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REVIEW

Bacterial meningitis in adults: a narrative review

Meningitis bacteriana en adultos: una revisión narrativa

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ABSTRACT

Objective: to identify the etiology, risk factors, treatment, and associated sequelae of bacterial meningitis in adults.
Design: a literature review based on a narrative synthesis. Data Sources: Scopus, Science Direct, Web of Science, Redalyc, Google Scholar, PubMed and Scielo.
Data Selection: documents were selected and analyzed through a critical literature review, considering inclusion and exclusion criteria.
Results: a total of 10 articles were analyzed, including 3 statistical analyses, 3 narrative reviews, 2 systematic reviews, and 2 clinical trials. The study populations included various categories: 6 articles focused on adults, 1 on males, 1 on individuals aged 25 to 50 years, and 2 involving animal experiments. Studies were conducted in various countries, including 2 in Africa, 2 in the U.S., 2 in Germany, and 1 each in Northern Ghana, Sweden, South Korea, and Egypt, contributing unique perspectives to the research. The clinical condition was characterized as follows: 3 articles highlighted the most frequent symptoms of bacterial meningitis, 4 focused on sequelae, 2 reported high fatality rates, and 1 examined early intensive care (EIC) and antibiotic recovery. Regarding socioeconomic status, 4 articles reported cases from low-income countries, 1 from high income countries, and 1 from a middle-income country.
Conclusions: bacterial meningitis represents a severe public health threat, particularly in vulnerable populations, such as older adults and those with underlying conditions. Despite the effectiveness of treatments like dexamethasone and antibiotics, the high mortality and morbidity rates emphasize the importance of early and accurate diagnosis.

Keywords: Bacterial Meningitis; Streptococcus Pneumoniae; Risk Factors; Sequelae; Etiology; Treatment.

RESUMEN

Objetivo: identificar la etiología, factores de riesgo, tratamiento y secuelas asociadas de la meningitis bacteriana en adultos.
Diseño: revisión bibliográfica basada en una síntesis narrativa. Fuentes de datos: Scopus, Science Direct, Web of Science, Redalyc, Google Scholar, PubMed y Scielo.
Selección de datos: los documentos fueron seleccionados y analizados a través de una revisión crítica de la literatura, teniendo en cuenta los criterios de inclusión y exclusión.
Resultados: se analizaron un total de 10 artículos, incluyendo 3 análisis estadísticos, 3 revisiones narrativas, 2 revisiones sistemáticas y 2 ensayos clínicos. Las poblaciones de estudio incluían diversas categorías: 6 artículos se centraban en adultos, 1 en varones, 1 en individuos de 25 a 50 años y 2 incluían experimentos

con animales. Los estudios se realizaron en varios países, incluidos 2 en África, 2 en EE.UU., 2 en Alemania y 1 en el norte de Ghana, Suecia, Corea del Sur y Egipto, lo que aportó perspectivas únicas a la investigación. La situación clínica se caracterizó de la siguiente manera: 3 artículos destacaron los síntomas más frecuentes de la meningitis bacteriana, 4 se centraron en las secuelas, 2 informaron de altas tasas de letalidad y 1 examinó los cuidados intensivos tempranos (CTI) y la recuperación de los antibióticos. En cuanto al nivel socioeconómico, 4 artículos informaban de casos procedentes de países de renta baja, 1 de países de renta alta y 1 de un país de renta media.
Conclusiones: la meningitis bacteriana representa una grave amenaza para la salud pública, especialmente en poblaciones vulnerables, como los adultos mayores y las personas con afecciones subyacentes. A pesar de la eficacia de tratamientos como la dexametasona y los antibióticos, las elevadas tasas de mortalidad y morbilidad subrayan la importancia de un diagnóstico precoz y preciso.

Palabras clave: Meningitis Bacteriana; Streptococcus Pneumoniae; Factores de Riesgo; Secuelas; Etiología; Tratamiento.

INTRODUCTION

Bacterial meningitis is a critical medical emergency, as it can be fatal within days without appropriate antibiotic treatment. This disease has a high global prevalence, affecting individuals of all ages, but is most common in neonates and older adults. The most frequent bacterial cause of this condition is Streptococcus pneumoniae, with immunocompromised patients at higher risk due to their exposure to environments conducive to microbial growth. This condition may result in neurological and auditory sequelae, and in cases where the infection enters the bloodstream, it can lead to sepsis or septicemia, further worsening the patient's condition.

Various studies have reported that bacterial meningitis has a high mortality rate, despite being susceptible to intravenous antibiotic therapy and dexamethasone (Hasbun, 2022b). Due to its urgency and complexity, bacterial meningitis requires a rapid and coordinated medical response to improve outcomes and mitigate its devastating effects (Fuentes et al., 2024).Sequelae from bacterial meningitis impose significant burdens, leading to high social and economic costs, affecting patients, families, and communities (Schiess et al., 2021). The most frequently reported sequelae include focal neurological deficits, hearing loss, cognitive impairment, and epilepsy (Marjolein et al., 2016), which negatively impact daily activities and quality of life (Block et al., 2022).

Thus, the objective of this study is to provide a brief narrative review of bacterial meningitis in adults, focusing on etiology, risk factors, treatment, and sequelae.

METHOD

A comprehensive narrative review was conducted to explore the scientific literature on bacterial meningitis in adults, using the following databases: Scopus, Science Direct, Google Scholar, PubMed, and Scielo. To refine the search, the keywords "Bacterial meningitis in adults", "Bacterial meningitis Streptococcus pneumoniae", "Risk factors in bacterial meningitis", "Sequelae of bacterial meningitis", "Etiology of bacterial meningitis", and "Treatment of bacterial meningitis" were used. Boolean operators ("AND") and quotation marks were applied to enhance and broaden the search scope. The search period spanned August to November 2024, considering articles published between 2017 and 2024. This search included only English-language texts, explicitly excluding case reports, interviews, letters to the editor, theses, and books, due to their less empirical nature or specific focus. Using the designed search strategy, an initial 114 articles were identified across the selected databases, of which 14 were from Scopus, 15 from Science Direct, 24 from Google Scholar, 43 from PubMed, and 18 from Scielo. After removing 11 duplicate articles, 63 articles were excluded for not aligning with the study objectives, while 30 articles did not meet the inclusion criteria. Following this screening and selection process, a final corpus of 10 relevant articles was included in the review.

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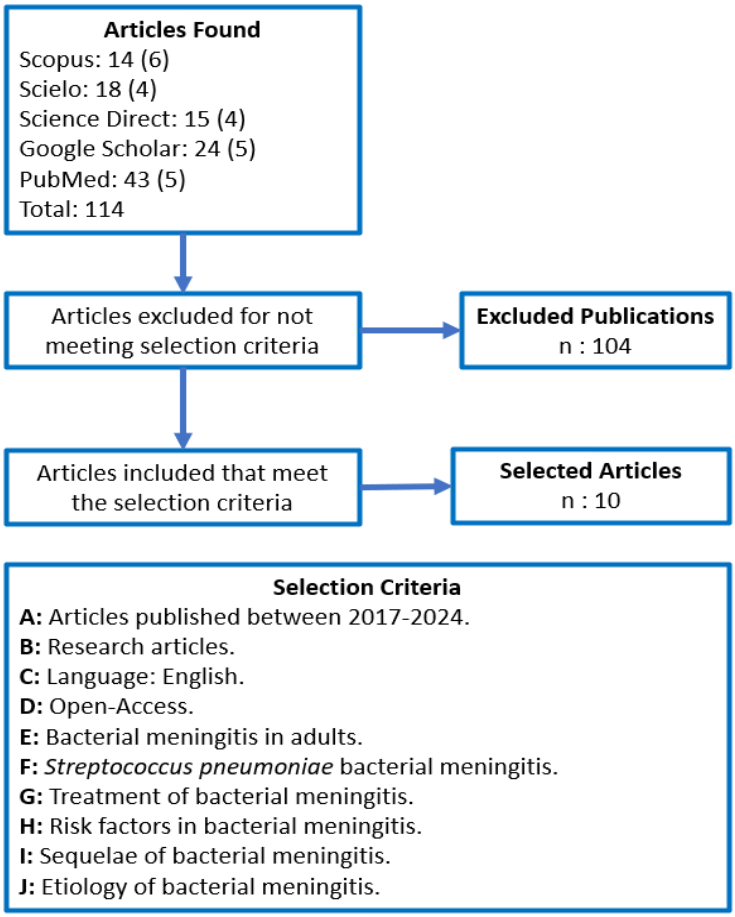

Figure 1. Search strategy

RESULTS

A total of 10 articles were analyzed, including 3 statistical analyses, 3 narrative reviews, 2 systematic reviews, and 2 clinical trials. The study populations included various categories: 6 articles focused on adults, 1 on males, 1 on individuals aged 25 to 50 years, and 2 involving animal experiments. The studies were conducted in various countries: 2 in Africa, 2 in the United States, 2 in Germany, 1 in Northern Ghana, 1 in Sweden, 1 in South Korea, and 1 in Egypt, each contributing a unique perspective to the research. The clinical condition was characterized by 3 articles highlighting the most common symptoms of bacterial meningitis, 4 focusing on sequelae, 2 reporting high fatality rates, and 1 examining early intensive care (EIC) and antibiotic recovery. Regarding socioeconomic factors, 4 articles mentioned cases from low-income countries, 1 from a high-income country, and 1 from a middle-income country.

Table 1. Analyzed articles

Study Title	Methodology	Objective / Sample	Key Findings
Case-Fatality and Sequelae Following Acute Bacterial Meningitis in South Africa, 2016-2020 (Meiring et al., 2022).	Quantitative research: Mann-Whitney test and Fisher/Mantel-Haenszel/ Chi-square tests.	Estimate case-fatality rates and sequelae of bacterial meningitis by country.	Bacterial meningitis due to S. pneumoniae is associated with underlying conditions such as HIV. Identified risk factors for in-hospital mortality. Vaccination and antibiotic use lower the probability of death.
Progress and Challenges in Bacterial Meningitis: A Review (Hasbun, 2023).	Observational studies, meta-analyses, review articles, and guidelines.	Highlight the high mortality and sequelae of bacterial meningitis in low-income countries.	Higher incidence in older adults. The most common pathogens in adults were S. pneumoniae and N. meningitidis.
Predictive Signs and Symptoms of Bacterial Meningitis Isolates in Northern Ghana (Weikem et al., 2023).	A validated form was used to extract patient data from the Disease Control Unit between 2015 and 2019.	Understand the predictive signs and symptoms of bacterial meningitis and their clinical outcomes.	Neck stiffness, seizures, altered consciousness, and abdominal pain are significant predictive symptoms of bacterial meningitis when adjusted for age.

The Impact and Burden of Neurological Sequelae Following Bacterial Meningitis: A Narrative Review (Schiess et al., 2021).	Meta-analyses, review articles, and guidelines.	Identify the impact of neurological sequelae and the disabling consequences of bacterial meningitis.	Common sequelae include long-term cognitive impairment, seizures, hearing loss, vision loss, and reduced quality of life.
Following Bacterial Meningitis: What Can We Learn About Postinfective Ischemic Sequelae? (Kumar & Kumar, 2023).	Review of imaging studies and samples in bacterial meningitis models to identify vascular damage patterns and their impact on postinfectious sequelae.	Analyze how bacterial meningitis pathogens affect different areas of cerebral blood vessels and the resulting neurological sequelae.	Cerebrovascular complications such as arterial occlusions and cerebral infarctions increase mortality and persistent neurological sequelae in bacterial meningitis.
Cefepime-Induced Encephalopathy in a Tertiary Medical Center in Korea (Jeon et al., 2020).	Observational study on patients treated with cefepime.	Assess the incidence and characteristics of cefepime-induced encephalopathy (CIE).	More frequent in older adults with impaired renal function.
HIF1α is Involved in Blood-Brain Barrier Dysfunction and Paracellular Migration of Bacteria in Pneumococcal Meningitis (Gayatri Devraj, 2020).	In vitro and in vivo studies in cerebral endothelial cells and murine models using immunohistochemistry, microscopy, and qRT-PCR techniques.	Investigate the role of the HIF-1α/VEGF pathway in Streptococcus pneumoniae transmigration across the blood-brain barrier (BBB) in pneumococcal	The HIF-1α/VEGF pathway increases brain permeability and promotes S. pneumoniae-induced transmigration.
German Guidelines on Community-Acquired Acute Bacterial Meningitis in Adults (Linn et al., 2023).	Review of clinical studies and expert consensus to develop diagnostic and treatment guidelines.	Guide physicians in the management of adult patients with acute bacterial meningitis.	Immediate administration of dexamethasone and empirical antibiotics is recommended.
Spatio-Temporal Brain Invasion Pattern of Streptococcus pneumoniae and Dynamic Changes in the Cellular Environment in Bacteremia-Derived Meningitis (Farmen et al., 2024).	Mouse model of bacteremia-derived meningitis using 3D brain imaging and microdissection.	Investigate the invasion pattern of pneumococcus in the brain and its effect on microvasculature and microglia.	Widespread brain invasion was observed, associated with neuroinflammation and cell death, impairing neuronal regeneration.
Comparative Efficacy of Antibiotics Alone or in Combination with Corticosteroids in Adults with Acute Bacterial Meningitis: A Systematic Review and Network Meta-Analysis (Rayanakorn et al., 2020).	Systematic review and meta-analysis.	Compare the relative efficacy of different antibiotic therapies with or without the addition of corticosteroids in adult patients.	The combination of antibiotics and corticosteroids reduces the risk of hearing loss and neurological complications.

DISCUSSION

This research aims to conduct a literature review on bacterial meningitis, focusing on its etiology, risk factors, treatment, and sequelae.

The purpose of this literature review is to identify and analyze the etiology, risk factors, treatment, and sequelae of bacterial meningitis from multiple perspectives presented by different authors. This review not only compiles relevant information but also seeks to compare and analyze existing perspectives to provide a deeper understanding of the disease.

Etiology

Bacterial meningitis is primarily caused by Streptococcus pneumoniae (Meiring et al., 2022), mainly affecting adults (Hasbun, 2022b) and presenting with symptoms such as neck stiffness, seizures, altered consciousness, and abdominal pain (Weikem et al., 2023).

This pathogen is responsible for two-thirds of bacterial meningitis cases worldwide (Prager et al., 2017), especially in adults aged ≥50 years, and is the most lethal across all age groups (Parellada et al., 2023). S. pneumoniae remains penicillin-sensitive, which allows antimicrobial treatment adjustments using crystalline sodium penicillin G (Cerda et al., 2022a).

Bacterial meningitis in adults (Hasbun, 2022) has a high mortality and morbidity rate, requiring constant medical vigilance (Van et al., 2017). Poor outcomes are associated with aphasia, mono- or hemiparesis, low Glasgow Coma Scale scores, high heart rate, elevated C-reactive protein levels, and increased leukocyte counts (Van Soest et al., 2022). It is therefore considered a medical emergency that necessitates immediate recognition and treatment (Mount & Boyle, 2017).

Symptoms include neck stiffness, seizures, altered consciousness, and abdominal pain (Weikem et al., 2023), as well as headache, general health deterioration, and hypertension, identified via CT scan and MRI, which are linked to poor prognosis (Niemelä et al., 2023). However, for a definitive diagnosis, recognizing

clinical syndromes, confirming meningeal inflammation, and identifying the causative agent in cerebrospinal fluid (CSF) are essential (Trocha et al., 2021). Avoiding delays in treatment caused by awaiting neuroimaging results remains a critical diagnostic skill for physicians (Young & Thomas, 2018).

Risk Factors

Bacterial meningitis is associated with underlying conditions such as HIV and in-hospital mortality (Meiring et al., 2022). Increased HIF-1α/VEGF expression leads to higher permeability and bacterial transmigration caused by S. pneumoniae (Gayatri et al., 2020). Additionally, advanced age is a poor prognostic factor and increases mortality risk.

HIV increases susceptibility to bacterial infections, autoimmune disorders, and inflammatory diseases (Lien et al., 2017). The majority of cases are hospital-acquired infections, where patients exhibit neurofunctional, functional, and physical disabilities at hospital discharge, persisting up to 12 months post-infection (Tubiana et al., 2020).

The HIF-1α/VEGF pathway increases blood-brain barrier permeability, allowing bacterial entry into the brain and causing severe neurological complications (Gayatri et al., 2020). This mechanism alters the blood-brain barrier through direct cellular damage from bacterial virulence factors and host protein activation (Yang et al., 2023). The interaction between different bacterial species and host cells facilitates bacterial invasion into the brain (Mazen & Mohd, 2018).

Advanced age is a poor prognostic factor for bacterial meningitis (Van Soest et al., 2022). Group B Streptococcus infections are a growing concern in older adults and those with chronic diseases, often presenting with concomitant bacteremia, making these cases more lethal (Tsalta et al., 2022). Additionally, Listeria monocytogenes is the third most common bacterial meningitis pathogen in this age group, presenting with a longer prodromal phase than other bacteria.

Treatment

The recommended treatment for bacterial meningitis includes immediate administration of dexamethasone and empirical antibiotics (Klein et al., 2023), which significantly reduce mortality risk (Meiring et al., 2022). Furthermore, the combination of antibiotics and corticosteroids lowers the risk of hearing loss and neurological complications in adults (Rayanakorn et al., 2020).

Dexamethasone and empirical antibiotic therapy (Klein et al., 2023) help mitigate central nervous system inflammation (Wall et al., 2021). Steroids are used as adjunct therapy to reduce inflammation and CNS infections (Gundamraj & Hasbun, 2020).

Vaccination significantly reduces mortality risk (Meiring et al., 2022). The introduction of pneumococcal and meningococcal conjugate vaccines has lowered the incidence of bacterial meningitis (Van et al., 2017), generally leading to better prognoses. Additionally, corticosteroid therapy significantly reduces adult mortality and sequelae incidence (Sánchez et al., 2021).

The combination of antibiotics and corticosteroids lowers the risk of hearing loss and neurological complications (Rayanakorn et al., 2020), with ceftriaxone and vancomycin being commonly used (Hamadalneel et al., 2024). However, ceftriaxone resistance has been reported worldwide, emerging as a major issue (Saavedr et al., 2019). To optimize ceftriaxone dosing, a nomogram using estimated glomerular filtration rate and total body weight as covariates has been developed to ensure adequate plasma concentrations (Grégoire et al., 2019).

Sequelae

The sequelae of bacterial meningitis include cognitive impairment, seizures, hearing loss, and vision loss, all of which negatively impact quality of life (Schiess et al., 2021). Brain invasion triggers neuroinflammation and cell death, preventing neuronal regeneration (Farmen et al., 2024), and cerebrovascular complications increase both mortality and long-term neurological sequelae (Kumar & Kumar, 2023a).

Long-term cognitive impairment is one of the most common sequelae of bacterial meningitis, often accompanied by seizures and reduced quality of life (Schiess et al., 2021). These sequelae affect key functions such as attention and memory (Kloek et al., 2020), with significant psychological and psychosocial consequences (Vecchia et al., 2023). The severity of sequelae varies widely among patients (Balint et al., 2024).

Brain invasion leads to neuroinflammation and cell death (Farmen et al., 2024), which contributes to post-meningitis cognitive decline and hampers neuronal regeneration (Giridharan et al., 2020a). This inflammatory response permanently alters brain function (Lay et al., 2021). Additionally, bacterial resistance complicates treatment and increases inflammation risk (Sunwoo et al., 2021).

Cerebrovascular complications, including arterial occlusions and cerebral infarctions, significantly increase mortality and persistent neurological sequelae (Kumar & Kumar, 2023b). Long-term effects include hearing loss (Jensen et al., 2023), often resulting from cochlear dysfunction and damage (Cerda et al., 2022b). Other rare

complications include vasospasms, disseminated intravascular coagulation, and septic emboli in patients with meningitis and endocarditis (Benadji et al., 2023).

During this review, several limitations were encountered. Initially, lack of clear direction led to the inclusion of irrelevant studies. Additionally, restricted access to certain journals and the predominance of pediatric studies over adult bacterial meningitis cases posed challenges in data collection and analysis.

CONCLUSIONS

Bacterial meningitis is primarily caused by Streptococcus pneumoniae, triggering specific symptoms and proving lethal for adults aged ≥50 years. However, it remains penicillin-sensitive as an antimicrobial treatment. Due to its high mortality and morbidity rates, bacterial meningitis requires urgent medical attention. Diagnostic procedures such as CT scans and MRIs should be supplemented by more precise diagnostic methods, including clinical syndrome recognition, confirmation of meningeal inflammation, and identification of the etiological agent in cerebrospinal fluid (CSF) to prevent delays in diagnosis and treatment.

Bacterial meningitis is associated with underlying conditions such as HIV, which increases susceptibility and severity of infections, particularly in hospital settings, where patients may experience disabilities upon discharge. Additionally, the activation of the HIF-1α/VEGF pathway facilitates bacterial entry into the brain, leading to severe neurological complications and blood-brain barrier dysfunction. Moreover, advanced age is a significant risk factor, with an increased prevalence of Group B Streptococcus and Listeria monocytogenes infections, the latter exhibiting a longer prodromal phase compared to other bacterial causes.

The treatment of bacterial meningitis involves immediate administration of dexamethasone and empirical antibiotics, such as third-generation cephalosporins combined with vancomycin, which helps reduce mortality and disease incidence. Steroids play a crucial role in reducing inflammation in the central nervous system (CNS), improving overall prognosis. However, ceftriaxone resistance is an emerging issue, leading to the development of a nomogram to optimize its dosing regimen.

Long-term cognitive impairment is a common sequela in bacterial meningitis survivors, affecting attention and memory, ultimately impacting their quality of life. Brain inflammation and neuronal cell death hinder neuronal regeneration and disrupt normal brain function. Additionally, cerebrovascular complications significantly increase mortality and neurological sequelae, with hearing loss being a prominent long-term effect. Less common complications include vasospasms and septic emboli in patients with meningitis and endocarditis.

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CONFLICT OF INTEREST

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