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REVIEW ARTICLE

# Emergency Neurologic Life Support: Meningitis and Encephalitis

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**Abstract** Bacterial meningitis and viral encephalitis, particularly herpes simplex encephalitis, are severe neurological infections that, if not treated promptly and effectively, lead to poor neurological outcome or death. Because treatment is more effective if given early, the topic of meningitis and encephalitis was chosen as an Emergency Neurological Life Support protocol. This protocol provides a practical approach to recognition and urgent treatment of bacterial meningitis and encephalitis. Appropriate imaging, spinal fluid analysis, and early empiric treatment is discussed. Though uncommon in its full form, the typical clinical triad of headache, fever, and neck stiffness should alert the clinical practitioner to the possibility of a central nervous system infection. Early attention to the airway and maintaining normotension is crucial in treatment of these patients, as is rapid treatment with anti-infectives and, in some cases, corticosteroids.

**Keywords** Meningitis · Encephalitis · Critical care · Emergency · Central nervous system infection · Neurocritical care

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## Introduction

Meningitis and encephalitis are potentially life-threatening central nervous system (CNS) diseases, which often present initially to the emergency department (ED). Many of these patients are critically ill and transported to the ED by Emergency Medical Services (EMS). Meningitis is strictly defined as inflammation of the meninges, while encephalitis is strictly defined as inflammation of the brain. If both are inflamed, the patient has meningoencephalitis. Meningitis causes fever, meningismus, and pain (e.g., headache, neck pain), but, other than depressing a patient's mental status, does not affect cortical brain function (e.g., aphasia, seizure, hemiparesis). Alternately, encephalitis typically causes cortical disturbance, particularly seizures. Most patients have a predominance of one or the other, but many have features of the combined meningoencephalitis syndrome. The two conditions that are most important to recognize in the first hour are bacterial meningitis and herpes encephalitis, as these diseases produce significant morbidity and mortality and have specific treatments that can improve patient outcome if administered quickly.

It is estimated that 500,000 cases of bacterial meningitis occur worldwide each year, of which more than 1/3 die ($\approx$170,000) and a large number of survivors are left with neurologic sequelae [1]. The incidence and common causative agents have changed considerably in developed countries since the introduction of conjugate vaccines for Haemophilus influenza B and Meningococcus [2] and in these countries meningitis and encephalitis have become rare diseases. Because of poverty and poor health care infrastructure, they remain significantly more common in developing and poor nations [3]. The annual incidence of bacterial meningitis in the U.S. is approximately three cases per 100,000 [1] and the highest

incidence occurs in children under 1 year of age (76.7/100,000) [1]. While accurate estimates of incidence are difficult to obtain, encephalitis is a less common disease than meningitis. The non-herpes varieties display seasonal variation.

Bacterial meningitis and bacterial or viral encephalitis are medical, neurologic, and, occasionally, neurosurgical emergencies, which carry substantial morbidity and mortality despite modern approaches. In one study, 48 % of patients with bacterial meningitis presented within 24 h of the onset of symptoms [4]. Therefore, patients who have a hyper-acute (hours) to acute (hours to days) onset of headache and altered mental status should be considered as potentially having meningitis or encephalitis. While children present similarly to adults, neonates are more likely to present with non-specific findings including decreased feeding, irritability, and lethargy [3].

Although fever is a major feature of these infectious illnesses, additional symptoms including stiff neck (typically elicited by neck flexion), fever, new rash, focal neurological findings, or new seizures should increase the clinical suspicion of CNS infection. Meningitis should be considered in the differential diagnosis of any lethargic, vomiting, irritable neonate. In a large series of 696 adult patients with bacterial meningitis, the classic triad of fever, neck stiffness, and change in mental status was present in only 44 % of patients, but 95 % of patients had at least two symptoms when a fourth symptom—headache—was added to the classic triad [4]. In contrast, another report pooling adult studies of patients with meningitis demonstrated that 95 % of patients had at least two of the three elements of the classic triad [5]. The absence of fever, altered mental status, or neck pain essentially eliminates the diagnosis of meningitis and suggests other diagnoses should be pursued [5].

A challenge in diagnosing meningitis or encephalitis is that there is no single definitive clinical symptom or sign. A review of papers on adult meningitis published between 1966 and 1997 found that Kernig's sign was the sign most frequently elicited when evaluating a patient for possible meningitis. Kernig's sign is elicited with the patient lying supine, and their hips and knees flexed to 90°. The clinician then extends the patient's knee, straightening the leg [5]. A positive sign is present when extension of the leg at the knee produces significant lower back or posterior thigh discomfort due to meningeal irritation. Brudzinski's sign, in contrast, is elicited by placing the patient in a supine position and passively flexing the patient's neck. The clinician observes whether this action triggers flexion at the hips and knees. Despite the fact that physicians learn these signs and their presence is taught as pathognomonic, the review found that the signs have not been sufficiently studied in a systematic fashion to comment on their sensitivity and specificity for diagnosing meningitis. A similar result from another study of 297 patients with suspected meningitis demonstrated the minimal utility of these maneuvers, except in patients with fulminant meningitis [i.e., cerebral spinal fluid (CSF) WBC $>1000$ cells/ml] [6]. Therefore, the absence of these signs should not be used to rule out meningitis. Another test that has been studied in patients suspected of having meningitis but who are cooperative and have normal mental status is the jolt accentuation test. The clinician instructs the patient to rotate their head horizontally at a frequency of two rotations per second. A positive jolt accentuation test produces exacerbation of the patient's headache [5] and in a small study had a sensitivity of 100 % and a specificity of 54 %.

The ENLS suggested algorithm for the initial management of meningitis and encephalitis is shown in Fig. 1. Suggested items to complete within the first hour of evaluating a patient with meningitis and encephalitis are shown in Table 1.

## Prehospital Considerations

In the prehospital setting, EMS personnel should approach the patient based upon the chief complaint, assess the basic ABCs of resuscitation (airway, breathing, circulation), and begin management as appropriate for the severity of the patient's presentation and the training level of the EMS providers. This may include obtaining basic vital signs, formal assessment of mental status utilizing the Glasgow Coma Score (GCS), measurement of serum glucose levels, placement of intravenous (IV) access, initiation of IV fluid resuscitation, and airway management. If IV access cannot be rapidly obtained in an unstable patient, placement of an intra-osseous (IO) cannula should be considered. Prehospital resuscitation of patients with life-threatening infections can expedite achievement of resuscitation goals including adequate mean arterial pressure (MAP) [7].

## Initial Assessment

As with all acute medical and neurological events, the basic ABCs of resuscitation should be evaluated immediately on presentation to the ED. Vital signs (including temperature, blood pressure, heart rate, and respiratory rate, along with peripheral oxygen saturation), a pain scale, assessment of GCS, and a rapid check of the patient's serum glucose level should be quickly obtained at triage and compared to those obtained by prehospital personnel.

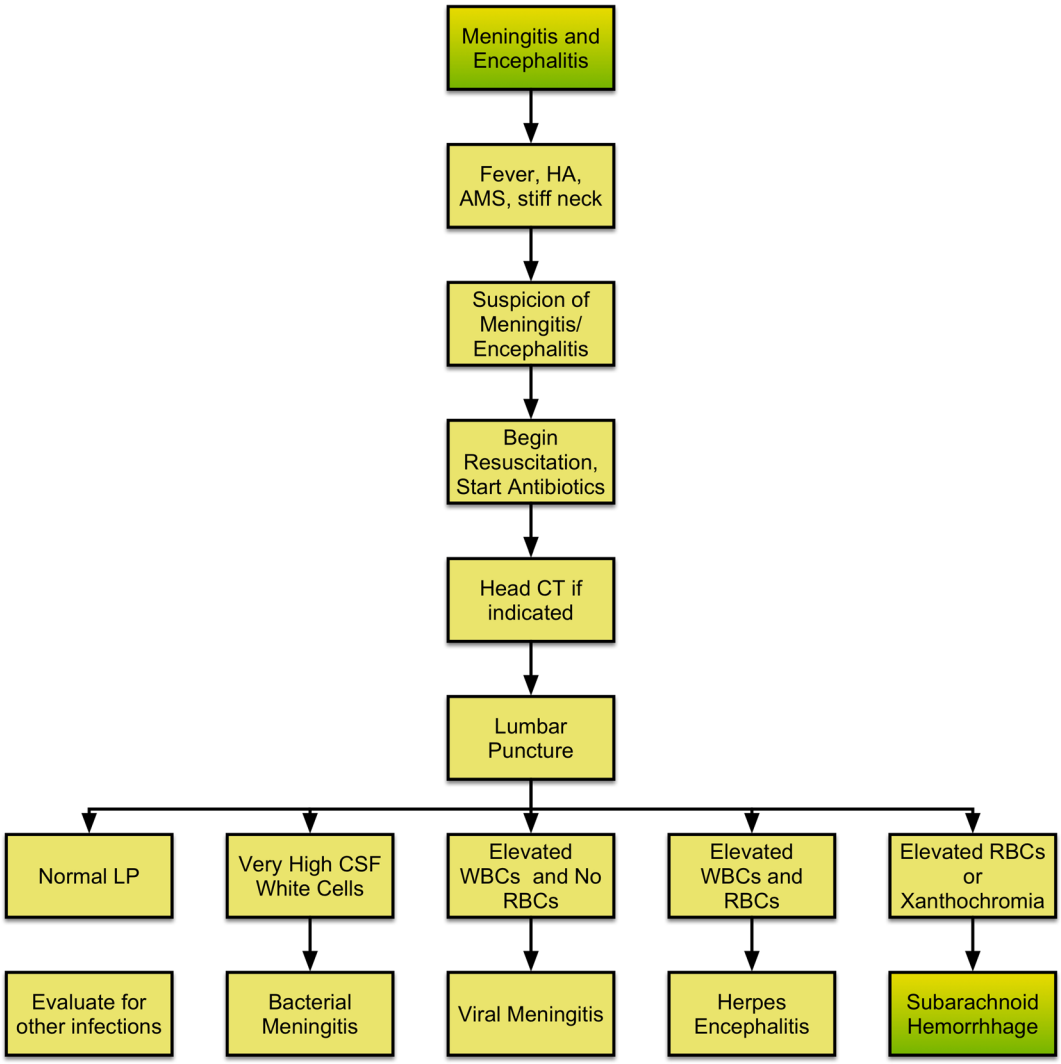


**Fig. 1** ENLS meningitis and encephalitis protocol

**Table 1** Meningitis and encephalitis checklist for the first hour

| Checklist |
|---|
| ☐ Vital signs, history, examination |
| ☐ IV access |
| ☐ Labs: CBC, platelets, PT/PTT, chemistries, blood cultures, lactate |
| ☐ IV fluids, treat shock |
| ☐ Immediately administer dexamethasone followed by appropriate antibiotics for presumptive bacterial meningitis |
| ☐ Consider acyclovir (if HSV a possibility) |
| ☐ Head CT, if patient neurological exam is abnormal |
| ☐ LP, if CT and results are available |
| ☐ If meningococcus, remember exposure prophylaxis |

In most instances, an oral temperature is adequate. Patients who are markedly tachypneic may not be able to keep their mouths closed during an oral temperature reading and may require a rectal temperature to ensure accuracy. Both fever (temperature $>38$ °C) and hypothermia (temperature $<36$ °C) are compatible with CNS infection.

If the patient is normothermic, the pre-test probability of bacterial meningitis or HSE encephalitis is decreased. However, newly immunocompromised patients, patients with viral meningitis, and even an occasional patient with bacterial meningitis may present to the ED without fever. In an evaluation of 696 patients with community-acquired acute bacterial meningitis, the mean reported temperature was 38.8 °C, and 77 % of patients were febrile. The evaluation did not report the number of patients who were hypothermic [4].

Patients with altered mental status are at risk for aspiration, have decreased ability to maintain a patent airway, and should be monitored for the need for endotracheal intubation. Intubation should be considered for any patient

whose GCS is ≤8 for airway protection. Patients with bacterial meningitis are at risk for lung or bloodstream infections with the same pathogen, further reinforcing the need to closely monitor vital signs and hemodynamics.

Immediately after vital signs are assessed in triage, patients at high risk for meningitis should have adequate IV access (a minimum of two 18 gage or larger peripheral IVs) placed, and blood samples sent for laboratory analysis, including a peripheral white blood cell (WBC) count and differential, basic metabolic panel, serum lactate, and blood cultures. An initial fluid bolus of 20–30 ml/kg of crystalloid solution should be immediately infused over 20–30 min and the patient's vital signs, mental status, and airway should be reassessed every 5 min during the proximal phase of treatment. If IV access cannot be obtained within a few minutes of presentation, IO access should be placed.

Similar to patients with other bacterial infections, some patients with bacterial meningitis will be hypotensive. This may result from sepsis or increased insensible fluid losses from fever, tachypnea, diaphoresis, and vomiting. In addition, bacterial meningitis, like other diseases causing septic shock, can trigger a pronounced inflammatory response, leading to vasodilation, capillary leak, and, in some cases, myocardial dysfunction.

The initial resuscitation strategy in critically ill patients with suspected meningitis or encephalitis should be identical to that recommended for other severe sepsis patients. For example, in guidelines focusing on initial resuscitation, the Surviving Sepsis Campaign recommends beginning a focused, algorithmic resuscitation immediately in patients with hypotension (systolic blood pressure <90 mmHg; MAP <65 mmHg) refractory to an initial fluid challenge (20–30 ml/kg of crystalloid over 30 min) or a serum lactate >4 mmol/l [8].

Further, the Campaign recommends a protocolized resuscitation strategy with specific resuscitation goals, including continued fluid infusion until the patient is fluid unresponsive, a central venous pressure (CVP) 8–12 mmHg, a MAP ≥65 mmHg, urine output ≥0.5 ml/(kg h), and a central venous oxygen saturation ($ScvO_2$) >70 %. Recent randomized trials of alternative resuscitation strategies in patients with severe sepsis and septic shock suggest that early identification, rapid fluid resuscitation, timely antibiotic administration, and careful monitoring may be more important than the specific resuscitation algorithm and goals [9, 10].

One liter boluses of crystalloid over 15 min should be given repeatedly until these goals are reached or the patient is stabilized, volume replete, and no longer fluid responsive. The rate of fluid infusion should be reduced to a maintenance level once goals are achieved or when the patient demonstrates rising filling pressures (increased CVP) without improvements in systemic perfusion (persistently low $ScvO_2$ or rising serum lactate levels). Norepinephrine should be used to support MAP if the patient remains hypotensive despite initial resuscitation.

However, the optimal translation of these recommendations to the management of patients with CNS infections is unclear, and, in particular, the relationship between aggressive early volume resuscitation and cerebral edema should be systematically investigated. The results of the recently completed ProCESS and ARISE studies contribute little to this discussion since less than 1 % of the patients enrolled in ProCESS and <2 % of the patients enrolled in ARISE had meningitis [9, 10].

## CBC and CT

If the patient has altered mental status, focal neurological deficits, papilledema, new onset seizures, or a history of neurological disease or immunosuppression, a cranial computed tomography (CT) should be expedited [11]. If circumstances permit, cranial CT should occur prior to lumbar puncture (LP) in patients with any of these concerning clinical signs. Obtaining a cranial CT and performing an LP should delay neither antibiotic administration nor initial resuscitation.

Much like body temperature, peripheral WBC can be elevated or depressed in patients with CNS infection, and blood frequently possesses increased immature forms [12]. A normal WBC count does not rule out meningitis.

Depending on body temperature, presenting symptoms, complete blood count (CBC), and the results of the head CT scan, the exploration of CNS infection may potentially include performance of a LP. A LP is helpful in evaluation of viral meningitis, so a patient without classic symptoms of neck stiffness, impaired alertness, and an elevated WBC may still benefit from CSF analysis.

## Suspicion of Infection

In patients in whom there is a moderate to high suspicion of CNS infection and for whom LP has not yet been performed, parenteral antimicrobials should not be delayed while waiting for a computed CT scan. With the most sensitive organisms, cerebrospinal fluid (CSF) sterilization occurs only after 4–6 h following initiation of antimicrobials.

As described in the Initial Management and CBC and CT sections above, head CT prior to LP should be performed in the patient with suspected CNS infection when any of the following are present: papilledema or loss of venous pulsations on fundoscopic examination; focal

neurological signs; immunocompromised patients; or known mass lesions.

In patients who do not present with these signs, have normal mental status, and have no focal neurologic deficits, a head CT is not always required prior to LP. However, in most patients who have a clinical presentation consistent with acute bacterial meningitis or encephalitis, there will be enough diagnostic uncertainty that CT is advisable prior to LP.

In a study of the need for head CT prior to LP among 301 patients with suspected bacterial meningitis, 78 % of patients had a head CT performed prior to LP [13]. Of these patients, 24 % had an abnormality on the CT reading, and 5 % had evidence of mass effect. Age $>60$ years; immunocompromised state; history of CNS disease; altered level of consciousness; and focal neurologic deficits were predictive of abnormal CT findings. If CT scans were ordered only on those individuals with a predictive sign of CT abnormality, the rate of CT acquisition would have been decreased by 41 % [13]. A normal head CT does not preclude the development of a herniation syndrome. Meningitis can be fulminant and characterized by progressive inflammation of the meninges and brain swelling. Patients can herniate after LP because of disease progression, not necessarily as a result of the diagnostic intervention.

Known or suspected immunocompromised patients may present with less classic signs of meningitis or encephalitis. For such patients, the clinician should lower his or her pretest probability for these diagnoses and err on the side of a more complete work-up, including emergent brain imaging and LP.

If the head CT shows a mass lesion or another condition, such as a subarachnoid hemorrhage (SAH), that adequately explains the patient's mental status, then the evaluation of bacterial meningitis can be aborted.

In cases with a normal (if performed) head CT in the presence of fever, abnormal WBC count, headache, and altered mental status, there should be moderate to high suspicion for meningitis or encephalitis (see the "Start Antibiotics" section). There is evidence for the use of dexamethasone in bacterial meningitis, particularly in CNS infections caused by *Streptococcus pneumoniae*. In situations where it is clearly evident that the suspected organism is something other than *S. pneumoniae*, then dexamethasone may be withheld. Otherwise, empiric use of dexamethasone until cultures return is reasonable. The Infectious Disease Society of America's practice guidelines state: "some authorities would initiate dexamethasone in all adults with suspected bacterial meningitis because the etiology of meningitis is not always ascertained at initial evaluation" [11]. Patients should be given 10 mg of IV dexamethasone immediately and every 6 h thereafter for a duration of 4 days [14]. Ideally, the steroid should be given prior to or at the start of antibiotic therapy.

## Start Antibiotics

Appropriate antimicrobials should be started as soon as possible after a patient with suspected CNS infection presents for medical care. In patients with septic shock, each hour delay in the administration of appropriate antimicrobials after onset of hypotension increases mortality an average of 7.6 %. These results were confirmed by another study of 261 patients treated with a protocolized resuscitation strategy [15]. When appropriate antimicrobials were administered within 1 h of triage, mortality was 19.5 %, whereas delays longer than 1 h after triage resulted in an increase in mortality to 33.2 %.

The applicability of these findings to patients with bacterial meningitis is limited by the small percentage of patients in each study who had primary CNS infections. Prior, less rigorous studies have demonstrated an association between time and antibiotic administration in bacterial meningitis and mortality. Delays in antibiotic administration are common. In a cohort of 122 patients with documented bacterial meningitis, one study found a mean time from triage to antibiotics of 3 h (interquartile range, or IQR, 1.6–4.3 h) with 90 % of this time occurring after the initial physician encounter [16].

The choice of empiric antimicrobials is based on several factors, including the time course of symptom progression, patient age, and other infectious risk factors. For suspected CNS infections that evolve over hours, bacterial meningitis, viral meningitis, and, less commonly, viral encephalitis may be considered.

Worldwide, *S. pneumonia*e and *Neisseria meningitides* account for the majority of cases of meningitis. Neonates have a permeable blood brain barrier and are at risk of infection caused by Group B *Streptococcus*, *Listeria monocytogenes,* and *Escherichia coli.* Children and young adults with suspected bacterial meningitis are at risk for *Haemophilus influenzae* (if not vaccinated), *N. meningitidis*, and *S. pneumoniae*. Middle-aged adults are at highest risk for *S. pneumoniae*. As such, both groups should be started on a third generation cephalosporin and vancomycin at doses appropriate for CNS penetration and renal function. The elderly and immunosuppressed population, including alcoholics, are at risk for *S. pneumoniae* and *L. monocytogenes*. As such, they should be started on ampicillin, a third generation cephalosporin, and vancomycin at doses appropriate for CNS penetration and renal function. Common initial antibiotic dosing for adults with normal renal function suspected of having bacterial meningitis are as follows: Ceftriaxone 2 g IV q 12 h, Vancomycin 15–20 mg/kg IV

every 8–12 h (not to exceed 2 g per dose or daily total of 60 mg/kg; adjust to achieve trough concentration of 15–20 mcg/ml), and Ampicillin 2 g IV q 4 h.

Vancomycin and trimethoprim–sulfamethoxazole can be used in patients with a severe penicillin allergy. If there is a high suspicion for viral encephalitis (cortical deficits, lymphocytic predominance in the CSF) treatment should begin with acyclovir at the doses listed below.

For suspected CNS infections that evolve over days, viral encephalitis and, particularly, herpes simplex encephalitis (HSE) should be considered. For patients with normal renal function, treatment should begin with IV acyclovir at 10 mg/kg (based on ideal body weight) every 8 h. The frequency of acyclovir administration will need to be adjusted for patients with renal insufficiency or end-stage renal disease. Hydration should be sufficient to achieve normovolemia, avoiding the complication of acyclovir-associated renal failure.

Other forms of viral encephalitis, such as those caused by the Arboviruses, may also have a sub-acute presentation. There are no pharmacotherapeutic interventions for these encephalitides, but until exclusion of HSE can be verified, empiric acyclovir is reasonable. For suspected CNS infections that evolve over days in an immunosuppressed patient, fungal meningitis should be considered. Prior history of the CNS disease or systemic fungal infections and rapid disease progression should raise the index of suspicion for fungal meningitis. Empiric amphotericin B should be administered during diagnostic testing.

## Lumbar Puncture (LP)

A lumbar puncture (LP) is essential for both establishing a diagnosis and tailoring therapy. Informed consent should be obtained, when possible, and the clinical team should perform a "time-out" prior to starting the procedure.

The patient should be optimally positioned in the left lateral decubitus position, as an opening pressure (OP) cannot be measured if the patient is sitting up. After prepping and draping the patient in the usual, sterile fashion, the OP should be measured with a manometer prior to the collection of CSF. An elevated OP is indicative of elevated intracranial pressure.

CSF should be collected in a minimum of four tubes. Tubes 1 and 4 should be sent for red blood cell (RBC) and WBC counts; tube 2 for protein, glucose, and lactic acid; tube 3 for Gram's stain, antigens, and culture (and India ink if fungal infection is suspected). If there is a suspicion for herpes encephalitis, a small amount of CSF from either tube 2 or 3 should be sent for herpes polymerase chain reaction (PCR).

Larger volumes of CSF increase the sensitivity of a Gram's stain and culture. Some laboratories perform bacterial antigen assays, which may be useful in certain circumstances. Additional laboratory tests that may be performed at some centers include bacterial PCR (particularly for Mycobacterium), Herpes simplex PCR, enterovirus PCR, immunoglobulin M (IgM) for arboviruses, fungal antigens, and viral culture.

If the spinal fluid pressure is found to be greatly elevated (e.g., $>400$ mm $H_2O$), the needle stylette should be left in place and mannitol administered. It may be prudent to recheck the pressure after a few minutes to determine that it has declined, before removing the needle.

## Normal LP

An LP is considered normal if there are no RBCs, fewer than five WBCs, the CSF glucose/serum glucose ratio is $>0.67$, the CSF protein $<50$ mg/dl, and no organisms are seen on Gram's stain. If all of the above are true, meningitis is excluded, as is encephalitis in most cases.

## Very High CSF White Cells

The finding of a marked elevation in WBCs (neutrophils of 100–1000 per HPF or higher without a significant number of RBCs) is consistent with bacterial meningitis. In addition, the CSF/serum glucose ratio will usually be significantly reduced ($<0.67$), and the CSF protein is usually markedly elevated and almost always $>50$ mg/dl. Organisms are seen on Gram's stain in approximately 70 % of cases.

## Mildly Elevated WBC and No RBCs

A mild elevation in CSF WBCs without RBCs is consistent with a viral meningitis or viral (not herpes) encephalitis. WBCs often range from 10 to several 100 and the CSF possesses a normal CSF glucose/serum glucose ratio, and protein $<50$ mg/dl. Organisms are absent on the Gram's stain.

Patients with an arbovirus encephalitis (West Nile virus, Eastern or Western Equine encephalitis, St. Louis virus encephalitis, and others) may present with a depressed level of consciousness. West Nile virus patients may also have significant neurological disease, including focal deficits, resting tremors, or neuromuscular weakness, occasionally requiring mechanical ventilation [17]. Seroconversion of HIV is also a consideration with this clinical scenario.

Although patients with the above findings are unlikely to have bacterial meningitis, in many cases they will be admitted to the hospital and continued on antibiotics until the CSF culture results are negative and clinical improvement is demonstrated.

## Elevated WBCs and RBCs

A patient with herpes encephalitis will typically have an elevated CSF RBC count (10–100 or higher), WBCs in the hundreds (typically with a lymphocytic predominance), CSF glucose/serum glucose ratio $>0.67$, a protein level that may either be $<50$ mg/dl or elevated, and no organisms on Gram's stain. The presence of seizures and findings of uni- or bi-lateral hypodensities in the temporal lobes on brain MRI, and rarely on brain CT scans, are also compatible with this diagnosis.

## Elevated RBCs or Xanthochromia

If the CSF reveals an elevated RBC count (100–1000 and higher), either a WBC count $<5$ or fewer than 1 WBC/500 RBC, a CSF glucose/serum glucose ratio $>0.67$, and a protein $<50$ mg/dl; no organisms are seen on Gram's stain; and xanthochromia is detected, then the patient likely has suffered a subarachnoid hemorrhage that was not detected on the CT scan. Xanthochromia may be absent if the LP was done within the first few hours of headache onset (when RBCs are typically not seen).

## Bacterial Meningitis

In patients with CSF demonstrating bacterial meningitis, clinicians should continue antibiotics, stop acyclovir, and continue dexamethasone. Subsequently, they should adjust antibiotics based on final Gram's stain and culture results and sensitivities.

In addition to antibiotics and dexamethasone, supportive care and management of other organ systems is important in patients with bacterial meningitis. Some patients may have a concomitant bloodstream infection with the offending pathogen and may require focused resuscitation for severe sepsis or septic shock. If the LP demonstrates an elevated intracranial pressure (ICP), monitoring and treatment of intracranial hypertension may be required.

## Viral Meningitis and Viral Encephalitis

The treatment for herpes encephalitis has been discussed above. The treatment of viral meningitis or non-herpetic viral encephalitis is primarily supportive in nature. Many of these patients will have a significantly depressed level of consciousness, making close observation and airway management crucial. For West Nile virus, there is risk of respiratory decompensation from neuromuscular weakness secondary to spinal cord involvement and depression of consciousness. Oxygen saturation may fall first due to aspiration, but more likely the patient's $pCO_2$ will rise as an early indicator of ventilatory failure. Admission to the intensive care unit (ICU) for observation is frequently warranted.

## Pediatric Considerations

Bacterial meningitis is an important contributor to pediatric morbidity and mortality [18]. Diagnosis can be difficult in infants who often have non-specific manifestations such as fever, hypothermia, lethargy, irritability, respiratory distress, poor feeding, vomiting, or seizures. In older children, clinical manifestations include fever, headache, photophobia, nausea, vomiting, and decreased mental status [19]. The major pathogens involved are dependent on the age of the child [18]:

- Birth to $<3$ months—Group B *Streptococcus*, Gram-negative enteric bacilli, *L. monocytogenes*, *S. pneumoniae*, *N. meningitides*
- $\geq 3$ months to 3 years—*S. pneumoniae*, *N. meningitides*, group B *Streptococcus*, Gram-negative bacilli
- $\geq 3$ to $<10$ years—*S. pneumonia*, *N. meningitides*
- $\geq 10$ years—*N. meningitides*

Bacterial meningitis is a true medical emergency and immediate diagnostic and therapeutic steps must be taken in these children (Fig. 2). The initial management should include evaluation and restoration of normal oxygenation, ventilation, and perfusion. Supportive care should also include detection and management of hypoglycemia, acidosis, and coagulopathy. Lumbar puncture and blood cultures should be performed without delay, and empiric antibiotics should be given immediately following its completion. If performance of blood cultures or the lumbar puncture is not possible or must be delayed (i.e., due to the need to obtain brain imaging), initiation of antibiotic therapy should not be postponed. Children with mass effect on brain imaging or signs of intracranial hypertension are at higher risk of cerebral herniation when a lumbar puncture is performed. In such cases, neurosurgical consultation may be warranted prior to the procedure. An empiric antibiotic regimen for infants $<3$ months of age should include ampicillin, gentamycin, and cefotaxime [11]. In older infants, children, and adolescents, the appropriate empiric treatment regimen should cover penicillin resistant S. *pneumonia*e and N. *meningitides*. This can be accomplished with administration of Vancomycin 60 mg/(kg day) IV in four divided doses (maximum 4 g/day) plus either cefotaxime 300 mg/(kg day) IV in 3–4 divided doses

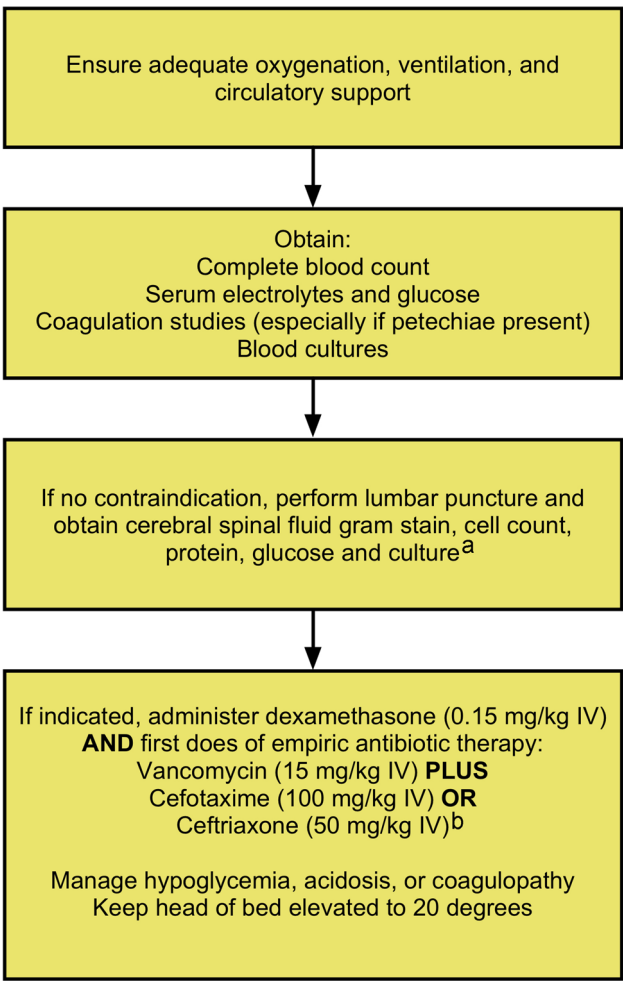


**Fig. 2** Approach to suspected CNS infection in infants and children. *a* Administration of empiric antibiotics should not be delayed if lumbar puncture cannot be performed. *b* Empiric antibiotics for infants $<3$ months of age should include ampicillin, gentamycin, and cefotaxime

(maximum 12 g/day) or ceftriaxone 100 mg/(kg day) IV in 1–2 divided doses (maximum 4 g/day) [20].

The empiric antibiotic regimen should be broadened in infants and children with immune deficiency, recent neurosurgery, penetrating head trauma, or other anatomic defects.

Adjunctive therapy with dexamethasone has been a topic of considerable debate. In a 2013 meta-analysis, the administration of dexamethasone did not affect mortality or serious neurological sequelae such as focal neurologic deficits, epilepsy, ataxia, memory, or concentration disturbance in children with bacterial meningitis. It did, however, reduce the incidence of severe hearing loss [21]. In subset analysis, this effect held truly only in children with H. influenzae meningitis (Hib) but not in those with meningitis caused by other organisms. Therefore, the American Academy of Pediatrics Committee on Infectious Diseases suggests that dexamethasone therapy may be beneficial in children with Hib meningitis if given before or at the same time as the first dose of antimicrobial therapy [22]. The committee also suggests that dexamethasone therapy be considered for infants and children with pneumococcal meningitis after weighing the potential risks and benefits. If given, dexamethasone should be administered before or within 1 h of the first dose of antibiotics. It is probably of no benefit if given more than 1 h later, although this time interval has not been clearly defined.

Children with encephalitis present with symptoms of CNS dysfunction including alterations of consciousness and ataxia. Additional signs and symptoms include fever, seizures, focal neurological findings, and abnormal neuroimaging [23]. As in the case of children with bacterial meningitis, the initial management includes restoration of normal oxygenation, ventilation, and perfusion, as well as detection and management of hypoglycemia, acidosis, and coagulopathy. Seizure detection and treatment are also vital.

**Table 2** Meningitis and encephalitis communication regarding assessment and referral

| Communication |
|---|
| ☐ Presenting signs, symptoms, and vitals on admission |
| ☐ Pertinent past medical history and history of present illness |
| ☐ Relevant laboratory results including white blood cell count, bicarbonate level, lactate level, and renal function |
| ☐ Whether CT was obtained, and results if obtained |
| ☐ Antibiotics administered, and time started |
| ☐ IV fluid administered, input/output |
| ☐ Results of LP, including opening pressure |
| ☐ Current vital signs |
| ☐ Ongoing concerns, active issues, outstanding studies/tests |
| ☐ Last physical and neurological exam findings prior to transfer |

## Communication

Transfer of care to the accepting health care team is an important step to maintain continuity of management. Most patients with bacterial meningitis and viral encephalitis require the oversight and care that an ICU can provide. Careful observation of the patient's respiratory status and close monitoring of his or her neurological exam with attention to decline is critical.

Table 2 outlines information that is important to pass along to the accepting health care team. Knowledge of whether the presentation was hyper-acute, acute, or subacute; the presenting and subsequent signs and symptoms; and the results of the imaging and LP (including OP) are vital pieces of information.

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