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The impact of obstructive sleep apnea on early surgical site infections in elderly PLIF patients: a retrospective propensity score-matched analysis

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Abstract

Background Obstructive sleep apnea (OSA) is a prevalent sleep disorder associated with intermittent hypoxia, oxidative stress, and systemic inflammation, posing risks for adverse postoperative outcomes, including surgical site infections (SSIs). Elderly patients undergoing posterior lumbar interbody fusion (PLIF) are particularly susceptible to SSIs due to advanced age, comorbidities, and prolonged surgical times. However, the role of OSA in increasing SSI risk among this population remains unclear.

Methods This retrospective cohort study analyzed 478 elderly PLIF patients from a single institution between May 2016 and June 2024. Of these, 113 were diagnosed with OSA. Propensity score matching (PSM) was performed to balance baseline characteristics, resulting in 83 matched pairs. SSI rates, hospital stays, and readmission rates were compared between the OSA and non-OSA groups. Subgroup analysis was conducted to evaluate the effects of continuous positive airway pressure (CPAP) or automatic positive airway pressure (APAP) therapy on postoperative outcomes.

Results After PSM, OSA patients demonstrated a significantly higher SSI incidence (13.3% vs. 3.6%, $p=0.04$) compared to non-OSA patients. On multivariate analysis, OSA was the only factor that remained significantly associated with an increased risk of SSIs (Odds Ratio = 4.509, 95% CI: 1.283–21.504, $p=0.03$). OSA patients also experienced longer hospital stays (10.1 ± 2.9 vs. 9.1 ± 2.0 days, $p=0.01$) and elevated 30-day readmission rates (9.6% vs. 1.2%, $p=0.02$). Subgroup analysis revealed that CPAP/APAP therapy reduced SSI incidence (3.9% vs. 17.5%, $p=0.08$) and shortened hospital stays (9.1 ± 1.5 vs. 10.5 ± 3.2 days, $p=0.03$) among OSA patients.

Conclusion OSA significantly increases the risk of early SSIs and prolongs hospital stays in elderly PLIF patients. Subgroup analysis suggests that CPAP/APAP therapy may have benefits to OSA patients, though this association requires validation through prospective studies. These findings emphasize the importance of preoperative OSA screening and management to improve surgical outcomes in this high-risk population.

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Keywords Obstructive sleep apnea, Surgical site infections, Posterior lumbar interbody fusion, Elderly patients, Perioperative management

Introduction

Obstructive sleep apnea (OSA) is a common sleep-related breathing disorder characterized by recurrent upper airway obstruction during sleep, resulting in intermittent hypoxia, oxidative stress, and systemic inflammation [1]. Affecting up to 38% of the adult population, OSA is a growing public health concern, particularly in elderly individuals who frequently present with multiple comorbidities [2]. Its consequences extend beyond impaired sleep quality to increased risks of cardiovascular disease, metabolic syndrome, and impaired immune function [3, 4].

Surgical patients with OSA face a heightened risk of adverse perioperative outcomes, including delayed recovery and higher rates of complications such as infections [5, 6]. Postoperative wound healing, a critical determinant of surgical success, is an intricate biological process dependent on adequate oxygenation, collagen synthesis, and a balanced inflammatory response [7, 8]. Intermittent hypoxia associated with OSA disrupts these pathways, potentially impairing tissue repair and increasing susceptibility to surgical site infections (SSIs) [6, 9].

In elderly patients undergoing posterior lumbar interbody fusion (PLIF), a standard procedure for addressing degenerative spinal disorders, the risk of early SSIs is already elevated due to advanced age, prolonged surgical times, and frequent comorbid conditions such as diabetes mellitus and obesity [10–12]. The presence of OSA as an additional risk factor may further exacerbate this vulnerability. Despite these concerns, the role of OSA in influencing SSI rates among PLIF patients remains underexplored.

This study aims to evaluate the impact of OSA on postoperative SSI rates in elderly patients undergoing PLIF. By analyzing retrospective cohort data, we seek to determine whether OSA serves as an independent risk factor for SSIs and to highlight the need for targeted perioperative management strategies. Through this investigation, we hope to provide insights into the implications of preoperative OSA screening and management in improving surgical outcomes in this high-risk population.

Methods

Study design and patient selection

This was a retrospective cohort study conducted in our department. Patients aged above 65 years who underwent PLIF during May 2016 to June 2024 were considered for inclusion. Exclusion criteria encompassed prior lumbar spine surgeries, active infections or antibiotic use at the time of surgery, known immunocompromised conditions (such as ongoing chemotherapy, advanced HIV, or chronic corticosteroid therapy), incomplete or missing key data in medical records (absence of essential preoperative variables, missing documentation of OSA diagnosis, or insufficient postoperative follow-up data for SSI assessment). All procedures and methods were approved by the research ethics committee of the college, and informed consent was obtained from all participants. All protocols were conducted in compliance with the ethical principles outlined in the Declaration of Helsinki.

Data collection

Patient data were extracted from electronic medical records, including demographics (age, sex, body mass index), comorbidities (diabetes mellitus, hypertension), smoking status, and American Society of Anesthesiologists (ASA) physical status classification. OSA diagnosis was confirmed through preoperative polysomnography reports or documented clinical diagnoses. Surgical details such as operative time, blood loss, and the use of instrumentation were also recorded.

SSI identification and outcome measures

The identification of SSIs was based on microbiological cultures, operative and hospital records, laboratory reports, and clinical symptoms of infection. Clinical assessments included daily wound inspections by attending surgeons during hospitalization followed by weekly outpatient evaluations until postoperative day 30, with documented criteria requiring either localized signs (erythema extending > 2 cm from incision margins, swelling, tenderness, or purulent discharge) or systemic manifestations (oral temperature > 38.5 °C on consecutive measurements or unexplained C-reactive protein elevation > 50 mg/L). Microbiological confirmation followed stratified protocols: superficial infections required wound swab cultures demonstrating $\geq 10^5$ CFU/mL of pathogenic organisms, while deep/organ-space infections mandated intraoperative tissue cultures or image-guided aspiration specimens, with all culture results interpreted independently by two blinded microbiologists. Centers for Disease Control and Prevention (CDC) criteria application involved a three-tier verification process comprising initial assessment by the surgical team using standardized checklists, secondary validation by infection control specialists, and final adjudication by a senior surgeon for discordant cases, supplemented by contrast-enhanced MRI or CT evidence of abscess formation for deep infections. The primary outcome was the occurrence of SSIs within 30 days postoperatively, classified

according to the CDC criteria into superficial incisional, deep incisional, and organ/space infections. Secondary outcomes included length of hospital stay and readmission rates related to SSIs.

CPAP/APAP therapy implementation

CPAP or APAP therapy was prescribed to patients with moderate to severe obstructive sleep apnea (OSA), defined by an apnea-hypopnea index (AHI) ≥ 15 events per hour, or to those with mild OSA (AHI 5–15 events per hour) who had significant symptoms such as daytime sleepiness. Device settings were individualized, with CPAP pressure typically set between 6 and 12 cm H_2O. APAP devices adjusted pressure based on airway resistance within this range. Therapy was initiated at least one week before surgery and continued postoperatively for a minimum of 4 h per night.

Surgical method

All surgeries were performed by the same experienced surgical team. General anesthesia was administered to all patients. The skin incision was made along the posterior median line. Each surgical procedure involved pedicle screw fixation, decompression, lumbar discectomy, and interbody fusion with a bone-filled cage. Prophylactic antibiotics (cefazolin or clindamycin) were administered 30 min prior to surgery, with two additional doses given 24 h postoperatively.

Statistical analysis

Continuous variables were expressed as means with standard deviations and compared using Student's t-test or Mann-Whitney U test, depending on data distribution. Categorical variables were presented as frequencies and percentages, analyzed using the chi-square test or Fisher's exact test as appropriate. Propensity score matching (PSM) analysis used the greedy nearest neighbor method for data matching, with ratio = 1:1 and caliper = 0.04. Age, sex, BMI, diabetes mellitus and smoking status were included as confounding variables in the matching process. A p-value of < 0.05 was considered statistically significant.

Results

Study population

A total of 512 elderly patients who underwent PLIF at our department between May 2016 and June 2024 were initially screened for inclusion in this study. After applying the inclusion and exclusion criteria, 478 patients remained eligible for analysis. Of these, 113 patients (23.6%) were diagnosed with OSA and 365 patients (76.4%) did not have OSA.

Since baseline characteristics differed significantly between the OSA and non-OSA groups, propensity score matching (PSM) was applied to balance these characteristics. After PSM, 83 matched pairs of patients were selected from each group for further analysis (Fig. 1).

Baseline characteristics before and after propensity score matching

Prior to matching, significant differences were observed between the OSA and non-OSA groups in key baseline characteristics. The OSA group was older, had a higher BMI, exhibited a greater prevalence of diabetes mellitus and had a higher smoking rate compared to the non-OSA group (Table 1). Specifically, the OSA group had a mean age of 74.8 ± 4.7 years, compared to 72.2 ± 4.6 years in the non-OSA group ($p < 0.001$). And OSA group had a higher BMI than non-OSA group (23.9 ± 2.8 vs. 22.6 ± 2.2, $p < 0.001$). The OSA group also had a higher proportion of patients with diabetes (52.2% vs. 31.0%, $p < 0.001$) and smoking rate (55.8% vs. 30.0%, $p < 0.001$). The incidence of SSIs was 19.5% in the OSA group, compared with 2.7% in the non-OSA group ($p < 0.001$).

After matching, no significant differences in these baseline variables were observed between the two groups (Table 2). This matching process effectively minimized potential confounding factors, allowing for a more accurate comparison of postoperative outcomes.

Incidence of SSIs

After propensity score matching, the incidence of SSIs remained significantly higher in the OSA group, with 11 patients (13.3%) experiencing SSIs compared to 3 patients (3.6%) in the non-OSA group ($p = 0.04$). Among the OSA group, 6 patients developed superficial infections compared to 3 in the non-OSA group. Additionally, 4 OSA patients experienced deep incisional infections, while no cases were observed in the non-OSA group. Organ/space infections were reported in 1 OSA patient, whereas none occurred in the non-OSA group (Fig. 2).

Multivariate logistic regression analysis for potential risk factors of SSIs

A multivariate logistic regression was performed to evaluate the independent risk factors for SSIs after PSM. The results of the analysis are shown in Table 3. Among the variables assessed, OSA was the only factor that remained significantly associated with an increased risk of SSIs (Odds Ratio = 4.509, 95% CI: 1.283–21.504, $p = 0.03$), indicating its independent role in SSI development. Other factors, including age, sex, BMI, diabetes mellitus, hypertension, and smoking, were not significantly associated with SSI risk ($p > 0.05$).

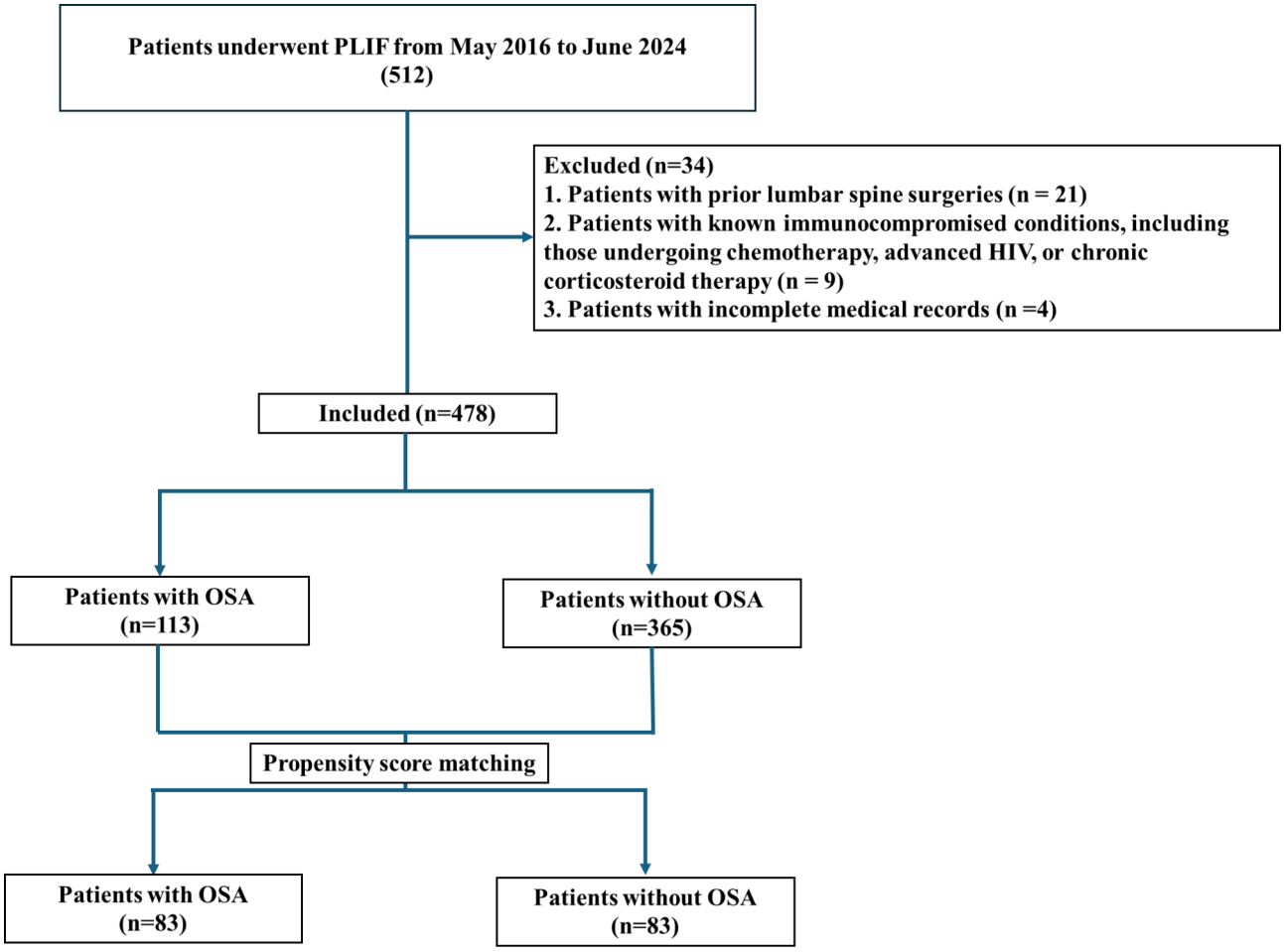

Fig. 1 Flowchart illustrating the patient selection process in this study

Table 1 Characteristics of the patients with and without OSA before propensity score matching

Variable	OSA group (*N* = 113)	Non-OSA group (*N* = 365)	*P* value
Age(years)	74.8 ± 4.7	72.2 ± 4.6	0.00*
Sex			
Male	79(69.9%)	189(51.8%)	
Female	34(30.1%)	176(48.2%)	0.00*
BMI(Kg/m^2)	23.9 ± 2.8	22.6 ± 2.2	0.00*
Diabetes Mellitus	59(52.2%)	113(31.0%)	0.00*
Hypertension	72(63.7%)	201(55.1%)	0.13
Smoking	63(55.8%)	109(30.0%)	0.00*
ASA classification	1.7 ± 0.5	1.6 ± 0.5	0.05
Operative time(min)	151.2 ± 33.6	147.0 ± 37.2	0.28
Blood loss	441.2 ± 71.6	431.9 ± 70.4	0.22
Screw number	4.5 ± 0.9	4.5 ± 0.9	0.88
SSIs	22(19.5%)	10(2.7%)	0.00*

BMI, Body Mass Index. * $P < 0.05$

Table 2 Characteristics of the patients with and without OSA after propensity score matching

Variable	OSA group (*N* = 83)	Non-OSA group (*N* = 83)	*P* value
Age(years)	73.3 ± 4.2	72.9 ± 4.5	0.55
Sex			
Male	49(59.0%)	50(60.2%)	
Female	34(41.0%)	33(39.8%)	0.99
BMI(Kg/m^2)	23.0 ± 2.6	23.2 ± 2.0	0.66
Diabetes Mellitus	34(41.0%)	36(43.4%)	0.88
Hypertension	42(50.6%)	31(37.3%)	0.12
Smoking	34(41.0%)	36(43.4%)	0.88
ASA classification	1.5 ± 0.5	1.4 ± 0.5	0.06
Operative time(min)	155.2 ± 35.6	152.1 ± 43.7	0.62
Blood loss	435.4 ± 58.3	427.8 ± 63.6	0.42
Screw number	4.7 ± 1.0	4.6 ± 0.9	0.62
SSIs	11(13.3%)	3(3.6%)	0.04*

OSA patients exhibit longer hospital stays and higher readmission rates

After propensity score matching, the median length of hospital stay was significantly longer in OSA patients

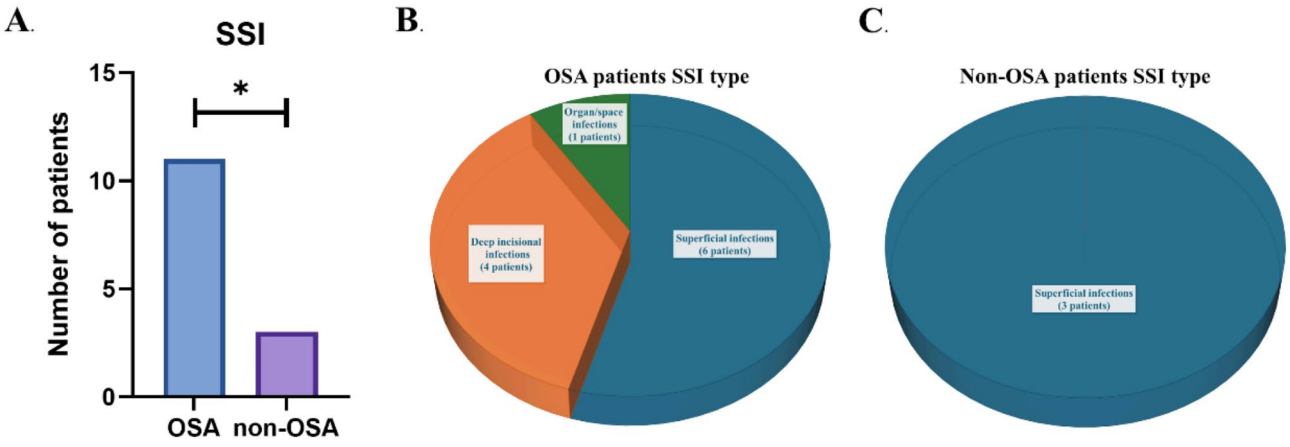

Fig. 2 Incidence and SSIs in OSA and Non-OSA groups. (**A**) bar chart comparing the overall incidence of SSIs between the OSA and non-OSA groups. (**B**) pie chart depicting the distribution of SSI subtypes in the OSA group. (**C**) pie chart showing the distribution of SSI subtypes in the non-OSA group

Table 3 Multivariate logistic regression analysis for potential risk factors of SSIs

Variable	Odds ratio	95% CI	*P* value
Age(years)	1.117	0.971 to 1.297	0.13
Female Sex	0.468	0.140 to 1.466	0.20
BMI(Kg/m^2)	1.139	0.900 to 1.439	0.27
Diabetes Mellitus	0.711	0.198 to 2.293	0.58
Hypertension	1.245	0.364 to 4.229	0.72
Smoking	0.981	0.285 to 3.206	0.97
OSA	4.509	1.283 to 21.504	0.03*

* $P < 0.05$

compared to non-OSA patients. The mean hospital stay for OSA patients was 10.1 ± 2.9 days versus 9.1 ± 2.0 days for non-OSA patients ($p = 0.01$). Additionally, the 30-day readmission rate due to SSIs was notably higher in the OSA group, with 8 patients (9.6%) readmitted compared to 1 patient (1.2%) in the non-OSA group ($p = 0.02$).

CPAP/APAP therapy reduces SSI incidence and shortens hospital stay in OSA patients

In a subgroup analysis of OSA patients, 26 individuals received continuous positive airway pressure (CPAP) or automatic positive airway pressure (APAP) therapy. Although there was no statistically significant difference, the incidence of SSIs was lower in the CPAP/APAP group, with only 1 patient (3.9%) developing SSIs compared to 10 (17.5%) in the non-CPAP group ($p = 0.08$). Furthermore, patients who underwent CPAP/APAP therapy experienced shorter hospital stays, with 9.1 ± 1.5 days compared to 10.5 ± 3.2 days in the non-CPAP group ($p = 0.03$). Notably, all the 30-day readmission cases occurred in the non-CPAP/APAP group.

Discussion

This study demonstrates a significant association between OSA and an increased incidence of early SSIs in elderly patients undergoing PLIF. Patients with OSA exhibited higher rates of early SSIs, extended hospital stays, and elevated readmission rates compared to their non-OSA counterparts.

OSA increased the risk of early SSIs in elderly PLIF patients

Previous studies have identified OSA as a risk factor for postoperative complications, including infections [13–16]. For instance, research has indicated that patients with OSA are more likely to develop bacterial pneumonia and exhibit a higher risk of invasive pneumococcal disease [17]. Moreover, a systematic review reported that individuals with OSA had higher rates of wound complications, such as infections and dehiscence, particularly following surgical procedures [16]. These studies support the notion that OSA contributes to adverse postoperative outcomes, consistent with our observations in the PLIF patient population.

OSA is characterized by intermittent hypoxia, which impairs tissue oxygenation and disrupts normal immune responses [9, 18]. Hypoxia leads to endothelial dysfunction [19, 20], altered neutrophil and macrophage activity [21], and delayed collagen synthesis [22]—all of which are critical to wound healing. In our study, the distribution of SSI subtypes revealed that superficial infections were the most common in both groups. Interestingly, deep incisional and organ/space infections were reported only in the OSA group. This pattern may reflect the severity of tissue hypoxia in OSA patients, particularly in deep tissues where oxygen delivery is critical for wound healing. Moreover, the hospital stays and 30-day readmission rate due to SSIs was also markedly higher in the OSA group. These results highlight the clinical and economic implications of untreated OSA in surgical patients, emphasizing

the need for enhanced perioperative management and postoperative monitoring strategies.

In addition to the intermittent hypoxia and immune dysregulation previously mentioned, obesity, diabetes, and advanced age contribute significantly to the elevated risk of SSIs observed in OSA patients [23]. Obesity is closely linked to chronic, low-grade inflammation and impaired wound healing, creating an environment conducive to bacterial colonization and infection [24]. Likewise, patients with diabetes exhibit microvascular changes and hyperglycemia-driven immune dysfunction, which further predispose them to surgical site complications [25]. These comorbidities often coexist with OSA, compounding the overall burden of hypoxia-induced oxidative stress and endothelial dysfunction, both of which can exacerbate tissue ischemia and impair leukocyte function. Indeed, our findings align with existing research linking OSA to higher morbidity, underscoring that the management of these overlapping risk factor is vital to mitigating SSI risk.

The role of CPAP/APAP therapy in reducing SSI incidence

Our subgroup analysis revealed that CPAP/APAP therapy may reduce SSI incidence, shortened hospital stays and decrease 30-day readmission rates in OSA patients. By maintaining airway patency and alleviating intermittent hypoxia, CPAP and APAP therapy enhance tissue oxygenation [26], which is essential for regulating the inflammatory response and facilitating wound repair. These findings suggest that preoperative screening for OSA and the implementation of CPAP/APAP therapy may improve postoperative outcomes in PLIF patients.

Clinical implications

The identification of OSA as a significant risk factor for SSIs in PLIF patients has important clinical implications. Given the high prevalence of OSA in elderly patients, routine preoperative screening for OSA should be incorporated into surgical workflows, particularly for elderly patients undergoing PLIF. Early diagnosis and management, particularly with CPAP/APAP therapy, could help reduce the adverse effects of intermittent hypoxia, improve immune function, and lower the risk of infections. Additionally, multidisciplinary perioperative management involving anesthesiologists, surgeons, and sleep specialists is crucial to ensure appropriate interventions for OSA patients [27, 28]. Enhanced recovery protocols that include optimized oxygen delivery, infection control measures, and early mobilization may further improve outcomes in this vulnerable population [29, 30].

Limitations and future directions

Despite the strengths of this study, several limitations should be considered. First, this was a retrospective study, which may introduce inherent biases despite PSM. Second, the study was conducted in a single center, potentially limiting the generalizability of our findings. Third, the sample size for OSA group after PSM and the CPAP/APAP subgroup was relatively small, which may affect the statistical power of the analysis. Future prospective studies should investigate the effects of preoperative CPAP/APAP therapy on SSIs in a larger, multicenter cohort, with a focus on long-term outcomes. Notably, comparative studies investigating the impact of OSA versus chronic obstructive pulmonary disease (COPD) on SSI risk are warranted, as both conditions involve chronic hypoxia but likely differ in perioperative management pathways. Moreover, exploring immune modulation strategies and their role in preventing SSIs in OSA patients may provide additional insights into improving surgical outcomes.

Conclusion

In conclusion, our study highlights OSA as a significant risk factor for early SSIs in elderly PLIF patients. The findings underscore the importance of preoperative screening for OSA. Given the increasing prevalence of OSA and its association with adverse surgical outcomes, early identification and management of OSA may play a key role in improving the safety and success of PLIF procedures in the aging population.

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Author contributions

J.L. designed the study and drafted the main manuscript text. H.X. and J.C. collected and analyzed the data. B.M. interpreted the results. J.H. contributed to data collection and analysis. Q.C. and S.L. supervised the study, critically reviewed the manuscript, and provided revisions. All authors reviewed and approved the final manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

This study was approved by the research ethics committee of North Sichuan Medical College. Informed consent was obtained from all participants in the study.

Consent for publication

All authors consent to the publication of this manuscript.

Competing interests

The authors declare no competing interests.

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