ORIGINAL RESEARCH

A Mathematical Prediction Model for Postoperative Infection Based on Logistic Multiple Regression Analysis in the Assessment of Surgical Outcome and Prediction of Infection in Elderly Spinal Fractures

Han Wang, MD; Tenghui Ge, MD; Qilong Wang, MD; Zhan Shi, MD; Yuqing Sun, MD

ABSTRACT

Objective • Investigating postoperative infection risk factors in elderly spinal fracture patients is crucial for optimizing surgical outcomes, improving patient safety, and guiding clinical decision-making in the management of these complex cases. To investigate the risk factors for postoperative infection in elderly patients with spinal fractures, with the goal of giving clinical care guidelines.

Methods • From January 2019 to January 2022, 120 elderly patients admitted to our hospital for elective spinal fracture surgery were featured as the study subjects, and the patients were divided into infected and non-infected categories according to whether they had postoperative infection or not. A mathematical prediction model was built after using logistic multiple regression to investigate the parameters influencing postoperative infection of a spinal fracture.

Results • There were 20 patients in the infected category and 100 patients in the non-infected category. Univariate analysis showed that the proportion of patients in the infected category with male, age ≥65 years, multiple fractures, use of hormones or combined diabetes was notably higher than that in the non-infected category ($P < .05$). Male gender, age ≥65 years, multiple fractures, and certain medical conditions are independent risk factors for postoperative infection.

Conclusions • Logistic regression analysis revealed that male, age ≥65 years, multiple fractures, use of hormones, or combined diabetes was an independent risk factor for postoperative infection in elderly patients with spinal fracture. Our study provides valuable insights that can guide clinical care and decision-making for elderly patients with spinal fractures. By applying these findings in practice, clinicians can refine their treatment strategies, improve patient outcomes, and enhance the overall quality of care provided to this vulnerable population. (*Altern Ther Health Med.* 2024;30(7):179-183).

Han Wang, MD, Attending doctor; **Tenghui Ge,** MD, Resident doctor; **Qilong Wang,** MD, Resident doctor; **Zhan Shi,** MD, Resident doctor; **Yuqing Sun,** MD, Chief physician; Department of Spine Surgery, Beijing Jishuitan Hospital, Capital Medical University, Xicheng District, Beijing, China; The Fourth Medical College of Peking University, Xicheng District, Beijing, China; Research Unit of Intelligent Orthopedics, Chinese Academy of Medical Sciences, Xicheng District, Beijing, China.

Corresponding author: Yuqing Sun, MD
E-mail: syuqing2004@126.com

INTRODUCTION

With the further development of an aging society, the number of elderly people in China is increasing, and so is the incidence of osteoporotic spinal fractures, a condition often seen in older age categories.[1] Osteoporosis is a bone disease that causes gradual loss of bone mass and bone quality and fractures. Osteoporosis and its effects have become a worldwide public health issue. One of the most prevalent types of osteoporotic fractures is osteoporotic spine fracture, and patients are at risk of secondary vertebral compression fractures.[2] In recent years, there has been a significant increase in the aging population, leading to a higher incidence of osteoporotic spinal fractures. According to statistical data, the prevalence of osteoporosis-related fractures in the elderly has been steadily rising. It is estimated that globally, around 1.6 million new cases of spinal fractures occur each year, with a higher incidence among individuals aged 65 and above. These statistics highlight the importance of studying risk factors for postoperative infection in elderly spinal fracture patients, as it addresses a growing health concern in an aging population. Osteoporotic spinal fractures have a significant impact on the quality of life of elderly patients. One major consequence is the increased level of pain experienced by these individuals. Spinal fractures often result in severe back pain, which can be chronic and debilitating. The pain may limit mobility and daily activities, leading to a decreased overall quality of life. Mobility

is also greatly affected by these fractures. Elderly patients with spinal fractures may experience difficulties in walking, bending, and maintaining balance. This may result in a loss of independence and increased reliance on assistive devices or caregivers, further impacting their quality of life. Moreover, osteoporotic spinal fractures increase the risk of further fractures. Once an initial fracture occurs, the structural integrity of the spine is compromised, making it more susceptible to subsequent fractures. This cycle of fragility fractures not only leads to increased pain and disability but also increases the risk of complications, including postoperative infections. Overall, osteoporotic spinal fractures significantly impair the physical function, cause persistent pain, and increase the risk of further fractures in elderly patients. These impacts substantially reduce the quality of life for these individuals, emphasizing the importance of identifying and mitigating risk factors for postoperative infection in this population. The two main healing options for spinal fractures are conservative treatment and surgical intervention. Conservative treatment focuses on pain management, healing promotion, and prevention of further injury. Surgical intervention is necessary for unstable fractures or when conservative treatment fails. However, surgical intervention carries risks, including the possibility of postoperative infection. Careful consideration of benefits and risks is crucial in deciding the appropriate healing option for each patient.

Previous studies have reported high mortality rates and reduced quality of life in patients with osteoporotic fractures. Elderly patients are less likely to recover after a fracture due to their reduced ability to heal themselves due to their own immune system and the deterioration of their organism's function.[3] Healing aims to reduce pain, restore mobility and reduce the risk of further vertebral fractures. Its healing consists of both conservative and surgical healing. Conservative healing helps restore bone healing through braces, orthoses or analgesic medication, but the clinical results are slow and unsatisfactory.[4] Surgical healing is more common, but the invasive nature of the procedure, combined with the longer duration of spinal fracture surgery, extensive tissue exposure, greater surgical trauma, and the implantation of more internal fixation materials, frequently results in a higher incidence of postoperative infection.[5] To limit the occurrence of surgical incisional infections, it is especially crucial to investigate the factors related to postoperative infection in spinal fractures. Building upon the background information, our study focuses on identifying risk factors for postoperative infection in spinal fracture patients. We aim to construct a predictive model using clinical data to better understand and anticipate the likelihood of infection following surgical intervention.We studied the clinical data of 120 elderly patients admitted to our hospital for spinal fracture surgery from January 2019 to January 2022 to ze the risk factors for postoperative infection and construct a mathematical prediction model for clinical application described below.

MATERIALS AND METHODS

General data

One hundred and twenty patients (older than 55 years old) admitted to our hospital for spinal fracture surgery consecutively from January 2019 to January 2022 were included in the study, of whom 24 (20.0%) were male and 96 (80.0%) were female. The patients were divided into infected and non-infected categories according to whether the infection occurred after surgery. The diagnostic criteria of surgical site infection we used here included surgical site signs (pain and tenderness) and raised blood tests (white blood cell and C-reactive protein) within 30 days after surgery7. Both superficial and deep surgical site infections were included. Patients with infection may or may not have systemic symptoms such as fever, rigor, or fatigue, and local symptoms such as surgical site swelling or exudation. We found 20 patients in the infected category and 100 patients in the non-infected category. Exclusion criteria: (1) patients with preoperative infection; (2) patients with combined cranio-cerebral, thoracic and abdominal important organ injuries; (3) patients with mental or behavioural disorders. Informed consent was obtained from the patients and their families for the above healings. Informed consent was obtained from all patients and their families, ensuring their understanding and agreement for the procedures and data collection involved in the study. Adhering to ethical considerations is crucial in medical research to protect the rights and well-being of the participants.

Methods

The data related to gender, age, fracture type, whether hormones were used or combined with diabetes mellitus, operation time, and intraoperative implants were analyzed and recorded in 120 patients and compared. Reference was made to the Diagnostic Criteria for Hospital Infections.[6] The criteria used for diagnosing surgical site infection (SSI) include fever, pain, erythema, swelling, purulent drainage, and positive cultures from the surgical site. These criteria help identify and classify SSIs accurately.

Statistical healing

Statistic Package for Social Science (SPSS) 22. 0 statistical software (IBM, Armonk, NY, USA) was used for data analysis, with measurement data expressed as ($\bar{x} \pm s$) and count data expressed as %; The chi-squared (χ^2) test was employed to compare categorical (count) data in this study. Initially, single-factor analysis was conducted to identify potential factors influencing postoperative infection. Subsequently, logistic regression was performed for multifactor analysis, allowing for a more comprehensive examination of the data. Single-factor analysis was first used to screen out factors that might influence postoperative infection in spinal fractures; the results obtained from single factors (variables with $P < .05$ in single factors) were included in a logistic regression model for multifactor analysis to establish a mathematical prediction model to screen out risk

Table 1. Univariate analysis of factors affecting postoperative infection in elderly patients with spinal fractures [n(%)]

Factor	Number of examples	Infection category (n = 20)	Non-infected category (n = 100)	χ^2	*P* value
Gender				18.375	.000
Male	24	11(45.8)	13(54.2)		
Female	96	9(9.4)	87(90.6)		
Age (years)				6.435	.011
55-65	34	1(2.9)	33(97.1)		
≥65	86	19(22.1)	67(77.9)		
Multiple fractures				44.947	.000
Yes	34	18(52.9)	16(47.1)		
No	86	2(2.3)	84(97.7)		
Type of surgery				3.687	.055
Open	33	9(27.3)	24(72.7)		
minimally-invasive	87	11(12.6)	76(87.4)		
Hormone use or combined diabetes				10.373	.001
Yes	51	15(29.4)	36(70.6)		
No	69	5(7.2)	64(92.8)		
Operating time (h)				1.535	.215
<2	51	6(11.8)	45(88.2)		
≥2	69	14(20.3)	55(79.7)		
Intraoperative implants				2.947	.086
Yes	63	14(22.2)	49(77.8)		
No	57	6(10.5)	51(89.5)		

factors influencing postoperative infection in spinal fractures, with $P < .05$ being as per stats different. The mathematical prediction model is intended to predict the risk of postoperative infection. It will be applied in clinical settings to assist healthcare professionals in making informed decisions regarding patient care and taking preventive measures. Its significance lies in its potential to improve patient outcomes by identifying individuals at higher risk, enabling timely interventions to reduce postoperative infection rates.

RESULTS

Univariate analysis of factors affecting postoperative infection in elderly patients with spinal fractures

Statistical results showed that the proportion of males, aged ≥65 years, multiple fractures, hormone use or comorbid diabetes mellitus was notably higher in the infected category than in the non-infected category ($P < .05$), Table 1.

Multifactor logistic regression analysis of post-operative infection in elderly patients with spinal fractures

The variables with $P < .05$ among the above univariate factors were included in the logistic regression model for multifactor analysis, which showed that male, age (Age) ≥ 65 years, multiple fractures, use of hormones or combined diabetes (Use of glucocorticoid or Diabetes) were associated with incisional infection and were independent risk factors for postoperative infection in elderly patients with spinal fractures, Table 2.

Postoperative infection prediction model and predictive efficacy

Based on the results of multifactorial logistic regression analysis, male, age (Age) ≥ 65 years, multiple fractures, Use of glucocorticoid or Diabetes were associated with incisional infection in elderly patients. Male, age (Age) ≥ 65 years, multiple fractures, Use of GC or Diabetes were independent risk factors for postoperative infection in elderly spinal

Table 2. Multifactor logistic regression analysis of postoperative infections in elderly patients with spinal fractures

Independent variables	β	SE	*P* value	OR	95%CI
Male	-2.102	0.539	.000	0.122	0.043-0.352
Age ≥ 65 years	-2.236	1.048	.033	0.107	0.014-0.833
Multiple fractures	3.855	0.794	.000	47.250	9.972-223.872
combined with diabetes mellitus	1.674	0.557	.003	5.333	1.791-15.885

Figure 1. Single indicator predicts ROC curve for post-operative infection in spinal fractures.

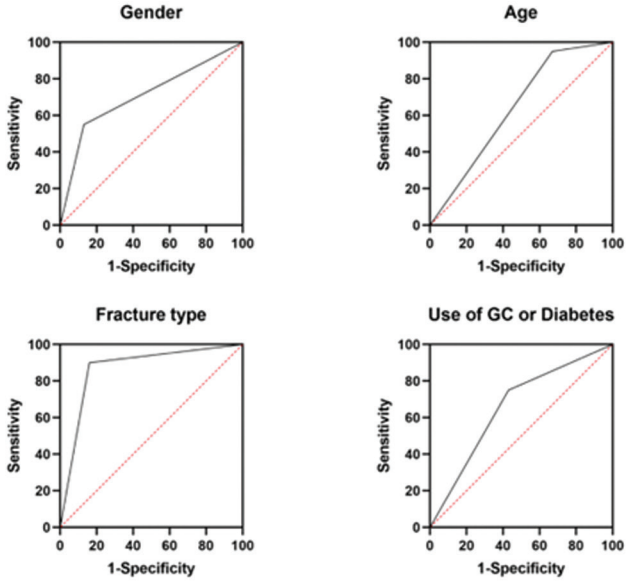
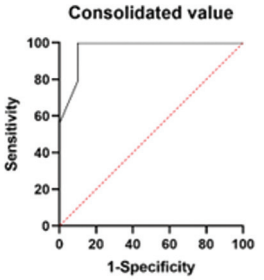


Figure 2. Consolidated value predicts ROC curve for post-operative infection in spinal fractures



fractures, and the results of ROC analysis showed that the four indicators in the model alone for The AUCs for predicting postoperative infection were 0.710(95CI: 0.571, 0.849), 0.640(95CI: 0.524, 0.756), 0.870(95CI: 0.783, 0.957), 0.660(95CI: 0.534, 0.786), Figure 1. In addition, we combined the above four indicators to make a ROC analysis, and the AUCs for the consolidated value was 0.968(95CI: 0.923, 1.000), Figure 2.

DISCUSSION

Because of physiological or pathological osteoporotic causes, older persons are more likely to suffer a spinal fracture. Even after receiving the best conservative treatment available, some individuals do not recover from their symptoms and suffer delayed neurological deficits due to

nerve compression caused by chronic vertebral abnormalities.[7] Furthermore, they are at a higher risk of recurring osteoporotic fractures, and these clinical processes may eventually lead to a loss of healthy life and increased mortality.[8] For this reason, the diagnosis of spinal fractures in the elderly usually requires surgical healing.[9] Postoperative infection following spinal fracture surgery is a serious complication that can add to the burden on society by increasing social, economic, and personal costs. Depending on diagnostic and surgical criteria as well as patient circumstances, the reported incidence of postoperative infections ranges from 1% to 10%.[10] Indeed, postoperative infection in spinal fracture surgery is difficult to manage, and this complication is critical to avoid, so it is critical to investigate the factors related to postoperative infection in spinal fracture surgery.

As per stats, we analysed the data and other relevant data of 120 elderly patients admitted to our hospital for spinal fracture surgery and developed a mathematical prediction model. The results showed that males, age ≥ 65 years, multiple fractures, use of GC or diabetes, and were associated with infection ($P < .05$). Multifactor logistic regression analysis showed that males, age ≥ 65 years, multiple fractures, use of GC, or diabetes are associated with incisional infection in patients and are independent risk factors for infection after spinal fracture surgery in the elderly. Older patients are at greater risk of postoperative infection because of their degenerative status and poor resistance to infection and tissue repair.[11] Furthermore, elderly patients frequently have underlying diseases such as coronary heart disease, diabetes mellitus, hypertension, hyperlipidaemia, and rheumatic diseases, which decrease the body's ability to fight pathogenic bacteria, which is not conducive to postoperative recovery.[12] Furthermore, aged patients are more vulnerable to secondary infection for various reasons.[13] Our study found no difference in infection rates between open surgery and minimally invasive surgery, indicating that open surgery has fine operation and complete hemostasis.[14] In addition, although the time of open surgery is longer than minimally invasive surgery, antibiotics will be routinely used to prevent infection after surgery.[15] As a result, open surgery does not increase the probability of infection.

In daily clinical practice, glucocorticoids are commonly used to treat a wide range of disorders, including chronic arthritis, systemic lupus erythematosus, rheumatic polymyalgia, allergies, chronic lung diseases (asthma, emphysema), and inflammatory bowel disease. Glucocorticoids are also utilized to minimise local oedema following spinal surgery, and their efficacy has been shown to be more beneficial.[16] However, the increase in blood glucose caused by glucocorticoid treatment contributes to an increased risk of infection following spinal fracture surgery. Diabetes mellitus is a systemic disease that alters blood glucose metabolism. There are many risks of systemic co-morbidities associated with microangiopathy and neuropathy in diabetic patients. Diabetes is considered for postoperative infection after orthopaedic surgery,[17] and Richards et al.[18] reported that hyperglycaemia was postoperative infection in orthopaedic patients without of diabetes mellitus. The incidence of postoperative infection was notably higher in diabetic patients (75%) than in non-diabetic patients (25%) ($P < .05$). Postoperative infections in diabetic patients occur through various pathogenic mechanisms, and the impaired transmission of nourishment and the availability of nutrients and oxy-gen to the perimeter tissues when microangiopathy is noted reduces the body's ability to resist infection.[19] Poor glycemic management impacts leucocyte functions such as binding, chemotaxis, engulfment, and endocytic clearance of drugs. Fibroblasts with faulty proliferation and collagen synapse might cause damage resolution to be delayed.[20] Neuropathy caused by autonomic nervous system dysfunction can cause skin dryness and disintegration, compromising its integrity and resistance to infection.[21] As a result, in diabetic patients, adequate glycemic management can effectively lower the risk of postoperative infection. To avoid postoperative infection, clinicians should rigorously regulate patients' blood glucose levels throughout the perioperative phase, as well as the justifications for glucocorticoid usage, with the help of a multidisciplinary approach. Furthermore, the risk of infection grows with the length of the procedure. In this regard, medical staff should pay attention to the awareness of aseptic operation strengthen the level of practice, regular training, and assessment in order to shorten the operation time and prevent postoperative infections.

It has been observed that males have a higher risk of infection following fractures. This could be due to differences in hormonal profiles, immune responses, or behavioral factors. Older individuals generally have a weaker immune system, reduced tissue healing capacity, and an increased likelihood of having comorbidities. These factors contribute to a higher susceptibility to infections. The presence of multiple fractures increases the injury burden on the body, leading to a greater disruption of the immune system and impaired tissue healing. This creates an environment favorable for the development of infections. Glucocorticoids are potent immunosuppressive drugs commonly prescribed for various conditions, including fractures. They inhibit immune responses, decrease inflammation, and impair wound healing processes, making individuals more prone to infections. Diabetes is associated with impaired immune function and reduced tissue perfusion, which hampers the body's ability to defend against pathogens and promote healing. Poor glycemic control further exacerbates the risk of infections in individuals with diabetes.

The limitations of this study first included that some potential factors were not addressed in our study, such as obesity, smoking history, personal hygiene situation, and antibiotics usage. Compared with a systemic review, a few possible risk factors were not considered in this research.[22] We need to supplement these possible factors in further study. Secondly, the single single-center study design limited

the number of patients. We look forward to research further in a multicenter approach with a larger sample scale.

In summary, independent factors for postoperative infection in spinal fractures are male, age ≥ 65 years, multiple fractures, use of GC, or diabetes. Perioperative prophylactic interventions by the medical staff should address these factors in order to control the risk of postoperative infection, which is important for improving the long-term prognosis of patients. Healthcare professionals can use this information to identify elderly spinal fracture patients who are at a higher risk of postoperative infections. They can implement preventive measures such as strict aseptic techniques during surgery, optimizing glycemic control in diabetic patients, considering alternative medications instead of glucocorticoids, and closely monitoring these high-risk individuals for signs of infection postoperatively.

ETHICAL COMPLIANCE

This study was approved by the ethics committee of Beijing Jishuitan Hospital. Signed written informed consents were obtained from the patients and/or guardians.

CONFLICT OF INTEREST

The authors have no potential conflicts of interest to report relevant to this article.

AUTHOR CONTRIBUTIONS

HW and YS designed the study and performed the experiments, TG and QW collected the data, TG, QW and ZS analyzed the data, HW and YS prepared the manuscript. All authors read and approved the final manuscript.

DATA AVAILABILITY

The dataset used in this paper are available from the corresponding author upon request.

FUNDING

This work was supported by the CAMS Innovation Fund for Medical Sciences (CIFMS) (2021-I2M-5-007)

REFERENCES

1. Ji C, Rong Y, Wang J, et al. Risk Factors for Refracture following Primary Osteoporotic Vertebral Compression Fractures. *Pain Physician*. 2021;24(3):E335-E340.
2. Prost S, Pesenti S, Fuentes S, Tropiano P, Blondel B. Treatment of osteoporotic vertebral fractures. *Orthop Traumatol Surg Res*. 2021;107(1S):102779. doi:10.1016/j.otsr.2020.102779
3. Porter JL, Varacallo M. *Osteoporosis*. 2023.
4. Ohara Y, Hara T, Abe E. [How to Treat Osteoporotic Vertebral Fracture?]. *No Shinkei Geka*. 2021;49(6):1286-1297. doi:10.11477/mf.1436204514
5. Utkan Karasu A, Karasu Y, Özakşit MG, Üstün Y, Üstün Engin Y. Comparison of osteoporotic fracture risk in surgical and natural menopausal patients. *Turk J Phys Med Rehabil*. 2021;67(3):322-327. doi:10.5606/tftrd.2021.5918
6. Fei Q, Li J, Lin J, et al. Risk Factors for Surgical Site Infection After Spinal Surgery: A Meta-Analysis. *World Neurosurg*. 2016;95:507-515. doi:10.1016/j.wneu.2015.05.059
7. Borchardt RA, Tzizik D. Update on surgical site infections: the new CDC guidelines. *JAAPA*. 2018;31(4):52-54. doi:10.1097/01.JAA.0000531052.82007.42
8. Anandasivam NS, Ondeck NT, Bagi PS, et al; Spinal fractures and/or spinal cord injuries are associated with orthopedic and internal organ injuries in proximity to the spinal injury. *N Am Spine Soc J*. 2021;6(100057. doi:10.1016/j.xnsj.2021.100057
9. Breitenbach M, Phan A, Botros M, et al. The fourth column of the spine: prevalence of sternal fractures and concurrent thoracic spinal fractures. *Injury*. 2022;53(3):1062-1067. doi:10.1016/j.injury.2021.12.040
10. Wiedl A, Förch S, Fenwick A, Mayr E. [Importance of surgical treatment of thoracolumbar vertebral fractures for the survival probability of orthogeriatric patients]. *Unfallchirurg*. 2021;124(4):303-310. doi:10.1007/s00113-020-00864-w
11. Węgłowski R, Polak P, Piech P. Evaluation of long-term surgical treatment outcomes of thoraco-lumbar spinal fractures - follow-up period of over 10 years. *Ann Agric Environ Med*. 2021;28(2):339-344. doi:10.26444/aaem/120051
12. Yamamoto T, Okada E, Michikawa T, et al. The impact of diabetes mellitus on spinal fracture with diffuse idiopathic skeletal hyperostosis: A multicenter retrospective study. *J Orthop Sci*. 2022;27(3):582-587. doi:10.1016/j.jos.2021.03.021
13. Kelly MA, McCabe E, Bergin D, et al. Osteoporotic Vertebral Fractures are Common in Hip Fracture Patients and are Under-recognized. *J Clin Densitom*. 2021;24(2):183-189. doi:10.1016/j.jocd.2020.05.007
14. Xin J, Liu X, Jing X, et al. Multifactor Analysis of Costal Pain in Osteoporotic Fracture of Thoracic Vertebra. *Pain Physician*. 2021;24(6):E795-E802. doi:10.36076/ppj.2021.24.E795
15. Morin SN, Yan L, Lix LM, Leslie WD. Long-term risk of subsequent major osteoporotic fracture and hip fracture in men and women: a population-based observational study with a 25-year follow-up. *Osteoporos Int*. 2021;32(12):2525-2532. doi:10.1007/s00198-021-06028-9
16. Messina OD, Vidal LF, Wilman MV, Bultink IEM, Raterman HG, Lems W. Management of glucocorticoid-induced osteoporosis. *Aging Clin Exp Res*. 2021;33(4):793-804. doi:10.1007/s40520-021-01823-0
17. Nguyen TV. Personalized fracture risk assessment: where are we at? *Expert Rev Endocrinol Metab*. 2021;16(4):191-200. doi:10.1080/17446651.2021.1924672
18. Richards JE, Kauffmann RM, Zuckerman SL, Obremskey WT, May AK. Relationship of hyperglycemia and surgical-site infection in orthopaedic surgery. *J Bone Joint Surg Am*. 2012;94(13):1181-1186. doi:10.2106/JBJS.K.00193
19. Egeberg A, Schwarz P, Harsløf T, et al; Association of Potent and Very Potent Topical Corticosteroids and the Risk of Osteoporosis and Major Osteoporotic Fractures. Association of Potent and Very Potent Topical Corticosteroids and the Risk of Osteoporosis and Major Osteoporotic Fractures. *JAMA Dermatol*. 2021;157(3):275-282. doi:10.1001/jamadermatol.2020.4968
20. Bouvard B, Annweiler C, Legrand E. Osteoporosis in older adults. *Joint Bone Spine*. 2021;88(3):105135. doi:10.1016/j.jbspin.2021.105135
21. Kim EG, Bae G, Kwon HY, Yang H. Aging and direct medical costs of osteoporotic fractures. *J Bone Miner Metab*. 2021;39(4):589-597. doi:10.1007/s00774-020-01192-0
22. Peng XQ, Sun CG, Fei ZG, Zhou QJ; Risk Factors for Surgical Site Infection After Spinal Surgery: A Systematic Review and Meta-Analysis Based on Twenty-Seven Studies. *World Neurosurg*. 2019;123(e318-e329. doi:10.1016/j.wneu.2018.11.158