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# Anatomical Localization of Traumatic Brain Injury Cases in Eastern Macedonia and Thrace, Greece: a 10-year Retrospective Observational Study

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**Conflict of Interest**
The authors have no financial conflicts of interest.

## ABSTRACT

**Objective:** Brain trauma is an extremely important economical and social issue with increasing daily incidence. It is important to observe and report brain trauma, in order to provide better conditions for improvement of the trauma prevention and management.
**Methods:** A ten-year retrospective observational analysis was performed on 292 (fatal and non-fatal) incidents of traumatic brain injury among 2,847 totally examined cases in the records of the laboratory of forensic sciences at Democritus University of Thrace between January 1, 2007 and December 31, 2016. The results were further analyzed and classified into pertinent categories associated with the purpose of the study.
**Results:** The average age was estimated at 47.24 years with an obvious male domination. The most common cause of TBI, according to the results, is transport accidents (61.85%) followed by trauma inflicted by blunt instrument (22.49%), fall from height (11.65%) and occupational accidents (4.02%). Mortality rates were evaluated for each type, revealing extremely disturbing numbers. Regarding the anatomical localization on the skull, the most common region of cranial fractures is the cranial base (16.48%), followed by the frontal (12.87%), occipital (11.29%) and parietal bones (11.06%). In the majority of the cases, there were associated injuries.
**Conclusion:** The management of traumatic brain injuries is difficult and sometimes impossible. Better prevention measures are required to minimize as much as possible the incidence of brain trauma.

**Keywords:** Forensic science; Forensic pathology; Traumatic brain injuries; Skull; Neuroanatomy

## INTRODUCTION

Traumatic brain injury (TBI), as it is described, is a condition leading to physiological deterioration, impairment of functionality, and worsening of the quality of life. Regardless the source, TBI is believed to be a chief cause of death and a major cause of posttraumatic disability.[6,7,9,22] In the early 90's, brain trauma was introduced as a "silent epidemic" to describe its enormous dimensions to public health.[9]

Nowadays, the incidence of TBI has elevated to a greater extend. As indicated by worldwide data, the principal cause of brain trauma are transport accidents, followed by domestic and occupational accidents, falls, gunshots, and scarcely, interpersonal violence, assaults and criminal acts.[6,7,9,22]

Therefore, the medical management of TBI is of high significance. Numerous guidelines and research data indicate different sequences of TBI treatment but all of them converge into the fact that rapid medical action on the evaluation and intervention are required. In order to facilitate the latter, proper trauma categorization is highly important. Guidelines tend to categorize brain trauma according to its management, which is the basic aim of health professionals, rather than its anatomical localization.[7] But since the 21st century's revolution comes with a higher frequency of TBIs, anatomical positioning of the trauma on the skull is necessary, especially to achieve faster diagnosis and reduce the response time of physicians. In this concept, the present research, based on forensic neuropathological examinations, aims to investigate the frequency of head trauma, as well as its anatomical localization on the skull, its causal mechanism, and the demographic characteristics of the patients.

## MATERIALS AND METHODS

In order to assess the anatomical localization of TBI, the authors investigated all cases in the laboratory of forensic sciences at Democritus University of Thrace spanning from January 1, 2007 to December 31, 2016. This laboratory is the center for forensic examination that covers a total area of 14,158 km$^2$: the entire region of Eastern Macedonia and Thrace including the municipalities of Evros, Rhodope, Drama, Xanthi, and Kavala.

In regard of the study sample, fatal and non-fatal TBI incidents were included in the study sample, reported only from the department of forensic science and toxicology. The sample examined in this study followed the criteria of the incidents examined in the laboratory of forensic sciences, therefore clinical information, including neurological examination (i.e. Glasgow coma scale) and clinical categorization (i.e. mild, moderate or severe) were not available.. The only available information from the forensic science' reports, regarding the clinical status of the injured, is the location of death (at the hospital or at the place of the incident) and whether the patient received any therapy (since they arrived at the hospital, therapeutical methods were applied) or neurosurgical care.

The latter were cases of severe bodily damage involving legal-status complications, for which a public prosecutor's order was issued. After forensic evaluation, a protocol was formulated reporting the causation of each incident, as well as basic information about the patient, neurosurgical and forensic findings detected at the moment of examination. The authors systematically studied 2,847 forensic cases (protocols), among which, the total amount of 292 TBI incidents emerged. The latter were divided into categories based on the year, causation, type of TBI (open/closed), size, number of skull fractures and anatomical localization of injuries. The patients' demographic data were recorded, the prefecture that each incident occurred, the concomitant traumatological findings accompanying head injuries as well as substance abuse as indicated by toxicological examination.

The authors' inclusion criteria were traumatic brain injuries due to transport accidents, occupational accidents, falls and blunt force. All blunt force injuries inflicted by blunt


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wounding instruments were classified under the term "blunt force" also including acts of violence, while traumatic brain injuries that occur in falls from height were assorted separately. Among the aforementioned 292 protocols of TBI cases, 43 were excluded for the following reasons: 36 were due to deliberate gunshots inflicted at a specific anatomical point of the head (self-inflicted gunshots in the context of suicidal acts or acts of violence), 5 involved injuries due to sharp force, one case involved the fatal outcome of a biopsy and 1 involved drowning and post-mortem brain injuries. The aforestated incidents were excluded from the study because the traumatic brain injuries were deliberately inflicted at a specific anatomical area as a consequence of either self-harm, homicidal acts or medical intervention. Therefore, the research sample of the present study comprises 249 cases. Thereafter the data was analyzed with SPSS v.17 (SPSS Inc., Chicago, IL, USA) statistical program.

## RESULTS

Regarding the causation of TBI in the present study sample, the majority of TBI incidents were due to transport accidents (61.85%), followed by trauma induced by blunt wounding agents (22.49%), falls (11.65%) and occupational accidents (4.02%).

### Patients' demographic characteristics-epidemiological study

Among the 249 TBI patients that were investigated in this study, 49 involved females, while 200 were male subjects (M:F, 4.08:1). The mean age was evaluated at 47.24 years of age for both sexes (**TABLE 1**). More specifically, the age range for females was 1–95 years with average age of 49.7 and in regard of males, the age ranged from 3 to 94 years with average age of 44.8. Divided into decades, females had a balanced allocation of TBI incidence, in contrast to males, who presented with a peak of TBI incidence (21.86%) in the third decade of their lives (21–30 years of age), followed by the seventh (61–70 years of age) (15.10%), fourth (31–40 years of age) (14.06%), and fifth decade (41–50 years of age) (13.54%).

In respect of the prefecture of occurrence, 166 incidents took place in Evros (66.67%), 47 in Rhodope (18.88%), 19 in Xanthi (7.63%), 14 in Kavala (5.62%), and 3 in Drama (1.20%).

### Toxicological findings

Every patient underwent toxicological examinations in order to evaluate substance-related influence. The toxicology results are summarized in **TABLE 1**. Alcohol was detected in nine

**TABLE 1.** Epidemiological data and toxicological findings

| Year | Total | Male | Female | Average age | Positive toxicological tests | Fatalities |
|---|---|---|---|---|---|---|
| 2007 | 26 | 20 | 6 | 51 | No | 22 |
| 2008 | 37 | 29 | 8 | 39 | 1 alcohol; 1 alcohol+opioids+cannabis | 34 |
| 2009 | 21 | 17 | 4 | 41.8 | 1 alcohol | 19 |
| 2010 | 35 | 25 | 10 | 41.5 | 4 alcohol | 30 |
| 2011 | 28 | 25 | 3 | 48.3 | No | 19 |
| 2012 | 26 | 23 | 3 | 54.5 | 2 alcohol | 22 |
| 2013 | 8 | 7 | 1 | 51.8 | No | 5 |
| 2014 | 26 | 23 | 3 | 52.9 | No | 17 |
| 2015 | 26 | 17 | 9 | 53 | 1 alcohol | 18 |
| 2016 | 16 | 14 | 2 | 38.6 | No | 6 |
| Total | 249 (100.00) | 200 (80.32) | 49 (19.68) | 47.24 | - | 192 (77.11) |

The result is significant at $p<0.05$. Genders: the $Z$-Score is 3.51507, the $p$-value is 0.00022; average age: the $Z$-Score is −3.74185, the $p$-value is .00009; toxicological results: the $t$-value is 8.83302, the $p$-value is <0.00001; fatalities: the $f$-ratio value is 16.31754, the $p$-value is 0.000023.

individuals (3.61% of the cases), while in one case, the influence of alcohol, opioids and cannabis was disclosed (0.40%).

### Fatalities

Among the investigated 249 incidents, 192 had a fatal outcome (77.11%) (mortality rate of the examined sample). Despite the fact that the majority of the sample was victim of polytrauma, the main cause of mortality was the brain injury. Seventy-four patients (total n=192) died in a hospital, 2/192 in an ambulance and 116/192 died at the place of the incidence.

### Non-fatal incidents

Fifty-seven (22.89%) of the aforementioned patients (total n=249) were alive at the moment of examination. The vast majority of TBI involved blunt force trauma inflicted by blunt wounding agents (82.46%, 47/57), while in seven cases injuries occurred due to falls from height (12.28%) (**TABLES 2** & **3**).

### Concomitant findings and other site injuries

Among TBI incidents, concomitant findings were recorded and classified in categories, mainly showing the condition of the central nervous system (**TABLE 4**). Other findings involved traumatic pathology of the extremities, abdomen and thoracic cavity (**TABLE 5**).

### TBI characteristics

The present categorization includes TBI designation into open (penetrating) and closed head injuries, as well as according to the injury size (length of the skull injury), causation, and number of injuries in the area of the head (**TABLES 2** & **3**). 174 subjects of the study bore open (penetrating) head injuries, while 75 suffered closed traumatic head injuries. Among males, the prevalence of open head injuries was 69% (138/200; 79.31% of total open TBI), while open

**TABLE 2.** TBI-related findings: trauma characteristics and causation

| Year | Open/closed head injuries | | Size of injury (cm) | Causation | | | |
|---|---|---|---|---|---|---|---|
| | Open | Closed | | Transport accidents | Blunt force (by instrument) | Falls | Occupational accidents |
| 2007 | 15 | 11 | 3–20 | 18 | 3 | 2 | 1 |
| 2008 | 27 | 10 | 2–35 | 29 | 5 | 3 | - |
| 2009 | 15 | 6 | 0.5–9 | 18 | 2 | 1 | 1 |
| 2010 | 28 | 7 | 1–35 | 22 | 6 | 5 | 2 |
| 2011 | 19 | 9 | 3–10 | 15 | 8 | 5 | - |
| 2012 | 14 | 12 | 0.5–8 | 16 | 5 | 4 | 1 |
| 2013 | 7 | 1 | 4–7 | 4 | 3 | 1 | - |
| 2014 | 22 | 4 | 2–18 | 14 | 11 | 1 | 1 |
| 2015 | 15 | 11 | 0.5–10 | 14 | 5 | 5 | 2 |
| 2016 | 12 | 4 | 2–7 | 4 | 8 | 2 | 2 |
| Total | 174 (69.88) | 75 (30.12) | 0.5–35 | 154 (61.85) | 56 (22.49) | 29 (11.65) | 10 (4.02) |

Data are presented as number (%).
Open/Closed head injuries: the *Z*-Score is 3.28829. The *p*-value is 0.001. The result is significant at $p<0.05$. Causation: the chi-square statistic is 25.3364. The *p*-value is 0.013307. The result is significant at $p<0.05$.

**TABLE 3.** Mortality rates of TBI-related cases per causation

| Variables | Causation | | | |
|---|---|---|---|---|
| | Transport accidents (n=154) | Blunt force (by instrument) (n=56) | Falls (n=29) | Occupational accidents (n=10) |
| Mortality rate (total: 77.11%; 192/249) | 153 (99.35) | 9 (16.07) | 22 (75.86) | 8 (80) |
| Survival rate (total: 22.89%; 57/249) | 1 (0.65) | 47 (83.93) | 7 (24.14) | 2 (20) |

Data are presented as number (%).
Causation and mortality rate: the chi-square statistic is 161.4291. The *p*-value is <0.00001. The result is significant at $p<0.05$.

**TABLE 4.** Concomitant findings from the central nervous system (n=249)

| CNS findings | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | Total (n=249) | Fatalities (n=192) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Traumatic subarachnoid hemorrhage | 20 | 24 | 14 | 21 | 14 | 17 | 4 | 10 | - | 4 | 128 (51.41) | 119 (61.98) |
| Complete or severe spinal cord injury | 3 | 12 | 4 | 8 | 7 | 5 | - | 5 | 10 | 2 | 56 (22.49) | 47 (24.48) |
| Brain hematoma | 10 | 9 | 2 | 5 | 8 | 5 | 1 | 5 | 6 | 4 | 55 (22.09) | 49 (25.52) |
| Brain contusion | 12 | 10 | 3 | 4 | 2 | 3 | - | 1 | - | - | 35 (14.06) | 33 (17.19) |
| Ejection of brain tissue | - | 5 | 3 | 4 | 3 | - | 3 | 6 | 2 | 1 | 27 (10.84) | 27 (14.06) |
| Brain edema | 12 | 6 | 1 | 1 | 3 | - | - | 1 | - | - | 24 (9.64) | 23 (11.98) |
| Cerebellar hemorrhage | 2 | 5 | 4 | 4 | 4 | 1 | - | 3 | 1 | - | 24 (9.64) | 24 (12.50) |
| Intraventricular hemorrhage | 3 | 1 | - | 1 | - | 1 | - | - | 1 | - | 7 (2.81) | 7 (3.65) |
| Cerebral herniation | - | - | - | 1 | - | - | - | - | 1 | - | 2 (0.80) | 2 (1.04) |

Data are presented as number (%).
The *f*-ratio value is 7.28469. The *p*-value is 0.00013. The result is significant at $p<0.05$. Mortality rate not available, not statistically significant at $p<0.05$; (*p*-value: 0.853667).

**TABLE 5.** Concomitant traumatological findings accompanying traumatic brain injuries (n=249)

| Concomitant findings | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | Total (n=249) | Fatal (n=192) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Severe thoracic injury | 22 | 22 | 11 | 9 | 12 | 15 | 4 | 9 | 14 | 4 | 122 (49.00) | 122 (63.54) |
| Severe abdominal injury | 12 | 14 | 7 | 7 | 9 | 9 | 2 | 6 | 10 | 1 | 77 (30.92) | 77 (40.10) |
| Hemothorax | 8 | 20 | 6 | 10 | 4 | 6 | 3 | 6 | 6 | 2 | 71 (28.51) | 70 (36.46) |
| Thoracic cavity fractures | 12 | 13 | 6 | 6 | 4 | 7 | 2 | 6 | 12 | 1 | 69 (27.71) | 64 (33.33) |
| Extremity fractures | 2 | 13 | 6 | 4 | 3 | 6 | 1 | 4 | 5 | 3 | 47 (18.88) | 43 (22.40) |
| Liver laceration | 6 | 6 | 3 | 1 | 3 | 6 | 1 | 4 | 6 | 1 | 37 (14.86) | 37 (19.27) |
| Hemoperitoneum | 7 | 8 | - | 2 | 3 | 4 | 2 | 2 | 4 | - | 32 (12.85) | 32 (16.67) |
| Renal rupture | 1 | 5 | 2 | 2 | 1 | 2 | - | - | 2 | - | 15 (6.02) | 15 (7.81) |
| Spleen rupture | 4 | 2 | 2 | 1 | 3 | - | - | - | - | - | 12 (4.82) | 12 (6.25) |
| Heart rupture | 1 | 1 | 1 | 1 | 1 | - | - | - | 3 | 1 | 9 (3.61) | 9 (4.69) |
| Perirenal hematoma | 3 | 2 | - | - | - | 1 | - | 1 | 1 | - | 8 (3.21) | 7 (3.65) |
| Diaphragm rupture | 1 | 1 | - | - | - | - | - | - | - | - | 2 (0.80) | 2 (1.04) |

Data are presented as number (%).
The *f*-ratio value is 3.40426. The *p*-value is 0.016256. The result is significant at $p<0.05$. Mortality rate not available, not statistically significant at $p<0.05$; (*p*-value: 0.951548).

TBI were detected in 73.47% of the female subjects (36/49; 20.69% of total open TBI) (M:F, 1:1.06). In regard of closed traumatic brain injuries, the respective rate for males was 31% (62/200; 82.67% of total closed TBI) and females 26.53% (13/49; 17.33% of total closed TBI) (M:F, 1.17:1).

TBI size (open) was found variable (length of the injury), ranging from 0.5 cm to 35 cm (the latter after surgical incision), while the average (open) TBI size ranged between 3 and 7 cm. The size of the injury, measured in the current study is an observational finding. As it occurs in many of the cases, fracture of the skull does not mean necessarily mortality. The fatality of the current sample is caused by the brain injury itself.

In regard of the number of traumatic brain injuries recorded per subject, 79 of the examined individuals had a single traumatic injury, 26 subjects bore two traumatic brain injuries, while multiple TBI were detected in 144/249 of the research sample.

Among the TBI cases associated with transport accidents (n=154), 31 involved females and 123 males (M:F, 1:1.03). The incidence of TBI due to transport accidents according to the age is presented in **TABLES 6** & **7**. Interestingly, transport accidents were the leading cause of traumatic brain injuries throughout all age-groups as well as the leading cause of lethality due to TBI throughout all age groups (**TABLES 2**, **3**, **7**). 101 cases occurred in Evros prefecture

**TABLE 6.** Age group allocation of TBI-related cases classified by causality

| TBI-related cases | Age, yr | | |
|---|---|---|---|
| | Below 44 | 45–64 | Over 65 |
| Transport accidents* | 62.34% of transport accidents; 71.11% of age group; M:F, 1.08:1 in age group (total, 96; M, 80; F, 16) | 17.53% of transport accidents; 42.86% of age group; M:F, 1.16:1 in age group (total, 27; M, 24; F, 3) | 20.13% of transport accidents; 60.78% of age group; M:F, 1:1.26 in age group (total, 31; M, 19; F, 12) |
| Blunt force (by instrument)† | 51.79% of TBI cases by blunt wounding agent; 21.48% of age group; M:F, 1.35:1 in age group (total, 29; M, 25; F, 4) | 33.93% of TBI cases by blunt wounding agent; 30.16% of age group; M:F, 1:1.83 in age group (total, 19; M, 15; F, 4) | 14.29% of TBI cases by blunt wounding agent; 15.69% of age group; M:F, 1:1.2 in age group (total, 8; M, 5; F, 3) |
| Falls‡ | 27.59% of falls; 5.92% of age group; M:F, 1:4.63 in age group (total, 8; M, 4; F, 4) | 41.38% of falls; 19.05% of age group; M:F, 1.6:1 in age group (total, 12; M, 11; F, 1) | 31.03% of falls; 17.65% of age group; M:F, 1.75:1 in age group (total, 9; M, 7; F, 2) |
| Occupational accidents§ | 20% of occupational accidents; 1.48% of age group (total, 2; M, 2; F, 0) | 50% of occupational accidents; 7.94% of age group (total, 5; M, 5; F, 0) | 30% of occupational accidents; 5.88% of age group (total, 3; M, 3; F, 0) |
| Total‖ | Age group 0–44: 54.22% of TBI cases (total, 135; M, 111; F, 24; M:F, 4.63:1) | Age group 45–65: 25.30% of TBI cases (total, 63; M, 55; F, 8; M:F, 6.88:1) | Age group over 65: 20.48% of TBI cases (total, 51; M, 34; F, 17; M:F, 2:1) |

The chi-square statistic is 21.6601. The *p*-value is 0.001395. The result is significant at $p<0.05$.
TBI: traumatic brain injury, M: male, F: female.
*Transport accidents: n=154, M=123, F=31 (M:F, 4.09:1); †Blunt force (by instrument): n=56, M=45, F=11 (M:F, 4.09:1); ‡Falls: n=29, M=22, F=7 (M:F, 3.14:1); §Occupational accidents: n=10, M=10, F=0; ‖Total: n=249, M=200, F=49 (M:F, 4.08:1).

**TABLE 7.** Age group allocation of TBI-related fatalities classified by causality

| TBI-related fatalities | Age, yr | | |
|---|---|---|---|
| | Below 44 | 45–64 | Over 65 |
| Transport accidents* | 61.69% of transport accidents; 62.09% of fatal transport accidents; 87.16% of age group; M:F, 1.25:1 in age group (fatal, 95; M, 79; F, 16) (total, 96; M, 80; F, 16) | 17.53% of transport accidents; 17.65% of fatal transport accidents; 67.5% of age group; M:F, 1:1.12 in age group (fatal, 27; M, 24; F, 3) (total, 27; M, 24; F, 3) | 20.13% of transport accidents; 20.26% of fatal transport accidents; 72.09% of age group; M:F, 1:1.18 in age group (fatal, 31, M, 19; F, 12) (total, 31; M, 19; F, 12) |
| Blunt force (by instrument)† | 7.14% of TBI cases by blunt wounding agent; 44.44% of fatal TBI cases by blunt wounding agent; 3.67% of age group; M:F, 1:3.95 in age group (fatal, 4; M, 2; F, 2) (total, 29; M, 25; F, 4) | 3.57% of TBI cases by blunt wounding agent; 22.22% of fatal TBI cases by blunt wounding agent; 5% of age group (fatal, 2; M, 2; F, 0) (total, 19; M, 15; F, 4) | 5.36% of TBI cases by blunt wounding agent; 33.33% of fatal TBI cases by blunt wounding agent; 7% of age group; M:F, 1.07:1 in age group (fatal, 3; M, 2; F, 1) (total, 8; M, 5; F, 3) |
| Falls‡ | 27.59% of falls; 36.36% of fatal falls; 7.34% of age group; M:F, 1:3.95 in age group (fatal, 8; M, 4; F, 4) (total, 8; M, 4; F, 4) | 24.14% of falls; 31.82% of fatal falls; 17.5% of age group; M:F, 1:1.50 in age group (fatal, 7; M, 6; F, 1) (total, 12; M, 11; F, 1) | 24.14% of falls; 31.82% of fatal falls; 16.28% of age group; M:F, 1.34:1 in age group (fatal, 7; M, 5; F, 2) (total, 9; M, 7; F, 2) |
| Occupational accidents§ | 20% of occupational accidents; 25% of fatal occupational accidents; 1.83% of age group (fatal, 2; M, 2; F, 0) (total, 2; M, 2; F, 0) | 40% of occupational accidents; 50% of fatal occupational accidents; 10% of age group (fatal, 4; M, 4; F, 0) (total, 5; M, 5; F, 0) | 20% of occupational accidents; 25% of fatal occupational accidents; 4.65% of age group (fatal, 2; M, 2; F, 0) (total, 3; M, 3; F, 0) |
| Total‖ | Age group 0–44: 56.77% of fatal TBI cases; 109 fatalities (M, 87; F, 22) (M:F, 3.95:1) | Age group 45–65: 20.83% of fatal TBI cases; 40 fatalities (M, 36; F, 4) (M:F, 9:1) | Age group over 65: 20.48% of fatal TBI cases; 43 fatalities (M, 28; F, 15) (M:F, 1.87:1) |

The chi-square statistic is 11.0232. The *p*-value is 0.087661. The result is significant at $p<0.10$.
TBI: traumatic brain injury, M: male, F: female.
*Transport accidents: n=153, M=122, F=31 (M:F, 3.94:1); †Blunt force (by instrument): n=9, M=6, F=3 (M:F, 2:1); ‡Falls: n=22, M=15, F=7 (M:F, 2.14:1); §Occupational accidents: n=8, M=8, F=0; ‖Total: n=192, M=151, F=41 (M:F, 3.68:1).

(65.58%), 23 in Rhodope (14.94%), 14 in Xanthi (9.09%), 13 in Kavala (8.44%), and 3 in Drama (1.95%).

Blunt force TBI cases due to impact with blunt wounding agents were observed in 45 males and 11 female subjects (M:F, 1:1) (**TABLES 2, 3, 6, 7**). 83.93% of the subjects survived injury throughout this category (mortality 16.07%). These incidents were also most commonly located in Evros (67.86%, 38/56), followed by Rhodope (30.36%, 17/56), and Xanthi (1.79%, 1/56).

TBI cases induced by falls from height accounted for 11.65% of the cases, among which 22 incidents involved males and seven involved female subjects (M:F, 1:1.30) (**TABLES 6** & **7**).


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75.86% mortality was recorded among these cases in general, while the highest statistical probability for fatality was recorded below the 44th year of age. Furthermore, 19 of the incidents happened within Evros prefecture (65.52%), 6 in Rhodope (20.69%), 3 in Xanthi (10.34%), and 1 in Kavala (3.45%).

Ten of the investigated TBI incidents were the outcome of occupational accidents, among which all involved male subjects (**TABLES 2**, **3**, **6**). The majority of these incidents also occurred in Evros prefecture (80%, 8/10) followed by Xanthi (10%, 1/10), and Rhodope (10%, 1/10).

### Anatomical localization

The guidelines categorize TBI into mild, moderate and severe. In the present paper, however, the authors opted to classify traumatic brain injuries according to their localization on the area of the skull. The total number of 443 skull fractures was recorded in the context of the present study. Due to mechanical reasons, numerous traumatic head injuries were associated with comminuted fractures involving multiple fracture lines. Among the latter, it was observed that the most common region traumatized on the skull was the cranial base (16.48%), followed by the frontal (12.87%), occipital (11.29%) and parietal bones (11.06%) (**TABLE 8**).

Interestingly, males–compared to females–followed different trends in regard of the anatomical localization rates (**TABLE 8**).

**TABLE 8.** Anatomical localization of skull fractures (n=443)

| Anatomical localization of TBI | Total number of injuries per localization | M | F | M:F |
|---|---|---|---|---|
| Skull base | 73 (16.48) | 63 (17.50) | 10 (12.05) | 1.45:1 |
| Frontal bone | 57 (12.87) | 43 (11.94) | 14 (16.87) | 1:1.41 |
| Occipital bone | 50 (11.29) | 35 (9.72) | 15 (18.07) | 1:1.86 |
| Parietal bone | 49 (11.06) | 39 (10.83) | 10 (12.05) | 1:1.11 |
| Facial bones | 47 (10.61) | 43 (11.94) | 4 (4.82) | 2.48:1 |
| Temporal bone | 36 (8.13) | 30 (8.33) | 6 (7.23) | 1.15:1 |
| Parieto-occipital | 23 (5.19) | 22 (6.11) | 1 (1.20) | 5.09:1 |
| Calvaria (comminuted fractures in multiple areas of the frontal, parietal, and occipital bones) | 20 (4.51) | 19 (5.28) | 1 (1.20) | 4.40:1 |
| Parieto-temporal | 20 (4.51) | 14 (3.89) | 6 (7.23) | 1:1.86 |
| Anterior cranial fossa | 10 (2.26) | 5 (1.39) | 5 (6.02) | 1:4.33 |
| Comminuted fractures in multiple areas of the skull (frontal, parietal, occipital, and temporal) | 8 (1.81) | 5 (1.39) | 3 (3.61) | 1:2.60 |
| Medial cranial fossa | 5 (1.13) | 4 (1.11) | 1 (1.20) | 1:1.08 |
| Frontoparietal | 5 (1.13) | 4 (1.11) | 1 (1.20) | 1:1.08 |
| Frontotemporal | 4 (0.90) | 4 (1.11) | 0 (0.00) | |
| Sphenoid Bone | 4 (0.90) | 2 (0.56) | 2 (2.41) | 1:4.30 |
| Temporo-occipital | 2 (0.45) | 2 (0.56) | 0 (0.00) | |
| Pterion | 2 (0.45) | 1 (0.28) | 1 (1.20) | 1:4.29 |
| Asterion | 1 (0.23) | 1 (0.28) | 0 (0.00) | |
| Petrous part of temporal bone | 1 (0.23) | 1 (0.28) | 0 (0.00) | |
| Mastoid process | 1 (0.23) | 0 (0.00) | 1 (1.20) | |
| Transverse sinus | 1 (0.23) | 1 (0.28) | 0 (0.00) | |
| Total | 443 | 360 | 83 | 4.34:1 |

Data are presented as number (%).
Clarification: fractures localized at a specific area (or bone) of the skull are listed exactly in the area that they were detected. The following results are written in a descending order. The *Z*-Score is 2.49764. The *p*-value is 0.01242. The result is significant at $p<0.05$.
TBI: traumatic brain injury, M: male, F: female.


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## DISCUSSION

TBI is a complex injury presenting with a wide variety of symptoms and a critical public health problem that often has a detrimental impact on the well-being of the patients and their families, as it leads to severe impairment or even a fatal outcome. In accordance with the most recent European epidemiological meta-analysis, TBI incidence culminates among age groups below the third decade and over the seventh decade of life.[18)] The mean age of the patients, however, varies strongly among studies throughout relevant literature (22–49 years), which has been attributed to different inclusion criteria.[3,15,18,20)] A study conducted by Mauritz et al.[15)] (n=1,172) indicated a mean age of 49 years among the overall amount of recorded patients. A multicenter study by Andriessen et al.[3)] (n=508) also suggested an average age of 48 years. Song et al.[20)] detected a higher TBI incidence among individuals older than 61 years of age (n=2,617). Furthermore, a male predominance was observed among TBI-related incidents of different studies, while a higher average age was disclosed among female subjects in comparison to males.[3,15,18)]

The outcome deriving from the present study disclosed comparable statistical results to the aforementioned worldwide references. Furthermore, a lower mean age was disclosed among male subjects in relation to females, which was in concordance with the results of the antecedent research studies.

The study conducted by Song et al.[20)] indicated that 52.6% of the TBI patients suffered from epidural/subdural hematoma, while 14.4% presented with subarachnoid hemorrhage (n=2,617). In addition, Mattioli et al. reported 61% incidence of traumatic subarachnoid hemorrhage among intensive-care unit admissions for severe TBI incidents (n=169), while Deepika and his colleagues reported 2.9% incidence for traumatic subarachnoid hemorrhage among mild TBI cases (n=1,149).[10,14)] Subarachnoid hemorrhage was associated with higher mortality rates.[17)]

The incidence of acute traumatic epidural hematoma (EH) among TBI-related incidents was estimated at 1% by Greenberg.[12)] Chen et al.[8)], however, reported that EH was present in 9.2% of their research sample, mainly among young individuals (n=412). Furthermore, Ndoumbe et al.[16)] reported an association of EH with skull fractures, especially in the calvaria, in 73.91% of the cases (n=46), and with brain contusions in 23.91% of the TBI-related sample. In addition, in the research study of Song et al.[20)], among the total number of 125 fatal TBI incidents, 80.8% died due to direct traumatic brain damage, while 3.2% presented with other site injury (except for brain trauma).

From the aforementioned studies, it can be assumed that acute traumatic EH and subdural hemorrhage are concomitant symptoms strongly accompanying traumatic brain injuries.[2,3,8,10,12,14-18,20,21)] The latter is also depicted in the results of the present study, as throughout the 10-year study sample, a sufficient number of TBI-related incidents was recorded associated with acute traumatic brain hematoma (22.09%) and an even bigger number of subarachnoid hemorrhage incidents (51.41%). Furthermore, the results of the present study also ascertain the fact that subarachnoid hemorrhage is linked to higher mortality (61.98% among TBI fatalities), as observed in the status of the included patients. The exact mortality rate for each symptom however cannot be estimated concretely through the present study, as the consistency of the research sample involves high level of bodily harm severity.


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According to Schaller et al.[19], the concomitant injuries that can occur in association to TBI among children and adolescents are lung contusions (18.4%), upper extremity fractures (24.5%), and facial fractures (42.9%). Ferreira et al.[11] reported the frequency of extremity fractures (16.8%), abdominal injuries (1.97%), thoracic injuries (5.04%) and cervical spine fractures (0.99%) (n=912). Due to the research sample and methodology of the present paper studying both autopsy and nonfatal TBI cases, the authors have recorded slightly different values regarding the additional injury sites in comparison to the ones already mentioned. The authors observed a prevalence of severe thoracic injury including lung contusions and lacerations in 49.00% of the study sample. A high incidence of the latter was also noted among fatal TBI incidents (63.54%). The incidence of acute traumatic hemothorax was recorded at 28.51%, while severe abdominal injury was noted in 30.92% of the subjects. In regard of extracalvarial bone fractures, thoracic fractures were the most frequent (27.71%), followed by spine fractures and spine traumatic dissection (22.49%), extremity fractures (18.88%), and facial fractures (10.61%).

Regarding anatomical localization, Marinheiro et al.[13] reported that frontal bone fractures, often accompanied by hematoma and brain edema, occur principally due to transport accidents (especially motorcycle crashes). Furthermore, Asha'Ari et al.[5] reported temporal bone fractures in 5.57% of the examined TBI cases (n=1,579), while 60.49% were associated with intracranial injury–among which 64.20% concerned temporal, 7.41% temporoparietal, 9.88% temporofrontal and 3.70% temporo-occipital skull fractures. Another study by Archer et al.[4] reported that anterior skull base fractures were also observed mainly in transport accidents and were accompanied by periorbital edema, ecchymosis, epistaxis, otorrhea, rinorrhea, subdural/subarachnoid hemorrhage, EH and herniation (n=43). In 30% of the cases, concomitant temporal fractures were present. Regarding pediatric TBI-related incidents, the temporal bone was revealed to be the most common area of fraction, followed by the occipital bone, the sphenoid bone, the petrous part of the temporal bone and the ethmoid bone.[1] The main additional findings were concomitant brain herniation, brain contusions, cerebral edema and subarachnoid hemorrhage. Furthermore, the mortality rate among the patients of the aforementioned sample was recorded to be higher in comparison to those without skull fractures. Regarding the fractures of facial bones in children, Ferreira et al. reported that in their study the mandibular bone presented with the highest frequency of fraction, followed by the zygomatic and alveolar bones.[11]

Compared to the latter, the present study concluded that the most common localization of skull fractures among TBI incidents was the skull base (16.48%), followed by the frontal (12.87%), occipital (11.29%), parietal (11.06%), facial (10.61%), and temporal bones (8.13%), while there was a high prevalence of transport accidents (61.85%) in the consistency of the research sample in comparison to falls from height (11.65%).

In regard of TBI causation, international research studies support that the principal cause of traumatic brain injuries lies in transport accidents, while patients suffering from traumatic brain injuries due to accidents with transportation vehicles are associated with a higher risk of mortality.[8,15,17,18] In relation to the latter, a significant prevalence (61.85%) of transport accidents was depicted among TBI-related incidents throughout the results of the present study, while transport accidents also stood for the leading cause of death among the aforestated cases.

Among older age groups, however, the rates tend to differentiate. Thompson et al.[21] found that the majority of TBI-related incidents among adults aged over 65 years are due to falls. The latter is also supported in the cohort study by Andelic et al.[2], which indicated that


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the incidence of falls as a TBI causation rises after the 45th year of age, while the highest prevalence of transport accidents is observed particularly in the first four decades of life. TBI mortality has been estimated at approximately 60% among elderly patients.[2,21)]

International data are comparable to the present investigation, which however indicated transport accidents as the principal causative factor for TBI-related cases among all age-groups with respect to the particular research sample. The results of the present study disclosed a slight increase in the incidence of TBI cases related to transport accidents after the 65th year of age, explained by the fact that the majority of the population in the region of East Macedonia and Thrace is aged and there is an increased need of self-care and self-service. The population in this region consists of different ethnical and religion subgroups, not equally educated, which could explain the high prevalence of TBIs.

Limitation here represents the fact that in the current study were included only reports from the department of forensic science and toxicology, thus lacking information about the clinical status, scores and findings, which makes difficult the additional evaluation of the TBIs, including mortality and morbidity. On the other hand, exactly this type of report provides information that was not available before, showing that indeed the anatomical localization plays a significant role, regarding the mortality, while therapeutical approach in brain trauma patients is statistically significant factor of survival.

## CONCLUSION

Deaths in East Macedonia due to TBI are a major cause of death and a public health problem. In order to minimize this problem, a restriction of the two major causes of TBIs, transportation and work-related accidents, is imperative. This can be possible with more strict enforcement of roadside rules in Evros, as part of a strategic plan of Greece, as also with more public awareness of workplace conditions. Both measures demand good background knowledge of the citizens, and to do so Greece needs to secure funding for education.

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