issue, we recommend that empirical treatment with antibiotics be withheld in patients with suspected infection of the spine until biopsy of site of suspected infection can be carried out. There are, however, circumstances (such as situations involving critically ill patients and those with deteriorating neurological status) in whom antibiotics may be started prior to the performance of biopsy.

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QUESTION 8: What is the incidence of infectious bacterial meningitis (PBM) following spinal surgery? Does the use of instrumentation affect this?

RECOMMENDATION: The incidence of PBM following spinal surgery varies from 0.1–0.4%. There is insufficient evidence to make any observations as to whether the use of instrumentation affects the incidence of PBM following spinal surgery.

LEVEL OF EVIDENCE: Consensus

DELEGATE VOTE: Agree: 100%, Disagree: 0%, Abstain: 0% (Unanimous, Strongest Consensus)

RATIONALE

PBM is a potentially devastating complication following spinal surgery. It could occur after any primary elective spinal surgery with or without instrumentation, traumatic fracture-dislocation or surgical site infection after spinal instrumented surgery [1–3]. This also presents as a delayed complication after scoliosis surgery and through a dural tear with cerebrospinal fluid (CSF) leakage [4,5].

The early diagnostic differentiation from PBM and postoperative aseptic meningitis (PAM) is difficult and depends on CSF culture results [6–7]. The success in the treatment of patients with PBM depends on the stage of diagnosis, speed of diagnostic evaluation and appropriate anti-microbial and adjunctive therapy [8–9].

PBM is a potentially life-threatening infection with higher rates of mortality and significant disabling morbidity [9]. Pneumococcal meningitis is the most prevalent and is associated with a mortality of 30% [10]. PBM can also be caused by staphylococci [11], aerobic gram-negative bacilli (including *P. aeruginosa*) [12] and methicillin-resistant *Staphylococcus aureus* (MRSA) [13].

The incidence of PBM is rare after spinal surgery and is considered to be related to incidental durotomy [14]. Patients who have the triad of fever, neck stiffness and consciousness disturbance during postoperative period should be suspected and subjected to further evaluations [14]. In a large retrospective study, Lin et al. reviewed 20,178 lumbar spinal surgeries and reported a PBM rate of 0.10% [14]. Another retrospective study by Twyman et al. reported the incidence of PBM to be 0.18% after spinal operations with and without instrumentation [15]. The incidence could be as high as 0.4% after spinal surgery, when epidural abscess, subdural empyema, brain abscess, bone-flap infections and wound infections are combined [16].

In their sub-analysis, Lin et al. found that dural tears, pseudomeningocele and poor wound healing contributed to the majority of the complications [14]. The optimal management of PBM required reoperation to repair dural tears and administration of parenteral antibiotics [17]. The occurrence of pseudomeningocele is a sequela of dural tear, imperfect suture of the dura or fascia and inappropriate administration of antibiotics [14,18,19]. Zhang et al. reported surgical intervention to be an effective method of treating PBM where initial conservative measures failed. They proposed the idea that it is important to consider the possibility of PBM in any patient with CSF leakage after spinal surgery. They recommended early diagnostic imaging and CSF cultures to ensure prompt diagnosis and treatment [20].

Spinal instrumentation surgery usually involves longer operative time, greater blood loss and a higher incidence of subsequent SSI compared to decompression surgery alone. These features of spinal instrumentation surgery could influence the incidence of PBM. There is little literature examining the potential association of instrumentation with PBM with no supporting evidence linking the use of instrumentation to the incidence of infectious meningitis after spinal surgery [14,15,20]. Therefore, based on available evidence, it is not possible to link the use of instrumentation during spine surgery with PBM.

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QUESTION 9: What are the early infectious complications after operations on the spine following the use of instrumentation?

RECOMMENDATION: Early infections are traditionally defined as those occurring within a month after surgery, typically becoming evident within two to three weeks of surgery. Recently, the definition has been broadened to include infection within 90 days of surgery.

LEVEL OF EVIDENCE: Consensus

DELEGATE VOTE: Agree: 60%, Disagree: 20%, Abstain: 20% (Super Majority, Weak Consensus)

RATIONALE

Early infections are traditionally defined as those occurring within a month of surgery, typically becoming evident within two to three weeks of surgery. Recently the definition of early infection has been broadened to include infection within 90 days of surgery [1]. Surgical site infections (SSIs) and wound dehiscence are among the most common complications following spine surgery. It has been reported that the incidence of SSIs after adult spine surgery varies from 2–20% following instrumented procedures [2].

A study based on the American College of Surgeons' National Surgical Quality Improvement Program database reported that in a total of 99,152 spine surgery cases between 2012 and 2014, the overall wound complication rate was 2.2% with superficial SSI, 0.9% with deep SSI, 0.8% organ space SSI and 0.4% dehiscence: 0.3%. Of all the patients who experienced wound dehiscence, 46% had concomitant SSI. The average postoperative day of occurrence was 14 days with a standard deviation of 9 days (superficial SSI: 16 ± 8, deep SSI: 13 ± 10, organ/space SSI: 11 ± 10, dehiscence: 17 ± 8) [3].

Similar to other SSIs, early infections after spine surgery may present as pain, fever, erythema, swelling, warmth, tenderness and wound drainage. Local pain may herald the development of infection, particularly when it is escalating in nature. Wound drainage is common for both superficial or deep SSIs and may be present in up to 90% of patients [4].

Early postoperative spinal infections are most frequently due to relatively virulent pathogens such as *Staphylococcus aureus*, beta-hemolytic streptococci and aerobic gram-negative bacilli. *Staphylococcus aureus* is the most common bacteria responsible for early postoperative infection after spinal surgery [5–7]. The majority of the cases are due to methicillin-sensitive *Staphylococcus aureus* (MSSA), however the incidence of methicillin-resistant *Staphylococcus aureus* (MRSA) is escalating [8]. The majority of early infections are due to a single pathogen [9]. There has been an increase in the frequency of infections caused by gram-negative bacteria and other organisms such as *Pseudomonas aeruginosa*, *Escherichia coli*, Enterobacter and Acinetobacter [10–12].

Utilization of posterior instrumentation is well-recognized as a risk factor for the development of postoperative spinal wound infections. However, this finding is largely based on suboptimal retrospective analyses. Multiple factors increase the rates of infection following instrumented spinal surgery, such as increased wound exposure to air due to longer surgical time, greater soft tissue dissection, increased muscle/skin retraction, greater blood loss and potentially larger dead spaces [13–15].

However, anterior spinal exposures were reportedly correlated with a reduced risk of infection as they typically traverse relatively avascular tissue planes and avoid significant muscle dissection [16–19]. It is yet to be determined whether minimally invasive spine surgery is associated with lower infection rates versus open surgery following the use instrumentation [20–21], although a recent study involving 108,419 procedures reported that the use of a minimally invasive approach was associated with a lower rate of infection for lumbar discectomy (0.4% vs. 1.1%, $p < 0.001$) and for transforaminal lumbar interbody fusion (1.3% vs. 2.9%, $p = 0.005$) [22].

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