



Surgical Trends in the Management of Duodenal Injury

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Abstract

Background Surgical management of traumatic duodenal injury remains challenging. While various surgical techniques have been described in the attempt to reduce complications and mortality, recent data suggests that surgical approach using less invasive procedures might be associated with improved patient outcomes. The purpose of this study was to determine the recent trend of surgical procedures performed for patients with duodenal injury and their outcome.

Methods A retrospective analysis of the National Trauma Data Bank (NTDB) from 2002 to 2014 was performed. A total of 2163 patients who sustained a traumatic duodenal injury requiring surgical intervention were included. Patient characteristics, injury data, procedures, and outcomes were examined. Types of duodenal procedures and patient outcomes were compared between two study periods (2002–2006 vs. 2007–2014).

Results The median age was 27 (IQR 20–39), 78.9% were male, and 63.8% sustained penetrating duodenal injury. The median injury severity score was 18 (IQR 13–26). In patients with isolated duodenal injury, the later study period (2007–2014) was significantly associated with the increased use of primary repair (OR 1.77; 95% CI 1.11–2.83, $p = 0.017$). Overall mortality was 11.7%. Patients in the later study group were significantly associated with lower odds of in-hospital mortality (OR 0.47, 95% CI 0.22–0.95, $p = 0.041$).

Conclusions A progressive trend toward less invasive procedures for duodenal injury was noted in the current study. In-hospital mortality has improved in the late study period.

Keywords Duodenal injury · Trends · Surgical management

Introduction

Duodenal injuries are rare, accounting for approximately 3 to 5% of all abdominal injuries after trauma.¹ These injuries,

however, carry a reported high mortality, ranging from 4 to 47%, driven by factors such as difficulty in diagnosis, technical challenges of management, and a high incidence of associated injuries.^{2,3} While various surgical procedures with a

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wide range of complexities have been described in the management of duodenal injuries, depending on the severity of the injury and the presence of associated trauma, the optimal surgical management remains unclear.^{4–6}

Since its introduction in the 1990s, the concept of damage control surgery (DCS) has gained a wide acceptance in trauma worldwide. DCS allows abbreviated surgical procedures with delayed definitive repair focusing on hemorrhage control, contamination control, temporary abdominal closure, and early patient resuscitation in the intensive care unit.⁷ To date, only scarce data are available on the application of DCS in patients with duodenal injury.⁸ Similarly, little is known whether there have been recent trends in surgical management of duodenal injury in the USA. The purpose of the current study was to evaluate the recent trend of surgical procedures performed for duodenal injury, and related patient outcomes. We hypothesized that there would be distinct trends toward less invasive surgical procedures performed for duodenal injuries and improved outcomes.

Patients and Methods

After approval by the Institutional Review Board, the National Trauma Data Bank (NTDB) was queried to identify adult patients (≥ 16 years) who sustained traumatic duodenal injury that required primary repair (International Classification of Diseases [ICD]-9 codes 46.71 and 46.79), pyloric exclusion (44.38 and 44.39), duodenojejunostomy (45.91), or pancreaticoduodenectomy (52.70) between January 2002 and December 2014. Patients transferred from an outside hospital and those that were dead on arrival were excluded from the study.

Variables extracted from the NTDB included patient demographics, comorbid conditions, mechanism of injury (blunt vs. penetrating), Abbreviated Injury Scale (AIS) in each body region, Injury Severity Score (ISS), and vital signs in the Emergency Department (ED). In order to examine the trend of surgical procedure performed for duodenal injury, our study patients were divided into two groups by time periods (early 2002–2006 vs. late 2007–2014). These year cutoffs were selected as an increasing number of studies reported the safety and efficacy of less invasive procedures in duodenal injury between 2006 and 2008.^{8–11} Our primary outcomes of interest were the respective rates of early and overall primary repair, pyloric exclusion, duodenojejunostomy, and pancreaticoduodenectomy. Secondary outcomes included 24-h and inhospital mortality. Severe duodenal injury was defined as OIS 3–5. Early surgical procedure was defined as an operative intervention performed within the first 24 h after ED admission. Isolated duodenal injury was defined as a duodenal injury with no other associated severe injuries with an AIS > 3 .

Statistical Analysis

Categorical variables were reported as percentages, while continuous variables were reported as medians with interquartile range (IQR). Univariate analysis was performed to identify differences between the early (2002–2006) and late (2007–2014) groups. The Mann-Whitney *U* test was used to compare continuous variables while Fisher Exact or Pearson's chi-squared test was used to compare proportions for categorical variables as appropriate. Variables with $p < 0.20$ in univariate analysis were included into a forward stepwise logistic regression to identify independent predictors for our study outcomes. Multicollinearity testing was performed to identify the correlation between variables. The accuracy of the test is calculated using the area under the curve with a 95% confidence interval. Variables with p value < 0.05 were considered significant. All statistical analyses were performed using SPSS for Windows version 23.0 (SPSS Inc., Chicago, IL).

Results

A total of 2163 patients were included for analysis. Of those, 344 (15.9%) were treated in the early study period and 1819 (84.1%) in the late period (Table 1). Patients in the late group were older (25 vs. 27, $p = 0.023$) and more likely to sustain a penetrating injury (56.1% vs. 65.3%, $p = 0.001$). Overall, 283 patients (13.5%) were hypotensive and 304 (14.7%) presented with decreased mental status (GCS < 9). Patients in the late group were more likely to have associated severe head, chest, abdominal, and extremity injuries. There was no significant difference in the incidence of associated pancreatic injury between the two groups. An isolated duodenal injury was diagnosed in 1198 patients (55.4%).

Overall, primary suture was the most adopted surgical procedure (78.5%) followed by pyloric exclusion (19.2%), duodenojejunostomy (19.1%), and pancreaticoduodenectomy (3.4%) (Table 2). Patients in the late group were more likely to undergo primary repair (79.4% vs. 73.8%, $p = 0.022$) and less likely to undergo pancreaticoduodenectomy (3.0% vs. 5.5%, $p = 0.019$). In patients who sustained an isolated duodenal injury, after adjusting for clinically relevant covariates in the logistic regression analysis, the late period was found to be significantly associated with early (odds ratio [OR] 1.71; 95% confidence interval [CI] 1.10–2.66, $p = 0.019$) and overall (OR 1.77; 95% CI 1.11–2.83, $p = 0.017$) primary repair of duodenal injury (Table 3). In the subgroup of patients who sustained an isolated severe duodenal injury (OIS ≥ 3), the use of early and overall primary repair were also significantly associated with the late study period.

Table 1 Patient characteristics and injury severity in study groups

	Total (<i>n</i> = 2163)		Early group (2002–2006) (<i>n</i> = 344)		Late group (2007–2014) (<i>n</i> = 1819)		<i>p</i> value
Demographics							
Gender, male	1704	(78.9)	275	(80.2)	1429	(78.6)	0.51
Age, median (IQR)	27	(20–39)	25	(19–37)	27	(20–40)	0.023
Age ≥ 65 years	89	(4.1)	8	(2.4)	81	(4.5)	0.09
Race/ethnicity							
Asian	38	(1.8)	1	(0.3)	37	(2.0)	0.02
African American	774	(35.8)	119	(34.6)	655	(36.0)	0.62
White	941	(43.5)	146	(42.4)	795	(43.7)	0.67
Mechanism of injury							
Blunt	753	(36.2)	150	(43.9)	603	(34.7)	0.001
Penetrating	1325	(63.8)	192	(56.1)	1133	(65.3)	
Comorbidities							
Overall	314	(14.5)	10	(2.9)	304	(16.7)	< 0.001
Respiratory disease	90	(4.2)	2	(0.6)	88	(4.8)	< 0.001
Myocardial infarction (< 6 months)	4	(0.2)	0	(0.0)	4	(0.2)	1.00
Stroke	4	(0.2)	0	(0.0)	4	(0.2)	1.00
Chronic renal failure	2	(0.1)	0	(0.0)	2	(0.1)	1.00
Cirrhosis	8	(0.4)	0	(0.0)	8	(0.4)	0.37
Hypertension	153	(7.1)	8	(2.3)	145	(8.0)	< 0.001
Diabetes	61	(2.8)	2	(0.6)	59	(3.2)	0.006
Obesity	75	(3.5)	0	(0.0)	75	(4.1)	< 0.001
ED vitals							
SBP < 90 mmHg	283	(13.5)	40	(12.2)	243	(13.8)	0.44
GCS < 9	304	(14.7)	40	(13.5)	264	(14.9)	0.51
Duodenal OIS							
OIS I/II	910	(42.1)	71	(20.6)	839	(46.1)	< 0.001
OIS III	483	(22.3)	39	(11.3)	444	(24.4)	
OIS IV	460	(21.3)	146	(42.4)	314	(17.3)	
OIS V	310	(14.3)	88	(25.6)	222	(12.2)	
Injuries							
ISS, median (IQR)	18	(13–26)	19	(16–26)	19	(11–26)	0.045
ISS > 15	1540	(71.7)	278	(84.2)	1262	(69.4)	< 0.001
Head AIS ≥ 3	167	(7.7)	7	(2.0)	160	(8.8)	< 0.001
Chest AIS ≥ 3	653	(30.2)	67	(19.5)	586	(32.2)	< 0.001
Abdomen AIS ≥ 3	1896	(87.7)	271	(78.8)	1625	(89.3)	< 0.001
Extremity AIS ≥ 3	339	(15.7)	41	(11.9)	298	(16.4)	0.037
Isolated duodenal Injury	1198	(55.4)	142	(41.3)	1056	(58.1)	< 0.001
Pancreatic injury	317	(14.7)	50	(14.5)	267	(14.7)	0.95

SBP systolic blood pressure, GCS Glasgow Coma Scale, OIS Organ Injury Scale, ISS Injury Severity Score, AIS Abbreviated Injury Severity, IQR interquartile range

Overall in-hospital mortality was 11.7%. In patients who sustained an isolated duodenal injury, the overall in-hospital mortality was 7.5%. The unadjusted mortality was significantly lower in the late group (6.6% vs. 12.0%, $p = 0.02$). The multiple logistic regression analysis showed that clinical factors including hypotension on

admission, GCS < 9, penetrating trauma, and ISS > 15 were significantly associated with increased in-hospital mortality (Table 4). The time period between 2007 and 2014 was significantly associated with improved survival in patients with isolated duodenal injury (OR 0.47, 95% CI 0.22–0.95, $p = 0.041$).

Table 2 Surgical procedures performed for duodenal injury

	Total patients	Early group	Late group	<i>p</i> value
Primary suture	1698 (78.5)	254 (73.8)	1444 (79.4)	0.022
Primary suture < 24 h	1549 (72.1)	225 (68.2)	1324 (72.8)	0.09
Pyloric exclusion	415 (19.2)	59 (17.2)	356 (19.6)	0.30
Pyloric exclusion < 24 h	241 (11.2)	35 (10.3)	206 (11.3)	0.59
Pancreaticoduodenectomy	74 (3.4)	19 (5.5)	55 (3)	0.019
Pancreaticoduodenectomy < 24 h	45 (2.1)	11 (3.2)	34 (1.9)	0.11
Duodenojejunostomy	413 (19.1)	56 (16.3)	357 (19.6)	0.15
Duodenojejunostomy < 24 h	247 (11.4)	40 (11.8)	207 (11.4)	0.82

Discussion

Operative management of duodenal injury, particularly for high-grade injuries, remains controversial. Varying surgical procedures can be considered based on factors including injury severity and time of presentation, as well as associated injuries. The purpose of the current study was to describe the national trend of surgical procedures performed for duodenal injury and the related outcomes over the course of 13 years from 2002 to 2014. Patients with isolated duodenal injury in the 2007–2014 time period were more likely to have undergone primary repair and less likely to have undergone pancreaticoduodenectomy, even after sustaining severe duodenal injury (OIS ≥ 3). The 2007–2014 time period was also found to be

associated with improved in-hospital mortality in isolated duodenal injury. Our results suggest that there is a significant trend toward less invasive procedures for duodenal injury which might be associated with improved mortality.

The repair of high-grade duodenal injury remains a widely controversial topic. Historically, more complex surgical techniques have been employed. In 1968, Berne et al. described duodenal “diverticulization” in the operative treatment of 16 patients.⁴ This approach allowed for diversion of gastric contents away from newly repaired duodenum while maintaining a patent gastrointestinal stream for nutrition. Vaughan described the first pyloric exclusion which involved a similar protective strategy of gastric diversion.⁵ In 1983, Martin et al. published a report supporting pyloric exclusion as the procedure of choice after demonstrating decreased incidence of

Table 3 Time-shift period as independent predictor for overall and early primary suture

	Overall primary suture* Adjusted <i>p</i> value	OR	95% CI
Duodenal injury (OIS I–V) Time-shift, 2007–14	0.51	1.11	(0.81–1.54)
Duodenal injury (OIS III–V) Time-shift, 2007–14	0.92	0.98	(0.67–1.43)
Isolated duodenal injury (OIS I–V) Time-shift, 2007–14	0.017	1.77	(1.11–2.83)
Isolated duodenal injury (OIS III–V) Time-shift, 2007–14	0.042	1.87	(1.02–3.41)
	Early primary suture* Adjusted <i>p</i> value	OR	95% CI
Duodenal injury (OIS I–V) Time-shift, 2007–2014	0.62	1.08	(0.79–1.47)
Duodenal injury (OIS III–V) Time-shift, 2007–2014	0.94	0.98	(0.69–1.40)
Isolated duodenal injury (OIS I–V) Time-shift, 2007–2014	0.019	1.71	(1.1–2.66)
Isolated duodenal injury (OIS III–V) Time-shift, 2007–2014	0.041	1.67	(1.1–2.72)

OR odds ratio, CI confidence interval

*Corrected for age ≥ 65, gender, hypotension, GCS < 9, ISS > 15, mechanism, OIS, pancreatic injury

Table 4 Logistic regression model for inhospital mortality in isolated duodenal injury

	Inhospital mortality		
	Adjusted <i>p</i> value	OR	95% CI
Age ≥ 65 years	0.08	3.61	(0.86–15.15)
Gender, male	0.32	1.55	(0.65–3.72)
SBP < 90 mmHg	< 0.001	4.02	(2.16–7.46)
GCS < 9	0.001	3.23	(1.66–6.53)
ISS > 15	< 0.001	5.63	(2.21–14.36)
Mechanism, blunt	0.01	0.30	(0.12–0.75)
OIS			
I–II	Reference	Reference	
III	0.22	1.64	(0.74–3.63)
IV	0.548	0.76	(0.31–1.86)
V	0.002	3.47	(1.58–7.65)
Time shift, 2007–2014	0.041	0.47	(0.22–0.95)

SBP systolic blood pressure, GCS Glasgow Coma Scale, OIS Organ Injury Scale, ISS Injury Severity Score, OR odds ratio, CI confidence interval

fistula formation and fewer complications secondary to duodenal leakage with the use of pyloric exclusion.⁶

However, in the last decade, the literature has demonstrated a shift away from the use of complex procedures in favor of simpler surgical approaches for the repair of duodenal injuries.^{8–11} A retrospective study by Seamon et al. in 2007 looked at 29 patients undergoing repair with or without pyloric exclusion.⁹ They reported a trend toward increased overall complication rate and an increased length of hospital stay in the pyloric exclusion group. A retrospective study by DuBose et al. using the NTDB reported on the outcomes of 147 patients with high-grade duodenal injuries.¹⁰ They found no difference in mortality between the groups of patients treated with either primary repair or pyloric exclusion. In addition, patients undergoing pyloric exclusion were found to have a longer hospital stay of 32.2 days vs. 22.2 days. The timing of such publications may have been contributing factors to our results demonstrating an increased likelihood of undergoing less invasive procedures during the 2007–2014 time-shift period. Furthermore, the Western Trauma Association (WTA) published recommendations in 2014 regarding the management algorithm of duodenal injuries.¹² These guidelines reflect the evolving landscape of surgical techniques used in duodenal repair. The WTA algorithm outlines the use of simple techniques for repair of the large majority of duodenal injuries, with tension-free primary closure as the recommended initial surgical approach, even in higher grade injuries (OIS ≥ 3).

In patients with isolated duodenal injury, we also found significantly improved mortality during the later study period. While we can speculate that the use of less invasive procedures may confer a mortality benefit, the improvement in

mortality rate is likely to be multifactorial. DCS and damage control resuscitation (DCR) are novel strategies that have been developed in trauma care in the last few decades. Previous studies have shown clear survival benefits in both military and civilian trauma settings.^{13,14} Widespread adoption of DCS and improving resuscitation practices in patients with duodenal injury may have contributed to the overall mortality benefit observed in our results. Increasing use of less invasive procedure during this time period is also consistent with the trend seen in our results which demonstrate an increased rate of primary repair within 24 h in the 2007–2014 time period. Additionally, Siboni et al. recently reported the results of a retrospective study demonstrating simple repair for isolated blunt duodenal trauma to be associated with shorter hospital length of stay and no change in mortality when compared with more complex procedures.¹⁵ Our study broadens their findings to include both blunt and penetrating duodenal trauma, thus suggesting that simple repair may be the preferred procedure in more contexts.

While our results and reports in the previous literature demonstrate an overall trend toward less invasive procedures for high-grade duodenal injuries, it is important to note that grade 5 injuries still require complex procedures. Grade 5 duodenal injuries involve massive destruction of the duodenopancreatic complex with devascularization of the duodenum, often resulting in devastating outcomes. Our results show grade 5 injury to be a significant independent risk factor for mortality. Even if a patient survives the initial DCS, a complex surgery is still required for reconstruction or repair in the following takebacks to the operating room.

There are several limitations to the current study. First, the number of participating centers in the NTDB has increased over the study period. Therefore, there was a discrepancy in the number of patients included in the two study groups. Although more than 900 trauma centers in the USA currently submit their data to the American College of Surgeons, the database may still underrepresent a total volume of patients with duodenal injury. Second, the year cutoff used to divide into two groups (2002–2006 and 2007–2014) was arbitrary based on consensus among the authors. We hypothesized that there would be a significant paradigm shift in the practice patterns supported by the studies from the US trauma centers between 2006 and 2008.^{8–11} Third, there are limitations related to the data coded in the NTDB. We identified our study patients that met our inclusion criteria using ICD-9 codes. Instead of a single ICD-9 code, operations performed for duodenal injury can be a combination of several procedures (e.g., duodenal diverticulization, “triple tubes”). Thus, we elected to focus on four operations commonly performed in patients with duodenal injury. These procedures, although it would be unlikely, could have been performed for injuries to other organs. Similarly, we were unable to examine the impact of surgical techniques used for the pyloric exclusion (suture

vs. staple) or pancreaticoduodenectomy (pylorus-preserving vs. standard). Finally, our results should be interpreted carefully, particularly when evaluating the impact of changes in duodenal procedures on patient outcomes including mortality and major complications. Simply, our study was not designed to answer that type of question.

Conclusion

In the current study using a nationwide trauma database in the USA, we observed a clear trend toward less invasive techniques performed for duodenal injury. Significantly improved survival was also observed over the last 13 years. Future studies are still warranted to evaluate the impact of this recent surgical trend on patient outcomes.

Author Contribution Study concept, design: Aiolfi, Matsushima, Chang, Bardes, Strumwasser, Lam, Inaba, Demetriades

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

References

- Asensio JA, Feliciano DV, Britt LD, Kerstein MD. Management of duodenal injuries. *Curr Probl Surg* 1993;30:1023–1093.
- Velmahos GC, Tabbara M, Gross R, Willette P, Hirsch E, Burke P, et al. Blunt pancreatoduodenal injury: a multicenter study of the Research Consortium of New England Centers for Trauma (ReCONNECT). *Arch Surg* 2009;144:413–419.
- Blocksom JM, Tyburski JG, Sohn RL, Williams M, Harvey E, Steffes CP, et al. Prognostic determinants in duodenal injuries. *Am Surg* 2004;70:248–255.
- Berne CJ, Donovan AJ, Hagen WE. Combined duodenal pancreatic trauma: the role of gastrojejunostomy. *Arch Surg*. 1968;96:712–722.
- Vaughan GD III, Frazier OH, Graham DY, Mattox KL, Petmecky FF, Jordan GL Jr. The use of pyloric exclusion in the management of severe duodenal injuries. *Am J Surg*. 1977;134:785–790.
- Martin TD, Feliciano DV, Mattox KL, Jordan GL Jr. Severe duodenal injuries: treatment with pyloric exclusion and gastrojejunostomy. *Arch Surg*. 1983;118:631–635.
- Rotondo MF, Schwab CW, McGonigal MD, Phillips GR 3rd, Fruchterman TM, Kauder DR, et al. ‘Damage control’: an approach for improved survival in exsanguinating penetrating abdominal injury. *J Trauma*. 1993;35:375–382.
- Talving P, Nicol AJ, Navsaria PH. Civilian duodenal gunshot wounds: surgical management made simpler. *World J Surg* 2006;30:488–494.
- Seamon MJ, Pieri PG, Fisher CA, Gaughan J, Santora TA, Pathak AS, et al. A ten year retrospective review: does pyloric exclusion improve clinical outcome after penetrating duodenal and combined pancreaticoduodenal injuries? *J Trauma*. 2007;62:829–833.
- Dubose JJ, Inaba K, Teixeira PGR, Shiflett A, Putty B, Green DJ, et al. Pyloric Exclusion in the Treatment of Severe Duodenal Injuries: Results from the National Trauma Data Bank. *Am Surg*. 2008;74:925–929.
- Velmahos GC, Constantinou C, Kasotakis G. Safety of repair for severe duodenal injuries. *World J Surg* 2008;32:7–12.
- Malhotra A, Biffl WL, Moore EE, Schreiber M, Albrecht RA, Cohen M, et al. Western Trauma Association Critical Decisions in Trauma: Diagnosis and management of duodenal injuries. *J Trauma*. 2015;79:1096–1101.
- Roberts DJ, Ball CG, Feliciano DV, Moore EE, Ivatury RR, Lucas CE, et al. History of the Innovation of Damage Control for Management of Trauma Patients: 1902–2016. *Ann Surg*. 2017;265:1034–1044.
- Cannon JW, Khan MA, Raja A, Cohen MJ, Como JJ, Cotton BA, et al. Damage control resuscitation in patients with severe traumatic hemorrhage: A practice management guideline from the Eastern Association for the Surgery of Trauma. *J Trauma*. 2017;82:605–617.
- Siboni S, Benjamin E, Haltmeier T, Inaba K, Demetriades D. Isolated Blunt Duodenal Trauma: Simple Repair, Low Mortality. *Am Surg*. 2015;81:961–964.