Predictors associated with perioperative blood transfusion and intraoperative blood loss in thoracolumbar tuberculosis

Chengchao Song  
Second Affiliated Hospital of Harbin Medical University

Chao Liu  
Second Affiliated Hospital of Harbin Medical University

Rongzhi Wei  
Second Affiliated Hospital of Harbin Medical University

Qiuhua Zhang  
Second Affiliated Hospital of Harbin Medical University

Feng Wu  
Second Affiliated Hospital of Harbin Medical University

Shengyu Wang  
Second Affiliated Hospital of Harbin Medical University

Jinglong Yan  
Second Affiliated Hospital of Harbin Medical University

yufu Wang (✉ 2468024042@qq.com)  
Second Affiliated Hospital of Harbin Medical University  https://orcid.org/0000-0003-2872-2104

Research article

Keywords: blood transfusion; intraoperative blood loss; risk factors; thoracic and lumbar tuberculosis

Posted Date: January 23rd, 2020

DOI: https://doi.org/10.21203/rs.2.21729/v1

License: ☑ This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License
Abstract

Background During operation on thoracic and lumbar tuberculosis infection, patients can lose a significant amount of blood and receive a perioperative blood transfusion. However, the risk factors were not identified for increased intraoperative blood loss and perioperative blood transfusion. The aim of this retrospective study is to determine the predictors associated with perioperative blood transfusion and intraoperative blood loss in thoracolumbar tuberculosis. Methods From 2008 to 2018, 336 patients who met the inclusion criteria were enrolled in the study. The predictors of allogenic blood transfusion were identified in a univariate and multivariate logistic regression analysis. Univariate and multivariate linear regression was attempted to investigate the factors influencing intraoperative blood loss. Results Altogether, 336 adult patients with thoracic and lumbar tuberculosis were included in this study. The mean patient age was 49.6 ± 15.5 (range 14-85) years for those patients. Our data revealed a significant relationship between blood transfusions and female gender, BMI, vertebral collapse/Kyphosis and intraoperative blood loss. Multivariable linear regression analysis revealed that BMI, levels of instrumentation, surgical approach and operative time were independent factors influencing intraoperative blood loss. Conclusions This study identified some clinical predictors for perioperative blood transfusion and intraoperative blood loss in patients undergoing thoracic and lumbar tuberculosis surgery. These results may contribute to preoperative blood transfusion planning and minimize intra- or post-operative complications.

Background

Subacute and chronic spinal infections is usually caused by a wide spectrum of pathogens, of which Mycobacterium tuberculosis is considered the most common. The typical spinal tuberculosis is spondylodiscitis. In the last two decades, there has been a resurgence of tuberculosis in developed countries. However, there are still challenges in the management of spinal tuberculosis. Surgical treatment is indicated for those whose infections are resistant to antibiotic therapy or who have bone destruction, kyphosis, neurologic impairment and severe pain. Generally, debridement and bone graft are the surgical procedures of first choice. In spite of advances in surgical techniques, the operation of spinal tuberculosis is still associated with substantial blood loss and many patients need perioperative blood transfusion. Owning to tuberculosis is a systemic disease, the use of autologous blood transfusion is not recommended for such patients. In addition to issues regarding shortages and cost, allogeneic blood transfusion can be associated with serious complications and prolonged length of stay in spine surgery. Thus, characterizing patients at high risk of intraoperative blood loss and the need for perioperative blood transfusion is an important step to improve postoperative outcomes, reduce complications and minimize health resource utilization.

To date, few studies have elucidated influencing factors of blood loss during spinal tuberculosis surgery. It is not identified which clinical predictors affect perioperative blood transfusion and blood loss in
patients undergoing debridement and reconstruction procedure. Therefore, the objective of the present study was to identify predictors of perioperative blood transfusion as well as high intraoperative blood loss from our series.

**Methods**

This study was approved by the university review board. A total number of 336 patients with thoracic and lumbar spinal tuberculosis underwent surgery was identified from two independent hospitals between January 2010 and November 2018. Diagnosis of spinal tuberculosis was based on the following criteria reported previously\(^9\),\(^{27}\): clinical manifestations, radiological evidence, response to antimicrobial therapy and results of microbiological examination. Indication for surgery including vertebral collapse and spinal instability, severe kyphotic deformity or progressive worsening of kyphosis, spinal cord compression by abscess or necrosis, formation of a hollow or sequestrum or no improvement in antimicrobial therapy. The study population consisted of patients > 18 years old. Patients with recurrence at the lesion site and who underwent deformity surgery without debridement was excluded.

The variables extracted for analysis includes patient age, gender, preoperative hemoglobin, Body mass index (BMI), location of the lesion (thoracic, thoracolumbar, lumbar or lumbosacral spine), vertebral collapse or kyphosis, discitis involved, levels of instrumentation, paraspinal/epidural abscess, surgical approach (anterior, posterior and combined procedure) and operative time, the amount of intraoperative blood loss and allogenic blood transfusion (Table 1). The recorded intraoperative blood loss was obtained from the anesthetist case records which also was confirmed by surgeons. The blood loss was further checked from the electronic records in the institutional database. The amount of blood loss over 30% of total blood volume during surgery was set as the cutoff for high levels of intraoperative blood loss. The total blood volume was calculated according to the previously reported method.\(^3\)\(^{20}\) The surgical procedures were classified into three categories. The anterior approach was performed by anterior or lateral-anterior debridement, autologous or allograft bone graft and instrumentation. The posterior approach was performed by posterior debridement, autologous or allograft bone graft and instrumentation. The combined approach was performed by posterior instrumentation combined with anterior debridement and autologous or allograft bone graft.

| Table 1 Characteristics of the Study Patients |
|---------------------------------------------|

**Statistical Analysis**

The independent factors used for prognostic modeling analysis were measured on either categorical or continuous variables. The logistic regression model was used in the univariable or multivariable analysis to identify the predictors of perioperative blood transfusion. To estimate the effect of different factors on intraoperative blood loss, both the univariate and multivariate linear regression was exploited. The level
| Characteristics | N  | %  | Mean± SD |
|-----------------|----|----|----------|
| Age (Years old) | 336| 49.5 | ± 15.6 |
| Gender          |    |     |          |
| Male            | 158| 47% |          |
| Female          | 178| 53% |          |
| BMI             |    | 22.24 | ± 3.69 |
| Preoperative hemoglobin (g/L) | 122.04 | ± 17.37 |
| Location        |    |     |          |
| Thoracic        | 117| 34.8|          |
| Thoracolumbar   | 15 | 4.5 |          |
| Lumbar/Lumbosacral | 204 | 60.7 |          |
| Vertebral collapse/Kyphosis |    |     |          |
| Without         | 266| 79.4|          |
| With            | 69 | 20.6|          |
| Abscess (paravertebral or epidural) |    |     |          |
| Without         | 99 | 29.5|          |
| With            | 237| 70.5|          |
| Levels of instrumentation |    |     |          |
| Two             | 186| 55.9|          |
| Three           | 67 | 20.1|          |
| Four or more    | 80 | 24.0|          |
| Surgical approach |    |     |          |
| Anterior        | 204| 60.7|          |
| Posterior       | 109| 32.4|          |
| Combined        | 23 | 6.8 |          |
| Operative time (min) | 244.98 | ± 107.51 |
| Intraoperative blood loss | 661.37 | ± 557.54 |
| Blood transfusion |    |     |          |
| Yes             | 221| 34.0|          |
| No              | 114| 66.0|          |

of significance was set at 0.05 in all analyses. Statistical analyses were performed using IBM SPSS statistical software (version 23.0, Armonk, NY, USA).

Table 2 Univariate and Multivariate Logistic Regression Analysis to Identify Predictors of Perioperative Blood Transfusion
| Variable                              | Perioperative Blood Transfusion                                                                 |
|--------------------------------------|-------------------------------------------------------------------------------------------------|
|                                      | Univariate analysis | Multivariate analysis |
|                                      | OR (95% CI)         | P       | OR (95% CI) | P       |
| Age (years)                          | 1.00 (0.99-1.02)    | 0.797   | 1.02 (0.98-1.68) | 0.233   |
| Gender                               | Ref.                | Ref.    | Ref.        | Ref.    |
| Female                               | 1.50 (0.95-2.36)    | 0.081   | 4.59 (1.56-13.47) | 0.006   |
| Preoperative hemoglobin (g/L)        | 0.99 (0.98-1.01)    | 0.791   | 1.01 (0.98-1.03) | 0.455   |
| BMI                                  | 0.71 (0.91-1.06)    | 0.709   | 0.84 (0.71-0.99) | 0.039   |
| Location                             | Ref.                | Ref.    | Ref.        | Ref.    |
| Thoracic                             | 0.86 (0.67-1.10)    | 0.17    | 4.07 (0.38-44.14) | 0.250   |
| Thoracolumbar                        | 0.76 (0.47-1.23)    | 0.26    | 1.43 (0.50-4.11) | 0.501   |
| Lumbar/Lumbosacral                   | Ref.                | Ref.    | Ref.        | Ref.    |
| Vertebral collapse/Kyphosis          | Ref.                | Ref.    | Ref.        | Ref.    |
| Without                              |                       |         |             |         |
| With                                 | 1.13 (0.64-1.99)    | 0.673   | 4.74 (1.34-16.79) | 0.016   |
| Discitis                             | Ref.                | Ref.    | Ref.        | Ref.    |
| One                                  | 2.02 (1.11-3.70)    | 0.020   | 1.00 (0.12-8.73) | 0.705   |
| Two                                  | 2.83 (1.35-5.97)    | 0.006   | 1.34 (0.18-10.12) | 0.997   |
| Three or more                        | Ref.                | Ref.    | Ref.        | Ref.    |
| Levels of instrumentation            | Ref.                | Ref.    | Ref.        | Ref.    |
| Two                                  | 2.37 (1.27-4.41)    | 0.007   | 3.92 (0.70-22.15) | 0.121   |
| Three                                | 4.57 (2.31-8.99)    | <0.001  | 3.27 (0.18-59.30) | 0.424   |
| Four or more                         | Ref.                | Ref.    | Ref.        | Ref.    |
| Abscess (paravertebral or epidural)  | Ref.                | Ref.    | Ref.        | Ref.    |
| Without                              | 0.96 (0.58-1.57)    | 0.862   | 0.48 (0.16-1.41) | 0.183   |
| With                                 | Ref.                | Ref.    | Ref.        | Ref.    |
| Approach                              | Ref.                | Ref.    | Ref.        | Ref.    |
| Anterior                             | 1.49 (0.91-2.46)    | 0.11    | 0.88 (0.06-14.19) | 0.933   |
| Posterior                            | 14.3 (1.89-108.26)  | 0.01    | 0.92 (0.06-14.47) | 0.928   |
| Operative time                       | 1.01 (1.00-1.02)    | <0.001  | 1.00 (0.99-1.01) | 0.486   |
| Intraoperative Blood Loss            | 1.01 (1.01-1.01)    | <0.001  | 1.01 (0.98-1.03) | <0.001  |

**Results**

Patient Demographics and Clinical characteristics
A total of 336 patients with thoracic and lumbar tuberculosis who underwent surgery were evaluated for this study. The mean patient age was 49.6 ± 15.5 (range 14-85) years for those patients. There were 178 female and 158 male patients, and the mean preoperative hemoglobin was 122.04 ± 17.37 g/L. Perioperative blood transfusion was received in 66.1 % of the cases. 11.3% of patients (38) had high intraoperative blood loss during surgery. For the entire cohort, the mean intraoperative blood loss was 661.37 ± 557.54 ml. The mean blood loss was 832.13 ± 590.17 ml for the patients who received blood transfusion and 276.75± 187.19 ml for the patients who did not. Table I demonstrates the characteristics of the study patients.

**Predictors of perioperative blood transfusion**

In univariable regression analysis (Table 2), numbers of involved discitis, levels of instrumentation, surgical approach, operative time and intraoperative blood loss was significantly associated with the perioperative blood transfusion. Furthermore, multivariable logistic regression analysis was performed to adjust for interaction between covariates and revealed the four predictors of allogeneic blood transfusion in the perioperative period (Table 2). The risk of allogenic blood transfusion increased with the female, vertebral collapse/kyphosis, and intraoperative blood loss. Higher levels of BMI decreased the risk of allogeneic blood transfusion in patients.

**Factors influencing intraoperative blood loss**

Through univariable linear regression analysis (Table 3), BMI, number of involved discitis, levels of instrumentation, surgical approach and operative time was found that correlated to the intraoperative blood loss. Moreover, multivariable linear regression analysis revealed that higher BMI, more levels of instrumentation, combined approach and prolonged operative time were linked to higher intraoperative blood loss (Table 3). The result showed that the amount of blood loss rises by increasing BMI (18.42 mL per 1kg/m² increase) and operative time (2.33 ml per min increase). In patients undergoing combined surgical approach increased the amount of blood loss by 325.78 ml. The amount of intraoperative blood loss was significantly higher in patients with four or more levels of instrumentation (514 ml more)

| Table 3 Results of univariate and multivariate analysis to determine intraoperative blood loss among different exposure variables |

**Discussion**

During operation on spinal tuberculosis infection, patients can lose a significant amount of blood, which may result in the patient receiving a blood transfusion. Therefore, it is important to evaluate the different risk factors for increased intraoperative blood loss and perioperative blood transfusion, which potentially can be used for preoperative planning and also for risk stratification to evaluate outcomes.

Through autologous blood transfusion contributed to reduce perioperative blood loss, the fact that spinal tuberculosis or brucellosis is the complication of a systematic disease makes it impossible to perform preoperative autologous blood donation and intraoperative autologous blood transfusion. Several
previous studies have investigated risk factors associated with risk of transfusion in spine surgical patient populations. In lumbar fusion surgery, ASA>1, prolonged operative time, multilevel fusion, sacrum involvement, and open posterior approach are predictors of transfusion. Similarly, Durand reported operative duration, surgical invasiveness, hematocrit, weight, and age as the most influential variables predicting blood transfusion. In addition, it is reported that preoperative hemoglobin level is an important variable. 

| Variable                                      | Univariate analysis | Multivariate analysis |
|-----------------------------------------------|---------------------|-----------------------|
|                                               | Regression coefficient ($b$) | 95% CI | $P$ | Regression coefficient ($b$) | 95% CI | $P$ |
| Age (years)                                   | -1.51               | -5.34-2.33            | 0.44 |                                               |         |     |
| Gender                                        |                     |                      |      |                                               |         |     |
| Male                                          | 1                   |                      |      |                                               |         |     |
| Female                                        | 3.30                | -116.75-123.36       | 0.96 |                                               |         |     |
| Preoperative hemoglobin (g/L)                 | 1.28                | -2.20-4.75           | 0.47 |                                               |         |     |
| BMI                                           | 30.24               | 11.35-49.13          | 0.002| 18.416                                         | 0.79-36.04| 0.04 |
| Location                                      |                     |                      |      |                                               |         |     |
| Thoracic                                      | 1                   |                      |      |                                               |         |     |
| Thoracolumbar                                 | 64.86               | -225.20-354.92       | 0.66 |                                               |         |     |
| Lumbar/Lumbosacral                            | -116.91             | -238.95-5.14         | 0.06 |                                               |         |     |
| Vertebral collapse/Kyphosis                   |                     |                      |      |                                               |         |     |
| Without                                       | 1                   |                      |      |                                               |         |     |
| With                                          | 49.71               | -98.55-197.98        | 0.51 |                                               |         |     |
| Discitis                                      |                     |                      |      |                                               |         |     |
| One                                           | 1                   |                      |      |                                               |         |     |
| Two                                           | 61.06               | -85.13-207.26        | 0.412| -37.62                                         | -285.96-210.72| 0.765 |
| Three or more                                 | 261.98              | 98.49-425.48         | 0.002| -168.55                                        | -437.66-10.55| 0.218 |
| Abscess (paravertebral or epidural)           | -106.04             | -236.98-24.91        | 0.11 |                                               |         |     |
| Approach                                      |                     |                      |      |                                               |         |     |
| Anterior                                      | 1                   |                      |      |                                               |         |     |
| Posterior                                     | 91.81               | -35.80-219.42        | 0.158| 124.82                                         | -3.92-253.55| 0.057 |
| Combined                                      | 282.30              | 46.97-517.64         | 0.019| 325.77                                         | 87.11-564.43| 0.008 |
| Levels of instrumentation                     |                     |                      |      |                                               |         |     |
| Two                                           | 1                   |                      |      |                                               |         |     |
| Three                                         | 56.09               | -94.10-206.28        | 0.463| 245.11                                         | -17.58-507.81| 0.067 |
| Four or more                                  | 432.05              | 298.97-565.14        | <0.001| 536.54                                         | 309.21-763.88| 0    |
| Operative time                                | 2.71                | 2.23-3.18            | <0.001| 2.33                                           | 1.64-3.02| <0.001 |


predictor of allogenic blood transfusion in perioperative duration for patients underwent surgery. However, through our analysis, preoperative hemoglobin is not a predictor of perioperative blood transfusion for patients with spinal tuberculosis. Our data revealed that preoperative hemoglobin level had a significant correlation with intraoperative high blood loss. A previous study showed that preoperative low hemoglobin level increases the postoperative complications for patients with spinal tuberculosis. In addition, several studies showed that preoperative anemia is associated with poor outcomes after surgery and increased health care use. Therefore, correction of preoperative anemia may contribute to improve the outcome in spinal tuberculosis surgery.

Several clinical factors, including the higher number of involved discitis, higher levels of instrumentation and combined surgical approach, was found that correlated to the increased rate of blood transfusion and intraoperative blood loss. However, after adjusting for interaction between covariates by multivariate analysis, the influence of these factors was not significant, and only the odds of transfusion increased by 4.5 times for the patients with pathological fracture or kyphosis. The choice of surgical approach was reported to be linked to the intraoperative blood loss. Previous studies reported that one-stage anterior operation had advantages when compared to posterior instrumentation, as both instrumentation and grafting are done as single-stage surgery through the same incision, which may minimize total blood loss. In contrast, other studies illustrated that posterior approach favors less intraoperative blood loss. This difference may be attributed to the preference and experience of the surgeons. Usually, combined approach often leads to prolonged operative time and more blood loss, which may be associated with significant kyphosis and multiple-level lesion. Furthermore, our investigation revealed that increased operative duration is strongly associated with higher likelihood of blood transfusion and higher amount of blood loss. Four or more levels of instrumentation is also a risk factor of intraoperative high blood loss. In fact, operating time and blood loss are associated with an increase in the number of levels fused or instrumentation in spine surgery. Kumar reported results of their review of 243 patients undergoing surgery for metastatic spinal tumors and identified primary tumor, type of surgery, and prolonged surgery time as factors predicting increased blood loss.

Our results showed that female and lower BMI were risk factors for blood transfusion. The possible explanation for the relationship of gender and BMI to blood transfusion is that smaller body size may increases the intraoperative blood loss. In our cohort, the mean age is 49.5 ± 15.6 years old. In North America, Europe and China, tuberculous spondylodiscitis is more commonly seen in adult patients with a mean age of 40 years. It has been reported that advanced age did not increase the morbidity associated with spinal operation. For most patients, robust compensatory mechanisms render hypotension an insensitive indicator of shock until more than 30% of the patient's blood volume has been lost, therefore intraoperative blood loss over 30% of the total blood volume was set as cutoff in this study. Intraoperative cues indicative of intraoperative blood transfusion includes low hematocrit and hemoglobin (<70 g/L), higher heart rate (>120 beats/min), a weak peripheral pulse, cool extremities with pale or mottled skin and so on.
There were several limitations to the study. This was a retrospective study and may have been limited sample size. A multicentered study is still warranted. Almost all the patients in this cohort were spondylodiscitis. Atypical form of spondylitis without disc involvement was not included in this study. There is also a lack of clinical information on commodities, medications, nutritional status and other variables. Tranexamic acid was not applied on patients in this cohort, therefore its effect on spinal tuberculosis surgery was not evaluated. It is reported that tranexamic acid could reduce both intraoperative-perioperative allogeneic transfusion rates and operative time in spinal surgeries.\textsuperscript{13} A recent study demonstrated that Tranexamic acid contributes to reduce the drainage and blood transfusion perioperative duration of tuberculosis patients, but it can't decrease intraoperative blood loss.\textsuperscript{11} Additionally, the cause of transfusion was not collected, but patients typically get transfused when their hemoglobin is less than 70 g/L and they present a change of symptomatic or vital signs. However, despite such limitations, we believe that we collected several important clinical variables that allowed us to calculate relationships between the evaluated surgeries and blood loss and risk of blood transfusions.

**Conclusions**

In conclusion, the findings from this study have substantial implications for perioperative management in patients with spinal tuberculosis. The study showed a significant variation in perioperative transfusion based on gender, vertebral collapse/kyphosis, BMI and intraoperative blood loss. Furthermore, the relationship between increased intraoperative blood loss and predictors was identified, including higher BMI, more levels of instrumentation, combined approach and prolonged operative time were linked to higher intraoperative blood loss. An understanding of these factors may contribute to preoperative planning and minimize postoperative complications.

**Abbreviations**

BMI—Body Mass Index

**Declarations**

**Ethics approval and consent to participate:** All subjects were familiarized with the experimental procedure and associated risks and the informed consent obtained from study participants was verbal. Because this study concealed relevant information such as patient's identifiable name, date of birth, contact information, and only retained the patient's gender, age, diagnosis, cause of disease, related auxiliary examination results, related medical history, and treatment effects. Essential information for identity research. This study was approved by The second affiliated Hospital of Haerbin Medical University review board and the committee's reference number is KY2019-246.

**Consent for publish:** All authors and the patients consent the manuscript for publication.
**Availability of data and materials:** The data used to support the findings of this study are available from the corresponding author upon request.

**Competing interests:** The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

**Funding** This work supported by the Fund of HMU-2nd Affiliated Hospital for Outstanding Young Scholars (Wang, YF).

**Authors’ contributions:** CS designed the study, performed all experiments and wrote the manuscript; CL designed the experiments, contributed to manuscript preparation; RW, QZ and FW contributed to manuscript preparation and helped data collection; YW, SW carried out making tables; JY conceived of the study and participated in its design. All authors have read and approved the manuscript, and ensure that this is the case. There is no conflict of Interest.

**Acknowledgments:** None.

**References**

1. Basques BA, Fu MC, Buerba RA, Bohl DD, Golivaux NS, Grauer JN: Using the ACS-NSQIP to identify factors affecting hospital length of stay after elective posterior lumbar fusion. *Spine (Phila Pa 1976)* 2014; 39:497-502.
2. Cannon JW: Hemorrhagic Shock. *N Engl J Med*, 2018; 378:370-379.
3. Carling MS, Jeppsson A, Eriksson BI, Brisby H: Transfusions and blood loss in total hip and knee arthroplasty: a prospective observational study. *J Orthop Surg Res*, 2015; 10:48.
4. Chen Y, Yang JS, Li T, Liu P, Liu TJ, He LM, et al: One-stage Surgical Management for Lumbar Brucella Spondylitis by Posterior Debridement, Autogenous Bone Graft and Instrumentation: A Case Series of 24 Patients. *Spine (Phila Pa 1976)*, 2017; 42:E1112-E1118.
5. Dai LY, Jiang LS, Wang W, Cui YM: Single-stage anterior autogenous bone grafting and instrumentation in the surgical management of spinal tuberculosis. *Spine (Phila Pa 1976)*, 2005; 30:2342-2349.
6. Dunn RN, Ben Husien M: Spinal tuberculosis. *Bone Joint J*, 2018; 100-B:425-431.
7. Durand WM, DePasse JM, Daniels AH: Predictive Modeling for Blood Transfusion After Adult Spinal Deformity Surgery: A Tree-Based Machine Learning Approach. *Spine (Phila Pa 1976)*, 2018; 43:1058-1066.
8. Elsamadicy AA, Adogwa O, Ongele M, Sergesketter AR, Tarnasky A, Lubkin DET, et al: Preoperative Hemoglobin Level is Associated with Increased Health Care Use After Elective Spinal Fusion (≥ 3 Levels) in Elderly Male Patients with Spine Deformity. *World Neurosurg.*, 2018; 112:E348-E354.
9. Erdem H, Elaldi N, Batirel A, Aliyu S, Sengoiz G, Pehlivanoglu F, et al: Comparison of brucellar and tuberculous spondylodiscitis patients: results of the multicenter "Backbone-1 Study". *Spine J*, 2015;
10. Fowler AJ, Ahmad T, Phull MK, Allard S, Gillies MA, Pearse RM: Meta-analysis of the association between preoperative anaemia and mortality after surgery. Br J Surg, 2015;102:1314-1324
11. Geng T, Chen; Y, Zhang L: Safety and efficacy of tranexamic acid in the application of spinal tuberculosis surgery. Int J Clin Exp Med, 2017;10:7
12. Hassan K, Elmorshidy E: Anterior versus posterior approach in surgical treatment of tuberculous spondylodiscitis of thoracic and lumbar spine. Eur Spine J, 2016;25:1056-1063
13. Hui S, Xu D, Ren Z, Chen X, Sheng L, Zhuang Q, et al: Can tranexamic acid conserve blood and save operative time in spinal surgeries? A meta-analysis. Spine J, 2018;18:1325-1337
14. Jain A, Sponseller PD, Newton PO, Shah SA, Cahill PJ, Njoku DB, et al: Smaller body size increases the percentage of blood volume lost during posterior spinal arthrodesis. J Bone Joint Surg Am, 2015;97:507-511
15. Janssen SJ, Braun Y, Wood KB, Cha TD, Schwab JH: Allogeneic blood transfusions and postoperative infections after lumbar spine surgery. Spine J, 2015;15:901-909
16. Jin W, Wang Q, Wang Z, Geng G: Complete debridement for treatment of thoracolumbar spinal tuberculosis: a clinical curative effect observation. Spine J, 2014;14:964-970
17. Kumar N, Zaw AS, Khine HE, Maharajan K, Wai KL, Tan B, et al: Blood Loss and Transfusion Requirements in Metastatic Spinal Tumor Surgery: Evaluation of Influencing Factors. Ann Surg Oncol, 2016;23:2079-2086
18. Li L, Xu J, Ma Y, Tang D, Chen Y, Luo F, et al: Surgical strategy and management outcomes for adjacent multisegmental spinal tuberculosis: a retrospective study of forty-eight patients. Spine (Phil Pa 1976), 2014;39:E40-48
19. Morcos MW, Jiang F, McIntosh G, Johnson M, Christie S, Wai E, et al: Predictors of Blood Transfusion in Posterior Lumbar Spinal Fusion: A Canadian Spine Outcome and Research Network Study. Spine (Phil Pa 1976), 2018;43:E35-E39
20. Park JH, Rasouli MR, Mortazavi SM, Tokarski AT, Maltenfort MG, Parvizi J: Predictors of perioperative blood loss in total joint arthroplasty. J Bone Joint Surg Am, 2013;95:1777-1783
21. Pellise F: Tuberculosis and Pott’s disease, still very relevant health problems. Eur Spine J 22 Suppl, 2013;4:527-528
22. Qureshi MA, Khalique AB, Afzal W, Pasha IF, Aebi M: Surgical management of contiguous multilevel thoracolumbar tuberculous spondylitis. Eur Spine J 22 Suppl, 2013;4:618-623
23. Ragab AA, Fye MA, Bohlman HH: Surgery of the lumbar spine for spinal stenosis in 118 patients 70 years of age or older. Spine (Phil Pa 1976), 2003;28:348-353
24. Skaf GS, Kanafani ZA, Araj GF, Kanj SS: Non-pyogenic infections of the spine. Int J Antimicrob Agents, 2010;36:99-105
25. Ulu-Kilic A, Karakas A, Erdem H, Turker T, Inal AS, Ak O, et al: Update on treatment options for spinal brucellosis. Clin Microbiol Infect, 2014;20:075-82
26. Wang H, Li C, Wang J, Zhang Z, Zhou Y: Characteristics of patients with spinal tuberculosis: seven-year experience of a teaching hospital in Southwest China. *Int Orthop*, 2012; 36:1429-1434

27. Wang LJ, Zhang HQ, Tang MX, Gao QL, Zhou ZH, Yin XH: Comparison of Three Surgical Approaches for Thoracic Spinal Tuberculosis in Adult: Minimum 5-Year Follow Up. *Spine (Phila Pa 1976)*, 2017; 42:808-817

28. Wang X, Pang X, Wu P, Luo C, Shen X: One-stage anterior debridement, bone grafting and posterior instrumentation vs. single posterior debridement, bone grafting, and instrumentation for the treatment of thoracic and lumbar spinal tuberculosis. *Eur Spine J*, 2014; 23:830-837

29. Yang P, Zang Q, Kang J, Li H, He X: Comparison of clinical efficacy and safety among three surgical approaches for the treatment of spinal tuberculosis: a meta-analysis. *Eur Spine J*, 2016; 25:3862-3874

30. Yanhua; C, Juan; L, Zixian; C, Xiaogang; Z, Jian D: Risk factors analysis of the postoperative complications in spinal tuberculosis patients. *Chinese Journal of Orthopaedics*, 2016; 36:1126-1132

31. Yin XH, Liu SH, Li JS, Chen Y, Hu XK, Zeng KF, et al: The role of costotransverse radical debridement, fusion and postural drainage in the surgical treatment of multisegmental thoracic spinal tuberculosis: a minimum 5-year follow-up. *Eur Spine J*, 2016; 25:1047-1055