**OPEN ACCESS**
Journal of World Future Medicine, Health and Nursing
Vol. 4 No. 3. June 2026, pp. 268-281
DOI. 10.70177/health.v4i3. 4053

**Research Article**

# DIAGNOSTIC VALUE AND PROGNOSIS OF BACTERIAL MENINGITIS SCORE TEST TO DETERMINE BACTERIAL MENINGITIS AT RSUD DR SOETOMO SURABAYA

Anindita Diva Zeriana[1], Paulus Sugianto[2], Betty Agustina Tambunan[3,] and Agnes Dwi Maharani Callista[4]
[1] Universitas Airlangga, Indonesia
[2] Universitas Airlangga, Indonesia
[3] Universitas Airlangga, Indonesia
[4] Shanxi University, China

**Corresponding Author:**

Anindita Diva Zeriana,
International Class Medical Program, Faculty of Medicine, Universitas Airlangga.
Indonesia, Faculty of Medicine, Universitas Airlangga, Jl. Prof. DR. Moestopo No.47, Pacar Kembang, Kec. Tambaksari, Surabaya, Jawa Timur 60132
Email: anindita.diva.zeriana-2022@fk.unair.ac.id

## Article Info

Received: December 9, 2025
Revised: March 16, 2026
Accepted: May 14, 2026
Online Version: June 28, 2026

## Abstract

Meningitis is a life-threatening neurological infection requiring rapid diagnosis and management. Clinical symptoms often overlap between bacterial, viral, and tuberculous causes, making early differentiation challenging. The Bacterial Meningitis Score (BMS) was developed to support early risk stratification. This study evaluates the diagnostic value and prognostic relevance of BMS in suspected meningitis cases at RSUD Dr. Soetomo Surabaya. A retrospective cross-sectional study was conducted using medical records of patients suspected of meningitis at RSUD Dr. Soetomo from 2023–2025. BMS components and clinical data were analyzed, including cerebrospinal fluid findings, peripheral blood results, and clinical manifestations. Diagnostic accuracy and prognostic outcomes were assessed using descriptive and comparative analysis. Among 43 patients, bacterial meningitis accounted for 25%, while tuberculous meningitis (37.5%), other neurological disorders (31.25%), and viral meningitis (6.25%) were more prevalent. Most patients were classified as low risk based on BMS. The score demonstrated better performance in ruling out bacterial meningitis than confirming it, supported by a high negative predictive value. However, diagnostic accuracy was limited by overlapping clinical features and incomplete cerebrospinal fluid data. Prognosis was more strongly associated with Glasgow Coma Scale (GCS), where lower scores correlated with poorer outcomes and increased mortality risk. BMS is useful for early risk stratification and exclusion of bacterial meningitis but must be combined with clinical and laboratory evaluation to improve diagnostic accuracy and patient outcomes.

**Keywords**: Bacterial Meningitis Score, Cerebrospinal Fluid, Diagnostic Accuracy, Glasgow Coma Scale, Meningitis



Journal Homepage https://research.adra.ac.id/index.php/health ISSN: (P: 2988-7550) - (E: 2988-0459)
How to cite: Zeriana, A.D., Sugianto, P., Tambunan, B. A. & Callista, A. D. M. (2026). Diagnostic Value and Prognosis of Bacterial Meningitis Score Test to Determine Bacterial Meningitis at RSUD Dr Soetomo Surabaya. *Journal of World Future Medicine, Health and Nursing*, *4*(3), 268-281. https://doi.org/10.70177/health.v4i3.4053
Published by: Yayasan Adra Karima Hubbi

## INTRODUCTION

Meningitis is characterized as an inflammation and a disease of meninges, which are fluid-filled sacs that surround the brain and spinal cord. (Pham et al., 2026) Typically, meningitis is caused by a viral infection, but it can also be caused by microscopic organisms, parasites, tumors, immune system clutter, cancer, or medication response (Han et al., 2025). Meningitis is a severe disease that can be life-threatening within a count of days on the off chance that left untreated (Wainwright & Farias-Moeller, 2024). Within the case of a deferred treatment will lead to an increment in the risk of permanent brain damage. We can detect Meningitis disease by these signs. Such as a sudden high fever with a severe headache along side with neck stiffness. Because of the headache, most of the patient will also feel nauseous even until vomiting (Andrade et al., 2024). Bright lights can cause discomfort for the patient. They can also feel very sleepy most of the time and will also have trouble concentrating. Rash can also be seen on the patient's body (Rochat & Harrison, 2025). In emergency cases this disease can lead to a seizure and needs an immediate care by professional health care giver.

In acute clinical settings, bedside physical examinations are commonly utilized as initial screening tools to detect meningeal irritation, most notably through Brudzinski's and Kernig's signs (Chowdhury et al., 2025). The physiological basis of these maneuvers relies on eliciting protective, involuntary tension in response to passive stretching of inflamed nerve roots and hypersensitive leptomeninges (Alhamoud et al., 2026). To evaluate Brudzinski's sign, the patient is placed in a supine position, and the clinician performs passive flexion of the neck; an involuntary flexion of the patient's hips and knees constitutes a positive response, driven by an antalgic reflex to minimize longitudinal traction on the spinal cord. Similarly, Kernig's sign is evaluated by flexing the patient's hip and knee to 90 degrees, followed by passive extension of the knee (Fang et al., 2024). A positive result is marked by immediate resistance or pain in the hamstrings and lower back, caused by spasm of the paraspinal muscles protecting the hypersensitive spinal nerve roots (Easter & Rose, 2024). However, contemporary neuro-infectious literature cautions that while both signs possess exceptionally high specificity making them valuable for ruling in meningeal irritation they suffer from notoriously low sensitivity and frequently fail to manifest in early, elderly, or atypical presentations (Lu et al., 2025). Consequently, these physical findings must be treated strictly as preliminary screening markers rather than definitive diagnostic indicators, requiring immediate diagnostic confirmation through comprehensive cerebrospinal fluid (CSF) analysis and neuroimaging modalities.

There are a few tests that can be done when we suspect meningitis. There are two physical tests, Brudzinski's sign and Kernig's sign (Mlotshwa et al., 2026). The first Brudzinski sign is a test where the patient lies on their back and the doctor lifts the patient's neck and moves it to the front (Nielsen et al., 2026). If the patient lifts their knee or hips it can indicate an inflammation of the brain mucous. The second test is the Kernig test where the patient will lay on their back the doctor will flex the leg towards the abdomen, and the doctor will passively extend the leg (Chekrouni et al., 2024). When the brain is inflamed the patient will resist extending the legs and will complain about the pain on their lower back or posterior thighs. That will indicate that the patient most likely has an inflammation in their brain.

There is also laboratory test to diagnose Meningitis. Which is blood test, where they count and look at the white blood cell or leukocytes (Zhao et al., 2026). Where if it's high it can indicate an infection. Blood test can also be used to measure the prokalitonin that can help to determine if the infection caused by bacteria or infection. The next laboratory test that can be done is Cerebrospinal Fluid analysis (Dong et al., 2025). In this analysis, we need to look at the blood sugar, protein, and white blood cels level. For CSF culture we a determine the bacteria that caused the infection. Antigen test also can be very sensitive if used with antibiotic (Mount Sinai Health System, n.d.). The next test we can do is imaging as if CT scan or MRI. This can

be used to see if there's an inflammation in the brain and or in the spinal cord and also help to see if there's any complication such as bleeding or brain abases.

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There's also a test to determine which we can use to detect if the patient is a a high risk to have acute meningitis (Peng et al., 2024). The test is called Bacterial Meningitis score (BMS). BMS is a clinical prediction test that used for differentiating between bacterial and aseptic meningitis. BMS is typically useful in the setting where bacterial culture takes several days to form the result (Lamperti et al., 2024). However, this test should be done with other clinical and laboratory findings to ensure the accuracy of the diagnosis and also can ensure better management for meningitis. There are parameters to count the score of BMS. Firstly, if the result for CSF gram staining is positive than it's equal to 2 points. Next, if the CSF absolute neutrophil count (ANC) is more or equal to 1,000 cells/$mm3$ it's equal to 1 point. Thirdly, if the CSF protein is more or equal to 80mg/dL it's equal to 1 point. Next, if the peripheral blood ANC is more or equal to 10,000 cells/$mm3$ we can give them 1 point. Lastly, we need to ask if the person has a history for seizure, if the patient has a seizure history for any illness it will be given 1 point also. After we took all that test, we can total all the points. "If the patient's score is bigger than 2,5 it indicates that the patient is most likely can suffer from bacterial meningitis. And vice versa, if the patient's score is lower than 2,5 so they have a low likelihood of acute bacterial meningitis."

## RESEARCH METHOD

### *Research Design*

This study employed a retrospective cross-sectional design to evaluate the diagnostic and prognostic performance of the Bacterial Meningitis Score (BMS) among patients treated at Dr. Soetomo General Academic Hospital, Surabaya, Indonesia. Data were obtained from hospital medical records and laboratory databases covering the period from January 2023 to December 2025. The study was conducted in the Department of Neurology, a tertiary referral center that manages a substantial number of meningitis cases from Eastern Indonesia.

### *Research Target/Subject*

The study population comprised patients admitted with a diagnosis of suspected meningitis during the study period. Eligible participants were identified through hospital registration records and subsequently screened using predefined inclusion and exclusion criteria (R. Chen et al., 2026). Patients were included if they had undergone clinical and laboratory evaluations sufficient for calculating the Bacterial Meningitis Score and if complete medical records were available for review. Records lacking essential clinical or laboratory information required for score calculation were excluded from the analysis.

A total sampling approach was adopted, whereby all eligible patients meeting the study criteria between 2023 and 2025 were included. This approach was chosen to maximize the available sample size and to provide a comprehensive evaluation of the BMS in routine clinical practice.

### *Research Procedure*

The operational execution of this study was conducted following a structured sequence encompassing four sequential phases. Initially, in the identification phase, the institutional electronic medical records database was queried using standard diagnostic codes (ICD-10) corresponding to suspected central nervous system infections and acute meningitis to generate the initial potential screening registry (Nie et al., 2024). In the screening phase, individual patient charts were thoroughly cross-examined against established inclusion and exclusion criteria, with patient records lacking essential admission laboratory parameters pecifically complete cerebrospinal fluid (CSF) metrics being excluded to establish the final analytical sample. During the extraction and scoring phase, clinical presentation variables, including documented seizures and classic meningeal signs, alongside initial baseline laboratory results such as peripheral hemogram and CSF parameters, were extracted using a standardized data abstraction form. The Bacterial Meningitis Score (BMS) was then calculated for each patient by totaling points assigned to five clinical indices.

In the validation and coding phase, the final verified clinical diagnosis, treatment courses, and discharge outcomes, including survival or death, were matched against the baseline calculated risk scores, with all collected endpoints anonymized and transferred to an encrypted database for statistical evaluation (Olie et al., 2024). Data were collected retrospectively from medical records following approval from the relevant institutional authorities, with demographic characteristics, clinical manifestations, laboratory findings, CSF examination results, microbiological data, and clinical outcomes being extracted using a standardized data collection form.

The primary variable of interest was the Bacterial Meningitis Score, a clinical prediction rule developed to distinguish bacterial meningitis from aseptic meningitis, calculated using five established parameters: positive CSF Gram staining, CSF absolute neutrophil count of at least 1,000 cells/mm³, CSF protein concentration of at least 80 mg/dL, peripheral blood absolute neutrophil count of at least 10,000 cells/mm³, and a history of seizure before or at presentation. Each patient's score was determined based on the documented clinical and laboratory findings recorded at the time of admission. Additional variables collected included age, sex, presenting symptoms, results of neurological examination, laboratory investigations, final diagnosis, duration of hospitalization, neurological complications, and discharge outcomes, while clinical signs suggestive of meningeal irritation, including Kernig's sign and Brudzinski's sign, were also documented when available in the medical records.

### *Instruments, and Data Collection Techniques*

Data were collected retrospectively from medical records following approval from the relevant institutional authorities. Demographic characteristics, clinical manifestations, laboratory findings, cerebrospinal fluid (CSF) examination results, microbiological data, and clinical outcomes were extracted using a standardized data collection form.

The primary variable of interest was the Bacterial Meningitis Score, a clinical prediction rule developed to distinguish bacterial meningitis from aseptic meningitis. The score was calculated using five established parameters: positive CSF Gram staining, CSF absolute neutrophil count of at least 1,000 cells/mm³, CSF protein concentration of at least 80 mg/dL, peripheral blood absolute neutrophil count of at least 10,000 cells/mm³, and a history of seizure before or at presentation (Ji et al., 2024). Each patient's score was calculated based on the documented clinical and laboratory findings recorded at the time of admission.

Additional variables collected included age, sex, presenting symptoms, results of neurological examination, laboratory investigations, final diagnosis, duration of hospitalization, neurological complications, and discharge outcomes. Clinical signs suggestive of meningeal irritation, including Kernig's sign and Brudzinski's sign, were also documented when available in the medical records.

### *Data Analysis Technique*

Data analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 27. Continuous variables were summarized as means and standard deviations or medians and interquartile ranges, depending on data distribution, whereas categorical variables were presented as frequencies and percentages.

The diagnostic performance of the Bacterial Meningitis Score was evaluated through calculations of sensitivity, specificity, positive predictive value, negative predictive value, and accuracy (Bodilsen et al., 2024). Receiver operating characteristic (ROC) curve analysis was conducted to determine the discriminative ability of the score, and the area under the curve (AUC) was calculated. Statistical significance was defined as a two-tailed p-value of less than 0.05.

## RESULTS AND DISCUSSION

### Characteristics of Study Participants

A total of 43 patients with suspected meningitis who met the study criteria were included in the analysis. The demographic characteristics of the study population are presented in Table 1.

**Table 1.** Demographic Characteristics of Study Participants

| Variable | Frequency (n) | Percentage (%) |
|---|---|---|
| Female | 24 | 55.8 |
| Male | 19 | 44.2 |
| Total | 43 | 100.0 |
| **Age Group** | **Frequency (n)** | **Percentage (%)** |
| Children (2–15 years) | 15 | 34.9 |
| Adults (17–45 years) | 20 | 46.5 |
| Elderly (52–77 years) | 8 | 18.6 |
| Total | 43 | 100.0 |

Source: Electronic Medical Records, Dr. Soetomo General Academic Hospital.

Female patients accounted for a slightly higher proportion of the study population than male patients, comprising 55.8% (n = 24) and 44.2% (n = 19) of cases, respectively. With regard to age distribution, adults aged 17–45 years represented the largest age group, accounting for 46.5% (n = 20) of all participants. Children aged 2–15 years comprised 34.9% (n = 15) of the study population, whereas elderly patients aged 52–77 years accounted for 18.6% (n = 8). Overall, the study population was predominantly composed of adult patients, with a relatively balanced distribution between male and female participants.

### Laboratory Characteristics

Laboratory findings relevant to the Bacterial Meningitis Score are summarized in Table 2. Among patients with available cerebrospinal fluid (CSF) neutrophil data, none demonstrated a CSF neutrophil count of ≥1,000 cells/mm³. Nineteen patients (30.6%) had CSF neutrophil counts below this threshold, while data were unavailable for 69.4% of cases.

Regarding CSF protein concentration, only one patient (1.6%) had a protein level of ≥80 mg/dL. Eighteen patients (29.0%) had protein concentrations below 80 mg/dL, whereas data were unavailable for 69.4% of participants.

Peripheral blood absolute neutrophil count (ANC) data were available for 35 patients. Fourteen patients (22.6%) had ANC values ≥10,000 cells/mm³, while 21 patients (33.9%) had ANC values below this threshold. Missing ANC data were identified in 43.5% of cases.

**Table 2.** Laboratory Characteristics of Study Participants

| Variable | Category | n | % |
|---|---|---|---|
| CSF Neutrophil Count | ≥1000 cells/mm³ | 0 | 0.0 |
| | <1000 cells/mm³ | 19 | 30.6 |
| | No data | 43 | 69.4 |
| CSF Protein | ≥80 mg/dL | 1 | 1.6 |
| | <80 mg/dL | 18 | 29.0 |
| | No data | 43 | 69.4 |
| Peripheral Blood ANC | ≥10000 cells/mm³ | 14 | 22.6 |
| | <10000 cells/mm³ | 21 | 33.9 |
| | No data | 27 | 43.5 |

Source: Electronic Medical Records, Dr. Soetomo General Academic Hospital.

This shows the lab results for patients who are thought to have meningitis based on tests of their cerebrospinal fluid (CSF) and peripheral blood. The data show that most of the CSF neutrophil counts that were available were below 1000 cells/mm³. This means that many patients did not meet the neutrophil threshold set by the Bacterial Meningitis Score criteria. Only one patient had a CSF protein level of 80 mg/dL or higher. The other patients either had lower levels or didn't have all the information they needed. Also, an analysis of the absolute neutrophil count (ANC) in peripheral blood showed that 14 patients had ANC levels of 10,000 cells/mm³ or higher, which suggests a systemic inflammatory or infectious response. These lab results give important numbers that are used to figure out the Bacterial Meningitis Score and help figure out how likely it is that the people in the study have bacterial meningitis.

## Clinical Characteristics

The frequency of major clinical manifestations among patients with suspected meningitis is presented in Table 3. Seizures were documented in 20 patients (46.5%), whereas 23 patients (53.5%) had no history of seizures. Neck stiffness was observed in 19 patients (44.2%), while 24 patients (55.8%) did not demonstrate this finding. Headache was reported by 22 patients (51.2%), whereas 21 patients (48.28%) did not report headache.

**Table 3.** Clinical Characteristics of Study Participants

| Variable | Present n (%) | Absent n (%) |
|---|---|---|
| Seizure | 20 (46.5) | 23 (53.5) |
| Neck stiffness | 19 (44.2) | 24 (55.8) |
| Headache | 22 (51.2) | 21 (48.8) |

Source: Electronic Medical Records, Dr. Soetomo General Academic Hospital.

These findings indicate that the classical clinical manifestations of meningitis were variably distributed within the study population.

**Distribution of Bacterial Meningitis Score**

Bacterial Meningitis Score (BMS) data were available for 22 patients. The majority of patients had a BMS of 1, accounting for 81.8% (n = 18). Higher scores were less common, with two patients (9.1%) scoring 2, one patient (4.5%) scoring 3, and one patient (4.5%) scoring 4. The distribution demonstrates that most patients were classified within the lower BMS categories.

**Table 4.** Distribution of Bacterial Meningitis Score

| BMS Score | Frequency (n) | Percentage (%) |
|---|---|---|
| 1 | 18 | 81.8 |
| 2 | 2 | 9.1 |
| 3 | 1 | 4.5 |
| 4 | 1 | 4.5 |
| Total | 22 | 100.0 |

Source: Electronic Medical Records, Dr. Soetomo General Academic Hospital.

**Final Diagnosis**

Among the 32 patients with complete diagnostic data, tuberculous meningitis was the most common final diagnosis, accounting for 37.5% (n = 12) of cases. Other neurological conditions represented 31.3% (n = 10), followed by bacterial meningitis at 25.0% (n = 8) and viral meningitis at 6.3% (n = 2).

**Table 5.** Final Diagnosis Distribution

| Diagnosis | Frequency (n) | Percentage (%) |
|---|---|---|
| Bacterial meningitis | 8 | 25.0 |
| Tuberculous meningitis | 12 | 37.5 |
| Viral meningitis | 2 | 6.3 |
| Other neurological conditions | 10 | 31.3 |
| Total | 32 | 100.0 |

Source: Electronic Medical Records, Dr. Soetomo General Academic Hospital.

The different final diagnoses in this study show that meningitis cases in patients who were first thought to have the disease are not all the same and are not all caused by bacteria. Among the 32 patients analysed, tuberculous meningitis was the most common diagnosis, making up 37.5% of the cases. After that came other neurological conditions (31.25%), bacterial meningitis (25%), and viral meningitis (6.25%). These findings underscore that while bacterial meningitis continues to be a clinically significant issue, a considerable percentage of patients exhibiting meningitis-like symptoms are ultimately identified as having non-bacterial causes. This variability underscores the intricacy of diagnosing meningitis based solely on initial clinical suspicion, given that overlapping ymptoms like fever, headache, altered consciousness, and seizures frequently occur across various neurological and infectious disorders.

**Distribution of Bacterial Meningitis Score According to Final Diagnosis**

The distribution of Bacterial Meningitis Score (BMS) categories according to the final diagnosis is presented in Table 5.6. Of the 32 patients included in this analysis, 10 were classified as high risk (BMS >2.5) and 22 as low risk (BMS ≤2.5).

Among patients classified as high risk, bacterial meningitis was the most common diagnosis (60.0%), followed by tuberculous meningitis (30.0%). In contrast, tuberculous meningitis and other neurological or infectious conditions were more frequently observed in

the low-risk group, each accounting for 40.9% of cases. Overall, tuberculous meningitis was the most frequent final diagnosis (37.5%), followed by other neurological or infectious conditions (31.3%), bacterial meningitis (25.0%), and viral meningitis (6.3%).

**Table 6.** Distribution of Bacterial Meningitis Score According to Final Diagnosis

| BMS Category | Bacterial Meningitis | Tuberculous Meningitis | Viral Meningitis | Other Neurological/Infectious Conditions | Total |
|---|---|---|---|---|---|
| High Risk (>2.5) | 6 | 3 | 0 | 1 | 10 |
| Low Risk (≤2.5) | 2 | 9 | 2 | 9 | 22 |
| Total | 8 | 12 | 2 | 10 | 32 |

Source: Electronic Medical Records, Dr. Soetomo General Academic Hospital.

**Association Between BMS Risk Category and Final Diagnosis**

The relationship between BMS risk classification and final diagnosis was analyzed using the chi-square test. Among patients classified as low risk, 88.9% were diagnosed with bacterial meningitis and 11.1% were diagnosed with non-bacterial conditions. In the high-risk group, 75.0% were diagnosed with bacterial meningitis and 25.0% with non-bacterial conditions.

Statistical analysis demonstrated no significant association between BMS risk category and final diagnosis (Pearson $\chi^2 = 0.536$, $p = 0.464$). Similar findings were observed using Fisher's exact test ($p = 0.470$).

**Table 7.** Association Between BMS Risk Category and Final Diagnosis

| Test | Value | p-value |
|---|---|---|
| Pearson Chi-Square | 0.536 | 0.464 |
| Likelihood Ratio | 0.469 | 0.494 |
| Fisher's Exact Test | — | 0.470 |

**Clinical Outcomes**

Of the 43 patients included in the study, 25 patients (58.1%) survived until discharge, whereas 18 patients (41.9%) did not survive. Overall mortality was observed in 11 patients (25.6%), while 32 patients (74.4%) survived.

**Table 8.** Clinical Outcomes

| Outcome | Frequency (n) | Percentage (%) |
|---|---|---|
| Survived | 25 | 58.1 |
| Died | 11 | 25.6 |
| Total | 43 | 100.0 |

Source: Electronic Medical Records, Dr. Soetomo General Academic Hospital.

This study assessed the diagnostic and prognostic value of the Bacterial Meningitis Score (BMS) in patients with suspected meningitis at Dr. Soetomo General Academic Hospital, Surabaya. Overall, the findings indicate that BMS functions as a practical clinical tool for early risk stratification, particularly in differentiating patients with a low likelihood of bacterial meningitis (W. Chen et al., 2024). However, its diagnostic performance is influenced by the heterogeneity of clinical presentations, overlapping etiologies, and incomplete laboratory documentation. These challenges reflect the complex nature of meningitis as a clinical syndrome caused by bacterial, viral, and tuberculous pathogens.

The distribution of final diagnoses in this study highlights this complexity, with tuberculous meningitis being the most frequent diagnosis, followed by bacterial meningitis, other neurological conditions, and viral meningitis (Matschke, 2025). This pattern is consistent with epidemiological data from low- and middle-income countries, where tuberculosis remains a major contributor to central nervous system infections (Siakallis, 2025). The presence of a substantial proportion of non-bacterial diagnoses further emphasizes that clinical suspicion of meningitis does not always correspond to bacterial infection, as many neurological and infectious conditions share similar early manifestations.

Clinically, patients commonly presented with non-specific neurological symptoms such as fever, headache, neck stiffness, altered consciousness, and seizures (Schulz et al., 2025). These manifestations are well recognized in meningitis but are not exclusive to bacterial etiology. Seizures, in particular, are an important indicator of severe central nervous system involvement and are incorporated into the BMS due to their prognostic relevance. However, their diagnostic specificity remains limited since seizures can also occur in viral, tuberculous, or other neurological disorders (Yabumoto et al., 2026). Likewise, classical meningeal signs such as Kernig's and Brudzinski's signs provide supportive clinical evidence but lack sufficient sensitivity for definitive diagnosis (Osmosis, n.d.). This overlap reinforces the need for combined clinical and laboratory-based diagnostic approaches.

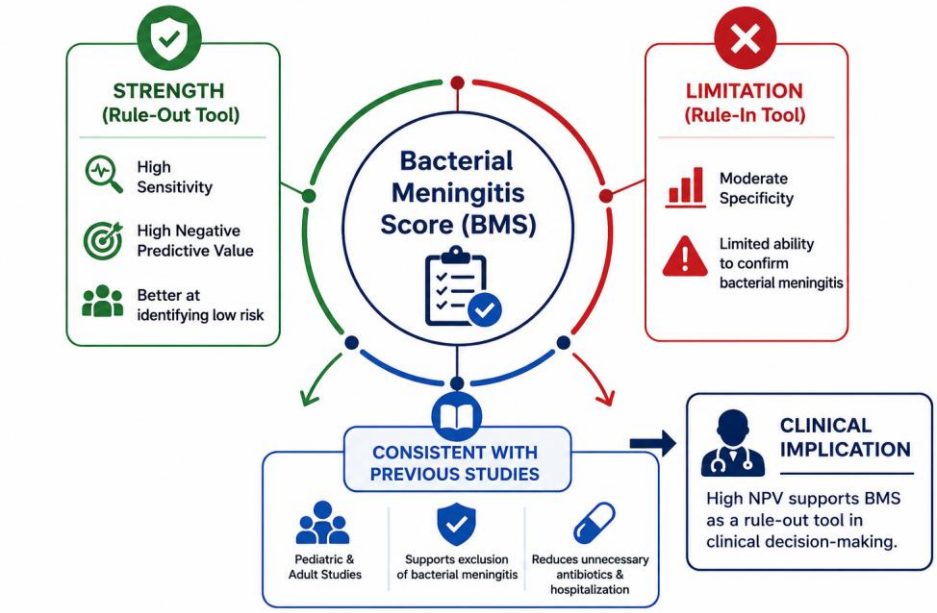


**Figure 1.** Bacterial Meningitis Score : Strengths, Limitations, and Clinical Implications

From a diagnostic perspective, the BMS demonstrated a tendency to perform better in identifying patients at low risk of bacterial meningitis rather than confirming bacterial infection (Y. Chen et al., 2024). This aligns with previous validation studies showing that BMS has high sensitivity and negative predictive value but only moderate specificity. Similar findings have been reported in pediatric and adult populations, where BMS effectively supports exclusion of bacterial meningitis and reduces unnecessary antibiotic exposure and hospitalization. In this study, the high negative predictive value further supports its role as a rule-out tool in clinical decision-making.

Nevertheless, the relatively low positive predictive value indicates that a proportion of patients classified as high risk did not have confirmed bacterial meningitis. This limitation has also been observed in other studies and highlights that BMS should not be used as a standalone diagnostic instrument (Jean-Clément et al., 2026). Instead, its clinical utility is maximized when integrated with cerebrospinal fluid (CSF) analysis, microbiological testing, and comprehensive clinical evaluation.

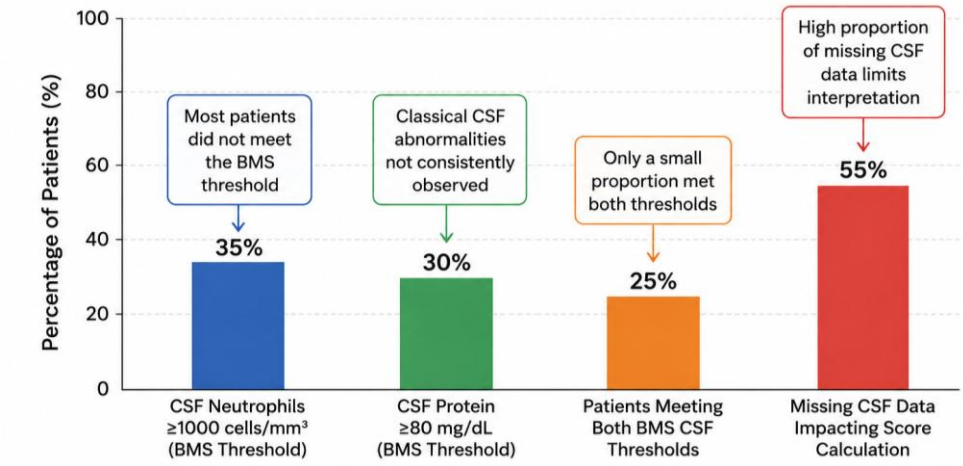


**Figure 2.** Laboratory Findings and Data Limitations in Retrospective Meningitis Study

Laboratory findings in this study further illustrate the limitations of retrospective data interpretation. Classical CSF abnormalities associated with bacterial meningitis, including elevated neutrophil counts and increased protein levels, were not consistently observed. Most patients did not meet the standard BMS thresholds, such as CSF neutrophils ≥1000 cells/mm³ and CSF protein ≥80 mg/dL. However, interpretation of these results is constrained by a significant proportion of missing CSF data, which may have influenced score calculation and diagnostic classification. This issue is commonly encountered in retrospective studies and has been reported as a key limitation in previous research evaluating meningitis diagnostic models.

Peripheral blood absolute neutrophil count (ANC) also showed limited diagnostic specificity (Charlier et al., 2026). Although elevated ANC is commonly associated with bacterial infections due to systemic inflammatory response, it is not specific to bacterial meningitis and may also occur in other infectious or inflammatory conditions. Therefore, ANC should be interpreted cautiously and always in conjunction with CSF findings and clinical presentation.

Beyond diagnostic considerations, prognostic evaluation using the Glasgow Coma Scale (GCS) demonstrated a clear association between neurological status and patient outcomes. Patients with lower GCS scores showed worse clinical outcomes, including increased mortality (Mohammed et al., 2025). This finding is consistent with previous literature identifying reduced consciousness as a strong predictor of poor prognosis in meningitis. Compared to BMS, which primarily supports diagnostic stratification, GCS provides a more direct and reliable indicator of disease severity and prognosis.

The integration of BMS into clinical practice therefore requires a multidimensional approach. Its greatest utility lies in early risk stratification, particularly in emergency settings where rapid clinical decisions are required (Sharma et al., 2025). However, optimal diagnostic accuracy is achieved when BMS is combined with clinical assessment, CSF analysis, and neurological evaluation. This combined approach reduces diagnostic uncertainty and improves patient management strategies.

Several limitations must be acknowledged. The retrospective design introduces the possibility of missing or incomplete data, particularly regarding CSF parameters. The relatively small sample size also limits statistical robustness, while the single-center design restricts generalizability (Song et al., 2024). Despite these limitations, the study provides valuable real-world evidence regarding the application of BMS in a tertiary referral hospital in Indonesia.

Overall, the Bacterial Meningitis Score remains a useful clinical tool for early risk stratification, particularly in ruling out bacterial meningitis (Le et al., 2025). However, its diagnostic accuracy is limited when used in isolation. Integration with clinical findings, laboratory data, and neurological assessment such as GCS is essential to improve diagnostic precision and optimize patient outcomes.

## CONCLUSION

This study demonstrates that the Bacterial Meningitis Score (BMS) is a useful clinical tool for early risk stratification in patients with suspected meningitis at RSUD Dr. Soetomo Surabaya. The findings indicate that BMS is more effective in ruling out bacterial meningitis than confirming the diagnosis, reflecting its high value as a screening instrument rather than a definitive diagnostic method. Diagnostic performance is limited by overlapping clinical manifestations among bacterial, viral, and tuberculous meningitis, as well as incomplete laboratory data, particularly cerebrospinal fluid parameters. Prognostically, patient outcomes were more strongly associated with the Glasgow Coma Scale (GCS), where lower scores indicated worse clinical outcomes. Overall, BMS should not be used in isolation but integrated with clinical assessment, CSF analysis, and laboratory investigations to improve diagnostic accuracy. Despite its limitations, BMS remains clinically relevant for supporting early decision-making and guiding initial management in suspected meningitis cases.

## DECLARATION OF AI AND AI ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this work, the authors utilized Deeply, an AI-based tool, to assist with language translation. Following its use, the authors carefully reviewed and edited the translated content as necessary, and assume full responsibility for the accuracy and integrity of the final publication.

## AUTHOR CONTRIBUTIONS

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.

Author 2: Conceptualization; Data curation; In-vestigation.

Author 3: Data curation; Investigation.

Author 4: Formal analysis; Methodology; Writing - original draft.

## DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## REFERENCES

Akintunde, J. K., Oluwajembola, A. M., Oladosu, M. A., Akintunde, D. G., Akintunde, O. G., Ojo, A. E., & Golagha, R. (2026). Cerebral malaria in resource-limited African regions: Diagnostic and therapeutic challenges. *Infectious Medicine*, *5*(2), 100255. https://doi.org/10.1016/j.imj.2026.100255

Alhamoud, A., BinHussain, I., Arishi, H., Alqassimi, H., Maashi, T., Matabi, S., Majrashi, M., Mobarki, M., Qumayri, M., & Dhayhi, N. (2026). A rare case of pythium brain infection presenting as severe neurological deterioration in a pediatric patient: A case report and literature review. *Radiology Case Reports*, *21*(2), 630–635. https://doi.org/10.1016/j.radcr.2025.10.042

Andrade, H. B., da Silva, I. R. F., Espinoza, R., Ferreira, M. T., da Silva, M. S. T., Theodoro, P. H. N., Detepo, P. J. T., Varela, M. C., Ramos, G. V., da Silva, A. R., Soares, J., Belay, E. D., Sejvar, J. J., Bozza, F. A., Cerbino-Neto, J., & Japiassú, A. M. (2024). Clinical features, etiologies, and outcomes of central nervous system infections in intensive care:

A multicentric retrospective study in a large Brazilian metropolitan area. *Journal of Critical Care*, *79*, 154451. https://doi.org/10.1016/j.jcrc.2023.154451

Bodilsen, J., D'Alessandris, Q. G., Humphreys, H., Iro, M. A., Klein, M., Last, K., Montesinos, I. L., Pagliano, P., Sipahi, O. R., San-Juan, R., Tattevin, P., Thurnher, M., de J. Treviño-Rangel, R., & Brouwer, M. C. (2024). European society of Clinical Microbiology and Infectious Diseases guidelines on diagnosis and treatment of brain abscess in children and adults. *Clinical Microbiology and Infection*, *30*(1), 66–89. https://doi.org/10.1016/j.cmi.2023.08.016

Charlier, C., Vijayaratnam, S., Jeanton-Seybel, C., Moura, A., Bracq-Dieye, H., Thouvenot, P., Tessaud-Rita, N., Valès, G., Leclercq, A., & Lecuit, M. (2026). Specificities of pediatric listeriosis beyond the neonatal period: A national prospective study. *Med*, *7*(2), 100933. https://doi.org/10.1016/j.medj.2025.100933

Chekrouni, N., van Soest, T. M., da Cruz Campos, A. C., Brouwer, M. C., & van de Beek, D. (2024). Bacterial load in cerebrospinal fluid predicts unfavourable outcome in pneumococcal meningitis: A prospective nationwide cohort study. *Clinical Microbiology and Infection*, *30*(6), 772–778. https://doi.org/10.1016/j.cmi.2024.03.012

Chen, R., Cai, Y., Zhang, S., Huo, Z., Song, M., Li, W., Yang, D., Hwang, S., Bai, L., Han, F., & Zhang, X. (2026). Contextualized biomedical language processing enhances ICU survival prediction. *iScience*, *29*(1), 114442. https://doi.org/10.1016/j.isci.2025.114442

Chen, W., Liu, G., Cui, L., Tian, F., Zhang, J., Zhao, J., Lv, Y., Du, J., Huan, X., Wu, Y., & Zhang, Y. (2024). Evaluation of metagenomic and pathogen-targeted next-generation sequencing for diagnosis of meningitis and encephalitis in adults: A multicenter prospective observational cohort study in China. *Journal of Infection*, *88*(5), 106143. https://doi.org/10.1016/j.jinf.2024.106143

Chen, Y., Luo, C., Zhou, G., Wang, H., Dai, K., Wu, W., Wang, S., Su, Z., Peng, F., & Jiang, Y. (2024). The discrimination between autoimmune glial fibrillary acidic protein astrocytopathy and tuberculous meningitis. *Multiple Sclerosis and Related Disorders*, *85*, 105527. https://doi.org/10.1016/j.msard.2024.105527

Chowdhury, A. Z. M. E., Mann, G., Morgan, W. H., Mehnert, A., & Sohel, F. (2025). A comprehensive survey of imaging-based methods of measuring intracranial pressure. *Biomedical Signal Processing and Control*, *107*, 107854. https://doi.org/10.1016/j.bspc.2025.107854

Dong, D. V., Sang, V. V., Hoan, N. X., Ha, N. V., Linh, N. T. K., Sy, B. T., The, N. T., Quang, H. X., Lien, T. T., Trang, V. D., Kremsner, P. G., Song, L. H., Peter, S., Nurjadi, D., & Velavan, T. P. (2025). Causative pathogens and predictors of unfavourable outcomes in central nervous system infections in resource-limited settings. *International Journal of Infectious Diseases*, *159*, 108002. https://doi.org/10.1016/j.ijid.2025.108002

Easter, J. S., & Rose, E. (2024). Advances in pediatric emergency from 2023. *The American Journal of Emergency Medicine*, *80*, 77–86. https://doi.org/10.1016/j.ajem.2024.03.010

Fang, M., Li, S., Mao, Z., Liu, X., Wang, X., Lu, S., & Shier, K. L. (2024). A retrospective study on intracranial mixed infection with tuberculous meningitis in Shenzhen, China. *Microbiology Spectrum*, *12*(7). https://doi.org/10.1128/spectrum.03747-23

Han, B., Shi, Y., Zhang, P., Liu, Y., Xu, M., Xia, J., Li, J., Li, Y., Zhang, M., Wang, J., Ren, Z., Yang, F., Chen, Y., & Feng, G. (2025). Clinical Application Value of Metagenomic Next-Generation Sequencing at Perioperative Period in Patients with Central Nervous System Infections in Neurosurgical Intensive Care Unit. *World Neurosurgery*, *196*, 123824. https://doi.org/10.1016/j.wneu.2025.123824

Jean-Clément, R., Marine, D., Mathilde, S., Christine, B., Geoffroy, B., Matthieu, L., Thibaut, B., & Jean-Vivien, S. (2026). Unmasking the unexpected: Neuroinvasive listeriosis complicating influenza pneumonia. *Diagnostic Microbiology and Infectious Disease*, *114*(3), 117214. https://doi.org/10.1016/j.diagmicrobio.2025.117214

Ji, L., Chen, X., Chen, B., Jin, N., & Yang, J. (2024). Diagnostic Value of Cerebrospinal Fluid Sequencing for Neurosyphilis with Cognitive Impairment. *Biomedical and Environmental Sciences*, *37*(11), 1334–1337. https://doi.org/10.3967/bes2024.167

Lamperti, M., Tufegdzic, B., Byrappa, V., Jain, A., & Manohara, N. (2024). Chapter Six—Brain edema. In I. Kapoor, H. Prabhakar, & C. Mahajan (Eds.), *Neurological and Neurosurgical Emergencies* (pp. 115–151). Academic Press. https://doi.org/10.1016/B978-0-443-19132-9.00022-4

Le, T. H. N., van Abeelen, K. C. J., Ardiansyah, E., Avila-Pacheco, J., Dian, S., Carstens, G., Schramke, L., Hai, H. T., Nguyen, T. B. M., Triet, T. M., Deik, A., Krejci, J., Pruyne, J., Dailey, L., Alisjahbana, B., Netea, M. G., Estiasari, R., Bich Tram, T. T., Donovan, J., … van Laarhoven, A. (2025). Pre-treatment untargeted cerebrospinal fluid metabolomic profiling in tuberculous meningitis uncovers pathways associated with mortality. *Med*, *6*(9), 100703. https://doi.org/10.1016/j.medj.2025.100703

Lu, W., Li, Y., Deng, J., Su, Y., Fan, H., & Huang, K. (2025). Advancements in the identification and utilization of cerebrospinal fluid immunological biomarkers for the diagnosis of tuberculous meningitis. *Microbial Pathogenesis*, *206*, 107826. https://doi.org/10.1016/j.micpath.2025.107826

Mahajan, A., & Mahajan, A. (2026). Chapter 13—Neuroimaging. In H. Prabhakar (Ed.), *Neuromonitoring Techniques (Second Edition)* (pp. 353–402). Academic Press. https://doi.org/10.1016/B978-0-443-32902-9.00013-1

Matschke, J. (2025). Head Trauma: Neuropathology of Traumatic Brain Injury. In J. Payne-James & R. W. Byard (Eds.), *Encyclopedia of Forensic and Legal Medicine (Third Edition)* (pp. 124–137). Elsevier. https://doi.org/10.1016/B978-0-443-21441-7.00104-7

Mlotshwa, P., Kumbakumba, E., Nyehangane, D., Rasti, R., Migisha, R., Nassejje, M., Nanjebe, D., Boum, Y., Mwanga-Amumpaire, J., Alfvén, T., & Gaudenzi, G. (2026). Aetiology, outcomes, and in-hospital mortality predictors of suspected paediatric central nervous system infections in southwestern Uganda: A prospective cohort study. *The Lancet Regional Health - Africa*, *3*, 100050. https://doi.org/10.1016/j.lanafr.2026.100050

Mohammed, H. E., Nasser, M., Abouelmagd, M. E., Haseeb, M. E., Darwish, M. K., Abdelqader, M. S., Tawfik, A., Abdel-Mawla, R. E. M., & Hindawi, M. D. (2025). Revealing the diagnostic value of cerebrospinal fluid presepsin (sCD14) as a new biomarker for postneurosurgical and nosocomial central nervous system infections: A systematic review and meta-analysis of diagnostic test accuracy studies. *Clinical Neurology and Neurosurgery*, *249*, 108767. https://doi.org/10.1016/j.clineuro.2025.108767

Nie, J., Zhang, W., Zhang, H., Yu, H., Li, A., Luo, C., & Hao, Y. (2024). Development and Validation of a Predictive Model for Postoperative Intracranial Infections in Neurosurgery with Risk Factor Analysis. *World Neurosurgery*, *189*, e126–e140. https://doi.org/10.1016/j.wneu.2024.05.184

Nielsen, H., Storgaard, M., Larsen, L., Hansen, B. R., Mens, H., Petersen, P. T., Tetens, M. M., Andersen, C. Ø., Grønholm Jepsen, M. P., Lüttichau, H. R., Wiese, L., Brandt, C. T., & Bodilsen, J. (2026). Community-acquired bacterial meningitis in adults in Denmark (2015–2023): A prospective, nationwide, population-based cohort study. *The Lancet Regional Health - Europe*, *64*, 101628. https://doi.org/10.1016/j.lanepe.2026.101628

Olie, S. E., Staal, S. L., ter Horst, L., van Zeggeren, I. E., Man, W. K., Tanck, M. W. T., van de Beek, D., & Brouwer, M. C. (2024). Diagnostic accuracy of inflammatory markers in adults with suspected central nervous system infections. *Journal of Infection*, *88*(3), 106117. https://doi.org/10.1016/j.jinf.2024.01.016

Peng, Z., Wang, X., Huang, J., & Li, B. (2024). Chapter 53—Pathogenic Escherichia coli. In Y.-W. Tang, M. Y. Hindiyeh, D. Liu, A. Sails, P. Spearman, & J.-R. Zhang (Eds.),

*Molecular Medical Microbiology (Third Edition)* (pp. 1065–1096). Academic Press. https://doi.org/10.1016/B978-0-12-818619-0.00069-1

Pham, X., Jeffcote, T., & Udy, A. (2026). 59—Disorders of consciousness. In D. Martin, J. M. Handy, & B. Venkatesh (Eds.), *Oh's Intensive Care Manual (Ninth Edition)* (pp. 715–728). Elsevier. https://doi.org/10.1016/B978-0-443-11611-7.00059-1

Rochat, R. H., & Harrison, G. J. (2025). 158—Herpes Simplex Viruses 1 and 2. In *Feigin and Cherry's Textbook of Pediatric Infectious Diseases (Ninth Edition)* (pp. 1467-1497.e9). Elsevier. https://doi.org/10.1016/B978-0-323-82763-8.00158-8

Schulz, L. N., Redwan, A., Edwards, S., Hamilton, M. G., & Isaacs, A. M. (2025). Hydrocephalus Pathophysiology and Epidemiology. *Adult Hydrocephalus and Intracranial Pressure Disorders*, *36*(2), 113–126. https://doi.org/10.1016/j.nec.2024.11.001

Shafiq, F., Butt, M. N., Baig, T., Kanwar, D., Laghari, A., & Ahsan, K. (2026). Chapter 2—Epidemiology of neurological diseases in resource-limited countries. In H. Prabhakar, I. Kapoor, & C. Mahajan (Eds.), *Practice of Neuroanesthesia in Resource Limited Countries* (pp. 9–49). Academic Press. https://doi.org/10.1016/B978-0-443-44155-4.00008-6

Sharma, P., Parmar, K., Datta, A., Ghosh, B., Sarmah, D., Borah, A., & Bhattacharya, P. (2025). Recent progress and challenges of acute encephalitis syndrome: An update on pathogenesis and interventional approaches. *Brain Disorders*, *19*, 100267. https://doi.org/10.1016/j.dscb.2025.100267

Siakallis, G. (2025). HIV/AIDS of the Central Nervous System. In S. R. Quah (Ed.), *International Encyclopedia of Public Health (Third Edition)* (pp. 182–202). Academic Press. https://doi.org/10.1016/B978-0-323-99967-0.00040-5

Song, B., Zheng, J., & Zhao, D. (2024). Primary amebic meningoencephalitis in children: A case report and literature review. *IDCases*, *37*, e02028. https://doi.org/10.1016/j.idcr.2024.e02028

Wainwright, M. S., & Farias-Moeller, R. (2024). 125—Disorders of Intracranial Pressure. In S. Ashwal & P. L. Pearl (Eds.), *Swaiman's Pediatric Neurology (Seventh Edition)* (pp. 1118-1126.e4). Elsevier. https://doi.org/10.1016/B978-0-443-10944-7.00125-6

Yabumoto, T., Sugiyama, S., Hosokawa, A., Sakiyama, H., Kobayashi, J., Kitagawa, K., & Nakano, M. (2026). Viral load and pathophysiology-based framework in varicella-zoster virus meningitis: Focus on altered consciousness and outcomes. *Journal of the Neurological Sciences*, *482*, 125810. https://doi.org/10.1016/j.jns.2026.125810

Zhao, Y., He, X., Han, Z., Guo, F., Xie, F., Lin, Z., Chen, L., Song, X., Luo, W., Liu, F., Zhang, L., Zhang, P., Peng, Z., & He, J. (2026). Balamuthia mandrillaris—EBV co-infective encephalitis diagnosed by MetaCAP: comparative mNGS validation and epidemiological landscape from 41 Chinese cases. *International Journal of Infectious Diseases*, *163*, 108302. https://doi.org/10.1016/j.ijid.2025.108302