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Surgical site infections in spinal neurosurgery

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Abstract

This review aims to present the latest data on surgical site infections in spinal neurosurgery. Infectious complications are the leading cause of unsatisfactory results of surgical treatment and prolonged hospital stay for patients after spinal surgery. Clinical and economic analyses reveal that each case of infection at the surgical intervention site causes an additional 7.3 days of hospital stay in the postoperative period and accounts for an extra $3152 per patient. Based on the literature, the incidence of wound infection in spinal neurosurgery varies from 0.7% to 11.9%, with the primary risk factors as an extended period from the moment of hospitalization to the surgery, significant blood loss, and long duration of surgical intervention. This study focuses on the development of wound infection because of malnutrition syndrome, because patients with this syndrome are at a considerably high risk of developing surgical site infections. The disturbed reparative processes in the wound and decreased level of immune defense are attributed to insufficient amounts of protein and energy substances. Wound infection is diagnosed by a comprehensive analysis of clinical and laboratory instrumental research methods. This review provides current data on the pathogens of surgical site infections, regimens of antibiotic prophylaxis, and effective methods of treatment (local and systemic antibiotic therapy, vacuum-assisted closure, flow-washing drainage, and hyperbaric oxygenation). Undoubtedly, early diagnosis and correct management of a patient allows the reversal of wound infection signs and avoids unfavorable clinical outcomes after surgical interventions on the spine.

Keywords: surgical site infections, spinal neurosurgery, interventions on the spine, wounds, antibiotic prophylaxis.

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Background

Infectious complications are the leading cause of unsatisfactory results of surgical treatment and increased hospitalization in patients after spinal surgery [1, 2]. According to the National Registry of Infections, surgical site infection (SSI) is the third most frequently registered nosocomial infection that accounts for 14%–16% of infections in all hospitalized patients [3]. Clinical and economic analyses reveal that each case of SSI causes an additional 7.3 bed-days in the postoperative period and accounts for an extra $3152 per patient [4].

The current classification of SSI is based on the layered structure of the surgical wound (Figure 1). Meanwhile, different types of SSI can either proceed in isolation from each other or can be combined with each other.

In spinal neurosurgery, SSI can develop after both the traditional removal of the herniated intervertebral disc and after significant decompressive and stabilizing surgeries with the development of adverse outcomes [5].

Of note, rapid and comprehensive treatment of SSI facilitates halting the inflammatory process and achieving the optimal recovery of motor function in patients. Despite the improvement of aseptic and antiseptic methods, as well as the active use of modern antibacterial drugs for preventive purposes, the incidence of SSIs has been rapidly increasing [6]. This problem is particularly crucial in spinal neurosurgery because the development of SSI after multilevel decompressive and stabilizing surgical interventions poses a risk of infection of the installed surgical hardware, which becomes an absolute indication for its dismantling [6, 7].

This review aims to analyze current literature data on morbidity, risk factors, and preventive regimens for the use of antibacterial drugs, treatment, and clinical outcomes of SSIs in patients after undergoing spinal surgery.

Epidemiology and risk factors for SSI development. According to the literature, the incidence rate of SSIs in spinal neurosurgery varies from 0.7% to 11.9% [8]. Meanwhile, the

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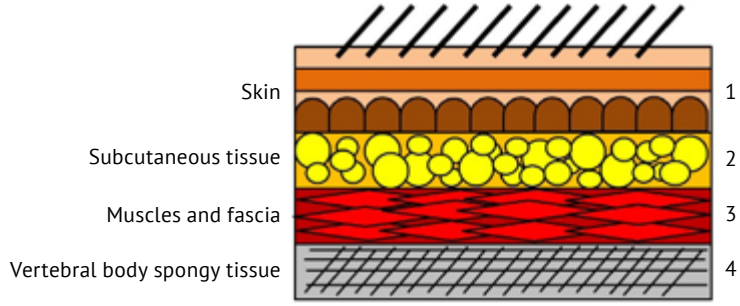

Fig. 1. Classification of surgical site infections (SSIs) based on the layered structure of the surgical wound: 1, 2, SSI of the surface incision; 3, deep SSI; 4, SSI of cavity/organ.

volume of surgical intervention performed significantly influences the probability of the development of SSIs (Table 1). Thus, the risk of SSI occurrence after performing lumbar microdiscectomy does not exceed 1% because of the short duration of surgical intervention and less traumatization to soft tissues, in contrast to primary decompressive and stabilizing surgeries on the spine [9]. Nevertheless, some researchers argue that even performing lumbar microdiscectomy is associated with a risk of SSI [10].

Performing decompressive interventions without stabilization increases the probability of SSI by 1.5%–2% [12]. In addition, lumbar stabilization with the use of bone auto-grafts significantly increases the time of surgery and the amount of blood loss and also requires the execution of an additional incision to harvest the auto-bone. Overall, it increases the probability of SSI occurrence by up to 20% [13]. Furthermore, modern methods of instrumental lumbar stabilization reduce the likelihood of SSI development by up to 3%–6% [14].

Other crucial risk factors for SSI development are an extended period from the moment of hospitalization to the surgery, a significant amount of blood loss (>1000 ml), and a long duration of surgical intervention (>3 h). Despite the fact that the likelihood of SSI in patients younger than 20 years is significantly lower than that in older patients, age is not a proven risk factor for the development of SSIs [15].

Role of malnutrition syndrome. The term "malnutrition" signifies a pathological state of nutrition in which a deficiency, excess, or imbalance of energy, proteins, and other nutritional components leads to pronounced adverse effects in the tissues of the body and compromises the processes of their normal functioning [11].

Reportedly, patients with malnutrition syndrome are at a considerably high risk of developing SSI. An insufficient amount of protein and energy substances causes a violation of reparative processes in the wound and a decline in the level of immune defense.

Hence, controlling the nutritional status of patients is imperative in the prevention of SSI development. The nutritional status constitutes the determination of the level of total protein and albumins in the blood plasma, as well as the control of the number of lymphocytes in the peripheral blood. Precisely, protein levels below 64 g/l, albumins below 33 g/l, and lymphocytes less than 1500/mm^3 in a patient indicate the presence of malnutrition syndrome. Because albumins react more quickly to the change in the protein-energy state, this fraction of plasma proteins is used as a marker of the efficiency of malnutrition syndrome treatment [16].

Furthermore, multistage surgical interventions on the spine profoundly influence the condition of patients' nutritional status. Kim et al. [17] observed a decline in appetite in their study patients after performing a lumbar spondylosyndesis surgery during the first hospitalization. In their study, 27 of 28 patients with SSI were diagnosed with malnutrition syndrome.

Wang et al. [18] assessed the results of single-stage and two-stage surgeries of lumbar spinal spondylosyndesis and concluded that 77% and 64% of patients from the group 1 and group 2, respectively, demonstrated signs of malnutrition syndrome in the early postoperative period. Thus, the incidence of SSI was significantly higher in the group of two-stage surgical interventions.

Diagnostics of SSI. Evidently, patients experience pain syndrome caused by the dissection of soft tissues when accessing the spine in the early postoperative period. An increase

Table 1. Risk factors for infection in surgical intervention [11]

Type of surgery	Comorbid states	Malnutrition syndrome	Other factors
Traditional removal of a herniated intervertebral disc	Diabetes mellitus	Total protein content <64 g/l	Presence of chronic infections
Decompression	Chronic heart and kidney failure	Concentration of albumins <33 g/l	Prolonged intake of glucocorticoids
Stabilization with the auto-bone	Rheumatoid arthritis	Number of lymphocytes <1500/mm^3	Smoking
Stabilization with surgical hardware	Obesity		Prolonged period from hospitalization to surgery
			Significant amount of blood loss (>1000 ml)
			Long duration of surgical intervention (>3 h)

in pain syndrome in the wound area or resuming it after a period of relative comfort is the most likely clinical manifestation of SSI. Often, SSI symptoms develop on average 2 weeks after surgical intervention, while postoperative drainages are installed in 93% of patients with SSI [19, 20].

In most cases, fever is absent in SSIs. Upon examination, the wound presents all signs of inflammation and rarely remains intact. Given the absence of pathognomonic symptoms of SSI, laboratory methods of research play an essential role in its diagnosis. Thus, in their clinical study, Yuwen et al. [21] revealed that in patients with SSI, the mean erythrocyte sedimentation rate amounted to 71.5 mm/h. Nevertheless, an elevation in this indicator could be attributed to the presence of concomitant somatic pathology and natural reparative processes in the body.

Iwata et al. [22] observed an increase in the level of C-reactive protein and erythrocyte sedimentation rate in patients in the postoperative period, without any verified complications. The level of C-reactive protein increased 2-3 days after the surgery and returned to normal within 2 weeks. In addition, the erythrocyte sedimentation rate reached its peak by day 5 after the surgery and decreased to the level of reference values in a week after that.

Although the determination of the C-reactive protein concentration and erythrocyte sedimentation rate in the diagnostics of SSI is not strictly specific, it has a high degree of sensitivity for this pathological condition [23].

Instrumental methods of diagnostics. Often, routine spondylography, multispiral computed tomography (MSCT), and magnetic resonance imaging (MRI) of the lumbosacral spine do not allow accurate verification of SSI with implanted surgical hardware [24–26]. However, analysis of postoperative spondylography data reveals that it is essential to consider the indirect signs of SSI development, such as the malposition of the screw system and cages, decrease in the height of adjacent interbody spaces, and presence of paravertebral shadows and foreign objects.

Indeed, MSCT and MRI of the lumbosacral spine are highly sensitive in the diagnostics of SSI, particularly in the formation of postoperative abscesses. Hegde et al. [25] suggested that contrast-enhanced MRI should be used for all patients in the postoperative period if SSI is suspected. Conversely, differential diagnostics of pathological fluid accumulations in the field of surgical intervention with routine T1- and T2-weighted images of MRI are challenging. Thus, sterile seroma and a postoperative abscess can have similar signal characteristics on standard MRI scans. Nevertheless, several studies report the successful use of MSCT and MRI in the differential diagnostics of postoperative hematomas, abscesses, and granulation tissue, despite possible artifacts from surgical hardware [26, 27].

One of the modern instrumental diagnostic methods that facilitates differentiating pathological accumulation of liquids and tissues is the diffusion-weighted MRI technique, which distinguishes between different volume formations by a numerical characteristic called the diffusion coefficient. As a rule, the diffusion coefficient value for postoperative abscesses

is insignificant and on average amounts to 800 mm^2/s [28].

Of note, MRI with the use of paramagnetic contrast agents, consisting of chelate complexes of the gadolinium ion, plays a paramount role in the diagnosis of postoperative spondylodiscitis. It is essential to remember that an increase in the intensity of the MRI signal from the intervertebral disc in post-contrast images does not always indicate the development of SSI. Thus, an increase in the signal may be caused by surgery directly performed on the spine and tissue edema of the intervertebral disc [29].

Furthermore, diffusion-weighted MRI plays an essential role in the diagnostics of postoperative spondylodiscitis [30].

Thus, none of the modern instrumental methods of research enable the precise diagnosis of SSI. Nevertheless, all patients with suspected SSI should undergo a complete range of diagnostic activities with an assessment of clinical status, laboratory data, and instrumental research methods.

Antibiotic prophylaxis. As in any other field of surgery, wounds in spinal neurosurgery can be aseptic, infected, and purulent.

Aseptic wounds occur when all rules of aseptics and antiseptics are observed, and there is no contact with the contents of the respiratory tract, gastrointestinal tract, and genitourinary system. The risk of SSI under conditions of aseptic wound does not exceed 1%–5% [31]. Nevertheless, most neurosurgeons use antibacterial agents for prophylactic purposes on aseptic wounds.

Kim et al. [32] demonstrated that the use of an antistaphylococcal preparation lincomycin in "pure" neurosurgical interventions on the spine significantly reduces the incidence of SSI from 5.1% to 2.3%. In another study, Kanayama et al. [33] confirmed the efficacy of lincomycin in preventing the development of SSI after lumbar microdiscectomy. In addition, a randomized, double-blind, placebo-controlled study demonstrated that the use of clindamycin reduces the incidence of SSI to 1.2%, compared with the placebo group with a frequency of up to 10.9% [34].

To date, several preventive schemes have been developed for the use of antibacterial drugs in the preoperative period. For instance, Singh et al. [35] proposed using a combination of an intramuscular injection of 80-mg gentamicin and intravenous injection of 1-g vancomycin during the anesthesia induction phase for preventing SSI. The authors claim that none of the 1732 operated patients reported SSI development.

Table 2. Main causative agents of infections in the field of surgical intervention [38]

Causative agent	Detecting frequency, %
S. aureus (including coagulase-negative)	20
S. epidermidis	14
Enterococcus spp.	12
E. coli	8
P. aeruginosa	8
Enterobacter spp.	7
P. mirabilis	3
K. pneumoniae	3
Other streptococci	3
C. albicans	3
Other gram-positive aerobes	2
B. fragilis	2

In addition, another study proved that the use of cefazolin (a first-generation antibiotic of the cephalosporin series) in the preoperative period is an effective method for the antibiotic prophylaxis of SSIs [36]. The authors of that study concluded that the combined use of gentamicin and vancomycin is not justified and is significantly inferior to monotherapy with cefazolin.

Nevertheless, at present, no study is investigating the timing of antibiotic prophylaxis in the pre- and postoperative periods of spinal neurosurgery. The Center of Neurosurgery of the Road Clinical Hospital at the Irkutsk-Passenger station of Russian Railways uses the scheme of antibiotic prophylaxis of SSI in the preoperative period, at the stage of wound suturing, and within 3 days after the surgery, regardless of its volume.

Microbiology. In most cases, the causative agent of SSI is the endogenous microflora of patients' skin. Apparently, performing a skin incision poses a risk of contamination of exposed tissues with endogenous microflora, which can be represented by both aerobic gram-positive cocci and gram-negative aerobes and anaerobic bacteria (Table 2) [37].

To date, the most frequent causative agents of SSI are *S. aureus* and *S. epidermidis*. In most cases, SSIs are a monoinfection, and only 8.3% cases comprise mixed infections [39].

Given the data mentioned above, the prevention of SSI using second- and third-generation cephalosporins is reasonable and supported by several studies. Conversely, the

incidence of SSIs has increased lately, which is caused by antimicrobial-resistant microorganisms, such as methicillin-resistant *S. aureus* and *S. epidermidis* or fungi (*C. albicans*) [38].

Treatment. Conservative treatment of SSI is rarely used, particularly in patients with immunodeficiency states. As a rule, it includes wound treatment with antiseptic solutions and other antimicrobial agents, daily dressings, and open wound care for healing by secondary intention. Early diagnostics of SSI and the selection of essential antibacterial drugs in an effective dose are necessary conditions for the successful treatment of such complications [40].

The literature around the world has not reached a consensus on the management of wounds in the development of SSI. Thus, several studies state that with the development of SSI, all wounds must be managed openly from the moment of verification of this complication. In contrast, one study discouraged the removal of sutures and open wound care in all cases of SSI [41]. Our experience in managing patients with SSI is also consistent with this opinion. Notably, the works mentioned above are challenging to compare with each other because of differences in patient management tactics adopted in these studies.

Furthermore, the surgical treatment of wounds with SSI should be as radical as possible, with the removal of necrotic tissues and foreign objects, primarily suture material. After revising the superficial layers of the wound, it is essential to ensure that SSI does not extend to the deep layers. Thus, additional research methods (e.g., ultrasonography, radiography, MRI, and MSCT) allow surgeons to ensure that the infectious process does not extend to the deep layers of the wound [42]. In this case, the wound with SSI can be managed carefully.

The revision of the deep layers of the wound necessitates the removal of the necrotic muscular and bone tissue as much as possible. The removal of bone auto-graft and surgical hardware is performed with the ineffectiveness of other methods of treatment and development of signs of the syndrome of systemic inflammatory reaction (SSIR) [43]. Nevertheless, Al-Mulhim et al. [44] reported dismantling of installed surgical hardware in 35% of patients with SSI without SSIR phenomena. We believe that the removal of stabilizing structures in patients with SSIR signs is strictly necessary because the formed biofilms of microorganisms on implants nullify the efficiency of systemic antimicrobial therapy.

The frequency and volume of the surgical treatment of wounds with SSI depend on several factors, such as the degree of infectious lesions of the wound (i.e., the number of layers involved), its external state, and also the type of isolated microorganisms.

Billières et al. [45] proved the efficiency of using a comprehensive method for the treatment of SSI in patients after decompression and stabilizing surgical interventions on the spine. The essence of the method was as follows. All wounds were treated and washed actively with a solution of bacitracin. If SSI was localized in the surface layers of the wound, the latter was sutured with the active drainage reserved. Conversely, if the deep layers of the wound were injured, the wound was managed openly with daily treatments, washing, and maintaining a gauze bandage.

With the regression of SSI symptoms, the wound was sutured with passive drainage and then re-treated for the next 5–7 days.

In the presence of SSI in the deep layers of the wound, the surgical hardware was not dismantled, and the treatment included daily surgical treatment and a 6-week course of antibiotic therapy with intravenous injection according to the sensitivity analysis of the isolated microorganisms.

The authors of the study revealed that in all cases, the symptoms of SSI were successfully arrested.

Other studies recommend using flow-washing systems at SSIs. Thus, Waly et al. [46] reported successful arresting of SSI symptoms in 22 patients with the daily use of a flow-washing system with antiseptic solutions for 5–10 days. In turn, Poorman et al. [47] confirmed the high efficiency of flow-washing systems in the treatment of SSIs of deep layers of the wound in patients with surgical hardware.

Recently, the technique of vacuum-assisted closure of postoperative wounds is actively used in surgery. Nevertheless, the use of this technique has not yet become widespread in spinal neurosurgery.

The technique of vacuum-assisted closure of wounds is performed as follows. The urethane-foam sponge is densely laid on the wound, with the sponge touching all the edges of the wound. After the formation of negative pressure, the edges of the wound are approximated and the contents of the wound are evacuated to the outside. To date, few studies have reported the use of vacuum-assisted closure of wounds in spinal neurosurgery, which does not allow remarking upon the proven efficacy of this method [48–50].

Conclusion. Evidently, each surgery on the spine is associated with an SSI risk; the more aggressive the surgical intervention is, higher is the risk. Many risk factors, particularly malnutrition syndrome, need to be corrected in the preoperative period. Thus, while performing the surgical access, excessive soft tissue trauma should be avoided.

On the day of surgery, we recommend the intramuscular administration of third-generation cephalosporins (ceftriaxone) and before suturing, rinsing of the wound with an antiseptic solution. In the postoperative period, one of the leading methods of preventing the development of not only SSIs but also other significant complications is the early activization of patients.

In the case of suspected development of SSI, it is necessary to perform complicated laboratory and instrumental diagnostics and initiate antimicrobial therapy with broad-spectrum antibiotics. Thus, it is crucial to use the parenteral route of administration of preparations. The antimicrobial therapy should be combined with surgical management of the wound and other methods of treatment (such as vacuum-assisted closure, flow-washing drainage, and hyperbaric oxygenation).

Thus, early diagnostics and carefully selected tactics of patient management enable arresting the SSI signs and avoiding adverse clinical events in patients after decompressive and stabilizing surgical surgeries on the spine.

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