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Risk factors for deep infection in the surgical site after spinal operations

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Introduction Despite significant steps in prevention and treatment of infectious complications after surgical treatment on the spine, many issues remain unsolved. There is a sufficient number of scientific reports on the treatment of postoperative infection, however, only a few studies present multivariate analysis of risk factors of developing deep infection after surgical intervention. In the domestic literature, such reports are rare. According to most sources, the rate of infection after spinal interventions ranges from 0.7 to 11.9 %. **Material and methods** We conducted a retrospective multivariate analysis of the data collected to determine the risk factors of deep surgical infection after spinal surgery at various levels and volumes. To fully determine the risk factors, not only surgical factors were evaluated, but also individual characteristics of patients contributing to the increase in infection rates. The purpose of this study was to compare patients who developed local deep infection after spine surgery, with a randomly selected group of patients who did not develop this complication, to identify modifiable risk factors. **Results** In the period from 2005 to 2016, we identified 79 cases of postoperative deep infection. The overall morbidity rate after 5564 operations (in 5328 patients) was 1.48 %. The most common causative agent of the infectious process was *S. epidermidis MRSE*. All patients underwent at least one revision intervention, with additional antibiotic therapy course. To reduce the number of infectious complications in patients at risk, preventive measures were carried out, including changes in the volume and type of surgery, prolonged administration of antibacterial drugs, etc. Of the surgical risk factors, the greatest differences between the groups were noted in the types of surgical interventions, implementation of spondylodesis, and previously performed operations on the spine. Also, the risk of purulent-septic complications increased in high BMI, diabetes and urinary tract infection. **Conclusion** The conducted multivariate analysis reliably confirms the significance of the risk factors identified.

Keywords: spondylodesis, spondylosynthesis, surgical infection, spinal infection, risk factors

INTRODUCTION

Infectious complications after surgical interventions on the spine are the most frequent and serious. Despite the use of antibacterial prophylaxis, improvement of surgical techniques and postoperative care, wound infection remains the main reason for increase in the length of hospitalization, economic costs and repeated interventions [1]. Compared with the majority of orthopedic procedures, such as primary total hip joint arthroplasty, spinal surgery is accompanied by higher rates of surgical site infection (SSI) [2]. According to the observations of Muilwijk J. [3], the incidence of such complications after primary hip joint arthroplasty averages 1.9 % for superficial infections and 0.9 % for deep SSI. Infectious complications after spinal surgery over the past 10 years, according to various authors, range from 0.7 to 11.9 % [4–7], and to some other reports up to 20 % [8].

The increase in the direct costs of treating patients with postoperative infectious complications is associated with prolonged hospital stays, frequent re-operations, X-ray examinations and numerous laboratory tests [1, 9]. Moreover, long-term treatment and rehabilitation period seriously affect the patient's emotional state and physical performance, even though the treatment was generally successful [10]. These factors influence the development and improvement of medical equipment, the improvement of equipment for the operating room, ventilation, sterilization and antiseptic agents, while the availability and development of antibacterial prophylaxis significantly reduces the risk of SSI after spinal surgery [11].

The factors contributing to the development of SSI can be divided into three main categories: those associated with surgical intervention, microbiological factors and factors associated with the patient [12].

The volume and type of surgery is perhaps the most significant component that might influence on the development of an infectious disease. Simple decompressive foraminotomy carries the risk of infection of less than 1 % due to shorter intervention hours and less damage to soft tissues. In extensive decompression without the implantation of metal components, the risk of infection increases to 1.5-2 % [13]. In large neuro-orthopedic interventions

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that require the implantation of an extended metal structure, the operation time and the volume of blood loss significantly increase, so the risk of secondary infection increases up to 3–6 % [14]. The use of various transpedicular, laminar, and other fixative systems creates the highest SSI risks [9, 15, 16]. The main pathogens of spinal infections are methicillin-resistant forms of Staphylococcus [17, 18]. SSI risks associated with the somatic condition of patients include diabetes, obesity, rheumatoid arthritis, long-term steroid use, alcohol abuse and smoking, previous infection, repeated or staged interventions on the spine, extended preoperative preparation periods, high blood loss, and long operation time [19, 20, 21].

Despite the fact that the methods of dealing with postoperative infection in spinal surgery have improved, the rates remain high. In the majority of works devoted to the prevention and treatment of wound infections, there is no systematic assessment of risk factors for SSIs with various spinal pathologies. Unlike previous studies, a large amount of clinical material was used in this work, which allowed comparing patients who developed deep SSI after spinal surgery with a randomly selected group of patients who did not develop this complication. The aim of our study was to improve the prevention of SSI by retrospectively analyzing the risk factors for infectious complications after spinal operations of varying complexity.

MATERIAL AND METHODS

All the interventions were performed at the department for neuro-orthopedics and bone oncology, as well as the department of purulent osteology of R.R. Vreden Russian Research Institute of Traumatology and Orthopedics. The clinic is a specialized center for surgical treatment of patients with injuries and diseases of the spine. In the period from 2005 to 2016, 5564 operations were performed in 5328 patients. Data of the hospital's medical database, archival medical records, and questionnaires were analyzed. All patients gave an informed consent on inclusion in this study.

Detection of surgical infection

SSI is a complication that occurs within 30 days after surgery or within 6 months if the operation included the implantation of metal structures. SSI was defined as deep if soft tissues, muscles and fascia were damaged in contrast to superficial infection, by which the area of infection is limited to subcutaneous fat tissue and skin. SSI criteria was hyperthermia, edema, hyperemia and wound discharge. The source of the inflammatory process was established on the basis of bacteriological tests of wound discharge, operative biopsy and elements of the removed metalwork.

Revision interventions were conducted at a specialized hospital (purulent osteology department). The necrotic soft tissues, bone grafts, if there were, were completely removed and the wound was washed with antiseptic solutions.

Deep infection of postoperative wound was detected in 79 patients. The diagnosis was confirmed by microbiological studies. With the help of a random number generator, 325 patients of the control group were selected from the total number of patients who underwent various spinal interventions with metal implantation and who did not have either superficial or deep inflammatory changes in the postoperative wound. Thus, the ratio between patients of the two groups was about 1 : 4 (infection / without infection).

Data collection

Preoperative risk factors included age at the time of surgery, body mass index, and primary diagnosis. Bad habits and previous surgical interventions on the spine were recorded. Comorbidities of special attention were diabetes mellitus type I and II, rheumatoid arthritis, cardiovascular and pulmonary diseases, prolonged use of hormones, nutrition disorders and the use of antibacterial drugs in the preoperative period. Surgical risk factors included the duration and type of surgery, amount of intraoperative blood loss, the use of donated blood, the use of metalwork and the length of spine fixation, as well as the presence and type of bone grafts.

Criteria for the inclusion of patients in the study were injuries or diseases of the spine of all locations and surgical interventions on the spine, regardless of the use of metal structures. Patients were not included if primary infection of the spinal column (tuberculosis of the spine), infectious diseases of the skin, cognitive or mental diseases, postoperative liquorrhea were present, as well as SSI patients who had undergone primary surgery outside our department.

Data analysis

Differences between the groups of infected and non-infected patients were studied using a two-way t-test, chi-square test or alternative non-parametric tests. In order to identify independent regressions (SSI risk factors), the logistic regression was applied with the RStudio Desktop software (ver. 1.1.442) for Windows. Possible risk factors were grouped; the first group was factors related to intervention and the second group was factors associated with the patient.

In case of the probability of infection risk <0.05 (a confidence interval of at least 95 %), this variable was preserved, otherwise the sign under investigation was excluded from the study. To determine the significance of the main risk factors and the model obtained, these data were tested in clinical practice.

RESULTS

Over the 11-year follow-up period, the overall incidence of deep postoperative wound infection was 1.48 % (79 cases). The annual rate of infection ranged from 0.0 to 2.41 %. The most frequent pathologies in the group of infectious complications and the control group were degenerative diseases of the spine, 35.4 % (28 patients) and 44.3 % (144 patients) and the consequences of spinal injuries (26.6 % and 18.7 %), respectively, from the total number of patients. Table 1 provides an overview of the pathologies in both groups.

The most common microorganism was methylene-resistant epidermal staphylococcus (*S. epidermidis MRSE*), which was isolated in 22.8 % in SSI group. *K. pneumoniae* and *S. aureus MRSA* were also isolated in a significant number of patients (13.9 % and 18.9 %, respectively). Together, these microorganisms were the cause of infectious complications in more than half of the SSI patients. In most cases, the source of the infection process was one microorganism (89.8 %), seven cases were mixed (2 microorganisms), and in one case three microorganisms were isolated. The quantitative characterization of the SSI pathogens is presented in Table 2.

The average period from surgery to identification of an infectious complication was 13.5 days for most patients (the interval (interquartile range) was 10–21 days), with a minimum of 6 days and a maximum of 143 days. In six cases, SSI could be classified as late infection, since the manifestation of the complication occurred after 30 days post-surgery. Sepsis developed in two (2.5 %) cases with multiple organ failure which was the cause of death.

Each patient underwent at least one repeated surgery to treat the infection (a total of 104 revision interventions). There were two revision interventions in 19 patients and three patients underwent three reoperations during single-period hospitalization. All non-viable tissues in the postoperative wound, loose bone grafts or artificial bone and unstable fixation elements were removed during the revision. Special attention was paid to treating metal structures; for this purpose, all tissues around the heads of pedicle screws, nuts, and metal bars were removed to the bone structures. The postoperative wound and metal structures were irrigated with various antiseptic solutions. In six (7.6 %) out of 79 SSI patients, complete removal of the metal structure was required to arrest the infection process. All patients after primary spinal surgery received antibiotics (cefuroxime, ampicillin + sulbactam) according to the standards for the prevention of infectious complications in orthopedic patients. Antibiotics were changed according to isolated microorganisms and depending on their sensitivity to antibacterial drugs. Antibacterial therapy was prolonged in nature and was used not only during the entire period of patient's hospitalization but also for 4–6 weeks after the patient was discharged.

Age, body mass index, the number of metal fixation levels, duration of surgery, blood loss, presence of drainage tubes were analyzed using t-test. The mean body mass index, duration of operation, blood loss, and the duration of drainage in the group of infectious complications differed significantly from those in the control group ($p < 0.05$, Table 3).

Based on the chi-square test, the effects of smoking, preoperative use of antibiotics and hormones, associated diseases such as diabetes, chronic obstructive lung disease, rheumatoid arthritis, and intraoperative blood transfusion, type of surgery, and previous surgical interventions on the development of SSI in the early postoperative period were studied. Statistically significant differences were found in indicators such as diabetes, chronic obstructive lung disease, osteoporosis, preoperative antibiotic prophylaxis and type of surgery in the SSI group when it was compared with the control group ($p < 0.05$, Table 4).

Table 1

Spinal pathologies in the groups

Diagnosis	SSI group (n = 79)	Control group (n = 325)
Spinal canal stenosis	19 (24 %)	97 (29.8 %)
Intervertebral disk hernia	9 (11.4 %)	47 (14.5 %)
Spondylolisthesis	4 (1.2 %)	20 (6.15 %)
Soliotic deformity (idiopathic and degenerative)	10 (12.6 %)	22 (6.7 %)
Kyphosis	3 (3.8 %)	13 (4 %)
Spinal tumors (primary and secondary)	13 (16.5 %)	65 (20 %)
Spinal injuries	21 (26.6 %)	61 (18.7 %)

Table 2

SSI group infection microorganisms

Microbe	Number of cases
S. aureus / MRSA	4 / 11 (18.9 %)
S. epidermidis / MRSE	4 / 17 (26.6 %)
E. coli / ESBL	2 / 6 (10.1 %)
E. faecalis	7 (8.8 %)
P. aeruginosa	9 (11.4 %)
K. pneumoniae	11 (13.9 %)
S. epidermidis MRSE + K. pneumoniae	3 (3.8 %)
S. aureus MRSA + Enterobacter	4 (5.1 %)
S. aureus + P. aeruginosa+ Enterobacter	1 (1.3 %)

Table 3

Risk factor differences in SSI and control groups, t-test findings

Risk factor	SSI group	Control group	t	p
Age (years)	54.58 ± 2.71	54.93 ± 0.55	0.1090	0.9132
BMI (kg/m2)	24.85 ± 0.92	22.76 ± 0.11	2.935	0.0034
Extension of fixation (levels)	5.423 ± 0.43	5.252 ± 0.07	0.3703	0.7112
Extension of approach (cm)	17.5 ± 4.32	18.4 ± 3.15	0.204	0.8455
Duration of surgery (min)	208.5 ± 7.43	170.7 ± 2.77	2.307	0.0212
Blood loss (ml)	916.2 ± 72.66	696.5 ± 12.79	2.886	0.0040
Drains (pieces)	1.538 ± 0.14	1.394 ± 0.03	0.7985	0.4248
Duration of drainage (days)	3.808 ± 0.33	2.146 ± 0.06	4.745	0.0001
Drainage loss (ml)	340.0 ± 45.92	296.7 ± 8.072	0.320	0.8117

Table 4

Analysis of the differences in risk factors in the SSI group and the control group with chi-square test

Risk factor		SSI group	Control group	χ^2	p
Smoking	yes	41	124	6.803	0.009
	no	38	227		
Diabetes	yes	15	21	10.79	0.001
	no	64	304		
COLD	yes	11	31	0.8836	0.3472
	no	68	294		
Osteoporosis	yes	20	62	1.168	0.2798
	no	59	263		
Rheumatoid arthritis	yes	7	12	2.7225	0.0989
	no	72	313		
Hypertension disease	yes	44	202	0.9178	0.338
	no	35	122		
Infection of urinary tract	yes	34	72	13.263	0.00027
	no	45	253		
Use of antibiotics	yes	10	45	0.00869	0.9257
	no	69	280		
Hormonal therapy	yes	16	40	2.7277	0.0986
	no	63	285		
Blood transfusion	yes	45	146	3.8281	0.1128
	no	34	179		
Type of operation	open	74	208	25.154	0.000005
	closed	5	117		
Previous interventions	yes	22	31	17.121	0.000003
	no	57	294		
Spondylodesis (autogenic, allogenic bone)	yes	58	182	7.2891	0.006938
	no	21	143		

Analysis of the data obtained by us showed that both groups were comparable by sex, age, anthropometric indicators and the presence of comorbidities. Of the surgical factors, the greatest differences between the groups were noted in the types of surgical interventions, performance of spinal fusion, history of previous operations on the spine, duration of operations and the amount of blood loss ($p < 0.05$). The type of surgery and surgical history of patients showed the greatest differences between the SSI group of patients and control group ($p = 0.000005$ and $p = 0.000003$, respectively). In the first group, most interventions were open (93.7 %), and every fourth patient underwent previous spinal surgeries (27.8 %).

Among the risk factors associated with the patient, smoking (51.9 %, $p = 0.009$) showed a serious impact. No significant differences were found in chronic somatic pathology, with the exception of diabetes mellitus and urinary tract infection. The ratio of diabetic patients was 18.9 % in the group of infectious complications and 6.7 % in the control group, respectively ($p = 0.001$). Urinary tract infection was more commonly seen in elderly people and patients with neurological deficit and was association of pathogenic and conditionally pathogenic microorganisms. Statistically significant differences were also detected in terms of BMI ($p = 0.003$); in the group with infectious complications, a higher proportion of patients with a BMI more than 25 was registered.

DISCUSSION

The purpose of this study was to determine the risk factors of developing infection after surgical treatment on the spine at one institution over an 11-year period. The study included 79 patients with deep infection developed in the postoperative period and compared with 325 randomly selected patients from the same institution who did not develop this complication. Factors that increase the SSI risk can be classified as related to the history and somatic condition of patient or related to surgical intervention [14, 22].

Our study confirmed that patients with a history of previous operations on the spine have an increased risk of infection compared with those who did not have surgical interventions. Opposite conclusions were made by Olsen and Fang [2, 4], as both reported insignificant risks of developing a postoperative infection with a history of spinal surgery. However, it is unclear whether Fang [4] reported on only previous spinal surgeries or previous operations, associated with a specific level of intervention. The presence of urinary tract infection almost six times increased the risk of infection of the postoperative wound site. This complication was mainly diagnosed in patients with severe neurological deficit, which required careful hygiene measures, and in some cases, preliminary treatment of urinary infection. Moreover, our results confirm the conclusion that patients with diabetes mellitus and nicotine addiction had an increased SSI risk. A number of authors also report on the serious influence of smoking on the development of surgical infection. The active forms of oxygen in smokers attack polyunsaturated fatty acids in biological membranes, which leads to lipid peroxidation and directly or indirectly causes lesions and functional changes in the cells. As a result, the surgical intervention site heals significantly slower in smokers, which increases the SSI risk [19]. Patients with diabetes mellitus have pathological changes in their blood vessels, especially of the microvasculature. Due to significant damage to soft tissues, their ischemia and hypoxia develop, which contributes to the activation of the infection process. Immune function in patients with diabetes mellitus is inhibited due to severe functional cell damage [20]. For the prevention of such changes, it is necessary to monitor blood glucose and correct blood glucose levels as it increases. Increased BMI in our study was also a statistically significant risk factor for postoperative infectious complications, according to reports [14, 12], BMI of more than 25 kg/m2 is associated with a 15 % increase in the risk of postoperative complications. Thus, during the early postoperative period, postoperative care of a surgical wound in patients with obesity, diabetes and smokers should be very careful.

A retrospective analysis showed that the infection rate in patients undergoing open surgery was significantly higher than with minimally invasive surgery. Koutsoumbelis et al. [16, 23, 24] found that the risks of infection during open surgery are associated not only with a great traumatic impact on soft tissues and local ischemia due to bleeding, but also with a soft tissues contact with air and surgical instruments, which also increases the SSI risk. Therefore it is necessary to consider minimally invasive interventions in patients with the high SSI risks due to somatic pathology, when preparing for an operation. Some researchers [25] report that when the volume of blood lost is > 800 ml, the risk of postoperative infection increases. In our analysis, we also found that high blood loss is a risk factor for SSI. The next significant surgical factor is duration of postoperative drainage. According to Brown [26], prolonged use of drainage can lead to deep infection. Ahmed et al. [27] believe that postoperative drainage for more than 72 hours significantly increases the SSI risk. Thus, we assume that the optimal drainage should continue 48 hours. Spinal fusion during surgery can contribute to development of infection. So, bone grafts should be completely removed since they served as a persistent focus for maintaining the infection.

CONCLUSION

The overall rate of deep postoperative wound infection, according to our research, was 1.48 %. Despite the measures aimed at reducing the SSI after spinal surgery, it remains one of the most common and dangerous complications. Surgeons should adequately analyze and evaluate risk factors in patients, and then develop an individual program for SSI prevention. Upon diagnosis, it is necessary to carry out a revision intervention to remove the source of infection, desirably preserving the metal implants, re-drainage of the postoperative wound, and in some cases, an irrigation of the postoperative wound with antiseptic solutions. In addition, antibiotic therapy should be used in accordance with the results of bacteriological cultures.

One of the shortcomings of this study is a relatively small sample size of patients with infection (n = 79). This may be due to the fact that only one type of infection (deep SSI) was studied. However, the homogeneous study group, long observation period, nature and volume of operations are reliable factors to assess the risk factors for spinal infection in the postoperative period.

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