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Mechanism of injury and in-hospital mortality in penetrating jugular vein injuries: a National Trauma Data Bank (NTDB) study

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Abstract. – OBJECTIVE: Timely intervention is the key to the successful management of penetrating injuries to jugular veins; however, the optimal clinical management of these perforations and associated risk factors for mortality are not fully established. This study examined the trauma characteristics, vital signs, and in-hospital mortality in penetrating external and internal jugular vein injuries (PEJVI and PIJVI, respectively).

PATIENTS AND METHODS: In this National Trauma Data Bank database study on patients with penetrating jugular vein injuries (PJVIs), details pertaining to demographics, comorbidities, type of injury, mechanism and intent of injury, Injury Severity Score (ISS), vital signs, treatment, and outcome, were abstracted. Multivariate logistic regression was used to identify the risk factors of in-hospital mortality.

RESULTS: A total of 548 patients with PJVIs were included in the final analysis. Patients with PEJVI were more likely to have a self-inflicted injury (*p*<.001) than those with PIJVI. In both groups, hemorrhage control surgery was performed in almost 60% of the patients within 24 hrs. of the injury (*p*=.767). Systolic blood pressure (OR 0.99, 95% CI: 0.98-1.00, *p*=.043), Glasgow coma scale (OR 0.88, 95% CI: 0.81-0.95, *p*<.001), ISS (OR 1.10, 95% CI: 1.06-1.14, *p*<.001), and the firearm as a mechanism of injury (OR 2.85, 95% CI: 1.19-6.79, *p*=.018) were found to be independently associated with the risk of in-hospital mortality.

CONCLUSIONS: The injury severity, hemodynamic stability, comma scale, intent, and mechanism of injury differed significantly in PEJVI and PIJVI; however, the type of PJVI did not have an independent association with in-hospital mortality.

Key Words:

Penetrating neck trauma, Blood vessel injury, Jugular vein, Mortality, Injury mechanism.

Introduction

The neck is an anatomically narrow region with a dense concentration of vital structures. Any penetrating injury to the neck may severely damage the arteries and veins there[1-3]. Although penetrating blood vessel injuries (PBVIs) of the neck are rare, they pose a severe mortality risk and may warrant an immediate intervention to control the hemorrhage[4,5]. Thankfully, such risks have decreased in the recent past because of improved trauma management practices and reduced time from the initial injury to arrival to the emergency department (ED). However, the outcome still greatly depends on the timely adoption of an appropriate management strategy[6-11].

Management of penetrating injuries to blood vessels in the neck demands a clear understanding of the vascular anatomy and function[12]. Operative management of PVBI involves neck exploration, followed by surgical ligation or repair of the identified injuries[13]. However, with the advances in trauma management tools and protocols, the emphasis is now on observation and selective use of imaging and endoscopy[9]. Angioembolization has evolved as a hemorrhage control modality. Nonoperative management (NOM) and the "no zone" approach are also receiving.

increasing acceptance[14]. Underscoring the urgency and accuracy of the intervention is the fact that even a temporary arrest of hemorrhage at the site of the accident has been reported to save the life of the patients. Under this setting of competing priorities, a selective surgical exploration only after a careful analysis of the type and severity of the PBVI is often considered an optimal approach[6-8]. However, it has also been observed that potentially lethal injuries to major

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vascular and visceral structures in the neck may go undetected if selective exploration criteria are used indiscriminately[15].

Venous injuries are the least common PBVIs[16]. The main veins in the neck region are the external jugular vein (EJV) and internal jugular vein (IJV)[9,17-19]. Jugular vein injuries (JVIs) are more likely to be caused by penetrating neck trauma[20]. Unlike arteries in the neck, the venous system is a low-pressure system; therefore, it has a considerably different risk profile. However, the existing literature on JVI is limited, and little information is available on the spectrum of these injuries and the associated trauma mechanism, intent, severity, Glasgow comma status, hemodynamic stability, and clinical management.

The National Trauma Data Bank (NTDB) is the world's largest trauma data repository[21-33]. The present study utilizes the NTDB database to investigate the demographic and clinical features of penetrating JVIs (PJVIs). The demographics, vital signs, type of injury, trauma mechanism, first surgery for hemorrhage control, and in-hospital mortality in patients with a PJVI were examined. The risk factors for in-hospital mortality were examined, and a subgroup analysis was conducted with respect to penetrating EJVs (PEJVs) and penetrating IJVs (PIJVs).

Patients and Methods

The NTDB database for 2017 was examined to identify patients who sustained an isolated traumatic JVI. Patients with blunt traumas and injuries to multiple blood vessels in the neck were excluded[5,34-37.] Furthermore, all patients with contaminant injuries in other organs were excluded. Only injuries in the neck/head ISS body region were included.

The key variables extracted from the NTDB database included demographics, types of blood vessels in the neck, comorbidities, mechanism of injury, Systolic Blood Pressure (SBP), Glasgow Coma Scale (GCS), Injury Severity Score (ISS), the First Type of Surgery for Hemorrhage Control (FSHC) within the first 24 h of ED/hospital arrival, and vital signs in the ED. The treatment modalities were also abstracted. The primary outcome was in-hospital mortality. The key secondary outcomes included in-hospital stroke, sepsis, length of stay (LOS) in the ICU, and LOS in the hospital.

GCS was classified into two groups: GCS<9 (severe)[38] and GCS ≥9. SBP was divided into two groups: SBP <90 mmHg (shock) and SBP≥90 mmHg[39]. The ISS scale was also classified into two groups: ISS>15 (major trauma) and ISS≤15[40]. These variables were analyzed both as continuous and dichotomous variables using the above-mentioned classification. The terminology used in the NTDB database was retained for the sake of standardization.

The mechanism of injury was defined as cut/pierce, firearms, and natural/environmental[41], broadly representing stabbing, gunshot, and other types of injuries, respectively. The key operative procedures (root operations) performed on the vessels were occlusion and repair. The term occlusion includes ligation too. NOM was defined as the absence of associated International Classification of Diseases, Tenth Revision, Procedure Coding System (ICD-PCS) procedures. In the NTDB database, the approach was defined as "open" or "percutaneous". The details of each injury and each vascular surgery procedure are given in the Supplementary Data (**Supplementary Tables I** and **II**).

Statistical Analysis

Categorical variables were reported as percentages, while continuous variables were reported as median with the interquartile range (IQR). Continuous variables were placed into clinically relevant groups. Univariate analysis was performed to identify differences between outcomes in the groups of interest. The Mann-Whitney U test was used to compare continuous variables, while Fisher's exact or Pearson's chi-square test was used to compare proportions for categorical variables. Variables with a p-value <.05 were considered significant. All statistical analysis was performed using STATA for Windows version 16.0.

Results

Overall Demographics and Clinical Characteristics

A total of 548 cases of the PJVI were observed in the NTDB database (Figure 1 and Table I). Patients with a PJVI were more likely to be men (81.0%). The median age of the patients was 35 (26-49) years, and only 51 (9.3%) patients were more than 60 years old. With respect to ED vital signs, 120 (21.9%) patients had GCS <9 and 73 (13.3%) had SBP<90

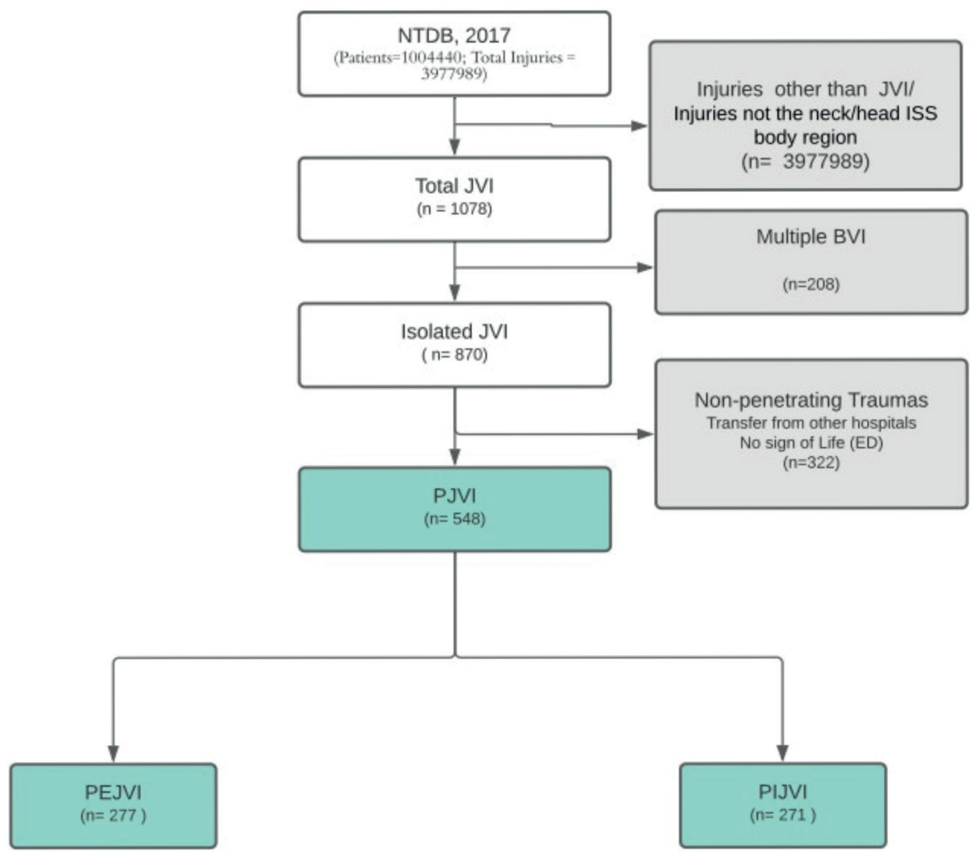

Figure 1. Study flow chart NTDB: National Trauma Data Bank, BVI: Blood vessel injury, JVI: Jugular vein injury, PEJVI: Penetrating external jugular vein, PIJVI: Penetrating internal jugular vein, n: Number of reported incidences.

mmHg. The median respiratory rate was 19.0 (16-22) per minute. The frequently observed comorbidities included hypertension and diabetes mellitus, which were observed in 57 (10.4%) and 28 (5.1%) patients, respectively. Assault was the most frequent intent of injury and was observed in 311 (56.8%) patients, followed by self-inflicted injuries observed in 184 (33.6%) patients. Cut/pierce (419, 76.5%) was the most commonly observed injury mechanism, followed by firearms (123, 22.4%). Natural/environmental mechanisms were responsible only for 6 (1.1%) injuries (Table I).

PEJVI and PIJVI: Demographics and Vital Signs

Table I presents the demographics and clinical characteristics of patients with PEJVI and PIJVI. The observed incidences of PEJVI and PIJVI were almost the same. For both PEJVI and PIJVI, the patients are more likely to be men. Patients in the PIJVI group were younger (p<.001). Median SBP was not statistically different between the groups, and both had approximately 13% of patients with SBP<90 (p>.001). The respiratory rate was higher in patients with PIJVI (p<.001). Approximately 25% of patients with PEJVI had ISS >15, whereas 41.7% of patients with PIJVI had ISS>15 (p<.001). There was no significant difference between the two groups in terms of the percentage of patients with preexisting diabetes, under anticoagulant therapy, or with a bleeding disorder. The relative incidences of self-inflected injury were significantly higher in patients with PEJVI (45.5%) than in those with PIJVI (21.4%, p<.001). In approximately 9% of patients with PEJVI, the trauma mechanism was a firearm, while it was in 36.2% of patients with PIJVI (p<0.001, Table I).

Table I. Demographics, clinical features, and trauma mechanisms in patients with PJVI.

		PEJVI (N = 277)	PIJVI (N = 271)	Total (N = 548)	*p*-value
Age (Years)	Median (Q1, Q3)	39.0 (28.0, 54.0)	32.0 (23.0, 45.0)	35.0 (26.0, 49.0)	<.001
	Age > 60	39 (14.1%)	12 (4.4%)	51 (9.3%)	<.001
Sex	Male	224 (80.8%)	219 (80.8%)	443 (80.8%)	.917
	Female	53 (19.1%)	52 (19.1%)	105 (19.1%)	
Ethnicity	Hispanic or Latino	55 (19.8%)	41 (15.1%)	96 (17.5%)	.128
	Others	222 (81.9%)	230 (84.8%)	452 (82.4%)	
Race	Black	242 (87.4%)	237 (87.5%)	479 (87.4%)	.975
	White	35 (12.6%)	34 (12.5%)	69 (12.6%)	
ED vital signs	GCS < 9	54 (19.5%)	66 (24.4%)	120 (21.9%)	.169
	GCS	15.0 (11.5, 15.0)	15.0 (9.0, 15.0)	15.0 (10.0, 15.0)	.817
	SBP < 90	36 (13.0%)	37 (13.7%)	73 (13.3%)	.821
	SBP	123.0 (101.0, 139.0)	122.5 (107.0, 140.0)	123.0 (104.0, 139.0)	.943
	Respiratory Rate	18.0 (16.0, 22.0)	20.0 (17.5, 22.0)	19.0 (16.0, 22.0)	.049
	Pulse Rate > 120	83 (30.0%)	83 (30.6%)	166 (30.3%)	.866
	ISS	10.0 (5.0, 14.0)	13.0 (8.0, 22.0)	10.0 (5.0, 18.0)	<.001
	ISS >1 5	69 (24.9%)	113 (41.7%)	182 (33.2%)	<.001
Comorbidity	Anticoagulant Therapy	2 (0.7%)	1 (0.4%)	3 (0.5%)	.576
	Bleeding Disorder	0 (0.0%)	1 (0.4%)	1 (0.2%)	.312
	Diabetes Mellitus	17 (6.1%)	11 (4.1%)	28 (5.1%)	.269
	Hypertension	37 (13.4%)	20 (7.4%)	57 (10.4%)	.022
	Myocardial Infarction	1 (0.4%)	1 (0.4%)	2 (0.4%)	.988
	CHF	1 (0.4%)	1 (0.4%)	2 (0.4%)	.988
	Unintentional	14 (5.1%)	20 (7.4%)	34 (6.2%)	
	Self-inflicted	126 (45.5%)	58 (21.4%)	184 (33.6%)	
	Assault	134 (48.4%)	177 (65.3%)	311 (56.8%)	
	Undetermined	3 (1.1%)	14 (5.2%)	17 (3.1%)	
	Others	0 (0.0%)	2 (0.7%)	2 (0.4%)	
Mechanism					<.001
	Cut/pierce	249 (89.9%)	170 (62.7%)	419 (76.5%)	
	Firearm	25 (9.0%)	98 (36.2%)	123 (22.4%)	
	Natural/environmental, bites and stings	3 (1.1%)	3 (1.1%)	6 (1.1%)	

PEJVI: Penetrating External Jugular Vein Injury, PIJVI: Penetrating Internal Jugular Vein Injury, GCS: Glasgow Coma Scale, SBP: Systolic Blood Pressure (mmHg), RR: Respiratory Rate (number per minute), PR: Pulse Rate (number per minute), ISS: Injury Severity Scale. Continuous variables are presented as median (Q1, Q3) and categorical variables as N (%). Chi-squared test was used for categorical and Kruskal–Wallis tests for continuous variables.

PEJVI and PIJVI: Trauma Management and Outcome

The time to emergency management service (EMS) response was slightly longer for patients with PIJVI (*p*=.049, Table II). An angiogram with embolization was used in 7 patients. FSHC in the neck region was performed in more than 50% of patients in both groups (*p*=.767). With respect to vascular surgery, repair of the JV was performed in 21% of patients and NOM was used in approximately 60% of cases. Specific details of all procedures are provided in Supplementary Table II.

The median LOS (ICU) was almost similar for patients with PIJVI and PEJVI (*p*=.503). However, the median LOS (hospital) was slightly higher for patients with PIJVI (*p*=.045). Stroke occurred in approximately 3.0% of patients with PIJVI and in 0.4% of patients with PEJVI (*p*=0.053). Cardiac arrest with CPR was observed in 2.9% of patients with PEJVI and in 6.3% of patients with PIJVI (*p*=.058).

In-Hospital Mortality in PEJVI and PIJVI

In-hospital mortality was 3.5% in the patients with PEJVI and 14.1% in those with PIJVI (*p*<.001, Table II). Results of both univariate and multivariate analyses of the potential risk factors for in-hospital mortality are presented in Table III. Univariate analysis revealed that SBP, GCS, firearm as a mechanism of injury, ISS, and type of JVI were associated with the risk of in-hospital mortality. Compared to the PEJVI, the PIJVI had an approximately 4 times higher risk for in-hospital mortality (OR 4.562.15-9.69, *p*<0.001). The

Table II. Trauma response, management, and outcome in different PJVIs.

	PEJVI (N = 277)	PIJVI (N = 271)	Total (N = 548)	*p*-value
Time to EMS Response (min)	7.0 (5.0, 10.0)	6.0 (4.0, 9.5)	7.0 (5.0, 10.0)	.049
Time EMS spent at scene (min)	11.0 (7.0, 16.0)	10.0 (6.0, 14.0)	11.0 (7.0, 15.0)	.010
Time from dispatch to hospital arrival (min)	33.0 (24.0, 48.0)	29.0 (23.0, 40.0)	31.5 (23.0, 42.5)	.003
Angiography (min)	130.0 (31.0, 173.0)	166.0 (57.0, 277.0)	149.5 (44.0, 248.0)	.389
Time to hospital procedure (min)	48.0 (34.0, 83.0)	55.0 (40.0, 104.0)	53.0 (38.0, 86.0)	.052
LOS (ICU)	3.0 (2.0, 5.0)	3.0 (2.0, 6.0)	3.0 (2.0, 5.0)	.503
LOS (Hospital, days)	4.0 (2.0, 8.0)	5.0 (3.0, 9.0)	4.0 (3.0, 9.0)	.045
Angiography				.298
None	85/96 (88.5%)	109/129 (84.5%)	194/225 (86.2%)	
Angiogram only	10/96 (10.4%)	14/129 (10.9%)	24/225 (10.7%)	
Angiogram with embolization	1/96 (1.0%)	6/129 (4.7%)	7/225 (3.1%)	
FSHC$				.025
None	8/97 (8.2%)	27/130 (20.8%)	35/277 (12.6%)	
Neck Surgery	58/97 (59.8%)	73/130 (56.2%)	131/277 (47.3%)	
Others	31/97 (32.0%)	30/130 (23.1%)	61/277 (22.0%)	
Vascular Surgery				.021
NOM	163 (58.8%)	184 (67.9%)	347 (63.3%)	
Occlusion	47 (17.0%)	30 (11.1%)	77 (14.1%)	
Repair	65 (23.5%)	50 (18.5%)	115 (21.0%)	
Others	2 (0.7%)	7 (2.6%)	9 (1.6%)	
Approach#				.078
NOM	163 (58.8%)	184 (67.9%)	347 (63.3%)	
Open	107 (38.6%)	80 (29.5%)	187 (34.1%)	
Percutaneous	7 (2.5%)	7 (2.6%)	14 (2.6%)	
Complications				
Cardiac arrest	8 (2.9%)	17 (6.3%)	25 (4.6%)	.058
Embolism	1 (0.4%)	2 (0.7%)	3 (0.5%)	.550
Intubation	3 (1.1%)	9 (3.3%)	12 (2.2%)	.073
Sepsis	2 (0.7%)	5 (1.8%)	7 (1.3%)	.242
Stroke	2 (0.7%)	8 (3.0%)	10 (1.8%)	.051
Pneumonia	1 (0.4%)	6 (2.2%)	7 (1.3%)	.053
Mortality	9 (3.2%)	36 (13.3%)	45 (8.2%)	<.001

$First type of surgery for hemorrhage control within the first 24 h of ED/hospital arrival. PEJVI: Penetrating External Jugular Vein Injury, PIJVI: Penetrating Internal Jugular Vein Injury, EMS: Emergency Management Service, LOS: Length of Stay (days), ICU: Intensive Care Unit. #The approach is defined as the technique used to reach the site of the procedure (details of specific procedures are provided in the Supplementary Information). Continuous variables are presented as median (Q1, Q3) and categorical variables as N (%). Chi-squared test was used for continuous and Kruskal-Wallis tests for categorical variables.

intent of injury was not associated with the risk of in-hospital mortality; however, firearm, as a mechanism of injury, had a markedly higher risk of mortality (OR 7.85 4.10-15.01, $p<0.001$) than the cut/pierce mechanism. Notably, the incidences of severe trauma (ISS>15) were also significantly higher in firearm than in the cut/pierce mechanism of injury (Figure 2).

All variables found significant in univariate analysis were also considered in the stepwise multivariate analysis. SBP (OR 0.99 0.98-1.00, p=.043), GCS (OR 0.880.81-0.95, p<.001), ISS (OR 1.101.06-1.14, p<.001), and the firearm as a mechanism of injury (OR 2.85 1.19-6.79, p=.018) were found to be independently associated with the risk of in-hospital mortality (Table III).

Discussion

Vascular injuries have always received great importance due to the concerns associated with mortality, limb viability, and long-term morbidity[9,15,18,20]. For a considerable period, ligation of the injured vessel remained the accepted form of treatment; however, the alarming rate of amputation that followed vascular injuries in the Second World War, Korean War, and Vietnam War forced surgeons to dramatically revise the surgical approach in favor of vascular repair[42]. Indeed, the vascular repair was hailed as the method of choice wherever practicable, and restoration of venous outflow was given the highest priority in the management of venous injuries.

Table III. Univariate and multivariate analyses of risk factors for mortality.

Variable	Univariate		Multivariatel	
	OR 95% CI	*p*-value	OR 95% CI	*p*-value
Sex (Women)	0.780.34-1.80	.557		
Age (Years)	1.000.98-1.02	.759		
SBP	0.98 0.97-0.99	.001	0.99 0.98-1.00	.043
PR	1.011.00-1.02	.102		
RR	1.01 0.96-1.07	.687		
GCS	0.810.76-0.86	<.001	0.880.81-0.95	.001
ISS	1.131.09-1.17	<.001	1.101.06-1.14	<.001
Intent				
Unintentional (base)	Ref	.		
Self-inflected	0.800.17-3.90	.786		
Assault	1.74 0.40-7.64	.465		
Undetermined	5.000.517-14.765	.084		
Mechanism				
Cut/Pierce	Ref	.	Ref	
Firearm	7.85 4.10-15.01	<.001	2.85 1.19-6.79	.018
JVI	4.562.15-9.69	<.001	2.23 0.85-5.88	.103
Angiography FSHC$	0.590.22-1.53	.277		
None	Ref			
Neck Surgery	0.880.30-2.57	.813		
Others	1.460.47-4.57	.784		
Venous surgery				
NOM	Ref			
Occlusion	0.35 0.11-1.18	.091		
Repair	0.47 0.19-1.16	.101		

$FSHC: First type of surgery for hemorrhage control within the first 24 h of ED/hospital arrival. PJVI: Penetrating jugular vein injury, GCS: Glasgow coma scale, SBP: Systolic blood pressure (mmHg), RR: Respiratory rate (number per minute), PR: Pulserate (number per minute), ISS: Injury Severity Scale.

This approach, however, was challenged later. Timberlake et al[13] in a seminal work on venous injuries, suggested that selective management based on factors such as injury mechanism, severity, and location, is a better approach[43]. Even today, the rarity of vascular injuries in the neck and the paucity of available literature limits our understanding of the factors associated with vascular trauma at the neck level. In this respect, PJVIs deserve specific attention as there is little information available on the trauma mechanism, hemodynamic stability, commas status, injury severity, and surgical management of PJVI.

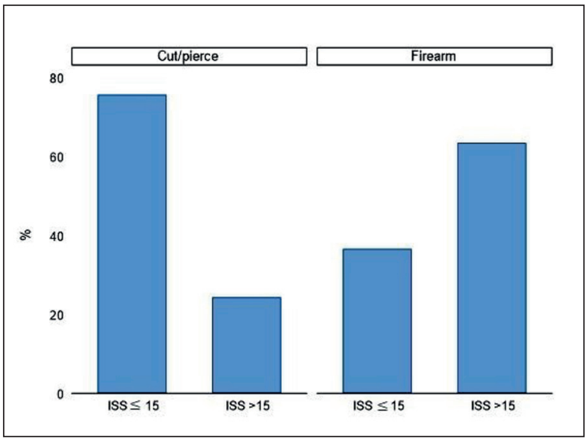

Figure 2. Relative incidences of severe trauma in cut/pierce and firearm mechanism.

JV can be broadly classified into external (EJV) and internal (IJV) jugular veins. Anatomically, EJVs are relatively superficial, and thus, they are more prone to neck trauma injuries than IJVs. On the other hand, injuries to IJVs are generally, more difficult to control due to the severity of the associated hemorrhage, accessibility of the site, and potential concomitant injuries. Using the NTDB database, the present study examined various aspects of PJVIs, including vital signs, injury severity, FSHC, vascular surgery, and in-hospital mortality. Our study revealed that patients with PJVIs are more likely to be young men. It is generally believed that men in their 30s and 40s are at a higher risk of penetrating injuries[9,44]. Our study revealed that this assertion is true for both types of PJVIs.

Approximately 20% of the patients were comatose (GCS<9), with no statistically significant difference between the PEJVI and PIJVI. However, patients with PIJVI were more likely to have severe trauma (ISS>15). The intent of injury was also significantly different, and the incidences of self-inflicted injuries in PJVI were considerably higher in PEJVI. Such a difference is expected as the self-inflicted injuries in the neck regions are less likely to reach IJV due to their anatomical location. With respect to the injury mechanism in JVIs, Inaba et al[9] reported 75% of the injuries were due to stabbing, and the remaining were due to gunshot. These results are close to the incidences observed in our study. Indeed, it is generally believed that the majority of penetrating neck injuries involve stab wounds, and the prevalence of gunshot injuries is minor. Our results suggest that PEJVIs and PIJVI are considerably different in terms of trauma mechanisms. The firearms, mechanism was responsible for only 10% of PEJVIs; however, a significantly higher fraction (~35%) of PIJVI involved firearms as the injury mechanism.

FSHC was used in more than 55% of patients with PJVIs. The frequency of FSHC was not statistically different between the patients with PIJVIs and those with PEJVIs. Angiography with embolization was rarely used. The LOS (hospital) was slightly higher in PIJVI than in PEJVI. Note that in the case of an injured EJV, the neurological status is rarely of concern in surgical management, and a major blood loss can be prevented by applying external pressure[45]. In contrast, the management of IJVs is more complex and greatly depends on the patient's hemodynamic stability. In the present study, the number of patients with SBP<90 was not different between the two groups, and only less than 15% of patients had SBP<90. Trauma management typically involved an open approach, suggesting that regardless of the increasing popularity of endovascular approaches, they are still not common in trauma management[22,27,28]. These results also support the fact that those open techniques, such as surgical repair or surgical ligation remain the standard surgical methods for JVI management[6,13,46,47].

The in-hospital mortality rate was 13% in patients with PIJVI and only 4% in those with PEJVI. However, no statistically significant difference was observed between the patients with PEJVI and those with PIJVI regarding other in-hospital complications. Note that in approximately 50% of cases in both groups, the FSHC was performed within 24 h. The mortality rate was 30% in patients in whom FSHC was performed and 50% when FSHC was not performed. However, the logistic regression did not suggest any association between the FSHC, or the procedure used for venous surgery (repair/occlusion) and in-hospital mortality. Univariate analysis showed that the PIJVI has more than 4 times higher risk of in-hospital mortality than PEJVI; however, after adjusting for confounders such as SBP, GCS, injury mechanism, and ISS, no statistically significant association was observed between the type of PJVI and in-hospital mortality. Only SBP, GCS, ISS, and the mechanism of injury had an independent association with in-hospital mortality. Lower SBP and GCS and higher ISS present an increased risk of in-hospital mortality.

The firearm as a trauma mechanism had a significantly higher risk of in-hospital mortality than the cut/pierce mechanism. This observation is in agreement with other studies on penetrating traumas wherein gunshot wounds have been reported to inflict more severe injury and lead to poor prognosis because of the higher local damage[41,48].

The NTDB database has been effectively utilized in a few previous studies to identify surgical management patterns and risk factors for morbidity and mortality in blood vessel injuries[21-26]. This study, however, is the first effort to analyze different aspects of PJVI. Since our study involves only cases with a single type and a single incidence of blood vessel injury, we did not consider the challenges posed by the compounding effects of multiple blood vessels.

Therefore, this study has clarified several aspects of a PJVI and elucidated potential risk factors for in-hospital mortality. However, the limitations of the study must be acknowledged. First, there is a lack of data granularity; because it is a registry-based study, many aspects of PJVI management could not be explored[49-54].

Second, retrospective studies have limited scope to explain the studied associations. To capture the status of PJVI management, this study included only the most recent (the year 2017) year's data. The inclusion of multiple year's data will help in establishing the historical trend in the epidemiology and management of PJVI. Furthermore, the injury and surgical procedure classifications in the NTDB database are based on ICD-10, and NTDB is not a population-based dataset[33]. Lastly, NTDB is a registry from the USA, and therefore our results may not be directly extrapolated to other countries with different trauma management practices and demographics. However, based on these findings, it seems prudent to have a lower threshold for FSHC as soon as possible and early surgical exploration guided by SBP, GCS and ISS, to reduce in-hospital mortality.

Conclusions

This study clarified injury severity, injury mechanism, vital signs, management, and mortality associated with the PJVI. Trauma mechanism and intent were considerably different in external and internal PJVIs, whereas the risk of in-hospital mortality did not differ significantly. The results showed that lower SBP and GCS and higher ISS are independent predictors of increased risk of in-hospital mortality in PJVIs. The risk of in-hospital mortality increased multiple times when the firearm was the mechanism of injury. Future studies should focus on validating the impact of comma scale, injury severity, and trauma mechanisms on the outcome in PJVI and on developing a comprehensive management protocol for traumatic venous injuries in the neck region.

Conflict of Interest
The Authors declare that they have no conflict of interests.

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Availability of Data and Material
The data that support the findings of this study are available from the corresponding author, Nasser A.N. Alzerwi, upon reasonable request.

Authors' Contribution
Nasser A.N. Alzerwi: Conceptualization, Literature-review, Writing - original draft preparation. Ahmad K. Alnemare: Formal analysis and investigation, technical review.

Ethics Approval
This article does not contain any studies with human or animal subjects performed by any of the authors.

Consent to Participate
Not applicable.

Consent for Publication
Not applicable.

References

1) Simmons JD, Ahmed N, Donnellan KA, Schmieg RE, Jr., Porter JM, Mitchell ME. Management of traumatic vascular injuries to the neck: a 7-year experience at a Level I trauma center. Am Surg 2012; 78: 335-338.
2) Shuker ST. Expanding hematoma's life-threatening neck and face emergency management of ballistic injuries. J Craniofac Surg 2016; 27: 1282-1285.
3) Tepas JJ. Chapter 22 - Vascular Injury. In: Grosfeld JL, O'Neill JA, Coran AG, Fonkalsrud EW, Caldamone AA, eds. Pediatric Surgery (Sixth Edition). Philadelphia: Mosby; 2006: 376-382.
4) Demetriades D, Asensio JA, Velmahos G, Thal E. Complex problems in penetrating neck trauma. Surg Clin North Am 1996; 76: 661-683.
5) Bagheri SC, Khan HA, Bell RB. Penetrating neck njuries. Oral Maxillofac Surg Clin North Am 2008; 20: 393-414.
6) Reva VA, Pronchenko AA, Samokhvalov IM. Operative management of penetrating carotid artery injuries. Eur J Vasc Endovasc Surg 2011; 42: 16-20.
7) Teixeira F, Menegozzo CA, Netto SD, Poggeti RS, Collet E Silva Fde S, Birolini D, Bernini Cde O, Utiyama EM. Safety in selective surgical exploration in penetrating neck trauma. World J Emerg Surg 2016; 11: 32.
8) Sekharan J, Dennis JW, Veldenz HC, Miranda F, Frykberg ER. Continued experience with physical examination alone for evaluation and management of penetrating zone 2 neck injuries: results of 145 cases. J Vasc Surg 2000; 32: 483-489.
9) Inaba K, Munera F, McKenney MG, Rivas L, Marecos E, de Moya M, O'Keeffe T, Pizano L, Cohn S. The nonoperative management of penetrating internal jugular vein injury. J Vasc Surg 2006; 43: 77-80.
10) Hundersmarck D, Reinders Folmer E, de Borst GJ, Leenen LPH, Vriens PWHE, Hietbrink F. Penetrating neck injury in two dutch level 1 trauma centres: the non-existent problem. Eur J Vasc Endovasc Surg 2019; 58: 455-462.
11) Jose A, Arya S, Nagori SA, Thukral H. management of life-threatening hemorrhage from maxillo-

facial firearm injuries using foley catheter balloon tamponade. Craniomaxillofac Trauma Reconstr 2019; 12: 301-304.

12) Prichayudh S, Choadrachataanun J, Sriussadaporn S. Selective management of penetrating neck injuries using no zone approach. Injury 2015; 46: 1720-1725.

13) Timberlake GA, O'Connell RC, Kerstein MD. Venous injury: to repair or ligate, the dilemma. J Vasc Surg 1986; 4: 553-558.

14) Ibraheem K, Khan M, Rhee P, Azim A, O'Keeffe T, Tang A, Kulvatunyou N, Joseph B. No zone approach in penetrating neck trauma reduces unnecessary computed tomography angiography and negative explorations. J Surg Res 2018; 221: 113-120.

15) Meyer JP, Barrett JA, Schuler JJ, Flanigan DP. Mandatory vs selective exploration for penetrating neck trauma. A prospective assessment. Arch Surg 1987; 122: 592-597.

16) Midwinter M, Bowyer MW. 24 - Vascular Trauma: Training the Surgeon of the Future. In: Rasmussen TE, Tai NRM, eds. Rich's Vascular Trauma (Third Edition). Philadelphia: Elsevier; 2016: 269-280.

17) Christian AB, Maithel S, Grigorian A, Kabutey NK, Dolich M, Kong A, Gambhir S, Sheehan BM, Nahmias J. Comparison of nonoperative and operative management of traumatic penetrating internal jugular vein injury. Ann Vasc Surg 2020: 20: 30841-30844.

18) Yen AJ, Conrad MB, Loftus PA, Kumar V, Nanavati SM, Wilson MW, Cooke DL. Internal jugular vein embolization to control life- threatening hemorrhage after penetrating neck trauma. J Vasc Interv Radiol 2018; 29: 435-437.

19) Babar SMA. Internal Jugular Vein Injuries. In: Babar SMA, ed. Neck Injuries. London: Springer London; 2000: 67-70

20) Rowe VL, Petrone P, García-Núñez LM, Asensio Ja. Chapter 30 - Carotid, Vertebral Artery, And Jugular Venous Injuries. In: Asensio JA, Trunkey DD, eds. Current Therapy of Trauma and Surgical Critical Care. Philadelphia: Mosby 2008: 203-206.

21) Mallicote MU, Isani MA, Golden J, Ford HR, Upperman JS, Gayer CP. Screening for blunt cerebrovascular injuries in pediatric trauma patients. J Pediatr Surg 2019; 54: 1861-1865.

22) Evans S, Talbot E, Hellenthal N, Monie D, Campbell P, Cooper S. Mesenteric vascular injury in trauma: an NTDB Study. Ann Vasc Surg 2021; 70: 542-548.

23) Taghavi S, Jones G, Duchesne J, McGrew P, Guidry C, Schroll R, Harris C, Nkansah R, Jacome T, Tatum D. Impact of trauma center volume on major vascular injury: an analysis of the National Trauma Data Bank (NTDB). Am J Surg 2020; 220: 787-792.

24) Haider AH, Saleem T, Leow JJ, Villegas CV, Kisat M, Schneider EB, Haut ER, Stevens KA, Cornwell EE 3rd, MacKenzie EJ, Efron DT. Influence of the National Trauma Data Bank on the study of trauma outcomes: is it time to set research best practices to further enhance its impact? J Am Coll Surg 2012; 214: 756-768.

25) Byerly S, Cheng V, Plotkin A, Matsushima K, Inaba K, Magee GA. Impact of inferior vena cava ligation on mortality in trauma patients. J Vasc Surg Venous Lymphat Disord 2019; 7: 793-800.

26) Byerly S, Cheng V, Plotkin A, Matsushima K, Inaba K, Magee GA. Impact of ligation versus repair of isolated popliteal vein injuries on in-hospital outcomes in trauma patients. J Vasc Surg Venous Lymphat Disord 2020; 8: 437-444.

27) Wu E, Marthi S, Asaad WF. predictors of mortality in traumatic intracranial hemorrhage: a National Trauma Data Bank study. Front Neurol 2020; 11: 587587.

28) Tsiklidis EJ, Sims C, Sinno T, Diamond SL. Using the National Trauma Data Bank (NTDB) and machine learning to predict trauma patient mortality at admission. PLoS one 2020; 15: e0242166.

29) Camarano JG, Ratliff HT, Korst GS, Hrushka JM, Jupiter DC. Predicting in-hospital mortality after traumatic brain injury: External validation of CRASH-basic and IMPACT-core in the national trauma data bank. Injury 2021; 52: 147-153.

30) Sharfman ZT, Parsikia A, Rocker TN, Kahn MD, Sokol SC, Stone ME Jr, McNelis J, Sen MK, Dimitroulias A. Increased morbidity and mortality in elderly patients with lower extremity trauma and associated injuries: a review of 420,066 patients from the national trauma database. Injury 2020: S0020-1383; 30837-30838.

31) Nguyen RK, Rizor JH, Damiani MP, Powers AJ, Fagnani JT, Monie DL, Cooper SS, Griffiths AD, Hellenthal NJ. The impact of anticoagulation on trauma outcomes: a National Trauma Data Bank study. Am Surg 2020; 86: 773-781.

32) Dvorak JE, Lester ELW, Maluso PJ, Tatebe L, Schlanser V, Kaminsky M, Messer T, Dennis AJ, Starr F, Bokhari F. The obesity paradox in the trauma patient: normal may not be better. World J Surg 2020; 44: 1817-1823.

33) Hashmi ZG, Kaji AH, Nathens AB. Practical guide to surgical data sets: National Trauma Data Bank (NTDB). JAMA Surg 2018; 153: 852-853.

34) Komisarow JM, Chen F, Vavilala MS, Laskowitz D, James ML, Krishnamoorthy V. Epidemiology and outcomes of acute respiratory distress syndrome following isolated severe traumatic brain injury. J Intensive Care Med 2020; 15: 885066620972001.

35) Park H, Kim K. Isolated common femoral artery injury resulting from blunt military trauma. Mil Med 2018; 183: e758-e761.

36) Golanov EV. Isolated blood vessel models for studying trauma. In: Lo EH, Lok J, Ning M, Whalen MJ, eds. Vascular Mechanisms in CNS Trauma. New York, NY: Springer New York 2014; pp. 353-359.

37) Angus LDG, Gerber N, Munnangi S, Wallace R, Singh S, Digiacomo J. Management and outcomes of isolated axillary artery injury: a five-year National Trauma Data Bank Analysis. Ann Vasc Surg 2020; 65: 113-123.

38) Petridou ET, Antonopoulos CN. Injury Epidemiology. In: Quah SR, ed. International Encyclopedia of Public Health (Second Edition). Oxford: Academic Press 2017; pp. 258-274.

39) Edelman DA, White MT, Tyburski JG, Wilson RF. Post-traumatic hypotension: should systolic blood pressure of 90-109 mmHg be included? Shock 2007; 27: 134-138.

40) Palmer C. Major trauma and the injury severity score-where should we set the bar? Annu Proc Assoc Adv Automot Med 2007; 51: 13-29.

41) Wolf AE, Garrison MM, Mills B, Chan T, Rowhani-Rahbar A. Evaluation of injury severity and resource utilization in pediatric firearm and sharp force Injuries. JAMA Network Open 2019; 2: e1912850-e1912850.

42) Asensio JA, Petrone P, Pérez-Alonso A, Verde JM, Martin MJ, Sánchez W, Smith S, Marini CP. Contemporary wars and their contributions to vascular injury management. Eur J Trauma Emerg Surg 2015; 41: 129-142.

43) Timberlake GA, Kerstein MD. Venous injury: to repair or ligate, the dilemma revisited. Am Surg 1995; 61: 139-145.

44) Schellenberg M, Owattanapanich N, Cowan S, Strickland M, Lewis M, Clark DH, Inaba K. Penetrating injuries to the vertebral artery: interventions and outcomes from US Trauma Centers. Eur J Trauma Emerg Surg 2020 Jun 21: 1-8. doi: 10.1007/s00068-020-01416-y. Epub ahead of print.

45) Spahn DR, Bouillon B, Cerny V, Duranteau J, Filipescu D, Hunt BJ, Komadina R, Maegele M, Nardi G, Riddez L, Samama CM, Vincent JL, Rossaint R. The European guideline on management of major bleeding and coagulopathy following trauma: fifth edition. Crit Care 2019; 23: 98.

46) Navsaria P, Omoshoro-Jones J, Nicol A. An analysis of 32 surgically managed penetrating carotid artery injuries. Eur J Vasc Endovasc Surg 2002; 24: 349-355.

47) Ledgerwood AM, Mullins RJ, Lucas CE. Primary repair vs ligation for carotid artery injuries. Arch Surg 1980; 115: 488-493.

48) Madsen AS, Laing GL, Bruce JL, Clarke DL. A comparative audit of gunshot wounds and stab wounds to the neck in a South African metropolitan trauma service. Ann R Coll Surg Engl 2016; 98: 488-495.

49) Dua A, Desai SS, Kuy S, Patel B, Dua A, Desai PJ, Darlow M, Shirgavi J, Charlton-Ouw K, Shortell C. Predicting outcomes using the National Trauma Data Bank: optimum management of traumatic blunt carotid and blunt thoracic injury. Perspect Vasc Surg Endovasc Ther 2012; 24: 123-127.

50) Li W, D'Ayala M, Hirshberg A, Briggs W, Wise L, Tortolani A. Comparison of conservative and operative treatment for blunt carotid injuries: analysis of the National Trauma Data Bank. J Vasc Surg 2010; 51: 593-599.

51) Reuben BC, Whitten MG, Sarfati M, Kraiss LW. Increasing use of endovascular therapy in acute arterial injuries: analysis of the National Trauma Data Bank. J Vasc Surg 2007; 46: 1222-1226.

52) Dua A, Desai SS, Kuy S, Patel B, Dua A, Desai PJ, Darlow M, Shirgavi J, Charlton-Ouw K, Shortell C. Predicting outcomes using the National Trauma Data Bank: optimum management of traumatic blunt carotid and blunt thoracic injury. Perspect Vasc Surg Endovasc Ther 2012; 24: 123-127

53) Avery LE, Stahlfeld KR, Corcos AC, Scifres AM, Ziembicki JA, Varcelotti J, Peitzman AB, Billiar TR, Sperry JL. Evolving role of endovascular techniques for traumatic vascular injury: a changing landscape? J Trauma Acute Care Surg 2012; 72: 41-46.

54) Zehtabchi S, Nishijima DK, McKay MP, Mann NC. Trauma registries: history, logistics, limitations, and contributions to emergency medicine research. Acad Emerg Med 2011; 18: 637-643.