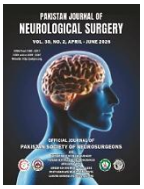

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Original Research

Role of Emergency Medicine in Identifying and Stabilizing Acute Neuroinfections

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ABSTRACT

Objective: Emergency medicine's contribution to early detection, imaging-based diagnosis, and initial stabilization of patients with acute neuroinfections (meningitis and encephalitis) in the context of tertiary care hospital care.

Materials and Methods: For this study, doctors observed patients in the Emergency Department of Lady Reading Hospital in Peshawar. A total of 200 patients who were suspected of having serious brain or nervous system infections were included. Their symptoms were checked, and brain scans using CT and MRI were done. The treatments given to patients were also recorded. The doctors compared the patients' symptoms with their scan results to see how well they matched. Finally, the findings were also compared with results from other studies in the medical literature.

Results: Out of 200 patients, 112 (56%) were male and 88 (44%) females, with a mean age of 34.2 ± 13.8 years. Sixty-one percent (61%) received a CT scan; 29% received an MRI scan, and 10% received both CT and MRI scans. The final diagnoses were bacterial meningitis (36%), viral encephalitis (19%), tuberculous meningitis (17%), brain abscess (14%), fungal infections (8%), and ventriculitis (6%). Radiological features were leptomeningeal enhancement (40.5%), ring-enhancing lesions (13%), temporal lobe restriction (9.5%), hydrocephalus (15.5%), and infarcts (7%). Significant statistical correlations were demonstrated between particular imaging patterns and end diagnosis (set at $p < 0.05$).

Conclusion: The early recognition and stabilization of CNS infections play a critical role for EDs. Early management (prompt neuroimaging, high clinical suspicion, and early empiric therapy initiation) is an important part of early management and improved outcomes. MRI, especially advanced sequences, offers valuable diagnostic information. Standardize emergency protocols to maximize care for neuroinfected patients, especially in resource-limited areas.

Keywords: Neuroinfection, Emergency Medicine, Meningitis, Encephalitis, Brain Abscess.

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INTRODUCTION

Neuroinfections like meningitis, encephalitis, brain abscess, and central nervous system (CNS) infection are time-urgent neurological emergencies that may cause high morbidity and mortality. Prompt clinical recognition and the early initiation of treatment are associated with poor neurological outcomes, including long-term disability and death, and are crucial in these conditions. Early decision-making is consequently a key aspect in determining prognosis in these patients in emergency medicine.

Patients with suspected CNS infections typically arrive in the emergency department (ED) with vague symptoms, but carry a high risk of infection to the CNS, such as fever, headache, altered mental status, seizures, vomiting, and stiff neck. There are, however, several other acute neurological and systemic conditions with similar clinical characteristics, including stroke, intracerebral hemorrhage, metabolic encephalopathy, toxic ingestion, and autoimmune encephalopathy. This diagnostic overlap is a problem for early recognition, especially in busy emergency departments where quick decision-making, triage, and management are needed. Therefore, the diagnosis is based upon clinical suspicion, prompt investigation, and prompt empirical therapy, and not definitive confirmation, in the emergency department.

The emergency department is the first line of contact for most patients with acute neuroinfections, and makes a critical contribution. First, the airway, breathing, and circulation should be assessed as quickly as possible, stabilized, and seizures controlled, and raised ICP managed, if present. Such early interventions are crucial in averting clinical deterioration, especially in patients who have diminished alertness or are in a severely compromised neurological state. At the same time, it is advisable to start empirical antimicrobial and antiviral treatment as soon as CNS infection is suspected, since several studies have demonstrated that treatment delay is linked to higher mortality and poor neurological outcome.

Neuroimaging is an integral part of the early evaluation in the emergency setting. Computed tomography (CT) is the initial imaging modality of choice because it is readily available and useful in the diagnosis of life-threatening abnormalities, including hydrocephalus, mass effect, midline shift, intracranial hemorrhage, and space-occupying lesions. CT is also helpful in ruling out contraindications to lumbar puncture, which may be necessary for definitive diagnosis. In this regard, however, there are limitations in detecting early changes in the parenchyma and meningeal aspects, especially in viral encephalitis, early meningitis, etc.

Magnetic Resonance Imaging (MRI): MRI is more sensitive and has better contrast of soft tissues, which helps detect early inflammatory changes in the brain and meninges. Use of advanced MRI sequences like diffusion-weighted imaging (DWI) and fluid-attenuated inversion recovery (FLAIR) and post-contrast imaging greatly increases the diagnostic usefulness in encephalitis, tuberculous meningitis, and brain abscesses. In many emergencies, however, MRI is not widely available and is not the first choice of imaging modality, as in resource-limited environments, CT becomes the first imaging modality.

While the CSF analysis is still the diagnostic gold standard for CNS infections, its use in the emergency setting is occasionally delayed due to contraindications, the requirement for prior

neuroimaging, or laboratory limitations related to capacity and turnaround time. In these cases, the decision to treat the patient rests almost entirely on the emergency physician's judgment, which is based upon imaging results and the results of basic laboratory tests. This is a reminder of the need for clinical judgment and standard emergency protocols that will lead to early management decisions.

Although the prevalence of CNS infections has decreased, it remains high in the low-resource-constrained settings of the LMC countries like Pakistan and low- and middle-income countries, where lack of timely presentation, access to advanced imaging, and resource constraints in the ED contribute to this. These challenges can place an undue burden on emergency physicians, requiring them to make swift and critical diagnostic and therapeutic decisions in high-pressure situations. Earlier detection and better outcomes can be achieved in these patients by strengthening emergency care systems and facilitating access to neuroimaging and the use of standardised protocols.

Hence, this study is aimed at assessing the contribution of emergency medicine in early detection, imaging diagnosis, and primary management of patients with suspected acute neuroinfections in the tertiary care emergency department. The study also emphasizes the need for prompt neuroimaging and empirical therapy to aid early clinical decision-making and optimize patient outcomes in a resource-limited environment.

MATERIALS AND METHODS

Design and Setting of the Study

This study was carried out over six months, from July to December 2024, in the Emergency Department of Lady Reading Hospital, a large teaching hospital in Peshawar that treats many patients with serious brain and nerve-related illnesses. It was a prospective observational study, meaning patients were observed and their condition was recorded as they were treated, without changing their usual care. The study was approved by the hospital's Institutional Review Board (Reference: NO. 220/LRH/MTI). Before taking part in the study, all patients or their legal guardians were asked to give written consent.

Inclusion Criteria

Two hundred patients who attended the ED with a clinical diagnosis of acute neuroinfection were included in the study. Clinical suspicion was categorized as having undergone a neurological symptom (altered mental status, headache, stiff neck, photophobia, vomiting, or seizures) and a fever.

All patients 1 year and older of either sex were included. Patients with a history of central nervous system malignancy, recent neurosurgical intervention, or inadequate or nondiagnostic imaging studies were excluded.

Exclusion Criteria

Patients who did not consent and who did not have adequate clinical information were also excluded. Assess the patient and begin treatment from the outset. Evaluate the patient and start treatment from the beginning.

Clinical Management

Vital signs, Glasgow Coma Scale (GCS), neurological exam, and systemic evaluation were performed by emergency physicians in all patients. Where necessary, immediate stabilization was carried out: airway protection, seizure control, and hemodynamic support. Empirical antimicrobial therapy was begun immediately, based upon clinical suspicion. For suspected bacterial infection, ceftriaxone and vancomycin were administered, and acyclovir was added if viral encephalitis was suspected. As soon as possible, and ideally within an hour of an injury being suspected, treatment

was started as per standard first aid and emergency care procedures.

Radiological Assessment

Neuroimaging was done while in the ED. Most patients initially received computed tomography (CT) imaging, which was both readily available and helpful in ruling out contraindications to lumbar puncture and distinguishing complications like hydrocephalus, hemorrhage, and/or mass effect. Magnetic resonance imaging (MRI) was used when clinically indicated and available. MRI sequences were T1-weighted, T2-weighted, fluid-attenuated inversion recovery (FLAIR), diffusion-weighted imaging (DWI), apparent diffusion coefficient (ADC), susceptibility-weighted imaging (SWI), and post-contrast T1-weighted. Clinical stability, need for diagnosis, and availability of imaging resources were used for the selection of the imaging modality.

Laboratory Investigations

Routine laboratory tests were done to determine baseline values of complete blood count (CBC), serum electrolytes, renal and liver function tests, and inflammatory markers (C-reactive protein [CRP]). Blood cultures were drawn before antibiotic therapy was started (if possible). Lumbar puncture was done when medically safe (excluding imaging results or clinical instability). Laboratory investigations of cerebrospinal fluid (CSF) encompassed cell count and differential, glucose, CSF protein, Gram stain, acid-fast bacilli (AFB) smear, and culture. Herpes simplex virus (HSV) and Mycobacterium tuberculosis (MTB) testing by polymerase chain reaction (PCR) was done as available. The data collection procedures and outcome measures used were recorded on a structured proforma, which included demographic variables, clinical presentation, imaging findings, laboratory findings, and treatment information. Diagnoses were made based on clinical evolution, imaging, CSF findings, and treatment response. Secondary outcomes were admission to the intensive care unit (ICU), neurosurgical management, and in-hospital death.

Statistical Analysis

SPSS 26.0 software was used for the analysis of the data. Demographic and clinical parameters were summarized using descriptive statistics. Categorical variables are presented in frequency and percent. Chi-square test was used to determine the association between imaging findings and final diagnosis. A p-value of <0.05 was deemed statistically significant.

RESULTS

Demographic Profile

A total of 200 patients with clinical suspicion of acute central nervous system (CNS) infection were included in this prospective observational study. The mean age was 34.2 ± 13.8 years (range: 1–70 years). There were 112 males (56%) and 88 females (44%).

Imaging Utilization

All patients underwent neuroimaging during emergency department evaluation. Computed tomography (CT) was performed in 122 patients (61%), magnetic resonance imaging (MRI) in 58 patients (29%), and both CT and MRI in 20 patients (10%). Imaging modality selection was based on clinical condition, urgency, and availability.

Table 1: *Demographic and Imaging Characteristics.*

Variable	Value
Total patients	200
Mean age (years)	34.2 ± 13.8
Age range (years)	1–70
Male	112 (56%)
Female	88 (44%)
CT performed	122 (61%)
MRI performed	58 (29%)
Both CT & MRI	20 (10%)

Final Diagnostic Categories

Based on clinical assessment, neuroimaging, and

laboratory findings, the final diagnoses were as follows.

Radiological Findings

Neuroimaging provided important diagnostic support, particularly in cases where lumbar puncture was delayed or contraindicated.

Table 2: *Final Diagnostic Categories.*

Diagnosis	Number of cases	Percentage (%)
Bacterial meningitis	72	36.0%
Viral encephalitis	38	19.0%
Tuberculous meningitis	34	17.0%
Brain abscess	28	14.0%
Fungal CNS infection	16	8.0%
Ventriculitis	12	6.0%

Association Between Imaging Findings and Final Diagnosis

Significant associations were observed between specific radiological patterns and final diagnoses. Ring-enhancing lesions showed a statistically significant association with brain abscess ($p < 0.001$). Temporal lobe diffusion restriction was significantly associated with viral encephalitis ($p = 0.002$), while hydrocephalus with basal meningeal enhancement demonstrated a significant association with tuberculous meningitis ($p = 0.005$).

Table 3: *Radiological Findings.*

Radiological Feature	Number of cases	Percentage (%)
Leptomeningeal enhancement	81	40.5%
Hydrocephalus	31	15.5%
Ring-enhancing lesions	26	13.0%
Temporal lobe diffusion restriction	19	9.5%
Infarcts	14	7.0%
Ventriculitis features	12	6.0%

Table 4: *Association Between Radiological Features and Final Diagnosis.*

Radiological Feature	Associated Diagnosis	p-value
Ring-enhancing lesions	Brain abscess	<0.001
Temporal lobe diffusion restriction	Viral encephalitis	0.002
Hydrocephalus + basal enhancement	Tuberculous meningitis	0.005

Neuroimaging played a crucial role in early diagnostic stratification in the emergency department. CT was primarily used for rapid exclusion of life-threatening conditions, while MRI provided higher diagnostic specificity, particularly in cases of encephalitis, tuberculous meningitis, and brain abscess. Imaging findings significantly supported early empirical treatment decisions in emergency settings.

DISCUSSION

Central nervous system (CNS) infections, such as meningitis, encephalitis, brain abscess, and ventriculitis, continue to be some of the most time-critical neurological emergencies in clinical practice. These conditions can be linked to considerable morbidity and mortality, especially if delayed diagnosis and treatment are ignored. The first few hours following patient presentation in emergency medicine are crucial, and timely recognition, stabilization, and treatment (empirical therapy) can make a huge difference in patient outcomes. The importance of the role of the emergency department (ED) in early detection and diagnosis and initial management of any patient who presents with a suspected acute neuroinfection is emphasized in the present study.

Bacterial meningitis was the most common diagnosis of CNS infection in our study, followed by tuberculous meningitis and viral encephalitis. This distribution is typical of the ongoing problem of infectious neurological diseases in low and middle-income countries, where delayed presentation, poor preventive health care, and infectious disease prevalence lead to high numbers. The relatively high occurrence of tuberculous meningitis also suggests the endemic

pattern of tuberculosis in our region, in accordance with other studies done in South Asia. An emergency medicine perspective is that a high level of suspicion for CNS infection must be kept in mind for all children with fever and altered mental status, particularly when at risk in the hospital environment.

Early clinical presentation of neuroinfections is often non-specific, which is one of the major difficulties in diagnosis during emergencies. The fever, headache, vomiting, and seizures are symptoms that may occur in a variety of other neurological and systemic illnesses, such as stroke, metabolic encephalopathy, intracranial hemorrhage, and toxic or autoimmune diseases. This diagnostic uncertainty frequently requires hasty decision-making with incomplete information. The results of this study do support the notion that no definitive laboratory confirmation is necessary and that early imaging and early empirical treatment are essential in the management of an emergency department.

Diagnostic imaging was a key component of the diagnostic process in our study population. Computed tomography (CT) was most frequently used for initial imaging because it was readily available and helped exclude life-threatening abnormalities like intracranial hemorrhage, mass lesions, hydrocephalus, and significant midline shift. These results are especially valuable in emergencies when lumbar puncture is contraindicated or delayed. CT, however, is not a particularly sensitive investigation for early detection of parenchymal or meningeal inflammation, and underdiagnoses early disease.

When available, magnetic resonance imaging (MRI) yielded a much higher degree of diagnostic sensitivity, especially for the diagnosis of viral encephalitis, tuberculous meningitis, and brain abscess. Advanced MRI sequences, including Diffusion Weighted Imaging (DWI) and Fluid-attenuated inversion recovery (FLAIR), were used to help detect subtle pathological changes early. Despite the fact that MRI is not routinely available in emergencies and it can be more time-consuming, its use in early evaluation pathways for the diagnosis of emergency conditions can be significant.

One of the important results of this study is the strong correlation between the radiological patterns and the diagnoses at the end of the study. Ring-enhancing lesions were strongly correlated with brain abscess, temporal lobe diffusion restriction with viral encephalitis, and hydrocephalus with basal meningeal enhancement with tuberculous meningitis. These findings are clinically relevant as they reinforce the idea of pattern diagnosis when interpreting the images of an emergency neuroimaging. In the clinical acutenity of real-life emergencies, microbiological confirmation can take hours to days, and these imaging patterns can help to inform early clinical decisions and empirical therapy.

The imaging correlations have direct implications in emergency medicine from the point of view of patient management. For instance, if the lesion is associated with a fever and neurological symptoms, then early antibiotic treatment with broad-spectrum antibiotic coverage and a referral to neurosurgery should be considered. Likewise, if a patient has an altered mental status and significant changes in the temporal lobe seen on MRI, think of viral encephalitis, specifically herpes simplex virus (HSV), and start antiviral therapy ASAP. Tuberculous meningitis should be strongly suspected in cases of hydrocephalus associated with basal meningeal enhancement, and early treatment with antitubercular treatment is warranted, with consideration of corticosteroid therapy. These results underscore the importance of imaging in the gap of diagnosis in emergency care.

The second issue to be stressed in our study is early empirical therapy. Definitive diagnosis by cerebrospinal fluid (CSF) analysis may be delayed in many situations because it is not logistically feasible or is contraindicated, or because of limited laboratory capacity. So frequently, the diagnosis in

an emergency is made on a combination of clinical and radiological suspicion, and treatment is initiated on that basis. This practice is supported by international guidelines that advise early administration of antibiotics and antivirals when CNS infection is suspected. Our results support this strategy and illustrate its applicability in an emergency context with limited resources available.

The study also emphasizes the need for the development of protocols for the structured management of suspected CNS infections at the emergency department. A standardized pathway combining a quick clinical evaluation, early neuro-imaging, and immediate empirical therapy can vastly shorten the time to treatment. If your ED is large, these procedures are critical to providing consistent and timely care. Moreover, education of emergency physicians on the recognition of neuroimaging patterns can improve the accuracy of diagnosis and improve the clinical outcomes.

Our results were similar to previous literature, which focused on the diagnostic importance of MRI in CNS infections and CT in the initial emergency triage. Our study brings the practical aspect of imaging and clinical judgment into the Emergency Management decision-making process, especially in resource-limited settings, however. This differs from tertiary neurology-based studies, as they represent the later, more differentiated stage of presentation of the patient, which is most applicable to emergency medicine practice.

There are some clinical implications of this study. First, there is a need to strengthen the need for rapid triage systems in the Emergency Departments, which prioritise the suspected cases of CNS infection. Secondly, it facilitates the incorporation of imaging-based diagnostic pathways within the emergency pathway. Third, it focuses on the need to treat patients with definite laboratory evidence, even in the absence of it, at an early stage. Lastly, it underscores the need for better access to high-end imaging techniques such as MRI in low-resource health care settings.

Therefore, CNS infections are a complex and difficult emergency medicine diagnosis and treatment. This research highlights the importance of the ED in early identification, imaging diagnosis, and early management. The combination of clinical evaluation with neuroimaging results greatly improves the accuracy of early diagnosis and assists in making timely decisions for management. Improving the availability of emergency care, the availability of imaging, and standardization of procedures are critical in minimizing morbidity and mortality for CNS infections, especially in endemic and resource-limited settings.

CONCLUSION

Neuroinfections (meningitis, encephalitis, and brain abscess) are important neurological emergencies and are still urgent emergencies that need to be promptly recognized and managed in the ED. The findings of this study highlight the important role emergency medicine plays in the early identification, stabilization, and empirical treatment of patients with suspected CNS infections.

In the Emergency setting, computed tomography (CT) was identified as an important diagnostic tool for a quick assessment and exclusion of life-threatening conditions, while magnetic resonance imaging (MRI) was more specific in diagnosis. The imaging characteristics were significantly associated with final diagnosis, with ring-enhancing lesions and brain abscess, temporal lobe diffusion restriction and viral encephalitis, and basal meningeal enhancement and tuberculous meningitis.

The results indicate that early diagnosis by clinical examination, together with early imaging, is a valuable aid to the diagnosis. In conclusion, the rapid empirical antibiotic therapy and evaluation in the ED continues to be a crucial aspect of improving outcomes in acute neuroinfections.

LIMITATIONS

There were some limitations to this study. First, it took place in a single tertiary care center, which might restrict the external validity of the results to other health care settings where resources and patient characteristics vary. Second, the imaging-based diagnostic evaluation might have been affected by variability in patient access to MRI, since not all patients had the same imaging modality.

Also, because the study was observational, it is not possible to determine the cause-and-effect relationships between the imaging results and clinical outcomes. Selection bias may also be present, as only patients who came to the emergency department with suspected CNS infection were included. Last, long-term neurological outcomes were not evaluated, with the study's focus largely on the initial evaluation and early management in the ED.

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Additional Information

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AUTHORS CONTRIBUTIONS

Serial Number	Author's Full Name	Intellectual Contribution to the Paper in Terms of
1.	Hamaad Gul Mohmand	Study design and methodology.
2.	Syed Ahmad Ali Shah	Paper writing.
3.	Sami Ullah Yousafzai	Data collection and calculations.
4.	Muhammad Ehtisham	Analysis of data and interpretation of results.
5.	Tehran Khan	Literature Review
6.	Abdul Hadi	Data collection and referencing