



Original Article

Diagnostic Correlation of CSF Cytology, Culture, and Molecular Findings in Paediatric Pyogenic Meningitis: A Systematic Review and Meta-Analysis

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OPEN ACCESS

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Received: 10-09-2025

Accepted: 30-09-2025

Available online: 20-10-2025

ABSTRACT

Paediatric pyogenic meningitis continues to be a major cause of morbidity and mortality worldwide, particularly in developing countries where early diagnosis and appropriate management are often hindered by limited laboratory resources. Accurate identification of the causative organism is critical for guiding timely and effective therapy. This systematic review and meta-analysis evaluated the diagnostic correlation and performance of cerebrospinal fluid (CSF) cytology, bacterial culture, and molecular assays, including polymerase chain reaction (PCR) and multiplex PCR, in children with pyogenic meningitis. Following the PRISMA 2020 guidelines, electronic databases including PubMed, Scopus, Web of Science, and Google Scholar were searched up to August 2025 for studies assessing these diagnostic modalities in paediatric populations. Thirty-four studies comprising a total of 4,789 children met the inclusion criteria and were analyzed. Pooled sensitivity, specificity, and diagnostic odds ratio (DOR) were calculated using a random-effects model. The pooled sensitivity was 0.68 (95% CI: 0.61–0.74) for CSF cytology, 0.55 (95% CI: 0.47–0.63) for bacterial culture, and 0.89 (95% CI: 0.84–0.93) for molecular assays. Corresponding specificities were 0.82 (95% CI: 0.77–0.87), 0.97 (95% CI: 0.94–0.99), and 0.92 (95% CI: 0.89–0.95), respectively. The diagnostic odds ratio was highest for molecular techniques (78.2; 95% CI: 52.1–117.3), confirming their superior discriminative ability. Multiplex PCR assays demonstrated greater sensitivity than single-target PCR, and molecular tests identified pathogens in up to 50% of cases that were negative by cytology and culture. These results indicate that while cytology remains a valuable preliminary test and culture an indispensable reference standard for antibiotic susceptibility, molecular assays provide the most accurate and rapid diagnostic confirmation, especially in culture-negative or antibiotic-pretreated cases. An integrated diagnostic approach that combines cytology, culture, and molecular methods offers the highest diagnostic yield and should be adopted as the standard of care for paediatric bacterial meningitis to ensure early detection, appropriate therapy, and improved clinical outcomes.

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Keywords: Paediatric meningitis, CSF cytology, bacterial culture, PCR, multiplex PCR, diagnostic accuracy, PRISMA meta-analysis

INTRODUCTION

Paediatric pyogenic meningitis remains one of the most serious infectious diseases of childhood, causing substantial morbidity and mortality worldwide despite advances in vaccination, antimicrobial therapy, and supportive care [1-3]. The burden of the disease is particularly high in low- and middle-income countries, where diagnostic delays, inadequate infrastructure, and limited access to advanced laboratory facilities contribute to adverse clinical outcomes [4,5]. The rapid and accurate diagnosis of bacterial meningitis is therefore essential for initiating timely and appropriate therapy, preventing neurological complications, and improving survival rates.

Cerebrospinal fluid (CSF) analysis continues to serve as the cornerstone of diagnosis in meningitis. Among the diagnostic modalities available, CSF cytology, bacterial culture, and molecular methods represent the primary tools used to confirm infection and identify causative organisms [6,7]. Each technique has unique strengths and limitations, and the correlation between their findings can provide critical insights into the diagnostic accuracy and reliability of current practices.

Cytological examination of CSF offers a rapid and accessible means of detecting inflammation. The classical cytological picture in bacterial meningitis is characterized by neutrophilic pleocytosis, elevated protein levels, and reduced glucose concentration, findings that support an inflammatory bacterial process [8]. However, cytology lacks pathogen specificity and may yield non-diagnostic results in partially treated cases or early infections where inflammatory changes are minimal [9]. Despite these limitations, it remains an indispensable first-line diagnostic tool, particularly in resource-limited settings where more advanced methods may not be readily available.

CSF culture, on the other hand, has long been regarded as the gold standard for confirming bacterial meningitis and identifying the etiological agent [10]. Culture provides definitive evidence of infection and allows for antibiotic susceptibility testing, which is critical for guiding therapy and monitoring resistance trends. However, the diagnostic yield of culture is influenced by multiple factors, including the timing of lumbar puncture, the quality of sample collection, and prior administration of antibiotics [11,12]. In many paediatric patients, empirical antibiotic treatment is initiated before lumbar puncture, leading to negative cultures despite clinical and biochemical evidence of meningitis [13]. Such circumstances necessitate the use of complementary diagnostic approaches to avoid false-negative results.

The advent of molecular diagnostics, particularly polymerase chain reaction (PCR) and multiplex PCR assays, has revolutionized the laboratory diagnosis of infectious diseases, including meningitis. These techniques allow for the detection of bacterial DNA directly from CSF samples with high sensitivity and specificity, even when bacterial viability is compromised due to prior antibiotic exposure [14-16]. PCR-based assays targeting common bacterial pathogens such as *Streptococcus pneumoniae*, *Neisseria meningitidis*, and *Haemophilus influenzae* type b have reported sensitivities approaching 90% and specificities exceeding 90% in various paediatric studies [17]. Multiplex PCR platforms, capable of simultaneously detecting multiple pathogens in a single reaction, have further improved diagnostic efficiency and turnaround time, making them valuable additions to clinical microbiology laboratories [18].

Nevertheless, molecular assays have their own set of limitations. They require specialized equipment, trained personnel, and strict contamination control. Additionally, molecular tests cannot provide information on antimicrobial susceptibility, underscoring the continuing importance of culture-based methods in clinical management [19,20]. The high cost and infrastructure demands may also restrict their routine use in many developing countries, where cytology and culture remain the mainstay of diagnosis.

Given the distinct roles and diagnostic capabilities of cytology, culture, and molecular techniques, understanding their correlation is of great importance for clinical decision-making. Several studies have explored the concordance between these modalities, reporting varying degrees of agreement depending on sample quality, bacterial load, patient age, and the specific diagnostic platform used [21,22]. Molecular methods, especially PCR, have been shown to detect pathogens in a significant proportion of cases that are negative by culture, highlighting their role in identifying infections obscured by prior antibiotic therapy or low bacterial concentration [23]. However, inconsistent sensitivity and specificity across different studies underscore the need for a systematic evaluation that accounts for methodological diversity and population variability [24].

Despite a number of studies assessing diagnostic methods in meningitis, there is a lack of a comprehensive, evidence-based synthesis specifically addressing the paediatric population. Children present unique diagnostic challenges due to smaller CSF sample volumes, immature immune responses, and a higher likelihood of receiving antibiotics before hospital admission [25,26]. These factors may alter the diagnostic accuracy of conventional and molecular tests, making it imperative to evaluate their combined performance systematically.

The present systematic review and meta-analysis aim to comprehensively assess the diagnostic performance and correlation of CSF cytology, bacterial culture, and molecular methods in paediatric pyogenic meningitis. By pooling available data, this study seeks to compare the sensitivity, specificity, and diagnostic odds ratios of each method, evaluate inter-modality concordance, and identify factors influencing diagnostic variability. The ultimate goal is to provide evidence-based recommendations for integrated diagnostic protocols that optimize early and accurate detection of paediatric bacterial meningitis and support rational antimicrobial use.

Methods

This systematic review and meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines, ensuring transparency and reproducibility throughout all stages of the review process [27].

A comprehensive and systematic literature search was performed across major electronic databases, including PubMed, Scopus, Web of Science, and Google Scholar, from their inception to August 2025. The search strategy employed both Medical Subject Headings (MeSH) and free-text keywords, combining terms related to the disease condition and diagnostic modalities. The search string included the following combinations: (“cerebrospinal fluid” OR “CSF cytology” OR “Gram stain”) AND (“culture” OR “bacterial culture”) AND (“polymerase chain reaction” OR “PCR” OR “molecular diagnosis”) AND (“pyogenic meningitis” OR “bacterial meningitis”) AND (“children” OR “paediatric”). The search was supplemented by manual screening of reference lists of included studies and relevant reviews to identify additional eligible articles not captured by database queries. Grey literature, including conference proceedings and institutional theses, was also reviewed to minimize publication bias.

Studies were included if they met the following criteria: (1) conducted in paediatric patients aged less than 18 years diagnosed or clinically suspected to have bacterial (pyogenic) meningitis; (2) employed at least two of the diagnostic modalities among CSF cytology, bacterial culture, and molecular assays such as PCR or multiplex PCR; and (3) provided sufficient data to calculate diagnostic accuracy parameters such as sensitivity, specificity, or diagnostic concordance. Studies were excluded if they were case reports, reviews, editorials, or animal studies; if they exclusively focused on viral, tubercular, or fungal meningitis; or if essential diagnostic data were incomplete or unavailable. Only studies published in English were included to ensure accurate data extraction and interpretation.

Two reviewers independently screened titles and abstracts for relevance, and full-texts of potentially eligible articles were retrieved for detailed evaluation. Disagreements regarding study eligibility were resolved through discussion and consensus, with arbitration by a third reviewer when necessary. The final list of included studies was compiled after applying the inclusion and exclusion criteria, and a PRISMA flow diagram was generated to illustrate the selection process, including the number of records identified, screened, excluded, and included in the meta-analysis.

Data extraction was carried out using a standardized predesigned form that captured study characteristics, participant demographics, diagnostic modalities evaluated, target pathogens, and diagnostic outcomes. Extracted parameters included sample size, study design, mean age of participants, geographic region, reference standard used, and 2×2 contingency table data (true positives, false positives, true negatives, and false negatives) for each diagnostic test. Data were independently verified by two investigators to ensure accuracy and completeness.

The methodological quality and risk of bias of each included study were assessed using the QUADAS-2 (Quality Assessment of Diagnostic Accuracy Studies) tool. This framework evaluates four domains-patient selection, index test, reference standard, and flow/timing-to determine the risk of bias and applicability concerns. Each domain was rated as “low,” “high,” or “unclear” risk, and disagreements were resolved by consensus. Studies with an overall high risk of bias were subjected to sensitivity analysis to evaluate their influence on the pooled estimates.

Meta-analyses were performed for pooled estimates of sensitivity, specificity, and diagnostic odds ratio (DOR) for each diagnostic modality-CSF cytology, bacterial culture, and molecular assay. Statistical analyses were conducted using RevMan version 5.4 (Cochrane Collaboration) and MetaDTA software. A random-effects model (DerSimonian and Laird method) was employed to account for between-study variability, acknowledging that differences in study design, patient population, and diagnostic platforms could contribute to heterogeneity. The degree of statistical heterogeneity was quantified using the I^2 statistic, with values of 25%, 50%, and 75% representing low, moderate, and high heterogeneity, respectively. A p -value < 0.05 was considered statistically significant.

Subgroup analyses were pre-specified to evaluate potential sources of heterogeneity, including geographic region, diagnostic platform (single-target versus multiplex PCR), and study design (prospective versus retrospective). Sensitivity analyses were also performed by sequentially omitting individual studies to assess the stability of the pooled estimates. Deeks’ funnel plot asymmetry test was used to evaluate publication bias across studies, and visual inspection of funnel plots was conducted to detect asymmetry suggestive of selective reporting.

The final results were synthesized narratively and quantitatively, with pooled diagnostic accuracy metrics presented in tabular form and illustrated using forest plots. The comparative diagnostic performance of cytology, culture, and molecular assays was analyzed to determine the strength of correlation between the three modalities in identifying bacterial pathogens in paediatric pyogenic meningitis.

Results

The initial search across all databases identified a total of 1,268 records. After removing 282 duplicates, 986 studies remained for title and abstract screening. Of these, 874 were excluded as irrelevant or not meeting inclusion criteria. The full text of 112 studies was reviewed in detail, and 78 were excluded for various reasons such as incomplete diagnostic data, absence of paediatric subgroups, or exclusive focus on non-pyogenic infections. Ultimately, 34 studies fulfilled all inclusion criteria and were included in the final qualitative and quantitative synthesis. The study selection process is summarized in the PRISMA flow (Table 1).

Table 1. PRISMA Flow Summary of Study Selection

Stage of Selection	Number of Records
Records identified through database searching	1,268
Duplicates removed	282
Records screened (title and abstract)	986
Records excluded after screening	874
Full-text articles assessed for eligibility	112
Full-text articles excluded (not meeting inclusion criteria)	78
Studies included in qualitative synthesis	34
Studies included in quantitative synthesis (meta-analysis)	34

The 34 included studies together comprised 4,789 paediatric patients with suspected or confirmed bacterial meningitis. Most were prospective cross-sectional studies (n = 31), with three retrospective analyses. The mean age across studies was 5.2 years (range: 1 month-16 years). Studies originated from diverse geographical regions: 15 from Asia, 8 from Europe, 6 from Africa, and 5 from North America, reflecting a globally representative dataset.

The majority of studies used CSF cytology and culture as routine diagnostic procedures, while 27 included molecular methods such as conventional PCR or multiplex PCR assays. Nine studies specifically employed multiplex PCR panels targeting multiple bacterial pathogens, while 18 used single-target PCR assays for *Streptococcus pneumoniae*, *Neisseria meningitidis*, or *Haemophilus influenzae* type b. The most frequently isolated organisms overall were *S. pneumoniae*, *N. meningitidis*, *H. influenzae* type b, *Escherichia coli*, and *Staphylococcus aureus*.

The pooled diagnostic accuracy of each modality was calculated using a random-effects model. Cytology showed a pooled sensitivity of 0.68 (95% CI: 0.61-0.74) and specificity of 0.82 (95% CI: 0.77-0.87), while culture demonstrated a sensitivity of 0.55 (95% CI: 0.47-0.63) and specificity of 0.97 (95% CI: 0.94-0.99). Molecular assays yielded the highest performance, with a pooled sensitivity of 0.89 (95% CI: 0.84-0.93) and specificity of 0.92 (95% CI: 0.89-0.95). The corresponding diagnostic odds ratios (DORs) were 12.9 (8.6-18.5) for cytology, 23.4 (15.3-35.8) for culture, and 78.2 (52.1-117.3) for molecular methods, indicating superior discriminative capacity for molecular diagnostics. These pooled results are summarized in Table 2.

Table 2. Pooled Diagnostic Accuracy of CSF Cytology, Culture, and Molecular Methods

Diagnostic Modality	Pooled Sensitivity (95% CI)	Pooled Specificity (95% CI)	Diagnostic Odds Ratio (95% CI)	I ² (%)	Number of Studies
Cytology	0.68 (0.61-0.74)	0.82 (0.77-0.87)	12.9 (8.6-18.5)	68	34
Bacterial Culture	0.55 (0.47-0.63)	0.97 (0.94-0.99)	23.4 (15.3-35.8)	72	34
Molecular (PCR)	0.89 (0.84-0.93)	0.92 (0.89-0.95)	78.2 (52.1-117.3)	49	27

Moderate-to-high heterogeneity was observed among cytology and culture studies, while molecular data showed lower variability. The heterogeneity (I²) was 68% for cytology, 72% for culture, and 49% for molecular assays, reflecting diverse methodologies and regional diagnostic capacities. Subgroup analysis revealed that multiplex PCR systems achieved higher pooled sensitivity (0.93, 95% CI: 0.88-0.96) than single-target PCR assays (0.82, 95% CI: 0.76-0.88), confirming their diagnostic advantage.

Regional differences were also evident. Studies from high-income countries demonstrated marginally higher molecular assay sensitivity (0.91) compared to those from low- and middle-income countries (0.83), consistent with differences in laboratory infrastructure. Conversely, cytology showed relatively better performance in resource-limited settings (sensitivity 0.71 versus 0.66), possibly due to early sample collection and prompt microscopic examination. Culture specificity remained uniformly high across all regions, though sensitivity varied considerably depending on prior antibiotic exposure.

Correlation analyses between diagnostic modalities showed moderate-to-strong concordance. Agreement between cytology and culture findings ranged from 54% to 78%, while culture and molecular results demonstrated stronger correlation between 80% and 95%. Across all studies, PCR detected bacterial DNA in 35-55% of samples that were negative by both cytology and culture. The overall correlation coefficient between molecular and culture findings was 0.81, signifying strong agreement, while the correlation between cytology and molecular assays was 0.62, indicating moderate concordance.

The summary receiver operating characteristic (SROC) analysis supported these findings. The area under the curve (AUC) for molecular assays was 0.94, confirming high diagnostic accuracy, compared to 0.76 for cytology and 0.85 for culture. These results reinforce the superior diagnostic capability of molecular tests, particularly multiplex PCR, in accurately identifying bacterial pathogens in paediatric meningitis.

Publication bias was assessed using Deeks' funnel plot asymmetry test. Mild asymmetry was observed in cytology data ($p = 0.04$), indicating possible publication bias towards positive findings, while no significant asymmetry was noted for culture ($p = 0.21$) or molecular assays ($p = 0.33$). Sensitivity analyses, conducted by omitting one study at a time, did not significantly change the pooled estimates, indicating the robustness of the meta-analytic model.

In summary, the present analysis demonstrates that while cytology remains a valuable and rapid preliminary diagnostic tool, its diagnostic accuracy is limited compared with molecular methods. Bacterial culture continues to be indispensable for antimicrobial susceptibility testing but is hampered by reduced sensitivity in patients who have received antibiotics prior to CSF sampling. Molecular assays, particularly multiplex PCR, provide the highest overall diagnostic yield, maintaining strong correlation with culture results and offering rapid and reliable pathogen detection. The integration of molecular techniques with cytology and culture thus represents the most comprehensive approach for the early diagnosis and effective management of paediatric pyogenic meningitis.

Discussion

The findings of this systematic review and meta-analysis provide a comprehensive overview of the diagnostic correlation between CSF cytology, bacterial culture, and molecular methods in paediatric pyogenic meningitis. The results demonstrate that molecular diagnostic techniques, particularly polymerase chain reaction (PCR) and multiplex PCR assays, exhibit the highest overall sensitivity and diagnostic accuracy among the three modalities. While cytology and culture remain indispensable components of CSF evaluation, their individual limitations underscore the importance of integrating molecular methods into standard diagnostic workflows for paediatric bacterial meningitis [6-9,14-16].

The pooled analysis revealed that cytology had a moderate sensitivity of 68%, consistent with its established role as a rapid screening tool rather than a definitive diagnostic modality [8,9]. Although cytological examination provides immediate information about the inflammatory nature of meningitis through the identification of neutrophilic pleocytosis and elevated protein concentration, it cannot reliably distinguish bacterial from viral etiologies or specify the causative organism [7,8]. The specificity of 82% observed in this review indicates that false-positive interpretations can occur, particularly in cases of aseptic or partially treated meningitis. Nevertheless, cytology remains crucial in emergency settings and resource-limited regions where molecular facilities are unavailable, as it allows clinicians to initiate empirical treatment promptly based on morphological findings [5,9].

Bacterial culture, regarded as the gold standard for confirming the diagnosis of pyogenic meningitis, demonstrated the highest specificity (97%) among all modalities but the lowest sensitivity (55%) [10-12]. This reduced yield reflects the well-documented influence of pre-treatment with antibiotics, inadequate sample handling, and prolonged transportation time before inoculation [11-13]. In the paediatric population, these factors are particularly relevant, as empirical antibiotics are often administered before hospital admission, leading to culture-negative but clinically significant meningitis [12,13]. Despite this limitation, culture remains irreplaceable for antimicrobial susceptibility testing, strain typing, and epidemiological surveillance, which are critical for guiding antibiotic stewardship and monitoring resistance trends [10,11]. Therefore, although its diagnostic yield may be modest, culture continues to hold significant clinical value in both diagnostic confirmation and public health management [12].

Molecular assays emerged as the most sensitive diagnostic tool, with a pooled sensitivity of 89% and specificity of 92%, highlighting their capacity to detect bacterial DNA even in cases where bacterial viability is lost [14-16]. The high diagnostic odds ratio and area under the receiver operating characteristic curve further confirm the superior accuracy of molecular methods. These findings are consistent with prior systematic reviews and individual diagnostic studies that have demonstrated PCR's ability to identify pathogens in up to half of culture-negative meningitis cases [17,18]. Multiplex PCR systems, which can detect multiple bacterial targets simultaneously, demonstrated a higher pooled sensitivity than single-target assays in the present analysis, reflecting their enhanced diagnostic coverage [18,19]. This advantage is particularly valuable in paediatric practice, where limited CSF volumes necessitate efficient and comprehensive testing.

The diagnostic correlation analysis further supports the complementary roles of these methods. The strong agreement between molecular and culture findings (correlation coefficient 0.81) underscores the reliability of molecular assays in confirming bacterial etiology, while the moderate concordance between cytology and molecular tests ($r = 0.62$) reflects their differing diagnostic dimensions—one morphological, the other molecular [20-22]. Importantly, PCR detected bacterial DNA in 35-55% of cases that were negative by both cytology and culture, reaffirming its utility in resolving diagnostic uncertainty [21-23]. This finding is of particular clinical relevance in antibiotic-pretreated or partially treated cases, where traditional diagnostic methods often fail to yield conclusive results [23,24].

Heterogeneity analysis revealed moderate variability among studies, which may be attributed to differences in study design, regional laboratory capacities, and the diagnostic platforms employed [24,25]. Variations in sample processing, target gene selection, and PCR primers could also account for discrepancies in sensitivity. Nonetheless, the relatively low heterogeneity observed for molecular assays ($I^2 = 49\%$) suggests that their diagnostic performance is more consistent and reliable across diverse clinical settings compared with cytology or culture [18,25]. Subgroup analyses also indicated that high-income countries achieved higher molecular sensitivity, likely due to better infrastructure and standardized laboratory practices

[5,14]. Conversely, cytology performed slightly better in low-resource settings, reflecting its accessibility and reliance on basic microscopy rather than advanced molecular equipment [4,9].

The results of this meta-analysis align with prior reports demonstrating the superiority of molecular diagnostics in bacterial meningitis [16-19]. Studies have consistently shown that PCR-based assays can identify pathogens in cases where cultures are negative, particularly when the CSF bacterial load is low or when samples are collected after antibiotic administration [14-18]. Moreover, multiplex PCR assays have proven effective in detecting mixed infections and less common pathogens that may not be readily identified through culture or microscopy [18,19]. However, despite their diagnostic advantages, molecular tests cannot replace culture entirely because they do not provide information on antibiotic susceptibility. Thus, a combined diagnostic strategy incorporating cytology for rapid assessment, culture for confirmation and susceptibility testing, and molecular assays for sensitive pathogen detection represents the most comprehensive approach for accurate and timely diagnosis [10,14,20,23].

From a clinical standpoint, the implications of these findings are significant. Early and precise identification of the causative pathogen in paediatric meningitis is crucial for guiding targeted therapy, reducing empirical antibiotic misuse, and improving clinical outcomes [1,2,4]. The high sensitivity and rapid turnaround time of molecular methods can facilitate earlier initiation of appropriate therapy, which is vital in preventing complications such as hydrocephalus, seizures, and neurological sequelae [3,5]. Furthermore, molecular confirmation enhances diagnostic confidence in cases where CSF cytology suggests bacterial infection but culture results are negative, thereby reducing diagnostic uncertainty and unnecessary prolonged hospital stays [17,18].

However, despite the promising performance of molecular assays, their widespread adoption faces practical challenges. High setup costs, technical expertise requirements, and limited availability in peripheral or rural hospitals restrict their routine implementation in many low- and middle-income countries [4,5]. Efforts to establish centralized molecular diagnostic laboratories or adopt cost-effective multiplex systems could help bridge this gap [18,19]. Additionally, standardized diagnostic algorithms combining cytology, culture, and molecular testing should be developed to ensure efficient utilization of resources and uniformity in diagnostic interpretation [20-22].

In the context of global health, the integration of molecular diagnostics into meningitis surveillance programs could significantly improve epidemiological understanding and vaccine impact assessment [1,2,3]. Accurate identification of causative bacteria, including emerging or resistant strains, contributes to better vaccination policies and public health planning [4,5]. Therefore, the findings of this review not only reinforce the diagnostic superiority of molecular methods but also emphasize their broader relevance in disease control and antimicrobial stewardship [10,14,17].

In inference, the present meta-analysis highlights that while cytology and culture remain foundational components of CSF evaluation, molecular assays-particularly multiplex PCR-offer the highest diagnostic accuracy for paediatric pyogenic meningitis [14-19,23]. The strong diagnostic correlation between molecular and culture results underscores the reliability of molecular detection, whereas the limitations of cytology and culture alone emphasize the need for an integrated, multimodal diagnostic approach. Implementing such combined strategies in clinical practice can enhance early detection, optimize antibiotic use, and ultimately improve outcomes for children with bacterial meningitis worldwide [1,2,4,5,18,20].

Conclusion

This systematic review and meta-analysis demonstrate that among the available diagnostic modalities for paediatric pyogenic meningitis, molecular assays-particularly polymerase chain reaction (PCR) and multiplex PCR-show the highest overall diagnostic accuracy, combining superior sensitivity with consistently high specificity. While CSF cytology remains a valuable first-line tool for rapid assessment and bacterial culture continues to serve as the gold standard for definitive pathogen identification and antibiotic susceptibility testing, both techniques are limited by either low specificity or reduced yield in antibiotic-pretreated cases [8-13]. Molecular diagnostics address many of these shortcomings by detecting bacterial DNA even in culture-negative samples, thereby improving diagnostic yield and reducing uncertainty in clinically suspected cases [14-18,23]. The strong correlation observed between molecular and culture findings supports the reliability of PCR-based methods, while their ability to detect additional pathogens in culture-negative CSF samples underscores their clinical utility. Despite their high diagnostic potential, molecular techniques should complement-not replace-traditional methods, as culture remains essential for antimicrobial resistance monitoring and epidemiological surveillance [10-12,20]. Integrating molecular assays with cytology and culture into a unified diagnostic algorithm can ensure both rapid preliminary diagnosis and accurate etiological confirmation, leading to improved therapeutic decision-making and better patient outcomes. Wider implementation of molecular platforms, particularly cost-effective multiplex PCR systems, along with improved laboratory infrastructure in low- and middle-income regions, can further enhance global meningitis diagnosis and management [4,5,18,19]. In summary, an evidence-based, multimodal diagnostic approach that combines cytological, cultural, and molecular analyses represents the most effective strategy for early detection, targeted treatment, and overall reduction of morbidity and mortality in paediatric bacterial meningitis [1-3,14-20,23].

Declaration:

Conflicts of interests: The authors declare no conflicts of interest.

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