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THE ROLE OF COMPUTED TOMOGRAPHY IN THE EVALUATION OF TRAUMATIC BRAIN INJURY: A CROSS-SECTIONAL STUDY

Original Research

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ABSTRACT

Background: Traumatic brain injury (TBI) represents a disruption of normal brain function caused by sudden physical impact, leading to significant global morbidity and mortality. It contributes substantially to long-term disability, cognitive decline, and socioeconomic burden, particularly in low- and middle-income countries. Computed tomography (CT) remains the primary imaging modality for early detection, classification, and management planning of intracranial injuries.

Objective: To evaluate the diagnostic role of CT scan in assessing the pattern and severity of traumatic brain injury in patients presenting to tertiary care hospitals in Peshawar.

Methods: A descriptive cross-sectional study was conducted from February to July 2023 in two tertiary care hospitals in Peshawar. A total of 350 patients of both genders and all age groups presenting with head trauma were included through convenience sampling. The severity of TBI was determined using the Glasgow Coma Scale (GCS), and CT scans were performed to identify and categorize hematomas. Patients with a history of cerebrovascular disease, anticoagulant use, hypertension, or bleeding disorders were excluded. Data were analyzed using SPSS version 26, with frequencies, percentages, and chi-square tests applied where appropriate ($p<0.05$ considered significant).

Results: Out of 350 patients, males constituted 73% (n=257) and females 27% (n=93). The most affected age group was 11–20 years (26.6%), followed by 21–30 years (22.9%). Road traffic accidents were the leading cause of TBI (54%), followed by falls (38%) and other causes (8%). Mild TBI was most common (59.7%), followed by moderate (24.0%) and severe (16.3%). Subdural hematoma was the most frequent CT finding (36%), followed by epidural (33%), intracerebral (20%), and subarachnoid hematomas (11%).

Conclusion: Traumatic brain injury was predominantly observed in young males, mainly due to road traffic accidents, with mild TBI and subdural hematoma being the most prevalent. Strengthening road safety regulations, improving public awareness, and ensuring timely CT evaluation are essential for reducing TBI-related morbidity and mortality.

Keywords: Brain Injuries, Traumatic; Computed Tomography; Epidemiology; Glasgow Coma Scale; Hematoma, Subdural; Pakistan; Road Traffic Accidents.

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INTRODUCTION

Traumatic brain injury (TBI) represents a disruption of normal brain function caused by sudden, excessive, or abnormal physical force to the head (1). It is one of the most significant public health challenges globally, with a disproportionately high burden in low- and middle-income countries (LMICs). TBIs often lead to mortality, long-term neurological impairment, and lasting cognitive or behavioral deficits that considerably reduce quality of life (2). Understanding the underlying mechanisms, clinical presentation, and diagnostic approaches is therefore essential for effective management in emergency and neurosurgical settings. TBI is generally classified into three main types—closed head injury, open head injury, and explosive blast injury—each differing in pathophysiological mechanisms and clinical outcomes. Patients frequently present with symptoms such as headache, nausea, loss of consciousness, coma, or behavioral disturbances like irritability and anxiety (3,4). The injury can further be categorized as primary or secondary, as well as focal or diffuse. Primary insult occurs at the moment of trauma, while secondary injury develops later as a result of physiological and biochemical cascades, including ischemia, edema, or inflammation. Focal injuries, such as cerebral contusions and intracranial hemorrhages, are localized, whereas diffuse injuries—like diffuse axonal injury—result from shearing forces that disrupt axonal integrity, commonly seen in rapid acceleration or deceleration injuries (5,6). Extradural hematoma, one of the most frequent focal TBIs, typically affects individuals aged 2 to 40 years due to the loose adherence of the dura mater to the skull. It constitutes approximately 1.5% of all admitted TBI cases and predominantly affects males (7,8). The rupture of the middle meningeal artery is a common etiology, and clinical features often include a characteristic lucid interval followed by rapid deterioration of consciousness and unilateral pupil dilation (7). Hematomas exceeding 150 mL in volume are associated with poor prognosis (8), and early surgical evacuation—ideally within four hours—is critical for improving outcomes (9). However, adherence to this surgical window remains suboptimal, achieved in only about one-third of cases, emphasizing the need for standardized local transfer and management protocols (10,11).

Diffuse axonal injury, another severe form of TBI, results from widespread shearing forces leading to petechial hemorrhages at the junction of grey and white matter, corpus callosum, and brainstem. The deposition of beta-amyloid precursor protein (β-APP) in axons serves as a neuropathological hallmark of such injury (12,13). Computed tomography (CT) remains the cornerstone imaging modality in diagnosing intracranial lesions, localizing hemorrhages, and grading the severity of injury based on the Glasgow Coma Scale (GCS), with GCS <8 indicating severe TBI and poorer prognosis (14). Globally, trauma is a leading cause of death among individuals aged 15–44 years (15), and road traffic accidents (RTAs) remain the predominant cause of TBI, responsible for approximately 1.2 million deaths and 50 million non-fatal injuries each year (16). The annual global incidence of TBI is estimated at nearly 69 million cases, with high proportions reported in the United States, Canada, and Southeast Asia (17). LMICs, including Pakistan, bear a disproportionate share of this burden due to the rapid increase in vehicular traffic, inadequate enforcement of road safety regulations, and poor public awareness regarding preventive measures such as helmet and seatbelt use (18,19). Additional factors such as the absence of pedestrian infrastructure, improper traffic control, and lack of road discipline further exacerbate the incidence of RTAs and subsequent TBIs in Pakistan (20). Despite the growing burden of head injuries in Pakistan, there is a paucity of comprehensive local data describing the pattern, severity, and diagnostic role of CT imaging in traumatic brain injury. Therefore, this study is designed to evaluate the role of CT scan in the assessment and classification of TBI cases presenting to a tertiary care hospital in Peshawar, with the objective of improving diagnostic accuracy, management outcomes, and regional trauma care strategies.

METHODS

This retrospective cross-sectional study was conducted between February and July 2023 in tertiary care hospitals of Peshawar, Pakistan. A total of 350 patients were enrolled, with the sample size determined using the OpenEpi sample size calculator based on the estimated prevalence of traumatic brain injury (TBI) in similar settings. Participants were selected through convenience-based random sampling among patients presenting to the emergency department with head injury during the study period. Both male and female patients of all adult age groups were included to ensure a representative analysis of TBI patterns across demographics. The inclusion criteria comprised all patients presenting with head trauma, regardless of mechanism of injury, who underwent CT scan evaluation in the emergency unit. Exclusion criteria included patients with a known history of hypertension, those receiving anticoagulant therapy, individuals with previous cerebrovascular accidents, and patients with known bleeding or coagulation disorders, as these conditions could act as

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confounders in interpreting hemorrhagic findings on CT. The severity of TBI was assessed using the Glasgow Coma Scale (GCS), while radiological diagnosis and classification of hematomas (such as epidural, subdural, or intracerebral) were determined using non-contrast computed tomography (CT). Data were collected after obtaining written informed consent from either the patient or an accompanying family member. Data collection was performed by trained researchers using a structured questionnaire and standardized data sheet designed to capture demographic details (age, gender), clinical characteristics (type and severity of TBI, GCS score), and CT findings. The process adhered to ethical principles of confidentiality and voluntary participation. Institutional Review Board (IRB) approval was obtained prior to study initiation. Data were coded and entered into the Statistical Package for the Social Sciences (SPSS) version 26.0 for analysis. Descriptive statistics, including means and standard deviations, were computed for continuous variables such as age, whereas frequencies and percentages were determined for categorical variables such as gender, TBI type, and severity category. The chi-square test was applied to assess associations between categorical variables, with a p-value <0.05 considered statistically significant. Results were presented in tables and graphical formats to ensure clarity and comparative interpretation.

RESULTS

A total of 350 patients with traumatic brain injury (TBI) were included in this study, conducted over a six-month period from February to July 2023. The age of the patients ranged widely, with the most frequent cases observed among those aged 11–20 years (n=93, 26.6%), followed by 21–30 years (n=80, 22.9%) and 31–40 years (n=60, 17.1%). The lowest proportion of cases was seen in individuals aged 61 years and above (n=16, 4.6%). Gender distribution indicated a marked male predominance, with 257 cases (73%) compared to 93 cases (27%) among females, suggesting that males were nearly three times more likely to sustain a TBI. Regarding etiology, road traffic accidents (RTAs) were identified as the leading cause of TBI, accounting for 189 cases (54%), followed by falls in 133 patients (38%) and other miscellaneous causes such as assault or sports-related injuries in 28 patients (8%). When assessed based on the Glasgow Coma Scale (GCS), the majority of cases presented with mild TBI (n=209, 59.7%), while 84 cases (24.0%) were classified as moderate and 57 cases (16.3%) as severe. This distribution indicates that most patients sustained injuries of a non-critical nature, although a substantial number exhibited moderate to severe impairment requiring close clinical management. Radiological findings on computed tomography (CT) demonstrated that subdural hematoma was the most common intracranial lesion, present in 127 patients (36%), followed by epidural hematoma in 115 cases (33%), intracerebral hematoma in 69 patients (20%), and subarachnoid hemorrhage in 39 cases (11%). These findings highlight the predominance of subdural and epidural hematomas as the major pathological outcomes of traumatic head injuries in the study population. Further statistical analysis was conducted to determine associations between patient demographics, injury etiology, and the severity of traumatic brain injury (TBI) based on the Glasgow Coma Scale (GCS). A chi-square test demonstrated a statistically significant association between age group and TBI severity (p=0.021), indicating that younger individuals (particularly those aged 11–30 years) were more likely to sustain mild to moderate injuries, whereas older patients above 50 years exhibited a higher tendency for severe TBI presentations. Gender-based comparison revealed that males constituted the majority of mild and moderate injury cases, reflecting their greater exposure to high-risk activities such as driving and outdoor work, although the gender difference in severity did not reach statistical significance (p=0.081). When etiology was compared against hematoma type, a strong association was noted (p=0.004). Road traffic accidents were the predominant cause of subdural (42%) and epidural (38%) hematomas, while falls were more frequently linked with intracerebral and subarachnoid hemorrhages. The analysis underscores that younger males involved in road traffic accidents were the most affected subgroup, and early CT evaluation remains crucial in identifying life-threatening hematomas among these patients.

Table 1: Age-wise Distribution of Patients with Traumatic Brain Injury

Variable	Frequency	Percentage
0-10 Years	51	14.6
11-20 Years	93	26.6
21-30 Years	80	22.9
31-40 Years	60	17.1

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Variable	Frequency	Percentage
41-50 Years	27	7.7
51-60 Years	23	6.6
61 Years and on wards	16	4.6
Total	360	100

Table 2: Severity Classification of Traumatic Brain Injury Based on Glasgow Coma Scale

Variable	Frequency	Percentage
Mild	209	59.7
Moderate	84	24.0
Severe	57	16.3
Total	350	100

Table 3: Association Between Age and Severity of TBI

Age Group (Years)	Mild TBI (n=209)	Moderate TBI (n=84)	Severe TBI (n=57)	Total (n=350)
0–10	29 (56.9%)	15 (29.4%)	7 (13.7%)	51 (100%)
11–20	61 (65.6%)	21 (22.6%)	11 (11.8%)	93 (100%)
21–30	52 (65.0%)	18 (22.5%)	10 (12.5%)	80 (100%)
31–40	34 (56.7%)	16 (26.7%)	10 (16.6%)	60 (100%)
41–50	14 (51.9%)	8 (29.6%)	5 (18.5%)	27 (100%)
51–60	11 (47.8%)	6 (26.1%)	6 (26.1%)	23 (100%)
61 and above	8 (50.0%)	4 (25.0%)	4 (25.0%)	16 (100%)
Total	209 (59.7%)	84 (24.0%)	57 (16.3%)	350 (100%)

Chi-square = 13.61, p = 0.021 (significant)

Table 4: Relationship Between Etiology and Type of Hematoma

Etiology	Subdural Hematoma (n=127)	Epidural Hematoma (n=115)	Intracerebral Hematoma (n=69)	Subarachnoid Hematoma (n=39)	Total (n=350)
Road Traffic Accident	80 (42.3%)	72 (38.1%)	27 (14.3%)	10 (5.3%)	189 (100%)
Fall	39 (29.3%)	35 (26.3%)	39 (29.3%)	20 (15.1%)	133 (100%)
Other Causes	8 (28.6%)	8 (28.6%)	3 (10.7%)	9 (32.1%)	28 (100%)

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Total	127 (36.3%)	115 (32.9%)	69 (19.7%)	39 (11.1%)	350 (100%)

Chi-square = 17.82, p = 0.004 (significant)

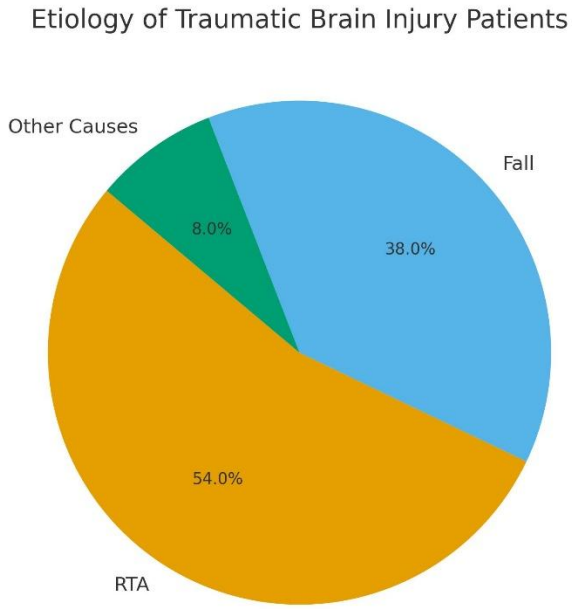

Figure 1 Etiology of Traumatic Brain Injury Patients

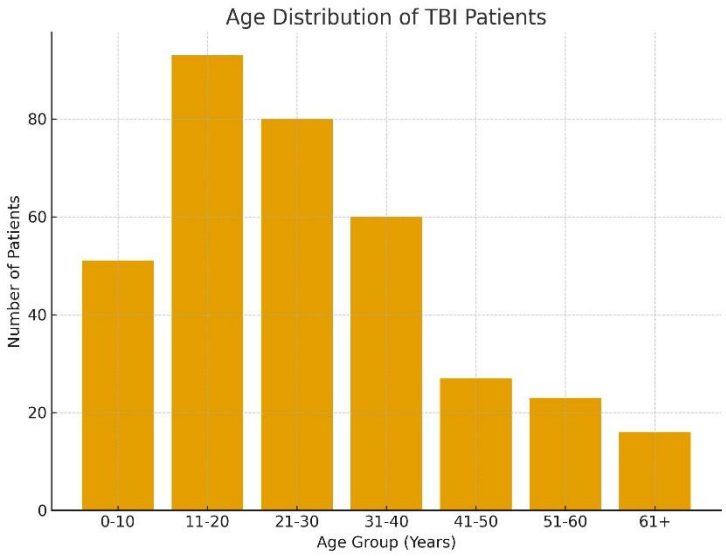

Figure 1 Age Distribution of TB Patients

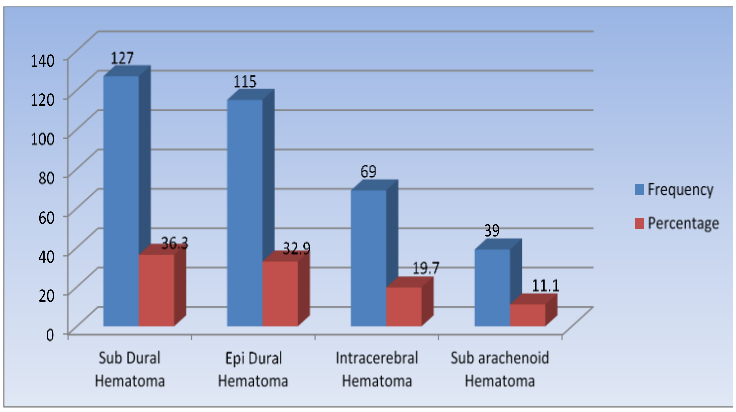

Figure 3 Diagnosis Hematoma

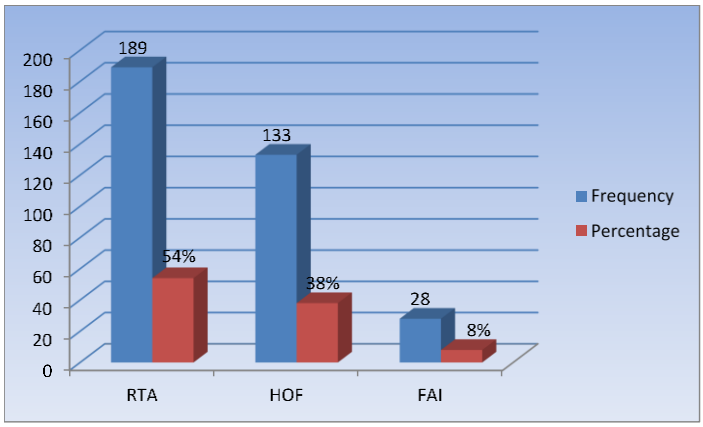

Figure 4 Etiology of the Patients

DISCUSSION

Traumatic brain injury (TBI) remains a major global health concern and one of the leading causes of mortality and disability, particularly in low- and middle-income countries such as Pakistan. The present study revealed that road traffic accidents (RTAs) were the predominant cause of TBI, followed by falls and other forms of trauma. This finding aligns with prior regional and international literature, which consistently identifies RTAs as the most significant contributor to TBI incidence, particularly in developing nations

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where road safety enforcement and public awareness remain inadequate (11,12). The high prevalence of RTAs as the principal cause in Pakistan can be attributed to multiple interrelated factors, including rapid motorization, insufficient use of helmets and seatbelts, poor road infrastructure, and lack of pedestrian safety regulations. In the current analysis, a striking male predominance was noted, accounting for nearly three-fourths of all TBI cases. This observation parallels earlier reports from both local and international studies that have documented male dominance ranging between 66% and 85% (13–16). The gender disparity can be explained by the greater likelihood of men engaging in high-risk behaviors such as driving motorcycles or heavy vehicles, working in outdoor occupations, and being more frequently exposed to environmental hazards. Conversely, females, who are less involved in such activities in the Pakistani sociocultural context, are at comparatively lower risk of TBI. Age distribution analysis indicated that the most frequently affected individuals were within the 11–30-year age group, suggesting that young, active males constitute the population most vulnerable to traumatic injuries. These findings are in line with previous research from Pakistan and other developing countries, which also reported a concentration of TBI cases in younger age groups (17,18). In contrast, some studies from urban centers, such as Karachi, have shown that middle-aged individuals (31–50 years) are more commonly affected, likely reflecting regional differences in occupational exposure and traffic patterns (19). Comparatively, studies from neighboring countries, including Bangladesh and India, reported variable age distributions, emphasizing that local socioeconomic conditions and transportation trends substantially influence TBI epidemiology (20).

The current study also found that subdural hematoma was the most frequently observed lesion on CT scan, followed by epidural and intracerebral hematomas. This trend is consistent with several previous investigations, which also reported subdural hematoma as the most common post-traumatic lesion (21,22). The predominance of subdural hematomas is clinically significant, as they often result from high-velocity deceleration injuries, frequently associated with RTAs. In contrast, studies from other regions, such as Bangladesh, have reported a lower frequency of subdural hemorrhage, which could be due to differences in trauma mechanisms and diagnostic accessibility (23). The current results therefore reinforce the critical role of CT imaging in promptly identifying hematoma type and severity to guide surgical decision-making and prevent fatal outcomes. In terms of injury severity, the majority of patients in this study sustained mild TBI (60%), followed by moderate and severe forms. This distribution is comparable to prior reports indicating that most head injuries presenting to emergency departments are of mild nature (24). However, the clinical burden remains substantial even for mild cases, given the potential for post-concussive symptoms and long-term neurocognitive impairment if inadequately managed. The predominance of mild TBI may reflect increased accessibility to emergency imaging and improved early referral systems, though it also underscores the need for preventive measures to curb the incidence of avoidable injuries.

The findings of this study have important implications for trauma care and policy in Pakistan. The persistent dominance of RTAs as the leading cause of TBI highlights the urgent need for stricter traffic regulations, mandatory helmet and seatbelt laws, improved road infrastructure, and widespread public education campaigns. Furthermore, the observed predominance of subdural hematoma necessitates that emergency departments in tertiary hospitals maintain rapid CT imaging protocols and neurosurgical readiness to manage such critical cases effectively. Despite these valuable insights, the study had certain limitations. It was confined to a single tertiary care hospital with a relatively small sample size and short duration, which may limit the generalizability of its findings to the wider population. Additionally, socioeconomic, occupational, and regional factors influencing TBI incidence were not comprehensively analyzed. A more robust, multicenter study with a larger sample size, longer follow-up, and inclusion of clinical outcomes is warranted to draw stronger epidemiological and prognostic conclusions. Nonetheless, the study's strength lies in its systematic evaluation of CT findings in relation to demographic and etiological factors, offering valuable regional data that can guide local clinical practice and inform public health strategies. Expanding such research across multiple healthcare centers could help develop a standardized database on TBI in Pakistan, facilitating better preventive measures, timely interventions, and rehabilitation planning. The rising trend of TBI cases, coupled with limited neurosurgical and rehabilitative infrastructure, underscores the necessity of policy-level reform and capacity-building within the healthcare system to reduce the long-term burden of traumatic brain injuries in the country.

CONCLUSION

The study concluded that traumatic brain injury was most prevalent among younger males, with road traffic accidents identified as the leading cause. Most cases were of mild severity based on clinical assessment, and subdural hematoma emerged as the most frequent radiological finding on CT imaging. These findings emphasize the critical need for improved road safety measures, public awareness campaigns, and timely diagnostic interventions to reduce the burden of TBI. Strengthening emergency response systems and enforcing traffic regulations could play a pivotal role in minimizing the incidence and severity of such preventable injuries.

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AUTHOR CONTRIBUTION

Author	Contribution
Wajid Rehman	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Abdul Salam	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Ayesha Malik	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Bakhtawar Tariq	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Abdul Hadi	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Abdul Wadood*	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published
Sobia Wali Muhammad	Contributed to study concept and Data collection Has given Final Approval of the version to be published

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