Associated Venous Injury Significantly Complicates Presentation, Management, and Outcomes of Axillosubclavian Arterial Trauma

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Abstract

Axillosubclavian vessel injury (ASVI) is associated with high morbidity and mortality. Most studies are single-center experiences of small numbers of patients with penetrating injury. We assessed 21st-century presentation and management of ASVI and focused on outcomes of combined arterial/venous injury. We reviewed the National Trauma Data Bank for patients with isolated arterial ASVI (group 1) and combined arterial/venous ASVI (group 2). Demographics, injury severity parameters, interventions, complications, and outcomes were compared. We identified 581 patients with ASVI (mean age 35.1; 88.1% male), with 466 isolated arterial injuries and 115 combined arterial/venous injuries. Group 2 had lower presenting systolic blood pressure and Glasgow Coma Scale, and had higher rates of operative repair (55.7 vs. 43.1%, $p = 0.016$) and higher mortality (33.9 vs. 13.9%, $p < 0.001$). There were no differences in amputation (5.2 vs. 2.4%, $p = 0.121$), compartment syndrome (2.6 vs. 1.9%, $p = 0.713$), and deep vein thrombosis (0.9 vs. 0.2%, $p = 0.357$). When separated by mechanism of injury, combined injuries from blunt trauma did increase amputation rates (27.8 vs. 4.2%, $p = 0.002$). Multivariate analysis revealed that combined arterial/venous injury significantly increased risk of death (odds ratio [OR], 2.99; confidence interval [CI], 1.73 to 5.17; $p = 0.0001$). Penetrating injury had higher odds of death than blunt injury (OR, 1.96; CI, 1.03 to 3.73; $p = 0.041$). ASVI is rare but extremely lethal. Concomitant venous and arterial injury is not associated with worse limb-related outcomes, except in blunt injuries and resultant amputations, but is associated with a threefold increase in mortality rates compared with isolated arterial injury.

Keywords

- axillary trauma
- subclavian trauma

Axillosubclavian vessel injury (ASVI) is uncommon but has profound implication on the care of the trauma population due to its high morbidity and mortality.^{1,2} About 3% of neck and chest penetrating trauma have associated ASVI.¹ Most patients with ASVI do not reach the hospital alive, with one large study documenting a 61% death on arrival rate³ and another study

documenting a 75% prehospital death rate.⁴ Penetrating injuries are much more common than blunt injuries.^{1,4} Surgical repair is notoriously difficult due to vessel inaccessibility and extensive blood loss. Thus, there have been numerous published studies on the management of ASVI. Most studies, however, are based on single-center experiences with small

numbers of patients. We therefore aim to shed light on the current management and outcomes of ASVI by reviewing a large multicenter trauma database. As most previous studies have focused solely on arterial injuries, we have incorporated venous ASVI and its impact on the management and outcome of arterial ASVI.

Methods

Collected and maintained by the American College of Surgeons Committee of Trauma, the National Trauma Data Bank (NTDB) is the largest trauma registry containing data of over 2.7 million trauma cases in over 900 US trauma centers. Data are collected from levels I to V trauma centers and then summarized in annual reports. We reviewed the NTDB Research Dataset version 7.2 which comprised admission years 2002 to 2006 for cases of ASVI. Data were submitted from 712 hospitals including 153 level I and 175 level II centers, which represented 78 and 71% of level I and level II trauma centers in the United States, respectively. The inclusion criteria for NTDB are all patients who were either admitted, died after receiving treatment, or dead on arrival.

The inclusion criteria for our study are patients who were discharged with the diagnosis of axillary or subclavian artery or vein injury (International Classification of Diseases-9 codes

901.1, 901.3, 903.0, 903.1, and 903.2). We excluded patients younger than 18 years old and those with associated severe head, cardiac, major intra-abdominal, and burn injuries to eliminate confounding contributors to complications and death.

Patients with isolated arterial ASVI (group 1) were compared with those suffering from combined arterial and venous ASVI (group 2). Demographics, injury severity parameters, interventions, and complications were compared. Outcomes included overall length of stay (LOS), intensive care unit (ICU) LOS, hospital mortality, upper limb amputation, and upper limb deep vein thrombosis (DVT).

Bivariate analysis compared group 1 and group 2 characteristics and outcome measures in the full sample, and additionally in blunt and penetrating injury strata. Fisher exact test was used for categorical measures and *t* test was used for all continuous measures, with exclusion of the LOS measures. Due to asymmetry of the LOS distribution, gamma regression was used for group comparison.

In multivariable analysis, logistic regression was used to compare hospital mortality across the groups adjusting for potential confounders. The full model included group, gender, race, age, trauma score, injury type, and an interaction term between group and injury type. Backward selection procedure, with type I error to stay in the model set at 0.2, was used to build the final parsimonious model.

Table 1 Demographic characteristics of axillosubclavian vessel injury

Characteristics	Overall (N = 581)	Isolated artery ASVI: group 1 (N = 466)	Combined artery and vein ASVI: group 2 (N = 115)	p value
Age, y				
Mean $\pm$ SD	35.1 $\pm$ 14.9	36.1 $\pm$ 15.4	30.9 $\pm$ 11.6	0.001
Median and IQ range	31 (23–44)	32.5 (23–45)	28 (22–37)	
Gender, N (%)				
Male	513 (88.3)	405 (86.9)	108 (93.9)	0.036
Female	68 (11.7)	61 (13.1)	7 (6.1)	
Race, N (%)				
Caucasian	235 (43.4)	203 (46.8)	32 (29.9)	0.014
African American	193 (35.7)	146 (33.6)	47 (43.9)	
Hispanic	82 (15.2)	61 (14.1)	21 (19.6)	
Other	31 (5.7)	24 (5.5)	7 (6.5)	
Region, N (%)				
Northeast	111 (19.4)	91 (19.7)	20 (17.9)	0.359
South	178 (31.1)	140 (30.4)	38 (33.9)	
Midwest	139 (24.3)	118 (25.6)	21 (18.8)	
West	145 (25.3)	112 (24.3)	33 (29.5)	
Type of insurance, N (%)				
Private/commercial	82 (15.5)	70 (16.7)	12 (10.9)	0.049
Government/military	107 (20.3)	88 (21.1)	19 (17.3)	
Self-pay	155 (29.4)	111 (26.6)	44 (40)	
Other	184 (34.8)	149 (35.6)	35 (31.8)	

Abbreviations: ASVI, axillosubclavian vessel injury; IQ, interquartile; SD, standard deviation; y, year.

For all tests, the type I error level was set at 0.05. All analyses were performed using SAS 9.2 (SAS Institute Inc., Cary, NC).

Results

We identified 723 patients with ASVI during the study period. Demographics are summarized in **Table 1**. Of the cohort, 466 (64.4%) had isolated arterial injuries, 142 (19.6%) had isolated venous injuries, and 115 (15.9%) had combined arterial and venous injuries. Males constituted 88.1% of the cohort and the mean age was 35.1 years old. Most patients were either Caucasian (43.4%) or African American (35.7%) with a lower percentage being Hispanic (15.2%). The geographic distribution was, for the most part, evenly divided between the northeast, south, midwest, and western regions (19.4, 31.1, 24.3, and 25.3%, respectively). Penetrating trauma was twice as common as blunt trauma (371 vs. 210 patients).

Table 2 shows data for the entire ASVI cohort. Blunt and penetrating ASVI were then analyzed separately in **Tables 3** and **4**. Group 2 had lower presenting systolic blood pressure (86.2 vs. 109.9 mm Hg, $p < 0.001$) and Glasgow Coma Scale

(GCS) (10.8 vs. 12.3, $p = 0.003$) than group 1. Although not significant, group 2 also had a higher Revised Trauma Score (18.7 vs. 17, $p = 0.073$). Interventions were performed in just less than half of the cohort with 45.1% receiving open operative repair and 4.3% receiving endovascular therapy. There was a significantly higher number of combined arterial and venous injury compared with isolated arterial injury (55.7 vs. 43.1%, $p = 0.016$) in the operative repair cohort.

There were no significant differences between group 1 and group 2 in amputation (2.4 vs. 5.2%, $p = 0.121$), compartment syndrome (1.9 vs. 2.6%, $p = 0.713$), fasciotomy (7.7 vs. 7%, $p = 0.999$), and DVT (0.2 vs. 0.9%, $p = 0.357$) rates. There were also no differences in length of hospital stay (10 vs. 8.3, $p = 0.241$) and length of ICU stay (4.8 vs. 3.9, $p = 0.327$) between the groups. Death, on the other hand, was significantly higher in group 2 than group 1 (33.9 vs. 13.9%, $p < 0.001$).

When reviewed separately based on mechanism of injury (penetrating and blunt), the same results held true. Combined injuries did not lead to differences in complications or most outcomes, with the exception once again being death. Blunt combined injuries had a statistically significant increase in

Table 2 Data for axillosubclavian vessel injury

Characteristics	Overall (N = 581)	Isolated artery ASVI: group 1 (N = 466)	Combined artery and vein ASVI: group 2 (N = 115)	p value
Injury severity				
Presenting systolic BP, mm Hg				
Mean $\pm$ SD	105.1 $\pm$ 47.7	109.9 $\pm$ 45.3	86.2 $\pm$ 52.1	< 0.001
Presenting GCS				
Mean $\pm$ SD	12 $\pm$ 4.9	12.3 $\pm$ 4.7	10.8 $\pm$ 5.4	0.003
Trauma score				
Mean $\pm$ SD	17.3 $\pm$ 9.4	17 $\pm$ 9.1	18.7 $\pm$ 10.5	0.073
Intervention				
Endovascular repair, N (%)	31 (5.3)	29 (6.2)	2 (1.7)	0.063
Operative repair, N (%)	265 (45.6)	201 (43.1)	64 (55.7)	0.016
Complications				
Fasciotomy, N (%)	44 (7.6)	36 (7.7)	8 (7)	0.999
Wound infection, N (%)	9 (1.5)	7 (1.5)	2 (1.7)	0.694
Compartment syndrome, N (%)	12 (2.1)	9 (1.9)	3 (2.6)	0.713
Outcomes				
Length of stay, d				
Mean $\pm$ SD	9.7 $\pm$ 12.3	10 $\pm$ 12.3	8.3 $\pm$ 12.2	0.241
ICU length of stay, d				
Mean $\pm$ SD	4.6 $\pm$ 9.4	4.8 $\pm$ 10	3.9 $\pm$ 6.9	0.327
Death, N (%)	104 (17.9)	65 (13.9)	39 (33.9)	< 0.001
Upper limb amputation, N (%)	17 (2.9)	11 (2.4)	6 (5.2)	0.121
Upper limb DVT, N (%)	2 (0.3)	1 (0.2)	1 (0.9)	0.357

Abbreviations: ASVI, axillosubclavian vessel injury; BP, blood pressure; d, days; DVT, deep vein thrombosis; GCS, Glasgow Coma Scale; ICU, intensive care unit; SD, standard deviation.

Table 3 Blunt axillosubclavian vessel injury

Characteristics	Overall (N = 210)	Isolated artery ASVI: group 1 (N = 192)	Combined artery and vein ASVI: group 2 (N = 18)	p value
Injury severity				
Presenting systolic BP, mm Hg				
Mean $\pm$ SD	118.5 $\pm$ 42.1	120.6 $\pm$ 41.8	97.4 $\pm$ 39.4	0.030
Presenting GCS				
Mean $\pm$ SD	12.8 $\pm$ 4.3	13 $\pm$ 4.2	11.1 $\pm$ 5.1	0.082
Trauma score				
Mean $\pm$ SD	17.4 $\pm$ 8.9	17.3 $\pm$ 9	19.4 $\pm$ 8	0.334
Intervention				
Endovascular repair, N (%)	13 (6.2)	13 (6.8)	0 (0.0)	0.609
Operative repair, N (%)	77 (36.7)	67 (34.9)	10 (55.6)	0.123
Complications				
Fasciotomy, N (%)	19 (9)	17 (8.9)	2 (11.1)	0.670
Wound infection, N (%)	5 (2.4)	3 (1.6)	2 (11.1)	0.060
Compartment syndrome, N (%)	8 (3.8)	7 (3.6)	1 (5.6)	0.518
Outcomes				
Length of stay, d				
Mean $\pm$ SD	13.2 $\pm$ 13.8	12.8 $\pm$ 12.7	17.3 $\pm$ 22.1	0.111
ICU length of stay, d				
Mean $\pm$ SD	5.9 $\pm$ 10.5	5.9 $\pm$ 10.5	6.7 $\pm$ 10.3	0.480
Death, N (%)	23 (11)	18 (9.4)	5 (27.8)	0.033
Upper limb amputation, N (%)	13 (6.2)	8 (4.2)	5 (27.8)	0.002
Upper limb DVT, N (%)	1 (0.5)	1 (0.5)	0 (0.0)	0.999

Abbreviations: ASVI, axillosubclavian vessel injury; BP, blood pressure; d, days; DVT, deep vein thrombosis; GCS, Glasgow Coma Scale; ICU, intensive care unit; SD, standard deviation.

death compared with arterial injuries alone (27.8 vs. 9.4%, $p = 0.033$), with similar results in the penetrating groups (35.1 vs. 17.2%, $p = 0.001$). The sole additional difference was that blunt combined injury lead to higher rates of upper limb amputation (27.8 vs. 4.2%, $p = 0.002$).

Multivariate analysis confirmed that combined arterial and venous injury was associated with a significantly increased risk of death (odds ratio [OR], 2.99; confidence interval [CI], 1.73 to 5.17; $p = 0.0001$) compared with isolated arterial injury when controlling for multiple factors (**Table 5**). Penetrating injury also carried a higher mortality risk than blunt injury (OR, 1.96; CI, 1.03 to 3.73; $p = 0.041$).

Discussion

Although the prevalence of traumatic ASVI is low, it is an important topic due to its high morbidity and mortality. Historically, there have been a disproportionate number of studies focusing on outcome of arterial ASVI compared with venous ASVI. The main focus is commonly on arterial ASVI with venous ASVI mentioned only as associated injuries. McKinley et al documented a 33% associated venous injury

in the 20-year review of 260 patients with axillosubclavian arterial injury.⁴ Sobnach et al reviewed 50 patients who underwent surgical repair of subclavian artery injury, of which 24% had concomitant venous injury.⁵ Our review of a larger multicenter trauma database showed a lower combined arterial and venous ASVI of 16%, which is more comparable to the experience of Demetriades and Asensio (20%).¹ It has been shown that venous injury portends a greater mortality risk than isolated arterial injury. Demetriades et al, in their series of 223 patients, had a 50% mortality rate for axillosubclavian venous injury compared with 34.2% for arterial injury ($p < 0.05$). Likewise, combined venous and arterial injuries also had a higher mortality rate of 45%.³ Lin et al, on the other hand, did not have the same increased mortality rate with concomitant venous injury. They reviewed their series of 54 patients with penetrating subclavian artery injury. Although they also had a high combined arterial and venous subclavian injury rate (44%), it did not confer a significant increase in mortality rate. Rather, the mortality rate was associated with increasing number of concomitant injuries; with three or more being significantly higher at 83% compared with 18% with two or fewer, $p < 0.01$.⁶ Our study

Table 4 Penetrating axillosubclavian vessel injury

Characteristics	Overall (N = 371)	Isolated artery ASVI: group 1 (N = 274)	Combined artery and vein ASVI: group 2 (N = 97)	p value
Injury severity				
Presenting systolic BP, mm Hg				
Mean $\pm$ SD	97.5 $\pm$ 49	102.4 $\pm$ 46.1	84.1 $\pm$ 54.2	0.002
Presenting GCS				
Mean $\pm$ SD	11.6 $\pm$ 5.1	11.9 $\pm$ 5	10.7 $\pm$ 5.5	0.063
Trauma score				
Mean $\pm$ SD	17.2 $\pm$ 9.7	16.7 $\pm$ 9.2	18.6 $\pm$ 10.9	0.107
Intervention				
Endovascular repair, N (%)	18 (4.9)	16 (5.8)	2 (2.1)	0.174
Operative repair, N (%)	188 (50.7)	134 (48.9)	54 (55.7)	0.288
Complications				
Fasciotomy, N (%)	25 (6.7)	19 (6.9)	6 (6.2)	0.999
Wound infection, N (%)	4 (1.1)	4 (1.5)	0 (0.0)	0.576
Compartment syndrome, N (%)	4 (1.1)	2 (0.7)	2 (2.1)	0.281
Outcomes				
Length of stay, d				
Mean $\pm$ SD	7.7 $\pm$ 10.8	8 $\pm$ 11.6	6.6 $\pm$ 8.5	0.228
ICU length of stay, d				
Mean $\pm$ SD	3.8 $\pm$ 8.7	4 $\pm$ 9.6	3.4 $\pm$ 6	0.436
Death, N (%)	81 (21.8)	47 (17.2)	34 (35.1)	0.001
Upper limb amputation, N (%)	4 (1.1)	3 (1.1)	1 (1)	0.999
Upper limb DVT, N (%)	1 (0.3)	0 (0.0)	1 (1)	0.261

Abbreviations: ASVI, axillosubclavian vessel injury; BP, blood pressure; d, days; DVT, deep vein thrombosis; GCS, Glasgow Coma Scale; ICU, intensive care unit; SD, standard deviation.

showed that combined arterial and venous injury patients had significantly higher mortality rates compared with isolated arterial injury patients, 34 versus 14%, respectively. This is not surprising considering that group 2 was more severely injured upon arrival, with worse injury severity parameters (initial hypotension, GCS, and Revised Trauma Score). In our multivariate analysis, group 2 still maintained a threefold increased mortality risk compared with group 1. Despite the increased mortality risk, group 2 did not have significant differences in any of the limb complications studied, with the

exception of higher amputation in the blunt combined injury patients.

Studies on outcomes of blunt ASVI are scarce as it is not as common as penetrating injury.¹ Blunt ASVI ranges from 4 to 33% of traumatic ASVI.^{4,7} Cox et al specifically compared blunt versus penetrating subclavian artery injury in their 13-year review study. Of 56 patients who sustained subclavian artery injuries, 25 patients (45%) had blunt injuries while 31 patients (55%) had penetrating injuries. There was no significant difference in mortality between the two groups (24% blunt

Table 5 Multivariate analysis shows significantly higher adjusted odds of death in artery + vein group compared with artery alone group

	Adjusted OR	Lower confidence limit	Upper confidence limit	p value
Artery + vein versus artery	2.9990	1.7394	5.1707	0.0001
Penetrating versus blunt	1.9600	1.0289	3.7337	0.0407

Abbreviation: OR, odds ratio.

Note: Initial model included following factors: group, gender, race, age, ISS, injury type, and an interaction term between group and injury type. Significant factors are presented in the table above.

vs. 19% penetrating).⁸ Similar to the 13-year study by Aksoy et al,⁷ one-third of our study group was blunt ASVI (33%). Comparison of the types of mechanism of injury by multivariate analysis showed a twofold increase in mortality risk with penetrating injury. Of note, concomitant arterial and venous injury remained a significant mortality risk in both blunt and penetrating subgroups.

Endovascular treatment of ASVI is an attractive treatment option considering the high morbidity of an open repair. There are multiple published series reporting the success and safety of this modality. du Toit et al reported a 100% technical success rate in their series of 57 patients undergoing stent-graft treatment for subclavian artery injuries. They had a 5% early graft failure rate, and these were all successfully treated in an endovascular fashion with catheter-directed thrombolysis, balloon angioplasty, or a second stent.⁹ Danetz et al defined a treating algorithm for endovascular repair of ASVI. They then applied this algorithm in a retrospective review of 46 cases of ASVI and determined that up to 37% of ASVI can be treated in an endovascular fashion.¹⁰ Most other studies have smaller patient populations, but all advocated the effectiveness of endovascular treatment of ASVI.^{11–13} Despite these single-center results, we found that endovascular treatment of ASVI only constituted 4.3% of the cohort. Although this low rate is subjected to multiple biases mentioned below, it most likely represents the true national trend as the NTDB encompasses a spectrum of hospital sizes as well as the endovascular expertise levels of different surgeons. Future prospective studies into the role of endovascular therapy in ASVI are warranted to examine whether a real mortality benefit can be achieved with less invasive methods of hemorrhage control or treatment. As endovascular interventions gain a more prominent role in the management algorithms of traumatic vascular injuries in general, these studies will provide critical data to establish the most modern benchmarks for handling ASVI.

There are limitations to our study; specifically biases that are inherent to any large database. Information is reported voluntarily from different hospitals and is subject to reporting bias. In addition, NTDB is not a population database and is subject to the limitations of each contributing institution. Likewise, variability of inclusion criteria of different hospitals confers selection bias. Lastly, NTDB has few required fields, which leads to a proportion of hospitals with missing data and therefore information bias. We attempted to circumvent these biases by using strict inclusion and exclusion criteria to make the cohort more homogenous.

Conclusions

ASVI is rare but highly lethal. Concomitant venous and arterial injury is not associated with worse limb-related outcomes but does lead to a threefold increase in mortality rate compared with isolated arterial injury. Similarly, penetrating trauma confers a twofold increase in mortality compared with blunt trauma. Although endovascular treatment of ASVI has gained acceptance as a viable treatment modality, it still only constitutes a very small percentage of the treatment of ASVI on a national level. Future studies are critical to determine if endovascular therapy can have the expected beneficial effects of lowering the currently elevated morbidity and mortality rates.

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