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CHANGES IN CEREBROSPINAL FLUID COMPOSITION DURING MENINGITIS AND ITS AGE-RELATED VARIATIONS

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ANNOTATION: Meningitis is an inflammation of the meninges, and cerebrospinal fluid (CSF) analysis is the most reliable criterion for diagnosing and assessing its progression. This article provides a detailed review of changes in CSF composition during bacterial, viral, and fungal meningitis. CSF alterations — including cell count (pleocytosis), protein concentration, glucose level, pressure, and color — vary according to age. In neonates, physiological pleocytosis and elevated protein are observed; in children, glucose decreases rapidly; and in adults, pressure and protein changes are more pronounced. Epidemiological data illustrate the distribution of the disease across different age groups.This article highlights the clinical importance of interpreting CSF findings according to age and serves as a guide for medical students and practicing physicians.,

Keywords: meningitis, cerebrospinal fluid, age-related changes, neonatal meningitis, bacterial meningitis, viral meningitis, fungal meningitis, pleocytosis, decreased glucose, elevated protein, diagnosis.

АННОТАЦИЯ: Менингит — это воспаление мозговых оболочек, и анализ цереброспинальной жидкости (ЦСЖ) является наиболее надежным критерием для диагностики и оценки течения заболевания. В данной статье представлен подробный обзор изменений состава ЦСЖ при бактериальном, вирусном и грибковом менингите. Изменения ЦСЖ — включая количество клеток (плеоцитоз), концентрацию белка, уровень глюкозы, давление и цвет — варьируются в зависимости от возраста. У новорожденных наблюдается физиологический плеоцитоз и повышенный уровень белка; у детей уровень глюкозы быстро снижается; у взрослых изменения давления и белка выражены более явно. Эпидемиологические данные иллюстрируют распространение заболевания среди различных возрастных групп.

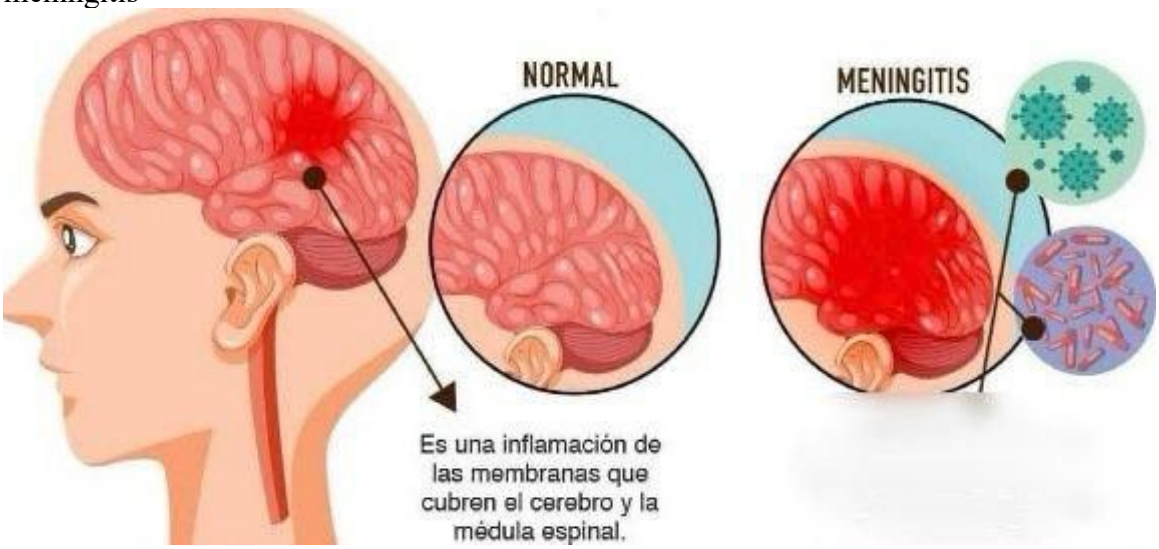
Статья подчеркивает клиническую значимость интерпретации результатов ЦСЖ с учетом возраста и служит руководством для студентов-медиков и практикующих врачей.

Ключевые слова: менингит, цереброспинальная жидкость, возрастные изменения, неонатальный менингит, бактериальный менингит, вирусный менингит, грибковый менингит, плеоцитоз, снижение глюкозы, повышение белка, диагностика

Introduction

Meningitis is a serious inflammatory disease of the meninges, the protective membranes surrounding the brain and spinal cord. The disease can develop rapidly and requires immediate clinical attention. Meningitis may be caused by bacterial, viral, or fungal pathogens, each of which induces distinct changes in cerebrospinal fluid (CSF) composition. CSF, the clear fluid circulating in the ventricles of the brain and the subarachnoid space, plays a crucial role in maintaining the homeostasis of the central nervous system (CNS), transporting nutrients, removing metabolic waste, and providing immune surveillance. Consequently, any inflammatory process in the meninges significantly affects CSF characteristics, which makes CSF analysis a cornerstone of meningitis diagnosis and prognosis.Globally, meningitis affects 2–2.5 million individuals annually, with mortality rates varying by age and etiology: 20–40% in neonates, 5–10% in children, and 15–25% in adults (WHO, 2023; CDC, 2022). The severity of clinical manifestations and the risk of neurological complications are directly linked to changes in CSF composition. Inflammatory processes lead to pleocytosis (increased white blood cell count), disruption of the blood-CSF barrier, elevation of protein concentration, alteration of glucose levels, and changes in CSF pressure and color. These alterations not only reflect the underlying pathogen but also indicate the degree of CNS involvement and the risk of complications.

CSF changes in different types of meningitis

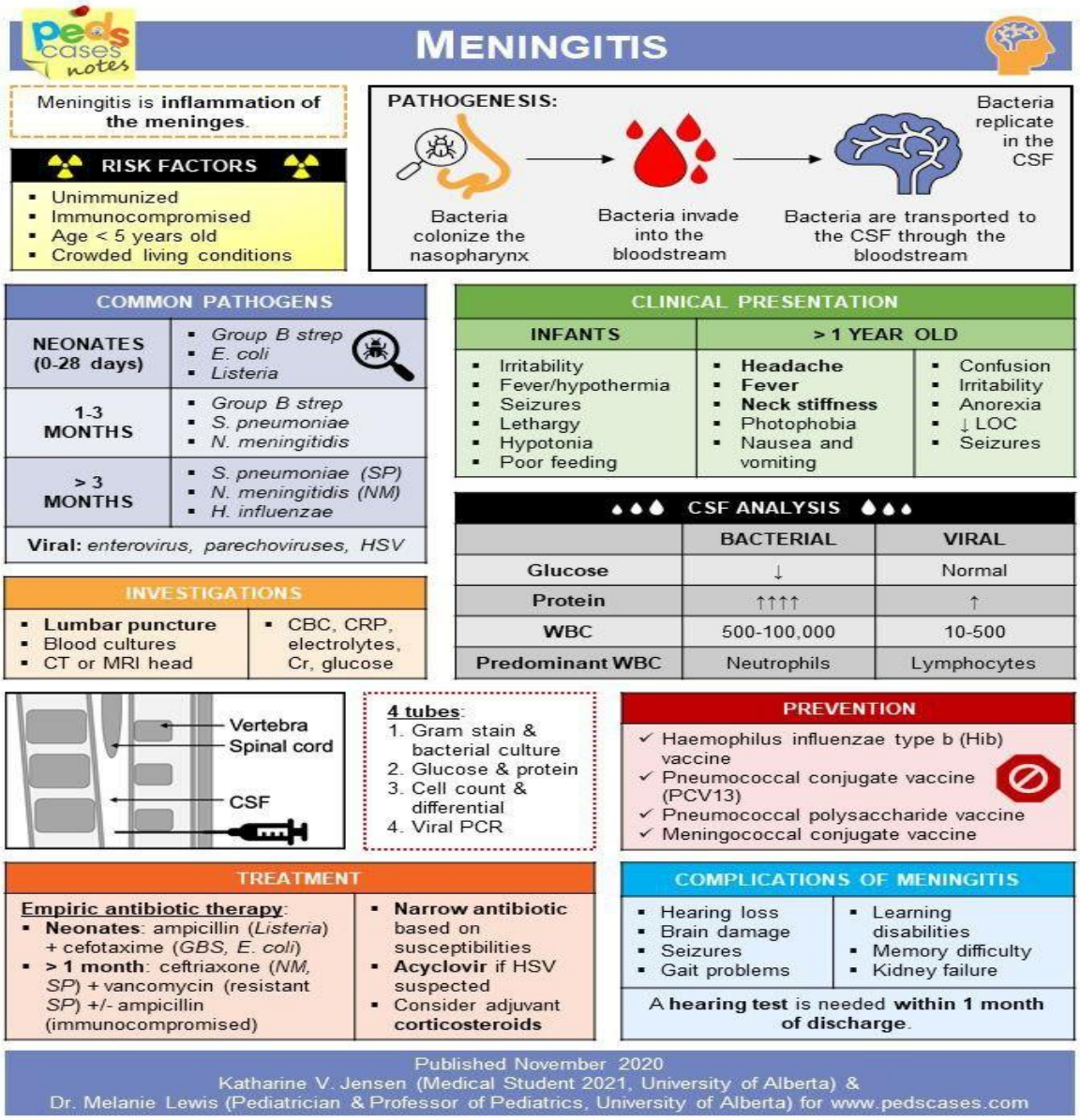


Bacterial meningitis: This form of meningitis is associated with rapidly progressive inflammation and marked CSF changes. CSF typically demonstrates neutrophilic pleocytosis, elevated protein concentration due to increased vascular permeability, decreased glucose as bacteria metabolize available sugar, and elevated CSF pressure caused by edema and impaired CSF circulation. Cloudy or turbid CSF is often observed due to high cellular content. Common pathogens include Streptococcus pneumoniae, Neisseria meningitidis, Haemophilus influenzae, Escherichia coli, Group B Streptococcus, and Listeria monocytogenes. CSF examination provides critical guidance for antibiotic selection and monitoring of treatment efficacy.

Viral meningitis: Usually manifests as lymphocytic pleocytosis, mild elevation of protein, and normal glucose levels. CSF is generally clear. The most common viruses include enteroviruses, herpes simplex virus (HSV), and adenoviruses. In neonates, early viral meningitis may present

with a mixed cellular response that mimics bacterial infection, highlighting the importance of careful CSF interpretation.

Fungal meningitis: Predominantly seen in immunocompromised adults, especially with Cryptococcus neoformans. CSF shows lymphocytic pleocytosis, decreased glucose, significantly elevated protein, and markedly increased CSF pressure. Chronic inflammation in fungal meningitis may also cause CSF xanthochromia or mild turbidity. Early CSF analysis is critical, as delayed diagnosis can lead to severe CNS damage, including hydrocephalus and cranial nerve deficits.



Age-related CSF characteristics:CSF parameters vary significantly with age, influencing the interpretation of pleocytosis, protein, glucose, and pressure.Neonates (0–28 days): Physiological pleocytosis is common (9–30 WBC/mm³), protein levels are higher (80–180 mg/dL), and glucose may be low due to immature glucose transport. Clinical signs are often subtle, including lethargy, poor feeding, hypotonia, apnea, and low-grade or absent fever. Neonatal CSF is

particularly sensitive to infection, and even minor changes can indicate severe bacterial or viral meningitis.

Infants and children (1 month–16 years): WBC counts in CSF rise sharply during infection. Glucose may drop below 60% of blood levels, protein moderately increases, and pleocytosis is more pronounced. Typical symptoms include fever, irritability, headache, vomiting, photophobia, and nuchal rigidity. Pediatric CSF analysis is critical for differentiating bacterial from viral etiologies, guiding antimicrobial therapy, and predicting complications.Adults: CSF pressure and protein elevation are more pronounced. Pleocytosis is significant, and glucose decreases mainly in bacterial meningitis. Adults commonly present with headache, neck stiffness, photophobia, fever, altered mental status, and occasionally seizures. CSF analysis in adults helps identify the pathogen, assess severity, and monitor response to treatment.Pathophysiological importance of CSF in meningitis:Inflammation of the meninges directly affects CSF homeostasis. The blood-CSF barrier, primarily maintained by choroid plexus epithelial cells, regulates the entry of immune cells, proteins, and pathogens. In meningitis, disruption of this barrier allows inflammatory cells and proteins to accumulate, leading to increased CSF pressure and potential CNS damage. Elevated protein levels correlate with the severity of inflammation, while decreased glucose reflects pathogen metabolism and impaired glucose transport. Changes in CSF color, such as xanthochromia or turbidity, indicate red blood cell lysis or high cellular content, which can provide diagnostic clues regarding the stage and type of meningitis.Age-specific CSF interpretation is vital because normal ranges differ markedly: neonates tolerate higher protein and WBC counts physiologically, whereas in adults, similar values would indicate pathology. Misinterpretation can delay therapy, increase the risk of neurological sequelae, and worsen prognosis.

Clinical relevance

CSF analysis is indispensable for:

Early diagnosis of meningitis

Determination of etiology (bacterial, viral, or fungal)

Guiding antimicrobial or antifungal therapy

Monitoring therapeutic response and disease progression

Predicting and preventing neurological complications, such as hydrocephalus, seizures, cranial nerve damage, and cognitive impairmentUnderstanding the dynamic changes of CSF in relation to age, pathogen type, and disease severity ensures timely intervention, reduces mortality, and improves long-term outcomes in patients with meningitis.

Conclusion

Meningitis is an inflammation of the meninges and is a serious condition that requires prompt diagnosis, skilled treatment, and regular monitoring. This disease can have a bacterial, viral, or fungal etiology, and each type causes specific pathological changes in the cerebrospinal fluid (CSF). CSF analysis is the most reliable tool for diagnosing meningitis, determining its etiology,

planning treatment, and monitoring the clinical condition of the patient.Changes in CSF composition are directly related to the severity of the disease, its etiology, and the patient's age. In bacterial meningitis, CSF typically shows neutrophilic pleocytosis, significant protein elevation, decreased glucose levels, and increased CSF pressure. In viral meningitis, there is usually lymphocytic pleocytosis, mild protein elevation, and normal glucose levels. In fungal meningitis, especially in immunocompromised patients, CSF demonstrates decreased glucose, marked protein elevation, increased pressure, and turbidity or xanthochromia. These parameters are crucial for accurately identifying the type of meningitis and guiding appropriate treatment.

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