ORIGINAL ARTICLE

Infections in the operated spine: Update on risk management and therapeutic strategies

J.-Y. Lazennec a,*, E. Fourniols a, T. Lenoir b, A. Aubry c, M.-L. Pissonnier a, B. Issartel d, M.-A. Rousseau a, French Spine Surgery Society

a Service de chirurgie orthopédique et traumatologie, groupe hospitalier Pitié-Salpêtrière, Assistance publique des Hôpitaux de Paris, 47, boulevard de l’hôpital, 75013 Paris cedex, France
b Service de chirurgie orthopédique et traumatologie, hôpital Beaujon, Assistance publique des Hôpitaux de Paris, 100, boulevard du Général-Leclerc, 92118 Clichy cedex, France
c Laboratoire de bactériologie, groupe hospitalier Pitié-Salpêtrière, Assistance publique des Hôpitaux de Paris, 91, boulevard de l’Hôpital, 75634 Paris cedex 13, France
d Service de médecine interne, maladies infectieuses et tropicales, centre de vaccinations internationales et de médecine des voyages, 35, rue du Tonkin, 69100 Villeurbanne, France

Accepted: 18 April 2011

KEYWORDS
Surgical site infection; Spinal infection; Complications of spinal surgery

Summary Among the possible risks of spine surgery, surgical site infection (SSI) is far from negligible. Incidence is higher than in other locomotor system procedures, with more severe local and general impact. Certain broad guidelines can be formulated. The risk of SSI should be taken into account in the choice of treatment options discussed with the patient. Antibiotic prophylaxis, surgical prevention of iatrogenic infection and an SSI surveillance protocol should be implemented. SSI should be suspected in case of any abnormality in postoperative course, and biological and imaging (MRI or CT) measures should be taken. Local sampling for bacteriological identification is mandatory. Treatment strategy should ideally be discussed in a multidisciplinary coordination meeting, and adapted in the light of local bacterial ecology and resistance data. The information provided to the patient should be transparent and adapted to the patient’s individual context.

Level of evidence: Level V.
© 2011 Elsevier Masson SAS. All rights reserved.
Introduction

Of the potential risks of spine surgery, septic complications require special consideration. The incidence of these surgical site infections (SSI) is higher than that reported in other orthopedic surgical interventions, with potentially more severe local and general complications.

Considerable progress has been made in reducing the risk of postoperative infections based on systematic protocols for preoperative patient preparation and management in the operating room, and thanks to the use of appropriate prophylactic antibiotics. The risk factors of infection are also better understood and screening has improved.

Early diagnosis and a precise identification of responsible germs are necessary to optimize treatment of postoperative infection. Therapeutic strategies must be continually updated in relation to the microbial ecology and potential bacterial resistances. They should integrate the neurological risk and the mechanical specificities of the discovertebral complex as well as the overall balance of the spine.

Incidence, epidemiology and factors influencing severity

The evaluation of postoperative spine infection is based on the anatomical location, on whether the infection is superficial or deep as well as whether symptoms develop in the early or later postoperative period. Associated comorbidities must be taken into account. All of these factors play an essential role in the natural history and process of infection and its therapeutic management. Thalgott et al. [1] have described a classification based on the severity of infection and the patient’s capacity to respond.

The severity of the infection was categorized into three groups:

• superficial infections or deep infections with a single germ;
• deep infections with several germs;
• deep infections and muscular necrosis with multiple or resistant germs.

The host response was divided into three categories:

• normal general immune defenses, normal vascularisation, no metabolic diseases;
• general infections and tumors;
• malnourished or immunodeficient patients.

The recommendations from the Société de Pathologie Infectieuses de Langue Française (SPIFL) in 2008 (short and long texts available at http://www.infectiologie.com/site/medias/_documents/consensus/inf-osseuse-court.pdf and http://www.infectiologie.com/site/medias/_documents/consensus/inf-osseuse-long.pdf) define early infections as those that develop during the first postoperative month, later infections as those that develop between 2 and 6 months after surgery and very late infections more than 6 months after surgery.

The rate of acute postoperative infections reported in the literature is between 0.5% and 20%. These very different rates can be explained by the wide heterogeneity of surgical interventions and surgical patients [2,3].

Postoperative spondylodiscites are differentiated from postoperative infections of the vertebral body (surgery by anterior approach) or of the posterior arch (surgery by posterior approach). Infections which develop after planned surgery (narrow lumbar canal, arthrodesis for scoliosis or vertebral metastases) must be differentiated from infections following treatment of a spine fracture.

Infections on spinal implants pose specific problems:

• the difficulty of diagnosis because of the depth of the surgical site and the confusing subacute evolution of the symptoms in some cases;
• the mechanical risk due to the usually long time to union and the risk of loss of correction in particular on the sagittal plane;
• the complexity of the therapeutic choice to remove or maintain implants.

There are three possible sources of postoperative contamination [4–7]:

• direct inoculation of bacteria during surgery;
• contamination during the early postoperative phase;
• contamination by hematogenous seeding.

A surgical site infection (SSI) is considered nosocomial if it occurs within 30 days after surgery without instrumentation. This delay is extended to one year if there is instrumentation. The prerequisite condition is the absence of infection before hospitalization and surgery.

A national investigation on prevalence in 2006 by the French network: Réseau d’Alerte, d’Investigation et de Surveillance des Infections Nosocomiales (RAISIN) found that nosocomial infections were the primary cause of surgical morbidity and mortality and that surgical site infections represented 15 to 20% of nosocomial infections (data available on URL: www.invs.sante.fr/ensp2006).

Risk factors: the impact of the surgical act and of the patient status

Influence of the type of surgery

The rate of infection reported for discectomies and laminectomies is less than 3%. If there is instrumentation, the rate may be as high as 12% [8–16].

The increased rate in case of instrumentation can be explained by longer surgery, more blood loss and the larger incision site in particular for posterior approaches. Revision surgery does not appear to be a significant risk factor in the literature [4,17–19].

In addition, instrumentation represents an avascular surface that bacteria can attach to, thanks to the biofilm called glycocalyx.
A bacterial inoculum of less than 1000 colony-forming units (whether they are perioperative, contiguous or hematogenous) is considered to be enough to initiate the infectious process. This begins by a process of reversible attraction-adhesion of bacteria to the implants. The bacteria then irreversibly colonize the implants. They develop a survival strategy within the biofilm where diffusion of antibiotics is poor. The biofilm is composed of a polysaccharide substance secreted by bacteria called “slime” allowing definitive adhesion to instrumentation.

Bacteria present in the biofilm organize into microcolonies (= small colony variant =) resulting in a stationary stage of growth. This situation results in:

- reduced activity of certain antibiotics which varies depending upon the strain of bacterial infection;
- escape from immune defense mechanisms.

Within a few days the biofilm extends over the entire surface of the implant, which explains why surgical lavage more than 15 days after surgery is usually ineffective. Nevertheless, theoretically glyocalyx adheres less well to implants with titanium alloys, which is the advantage of this material.

These physiopathological explanations show why it is usually necessary to remove instrumentation, especially in later infections and if the patient’s immune status is poor [20—24].

The implants sometimes have complex mechanical connections, with several different metallic components. The micromobility of these metallic interfaces can generate metallosis and a granuloma which becomes a potential site for bacterial colonization.

Patients operated on for a spine fracture are at greater risk of postoperative infection (severe lesions of the soft tissues caused by trauma, patient immune deficiency in case of multiple traumas). The risk is increased in case of severe neurological injuries [25]. The series in the literature report a rate of infection between 9 and 15% which is much higher than that reported for elective surgery [8,26,27].

Reported rates are 50% less in the literature in case of thoracic or lumbar spine surgery by anterior approach. This can be explained by better local vascularisation and the absence of a postoperative dead space. Surgery associating an anterior and posterior approach does not seem to increase the risk of infection compared to surgery by posterior approach alone. [25].

The rate of septic complications for surgery by anterior approach of the cervical spine are very low, between 0 to 1% [28—30].

Risk factors associated with the patients

A significant increase in the risk of SSI in orthopedic surgery has been found with several risk factors: age above 65 years old, the presence of a site of infection in the patient, hospitalization of more than 4 days in the 6 weeks after surgery. The risk increases slightly in case of obesity, corticosteroid therapy, smoking, recent radiotherapy on the surgical site, well-known healing difficulties, a bed sore on the surgical site and the development of a hematoma.

Poorly controlled diabetic patients are a population at high risk of SSI with an estimated rate of 17%. Moreover, these patients often have significant co-morbidities (cardiovascular disease, renal insufficiency). Besides these cases of poorly controlled diabetes, elevated perioperative glycemia seems to have a negative effect on the development of sepsis [31].

Obese subjects, who often have several associated comorbidities, are also considered to be at a very high risk of postoperative infection [32—34]. In these patients surgery is more difficult, longer, and there is more bleeding. A much wider dissection of adipose tissue is necessary, and the resulting necroses are a favorable environment for infection.

For optimal medical management of the patient certain factors should be taken into account (rheumatoid arthritis, immune deficiencies, adrenal insufficiencies, prolonged corticosteroid use, and tumors).

In particular the influence of a patient’s treatment is essential in cases of rheumatoid polyarthritis or highly inflammatory rheumatic diseases. It is not recommended to stop corticosteroid treatment at the time of surgery because of a risk of acute adrenal insufficiency. Continued treatment with methotrexate does not increase the risk of SSI. Data on continuing or stopping anti-TNF are still lacking. Nevertheless, in accordance with the recommendations of the Haute Autorité de santé (HAS) (French Health Authorities), it is strongly recommended to stop anti-TNF treatment from two to five half-lives before surgery and until the skin wound has completely healed. This treatment must be stopped when infection of instrumentation is diagnosed.

The influence of other risk factors such as cirrhosis, sickle cell anemia, or chronic renal insufficiency have not yet been clarified [31].

Clinical aspects

Classically postoperative infections are divided into “superficial infections” (above the deep fascia) and “deep infections”. Hermetic closing of the fascia can allow a deep infection to develop quietly with no superficial symptoms. Nevertheless, the differentiation between deep and superficial infections remains theoretical: a deep infection should be systematically suspected in the presence of any signs of infection and the diagnosis of a superficial infection is eliminatory.

Certain local or general signs should alert the physician and suggest infection:

- abnormally intense pain or reappearance of pain, after a pain-free interval;
- purulent incision site;
- wound dehiscence, necrosis or an inflamed scar.

The development of general signs (fever, chills) increases the probability of an infection and requires blood cultures and additional diagnostic tests.

Later infections more than 2 months after surgery can be difficult to diagnose in the absence of obvious symptoms. While the incision may appear to be healed, the development of redness and recurrent pain can suggest
postoperative infection. In patients who have undergone cervical spine surgery by the anterior approach, a retropharyngeal abscess should be considered in case of difficulty swallowing; a mediastinal contamination is also possible.

In case of a meningeal syndrome, meningitis or epidural infection should be considered in case of a poorly healing lumbar wound and a cisternal puncture should be performed instead of a lumbar puncture.

**Biological work-up**

Blood tests are one of the first diagnostic tests to be used in case of suspected postoperative infection.

Changes in the blood count are not an absolute indicator of infection. In the immediate postoperative period, surgical stress can result in demargination of leucocytes and an increase in the number of leucocytes without this being pathological. On the other hand, if leucocytes are not increased, this does not mean that there is no infection.

The sedimentation rate (SR) increases after surgery and may remain abnormal several weeks after surgery, especially if the intervention is highly invasive [35]. A postoperative increase in the C-reactive protein (CRP) value does not progress in the same manner as the sedimentation rate [36]. The CRP value decreases more rapidly than the sedimentation rate with a peak around the third day after surgery and a return to normal at between 10 and 15 days. This rapid normalization of the CRP value is in fact a more sensitive indicator of infection in the immediate postoperative period. Thus in the months after surgery, progression of the CRP value and not its absolute value is an indicator of infection [37,38]. A persistently elevated sedimentation rate and CRP value more than 15 days after surgery strongly suggests infection, but normal SR and/or CRP values do not exclude this diagnosis.

In case of suspected infection after 3 months, it is recommended to measure the SR and CRP. Results of the SR should be interpreted in relation to the patient’s age and renal function. Minimal thresholds for suspected infection are between 22 and 30 mm for the SR and 10 and 13.5 mg/L for the CRP value (depending on laboratory norms).

**Bacteriological diagnosis**

A precise identification of the responsible germ(s) is an essential step.

The cultures obtained from superficial samples are usually contaminated by cutaneous flora and have no diagnostic value. It is not recommended to obtain samples from the orifices of any existing fistula.

In case of fever and general signs of infection, aerobic and anaerobic blood cultures must be obtained and any abscess should be punctured to begin empiric antibiotic therapy before planning surgery. If no fluctuation is detected, CT scan guided puncture may provide additional information.

A negative result does not exclude a diagnosis of infection.

The most reliable samples are those obtained during surgical exploration before administering antibiotics. To reduce the risk of obtaining false negative samples, a minimum delay of 15 days should ideally be respected before beginning antibiotic therapy. Aerobic and anaerobic blood culture tubes can be inoculated if the transfer and seeding delay is above two hours. This should also be done in case of recent antibiotic therapy in addition to dry tube samples.

Most postoperative infections are linked to gram-positive cocci. The most frequently isolated germ is the *Staphylococcus aureus* which is the cause of more than 50% of infections in certain series [17,29,30,32,33]. Other frequent germs include *Staphylococcus epidermidis* and beta-hemolytic *Streptococcus*.

Gram-negative germs include *Escherichia coli*, *Pseudomonas*, *Klebsiellae* and *Enterobacter cloacae*.

The types of germs isolated can be influenced by the anatomical location of the surgical act. Digestive contaminations are more often found in the lumbar spine and the lumbosacral region. Anaer or bladder incontinence or retention can result in a predisposition to contamination by gram-negative germs especially during surgery by posterior approach [32,39—41].

Infections which develop in the later postoperative period are usually caused by less virulent germs such as coagulase-negative *Staphylococcus* and *Propionibacterium acnes*.

These germs are present in the normal cutaneous flora. Contamination can be favored by inadequate skin preparation, prolonged postoperative drainage, or cutaneous maceration in postoperative bedridden patients. Identification of these germs may require prolonged cell cultures, in particular for *Propionibacterium acnes* [7,42—44].

Hematogenous contamination may also cause surgical site infections. These are frequently gram-negative bacteria. These infections are often associated with a deterioration in the patient’s general condition and can be found in immunodeficient patients and during prolonged hospitalisation [33].

**Imaging techniques**

**Standard X-rays**

These are often the first postoperative imaging test. The literature insists that in the first 4 weeks after surgery these images do not provide much information. Indeed, the development of signs of bone lysis or mobile areas around instrumentation often occurs later [38]. However, in case of postoperative discitis, disc collapse can be one of the first significant signs. This generally occurs between 4 and 6 weeks after surgery. Ossifications, changes in vertebral end plates and mechanical deterioration generally occur later, at least 2 months after surgery.

**Ultrasound**

It is easy to perform and can be used to identify any superficial fluid collections and to guide a puncture.
**Postoperative CT scan**

It provides interesting information for an early diagnosis. Changes in the vertebral endplates, bone lysis (in particular in contact with instrumentation) and especially fluid collections can be analyzed. An intravenous iodated contrast medium should be injected whenever possible. Artifacts from implants can make a thorough analysis in the area difficult in instrumented patients.

CT scan can be used to evaluate fluid collections with intense contrast enhancement of the thick walls. This can be differentiated from pseudo-meningeal collections and to detect the development of fistula. The presence of air bubbles is not specific in the early postoperative period. CT scan guided biopsies can also be used to obtain samples from areas where infection is suspected.

**Magnetic Resonance Imaging**

Magnetic Resonance Imaging (MRI) is essential in the evaluation of postoperative infection, in particular for discites and epidural abscess. As with other techniques, it may be difficult to differentiate changes due to surgery from those due to infection.

After a discectomy, infiltration and contrast enhancement are usually found in the soft tissues and the epidural space. A change in signal is observed in the disk with a high-intensity signal and contrast enhancement of the endplates on T2 sequences. A diagnosis of discitis is suggested by a clearly high-intensity signal in the disc and the adjacent vertebral bodies on T2 sequences and intradiscal or paravertebral fluid collection. Intense contrast enhancement is a good sign. Epidural abscess presents as rim enhancement on gadolinium enhanced T1 sequences. Signal anomalies of the posterior articulations are not specific.

MRI also provides precise visualization of soft tissue anomalies in case of infection on instrumentation. Unfortunately, spinal instrumentation especially with "stainless steel" alloys can cause artifacts reducing the reliability of this examination [29].

Sequences which reduce artifacts from instrumentation (fast spin-echo) and intravenous gadolinium enhanced sequences are recommended. The radiological signs suggesting infection of instrumentation are the following: [45–47]:

- an enhanced high-intensity T2 signal of inflammatory soft tissue edema after gadolinium injection;
- a high-intensity T2 signal with ringed enhancement of intraosseous or soft tissue fluid collections after gadolinium injection;
- high-intensity T2 signal of the path of a fistula with significant enhancement after gadolinium injection.

Of course enhancement of the disc and epidural space is systematically looked for.

The choice between CT scan and MRI depends upon the suspected infection and the presence or not of surgical instrumentation. If there is no instrumentation or if spondylodiscitis is suspected, MRI is the first line examination. If a posterior fluid collection is suspected in cases of fusion with metallic instrumentation, contrast-enhanced CT scan will provide the best diagnostic results. Sometimes comparing the two examinations can be of interest.

Finally, the diagnostic value of gallium-technetium scintigraphy seems to be very limited.

**The principles of treatment**

Management can be optimized by early diagnosis and a rigorous evaluation of the severity of infection. When a diagnosis of postoperative infection of the spine is suspected or has been confirmed, three points should be analyzed:

- Is the disk affected?
- Is there a breach in the dura mater? Meningitis?
- Is there neurological compression?

If discal damage is suspected, a percutaneous biopsy is recommended to obtain samples for bacteriological and anatomopathological study. The development or worsening of neurological signs (meningeal syndrome, consciousness disturbances...) suggests a diagnosis of meningitis requiring emergency measures (spinal fluid puncture, immediate surgery).

Treatment depends upon the type of infection and the immune, neurological and clinical status of the patient. The strategy is also dependent upon the individual anatomy of the spine. The goals are to eradicate the germ, to obtain wound closure, to maintain spinal/vertebral stability and to obtain union of any grafts.

Extremely superficial infections such as small abscesses on the suture can be treated locally. These are rare. Most superficial and deep infections require aggressive excision of tissue associated with initial intravenous antibiotic therapy.

When prescribing antibiotic therapy it is necessary to:

- identify the source of infection;
- as soon as surgery is deemed necessary, begin empiric antibiotics after obtaining microbiological samples and while waiting for the results:
  - begin combination antibiotics,
  - obtain high plasma concentrations,
  - use molecules that have a good diffusion in bone tissue,
  - in case of *Staphylococcus* infection, never prescribe rifampicin, fusidic acid, fluoroquinolones or fosfomycin as monotherapy.

The duration of initial parenteral antibiotic treatment is usually 15 days.

It is then recommended to propose oral antibiotics as long as the antibiotics have good bioavailability, bone tissue diffusion and gastrointestinal tolerance.

Treatment observance and an absence of drug interactions should be confirmed to prevent decreasing the efficacy of antibiotic treatment. Prescriptions of antacids and iron should be avoided as they may reduce the absorption of antibiotics. In any case, an infectious disease specialist should be consulted when determining the treatment strategy.
Table 1 Recommendations for the treatment of *Staphylococcus* infections (summary): suggestions to be adapted depending on the antibiotic and the field.

<table>
<thead>
<tr>
<th>Methillin-sensitive</th>
<th>Staphylococcus</th>
<th>Initial treatment</th>
<th>Switch to per os</th>
</tr>
</thead>
<tbody>
<tr>
<td>15/15 days IV: oxacillin or cefazolin (clindamycina or vancomycin if allergic to penicillin)</td>
<td>Rifampicinc + fluoroquinolonea</td>
<td>cefazolinb or fusidic acidc or clindamycind</td>
<td>Fusidic acidd + fluoroquinolonea or clindamycind</td>
</tr>
<tr>
<td>+ gentamicin (5–7 days maximum) or rifampicin</td>
<td>Rifampicin + cotrimoxazol (if there is no other choice)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Methillin-resistant</th>
<th>Staphylococcus</th>
<th>Initial treatment</th>
<th>Switch to per os</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 days IV: glycopeptide (if IMC ≤ 4 mg/L) + rifampicin or fusidic acidd</td>
<td>Rifampicin + fluoroquinolonea or clindamycinde</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**Staphylococcus infections**

Suggested treatments are presented in Table 1 (*Staphylococcus* germs sensitive to or resistant to meticillin). In the event of methicillin resistant *Staphylococcus* strains, the IMC to glycopeptides must be determined. Vancomycin is the only glycopeptide which is effective against strains of *Staphylococcus* with a reduced sensitivity to glycopeptides (IMC < 4 μg/L).

In case of a IMC < 4 μg/L, the choice of other antibiotics can be considered based on the opinion of the infectious disease specialist.

When vancomycin is prescribed for severe sepsis (in case of methicillin resistant *Staphylococcus* or an allergy to penicillin) gentamicin should be associated for between 48 and 72 hours because of the time necessary for vancomycin to reach effective serum levels.

**Other common infections**

In case of beta-hemolytic *Streptococcus* infection, amoxicillin is the molecule of choice.

In case of *Enterococcus* infection, amoxicillin is the treatment of choice. This can be associated with gentamicin for 5 to 7 days then the aminoside can be replaced by rifampicin while continuing amoxicillin. In the presence of a beta-lactamase resistant *Enterococcus* strain, glycopeptides are recommended.

In case of *Enterococcus* Gram-positive anaerobic infections (*Propionibacterium acnes, Peptostreptococcus*), amoxicillin can be proposed (either cefazolin or clindamycin, if the strain is erythromycin sensitive).

In all cases, the goal of surgery is to drain the deep or epidural abscess, and perform wide margin debridement. The edges of the scar should be completely excised (total revision of the incision and layer by layer excision). Deep exploration of the incision until the spine is reached should be systematic and of the surgical instrumentation if necessary, even if the fascia seems to be hermetic. Samples should be taken from different zones and different layers of the surgical site.

There are specific problems associated with infections on instrumentation: indeed, the biofilm is a barrier against the penetration of antibiotics. Ablation of infected instrumentation which is stable and well attached to the vertebrae is very controversial in the literature.

**Late infections**

If it is a very late infection (more than 3 months after surgery), union has generally been obtained (between 3 and 6 months) and ablation of instrumentation is recommended.

**Early or delayed infections**

If the infection is early or late (between surgery and the third postoperative month) all suspicious tissue should be excised until healthy, well vascularised tissue is reached. All cavities should be collapsed. Grafts are washed and reimplanted except if they are necrotic [1,15,16,48]. Nevertheless determining the quality and viability of the graft is often difficult. In particular if the implants are stable, it is recommended to leave them in place if it is felt that they can facilitate union [49]. The path of pedicle screws should be carefully evaluated to identify any potential contamination of the disc, which would require their removal.

If there are signs of obvious mobility in the implants, they should be removed and possibly replaced by new instrumentation if there is significant instability. This is especially true for posterior instrumentations. Infection of anterior instrumentations requires ablation with pre- and perioperative vascular precautions because of the risk of vascular septic lesions.

In most cases, preserving the instrumentation does not seem to prevent eradication of infection, but there is still a risk of pseudarthrosis. It is therefore advised to administer long-term antibiotics (for up to 3 months) to limit the risk of recurrent infection while waiting for bone union (when ablation of instrumentation is possible) [7,15,50–52].
The wound is closed on an aspiration drain. For some the postoperative drain should be removed as quickly as possible because of a theoretical risk of contamination. For others, the drain should only be removed when it is no longer useful; cultures are regularly obtained to monitor the progression of infection.

Certain groups suggest a "second look" 48 to 72 hours after initial surgery, in cases of severe infection. [7,15,43].

In rare cases, the severity of muscular necrosis may require repeated debridement, and the wound may not be able to be closed at first. The use of vacuum assisted closure (VAC) has been described in these cases [53,54]. The use of a flap is very rarely necessary to close a wound with significant substance loss [55,56].

There is very little information in the literature on infections, which develop on intersomatic cages (whatever the approach) or on a discal implants. Ablation should be performed in infections on posterior lumbar ligaments.

In all cases, medical and nutritional measures are a necessary element for optimal patient management.

Postoperative infections which develop from antibiotic resistant germs require special measures including isolating the patient. The duration of combination antibiotics is critical for effective eradication of all types of postoperative infections. An infectious disease specialist should be consulted. Combination antibiotic treatment should be continued as long as possible. In case of *Staphylococcus* infections, this strategy should be continued for at least 6 weeks (with rifampicin as a the first choice in sensitive bacteria and as long as this molecule is never used as monotherapy).

In case of infection by gram-negative *Streptococcus* or *Enterococcus* bacteria, the duration of combination therapy has not been clearly defined. Treatment with aminosides should not be continued for more than 7 days.

Evaluation of treatment is based on clinical monitoring of markers of infection in particular CRP.

Efficacy is evaluated first clinically (appearance of the wound, disappearance of fever, reduction of pain) then by biological parameters (mainly CRP, although the normalization of this parameter does not prove that the infection has been eradicated).

Tolerance is evaluated by questioning the patient and by biological parameters (blood platelet count, biological liver tests, renal function).

Antibiotics which may have significant interindividual serum concentrations must be dosed. Peak aminoside and glycopeptides concentrations should be dosed. If rifampicin is used, pharmacological dosing of associated antibiotics should be performed to confirm that they are not under-dosed. For example rifamicin reduces plasma concentrations of clindamycin by half, which can result in significant under-dosing.

MRI may be performed after the third or fourth month to make sure there is no decrease in enhancement following gadolinium injection, although this is not absolutely reliable [49].

The patient should be followed up for at least a year, but there is no consensus on the duration of this follow-up. Criteria for a cure are the absence of recurrent infection and mechanical deterioration.

The prevention and reduction of risk

The efficacy of prophylactic antibiotics has been confirmed. The classic recommendation is one parenteral injection of antibiotics 30 to 60 minutes before surgery begins to obtain sufficient tissue and systemic diffusion [57,58]. First generation cephalosporins are frequently used because they provide good coverage of gram-positive germs including *Staphylococcus aureus* and *Staphylococcus epidermidis*. Moreover these antibiotics act against common gram-negative germs (*Escherichia Coli* and *Proteus*). Peak concentrations are rapidly obtained after injection. For prolonged surgery, additional doses of antibiotics should be administered at intervals of one to two times the half-life of the molecule during surgery because antibiotic tissue and serum concentrations will decrease, especially in case of significant bleeding [59,60].

Certain risk factors can be limited:

- preoperative hospitalization should not exceed 4 days;
- stopping smoking for 6 to 8 weeks is associated with a decrease in postoperative complications, mainly on the surgical wound;
- reducing obesity and managing malnutrition are necessary [61,62].

Recommendations for skin preparation were made in a consensus conference [63]. This is a fundamental step, which must follow a strict protocol. Traceability is important to monitor good practices. The goal is to reduce the residing flora as much as possible and eliminate transitory flora. Depilation should be avoided. If body hair must be removed this should be performed by shaving or chemically.

Infections at a distance from the surgical site should be actively searched for and treated. Even if there are no data showing that searching for and treating a urinary infection plays a role in the prevention of SSI in orthopedic surgery, this is recommended.

Diabetes is a known risk factor for SSI. Glycemia should be normalized during surgery, and intravenous insulinotherapy should be used if necessary.

Nasal *Staphylococcus aureus* screening has been the subject of much debate. For the moment, systematic screening for methicillin-sensitive *Staphylococcus aureus* for preoperative eradication is not recommended for any type of surgery. Systematic mupirocin is not recommended to prevent SSI in MRSA carriers. On the other hand, if the prevalence of *Staphylococcus aureus* SSI is abnormally high in a healthcare institution after having taken the usual measures for the prevention of SSI, nasal screening of personnel and perioperative nasal screening of patients is recommended. In this case treatment by mupirocin is advised. Nasal screening for methicillin-resistant *Staphylococcus aureus* (MRSA) is recommended in patients who are scheduled for orthopedic surgery and who arrive from intensive care, from a long or intermediate term healthcare structure, or in case of chronic skin lesions.

The literature does not support the postoperative administration of antibiotics in addition to standard preoperative prophylactic antibiotics. [64].
Management of potential entry points of infection is essential.

The duration of urinary catheters should be limited, and rules of sterilization must be respected when they are placed. Except for obvious soiling or hemorrhage, the bandage applied at the end of surgery should not be opened for 24 to 48 hours after surgery, and it should be applied under strictly sterile conditions. Because of the type of surgery, the creation of dead spaces filled with hematoma in particular during posterior surgery of the spine is a perfect environment for bacterial proliferation. Postoperative drainage has not been clearly shown to be effective in the prevention of infection. [65–67]. Nevertheless, if drains are used, they should not remain in place more than 48 hours except in case of excessive bleeding because drains are quickly contaminated.

Correct management of the surgical environment is important to reduce the risk of potential contamination. The number of participants and the movement of the surgical team should be limited. The systematic use of a protective iodine-impregnated film on the surgical field is often used; certain authors feel that this is a useful way to reduce inoculation of the surgical wound [15].

Certain publications insist on double gloving and regularly changing gloves (after a maximum of one hour) to reduce the risk of contamination by the surgeon. Limiting bleeding during surgery and careful hemostasis, excision of necrotic tissue and regularly unspeading retractors can also help reduce the risk of infection [48].

Draining is sometimes used during surgery to reduce the risk of infection. There are no clear clinical data to support the use of irrigation by antibiotics during spine surgery. Pulsed lavage irrigation can improve the evacuation of contaminants from the bone and soft tissues. In vitro studies have shown a significant reduction in bacterial colonies with this technique [68].

These "standard" measures of hygiene are usually enough. They should sometimes be associated with additional "contact precautions" in patients at high risk of cross transmission of multiresistant bacteria.

In these cases (oozing dehiscent wound, permeable bandage, multiresistant bacteria carrier), the patient should be placed in a single room to make it easier to follow the measures of hygiene between two patients, which does not prevent the patient from circulating outside his/her room if "contact" measures are taken.

Conclusion

Postoperative infections can occur after all types of spine surgery. This risk should be explained to the patient before surgery; it should be discussed along with other potential complications when the choices of treatment are being discussed.

Optimized preoperative medical preparation is an important aspect of prevention. Preoperative prophylactic antibiotics and strict surgical discipline can prevent iatrogenic surgical site contaminations. The surgical community must participate in programs for the prevention and monitoring of SSI [69].

Despite all of these pre-peri- and postoperative precautions, infections can occur. The surgeon should systematically consider a diagnosis of postoperative infection in any patient presenting with an unusual postoperative course after an initially normal course. Additional biological tests, CT scan and especially MRI can help confirm the diagnosis and the results of culture samples. Culture samples are essential to identify the germ and to begin antibiotic treatment.

The best therapeutic strategy can be determined during pluridisciplinary meetings, including various professionals trained in the management of these situations and in beginning treatment in a timely fashion. The patient should be informed of the therapeutic options during each step of the course of treatment. As with all postoperative complications, the situation should be explained to the patient with empathy while taking into account the psychology of the patient and his/her family.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References

Review: Infection of spine operative site


