

Risk factors and care of early surgical site infection after primary posterior lumbar interbody fusion



Original Article

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Abstract: Objectives: To explore the risk factors and nursing measures of early surgical site infection (SSI) after posterior lumbar interbody fusion (PLIF).

Methods: A total of 468 patients who received PLIF in our hospital from January 2017 to June 2020 were enrolled into this study. According to the occurrence of early SSI, the patients were divided into two groups, and the general data were analyzed by univariate analysis. Multivariate logistic regression analysis was conducted with the dichotomous variable of whether early SSI occurred and other factors as independent variables to identify the risk factors of early SSI and put forward targeted prevention and nursing measures.

Results: Among 468 patients with PLIF, 18 patients developed early SSI (3.85%). The proportion of female, age, diabetes mellitus and urinary tract infection (UTI), operation segment, operation time, post-operative drainage volume, and drainage time were significantly higher than those in the uninfected group, with statistical significance ($P < 0.05$), whereas the preoperative albumin and hemoglobin in the infected group were significantly lower than those in the uninfected group, with statistical significance ($P < 0.05$). There was no significant difference between the two groups in the American Society of Anesthesiologists (ASA) grading, body mass index (BMI), complications including cardiovascular and cerebrovascular diseases or hypertension ($P > 0.05$). Logistic regression analysis showed that preoperative diabetes mellitus (OR = 2.109, $P = 0.012$)/UTI (OR = 1.526, $P = 0.035$), prolonged drainage time (OR = 1.639, $P = 0.029$) were risk factors for early SSI. Men (OR = 0.736, $P = 0.027$) and albumin level (OR = 0.526, $P = 0.004$) were protective factors in reducing early SSI.

Conclusions: Women, preoperative diabetes/UTI, hypoproteinemia, and prolonged drainage time are risk factors for early SSI after PLIF. Clinical effective preventive measures should be taken in combination with targeted nursing intervention to reduce the risk of early SSI.

Keywords: incisional infection • nursing measures • posterior lumbar interbody fusion • risk factors • multivariate regression analysis

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1. Introduction

Following the rapid increase of the aging population in the society, the incidence of lumbar degenerative disease is rising annually. This often causes lower back

and limb pain, even leading to motor dysfunction, resulting in a huge economic burden to the patients, families, and society. Statistics shows that 3.6% of the world's

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population suffers from low back pain as a result of lumbar disease.¹ In 2010 alone, about 83 million people lost their working ability due to low back pain, and this trend will continue to rise with the growth in the aging population.² Surgical treatment still remains the best option for patients with poor outcomes following conservative treatment.³ Posterior lumbar interbody fusion (PLIF) is a procedure performed via a posterior lumbar approach aimed at nerve decompression, using bone grafts to fuse adjacent vertebral bodies, restoring vertebral height and stabilizing adjacent vertebral segments.⁴ This procedure has the following characteristics: complete decompression of nerve roots with symptom alleviation, restoration of vertebral column stability, and motor function improvement with a few complications.⁴ PLIF as a classic surgical procedure has been widely used for primary lumbar disk diseases, unstable lumbar segments, spondylolisthesis, spinal revision, lumbar spine tuberculosis, and so on.³ Following the widespread use of this technique, the associated complications have equally increased, including nerve injury, surgical site infection (SSI), bone graft nonunion, post-operative (post-op) degenerative changes of adjacent bony segments, and so on.⁵ One of the most severe early post-op complications is SSI. A 10-year follow-up study revealed that, primary lumbar surgeries have an infection rate of 9.2%, while revision surgery has a total infection rate of 14.1%.⁶ The incidence of SSI can lead to nerve injury, implant failure, sepsis, and can even lead to death and other more severe complications, often leading to prolonged hospitalization and high treatment costs; some patients even require debridement surgery and vacuum-assisted closure to enhance wound healing.⁵ In cases of severe infection, implants have to be removed with prolonged bed rest.⁶ Thus, regarding the incidence and treatment difficulty of SSI, medical personnel have to fully understand the risk factors of SSI and adopt specific prevention measures. The present study analyzed 468 cases for early SSI after PLIF, investigating its associated risk factors and stipulating specific nursing measures, enhancing collaboration among medical personnel, and providing a theoretical basis for reducing the incidence of early SSI after PLIF.

2. Methods

2.1. Inclusion and exclusion criteria

Inclusion criteria: (1) Conservative treatment ≥ 3 months without any significant improvement, continuous lower back, and limb pain or neurogenic claudication. (2) Progressive neurological dysfunction or cauda equina syndrome. (3) Above grade 2 spondylolisthesis and degenerative lumbar instability. (4) Patients undergoing

primary PLIF. (5) Patients with no cardiovascular or cerebrovascular incidents 6 months prior to surgery. (6) Complete medical history files.

Exclusion criteria: (1) Patients with coagulation disorders. (2) Patients with severe heart, liver or kidney complications. (3) Patients with severe poor nutritional status. (4) Patients undergoing revision lumbar surgery. (5) Patients who underwent any other surgeries during the perioperative period.

2.2. Demographics

Based on the aforementioned inclusion and exclusion criteria, 468 patients who underwent primary PLIF at our spine unit from January 2017 to June 2020 were recruited into the study; 237 were male and 231 were female with a mean age of 56.68 ± 8.24 years. A retrospective analysis was performed using electronic medical records. The present study was reviewed and approved by the hospital ethical committee and informed consent was obtained from all patients.

2.3. Surgical procedure

All patients received a posterior lumbar midline incision; a periosteal elevator was used to dissect and expose the lamina. Laminectomy and spinal decompression were then performed followed by complete discectomy, and the interbody fusion device was then inserted. Pedicle screws were placed with rods on either side, above and below the fusion level. After applying compression, the vertebral canal and intervertebral space were repeatedly irrigated with normal saline, hemostasis was strictly secured, a surgical drain was inserted, and the surgical site sutured in layers. Intraoperative blood loss was meticulously recorded. The anesthesiologist regulated the blood pressure during the operation, maintaining the blood pressure at around 110/70 mmHg.

Apart from routine post-op infection prophylaxis, all the patients were drilled on bed exercises; intermittent pneumatic compression of the lower limbs was applied to prevent deep vein thrombosis. The surgical drain was removed within 3 d, depending on the amount of drainage. Clean dry wound dressings were changed after 3 d, while soiled dressings were changed immediately till the patients were discharged.

2.4. Evaluation criteria for SSI

During hospital stay, if patients presented with rigors, fever without any obvious cause, heat, pain, redness and swelling around the wound on inspection with or without pus discharge, positive bacterial culture of drainage fluid, or wound discharge, SSI was determined based on

fulfilling any of the following criteria: (1) Wound inspection by a surgeon or dehiscence revealing purulent discharge with local tenderness or pain and body temperature $>38^{\circ}\text{C}$. (2) Deep wound purulent drainage or purulent fluid on needle aspiration. (3) Radiological examination, surgical site exploration, or histopathological examination revealing deep incision site abscess or the presence of any other evidence of infection.⁷

2.5. Observation indices

Records indicated whether or not patients presented with early SSI after PLIF. Patient baseline data was collected including, gender, age, American Society of Anesthesiologists (ASA) score, body mass index (BMI), preoperative comorbidities, albumin and hemoglobin levels, operated level, operative time, intraoperative blood loss, intraoperative allogeneic blood transfusion, post-op drainage, and draining time.

2.6. Statistical method

The statistical software pack SPSS version 24 was used for analysis, measurement data was expressed as mean $\pm$ standard deviation ($\bar{x} \pm s$), and independent *t* test was used to compare groups; count data was expressed as “n” and the chi square test was used, Wilcoxon rank sum test was used for ranked data, logistic regression analysis was performed with the binary dependent variable as “occurrence or not of SSI,” and “other factors” as independent variables; $P < 0.05$ was considered as statistically significant.

3. Results

3.1. Incidence of early SSI after PLIF

Based on the aforementioned post-op evaluation criteria for SSI, 18 of the 468 cases had SSI, accounting for 3.85% of the patients.

3.2. Univariate comparison between the SSI and non-SSI groups

Based on the occurrence or not of early SSI post-operatively, patients were divided into two groups: SSI group with 18 patients and non-SSI group with 450 patients. Patient baseline data for both groups accorded with the normal distribution and homogeneity of variance; the results are illustrated in Table 1. For the SSI group, the female proportion, age, preoperative comorbidities (diabetes and urinary tract infection [UTI]), operated level, operative time, post-op

drainage, and draining time were all higher than the non-SSI group and the differences were statistically significant ($P < 0.05$). On the other hand, the SSI group preoperative albumin and hemoglobin levels were all lower than the non-SSI group, and the differences were statistically significant. Differences in ASA score, BMI, preoperative cardiovascular, cerebrovascular disease or hypertension, intraoperative blood loss, and intraoperative allogeneic blood transfusion between both groups were not statistically significant ($P > 0.05$).

3.3. Multivariate analysis of factors affecting early SSI occurrence after PLIF

Results of multiple logistic regression analysis with the binary dependent variable as “occurrence or not of SSI” and “other factors” as independent variables are shown in Table 2. The validity of the model was tested with chi square test ($\chi^2 = 82.462$, $P < 0.001$), the classification ability of the model was 83.53%. The results indicate that preoperative diabetes, preoperative UTI, and prolonged post-op draining time are SSI risk factors following PLIF surgery ($P < 0.05$). For males, preoperative albumin level is a protective factor for SSI.

3.4. Nursing measures for early prevention

Based on the above results, the following specific preventive measures to reduce SSI incidence after PLIF can be put forward: (1) A complete preoperative assessment should be performed in order to control risk factors like diabetes and UTI, especially in female patients, preoperative baths, skin shaving and preparation should be thorough, skin injury should be avoided, aim for skin shaving 2 h before surgery, preoperative blood sugar levels should be monitored closely, with the collaboration of the attending surgeon, and blood sugar levels should be brought down to safe levels. (2) Scrub nurses have to ensure strict aseptic technique during the procedure, work hand in hand with the operating surgeon to reduce operative time as much as possible, operating room nurses have to limit personnel entering and exiting the theater, and prepare all necessary surgical supplies all at once before surgery. Attention should be paid to keep patients warm, and the operation theater room temperature should be optimized. (3) On post-operation days (POD) 1–3, if there is wound discharge, dressing has to be immediately changed and kept clean and dry. Dressings should be routinely changed in the morning of POD 3 and wound healing assessed. If wound healing is satisfactory, from POD 4–13, dressings should be routinely changed once every 3 d, on POD 14 stitches should be removed and the patient offered

Variables	SSI group (n = 18)	Non-SSI group (n = 450)	Statistical value	P value	OR	95% CI	
						Lower limit	Upper limit
Gender (male/female)	5/13	242/208	$\chi^2 = 3.922$	0.047**	1.769	1.159	3.154
Age (years, $\bar{x} \pm s$)	59.72 $\pm$ 7.19	56.34 $\pm$ 8.53	$t = 2.472$	0.012***	2.106	1.267	4.171
ASA score (e.g., I/II/III)	9/7/2	192/238/20	$Z = -0.774$	0.452**	0.972	0.984	1.013
BMI (kg/m ²)	23.92 $\pm$ 3.11	24.28 $\pm$ 3.21	$t = 0.054$	0.955*	1.001	0.998	1.005
Preoperative comorbidities							
cardiovascular or cerebrovascular disease (e.g., yes/no)	2/16	33/417	$\chi^2 = 0.216$	0.635*	0.805	0.475	1.592
Diabetes (e.g., yes/no)	9/9	45/405	$\chi^2 = 24.705$	<0.001***	1.035	1.127	1.225
Hypertension (e.g., yes/no)	4/14	76/374	$\chi^2 = 0.060$	0.805*	1.168	1.117	1.692
UTI (e.g., yes/no)	7/11	29/421	$\chi^2 = 23.131$	<0.001***	1.006	1.002	1.021
Preoperative albumin (g/L)	36.12 $\pm$ 3.20	40.27 $\pm$ 3.08	$t = -2.739$	0.018***	1.702	1.049	2.283
Preoperative hemoglobin (g/L)	134.27 $\pm$ 7.38	138.52 $\pm$ 8.59	$t = -3.658$	0.008***	1.533	1.063	2.161
Operated level (e.g., single level/multiple levels)	5/13	289/161	$\chi^2 = 13.621$	<0.001***	1.701	1.129	2.147
Operative time (min)	206.37 $\pm$ 15.58	181.15 $\pm$ 13.12	$t = 8.515$	<0.001***	1.604	1.302	2.315
Intraoperative blood loss (mL)	262.24 $\pm$ 51.30	258.35 $\pm$ 49.06	0.320	0.731*	1.157	1.078	1.703
Intraoperative allogeneic blood transfusion (e.g., yes/no)	2/16	45/405	0.047	0.825*	1.021	1.019	1.475
Post-operative drainage (mL)	329.27 $\pm$ 53.69	291.52 $\pm$ 48.71	3.246	0.001***	1.005	1.035	1.081
Post-operative draining time (d)	2.41 $\pm$ 0.45	2.02 $\pm$ 0.41	4.145	<0.001***	1.028	1.205	2.039

Note: ASA, American Society of Anesthesiologists; BMI, body mass index; SSI, surgical site infection; UTI, urinary tract infection.

*Statistically non-significant; **Statistically significant; ***Statistically highly significant.

Table 1. Baseline data and univariate comparison between both groups.

Variables	Regression coefficient	Standard error	P value	OR	95% CI	
					Lower limit	Upper limit
Gender	-0.235	0.163	0.027	0.736	0.437	1.285
Preoperative diabetes	0.778	0.315	0.012	2.109	1.175	3.866
Preoperative UTI	0.510	0.162	0.035	1.526	1.008	2.869
Preoperative albumin	-0.602	0.276	0.004	0.526	0.317	0.925
Time of draining	0.539	0.175	0.029	1.639	1.196	3.053

Note: PLIF, posterior lumbar interbody fusion; SSI, surgical site infection; UTI, urinary tract infection.

Table 2. Multivariate logistic regression analysis results for early SSI after PLIF.

a lumbar brace on discharge with follow-up outpatient appointment at 6 weeks post-operation. During dressing change, the wound and surrounding skin is cleaned with antiseptic solution, and covered with sterile gauze.⁸ Silver sulfadiazine-impregnated hydrocolloid dressing with anti-inflammatory and antimicrobial properties can be used to cover the wound.⁷ Dressings have to

be timely changed if there is discharge or fecal/urinary soiling. Before the patient goes to the toilet, the wound dressing can be covered with an extra adherent film, which can be taken off after to prevent dressing soiling. On POD 14 during the wound inflammation phase, 10% NaCl can be used to moisten the dressing which is covered externally with sterile gauze for protection. Elastic

adhesive bandage can be used to reduce local wound tension and stimulate healing. After removal of stitches, patients have to be reminded absolutely not to bend the waist or lift heavy weights and so on. They should sleep on hard mattresses, maintain correct standing, sitting and lying postures, and lifting weights less than 5 kg only should be allowed 6 months post-operation.⁸ Attention should be paid to the wound surrounding skin protection and prevention of wound dehiscence. Post-op surveillance of the surgical drain should be intensified, a sterile dressing should be placed over the drain insertion site and kept dry and clean, the draining should be closely monitored and tube clogging prevented, normal saline can be used to flush the tube when necessary, strict monitoring of the indications for drain removal, when the drainage fluid reduces and is clear, and the drain can be removed so as to avoid secondary infection from long-term indwelling tubes; (4) after the effects of anesthesia have worn off, patients should be instructed to begin limb joint activities, and isometric and isotonic muscle exercises. Each exercise should include 10 s of muscle contraction and 10 s of relaxation, 10 exercises per set, 10 sets per session, one session thrice daily, that is, in the morning, afternoon, and evening.⁸ Three to five days post-operation, patients should be guided on performing straight leg raising exercise of both the lower limbs to prevent nerve root adhesion. Post-op 2 weeks, patients are instructed on using bridges method for lower back muscle exercise, 20 exercises per session 3 times daily, based on patient physical strength; the number can be gradually increased to 50 each time. Post-op 2 weeks, lower limb venous Doppler should be performed. If thrombosis is present, lower limbs should be elevated to stimulate venous backflow. Massage and warm compresses of the lower extremities as well as strenuous exercises of the lower limbs should be avoided to prevent thrombosis detachment. After patients have started mobilizing out of bed, the leg raising exercise can be progressively increased, and aerobic exercises such as *taichi*, *baduanjin*, and *qigong* can be performed as pain allows. These perioperative modalities are important for promoting early rehabilitation of geriatric patients, prevention of SSI, and occurrence of other complications.

Based on the aforementioned inclusion and exclusion criteria, 327 patients who underwent primary PLIF at the spinal department of our hospital from August 2020 to August 2022 were managed based on the early prevention protocol. Participant demographics include 169 male, 158 female; average age (58.74 ± 6.02) years. This study was approved by the hospital ethics committee and all participants signed consents prior to participation. Results revealed that (1) 7 of the 327 PLIF patients developed early SSI post-operatively, accounting for 2.14%, lower than previous records. Wound

sample cultures were taken for all infections; 4 had a positive culture growth with 4 different bacteria including *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Escherichia coli*, and *Enterococcus*. Five cases were managed successfully with just antibiotics and wound hygiene. The other 2 cases could not be resolved by antibiotics, so debridement surgery was performed. On discharge all SSI cases were symptomatically controlled and antibiotics were stopped. Implant material were not removed (Figure 1). (2) With regard to patient satisfaction, the "Patient discharge nursing satisfaction questionnaire" designed in 2010 by Zhang et al.⁹ was used for the small group. The questionnaire comprises 5 domains (Patient care, Service attitude, etc.), and 15 items. Each item has 3 scales scored at 1 point, 3 points, and 5 points. The total scores are calculated as "score obtained/75(total score) $\times$ 100%", and reliability of the questionnaire is 0.840. The questionnaires were administered to patients on the day of discharge by the nurse in charge. Questionnaires were filled and collected on-site. Results showed that, patient satisfaction on discharge was 93.22 ± 2.40 points; this was higher than previous scores, with statistically significant difference ($t = 15.38$, $P < 0.05$).

4. Discussion

Posterior lumbar internal fixation is a common clinical procedure for the treatment of lumbar degenerative disease. This procedure can fully relieve nerve root compression, reconstruct spinal height and stability, and alleviate clinical symptoms.¹⁰ As a classical spine surgery procedure, posterior lumbar internal fixation is a widely accepted and used technique, its surgical complications have also gradually become clearer amongst which early SSI is the most prominent. This often leads to longer hospitalization, and in severe cases debridement and removal of implants are necessary, causing poor prognosis which greatly affects the surgical outcome.¹¹ Identifying and assessing SSI risk factors preoperatively, and taking necessary measures can reduce the incidence of infection. Pei et al.¹² defined factors that increase post-op infection into three categories: pre-operative, intra-operative, and post-operative factors. Preoperative factors include age (>60 years), smoking, male, alcoholic, obesity ($\text{BMI} > 30 \text{ kg/m}^2$), malnutrition, weight loss, and so on. Intraoperative factors include: prolonged operative time, high blood loss, inadequate irrigation, less than 50% intraoperative inspired oxygen fraction, and so on. Post-op factors include: prolonged hospital stay time, prolonged drain and urinary catheter duration times, and so on. Different studies have different reports on risk factors.¹² In the present study, 18 of the 468 patients had early SSI after posterior lumbar

internal fixation. The infection rate was 3.85%, much lower than that reported in previous studies; this may be due to the high standard of nursing measures employed during the perioperative period, which reduced the infection incidence rate. The study¹³ showed that the Orem's Self Care Theory has positive application effects in elderly patients with lumbar SSI. Assessing patient and family members' self-care ability, and developing tailored self-care plans, can reduce the infection rate and incidence of other complications, increase nursing satisfaction, and improve the patient's quality of life. The study¹³ also showed that nursing based on the Knowledge-Attitude-Behavior theory can effectively improve blood markers for SSI in patients undergoing orthopedic surgery. Another study¹⁴ applied the concept of accelerated surgical rehabilitation on PLIF patient's perioperative management. This can effectively reduce the post-op SSI incidence, regulate inflammatory markers into a reasonable range, and promote patient rehabilitation prognosis. Traditional Chinese Medicine (TCM) intervention methods such as based on TCM analysis, providing patients with Chinese herbal decoction prescriptions for promoting blood circulation and pain relief, antimicrobial and anti-inflammatory effects, fever relief and detoxification effects (Chinese prescriptions include: *Mu Xiang*, *Qing Pi*, *Hou Po*, *Huang Qi*, *Huang Lian*, *Lian Chi*, *Jin Yin Hua* etc. decocted in water), all these can prevent wound infection.¹⁵ Others have used moxibustion at the wound site and "three yin intersection point" to eliminate cold and dampness, regulate yin-yang function thus accelerating wound healing.¹⁶ This study analyzed the risk factors of early SSI in patients undergoing primary PLIF, thus excluding the possible influence from lumbar revision surgery cases. Multivariate logistic regression analysis results showed that preoperative diabetes or UTI and prolonged draining time are risk factors for early SSI, while in males, albumin level is a protective factor for early SSI.

Previous studies have shown that patients with diabetes have a significantly increased risk of early SSI after PLIF. Diabetic patients have increased blood vessel fragility, large numbers of micro-vessels are ruptured and occluded during the operation, resulting in poor local blood supply at the incision site, affecting wound healing, and even inducing infection. Also, due to high baseline blood sugar levels and immunosuppression in diabetic patients, the microenvironment around the incision is a good medium for bacterial growth. Thus, during the perioperative period, any small amounts of pathogens can induce infection. This is also consistent with the results from the study by Hikata,¹⁷ among 36 patients with type 2 diabetes who underwent thoracolumbar fusion, 6 had early SSI, with an infection rate of up to 16.7%, while among 309 patients with no diabetes

just 10 patients had SSI with an infection rate of 3.2%. In addition, further studies have also shown that when glycosylated hemoglobin levels were less than 7%, there was no incidence of SSI, but when glycosylated hemoglobin levels were higher than 7%, the post-op incidence of early SSI increased by 35.3%. The present study used logistic regression analysis to show that diabetes was an independent risk factor for early SSI after PLIF (OR = 2.109, $P = 0.012$), the risk of infection in patients with diabetes was 2.109 times that of non-diabetic patients. Therefore, for diabetic patients, nursing staff should closely monitor and strictly control their blood sugar levels, and effectively communicate and educate all parties involved. The study by Nakamura et al.¹⁸ showed that in diabetic patients, preoperative blood sugar levels >6.9 mmol/L, and post-op levels >11.1 mmol/L can significantly increase infection risks, thus, adequate management of perioperative blood sugar levels in diabetic patients can reduce the risks of infection. Based on Berríos-Torres et al.⁸, blood sugar levels in diabetic patients should be maintained at 200 mg/dL.

Presently, there are few studies on UTI and early SSI with controversies on the relationship between both. Results from the present study indicated that preoperative UTI was a risk factor for early SSI post-operatively (OR = 1.526, $P = 0.035$). Golubovsky et al.¹⁹ in his retrospective analysis of 1592 patients who underwent lumbar fusion surgery, found that some patients with UTI developed sepsis, which finally led to acute SSI. Pei et al.¹² conducted a retrospective analysis of 330 patients who underwent PLIF. Although results from the logistic regression analysis did not indicate UTI as an independent risk factor, the univariate analysis results revealed a statistically significant difference ($P = 0.009$) between patients with UTI and those without UTI for acute SSI after PLIF. Although the relationship between UTI and SSI after PLIF is not clear, the results of this study show that it is an independent risk factor for SSI. We believe that this may be caused by the direct migration of urinary tract bacteria or hematogenous spread to the incision site leading to the release of large amounts of pro-inflammatory factors. Thus, with regard to patients with UTI, more care and attention is required for indwelling urinary catheters, and the characteristics of the urine have to be monitored, noting any turbidity or other abnormalities.²⁰ Preventive measures for UTI include choosing appropriate catheter tube size, following aseptic technique, improving perineal hygiene, and encouraging patients to increase oral fluid intake. Clinical research has shown that, instructing patients to avoid too much intake of mineral rich foods, and encouraging patients to increase fluid intake (2500–4000 mL/d), but limited to <2000 mL/d with an average rate of 125 mL/h during intermittent catheterization, can effectively reduce UTI

with physiologic internal flushing replacing mechanical flushing of the urinary tract.¹⁹ Generally, 72 h of continuous catheterization can lead to bacteria growth and proliferation in urine. Bladder function recovery is closely related to infection. Therefore, if there are no obvious issues 2 d after surgery, urinary catheters should be taken out as soon as possible.¹⁹

Unlike hip or knee arthroplasty, placement of surgical drains after spinal fusion surgery is considered an effective way of reducing the risk of infection and preventing epidural hematoma.²⁰ Placing of drains can timely evacuate effusions and seroma from the surgical site; however, the drainage tube is a foreign material communicating with the external environment, so prolonged indwelling can increase post-op infection risk. The results of this study showed that each time draining was prolonged by 1 d, the probability of post-op infection increased by 0.639-fold (OR = 1.639, $P = 0.029$). Therefore, drains should be removed as soon as the removal indications are met. During the draining time, close monitoring and care of the drain and wound is required, and the drain insertion site should be kept sterile.²¹ Post-operatively, we routinely leave 1–2 drains around the incision. If there was no CSF leak intraoperatively, negative pressure drainage can be used to enhance hematoma elimination. Based on our department management protocols, we change wound dressing POD 1 with strict antiseptic cleaning of the wound and drain puncture site, skin drain site is covered with gauze, drainage bulb reservoirs are not changed except when full, and wound contact with the external environment is kept to a minimum. The criteria for drain removal is drainage fluid less than 50 mL for 24 h.²¹ In clinical practice if there was no CSF leak, drains are taken out on POD 2 or POD 3. This is based on some research reports which indicate that indwelling drains for more than 5 d is a risk factor for infection.²⁰ Thus, meticulous intraoperative hemostasis has to be observed to facilitate early drain removal; a single drain can be used based on clinical judgement; surgical wound and drain hygiene have to be observed for the duration time of the drain; drain exposure to the external environment should be reduced; skin drain sites should remain sterile.

Preoperative albumin and hemoglobin levels can better reflect the patient's immune and nutritional status. This study revealed that preoperative albumin level is a protective factor for early SSI after PLIF (OR = 0.526, $P = 0.004$). This is consistent with the results of previous studies. McGirt et al.²⁰ stated that patients with albumin levels less than 35 g/L after PLIF have a significantly higher risk of post-op infection.²² Therefore, for patients with poor perioperative nutritional status, the nursing should involve education, eliminate anxiety, and improve

patients' nutritional status to reduce the occurrence of complications after PLIF.²² Encourage patients to consume diets with high calorie, protein and vitamins, easily digestible foods. Red blood cells, plasma, and albumin transfusions can be administered if required to increase immunity.²²

There is limited research on the association between male gender as a risk factor and post-op infection. Other than the positive results mentioned above, males are a protective factor for early SSI after PLI surgery. This result further justifies reports from previous studies. We believe that this might be due to low baseline hemoglobin levels in females, thicker subcutaneous fat at the surgical site, and because female patients are more prone to post-op fat liquefaction around the incision leading to delayed healing and secondary infection.²² Thus, with regard to elective PLIF procedures in female patients, the nursing staff have to intensify perioperative care, especially the inspection of wound dressings, ensuring that it remains clean and dry.²³

Limitations of the present study include the following: (1) The study is a retrospective analysis; all the data used were from the hospital medical records system and phone call follow-up. This can easily lead to selection bias and recall bias. A further prospective study can justify the results from this study. (2) This study is a single-center study, with a relatively small number of cases. A larger-sample multi-center study can be further conducted to clarify the risk factors of SSI. (3) The study²⁴ suggests that fat infiltration into the multifidus muscle increases its post-op healing difficulty, thus increasing soft tissue necrosis and risk of dead space formation, and ultimately increasing post-op infection risks. So, comparing multifidus muscle fat proportion in both groups can be used to clearly elaborate the relationship between multifidus muscle and post-op SSI. We seldom perform post-op MRI assessment because we almost never have any post-op issues; thus, we do not have the data to further prove the relationship between multifidus and post-op infection, and further research is required to establish this.

5. Conclusions

In summary, early SSI after PLIF not only prolongs patient recovery, but also increases hospitalization. In severe cases, a second operation is required, which increases economic burden. Females, preoperative diabetes/UTI, hypoalbuminemia, and prolonged draining time are risk factors for early SSI after PLIF. Therefore, targeted measures should be taken during clinical care of patients with these risk factors in the perioperative period to reduce the risk of early SSI.

Ethical approval

Ethical issues are not involved in this paper.

Conflicts of interest

All contributing authors declare no conflicts of interest.

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