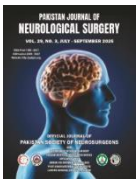

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Original Research

Correlation of Radiological and CSF Patterns in Adults with Meningitis: A Retrospective Analysis from a Tertiary Care Hospital in Peshawar

Adnan Ahmed[1], Shamsullah Burki[2], Nazahat Pasha[3], Muhammad Qasim[4], Afifa Qureshi[5] Nadeem Shahzad[6]

[1]*Department of Radiology, Hayatabad Medical Complex, Peshawar*
[2]*Department of Interventional Radiology, PAF Hospital, Islamabad*
[3]*Department of Radiology, Chaudry Pervaiz Elahi Institute of Cardiology, Multan*
[4]*Department of Radiology, Bacha Khan Medical Complex, Swabi*
[5]*Department of Radiology, Liaquat National Hospital, Karachi*
[6]*Department of Radiology, PAEC General Hospital, Islamabad, Pakistan*

ABSTRACT

Objective: This study aimed to assess the correlation between radiological imaging findings and cerebrospinal fluid (CSF) parameters in adult patients with bacterial and tuberculous meningitis, to identify distinct diagnostic patterns that could enhance differentiation and improve clinical management.

Materials and Methods: A total of 97 cases, comprising individuals aged fourteen years and above, were retrospectively examined over a twelve-month timeframe following a confirmed diagnosis of meningitis. Data included clinical presentation, CSF analysis, and imaging findings from MRI and CT scans. Statistical tests, including chi-square, were used to evaluate the association between radiological and CSF patterns.

Results: Tuberculomas were exclusively associated with tuberculous meningitis ($p = 0.013$), while infarcts were more prevalent in bacterial cases ($p = 0.002$). Hydrocephalus was observed more frequently in bacterial meningitis, but it was not statistically significant ($p = 0.155$). CSF profiles highlighted elevated protein levels and lymphocyte dominance in tuberculous cases, contrasting with neutrophilic inflammation and variable glucose levels in bacterial meningitis. The integration of radiological and biochemical data enhanced diagnostic precision.

Conclusion: This study highlights the importance of combining radiological imaging with CSF analysis in diagnosing meningitis. The findings provide valuable insights into local patterns, improving differential diagnosis and patient outcomes. Prospective studies are recommended to validate these findings and refine therapeutic protocols.

Keywords: Meningitis Diagnosis, Radiological Patterns, CSF Analysis, Bacterial Meningitis, Tuberculous Meningitis.

Corresponding Author: Shamsullah Burki
Department of interventional Radiology, PAF hospital, Islamabad
Email: *shamsullahburki@gmail.com*

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INTRODUCTION

Meningeal inflammation, which involves the protective coverings encasing the brain and spinal cord, continues to represent a significant health challenge worldwide, particularly within developing nations, despite the advancements achieved in modern medical care. Among various etiological factors, acute bacterial (ATM) and tuberculous meningitis (TBM) are associated with higher morbidity and mortality rates, necessitating accurate and timely diagnosis and intervention[1]. Thus, dependent on the etiological factor, meningitis may show multiple clinical symptoms and complications. The distinction of ABM and TBM forms against meningitis is very crucial because their management and therapeutic approaches differ quite from one another [2]

Advancing diagnostic technologies, including diagnostic imaging and the analysis of cerebrospinal fluid over recent decades, have greatly improved our capabilities for the earlier diagnosis of meningitis. Magnetic resonance imaging (MRI) provides a detailed visualization of anatomical and pathological changes and has become a benchmark modality in the diagnosis of meningitis.[3] MRI not only demonstrates meningeal inflammation, but it can also early detect complications such as hydrocephalus, infarcts, and tuberculomas, thus helping differentiate ABM from TBM.[4] Traditional CSF analysis, which relies on biochemical and cytological parameters, while MRI directly visualizes pathophysiological processes occurring within the brain and spinal cord.

CSF analysis continues to play a complementary role.[5] Bacterial meningitis typically shows an increase in neutrophils, high protein levels, and very low glucose levels. TBM often demonstrates lymphocytic pleocytosis, a chronic inflammatory marker. Thus, combining MRI findings with CSF analysis can provide us with a better understanding of disease etiology and enable us to refine diagnostic precision and improve patient management and outcomes.[6]

Despite all the above, there are gaps in our understanding of how radiological patterns correlate with CSF biomarkers in both clinical presentations of meningitis. By examining the radiological and CSF findings in adults diagnosed with meningitis, our study aims to bridge this gap. By exploring the relationships between these diagnostic tools, we aim to contribute to improving the diagnostic framework for distinguishing ABM from TBM.[7]

MATERIALS AND METHODS

Study Design

This retrospective study was conducted at Lady Reading Hospital, Peshawar, including patients diagnosed with meningitis between September 2023 and September 2024. The study aimed to correlate radiological imaging findings with cerebrospinal fluid (CSF) parameters in bacterial and tuberculous meningitis cases to identify distinct diagnostic patterns. Ethical approval was obtained from the ethical committee of LRH .Ref No (538/LRH/MTI)

Study Population

This investigation incorporated 97 individuals, all aged 14 years or older, who had been identified as having either bacterial or tuberculous meningitis.

Inclusion Criteria

Patients suspected of meningitis were included if they had a confirmed diagnosis based on MRI

findings. Eligibility criteria were restricted to adult patients aged 14 years and above. Furthermore, only those who underwent cerebrospinal fluid (CSF) analysis following MRI evaluation were selected for inclusion in the study.

Exclusion Criteria

Patients were excluded from the study if they lacked MRI imaging, had an MRI-confirmed diagnosis of meningitis without subsequent CSF analysis, or were below 14 years of age. Furthermore, individuals with other intracranial pathologies, such as brain tumors, were excluded to minimize potential confounding variables.

Data Collection

All information for this study was obtained from the hospital's digital patient records. For each participant, several key details were gathered, including basic demographics like age and sex, along with detailed MRI observations. Enlargement of the brain's ventricles, along with blockage of cerebrospinal fluid flow, was used to diagnose hydrocephalus. Infarctions were identified as bright signal areas on T2-weighted magnetic resonance sequences. Tuberculomas were identified by either nodular or ring-like enhancements following contrast administration, especially in tuberculous meningitis cases. Cerebritis was recognized by low-intensity regions on T1 scans and high-intensity zones on T2 scans, occasionally with circular or widespread enhancement after gadolinium injection. Brain abscesses appeared as well-defined ring-like lesions containing a dark center on T1 and a bright center on T2, often surrounded by edema. Fluid collections beneath the skull bone, causing compression of brain tissue, were classified as subdural collections. Other notable complications, including brain bleeding, clotting in venous sinuses, and inflammation of the brain's fluid chambers (ventriculitis), were also assessed according to their distinct MRI appearances.

CSF Analysis

Cerebrospinal fluid (CSF) samples were obtained through lumbar puncture and subjected to standard biochemical and cytological analysis. Parameters included glucose levels, measured in mmol/L, and protein concentration, recorded in mg/dL. Total white blood cell (WBC) count was documented, along with differential counts specifying the proportion of lymphocytes and neutrophils. Additionally, the macroscopic appearance of the CSF was assessed and categorized as either turbid or non-turbid.

Imaging Equipment and Interpretation

Magnetic resonance imaging was conducted utilizing a Toshiba 1.5 Tesla system. All scan interpretations were independently assessed by two certified radiologists specializing in neuroimaging, both of whom were kept unaware of the patients' clinical information to prevent bias. Any differences in interpretation were addressed through mutual agreement.

In this research, MRI examinations were carried out during admission or immediately thereafter, providing a singular snapshot of the disease at presentation. Follow-up imaging was deliberately excluded from the study, and cases with initially normal scans who later developed abnormalities were not included in the analysis. This method ensured uniformity across study subjects and remained aligned with the primary objective of evaluating baseline radiological patterns alongside early clinical and CSF characteristics.

Statistical Analysis

All statistical evaluations were performed using SPSS version 26.0. Basic demographic data, clinical attributes, imaging results, and cerebrospinal fluid (CSF) profiles were presented through descriptive statistical methods. For categorical information, proportions and frequency counts were

determined, while continuous variables such as patient age and illness duration were expressed as averages along with standard deviation values. Comparative assessments were conducted through independent t-tests, and relationship strengths between variables were examined using Pearson's correlation coefficient. Statistical relevance was established at a significance threshold of p-value less than 0.05.

RESULTS

Patient Demographics

The study included a total of 97 adult meningitis patients, with 56.7% males and 43.3% females. The mean age was 28.85 years. Bacterial meningitis was more prevalent (86.6%) compared to tuberculous meningitis (13.4%).

Table 1: *Demographics Summary.*

Parameter	Value
Total Cases	97
Total Male	55
Total Female	42
Mean Age	28.85
Tuberculous Meningitis	13
Bacterial Meningitis	84

Distribution of Radiological Complications

Imaging assessments identified cerebral infarctions as the predominant complication, accounting for 29.9%, with hydrocephalus observed in 19.6% of cases, and tuberculoma formations detected in 11.3% of the study population. Other less common findings included cerebritis (5.2%), subdural collection (3.1%), hemorrhage (2.1%), and abscess (1%). Venous sinus thrombosis was not observed.

Table 2: *Radiological Complications Distribution (n = 97).*

Complication Type	Frequency (n)	Prevalence (%)
Tuberculomas	11	11.3%
Infarcts	29	29.9%
Hydrocephalus	19	19.6%
Cerebritis	5	5.2%
No Complication	42	43.3%
Hemorrhage	2	2.1%
Abscess	1	1.0%
Subdural Collection	3	3.1%
Venous Sinus Thrombosis	0	0.0%

Cerebrospinal Fluid (CSF) Parameter Variations

CSF analysis showed wide variability in parameters. Glucose ranged from 5–168 g/dL, proteins from 10–2500 g/dL, and WBC counts from 2–11,900 cells/µL. Neutrophils and lymphocytes varied significantly among patients. Turbid CSF was noted in 9.3% of cases.

Table 3: *CSF Parameter Ranges.*

Parameter	Range
Glucose (g/dL)	5.0 – 168.0
Protein (g/dL)	10.0 – 2500.0
Total WBCs (cells/µL)	2.0 – 11,900.0
Neutrophils (%)	0.0 – 90.0
Lymphocytes (%)	0.1 – 100.0
Turbidity	9 turbid, 89 clear

Comparative Analysis of CSF Protein Levels

Mean CSF protein was higher in tuberculous meningitis (294.08 g/dL) than bacterial meningitis (179.48 g/dL), but the difference was statistically insignificant (p=0.54).

Table 4: *CSF Protein Comparison Between Meningitis Types.*

Group	Mean Protein (mg/dL)	n
Bacterial Meningitis	179.48	84
Tuberculous Meningitis	294.08	13
Comparison	t = -0.62, p = 0.54	—

Correlation Between Radiological Findings and CSF Parameters

Correlation analysis revealed weak or no significant associations between MRI findings and CSF values. Hydrocephalus showed a weak positive correlation with protein (r=0.263), while infarcts and cerebritis had minimal to no correlations.

Table 5: *Correlation Between Radiological Findings and CSF Parameters.*

Test Parameter	Correlation Coefficient	Interpretation
Hydrocephalus vs Protein	0.263	Weak Positive
Infarcts vs Glucose	-0.001	No Correlation
Cerebritis vs Protein	-0.045	Negligible Negative

DISCUSSION

This study emphasizes the correlation of radiological findings with cerebrospinal fluid (CSF) parameters to improve the diagnosis of different varieties of meningitis in adults. Diagnoses of ABM and TBM were largely formed by MRI findings, with CSF data providing essential supplementary information.[8]

Cerebral infarcts were the most common finding (29.9%), followed by hydrocephalus (19.6%) and tuberculomas (11.3%). Tuberculomas, primarily linked to tuberculous meningitis, align with the chronic, granulomatous inflammation characteristic of this condition.[9] Shared complications, such as infarcts and hydrocephalus, were present in both bacterial and tuberculous meningitis, reflecting their nonspecific but clinically significant role as indicators of disease severity.[10]

Rare complications included hemorrhage (2.1%) and abscess formation (1.0%), while subdural collections occurred in 3.1% of cases, predominantly in bacterial meningitis. Notably, venous sinus thrombosis was absent in this cohort, underscoring its rarity. These findings are consistent with other studies that document the variable but predictable radiological manifestations of meningitis.[11] Radiological findings, particularly those highlighting complications like tuberculomas and hydrocephalus, play a pivotal role in understanding disease progression and informing diagnoses.

CSF analysis demonstrated significant variability in protein, glucose, and white blood cell (WBC) counts, highlighting diverse inflammatory and metabolic responses in meningitis. Protein levels were higher in tuberculous meningitis (294.08 g/dL) compared to bacterial meningitis (179.48 g/dL), consistent with chronic inflammation in tuberculous cases.[12] However, this difference was not statistically significant (P = 0.54), likely due to the smaller sample size for tuberculous meningitis cases. This finding aligns with other studies indicating that protein levels, while reflective of pathophysiology, have limited diagnostic specificity.[13]

Glucose levels ranged widely (5.0–168.0 g/dL) and overlapped between bacterial and tuberculous meningitis cases (P = 0.471). While hypoglycorrhachia is characteristic of bacterial meningitis, the overlap underscores its limited discriminatory value. Similarly, WBC counts exhibited broad variability, with neutrophil predominance in bacterial meningitis and lymphocyte predominance in tuberculous meningitis, consistent with their respective acute and chronic inflammatory profile.[14] This variability underscores the need to interpret CSF parameters in conjunction with other diagnostic tools.

Moderate correlations emerged between radiological findings and CSF parameters, shedding light on the underlying disease processes. In tuberculous meningitis, a correlation coefficient of 0.413 was observed between severe MRI abnormalities, such as tuberculomas and hydrocephalus, and elevated CSF protein and glucose levels. This reflects the prolonged inflammation characteristic of tuberculous meningitis.[15]

Conversely, bacterial meningitis exhibited a weaker correlation (r = 0.346) between imaging abnormalities, such as infarcts and hydrocephalus, and CSF parameters. This may be due to the heterogeneous and acute nature of bacterial infections.[16] These findings underscore the complementary roles of imaging and CSF analysis in understanding meningitis pathophysiology and guiding clinical decisions.[17]

Gender differences were evident in radiological complications and CSF profiles. Tuberculomas were slightly more common in females (6.2%) than in males (5.2%), while hemorrhage occurred exclusively in males (2.1%). Subdural collections and infarcts showed nearly equal gender distribution, while a higher percentage of males (26.8%) had no radiological complications compared to females (16.5%).[18]

CSF parameter ranges also varied by gender. Males exhibited broader ranges in protein (10.0–2500.0 g/dL) and WBC counts (2.0–11,900.0 cells/μL), whereas females had higher upper limits for glucose (168.0 g/dL) and lymphocyte percentages (100.0%). These findings highlight the importance of considering gender as a variable in interpreting diagnostic data.[19]

The absence of statistically significant differences in CSF protein and glucose levels between bacterial and tuberculous meningitis underscores their limited standalone diagnostic utility. While elevated protein levels in tuberculous meningitis are consistent with its pathophysiology, overlapping glucose values diminish their specificity.[20] MRI findings, particularly tuberculomas, remain critical for diagnosing tuberculous meningitis, while shared complications like infarcts highlight the need for a comprehensive diagnostic approach.

CONCLUSION

This study further highlights the need to combine radiological findings with CSF analysis in the meningitis diagnosis. While modalities like MRI are essential for differentiating between bacterial and tuberculous meningitis, CSF parameters also provide valuable additional information. MRI features of tuberculous meningitis include tuberculomas and hydrocephalus, while shared features such as infarcts underscore the need for a comprehensive diagnostic approach. Any future study should involve larger, more balanced patient groups and possibly incorporate molecular diagnostic tools to further enhance diagnostic precision.

LIMITATIONS

The study had certain limitations. Firstly, the imbalance in sample sizes between tuberculous meningitis (13 cases) and bacterial meningitis (84 cases) may have reduced the statistical power to identify significant differences between groups. Secondly, the reliance on MRI as the primary diagnostic tool may limit the generalizability of the findings, particularly in resource-limited settings where access to advanced imaging modalities is restricted.

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Additional Information

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Data Availability Statement: For data sharing, interested researchers can contact the corresponding authors.

AUTHOR CONTRIBUTION TABLE

Sr. No.	Author's Full Name	Intellectual Contribution to Paper in Terms of:
1.	Adnan Ahmed	Study design, data collection, and primary manuscript writing.
2.	Shamsullah Burki	Statistical analysis and radiological data interpretation.
3.	Nazahat Pasha	Literature review and quality control.
4.	Muhammad Qasim	Supervision and final approval of the manuscript.
5.	Afifa Qureshi	Critical revision.
6.	Nadeem Shahzad	Editing of the manuscript.