

Etiology and pathophysiology of the civil arterial trauma: Does age matter?

Vitaliy Petrov 

Department of Surgery, Danylo Halatsky Lviv National Medical University, Lviv, Ukraine

ABSTRACT

Objectives: This study aims to characterize the etiology and pathophysiology of the civil arterial traumas (ATs) in patients of various ages.

Patients and methods: Between January 1993 and December 2018, a total of 222 patients (185 males, 37 females; median age 32 years; range, 8 days to 84 years) with ATs in the vascular surgery clinic of the Lviv Clinical Regional Hospital in Ukraine were retrospectively analyzed. The patients were divided into seven groups according to the age as follows: infancy (≤ 2 years), early childhood (3-6 years), childhood (7-12 years), teens (13-18 years), young adults (19-40 years), adults (41-65 years), and elderly (≥ 66 years).

Results: Domestic accidents occurred in 45.5% of the patients, and none of the infants had domestic accidents ($p < 0.01$). Interpersonal conflicts were seen in 20.2%, more frequently in the young adults ($p < 0.05$). Iatrogenia developed in 15.8%, typical in the infants ($p < 0.01$) and rare in the young adults ($p < 0.01$). Injuries were penetrating in 69.4% and non-penetrating in 23.9%, irrespective of the age ($p > 0.1$). Arterial traumas with partial vessel disruption developed in 52.3%, complete disruption in 26.1%, and without disruption in 10.8%, indicating no significant difference among the age groups ($p > 0.1$). In the regression model, the trauma mechanism, but not the age or etiology, was the determinant of the type of ATs.

Conclusion: Patients of various ages acquire ATs from different etiologies, but the majority of these are penetrating mechanisms. The trauma mechanism is the main determinant of the type of vessel injuries in all age groups.

Keywords: Age, artery injuries, etiology, pathophysiology, trauma.

Arterial traumas (ATs) in the civil setting are infrequent accidents. In children, they are seen in 0.4 to 4.0% of pediatric traumas and 0.6 to 3.4% of all traumas in adults.^[1-5] The low incidence of the disease per se carries certain obstacles for the researchers, reflected by the relatively limited numbers of patients in their studies.^[1,3-6] The condition is further complicated by the diversity of vascular injury patterns, may be disruptions of arteries, veins or both, polymorphic etiologies and mechanisms, divergent post-traumatic pathologies in the vessels, injury locations, or associated conditions. All these draw an attention to every publication on this topic.

In the present study, we review our experience of the ATs management and to characterize the etiology and pathophysiology of ATs in children and adults of various ages.

PATIENTS AND METHODS

This single-center, retrospective study was conducted at Vascular Surgery Division of the Lviv Clinical Regional Hospital, Ukraine between January 1993 and December 2018. There were no specific inclusion criteria, except for the recognized AT condition. If the patient had concomitant arterial and venous injuries, only the AT was analyzed. Exclusion criteria were arterial injuries from drug abuse and traumas of the thoracic aorta. Finally, medical records of a total of 222 patients (185 males, 37 females; median age 32 years; range, 8 days to 84 years) with ATs were retrospectively analyzed. A written informed consent was obtained from each patient. The study protocol was approved by the Ethics Committee of Danylo Halatskiy Lviv National Medical University (No. #2; Date: 17/10/2018).

Received: October 07, 2019 Accepted: November 28, 2019 Published online: January 10, 2020

Correspondence: Vitaliy Petrov, MD. Danylo Halatsky Lviv National Medical University, Surgery Department #2, Pekarska str., 69, 79010 Lviv, Ukraine.
e-mail: medicine_mail@yahoo.com

Citation:

Petrov V. Etiology and pathophysiology of the civil arterial trauma: Does age matter? Turk J Vasc Surg 2020;29(1):13-18

The study was conducted in accordance with the principles of the Declaration of Helsinki.

Data including age, gender, AT etiology (domestic, interpersonal conflict, iatrogenic, traffic, workplace, or others), AT mechanism (penetrating or non-penetrating), AT type (without disruption, with partial disruption and with complete disruption), and injury topography (head, neck, arm, chest, abdomen, or leg) were recorded. The patients were, then, divided into seven groups according to the age as follows: infancy (≤ 2 years, Group 1), early childhood (3-6 years, Group 2), childhood (7-12 years, Group 3), teens (13-18 years, Group 4), young adults (19-40 years, Group 5), adults (41-65 years, Group 6), and elderly (≥ 66 years, Group 7). According to the types of ATs as described by Chen et al.,^[7] three vessel injury types were described: without disruption, with partial disruption and with complete disruption, and each type was specified into three subtypes as follows: mild, moderate, and severe. For the ease of data analysis and due to the retrospective nature of the study, only the general types were considered and subtypes were eliminated.

The seven age groups were formed, as previously described by Quinn.^[8] The age grading principles and patient distribution between the groups are shown in Table 1.

Statistical analysis

Statistical analysis was performed using the STATISTICA version 13.3 software (StatSoft Inc., Tulsa, OK, USA). Descriptive data were expressed in mean \pm standard deviation (SD) or number and frequency for Gaussian distribution cohorts and in median (min-max or interquartile range [IQR] 25th-75th) values for non-Gaussian distribution cohorts. Categorical variables were compared using the chi-square (χ^2) test. Multiple regression model was

used to investigate possible relationships between the variables. A p value of <0.05 was considered statistically significant with 95% confidence interval (CI).

RESULTS

The etiologies of ATs were as follows: domestic (n=101, 45.5%), interpersonal conflicts (n=45, 20.2%), iatrogenic (n=25, 15.8%), traffic (n=9, 4.1%), workplace (n=7, 3.1%), and others (including sport, suicide, casuistic cases; n=25, 11.3%). The mechanism of AT was penetrating injury in 154 (69.4%) and non-penetrating injury in 53 patients (23.9%), while the underlying mechanism was undetermined in the remaining 15 patients (6.7%). Three vessel injury types were detected: with partial disruption (n=116, 52.3%), complete disruption (n=58, 26.1%), and without disruption (n=24, 10.8%). In 24 patients (10.8%), the AT type was unable to be identified. The topography of the ATs was as follows: leg (n=99, 44.6%), arm (n=78, 35.1%), neck (n=16, 7.2%), head (n=12, 5.4%), abdomen (n=10, 4.5%), and chest (n=8, 3.6%).

The frequencies of different etiologies, trauma mechanisms, injury types, and vessel topographies were compared among the prespecified age groups. The etiology of the ATs varied among the age groups ($p<0.01$). In general, domestic accidents were observed in 21.2 to 57.2% (95% CI) of various age groups, although none of the infants had any domestic accidents leading to ATs (0/9, $p<0.01$). Interpersonal conflicts resulted in 0.1 to 20.6% (95% CI) of ATs, and they were more prominent in the young adults (30/108, 27.8%, $p<0.05$) and we had no such patients in Groups 1-3. Iatrogenia occurred in 3.2 to 61.4% of the patients (95% CI), and they were particularly typical in the infants (9/9, 100%, $p<0.01$), while it was relatively rare in the young adults (6/108, 5.5%, $p<0.01$). The least common causes of ATs were traffic (0.1 to 7.3%, 95% CI) and workplace accidents (0.1 to 3.0%, 95% CI). Other etiologies were seen in 2.5 to 16.3% of the patients (95% CI).

Domestic accidents mainly resulted from three injury classes: stab wounds from glass, knife, saw, and crotch (45/101, 44.5%), falls without bone fractures and joint dislocations (32/101, 31.7%), and AT complicating bone fractures or joint dislocations (24/101, 23.8%). As the infants did not experience any domestic ATs in this study, their group was excluded from the statistical analysis. The distribution of the three domestic contributors appeared to significantly differ among the age groups ($p<0.05$), due to the fact that the stab wounds occurred rather frequently in

Table 1. Age grading criteria and patient distribution among the age groups

#	Age groups	n	%
1	Infancy (≤ 2 years)	9	4.05
2	Early childhood (3-6 years)	2	0.9
3	Childhood (7-12 years)	9	4.05
4	Teens (13-18 years)	25	11.3
5	Young adults (19-40 years)	108	48.6
6	Adults (41-65 years)	55	24.8
7	Elderly (≥ 66 years)	14	6.3

the teenagers (6/10, 60%) and young adults (26/50, 52%). Falls were more typical among the teenagers (4/10, 40%) and adults (12/26, 46.2%). Arterial traumas complicating bone fractures or joint dislocations were common in Groups 2-4 (3/5, 60%) and adults of Group 7 (5/8, 62.5%). In addition, interpersonal conflicts with gunshot injuries were seen only in the young adults (3/30, 10%) and adults (2/12, 16.7%), but not in the teenagers (0/4, 0%) ($p=0.6$).

Three types of iatrogenic ATs were identified: complications after arterial catheterizations (19/34, 56%), venous catheterizations (8/34, 23.5%), and surgeries (7/34, 20.5%). Complications after arterial catheterizations followed conventional arteriography procedures, endovascular therapeutic interventions, and invasive blood pressure measurement. Sequelae after venous catheterizations appeared, when the near lying artery was damaged from the central or peripheral venous catheter insertion. Surgery adverse events occurred in the abdominal and orthopedic operations. All iatrogenic ATs in the infants (9/9, 100%) occurred after vessel catheterizations, while in the children of Groups 2-4 iatrogenic ATs emerged from both surgeries (3/6, 50%) and vessel catheterizations (3/6, 50%) ($p<0.05$). In the young adults, surgery complications were as frequent (3/6, 50%) as in the children, but less common than in their older peers. In the adults and the elderly, ATs from coronary artery interventions (11/12, 91.7%) dominated over

the surgeries (1/12, 8.3%, $p<0.01$). Finally, we found no workplace accidents in Groups 1-4 ($p=0.2$), and all traffic traumas were found in Groups 4-7 ($p=0.1$).

Penetrating injuries caused ATs in 52.1 to 83.5% patients (95% CI), while non-penetrating injuries were present in 0.01 to 15.5% patients (95% CI). Penetrating trauma was the leading mechanism of ATs in all age groups, from the infancy to the elderly ($p=0.55$). In addition, ATs with partial disruption developed in 43.7 to 83.5% (95% CI), complete disruption in 5.7 to 31.6% (95% CI), and without disruption in 5.4 to 15.3% patients (95% CI). The frequency of various arterial injury types did not significantly differ among the age groups ($p=0.55$). Figure 1 depicts the three AT types.

The distribution of AT types differed between the penetrating and non-penetrating trauma groups ($p<0.01$). In the penetrating trauma, ATs without disruption occurred in 6 of 150 patients (4%) and partial disruption ATs in 93 of 150 patients (62%), while in the non-penetrating trauma, ATs without disruption occurred in 14 of 56 patients (25%) and ATs with partial disruption occurred in 19 of 56 patients (33.9%) ($p<0.01$). The ratio of complete vessel disruptions did not significantly differ between the penetrating and non-penetrating groups ($p>0.05$). The AT topography did not significantly differ among the age groups, either ($p>0.1$).

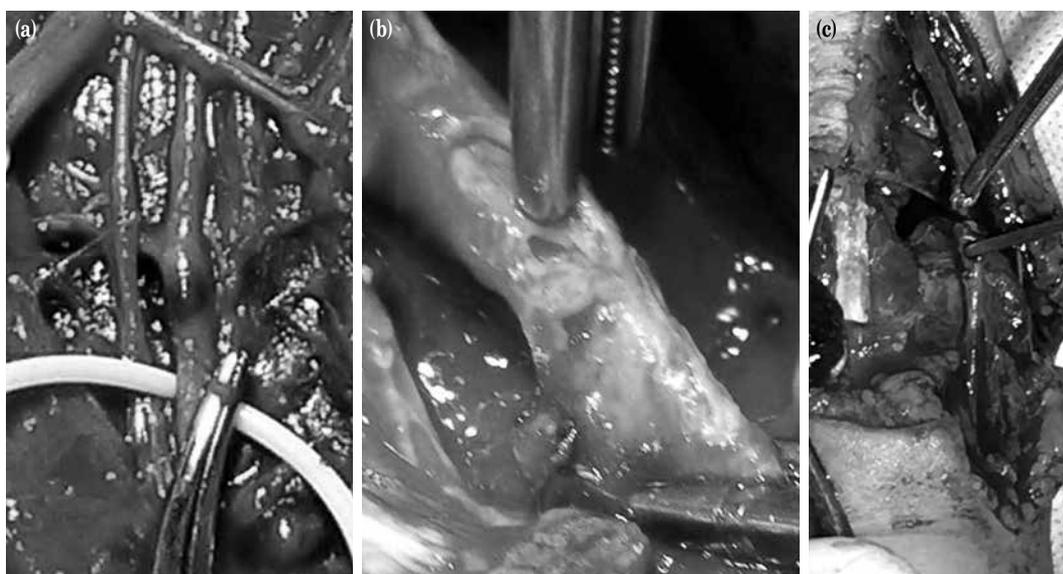


Figure 1. Three AT types, (a) AT without disruption, *a. brachialis* dissection and thrombosis in an eight-year-old patient with a supracondylar fracture of the humerus, (b) AT with partial disruption, *a. tibialis ant.* partial incision in a 33-year-old patient with a stab wound, (c) AT with complete disruption, *a. radialis* complete incision in a 40-year-old patient with a workplace trauma.

AT: Arterial trauma.

In the multiple regression model, the depended variable was the AT type (without disruption, partial disruption, complete disruption), while the independent variables were the age category (Groups 1-7), etiology (domestic, interpersonal conflicts, iatrogenic, traffic, industrial, or others), and trauma mechanism (penetrating, non-penetrating). The results of the regression model showed that the trauma mechanism ($p=0.004$), but not the age category ($p=0.3$) or the etiology ($p=0.08$), was the main determinant of the AT type.

DISCUSSION

The bottom line of this paper consists of two key results. First, the AT etiologies varied among different age groups, and at the same time attributed to the penetrating mechanisms predominantly. Second, the injury mechanisms determined the pathomorphological changes of the arteries in all ages. These findings should be reviewed through the prism of our age classification approach.

Some authors respected the age of the patients with civil vascular injuries, but it was not infrequently limited to the description of the demographic characteristics of the patient cohorts.^[9-11] In their extensive study of 4,459 patients with cardiovascular injuries, Mattox et al.^[9] divided patients according to their life decades (0-10 years, 11-20 years and etc.) and obtained eight age groups. The authors provided with a glance on the disease incidence in various ages and showed the young adults' dominance in the epidemiology. In another study, Jaha et al.^[10] collected data on 120 patients with vessel injuries and performed the patient parceling identical to the team of Mattox et al.^[9] This allowed the authors to conclude that vessel injuries occurred most frequently in individuals aged 20 to 39 years. In their study including 100 vascular trauma patients, Sah et al.^[11] adopted the same approach and found that the disorder was more typical for those aged 25 to 55 years.

The majority of the vascular trauma researchers opted the approach of dealing with children or adults separately.^[1,3-5,12-19] Allen et al.^[1] experienced 81 children with ATs, and they divided the patients into two groups (under 13 years and 14 to 17 years). The authors compared the topography and treatment methods between the age groups. In another study, Ammar^[12] reported data on 36 children, divided them into three groups (under 2 years, 2 to 7 years, and 7 to 12 years), and compared the trauma mechanisms. Similarly, Jaipuria et al.^[3] had 83 pediatric AT cases,

classified them into three groups (under 6 years, 6 to 13 years, and 14 to 18 years), and compared the trauma mechanisms and topography. Silva et al.^[13] also treated vascular trauma in 37 children and had three groups (under 6 years, 6 to 14 years, and 14 to 17 years). Wahlgren and Kragsterman^[14] collected data on 222 children and divided them into four groups (under 2 years, 2 to 6 years, 7 to 12 years, and 12 to 15 years). However, some others did not classify the patients into pediatric age subgroups.^[15,16] Baram et al.^[17] had 47 adult vascular trauma cases with a mean age of 24.8 years; Perkins et al.^[4] analyzed 256 patients aged older than 14 years; and Gupta et al.^[18] reported about 153 patients with a median age of 32 years. All these contributors did not perform division of their cohorts into more specific age groups. Fingerhut et al.^[19] collected data about vascular trauma patterns in the European countries and Sonneborn et al.^[5] performed a similar study among Latin America centers; albeit the age aspects were not specified in their publications.

Barmparas et al.^[2] conducted the United States National Trauma Databank analysis and collected data from more than 900 trauma centers. The authors had two general groups of patients as children ($n=1,138$, 5.1%) and adults ($n=20,951$, 94.9%) and compared the etiology and trauma mechanisms between the two groups.

As opposed to the previous studies, in the current study, we classified the ageing through using the classification of the human development as clarified by Quinn.^[8] The aim of this approach was to address the age differences less mechanistically and in a more socially-oriented mode. We, therefore, distinguished between the evident features of various periods of life and emphasized certain differences associated with the maturation and aging. Based on the study results, the more precise division of the patient cohort into seven age groups with subsequent comparison delineated their etiological factors rather an observant state.

In patients of various ages, the AT etiologies were different. The infants appeared to acquire ATs from complications after medical interventions; however, as the child developed and became sufficiently self-active, domestic accidents contributed to the morbidity more significantly. As soon as the individuals reached their teens, the vascular injuries came from etiologies which were typical for the young adults. The latter includes domestic accidents, interpersonal conflicts, traffic, and workplace events. Aging was associated with a gradual decline of the frequency of interpersonal conflicts, but with the spread of iatrogenic ATs.

Pathomorphological changes in the injured vessels are traditionally appreciated as penetrating or blunt with the varying degrees of the wall damage.^[20,21] This approach addresses the mechanism of the vessel trauma clearly, albeit may lack information about the resulting vessel condition. In our opinion, the recent classification by Chen et al.^[7] describes the vascular status accurately and in a clinically comprehensive manner. Using their system, we found that partial disruptions of the arteries came into the view of the health care practitioners most frequently. Probably, this is the nature of the disease, when fractional damage of the artery may cause a significant clinical picture and life-threatening complications which explains why the patient would be referred to the vascular surgery even with a partial vessel disruption. We also speculate that the civil etiology of AT is often less ominous than seen in the combat conditions and expect the frequency of complete vessel disruptions to be significantly higher in the wartime.

In spite of the fact that etiologies of the ATs in the various age groups differed, this was the injury mechanism, but not the etiology or age which dictated the pathomorphological sequelae in the arteries, according to the regression model. This finding underscores the mechanistic nature of the vessel alteration: the effect non-affiliated by the individual's age.

There are several limitations in this study. The retrospective nature of the observation poses certain disadvantages associated with the design. Exclusion criteria also caused underestimation of the real-world modern clinical entirety of the problem. The simplified classification of the AT types used for the purpose of the analysis avoided specifications of the vessel injuries (spasm, thrombosis, local hematoma, disruption by less or more than 50% of the perimeter of the vessel wall, status of the disrupted ends in complete disruption, arteriovenous fistula) which, in turn, could suppress the correlation between the etiology and the artery status in the mathematical model. The Vascular Surgery Division of the Lviv Clinical Regional Hospital, which is the basis for this research, is the largest in the area; however, at least more two adults and two pediatric trauma centers of the town provide trauma care, indicating a number of patients with other vascular injuries have been out of our scope.

In conclusion, patients of various ages acquired their ATs from different etiologies, such as domestic accidents, interpersonal conflicts, iatrogenic complications, traffic, and workplace events; albeit

the majority of these can be attributed to penetrating mechanisms. The frequencies of etiological factors vary between the age groups of children and adults. The injury mechanisms are the main determinants of the type of vessel alteration the patients acquire, regardless of their age.

Declaration of conflicting interests

The author declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding

The author received no financial support for the research and/or authorship of this article.

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