NEUROIMAGING RECOMMENDATIONS IN PAEDIATRIC BACTERIAL MENINGITIS

PROVIDED BY: MONASH HEALTH LIBRARY **DATE:** 22 NOVEMBER 2023

Please find following a summary of a literature search and relevant results. All articles can be provided in full - email library@monashhealth.org for a list of the articles you require.

QUESTION

In children with bacterial meningitis, what is the role of CNS/Brain imaging – focus on MRI – in the management (i.e. once diagnosis made, after lumbar puncture) to guide antibiotic treatment decisions including duration of treatment, anticoagulation or neurosurgical interventions?

Subcategories:

(i) is there evidence or guidance that suggest ALL patients with bacterial meningitis require ROUTINE cranial imaging to guide antibiotic treatment decisions, or detect subclinical complications?

(ii) is there evidence or guidance that patients with complicated bacterial meninigitis (seizures, non-resolving neurological deficits, persistent fevers, focal neurology) require cranial imaging?

(iii) should cranial imaging be done routinely in specific age groups (eg infants)? Complications of meningitis Hydrocephalus Cerebral infarct Brain abscess (cerebritis) Subdural empyema Venous sinus thrombosis

RESULTS

ONLINE RESOURCES (GREY LITERATURE)

GUIDELINES FROM GOVERNMENT, ASSOCIATIONS, & INTEREST GROUPS

Canadian Paediatric Society. (2020). **Guidelines for the management of suspected and confirmed bacterial meningitis in Canadian children older than 2 months of age: position statement.** Link.

- From section *Modifying therapy after laboratory cultures or molecular diagnosis become available*: "CNS imaging is recommended when there is failure of sterilization of CSF, or if neurological symptoms or other specific complications develop during the course of treatment."

French Infectious Diseases Society (SPILF). (2019). **Management of acute community-acquired bacterial meningitis (excluding newborns)**. Link.

- See p. 380 for section 1.5.2: *When are imaging tests indicated?*
- From p. 378: "When the clinical outcome is unfavorable after 48–72 hours of treatment (no improvement of consciousness disorders and/or signs of sepsis), systematic brain imaging is recommended (ideally an MRI) to detect an empyema or intracranial complications that could require surgery."

Meningitis Research Foundation. (2018). **Management of bacterial meningitis in children and young people.** Link.

- Algorithm – CT scan indicated in the event of "reduced or fluctuating conscious level or focal neurological signs".

- Related: Management of bacterial meningitis in infants under three months of age

Tunkel, A. R. et. al. (2017). **2017 Infectious Diseases Society of America's Clinical Practice Guidelines for Healthcare-Associated Ventriculitis and Meningitis**. Link.

- See Recommendation *IV. What is the Role of Imaging in Patients with Suspected Healthcare-Associated Ventriculitis and Meningitis?* – recommends MRI for detecting abnormalities.

European Society of Clinical Microbiology and Infectious Diseases. (2016). **ESCMID guideline: diagnosis and treatment of acute bacterial meningitis**. Link.

- From p. S56: "Neurologic and systemic complications occur in a large proportion of children and adults with bacterial meningitis. In patients with neurologic deterioration, cranial imaging (MRI or CT) is often indicated, and repeated lumbar puncture and EEG may be indicated in selected cases."

NICE [UK]. (Updated 2015; pending update in 2024). **Meningitis (bacterial) and meningococcal septicaemia in under 16s: Recognition, diagnosis and management.** Link.

- See p. 48 for recommendations re: CT scans in suspected bacterial meningitis only.
- Related: NICE Evidence review for role of neuroimaging prior to lumbar puncture (2023)

Ministry of Health, Social Services and Equality [Spain]. (2013). **Clinical Practice Guideline on the management of invasive meningococcal disease**. (IACS No. 2011/01). Link.

- See p. 143 for *Algorithm 4: Hospital management of meningococcal meningitis* – CT scan indicated if reduced or fluctuating level of consciousness or focal neurological signs.

European Federation of Neurological Societies. (2008). **EFNS guideline on the management of community-acquired bacterial meningitis: report of an EFNS Task Force on acute bacterial meningitis in older children and adults**. Link.

- P. 652: "In uncomplicated meningitis, plain CT and MR scans are often normal. Contrast scans may show abnormal enhancement of basal cisterns and subarachnoid space (involving convexity, falx, tentorium, base of the brain) because of the presence of inflammatory exudates [w17,w18,w19]; some MRI methods may have high sensitivity [w20]."

GUIDELINES FROM HEALTH SERVICES

Children's Minnesota [US]. (2023). **Suspected meningitis: Age 29 days – 24 years**. Link.

- Note 5 on p. 3: "MRI: not routinely needed except if: complicated course, certain pathogens (e.g., Cronobacter, Citrobacter, S. aureus), persistently positive CSF, neonates or older infants with typical neonatal pathogens (GBS, enteric gram negs, listeria) since clinical clues can be limited." – *Per p. 2, applies after culture or PCR has confirmed bacterial meningitis*.

Perth Children's Hospital. (2022). **Meningitis**. Link.

- "Cranial CT: This is of limited use in acute bacterial meningitis… CT does have a role when the diagnosis is in doubt (e.g. posterior fossa tumours can also cause meningism), or when complications of meningitis (e.g. brain abscess) are suspected."

Leicester Children's Hospital [UK]. (2022). **Management of bacterial meningitis in children**. Link.

- See p. 4 for 'Indication for CT Scan'.

Starship Child Health [NZ]. (2022). **Meningitis**. Link.

- "CT scan should be done if there are any focal neurological signs."

The Royal Children's Hospital. (2020). **Meningitis and encephalitis: Clinical practice guidelines.** Link.

- See *Management* section for neuroimaging indications, and statement that "[neuroimaging] Is not routine in meningitis but is used to look for complications eg abscess, thrombosis".

UPTODATE

Edward, M. S. et al. (2023). **Bacterial meningitis in the neonate: Treatment and outcome.** Link.

- "We perform neuroimaging (typically with magnetic resonance imaging [MRI]) 48 to 72 hours before the anticipated end of therapy in all neonates with confirmed bacterial meningitis, even those with an apparently uncomplicated course." – Link to this section
- Discusses MRI vs CT.

Edward, M. S. et al. (2023). **Bacterial meningitis in the neonate: Neurologic complications.** Link.

- Discusses the role of neuroimaging in the diagnosis of various acute complications.

Kaplan, S. L. (2023). **Bacterial meningitis in children older than one month: Treatment and prognosis**. Link.

- "The response to therapy is monitored with clinical and laboratory parameters (eg, fever curve, resolution of symptoms and signs, normalization of inflammatory markers) and by neuroimaging."
- Lists indications for neuroimaging during the course of treatment – link to section.

BMJ BEST PRACTICE

BMJ Best Practice. (2023). **Bacterial meningitis in children.**

- Indications for MRI and cranial CT discussed under 'Investigations to consider' (bottom of page).

PEER-REVIEWED LITERATURE – MOST RECENT FIRST

Articles are grouped by theme:

- Neuroimaging in the management of acute bacterial meningitis (ABM) – Neonates & infants
- Neuroimaging in the management of ABM – Children
- Role in detecting complications
- Complications seen on MRI (retrospective studies)
- Detection of stroke & hydrocephalus (retrospective studies)
- Detection of subdural empyemas & abscesses (retrospective studies)

Each article summary contains excerpts from the abstract and an online link.

NEUROIMAGING IN THE MANAGEMENT OF ABM – NEONATES & INFANTS

S. F. Kralik, et al. (2022). **Diagnostic Accuracy of MRI for Detection of Meningitis in Infants**. *AJNR. American Journal of Neuroradiology*, *43*(9), 1350-1355. Full-text.
Retrospective review of infants less than 1 year of age who underwent a brain MR imaging for meningitis from 2010-2018. RESULTS: Two hundred nine infants with mean age 80 days (range 0-347 days) were included.
From Materials and Methods section: Because of the retrospective nature of this study, decision to perform an MR imaging was based on standard clinical care and at our institution this includes routine MR imaging for infants less than 6 weeks and after 6 weeks is based on physician judgment of severity or potential for complications of meningitis.

T. Tavares, et al. (2022). **Group B Streptococcal Neonatal Meningitis**. *Clinical Microbiology Reviews*, *35*(2), e00079-21. Full-text.
In this review, we provide updated clinical information regarding the understanding of neonatal GBS meningitis, including epidemiology, diagnosis, management, and human evidence of the disease's underlying mechanisms. Finally, we explore the experimental models used to study GBS meningitis and discuss their clinical and physiologic relevance to the complexities of human disease.
From p. 10: Neuroimaging techniques, such as cranial ultrasound, computed tomography, and magnetic resonance imaging (MRI), have emerged as helpful tools alongside laboratory testing and clinical evaluation. Although these techniques are more valuable for evaluating complications than diagnosing bacterial meningitis, since infected babies may present with no structural changes, thus showing no abnormalities in radiological findings (4), they can be helpful in preliminary diagnosis and aid in clinical management decisions.

S. Bourne, et al. (2019). **The utility of neuroimaging in neonates and infants with bacterial meningitis**. *Paediatrics and Child Health (Canada)*, *24*(Supplement 2), e17-e18. View complete abstract.
Anecdotally, there is wide variation in the management of Canadian neonates and infants diagnosed with bacterial meningitis regarding the timing, modality, and indications for neuroimaging. Magnetic Resonance Imaging (MRI) imaging has become widely available in tertiary centres, but not in smaller hospitals. OBJECTIVE(S): To review current literature regarding neuroimaging in neonates and infants with bacterial meningitis and summarize the utility of neuroimaging in this population in Canada. The most common indications for MRI imaging were failure of cerebrospinal fluid sterilization, seizures, or abnormal findings on neurologic examination. Abnormal imaging results led to a change in management in 47% of infants, regardless of causative pathogen. Changes in management included prolongation of antimicrobial therapy, addition of anticoagulant therapy, and neurosurgical intervention.
Note: This a conference abstract only; no full-text is available.
Related conference abstracts:

- Variability in lumbar punctures and neuroimaging in infants less than 90 days with acute bacterial meningitis at a provincial children's hospital in Canada (2020)
- Brain magnetic resonance imaging appearances in neonatal bacterial meningitis (2017) – see p. 103, item #162.

A. Di Mauro, et al. (2019). **Neonatal bacterial meningitis: A systematic review of European available data**. *Minerva Pediatrica*, *71*(2), 201-208. Request full-text.
The aim of this article was to summarize current knowledge about this topic with particular

attention to management of neonatal meningitis in order to provide a useful tool for clinicians. We reviewed the existent literature from five European Countries (France, German, Italy, Spain and UK) on the effectiveness of treatments for bacterial meningitis in newborns taking into consideration the antibiotic resistance phenomenon. EVIDENCE SYNTHESIS: There are few data available on this topic; bacterial neonatal meningitis treatment and management is currently based more on experience than on high quality evidences. CONCLUSION(S): Identification of the knowledge gaps may stimulate researchers to design new studies aiming to better define management strategies of bacterial meningitis in newborns.

D. Swanson. (2015). **Meningitis**. *Pediatrics in Review*, *36*(12), 514-6. Full-text.
From p. 523: Neonatal meningitis. …Some experts routinely obtain a head CT scan or magnetic resonance imaging (MRI) with contrast 1 to 3 days before the expected end of therapy, even in apparently uncomplicated cases. (2) Such imaging is designed to identify any potential complications, such as cerebritis or parenchymal abscesses, that would require prolonged antimicrobial therapy. In addition, it might provide prognostic information and indicate the need for early interventional services. Contrast enhanced neuroimaging with CT scan or MRI is important for infections from *Citrobacter* sp, *Serratia marcescens*, *Proteus mirabilis*, and *Cronobacter* (formerly *Enterobacter*) *sakazakii* because of their tendency to cause brain abscesses.
From p. 523: Postneonatal meningitis. …Routine neuroimaging with CT scan or MRI is usually not necessary during the management of bacterial meningitis in the older infant and child. However, head CT scan or MRI with contrast is indicated in certain circumstances, including…

D. W. Kimberlin. (2002). **Meningitis in the Neonate**. *Current treatment options in neurology*, *4*(3), 239-248. Full-text.
Group B beta-hemolytic streptococci and Escherichia coli strains account for approximately two thirds of all cases of neonatal meningitis, while bacteria that typically account for meningitis in older age groups (Haemophilus influenzae type B, Neisseria meningitidis, and Streptococcus pneumoniae) are infrequent causes of meningitis in the neonatal population. … All neonates should undergo repeat CSF examination and culture at 48 to 72 hours after initiation of therapy. If organisms are observed on gram stain, modification of the therapeutic regimen should be considered, and neuroimaging should be performed.
Note: See p. 246 for further indications for neuroimaging.

NEUROIMAGING IN THE MANAGEMENT OF ABM – CHILDREN

L. R. A. Uchôa, et al. (2023). **Newer Updates in Pediatric Intracranial Infection**. *Seminars in Roentgenology, 58*(1), 88–109. Full-text.
The objective of this paper is to review the most emblematic clinical presentations and imaging characteristics of pediatric CNS infections, focusing on new entities and archetypical pathogens.
From p. 94: The diagnosis of meningitis is established by CSF evaluation. Neuroimaging is employed to confirm the diagnosis and look for possible complications like hydrocephalus, abscesses, and empyemas; or for excluding herniation before lumbar puncture. … Contrast-enhanced T1-weighted MR imaging (T1WI) may show pia-subarachnoid space enhancement, is typical and more common than dura-arachnoid enhancement and is the standard method of imaging for nearly all intracranial meningitis.

P. Brooke, et al. (2023). **Pneumococcal meningitis in children**. *Paediatrics and Child Health*, *33*(10), 289-294. Full-text.
This article considers current epidemiology and management of pneumococcal meningitis within [a] shifting landscape and offers practical advice to healthcare professionals working with children and

young people.
Note: Recommendations for neuroimaging discussed at various points, including sections on *Imaging*; *Antibiotic treatment duration and treatment failure;* and *Outcomes and sequelae.*
P. 293: Inpatient neuroimaging is indicated during investigation for acute neurological complications such as focal neurology, prolonged coma, increasing head circumference and new seizures after commencing treatment. In one study 70% of children had evidence of an infarction on MRI.

S. Sarfaraz, et al. (2022). **Role of Computed Tomography Scan in the Management of Pediatric Acute Bacterial Meningitis: An Experience from a Tertiary Care Hospital in Lahore**. *Pakistan Journal of Medical and Health Sciences*, *16*(8), 226-228. Full-text.
Objective(s): To determine the frequency of radiological findings on computed tomography (CT) of the brain among children presenting with acute bacterial meningitis. Material(s) and Method(s): This cross-sectional study was conducted in Department of Pediatrics KEMU/Mayo Hospital Lahore after IRB approval. Patients with CSF-proven ABM whose CT brains had been performed were enrolled retrospectively. Result(s): A total of 165 ABM patients with a mean age of 6.2 +/-1.3 years; 68.5% (113) males and 31.5% (52) females were included. CT brain was normal in 92 (55.8%), while 29 (17.6%) had cerebral edema, 20 (12.1%), 11 (6.7%) and 13 (7.9%) had cerebral infarct, hydrocephalus and cerebral abscess respectively. Conclusion(s): Computed Tomography is a useful tool for detecting intracranial complications of ABM. But routine use of CT-brain in every patient without clear indications should be avoided to decrease the risk of radiation exposure as well as to save resources.

S. Masuoka, et al. (2022). **Predisposing conditions for bacterial meningitis in children: what radiologists need to know**. *Japanese Journal of Radiology*, *40*(1), 1-18. Full-text.
When a structural defect is suspected in a patient with BM, computed tomography (CT) of the head and magnetic resonance (MR) imaging are first-line imaging examinations. Radionuclide cisternography should be implemented as a second-line step to identify the CSF leak site. In patients with suspected parameningeal infection without any structural defect, such as sinusitis or otitis media/mastoiditis, CT or MR images can identify not only the disease itself but also the associated intracranial complications. The purpose of this article is to discuss the diagnostic approach and imaging findings associated with the variety of conditions predisposing patients to recurrent BM, focusing on the role of radiology in their management.
See bottom of p. 2 onwards: Radiological examinations should be implemented for further assessment once a predisposing condition is suspected after non-radiological examinations. In patients with a suspected DST, spinal ultrasound (US) and MR imaging are useful…

Z. Alamarat, et al. (2020). **Management of Acute Bacterial Meningitis in Children**. *Infection and drug resistance*, *13*(101550216), 4077-4089. Full-text.
This review will present the epidemiology of ABM in children, indications of cranial imaging, role of different models and serum biomarkers in diagnosing ABM, and management including the use of adjunctive therapies and methods of prevention.
From p. 4079: Neuroimaging is not essential for the diagnosis or management in the majority of patients with acute bacterial meningitis. … CT or MRI of brain can be useful in showing meningeal enhancement, areas of ischemia due to secondary vasculitis, define pathology of the base of skull that may be causative and require rapid therapeutic intervention and surgical consultation and to identify potential sources of infection such as fractures of the paranasal sinus or petrous bone as well as inner ear infection and mastoiditis.
From p. 4082: CSF values of neutrophils >30%, glucose <20 mg/dL, or CSF-to-blood glucose ratio <20% are non-reassuring and in these circumstances, CSF examination as well as neuroimaging can

assist in determining an optimal duration of antibiotic therapy to prevent relapse.

M. H. Beaman. (2018). **Community-acquired acute meningitis and encephalitis: a narrative review**. *The Medical journal of Australia*, *209*(10), 449-454. Full-text.
Meningitis and encephalitis are medical emergencies. Patients need prompt evaluation and immediate empiric therapy to reduce the likelihood of fatal outcomes and chronic neurological sequelae. … Neuroimaging delays the treatment of meningitis and is not needed in most cases.

M. De Gaudio, et al. (2010). **Therapeutic management of bacterial meningitis in children: A systematic review and comparison of published guidelines from a European perspective**. *Journal of Chemotherapy, 22*(4), 226-237. Request full-text.
We compared the most recent international guidelines and recommendations on bacterial meningitis management in infants and children in developed countries, in terms of initial management approach, empirical antimicrobial therapy, timing, dosages, and duration of antimicrobial therapy, and possible adjunctive treatment with dexamethasone.
From p. 235: Usually clinical features such as depressed level of consciousness, seizures, focal neurologic features, or persistent fever, suggest a need for neuroimaging for the possible risk of complications requiring neurosurgery.

ROLE IN DETECTING COMPLICATIONS

A. Woodhouse. (2021). **Bacterial meningitis and brain abscess**. *Medicine (United Kingdom), 49*(11), 667-674. Full-text.
From p. 671, regarding brain abscess: Presentation can be rapid but is often subacute with symptoms and signs developing over a period of days. Presenting neurological features depend on the area of brain involved, with neurological deficits reflecting the anatomical location of the abscess. Focal neurological deficits are common (48%),3,5 although not universal, by the time of presentation. If there is concern about the possibility of brain abscess, appropriate diagnostic imaging should be undertaken. ...cerebral imaging should be undertaken as soon as the possibility of brain abscess is considered.

M. S. Jacob, et al. (2020). **Clinical profile and outcome of patients with cerebral venous thrombosis secondary to bacterial infections**. *Annals of Indian Academy of Neurology*, *23*(4), 477-481. Full-text.
In this study, we describe the clinical profile, diagnosis, and management of patients with CVT secondary to an infectious aetiology. Method(s): This retrospective study included all adult patients over 15 years (1 January 2002 to 1 January 2017). Adult patients with a diagnosis of infective CVT secondary to bacterial infections were included in the study. Result(s): Totally, 22 patients were identified with CVT complicating bacterial infections. The focus of infection in 12 (54.54%) patients was pyogenic meningitis, 9 (40.9%) patients had a parameningeal focus and one patient developed CVT secondary to bacterial sepsis from a remote focus. The most common organism in the meningitis group was Streptococcus species, and in the parameningeal group was Staphylococcus aureus. At presentation MRI identified CVT in all 7 patients as compared to CT brain with contrast in 2/3 (66.6%).
See p. 480 for role of MRI in diagnosing CVT. Note: mean age was 43 years.

R. Suthar, et al. (2019). **Bacterial Infections of the Central Nervous System**. *Indian journal of pediatrics*, *86*(1), 60-69. Full-text.
In this review, authors discuss the current updates on the diagnostic and therapeutic aspects of

bacterial infections of the CNS in children (post-neonatal age group).
Example from p. 62, Neuroimaging: The diagnosis of bacterial meningitis is clinical and confirmation is done with CSF analysis. Imaging adds very little to the diagnosis of uncomplicated meningitis. The value of neuroimaging lies in excluding other pathological processes and in the investigation of complications (Fig.1). MRI is superior to CT scan in the identification of complications in children with bacterial meningitis.
From p. 65: The duration of antimicrobial therapy is 6–8 wk. Cranial neuroimaging should be repeated immediately if there is neurological deterioration, after 1–2 wk if there is no clinical improvement and biweekly once recovery is evident until 3 mo.

COMPLICATIONS SEEN ON MRI (RETROSPECTIVE STUDIES)

N. Lummel, et al. (2016). **Spectrum and Prevalence of Pathological Intracranial Magnetic Resonance Imaging Findings in Acute Bacterial Meningitis**. *Clinical Neuroradiology*, *26*(2), 159-67. Full-text.
Aim of this study was to determine the spectrum and prevalence of pathological intracranial magnetic resonance imaging (MRI) findings in patients with acute bacterial meningitis. METHODS: We retrospectively identified all consecutive patients with cerebral spinal fluid proven bacterial meningitis who presented at our neurology department between 2007 and 2012. RESULTS: A total of 136 patients with purulent bacterial meningitis were identified. In 114 cases the bacterial pathogen agent was proven and in 75 patients an MRI was available. In 62 of the 75 (82.7 %) patients meningitis-associated pathologic imaging findings were evident on MRI. CONCLUSION: Pathological MR findings are frequently found in patients with acute bacterial meningitis. Intraventricular diffusion restrictions, i.e., signs of pyogenic ventriculitis, are more often found in patients with streptococcal, especially pneumococcal, infection.

C. R. Oliveira, et al. (2014). **Brain magnetic resonance imaging of infants with bacterial meningitis**. *The Journal of Pediatrics*, *165*(1), 134-9. Full-text.
OBJECTIVES: To describe the results of brain magnetic resonance imaging (MRI) of infants with bacterial meningitis and how the findings affected clinical management. STUDY DESIGN: This retrospective study included all infants <12 months of age who were hospitalized at Children's Medical Center, Dallas and had culture-confirmed bacterial meningitis and a brain MRI from January 1, 2001 to December 1, 2011. RESULTS: Of the 440 infants who had a positive CSF culture result, 111 (25%) had a pathogen isolated from CSF and were enrolled in the study. Of these, 68% (75/111) had a brain MRI performed during the hospitalization; abnormalities included leptomeningeal enhancement (57%), cerebral infarct (43%), subdural empyema (52%), cerebritis (26%), hydrocephalus (20%), and abscess (11%). CONCLUSIONS: Brain MRIs were performed frequently and often were abnormal in infants with bacterial meningitis, leading to changes in clinical management.
Please note related items:

- Correction to some data in the above article.
- Commentary on the article.

C.-J. Chang, et al. (2004). **Seizures complicating infantile and childhood bacterial meningitis**. *Pediatric Neurology*, *31*(3), 165-71. Request full-text.
In this study, 116 patients, at least 1 month of age but younger than 5 years, were identified with culture-proven bacterial meningitis. A comparison was made between the clinical data of the patients with and without seizures during hospitalization. … A strong correlation between the findings of abnormalities through neuroimaging and the occurrence of seizures during

hospitalization was observed.
From p. 166: Cranial ultrasonographies in the infantile patients were performed every week, and our standard was to follow up with magnetic resonance imaging if (1) clinical deterioration, the presence of focal neurologic signs, or persistent disturbed consciousness was found; (2) the electro-encephalogram reading indicated a predominantly unilateral abnormality; and (3) cranial ultrasonographies revealed ventriculitis or subdural empyemas.

W. Jan, et al. (2003). **Diffusion-weighted imaging in acute bacterial meningitis in infancy**. *Neuroradiology*, *45*(9), 634-639. Full-text.
Our aim was to demonstrate the complications of meningitis by diffusion weighted imaging (DWI) in patients who deteriorated despite therapy. We studied 13 infants between the ages of 1 day and 32 months who presented with symptoms ranging from fever and vomiting to seizures, encephalopathy and coma due to bacterial meningitis, performing MRI, including DWI, 2-5 days after presentation. Multiple infarcts were found on DWI in 12 of the 13, most commonly in the frontal lobes (in 10). Global involvement was seen in four children, three of whom died; the fourth had a very poor outcome. In one case abnormalities on DWI were due to subdural empyemas. We diagnosed vasculitis in three of five patients studied with MRA. We think DWI an important part of an MRI study in infants with meningitis. Small cortical or deep white-matter infarcts due to septic vasculitis can lead to tissue damage not easily recognized on routine imaging and DWI can be used to confirm that extra-axial collections represent empyemas.

DETECTION OF STROKE & HYDROCEPHALUS (RETROSPECTIVE STUDIES)

L. Huo, et al. (2019). **Clinical Features of and Risk Factors for Hydrocephalus in Childhood Bacterial Meningitis**. *Journal of Child Neurology*, *34*(1), 11-16. Full-text.
Objective: To explore the clinical characteristics of and analyze the risk factors for hydrocephalus in children with bacterial meningitis. Method(s): Retrospective study of a sample of children with bacterial meningitis seen on the pediatric service of Shengjing Hospital of China Medical University between January 1, 2010, and December 31, 2016. Result(s): Overall, 9.36% (25/267) of patients presented with hydrocephalus. The most significant results of multivariate analysis for hydrocephalus were a rural living situation, altered level of consciousness, previous treatment with antibiotics, initial cerebrospinal fluid protein >2 g/L, C-reactive protein >100 mg/L, and dexamethasone use.
From p. 12: Every child underwent neuroimaging at admission and with any change in clinical presentation. The diagnosis of hydrocephalus was based on neurologic examination and the neuroimaging report.

S. F. Kralik, et al. (2019). **Comparison of CSF and MRI Findings among Neonates and Infants with E coli or Group B Streptococcal Meningitis**. *AJNR. American Journal of Neuroradiology*, *40*(8), 1413-1417. Full-text.
The purpose of this study was to determine whether CSF and/or MR imaging findings differ between infants with group B streptococcal or E coli meningitis. A retrospective review was performed among neonates (younger than 28 days) and infants (younger than 120 days) with proved group B streptococcal (n = 57) or E coli meningitis (n = 50). CONCLUSIONS: Although neonates and infants with group B streptococcal or E coli meningitis had similar age and CSF laboratory values, patients with group B streptococcal meningitis more frequently demonstrated infarcts, while those with E coli more frequently had early onset of hydrocephalus.
From p. 1416: Finally, because both infarcts and hydrocephalus can result in injury to the brain

parenchyma, these findings are important for patient prognosis and indicate the need for imaging to detect these complications. … At our institution, it has become the standard of care for these patients to undergo MR imaging of the brain, so it is unlikely to result in a selection bias.

M. Dunbar, et al. (2018). **Stroke in Pediatric Bacterial Meningitis: Population-Based Epidemiology**. *Pediatric Neurology*, *89*(aa5, 8508183), 11-18. Full-text.
The purpose of this study is to assess the incidence, risk factors, patterns, and outcomes in pediatric meningitis complicated by stroke. METHODS: The study design was a population-based, 10-year retrospective (2002 to 2012) cohort study set in Southern Alberta, Canada. The inclusion criteria were: (1) age from newborn to 18 years, (2) brain magnetic resonance imaging (MRI) including diffusion-weighted imaging during admission, and (3) laboratory confirmed acute bacterial meningitis. CONCLUSIONS: More than one-third of children with acute bacterial meningitis and clinically indicated MRI had ischemic stroke. Stroke was associated with clinical factors including duration of illness, seizures, and causative organisms. Stroke was associated with higher mortality and morbidity, warranting consideration of increased MRI screening and new approaches to treatment.

DETECTION OF SUBDURAL EMPYEMAS & ABSCESSES (RETROSPECTIVE STUDIES)

Lundy, P. et al. (2019). **Intracranial subdural empyemas and epidural abscesses in children.** *Journal of Neurosurgery. Pediatrics, 24* (1), 14-21. Full-text.
The authors conducted a retrospective analysis of a consecutive series of children with intracranial subdural empyemas (SEs) and epidural abscesses (EAs) to highlight the important clinical difference between these two entities. They describe the delays and pitfalls in achieving accurate diagnoses and make treatment recommendations based on clinical and imaging findings. CONCLUSIONS: Regardless of the initial imaging interpretation, any child presenting with focal neurological deficit or seizures and sinusitis should be assumed to have an SE or meningitis, and a careful review of high-resolution imaging, ideally MRI with contrast, should be performed.
Note: Case series of 16 children; not all had meningitis.

Y.-D. Tsai, et al. (2003). **Intracranial suppuration: a clinical comparison of subdural empyemas and epidural abscesses**. *Surgical Neurology*, *59*(3), 191-196. Request full-text.
We compared the clinical features and therapeutic outcomes of intracranial suppurations (IEs) caused by sub-dural empyema (SDEs) and epidural abscesses (EAs). METHODS: Twenty-four patients with IE were retrospectively identified at our institution over a period of 14 years. RESULTS: Among them, 15 had SDE and nine had EA with or without SDE. CONCLUSION: …Inpatients with meningitis or who undergo postneurosurgical procedures and develop fever, progressive disturbed consciousness, seizures, and focal neurologic signs, immediate neuroimaging studies should be performed to determine whether IE is present. Early surgical drainage and aggressive antimicrobial therapy are necessary.

APPENDIX

SEARCH METHODOLOGY

A systematic search was conducted for literature. The results were screened by librarians using Covidence.

SEARCH LIMITS

- English-language.
- Published after 2000.
- All study designs except for case reports and small case series (<10 cases).

DATABASES SEARCHED

- Medline – index of peer reviewed articles across health sciences and medicine.
- Embase – index of biomed and pharmacological peer reviewed journal articles.
- Emcare – index of nursing, allied health, critical-care medicine and more.
- Cochrane Library – collection of databases containing high-quality independent evidence.
- UpToDate & BMJ Best Practice – synthesised evidence for patient care.
- Grey literature – Google, Google Scholar, Trip database, Biomed Central Proceedings, relevant guideline portals (e.g. GIN, NICE, SIGN)

SEARCH TERMS

Concept	MeSH headings	Keywords
Bacterial meningitis	Meningitis, Bacterial/, Meningitis, Escherichia coli/, Meningitis, Listeria/, Meningitis, Haemophilus/, Meningitis, Pneumococcal/	bacterial meningitis, bacterial meningitides
Paediatric (infants, children, & adolescents)	Pediatrics/, Adolescent/, Child/, Adolescent Health Services/, Infant/, Infant, Newborn/, Child, Preschool/, Child Health Services/	paediatric(s/ian) or pediatric(s/ian) or child or children or adolescen(t/ce) or youth or young people or teen(s/ager) or infant(s) or infancy or neonat(e/es/al) or newborn(s) or baby or babies
MRI or neuroimaging	Magnetic Resonance Imaging/, Neuroimaging/	cranial or brain + imaging or image(s/d) or ultrasound(s) or sonograph(s/y/er) or ultrasonograph(s/y/er) or scan(s/ned/ning)

MEDLINE SEARCH STRATEGY

Ovid MEDLINE(R) ALL <1946 to November 10, 2023>

1 Meningitis, Bacterial/co, dg, dt, mo, su, th or Meningitis, Escherichia coli/co, dg, dt, mo, su, th or Meningitis, Listeria/co, dg, dt, mo, rt, su, th or Meningitis, Haemophilus/co, dg, dt, mo, su, th or Meningitis, Pneumococcal/co, dg, dt, mo, su, th 6389
2 bacterial meningit*.ti,ab,kf. 8318
3 1 or 2 12195
4 Pediatrics/ or Adolescent/ or Child/ or Adolescent Health Services/ or Infant/ or Infant, Newborn/ or Child, Preschool/ or Child Health Services/ 4013201
5 (paediatric* or pediatric* or child or children or adolescen* or youth or young people or teen* or infant* or infancy or neonat* or newborn* or baby or babies).ti,ab,kf. 2638496
6 4 or 5 4741423
7 Magnetic Resonance Imaging/ or Neuroimaging/ 489726
8 ((cranial or brain) adj5 (imaging or image* or ultrasound* or sonograph* or ultrasonograph* or scan*)).tw. 80086
9 (neuro-imag* or neuroimag*).ti,ab,kf. 71156
10 7 or 8 or 9 574734
11 3 and 6 and 10 350
12 limit 11 to (english language and yr="2000 -Current") 216
13 case report*.pt. 2368038
14 12 not 13 97

PRISMA CHART