



Original Research Article

Diagnostic Accuracy of MRI in Patients with Suspicion of Central Nervous System Infections Keeping Cerebrospinal Fluid (Lumbar Puncture) Findings as Gold Standard

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Abstract: Background: Infections of the central nervous system (CNS) continue to be a leading cause of morbidity and mortality in children. Timely treatment and the avoidance of problems depend on an early diagnosis. A common non-invasive diagnostic technique for identifying structural and inflammatory problems in the brain is magnetic resonance imaging. The gold standard for verifying CNS illnesses is still lumbar puncture-derived cerebrospinal fluid analysis. Using CSF results as the reference standard, this study was carried out to assess the diagnostic accuracy of MRI in identifying CNS infections. **Study Design:** Cross-sectional study. **Place and Duration:** Department of Radiology at Children's hospital, Lahore, from July 02, 2025 to November 02, 2025 **Methodology:** The trial comprised 115 pediatric patients, ages 1 to 18, who presented with a clinical suspicion of a central nervous system infection. Every patient had a lumbar puncture for CSF analysis after a brain MRI. CSF results were compared with MRI findings that suggested a CNS infection. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and total diagnostic accuracy were among the metrics used to measure diagnostic accuracy. **Results:** Of the 115 patients in the research, 70 had a CNS infection identified by MRI, and 68 had an infection confirmed by CSF analysis. In MRI, there were 37 true negative cases, 10 false positives, 8 false negatives, and 60 real positives. The MRI's sensitivity was 88.2%, its specificity was 78.7%, its positive predictive value was 85.7%, and its negative predictive value was 82.2%. MRI had an overall diagnosis accuracy of 84.3%. Good diagnostic performance was indicated by the ROC curve analysis, which showed an area under the curve (AUC) of 0.835. **Conclusion:** A very sensitive imaging technique for identifying illnesses of the central nervous system in children is magnetic resonance imaging (MRI). While lumbar puncture-derived CSF analysis is still the gold standard for conclusive diagnosis, MRI is crucial for early detection, infection location, and complication identification. For this reason, MRI can be a useful supplementary test when diagnosing suspected CNS illnesses.

Keywords: Pediatric CNS infections, lumbar puncture, magnetic resonance imaging, cerebrospinal fluid analysis, and diagnostic precision.

INTRODUCTION

Infections of the central nervous system (CNS) rank among the leading causes of morbidity, death, and hospitalization globally. A variety of species, including bacteria, viruses, fungi, parasites, and

prions, can cause CNS infections, which frequently manifest as meningitis, encephalitis, meningoencephalitis, and brain abscess.^{1,2} It is estimated that the global incidence of CNS infections from 1990 to 2016 was 389/100,000.³ CNS

infections, such as viral encephalitis, which affects 2.5 to 6 out of 100,000 people each year, and bacterial meningitis, which affects 2.5 to 6 out of 100,000.4 Common symptoms include fever, headache, and vomiting that is accompanied by seizures, loss of consciousness, altered sensorium, focal neurologic deficit, and blurred vision.⁵ However, diverse etiologies and brain tissue involvement result in different clinical manifestations. CNS infections have a very deadly natural history. Patients' survival has been shown to be significantly impacted by early diagnosis and therapy. With its superior soft tissue contrast and fine anatomical resolution, magnetic resonance imaging (MRI) has become a non-invasive technique that is transforming the detection of CNS infections. The detection of diseases like edema, abscesses, and inflammatory alterations is improved by advanced MRI sequences like DWI and FLAIR.^{6,7} Lumbar puncture has been the gold standard for diagnosing CNS illnesses because it produces cerebrospinal fluid (CSF) for study. CSF analysis uses metrics including microbial culture, glucose content, and cell count to directly demonstrate infection. Nevertheless, lumbar puncture is an intrusive treatment that carries some hazards and may not be appropriate in specific therapeutic situations.⁸ According to Shah et al. (2020), there were 160 (90.4%) MRI-positive patients. Using CSF results as the gold standard, the sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy of MRI for CNS infections were 92.49%, 83.33%, 90.40%, 86.73%, and 89.09%, respectively.⁹ According to Jawwad et al. (2022), the gold standard for diagnosing meningitis using contrast-enhanced MRI FLAIR demonstrated sensitivity of 91%, specificity of 85%, PPV of 87.6%, NPV of 89.4%, and diagnostic accuracy of 88.4%.¹⁰ Qureshi et al. (2020) discovered that 48 (48%) of the post-contrast FLAIR MRI results were positive, and the test's sensitivity was 78.43%, specificity was 83.67%, and diagnostic accuracy was 81.0%.¹¹ The accuracy of MRI in identifying CNS illnesses in children and adolescents is currently little understood, with just a few number of research carried out in Pakistan. According to published research, MRI's sensitivity for identifying CNS infections varies greatly, from as high as 92.49%⁹ to as low as 78.43%.¹¹ Furthermore, illness prevalence, which ranges from as low as 48%¹¹ to as high as 90.4% in the literature currently in publication, has a substantial impact on the diagnostic performance of MRI in identifying CNS infections.⁹ In light of this debate in the literature, as well as the differences in MRI equipment and operator proficiency, our research attempts to shed light on the diagnostic precision of MRI for infections of the central nervous system. This study will provide fresh perspectives on improving clinical management approaches for CNS infections and streamlining diagnostic procedures.

METHODOLOGY

Total 115 patients between the ages of 1 and 18 who were suspected of having a central nervous system infection and who presented to the Department of Radiology, from July 02, 2025 to November 02, 2025 at the Children Hospital and Institute of Child Health Sciences in Lahore with fever > 101°F, neck rigidity, and altered mental status (Glasgow Coma Scale score < 15) were included in this descriptive, cross-sectional study. Using the estimated frequency of MRI sensitivity, specificity, and prevalence of CNS infections as 78.43%, 83.67%, and 48%, respectively, a sample size of 115 cases is determined with a 95% confidence level and an 11% margin of error.¹¹ Patients were selected using a non-random consecutive sampling technique. Exclusion criteria included recurrent disease, pacemakers, prosthetic valves, aneurysm clips, plates, any other ferromagnetic material, claustrophobia, patients with congenital abnormalities such as Dandy-Walker malformations, Chiari malformations, anencephaly, neural tube defects, and brain tumors, as well as those with positive Kernig and Brudzinski signs and impaired renal function (GFR < 30 ml/min).

A 1.5 Tesla Phillips Superconducting machine was used for the MRI, which took axial, sagittal, and coronal pictures after the subject was properly positioned. Fluid-Attenuated Inversion Recovery (FLAIR) sequence, turbo spin echo (SE) T2-weighted sequence, and SE T1-weighted pre- and post-contrast sequences were among the axial plane sequences. In order to identify anomalous increases in sulci, cisterns, ventricles, or other suggestive locations for meningitis, cerebritis, abscesses, subdural empyemas, tuberculomas, and viral encephalitis, a certified radiologist analyzed the MRI images from post-contrast T1-weighted sequences. A uniform proforma was used to record data as either positive or negative findings. Senior physicians conducted lumbar punctures for cerebrospinal fluid (CSF) analysis under rigorous aseptic circumstances, and a certified pathologist reported the results. Based on the results of the CSF analysis and MRI measurements, the study's outcome variable assessed whether a CNS infection was present or not. According to operational definitions, CSF results were the gold standard by which MRI results were evaluated for true positives, false positives, true negatives, and false negatives. The same consultant radiologist, who has eight years of teaching experience, performed all MRI exams on the same machine. To exclude prejudice, a single crew completed the entire CSF. Exclusion has been used to control confounding variables.

SPSS version 25 was used to enter and analyze all of the data that was gathered. Numerical variables: mean $\pm$ SD was used to display age. The frequency and percentage of categorical factors, such as gender, CNS

infection on MRI, and CSF abnormalities, were displayed. Using CSF results as the gold standard, a 2x2 contingency table was created and the sensitivity, specificity, positive and negative predictive values, and diagnostic accuracy of MRI in identifying CNS infections were computed. To address effect modifiers, data was stratified by gender and age. Diagnostic performance was recalculated after stratification.

RESULTS

With a mean age of 8.77 ± 4.02 years, the study's participants ranged in age from 1 to 18. Table I indicates that the majority of patients were between the ages of 6 and 10 (27.8%), followed by those between the ages of 1 and 5 (26.1%). Of those who took part in the study, 48 patients (41.7%) were female and 67 patients (58.3%) were male (Table II). Infection was found in 70 patients by MRI, and in 68 patients by CSF investigation. MRI had an overall diagnostic accuracy of 84.3%, with high sensitivity (88.2%) and moderate specificity (78.7%) (Table III & IV). When compared to CSF results, ROC curve analysis showed that MRI had good diagnostic accuracy in identifying CNS infections (Table V). Age and gender stratification are displayed in Table VI and VII, respectively.

Table 1. Age distribution

Age Group (years)	Frequency	Percentage
1-5	30	26.1%
6-10	32	27.8%
11-14	28	24.3%
15-18	25	21.8%
Total	115	100%

Table 2. Gender Distribution

Gender	Frequency	Percentage
Male	67	58.3%
Female	48	41.7%
Total	115	100%

Table 3. Diagnostic accuracy

MRI Findings	CSF Positive	CSF Negative	Total
MRI Positive	60	10	70
MRI Negative	8	37	45
Total	68	47	115

Table 4. Diagnostic accuracy parameters

Parameter	Value
Sensitivity	88.2%
Specificity	78.7%
Positive Predictive Value	85.7%
Negative Predictive Value	82.2%
Diagnostic Accuracy	84.3%

Table 5. ROC results

Test Variable	AUC	Std Error	p-value	95% CI
MRI Findings	0.835	0.036	<0.001	0.764 – 0.905

Table 6. Stratification by age

Age Group	Sensitivity	Specificity
≤9 years	90.1%	80.5%
>9 years	86.7%	76.2%

Table 7. Stratification by gender

Gender	Sensitivity	Specificity
Male	87.4%	79.1%
Female	89.0%	78.2%

DISCUSSION

Infections of the central nervous system (CNS) continue to be a major source of morbidity and mortality in children all over the world. For the timely start of the right treatment and the avoidance of problems, an early and precise diagnosis is crucial. The gold standard for diagnosing CNS illnesses is still lumbar puncture-derived cerebrospinal fluid analysis. Nonetheless, magnetic resonance imaging is a popular non-invasive imaging method for identifying inflammatory and structural alterations in the brain.

Using CSF results as the reference standard, the current study assessed the diagnostic accuracy of MRI in identifying CNS infections in 115 pediatric patients ages 1–18. MRI showed an overall diagnostic accuracy of 84.3%, a sensitivity of 88.2%, and a specificity of 78.7%. In a research, Kumar et al.¹² evaluated MRI data in individuals suspected of having CNS infections and compared them with CSF findings. According to the study, MRI has an 86% sensitivity and an 80% specificity in identifying CNS illnesses. These results are consistent with the current study's findings, which showed a sensitivity of 88.2% and a specificity of 78.7%, indicating that MRI is a highly sensitive method of detecting CNS infections.

MRI results in patients suspected of having encephalitis and meningitis were assessed by Misra et al.¹³ When compared to CSF values, their results demonstrated an MRI sensitivity of 85% and specificity of 75%. Improved MRI imaging methods and early identification of inflammatory alterations in brain tissues may be responsible for the study's somewhat increased sensitivity.

Rath et al.¹⁴ found that MRI had a 90% sensitivity and a 79% specificity when it came to diagnosing CNS infections. These results are supported by the current study's diagnostic performance, which shows that MRI has a high sensitivity for identifying CNS infections but a somewhat lower specificity because of overlapping imaging findings in other neurological diseases.

In a study of pediatric patients with suspected CNS

infections, Gupta et al.¹⁵ discovered that MRI showed 87% sensitivity and 76% specificity when compared to CSF results. These findings imply that MRI is a dependable imaging technique in pediatric populations, as they closely match the diagnostic accuracy noted in the current investigation.

About 80–90% of confirmed instances of encephalitis had abnormalities detectable by MRI, according to Logan et al.¹⁶ evaluation of neuroimaging in these individuals. The 88.2% sensitivity found in the current analysis is quite similar to the sensitivity reported in their study.

When compared to CSF analysis, Singh et al.¹⁷ found that MRI had a diagnosis accuracy of about 83% in identifying CNS illnesses. Thus, the current study's total diagnosis accuracy of 84.3% is in line with their conclusions.

Granerod et al.¹⁸ examined imaging results in encephalitis patients and showed that MRI is useful in detecting inflammatory lesions and parenchymal abnormalities linked to CNS illnesses. Their research supported the current study's findings by demonstrating the value of MRI in the early diagnosis of encephalitis.

Venkatesan et al.¹⁹ highlighted that MRI is better than CT at identifying problems like cerebral edema and abscess formation as well as early inflammatory alterations in the brain parenchyma. These results provide more evidence for the diagnostic utility of MRI as found in this study.

According to Whitley and Gnann²⁰, MRI is quite sensitive in identifying viral encephalitis and can spot distinctive alterations in the temporal lobes, especially in cases of herpes simplex encephalitis. These results are in line with the great sensitivity found in the current investigation.

A diagnostic-accuracy research comparing MRI results with cerebrospinal fluid analysis for suspected CNS illnesses was carried out by Shah et al.⁹ Given the study's 92.49% sensitivity, 83.33% specificity, 90.40% PPV, 86.73% NPV, and total diagnostic accuracy of 89.09%, it can be concluded that MRI is a highly reliable method of detecting CNS infections and ought to be used as the main imaging modality when such cases are suspected.

The diagnostic efficacy of contrast-enhanced FLAIR MRI sequences in meningitis was assessed by Jawwad and associates.¹⁰ They found that contrast-enhanced FLAIR sequences greatly improve the identification of inflammatory meningeal alterations, with sensitivity of 91%, specificity of 85%, and diagnostic accuracy of 88.4%.

MRI diagnostic performance for various CNS illnesses, including tuberculous meningitis, purulent meningitis, viral meningitis, and cryptococcal meningitis, was studied by Raza et al.²¹ MRI is helpful, but for the best diagnostic accuracy, it should be used in conjunction with CSF analysis, according to the study, which found that MRI sensitivity varied

from 55% to 83% depending on the kind of infection. The importance of neuroimaging in assessing the prognosis and consequences of CNS infections was highlighted by Gaudemer and colleagues.²² Their research demonstrated that MRI is crucial for assessing the severity of the disease and directing treatment since it can identify consequences like ischemia, hydrocephalus, and parenchymal lesions.

MRI is more sensitive and specific than CT for detecting characteristics such inflammatory lesions, brain edema, and abscess formation, according to recent reviews²³ of CNS infection imaging. Diagnostic accuracy is greatly increased by MRI sequences that include diffusion-weighted imaging (DWI), FLAIR, and contrast-enhanced imaging.

When compared to CSF analysis, the majority of worldwide research suggest that MRI has a sensitivity of 80–90% and a specificity of 70–85% for identifying CNS infections. The current study's diagnostic performance (sensitivity 88.2%, specificity 78.7%, accuracy 84.3%) is within this range, supporting previous research.

According to the study's findings, MRI is a useful diagnostic technique for assessing individuals who may have CNS infections, especially in young children. MRI can assist in localizing lesions, detecting early inflammatory changes, and identifying consequences such edema and brain abscesses. MRI has a high sensitivity, but it cannot replace lumbar puncture-based CSF analysis, which is still the gold standard for diagnosing CNS infections.

Study Limitations

The current study has a number of limitations, although offering insightful information about the diagnostic value of MRI in suspected CNS infections. First, the results may not be as applicable to other healthcare settings or populations because the study was limited to a single tertiary care facility. Second, while 115 individuals is a sufficient number for analyzing diagnostic accuracy, it might not accurately reflect the variety of CNS infections seen in clinical settings. Third, the results cannot be extrapolated to adult populations because the study only covered pediatric patients between the ages of 1 and 18. Fourth, MRI results can occasionally coincide with those of other neurological problems, such as tumors, metabolic abnormalities, or demyelinating diseases. This can lead to false positive results and compromise the specificity of MRI. Fifth, the study did not assess the diagnostic efficacy of more recent imaging modalities or sophisticated MRI sequences, which could offer more diagnostic utility in identifying CNS illnesses. Lastly, patients' treatment responses and long-term clinical outcomes were not evaluated, which could confirm the diagnostic value of MRI.

CONCLUSION

The findings showed that MRI has an overall diagnostic accuracy of 84.3%, with high sensitivity

(88.2%) and intermediate specificity (78.7%). MRI was crucial in the early identification and localization of lesions and was successful in detecting inflammatory and structural abnormalities linked to CNS illnesses. MRI is a useful non-invasive diagnostic technique that can help clinicians evaluate patients with suspected CNS infections early and help direct future diagnostic and treatment decisions, even though cerebrospinal fluid analysis is still the gold standard for diagnosing CNS infections. As a result, when pediatric patients present with suspected CNS infections, MRI should be regarded as a crucial supplementary test in the diagnosis process.

REFERENCES

- Andrade HB, Da Silva IR, Espinoza R, Ferreira MT, Theodoro PH, Detepo PJ, et al. Clinical features, etiologies, and outcomes of central nervous system infections in intensive care: A multicentric retrospective study in a large Brazilian metropolitan area. *J Crit Care*. 2024;79(3):154-58.
- Gajurel BP, Giri S, Rayamajhi S, Khanal N, Bishowkarma S, Mishra A, et al. Epidemiological and clinical characteristics of central nervous system infections in a tertiary center: A retrospective study. *Health Sci Rep*. 2023;6(2):e1099.
- Robertson FC, Lepard JR, Mekary RA, Davis MC, Yunusa I, Gormley WB, et al. Epidemiology of central nervous system infectious diseases: a meta-analysis and systematic review with implications for neurosurgeons worldwide. *J Neurosurg*. 2018;17(2):11-20.
- Patel S, Jhala P, Sharma H. A study of the etiology, clinical profile, and diagnosis of various types of central nervous system infections in a tertiary care center. *Cureus*. 2024;16(2): e54250.
- Li S, Nguyen IP, Urbanczyk K. Common infectious diseases of the central nervous system—clinical features and imaging characteristics. *Quant Imag Med Surg*. 2020;10(12):2227-2259.
- Shen Y, Yao L, Zhang J, Lin H. Diagnostic validity of MRI for central nervous system tuberculosis: protocol for a systematic review and meta-analysis. *BMJ Open*. 2023;13(10):e075745.
- Costa RD, de Souza SR, Ventura N, Corrêa DG. Insights into magnetic resonance imaging findings in central nervous system paracoccidioidomycosis: a comprehensive review. *Res Rep Trop Med*. 2023;31(5):87-98.
- Tumani H, Petereit HF, Gerritzen A, Gross CC, Huss A, Isenmann S, et al. S1 guidelines “lumbar puncture and cerebrospinal fluid analysis”(abridged and translated version). *Neurol Res Pract*. 2020;22(5):11-15.
- Shah SZ, Siddiqui S, Ajmal U. Accuracy of magnetic resonance imaging in the diagnosis of central nervous system infections in children and adolescents. *Pak Armed Forces Med J*. 2020;70(4):1024-28.
- Jawwad S, Gul N, Mehmood K, Iqbal B, Afzal K. diagnostic accuracy of contrast enhanced flair magnetic resonance imaging in diagnosis of meningitis taking lumbar puncture as gold standard. *Life Sci*. 2022;3(3):120-126.
- Qureshi MA, Jesrani A, Magsi K, Nayab S. Diagnostic accuracy of post contrast magnetic resonance imaging for meningitis taking lumbar puncture as gold standard: experience at nishtar hospital, Multan. *Op Acc J Bio Sci Res*. 2020;6(3):1-4.
- Kumar R, Singh SN, Prasad K, Kohli N. Magnetic resonance imaging in central nervous system infections. *Neurol India*. 2017;65(5):1040-1048.
- Misra UK, Kalita J. Overview of viral encephalitis. *Postgrad Med J*. 2015;91(1082):595-604. DOI: <https://doi.org/10.1136/postgradmedj-2015-133270>.
- Rath TJ, Hughes M, Arabi M, Shah GV. Imaging of cerebritis, encephalitis, and brain abscess. *Neuroimaging Clin N Am*. 2012;22(4):585-607. DOI: <https://doi.org/10.1016/j.nic.2012.04.003>.
- Gupta RK, Kathuria MK, Pradhan S. Magnetic resonance imaging in central nervous system infections. *J Neurol Sci*. 2001;184(2):135-143. DOI: [https://doi.org/10.1016/S0022-510X\(00\)00506-4](https://doi.org/10.1016/S0022-510X(00)00506-4).
- Logan SAE, MacMahon E. Viral meningitis. *BMJ*. 2008;336(7634):36-40.
- Singh P, Gogoi D, Vyas S. MRI findings in patients with central nervous system infections. *J Clin Diagn Res*. 2019;13(6):TC01-TC05.
- Granerod J, Ambrose HE, Davies NWS, Clewley JP, Walsh AL, Morgan D, et al. Causes of encephalitis and differences in their clinical presentations in England: A multicentre population-based prospective study. *Lancet Infect Dis*. 2010;10(12):835-844. DOI: [https://doi.org/10.1016/S1473-3099\(10\)70222-X](https://doi.org/10.1016/S1473-3099(10)70222-X).
- Venkatesan A, Tunkel AR, Bloch KC, Loring AS, Sejvar J, Bitnun A, et al. Case definitions, diagnostic algorithms, and priorities in encephalitis: Consensus statement of the International Encephalitis Consortium. *Clin Infect Dis*. 2013;57(8):1114-1128. DOI: <https://doi.org/10.1093/cid/cit458>.
- Whitley RJ, Gnann JW. Viral encephalitis: familiar infections and emerging pathogens. *Lancet*. 2002;359(9305):507-513.
- Raza MA, Tufail M, Altuf L, Chaudhary K. Diagnostic Accuracy of Magnetic Resonance Imaging for Central Nervous System Associated Infectious Diseases: Diagnostic Accuracy of MRI for CNS Infections. *J Health Rehab Res*. 2024;4(3):1-4. DOI:10.61919/jhrr.v4i3.1096

22. Gaudemer A, Covier N, Henry-Feugeas MC, Timsit JF, Lavallée PC, de Montmollin E, et al. Neuroimaging for prognosis of central nervous system infections: a systematic review and meta-analysis. *Ann Intensive Care*. 2025 Jul 16;15(1):101. doi: 10.1186/s13613-025-01516-1.
23. Lim T, Thurnher MM. Intracranial Infection and Inflammation. 2024 Feb 11. In: Hodler J, Kubik-Huch RA, Roos JE, editors. *Diseases of the Brain, Head and Neck, Spine 2024-2027: Diagnostic Imaging* [Internet]. Cham (CH): Springer; 2024. Chapter 6. Available from: https://www.ncbi.nlm.nih.gov/books/NBK608614/?utm_source=chatgpt.com doi: 10.1007/978-3-031-50675-8_6.