Penetrating injuries to the duodenum: An analysis of 879 patients from the National Trauma Data Bank, 2010 to 2014

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BACKGROUND: Despite wide belief that the duodenal Organ Injury Scale has been validated, this has not been reported in the published literature. Based on clinical experience, we hypothesize that the American Association for Surgery of Trauma Organ Injury Scale (AAST-OIS) for duodenal injuries can independently predict mortality. Our objectives were threefold: (1) describe the national profile of penetrating duodenal injuries, (2) identify predictors of morbidity and mortality, and (3) validate the duodenum AAST-OIS as a statistically significant predictor of mortality.

METHODS: Using the Abbreviated Injury Scale 2005 and International Classification of Diseases—9th Rev.—Clinical Modification (ICD-9-CM) E-codes, we identified 879 penetrating duodenal trauma patients from the National Trauma Data Bank between 2010 and 2014. We controlled patient-level covariates of age, biological sex, systolic blood pressure (SBP), Glasgow Coma Scale (GCS) score, 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 14.4%. Approximately 10% of patients died within 24 hours of admission, of whom 76% died in the first 6 hours. Patients averaged approximately five associated injuries, 45% of which involved the liver and colon. Statistically significant independent predictors of mortality were firearm mechanism, SBP, GCS, pulse, ISS, and AAST-OIS grade. Specifically, odds of death were decreased with 10 mm Hg higher admission SBP (13% decreased odds), one point higher GCS (14.4%), 10-beat lower pulse (8.2%), and 10-point lower ISS (51.0%).

CONCLUSION: This study is the first to report the national profile of penetrating duodenal injuries. Using the National Trauma Data Bank, we identified patterns of injury, predictors of outcome, and validated the AAST-OIS for duodenal injuries as a statistically significant predictor of morbidity and mortality. (*J Trauma Acute Care Surg.* 2017;83: 810–817. Copyright © 2017 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Epidemiologic/Prognostic, level IV.

KEY WORDS: Duodenal trauma; penetrating trauma; tiger country; Organ Injury Scale; National Trauma Data Bank.

Many authors have appreciated the lethality of injuries to the c-loop of the duodenum, pancreatic body, and surrounding vascular structures (see Figure, Supplemental Digital Content 1, http://links.lww.com/TA/A981). In fact, this general anatomic area has been described by Hirschberg and Mattox[1] as the "surgical soul" but from our experience in areas of conflict, we prefer the term "tiger country" due to the challenging nature of this region. The first study of duodenal injuries was reported by Berry in 1909 from his experience with 132 patients in 10 London hospitals.[2] Even today, injuries to the duodenum are rare with a reported incidence of 0.5% to 5% in abdominal trauma.[3,4] Duodenal trauma has a reported mortality of 15% to 47% and morbidity of 39% to 56%.[5] Penetrating mechanisms, particularly gunshot wounds, are responsible for approximately 85% of these injuries.[6] Increasing number and type of associated injuries contribute to higher mortality.[7] In fact, mortality has been reported to increase up to 67% with seven or more abdominal injuries, independent of duodenal injury severity.[8]

Our objectives in this study were threefold. First, we sought to characterize the national profile of penetrating duodenal injuries, including patient demographics, injury mechanism, associated injuries, procedures, and time to exploratory laparotomy. Our second objective was to identify predictors of mortality as well as morbidity based on intensive care unit (ICU) length of stay (LOS), hospital LOS (HLOS), and ventilator (vent) days. Our third aim was to validate the American Association for Surgery of Trauma Organ Injury Scale (AAST-OIS) grades for duodenal injuries as a statistically significant predictor of mortality. Despite wide belief that the duodenal Organ Injury Scale has been previously validated, we cannot find a single report in the world's literature describing OIS as a statistically significant predictor of mortality.

METHODS

Data Source and Study Population

We identified penetrating duodenal trauma patients from the National Trauma Data Bank (NTDB) research data set (version 6.1 issued in 2007). Due to poor adherence to mandatory data reporting to the NTDB, much of the data between 2007 and 2009 was incomplete and unreliable. Thus, we excluded these years from our study and focused on data from 2010 to 2014. The NTDB is supported by the American College of Surgeons and collects annual data from approximately 900 United States trauma centers. It is important to note that the research data set is not a population-based data set, and it is unknown whether a unique patient had multiple trauma incidents.

We identified duodenal trauma patients using the Abbreviated Injury Scale 2005 with 2008 update (AIS05) scoring that included 541010.2, 541022.2, 541021.2, 541023.3, 541025.3, 541024.4, and 541028.5 (see Table 1). Within these patients, we identified a penetrating mechanism based on ICD-9-CM external causes of injury codes (E-codes) for firearm injuries (E922.x, E955.0-E955.4, E965.0-E965.4, E970, E979.4, and E985.0-E985.4) and cut/pierce injuries (E920.x, E956, E966, and E974). Unlike many other NTDB-based studies, the patients included in our final analysis had complete data 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, patients who had multiple pancreatic AIS05 scores, and patients with obviously miscoded values (e.g., GCS score, > 15). Based on these criteria, a total of 879 patients were included in our final sample (see Fig. 1).

Outcomes

Our primary outcome was in-hospital mortality defined using hospital and emergency department discharge disposition. Secondary outcomes included total in-hospital LOS, ICU LOS, and number of days on vent, all of which were modeled using only patients who were discharged alive. To provide further detail of our sample, we also evaluated procedure codes, associated

TABLE 1. Correlating Duodenal AIS05 Codes to OIS Grades

Grade	OIS Grade Description	AIS05 Description	AIS05
I, II	Grade I: Involving single portion of the duodenum Grade II: Involving more than 1 portion	Contusion/Hematoma	541010.2
I	Partial thickness, no perforation	No perforation; partial thickness; serosal tear	541022.2
II	Disruption of <50% of circumference	Disruption <50% circumference	541021.2
III	Disruption of 50–100% of circumference of D1, D3, or D4	Disruption 50%–100% circumference in D1 (superior portion), D3 (transverse portion 3rd part), or D4 (distal portion 4th portion)	541023.3
III	Disruption of 50–75% of circumference of D2	Disruption 50–75% of D2 (descending portion)	541025.3
IV	Disruption >75% of circumference of D2	Disruption >75% of D2	541024.4
V	Massive disruption of duodenopancreatic complex or devascularization of duodenum	Massive, avulsion, complex, rupture, tissue loss, devascularization, massive disruption	541028.5

injuries by AIS05, as well as comorbid conditions, complication rates, and discharge disposition.

Predictors of Mortality, LOS, and Ventilator Days

Haider et al.[9] have 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. Therefore, we designed our approach based on these recommendations and included patient-level predictor variables of age, biological sex, SBP, GCS score, pulse, ISS-ICD, and Organ Injury Scale (OIS) grade determined by the patient's duodenal AIS05 score. ISS-ICD (hereafter referred to as simply 'ISS') was chosen based on previous literature documenting its increased accuracy as a predictor of survival over hospital-reported ISS.[10,11] Currently, OIS grade is not a reporting variable of the NTDB and thus cannot be directly used for analysis. Although previous studies[12] have used ICD-9 codes (see Table, Supplemental Digital Content 2, http://links.lww.com/TA/A982) as surrogates for OIS grade, we were unable to reproduce their methods. As such, we chose to align OIS grades with AIS05 codes, which is a reported element of the NTDB (Table 1). Duodenal AIS05 codes correlate well to most of the OIS grades, except grades I and II, which could not be separated with unique codes. "Hematoma" is defined in both grades I and II; however, AIS05 combines contusion/hematoma in a single category thus requiring us to group Grades I and II together (see Table 1).

Statistical Analysis

Depending on their distribution, continuous variables are presented as either mean ± standard deviation or median and interquartile range; categorical variables are presented as

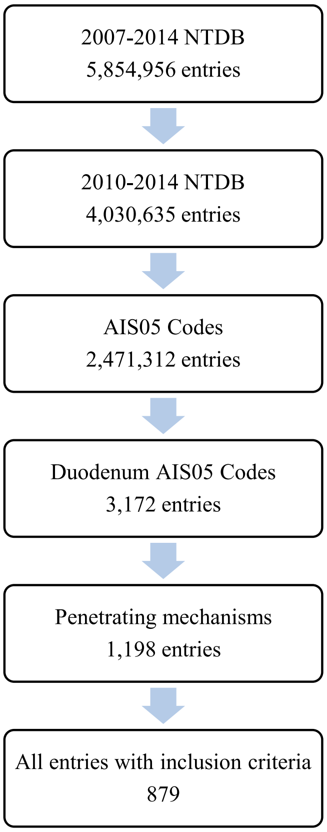

Figure 1. Identifying the sample set.

frequency and percent. To account for the nesting of patients within trauma centers,[13] we estimated mixed-effects logistic regression model to identify predictors of in-hospital mortality,

TABLE 2. Descriptive Statistics of All Patients

Age, y	28 (23–38)
SBP	125 ± 30
Pulse	101 ± 24
GCS score	15 (14–15)
ISS (ICD)	14 (9–18)
hLOS	12 (7–23)
ICU LOS*	5 (2–12)
Vent days**	3 (2–9)
Male	777 (88)
Mechanism	
Firearm	740 (84)
Cut/pierce	138 (16)
Both	1 (0)
OIS grade	
I/II	481 (55)
III	265 (30)
IV	92 (11)
V	127 (15)

Continuous variables are presented as mean ± standard deviation or median (IQR). Values in parentheses indicate percent of *n*.
*n = 691.
**n = 515.

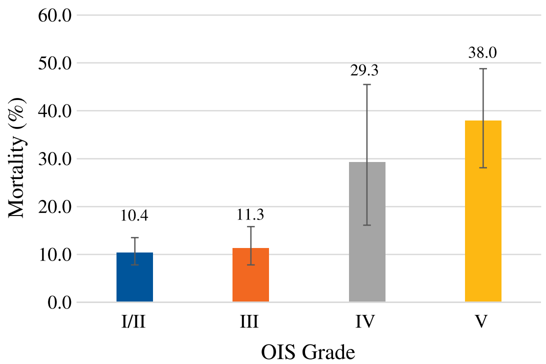

Figure 2. Mortality by duodenum OIS grade.

whereas we estimated mixed-effects negative binomial regression models to identify predictors of total hospital and ICU LOS as well as number of vent days. Before estimating the mixed-effects logistic model, the adequacy of expected frequencies assumption for categorical variables (biological sex, injury mechanism, and OIS grade) was evaluated using contingency tables. For all outcomes, the functional form of each continuous variable (age, SBP, GCS score, pulse, ISS) was evaluated using LOESS models.[14] Two-way interaction effects were estimated based on clinical relevance, with any moderation less than 1% defined to be clinically nonsignificant. All analyses were conducted using SAS v. 9.4 (SAS Institute, Cary, NC), in which p less than 0.05 indicated statistical significance. A complete description of the statistical methods can obtained in the supplementary addendum (see Methods, Supplemental Digital Content 3, http://links.lww.com/TA/A983) or from the author RWW.

RESULTS

Patient Demographic and Clinical Characteristics

Descriptive demographic and clinical characteristics of our final sample are presented in Table 2 (see also Tables and Figure, Supplemental Digital Contents 4–6, http://links.lww.com/TA/A984, http://links.lww.com/TA/A985, http://links.lww.com/TA/A986). Because AIS05 combines contusion/hematoma in a single category,[15] we were required to group OIS grades I and II together. We found that mortality was related to increasing OIS grade (see Fig. 2). Overall mortality in this sample was 14.4%, and interestingly, the rate did not significantly change across the 5-year study period (see Figure, Supplemental Digital Content 7, http://links.lww.com/TA/A987). Of those who died, nearly 80% died within the first 5 days from admission (see Figure, Supplemental Digital Content 8, http://links.lww.com/TA/A988).

In our study, patients averaged approximately five associated organ injuries (mean, 4.9; median, 4) (see Figure 3 and Supplemental Digital Content 9, http://links.lww.com/TA/A989). For each additional associated injury, the odds of in-hospital mortality increased by approximately 24.7% ($p < 0.001$). The most common associated organ injuries occurred to the liver (396, 45.1%) and colon (395, 44.9%) (see Table, Supplemental Digital Content 10, http://links.lww.com/TA/A990). The pancreas was concomitantly injured in 213 (24.2%) patients and carried the highest mortality rate of the nonvascular associated injuries (23.5%). Major vascular injuries occurred in 270 (30.7%) patients, and of these, 166 (61.5%) were from injuries to the inferior vena cava (see Figure, Supplemental Digital Content 11, http://links.lww.com/TA/A991). Patients with any vascular injury had a mortality rate of 32.2%. The most common extra-abdominal injury was hemothorax/pneumothorax (166, 18.9%).

Regarding procedures, 637 (72.7%) patients underwent exploratory laparotomy, with 235 (36.9%) of those patients undergoing additional reexploration. Mortality of patients undergoing exploratory laparotomy by OIS was grade I/II, 11.6%; III, 10.8%; IV, 34.5%; and V, 40.3% (see Table, Supplemental Digital Content 12, http://links.lww.com/TA/A992). Time to first exploratory laparotomy was not associated with mortality ($p = 0.532$). Of the 637 patients undergoing laparotomy, 437 (68.6%) had duodenum-specific procedures. The most common procedures were on the colon (463, 53%), small intestine (425, 48%), and duodenum (411, 47%). Procedures with the highest mortality rates involved the spleen (28.6%) and pancreas (24.4%) (see Table, Supplemental Digital Content 13, http://links.lww.com/TA/A993). Interestingly, 16 (1.8%) patients had a traumatic pancreaticoduodenectomy (Whipple procedure) with a subsequent mortality rate of 18.8%. In addition, cardiopulmonary resuscitation was performed on 40 (4.6%) patients, with an 82.5% mortality rate. Open cardiac massage was performed in 26 (3.0%) patients, with a 92.3%

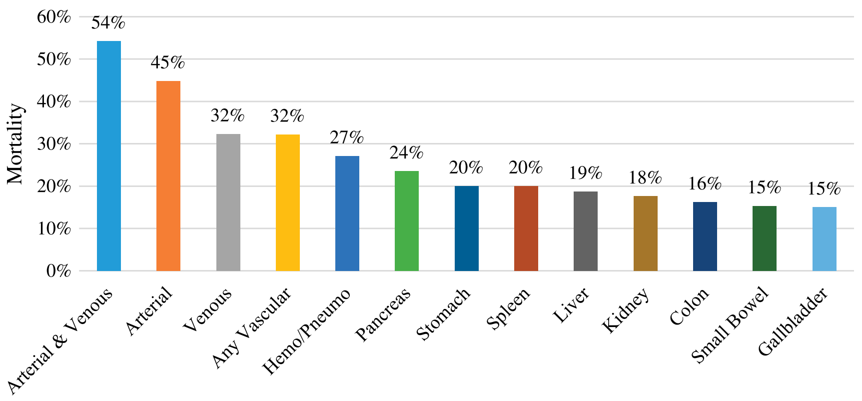

Figure 3. All patients mortality of associated injuries.

TABLE 3. Independent Predictors of Outcome

Independent Predictor	*p*
Mortality	
↓ SBP	<0.001
↓ GCS score	<0.001
↑ Pulse	<0.001
↑ ISS	<0.001
Firearm mechanism (vs. cut/pierce)	0.050
Grade IV (vs. grade I/II)	0.034
Grade V (vs. grade I/II)	0.001
Grade IV (vs. grade III)	0.027
Grade V (vs. grade III)	<0.001
hLOS	
↑ Age	<0.001
↓ SBP	0.017
↓ GCS score	0.027
↑ Pulse	<0.001
↑ ISS	<0.001
Firearm mechanism (vs. cut/pierce)	<0.001
Grade III (vs. grade I/II)	<0.001
Grade V (vs. grade I/II)	<0.001
ICU LOS	
↑ Age for men	<0.001
Female sex when age 20 y	0.015
↓ GCS score	0.014
↑ Pulse	<0.001
↑ ISS	<0.001
Firearm mechanism (vs. cut/pierce)	<0.001
Grade III (vs. grade I/II)	0.003
Grade V (vs. grade I/II)	0.001
Vent days	
↑ Age	0.004
↑ Pulse	0.017
↑ ISS	0.009
Firearm mechanism (vs. cut/pierce)	0.001
Grade III (vs. grade I/II)	0.03
Grade V (vs. grade I/II)	0.004

mortality rate. Further, 345 (39.2%) patients received transfusions of blood with a 24.1% mortality rate, 243 (27.6%) patients received plasma/coagulation factors with a 25.1% mortality rate, and 176 (20.0%) patients received platelets with a 30.1% mortality rate.

The most common comorbidities in this patient population included smoking (208, 23.7%), drug use disorder (75, 8.5%), and alcohol use disorder (71, 8.1%) (see Table, Supplemental Digital Content 14, http://links.lww.com/TA/A994). The most common complications included pneumonia (74, 8.4%), acute kidney injury (54, 6.1%), deep venous thrombosis (51, 5.8%), and severe sepsis (50, 5.7%) (see Table, Supplemental Digital Content 14, http://links.lww.com/TA/A994).

Finally, of the 752 (85.5%) patients who survived, 604 (80.3%) were discharged to home, 64 (8.5%) patients were discharged to either skilled nursing or long-term acute care facilities, and another 60 (8.0%) were discharged to rehabilitation.

Predictors of Mortality

Before analysis, the adequacy of expected frequencies was assured for biological sex, mechanism of injury, and OIS grade; all continuous predictors were found to have a linear functional form. Further, no statistically significant contextual effects were indicated. Final model results indicated that, holding all other predictors constant, patients had increased probability of death with lower SBP, lower GCS score, as well as higher pulse, higher ISS, and higher OIS grades. Age, biological sex, and mechanism of injury (firearm vs. cut/pierce) were not associated with mortality (see Table 3 and Figure 4 and Supplemental Digital Content 15, http://links.lww.com/TA/A995). Specifically, after controlling for the other predictors of mortality, a 10-mm Hg higher admission SBP was associated with a 13.0% decreased odds of death ($p < 0.001$), whereas a 1-point higher GCS score was associated with 14.4% lower odds of death ($p < 0.001$). By contrast, patients with 10-beat higher pulse averaged 18.2% greater odds of death ($p < 0.001$) and a 10-point higher ISS was associated with 51.0% greater odds of death ($p < 0.001$). Finally, patients with an OIS grade I/II injury averaged 61.9% lower odds of death compared with patients with a grade IV injury ($p = 0.034$) and 79.3% lower odds of death compared with patients with a grade V injury ($p < 0.001$).

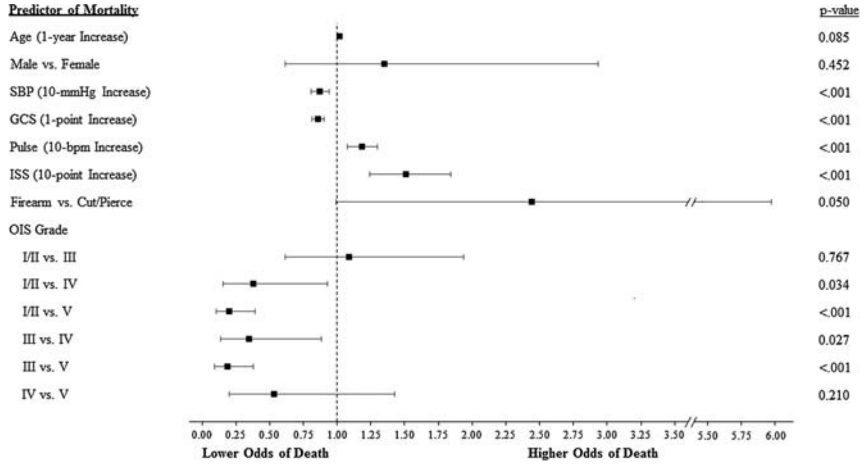

Figure 4. Forrest plot of predictors of mortality.

Similarly, patients with an OIS grade III injury averaged 65.1% lower odds of death compared with patients with a grade IV injury ($p = 0.027$) and 81.4% lower odds of death compared with patients with a grade V injury ($p < 0.001$).

Predictors of Hospital and ICU LOS and Days on Ventilator

Of the 878 patients included in our primary analysis, 751 (85.5%) were discharged alive. All continuous predictors were found to have a linear functional form, and no statistically significant contextual effects were indicated for any secondary outcomes. Complete results of these multivariable models are presented in the supplementary appendix (see Figures, Supplemental Digital Content 15–17, http://links.lww.com/TA/A995, http://links.lww.com/TA/A996, http://links.lww.com/TA/A997).

Results indicated that when holding the other predictors constant, an increased hLOS was associated with being older at admission ($p < 0.001$), lower SBP ($p = 0.016$), lower GCS score ($p = 0.026$), higher pulse ($p < 0.001$), higher ISS ($p < 0.001$), and firearm injuries ($p < 0.001$) (see Table 3 and Figure, Supplemental Digital Content 15, http://links.lww.com/TA/A995). In general, increased hLOS was associated with higher OIS grades; however, statistically significant differences were indicated between OIS grade I/II versus grade III ($p < 0.001$) and grade III versus grade V ($p < 0.001$).

A total of 619 (82.4%) patients who were discharged alive spent time in the ICU. Holding the other predictors constant, increased ICU LOS was associated with lower GCS score ($p = 0.014$), higher pulse ($p < 0.001$), higher ISS ($p < 0.001$), and a firearm injury ($p < 0.001$) (see Table 3 and Figure, Supplemental Digital Content 16, http://links.lww.com/TA/A996). Further, a significant two-way interaction was observed between age and biological sex ($F_{1,411} = 6.1, p = 0.014$), such that men averaged significantly shorter ICU LOS compared with women only until age 26 years ($p = 0.042$), after which the difference between men and women was not statistically significant. Further, a 1-year increase in age was associated with longer ICU LOS for men ($p < 0.001$), but not for women ($p = 0.527$). Finally, decreased ICU LOS was associated with OIS grades I/II compared with grade III ($p = 0.003$) and grade V ($p < 0.001$).

A total of 425 (56.6%) patients who were discharged alive required mechanical ventilation. Holding the other predictors constant, a greater number of vent days was associated with older patients ($p = 0.004$), higher pulse ($p = 0.017$), higher ISS ($p = 0.009$), and firearm injuries ($p < 0.001$) (see Table 3 and Figure, Supplemental Digial Content 16, http://links.lww.com/TA/A996). Finally, fewer vent days was associated with OIS grades I/II compared to grade III ($p = 0.030$) and grade V ($p = 0.004$).

DISCUSSION

This is the first study to analyze penetrating duodenal injuries from the NTDB. Our objectives in this study were threefold: (1) to describe the national profile of penetrating duodenal injuries, (2) to identify predictors of morbidity and mortality, and (3) to validate the AAST-OIS grades for duodenal injuries as a statistically significant predictor of mortality. OIS grades are used ubiquitously in documentation and communication between trauma surgeons, yet duodenal OIS grades have not been validated as predictors of mortality. Single-institution studies reported by Ordonez (n = 44),[16] Schroeppel (n = 145),[17] Flynn (n = 81),[18] Kline (n = 101),[19] Talving (n = 75),[20] and Velmahos (n = 91)[21] have attempted this, but ultimately lacked large enough sample sizes for rigorous statistical analyses. Several studies have documented that duodenal injury grade is not a predictor of morbidity or mortality; however, this finding has been attributed to inadequate sample size.[5,6,22–24] In fact, Rickard et al.[8] conceded that a small sample size was likely responsible for the lack of statistical significance between mortality and injury grade in his study. Despite wide belief that the duodenal OIS has been previously validated, we did not find a single report in the world's literature describing OIS as a statistically significant predictor of mortality in penetrating duodenal injuries.[4]

The overall mortality rate in our study was 14.4%, which is significantly lower than cumulative mortality reported over the last 40 years, which was as high as 47% in Verma's 1994 study.[25] Although we expected advances in medical and surgical knowledge to result in decreasing mortality over time, mortality was consistent during our 5-year study period. The profile of patients suffering penetrating duodenal injuries is consistent across reports in the literature. Similar to our findings, previous studies have reported that these patients are typically men (comprising 69–94%)[5,6,16,26] with a mean age of 24 years to 32 years,[5,6,26] suffering from gunshot wounds (64–92%).[5,16,27] In this study, mean HLOS (19 days) and ICU LOS (10 days) were consistent with previous studies on penetrating duodenal injuries which reported HLOS ranging 16 days to 24 days[5,6,16,26] and ICU LOS ranging 6 days to 11 days.[5,16,26] However, our mean ISS of 16 was lower than other reports.[5,6,17,26,28]

In our study, independent predictors of mortality in penetrating duodenal trauma were decreasing SBP, decreasing GCS score, increasing pulse, increasing ISS, firearm mechanism, and AAST-OIS grade. Previous reports have documented significant correlation between ISS,[5,24,29] GCS score,[5] SBP,[5,6] firearm mechanism,[23] and mortality. However, these reports were based on single institutional experiences.

Associated Injuries

The rate of associated injuries has been reported at 96% to 100%[16,22,27] with two to four associated injuries per patient on average.[5,16,28] This is similar to our finding of 98% with 4.9 associated injuries per patient. The most common associated injuries were liver (45%) and colon (45%), which is consistent with several other studies.[5,6,16,22,23] Although spleen and gallbladder are frequently reported associated injuries in the literature, they represented only 6% and 12% in our study, respectively.[5,16,22,27] The pancreas was concomitantly injured in 24% of patients and had the highest mortality rate (24%) of nonvascular associated injuries. This rate is also similar to reports of pancreaticoduodenal injuries in the literature.[29,30] The most common extra-abdominal injuries were diaphragm (11%) and hemothorax/pneumothorax (19%). Previous studies have also reported associated diaphragmatic injuries at a rate of 11% to 18%.[6,16]

The reported mortality of isolated duodenal injuries is low, ranging from 0% to 2% in previous studies[16,23] and 0% in our study. This supports the idea that most deaths in penetrating duodenal trauma result from major vascular injuries and an increasing number of associated injuries.

Procedures

In the NTDB, procedures are reported by ICD-9 p-codes. These codes were designed for billing purposes and often lack clinical relevance. For this reason, we were able to report basic information but could not delineate specific trauma-related procedures (see Tables, Supplemental Digital Contents 13 and 18, http://links.lww.com/TA/A993 and http://links.lww.com/TA/A998).

The frequency of exploratory laparotomy in the setting of penetrating duodenal injuries is unclear due to the large number of studies that focus specifically on types of surgical management. Antonacci reported 11% of patients undergo reexploration,[4] which is substantially less than our finding of 20%. Interestingly, we found that the mortality rate of patients receiving one reexploration (17.5%) was not significantly different from those undergoing two or more (15.6%), and neither was significantly different than overall mortality (14.5%). However, we found that mortality of exploratory laparotomy generally increased with higher OIS grades: 11.6% mortality of laparotomy in grade I/II, 10.8% in III, 34.5% in IV, and 40.3% in V (see Table, Supplemental Digital Content 12, http://links.lww.com/TA/A992).

Sixteen (1.8%) patients had a traumatic pancreaticoduodenectomy (Whipple procedure) with a subsequent 19% mortality rate. Although this procedure has been documented to occur at similar frequencies in the literature (range, 2.2–8.8%),[31–35] our mortality rate was much lower than the average reported mortality rate of 32% for a traumatic Whipple.[30,35,36] This lower mortality rate may be due to overall improvement in surgical technique and intensive care. There might also be a "modern" selection bias—that is, patients now typically undergo their first damage control procedure before the "traumatic Whipple" is performed. Previously, the "trauma Whipple" was commonly performed in the acute setting before patients were physiologically stable.

Time to surgery has been considered an important predictor of mortality.[37] In this study, we did not find a statistical difference in time to surgery between alive and dead, which were 3.6 hours and 5.0 hours, respectively. However, this 2.5-hour difference may be clinically important.

Comorbidities, Complications, and Disposition

Coding methods for reporting comorbidities and complications to the NTDB are constantly evolving. Between 2010 and 2014, only 31 complication codes and 27 comorbidity codes were available to report in the NTDB.[38] Due to these limitations, rates in this study were significantly lower than in previous studies.[34,39,40] This is also likely due to the infrequent and unreliable reporting of complications and comorbidities to the NTDB. In addition, organ-specific complications are not included in the NTDB, so we were unable to analyze the rate of duodenal-related complications.

In this series, the far majority of survivors (73%) were discharged directly to home. The remainder were discharged either to a rehabilitation center or nursing facility.

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; there is a disproportionate amount of larger hospitals that report data on younger and more severely injured patients.[41] 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.

There are limitations in current coding methods that should serve as a discussion point in future revisions to the OIS. Moore et al. originally stated that the OIS scales were meant to be dynamic and revised as necessary.[42] However, it is difficult to identify necessary revisions when most of the injury scales have not been validated by national studies. There is also poor adherence to mandatory data reporting to the NTDB, rendering much of the data unreliable and incomplete. For example, in the study period from 2010 to 2014, only 61% of entries contained AIS05 codes. Several years of data (2007–2009) were excluded from our study for this reason.

CONCLUSION

This study is the first to describe penetrating duodenal injuries using the NTDB and the first to document AAST-OIS grade as a statistically significant predictor of mortality based on a national sample of patients in the United States. Overall mortality in this series was 14.4%. Most patients undergo exploratory laparotomy, but time to operation was not predictive of mortality. Although we expected advances in medical and surgical knowledge to result in decreasing mortality over time, mortality was consistent during the 5-year study period. After controlling for covariance based on Haider's recommendations,[9] we found that lower SBP, lower GCS score, as well as higher pulse, higher ISS, and higher OIS grades predicted the likelihood of death after penetrating duodenal injury. Thus, AAST-OIS duodenal grades appropriately indicate the relative severity and mortality of these injuries to "tiger country."

AUTHORSHIP

B.P. designed the systematic study approach, wrote original content, contributed to data interpretation, performed critical revisions, and oversaw all coauthors. L.T. contributed to study design and data interpretation, wrote original content, and performed critical revisions. D.M. aided in study design, data interpretation, and revisions. A.M. wrote original content for the background. R.W. was involved in study design, performed data collection and analysis, contributed to data interpretation, and wrote original content.

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DISCLOSURE

Conflict of Interest Statement: All authors declare that we have no conflict of interest in either the preparation or submission of this manuscript. Compliance with Ethical Standards: All authors state clearly that we have nothing to disclose regarding potential conflicts of interest. This collective review 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. External sources of funding were not used in either the preparation or submission of this manuscript.

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