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The Effect of Associated Vascular Injuries in Penetrating Trauma to the Duodenum and Pancreas

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Abstract

Objectives: Major vascular injuries contribute significantly to the mortality of pancreatic and duodenal trauma. We hypothesized that in the setting of penetrating trauma to the pancreas and/or duodenum, independent predictors of mortality associated with vascular injuries could be identified. Our objectives in this study were to describe the national profile of major vascular injuries as well as to identify predictors of morbidity and mortality.
Methods: Using the abbreviated injury scale 2005 and ICD-9-CM E-codes, we identified 597 penetrating pancreatic, duodenal, and pancreaticoduodenal trauma patients with major vascular injuries from the NTDB between 2010 and 2014. We controlled patient-level covariates of age, biological sex, systolic blood pressure (SBP), Glasgow coma score (GCS), pulse, injury severity score (ISS), and organ injury scale (OIS) grade. We estimated multivariable generalized linear mixed models to account for the nesting of patients within trauma centers.
Results: Our results indicated an overall mortality rate of 26.1%. Approximately 19% of patients died within 24 hours of admission, and of those, 78% died in the first 6 hours. The inferior vena cava was the most commonly injured vessel. The average number of associated injuries was 4.9 in pancreatic or duodenal trauma and 5.4 in pancreaticoduodenal. Statistically significant independent predictors of mortality were firearm mechanism, SBP, GCS, and pulse. Specifically, odds of death were decreased with a 10-mmHg higher admission SBP (7.7% decreased odds), one-point higher GCS (12.8%), and a 10-beat lower pulse (11.6%).
Conclusions: This study is the first to examine the effect of major vascular injuries in the setting of penetrating trauma to the pancreas and/or duodenum utilizing the NTDB. We have identified patterns of injury and statistically significant independent predictors of morbidity and mortality.

Keywords: Abdominal Vascular Trauma, Penetrating Trauma, Tiger Country, National Trauma Data Bank

1. Background

This study examines the effect of vascular injuries that occur in association with penetrating trauma to the pancreas and/or duodenum. Many surgeons have appreciated the lethality of injuries to the c-loop of the duodenum, pancreatic body, and surrounding vascular structures. The rarity, anatomic location, and frequency of associated organ and vascular injuries render this area formidable. In single institutional studies, major vascular injuries occur in 26% - 48% of duodenal trauma (1, 2). 16% - 52% in pancreatic (3, 4) and 46% - 67% in pancreaticoduodenal (5, 6). Most cases of acute mortality in these patients results from hemorrhage, exsanguination, and shock (6-10).

However, the effect of major vascular injuries in this patient population has never been reported utilizing the National Trauma Data Base (NTDB). As such, our objectives were to describe the national profile of major vascular injuries as well as to identify predictors of morbidity and mortality in the setting of penetrating trauma to an area that we have previously described as "Tiger Country."

2. Methods

2.1. Data Source and Study Population

The American College of Surgeons created the framework for a national data collection system in 1987, which was established to aggregate data from trauma centers throughout the United States for analyses and to promote improved patient outcomes (11). The National Trauma Data Bank collects data from approximately 900 trauma centers that voluntarily participate within the United States (11) and we identified trauma patients listed from the period January 1, 2010 to December 31, 2014. Although the NTDB contains data prior to 2010, the collection system was not well established before this time due to poor adherence in mandatory reporting (12).

Patients were identified by the presence of a penetrating injury based on the ICD-9-CM E-codes and included firearm (922.0 - 922.3, 922.8 - 922.9, 955.0 - 955.4, 965.0 - 965.4, 970, 979.4 or 985.0 - 985.4) and cut/pierce (920.0 - 920.9, 956, 966, 974 or 986) injuries. Within these patients, we used abbreviated injury scale 2005 with 2008 update (AIS05) scoring to identify individuals with a duodenal (541010.2, 541021.2, 541022.2, 541023.3, 541024.4 or 541028.5) and/or pancreatic injury (542812.2, 542814.3, 542822.2, 542824.3, 542826.4, 542828.4, 542830.4 or 542832.5) (Appendix 1 in Supplementary File) who also had at least one associated vascular injury (4202xx.x, 4218xx.x, 5202xx.x, 5204xx.x, 5206xx.x, 5208xx.x, 5210xx.x, 5211xx.x, 5212xx.x, 5214xx.x, 5216xx.x, or 543800.2) (Appendix 2 in Supplementary File). We included only patients for whom complete data was available for age, biological sex, admission systolic blood pressure (SBP), admission total Glasgow coma scale (GCS) score, admission pulse, admission injury severity score (ISS-ICD), mechanism of injury (i.e., firearm vs. cut/pierce), and in-hospital mortality. We excluded patients younger than 15 years of age, patients who had multiple pancreatic AIS05 scores, and patients with obviously mis-coded values (e.g., GCS > 15). "Retroperitoneal hemorrhage or hematoma" (AIS05 543800.2) was initially reported but excluded from statistical analyses given its imprecise and broad definition, as well as the fact that a large number of injured structures could have led to its formation. Based on these criteria, a total of 597 patients were included in our final sample (Figure 1). Note that given the de-identified nature of these data, it was not possible to determine if any individual patient had sustained multiple traumatic events, as such all 597 cases were considered mutually exclusive.

2.2. Outcomes

Our primary outcome was in-hospital mortality defined using hospital and emergency department discharge disposition. Secondary outcomes included total in-hospital length of stay, ICU length of stay, and number of days on ventilator, all of which were modeled using only patients who were discharged alive. To provide further detail of our sample, we also evaluated time-to-death, procedure codes, associated injuries by AIS05, as well as comorbid conditions, complication rates, and discharge disposition.

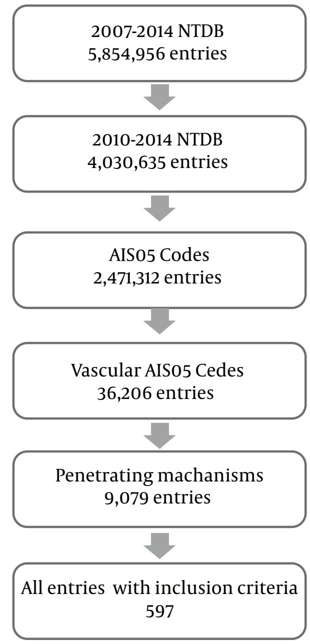

Figure 1. Identifying the sample set

2.3. Predictors of Mortality, Length of Stay, and Ventilator Days

Haider has previously described five "basic minimum" covariates to improve the reliability and generalizability of NTDB outcome studies: age, sex, anatomic severity, physiologic severity, and type of injury (13). Therefore, we collected patient-level covariates that included age, biological sex, SBP, GCS, pulse, and ISS-ICD. We also estimated each patient's organ injury scale (OIS) grade based on their duodenal and/or pancreatic AIS05 score. Duodenal AIS05 codes correlate well to most of the OIS grades, except grades I and II, which could not be separated with unique codes as hematoma is defined in both grades (Appendix 1 in Supplementary File). As such, grades I and II were necessarily grouped together for patients with duodenal injuries. With that said, we could not include OIS scores in any multivariable model because a pancreatic OIS score would be missing for patients with only a duodenal injury, likewise a duodenal OIS score would be missing for patients with only a pancreatic injury. Because these multivariable models are "complete data" techniques, any patient missing at least one data point would be excluded from analysis. As such, the multivariable model that included OIS scores would be based only on the 64 patients who had a pancreaticoduodenal injury.

2.4. Statistical Analysis

Clinical and demographic characteristics are presented as mean and standard deviation or median and interquartile range for continuous variables, compared using the Mann-Whitney test, whereas categorical variables are presented as frequency and percent, compared using the Chi-square test. All multivariable models accounted for the nesting of patients within trauma facilities. We estimated a mixed-effects logistic regression model to predict mortality, whereas mixed-effects negative binomial regression models were estimated for length of stay and ventilator days. We examined expected frequencies for inclusion of categorical variables and evaluated continuous variable with LOESS models to determine if polynomial terms were relevant. Two-way interaction terms were considered based on clinical relevance of their impact on each outcome. All analyses were conducted using SAS version 9.4 (SAS Institute Inc., Cary, NC). A complete description of the statistical methods can be requested from authors SA or RWW and is included as a Supplementary File.

This study did not directly involve human participants and/or animals. As such, informed consent was not required. External sources of funding were not used in either the preparation or submission of this manuscript and institutional IRB approval was not required for this study.

3. Results

3.1. Patient Demographic and Clinical Characteristics

We identified 597 patients from the NTDB that met inclusion criteria (Figure 1). Clinical and demographic characteristics are presented in Table 1 (Appendices 3 - 5 in Supplementary File). Overall, 26.1% of patients died from their traumatic injuries. Interestingly, this mortality rate did not change significantly across the 5-year study period (Appendix 6 in Supplementary File). The mortality of vascular injuries was 29.8% in duodenal trauma, 33.2% in pancreatic, and 41.8% in pancreaticoduodenal (Figure 2). When considering all 597 patients, the most common vascular injuries were retroperitoneal hemorrhage/hematoma (38.4%), followed by injuries to the inferior vena cava (IVC; 32.8%), other named veins (26.2%; defined by AIS05 as portal, renal, splenic, and superior mesenteric veins) and other named arteries (20.8%; defined as hepatic, renal, and splenic arteries) (Table 2). A similar pattern of injuries to the IVC, other named veins, and other named arteries held for the 295 patients with duodenal injury without associated pancreatic injury. However, in the 238 patients with a pancreatic injury in the absence of a duodenal injury, retroperitoneal hemorrhage/hematoma was observed in 34.9% of patients, followed by injuries to other named veins (34.0%), other named arteries (28.6%), and to the IVC (22.3%), whereas in the 64 patients with a pancreaticoduodenal injury, an injury to the IVC was observed in 51.6% of patients followed by injuries to other named veins (37.5%), and retroperitoneal hemorrhage/hematoma in 31.3%.

Table 1. Descriptive Statistics (N = 597)[a]

Descriptive Statistics	Values
Age	28 [23 - 39]
SBP	118 ± 31
Pulse	104 ± 27
GCS	15 [12 - 15]
ISS (ICD)	17 [10 - 25]
Hospital LOS, d	14 [6 - 26]
ICU LOS, d[b]	5 [2 - 12]
Ventilator, d[c]	4 [2 - 10]
Male	523 (88)
Mechanism	
Firearm	514 (86)
Cut/Pierce	83 (14)

[a]Values are expressed as mean ± SD, No. (%), or median [IQR].
[b]n = 480.
[c]n = 420.

Figure 2. Mortality by type of vascular injury (defined by AIS05). 'All major vascular' includes all arterial and all venous, as listed below. 'All arterial' includes the thoracic aorta, celiac artery, iliac artery, superior mesenteric artery, and other named arteries (hepatic, renal, and splenic). 'All venous includes the superhepatic IVC, common iliac vein, internal and external iliac vein, and other named veins (portal, renal, splenic, and superior mesenteric).

When considering all 597 patients, arterial injuries carried a higher mortality rate relative to venous injuries (40.3% vs. 33.4%, respectively), with injuries to the thoracic or abdominal aorta having the highest mortality rate (85.7% and 64.7%, respectively) (Figure 2). In patients with a duodenal injury in the absence of pancreatic injury, mortality was highest with concurrent injury to the abdominal aorta (68.2%) and internal/external iliac vein (66.7%), whereas in patients with a pancreatic injury in the absence of duodenal injury, mortality was highest with concurrent injury to the thoracic aorta (100%) or superior mesenteric artery (63.2%). Finally, in patients with a pancreaticoduodenal injury, associated injury to the abdominal aorta carried an 80.0% mortality rate whereas injuries to other named veins had a 54.2% mortality rate.

Patients with a pancreaticoduodenal and vascular injury had on average 5.4 additional associated injuries (Appendix 7 in Supplementary File), whereas patients with ei-

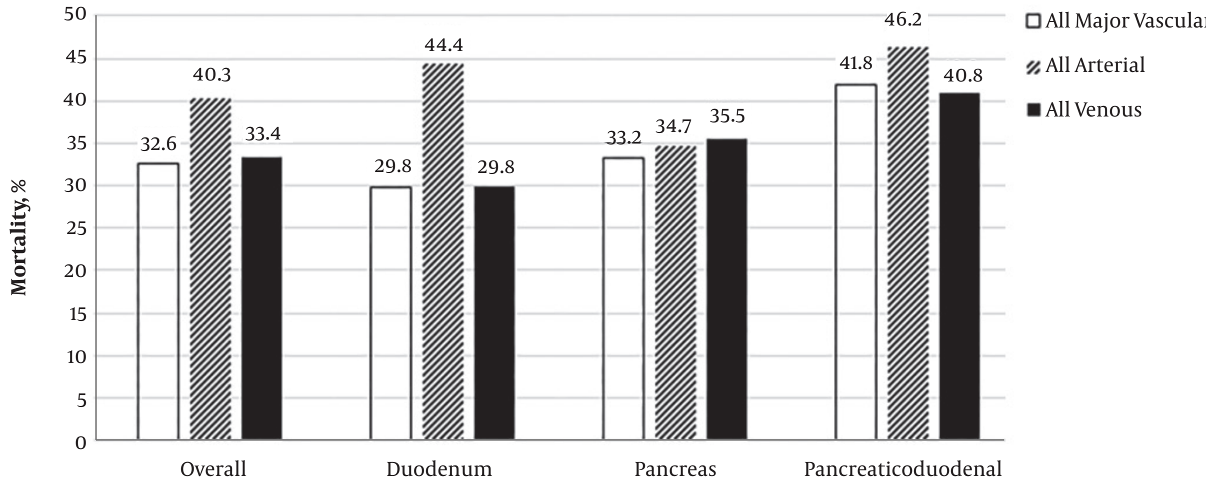

Figure 2. Mortality by type of vascular injury (defined by AIS05). 'All major vascular' includes all arterial and all venous, as listed below. 'All arterial' includes the thoracic aorta, abdominal aorta, celiac artery, iliac artery, superior mesenteric artery, and other named arteries (hepatic, renal, and splenic). 'All venous includes the superhepatic IVC, common iliac vein, internal and external iliac vein, and other named veins (portal, renal, splenic, and superior mesenteric).

Table 2. Frequency and Mortality (%) by Vascular Injury[a]

Definition	Overall		Duodenum		Pancreas		Pancreatico-Duodenal	
	Count	Mortality	Count	Mortality	Count	Mortality	Count	Mortality
Thoracic aorta	7	85.7	2	50.0	5	100.0	0	-
Abdominal aorta	51	64.7	22	68.2	19	52.6	10	80.0
Celiac artery	4	50.0	0	-	4	50.0	0	-
Iliac artery	16	50.0	14	50.0	1	100.0	1	-
Iliac vein	17	41.2	11	54.6	3	33.3	3	-
All arterial	226	40.3	99	44.4	101	34.7	26	46.2
SMA	55	40.0	25	24.0	19	63.2	11	36.4
Other named veins	157	38.2	52	34.6	81	35.8	24	54.2
IVC	217	33.7	122	28.7	61	41.0	33	39.4
All venous	341	33.4	168	29.8	124	35.5	49	40.8
All major vascular	448	32.6	215	29.8	178	33.2	55	41.8
Other named arteries	124	32.3	44	47.7	68	20.6	12	41.7

Abbreviations: IVC, inferior vena cava; SMA, superior mesenteric artery.
[a]Per AIS05, 'Other named arteries' is defined as hepatic, renal, splenic arteries. 'Other named veins' is defined as portal, renal, splenic, and superior mesenteric veins.

ther a duodenal or pancreatic injury in conjunction with a vascular injury averaged 4.9 additional injuries. Associated injuries to the liver were observed in 49.7% of patients, whereas 42.7% of patients had associated injuries to the colon and 34.3% to the stomach (Appendices 8 and 9 in Supplementary File). Injury to the diaphragm had the highest mortality rate at 36.2% followed by pneumothorax/hemothorax and colon (32.2% and 30.2%, respectively).

Regarding procedures, an exploratory laparotomy was performed in 477 patients with 405 patients requiring reexploration (Appendices 10 and 11 in Supplementary File). Excluding laparotomy, the most common procedures involved the colon (42.5%) and the small intestine (36.9%) (Appendix 12 in Supplementary File). The highest mortality related to procedures involved the liver (32.0%) and spleen (27.4%). Six patients underwent a Whipple procedure, which had an associated 16.7% mortality. Also, 53 patients underwent CPR with an associated mortality of

73.6%. Finally, transfusions of blood products were administered to 313 patients with an associated mortality of 30.7%, 178 patients required plasma/coagulation factors (mortality rate: 32.6%), and 178 patients required platelets (mortality rate: 31.1%).

The most frequently reported comorbid conditions included smoking (20.3%), drug use (9.0%), and alcohol use disorder (8.0%). The most common in-hospital complications included pneumonia (12.2%), acute kidney injury (9.7%), and deep vein thrombosis (8.0%) (Appendix 13 in Supplementary File).

3.2. Patient Characteristics of Early Deaths

Of the 156 patients who died during their hospital stay, 114 (73.1%) deaths occurred within the first 24 hours after admission, which we defined as "Early Deaths" (Figure 3). Of these early deaths, 89 (78.1%) occurred within the first six hours of admission. When comparison to patients who died, but had longer than a 24-hour length of stay, patients experiencing Early Death were significantly younger (30.5 vs. 34.5 years, P = .037), but had statistically similar demographic data for admission SBP (112 vs. 107.5 mmHg), pulse rate (115 vs. 104.5 bpm), ISS (18 vs. 18.5), and GCS (12.5 vs. 14.5). Both groups had similar proportions of males (90.4% vs. 83.3%) and firearm-related injuries (93.9% vs. 88.1%). Further, all patients experiencing Early Death had at least one vascular injury, with 44.7% having a dual arterial and venous injury, 38.6% having a venous injury, and the remaining 16.7% having an arterial injury. Regarding the most common vascular injuries, the IVC was affected in 43.0% of early deaths, followed by other named veins (37.7%), and other named arteries (29.0%). Similar percentages were observed in patients who died within six hours of admission. For non-vascular associated injuries, 56.1% of patients suffering Early Death sustained an associated injury to the liver, 48.2% had an associated colon injury, and 36.0% had an injury to the stomach (Appendix 14 in Supplementary File). Laparotomy was the most common procedure (81.6%). In addition, packed cells were transfused in 70.2% of patients, serum in 47.4%, and platelets in 39.5%.

3.3. Predictors of Mortality

Using all 597 patients, we next examined the relationship between patient clinical and demographic characteristics and mortality. Prior to analysis, the adequacy of expected frequencies was assured for biological sex and mechanism of injury; all continuous predictors were found to have a linear functional form and no statistically significant contextual effects were indicated. Results indicated that, holding all other predictor variables constant, a 10-mmHg increase in admission SBP was associated with

Table 3. Significant Independent Predictors of Outcome

Independent Predictor	P Value
Mortality	
↓ SBP	0.013
↓ GCS	< 0.001
↑ Pulse	0.009
Firearm mechanism (vs. cut/pierce)	0.030
Hospital length of stay	
↑ Age	0.003
↑ Pulse	< 0.001
↑ ISS	< 0.001
Firearm mechanism (vs. cut/pierce)	< 0.001
ICU length of stay	
↑ Age	< 0.001
GCS = 3	0.005
GCS = 15	0.001
↑ Pulse	< 0.001
↑ ISS	0.014
Firearm mechanism (vs. cut/pierce)	0.001
Ventilator days	
↑ Age	0.004
↑ Pulse	< 0.001

7.7% lower odds of dying (P = 0.013), a one-point increase in GCS was associated with lower odds of dying by 12.8% (P < 0.001), a 10-bpm pulse increase was associated with 11.6% higher odds of dying (P = 0.009), and patients with a firearm injury had 2.1 times higher odds of dying relative to those with cut/pierce injuries (P = 0.03) (Table 3 and Figure 4).

3.4. Predictors of Hospital and ICU Length of Stay and Days on Ventilator

Next, we evaluated predictors of hospital and ICU length of stay as well as days on mechanical ventilation for the 441 patients who were discharged alive (Table 3 and Appendices 15 - 17 in Supplementary File). Median hospital length of stay was 14 days (IQR: 6 to 26 days), with a one-year increase in age associated with 0.8% longer hospital length of stay (P = 0.003), a 10-bpm increase in admission pulse rate associated with an 8.3% increased hospital length of stay (P < 0.001), a 10-point increase in ISS associated with an 11.6% increased hospital length of stay (P < 0.001), and a firearm injury associated with a 56.8% increased length of stay compared to a cut/pierce injury (P < 0.001).

When predicting ICU length of stay (median: 6 days; IQR: 3 to 15 days), a one-year increase in age was associ-

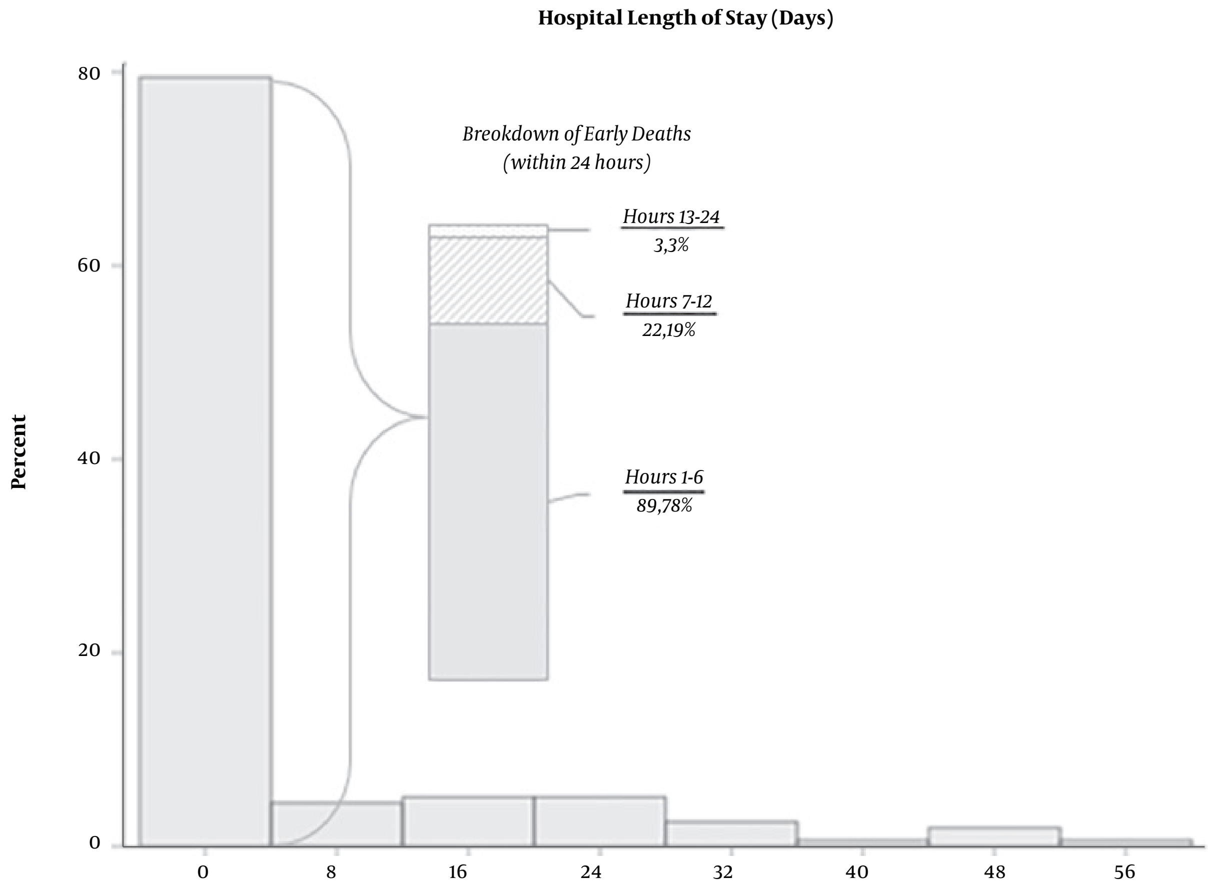

Figure 3. Distribution of time to death (N = 156). Bars represent hospital length of stay for parents who died (N = 156). Approximately 73.1% of patients had ≤ 1-day length of stay (n = 114).

ated with 1.4% longer length of stay ($P < 0.001$), a 10-bpm increase in admission pulse rate was associated with an 11.6% longer ICU stay ($P < 0.001$), a 10-point ISS increase was associated with a 10.5% increase in ICU stay ($P = 0.014$), and a firearm injury increased length of stay by 58.4% relative to a cut/pierce injury ($P = 0.001$). Further, a significant quadratic effect was found for GCS ($P < 0.001$), such that the although the effect of increasing GCS was associated with shorter ICU length of stay the association was weaker in patients with higher GCS scores.

Finally, when predicting ventilator days (median: 4 days; IQR: 2 to 10 days), results indicated that a one-year increase in age was associated with 1.4% more ventilator days ($P = 0.004$), whereas a 10-bpm pulse rate increase was associated with 9.3% increase in ventilator days ($P < 0.001$).

4. Discussion

This study examines the effect of major vascular injuries within the setting of penetrating trauma to the pancreas and/or duodenum using the National Trauma Data Bank. From years 2010 to 2014, the incidence of pancreatic, duodenal, and pancreaticoduodenal trauma was 0.12%, 0.13%, and 0.02%, respectively. Despite the rarity of these injuries, the proximity to major vascular structures presents a significant challenge to trauma surgeons. Major vascular injuries contribute significantly to the mortality of penetrating pancreatic and duodenal trauma (3, 14) with rates ranging from 25% to 74% (3, 6, 15, 16). In the literature, the inferior vena cava (IVC) is the most commonly affected vessel, accounting for 21% - 43% of vascular injuries (3, 5, 10, 15, 17-19). In addition, associated IVC injuries have been documented as an independent predictor of mortality (20). In our study, IVC injuries were also the most common affected vessel (36%) and had a 34% mortality rate. Blocksom

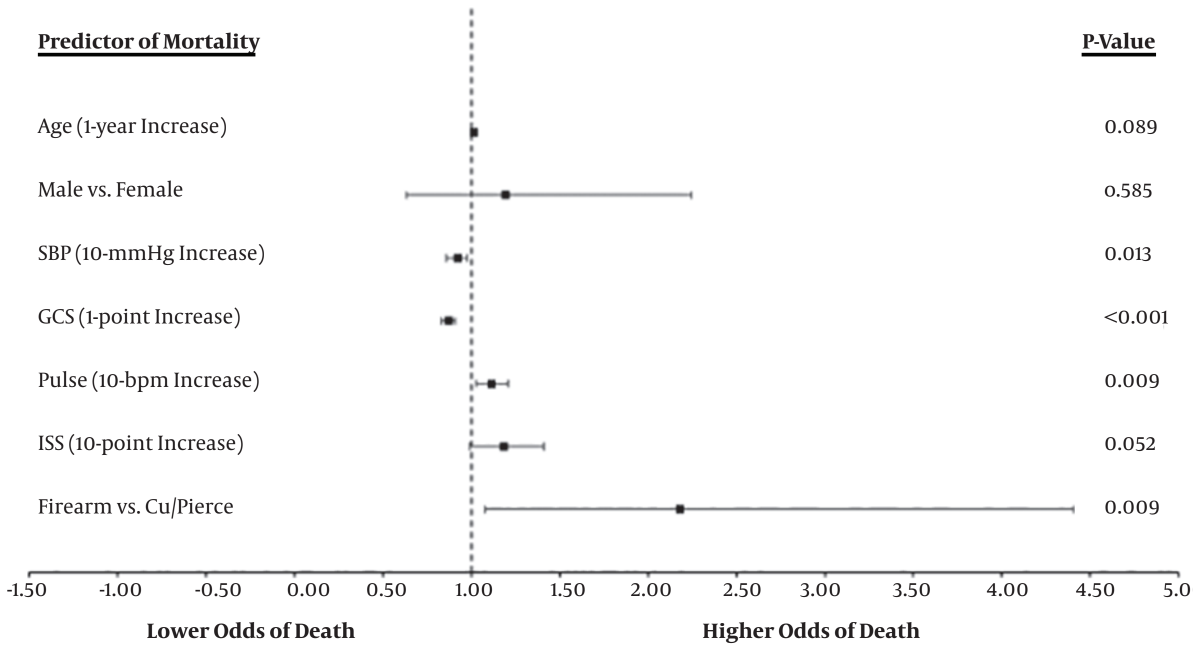

Figure 4. Forrest plot of predictors of mortality

et al. (21) reported 142 major vascular injuries and, of these, 33% were arterial and 67% were venous with mortality rates of 40% and 34%, respectively. Similarly, we found 38% arterial and 57% venous injuries with mortality rates of 40% and 33%, respectively. In our analysis, of all arterial injuries, those to the thoracic aorta were the most lethal (7/226; 86% mortality). Within venous injuries, those to the internal or external iliac vein had the highest mortality (8/341; 50% mortality) (Table 2).

In his study of 79 patients with pancreatic trauma, Krige et al. (3) found that mortality increased threefold in the presence of major vascular injuries ($P < 0.01$), major visceral venous injuries ($P < 0.01$), and with the combination of vascular and associated organ injuries ($P < 0.04$). Tyburski et al. (4) found a significant difference in the occurrence of major vascular injuries between patients with duodenal, pancreatic, and pancreaticoduodenal ($P < 0.05$ between each group). Specifically, vascular injuries were found significantly more often in pancreaticoduodenal trauma (62%), followed by the duodenum (39%) and then the pancreas (16%) (4). Interestingly, we found the opposite trend with duodenal trauma accounting for 48% of the vascular injuries, pancreas 40%, and pancreaticoduodenal 12%. This difference may be attributed to the difference in samples size with 53 vascular injuries in Tyburski et al. study (4) and 597 in the current study. However, we did find a similar pattern in mortality with the highest rate in pancreaticoduodenal injuries, followed by pancreatic and then duodenal (42%, 33%, and 30%, respectively) (Figure 2).

4.1. Early Deaths

In our study, 73% of deaths occurred within 24 hours from admission. Of those patients, 78% died within 6 hours (Figure 3). It is widely suspected that vascular injuries contribute to this high proportion of early deaths. However, these findings have not been previously reported in the published literature. This is one of the most important pieces of data from our analysis and should be a major consideration when trauma surgeons try to improve overall outcomes associated with these injuries: over 70% of deaths occur in the first 24 hours and of these, nearly 80% die within the first 6 hours.

Antonacci reported that hemodynamic status on admission was a statistically significant predictor of mortality (22). Blocksom found that an initial systolic blood pressure < 90 mmHg in patients with duodenal trauma was associated with a 46% mortality rate compared to 4% in patients not in shock (21). Vasquez reported that patients admitted in shock had a significantly higher risk of dying ($P < 0.001$) and most died within 24 hours from admission (9). Similarly, we found that SBP and pulse were statistically significant independent predictors of mortality (Table 3 and Figure 4). Patients with early deaths had more transfusions of packed cells (70.2% vs. 52.4% overall), serum (47.4% vs.

39.4%), and platelets (39.5% vs. 29.8%), which also suggest a correlation between vascular injuries and acute mortality.

4.2. Associated Injuries

In our study, the average number of associated injuries was 4.9 in patients with either pancreatic or duodenal trauma and 5.4 in pancreaticoduodenal trauma (Appendices 9 and 14 in Supplementary File). Previous studies on pancreatic and duodenal trauma have not reported on associated injuries specifically within patients with vascular injuries. In the setting of pancreatic or duodenal trauma regardless of vascular involvement, the liver and colon are most commonly injured (21, 22). We found similar patterns of associated injuries with liver occurring in 50% and colon in 43% (Appendix 8 in Supplementary File).

4.3. Procedures

Procedures are reported using ICD-9 p-codes in the NTDB. Thus, only rudimentary information is available, and details on trauma-specific procedures cannot be elucidated. In our study, 77% of patients underwent an exploratory laparotomy and, of those, 88% had at least one reoperation (Appendix 11 in Supplementary File). This high frequency of re-operation is likely reflective of widespread use of damage control surgery. In fact, Rickard et al. (23) noted that damage control and reoperation were commonly required due to the frequency of vascular injuries associated with pancreatic and duodenal trauma. In our study, most of the patients who died early were taken to the OR (82%). Since 78% of early deaths happened in the first 6 hours of admission, it is likely that these deaths occurred during or shortly after surgery.

Six patients underwent a traumatic pancreaticoduodenectomy (Whipple procedure) with a mortality rate of 16.7%. Interestingly, this rate is lower than our previous finding of 18.8% in duodenal trauma (24) and the average reported rate of 32% (18, 25, 26). This may be due to increased use of damage control procedures and improvements in surgical technique and critical care.

Although the time to surgery has been considered an important predictor of mortality, we did not find a statistically significant difference in time between survivors (3.3 hours) and nonsurvivors (5.8 hours) who were taken to the OR. However, this 2.5-hour difference may still be clinically meaningful.

4.4. Comorbidities, Complications, and Disposition

The methods for reporting comorbidities and complications to the NTDB are always changing. During this study period, there were 31 complications and 27 comorbidity codes available to report to the NTDB (27). Because of this limitation, we found lower rates than previous studies (6, 16, 28). In addition, the unreliability of NTDB reporting and the lack of organ-specific data limited our ability to analyze this data (Appendix 13 in Supplementary File).

While our report of specific complications was limited by NTDB data, we identified several statistically significant predictors of morbidity. In our study, increased age, pulse, ISS, and presence of a firearm injury independently predicted the length of hospital ICU stay. 74% of survivors were discharged directly to home. Most of the remaining survivors were discharged to rehabilitation (12%) or skilled nursing facilities (12%).

4.5. Limitations

There are several limitations to our study due its retrospective design and use of the NTDB, which is a registry database. The NTDB contains a convenience sample that is not representative of all trauma centers in the United States. Per the NTDB User Manual, there is a disproportionate amount of larger hospitals that report data on younger and more severely injured patients (11). The NTDB also contains limited variables and does not include details on exact procedures or injury grading. This data is subject to errors, incompleteness, and inter-hospital differences. Despite these limitations, the NTDB remains a powerful tool when thoughtful methodology and appropriate statistical analysis are applied.

Throughout our NTDB series on "Tiger Country," we have identified concerns related to data collection and subsequent reporting. First, there are limitations in current coding methods that should serve as a discussion point in future revisions to the AAST OIS. Moore et al. originally stated that the OIS were meant to be dynamic and revised as necessary (29). However, it is difficult to identify necessary revisions when most of the injury scales have not been validated by national studies. Second, there is poor adherence to mandatory data reporting to the NTDB, rendering the much of the data unreliable and incomplete. For example, in the study period from 2010 - 2014, only 61% of entries contained AIS05 codes. Several years of data (2007 - 2009) were excluded from our study for this reason.

4.6. Conclusions

This study is the first to describe major vascular injuries in the setting of penetrating trauma to the pancreas and/or duodenum using the National Trauma Data Bank. While many surgeons have observed the effect of vascular injuries in this anatomic region, our findings have not been previously reported in the published literature. The overall mortality in this series was 26.1% and remained consistent during the 5-year study period. Over 70% of deaths occurred in the first 24 hours of admission and of these, nearly 80% died within the first 6 hours. After controlling for covariance based on Haider et al. recommendations (13), we found that firearm mechanism, lower SBP, lower GCS, and higher pulse predicted the likelihood of death following vascular injuries in penetrating trauma to Tiger country.

4.7. NTDB Required Statements

Supplementary Material

Supplementary material(s) is available here [To read supplementary materials, please refer to the journal website and open PDF/HTML].

Footnotes

Authors' Contribution: Bradley J Phillips designed the systematic study approach, contributed to data interpretation, wrote original content, performed critical revisions, and oversaw all coauthors. L. Turco contributed to study design and data interpretation, wrote original content, and performed critical revisions. Sarah Aurit and Ryan W. Walters were both involved in study design, performed data collection and analysis, contributed to data interpretation, and wrote original content

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Ethical Considerations: This study did not directly involve human participants and/or animals. As such, informed consent was not required. This article does not contain any studies with human participants or animals performed by any of the authors.

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