The mortality for surgical repair is similar to ligation in patients with traumatic portal vein injury

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ABSTRACT

Background: Portal vein injury is uncommon, and the optimal treatment is controversial. We compared the outcomes of ligation vs repair of portal injury using the National Trauma Data Bank.

Methods: Adult patients who suffered portal injury were identified from the National Trauma Data Bank (2002-2014) by *International Classification of Diseases, Ninth Revision* diagnosis codes. Patients were stratified by treatment modality into no surgery, ligation, and surgical repair using *International Classification of Diseases* procedure codes. Outcomes including hospital mortality, bowel resection, and length of stay between ligation and surgical repair were compared by Kruskal-Wallis or Fisher exact test as appropriate. Multivariable analyses were performed with logistic regression.

Results: Among 752 patients with portal vein injury, 345 patients (45.9%) underwent no surgery, 103 patients (13.7%) had ligation, and 304 (40.4%) underwent surgical repair. Overall mortality was 49%. Age, sex, Injury Severity Score, Glasgow Coma Scale score, presenting blood pressure, and heart rate were similar between groups that underwent ligation and surgical repair. The hospital mortality (59.2% vs 47.7%; $P = .08$), bowel resection (1.9% vs 1.0%; $P = .55$), and length of stay (12.5 vs 15.0 days; $P = .08$) were also comparable between ligation and repair in univariate analysis. In multivariable analysis, hospital mortality for surgical repair was similar to ligation (risk ratio, 0.69; 95% confidence interval, 0.41-1.16; $P = .16$).

Conclusions: Portal vein injury is associated with significant mortality and morbidity. Surgical repair showed a trend for lower postoperative mortality than ligation, but this was not statistically significant on multivariate analysis. Repair of a traumatic portal vein injury should be attempted, but ligation is an acceptable alternative without an increase in bowel resection rates or a statistically significant increase in mortality. (J Vasc Surg: Venous and Lym Dis 2019;7:399-404.)

Keywords: Trauma; Vascular injury; Portal vein; Database

Portal vein injury is uncommon but frequently lethal. Averaging 2 cm in diameter, the portal vein carries 1 L/min of blood.[1] Injury to the portal vein is usually due to penetrating trauma, and mortality is high, ranging from 38% to 71%.[2-13] Petersen et al[4] described the location of the injuries in their series: 21% to the hilum of the liver, 39% to the midportion of the portal vein, and 39% to the confluence of the splenic and superior mesenteric veins. The ideal management of portal vein trauma is controversial. Isolation, exposure, and repair of a portal vein injury can be difficult, time-consuming, and not practical during a trauma operation, especially with concomitant injuries present. Options for repair include lateral venorrhaphy, end-to-end anastomosis, and interposition graft.[14] Portal-systemic shunting is another option when there is excessive portal hypertension or inadequate venous return to the heart, but it is associated with encephalopathy and hepatic insufficiency.[14]

An alternative to repair of the portal vein is ligation of the vein. The question of portal vein ligation was studied experimentally by Child.[15-17] Based on his experimental animal studies and case reports, Child originally estimated that up to 80% of patients might be able to tolerate acute ligation of the portal vein. Despite this, in practice, significant bowel edema causing compartment syndrome, ascites, respiratory failure, liver failure, bowel ischemia, and death can occur after ligation of the portal vein, as reported by Mattox et al[2] and Graham et al.[3] They reported up to 100% mortality associated with portal vein ligation in trauma patients. In these series, patients who underwent repair of the portal vein injury, even those with complete transection of the portal vein, had a higher survival rate up to 75%.

With no large series to guide management and existing data limited to small series, case reports, and anecdotal evidence, the optimal management of portal vein trauma is still controversial. Our goal in this paper was

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to use the National Trauma Data Bank (NTDB)[18] to compare the outcomes of patients undergoing ligation and repair after traumatic portal vein injury.

METHODS

We retrospectively identified adult patients (18 years or older) who suffered portal vein injury from the NTDB (2002-2014) by *International Classification of Diseases, Ninth Revision* diagnosis code (902.33). Those who were dead on arrival and younger than 18 years were excluded from the analysis. Patients were then stratified by treatment modality into no surgery, ligation, and surgical repair using *International Classification of Diseases* procedure codes (Appendix). The NTDB, established by the American College of Surgeons (ACS), is the largest trauma-related database in the United States for public repository of data. The data are voluntarily and prospectively reported by the participating trauma centers and are subject to quality screening for consistency and validity. The study was approved by our local ethical review board.

Preoperative demographics, such as age, sex, race, Injury Severity Score (ISS), Glasgow Coma Scale (GCS) score, systolic blood pressure, pulse rate, mechanism of injury, injury intent, ACS trauma center level, transfer status, body region, associated vascular injury, and associated solid organ injury, were reviewed. These preoperative characteristics were compared among patients who underwent no surgery, patients who underwent ligation, and patients who underwent repair of a portal vein injury. Differences in preoperative characteristics among the three groups were tested for significance with Kruskal-Wallis for continuous variables and Fisher exact test for categorical data.

The primary outcome measured was in-hospital mortality between the two surgical groups. Secondary outcomes including bowel resection and length of stay (LOS) between ligation and surgical repair were also compared. Multivariable analyses were performed with odds ratio derived from logistic regression for binary outcomes. The ratio of two estimated geometric means derived from a linear regression model based on the log-transformed LOS, intensive care unit (ICU) LOS, and ventilation days, respectively, was also performed. These were then adjusted for age, ISS >24, GCS score ≥ 8, and associated vascular injury. The association was expressed as risk ratio (RR) with corresponding 95% confidence interval (CI). $P < .05$ was considered to be statistically significant. Analyses were performed using SAS 9.3 software (SAS Institute, Cary, NC).

RESULTS

There were 752 patients identified with portal vein injury between 2002 and 2014 who were included in the study cohort. The average age was 37 years, 80% were male, and 43% were white (Table I); 64% had an ISS >24, and 65% had a GCS score ≥8. Nearly 50% presented to an ACS level I trauma center and 13% of patients were transferred to a level I trauma center. Associated injuries to the chest were the most common (61%), followed by injuries to the lower extremity (27%). The most common associated vascular injury was inferior vena cava injury (25%), followed by renal artery or vein (8%).

Among 752 patients with portal vein injury, 345 patients (45.9%) underwent no procedure, 103 patients (13.7%) underwent ligation, and 304 patients (40.4%) underwent surgical repair (Table I). Sex, race, ISS, GCS score, and heart rate on presentation were similar among the three groups (Table I). Patients who had no surgery and surgical repair were younger than patients who had ligation. Patients undergoing operative management had lower systolic blood pressure (106 mm Hg vs 113 mm Hg; $P = .01$). More patients undergoing repair had an associated upper extremity injury than those treated with ligation (26.3% vs 17.5%; $P = .02$). Associated aorta injury was also more common in the repair group than in the ligation group (5.6% vs 0%; $P = .01$), whereas celiac artery injury was more common in the ligation group (5.8% vs 2.3%; $P = .01$).

In Table II, the factors associated with mortality are shown. Nonwhite patients were nearly twice as likely to die of traumatic portal vein injury. Those with ISS >24 were more than two times as likely to die. A GCS score ≥8 had an odds ratio of 0.34 for mortality. Finally, an associated vascular injury carried a nearly threefold risk of mortality.

Next, in Table III, univariate analysis was performed to compare the odds ratio or relative risk of perioperative

ARTICLE HIGHLIGHTS

- **Type of Research:** Retrospective analysis of data from the National Trauma Data Bank
- **Key Findings:** In 752 patients with portal vein injury, 345 (46%) had no surgery, 103 (14%) underwent portal vein ligation, and 304 (40%) had portal vein repair with an overall mortality of 49%, with no significant demographic differences in the three groups. In the surgery groups, there was a trend but no significant difference in survival in the repair group vs ligation (59.2% vs 47.7%; risk ratio, 0.69; 95% confidence interval, 0.41-1.16; $P = .16$), with no differences in bowel resection (1.9% vs 1.0%; $P = .55$) or length of stay (12.5 vs 15.0 days; $P = .08$).
- **Take Home Message:** Portal vein repair should be attempted for injury, but ligation is an acceptable alternative, depending on the nature of the injury, the clinical circumstances, and the individual surgeon's ability to perform portal vein repair without an increase in bowel resection rates.

Table I. Characteristics of patients with portal vein injury

Characteristic	Portal vein injury (N = 752)	No surgery (n = 345)	Ligation (n = 103)	Repair (n = 304)	*P* value[a]
Age, years	36.63 ± 15.75	36.80 ± 15.84	40.24 ± 17.37	35.22 ± 14.90	<.05
Sex					
Male	598 (79.52)	276 (80.00)	80 (77.67)	242 (79.61)	.93
Female	151 (20.08)	68 (19.71)	23 (22.33)	60 (19.74)	
Unknown	3 (0.40)	1 (0.29)	0 (0.00)	2 (0.66)	
Race					
White	322 (42.82)	159 (46.09)	40 (38.83)	123 (40.46)	.14
African American	261 (34.71)	112 (32.46)	38 (36.89)	111 (36.51)	
Asian	17 (2.26)	6 (1.74)	7 (6.80)	4 (1.32)	
American Indian	4 (0.53)	1 (0.29)	0 (0.00)	3 (0.99)	
Others	101 (13.43)	43 (12.46)	16 (15.53)	42 (13.82)	
Unknown	47 (6.25)	24 (6.96)	2 (1.94)	21 (6.91)	.13
ISS (>24)	446 (63.99)	202 (63.32)	60 (63.83)	184 (64.79)	.93
GCS total score (≥8)	462 (64.98)	216 (66.46)	64 (66.67)	182 (62.76)	.60
Systolic blood pressure, mm Hg	109.25 ± 31.25	113.46 ± 31.21	105.86 ± 26.35	105.78 ± 32.08	.01
Pulse rate, beats/min	105.71 ± 30.03	103.86 ± 30.08	108.06 ± 30.68	107.03 ± 29.76	.31
Injury intent					
Unintentional		24 (6.96)	5 (4.85)	12 (3.95)	.05
Self-inflicted		1 (0.29)	2 (1.94)	1 (0.33)	
Assault		18 (5.22)	6 (5.83)	25 (8.22)	
Undetermined or other		302 (87.54)	90 (87.38)	266 (87.50)	1.00
ACS trauma center level					
I	372 (49.47)	167 (48.41)	61 (59.22)	144 (47.37)	.02
II	109 (14.49)	49 (14.20)	6 (5.83)	54 (17.76)	
III	4 (0.53)	2 (0.58)	0 (0.00)	2 (0.66)	
IV	0 (0)	0 (0.00)	0 (0.00)	0 (0.00)	
Not applicable	267 (35.51)	127 (36.81)	36 (34.95)	104 (34.21)	.79
Transfer	96 (12.77)	49 (14.20)	18 (17.48)	29 (9.54)	.06
Body region					
Traumatic brain injury	110 (14.63)	58 (16.81)	8 (7.77)	44 (14.47)	.07
Head, face, and neck	128 (17.02)	67 (19.42)	11 (10.68)	50 (16.45)	.11
Spinal or vertebral	25 (3.32)	11 (3.19)	4 (3.88)	10 (3.29)	.92
Chest	455 (60.51)	220 (63.77)	59 (57.28)	176 (57.89)	.23
Abdomen	752 (100)	4 (1.16)	0 (0.00)	4 (1.32)	.79
Upper extremity	8 (1.06)	106 (30.72)	18 (17.48)	80 (26.32)	.02
Lower extremity	204 (27.13)	76 (22.03)	13 (12.62)	66 (21.71)	.09
Associated vascular injury					
Aorta	27 (3.59)	10 (2.90)	0 (0.00)	17 (5.59)	.01
Inferior vena cava	189 (25.13)	81 (23.48)	26 (25.24)	82 (26.97)	.59
Celiac artery	16 (2.13)	3 (0.87)	6 (5.82)	7 (2.30)	.01
Superior mesenteric artery	40 (5.32)	14 (4.06)	8 (7.77)	18 (5.92)	.28
Renal artery and vein	61 (8.11)	22 (6.38)	11 (10.68)	28 (9.21)	.22
Iliac artery and vein	6 (0.80)	4 (1.16)	0 (0.00)	2 (0.66)	.63
Associated solid injury					
Liver	10 (1.33)	8 (2.32)	0 (0.00)	2 (0.66)	.11
Spleen	10 (1.33)	4 (1.16)	2 (1.94)	4 (1.32)	.75
Kidney	3 (0.40)	1 (0.29)	1 (0.97)	1 (0.33)	.52

ACS, American College of Surgeons; *GCS*, Glasgow Coma Scale; *ISS*, Injury Severity Score.
Categorical variables are presented as number (%). Continuous variables are presented as mean ± standard deviation.
[a]Derived from the Kruskal-Wallis test.

Table II. Factors associated with mortality among patients with traumatic portal vein injury

Variable	OR (95% CI)	*P* value
Race (nonwhite)	1.93 (1.39-2.69)	<.0001
ISS (>24)	2.36 (1.72-3.25)	<.0001
GCS score (≥8)	0.34 (0.25-0.47)	<.0001
Associated vascular injury	2.97 (2.17,4.07)	<.0001

CI, Confidence interval; *GCS*, Glasgow Coma Scale; *ISS*, Injury Severity Score; *OR*, odds ratio.

mortality, bowel resection, hospital LOS, and ICU LOS between the two surgical treatment cohorts (ligation vs repair). The rate of bowel resection (1.9% vs 1%; $P = .5$), ICU LOS (11.2 vs 11.2 days; $P = .45$), and ventilator days (7 vs 8 days; $P = .32$) were similar. Hospital LOS was longer in the repair group (12.5 vs 15.0 days; $P = .05$), and the mortality rate was significantly higher in the ligation group (59.2% vs 47.7%; $P = .04$). In multivariable analysis, after controlling for age, ISS >24, GCS score ≥8, and associated vascular injuries, the mortality rate (RR, 0.69; 95% CI, 0.41-1.16; $P = .16$), bowel resection rate (RR, 0.42; 95% CI, 0.05-3.32; $P = .41$), and hospital LOS (RR, 1.34; 95% CI, 0.93-1.94; $P = .12$) were similar between repair and ligation groups.

DISCUSSION

Portal vein injury is associated with significant mortality, and the optimal management of this injury is unclear. In this study, we evaluated the effect of ligation and surgical repair on the outcomes of patients with portal vein injuries using a large national database. The majority of pre-existing literature on portal vein injury was from small series and case reports (Table IV). Our overall mortality for portal vein injury was 49%, within the published range of 38% to 71%. The mortality for patients undergoing repair was 47% compared with 0% to 50% in the literature. The mortality for patients undergoing ligation was 59% compared with 0% to 100% in the literature. Our most significant finding is that the mortality of surgical ligation is not statistically significantly elevated compared with patients undergoing repair of portal vein injury, although there is a trend for survival advantage among patients who underwent repair and reconstruction instead of ligation. Furthermore, the data show that ligation of the portal vein is compatible with survival and does not lead to any increased risk of bowel resection.

Fish[14] described several methods for reconstruction of the portal vein. The simplest is lateral repair of the vein. A side-biting clamp can be placed on the portal vein to exclude the venotomy. With a complete transection, an end-to-end anastomosis can be made after débridement of the edges of the vein. If there is not enough length for primary anastomosis, an interposition graft can be performed. Finally, a portocaval shunt can be performed if there is evidence of severe portal hypertension, but this is strongly associated with hepatic insufficiency.[14]

The initial experimental work with monkeys and case reports by Child[15-17] suggested that portal vein ligation would be well tolerated by humans, up to 80% estimated survival, albeit with risk for development of portal hypertension. Child observed that on ligation of the portal vein, there is a drop in systemic blood pressure of 30 mm Hg, which normalizes within 30 minutes. There is also an increase in portal venous pressure and a decrease in liver volume. Ten days after ligation, liver function test results and biopsy findings of the liver are normal. Immediate drainage is through pelvic collaterals, with porta hepatis hilar collaterals forming and increasing in size during the course of 1 to 6 months. Subsequently, patients may develop significant ascites or bowel edema and may later require decompressive laparotomy and a procedure to relieve portal hypertension. Patton and Johnston[19] described two cases of traumatic abdominal injuries that resulted in portal hypertension. In one case, the patient's portal vein was ligated; in the other, there was an attempt at repair, but this later thrombosed. Procedures to relieve portal hypertension include portocaval shunt and mesocaval

Table III. Comparisons of perioperative outcome variables between ligation only and repair only/both for portal vein injury

Outcome	All portal vein injuries (N = 752)	Ligation only (n = 103)	Repair only/both (n = 304)	OR[a]/RR[b] (95% CI; *P* value)	
				Unadjusted	Adjusted[c]
Mortality	368 (48.94)	61 (59.22)	145 (47.70)	0.63 (0.40-0.99; .04)	0.69 (0.41-1.16; .16)
Bowel resection	8 (1.06)	2 (1.94)	3 (0.99)	0.50 (0.08-3.06; .45)	0.42 (0.05-3.32; .41)
LOS, days	12.46 ± 21.76	12.46 ± 23.63	14.97 ± 25.84	1.42 (0.99-2.02; .05)	1.34 (0.93-1.94; .12)
LOS in ICU, days	10.85 ± 15.15 (n = 477)	11.20 ± 16.05	11.10 ± 15.40	1.16 (0.79-1.71; .45)	1.11 (0.75-1.66; .60)
Ventilator days	7.66 ± 13.07 (n = 421)	7.02 ± 10.37	8.11 ± 12.17	1.22 (0.82-1.80; .32)	1.10 (0.74-1.63; .64)

CI, Confidence interval; *ICU*, intensive care unit; *LOS*, length of stay; *OR*, odds ratio; *RR*, risk ratio.
Categorical variables are presented as number (%). Continuous variables are presented as mean ± standard deviation.
[a]Odds ratio derived from logistic regression for binary outcomes (ie, mortality and bowel resection).
[b]Ratio of two estimated geometric means derived from a linear regression model based on the log-transformed LOS, ICU LOS, and ventilation days, respectively.
[c]Adjusted for age, Injury Severity Score (ISS) > 24, Glasgow Coma Scale (GCS) score ≥ 8, and associated vascular injury.

Table IV. Case series of portal vein trauma

Author	Year	Mechanism	Total size, No.	Mortality, % (No.)	Survival, % (No.)	
					Ligation	Repair
Mattox et al[2]	1975	Penetrating 90.9%	22	50 (11)	0 (4)	75 (9)
Graham et al[3]	1978	Penetrating 82%	37	51.3 (19)	0 (4)	61.5 (16)
Petersen et al[4]	1979	Penetrating 89.2%	28	39 (11)	60 (3)	68 (13)
Cohen et al[5]	1980	Penetrating 90.9%	8	37.5 (3)	NR	60 (3)
Kashuk et al[6]	1982	Penetrating 88%	9	67 (6)	0 (1)	NR
Stone et al[7]	1982	Penetrating 93%	41	46 (19)	50 (9)	70.5 (12)
Wiencek and Wilson[8]	1986	Penetrating 96%	31	51 (16)	0 (3)	50 (6)
Ivatury et al[9]	1987	Penetrating 100%	14	50 (7)	100 (1)	60 (6)
Dawson et al[10]	1991	Penetrating 61.9%	14	63.6 (7)	0 (2)	100 (4)
Jurkovich et al[11]	1995	Penetrating 69%	55	64 (35)	10 (1)	58 (19)
Tyburski et al[12]	2001	Penetrating 89%	36	69 (25)	NR	NR
Pearl et al[13]	2004	Penetrating 100%	15	40 (6)	67 (2)	86 (6)

NR, Not reported.

shunt but have a high rate of encephalopathy.[14] In our study, there was no increase in bowel resection rates among patients undergoing ligation of the portal vein.

However, as summarized in Table IV, the early trauma literature by Mattox et al[2] and Graham et al[3] supported repair as the results with ligation were poor. Alternatively, the report of Petersen et al[4] described 28 patients who had portal vein injuries. In their series, the main risk factor for mortality was an associated vascular injury. Ligation of the portal vein was successful in three of five patients, and none of them required a portosystemic shunt or had small bowel infarction. They reported a higher survival rate of 68% with repair. Contemporary series, such as those by Dawson et al,[10] Jurkovich et al,[11] and Pearl et al,[13] also supported high survival rates with repair instead of ligation. However, the number of cases in these series is relatively small. More recently, a hybrid approach of embolization of the portal vein by laparotomy has also been described.[20]

In this study, we identified 752 portal vein injuries, 407 of which were managed operatively; 304 underwent repair vs 103 that underwent ligation. Portal vein injuries are associated with significant mortality, approximately 50% in this study. We found that mortality was high for both treatment groups. Mortality was 59% for patients undergoing ligation and 47% for repair. This was not statistically significantly different in multivariate analysis. Our findings provide evidence supporting the approach of ligation in patients with portal vein injuries that cannot be repaired because of the surgeon's ability, the patient's instability, or the nature of the injury.

The type of repair depends on the extent of injury, but lateral venorrhaphy should be performed if possible. Complete transection is rare, and an end-to-end anastomosis or interposition graft is rarely indicated. Portal vein reconstruction should also be performed if there is concomitant injury to the hepatic artery because of the high risk of hepatic infarction. Although it is not well studied, limited follow-up has demonstrated patency if repair is performed. In the series by Ivatury et al,[9] the authors followed up three patients undergoing venorrhaphy with duplex ultrasound.[9] They documented patency in two patients, and in the third patient, the thrombosis resolved with anticoagulation. Nevertheless, ligation of the portal vein may be compatible with survival. If there is uncontrolled hemorrhage, ligation may be preferred and should be performed early. One series documented a higher rate of survival (for both superior mesenteric vein and portal vein injuries) when the vein is ligated earlier rather than later.[7] In these cases of ligation, planning on or having a low threshold for a second-look laparotomy is advisable.

As a retrospective review of a prospective databank, this study has several limitations and factors that could contribute to selection bias. First and foremost, patients are not randomized to receive ligation or surgical repair of the portal vein. There could be a significant treatment bias that patients who were in extremis were more likely to undergo ligation of the portal vein than patients who were more stable. We performed a multivariate analysis to correct for age, ISS, GCS score, and associated vascular injury in an attempt to correct for this. However, we are limited by the variables collected by the databank. Variables that may be useful in estimating the complexity of surgery or the intraoperative condition of the patient, such as length of surgery and intraoperative vital signs, are not recorded in the databank. We could not identify which patients may have had a transection of the portal vein vs a simple laceration. We did observe that ISS, GCS score, blood pressure, and pulse rate were

similar in both surgical groups. Nevertheless, the severity and location of the portal vein injury are not captured in the databank. In addition, we are unable to control for the surgeon who may have been unable to repair the portal vein and therefore may have been biased toward ligation. Despite these limitations, we did detect a trend toward a survival advantage for repair, but this effect was no longer statistically significant when controlled for age, ISS, GCS score, and associated vascular injuries. We also found that the rate of bowel resection was similarly low for both repair and ligation of the portal vein.

CONCLUSIONS

Until now, data on whether to perform ligation or repair have largely been anecdotal and based on small series. Our study, using a national database to evaluate the outcomes of patients who underwent surgery for portal vein injury, has shown statistically similar perioperative survival for ligation and surgical repair with a trend toward increased survival with repair. Our observation supports the repair of traumatic portal vein injuries when it is technically possible and feasible, but ligation of the portal vein is an acceptable approach in those who are critically ill or unstable or in whom simple repair is not possible.

AUTHOR CONTRIBUTIONS

Conception and design: JS, CH, QC, TT
Analysis and interpretation: JS, CH, QC, TT
Data collection: QC, TT
Writing the article: JS, CH, QC, TT
Critical revision of the article: JS, CH, QC, TT
Final approval of the article: JS, CH, QC, TT
Statistical analysis: JS, CH, TT
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Overall responsibility: JS

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APPENDIX.

International Classification of Diseases, Ninth Revision **procedure codes for ligation and open repair.**

Ligation (division/ligation of blood vessel): 38.86, 38.87, 38.8

Open repair

Primary repair (resection of vessel with anastomosis): 38.36, 38.37, 39.3, 39.30, 39.31, 39.32

Interposition (resection of vessel with replacement or graft): 38.46, 38.47, 39.56, 39.57, 39.58