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FREQUENCY AND RADIOLOGICAL EVALUATION OF TRAUMATIC BRAIN INJURIES USING COMPUTED TOMOGRAPHY AT HAYATABAD MEDICAL COMPLEX, PESHAWAR

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Abstract

Background: Traumatic brain injuries (TBI) are a major cause of death and disability worldwide, including in Pakistan, where thousands of cases occur annually. Computed Tomography (CT) is commonly utilized for the diagnosis and assessment of TBI due to its speed and accuracy. However, CT imaging may also reveal incidental findings that are not directly linked to the trauma itself.
Method: A descriptive cross-sectional study was conducted over Six months (march 2025 to august 2025) involving 188 patients who underwent CT brain scans at Hayatabad Medical Complex, Peshawar. Data were collected to evaluate both traumatic and incidental findings. Scans were performed using a 128-slice multidetector CT scanner (GE) to ensure high-resolution imaging and accurate diagnosis.
Results: A total of 188 head trauma patient who referred for head trauma CT were evaluated. The effected age group

was 1 to 90 years. Among 188 the mean age of the patient was (34.2). Male (83%), female (17%). Trauma brain Injury was commonly caused by RTA (69.1%), HOF (18.1%), and LOC (4.3%), FAI (2.7 %,) physical assault (3.7%, 7 cases), sports-related injuries (2.1%, 4 cases). The common CT finding was Skull Fracture include multiple skull fracture 54.8%, followed by frontal fracture 12.8% and temporal fracture 8.0%., patients with abnormal intracranial findings, Parenchymal injuries were the most common, intracerebral hemorrhage 13.8% and cerebral contusion 8%, subarachnoid hemorrhage was the next most frequent finding, present in 13.3% of patients. Intraventricular hemorrhage 3.2 % Focal hematomas, such as subdural was 3.7% and epidural hematomas 2.7, were less common, collectively accounting for 6.4% of cases. Other significant findings, including non-hemorrhagic changes and features suggestive of diffuse axonal injury, were identified in 13.3% (n=25) of patients.
Conclusion: Our study validates CT imaging as an indispensable tool for evaluating TBI at HMC, with high rates of skull fractures, intracranial hemorrhage, and incidental findings. The predominance of RTAs and male young adults underscores the need for preventive public health strategies. Integrating evidence-based CT utilization protocols, improving trauma systems, and enhancing neurosurgical infrastructure are vital steps toward reducing the burden of TBI in Pakistan.

Introduction

Traumatic brain injury (TBI) represents a critical global health challenge, characterized by significant morbidity, mortality, and long-term disability. As defined in the literature, TBI results from external forces such as blows to the head, falls, or accidents, leading to neuropathology and impaired brain function (1). This condition affects an estimated 69 million individuals annually worldwide, with road accidents, falls, and assaults being the primary causes, particularly among teenagers and young adults (3, 4). The severity of TBI is classified using the Glasgow Coma Scale (GCS), categorizing injuries as mild (GCS > 12), moderate (GCS 9–12), or severe (GCS < 8), which can result in short-term or permanent neurological deficits, including cognitive impairments, personality changes, and post-traumatic epilepsy (2).

In regions like Pakistan, TBI poses an escalating public health crisis due to high rates of traffic accidents, violence, and falls, exacerbated by socioeconomic factors (3). For instance, Pakistan reports an annual TBI incidence of approximately 50 per 100,000 individuals, with a disproportionate impact on young males engaged in high-risk activities such as driving or manual labor. Local data from institutions like Hayatabad Medical Complex (HMC) in Peshawar indicate rising morbidity, with rates increasing by 0.1% annually and significant mortality, as evidenced by 245 deaths in 2006 and 352 in 2007. These statistics underscore the need for effective diagnostic tools, such as computed tomography (CT) scans, which are essential for identifying intracranial abnormalities like hematomas, contusions, and fractures in acute settings (4).

Computed tomography (CT) serves as the gold standard for initial TBI evaluation, offering rapid detection of life-threatening lesions such as epidural hematomas, subdural hematomas, cerebral edema, and skull fractures (5). However, while CT is highly effective for moderate to severe cases, it has limitations, including its inability to reliably detect diffuse axonal injury (DAI) or mild contusions, and concerns about radiation exposure. In low-resource settings like Pakistan, where TBI is prevalent, CT utilization must balance diagnostic accuracy with cost-effectiveness, as indiscriminate use can strain healthcare systems. Despite these advancements, gaps in integrating CT findings with clinical severity and outcomes persist, highlighting the need for targeted research in high-burden areas (6).

A retrospective study from the New York State Trauma Registry examined CT scan reports of 957 trauma patients, revealing that 40% (385 patients) had incidental abnormalities, with 37% of these involving multiple findings. The analysis highlighted demographic trends, noting that patients with incidental findings were significantly older (average age 62.0 ± 22.3 years) compared to those without (49.2 ± 29.5 years), and that individuals aged 65 and above had higher rates (53% vs. 39%). This underscores the importance of comprehensive CT reviews in older trauma populations, as incidental findings could influence both traumatic and non-traumatic outcomes, emphasizing the need for integrated diagnostic approaches in TBI management (7).

In contrast, studies from Curitiba, Brazil, and Lublin, Poland, provide insights into TBI patterns in diverse populations. A large-scale analysis of 2,000 patients with minor head trauma in Brazil found that 25.9% exhibited CT-detected injuries, with skull fractures and soft tissue edema being the most common, alongside incidental findings like brain atrophy and vascular lesions (8). Similarly, a cross-sectional study of 644 pediatric patients in Poland reported that 31.9% had incidental findings and 11.34% had both incidental and trauma-related abnormalities on CT scans, with cerebral calcifications being prevalent (9). These findings illustrate the global variability in TBI radiological patterns and the role of CT in identifying both primary injuries and unrelated anomalies, particularly in vulnerable groups such as children and young adults.

Despite the wealth of global data on TBI, significant research gaps exist, particularly in resource-limited settings like Peshawar, Pakistan. Existing studies have primarily focused on epidemiological trends and broad clinical presentations, with limited attention to the correlation between CT findings, clinical severity (e.g., mild, moderate, or severe TBI), and patient outcomes (2.9). At Hayatabad Medical Complex, there is a paucity of local data on CT utilization, appropriateness, and cost-effectiveness, as well as the underreporting of mild and moderate cases due to resource constraints and non-standardized protocols (2.9). This lack of integration hinders evidence-based decision-making, such as using CT as a prognostic tool, and fails to address how radiological patterns might inform regional management strategies, necessitating targeted studies to bridge these gaps and enhance TBI care in similar contexts (10).

TBI remains a leading cause of disability and death worldwide, with CT scans playing a pivotal role in diagnosis and management. By addressing the identified research gaps, this study at Hayatabad Medical Complex aims to provide comprehensive insights into the frequency, etiology, and radiological spectrum of TBI in Peshawar. Specifically, the objectives are: 1) to assess the frequency of traumatic brain injuries in patients undergoing CT scans, and 2) to categorize and describe the radiological spectrum of TBI identified on computed tomography (11). These findings will not only improve local diagnostic and treatment protocols but also contribute to global efforts in reducing TBI-related morbidity and mortality in low-resource settings.

METHODOLOGY

Study design

A descriptive cross-sectional study design

Study duration

The study duration was six months from March to august 2025, at the Radiology Department of Hayatabad Medical Complex (HMC), Peshawar

Study setting

The study was conducted at the Radiology Department of Hayatabad Medical Complex (HMC), Peshawar a tertiary care teaching hospital located in the capital city of Khyber Pakhtunkhwa, Pakistan.

Sample selection

Inclusion criteria

Patients with a history of traumatic brain injury (TBI)
Patient's age between 1 to 90 years included (12)
Both genders – male and female patients included

Exclusion criteria

Patient with a history of previous surgery and post trauma
Patients with known bleeding disorders
Patients who are on anti-coagulant therapy

Sample size

There were 188 patients in this study who visited the radiology department of the Hayatabad Medical Complex in Peshawar. The sample size was determined using the Open EPI online sample size calculator by inputting the relevant data into the formula. The anticipated frequency of radiological evaluation of traumatic brain injury (TBI) using CT was taken as 14.2% based on
The anticipated frequency according to (5) is 14.2%, sample size of our study was 188 (13).

Anticipated Frequency (p): 14.2%
The confidence level: 95%
The margin of error is (d): 5%

Sampling technique

Non-probability convenience sampling was used for this study. Patients presenting with clinical suspicion of traumatic brain injury (TBI) who underwent non-contrast CT scans at the Radiology Department of Hayatabad Medical Complex, Peshawar, were included based on their availability and willingness to participate. Verbal informed consent was obtained prior to data collection.

Data collection procedure

Ethical approval for data collection was obtained from the Radiology Department of Hayatabad Medical Complex (HMC), Peshawar. Data were collected through questioner. The research questioner consists of patient demographics, computed tomography assessment scan and incidental findings. Information was gathered on 128 slices of GE CT scan.

Statistical analysis

Version 22 of SPSS (Statistical Package for Social Sciences) was used for the statistical analysis. Only descriptive statistics were applied to calculate frequencies and percentage of various variables. The results were presented in the form of figures, graph, and tables.

RESULTS:

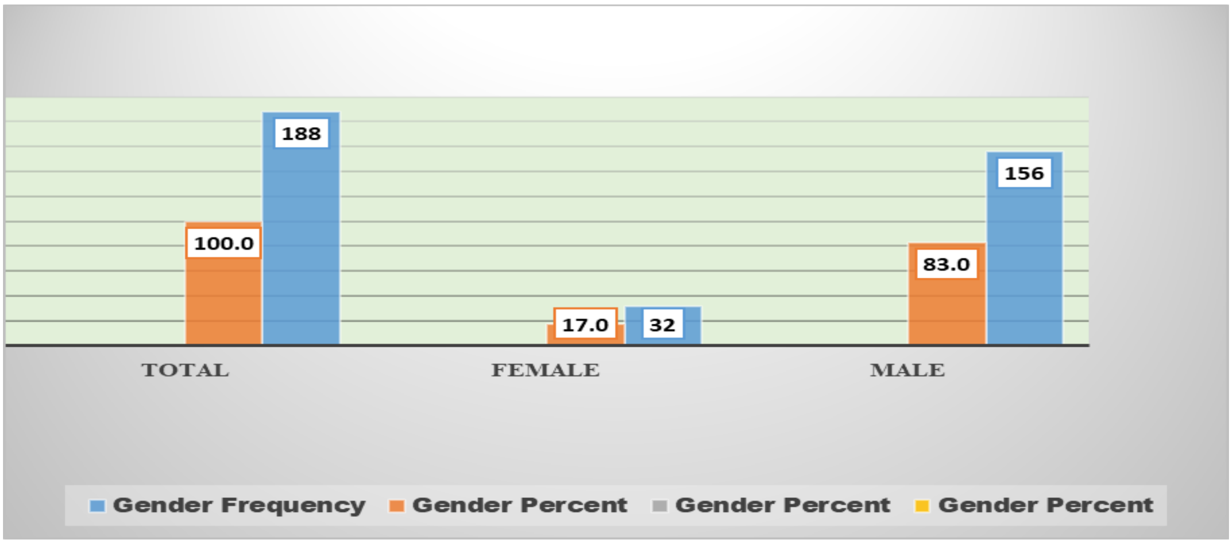
The results from the research's data collection phase are presented in this chapter. An overview of the participants' ages and demographic data is presented first, followed by injury details and a CT scan evaluation. The results are arranged methodically, with any pertinent table coming first, then a synopsis and any related graphs. Gender:

Our study involved 188 participants in total of which had 32 female participants and 152 male participants. 83% of the population was male, and 17% was female. The details are mentioned in table 1 and Figure 1.

Table 1: frequency and percentage of participant gender

Gender	Frequency	Percentage
Male	156	83.0
Female	32	17.0
Total	188	100.0

Figure 1: Gender distribution of participants

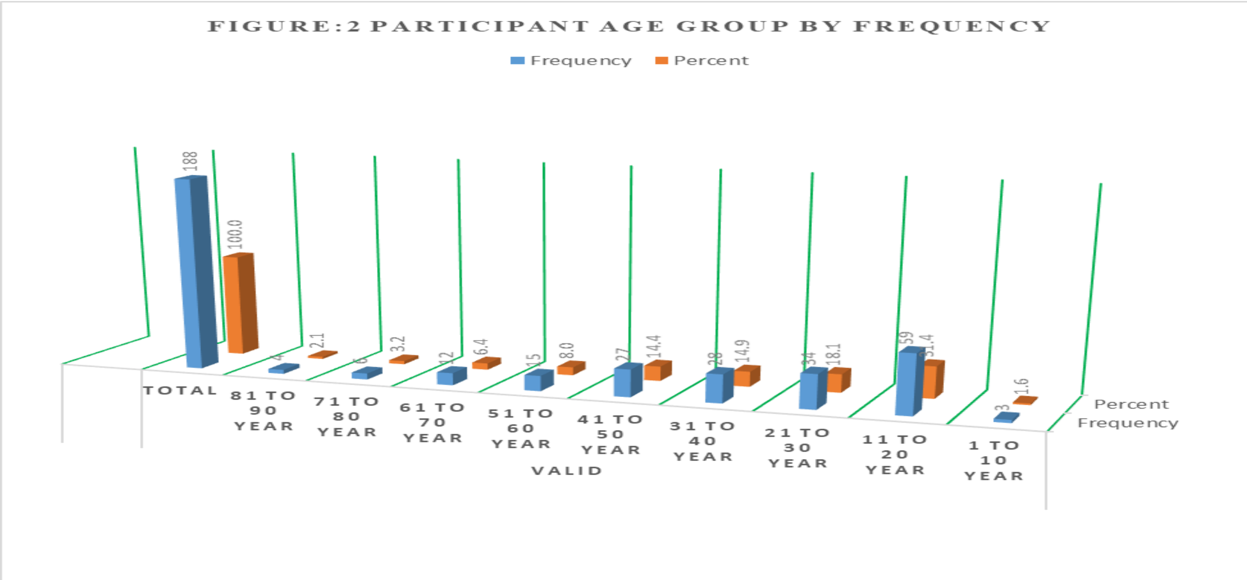


Participants in the study ranged in age from 1 year to 90 years. Only 3 individuals, or 1.6% of the total, were between the ages of one and ten. Fifty-nine participants, or 31.4% of the total, were between the ages of 11 and 20. A total of 34 participants, or 18.1% of the total, were between the ages of 21 and 30. A total of 28 participants, or 14.9% of the total, were between the ages of 31 and 40. 27 participants, or roughly 14.4% of the total, were between the ages of 41 and 10.There were 15 participants, or roughly 8% of the total, who were between the ages of 51 and 60. Twelve individuals, or 6.4% of the total, were between the ages of 61 and 70. There were six participants, or 3.2% of the total, who were between the ages of 71 and 80. Only 4 participants, or 2.1% of the total, were between the ages of 81 and 90. Details are mentioned in table 02 and Figure 02.

Age Class Limit	Frequency	Percentage
1 to 10 year	3	1.6
11 to 20 year	59	31.4
21 to 30 year	34	18.1
31 to 40 year	28	14.9
41 to 50 year	27	14.4
51 to 60 year	15	8.0

Table 2: Distribution of Patients by Age Group (Frequency and Percentage)

Age Class Limit	Frequency	Percentage
1 to 10 year	3	1.6
11 to 20 year	59	31.4
21 to 30 year	34	18.1
31 to 40 year	28	14.9
41 to 50 year	27	14.4
51 to 60 year	15	8.0
61 to 70 year	12	6.4
71 to 80 year	6	3.2
81 to 90 year	4	2.1
Total	188	100.0

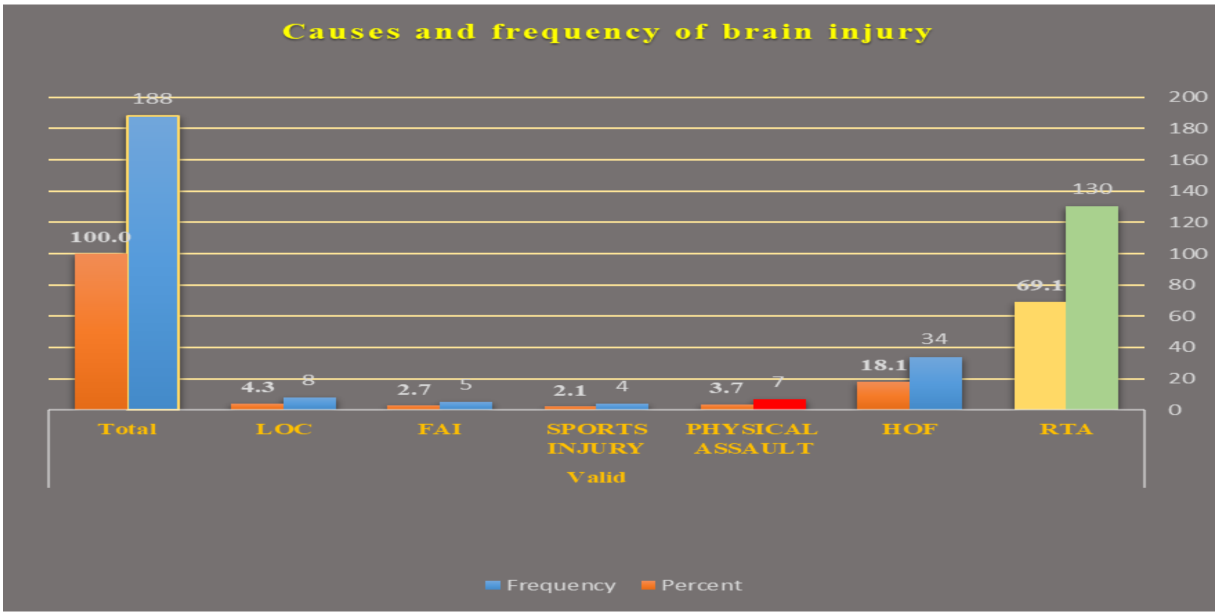


In the study sample of 188 cases, road traffic accidents (RTAs) were the predominant cause of injury, accounting for 130 cases (69.1%), closely followed by falls from height (HOF) in 34 cases (18.1%)—together comprising 87.2% of all injuries. Notably, firearm injuries (FAI) were recorded in 5 cases (2.7%), Additional causes included physical assault (3.7%, 7 cases), sports-related injuries (2.1%, 4 cases), and loss of consciousness-related injuries (4.3%, 8 cases). Details are mentioned in table 03 and Figure 03.

Table: 03 Causes of Brain Injury with Corresponding Frequencies

Causes	Frequency	Percentage
RTA	130	69.1
HOF	34	18.1
PHYSICAL ASSAULT	7	3.7
SPORTS INJURY	4	2.1
FAI	5	2.7
LOC	8	4.3
Total	**188**	**100.0**

Figure: 03 Causes of Brain Injury with Corresponding Frequencies

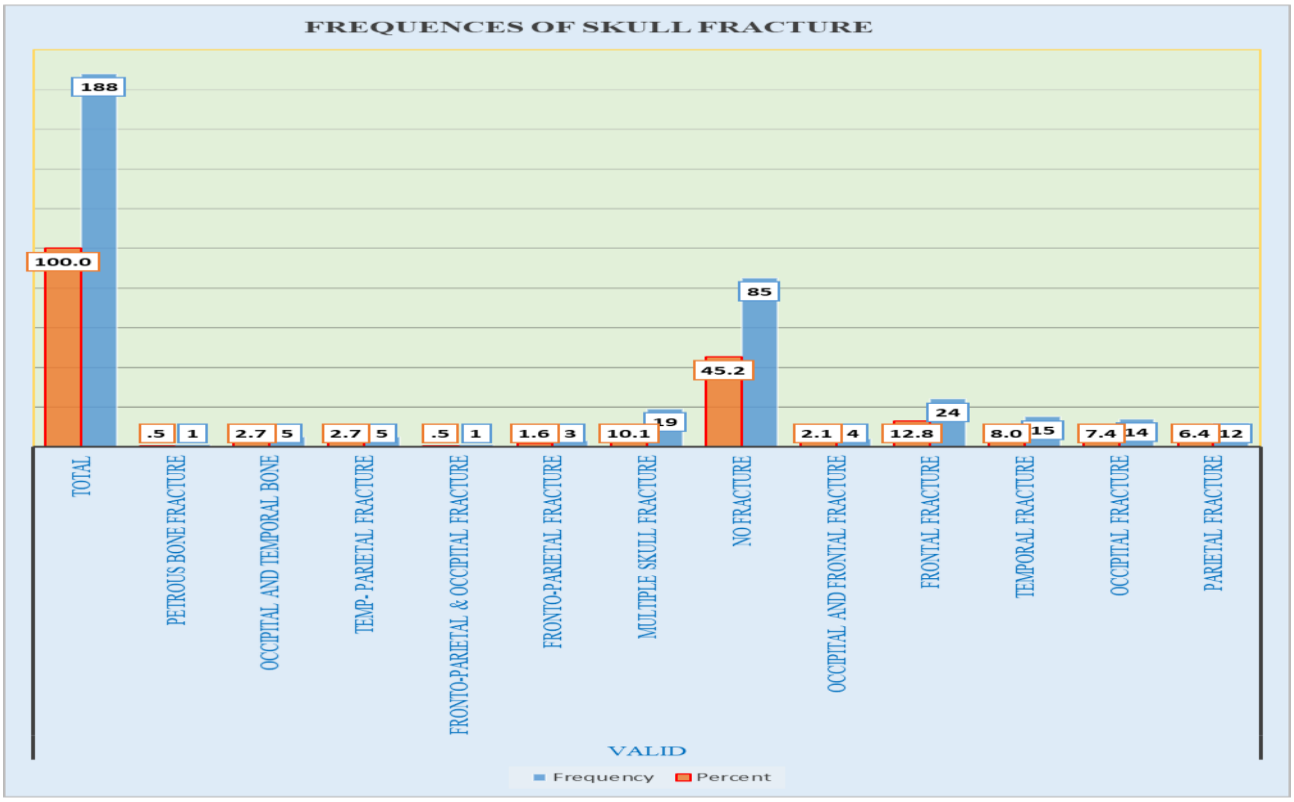


Of the 188 patients, 45.2% had no skull fracture, and 54.8% had some kind of cranial fracture, with frontal fractures (12.8%), temporal fractures (8.0%), occipital fractures (7.4%), and parietal fractures (6.4%) being the most common among those with fractures; complex injury patterns were also observed: multiple skull fractures in 10.1% of cases, occipital–frontal combined fractures in 2.1%, temporal–parietal fractures in 2.7%, and occipital–temporal fractures in 2.7% of cases; front parietal (1.6%), front parietal–occipital (0.5%), and petrous bone fractures (0.5%) were less common presentations, and 19 cases had multiple fractures, suggesting that multi-site impact was a significant concern in roughly one out of 10 patients. The details are mentioned in table 4 and Figure 4.

Table 04: Frequency of Skull Fractures among Patients

Skull fracture	Frequency	Percentage
Parietal Fracture	12	6.4
Occipital Fracture	14	7.4
Temporal Fracture	15	8.0
Frontal Fracture	24	12.8
Occipital And Frontal Fracture	4	2.1
No Fracture	85	45.2
Multiple Skull Fracture	19	10.1
Fronto-Parietal Fracture	3	1.6
Fronto-Parietal & Occipital Fracture	1	.5
Temp- Parietal Fracture	5	2.7
Occipital And Temporal Bone	5	2.7
Petrous Bone Fracture	1	.5
Total	**188**	**100.0**

Figure 04: frequency of skull fractures among patients

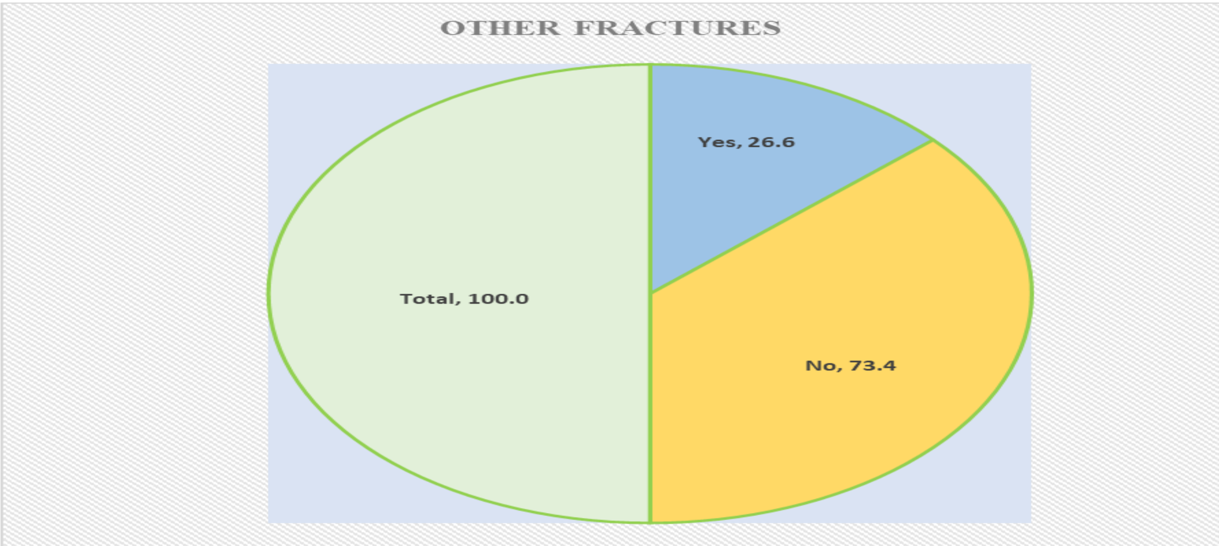


Of the 188 patients that were part of the study, 50 (26.6%) had other fractures that involved parts of the body other than the head, and 138 (73.4%) did not have any other fractures. details are mentioned in table 05 and pie chart?

Table 05: Frequency and Percentage of Other Fractures

Other fracture	Frequency	Percentage
Yes	50	26.6
No	138	73.4
Total	**188**	**100.0**

Pie Chart 05: Frequency and Percentage of Other Fractures

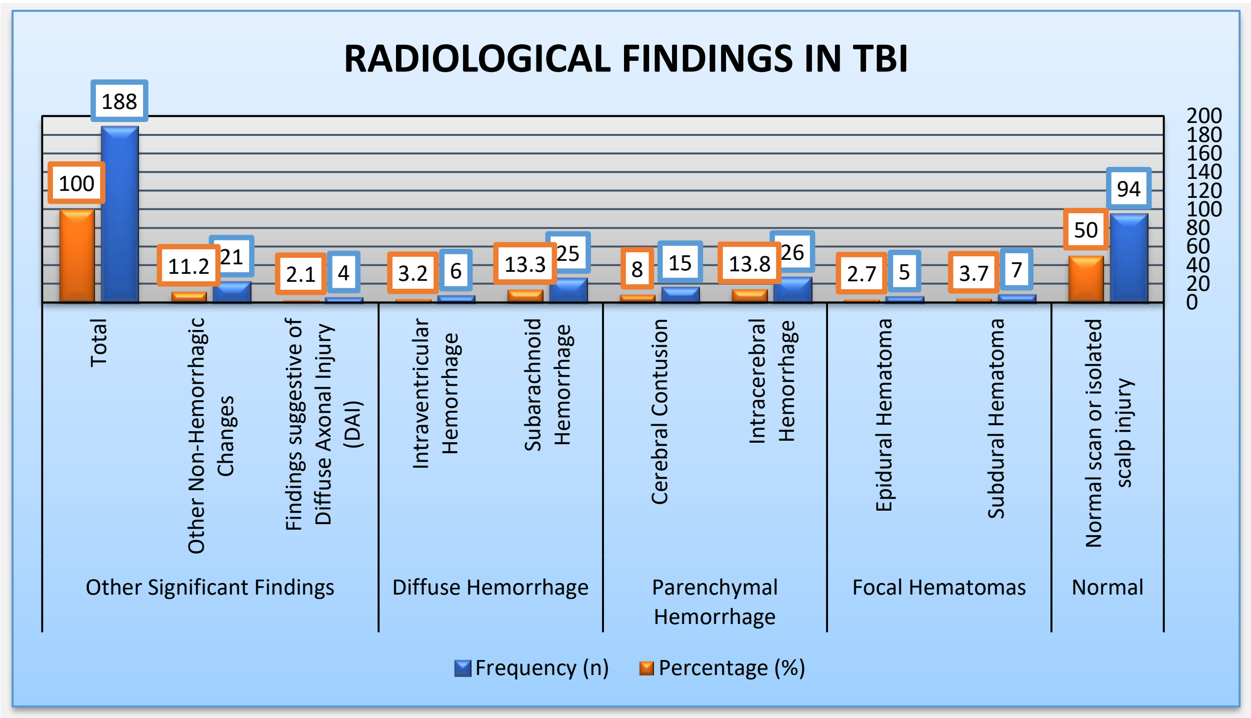


A total of 188 patients who presented with head trauma and underwent a non-contrast CT scan were included in this study. The analysis of the CT scans shows a diverse spectrum of traumatic brain injuries. The most common finding was a normal CT scan or the presence of only an isolated scalp injury, which was show in 94 patients, consider for half of all patients (50.0%). Among the 94 patients (50.0%) with abnormal intracranial findings, parenchymal hemorrhages were the most common type of injury, identified in 41 patients (21.8% of the total cohort). Within this category, intracerebral hemorrhage (ICH) was the predominant finding (13.8%), followed by cerebral contusions (8.0%). Diffuse hemorrhage patterns were the next most common, seen in 31 patients (16.5%). Subarachnoid hemorrhage (SAH) was the most notable finding in this group, present in 13.3% of all patients. Focal hematomas, including subdural hematoma (SDH) (3.7%) and epidural hematoma (EDH) (2.7%), were less common, collectively accounting for 6.4% of findings. Other significant findings, which included non-hemorrhagic changes and radiological features suggestive of diffuse axonal injury (DAI), were present in 25 patients (13.3%). Notably, classic signs of DAI were identified in only 4 cases (2.1%). the frequency and distribution of the specific radiological findings are summarized in Table 6 and figure 6.

Category	Specific Finding	Frequency (n)	Percentage (%)
Normal	Normal scan or isolated scalp injury	94	50.0
Focal Hematomas	Subdural Hematoma	7	3.7
	Epidural Hematoma	5	2.7
Parenchymal Hemorrhage	Intracerebral Hemorrhage	26	13.8
	Cerebral Contusion	15	8.0
Diffuse Hemorrhage	Subarachnoid Hemorrhage	25	13.3
	Intraventricular Hemorrhage	6	3.2
Other Significant Findings	Findings suggestive of Diffuse Axonal Injury (DAI)	4	2.1
	Other Non-Hemorrhagic Changes	21	11.2
	Total	**188**	**100.0**

Table 06: Frequency and Distribution of CT scan Findings in Patients with Traumatic Brain Injury

Figure 06: Frequency and Distribution of CT scan Findings in Patients with Traumatic Brain Injury



DISCUSSION:

This study provides valuable insights into the demographics, etiology, and radiological patterns of traumatic brain injury (TBI) among 188 patients at Hayatabad Medical Complex (HMC) in Peshawar, Pakistan. Our findings underscore the high burden of TBI in a resource-limited setting, with a focus on road traffic accidents

(RTAs) as the dominant cause and computed tomography (CT) as a critical diagnostic tool. By comparing our results with national and international data, we highlight patterns that align with broader trends while identifying unique challenges in Pakistan. These observations not only reinforce the need for targeted interventions but also emphasize the role of evidence-based guidelines in optimizing TBI management.

The demographic profile of our cohort revealed a marked male predominance (83%), consistent with national studies in Pakistan that report similar ratios (70–80%), attributed to men's greater exposure to high-risk activities such as driving and manual labor. This gender disparity echoes global reports, where younger males are at elevated risk due to behavioral factors and traffic-related exposures. In our study, the most affected age groups were 11–20 years (31.4%) and 21–30 years (18.1%), slightly differing from multicenter data in Pakistan, which identified a peak in the 21–30 age bracket (~34.1%) (14). These findings suggest that adolescents and young adults in Pakistan face heightened vulnerability, possibly linked to inadequate road safety measures and socioeconomic pressures. Overall, our results align with international epidemiology, highlighting the need for age- and gender-specific prevention strategies to mitigate TBI incidence in high-risk populations.

Road traffic accidents (RTAs) emerged as the primary etiology in our cohort, accounting for 69.1% of cases, with falls from height contributing 18.1%. This distribution is in line with reports from other Pakistani centers, such as a tertiary facility in Mardan (48% RTAs and 31% falls) and a large-scale study in Karachi (62% RTAs, 31.7% falls, and 5.5% assaults) (15). The prominence of RTAs reflects Pakistan's high road traffic mortality rate (~25.5 per 100,000 population), underscoring systemic issues like poor traffic enforcement and infrastructure (16). Compared to global data, our findings reinforce RTAs as a leading cause of TBI worldwide, particularly in low- and middle-income countries. This consistency highlights the urgency for multifaceted interventions, including enhanced road safety campaigns and helmet mandates, to address the root causes of these injuries.

Our CT analysis revealed a diverse spectrum of findings, with skull fractures present in 54.8% of cases, including frontal (12.8%), temporal (8%), occipital (7.4%), and parietal (6.4%) fractures, and complex or multiple fractures in 10.1% (17). These results suggest high-impact mechanisms, such as RTAs, and align with studies from DG Khan, which reported a 28.4% prevalence of skull fractures and 20.6% extra Dural hematomas (18). Additionally, non-cranial fractures were noted in 26.6% of patients, emphasizing the multisystem nature of TBI and the need for comprehensive trauma assessments. The high rate of normal scans (50%) is consistent with literature on mild TBI, supporting the use of clinical decision rules like the Canadian CT Head Rule to optimize imaging (19). Parenchymal injuries, including intracerebral hemorrhage and cerebral contusions (21.8%), dominated our findings, reflecting coup-contrecoup dynamics as described in prior research (20). The spectrum of hemorrhages—subarachnoid (13.3%), intraventricular (3.2%), epidural (2.7%), and subdural (3.7%)—fell within expected ranges, with the lower incidence of surgical lesions indicating a predominance of mild-to-moderate severity (21). These patterns highlight CT's utility in detecting both focal and diffuse injuries, though the rarity of certain hemorrhages suggests opportunities for early intervention in high-risk cases.

The clinical implications of our findings underscore the challenges of TBI management in Pakistan, particularly regarding CT utilization and resource constraints. While CT remains central to TBI evaluation, its overuse can lead to unnecessary radiation exposure and costs; thus, guidelines like the Canadian CT Head Rule (CCHR) and New Orleans Criteria (NOC) are vital for targeting high-risk patients (e.g., GCS <15 after 2 hours, suspected skull fracture) (22). However, the absence of a country-specific adaptation limits their applicability in Pakistan, where only 40% of TBI patients access CT due to financial barriers (e.g., USD 16 per scan) and infrastructure deficits (23). Our data support the need for follow-up imaging in cases of hematomas or fractures, as serial CT scans can detect progressive injuries in up to half of moderate TBI patients, potentially altering treatment plans (24). Addressing these gaps through localized protocols could enhance outcomes, reduce healthcare burdens, and promote equitable access to neuroimaging.

When compared to pediatric-specific studies in Pakistan, our broader age-range cohort showed partial alignment, with falls being the predominant mechanism in children (60–79%) versus RTAs in adults (25). Pediatric data frequently reported higher rates of skull fractures, contusions, and pneumocephalus, emphasizing the vulnerability of younger patients to low-impact injuries (26). In our study, RTAs remained dominant across all ages, but early hospital arrival and ambulance transport—factors linked to reduced mortality in pediatric cases—were also relevant for adults (27). These differences highlight the importance of age-stratified approaches in TBI research and management, as pediatric patterns may inform preventive strategies for adolescents at risk from traffic-related trauma.

In conclusion, this study at HMC corroborates national and global trends in TBI demographics, etiology, and CT findings, while revealing critical gaps in resource availability and guideline implementation in Pakistan (28). The predominance of RTAs and the high yield of CT in detecting injuries underscore the need for integrated public health measures, including enhanced traffic safety and optimized imaging protocols. By addressing these issues, future research can contribute to reduced TBI morbidity and mortality, particularly in resource-constrained settings. Limitations, such as the retrospective design and single-center focus, suggest the value of larger, multicenter studies to validate these findings and guide policy (29,30).

CONCLUSION:

In conclusion, this study at Hayatabad Medical Complex affirms the critical role of CT imaging in evaluating traumatic brain injury, revealing high incidences of skull fractures, intracranial hemorrhage, and incidental findings, while highlighting the predominance of road traffic accidents among young male adults, thus necessitating robust public health strategies for prevention. To address these challenges, we recommend developing context-specific CT triage guidelines adapted from established frameworks like the Canadian CT Head Rule and New Orleans Criteria to suit Pakistani emergency settings; enhancing pre-hospital systems through better ambulance transport, early triage, and prompt CT access; establishing multidisciplinary trauma units with expanded neurosurgical capacity for managing complex injuries; and implementing protocols for incidental findings, including referral and follow-up pathways. However, the study's limitations, such as its single-center design limiting external validity, a relatively small sample size (n=188) hindering subgroup analysis, the absence of MRI potentially missing diffuse pathologies like diffuse axonal injury (which affects up to 50% of severe cases), and the lack of long-term follow-up data, restrict broader prognostic insights and underscore the need for larger, more comprehensive future investigations.

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