ORIGINAL PAPER

CORRELATION OF TRAUMA CIRCUMSTANCES AND MECHANISM WITH THE TYPE, LOCALIZATION AND RANGE OF CRANIAL AND INTRACRANIAL INJURIES IN TRAFFIC ACCIDENT CASUALTIES

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Summary
A large number of traffic accident casualties are subjects to head traumas, causing difficulties in fast and correct diagnostics on site. It may lead to so called underdiagnosis and qualification of the case as 'not urgent'.

Objective. The objective of the study was to obtain data, which would help to foresee the nature of intracranial injuries in traffic accident casualties based on circumstances of the trauma and visible injuries within head integument. We tried to capture possible relations between the mechanism of trauma, external injuries and serious intracranial pathologies, eventually causing the victim's death.

Material and methods. Documentation of 219 traffic accident casualties kept by the Forensic Medicine Department, Medical University of Warsaw.

Results. Among casualties of traffic accidents leading to a fatal head trauma, males constituted the considerable majority (78.1%). The average age amounted to 29.9 in male casualties and 44.77 in female casualties. Victims exposed to angular acceleration or angular acceleration associated with direct impact suffered from injuries in the form of subarachnoid bleeding, intracerebral/intraventricular bleeding and/or tear of deep cerebral structures, whereas casualties with the injury mechanism qualified as linear acceleration significantly more often suffered from cortical contusion and epidural haematomas. Among injuries of deep cerebral structures, cases of brain stem contusion most frequently referred to casualties who experienced rotation as an additional damage mechanism.

Conclusions. Casualties of accidents suffering of trauma caused by rotation mechanism are exposed to considerably more severe injuries of cranial cavity structures than casualties of traumas caused by a different mechanism. Cerebral injuries induced by the mechanism of angular acceleration refer to the brain stem in particular. In cases where head protection has been used, they may occur without visible head injuries.

Key words: traffic accidents, head traumas, intracranial traumas, head trauma mechanism

INTRODUCTION

Growing numbers of traffic accidents and casualties create a serious medical and social issue. Along with expanding road traffic, mass casualty accidents and catastrophes become increasingly more common, which in view of paucity of medical professionals considering the needs, require the use of procedure algorithms. The problem in emergency medicine is that some subjects with serious injuries are underdiagnosed on the accident scene and due to being qualified as 'not urgent cases' they are referred to be managed or transported subsequently (1). Cases of underdiagnosis are mainly related to head traumas. It results from the fact, that external injuries of the head or cranial fractures are not always accompanied by intracranial injuries as well as serious intracranial injuries sometimes are not reflected by external injuries (2, 3).

Despite the significance of the issue consisting in predicting localization and severity of intracranial injuries based on local condition available for physical examination, studies regarding this problem are relatively scarce (2, 3, 4, 5, 6, 7, 8). Shortage of exploratory studies with autopsy material is apparent in particular, with a vast majority of publications covering only clinical material. In spite of progress in imaging diagnostics, only the autopsy may provide complete data in the scope of pathomorphologic lesions occurring in the cranial cavity.

AIM OF STUDY

The aim of the study was to obtain data allowing prediction of the intracranial injuries' nature in traffic accidents casualties based on circumstances of the injury and visible head integument injuries. We tried to capture possible relations between the mechanism of trauma as well as external injuries and serious intracranial pathologies eventually leading to death of the patient.

MATERIAL AND METHODS

The analysis covered documentation of the Forensic Medicine Department, Medical University of Warsaw, collected between 1990 and 2004 concerning subjects deceased in result of traffic accidents. Cases included in the study were casualties managed on the scene, transported or hospitalised, who died due to injuries of the cranial cavity. Cases of casualties, who died instantly (dead on arrival or unsuccessful resuscitation) or in whom death was caused by other, concomitant injuries, were excluded from the study. The analysis included 219 reports. The local Bioethics Committee at the Medical University of Warsaw was informed on the objective of the study, material, and suggested methods and did not report any reservations.

The analysed parameters included circumstances of the injury, time and place of the event, anamnesis and physical examination, results of consultation and additional examinations, time and cause/causes of death.

The Student's t-test was used to investigate differences between the mean values of constant variables (age, time of survival). Pearson's chi-square test for quality variables or chi-square test with the Yates' correction were used to analyse frequency differences in the scope of individual phenomena and to verify hypotheses, that phenomena observed in individual populations are independent. The Pearson's C contingency coefficient or Cramer's V association coefficient were used to assess the power of relation between individual variables, measurement of which are expressed in nominal scales.

Statistical analysis was performed with the use of STATISTICA 6.0 and IDAMS statistical packages. For statistical hypotheses testing the significance level of $\alpha=0.05$ was assumed and two-sided critical region when the choice was left to the investigator's discretion.

RESULTS

The group of 219 accident casualties included 171 (78.1%) males and 48 (21.9%) females. Age of the casualties ranged from 13 to 78 (mean victim's age being 33.33). The mean age of males was 29.9 (SD = 14.91) and females – 44.77 (SD = 18.5). The median for males amounted to 24 and for females – to 50. Age of males was significantly lower ($p < 0.001$) both, in regard of all the accidents jointly as well as the traffic accidents as a separate group. Males took part in traffic accidents, mostly motorbike and bicycle accidents, more frequently in a statistically significant manner ($p = 0.007$). Only in case of railway accidents no significant differences between genders were found. Table 1 shows distribution of material according to the accident category.

Reconstruction of the injury mechanism was based on autopsy findings and description of the injury course and circumstances. In the scope of data regarding the description of accidents with participation of pedestrians, cyclists and motorcyclists, the main focus was on

Table 1. Categories of traffic event resulting in fatal cases among traffic participants identified in the examined material according to the gender.

Type of accident		Number of casualties	
		Female casualties	Male casualties
Road traffic	Pedestrian	7	10
	Cyclist	3	31
	Motorcyclist	4	38
	Driver	13	32
	Car passenger	17	44
Road traffic accidents jointly		44	155
Railway	Knocked down en-route	0	4
	Event within a railway station	0	5
	Train passenger	4	7
Railway accidents jointly		4	16
Total number of casualties according to gender		48	171
Total number of casualties knock down		219	

whether the casualty was recoiled to the side or along the movement vector only, bringing into consideration the inertial rotational force in the first case. The crash helmet on a cyclist's head and the fact of being recoiled to a soft shoulder (2 cases) caused far smaller range of external injuries comparing to other cases. One of these cases was qualified as a 'clear' linear acceleration type (straight line impact) in view of no cranial fractures. Also, if the description of a car accident included information about the vehicle hit by its side or/and somersaulting, rotation forces were examined. In situations, when a vehicle was equipped with pneumatic protection system (airbags, side airbags, curtain airbags), fact being confirmed by event description or model characteristics, usually no cranial fractures were observed and the events were qualified as the effect of 'clear' acceleration forces. In case of railway accidents with participation of the train passengers, the description of the event did not include information on what happened to the individual carriages during the accident. The results are compiled in table 2.

Casualties exposed to the effect of angular acceleration or angular acceleration with a direct effect of a force, significantly more often suffered from injuries in the form of subarachnoid bleeding, intracerebral/intraventricular bleeding and/or a tear of deep cerebral structures, whereas casualties with the injury mechanism qualified as linear acceleration significantly more frequently suffered from cortical contusion and epidural haematomas ($p = 0.0214$).

More comprehensive analysis of the material demonstrated that among injuries of deep cerebral structures, cases of brain stem contusion most frequently referred to casualties subjects to rotation as the main or additional damage mechanism (tab. 3).

Another issue to be examined was a possible relation between hypothetic injury mechanisms defined as stated above and the time of casualties' survival. The latter seemed to constitute a good parameter for comparison of individual situations, since autopsy data covered mainly the 'flat' description, i.e. there was no information about the volume and hence the actual size of described lesions but only the lesion range in the surface projection or cross-section of the cerebrum. Moreover, the statement of 'disruption of the thalamus' without providing location and range of the injury, seemed to represent

Table 3. Brain stem contusion cases vs. the injury mechanism.

Injury mechanism	Brain stem contusion	
	Number of cases	**Percentage in the total number of casualties**
Linear acceleration (N=10)	2	20%
Direct contact/linear acceleration (N=141)	54	38.3%
Angular acceleration (N=39)	19	48.72%
Direct contact/angular acceleration (N=29)	16	55.17%

Table 2. Compilation of the number of intracranial pathologies found during autopsy in the examined material on a probable injury mechanism basis.

Injury mechanism/ /injury type	Intracranial injury type							
	Epidural haematoma	**Subdural haematoma**	**Sub--arachnoid haematoma**	**Intracerebral/ /intra--ventricular bleeding**	**Cortical contusion**	**Deep structure contusion**	**Disruption of cerebral tissue**	**Generalised oedema**
Linear acceleration (N=10)	0	17	3	2	10	4	1	9
Direct contact/linear acceleration (N=141)	98	89	4	9	141	78	4	121
Angular acceleration (N=39)	2	19	17	31	11	29	26	32
Direct contact /angular acceleration (N=29)	13	15	15	22	29	22	17	22

an argument too weak for further practical conclusions. Table 4 shows the results of this analysis.

Testing differences between the mean values contained in table 4 demonstrated that casualties exposed to the rotational force as the main or even additional component of the injury mechanism, presented significantly shorter time of survival compared to other cases, i.e. situation, when only linear acceleration occurs or it constitutes one of the components. Particularly highly significant were differences between cases with linear acceleration only and cases with angular acceleration only (p = 0.0008) or angular acceleration as a component (p = 0.00071), and further on – between cases with angular acceleration as a sole factor and cases with angular acceleration as a component (p = 0.00059).

Table 4. Survival time of accident casualties expressed in hours with individual injury mechanisms.

Injury mechanism	Survival time since accident		
	Arithmetic mean	Standard deviation	Variation range
Linear acceleration (N=10)	83.8	60.52	7-200
Direct contact/linear acceleration (N=141)	96.23	61.26	3-333
Angular acceleration (N=39)	41.74	34.76	2-144
Direct contact/angular acceleration (N=29)	51.24	41.59	2-211

Table 5 presents individual intracranial pathologies in different types of neurocranial fractures. Analysis of data included in the table allowed to demonstrate, that cases of basal fractures significantly more often involved deep structures' contusion, intracerebral bleeding, and disruption of cerebral tissue (p = 0.008).

DISCUSSION

The mean age of traffic accident casualties in this study was higher than stated in other publications. The bibliography suggested that the highest number of post-traumatic cerebral damage refers to the 15-24 age group but the mean age of casualties has recently increased, particularly in the highly developed countries (2, 3, 9, 10, 11). Moreover, adults over 80, who are exposed to falls, constitute a special risk group (12). These situations were not analysed as they did not meet the inclusion criteria. The mean age of post-traumatic cerebral damage casualties is lowered by fight victims, particularly fights with the use of heavy tools and victims of firearms. These situations were not covered in the analysed material either.

Concerning the gender of casualties, significant predominance of males over females was noticed and the male to female ratio in the investigated material was equal 3.56:1. This result is comparable to the data from relevant publications, as the frequency of traumatic cerebral injuries is higher in males regardless to age of victims (2, 3, 7, 10, 13).

Over half of the analysed cases were injuries resulting from the effect of mixed mechanism – impact-acceleration type which corresponds to data available in literature (14-20).

The group of casualties, diagnosed with intracranial pathologies without a cranial fracture, included 49 cases (22.37%) and is comparable to the number of 12% of casualties stated by Menon et al. (2) with no cranial fracture found. The percentage of casualties with cranial cavity pathologies concomitant with cranial fractures amounted to 38.9% in the material

Table 5. Intracranial injury types observed in individual cranial fracture types.

Cranial fracture type	Intracranial injuries								
	Epidural haematoma	Subdural haematoma	Sub--arachnoid haematoma	Intracerebral/ /intra--ventricular bleeding	Cortical contusion	Deep structure contusion	Disruption of cerebral tissue	Generalised oedema	None
Linear (N=31)	13	19	2	2	31	11	1	29	21
Compressed (N=25)	13	14	6	3	25	9	4	21	7
Diastatic (N=80)	65	71	11	17	80	51	12	75	21
Basal (N=34)	8	14	12	21	34	29	11	31	0

investigated by Yavuz et al., whereas the percentage of casualties presenting cranial fractures among all cases with intracranial pathologies accounted for 50.3%.

It was proved that casualties exposed to the effect of angular acceleration or angular acceleration combined with a direct effect of a destructive force (contact injury) significantly more often suffered from injuries in the form of subarachnoid bleeding and a tear of deep cerebral structures, whereas casualties of accidents with a predominant linear acceleration suffered from cortical contusion and epidural haematomas significantly more frequently. Among deep cerebral contusion cases, brain stem contusion mainly referred to casualties with the rotary movement as the main or additional destructive mechanism. Therefore, it should be stated that, regardless of the range of separate injury types in individual subjects, accident casualties exposed to additional or main effect of angular acceleration usually suffered from cerebral injuries, which were more serious, located deeper, and associated with worse prognosis. Available publications did not provide any studies related to this issue.

As far as the localization of cortical contusion, deep contusion and epidural haematomas quite strictly correlated with application of force against the skull and the direction of the force, no logical relation was found between the force parameters and location of epidural haematomas. The observation of other authors in regard of actually unpredictable location of epidural haematomas was hence confirmed.

CONCLUSIONS

1. Casualties of accidents with rotational movement are exposed to considerably more severe damage of the cranial cavity structures than casualties of accidents with a different mechanism.
2. Cerebral damage in case of angular acceleration mechanism refers to the brain stem in particular.
3. Traumas resulted from the effect of the rotational force in protected traffic participants usually caused minimal external injuries with very serious internal injuries. □

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