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EXPLORATION OF CT SCAN USAGE AND ITS ECONOMIC IMPACT; USED TO DIAGNOSE MILD HEAD TRAUMA IN DIFFERENT SELECTED CITIES OF PUNJAB, PAKISTAN

Original Research

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ABSTRACT

Background: Computed tomography (CT) scans are a widely utilized imaging modality for diagnosing and managing head trauma, particularly mild head injuries (MHI). While effective, their increasing use raises concerns about unnecessary radiation exposure, financial burden, and adherence to diagnostic guidelines. This study focuses on understanding current CT scan utilization rates, associated costs, patient awareness of radiation risks, and diagnostic practices in public and private healthcare settings to identify disparities and propose improvements.

Objective: To evaluate the current rates of brain CT scan utilization, adherence to diagnostic guidelines, cost implications, financial burden, and radiation awareness among patients with mild head trauma in public and private healthcare sectors.

Methods: This cross-sectional observational study included data from 384 patients of all age groups presenting with Glasgow Coma Scale (GCS) scores between 13 and 15. After excluding 60 patients who did not meet the inclusion criteria, the final dataset comprised 324 patients. Participants were divided into five groups: four based on adherence to established guidelines (NICE, NOC, ACEP, CCHR) and one for scans performed without guideline adherence. Data analysis was performed using SPSS software, focusing on demographic variables, hospital sector, diagnostic criteria, referral source, cost, and radiation awareness. Statistical significance was assessed for relationships between these variables.

Results: The mean age of the 324 patients was 38.15 ± 21.315 years (range: 1–90 years), with 174 females (53.7%) and 150 males (46.3%). An equal distribution was observed between private (162) and public (162) hospitals. Nearly half (49.7%) paid a fee of Rs. 4500, while 62.7% expressed discomfort with the cost. Radiation awareness was low in 59.3% of patients, and this varied significantly by fee category (p=0.000). Diagnostic criteria adherence was observed in 55.2% of cases, with private hospitals predominantly using NICE (18.5%), while public hospitals often followed no criteria (31.5%). Gender had no significant relationship with hospital sector or diagnostic criteria (p=0.656).

Conclusion: This study highlights critical disparities in CT scan utilization, cost burdens, and adherence to diagnostic standards between public and private healthcare sectors. Improved adherence to guidelines, enhanced patient education about radiation risks, and equitable cost structures are essential to achieving better patient outcomes and addressing inequalities across healthcare systems.

Keywords: Computed Tomography (CT), Diagnostic Imaging, Glasgow Coma Scale (GCS), Head Trauma, Mild Head Injury (MHI), Radiation Awareness, Traumatic Brain Injury (TBI).

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INTRODUCTION

Traumatic brain injury (TBI) is a significant medical and socio-economic concern, posing challenges to healthcare systems worldwide. The Glasgow Coma Scale (GCS) remains the standard for categorizing traumatic head injuries into severe, moderate, or mild; however, its effectiveness is limited in scenarios involving paralysis, medical sedation, intoxication, or endotracheal intubation, especially in patients presenting with a low GCS score (1, 2, 3). Mild head injury, characterized by a jolt or rapid movement of the brain, is generally non-fatal but can result in various symptoms and complications. Patients frequently visit emergency departments with mild head injuries (MHI), typically presenting GCS scores of 14 or 15. Despite the low risk of serious complications associated with MHI, computed tomography (CT) scans reveal no abnormalities in approximately 95% of these cases (4, 5).

Since the introduction of CT technology in the early 1970s, its utilization has grown exponentially across the globe, including in Pakistan, leading to increasing medical radiation exposure. Currently, CT scans contribute to nearly 50% of the total medical radiation burden to patients, making them the highest source of diagnostic radiation (6, 7). The intensity and frequency of head trauma significantly influence acute and chronic pathophysiological reactions in the brain, necessitating effective diagnostic tools for accurate evaluation (8). Several evidence-based guidelines, such as ACEP, NOC, CCHR, and NICE, assist clinicians in determining the necessity of CT scans for patients with mild trauma. Indications such as advanced age, persistent memory loss, or vomiting often guide these decisions. However, despite these criteria, concerns regarding the overuse of CT scans persist, particularly in cases with mild symptoms (9). Radiation exposure from CT scans presents notable health risks. Children undergoing CT scans are especially vulnerable, with an increased risk of developing blood, brain, or bone cancers, sometimes up to three times higher than unexposed populations (10). Similarly, the lens of the eye, being among the most radiosensitive tissues in the human body, is particularly susceptible to radiation-induced cataracts—a risk exacerbated by frequent diagnostic CT imaging (12). Furthermore, while certain patients recover swiftly from mild head injuries, others experience prolonged symptoms, significantly impacting their quality of life over months or even years (11). This variability underscores the importance of judicious decision-making in diagnostic imaging.

Unnecessary CT scans for mild head trauma, especially in the absence of loss of consciousness or severe symptoms, remain a growing concern. Overutilization of this diagnostic modality not only exposes patients to harmful radiation effects but also places undue financial burdens on healthcare systems. It risks diverting resources away from patients who genuinely require imaging, compromising timely and effective care. Moreover, excessive diagnostic measures may contribute to patient anxiety, public health risks, and long-term sustainability challenges for healthcare systems (4, 13, 14).

The objective of this exploration is to analyze the utilization of CT scans in diagnosing mild head trauma and assess its economic impact across selected cities of Punjab, Pakistan. This study aims to rationalize CT scan use by addressing the balance between clinical necessity and public health sustainability.

METHODS

The study was designed as a cross-sectional observational analysis involving data collected from 384 patients across all age groups who presented with Glasgow Coma Scale (GCS) scores between 13 and 15. The sample was selected through non-probability convenience sampling to ensure accessibility. However, 60 patients were excluded from the analysis as their data did not meet the study's inclusion criteria or align with established guidelines. Consequently, the final dataset consisted of 324 patients who met the eligibility requirements. In adherence to diagnostic guidelines, patients were categorized into four groups based on the NICE, NOC, ACEP, and CCHR criteria. An additional fifth group was included for patients who underwent CT scans without adherence to any recognized guidelines, allowing for a comparative analysis of guideline-based and non-guideline-based imaging practices. Data collection focused on multiple parameters, including the mechanism of trauma, the type of hospital (public or private sector), geographic region, patient demographics such as age, referral status, clinical history, financial cost of the CT scan, and the patient's awareness of radiation risks.

Data analysis was conducted using SPSS software to assess trends in CT scan utilization and their financial implications. The study explored the impact of variables such as trauma severity, regional disparities, referral patterns, and patient characteristics on the frequency of CT scan usage. Furthermore, the study evaluated the economic burden on patients, linking the findings to broader concerns about healthcare sustainability and overuse of diagnostic imaging. Ethical approval for the study was obtained from the Research Ethics

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and Support Committee. Informed consent was secured from all patients or their legal guardians, ensuring compliance with ethical standards. It is worth noting that while the inclusion of a fifth group of patients undergoing CT scans without any guideline-based justification provided a unique perspective, it also raises concerns about the rationale and consistency of imaging practices. This group's inclusion highlights potential areas for improvement in clinical decision-making and resource allocation.

RESULTS

The study explored the utilization of CT scans and their economic impact in diagnosing mild head trauma across selected cities in Punjab, Pakistan. Data from 324 patients fitting the inclusion criteria were analyzed, revealing significant findings regarding demographics, referral patterns, diagnostic criteria, and patient awareness of radiation risks. The demographic analysis showed a mean patient age of 38.15 ± 21.315 years, with a minimum age of 1 year and a maximum of 90 years. Gender distribution was slightly skewed, with 174 females and 150 males. The hospital sector was evenly distributed, with 162 patients each from public and private hospitals. All patients underwent CT scans specifically for brain trauma, with car-car accidents identified as the leading mechanism of injury (17.6%). The majority of referrals were made by neurophysicians (32.1%), and a significant portion of patients reported episodic loss of consciousness (33.6%) as a key symptom.

Diagnostic practices were found to vary significantly between private and public hospitals (p=0.000). Among patients, 55.2% underwent CT scans based on established criteria, with the remaining 44.8% undergoing scans without adherence to guidelines. The breakdown of diagnostic criteria indicated a higher adherence to national and international protocols in public hospitals, whereas private hospitals exhibited a larger percentage of patients who underwent scans without any criteria. Furthermore, radiation awareness was notably low, with 59.3% of patients unaware of the associated risks, highlighting an area for improvement in patient education and informed consent processes. Economic analysis revealed that 49.7% of patients paid a fee of 4500 PKR, with 62.7% expressing discomfort regarding the expense. While this discomfort was not statistically significant (p=0.261), the relationship between radiation awareness and fee structure was significant (p=0.000). Private hospitals predominantly charged higher fees, with 81 patients paying 4500 PKR and an additional 81 paying 5000 PKR. Public hospitals did not charge patients beyond 2500 PKR, illustrating a stark contrast in financial accessibility between the two sectors. These findings underscore the need for standardized diagnostic practices, enhanced radiation awareness, and equitable cost structures to improve patient outcomes and healthcare sustainability.

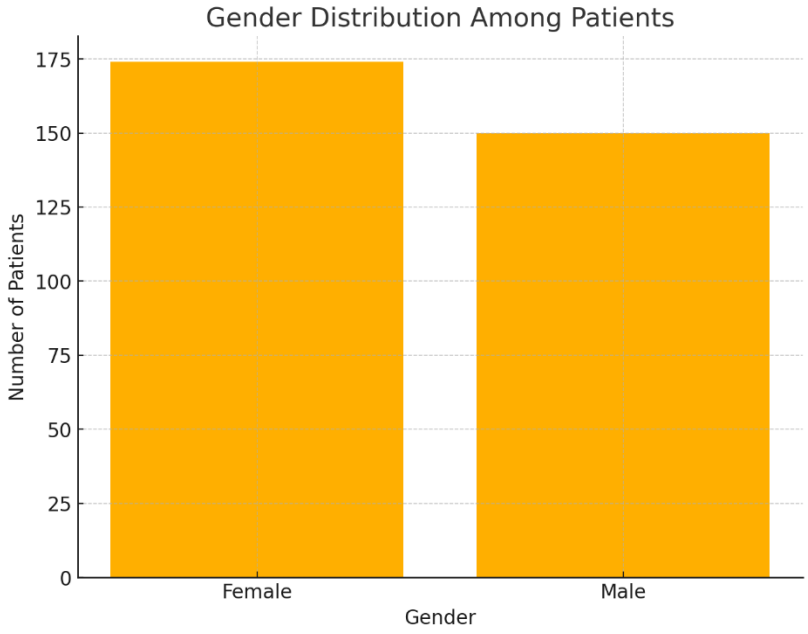


Figure 1 Gender Distribution Among Patients

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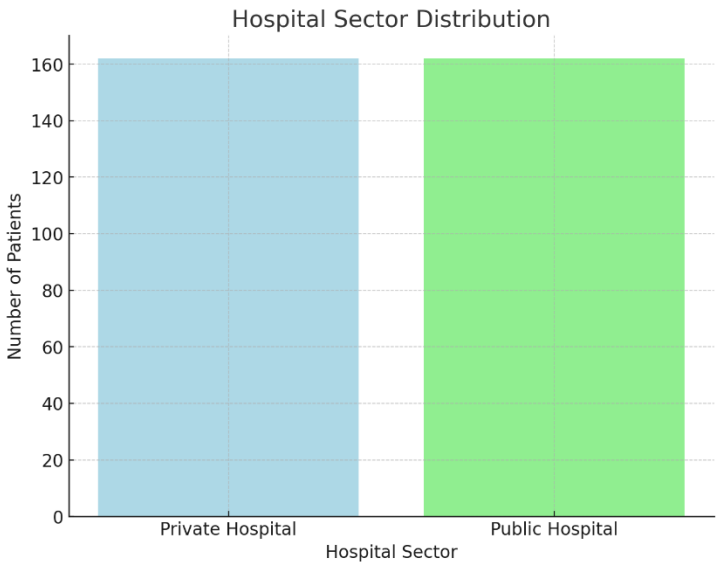


Figure 2 Hospital Sector Distribution

The Gender Distribution chart illustrates that out of 324 patients included in the study, 174 were female, accounting for 53.7% of the total, while 150 were male, representing 46.3%. The Hospital Sector Distribution chart highlights an equal representation of patients between private and public hospitals, with 162 patients (50%) in each sector. This balance provides a comparative basis for analyzing diagnostic practices and financial impacts across different healthcare settings.

Table 1 Summary of Referral and Patient Data

Category	Details
Highest references range of patients	Neuro physicians (32.1%)
Mechanism of Trauma	Car-car accidents (17.6%)
History	Episodic Loss of Consciousness (LOC) (33.6%)
Diagnostic Criteria	Established Criteria (55.2%)
Patient Awareness	No (59.3%).

The referral and patient data analysis revealed that the highest percentage of referrals came from neurophysicians, accounting for 32.1% of cases. The most common mechanism of trauma was car-to-car accidents, reported in 17.6% of patients. A significant portion, 33.6%, experienced episodic loss of consciousness (LOC) as a key symptom. Diagnostic imaging based on established criteria was observed in 55.2% of cases, while 59.3% of patients lacked awareness about the potential risks of radiation exposure from CT scans. These findings highlight gaps in both patient education and adherence to diagnostic guidelines.

Table 2 Summary of Fee Analysis

Category		Fee			Total	p value
		2500	4500	5000		
Patient Comfortable with fee	No	48	108	47	203	.261
	Yes	34	53	34	121	
Patient Awareness about radiations	No	38	85	69	192	.000
	Yes	44	76	12	132	
Hospital Sector	Private	0	81	81	162	.000

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	Public	82	80	0	162

The fee analysis indicated that 49.7% of patients paid 4500 PKR for their CT scans, while 62.7% (203 patients) expressed discomfort with the fees, although this discomfort was not statistically significant (p=0.261). Radiation awareness was notably low among patients paying higher fees, with 192 patients (59.3%) unaware of radiation risks, a relationship that was statistically significant (p=0.000). Fee distribution varied by hospital sector, with private hospitals charging 4500 or 5000 PKR for all 162 patients, while public hospitals charged 2500 PKR for their 162 patients, reflecting a significant difference between the two sectors (p=0.000).

Table 3 Summary of Statistical Significance Between Variables and Hospital Sector

Category		**Hospital Sector**		**Total**	**p value**
		Private	Public		
Gender	Female	89	85	174	.656
	Male	73	77	150	
Diagnostic Criteria	Group A=National Institute of Health and Clinical Excellence	60	0	60	.000
	Group B = New Orleans Criteria	38	0	38	
	Group C = American College of Emergency Physician	1	47	48	
	Group D = Canadian Computed Tomography Head Rules	0	33	33	
	Group E= No Criteria Followed	43	102	145	

The statistical analysis showed no significant relationship between gender and hospital sector distribution, with 89 females and 73 males in private hospitals and 85 females and 77 males in public hospitals (p=0.656). Diagnostic criteria use varied significantly by hospital sector (p=0.000). In private hospitals, 60 patients were evaluated using the NICE criteria, 38 using the New Orleans Criteria, and 43 underwent scans without any established guidelines. In contrast, public hospitals had 47 patients assessed with ACEP criteria, 33 with Canadian CT Head Rules, and 102 without adherence to any diagnostic guidelines. This highlights a disparity in adherence to diagnostic standards between the two sectors.

DISCUSSION

The findings of this study highlighted critical disparities in brain CT usage, diagnostic practices, and economic impact across public and private healthcare sectors in Punjab, Pakistan. The analysis of 324 patients revealed significant variation in fees, adherence to diagnostic criteria, and patient awareness of radiation risks. Private hospitals predominantly utilized specific diagnostic criteria such as NICE, whereas public hospitals showed a higher prevalence of scans conducted without adherence to any guidelines. This discrepancy underscores the uneven implementation of clinical decision rules and the potential for overuse of CT scans in settings lacking standardized protocols.

One of the study's key strengths was its balanced sample distribution between public and private hospitals, which allowed for meaningful comparisons of diagnostic practices and associated costs. It revealed that public hospitals primarily served patients at lower fees, such as Rs. 2500, whereas private hospitals charged significantly higher fees, such as Rs. 4500 and Rs. 5000 (p=0.000). The discomfort expressed by 62.7% of patients regarding these fees, coupled with the low awareness of radiation risks in 59.3% of patients, highlights gaps in financial accessibility and patient education. Private facilities provided easier access to services, but the higher costs imposed financial strain on patients, indicating the need for more equitable healthcare financing mechanisms.

Despite the strengths of the study, limitations included reliance on non-probability sampling, which may have introduced selection bias, and the absence of long-term follow-up data to assess patient outcomes after imaging. Furthermore, while public hospitals provided cost-effective services, their frequent non-adherence to guidelines, as observed in 44.8% of cases, reflected inefficiencies in diagnostic

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decision-making. Overuse of CT scans, especially in cases not meeting any established criteria, contributes to unnecessary radiation exposure, increased healthcare costs, and resource misallocation. These findings align with global evidence, such as studies in Kerala and Palestine, which also reported overuse of CT scans, inconsistent adherence to diagnostic standards, and the need for enhanced clinician education on radiation risks and cost-effective care (15, 17). The study also emphasized the utility of clinical decision rules such as the New Orleans Criteria and the Canadian CT Head Rule in improving diagnostic accuracy. Existing evidence supports the effectiveness of these guidelines in reducing unnecessary imaging and promoting more targeted use of CT scans, thereby lowering costs and enhancing patient outcomes (18, 19). The Rotterdam criteria have been identified as a strong predictor of outcomes in traumatic brain injury cases, reinforcing the importance of adherence to evidence-based practices (18). The findings of this study suggest that adopting standardized protocols, particularly in public hospitals, could mitigate overuse, reduce financial strain on patients, and enhance care delivery (20).

A recent comparative study conducted in India examined CT scan utilization in urban and rural healthcare settings to evaluate diagnostic adherence and economic burden. The study involved 410 patients presenting with mild head trauma and compared adherence to NICE, NOC, and ACEP guidelines across public and private hospitals. In urban centers, private hospitals adhered to guidelines in 71% of cases, while public hospitals showed adherence in only 54%. Rural hospitals exhibited significantly lower adherence, with private and public facilities adhering in just 38% and 29% of cases, respectively. The economic analysis revealed that urban private hospitals charged nearly twice as much as public hospitals for CT scans, while rural hospitals showed minimal cost variations between sectors but still struggled with diagnostic overuse. The study concluded that urban centers generally performed better in following clinical decision rules, reducing unnecessary imaging and radiation exposure. However, rural areas experienced widespread overuse and inadequate adherence, largely driven by resource limitations and lack of clinician training. These findings parallel the disparities identified in this study between public and private hospitals in Punjab, further emphasizing the global relevance of standardizing diagnostic practices and enhancing healthcare equity (21).

Another recent comparative study conducted in Turkey explored CT scan usage and diagnostic adherence in 450 patients with mild head trauma across tertiary and secondary care hospitals. The research found that tertiary care hospitals adhered to established clinical guidelines, such as the Canadian CT Head Rule (CCHR), in 68% of cases, while secondary care hospitals demonstrated adherence in only 42% of cases. The study also highlighted significant disparities in patient awareness, with 57% of patients in tertiary hospitals being informed about radiation risks, compared to only 24% in secondary hospitals. Cost analysis revealed that tertiary hospitals charged approximately 20% higher fees than secondary hospitals, but their stricter adherence to diagnostic guidelines resulted in lower rates of unnecessary imaging. The findings emphasized the role of advanced infrastructure and clinician training in promoting evidence-based practices. This aligns with the results of the current study, which revealed better diagnostic adherence in private hospitals, albeit at a higher cost, and highlights the need for standardized protocols across all healthcare settings (22).

CONCLUSION

This study underscores significant disparities in diagnostic practices and financial burdens associated with brain CT scans across private and government healthcare settings. The findings highlight the critical need for improved adherence to established diagnostic standards, enhanced patient awareness of radiation risks, and greater transparency in cost structures. Bridging these gaps could promote equitable access to diagnostic imaging, reduce unnecessary radiation exposure, and alleviate financial strain on patients. Addressing these challenges aligns with the broader objective of improving patient outcomes and fostering a more sustainable and balanced healthcare system.

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AUTHOR CONTRIBUTIONS

Author	Contribution
Maha Shafi	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Huma Akbar	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
Qurat Ul Ain*	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Ifra Mustafa	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Ayesha Mehmood	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Areej Hassan	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published
Toheed Ahmad Danish	Contributed to study concept and Data collection Has given Final Approval of the version to be published

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