Subdural Empyema

John E. Greenlee, MD

Address
Department of Neurology, University of Utah Health Sciences Center,
50 North Medical Drive, Salt Lake City, UT 84132, USA.
E-mail: john.greenlee@hsc.utah.edu

Current Treatment Options in Neurology 2003, **5:**13–22
Current Science Inc. ISSN 1092-8480

Opinion statement

Subdural empyema represents loculated infection between the outermost layer of the meninges, the dura, and the arachnoid. The empyema may develop intracranially or in the spinal canal. Intracranial subdural empyema is most frequently a complication of sinusitis or, less frequently, otitis or neurosurgical procedures. Spinal subdural empyema is rare and may result from hematogenous infection or spread of infection from osteomyelitis. The most common organisms in intracranial subdural empyema are anaerobic and microaerophilic streptococci, in particular those of the *Streptococcus milleri* group (*S. milleri* and *Streptococcus anginosus*). *Staphylococcus aureus* is present in a minority of cases, and multiple additional organisms, including Gram-negative organisms, such as *Escherichia coli*, and anaerobic organisms, such as *Bacteroides*, may be present. *Pseudomonas aeruginosa* or *Staphylococcus epidermidis* may be present in cases related to neurosurgical procedures, and *Salmonella* species have been detected in patients with advanced AIDS; multiple organisms may be present simultaneously. Spinal subdural empyemas are almost invariably caused by streptococci or by *S. aureus*. Subdural empyema—whether it occurs in the skull or the spinal canal—may cause rapid compression of the brain or spinal cord, and represents an extreme medical and neurosurgical emergency. The diagnostic procedure of choice for intracranial and spinal subdural empyema is MRI with gadolinium enhancement. Computed tomography scan may miss intracranial subdural empyemas detectable by MRI. Conversely, occasion spinal subdural empyemas may be detected by CT myelography where MRI is negative. Treatment in virtually all cases of intracranial or spinal subdural empyema requires prompt surgical drainage and antibiotic therapy. Pus from the empyema should always be sent for anaerobic, as well as aerobic, culture. Because intracranial subdural empyemas may contain multiple organisms, provisional antibiotic therapy of intracranial subdural empyema, where the organism is unknown, should be directed against *S. aureus*, microaerophilic and anaerobic streptococci, and Gram-negative organisms. Antibiotics should include 1) nafcillin, oxacillin, or vancomycin; *plus* 2) a third generation cephalosporin; *plus* 3) metronidazole. Provisional antibiotic therapy of spinal subdural empyemas should be directed against *S. aureus* and streptococci, and should include nafcillin, oxacillin, or vancomycin. Morbidity and mortality in intracranial and spinal subdural empyema relate directly to the delay in institution of therapy. Both conditions should, thus, be treated with great urgency.

Introduction

Subdural empyema represents loculated infection between the outermost layer of meninges, and may occur either intracranially or in the spinal canal. Of the two, spinal subdural empyema is by far the less common, with relatively few cases—and no large case series—reported in the literature. Because the etiologic organisms, course, and treatment of intracranial and spinal subdural empyema are somewhat different, the Introduction of this article will discuss these two entities separately.

INTRACRANIAL SUBDURAL EMPYEMA

The brain is surrounded by the following three layers of meninges: the dura, the arachnoid, and the pia. The outermost of these membranes, the dura and arachnoid, are joined only at the base of the brain, along the falx cerebri, and at the tentorium cerebelli; elsewhere, the dura and arachnoid are held against each other by the outward pressure of brain and cerebrospinal fluid (CSF). Between the dura and arachnoid exists a potential space in which infection can rapidly spread to involve entire cerebral hemisphere, the interhemispheric fissure, or a large portion of the posterior fossa [1•,2•, Class III].

Intracranial subdural empyema is usually a complication of sinusitis. Less frequently, subdural empyema may arise as a complication of otitis media and mastoiditis [1•, Class III]. In both cases, organisms spread from infected sinuses, middle ear, or mastoid by septic thrombophlebitis of the emissary veins, which bridge the superficial cranial venous drainage and the intracranial venous system [1•,3, Class III]. Less often, organisms may spread inward through Haversian channels in bone as a complication of osteomyelitis. Subdural empyema may also occur as a complication of neurosurgical procedures or, occasionally, after head trauma; in this latter setting, subdural empyema can occur months or years after the injury [4, Class III]. Rarely, subdural empyema will develop after bacteremic seeding of a pre-existing subdural hematoma, transforming the hematoma from a relatively indolent pathologic process into a rapidly progressive one [5,6, Class III].

Intracranial subdural empyema may involve the base of the brain, the cerebral convexity, the interhemispheric fissure along the falx cerebri, or, less frequently, the posterior fossa. The empyema causes an intense inflammatory reaction in the subdural space; this may be accompanied by CSF pleocytosis and cortical encephalitis [1•,7, Class III]. Inward venous extension of infection may result in hemorrhagic infarction or superficial abscess. Cerebral edema develops rapidly beneath the empyema, and the combined mass effect of cerebral edema and the empyema leads to transtentorial herniation, brainstem compression, and death [2•,8, Class III]. Subdural empyema arising from sinusitis, otitis, or other pericranial infections may be preceded by epidural abscess or accompanied by deeper infectious complications of meningitis, brain abscess, or septic intracranial venous thrombosis.

Intracranial subdural empyema predominantly affects children and young adults, such that approximately 70% cases occur in the second and third decades of life [9•,10••,11, Class III]. The condition is significantly more common in men than in women. Symptomatic or occult sinusitis or otitis is present in 60% to 90% of cases. The onset of symptoms is usually rapid, and may be fulminant [9•,10••, Class III]. Initial symptoms of fever and focal headache progress to vomiting and signs of meningeal irritation, followed by development of signs indicating involvement of an entire cerebral hemisphere or posterior fossa structures [1•, Class III]. Altered consciousness at presentation is found in up to 50% of patients. Focal neurologic deficits, including hemiplegia, develop in the majority of patients [1•,9•, Class III]. Parafalcine empyemas may produce unilateral or bilateral leg weakness as an early sign. Focal or generalized seizures occur in approximately 50% of cases [9•, Class III]. Observed enlargement of the empyema produces ominous findings of increased intracranial pressure, stupor, and coma. Growth of the empyema may be so rapid that coma and death can occur before papilledema becomes clinically evident. Occasionally, subdural empyemas may develop over 2 to 3 weeks. In such cases, focal cranial pain may not occur, and prior antibiotic treatment of sinusitis or otitis may mask superficial symptoms, so that the empyema may present with symptoms suggestive of brain abscess. Development of subdural empyemas after neurosurgical procedures may also be insidious [1•, Class III]. Subdural empyema arising in a pre-existing subdural hematoma may have an extremely atypical presentation, and any delay in diagnosis in this setting may lead to higher mortality.

The causative agents of intracranial subdural empyema are representative of those found in sinusitis or otitis and resemble those found in intracranial epidural abscess or brain abscess. Compared with infections elsewhere in the body, multiple organisms are frequently present. Aerobic, microaerophilic, and anaerobic streptococci, including *Streptococcus miller* and *Streptococcus anginosus*, are common [3,9•,10••,11,12•,13,14•, Class III]. Multiple additional organisms, including *Bacteroides* species and enteric bacteria such as *Escherichia coli*, *Proteus* species, or *Pseudomonas* species, may also be present in this setting [12•, Class III]. Subdural empyema in the setting of advanced AIDS may be caused by nontyphoidal *Salmonella* [15, Class III]. Anaerobic organisms have been detected in up to 100% of cases in which great care is taken in obtaining anaerobic cultures [12•, Class III]. *Staphylococcus aureus* occurs in approximately 17% of cases associated with sinusitis and is the most common organism in cases associated with cranial trauma or surgical procedures. Subdural empyema complicating head trauma may also be caused by coagulase-negative strains of *Staphylococcus*, anaerobes, or Gram-negative organisms, including *Campylobacter fetus*. Subdural empyema after neurosurgical procedures may be caused by *Pseudomonas aeruginosa* or clostridial organisms [1•,2•, Class III]. Subdural empyema in infants and small children is usually a complication of meningitis, and isolates from

subdural fluid are usually identical to those causing the meningitis [1•, Class III].

Intracranial subdural empyema should be considered in any patient with overt or radiologically diagnosed sinusitis or otitis who develops fever accompanied by focal cranial pain or diffuse headache. The diagnosis should also be kept in mind after head trauma or craniotomy, and should also be considered in alcoholics or other individuals at risk for subdural hematomas who develop precipitous deterioration in neurologic status. Neurologic examination may show focal cerebral or posterior fossa signs that extend to suggest either widespread hemispheric or posterior fossa involvement. Routine blood studies are not diagnostic, although leukocytosis and elevated erythrocyte sedimentation rate are usually present. The diagnostic procedure of choice is MRI with gadolinium enhancement (Fig. 1) [2•,16,17, Class III]. This procedure, used emergently with a high level of suspicion, may diagnose subdural empyema at a time when symptoms are confined to headache and fever, without focal neurologic signs [18, Class III]. Sedation, with meticulous patient monitoring, may be essential to achieve an adequate study. Computed tomography will detect many subdural empyemas, but—even if contrast is used—may fail to identify empyemas that are easily visible via MRI [1•,16,17,19, Class III]. For this reason, emergent angiography may be required in cases in which MRI is not available and subdural empyema is suspected, despite negative CT. The MRI should be carefully studied for evidence of epidural abscess, meningitis, or brain abscess, because each of these may also be present. Magnetic resonance imaging or CT may also demonstrate sinusitis, otitis, or mastoiditis. Lumbar puncture is contraindicated in suspected subdural empyema. Spinal fluid is usually sterile, changes in cell count, glucose concentration, and protein are almost always nonspecific, and the procedure carries substantial risk of brain herniation and death [2•,9•, Class III]. The possible role of high-resolution ultrasound to diagnose subdural empyema in infants has already been discussed [20, Class III].

SPINAL SUBDURAL EMPYEMA

Compared with intracranial subdural empyema, spinal subdural empyema is rare [1•, Class III]. Infection of the subdural space is usually hematogenous, although cases have arisen as a complication of osteomyelitis and meningitis. The majority of cases are caused by *S. aureus* and streptococci. Magnetic resonance imaging is the diagnostic procedure of choice, because of its ability to image the spine over its entire length. Cases of spinal empyema have been reported, however, in which CT myelography was diagnostic in the face of negative MRI.

Treatment

Diet and lifestyle

- Neither intracranial nor spinal subdural empyema is influenced by diet or lifestyle.
- Treatment of sinusitis, otitis, or mastoiditis will lessen the likelihood of intracranial subdural empyema; however, sinusitis or otitis may be clinically silent.

Pharmacologic treatment

- Table 1 shows pharmacologic therapies for subdural empyema.
- Intracranial subdural empyema has been termed *the most imperative of all neurosurgical emergencies*. Antibiotic therapy of subdural empyema is almost invariably adjunctive to surgical drainage. Unless the empyema is too small to drain, treatment should not be attempted with antibiotics alone.
- Antibiotic therapy of intracranial subdural empyema requires that the agents that are used must reach bactericidal levels within the empyema itself. Also, because meningitis or brain abscess or brain abscess may be present, the antibiotics selected should also reach bactericidal concentrations in both CSF and brain parenchyma.
- Controlled studies of antibiotic therapy or surgical approaches for intracranial or spinal subdural empyema do not exist, nor has penetration of antibiotics into subdural empyemas been well studied. For this reason, recommendations for antibiotic therapy, in almost all reviews, have involved extrapolation from more detailed studies of brain abscess.

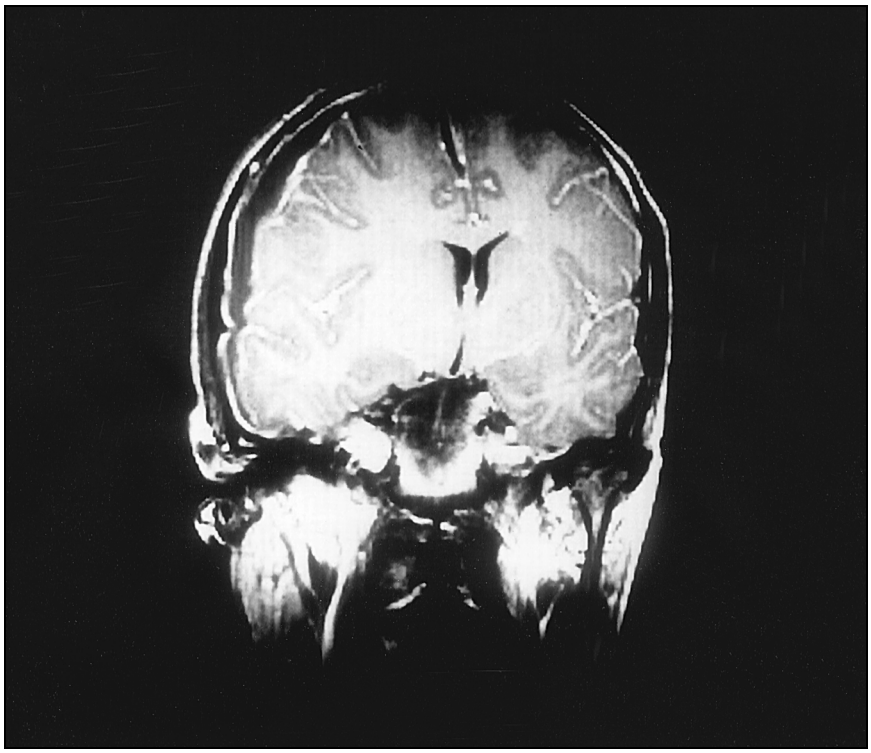

Figure 1. Intracranial subdural hematoma overlying the cerebral convexity. A single frame of the MRI, although documenting the presence of the empyema, gives a false impression of the amount of purulent material present—the empyema extends over the entire cerebral convexity and may contain over 50 mL of pus.

- Provisional antibiotic coverage must recognize that one may be treating a polymicrobial infection in which *S. aureus* or a streptococcal organism, a Gram-negative organism, or *Bacteroides* may be present concurrently [2•, Class III].
- Where the organism is unknown, one should consider using nafcillin or oxacillin, ceftriaxone or cefotaxime, and metronidazole concurrently [2•, Class III].
- If there is suspicion of a nafcillin-resistant organism, or if penicillin allergy is present, then vancomycin should be used in place of nafcillin or oxacillin [2•, Class III].
- Ceftazidime should be used in place of ceftriaxone or cefotaxime if *P. aeruginosa* is strongly suspected, as in cases after neurosurgical procedures [21, Class III].
- Agents used for treatment of intracranial subdural empyema in neonates should be those used for therapy of the accompanying meningitis.
- Provisional treatment of spinal subdural empyema should be directed against *S. aureus* and should include oxacillin or nafcillin, using vancomycin if there is a history of allergy to penicillins or if there is any question of nafcillin resistance [21, Class III].
- The antibiotic regimen used in a given patient may need to be revised as data become available from Gram stain or cultures obtained at surgery. Length of therapy is determined by patient course and follow-up MRI or CT. In general, antibiotics should be continued for 3 to 4 weeks if surgery is not undertaken or 6 to 8 weeks if osteomyelitis is present.
- Careful follow-up of the infection by MRI or, less optimally, by CT is essential if the empyema is treated with only antibiotics.

Table 1. Pharmacologic therapy for subdural empyema

Clinical setting	Suspected organism	Recommended antibiotics
Intracranial subdural empyema: source of infection is unknown	Aerobic or microaerophilic streptococci; *Staphylococcus aureus*; *Bacteroides* species	Nafcillin or oxacillin, plus ceftriaxone or cefotaxime, plus metronidazole Vancomycin should be used in place of nafcillin or oxacillin if any suspicion of methicillin-resistant *S. aureus* is known to be high or if penicillin allergy is present
Intracranial subdural empyema: sinusitis or otitis media	Aerobic or microaerophilic streptococci; *S. aureus*; *Bacteroides* species	Nafcillin or oxacillin, plus ceftriaxone or cefotaxime, plus metronidazole Vancomycin should be used in place of nafcillin or oxacillin if any suspicion of methicillin-resistant *S. aureus* is known to be high or if penicillin allergy is present
Intracranial subdural empyema after cranial trauma	*S. aureus*; streptococci	Nafcillin or oxacillin Vancomycin should be used in place of nafcillin or oxacillin in areas where the incidence of methicillin-resistant *S. aureus* is known to be high or penicillin allergy is present
Intracranial subdural empyema after neurosurgical procedures	*S. aureus*; *Staphylococcus epidermidis*; *Pseudomonas aeruginosa*	Vancomycin plus ceftazidime
Intracranial subdural empyema in neonates	The organism is usually that of an accompanying meningitis, usually Gram-negatives or group B streptococci	Agents used should be those used to treat the meningitis
Spinal subdural empyema	*S. aureus*; streptococci	Nafcillin or oxacillin Vancomycin should be used in place of nafcillin or oxacillin in areas where the incidence of methicillin-resistant *S. aureus* is known to be high or penicillin allergy is present

Nafcillin and oxacillin

	Nafcillin and oxacillin are used in treatment of suspected infections caused by methicillin-sensitive strains of *S. aureus*, and also have activity against a wide range of Gram-positive organisms [22, Class III].
Standard dosage	Identical for nafcillin and oxacillin—12 g per day intravenously, administered as 2 g every 4 hours. For children less than 50 kg—200 mg/kg per day intravenously (administered in divided doses every 4 hours). For infants less than 2 months of age—100 mg/kg per day intravenously (administered in divided doses every 6 to 8 hours).
Contraindications	Nafcillin and oxacillin should be avoided in patients with allergy to penicillin. The drugs should be used with caution if the patient has known allergy to cephalosporins and in infants. Adjustment of dosage may be required in renal or hepatic failure.
Main drug interactions	Nafcillin may be synergistic with aminoglycosides or streptomycin. Levels of nafcillin and oxacillin may be raised by probenecid, which decreases renal excretion and may also alter transport of these antibiotics out of CSF. Both drugs can increase levels of methotrexate and can decrease levels of oral contraceptives, cyclosporine, and tacrolimus. Both agents may lower International Normalized Ratio (INR) in patients taking warfarin.

Main side effects The most serious complication of nafcillin or oxacillin is anaphylaxis. Less serious degrees of allergic reaction, including urticaria, may also occur. Other side effects may include neutropenia or agranulocytosis, thrombocytopenia, pseudomembranous colitis, hepatic injury, and interstitial nephritis. Hemolytic anemia has been reported with oxacillin. Both drugs may also be associated with nausea, vomiting, diarrhea, and oral or vaginal candidiasis.

Special points Oxacillin is somewhat less irritating to veins than nafcillin.

Cost/cost effectiveness Cost of nafcillin is $2.79 per gram. Cost of oxacillin is $2.88 per gram.

Vancomycin

Vancomycin, like nafcillin and oxacillin, has excellent activity against staphylococci and other Gram-positive organisms. Unlike nafcillin or oxacillin, vancomycin is effective against methicillin-resistant strains of *S. aureus*, as well as against *Staphylococcus epidermidis* [23, Class III]. Vancomycin penetrates brain tissue, and achieves adequate therapeutic concentrations in brain abscess [24, Class III].

Standard dosage 2 to 3 g per day intravenously, administered in divided doses every 6 to 8 hours. For children less than 50 kg—40 mg/kg per day intravenously (administered in divided doses every 6 hours).

Contraindications No data available.

Main drug interactions The combined use of vancomycin with aminoglycosides or caboplatin or cisplatin may be nephrotoxic or ototoxic. The combination of vancomycin and cidofovir may be nephrotoxic, and vancomycin should be avoided within 7 days of beginning cidofovir. The combination of vancomycin plus glyburide or metformins may also be nephrotoxic and may alter INR. The use of vancomycin with metformin may increase the risk of lactic acidosis. Vancomycin may prolong the action of nondepolarizing neuromuscular blocking agents, such as vecuronium or rocuronium.

Main side effects Major side effects of vancomycin are anaphylaxis, Stevens-Johnson syndrome (toxic epidermal necrolysis), neutropenia or thrombocytopenia, and ototoxicity. The drug has been associated with red-man syndrome, especially if the drug is administered too rapidly, and with fever, tinnitus, nausea, or less severe allergic reactions, such as rash or urticaria.

Special points Ototoxicity results in auditory nerve damage and may be heralded by tinnitus and high-tone hearing loss. Ototoxicity is unusual with serum levels below 30 mg/L and is increased at levels of 80 mg/L or above [23, Class III].

Cost/cost effectiveness Cost of vancomycin is $8.90 per gram.

Ceftriaxone

Ceftriaxone is active against both Gram-positive and Gram-negative organisms, with the exception of *Bacteroides fragilis*. The drug has limited activity against non-methicillin resistant strains of *S. aureus* [25, Class III].

Standard dosage 4 g per day intravenously, administered as 2 g every 12 hours. For infants and children—75 mg/kg intravenously followed by 50 mg/kg intravenously over 10 minutes every 12 hours.

Contraindications The only contraindication to the use of ceftriaxone is known hypersensitivity. The drug should be used with caution in patients with penicillin allergy, in patients with renal or hepatic failure, or in patients taking nephrotoxic drugs. Dose reduction may be required in patients with combined renal and hepatic disease.

Main drug interactions The drug may be synergistic with aminoglycosides, but use of these drugs together may also increase risk of nephrotoxicity. Use of probenecid may raise ceftriaxone blood levels. Ceftriaxone may decrease efficacy of oral contraceptives.

Main side effects These include anaphylaxis, hypoprothrombinemia, and pseudomembranous colitis. Less severe side effects include urticaria, nausea, vomiting, diarrhea, leukopenia, oral candidiasis, elevated liver transaminase, and elevated blood urea nitrogen and creatinine.

Cost/cost effectiveness Cost of ceftriaxone is $51.16 per gram.

Cefotaxime

	Cefotaxime has a spectrum of activity essentially identical to that of ceftriaxone [25, Class III].
Standard dosage	6 g per day intravenously, administered in divided doses at 8-hour intervals. For children 1 month to 12 years of age (less than 50 kg)—150 to180 mg/kg per day intravenously (administered in divided doses every 6 hours). For infants under 1 week of age—50 mg/kg every 12 hours. For infants 1 to 4 weeks of age—50 mg/kg every 8 hours.
Contraindications	The only contraindication to the use of cefotaxime is known hypersensitivity. The drug should be used with caution in patients with penicillin allergy, renal failure or treatment with nephrotoxic drugs, or a history of gastrointestinal disease, in particular colitis.
Main drug interactions	The drug may be synergistic with aminoglycosides but use of both drugs together may increase risk of nephrotoxicity. Use of probenecid may raise cefotaxime blood levels. Cefotaxime may decrease efficacy of oral contraceptives.
Main side effects	These include anaphylaxis and Stevens-Johnson syndrome (toxic epidermal necrolysis), agranulocytosis, neutropenia, or thrombocytopenia, hemolytic anemia, pseudomembranous colitis, interstitial nephritis, erythema multiforme, and seizures. Less severe side effects include urticaria, nausea and vomiting, elevated liver transaminase, and elevated blood urea nitrogen and creatinine.
Cost/cost effectiveness	Cost of cefotaxime is $11.00 per gram.

Ceftazidime

Standard dosage	6 g per day intravenously, administered in divided doses at 8-hour intervals. For children less than 50 kg—150 mg/kg per day intravenously (administered in divided doses every 8 hours). For infants 4 to 8 weeks of age—150 mg/kg per day intravenously (administered in divided doses every 8 hours). For infants 0 to 4 weeks of age—30 mg/kg every 12 hours.
Contraindications	The only contraindication to the use of ceftazidime is known hypersensitivity. The drug should be used with caution in patients with penicillin allergy, in patients with renal failure, or in patients taking nephrotoxic drugs.
Main drug interactions	The drug may be synergistic with aminoglycosides, but use of these drugs together may also increase risk of nephrotoxicity. Use of probenecid may raise blood levels. Ceftazidime may decrease efficacy of oral contraceptives.
Main side effects	These include anaphylaxis, agranulocytosis, thrombocytopenia, hemolytic anemia, pseudomembranous colitis, and seizures. Less severe side effects include urticaria, nausea, vomiting, diarrhea, elevated liver transaminase, and elevated blood urea nitrogen and creatinine.
Special points	Unlike ceftriaxone or cefotaxime, ceftazidime is effective against *P. aeruginosa* (and should be used if the organism is suspected) [25, Class III].
Cost/cost effectiveness	Cost of ceftazidime is $14.58 per gram.

Metronidazole

	Metronidazole has activity against a wide spectrum of Gram-positive and Gram-negative organisms, and it is the most effective agent known against *B. fragilis* [26, Class III]. The drug diffuses widely in the body and reaches bactericidal concentrations in both CSF and brain abscess; its penetration into subdural collections of pus is assumed to be similar.
Standard dosage	15 mg/kg loading dose over 1 hour, followed 6 hours after the loading dose with 7.6 mg/kg every 6 hours. For children over 4 weeks of age—15 mg/kg loading dose over 1 hour followed 8 hours after the loading dose with 7.5 mg/kg every 8 hours. Oral dosage is equivalent to parenteral dose and is discussed under the Special points.
Contraindications	The drug is contraindicated during the first trimester of pregnancy and in individuals with known hypersensitivity. It should be used with care in patients with known blood dyscrasia or impaired liver function.

Main drug interactions Metronidazole is closely related to disulfiram and may cause disulfiram-like reactions in patients using ethanol (possibly a problem at admission with the patients with an infected subdural hematoma) or patients taking lopinavir/ritonavir or ritonavir (the oral solutions for these drugs contain alcohol). Metronidazole may increase the risk of propylene glycol toxicity in patients using amprenavir oral solution. The drug may be additive with disulfiram, in terms of neurologic and peripheral nerve toxicity, and may enhance peripheral neurotoxicity of didanosine, stavudine, and zalcitabine. Metronidazole may increase INR in patients taking warfarin and may increase levels of phenytoin or tacrolimus and cyclosporine

Main side effects The most serious of these are central nervous toxicity, including encephalopathy, cerebellar ataxia, or seizures and neutropenia [27,28, Class III]. Pseudomembranous colitis has also been reported. Peripheral neuropathy is a concern with protracted therapy, but is rarely of concern acutely. Common reactions include rash or pruritus, nausea, vomiting, diarrhea, headache, and, rarely, central nervous system complications of dizziness or vertigo, ataxia, confusion, furry tongue, or drug-related fever. Use of metronidazole may result in dark red urine.

Special points Unlike the other antibiotics listed, metronidazole levels following oral administration essentially equal to those after intravenous administration. Thus, although intravenous therapy should be used initially, the drug may be used orally once the patient is stable. Adult oral dose is 1 to 2 g total, administered in divided doses at 6 to 12 hour intervals.

Cost/cost effectiveness Cost of metronidazole is $2.77 per 500 mg in parenteral solution or $0.57 for 500-mg tablets.

Surgery

- Except during its earliest stages, subdural empyema is a neurosurgical condition, and emergent drainage is absolutely mandatory.
- Surgical drainage may involve either multiple burr holes or craniotomy. The merits of burr holes versus craniotomy have been debated for many years. The efficacy and morbidity the two procedures have never been evaluated in a controlled study [2•,29,30, Class III]. Burr holes have been found to compare favorably with more extensive surgical procedures in one retrospective case series [30, Class III], but other studies have suggested that more aggressive surgical drainage may be more effective [29, Class III]. In general, large or multiloculated infections may require craniotomy, as may empyemas refractory to drainage by burr holes or stereotactic aspiration.
- Sinusitis, otitis, or mastoiditis may also require emergent surgical treatment. Blood and purulent material obtained at surgery should be submitted specifically for aerobic and anaerobic culture.

Other therapies

- Seizures may require emergent treatment with phenytoin or other agents and may develop either during the acute illness or up to 2 years thereafter [31, Class III].

Physical/speech therapy and exercise

- These may or may not be required, depending on the degree and nature of neurologic sequelae.

Emerging therapies

- Magnetic resonance imaging-guided stereotactic surgery has been successful to drain an empyema involving the tentorium cerebelli [32, Class III], and this technique, which is more precise than burr holes and less invasive than craniotomy, may prove to be an extremely valuable approach.

Pediatric considerations

- The clinical course of subdural empyema in children above the age of 6 years resembles that seen in adults [13]. Etiologic organisms found in children resemble those found in adults [33, Class III].
- Intracranial subdural empyema in younger children and infants is most often a complication of bacterial meningitis [1•,34, Class III]. In infants and small children, symptoms of the empyema may be obscured by those of meningitis, and the diagnosis may be suspected only as the patient fails to improve despite antibiotic treatment [1•].
- In infants, a bulging fontanelle may be present, as it may in meningitis. The empyema may be sufficiently turbid that transillumination may be negative. In this setting, high-resolution ultrasound has been used as a rapid diagnostic tool that does not require patient sedation [20, Class III].
- Treatment of subdural empyemas in children involves antibiotic therapy and, almost invariably, drainage by aspiration or surgery. Recurrence of the empyema after aspiration may require subsequent surgical intervention [1•].

References and Recommended Reading

Papers of particular interest, published recently, have been highlighted as:
- • Of importance
- •• Of major importance

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