hospitalization (missing n=1 (0%))	9 [3,20]	13 [7,24]	**<0.001**
Intensive Care Unit (missing n=17 (1%))	7 [3,18]	6 [3,14]	0.45
Discharge Disposition (survived to discharge) (n (%))			0.37
Rehab/further care	140 (35)	224 (30)	
Discharge to home (any)	244 (61)	469 (64)	
Other (hospice, law enforcement, etc)	12 (3)	18 (2)	
Left AMA	5 (1)	5 (12)	
Missing n=40 (3%))			

Data was complete for variables where no missing data are reported.

2.3.5 Association of TIE with In-Hospital Mortality among Trauma Patients

The ICC for mortality was estimated to be 0.011 (95% CI: 0.009, 0.012), which is in line with ICCs reported in other NTDB studies that have examined mortality[35,36]. Among all injured patients in the study cohort, older patients, males, those with higher ISS, and those who experienced a TIE were associated with higher in-hospital mortality, both in univariate and multivariable analysis (Table 2.5). After adjustment for age, sex, and ISS, trauma patients with TIE had 1.4 times the odds of mortality as compared to patients without TIE.

Table 2.5: Association between TIE and mortality among Trauma Patients					
Variable	**Descriptive Statistics by Mortality**			**Univariate Models**	**Multivariable Model**
		Died=0 (n=3,016,611)	**Died=1 (n=126,657)**	**OR [95% CI]**	**OR [95% CI] {n=3,081,993}**
Age	Mean (SD)	52.9 (22.9)	59.2 (23.6)	1.1 [1.1,1.1]	1.3 [1.3,1.3]
Male sex (missing n=1,215 (0%))	n (%)	1,805,913 (60)	85,561 (68)	1.4 [1.4,1.4]	1.4 [1.4,1.5]
ISS (missing n=76,105 (2%))	Median [IQR]	9 [4,13]	25 [13,30]	3.0 [3.0,3.0]	3.3 [3.3,3.4]
TIE	n (%)	1,117 (0)	254 (0)	5.4 [4.7,6.2]	1.4 [1.1,1.7]

GEE models were used to account for clustering of patients within facility. ORs for continuous variables (age and ISS) are reported for units of 10.

2.3.6 Subgroup Analyses by ISS, Sex, and Trauma Center Level

TIE was also described within strata defined by ISS, sex, and trauma center level (Appendix 4). Individuals with higher ISS were more likely to be younger, male, and white (with the exception of patients with ISS 10-15 who were younger than those with ISS 16-24). The proportion of patients with penetrating trauma generally increased with higher ISS. There were over 4 times as many males with TIE (n=1,139) as females (n=272). Male patients were younger, were less likely to be white, and had a greater proportion of patients that suffered a penetrating trauma. Male patients also generally had higher injury severity and esophageal injury grade. Trends among trauma center levels were similar to those among ISS categories. Patients at Level I trauma centers were generally younger and less likely to be white. The proportion of patients with penetrating injuries was also higher in higher trauma center levels.

2.4 DISCUSSION

We described the clinical characteristics and outcomes of patients with traumatic injury of the esophagus. Our study is the first to comprehensively describe these factors in patients with blunt TIE and compare those characteristics and outcomes to those of patients with penetrating TIE. Analyzing six years of data from the NTDB and 1,411 adult patients with TIE, we found that TIE is extremely rare and occurs in only 37 out of 100,000 trauma patients, though TIE was more common among the most severely injured patients with ISS $\geq$ 25. Approximately one-third of patients with TIE sustained a blunt trauma. Overall in-hospital mortality was very high at 19%, and even after adjusting for age, sex, and overall injury severity, the presence of TIE was found to be independently associated with increased mortality.

Contrary to our hypothesis and most previous studies that found greater injury severity, more complications, and higher mortality in blunt trauma[26-28], we found that patients with blunt TIE did not experience worse outcomes as compared to those with penetrating TIE. There was no significant difference in mortality compared between blunt and penetrating TIE, and patients with penetrating TIE were more likely to have reported complications and overall longer average hospital stays. These results were consistent with one NTDB study investigating insurance status as a predictor of mortality in trauma, however, which found that patients with penetrating trauma had greater mortality[37].

In our analysis, male sex also had a positive association with mortality, despite adjustment for injury severity. Males are more likely to sustain more severe injuries[38,39] and be intoxicated by substances of abuse[40]. The greater risk of in-hospital mortality in males may be accounted for by residual sex differences in injury severity; ISS accounts for only the three most severe injuries, and other variables, such as drug or alcohol use or comorbidities, which were not included in our analysis due to the extensive missingness of these data[36,41], may also contribute to the effect of male sex on mortality and residually confound the TIE-mortality association.

Our study found that a significantly greater proportion of patients with blunt versus penetrating TIE had associated spine injuries, indicating a possible association between spine injuries and blunt traumatic esophageal injury. However, since the NTDB does not include information on the sequence of injuries, this association could not be further explored.

2.4.1 Prevalence of TIE among Trauma Patients

Our study described a cohort of patients similar to previous descriptions of typical trauma patients; trauma patients in our cohort were primarily male, middle-aged, mildly-to-moderately injured, and were most likely to have sustained blunt trauma due to falls or motor-vehicle accidents[42,43]. Though there are relatively few studies with estimates of TIE prevalence, we found that TIE was generally less common than previously reported. The prevalence of TIE in our study (0.04%) was lower than that reported in an analysis of the Pennsylvania Trauma Outcome Study (PTOS) (0.14%), as well as a multicenter study in Scotland (0.06%). We found that more severely injured patients were more likely to have TIE. The higher prevalence of TIE in both the PTOS and Scotland studies may be accounted for by more severely injured patient cohorts (higher ISS as compared to the median 22 in our study) and imprecision related to significantly smaller sample sizes[19,22].

2.4.2 In-Hospital Mortality in TIE

TIE mortality was higher in more severely-injured male patients, as well as patients with grade 5 esophageal injuries (Figure 2.2). Mortality in cases of TIE was lower in Level I or II trauma centers as compared to the combined Level III-IV trauma centers category, likely attributable to fewer resources in lower level centers[5].

Mortality in TIE reported in the literature varies widely, and the results in our study were inconsistent with several other studies. A recent analysis of the NTDB dataset for the years 2007-2014 found an overall 12% mortality among patients with TIE (Aiolfi et al, 2017)[24]. In their study, the mortality in cases of penetrating TIE in their study was half that observed in ours (10% as compared to 20%). These inconsistencies can likely be explained by differing inclusion and exclusion criteria: they excluded patients transferred from outside hospitals, and, due to their study primarily comparing cervical versus thoracic esophageal injuries, they also excluded a large proportion (41%) of patients with TIE missing information on specific esophageal injury site. While transfer patients are typically stable enough to survive initial management, a greater severity of injuries is often the reason for transfer[3]; excluding these patients may lead to an underestimate of mortality.

Our study found significantly lower in-hospital mortality compared to the PTOS and Scotland studies (29%[22] and 70%[19] mortality in TIE, respectively), and the inconsistency may be again attributable to the greater injury severity and small sample size in both cohorts. Additionally, the Scotland study represents a different patient population (patients were on average younger with a greater proportion of males). Compared to previous studies investigating penetrating TIE only, the mortality in our study was relatively consistent with that found by a large multicenter study (19%)[21], but another study utilizing the NTDB for the years 2007-2008 found a notably higher mortality of 44%, though their study included patients who were dead on arrival[7].

Similar to the findings of the PTOS study[22], we found that the presence of TIE was associated with a greater risk of in-hospital mortality among trauma patients, after adjusting for age, sex, and ISS. Though Makhani and colleagues found a greater odds of mortality than we did, they had a larger proportion of blunt TIE (61% as compared to 39% in ours), and while there was no significant difference in mortality in our study when stratified by injury mechanism, previous studies have found greater mortality in blunt TIE[19,24]. Taken together, a greater mortality risk in blunt TIE and the greater proportion of blunt TIE in their cohort could have contributed to a higher odds ratio.

2.4.3 Study Strengths and Limitations

Strengths of our study include a large sample size of trauma patients and representation of a broad range of trauma centers. Our study is the first to describe the patient characteristics and outcomes in cases of blunt TIE. Our analysis of the occurrence of TIE and its association with mortality accounted for the clustering of patients within individual trauma centers to avoid artificially narrow confidence intervals[44,45]. Additionally, although several previous studies used ICD-9 codes for identification of TIE[7,22,24], our study utilized AIS-98 codes. While institutions primarily use ICD codes for billing purposes, AIS codes provide greater detail on specific injuries such as injury severity. Methodologies have been developed to map between ICD and AIS codes, but inaccuracies exist due to different purposes of the two coding systems[46,47].

Our study has several limitations. Missing data was a concern with using a large trauma registry[34,41,48,49]; missingness was relatively low (<5%) for most of the variables described but was significant for procedures data. The diagnosis of penetrating TIE is often clinical; in cases of blunt TIE there may be no obvious external injuries, and the injury can generally only be diagnosed through diagnostic procedures (i.e., imaging, endoscopy, etc) or incidental findings during surgery. Yet, fewer than half of patients with blunt TIE in our study cohort had a record of a diagnostic procedure, and even among patients with complete records of procedures received, over one-fourth were still missing time to procedures data. Additionally, missingness in procedures data was significantly different between patients with blunt and penetrating TIE, and therefore likely nonrandom. Simply excluding patients with nonrandom missing data can lead to biased estimates[45], and we therefore could not make any inferences from this data on whether TIE is associated with delays or whether those delays are associated with poor outcomes.

Only patients who have presented to participating institutions are included by the NTDB, and we excluded patients who were dead on arrival to the ED; this introduces a source for potential selection bias and limits the generalizability of our results to trauma patients who have presented to hospitals. Patients who died prior to arrival to the emergency department or prior to diagnosis of the injury, or patients with injuries not severe enough to justify an ED visit, would not have been captured[41]. We found that significantly fewer patients who died during their admission had pre-existing comorbidities, despite the expectation that patients with significant comorbidities might have greater risk of dying from trauma. Those patients may be more likely to have died prior to arrival to the ED (and therefore not captured by the NTDB), resulting in nonrandom missingness of comorbidity data, which has been previously reported[34].

The NTDB also does not include information on the temporal relationship between events (e.g., procedures, complications) or information on how clinical decisions were made; therefore, causal relationships between many variables cannot be inferred from this data.

2.4.4 Future Directions

While there are strengths to a secondary analysis of a large dataset including data on a large sample size of trauma patients and trauma centers that has already been collected, consistency in data collection remains a challenge. A prospective multicenter investigation of management and outcomes in TIE would be ideal for studying the associations between time to procedures and outcomes, given the relatively short follow-up period of the injury, though long recruitment periods and significant expense may be required due to the rarity of these injuries. Additionally, using the findings from this study to develop clinical prediction models applying readily-available variables to patients at the highest risk on admission to the emergency department may help identify undetected cases of TIE, allowing for additional evaluation and earlier detection of the injury.

An update to the Abbreviated Injury Scale in 2005 (AIS-05) offers additional specificity for identification of esophageal injury by differentiating between injuries in the cervical and thoracic regions. AIS-05 was only made mandatory for NTDB submission beginning with January 2016 admissions, and therefore our study did not utilize AIS-05 coding as AIS-98 was more complete for injury information. Further studies are needed to evaluate the differences in TIE occurring in different anatomical locations.

2.4.5 Conclusion

Our study provides an overview of trauma patients in the U.S. who sustain TIE. We found that while extremely rare, the presence of TIE is independently associated with a marked increase in mortality. This understanding of these patients and their demographic and clinical characteristics and outcomes can provide a basis for better recognition and treatment of TIE and to improve outcomes.

CHAPTER 3: DISCUSSION

In this study, we aimed to investigate the clinical characteristics and outcomes of patients with traumatic injury of the esophagus using a large national dataset. Analyzing six years of data from the National Trauma Data Bank and a total of 3,838,895 adult patients who experienced a trauma during our study period, we identified 1,411 patients with TIE. Consistent with the previous literature, we found that TIE is extremely rare, occurring in fewer than 37 patients out of 100,000 who experienced a traumatic episode during the years 2010-2015. However, in patients who do sustain TIE, overall in-hospital mortality was found to be very high at 19%, and even after adjusting for age, sex and the overall injury severity of patients, and accounting for clustering of patients within trauma centers, experiencing a TIE was found to be independently associated with markedly increased mortality. Contrary to our hypothesis, however, we found that patients with blunt TIE did not experience poorer outcomes as compared to those with penetrating TIE; there was no significant difference in mortality as compared between the two mechanisms of injury, and patients with penetrating TIE had a lower proportion with no complications and overall longer average hospital stays.

We described a cohort of patients that were similar to previous descriptions of typical trauma patients: generally, trauma patients are more likely to be male and middle-aged, while having mild to moderate overall injury severity, and the most common mechanisms of injury are blunt and are primarily due to falls or motor-vehicle accidents[42,43]. Beyond describing the demographics, clinical characteristics, and outcomes of patients with these esophageal injuries, our study is also the first to compare the characteristics and outcomes of patients with TIE due to blunt and penetrating mechanisms using a large national dataset.

3.1 Evaluation of Management of TIE and Associations with Outcomes

Our study was limited by missing data within the registry. While missingness was generally low (<5%) for most variables described in our study, the proportion of procedures data missing was significant. The diagnosis of penetrating TIE is often clinical, but blunt TIE cannot be easily visualized, and patients can generally only be diagnosed with TIE from blunt mechanisms through a diagnostic procedure (i.e., imaging, endoscopy, etc) or incidental findings during surgery for another injury. However, in our dataset from the NTDB, fewer than half of patients with blunt TIE had a record of a diagnostic procedure, and 35% of patients with blunt TIE had the procedures field recorded as “missing.” Even in patients with complete data on procedures received, over one-fourth were still missing data on the time to procedure. Due to the limited quality of data, we were therefore unable to draw inferences from this dataset on whether traumatic esophageal injuries are associated with delays in management or whether those delays may be associated with poorer outcomes such as more complications and greater mortality.

Multiple imputation is one option to account for the missingness within the NTDB[48,49]. However, missingness in procedures data was significantly different between patients with blunt and penetrating TIE, suggesting that the missingness was nonrandom. Without significant additional assumptions or knowledge of the distribution of missing data, such techniques would be flawed[44].

Despite the strengths of using a large dataset, the association between management delays and outcomes may be better explored with a prospective multicenter investigation, where data collection may be more consistent, particularly given the generally short follow-up period of the injury. However, long recruitment periods and significant expense would likely be required due to the rarity of these injuries.

3.2 Evaluation of Anatomical Region of Esophageal Injury

The esophagus spans the neck, chest, and abdominal anatomical regions; our study was unable to evaluate TIE in multiple body regions. For completeness of the data, we utilized AIS-98 codes in our study to identify cases of TIE, which categorize esophageal injuries entirely within the thoracic region. The Abbreviated Injury Scale was updated in 2008 (AIS-05) and offers further specificity for identification of TIE by differentiating between esophageal injuries in the cervical and thoracic regions. A recent study of the NTDB (Aiolfi et al) for the years 2007-2014 identified TIE using ICD-9 codes, but utilized AIS-05 codes to categorize the injuries to the available anatomical regions (cervical and thoracic)[24]. However, while the AIS-05 code standard has been available for data submission to the NTDB since 2007 and the number of institutions utilizing the updated scale has been growing, AIS-05 codes were only made mandatory for acceptance into the registry dataset starting with January 2016 admissions. The previous study's primary focus was to compare TIE between cervical and thoracic injury sites, and the authors excluded over 41% of patients from the study population due to missing injury site location information (AIS-05 codes) for those patients, potentially introducing a source of selection bias.

All future evaluation of TIE using the NTDB should fully utilize AIS-05 coding to fully-investigate patterns and outcomes of esophageal injury locations, particularly as compared between different mechanisms of injury.

Additionally, AIS-05 coding still does not include the abdominal anatomical region for esophageal injuries. With this limitation, evaluation of specifically abdominal esophageal injuries would require a different set of data.

3.3 Prediction of TIE in a Clinical Setting

Due to the anatomy of the esophagus, particularly in cases of blunt mechanism trauma with which there are no obvious external injuries, TIE can be missed on initial emergency department evaluations. While clinical prediction models for TIE may not be immediately clinically useful when applied to the general trauma patient population given the low prevalence of the injury, evaluating only the highest-risk group patients may be more applicable. Cervical spine injuries have been previously hypothesized as a possible cause of blunt TIE, and we found in our study that a significantly greater proportion of patients with blunt TIE than patients with penetrating TIE had spine injuries, indicating an association between spine injuries and blunt traumatic esophageal injury. Using the findings from our study to identify the highest-risk group of patients as well as the strongest predictors of TIE from readily-available variables on admission to the emergency department, may help identify undetected cases of TIE, allowing for additional evaluation and earlier detection of the injury.

3.4 Conclusion

In conclusion, our study provides a descriptive overview of trauma patients within the United States who have sustained a traumatic esophageal injury. While TIE is extremely rare, the presence of TIE was found to be independently associated with a marked increase in mortality. Future studies further exploring the clinical characteristics and management of patients with TIE would serve to increase our understanding of the injury, as well as facilitate the application of this understanding to the clinical setting and provide a basis for better recognizing and managing TIE to improve outcomes.

CHAPTER 4: APPENDIX

4.1 Appendix 1: Literature Review

Table 4.1: Prevalence and characteristics of TIE in Previous Literature

Author (yr) (Country)	Study Design	Setting/population	# TIE (% penetrating/ % blunt)	Prevalence	Age	Sex (% male)	ISS	Injury Site
Aiolfi (2017) (US)	Retrospective multicenter cohort	Patients presenting to US trauma centers in the NTDB 2007-2014	944 (50.6/49.4)	0.02%	Median: 35, IQR: 24,52	77.6%	Median 24, IQR: 16-33	65% thoracic, 35% cervical
Yeh (2015) (US)	Retrospective multicenter cohort	Patients presenting to Level I & II US trauma centers in the NTDB 2008-2010	280 (100/0)	NR	Mean: 30.7±14.2 in PDE; 30.4±13.3 non-PDE	76% in PDE; 82.9% in non-PDE	Mean: 24.6±11.4 non-PDE, 22.9±11.2 PDE	NR
Makhani (2014) (US)	Retrospective multicenter cohort	Patients presenting to 20 level 1 trauma centers in Pennsylvania (PTOS) 2004-2010	327 (60/40)	0.14%	Mean: 29.7±20.5	81.7%	Mean: 26.3±20	58.1% cervical, 37.6% thoracic, 4.3% both
Patel (2013) (US)	Retrospective multicenter cohort	Patients presenting to Level I & II US trauma centers in the NTDB 2007-2008	227 (100/0)	NR	Mean: LOS<24hr: 25.5±11.5; LOS>24hr: 30.8±14.2	85.7%	Mean: LOS<24hr: 42.6±25.4, LOS>24hr: 23.6±16.1	NR
Skipworth (2012) (Scotland)	Retrospective multicenter cohort	Trauma patients admitted to 25 hospitals 1992-2002 in the Scottish Trauma Audit Group	30 (43.3/56.7)	0.06%	Mean: 32	86.7%	Mean: 32	NR

PDE: pre-diagnostic evaluation. NR: not reported.

Table 4.1: Prevalence and characteristics of TIE in Previous Literature (Continued)								
Author (yr) (Country)	**Study Design**	**Setting/population**	**# TIE (% penetrating/ % blunt)**	**Prevalence**	**Age**	**Sex (% male)**	**ISS**	**Injury Site**
Smakman (2004) (South Africa)	Retrospective single center cohort	Patients presenting to level 1 trauma center Sept 1994-July 2002	52 (100/0)	NR	Mean: 28.7	83%	NR	23 cervical, 23 thoracic, 4 abdominal
Asensio (2001) (US)	Retrospective multicenter cohort	Patients presenting to 34 US trauma centers under the AAST Multi-institutional Trials Committee Jun 1988-Dec 1998	405 (100/0)	NR	Mean: 29	87.7%	Mean: 28	56.5% cervical, 30% thoracic, 17% abdominal
Asensio (1997) (US)	Retrospective single center cohort	Patients with penetrating TIE admitted to urban Level 1 trauma center Jan 1990-Dec 1995	43 (100/0)	0.11%	Mean: 25.2	84%	Mean: 28.1±21 survivors, 45.4 non-survivors	51% cervical, 28% thoracic, 21% abdominal
Glatterer (1985) (US)	Retrospective single center cohort	Patients presenting to University of Texas Health Science Center 1969-1984	26 (84.6/15.4)	NR	Mean: 34	100%	NR	21 cervical (17 penetrating, 4 blunt), 5 thoracic
Yap (1984) (US)	Retrospective single center cohort	Patients presenting with esophageal perforation at Henry Ford Hospital 1970-1981	13 (NR/NR)	NR	NR	100%	NR	6 cervical, 5 thoracic, 2 abdominal

PDE: pre-diagnostic evaluation. NR: not reported.

Table 4.2: Clinical outcomes in TIE in Previous Literature

Author (yr) (Country)	Surgery/No Surgery	Time to Surgery	Mortality Rate	Complications	ICU/Hosp LOS
Aiolfi (2017) (US)	37% surgery	29% treatment </= 24 h	12% (19% blunt, 10% penetrating)	24% complications	ICU: median 7 days, IQR: 3-15, Hospital: median 12 days, IQR: 5-23
Yeh (2015) (US)	280/74	NR	5.4% non-PDE, 0% PDE	NR	NR/18 non-PDE, NR/13 PDE
Makhani (2014) (US)	117/210	69 < 24 hrs, 6 > 24 hrs, 42 other	29.1%	18 PNA, 11 UTI, 10 DVT, 255 none	ICU: 43.4% none, 35.8% 1-5 days, 20.8% >5 days
Patel (2013) (US)	62% primary repair, 13% drainage, 4% resection, 1% diversion, 20% unspecified	LOS<24hr: 0.4h, LOS>24hr: 14.4h	44%	83% (32% esophagus related)	NR/19<24hr, 135>24hr
Skipworth (2012) (Scotland)	30% died in ED, 20% nonoperative, 50% OR (6 laparotomy, 4 thoracotomy)	OR median time 100 min	70% (82.4% blunt, 53.8% penetrating)	NR	NR/9 survivors: 12 days
Smakman (2004) (South Africa)	38/14	Primary Repair: 17.5h, Primary repair 1st + drainage 2nd: 36.7h	6%	29% esophageal related, 38% non-esophageal related	NR/27.7 days (61.9 with esophageal complications, 12.3 without)
Asensio (2001) (US)	346/59	13h PDE, 1h non-PDE	19%	Non-esophageal: 115, esophageal: 106	ICU: 11 preop, 7 no preop; HOSP: 22 preop, 11 no preop
Asensio (1997) (US)	NR	9.8 hrs	26%	41% PDE, 38% non-PDE	non-PDE: 7.3/NR; PDE: 5.5/NR
Glatterer (1985) (US)	26	NR	15%	13 patients	NR/25 days (22 blunt cervical, 26 penetrating cervical, 24 penetrating thoracic)
Yap (1984) (US)	13	NR	0%	NR	NR/NR

PDE: pre-diagnostic evaluation. NR: not reported.

4.2 Appendix 2: Pre-existing Comorbidities and Complications

Table 4.3: Pre-existing Comorbidities Available in the NTDB	
Comorbidity Category	**Pre-existing Comorbidity**
Cardiopulmonary	Congestive heart failure History of angina within 30 days History of myocardial infarction History of peripheral vascular disease Hypertension requiring medication Respiratory disease Current smoker Pre-hospital cardiac arrest with resuscitation (2012-2014)
Hematologic	Bleeding disorders
Compromised Immunity	Chemotherapy for cancer Disseminated cancer Steroid use
Endocrine and Metabolic	Diabetes mellitus Obesity (2010-2014)
Hepatobiliary	Esophageal varices (2010-2014) Alcoholism Ascites within 30 days (2010-2014) Cirrhosis (2011-2015)
Neuropsychologic	Cerebrovascular accident/residual neurologic deficit Impaired sensorium (2010-2011) Dementia (2012-2015) Major psychiatric illness (2012-2015) Drug abuse or dependence (2012-2015) Attention deficit disorder/attention deficit hyperactivity disorder (2015)
Renal	Currently requiring or on dialysis/chronic renal failure
Neonatal	Congenital anomalies Prematurity
Health Status	Functionally dependent health status Do not resuscitate status
Other	Comorbidities not specifically designated in the NTDB

Variables were available for all years of study where no years are reported.

Table 4.4: Complications Available in the NTDB	
Complications Category	**Complications**
Potentially esophagus-related complications	Acute respiratory distress syndrome Deep surgical site infection Organ/space surgical site infection Pneumonia Superficial surgical site infection Systemic sepsis (2010) Severe sepsis (2011-2015) Unplanned intubation Wound disruption (2010) Unplanned return to OR (2011-2015) Unplanned admission to the ICU (2011-2015)
Non-esophagus-related complications	Abdominal compartment syndrome (2010) Abdominal fascia left open (2010) Acute renal failure Base deficit (2010) Bleeding (2010) Cardiac arrest with cardiopulmonary resuscitation Coagulopathy (2010) Coma (2010) Decubitus ulcer Drug or alcohol withdrawal syndrome Deep venous thrombosis/thrombophlebitis Extremity compartment syndrome Graft/prosthesis/flap failure Intracranial pressure (2010) Myocardial infarction Pulmonary embolism Stroke Urinary tract infection (2011-2015) Catheter-related blood stream infection (2011-2015) Osteomyelitis (2011-2015)
Other	Complications not specifically designated in the NTDB

Variables were available for all years of study where no years are reported.

4.3 Appendix 3: Procedures

4.3.1 Appendix 3.1 Selection of Procedures

Procedures potentially associated with the diagnosis or management of TIE available in the NTDB were identified by their ICD-9 (International Classification of Diseases, Ninth Revision) codes and categorized as either diagnostic or therapeutic (Table 4.5). For patients with conflicting procedure data (i.e., the presence of a procedure code as well as a code indicating the patient had no procedures, or was missing procedure data), the presence of the procedure was retained. Where available, time to procedures was also reported.

Table 4.5: Procedures and ICD-9 codes associated with diagnosis and management of TIE

Procedure	Procedure Code
Diagnostic Procedures	
Other esophagoscopy	42.23
Other diagnostic procedures on esophagus	42.29
Esophagogastroduodenoscopy [egd] with closed biopsy	45.16
Computerized axial tomography of thorax	87.41
Other tomography of thorax	87.42
Barium swallow	87.61
Upper GI series	87.62
Therapeutic Procedures	
Exploratory thoracotomy	34.02
Incision of mediastinum	34.1
Other incision of esophagus	42.09
Esophagostomy, not otherwise specified	42.1
Cervical esophagostomy	42.11
Operative esophagoscopy by incision	42.21
Esophagectomy, not otherwise specified	42.4
Partial esophagectomy	42.41
Total esophagectomy	42.42
Other repair of esophagus	42.89
Other operation on esophagus	42.99

Procedures not included in this list and unrelated to esophageal injury were not reported.

4.3.2 Appendix 3.2 Clinical Management of Blunt and Penetrating TIE

There were significant amounts of missing data for procedures in the NTDB, with 29% of TIE patients missing procedure data; among patients with procedure-related information, only 74% had a recorded time to procedure. Procedures in patients with blunt and penetrating TIE are summarized in Table 4.6. A total of 46% and 45% of patients with blunt TIE and penetrating TIE, respectively, had a record of a diagnostic procedure. Missingness in procedures data was significantly different between patients with blunt and penetrating TIE (35% vs 25%, $p < 0.001$).

Among patients with procedure data, more patients with blunt TIE received diagnostic procedures than those with penetrating TIE (70% vs 59%, $p < 0.001$). A significantly greater proportion of patients with penetrating TIE received therapeutic procedures (36% in penetrating TIE vs 16% in blunt TIE, $p < 0.001$). There was no significant difference in proportion of patients without any procedures between blunt and penetrating TIE.

When only patients who had a record of any procedure (diagnostic or therapeutic) were included, 26% of patients were missing data on time to procedure. In the available time to procedure information, median time to the first diagnostic procedure was similar between patients with blunt and penetrating TIE (blunt TIE: 2 hours, IQR = 1, 3; penetrating TIE: 2 hours, IQR = 1, 11). Median time to receipt of the first therapeutic procedure was 2 hours (IQR = 1, 8) for patients with penetrating TIE and 10 hours (IQR = 4, 76) for patients with blunt TIE.

Table 4.6: Clinical Management of Adult TIE patients according to Mechanism of Injury		
Injury Mechanism	Blunt (n=523)	Penetrating (n=888)
Procedures (n (%))		
Diagnostic	239 (46)	395 (45)
Therapeutic	56 (11)	241 (27)
None	11 (2)	16 (2)
Missing n=405 (29%)	182 (35)	223 (25)
Procedures (n (%)) (patients with procedure data)	n=341	n=665
Diagnostic	239 (70)	395 (59)
Therapeutic	56 (16)	241 (36)
None	11 (3)	16 (2)
Time to 1st Procedure (any)	n=264	n=522
Median hr [IQR] (missing n=201 (26%))	2 [1,5]	2 [1,6]
Missing (n (%))	74 (28)	127 (24)
Time to 1st Procedure (diagnostic)	n=239	n=395
Median hr [IQR] (missing n=175 (28%))	2 [1,3]	2 [1,11]
Missing (n (%))	71 (30)	104 (26)
Time to 1st Procedure (therapeutic)	n=56	n=241
Median hr [IQR] (missing n=70 (24%))	10 [4,76]	2 [1,8]
Missing (n (%))	12 (21)	58 (24)

Data was complete for variables where no missing data are reported.

4.4 Appendix 4: Supplementary Analyses

Table 4.7: Geographic Region, Comorbidities, and Associated Injuries of Adult TIE patients according to Mechanism of Injury			
Injury Mechanism	Blunt (n=523)	Penetrating (n=888)	p-value
Geographic Region (n (%)) (missing n=17 (1%))			0.06
Midwest	110 (21)	174 (20)	
Northeast	97 (19)	131 (15)	
South	209 (41)	363 (41)	
West	98 (19)	212 (24)	
Comorbidities (n (%))			
Cardiopulmonary	193 (37)	253 (29)	**0.001**
Endocrine and Metabolic	69 (13)	51 (6)	**<0.001**
Hepatobiliary	47 (9)	57 (6)	0.09
Hematologic	22 (4)	6 (1)	**<0.001**
Health Status	14 (3)	7 (1)	**0.006**
Neuropsychologic	25 (5)	87 (10)	**<0.001**
Renal	4 (1)	0 (0)	**0.02**
Compromised Immunity	3 (1)	4 (1)	0.71
Neonatal	2 (0)	2 (0)	0.63
Other	109 (21)	155 (18)	0.12
None	167 (32)	323 (36)	0.09
Missing n=117 (8%)			
Associated Injuries (n (%))			
Head	217 (42)	84 (10)	**<0.001**
Thorax	374 (72)	655 (74)	0.39
Face	179 (34)	151 (17)	**<0.001**
Abdomen	183 (35)	272 (31)	0.10
Neck	77 (15)	352 (40)	**<0.001**
Spine	223 (43)	239 (27)	**<0.001**
Upper Extremity	178 (34)	294 (33)	0.73
Lower Extremity	191 (37)	114 (13)	**<0.001**
Other and external	70 (13)	61 (7)	**<0.001**
None	33 (6)	43 (5)	0.27

Data was complete for variables where no missing data are reported.

Table 4.8: Characteristics, Management, and Outcomes of Adult TIE patients according to ISS				
Injury Severity	Mild (ISS 0-9) (n=183)	Moderate (ISS 10-15) (n=172)	Severe (ISS 16-24) (n=400)	Critical (ISS ≥ 25) (n=621)
Demographics				
Age (mean yrs) (SD)	42.4 (19.4)	39.4 (17.4)	39.7 (18.0)	35.6 (17.2)
Male (n (%))	141 (77)	129 (75)	318 (80)	528 (85)
Race (n (%)) (missing n=59 (4%))				
White	114 (65)	89 (54)	200 (52)	271 (46)
Black	41 (23)	51 (31)	129 (34)	236 (40)
Other	21 (12)	25 (15)	54 (14)	87 (15)
Hispanic (n (%)) (missing n=201 (14%))	11 (7)	16 (11)	58 (17)	92 (17)
Vital Signs (n (%))				
HR >100 bpm (missing n=33 (2%))	55 (31)	61 (36)	162 (41)	277 (46)
SBP <80 mmHg (missing n=43 (3%))	3 (2)	5 (3)	32 (8)	127 (21)
GCS <13 (missing n=53 (4%))	19 (11)	41 (25)	102 (26)	296 (50)
O_2 Saturation <90% (missing n=241 (17%))	4 (3)	7 (5)	23 (7)	92 (18)
RR >20 bpm (missing n=78 (6%))	34 (19)	35 (21)	136 (35)	206 (36)
Trauma Center Level (n (%))				
I	101 (58)	105 (64)	263 (68)	439 (72)
II	56 (32)	51 (31)	103 (27)	149 (24)
III-IV	17 (10)	9 (5)	18 (5)	22 (4)
Missing n=45 (3%)				
Geographic Region (n (%))				
Midwest	52 (29)	30 (18)	69 (18)	132 (21)
Northeast	34 (19)	26 (15)	76 (19)	92 (15)
South	58 (32)	76 (45)	158 (40)	250 (41)
West	36 (20)	37 (22)	90 (23)	143 (23)
Missing n=17 (1%)				
Injury Mechanism (n (%))				
Penetrating	80 (44)	109 (63)	253 (63)	416 (67)
Cutting/piercing	63 (34)	63 (37)	97 (24)	44 (7)
Firearm	17 (9)	46 (27)	156 (39)	372 (60)
Blunt	103 (56)	63 (37)	147 (37)	205 (33)
Fall	23 (13)	21 (12)	33 (8)	24 (4)
Machinery	3 (2)	1 (1)	3 (1)	5 (1)
MVT	38 (21)	29 (17)	87 (22)	145 (23)
Pedal cyclist collision	4 (2)	1 (1)	0 (0)	0 (0)
Pedestrian collision	0 (0)	0 (0)	1 (0)	2 (0)
Strike	28 (15)	7 (4)	11 (3)	13 (2)
Transport collision	7 (4)	4 (2)	12 (3)	16 (3)
Overall Injury Severity (median [IQR])	8 [5,9]	13 [10,14]	18 [17,21]	34 [29,42]
Missing n=35 (2%)				
Esophageal Injury Grade (n (%))				
2	135 (74)	65 (38)	120 (30)	179 (29)
3	48 (26)	106 (62)	132 (33)	163 (26)
4	0 (0)	1 (1)	148 (37)	222 (36)
5	0 (0)	0 (0)	0 (0)	57 (9)
Comorbidities (n (%))				
Cardiopulmonary	81 (44)	64 (37)	135 (34)	154 (25)
Endocrine and Metabolic	16 (9)	12 (7)	42 (11)	47 (8)
Hepatobiliary	19 (10)	11 (6)	35 (9)	38 (6)
Hematologic	5 (3)	7 (4)	6 (2)	10 (2)
Health Status	1 (1)	4 (2)	8 (2)	8 (1)
Neuropsychologic	15 (8)	14 (8)	30 (8)	51 (8)
Renal	1 (1)	1 (1)	0 (0)	2 (0)
Compromised Immunity	1 (1)	0 (0)	2 (1)	4 (1)
Neonatal	0 (0)	0 (0)	0 (0)	4 (1)
Other	41 (22)	29 (17)	67 (17)	118 (19)
None	50 (27)	56 (33)	135 (34)	234 (38)
Missing n=117 (8%)				

Table 4.8: Characteristics, Management, and Outcomes of Adult TIE patients according to ISS (Continued)				
Injury Severity	Mild (ISS 0-9) (n=183)	Moderate (ISS 10-15) (n=172)	Severe (ISS 16-24) (n=400)	Critical (ISS ≥ 25) (n=621)
Associated Injuries (n (%))				
Head	21 (12)	23 (13)	73 (18)	180 (29)
Thorax	59 (32)	91 (53)	299 (75)	553 (89)
Face	24 (13)	47 (27)	98 (25)	157 (25)
Abdomen	12 (7)	38 (22)	93 (23)	299 (48)
Neck	48 (26)	65 (38)	123 (31)	177 (29)
Spine	20 (11)	43 (25)	131 (33)	259 (42)
Upper Extremity	26 (14)	56 (33)	133 (33)	243 (39)
Lower Extremity	14 (8)	20 (12)	75 (19)	193 (31)
Other and external	9 (5)	11 (6)	40 (10)	70 (11)
None	52 (28)	2 (1)	21 (5)	1 (0)
Procedures (n (%))				
Diagnostic	70 (38)	76 (44)	196 (49)	282 (45)
Therapeutic	15 (8)	20 (12)	78 (20)	179 (29)
None	9 (5)	3 (2)	5 (1)	15 (2)
Missing n=405 (29%)				
Procedures (n (%)) (patients with procedure data)	n=98	n=112	n=288	n=487
Diagnostic	70 (71)	76 (68)	196 (68)	282 (58)
Therapeutic	15 (15)	20 (18)	78 (27)	179 (37)
None	8 (8)	3 (3)	5 (2)	11 (2)
Time to 1st Procedure (any)	n=79	n=84	n=232	n=378
Median hr [IQR] (missing n=201 (26%))	3 [1,8]	2 [1,8]	2 [1,5]	1 [1,5]
Time to 1st Procedure (diagnostic)	n=70	n=76	n=196	n=282
Median hr [IQR] (missing n=175 (28%))	3 [1,8]	2 [1,10]	2 [1,6]	2 [1,6]
Time to 1st Procedure (therapeutic)	n=15	n=20	n=78	n=179
Median hr [IQR] (missing n=70 (24%))	4 [2,10]	2 [2,7]	3 [1,32]	2 [1,10]
Complications (n (%)) (missing n=63 (4%))				
Esophageal-related	10 (6)	14 (8)	74 (19)	168 (27)
Non-esophageal-related	8 (4)	11 (6)	59 (15)	165 (27)
Other	46 (25)	41 (24)	114 (29)	243 (39)
None	121 (66)	104 (61)	196 (49)	226 (36)
LOS (all patients) (median days [IQR])				
Hospitalization (missing n=3 (0%))	4 [2,8]	8 [4,13]	11 [6,20]	12 [1,26]
Intensive Care Unit (missing n=26 (2%))	3 [2,6]	3 [2,6]	6 [3,12]	8 [4,19]
LOS (survived to discharge) (median days [IQR])	n=178	n=168	n=374	n=407
Hospitalization (missing n=1 (0%))	4 [2,8]	8 [4,13]	12 [7,21]	20 [11,34]
Intensive Care Unit (missing n=17 (1%))	3 [2,5]	3 [2,6]	6 [3,12]	11 [6,21]
Ventilator Days (median [IQR]) Missing n=54 (4%)	3 [2,5]	2 [2,5]	4 [2,10]	5 [2,14]
Discharge Disposition (survived to discharge) (n (%))				
Rehab/further care	31 (18)	40 (25)	109 (31)	176 (44)
Discharge to home (any)	129 (75)	114 (71)	236 (66)	212 (53)
Other (hospice, law enforcement, etc)	6 (4)	3 (2)	8 (2)	13 (3)
Left AMA	5 (3)	3 (2)	2 (1)	0 (0)
Missing n=40 (3%))				
Mortality (n (%)) (missing n=40 (3%))	5 (3)	4 (2)	26 (7)	214 (35)

Data was complete for variables where no missing data are reported.

Table 4.9: Characteristics, Management, and Outcomes of Adult TIE patients according to Sex		
Sex	Male (n=1139)	Female (n=272)
Demographics		
Mean Age in yrs (SD)	36.6 (17.0)	44.9 (20.1)
Race (n (%)) (missing n=59 (4%))		
White	517 (47)	169 (66)
Black	417 (38)	59 (23)
Other	163 (15)	27 (11)
Hispanic Ethnicity (n (%)) (missing n=201 (14%))	152 (15)	28 (12)
Vital Signs (n (%))		
HR >100 bpm (missing n=33 (2%))	451 (41)	112 (42)
SBP <80 mmHg (missing n=43 (3%))	147 (13)	26 (10)
GCS <13 (missing n=53 (4%))	395 (36)	76 (29)
O_2 Saturation <90% (missing n=241 (17%))	101 (11)	25 (12)
RR >20 bpm (missing n=78 (6%))	335 (31)	85 (33)
Trauma Center Level (n (%)) (missing n=45 (3%))		
I	762 (69)	176 (67)
II	291 (26)	71 (27)
III-IV	49 (4)	17 (6)
Geographic Region (n (%)) (missing n=17 (1%))		
Midwest	229 (20)	55 (20)
Northeast	176 (16)	52 (19)
South	461 (41)	111 (41)
West	259 (23)	51 (19)
Injury Mechanism (n (%))		
Penetrating	751 (66)	137 (50)
Cutting/piercing	208 (18)	69 (25)
Firearm	543 (48)	68 (25)
Blunt	388 (34)	135 (50)
Fall	69 (6)	36 (13)
Machinery	12 (1)	0 (0)
MVT	221 (19)	79 (29)
Pedal cyclist collision	4 (0)	1 (0)
Pedestrian collision	2 (0)	1 (0)
Strike	50 (4)	9 (3)
Transport collision	30 (3)	9 (3)
Overall Injury Severity (median [IQR]) (missing n=35 (2%))	22 [16,33]	20 [13,29]
ISS (Categorical) (n (%)) (missing n=35 (2%))		
ISS 0-9 (mild)	141 (13)	42 (16)
ISS 10-15 (moderate)	129 (12)	43 (17)
ISS 16-24 (severe)	318 (28)	82 (32)
ISS ≥25 (critical)	528 (47)	93 (36)
Esophageal Injury Grade (n (%))		
2	389 (34)	111 (41)
3	389 (34)	80 (29)
4	313 (28)	70 (25)
5	48 (4)	11 (4)
Comorbidities (n (%))		
Cardiopulmonary	341 (30)	105 (39)
Endocrine and Metabolic	86 (8)	34 (13)
Hepatobiliary	85 (8)	19 (7)
Hematologic	19 (2)	9 (3)
Health Status	13 (1)	8 (3)
Neuropsychologic	98 (9)	14 (5)
Renal	4 (0)	0 (0)
Compromised Immunity	6 (1)	1 (0)
Neonatal	3 (0)	1 (0)
Other	208 (18)	56 (21)
None	407 (36)	83 (31)
Missing n=117 (8%)		

Table 4.9: Characteristics, Management, and Outcomes of Adult TIE patients according to Sex (Continued)		
Sex	Male (n=1139)	Female (n=272)
Associated Injuries (n (%))		
Head	233 (21)	68 (25)
Thorax	850 (75)	179 (66)
Face	257 (23)	73 (27)
Abdomen	372 (33)	83 (31)
Neck	342 (30)	87 (32)
Spine	363 (32)	99 (36)
Upper Extremity	371 (33)	101 (37)
Lower Extremity	246 (22)	59 (22)
Other and external	98 (9)	33 (12)
None	57 (5)	19 (7)
Procedures (n (%))		
Diagnostic	508 (45)	126 (46)
Therapeutic	246 (22)	51 (19)
None	20 (2)	7 (3)
Missing n=405 (29%)		
Procedures (n (%)) (patients with procedure data)	n=824	n=182
Diagnostic	508 (62)	126 (69)
Therapeutic	246 (30)	51 (28)
None	20 (2)	7 (4)
Time to 1st Procedure (any)	n=638	n=148
Median hr [IQR] (missing n=201 (26%))	2 [1,5]	2 [1,6]
Time to 1st Procedure (diagnostic)	n=508	n=126
Median hr [IQR] (missing n=175 (28%))	2 [1,7]	2 [1,5]
Time to 1st Procedure (therapeutic)	n=246	n=51
Median hr [IQR] (missing n=70 (24%))	2 [1,10]	8 [2,24]
Complications (n (%)) (missing n=63 (4%))		
Esophageal-related	231 (20)	47 (17)
Non-esophageal-related	196 (17)	52 (19)
Other	371 (33)	99 (36)
None	532 (47)	122 (45)
Length of Stay (all patients) (median days [IQR])		
Hospitalization (missing n=3 (0%))	10 [2,20]	9 [3,20]
Intensive Care Unit (missing n=26 (2%))	6 [3,14]	5 [3,13]
Length of Stay (survived to discharge) (median days [IQR])	n=920	n=237
Hospitalization (missing n=1 (0%))	12 [6,23]	11 [5,23]
Intensive Care Unit (missing n=17 (1%))	7 [3,15]	5 [3,14]
Ventilator Days (median [IQR]) (missing n=54 (4%))	4 [2,12]	4 [2,9]
Discharge Disposition (survived to discharge) (n (%))		
Rehab/further care	275 (31)	89 (39)
Discharge to home (any)	579 (65)	134 (59)
Other (hospice, law enforcement, etc)	27 (3)	3 (1)
Left AMA	9 (1)	1 (0)
Missing n=40 (3%))		
Mortality (n (%)) (missing n=40 (3%))	219 (20)	35 (13)

Data was complete for variables where no missing data are reported.

Table 4.10: Characteristics, Management, and Outcomes of Adult TIE patients according to Trauma Center Level			
Trauma Center Level	I (n=938)	II (n=362)	III-IV (n=66)
Demographics			
Age (mean yrs) (SD)	37.3 (17.2)	39.2 (19.0)	43.5 (19.1)
Male (n (%))	762 (81)	291 (80)	49 (74)
Race (n (%)) (missing n=59 (4%))			
White	443 (49)	182 (53)	40 (69)
Black	345 (38)	102 (30)	13 (22)
Other	123 (14)	60 (17)	5 (9)
Hispanic Ethnicity (n (%)) (missing n=201 (14%))	120 (14)	52 (17)	6 (12)
Vital Signs (n (%))			
HR >100 bpm (missing n=33 (2%))	385 (42)	143 (40)	20 (31)
SBP <80 mmHg (missing n=43 (3%))	120 (13)	42 (12)	11 (17)
GCS <13 (missing n=53 (4%))	330 (37)	111 (32)	5 (10)
O_2 Saturation <90% (missing n=241 (17%))	85 (11)	35 (12)	5 (10)
RR >20 bpm (missing n=78 (6%))	284 (32)	107 (31)	13 (21)
Geographic Region (n (%)) (missing n=17 (1%))			
Midwest	187 (20)	70 (19)	8 (13)
Northeast	167 (18)	56 (16)	2 (3)
South	408 (44)	115 (32)	33 (52)
West	168 (18)	120 (33)	21 (33)
Injury Mechanism (n (%))			
Penetrating	617 (66)	225 (62)	25 (38)
Cutting/piercing	174 (19)	82 (23)	12 (18)
Firearm	443 (47)	143 (40)	13 (20)
Blunt	321 (34)	137 (38)	49 (74)
Fall	62 (7)	26 (7)	12 (18)
Machinery	8 (1)	2 (1)	1 (2)
MVT	192 (21)	79 (22)	19 (29)
Pedal cyclist collision	2 (0)	2 (1)	0 (0)
Pedestrian collision	1 (0)	2 (1)	0 (0)
Strike	34 (4)	16 (4)	6 (9)
Transport collision	22 (2)	10 (3)	3 (5)
Overall Injury Severity (median [IQR]) (missing n=35 (2%))	24 [16,34]	20 [13,30]	18 [9,28]
ISS (Categorical) (n (%)) (missing n=35 (2%))			
ISS 0-9 (mild)	101 (11)	56 (16)	17 (26)
ISS 10-15 (moderate)	105 (12)	51 (14)	9 (14)
ISS 16-24 (severe)	263 (29)	103 (29)	18 (27)
ISS ≥25 (critical)	439 (48)	149 (42)	22 (33)
Esophageal Injury Grade (n (%))			
2	328 (35)	128 (35)	29 (44)
3	301 (32)	129 (36)	20 (30)
4	268 (29)	91 (25)	13 (20)
5	41 (4)	14 (4)	4 (6)
Comorbidities (n (%))			
Cardiopulmonary	299 (32)	117 (32)	17 (26)
Endocrine and Metabolic	89 (10)	23 (6)	5 (8)
Hepatobiliary	71 (8)	29 (8)	1 (2)
Hematologic	21 (2)	7 (2)	0 (0)
Health Status	14 (2)	6 (2)	1 (2)
Neuropsychologic	85 (9)	22 (6)	3 (5)
Renal	1 (0)	2 (1)	0 (0)
Compromised Immunity	4 (0)	3 (1)	0 (0)
Neonatal	4 (0)	0 (0)	0 (0)
Other	171 (18)	67 (19)	16 (24)
None	311 (33)	137 (38)	25 (38)
Missing n=117 (8%)			

Table 4.10: Characteristics, Management, and Outcomes of Adult TIE patients according to Trauma Center Level (Continued)			
Trauma Center Level	I (n=938)	II (n=362)	III-IV (n=66)
Associated Injuries (n (%))			
Head	201 (21)	74 (20)	19 (29)
Thorax	707 (75)	250 (69)	39 (59)
Face	224 (24)	83 (23)	14 (21)
Abdomen	318 (34)	105 (29)	24 (36)
Neck	297 (32)	111 (31)	12 (18)
Spine	326 (35)	106 (29)	17 (26)
Upper Extremity	321 (34)	125 (35)	14 (21)
Lower Extremity	210 (22)	78 (22)	11 (17)
Other and external	88 (9)	35 (10)	7 (11)
None	48 (5)	15 (4)	9 (14)
Procedures (n (%))			
Diagnostic	444 (47)	149 (41)	22 (33)
Therapeutic	226 (24)	58 (16)	7 (11)
None	16 (2)	15 (4)	0 (0)
Missing n=405 (29%)			
Procedures (n (%)) (patients with procedure data)	n=692	n=246	n=38
Diagnostic	444 (64)	149 (61)	22 (58)
Therapeutic	226 (33)	58 (24)	7 (18)
None	11 (2)	15 (6)	0 (0)
Time to 1st Procedure (any)	n=559	n=178	n=27
Median hr [IQR] (missing n=201 (26%))	2 [1,6]	1 [1,4]	2 [1,2]
Time to 1st Procedure (diagnostic)	n=444	n=149	n=22
Median hr [IQR] (missing n=175 (28%))	2 [1,9]	1 [1,3]	1 [1,2]
	120 (27)	44 (30)	9 (41)
Time to 1st Procedure (therapeutic)	n=226	n=58	n=7
Median hr [IQR] (missing n=70 (24%))	3 [1,16]	3 [2,8]	2 [2,2]
Complications (n (%)) (missing n=63 (4%))			
Esophageal-related	224 (24)	40 (11)	6 (9)
Non-esophageal-related	200 (21)	42 (12)	1 (2)
Other	334 (36)	107 (30)	13 (20)
None	392 (42)	195 (54)	45 (68)
Length of Stay (all patients) (median days [IQR])			
Hospitalization (missing n=3 (0%))	11 [4,22]	8 [2,17]	2 [1,8]
Intensive Care Unit (missing n=26 (2%))	7 [3,15]	5 [2,10]	6 [2,10]
Length of Stay (survived to discharge) (median days [IQR])	n=762	n=303	n=53
Hospitalization (missing n=1 (0%))	14 [7,26]	10 [4,19]	3 [1,10]
Intensive Care Unit (missing n=17 (1%))	7 [4,16]	5 [3,11]	6 [3,14]
Ventilator Days (median [IQR]) (missing n=54 (4%))	5 [2,12]	4 [2,10]	3 [1,10]
Discharge Disposition (survived to discharge) (n (%))			
Rehab/further care	236 (31)	105 (36)	16 (42)
Discharge to home (any)	496 (66)	175 (60)	21 (55)
Other (hospice, law enforcement, etc)	19 (3)	9 (3)	1 (3)
Left AMA	6 (1)	3 (1)	0 (0)
Missing n=40 (3%))			
Mortality (n (%)) (missing n=40 (3%))	176 (19)	59 (17)	13 (25)

Data was complete for variables where no missing data are reported.

CHAPTER 5: BIBLIOGRAPHY

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