PREDICTION OF SURGICAL SITE INFECTION IN SPINE SURGERY

V.M. Haydarov[1, 2], A.N. Tkachenko[1], I.A. Kirilova[2], D.Sh. Mansurov[1]
[1]*Mechnikov North-West State Medical University, St. Petersburg, Russia*
[2]*Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan, Novosibirsk, Russia*

Objective. To analyze prognostic factors for the development of surgical site infection following spine surgery and evaluate rating values for each of them.

Material and Methods. The data on 325 patients who underwent spinal surgery were analyzed. Data on 177 patients of the retrospective group who underwent spinal surgery without infectious complications were compared with the data of patients who had local complications of infectious genesis within one year after the operation (36 observations).

Results. The study resulted in creation of a learning matrix which became the basis for mathematical prediction and algorithm for the prevention of local infectious complications in patients who underwent spinal surgery. Seventeen criteria for predicting the development of surgical site infection were identified.

Conclusion. Approbation of the program in a prospective study (112 cases) with a follow-up period of 12 months after surgery demonstrated significant decrease in the incidence of surgical site infection as compared with that in the retrospective study group (from 16.9 to 9.8 %).

Key Words: spinal surgery, surgical site infection, prognosis.

Please cite this paper as: *Haydarov VM, Tkachenko AN, Kirilova IA, Mansurov DSh. Prediction of surgical site infection in spine surgery. Hir. Pozvonoc. 2018; 15(2):84–90. In Russian.*
DOI: http://dx.doi.org/10.14531/ss2018.2.84-90.

Recently, there has been a steady trend of increasing number of spine surgeries both in Russia and most of the developed countries [3, 5]. These surgical interventions are accompanied by complications in a number of cases (4 to 33 %), up to 20% of which can be due to surgical site infection [2, 5, 19, 13–15, 17]. The number of publications (local and international) discussing prognosis of infectious complications in spinal surgery has been recently increasing. However, the information on the capabilities of such prognosis is contradictory: different authors present information on different risk factors [6–8, 10–12, 16, 18]. In this regard, the study of the aspects related to the development of methods for predicting surgical site infection (SSI) in spinal surgery can be considered as an important and vitally significant topic of scientific medical research studies.

Aim of the current study is to analyze prognostic factors for the development of surgical site infection following spine surgery and evaluate rating values for each of them.

Material and Methods

A total of 373 patients aged 20–85 years (mean age, 57.1 ± 9.4 years) underwent spine surgery at the clinic of traumatology and orthopedics at Mechnikov State Medical University in the period of 2011–2015. The mortality in postoperative group was 1.9 % (7 cases). Causes of death were as follows: pulmonary thromboembolism (3 patients), acute CVA (2 patients), and acute cardiovascular insufficiency (2 patients). A total of 366 people were discharged from the medical center. Long-term results within the period of one year were evaluated in 325 (88.8 %) of these patients. In 42 (11.2 %) patients, the results could not be evaluated in 12-month follow-up period after surgery due to loss of communication with them or their death.

The data on 325 patients were divided into two groups in the study: retrospective group (213 people who underwent surgery in 2011–2013) and prospective group (112 people who underwent spine surgery in 2014–2015).

Both superficial infection at incision site and deep SSI were taken into account [4].

In the retrospective group, preoperative preparation and SSI prevention was carried out according to a standard procedure. 178 (83.6 %) patients underwent surgeries using metal implants. Spine surgeries without using metal implants were performed in 35 (16.4 %) cases. Local infection was found in 36 (16.9 %) cases among retrospective group patients within one year after surgery, deep infection was noted in 9 (4.2 %) patients.

Patients of the prospective group underwent preoperative prophylaxis depending on the prognosis and using the developed algorithms.

The retrospective group was divided into two subgroups: group I, which included cases with no SSI diagnosed within 12 months after surgery (177 patients), and group II, which included cases of superficial and deep SSI (36 patients).

Comparative analysis of data between the two retrospective subgroups was carried out with identification of risk factors for the development of SSI and evaluation of their rating values. We propose a model for predicting the course of the postoperative period in patients following spine surgery based on the data of quantitative equivalents of the risk of SSI development revealed retrospectively.

Clinical approbation of the prognosis of SSI development following spine surgery was performed in 112 patients of the prospective study group. The method of sequential analysis by A. Wald [1], which allows prediction at different stages of the treatment, including cases with incomplete set of characteristics, was used in the study.

Results

A total of 17 parameters were selected from 90 demographic, clinical and laboratory ones. The selected parameters formed the basis for the mathematical model of SSI prediction. They included general data (the patient's social status, time of the year when the intervention was performed, etc.), individual data (age, gender, data on concomitant diseases, body mass index, etc.), as well as information on the duration of surgery, volume of intraoperative blood loss, type of intervention, etc. A series of laboratory and instrumental parameters were analyzed separately. The risk factors for SSI prediction included parameters with reliable differences ($p < 0.05$) between the study groups, as well as prognostic factors with error probability (p-level) exceeding the conventional value but with a tendency to at least 1.5-fold percentage difference. In addition, the study also considered expert evaluation by other researchers with statistically confirmed p-level of the analyzed risk factor.

Among 17 prognostic factors selected for the program, 12 were diagnosed in the preoperative period, 4 were noted during surgery and one was registered in the early postoperative period. Data on the duration of surgery, as one of the risk factors for SSI, are presented in Table 1.

Among the patients with a favorable postoperative period, the number of cases with less than 1-hour surgery duration was 32 (18.1 %). Such clinical observations were twice as rare (8.3 %) among patients with SSI. The situation was opposite for the group with ≥3-hour surgery duration: there were 37.3 % of such patients in the uncomplicated group and 52.8 % patients in the group with SSI. Thus, the duration of surgery was taken into account when developing a mathematical model for SSI prediction. The same approach was applied to the selection of other criteria for predicting the development of SSI.

Once a complete list of prognostic factors was generated, the correlation index and prediction coefficient were calculated. The correlation index was a ratio between the frequency rate of the factor in the group of patients with favorable postoperative course and the frequency rate of the factor among patients with SSI. The prediction coefficient was a natural logarithm (ln) of the correlation index multiplied by 10 for convenience of calculations.

As a result, the prediction coefficient equaled +8.1 in cases with less than 1-hour surgery duration, +4.9 for 1- to 2-hour surgery duration, -0.4 for 2- to 3-hour surgery duration, and -3.4 for longer than 3-hour surgeries (Table 2). This allowed us to conclude that the risk of SSI development increases with an increase in surgery duration.

Next, all prediction coefficients known by the time of examination were summarized. The result is a prediction index. This parameter was determined at different stages of patient's examination and treatment. Prediction index was calculated using 12 parameters prior to surgery, 16 parameters during surgery, while 17 parameters were used in the early postoperative period with a confidence interval of -14 to +14.

If the overall prediction index equaled +14 or more, a favorable course of the postoperative period without SSI was predicted with more than 80% probability. SSI development could be expected with the same probability at <+14. If the index was in the range of -14 to +14, the prognosis was considered ambiguous. A complete list of prognostic factors with calculation of prediction coefficients for the development of local infectious complications is presented in Table 2.

Discussion

In the literature, methods for predicting surgical site infection in spinal surgeries are quite common. However, there is still no single generally accepted method. For instance, Abdul-Jabbar et al. [6] studied the results of the outcomes of 6,628 spinal surgeries and identified the following risk factors for SSI development: interventions in the sacrum region, the use of metal implants covering more than seven levels, more than 5-hour duration

Table 1

Duration of spinal surgery as prognostic factor for the development of surgical site infection (SSI)

Surgery duration	Course of postoperative period, n (%)	
	no complications	SSI
Up to 1 hour	32 (18.1)	3 (8.3)
1 to 2 hours	31 (17.5)	4 (11.1)
2 to 3 hours	48 (27.1)	10 (27.8)
3 hours	66 (37.3)	19 (52.8)
Total	177 (100.0)	36 (100.0)

of surgery, cases of osteotomy, concomitant diabetes mellitus, coagulopathy, etc.

Cizik et al. [8] use the term "spine surgical invasiveness index", the values of which range from 0 to 48. Based on the experience of 1,532 spinal interventions, these researchers consider the following criteria as the most significant ones for SSI prediction: obesity, hypertension, kidney diseases, thoracic or lumbosacral spinal fusions, and invasiveness index of more than 21. Moreover, it is the invasiveness index that considered by the authors to be the most important factor in predicting local infective-inflammatory complications.

Chikawa et al. [7] studied the risk factors for early deep SSI in spinal surgery developing in the first month after surgery and concluded that the main unfavorable prognostic factor for the formation of a purulent focus under the deep fascia is hemodialysis procedures. Of 8,154 patients, early deep SSI was verified in 1.1% of cases, while this index equaled 7.1 % among patients receiving hemodialysis.

Watanabe et al. [18] studied data on the results of treatment of 223 patients with spine pathology. The authors believe that diabetes mellitus, insufficient drainage and more than 3-hour surgery duration are the most significant risk factors of SSI. At the same time, the elderly and senile age, elevated BMI, gender, and smoking are not statistically reliable risk factors of infectious complications in the surgical wound.

A randomized study performed by the specialists from the USA and based on the results of examination and treatment of 5,541 patients presents data on the following risk factors: BMI, chronic steroid therapy, low albumin level, low platelet count and hematocrit, high anesthetic risk (according to ASA), long surgery duration [16]. The authors recommend planned surgical treatment with taking into account the risk factors for SSI and preoperative correction of a number of indicators.

The main drawbacks of these studies are as follows: in most cases, researchers reveal only statistically significant differences that allow considering a criterion to be predictive. At the same time, the authors do not provide recommendations on the practical use of such information. There are some publications on the attempts to assess the risk of SSI using the developed scoring system which takes into account the quantitative equivalent of each risk factor and the total indicator as well, which allows identification of the SSI risk group among patients. However, these publications contain no information on the approbation of the proposed systems and algorithms in their own prospective studies.

Using the developed algorithm for SSI prediction, we managed to identify a group of patients. The results were evaluated in the prospective study group, which included 112 clinical observations in total. The risk was expected in 18 (16.2 %) patients. These 18 patients (of the high-risk SSI group) and 27 (24.1 %) patients with the risk assessed as indeterminate were subjected to a series of preventive measures (local, general and antibiotic prophylaxis). All patients with unfavorable or indeterminate prognosis underwent prophylaxis: correction of body weight, selection of the season time for surgery, monitoring, drug treatment (antibacterial treatment and prophylactic antibiotics, drugs for improving blood, detoxification agents, symptomatic treatment, and etc.), optimization of surgery sheduling, ultrasound examination of the area of surgery in the postoperative period, and etc.

After implementation of preventive measures, SSI was diagnosed in 11 (9.8 %) patients out of 18 cases with predicted high risk of infective-inflammatory complications after spinal surgery. Moreover, deep infection was developed only in 2 (1.8 %) patients.

Conclusion

The use of mathematical prediction models of SSI development and the use of preventive measures in patients of the risk group allowed achieving reduction in the incidence of infections following spine surgery from 6.9 to 9.8 % (i.e. 1.7-fold). At the same time, the incidence of deep infection was decreased from 4.2 to 1.8 %. Clinical approbation of the prediction and prophylaxis in patients of the prospective group confirms the correct choice of SSI risk factors in spinal surgery.

The most significant criteria were the ones that had the maximum range between the positive and negative values of the prediction coefficient. In the preoperative prognosis, the most adverse factors were spine oncology as an indication for surgery, concomitant diseases of the respiratory and urinary systems, as well as preoperative hospital stay exceeding 10 days. Among the intraoperative criteria for SSI development are significant intraoperative blood loss (more than 1 L) and the duration of surgery exceeding 3 h.

Identification of the high risk SSI group among patients and prophylaxis allows SSI prevention in almost half of cases. The procedure for calculating the prediction index of SSI development following spine surgeries does not require special training or equipment. The obtained data demonstrate that application of modern technological and organizational approaches in patients requiring spine surgery allows preventing SSI development without additional financial expenses.

The study did not have any sponsorship. The authors declare no conflict of interest.

Table 2

Structure of weight coefficients for the prognostic factors of surgical site infection (SSI) in patients after spine surgery

Prognostic factor	Case frequency, %		Correlation index	Prediction coefficient
	no complications	SSI		
Prior to surgery				
1. Gender:				
male	46	33	1.394	3.3
female	54	67	0.806	-2.2
2. Age, years:				
18–29	2	6	0.333	-11.0
30–44	19	8	2.375	8.6
45–59	26	28	0.929	-0.7
60–74	45	47	0.957	-0.4
75–89	8	11	0.727	-3.2
3. Work ability:				
preserved	59	36	1.639	4.9
no occupation, retired	41	64	0.641	-4.4
4. Concomitant respiratory disease:				
COPD	9	28	0.321	-11.4
no COPD	91	72	1.264	2.3
5. Concomitant endocrine system disease:				
diabetes mellitus	17	31	0.548	-6.0
no diabetes mellitus	83	69	1.203	1.8
6. Concomitant pathology of excretory system:				
chronic pyelonephritis	14	42	0.333	11.0
no chronic pyelonephritis	86	58	1.483	3.9
7. Body mass				
reduced	18	31	0.508	-6.8
normal	59	33	1.788	5.8
overweight	23	36	0.639	-4.5
8. Localization of the pathological process:				
cervical spine	11	6	1.833	6.1
thoracic spine	35	36	0.972	-0.3
lumbar spine	46	52	0.885	-1.2
sacral spine	8	6	1.333	2.9
9. Indications to surgery:				
spine oncology	46	64	0.719	-3.3
degenerative spinal diseases	38	31	1.226	2.0
spinal injuries and complications	16	5	3.200	11.6
10. Time of surgery:				
winter	23	22	1.045	0.0
spring	30	42	0.714	-4.6
summer	19	17	1.118	0.5
autumn	30	19	1.579	4.5

Table 2 (ending)

Prognostic factor	Case frequency, %		Correlation index	Prediction coefficient
	no complications	SSI		
11. Preoperative bed-days:				
1–10	70	42	1.667	5.1
≥11	30	58	0.517	-6.6
12. Risk of anesthesia, ASA:				
1	6	3	2.000	6.9
2	18	11	1.636	4.9
3	63	64	0.984	-0.2
4	13	22	0.591	-5.3
Surgery				
13. Number of segments involved in surgery, n:				
1	34	14	2.429	8.9
2	24	28	0.857	-1.5
≥3	42	58	0.724	-3.2
14. Type of implant:				
bone cement	13	8	1.625	4.9
cage	14	8	1.750	5.6
mesh	9	6	1.500	4.1
transpedicular fixation	60	75	0.800	-2.2
no implant (biopsy)	4	3	1.333	2.9
15. Duration of surgery:				
up to 1 hour	18	8	2.250	8.1
1 to 2 hours	18	11	1.636	4.9
2 to 3 hours	27	28	0.964	-0.4
3 hours	37	53	0.698	-3.4
16. Intraoperative blood loss:				
up to 0.5 L	49	20	2.450	9.0
0.5 to 1 L	25	33	0.758	-2.8
1 to 1.5 L	12	22	0.545	-6.1
1.5 L	14	25	0.560	-5.8
Postoperative period				
17. Hematoma:				
present	16	36	0.444	-8.1
no hematoma	84	64	1.313	2.7

References

1. **Wald A.** Sequential Analysis. Transl. from English. Moscow, 1960. In Russian.
2. **Dolotin DN, Mikhailovsky MV.** Early infection in surgery of idiopathic scoliosis. Hir. Pozvonoc. 2016;13(2):24–27. In Russian. DOI: http://dx.doi.org/10.14531/ss2016.2.24-27.
3. **Kolesov SV.** Surgical Treatment of Spinal Deformity. Moscow, 2014. In Russian.
4. Sanitary and epidemiological requirements to the organizations performing medical activity. Sanitary and epidemiological rules and standards: The resolution of the Chief State health officer of the Russian Federation of 18.05.2010 No. 58 «About the statement the SanPiN 2.1.3.2630-10. "Sanitary and epidemiological requirements to the organizations performing medical activity» (Registered in the Ministry of Justice of the Russian Federation 09.08.2010, registration No. 18094). Add. SanPiN 2.1.3.2630-10. In Russian.
5. **Fadeev EM, Haydarov VM, Vissarionov SV, Linnik SA, Tkachenko AN, Usikov VV, Mansurov DS, Nur OF.** Rate and structure of complications in spine surgery. Pediatric Traumatology. Orthopaedics and Reconstructive Surgery. 2017;5(2):75–83. In Russian. DOI: 10.17816/PTORS5275-83.
6. **Abdul-Jabbar A, Takemoto S, Weber MH, Hu SS, Mummaneni PV, Deviren V, Ames CP, Chou D, Weinstein PR, Burch S, Berven SH.** Surgical site infection in spinal surgery: description of surgical and patient-based risk factors for postoperative infection using administrative claims data. Spine. 2012;37:1340–1345. DOI: 10.1097/BRS.0b013e318246a53a.
7. **Chikawa T, Sakai T, Bhatia NN, Sairyo K, Utunomiya R, Nakamura M, Nakano S, Shimakawa T, Minato A.** Retrospective study of deep surgical site infections following spinal surgery and the effectiveness of continuous irrigation. Br J Neurosurg. 2011;25:621–624. DOI: 10.3109/02688697.2010.546902.
8. **Cizik AM, Lee MJ, Martin BI, Bransford RJ, Bellabarba C, Chapman JR, Mirza SK.** Using the spine surgical invasiveness index to identify risk of surgical site infection: a multivariate analysis. J Bone Joint Surg Am. 2012;94:335–342. DOI: 10.2106/JBJS.J.01084.
9. **Gerometta A, Rodrigues Ol**averri JC, Bitan F. Infections in spinal instrumentation. Int Orthop. 2012;36:457–464. DOI: 10.1007/s00264-011-1426-0.
10. **Korol E, Johnston K, Waser N** Sifakis F, Jafri HS, Lo M, Kyaw MH. A systematic review of risk factors associated with surgical site infections among surgical patients. PLoS One. 2013;8:e83743. DOI: 10.1371/journal.pone.0083743.
11. **Lonjon G, Dauzac C, Fourniols E, Guigui P, Bonnomet F, Bonnevialle P.** Early surgical site infections in adult spinal trauma: A prospective, multicentre study of infection rates and risk factors. Orthop Traumatol Surg Res. 2012;98:788–794. DOI: 10.1016/j.otsr.2012.07.006.
12. **Meng F, Cao J, Meng X.** Risk factors for surgical site infections following spinal surgery. J Clin Neurosci. 2015;22:1862–1866. DOI: 10.1016/j.jocn.2015.03.065.
13. **Saeedinia S, Nouri M, Azarhomayoun A, Hanif H, Mortazavi A, Bahramian P, Yarandi KK, Amirjamshidi A.** The incidence and risk factors for surgical site infection after clean spinal operations: A prospective cohort study and review of the literature. Surg Neurol Int. 2015;6:154. DOI: 10.4103/2152-7806.166194.
14. **Samdani AF, Belin EJ, Bennett JT, Miyanji F, Pahys JM, Shah SA, Newton PO, Betz RR, Cahill PJ, Sponseller PD.** Major perioperative complications after spine surgery in patients with cerebral palsy: assessment of risk factors. Eur Spine J. 2016;25:795–800. DOI: 10.1007/s00586-015-4054-3.
15. **Satake K, Kanemura T, Matsumoto A, Yamaguchi H, Ishikawa Y.** Predisposing factors for surgical site infection of spinal instrumentation surgery for diabetes patients. Eur Spine J. 2013;22:1854–1858. DOI: 10.1007/s00586-013-2783-8.
16. **Sebastian A, Huddleston P** 3rd, Kakar S, Habermann E, Wagie A, Nassr A. Risk factors for surgical site infection after posterior cervical spine surgery: an analysis of 5,441 patients from the ACS NSQIP 2005–2012. Spine J. 2016;16:504–509. DOI: 10.1016/j.spinee.2015.12.009.
17. **Tirrell S, Handa S.** Spinal infections: vertebral osteomyelitis, epidural abscess, diskitis. Hosp Med Clinic. 2013;2:e509–e524. DOI: 10.1016/j.ehmc.2013.04.010.
18. **Watanabe M, Sakai D, Matsuyama D, Yamamoto Y, Sato M, Mochida J.** Risk factors for surgical site infection following spine surgery: efficacy of intraoperative saline irrigation. J Neurosurg Spine. 2010;12:540–546. DOI: 10.3171/2009.11.SPINE09308.

Address correspondence to:
Tkachenko Alexandr Nikolayevich
Mechnikov North-West State Medical University,
Piskarevsky ave., 47,
St. Petersburg, 195067, Russia,
altkachenko@mail.ru

Received 23.10.2017
Review completed 22.11.2017
Passed for printing 29.11.2017

Valery Mikhailovich Haydarov, teaching assistant of the Department of Traumatology, Orthopaedics, and Field Surgery, Mechnikov North-West State Medical University, Piskarevsky ave., 47, 195067, St. Petersburg, Russia; applicant, Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan, Frunze str., 17, Novosibirsk, 630091, Russia, val-era_1991_91@mail.ru;
Alexandr Nikolayevich Tkachenko, DMSc, Prof., Department of Traumatology, Orthopaedics, and Field Surgery, Mechnikov North-West State Medical University, Piskarevsky ave., 47, 195067, St. Petersburg, Russia, altkachenko@mail.ru;
Irina Anatolyevna Kirilova, DMSc, Deputy Director for Research Affairs, Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan, Frunze str., 17, Novosibirsk, 630091, Russia, IKirilova@niito.ru;
Djalolidin Shamsidinovich Mansurov, aspirant Department of Traumatology, Orthopaedics, and Field Surgery, Mechnikov North-West State Medical University, Piskarevsky ave., 47, 195067, St. Petersburg, Russia, jalolmedic511@gmail.com.