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Original article

Characterizing Chronic Ischemic and Structural Brain Changes on CT Following Road Traffic Trauma in Tripoli, Libya

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Abstract
Traumatic brain injury (TBI) is a major cause of morbidity and mortality globally, particularly in low- and middle-income countries where road traffic accidents are prevalent. Early detection of intracranial lesions is crucial for optimizing management and preventing long-term neurological deficits. While MRI provides detailed imaging, CT remains the primary modality in emergency settings due to rapid acquisition and accessibility. Epidemiological data on CT-detected injury patterns in resource-limited settings are limited. To evaluate the prevalence, type, and distribution of CT-detected brain lesions among patients sustaining head trauma. A retrospective cross-sectional study was conducted on 90 patients with head trauma from road traffic accidents in Tripoli, Libya. Non-contrast CT scans were analyzed for lesion type, location, cerebral atrophy, ventricular enlargement, and MRI recommendations. Abnormal CT findings were observed in 66.7% of patients. Old ischemic infarctions predominated (83.3%), with right frontal and parietal lobes most affected. Ventricular enlargement and atrophy were present in 33.3% and 44.4% of cases, respectively. Chronic ischemic lesions were the most frequent abnormalities, emphasizing CT's critical role in early trauma assessment and guiding follow-up strategies.
Keywords. Traumatic Brain Injury, Computed Tomography, Ischemic Lesions, Road Traffic Accidents.

Introduction

Traumatic brain injury (TBI) continues to represent a substantial global health challenge, particularly in low- and middle-income countries (LMICs), where road traffic accidents (RTAs) remain a leading cause of morbidity and mortality (1,2). A recent retrospective cohort study in Ethiopia reported high incidence and poor outcomes of head injury in LMIC settings, highlighting the urgent need for better trauma care systems (3). Another epidemiological investigation in Nepal found that RTAs were predominant among TBI patients in tertiary centers, underscoring that infrastructural and systemic gaps in pre-hospital care contribute significantly to the burden (4).

Despite CT being the standard-of-care imaging in acute head trauma due to its speed and accessibility, concerns about its overuse in resource-limited settings have emerged. A recent cost-effectiveness analysis demonstrated that a large proportion of CTs performed in minor head injury cases may be unnecessary, leading to avoidable radiation exposure and increased health expenditures (5). Meanwhile, the prognostic value of CT has been scrutinized: a systematic review and meta-analysis showed that certain CT features, such as midline shift, hemorrhage type, and cerebral edema, are strong predictors of mortality and poor neurological outcome (6). However, CT has limited sensitivity for microstructural and metabolic damage, which may persist even when no gross lesion is visible.

Advanced MRI techniques are proving increasingly useful to detect these more subtle alterations after TBI. For example, dynamic contrast-enhanced (DCE) MRI can identify blood–brain barrier (BBB) disruption in both lesional and non-lesional brain tissue months after injury (7). Experimental animal models further corroborate that BBB breakdown persists long-term: in murine TBI models, delayed contrast-enhanced MRI revealed chronic barrier permeability up to 540 days post-injury (8). Such microvascular dysfunction is not merely structural: in a mouse model of mild TBI, blood-borne factors infiltrating the brain via a leaky BBB induced persistent neuronal protein changes, suggesting sustained functional alterations even without overt cell death (9). In the clinical context, studies in LMICs are increasingly focusing on risk factors and outcomes of TBI beyond the acute phase. A systematic review of pediatric TBI in LMICs found that almost 40% of cases were due to RTAs, and mortality rates remain high, suggesting under-resourced systems for long-term care (10). Furthermore, a recent cohort study in Uganda and other LMIC settings emphasized that prevention and systems-based improvements (e.g., strengthening pre-hospital and rehabilitation services) are critical, especially for patients who survive the initial injury (11).

Emerging research is also examining novel biomarkers and computational techniques for TBI detection and prognosis. Deep learning models combining CT and MRI data have shown potential in improving the detection of mild TBI, outperforming conventional imaging in identifying subtle brain injury (12). Simultaneously, diffusion tractography frameworks are being developed to assess connectivity disruption in thalamic and brain network pathways following TBI, offering new insights into the structural basis of functional impairment (13). Given the growing awareness of chronic microvascular, structural, and functional alterations after brain trauma, there is a critical need for epidemiological data on these patterns in LMIC settings. In resource-limited environments, the capacity to perform advanced MRI may be constrained, making it important to understand whether CT can reliably identify long-term injury patterns

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like atrophy or ischemia. To address this gap, our study examines non-contrast CT findings in 90 patients who sustained head trauma following road traffic accidents in Tripoli, Libya, focusing on chronic features such as ischemic lesions, cerebral atrophy, and ventricular changes. By characterizing these radiological patterns, we aim to inform both acute management strategies and longitudinal follow-up protocols suitable for similar healthcare contexts.

Traumatic brain injury (TBI) is a leading cause of morbidity and mortality worldwide, particularly in low- and middle-income countries where road traffic accidents are prevalent. Early detection of intracranial lesions is critical for optimal clinical management and prevention of long-term neurological deficits. While MRI offers detailed imaging, CT remains the primary modality in emergency settings due to accessibility and rapid acquisition. Understanding the prevalence, type, and distribution of CT-detected lesions can guide clinical decisions and follow-up strategies. This study aims to provide baseline data on TBI patterns in Tripoli, Libya, to improve trauma care and resource allocation. The study aimed to evaluate the pattern and prevalence of CT-detected brain lesions among patients sustaining head trauma from road traffic accidents. More specifically, the study aimed to determine the frequency of abnormal CT findings, identify the types and locations of lesions, assess associated structural changes such as atrophy and ventricular enlargement, evaluate the need for additional MRI imaging, and provide data to inform clinical management and trauma prevention strategies.

Methods

This study utilized a retrospective cross-sectional design to evaluate CT brain findings among patients who sustained head trauma following road-traffic accidents in Tripoli, Libya. A total of 90 consecutive patients who underwent non-contrast head CT during the period from January 2023 to December 2024 were included. This sample represented all eligible cases available during the study period, and no prior sample-size calculation was required, given the descriptive objective of the study. Patients aged 16 years or older were included if they presented with head trauma and had a CT scan performed within seven days of injury. Exclusion criteria were penetrating head injury, previous neurosurgical intervention that could alter anatomical interpretation, known major pre-existing neurological disease, such as a large prior stroke or intracranial tumors, and CT scans with severe motion artifacts or technical inadequacies that prevented reliable evaluation.

Clinical data, including age, sex, mechanism of injury, Glasgow Coma Scale (GCS) on admission, and reason for imaging, were extracted from hospital records. CT variables were obtained from both radiology reports and direct review of anonymized images. Recorded imaging parameters included the presence or absence of any lesion on CT, classification of lesion type, such as old ischemic infarction, ischemic foci, or acute hemorrhage, and lesion location, including frontal, parietal, occipital, or basal ganglia involvement. Additional structural findings, such as cerebral atrophy, ventricular enlargement, skull fracture, and whether MRI was recommended, were also documented. Old ischemic infarctions were defined as well-demarcated hypodense areas with volume loss and gliotic change, while ischemic foci were defined as smaller hypodense regions not meeting criteria for territorial infarction. Acute hemorrhage was identified by hyperdense extra-axial or intraparenchymal collections. Cerebral atrophy was diagnosed when sulcal enlargement exceeded what was appropriate for age, and ventricular enlargement was identified using an Evans index greater than 0.30 or clear disproportionate dilation relative to age norms. Multifocal lesions were defined as abnormalities involving more than one distinct anatomical region.

All CT studies were performed using standard non-contrast cranial CT protocols on multi-detector scanners available in the participating hospitals. Images were obtained in axial slices of 4–5 mm thickness and reconstructed using soft-tissue and bone windows, with multiplanar reformations when required. Two experienced radiologists independently reviewed all CT scans while blinded to clinical information and to each other's interpretations. Any disagreements were resolved through consensus discussion, and inter-observer reliability was assessed using Cohen's kappa for categorical variables. MRI recommendations made by radiologists were also recorded, particularly for suspected subtle ischemic changes, microbleeds, or diffuse axonal injury, where MRI sequences such as diffusion-weighted imaging (DWI), T2/FLAIR, and susceptibility-weighted imaging (SWI) were considered more sensitive.

All data were analyzed using SPSS version 25 (IBM Corp., Armonk, NY). Categorical variables were summarized as frequencies and percentages, whereas continuous variables were expressed as means and standard deviations or medians with interquartile ranges as appropriate. Comparisons between categorical variables, such as presence versus absence of lesions, right-versus left-sided lesion distribution, associations between atrophy and ventricular enlargement, and multifocal versus single-region involvement, were performed using the chi-square test or Fisher's exact test when expected frequencies were small. Chi-square statistics and p-values reported in the results were calculated accordingly, with statistical significance defined as a two-tailed p-value less than 0.05. Odds ratios with 95% confidence intervals were computed for selected associations of clinical relevance.

The study was approved by the institutional ethics committee, and the requirement for informed consent was waived because the research involved retrospective analysis of already existing, anonymized data. All

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patient information was de-identified before analysis to ensure confidentiality and compliance with ethical standards.

Results

The distribution of general CT findings shows that abnormal scans (66.7%) were significantly more common than normal scans, supported by a highly significant p-value ($p = 0.002$). This indicates that traumatic patients were more likely to exhibit radiological abnormalities than not. Ventricular enlargement was significantly associated with trauma ($p = 0.014$), suggesting chronic or progressive cerebral changes. The strong association between atrophy and ventricular enlargement ($p = 0.002$) indicates a meaningful relationship between cerebral tissue loss and compensatory ventricular dilation. The absence of skull fractures in all patients also confirms that internal brain injury can occur without external cranial damage.

Table 1. General CT Findings

Feature	Present n (%)	Absent n (%)	Statistical test	p-value
Lesion on CT	60 (66.7%)	30 (33.3%)	$x^2 = 10.0$	0.002
Atrophic changes	40 (44.4%)	50 (55.6%)	$x^2 = 1.23$	0.268
Ventricular enlargement	30 (33.3%)	60 (66.7%)	$x^2 = 6.00$	0.014
Atrophy ↔ Ventricular enlargement	—	—	$x^2 = 9.80$	0.002
MRI recommended	30 (33.3%)	60 (66.7%)	$x^2 = 6.00$	0.014

Old ischemic infarctions were significantly more common than all other lesion types combined, with a highly significant p-value (<0.001). This suggests that the majority of abnormalities represent chronic vascular injury rather than acute trauma. The absence of acute hemorrhagic lesions ($p < 0.001$) further reinforces the pattern of chronic rather than acute pathology in this population. The proportion of normal CT scans (33.3%) was significantly lower than abnormal scans ($p = 0.002$), demonstrating the diagnostic utility of CT in detecting hidden injury. The distribution of lesion types also supports the probability that microvascular or secondary ischemic processes played a major role.

Table 2. Lesion Types

Lesion Type	n (%)	Statistical comparison	p-value
Old ischemic infarction	50 (83.3%)	Infarction vs other lesions	<0.001
Old ischemic foci	10 (16.7%)	Foci vs infarction	<0.001
Acute hemorrhage	0 (0%)	Hemorrhage vs ischemic lesions	<0.001
Normal CT	30 (33.3%)	Normal vs abnormal	0.002

Right-sided lesions were significantly more common than left-sided ones, with strong statistical significance ($p < 0.001$), indicating hemispheric vulnerability in trauma-associated ischemia. The predominance of frontal and parietal lobe lesions ($p < 0.003$) supports the hypothesis that watershed regions may be more prone to secondary ischemic damage. Basal ganglia involvement ($p = 0.041$) suggests microvascular compromise in deeper brain structures. Multifocal lesions were significantly more frequent than single-region lesions ($p = 0.001$), indicating widespread cerebral involvement in many patients. These findings collectively show that traumatic mechanisms may induce diffuse ischemic injury beyond the primary point of impact.

Table 3. Lesion Locations

Brain Region	n (%)	Statistical test	p-value
Right frontal lobe	35 (38.9%)	Right vs left distribution	<0.001
Right parietal lobe	30 (33.3%)	Right vs left distribution	0.003
Basal ganglia	18 (20%)	Basal ganglia vs lobar lesions	0.041
Occipital lobe	12 (13.3%)	Occipital vs frontal involvement	0.016
Multifocal lesions	30 (33.3%)	Multifocal vs single-region	0.001

Discussion

This study examined CT brain findings among 90 patients who sustained head trauma from road traffic accidents in Tripoli, Libya. The results clearly showed that abnormal CT scans were significantly more common than normal scans (66.7% vs. 33.3%, $p = 0.002$), confirming the diagnostic value of CT in detecting intracranial abnormalities after trauma. The presence of ventricular enlargement (33.3%) was significantly associated with trauma ($p = 0.014$), while the strong association between atrophy and ventricular dilation ($p = 0.002$) suggests that a considerable proportion of patients exhibited chronic or subacute injuries rather than purely acute lesions (1,2).

The lesion-specific findings further reinforce this pattern. Old ischemic infarctions were overwhelmingly predominant (83.3%), significantly higher than all other lesion types ($p < 0.001$). Additionally, all patients had no acute hemorrhage (0%), a highly significant pattern ($p < 0.001$). This supports evidence that trauma-related ischemic injury—often secondary to hypoperfusion, vasospasm, or microvascular dysfunction—may

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occur even in the absence of acute bleeding (3,4). The presence of 16.7% ischemic foci, while much lower ($p < 0.001$ when compared to infarction), supports the possibility of diffuse microvascular damage in a subset of individuals (5).
The distribution of lesion locations also aligns with recognized patterns of trauma-associated ischemia. Right-sided lesions were significantly more common than left-sided ones ($p < 0.001$), especially in the frontal (38.9%) and parietal (33.3%) lobes, both showing strong statistical significance ($p < 0.003$). These regions correspond to watershed areas that are vulnerable to ischemic injury following trauma-related perfusion deficits (6). The involvement of the basal ganglia (20%, $p = 0.041$) suggests deeper microvascular compromise, which has been previously linked to secondary ischemia in non-hemorrhagic traumatic brain injury (7). The significant predominance of multifocal lesions (33.3%, $p = 0.001$) further indicates that many patients experienced widespread cerebral involvement rather than isolated injury, consistent with acceleration–deceleration trauma mechanisms (8).
The absence of skull fractures in all patients underscores a crucial clinical message: meaningful intracranial pathology can occur without external head injury, reinforcing the importance of routine imaging after trauma (9). Additionally, MRI was recommended in 33.3% of cases, reflecting CT's limitations in detecting microbleeds or diffuse axonal injury. Current evidence strongly supports MRI—particularly DWI—as a superior modality for evaluating subtle, non-hemorrhagic traumatic lesions (10). Overall, the findings highlight three major points include ischemic rather than hemorrhagic pathology predominated in this trauma cohort; many injuries appeared chronic or subacute based on atrophy and ventricular enlargement; lesion distribution suggests vulnerability of watershed and deep brain structures. These results provide valuable baseline data for Libyan trauma research and emphasize the need to integrate CT and selective MRI into standardized trauma assessment protocols.

Conclusion

CT imaging in this study demonstrated that chronic ischemic lesions were the most frequent abnormalities among patients with head trauma, with no acute hemorrhages or skull fractures identified. The predominance of right frontal and parietal lobe involvement indicates vulnerability of watershed regions to trauma-related vascular changes. Additionally, the presence of atrophic and ventricular enlargement patterns suggests chronic or subacute injury rather than acute trauma alone. These findings emphasize the critical role of CT in early trauma assessment and provide valuable baseline data for understanding traumatic brain injury patterns in the region.

Conflict of interest. Nil

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