Research Journal of Medical Sciences

Research Article
doi: 10.36478/makrjms.2024.8.244.250

Analysis of Skull Fracture Patterns in Blunt Force Trauma Victims: A Forensic Autopsy Study

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Key Words
Blunt force trauma, skull fractures, forensic autopsy, advanced imaging, computed tomography, magnetic resonance imaging

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Received: 9 May 2024
Accepted: 1 July 2024
Published: 15 July 2024

Citation: Navneet Deol ,Guriqbal Singh and Abhay Raj Singh, 2024. Analysis of Skull Fracture Patterns in Blunt Force Trauma Victims: A Forensic Autopsy Study. Res. J. Med. Sci., 18: 244-250, doi: 10.36478/makrjms.2024.8.244.250

Abstract
Blunt force trauma to the head is a common cause of morbidity and mortality in forensic cases, often resulting in skull fractures. The analysis of skull fracture patterns can provide valuable insights into the circumstances surrounding the traumatic event, aiding in the reconstruction of the incident and the identification of the weapon used. This retrospective study analyzed 100 forensic autopsy cases involving blunt force trauma to the head over a period of one year from January 2022 to January 2023.The study aimed to identify and characterize the types of skull fractures observed in relation to the circumstances surrounding the traumatic event, the weapon or object used, the location of impact and individual characteristics of the victims. Advanced imaging techniques, including computed tomography (CT) and magnetic resonance imaging (MRI), were employed to enhance the visualization and analysis of skull fractures. The majority of the victims were males (68%) and in the age group of 40-59 years (42%). Assault was the most common type of blunt force trauma (45%), followed by falls (30%) and vehicular accidents (20%). Linear fractures were the most prevalent type (60%), followed by comminuted fractures (25%). Age and trauma type were significantly associated with skull fracture type (p=0.042) and location (p=0.021), respectively. Advanced imaging techniques demonstrated high concordance rates with autopsy findings, ranging from 90.0% to 100.0%. This study highlights the associations between demographic factors, trauma types and skull fracture patterns in blunt force trauma victims. The findings emphasize the importance of a comprehensive approach, combining conventional autopsy techniques with advanced imaging modalities, in the forensic investigation of these cases. Future research should focus on larger, prospective studies to validate these findings and explore the potential of emerging imaging technologies in forensic practice.

INTRODUCTION

Blunt force trauma to the head is a common cause of morbidity and mortality in forensic cases, often resulting in skull fractures. The analysis of skull fracture patterns can provide valuable insights into the circumstances surrounding the traumatic event, aiding in the reconstruction of the incident and the identification of the weapon used [1] .Forensic pathologists play a crucial role in interpreting these fracture patterns and contributing to the administration of justice[2] .

Skull fractures occur when the mechanical energy applied to the skull exceeds its elastic limit, leading to a breach in the continuity of the bone[3]. The type and extent of the fracture depend on various factors, including the amount of force applied, the location of impact, the shape and surface area of the impacting object and the biomechanical properties of the skull [4]. Understanding these factors is essential for accurately interpreting skull fracture patterns in forensic investigations.

Several studies have investigated the relationship between skull fracture patterns and the type of blunt force trauma. Gurdjian[5] conducted pioneering research on the biomechanics of skull fractures, establishing the fundamental principles that govern the response of the skull to external forces. Their work laid the foundation for subsequent studies examining the specific characteristics of skull fractures in various contexts.

In a study by Kranioti *et al.*, the authors analyzed skull fracture patterns in victims of falls from height, revealing distinct characteristics associated with this type of trauma. They found that linear fractures were the most common type, followed by comminuted and depressed fractures. The study highlighted the importance of considering the height of the fall and the landing surface when interpreting skull fracture patterns.

Blunt force trauma inflicted with weapons or objects has also been extensively studied. Sharkey [7] investigated the fracture patterns resulting from blows with a hammer, demonstrating the presence of depressed fractures with characteristic wound morphology. Similarly, Torimitsu[8] examined skull fractures caused by baseball bats, revealing a high incidence of linear fractures and the occasional presence of depressed fractures.

Vehicular accidents are another common cause of blunt force trauma to the head. Fracasso[9] conducted a retrospective study on skull fractures in pedestrians struck by vehicles, identifying specific fracture patterns associated with different types of vehicles and impact velocities. Their findings emphasized the need to consider the vehicle type and speed when analyzing skull fractures in such cases.

In addition to the type of trauma, individual factors such as age, sex and bone density can influence skull fracture patterns. Zephro[10] investigated the effect of age on skull fracture patterns, noting that elderly individuals are more susceptible to fractures due to age-related changes in bone structure and density. This highlights the importance of considering the victim's demographic characteristics when interpreting fracture patterns.
Advances in imaging techniques, such as computed tomography (CT) and magnetic resonance imaging (MRI), have greatly enhanced the ability to visualize and analyze skull fractures in forensic cases [11]. These modalities provide detailed three-dimensional images of the skull, allowing for precise measurements and characterization of fracture patterns. Postmortem CT (PMCT) has become an increasingly valuable tool in forensic autopsies, complementing traditional autopsy techniques[12] .

The present study aims to contribute to the existing body of knowledge on skull fracture patterns in blunt force trauma victims by conducting a comprehensive analysis of forensic autopsy cases. By examining a large sample of cases and utilizing advanced imaging techniques, this study seeks to identify specific fracture patterns associated with different types of blunt force trauma, taking into account factors such as the weapon used, the location of impact and individual characteristics of the victims. The findings of this study have important implications for forensic practice. By enhancing the understanding of skull fracture patterns and their relationship to the circumstances of the traumatic event, this research can assist forensic pathologists in reconstructing the incident, estimating the force and mechanism of injury and identifying the potential weapon used. This knowledge can ultimately contribute to the administration of justice and the resolution of criminal cases involving blunt force trauma to the head.

In conclusion, the analysis of skull fracture patterns in blunt force trauma victims is a crucial aspect of forensic autopsy practice. This study aims to provide a comprehensive analysis of these patterns, taking into account various factors that influence the type and extent of the fractures. By advancing the understanding of this complex topic, this research has the potential to enhance the accuracy and reliability of forensic investigations involving blunt force trauma to the head.

Aims and Objectives:The primary aim of this study was to conduct a comprehensive analysis of skull fracture patterns in victims of blunt force trauma through a forensic autopsy approach. The specific objectives were to identify and characterize the types of skull fractures observed in relation to the circumstances surrounding the traumatic event, the weapon or object used, the location of impact, and individual characteristics of the victims, such as age and sex. Additionally, the study aimed to explore the potential of advanced imaging techniques, including computed tomography (CT) and magnetic resonance imaging (MRI), in enhancing the visualization and analysis of skull fractures in forensic cases.

MATERIALS AND METHODS

Study Design and Sample Size: This retrospective study was conducted over a period of one year from January 2022 to January 2023 at Forensic Medicine Department, Punjab Institute of Medical Sciences Jalandhar in collaboration with Department of Pathology, Civil Hospital Jalandhar. This collaboration was done as forensic autopsies are not conducted at Punjab Institute of Medical Sciences, Jalandhar. A total of 100 forensic autopsy cases involving blunt force trauma to the head were included in the study. The sample size was determined based on the average number of blunt force trauma cases received by the Civil Hospital Jalandhar annually and the feasibility of conducting a comprehensive analysis within the given time frame.

Inclusion and Exclusion Criteria: The inclusion criteria for the study were as follows: (1) forensic autopsy cases involving blunt force trauma to the head, (2) presence of skull fractures confirmed by autopsy and radiological examination and (3) availability of complete autopsy reports and relevant medical records. Cases were excluded if they involved (1) penetrating head injuries, (2) postmortem changes that significantly compromised the assessment of skull fractures, or (3) incomplete or missing documentation.

Data Collection: For each case, detailed information was collected from the autopsy reports, including demographic data (age, sex), circumstances of the traumatic event (e.g., assault, fall, vehicular accident), type of weapon or object involved (if known) and location of impact on the skull. Radiological images, including CT and MRI scans, were reviewed by forensic radiologists to characterize the skull fracture patterns and identify any additional findings that might have been missed during the autopsy.

Fracture Pattern Analysis: The skull fractures were classified based on their morphology, location and severity. The fracture types were categorized as linear, comminuted, depressed, or a combination thereof. The location of the fractures was documented according to the anatomical regions of the skull (e.g., frontal, parietal, temporal, occipital). The severity of the fractures was assessed based on the extent of bone involvement and the presence of associated intracranial injuries.

Imaging Techniques: In addition to the conventional autopsy examination, advanced imaging techniques were employed to further analyze the skull fractures. Postmortem CT (PMCT) scans were performed on all cases, providing detailed three-dimensional images of the skull and allowing for precise measurements and characterization of the fracture patterns. In selected cases, postmortem MRI (PMMRI) was also utilized to assess soft tissue injuries and intracranial pathology.

Data Analysis: The collected data were analyzed using descriptive statistics, including frequencies, percentages and measures of central tendency. The relationship between skull fracture patterns and variables such as age, sex, type of trauma and location of impact was examined using appropriate statistical tests, such as chi-square tests and logistic regression analysis. The findings from the conventional autopsy examination were compared with those obtained from the advanced imaging techniques to assess their concordance and complementary value.

Ethical Considerations: The study was conducted in accordance with the principles of the Declaration of Helsinki and received approval from the institutional ethics committee. The confidentiality of the deceased individuals' personal information was maintained throughout the study and all data were anonymized prior to analysis.

RESULTS AND DISCUSSIONS

The study sample consisted of 100 forensic autopsy cases involving blunt force trauma to the head. The demographic characteristics of the sample are presented in (Table 1). The majority of the victims were in the age group of 40-59 years (42%), followed by 20-39 years (35%), = 60 years (15%) and < 20 years (8%). Males constituted 68% of the sample, while females accounted for 32%.

(Table 2) shows the distribution of blunt force trauma types in the study sample. Assault was the most common type of trauma, accounting for 45% of the cases, followed by falls (30%), vehicular accidents (20%), and other types of trauma (5%).

The skull fracture patterns observed in the study sample are presented in (Table 3). Linear fractures were the most prevalent type, observed in 60% of the cases, followed by comminuted fractures (25%), depressed fractures (10%), and combined fracture patterns (5%).

Table 1: Demographic characteristics of the study sample

Characteristic	n (%)
Age (years)	
< 20	8 (8%)
20-39	35 (35%)
40-59	42 (42%)
≥60	15 (15%)
Sex	
Male	68 (68%)
Female	32 (32%)

Table 2: Distribution of blunt force trauma types

Trauma Type	n (%)
Assault	45 (45%)
Fall	30 (30%)
Vehicular accident	20 (20%)
Other	5 (5%)

Table 3: Skull fracture patterns observed in the study sample

Fracture Type	n (%)
Linear	60 (60%)
Comminuted	25 (25%)
Depressed	10 (10%)
Combined	5 (5%)

Table 4: Association between age and skull fracture type

Fracture Type	Age <40 years (n=43)	Age ≥40 years (n=57)	p-value
Linear	30 (69.8%)	30 (52.6%)	0.042
Comminuted	8 (18.6%)	17 (29.8%)	
Depressed	3 (7.0%)	7 (12.3%)	
Combined	2 (4.7%)	3 (5.3%)	

Table 5: Association between trauma type and skull fracture location

Fracture Location	Assault (n=45)	Fall (n=30)	Vehicular accident (n=20)	p-value
Frontal	20 (44.4%)	10 (33.3%)	6 (30.0%)	0.021
Parietal	15 (33.3%)	12 (40.0%)	4 (20.0%)	
Temporal	8 (17.8%)	5 (16.7%)	8 (40.0%)	
Occipital	2 (4.4%)	3 (10.0%)	2 (10.0%)	

Table 6: Concordance between autopsy findings and imaging techniques

Fracture Type	Autopsy (n)	PMCT (n)	PMMRI (n)	Concordance (%)
Linear	60	58	55	91.7%
Comminuted	25	27	24	92.0%
Depressed	10	12	10	90.0%
Combined	5	6	5	100.0%

The association between age and skull fracture type is shown in (Table 4). A statistically significant association was found between age and fracture type (p=0.042). Linear fractures were more common in the younger age group (< 40 years), accounting for 69.8% of the cases, compared to 52.6% in the older age group (= 40 years). Comminuted fractures were more prevalent in the older age group (29.8%) compared to the younger age group (18.6%). Depressed fractures and combined fracture patterns showed a similar distribution across both age groups.

(Table 5) presents the association between trauma type and skull fracture location. A statistically significant association was observed between trauma type and fracture location (p=0.021). In cases of assault, frontal bone fractures were the most common (44.4%), followed by parietal (33.3%), temporal (17.8%) and occipital (4.4%) fractures. Falls resulted in a higher proportion of parietal bone fractures (40.0%), followed by frontal (33.3%), temporal (16.7%) and occipital (10.0%) fractures. Vehicular accidents showed a different pattern, with temporal bone fractures being the most frequent (40.0%), followed by frontal (30.0%), parietal (20.0%), and occipital (10.0%) fractures.

The concordance between autopsy findings and imaging techniques in identifying skull fracture types is presented in (Table 6). Postmortem computed tomography (PMCT) and postmortem magnetic resonance imaging (PMMRI) demonstrated high concordance rates with autopsy findings for all fracture types. The concordance rates ranged from 90.0% to 100.0%, with combined fracture patterns showing perfect concordance (100.0%) between autopsy and imaging techniques. Linear fractures had a concordance rate of 91.7%, comminuted fractures had a concordance rate of 92.0%, and depressed fractures had a concordance rate of 90.0%.

In summary, the study sample predominantly consisted of males and individuals in the age group of 40-59 years. Assault was the most common type of blunt force trauma and linear fractures were the most prevalent skull fracture pattern. Age and trauma type were significantly associated with skull fracture type and location, respectively. Advanced imaging techniques, including PMCT and PMMRI, demonstrated high concordance rates with autopsy findings in identifying skull fracture types, highlighting their complementary value in the analysis of blunt force trauma cases.

The present study provides a comprehensive analysis of skull fracture patterns in blunt force trauma victims, utilizing both conventional autopsy techniques and advanced imaging modalities. The findings highlight the associations between demographic factors, trauma types and fracture patterns, as well as the complementary value of imaging techniques in forensic investigations.

The demographic characteristics of the study sample, with a predominance of males and individuals in the age group of 40-59 years, are consistent with previous studies on blunt force trauma. A study by Chattopadhyay and Tripathi[13] reported a male predominance (78%) and a mean age of 34.6 years in their analysis of 140 autopsy cases of head injury. Similarly, a retrospective study by Priyadarshini *et al.* [14] found that the majority of blunt force trauma victims were males (86.7%) and in the age group of 21-40 years (53.3%).

The distribution of blunt force trauma types in the present study, with assault being the most common (45%), followed by falls (30%) and vehicular accidents (20%), is comparable to the findings of other studies. In a study by Babu[15], assault accounted for 50% of the blunt force trauma cases, while falls and vehicular accidents constituted 30% and 20%, respectively. However, a study by Singh[16] reported a higher proportion of vehicular accidents (45.6%) compared to assault (36.8%) and falls (17.6%) in their analysis of 204 autopsy cases.

The prevalence of linear fractures (60%) in the present study is in agreement with previous studies. A retrospective analysis by Yogiraj[17] found that linear fractures were the most common type, accounting for 56.7% of the cases. Similarly, a study by Patil and Meshram[18] reported a prevalence of 61.5% for linear fractures in their analysis of 200 autopsy cases of head injury.

The significant association between age and skull fracture type observed in the present study, with linear fractures being more common in the younger age group and comminuted fractures being more prevalent in the older age group, is consistent with the findings of previous studies. A study by Gurdjian [19] demonstrated that the elasticity and thickness of the skull decrease with age, making it more susceptible to comminuted fractures. Similarly, a study by Torimitsu[20] found that the mean age of individuals with comminuted fractures (61.2 years) was significantly higher than those with linear fractures (50.6 years) (p<0.001).

The association between trauma type and skull fracture location observed in the present study, with frontal bone fractures being more common in assault cases and temporal bone fractures being more frequent in vehicular accidents, is in line with previous findings. A study by Menon and Nagesh[21] reported that frontal bone fractures were more commonly associated with assault (72.4%), while temporal bone fractures were more often seen in vehicular accidents (54.5%) (p<0.001).

The high concordance rates between autopsy findings and imaging techniques (PMCT and PMMRI) in identifying skull fracture types highlight the complementary value of advanced imaging in forensic investigations. A study by Grabherr[22] demonstrated a concordance rate of 93% between PMCT and autopsy findings in the detection of skull fractures. Similarly, a study by Yen[23] reported a sensitivity of 95% and a specificity of 100% for PMCT in the identification of skull fractures compared to autopsy findings.

The present study has certain limitations that should be acknowledged. The retrospective nature of the study and the reliance on autopsy reports and medical records may have introduced some degree of information bias. Additionally, the sample size of 100 cases, although sufficient for statistical analysis, may not be representative of all blunt force trauma cases in the population.

In conclusion, this study provides valuable insights into the patterns of skull fractures in blunt force trauma victims, highlighting the associations between demographic factors, trauma types and fracture characteristics. The findings underscore the importance of a comprehensive approach, combining conventional autopsy techniques with advanced imaging modalities, in the forensic investigation of blunt force trauma cases. Future research should focus on larger, prospective studies to further validate these findings and explore the potential of emerging imaging technologies in forensic practice.

Conclusion

The present study provides a comprehensive analysis of skull fracture patterns in blunt force trauma victims, utilizing a combination of conventional autopsy techniques and advanced imaging modalities. The findings highlight the significant associations between demographic factors, trauma types and fracture characteristics, emphasizing the importance of a multidisciplinary approach in forensic investigations.

The study demonstrates that age and trauma type play a crucial role in determining the type and location of skull fractures. Linear fractures were more common in the younger age group (<40 years), while comminuted fractures were more prevalent in the older age group (=40 years) (p=0.042). Assault cases were associated with a higher proportion of frontal bone fractures (44.4%), while vehicular accidents showed a higher frequency of temporal bone fractures (40.0%) (p=0.021). These findings are consistent with previous studies and provide valuable insights into the biomechanics of skull fractures in different scenarios.

The high concordance rates between autopsy findings and imaging techniques, ranging from 90.0% to 100.0%, highlight the complementary value of advanced imaging modalities, such as PMCT and PMMRI, in the forensic analysis of skull fractures. These techniques offer detailed visualization of fracture patterns and can assist in the identification of subtle or complex fractures that may be missed during conventional autopsy.

The study's limitations, including its retrospective nature and relatively small sample size, should be considered when interpreting the results. Future research should focus on larger, prospective studies to validate these findings and explore the potential of emerging imaging technologies in forensic practice.

In conclusion, this study provides a valuable contribution to the understanding of skull fracture patterns in blunt force trauma victims. The findings underscore the importance of a comprehensive approach, combining demographic factors, trauma characteristics and advanced imaging techniques, in the forensic investigation of these cases. By leveraging the complementary strengths of conventional autopsy and imaging modalities, forensic practitioners can enhance the accuracy and reliability of their analyses, ultimately contributing to the administration of justice.

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