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EFFICIENCY OF CT SCAN ON DETECTING SKULL FRACTURES MISSED ON PLAIN RADIOGRAPHY IN TRAUMA PATIENTS

Original Research

Muhammad Yasir[1]*, Rashida Perveen[2], Fariha Yaseen[3], Muhammad Nauman Saleem[4]

[1] Master of Science in Allied Health Sciences, Department of Allied Health Sciences, Superior University Lahore, Pakistan.

[2] Professor, Department of Allied Health Sciences, Superior University Lahore, Pakistan.

[3] Bachelor of Sciences in Radiography and Imaging Technology, GC University Faisalabad, Pakistan.

[4] Master of Sciences in Diagnostic Ultrasound, University Institute of Radiological Sciences and Medical Imaging Technologies (UIRSMIT) Faculty of Allied Health Sciences (FAHS), The University of Lahore, Lahore, Pakistan.

Corresponding Author: Muhammad Yasir, Master of Science in Allied Health Sciences, Department of Allied Health Sciences, Superior University Lahore , aryanyasir86@gmail.com

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ABSTRACT

Background: Timely and accurate diagnosis of skull fractures in patients with head trauma is crucial to prevent severe neurological outcomes and guide immediate management. Although plain radiography (X-ray) is widely used for its accessibility and low cost, its diagnostic limitations in complex cranial regions often result in missed fractures. Computed tomography (CT), known for its high-resolution imaging, has emerged as the preferred modality in trauma settings due to its superior sensitivity and anatomical precision.

Objective: To assess and compare the diagnostic efficiency of CT and plain radiography in detecting skull fractures among patients presenting with traumatic head injuries.

Methods: A retrospective cohort study was conducted on 130 patients with traumatic brain injury who underwent both X-ray and CT imaging within 24 hours of hospital admission. Imaging was performed using FUJIFILM DR27936 for X-ray and a TOSHIBA 128-slice scanner for CT. Data on fracture presence, location, and complexity were extracted from radiologist reports. Diagnostic metrics including sensitivity, positive predictive value (PPV), and negative predictive value (NPV) were calculated using SPSS.

Results: CT scans identified skull fractures in 119 patients (91.5%), while X-rays detected fractures in only 89 patients (68.5%). X-rays failed to detect 30 fractures that CT revealed. The sensitivity, PPV, and NPV of CT were 91.5%, 100.0%, and 26.8% respectively. Fractures were most commonly located at the skull base (34.6%), followed by the frontal (24.6%) and parietal bones (17.7%). Complex fractures were more prevalent (53.1%) than simple fractures (45.4%).

Conclusion: CT scanning significantly outperforms plain radiography in detecting skull fractures, particularly in anatomically complex regions. Its high sensitivity and diagnostic accuracy make it essential for trauma assessment, and its use should be prioritized in emergency settings to ensure prompt and effective patient care.

Keywords: Craniocerebral Trauma, Diagnostic Imaging, Emergency Medical Services, Radiography, Sensitivity and Specificity, Skull Fractures, Tomography, X-Ray Computed.

INTRODUCTION

Skull fractures are a frequent and critical consequence of traumatic head injuries, necessitating prompt and accurate diagnosis to ensure appropriate medical intervention and minimize the risk of severe complications. Traumatic brain injuries (TBI) remain a leading cause of mortality and long-term disability worldwide, often resulting from falls, motor vehicle accidents, and interpersonal violence. In many cases, skull fractures accompany intracranial injuries, including hemorrhage and brain contusions, making early detection vital to patient outcomes (1). Among trauma patients undergoing imaging, approximately 32% are found to have maxillofacial fractures, often coinciding with cranial injuries (2). Skull base fractures alone are reported in 4% to 30% of hospitalized head injury cases, with the temporal bone being involved in nearly 40% of these instances (3). Traditionally, X-rays have been employed as the first-line imaging modality due to their accessibility, speed, and cost-effectiveness. However, the complexity of cranial anatomy, particularly in regions like the skull base, poses significant diagnostic challenges when using plain radiography. Overlapping bone structures and subtle fracture lines are often obscured, resulting in missed or delayed diagnoses (4). Studies have shown that X-rays may fail to identify up to 6.2% of skull fractures compared to advanced imaging methods (5). This shortfall carries potential risks, including delayed treatment and a higher likelihood of complications such as increased intracranial pressure, persistent neurological deficits, or even fatality (6).

Computed tomography (CT) has emerged as the superior imaging technique in the assessment of cranial trauma. With its high-resolution, cross-sectional imaging capabilities, CT allows for more accurate identification of fracture lines, even in anatomically complex regions. It demonstrates significantly higher sensitivity (83.72%), specificity (98.87%), and diagnostic accuracy (94.08%) than X-rays for detecting facial and skull fractures (7). In one study of 113 patients, CT identified 64 fractures (56.64%) while X-rays detected only 57 fractures (50.44%), highlighting CT's enhanced diagnostic yield (8). Furthermore, CT's reliability in identifying subtle or non-displaced fractures underscores its clinical value in acute trauma settings where timely intervention can alter patient prognosis (4,8). Despite the clear diagnostic advantages of CT, many healthcare settings-particularly in low-resource environments-continue to rely on X-rays due to limited access to advanced imaging modalities (9). This dependence often results in underdiagnosis and suboptimal care, particularly when injuries involve complex anatomical regions (10). While the clinical utility of CT in skull fracture evaluation is increasingly recognized, there remains a gap in standardized imaging protocols, especially regarding when to escalate from X-ray to CT. This lack of clarity in practice guidelines can result in inconsistent care and potentially adverse outcomes (11). The present study seeks to address this gap by evaluating the diagnostic efficacy of CT compared to plain radiography in the detection of skull fractures. The objective is to inform clinical decision-making and contribute to the development of evidence-based imaging protocols that prioritize patient safety, cost-effectiveness, and improved healthcare delivery.

METHODS

The researchers conducted a four-month retrospective cohort study within a clinical trauma setting to compare the diagnostic performance of X-ray and computed tomography (CT) in detecting skull fractures among patients with head trauma. The study included 130 patients who sustained traumatic head injuries and underwent both X-ray and CT imaging within 24 hours of hospital admission. Inclusion criteria required complete medical records and diagnostic-quality imaging. Patients were excluded if they had incomplete documentation, suboptimal image quality, or a history of prior skull surgery that could obscure radiological interpretation (2,3). As a retrospective study, all data were obtained from existing hospital records and imaging archives without direct patient interaction. Imaging had been previously conducted using FUJIFILM DR27936 digital radiography systems for X-rays and a TOSHIBA 128-slice CT scanner for computed tomography. All images were independently reviewed by experienced radiologists, blinded to each other's findings, in accordance with standard hospital diagnostic protocols.

Fractures identified on both imaging modalities were recorded and categorized based on anatomical location and fracture complexity. Additional data on patient demographics, clinical presentation, and injury mechanisms were extracted from medical records using a structured data collection form. No new questionnaires were administered, and no direct patient contact occurred, consistent with retrospective study design principles. Statistical analysis was performed using SPSS software to calculate sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) for each imaging modality. A p-value of less than 0.05 was considered statistically significant. Ethical approval for the study was obtained from the Institutional Review Board (IRB), and data confidentiality

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was maintained by anonymizing all patient information. Since this was a retrospective analysis of existing records, informed consent was waived by the ethics committee in accordance with institutional guidelines.

RESULTS

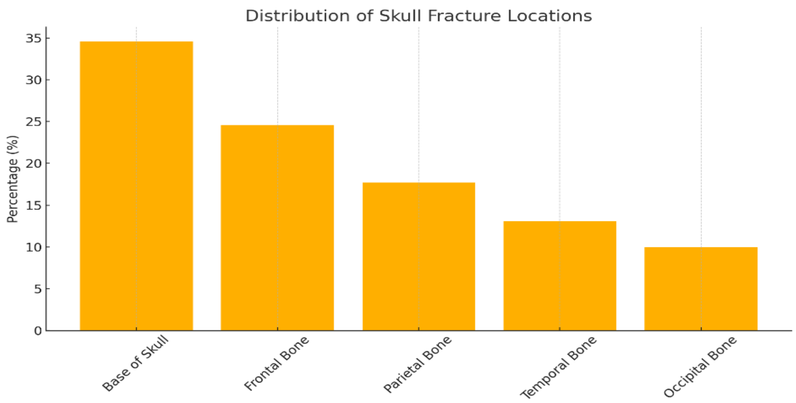
The study included 130 patients who presented with traumatic head injuries and underwent both X-ray and CT imaging within 24 hours of hospital admission. The mean age of participants was 49.98 years, ranging from 18 to 80 years. The sample had an almost equal gender distribution, comprising 66 males (50.8%) and 64 females (49.2%). CT imaging demonstrated superior diagnostic performance, detecting skull fractures in 119 out of 130 patients (91.5%). In contrast, X-ray imaging identified fractures in only 89 patients (68.5%), indicating that X-rays failed to detect fractures in 30 cases (31.5%) that were subsequently confirmed by CT. A comparison of detection rates revealed that CT identified all fractures seen on X-ray and additional cases that were missed, particularly in anatomically complex regions. Anatomical distribution of fracture locations showed that the base of the skull was the most commonly affected area, accounting for 34.6% of all cases. Frontal bone fractures were observed in 24.6%, parietal bone in 17.7%, temporal bone in 13.1%, and occipital bone in 10.0% of patients. This distribution underscored the challenge of detecting skull base and temporal bone fractures on plain radiographs due to structural complexity and overlapping anatomy.

In terms of fracture complexity, 69 patients (53.1%) had complex fractures, whereas 59 (45.4%) sustained simple fractures. A minor portion of the data (1.6%) included redundantly labeled entries (e.g., both "complex" and "Complex"), which were merged for consistency. The higher frequency of complex fractures further reinforced the diagnostic advantage of CT imaging over X-ray, which struggles with fine or obscured fracture lines. The analysis of injury mechanisms revealed that assault was the leading cause, responsible for 30.8% of cases, followed by falls at 26.9% and motor vehicle crashes at 26.2%. Road traffic accidents accounted for 6.2% of injuries. Less common causes included falls from stairs (3.1%), bike accidents (2.3%), car accidents (2.3%), and rare events such as street fights or falls associated with vertigo (each 0.8%). A cross-tabulation of fracture detection revealed that CT identified all 89 cases previously detected on X-ray and additionally uncovered 30 fractures missed by X-ray. Only 11 patients had no fractures detected on either imaging modality. Using this data, the sensitivity of CT in detecting skull fractures was calculated to be approximately 91.5%, based on 119 true positives and 11 false negatives.

Based on the cross-tabulated data comparing X-ray and CT fracture detection, additional diagnostic performance metrics were calculated to complement the previously established sensitivity. The positive predictive value (PPV), which represents the likelihood that patients with a fracture detected on X-ray truly had a fracture confirmed by CT, was 100% (PPV = 89 / [89 + 0]). The negative predictive value (NPV), reflecting the probability that patients with no fracture detected on X-ray truly did not have a fracture as confirmed by CT, was 26.8% (NPV = 11 / [11 + 30]). These findings reinforce the conclusion that while X-ray has high confirmatory value when a fracture is detected, it has poor reliability in ruling out fractures when none is observed, highlighting its limitations as a standalone diagnostic tool in trauma cases.

Table 1 Age Descriptive

N	Valid	130
	Missing	0
Mean		49.98
Minimum		18
Maximum		80



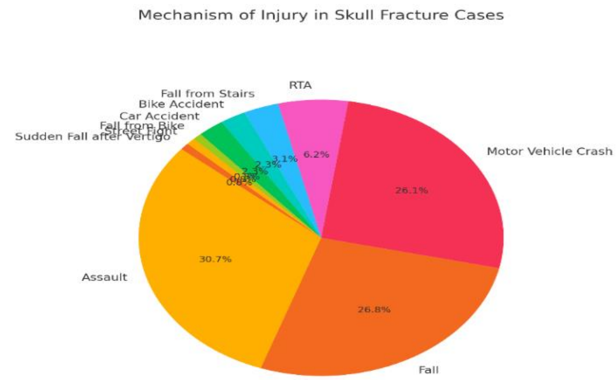


Table 2 Mechanism of Injury

	Frequency	Percent	Valid Percent	Cumulative Percent
Assault	40	30.8	30.8	30.8
Bike Accident	3	2.3	2.3	33.1
Car Accident	3	2.3	2.3	35.4
Fall	35	26.9	26.9	62.3
Fall From Bike	1	.8	.8	63.1
Fall From Stairs	4	3.1	3.1	66.2
Motor Vehicle Crash	34	26.2	26.2	92.3
RTA	8	6.2	6.2	98.5
Street Fight	1	.8	.8	99.2
Sudden Fall after Vertigio	1	.8	.8	100.0
Total	130	100.0	100.0	

Table 3 Distribution of Skull Fractures by Anatomical Location and Fracture Type

Fracture Location	**Frequency (n)**	**Percentage (%)**	**Fracture Type**	**Frequency (n)**	**Percentage (%)**
Base of Skull	45	34.6	Complex	70	53.8
Frontal Bone	32	24.6	Simple	60	46.2
Occipital Bone	13	10.0	—	—	—
Parietal Bone	23	17.7	—	—	—
Temporal Bone	17	13.1	—	—	—
Total	130	100.0	Total	130	100.0

Table 4 Cross table between Fracture Detected on X-Ray and Fracture Detected on CT

		CT Fracture Detected		Total
		No	Yes	
X-ray Fracture Detected	No	11	30	41
	Yes	0	89	89
Total		11	119	130

Table 5 Diagnostic Performance of X-Ray Compared to CT in Skull Fracture Detection

Metric	Value	Formula
Sensitivity	91.5%	119 / (119 + 11)
Positive Predictive Value (PPV)	100.0%	89 / (89 + 0)
Negative Predictive Value (NPV)	26.8%	11 / (11 + 30)

DISCUSSION

The findings of this study confirmed the diagnostic superiority of computed tomography (CT) over plain radiography in detecting skull fractures in trauma patients. CT scans identified fractures in 91.5% of cases, while X-ray imaging detected fractures in only 68.5%, with 31.5% of fractures missed by X-rays subsequently confirmed on CT (12). These results align with existing literature that consistently demonstrates CT as a more sensitive and specific modality, particularly in complex or anatomically challenging regions of the skull. The higher detection rate of CT was evident in fractures involving the base of the skull and temporal bones, regions commonly associated with overlapping structures that hinder visibility on plain radiographs (13). This reinforces the clinical utility of CT in trauma settings where early and accurate diagnosis is paramount for preventing complications. The present study also reflected prior evidence suggesting that X-rays have limited diagnostic value, particularly in cases involving complex fracture patterns or pediatric patients with incomplete skull ossification (14). Despite technological advancements and the emergence of AI-assisted radiographic interpretation, plain radiography remains insufficient in reliably identifying skull fractures across diverse patient demographics. CT, by comparison, has consistently demonstrated high sensitivity and remains the gold standard in cranial trauma evaluation. The observed predominance of complex fractures (53.1%) further underscored the limitations of X-ray imaging, which lacks the resolution to adequately visualize multiple fragments and subtle discontinuities (15).

In terms of anatomical distribution, the base of the skull accounted for the highest number of fractures (34.6%), followed by the frontal (24.6%) and parietal (17.7%) bones. These findings are consistent with earlier studies that reported skull base fractures in approximately one-third of patients with head trauma (16). The ability of CT to accurately detect fractures in these regions is critical, as delayed or missed diagnoses may lead to serious complications, including cerebrospinal fluid leaks, cranial nerve deficits, or intracranial hemorrhage. This diagnostic edge of CT is crucial in guiding clinical decisions, determining the need for surgical intervention, and preventing long-term morbidity (17). Although CT demonstrates clear advantages, concerns related to cost, accessibility, and radiation exposure persist. Some studies have emphasized the need for optimized imaging protocols that balance diagnostic efficacy with patient safety and healthcare resource utilization (18). The high number of fractures missed by X-ray in this study highlights the clinical and medico-legal risks associated with underdiagnosis. While CT should not be used indiscriminately, its selective use in high-risk patients or when initial X-ray findings are inconclusive is both justified and necessary (19). Future investigations should focus on refining criteria for CT utilization, exploring the efficacy of low-dose CT protocols, and evaluating the role of advanced radiographic interpretation tools, such as AI-enhanced algorithms, to minimize unnecessary imaging without compromising diagnostic quality.

One of the strengths of this study lies in its real-world clinical relevance, offering valuable insights into the comparative performance of imaging modalities in an acute trauma setting. The retrospective design, however, limits the generalizability of findings due to the single-center scope and relatively small sample size. Moreover, the absence of magnetic resonance imaging (MRI) as a secondary reference standard restricted the ability to assess associated soft tissue injuries, which could have provided a more comprehensive evaluation of cranial trauma. Future research should consider multi-center designs with larger patient cohorts and include MRI comparisons to further validate fracture detection strategies and enhance the overall diagnostic approach (20). In conclusion, the study reaffirmed CT as the preferred imaging modality for accurate and timely diagnosis of skull fractures, particularly in cases involving complex anatomical locations or fracture patterns. While X-ray remains a widely accessible first-line tool, its limited sensitivity necessitates caution in interpreting negative findings. The integration of evidence-based imaging protocols, supported by advanced technologies and risk-based triage strategies, remains essential for optimizing trauma care and patient outcomes.

CONCLUSION

This study concludes that computed tomography (CT) is a more reliable and clinically valuable imaging modality than plain radiography for the detection of skull fractures, particularly in anatomically complex regions where X-rays often fail to provide accurate results. The findings underscore the importance of prioritizing CT in trauma settings to ensure timely and precise diagnosis, reduce the risk of missed injuries, and guide appropriate patient management. By highlighting the diagnostic limitations of X-ray and reinforcing the strengths of CT, the research supports the integration of CT-based protocols in emergency care, offering significant contributions to improved clinical outcomes and patient safety.

Author Contribution

Author	Contribution
Muhammad Yasir*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Rashida Perveen	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
Fariha Yaseen	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Muhammad Nauman Saleem	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published

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