Rom J Leg Med [29] 28-36 [2021]
DOI: 10.4323/rjlm.2021.28

TRAUMATIC BRAIN INJURY- AUTOPSY FINDINGS AND COMPARISON WITH ANTEMORTEM CT FINDINGS

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Abstract: *Background.* Traumatic brain injuries (TBI) remains one of the leading causes of high mortality both in Europe and globally. The age of people with head injury tends to change, in recent years an increased incidence among the elderly has been observed, especially due to falls. Medico-legal autopsy is mandatory in all head trauma patients, not only revealing the contributions of the injury in the occurrence of death but also in providing information about the pathological mechanism of trauma.

Aims. This study aims to describe autopsy findings in patients with TBI and to compare them with primary CT findings, using imagistic investigations reports and clinical data.

Methods. We included in the study 479 autopsies performed between January 2017 and December 2018 at "Mina Minovici" National Institute of Legal Medicine, Bucharest, in which craniocerebral trauma was a cause in the chain of events leading directly to death. Data were collected from autopsy reports and medical records.

Results. In our study the analyzed population was represented by men in proportion of 76.2% and the most affected age group was between 61 and 80 years. The most common cause of TBI were road accidents (n=137/479; 28.60%) followed by falls from the same level (n=136/479; 28.39%). In the studied group the average survival time was 79.83 days. The most common autopsy findings were cerebral oedema (n=443/479, 92.5%) and subarachnoid haemorrhage (n=425/479, 87.7%). Comparative analysis of 190 cases of TBI showed that only 59.8% of the autopsy findings were diagnosed by antemortem primary CT investigation.

Conclusions. TBI patterns and the cause of injury change with age, having high mortality among elderly patients. Medico-legal autopsy is a source of valuable information, referring not only to medical diagnoses but also to the circumstances of traumatic injuries. Antemortem investigations and medical history are useful tools in documenting the progression of a brain injury especially in patients with long-term survival and also in establishing causality between traumatic injuries and death.

Keywords: traumatic brain injury, autopsy, postmortem findings, CT findings.

INTRODUCTION

Traumatic brain injury remains one of the leading cause of mortality and morbidity worldwide. The global the incidence of craniocerebral trauma has been reported to be at 939 cases per 100000 people [1]. To better highlight the importance of the brain damage in craniocerebral trauma, the term" head injury" has been replaced with" traumatic brain injury" [2].

Definition of traumatic brain injury was changed a decade ago, focusing more on the importance of cerebral tissue. Currently TBI is define as: "An alteration in brain function, or other evidence of brain pathology, caused by an external force" [3].

A systematic review describing the epidemiology of TBI in European countries, conducted by Wouter Peeters *et al.*, showed an overall incidence rate of 262 per 100.000 per year and an average rate of mortality of 10.53 per 100.000 per year [4].

The most common classification system for TBI is based on the assessment of level of consciousness and level of neurological functions (Glasgow coma scale) at the time of the injury, duration of post-traumatic amnesia (PTA), and duration of altered mental state or loss of consciousness (LOC). CGS classifies brain injuries in mild (GCS 13-15), moderate (GCS 9-12)

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and severe (CGS 3-8) by evaluating three components of neurological functions: eye-opening, motor response and verbal response [5].

These clinical criteria for assessing TBI severity are considered by modern practitioners limited as long as GCS score can be affected by prehospital sedation, intoxication or paralysis and with an increased risk of failing in identification of complexity of severe injuries [6,7].

In clinical practice, computer tomography scans and magnetic resonance imaging are widely used for identification of structural damages and in assessing severity. Because none of these criteria can generate a prognosis on their own, researchers and clinicians recommend using them in a single classification system to classify TBI in three categories which reflects current clinical knowledge and relevance, Malec *et al.* proposed the Mayo classifications system for TBI severity (Table 1) [8].

Usually all head trauma deaths are reported as violent deaths and they are the subject of medico-legal autopsy at the request of the legal authority responsible for the investigation of unnatural, suspicious and criminal deaths. The main purpose of the medico-legal autopsy is to determine the cause and the manner of death, to document the injuries and the mechanism of the injuries.

Objectives

The aim of this study was to describe the autopsy findings in TBI, for all forrensic cases where the main cause of death was craniocerebral trauma and to compare them with ante-mortem CT findings.

MATERIAL AND METHODS

In this study we retrospectively analysed 479 cases of forensic autopsies performed between January 2017 and December 2018 at the "Mina Minovici" National Institute of Legal Medicine, Bucharest, Romania.

For collection of data, the autopsy reports were reviewed. We included in this study the cases with cranio-cerebral trauma whose death occurred immediately after the trauma (n=61/479), as well cases that survived and required hospitalization before death (n=418/479).

For all the cases included, autopsy findings established that the head injury provided a major contribution in death and craniocerebral trauma was a cause in the chain of events leading directly to death. For the hospitalized cases we had at our disposal the medical history and the radio-imaging examinations performed during hospitalization.

The autopsies were carried out between 1 and 4 days after death. A full body autopsy was performed for each case and all the autopsy findings were photographed and documented in the autopsy report. In all the autopsies procedure the brain was removed and examined immediately without additional fixation in formalin. The brain was first examined for surface abnormalities and then sectioned into parallel fronto-occipital sections.

RESULTS

Demografic population and epidemiology of TBI

A higher incidence of craniocerebral trauma was observed among men, representing 76.2%

Table 1. Mayo Classifications system for TBY severity [8]

Definite TBI (Moderate- Severe) One or more criteria apply	Probable TBI (Mild) One or more criteria apply	Possible TBI (Symptomatic) One or more of the following symptoms
- Death - Loss of consciousness for at least 30 minutes - Post-traumatic anterograde amnesia for more than 24 hours - Worst GCS full score in first 24 hours <13 - At least one of the following structural damages: – Intracerebral hematoma – Epidural hematoma – Subdural hematoma – Subarachnoid hemorrhage – Cerebral concusion – Hemarrhagic contusion – Penetrating TBI – Brain stem injury	- Loss of consciousness less than 30 minutes - Post-traumatic anterograde amnesia of momentary to less than 24 hours - Depresses, basilar or linear fracture (dura intact)	- Blurred vision - Confusion - Dazed dizziness - Focal neurologic symptoms - Headache - Nausea

(n=365/479) of the studied group, while women are affected in a proportion of 23.8 % (n=114/479). Patients were divided into nine age groups, as indicated in Table 2. The age of the studied population varies from 2 months to 93 years and the highest incidences can be observed among people aged between 61 and 80 years. In all age groups, the number of men with TBI was predominant (Fig. 1).

Out of the total 479 cases, in 61 cases the death occurred immediately after the trauma so that the GSC score was not determined, and 418 cases required hospitalization. Out of the total number of hospitalized cases, for 415 cases the initial severity of traumatic craniocerebral injuries was assessed by the GSC score evaluated at the time of admission to the hospital. Three cases (0.63%) out of the 418 hospitalized, did not have the GCS score recorded in the medical files (undetermined). Hospitalized cases were classified at admission at mild TBI= 66 (13.78%) cases, moderate TBI= 74 (15.45%) cases and severe TBI= 275 (57.41%) cases (Fig. 2).

Table 2. Number of cases in different age groups

Group age	No. of cases	Percentage
0-10 years	20	4.18
11-20 years	15	3.13
21-30 years	25	5.22
31-40 years	33	6.89
41-50 years	66	13.78
51-60 years	76	15.87
61-70 years	91	19.00
1-80 years	87	18.16
>81 years	66	13.78

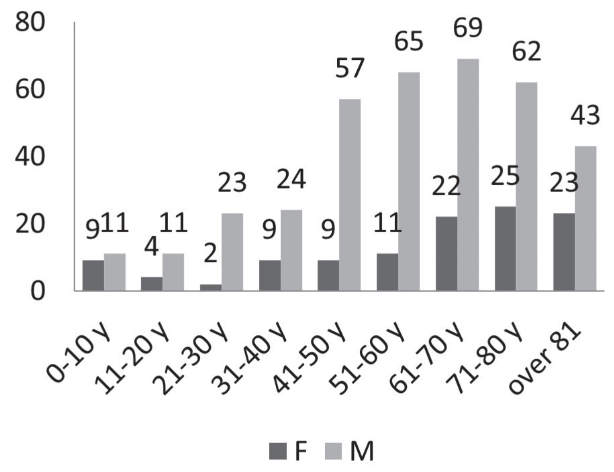

Figure 1. Age and sex distribution of the cases.

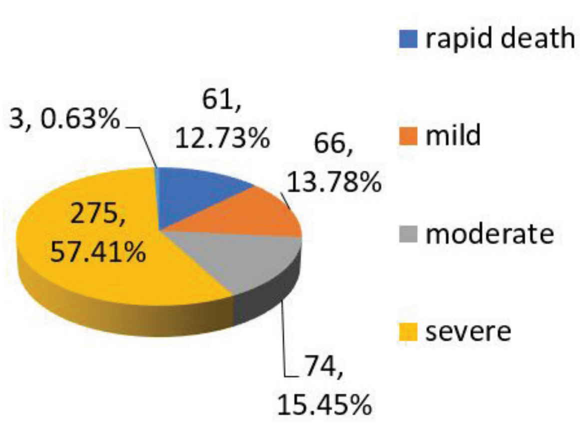

Figure 2. Severity of TBI by GCS score assessment.

Traffic accidents were the most frequent cause of head trauma (n=137/479; 29%), closely followed by falls from the same level (n=136/479 cases; 28%). All hospitalized cases with craniocerebral injuries in which circumstances were not known, were classified as unspecified (n=120/479, 25.05%). Falls from height (more than 2 meters) represented 11,27% (n=54/479) from the total cases, 51 of them as a result of suicide and 3 accidental falls. In only 2 cases the traumatic brain injuries were caused by shooting and in one case by an explosion (Fig. 3).

Victims of road traffic accidents (n=137/479) who suffered craniocerebral trauma were mostly pedestrians, 57.66 % (n=79/137). 17.52% (n=24/137) of the deceased were cyclists or motorcycle riders, 17.52% (n=20/137) passengers and 8,03% (n=11/137) drivers. In the studied group, we had 3 victims of railway, all of them victims of suicides (Table 3).

Of the 479 analyzed cases, 61 (12.73%) died immediately after trauma or within the first hour, 46 cases (9.60%) died within 24 hours of reaching a medical unit and 254 (53.03%) had a survival period between 2 and 10 days; 29 cases (6.05%) had a survival time over 30 days, the longest hospitalization period being of 240 days (Table 4).

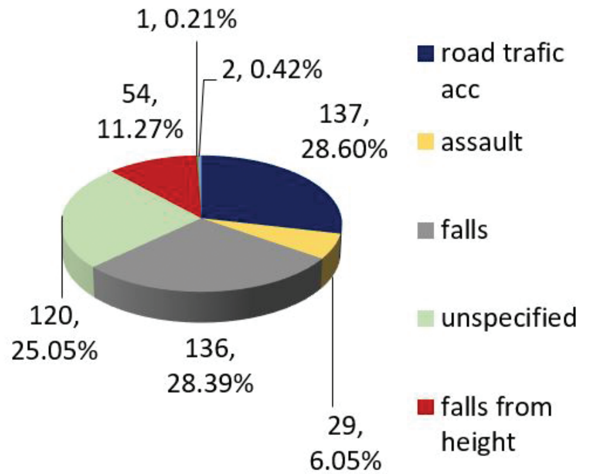

Figure 3. Frequent cause of TBI in the studied group.

Autopsy findings

The most common brain abnormality found at the autopsy was cerebral edema (n=443/479, 92.5%), followed by subarachnoid hemorrhage (n=425/479, 87.7%) and subdural hamorrhage (n=392/479 cases, 81.8%); the least found were intracerebral hemorrhage (n=79/479 cases, 16.5%) and epidural hemorrhage (88/479 cases, 18.4 %). These findings overlapped with each other in the majority of cases. 81.6% of cases (n=391/479) had scalp injuries (Table 5).

Skull fractures identified at autopsy were grouped according to anatomical sites. 119 cases (24.8%) had no skull fracture. Linear fracture of the cranial vault occurred in 44 cases (9.2%), and isolated linear cranial base fractures were found in 2.3% cases. (n=11). Fractures of the cranial vault combined with base fracture occurred in 202 cases (42.2%) representing the most common type of cranial fracture encountered. Comminute fractures of the maxillo-facial bones associated either with fractures of the cranial base or with fracture of the cranial vault were diagnosed at autopsy in 74 cases (15.4%) and were classified as neuro and viscerocranium fractures.

Fractures located strictly at the level of the viscerocranium without associating other fractures accounted for 3.5% (17 cases) of cases. In 12 cases (2.5%) the entire cephalic extremity showed marked comminution with multi-squamous fragmentation of the skull (Fig. 4).

Table 3. Characteristics of road traffic accidents

Road traffic	No. of cases	Percentage
Pedestrian	79	57.66
Driver	11	8.03
Passenger	20	14.60
Bike/motor rider	24	17.52
Railway	3	2.19
Total	137	100.0

Table 4. Survival time and length of medical admission from trauma to death

Survival Time	No. of cases	Percentage
Imediat death	61	12.73
1 day (<24h)	46	9.60
2-10 days	254	53.03
11-20 days	60	12.53
21-30 days	29	6.05
> 31 days	29	6.05
Total	479	100.0

Ante-mortem CT scan findings

At the time of admission in the medical unit, 404 cases underwent CT investigations. CT scans showed an increased frequency of subdural hemorrhage (n=280/404 cases, 69%), followed closely by subarachnoid hemorrhage (n=253/404 cases, 62.5%) and cerebral edema (n=250/404 cases, 61.7%). Epidural hematoma was seen on CT scans in only 52 cases (12.8%) and intracerebral hemorrhage in 65 cases (16.1%). Skull fractures were diagnosed in 225 cases (55.6%) (Table 6).

Comparative analysis between autopsy and ante-mortem CT scans

Out of the 479 cases, we compared 190 cases considering each brain injury.

For the comparative analysis of the autopsy findings with the primary CT findings, we excluded

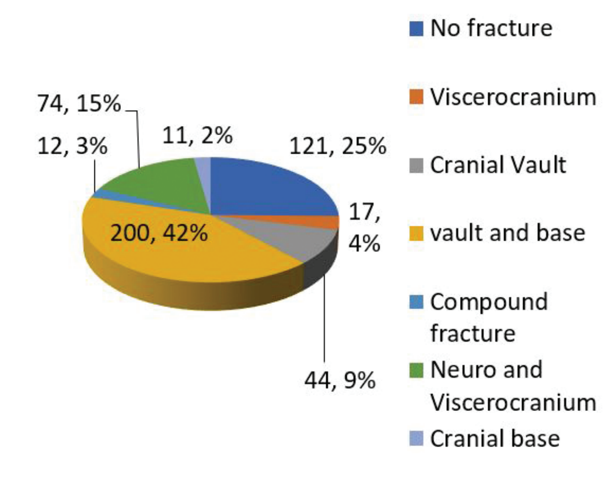

Figure 4. Anatomical localization of skull fractures.

Table 5. Autopsy findings- Type of intracranial hemorrhage and brain damage

Intracranial haemorrhage and brain damage	No. of cases	Percentage
Epidural hematoma	88	18.4
Subdural hemorrhage	392	81.8
Subarachnoid hemorrhage	425	87.7
Cerebral edema	443	92.5
Cerebral contusions	362	75.6
Cerebral lacerations	242	50.5
Intracerebral hemorrhage	79	16.5
Skull fractures	360	75.2
Scalp injuries	391	81.6

the hospitalized cases that underwent neurosurgical intervention, the cases with short time survival without CT investigation, as well as the cases in which the medical history was limited.

Out of the 190 cases, in 159 cases, the presence and the absence of epidural hematoma was similarly diagnosed by the two examinations, (comparative analysis of data showed that 150 cases had no diagnosis of HED neither at autopsy nor at CT and 9 cases with HED were similary diagnosed by both methods). In 18 cases, HED was identified only at the autopsy, while in 13 cases HED initially diagnosed by CT, was no longer found at the autopsy (Table 7).

Diagnosis of subdural hematoma was established by both autopsy and CT scans in 100 cases. In 27 cases both examinations noted the absence of subdural hematoma. In 63 cases these two examinations had different results (in 4 cases HSD was identified only by CT examination, while in 59 cases the autopsy established the presence of HSD, not previously diagnosed by CT investigation (Table 8).

123 cases with subarachnoid hemorrhage at autopsy were previously diagnosed by CT examination; in comparison, 9 and 44 cases were classified differently by autopsy and CT examination. 44 cases with subarachnoid hemorrhage at autopsy did not show this type of injury at the antemortem CT examination, while in 9 previously diagnosed cases, the autopsy did not identify the presence of HAS (Table 9).

Comparative analysis of the presence of cerebral edema identified that 112 cases were diagnosed similarly by both autopsy and CT; 2 cases without cerebral edema at the autopsy and CT examination and 110 cases with cerebral edema diagnosed by both types of examinations. 1 and 77 cases were classified differently by autopsy and CT examinations (Table 10).

Our of the 190 cases, 140 had cerebral contusions at the autopsy. In 44 of these cases, primary CT

Table 6. CT finding- Type of intracranial hemorrhage and brain damage

Intracranial haemorrhage and brain damage	No. of cases	Percentage
Epidural hematoma	52	12.8
Subdural haemorrhage	280	69
Subarachnoid hemorrhage	253	62.5
Cerebral edema	250	61.7
Cerebral contusions	203	50.1
Intracerebral hemorrhage	65	16.1
Skull fractures	225	55.6

Table 7. Epidural hematoma autopsy* epidural hematoma CT Crosstabulation

			HED CT		Total
			0	1	
HED autopsy	0	Count	**150**	13	163
		% within HED autopsy	92.0%	8.0%	100.0%
		% within HED CT	89.3%	59.1%	85.8%
	1	Count	18	**9**	27
		% within HED autopsy	66.7%	33.3%	100.0%
		% within HED CT	10.7%	40.9%	14.2%
Total		Count	168	22	190
% within HED autopsy		88.4%	11.6%	100.0%	
% within HED CT		100.0%	100.0%	100.0%	

Table 8. Subdural hematoma- autopsy* subdural hematoma- CT Crosstabulation

			HSD CT		Total
			0	1	
HSD autopsy	0	Count	**27**	4	31
		% within HSD autopsy	87.1%	12.9%	100.0%
		% within HSD CT	31.4%	3.8%	16.2%
	1	Count	59	**100**	159
		% within HSD autopsy	36.9%	63.1%	100.0%
		% within HSD CT	68.6%	96.2%	83.8%
Total		Count	86	104	190
% within HSD autopsy		45.0%	55.0%	100.0%	
% within HSD CT		100.0%	100.0%	100.0%	

examination did not show the presence of contusions. In 13 cases, cerebral contusion were diagnosed exclusively by CT examination, the macroscopic appearance of the autopsy not being similar (Table 11).

Skull fractures were found at the autopsy in 148 cases, from these, 118 cases were diagnosed antemortem. In 30 cases, CT scans failed to identify the cranial fracture, while the necropsy examination found in 2 cases the absence of fractures, although they had been initially diagnosed by CT examination (Table 12).

Table 9. Subarachnoid hemorrhage-autopsy * Subarachnoid hemorrhage –CT Crosstabulation

			HAS CT		Total
			0	1	
HAS autopsy	0	Count	**14**	9	23
		% within HAS autopsy	60.9%	39.1%	100.0%
		% within HAS CT	24.1%	6.8%	12.1%
	1	Count	44	**123**	167
		% within HAS autopsy	26.3%	73.7%	100.0%
		% within HAS CT	75.9%	93.2%	87.9%
Total		Count	58	132	190
% within HAS autopsy		30.5%	69.5%	100.0%	
% within HAS CT		100.0%	100.0%	100.0%	

Table 10. Cerebral edema at autopsy* cerebral edema on CT Crosstabulation

			Edem CT		Total
			0	1	
C.E autopsy	0	Count	**2**	1	3
		% within C.E autopsy	66.7%	33.3%	100.0%
		% within Edem CT	2.5%	0.9%	1.6%
	1	Count	77	**110**	187
		% within C.E autopsy	41.2%	58.8%	100.0%
		% within Edem CT	97.5%	99.1%	98.4%
Total		Count	79	111	190
% within C. E autopsy		41.6%	58.4%	100.0%	
% within Edem CT		100.0%	100.0%	100.0%	

Table 11. Cerebral contusions –autopsy* cerebral contusion –CT Crosstabulation

			Contusion CT		Total
			0	1	
Contusions	0	Count	**37**	13	50
		% within Contusions autopsy	74.0%	26.0%	100.0%
		% within Contusions CT	45.7%	11.9%	26.3%
	1	Count	44	**96**	140
		% within Contusions autopsy	31.4%	68.6%	100.0%
		% within Contusions CT	54.3%	88.1%	73.7%
Total		Count	81	109	190
% within Contusions autopsy		42.6%	57.4%	100.0%	
% within Contusions CT		100.0%	100.0%	100.0%	

Table 12. Skull Fracture - autopsy * Skull Fracture - CT Crosstabulation

			Fr CT		Total
			0	1	
Fr autopsy	0	Count	**40**	2	42
		% within Fr autopsy	95.2%	4.8%	100.0%
		% within Fr CT	57.1%	1.7%	22.1%
	1	Count	30	**118**	148
		% within Fr autopsy	20.3%	79.7%	100.0%
		% within Fr CT	42.9%	98.3%	77.9%
Total		Count	70	120	190
% within Fr autopsy		36.8%	63.2%	100.0%	
% within Fr CT		100.0%	100.0%	100.0%	

In the comparative analysis of cases with intracranial hemorrhage, both autopsy and CT examination had the same results in 157 cases, the absence of intracerebral hemorrhage was similarly diagnosed in 144 cases and the presence of HI in 13 cases.

15 cases had intracerebral hemorrhage only at CT examination, while in 18 cases the autopsy identified the presence of hemorrhage that had not been previously diagnosed by CT scans (Table 13).

The pathological findings of traumatic brain injury proved to be comparable between autopsy and ante-mortem CT. In some case brain lesions that were obviously present at CT were no longer found at the autopsy. In addition, the autopsy found the presence of brain injuries that was not diagnosed by the initial imaging examination (Fig. 5).

DISCUSSION

One of the aims of the study was to describe the clinical features of TBI leading to death, thus becoming the subject of forensic autopsy. In all the studied cases, the autopsy established that cranio-cerebral trauma was the cause of death.

In the studied population, patients were mainly males, as common with TBI. Currently, TBI affects the elderly population more frequently as a result of falls

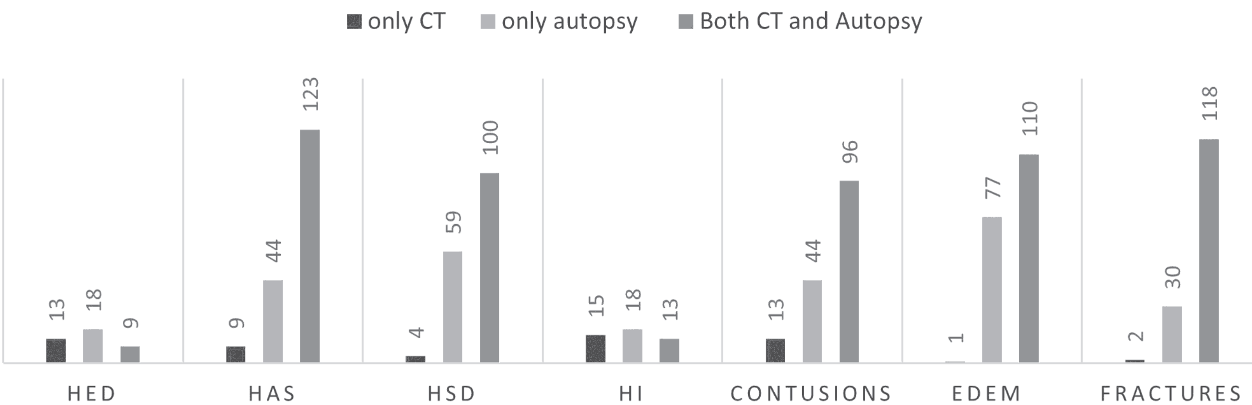

Figure 5. Comparison of injuries as in autopsy and CT scans.

Table 13. Intracerebral hemorrhage-autopsy* intracerebral hemorrhagee- CT Crosstabulation

			HI CT		Total
			0	1	
HI autopsy	0	Count	**144**	15	159
		% within HI autopsy	90.6%	9.4%	100.0%
		% within HI CT	89.4%	55.6%	84.6%
	1	Count	18	**13**	31
		% within HI autopsy	58.6%	41.4%	100.0%
		% within HI CT	10.6%	44.4%	15.4%
Total		Count	162	28	190
% within HI autopsy		85.6%	14.4%	100.0%	
% within HI CT		100.0%	100.0%	100.0%	

Table 14. Age group survival time

	Imediat	1 d	2-10 d	11-20 d	21-30 d	>31 d	Total
0-10 y	2	4	7	3	3	1	20
11-20 y	3	0	9	2	1	0	15
21-30 y	6	2	15	1	1	0	25
31-40 y	4	3	17	3	2	4	33
41-50 y	15	9	32	4	3	3	66
51-60 y	9	6	41	11	3	6	76
61-70 y	11	3	51	14	6	6	91
71-80 y	4	11	49	12	5	6	87
Over 81	7	8	33	10	5	3	66
Total	61	46	254	60	29	29	479

[9]. In this study the average age was 58 years ranging from 2 months to 97 years an most fatal head injuries were in age groups between 61 and 80 years (37% of the cases). Elderly patients tend to have an worse outcome due to associated co-morbidities or anticoagulant treatment which can aggravate the initial brain damage [10].

The global overall incidence of TBI severity was estimated at 81% for mild TBI, 11% for moderate TBI and 8% for severe TBI [1].

In our study the initial clinical evaluation at the time of admission to the hospital, established for 415 patients the severity of the TBI by assessing the GCS score. Most fatal head injuries (275, 57.4%) were classified as severe TBI with a GCS lower than 8. Patients deaths with mild and moderate TBI were closely reported (66 cases of mild TBI and 74 cases of moderate TBI). Mild TBI is known to be an independent significant risk factor of death especially for the elderly [11].

CT examination is recommended for all head trauma patients with a GCS of 13 or lower at the time of admission and it is considered to be a reliable method of investigation in order to diagnose the presence of intracranial lesions and the extension of the injuries [12]. In mild TBI, initial CT scanning may fail to identify subacute brain injury [2].

In the studied group the average survival time was 79,83 days. Length of hospitalization varied from few hours (<24 hours) up to 240 days, most patients died within 2-10 days (254 patients). No patient aged between 11-30 years had a survival longer than 30 days (Table 14).

Road accidents and falls are the most common causes of head trauma in Europe as well as globally [13,14]. In our study leading cause of TBI were road traffic collisions (28.60 %) and falls. The falls were divided into two categories - falls from the same level (28.39%) and fall from more than 2 meters high (11.27%). We had a group of 120 deceased (25.05%) with TBI in unspecified conditions. This diagnosis is usually established at admission when the patient has head injuries but no history of circumstances can be obtained. Autopsy findings and subsequent police investigation usually conclude that in most cases these patients suffered traumatic brain injuries in the event of a fall from the same level.

Autopsy examination of the 479 cases found that the most common intracranial hemorrhage was subarachnoid hemorrhage (425/479, 87.7%), followed by subdural hemorrhage (392/479, 81.8%) and the least common types of injury were epidural hematoma (88/479; 18.4%) and intracerebral hemorrhage (79/479; 16.5%).

These findings were similar to the findings of the antemortem CT examinations performed in the case of 404 patients of the studied group as well as with the results of other studies [15].

For the comparative analysis between the diagnosis of brain lesions found at autopsy and those found at CT examination, we excluded a number of 289 cases (immediate death or in a time interval that did not allow the CT investigation and also all the cases that underwent neurosurgical interventions in order to eliminate gross discrepancy given by this). Thus, 190 cases were analyzed in comparison. This comparison was made with the initial CT, performed the admission in the medical unit.

The difference between antemortem and post-mortem findings could be explained due to progression of the initial injury and apparition of secondary changes, recognized by medical practice and scientific literature [16,17]. For patients whose CT scan is earlier than 2 hours from trauma the rate of brain damage progression is close to 50% [18].

In our study, CT investigation failed to identify skull fractures in 20.3% of cases (30/190) and misdiagnosed the presence of fractures in 2 cases. This difference in findings can be due to the location of the fractures, the CT diagnosis of fractures of the anterior fossa being more difficult [19].

In conclusion, forensic autopsy represents the final examination of a body and is the gold standard method to determine the cause of death. It is a source of valuable information, referring not only to medical diagnoses but also to the circumstances of traumatic injuries and determination of causality between traumatic injuries and the occurrence of death. TBI patterns and cause of injury change with age, having high mortality among elderly patients.

Antemortem investigations and medical history are useful tools in documenting the progression of a brain injury especially in patients with long-term survival. Moreover autopsy provides a chance to reveal missed injuries.

Conflict of interest

The authors declare that they have no conflict of interest.

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