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Maruquin, JCR, Viado, JR. The Accuracy of Bacterial Meningitis Score (BMS) in Identifying Pediatric Patients at High Risk for Bacterial Meningitis in a Tertiary Level Hospital: A Cross-sectional Study
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ORIGINAL ARTICLE

# THE ACCURACY OF BACTERIAL MENINGITIS SCORE (BMS) IN IDENTIFYING PEDIATRIC PATIENTS AT HIGH RISK FOR BACTERIAL MENINGITIS IN A TERTIARY LEVEL HOSPITAL: A CROSS-SECTIONAL STUDY

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## ABSTRACT

**Background:** Differentiating bacterial from aseptic meningitis in children is critical for optimal treatment. While symptoms overlap, bacterial meningitis demands immediate antibiotics. Traditionally, CSF culture has been the gold standard for diagnosis, but its yield has declined with widespread vaccination. Consequently, some children with negative cultures may still have bacterial meningitis. The Bacterial Meningitis Score (BMS), a validated clinical prediction rule, offers a valuable tool, particularly in resource-limited settings, to better identify high-risk children and guide more effective treatment strategies.

**Objective:** To evaluate the clinical utility and diagnostic accuracy of the BMS in identifying pediatric patients at high risk for bacterial meningitis.

**Methodology:** This retrospective cross-sectional study included 75 pediatric patients (aged 29 days to 18 years) with suspected meningitis seen at the Emergency Room of the Pediatrics Department in Mariano Marcos Memorial Hospital and Medical Center from March to November 2023. Eligible patients underwent lumbar puncture for CSF analysis. The BMS, a five-variable clinical tool including CSF Gram stain, CSF absolute neutrophil count, CSF protein, peripheral absolute neutrophil count, and seizure, were used to classify patients as very low risk (BMS=0) or not very low risk (BMS ≥1).

**Results:** The diagnostic performance of the Bacterial Meningitis Score (BMS) across different cut-off thresholds is as follows: At a cut-off of ≥1, sensitivity is 100%, specificity is 36.80%, positive predictive value (PPV) is 33.3% (95% CI: 22% – 46%), negative predictive value (NPV) is 100% (95% CI: 84.5% – 100%), positive likelihood ratio (LR+) is 1.58 (95% CI: 1.29 – 1.93), negative likelihood ratio (LR–) is 0 (95% CI: 0 – NaN), and Youden's index is 0.36. For a cut-off of ≥2, sensitivity is 88.90%, specificity is 78.90%, PPV is 57% (95% CI: 39% – 73%), NPV is 95% (95% CI: 85% – 98%), LR+ is 4.21 (95% CI: 2.48 – 7.16), LR– is 0.14 (95% CI: 0.03 – 0.52), and Youden's index is 0.67. At a cut-off of ≥3, sensitivity drops to 61.10%, specificity increases to 98.20%, PPV rises to 91% (95% CI: 64% – 98%), NPV is 88% (95% CI: 78% – 94%), LR+ is 33.94 (95% CI: 4.82 – 251.61), LR– is 0.39 (95% CI: 0.22 – 0.70), and Youden's index is 0.59. Finally, at a cut-off of ≥4, sensitivity is markedly low at 5.56%, specificity is perfect at 100%, PPV is 100% (95% CI: 20% – 100%), NPV is 77% (95% CI: 66% – 85%), LR+ is not applicable, LR– is 0.94 (95% CI: 0.84 – 1.05), and Youden's index is 0.056. The optimal cutoff based on Youden's index (0.67) was BMS ≥2, providing a more balanced trade-off between sensitivity (88.90%) and specificity (78.90%).

**Conclusion:** The BMS is a highly sensitive initial screen for bacterial meningitis in children, but its low specificity at the ≥1 cutoff necessitates a more judicious approach. Employing a ≥2 cutoff (Youden index 0.67) significantly improves diagnostic accuracy, optimizing resource utilization and enabling targeted interventions. While definitive diagnosis requires confirmatory testing, the BMS strategically guides initial triage, particularly crucial in resource-constrained environments.

**KEYWORDS:** *RT-PCR Respiratory Panel 2.1, respiratory pathogens, pediatric infections, pneumonia, mechanical ventilation use*

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The authors declare that the data presented are original material and have not been previously published, accepted or considered for publication elsewhere; that the manuscript has been approved by all authors, and that the authors have met the requirements for authorship.

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## INTRODUCTION

Meningitis, an inflammation of the protective membranes surrounding the brain and spinal cord, can be caused by various factors, including viral, bacterial, or fungal infections, as well as certain medications and autoimmune diseases. Common symptoms include fever, headache, neck stiffness, and sensitivity to light. While both bacterial and viral meningitis can present with similar symptoms, bacterial meningitis typically has a sudden and severe onset, while viral meningitis often has a milder beginning and develops more gradually. Differentiating between the two is crucial for accurate diagnosis and appropriate treatment, as bacterial meningitis requires prompt antibiotic therapy to prevent life-threatening complications.

The burden of CNS infections, including meningitis, is disproportionately high in low- and middle-income countries.[1] The Global Burden of Disease study estimated 2.82 million cases of meningitis globally in 2016, resulting in 318,400 deaths.[2] While vaccination has contributed to a decline in CNS infection incidence, the diagnosis of bacterial meningitis can remain challenging due to nonspecific symptoms and signs, particularly in young children. Traditional diagnostic methods, such as cerebrospinal fluid (CSF) analysis and culture, remain the gold standard, but they can be time-consuming and expensive.[3]

Clinical prediction rules like the Bacterial Meningitis Score (BMS) are valuable for improving diagnostic accuracy. The BMS, a five-variable clinical tool, stratifies patients into "very low risk" and "not very low risk" categories for bacterial meningitis.[5,6] The BMS stratifies children into risk categories for bacterial meningitis, guiding antibiotic decisions while awaiting CSF culture results. This is particularly important because CSF cultures, while the gold standard, have decreased yields due to vaccination, meaning some children with negative cultures still have bacterial meningitis. The primary purpose of the BMS is to help prevent missing these cases by identifying high-risk children who may require immediate treatment, even with a negative culture. This study assessed the BMS's accuracy specifically within the Filipino pediatric population.

## MATERIALS AND METHODS

**Design** Cross-sectional study. **Setting and period** Conducted at Mariano Marcos Memorial Hospital and Medical Center, Emergency Room Pediatrics Department for nine months from March 2023 to November 2023. **Population** We included all admitted patients with signs and symptoms of CNS infection who met the inclusion criteria. **Sample size** The required sample size was calculated using the formula: $n = \frac{DEFF \cdot N \cdot p(1-p)}{\left(\frac{d^2}{Z^2_{1-\frac{\alpha}{2}}}\right)(N-1)+p(1-p)}$, where $N$=75 (estimated population), $p$=0.5 (maximum variability), $d$=0.05 (margin of error), $Z$=1.96 (for 95% confidence level), and $DEFF$=1. Using this formula, a minimum sample size of 63 patients was required to estimate a population proportion with 95% confidence and ±5% precision. **Inclusion Criteria** Pediatric patients (ages 29 days to 18 years and 364 days) who arrived at the emergency room (ER) exhibiting clinical indications of CNS infection/meningitis, including fever, headache, vomiting, bulging fontanelle, nuchal stiffness, and Kernig's and Brudzinski's signs and symptoms. **Exclusion criteria** Patients with CSF pleocytosis who would need to be admitted to the hospital regardless of the possibility of bacterial meningitis were excluded. These patients included children with any of the following clinical findings or conditions: immunosuppression; recent neurosurgery; purpura; ventricular shunt device presence; critical illness (defined as significantly altered mental status, evidence of cerebral herniation, need for respiratory or blood pressure support); other bacterial infections requiring inpatient antibiotic therapy (e.g., urinary tract infections in infants <3 months, periorbital cellulitis, deep abscess, bone or joint infections, or known bacteremia); or active Lyme disease. We also excluded patients who had taken oral or parenteral antibiotics within 72 hours of their lumbar puncture since antibiotic pretreatment can change CSF profiles and lead to erroneously negative blood cultures, CSF cultures, or both. **Study population** The study was conducted among eligible pediatric patients seen at the tertiary referral hospital. Patients with a high index of suspicion admitted for CNS Infection at the ER were included and were screened as to the inclusion and exclusion criteria of the study pending the lumbar puncture result. A parent or legal guardian gave and signed a consent form. Lumbar punctures were performed in all the study patients to analyze the cerebrospinal fluid (CSF) for its total cell count, white blood cell count, red blood cell count, polymorphonuclear cells, mononuclear cells, sugar, and protein. Included in the analysis of the CSF were India ink and Gram stain and culture sensitivity tests. BMS was

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then used as a clinical prediction rule scoring the following high-risk predictors: positive CSF Gram stain (2 points), CSF absolute neutrophil count ≥1000 cells/uL (1 point), CSF protein ≥80mg/dL (1 point), peripheral absolute neutrophil count ≥10,000 cells/uL (1 point), seizure before or at the time of presentation (1 point) and classified as to very low risk for bacterial meningitis (BMS=0) and not very low risk (BMS ≥1). **Outcome Measure** Sensitivity, specificity, PPV, and NPV were calculated using a 2x2 contingency table based on a classification of bacterial meningitis cases as very low risk (BMS score = 0) and not very low risk (BMS score > 0)**.** The **gold standard** for diagnosing bacterial meningitis is **cerebrospinal fluid (CSF) culture**. This means identifying the presence of viable bacteria in the CSF sample obtained through a lumbar puncture. **Primary Outcomes** The diagnostic performance of the BMS, including sensitivity, specificity, positive and negative predictive values, and likelihood ratios. **Secondary Outcomes** The secondary outcomes included the demographic and clinical profiles of patients with CNS infection and the frequency of individual BMS predictors. **Statistical Methods** Demographic and clinical profile of patients was summarized using descriptive statistics. Categorical variables were presented using frequency and proportion, while continuous variables were represented by mean and standard deviation (SD); the sensitivity and specificity, negative predictive value and positive predictive value, and positive likelihood ratio and negative likelihood ratio of the BMS were computed using a 2x2 contingency table. Receiver operating characteristic (ROC) curves and area under the curve (AUC) were computed using the QI Macros SPC Software for Excel. **Ethical Considerations** The study adhered to the ethical principles outlined in the Declaration of Helsinki. Prior to the study commencement, the hospital Institutional Ethics Review Board carefully examined and approved the protocol. A verbal assent (for 7-12 years old), simplified assent (for >12 to 15 years old), and parental information and informed consent form for all patients were obtained. Patients aged 15-18 years also co-signed the informed consent form. The risk to the subject's privacy was minimal, and no sensitive information was obtained. The investigator ensured that the subject's anonymity was maintained by using a code name, and data was kept in a sealed locker and computer wherein only the primary investigator knew the password.

## RESULTS

**Table 1. Demographic and clinical profile of patients with CNS infection**

| Patient characteristics | Aseptic meningitis N=57 | Bacterial meningitis N=18 |
|---|---|---|
| **Age** | **f (%)** | **f (%)** |
| 4 weeks – 12 months | 14 (24) | 3 (16.66) |
| 1–3 years old | 17 (29) | 11 (61.11) |
| 3–4 years old | 1 (1) | 2 (11.11) |
| 4–10 years old | 8 (14) | 1 (5.5) |
| 10–18 years old | 17 (29) | 1 (5.5) |
| *Min-max* | 1-18 | 1-12 |
| *Mean ± SD* | 5.84 ± 4.93 | 4.17 ± 3.96 |
| **Gender** | | |
| Male | 32 (56) | 12 (66.6) |
| Female | 25 (43) | 6 (33.33) |
| **Clinical manifestations** | | |
| Fever | 57 (100) | 14 (77.77) |
| Headache | 11 (19.29) | 4 (22.22) |
| Nuchal rigidity | 4 (7.01) | 0 (0) |
| Vomiting | 17 (29.82) | 2 (11.11) |
| Altered mental status | 4 (7.01) | 3 (16.67) |
| Seizure | 33 (57.89) | 14 (77.77) |
| Lethargy | 13 (22.80) | 3 (16.67) |
| Poor activity | 6 (10.52) | 2 (11.11) |

Table 1 displays the demographic and clinical characteristics of 75 patients diagnosed with central nervous system (CNS) infections. The inclusion criteria were met by a total of 75 patients. More than half of patients had aseptic meningitis: 57 (76%) with bimodal age distribution at 1-3 years old (29%) and 10-18 years old (29%). The age range is 1-18 years old with a mean ± SD of 5.84 ± 4.93 with male preponderance (56%). 18 (24%) patients had bacterial meningitis, with the highest incidence among 1-3 years old (61.11%) and age range from 1-12 years old with mean ± SD of 4.17 ± 3.96 and male preponderance (66.66%). The most common manifestation seen in all patients with aseptic meningitis is fever. It also accounts for 77.77% of bacterial meningitis. Two out of 18 patients with bacterial meningitis had positive Gram stains and cultures of *Staphylococcus hominis* and *Staphylococcus* pneumonia. The other 16 are classified as having bacterial meningitis based on corrected glucose to CSF and serum ratio of at least <50%, along with clinical evidence of acute meningitis. The lack of a PCR test is a limitation for the aseptic meningitis group.

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**Table 2. Bacterial Meningitis Score and predictor frequency among patients with CNS infection**

| | High risk predictors | f(%) |
|---|---|---|
| **#1 predictor** | Seizure before or at the time of presentation | 49 (65.33) |
| **#2 predictor** | Peripheral absolute neutrophil count ≥10,000 cells/uL | 19 (25.33) |
| **#3 predictor** | CSF protein ≥ 80mg/dL | 18 (24) |
| **#4 predictor** | CSF absolute neutrophil count >/1000 cells/uL | 20 (26.67) |
| **#5 predictor** | Positive CSF Gram stain | 2 (2.67) |
| **BMS score** | Very low risk (0) | 14 (18.67) |
| | Not very low risk (≥1) | 61 (81.33) |

Table 2 presents the BMS and its individual predictor variables for patients diagnosed with central nervous system (CNS) infections. Seizure before or during presentation is the most common predictor seen in 49 (65.33%) patients. CSF absolute neutrophil count ≥1000 cells/uL, peripheral absolute neutrophil count ≥10,000 cells/uL and CSF protein ≥ 80mg/dL almost has the same frequency. The least predictor is a positive CSF Gram stain (2.67%). Among the 75 study patients diagnosed with CNS infection, 61 had a BMS score indicating a low risk for bacterial meningitis, whereas 14 had a very low risk for bacterial meningitis.

**Table 3. Stratified risk of bacterial meningitis based on the number of positive Bacterial Meningitis Score predictors**

| BMS predictors present | High-risk predictors | No. of patients *with not very low risk* | No. of patients *with bacterial meningitis* |
|---|---|---|---|
| **One (1) predictor** | Seizure before or at the time of presentation | 25 | 4 |
| | Peripheral ANC ≥10,000 cells/uL | 1 | 0 |
| | CSF Protein ≥ 80mg/dL | 4 | 0 |
| | CSF ANC ≥1000 cells/uL | 2 | 1 |
| **Two (2) predictors** | Seizure before or at the time of presentation *and* Peripheral ANC ≥10,000 cells/uL | 11 | 4 |
| | Seizure before or at the time of presentation *and* CSF Protein ≥ 80mg/dL | 1 | 0 |
| | Seizure before or at the time of presentation *and* CSF ANC ≥1000 cells/uL | 1 | 1 |
| | Seizure before or at the time of presentation *and* Positive CSF Gram stain | 2 | 2 |
| | Peripheral ANC ≥10,000 cells/uL *and* CSF ANC ≥1000 cells/uL | 1 | 1 |
| **More than three (≥3) predictors** | All combinations | 13 | 5 |

*Total patients with ≥1 predictors: 61; Abbreviations: ANC, absolute neutrophil count; CSF, cerebrospinal fluid*

Table 3 presents the risk of bacterial meningitis stratified by the number of positive BMS predictor variables (1, 2, or more). It showed 61 patients who were classified as "not very low risk" for bacterial meningitis and accumulated scores. Thirty-two patients (52.45%) had one predictor. The most identified is seizure before or at the time of presentation. Among those patients with one predictor, 4/25 (16%) had bacterial meningitis. Among those 2 predictors, the combination of seizure before or at the time of presentation and peripheral absolute neutrophil count ≥10,000 cells/uL showed the highest number of patients with bacterial meningitis 4/11(36%). And among those patients with more than or equal to 3 predictors, 5/13 (38.46%) had bacterial meningitis. The addition of another risk factor increases the percentage of having bacterial meningitis.

**Table 4 Performance of Bacterial Meningitis Score (BMS)**

| | BMS score cut-off | | | |
|---|---|---|---|---|
| | **Cut-off ≥1** | **Cut-off ≥2** | **Cut-off ≥3** | **Cut-off ≥4** |
| **Sensitivity (%)** | 100 | 88.90 | 61.10 | 5.56 |
| **Specificity (%)** | 36.80 | 78.90 | 98.20 | 100 |
| **Positive predictive value (%)** | 0.33 [0.22 – 0.46] | 0.57 [0.39 – 0.73] | 0.91 [0.64 – 0.98] | 1 [0.20 – 1] |
| **Negative predictive value (%)** | 1 [0.845 – 1] | 0.95 [0.85 – 0.98] | 0.88 [0.78 – 0.94] | 0.77 [0.66 – 0.85] |
| **Positive likelihood ratio (LR+)** | 1.58 [1.29 – 1.93] | 4.21 [2.48 – 7.16] | 33.94 [4.82 – 251.61] | — |
| **Negative likelihood ratio (LR–)** | 0 [0 – NaN] | 0.14 [0.03 – 0.52] | 0.39 [0.22 – 0.70] | 0.94 [0.84 – 1.05] |
| **Youden's index** | 0.36 | 0.67 | 0.59 | 0.056 |

*Prevalence of Bacterial Meningitis 24%; Pretest Odds 0.32; Post-test Odds: 0.50 – 10.71; Post-test Probability 33.33% – 91.5%*

The diagnostic performance of the BMS was evaluated across a range of cutoff thresholds, with results summarized in Table 4. A threshold of BMS ≥1 demonstrated perfect sensitivity (100%), indicating that all cases of bacterial meningitis were correctly identified. However, this was accompanied by low specificity (36.8%), resulting in a high false-positive rate and consequently a low positive predictive value (PPV, 33.3%). Although the negative predictive value (NPV) was 100%, the modest Youden index (0.36) reflects the limited overall discriminative ability of this threshold. This implies that while the BMS ≥1 threshold effectively rules out bacterial meningitis (high NPV), its inability to accurately identify true positives (low PPV) limits its clinical utility, particularly in resource-constrained settings where minimizing unnecessary interventions is paramount.

Elevating the threshold to BMS ≥2 significantly improved the diagnostic profile. Specificity increased substantially to 78.9%, while maintaining a high sensitivity of 88.9%. This resulted in the highest Youden index (0.67) among the evaluated thresholds, indicating the optimal balance between sensitivity and specificity. The corresponding PPV (57.1%) and NPV (95.7%) suggest a more robust diagnostic performance compared to the BMS ≥1 threshold. Likewise, the corresponding likelihood ratios (LR+ = 4.21, LR− = 0.14) and post-test probability (57.1%) indicate improved utility for guiding clinical decisions. This threshold offers a more balanced

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approach, reducing the number of false positives while maintaining a high rate of true positive identification.

Further increasing the threshold to BMS ≥3 yielded even higher specificity (98.2%) and PPV (91.7%), but at the cost of reduced sensitivity (61.1%), leading to an increase in false negatives. While this threshold offers excellent accuracy in identifying true positives, the potential for missing cases of bacterial meningitis necessitates cautious consideration of its clinical application. The trade-off between sensitivity and specificity becomes particularly relevant in the context of resource allocation and the potential for delayed treatment. And a threshold of BMS ≥4, while achieving perfect specificity (100%), proved clinically unsuitable due to its extremely low sensitivity (5.6%).

Furthermore, post-test probabilities based on Bayes' theorem support these thresholds. At BMS ≥1, a positive result yields a 33.3% post-test probability of bacterial meningitis, compared to 57.1% at BMS ≥2 and 91.5% at BMS ≥3. These values contextualize the real-world implications of each cutoff for clinicians assessing risk and making treatment decisions.

Overall, this highlights the critical need for a balanced approach in threshold selection. The results demonstrated a clear trade-off between sensitivity and specificity across different BMS thresholds. While lower thresholds prioritize sensitivity to minimize missed diagnoses, higher thresholds offer improved specificity and PPV, reducing unnecessary interventions and resource utilization. The optimal threshold (BMS ≥2) identified offers a practical compromise, balancing the need for early identification of patients requiring urgent treatment with the efficient allocation of resources.

Receiver operating characteristic (ROC) analysis demonstrated the overall diagnostic accuracy of the BMS as depicted in Figure 1. The area under the ROC curve (AUC) was 0.70, indicating moderate discriminative ability. Among the evaluated thresholds, BMS ≥2 produced the highest Youden's index (0.67), suggesting it offers the best trade-off between sensitivity and specificity in this cohort. While BMS ≥1 provides maximal sensitivity for ruling out disease, thresholds of BMS ≥2 or ≥3 may be better suited for ruling in bacterial meningitis (i.e., identifying those more likely to have it) or guiding admission decisions in settings where overtreatment and resource allocation are significant concerns. These findings are consistent with those of Nigrovic and colleagues, demonstrating the BMS's utility in distinguishing bacterial from aseptic meningitis, enabling prompt and appropriate management.

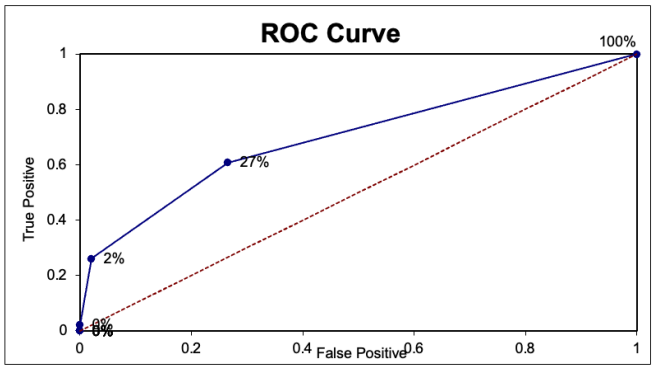


**Figure 1 Receiver Operating Characteristic (ROC) Curve of the Bacterial Meningitis Score (AUC = 0.70)**

## DISCUSSION

The results of our study showed that the most common age group of CNS infection is 1-3 years old, with male predominance, consistent with the study published by Blanco,[7] Farag,[8] and Calegari.[9] The predominant clinical symptoms for both in this study were fever (aseptic meningitis 57, 100% and bacterial meningitis 14, 77.77%) and seizure (aseptic meningitis 33, 57.89% and bacterial meningitis 14, 77.77%), just like in the study of Farag.[8] Seizure before or at the time of presentation (49, 65.33%) as a clinical predictor for bacterial meningitis is the most common presentation for patients with CNS infection. Seizure is a presenting symptom or a significant neurological complication in CNS infections such as meningitis, encephalitis, brain abscess, and subdural empyema.[10] A positive CSF Gram stain (2, 2.67%) is the least predictive among the predictors using BMS. While the gold standard for diagnosing bacterial meningitis is culture, about 90% of patients coming to the emergency room with meningitis have a negative Gram stain, which presents a significant diagnostic problem that needs to be thoroughly investigated in the era of molecular diagnostics.[10] Gram stain is highly specific, but falsely negative in up to 40% of cases, so it cannot be solely relied upon.[4] The association between seizure and bacterial meningitis (BM) is well established.[11] In this study, the high-risk predictors from the BMS for having bacterial meningitis identified seizure (25/61, 40.98%) as the most common single predictor that classified them as "not low risk" with 16% (4/25) of having bacterial meningitis. Just like in the study conducted by Vieira, where they evaluated 202 patients with bacterial

meningitis aged between 0 and 12-year-old showing that 41.1% had neurological complications, and the most common problems were seizures, occurring in 38 patients (18.8%). Furthermore, in a recent study published, Davenport et al. evaluated 81 children with bacterial meningitis with an average age of 7.5-year-old and showed that 18.5% evolved with neurological complications; the most frequent were seizures (8/9.9%), cerebral ischemia (5/6.2%), hydrocephalus (4/4.9%) and syndrome of inappropriate secretion of antidiuretic hormone (3/3.7%). In children and young adults, seizures are among the most typical signs of bacterial meningitis.[12] A combination of seizure and peripheral ANC ≥10,000 cells/uL (11/61, 18%) are the two most frequent predictors in classifying "not very low risk" using BMS that resulted in the identification of 36% as bacterial meningitis.

In a meta-analysis by Nigrovic et al. published in 2002 and 2012, the sensitivity of the BMS score was 99.3% (95% CI, 98.7-99.7%), and the negative predictive value was 98.3% (95% CI, 96.6%-99.3%).[5,6] It is further justified by a systematic analysis of numerous bacterial meningitis prediction rules published in 2013 by Kulik et al., who concluded that, out of all the research they examined, the BMS had the best performance and the most significant level of evidence. In two small pediatric studies in France and Belgium (including 166 and 277 meningitis study participants, respectively), the BMS has previously been independently verified (prospective and retrospectively) and demonstrated to perform very well.[13,14,15] Regardless of the number of high-risk predictors present, none of the patients with a BMS in the very low risk group developed bacterial meningitis (negative predictive value, 100% for both trials), which is consistent with our findings.

The conventional bacterial meningitis score (BMS) cutoff of ≥1, while exhibiting perfect sensitivity (100%), suffers from low specificity, resulting in a high false-positive rate. This compromises its utility in resource-constrained environments where antibiotic stewardship and bed capacity are critical considerations. Analysis using Youden's index revealed that a BMS cutoff of ≥2 optimizes diagnostic performance, achieving a Youden index of 0.67. This represents the optimal balance between sensitivity and specificity, significantly reducing false positives. Employing this stricter threshold enhances the positive predictive value (PPV), thereby improving the identification of patients with a substantially elevated probability of bacterial meningitis. This refined approach enables targeted empirical antibiotic therapy and hospital admission, prioritizing patients at the highest risk while minimizing unnecessary interventions and resource utilization. The improved PPV associated with the ≥3 cutoff is particularly advantageous in settings with limited resources, ensuring that antibiotic use and hospital beds are allocated efficiently to those most likely to benefit.

In the context of the BMS, high specificity means the test is good at correctly identifying individuals who do *not* have bacterial meningitis. This is crucial because a false positive (incorrectly diagnosing bacterial meningitis) could lead to unnecessary antibiotic treatment, with potential side effects and the development of antibiotic resistance. Moreover, the BMS's specificity directly impacts its overall accuracy. Accuracy is a measure of how often the test gives the correct result (both true positives and true negatives). While high sensitivity (correctly identifying those *with* the condition) is important for early detection, high specificity is equally vital to minimize misdiagnosis and inappropriate treatment. A test with high sensitivity but low specificity might frequently flag individuals who are healthy, leading to unnecessary interventions and resource consumption. Therefore, both high sensitivity and high specificity are needed for a highly accurate test. A BMS with 100% specificity would mean that every individual identified as *not* having bacterial meningitis truly does not have the disease. However, this level of specificity is rarely achieved in practice.

Overall, the results of this study demonstrate that it is not entirely accurate to diagnose bacterial meningitis using BMS as a clinical prediction rule. It is imperative that this prediction rule is seen as a valuable tool for clinical management rather than as exact rules for therapeutic decision-making. Of note, our goal was not to look at the decision rule determining when a lumbar puncture is appropriate. Our findings indicate that, regardless of the CSF result, the five-parameter Nigrovic scoring system is nearly always linked to a diagnosis of bacterial meningitis. One clinical criterion that might be the cause of this is a seizure, which is factored into the scoring system; the presence of this indicates already a not-very-low risk for bacterial meningitis.

## CONCLUSION

The Bacterial Meningitis Score (BMS) serves as a valuable preliminary screening tool to identify patients requiring further evaluation for bacterial meningitis, but it should not be used as a standalone diagnostic test. The optimal BMS threshold (≥1 vs. ≥2) depends on the specific clinical setting and resource availability. The BMS ≥2 threshold, with its superior balance between sensitivity and specificity and higher PPV, may be preferable in settings where efficient resource allocation and minimizing unnecessary interventions are priorities. Conversely, a lower BMS threshold (≥1) may still be appropriate in resource-limited settings where missing cases outweigh concerns over false positives. Therefore, the choice of threshold necessitates careful consideration of the balance between sensitivity, specificity, and the practical constraints of the healthcare environment.

## LIMITATIONS OF THE STUDY/RECOMMENDATIONS

Our study has several limitations. First, only a small number of cases with bacterial meningitis were included in this single-center study. Nonetheless, the findings are still significant because this is the first study in the Philippines to evaluate BMS's accuracy for bacterial meningitis in the present healthcare setting. Second, to rule out aseptic meningitis as a differential diagnosis, we could not conduct polymerase chain reaction (PCR) or viral culture. Third, in cases of meningitis with a negative Gram stain, this score should be retested because when the result of the predictor test is positive, the diagnosis of meningitis is complete, and no more testing is necessary[15,36]. Fourth, there was a great deal of variation in the definition of meningitis employed in various studies, which reflected variations in the actual world of managing patients. Fifth, different countries may have different distributions of bacterial meningitis causes, affecting how well the BMS works. However, the primary pathogens responsible for bacterial meningitis are likely distributed similarly in other countries with comparable immunization programs and coverage, and the BMS can assist in identifying those at risk for bacterial meningitis. In addition, as is the case with every rule, physicians must be aware that no criteria can entirely rule out the chance of BM and that rare patients with CSF pleocytosis and a BMS score suggesting low risk can also develop BM. Lastly, comparing this to clinical judgment alone is still difficult because it was not assessed in any of the studies.

A comprehensive, multicenter, prospective study is needed to determine which results are most helpful in predicting bacterial meningitis. Further study should incorporate or integrate novel methods for assessing the degree of inflammatory response, such as CRP, procalcitonin, and interleukin, or for the direct or indirect assay for bacterial antigens or a variety of genetic techniques for the microbiological diagnosis of meningitis.

## CONFLICT OF INTEREST

None declared.

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