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Forensic assessment of blunt thoracic trauma – correlations between pattern of injuries and trauma dynamics

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Abstract: The forensic pathologist often has to assess - solely based on the traumatic injuries - the mechanism and circumstances of trauma. We have reviewed 747 cases with blunt thoracic trauma, focusing on the aspect, presence and particularities of traumatic injuries noted, in relation to the circumstances of their occurrence. The parameters analyzed included the number and localization of rib fractures, the presence of first and second rib fractures, and the presence of pulmonary contusions and cardio-vascular injuries. We have ascertained a correlation between the parameters listed above and the circumstances of injury (assault, motor vehicle accident and fall from height). The presence of more than 3 consecutive rib fractures, double or multiple fractures of the same rib, first and second rib fractures, pulmonary contusions and cardiac or great vessels injury were indicators to exclude an assault. The association of aortic injuries with cardiac contusion or rupture was indicator for the possibility of motor vehicle accident (driver/occupant). Pulmonary artery injuries were found to be indicative for falls from height. From a purely statistical point of view the traumatic pattern can be used for deducting the circumstances of injury, but a global assessment of injuries and corroboration with evidence from the scene and any anamnesis data available is advised in particular cases.

Key words: blunt thoracic trauma, circumstance of injury, particular rib fractures, pulmonary contusion, assault.

Severe blunt injury to the chest continues to be one of the leading causes of morbidity and mortality in both young and old trauma victims, because blunt trauma is more common than penetrating chest injury, accounting for more than 90% of thoracic injuries [6].

Regardless of the outcome of an injury (whether the victim survived or not), the forensic pathologist is often required to answer some questions concerning the mechanism and circumstances of the injuries, with the aim of providing evidence-based scientific answers to help the police investigation. Not infrequently, the forensic pathologist has to decide (based on the aspect of the traumatic lesions alone) whether it concerns a death following an assault, a motor vehicle accident, or a falling, in the absence of any crime scene investigation data.

On the other hand, the scientific information literature data do not focus on a comprising differential diagnosis regarding the circumstances surrounding a blunt thoracic trauma based on the traumatic lesions and anatomic and clinical features.

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Scope, Material and Method

Traumatic lesions occur following different mechanisms. Those mechanisms vary depending on the circumstances in which thoracic trauma occurs. Hence, there will be a difference between the type of traumatic injuries inflicted by an assault, for example, and those inflicted by a motor vehicle accident or a fall from height. This difference results from different mechanisms involved (i.e. direct transfer of energy or deceleration), as well as from various degrees of impact force within the same mechanism.

To assess the possible differences between these mechanisms of injury (and subsequently the circumstances in which the thoracic injuries occur), we have conducted a retrospective study in a series of 747 cases of blunt thoracic trauma victims registered in 2006 at the National Institute of Legal Medicine in Bucharest (212 lethal thoracic trauma cases - representing 25,2% of all traumatic deaths, and 535 non-lethal thoracic trauma cases - representing 5,5% of all non-lethal trauma). We have studied a number of traumatic lesions (including rib fractures, pulmonary contusions and cardiac and great vessels trauma) in relation to the circumstances of injuries. The data obtained has been analyzed using SPSS and Microsoft Excel programs.

Results

The male/female ratio of the group was 1,63/1, with a mean age of 44,7 years, varying from 30,3 years (drivers and occupants involved in motor vehicle accidents) to 62 years (pedestrians involved in MVAs). The mean age for assault victims was 38,6 years.

Regarding the severity of blunt thoracic trauma, we have noted an overall mortality rate of 28,4%. However, a large variation in mortality rates was observed: there were no deaths in blunt chest injuries from assaults, in contradistinction to train accident victims and falls from height (over 90%). Pedestrian injuries in MVA had a 50/50 mortality rate.

External thoracic lesions were represented by ecchymoses and abrasions of the skin.

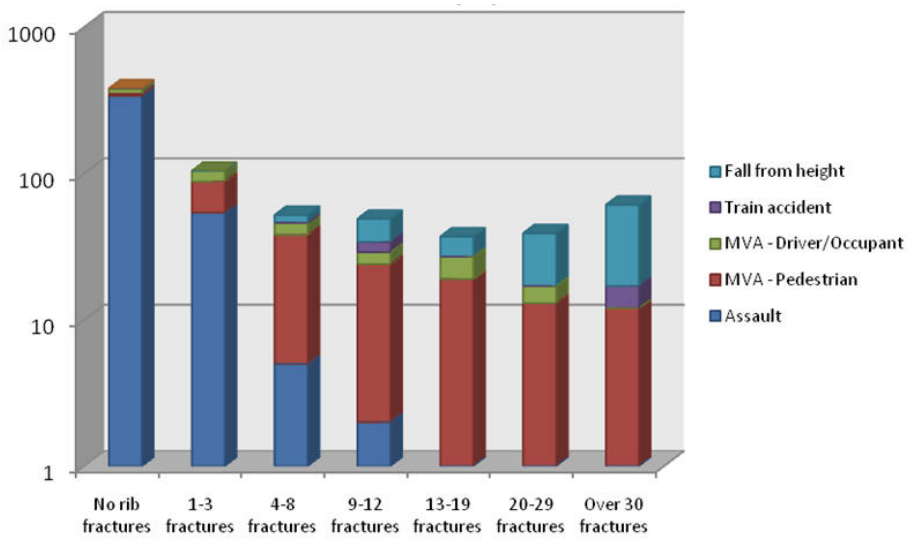

Fig. 1 The number of rib fractures in relation to circumstances of injury

There was no correlation neither between the presence of external signs of trauma (bruises or abrasions) and the severity of the injuries, nor between the presence of external lesions and the circumstances of injury. An important evaluation factor is represented by the disposition and number of the rib fractures.

Rib fractures were noted between 15% (assault) and over 90% (pedestrians, train accidents and falls from heights). The drivers and occupants involved in motor vehicle accidents had rib fractures in 60% of the cases. The number of rib fractures is related to the intensity of the impact force, hence the assaults accounted for up to 9 rib fractures, with an average of 1,8. Motor vehicle accidents tend to have a greater force of impact, resulting in an average number of rib fractures of 11,8 for pedestrians and 8,2 for drivers and occupants. At the other end of the scale are the injuries from falls from height and train accidents, with an average of around 30 rib fractures (Figure 1).

The frequencies of appearance of those particular aspects in relation to the circumstances of thoracic injuries are noted in Table 2.

Table 2 Particular rib fracture aspects, in relation to the circumstances of injury.

	Posterior arch fractures		First/second rib fractures		Double/multiple fractures (same rib)		Number of consecutive ribs fractured	
	No	Yes	No	Yes	No	Yes	Less than 3	More than 3
Assault	58 (95,1%)	3 (4,9%)	56 (91,8%)	5 (8,2%)	61 (100%)	0 (0%)	59 (96,7%)	2 (3,3%)
MVA pedestrian	43 (32,3%)	90 (67,7%)	52 (39,1%)	81 (60,9%)	77 (57,9%)	56 (42,1%)	53 (39,8%)	80 (60,2%)
MVA occupants	24 (58,5%)	17 (41,5%)	14 (34,1%)	27 (65,9%)	29 (70,7%)	12 (29,3%)	18 (43,9%)	23 (56,1%)
Fall from height	5 (5,2%)	92 (94,8%)	2 (2,1%)	95 (97,9%)	11 (11,3%)	86 (88,7%)	0 (0%)	97 (100%)

Regarding the type and localization of the rib fractures, we have noted several characteristics that could differentiate the mechanisms and circumstances of injury. Amongst these characteristics were: the region of the costal arch (anterior, lateral or posterior), fractures of the first and second ribs, the presence of more than one fracture on the same rib, and the number of consecutive ribs fractured in roughly the same region.

Table 3 Presence of pulmonary contusions in relation to circumstances of injury

			Pulmonary contusions		Total
			No	Yes	
Circumstances of injury	Assault	Count	400	0	400
		% within Circumstances of injury	100.0%	.0%	100.0%
	MVA - Pedestrian	Count	74	65	139
		% within Circumstances of injury	53.2%	46.8%	100.0%
	MVA - Driver/Occupant	Count	42	26	68
		% within Circumstances of injury	61.8%	38.2%	100.0%
	Train accident	Count	5	5	10
		% within Circumstances of injury	50.0%	50.0%	100.0%
	Fall from height	Count	20	78	98
		% within Circumstances of injury	20.4%	79.6%	100.0%
	Other	Count	17	8	25
		% within Circumstances of injury	68.0%	32.0%	100.0%
Total		Count	558	182	740
		% within Circumstances of injury	75.4%	24.6%	100.0%

Pulmonary contusions were observed in about half the cases involved in motor vehicle or train accidents, and in about 80% of the fall from height victims (Table 3). No pulmonary contusions were noted in assault victims.

Traumatic injuries of the heart and great vessels were accounted for only 7,1% (53 cases) of blunt thoracic trauma cases. Most of them (44 cases) were noted in falling from height, and consisted of heart ruptures (18 cases), as well as aortic and pulmonary artery ruptures (35 cases). Pedestrians involved in motor vehicle accidents accounted for only 13 cases (9 contusions and 4 heart ruptures), meanwhile the drivers and front seat occupants had presented with both cardiac (6 contusions) and aortic injuries (5 ruptures and 4 contusions). No cardio-vascular injuries were noted in assault victims (Figure 4).

Discussion

The results obtained in this study were generally consistent with literature data, although some features were slightly different. Two mechanisms occur in blunt trauma: (1) the direct transfer of energy to the chest wall and thoracic organs, and (2) differential decelera-tion, experienced by the thoracic organs at the time of the impact [6].

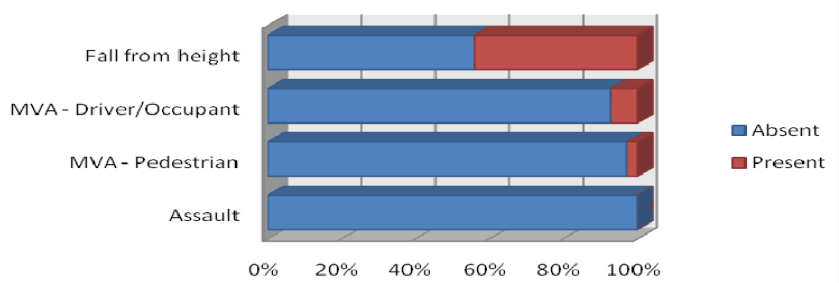

Fig. 4 Traumatic injuries of the heart and great vessels

The *direct transfer of energy* occurs when the relatively stationary body is struck with a moving object (i.e. a baseball bat, a fist, a moving vehicle, etc), whereas the *deceleration injury* encompasses a variety of thoracic injuries resulting when the moving thorax decelerates rapidly as a result of impact against a stationary or relatively stationary object. The direct transfer of energy can occur either from a relatively mild force of impact (as seen in most of the assault injuries), from a high force of impact (i.e. the initial impact in a pedestrian road traffic accident, exceeding by far the human force of impact), or even by thoracic compression. The deceleration injuries can occur either from a simple fall (i.e. a back fall, hetero or auto-propelled) or by falls from height, in which the force of impact is also considerable (in relation to the kinetic energy of the body).

With reference to external thoracic lesions (ecchymoses and/or abrasions of the skin), we found no correlation between their presence and the severity of the thoracic trauma, in concordance to other studies [8]. Furthermore, there was a negative correlation between the presence of bruising and the severity and circumstances of injury (Correlation coefficients between -0.45 and -0,48). This finding is explicable, considering that in an assault, the impact tends to be localized (even though the impact force is reduced), and therefore the energy is absorbed strictly by the adjacent soft tissue.

Regarding rib fractures, scientific literature [1, 4] describes two major poles, with a large diversity of intermediary aspects in-between them: unilateral fractures of up to 3 adjoining ribs (as seen in direct transfer of energy with low-medium force of impact), and bilateral multiple fractures, involving more than 3-5 adjoining ribs, usually associated with internal organ injury. Within the study, we found some features of rib fractures that could differentiate between assaults, motor vehicle accidents and falls from heights.

In assaults, the injuries occur from direct transfer of a limited amount of impact energy to the thoracic region, resulting in 1-2 adjoining rib fractures, mostly at the lateral costal arch. Fractures of the first rib imply a violent force [5], therefore these traumatic lesions tend to occur more frequently in motor vehicle accidents or falling injuries rather than in assaults, aspect that was also observed. Another aspect worth mentioning is the posterior localization of the rib fractures in deceleration injuries, associated with motor vehicle accidents and especially with falls from height.

Last but not least, the presence of more than one fracture on the same rib (double / multiple fractures) wasn't noted in assault cases, this type of injury resulting from an intense force of impact [3].

In relation to internal injuries in blunt thoracic trauma, we have found that the presence of pulmonary contusions associated with traumatic injuries of the heart and great vessels can exclude an assault. Studies focused on pulmonary contusion concluded that blunt trauma, especially motor vehicle accidents (72.2%) and falls (17.1%), were the most frequent causes of chest injury (95.8%) [10]. Other studies note the presence of pulmonary contusion in about 10% of the assault victims [11]. The present study found no evidence of pulmonary contusion in any of the 400 cases of assault reviewed. This finding is otherwise explicable, considering that pulmonary contusions are typical deceleration injuries.

In regard to major vascular injuries, literature data accepts that the "classic" deceleration lesion in this category is aortic injury, associated with large magnitude forces, as seen in motor vehicle accidents or falling injuries. Multiple mechanisms of injury have been proposed [7], including the transmission of a shearing force at the ligamentum arteriosum [9], a compression and upward thrust of the heart [12] and differential deceleration of the heart and aortic arch relative to

the anchored segments of the thoracic aorta, mechanism we consider to be the most relevant with regard to physio-pathological and anatomical features of the thoracic region.

Traumatic rupture of the thoracic aorta is recognized as a common cause of occupant, as well as pedestrian death after rapid deceleration in motor vehicle collisions [2]. In our study, we have observed a correlation between aortic and cardiac injuries and occupants involved in motor vehicle accidents. Associated pulmonary artery injury however, tends to occur mainly in falls from height.

Resuming the aspects discussed above, the presence of the analyzed traumatic injuries can correlate with the circumstance of occurrence in various degrees, from improbable (usually not present, but the presence doesn't exclude the mechanism in question), to uncertain (their sole presence doesn't certify a certain mechanism, and the absence doesn't exclude the mechanism), probable and highly probable (Table 5). In our opinion, the presence of some injuries can even exclude a circumstance (i.e. cardio-vascular injuries associated with pulmonary contusion can exclude an assault).

Table 5 Forensic criteria for assessing circumstances of injury

	Fracture of more than 3 adj. ribs	First/second rib fracture	Double/ multiple fract (same rib)	Pulmonary contusions	Aortic and/or cardiac injuries	Associated pulmonary artery injury
Assault	Improbable	Highly improbable	Highly improbable	Highly improbable	Excluded	Excluded
MVA Pedestrian	Possible	Possible	Possible	Uncertain	Uncertain	Improbable
MVA Driver/occup	Uncertain	Uncertain	Uncertain	Uncertain	Possible	Improbable
Falls from height	Highly probable	Highly probable	Possible	Possible	Possible	Highly probable

Conclusions

The mechanism and circumstance of a blunt chest injury can be assessed in relation to the number and localization of rib fractures, the presence of double or first and second rib fractures, as well as to the presence of pulmonary contusions and cardiac and major vascular injuries.

Findings of more than 3 rib fractures (including first and second rib) on a posterior line, associated with pulmonary contusion and cardiac or vascular injuries will exclude an assault, directing the investigation towards a fall from height (in the presence of associated pulmonary artery injury), or a motor vehicle accident. Nevertheless, these cases need to be addressed prudently; therefore, a global assessment of all injuries and corroboration with evidence from the crime scene and with any anamnesis data available is advised.

References

1. Belis V.: Tratat de Medicina Legala, Editura Medicala, Bucuresti, 1995.
2. Brundage, Susan I, Harruff R, Jurkovich G, Maier RV: The Epidemiology of Thoracic Aortic Injuries in Pedestrians. Journal of Trauma-Injury Infection & Critical Care. 1998, 45(6):1010-1014.
3. Collins, J: Chest wall trauma. Journal of Thoracic Imaging 2000; 15(2): 112-119.
4. Dermengiu, D: Patologie Medico-Legala, Editura Viata Medicala Romaneasca, Bucuresti, 2002.
5. Fabian TC, Croce MA, Minard G.: Current issues in trauma. Curr Probl Surg. 2002;39(12):1160-244.
6. Khan, AN: Thorax, Trauma. in: http://emedicine.medscape.com - updated dec. 2008.
7. McGwin G, Jr., Metzger J, Moran SG, Rue LW, 3rd.: Occupant- and collision-related risk factors for blunt thoracic aorta injury. J Trauma 2003;54(4):655–60.
8. Peters M.L., Starling S.P., Barnes-Eley M.L., Heisler K.W.: The Presence of Bruising Associated With Fractures. Arch Pediatr Adolesc Med. 2008;162(9):877-881.
9. Sanchez-Ross M, et al.: Aortic rupture: comparison of three imaging modalities. Emerg Radiol. 2006;13(1):31-33.
10. Segers P., Van Schil P., Jorens Ph., Van Den Brande F.: Thoracic trauma: an analysis of 187 patients. Acta chirurgica Belgica 2001 (6): 277-282.
11. Sırmalı M et al: A comprehensive analysis of traumatic rib fractures: morbidity, mortality and management. European Journal of Cardio-Thoracic Surgery, 2003, 24(1): 133-138.
12. Williams JS et al**:** Aortic injury in vehicular trauma. The Annals of Thoracic Surgery, 1994, 57: 726-730.