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Comprehensive analysis of risk factors for postoperative wound infection following open reduction and internal fixation of Rib fractures

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Abstract

Background Postoperative wound infections (PWIs) significantly impact patient outcomes following open reduction and internal fixation (ORIF) of rib fractures. Identifying and understanding risk factors associated with these infections are crucial for improving surgical outcomes and patient care.

Methods This retrospective study, conducted from January 2020 to October 2023 at our institution, aimed to analyze the risk factors for PWIs in patients undergoing ORIF for rib fractures. A total of 150 patients were included, with 50 in the infected group and 100 in the non-infected control group, matched for demographic and clinical characteristics. Data on variables such as intraoperative blood loss, hospital stay duration, body mass index (BMI), operation time, presence of anemia, drainage time, diabetes mellitus status, smoking habits, and age were collected. Statistical analysis involved univariate and multivariate logistic regression using SPSS software (Version 27.0), with p-values < 0.05 considered statistically significant.

Results Univariate analysis revealed no significant association between intraoperative blood loss or hospital stay duration and PWIs. However, operation time ≥ 5 h, anemia, drainage time ≥ 7 days, diabetes mellitus, smoking, and age ≥ 60 years were significantly associated with higher PWI rates. Multivariate logistic regression confirmed these factors as independent predictors of PWIs, with operation time and diabetes mellitus showing particularly strong associations.

Conclusions Prolonged operation time, anemia, extended drainage, diabetes mellitus, smoking, and advanced age significantly increase the risk of PWIs following ORIF for rib fractures. Early identification and targeted management of these risk factors are essential to reduce the incidence of infections and improve postoperative outcomes.

Keywords Postoperative wound infections, Open reduction and internal fixation, Rib fractures, Risk factors

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Introduction

Multiple rib fractures in thoracic trauma provide a considerable therapeutic challenge, requiring precise and effective care to prevent sequelae and facilitate optimal recovery [1]. The surgical method, particularly open reduction and internal fixation (ORIF) is increasingly recommended for numerous rib fractures when nonoperative care does not provide stability or when significant displacement threatens respiratory function and pain management. ORIF provides considerable benefits, such as restoring chest wall integrity, promoting lung reexpansion, and significantly alleviating discomfort, which accelerates patient recovery and shortens hospitalization length [2, 3].

Nonetheless, the surgical procedure, although advantageous, is not without hazards, with postoperative wound infections (PWIs) being among the most significant. PWIs can significantly diminish the advantages of ORIF, resulting in heightened morbidity, prolonged hospitalizations, higher antibiotic need, and, in certain instances, the necessity for further surgical procedures [4]. The incidence of PWIs strains the healthcare system regarding resources and expenses, while also adversely affecting patient quality of life, perhaps resulting in long-term consequences and protracted rehabilitation [5].

The risk factors for post-operative pulmonary complications following open reduction and internal fixation of rib fractures are multifaceted, including patient-specific characteristics, surgical elements, and postoperative care considerations. Factors associated to the patient encompass, but are not restricted to, age, comorbidities such as diabetes mellitus or chronic pulmonary diseases, dietary status, and smoking behaviors, all of which may impair immune function and wound healing. The intricacy of the fracture, the length of the surgical procedure, and the technique utilized can affect the risk of infection from a surgical standpoint. The effectiveness of postoperative care, encompassing wound management techniques and the prudent application of prophylactic antibiotics, is crucial in reducing the risk of PWIs [6, 7].

Previous studies have demonstrated the benefits of ORIF in improving outcomes for patients with multiple rib fractures, particularly in terms of reducing pain, facilitating respiratory function, and shortening hospitalization time [8, 9]. However, these studies have also highlighted the risk of PWIs as a significant complication following ORIF. PWIs can lead to increased morbidity, prolonged recovery, and a higher burden on healthcare resources. Various risk factors for PWIs have been suggested, including patient age, comorbidities such as diabetes, and the length of the surgical procedure. While some risk factors have been identified, the literature lacks comprehensive studies that systematically analyze the multifactorial risk factors for PWIs in the context of ORIF for multiple rib fractures. Specifically, there is limited data on the relative impact of modifiable and non-modifiable risk factors, as well as the role of perioperative management strategies, such as prophylactic antibiotic regimens, in mitigating infection risks. Our study aims to address these gaps by conducting a detailed analysis of the risk factors associated with PWIs following ORIF and providing insights to enhance preventive strategies.

Materials and methods

Study design

A retrospective analysis was conducted at our institution to clarify the risk factors linked to PWIs following the ORIF of rib fractures. The research period extended from January 2020 to October 2023. A total of 50 individuals exhibiting PWIs following ORIF were carefully selected for the case group. A control group of 100 patients, who underwent ORIF over the same period without experiencing PWIs, was established to enable a comparison study, ensuring demographic and clinical variables were equivalent across the groups. The study's design, aims, and implementation underwent thorough evaluation and received approval from our institution's Ethics Committee (L-2023067, December 17, 2023), guaranteeing compliance with ethical norms, including the safeguarding of patient confidentiality and rights. Informed consent was obtained from all participants, who were thoroughly informed about the study's objectives, methodologies, and potential consequences, in accordance with ethical research standards. All procedures were executed in compliance with pertinent rules and regulations, conforming to the ethical norms for medical research involving human beings as delineated in the Declaration of Helsinki. To safeguard participant privacy, data was managed anonymously, and all personal identifiers were eliminated before analysis.

Inclusion and exclusion criteria

Inclusion Criteria:

1) Patients aged 18 years and above who underwent ORIF for simple (closed) rib fractures at our institution during the study period (January 2020 to October 2023).
2) Documented rib fractures confirmed by radiographic imaging (X-ray, CT scan) prior to ORIF.
3) Completion of the ORIF procedure by a board-certified thoracic or trauma surgeon from the same surgical team.
4) Availability of comprehensive medical records detailing the perioperative management and postoperative follow-up.

Exclusion Criteria:

1) Presence of compound (open) rib fractures.
2) Presence of pre-existing wound infections or systemic infections at the time of ORIF.
3) Prior thoracic surgeries within 6 months before the ORIF for rib fractures.
4) Immunocompromised patients, including those with chronic steroid use, chemotherapy, or known HIV/AIDS.
5) Refusal or inability to provide informed consent for participation in the study.

Data collection and variables examined

To identify the factors influencing surgical outcomes, our data collection included a comprehensive array of patient-specific variables. Intraoperative blood loss, length of hospital stays, body mass index (BMI), duration of surgery, anemia status, drainage period, diabetes mellitus status, smoking history, and patient age were systematically documented. The choice of these specific variables was based on a comprehensive approach to assessing various factors that could influence both surgery and postsurgical outcomes, particularly with the incidence of PWIs. The data collection method adhered strictly to established ethical criteria, ensuring that the collected information was accurate and reliable, so establishing a solid platform for subsequent analytical examination.

Statistical analysis

Utilizing SPSS software (Version 27.0), we executed our statistical analyses with meticulous accuracy. We depicted categorical variables through their corresponding frequencies and proportions. The Chi-square ($\chi 2$) test was our principal instrument for analyzing the connections and independencies among these variables. The variables that shown a statistically significant correlation with the occurrence of PWIs in the preliminary univariate analysis were then analyzed in depth using multivariate analysis. In this multivariate framework, logistic regression was employed to get odds ratios and their associated confidence intervals, clarifying the factors that significantly influence the incidence of SSIs. All tests performed utilized bidirectional hypothesis testing, with a p-value threshold of less than 0.05 set as the criterion for statistical significance.

Results

A total of 173 patients were assessed for eligibility in this study. Of these, 23 patients were excluded: 16 did not meet the inclusion criteria, 5 declined to participate, and 2 were excluded due to incomplete medical records. Ultimately, 150 patients were included in the final analysis. The case group consisted of 50 patients who developed PWIs following ORIF, while the control group included 100 patients who underwent ORIF during the same period but did not experience PWIs (Fig. 1). Both groups were matched for demographic and clinical characteristics to facilitate a comparative analysis.

Upon comparing the baseline characteristics between the infected and non-infected groups, several significant differences were observed. Patients in the infected group were notably older, with a significantly higher proportion aged 60 years or older (82% vs. 29%, $p<0.001$). Gender distribution did not differ significantly between the groups. The prevalence of diabetes mellitus was markedly higher in the infected group (66% vs. 18%, $p<0.001$), while other comorbidities, such as hypertension, ischemic heart disease, and chronic obstructive pulmonary disease (COPD), showed no significant differences. Anemia, indicated by lower hemoglobin levels, was more common in the infected group (44% vs. 18%, $p=0.001$). Although HbA1c values were available only for diabetic patients, glycemic control appeared poorer in the infected group, though not statistically significant. All patients in the study had simple (closed) rib fractures, as compound fractures were excluded. Although patients with a body mass index (BMI) ≥ 25 kg/m^2 were more common in the infected group (66% vs. 48%), this difference did not reach statistical significance ($p=0.056$). Additionally, smoking history was significantly more prevalent among infected patients (68% vs. 20%, $p<0.001$). These baseline differences indicate that age, diabetes, anemia, and smoking history may play a role in postoperative wound infection risk, setting the foundation for further analysis (Table 1).

In both the infected and non-infected groups, prophylactic antibiotics were administered to prevent postoperative wound infections. The standard antibiotic regimen used was cefuroxime, administered intravenously 30 min prior to the incision, with a subsequent dose postoperatively, and discontinued within 24 h. The antibiotic regimen was identical between the two groups.

Univariate analysis outcomes of risk factors for postoperative wound infections

In the univariate analysis of PWIs following ORIF for rib fractures, several factors were examined for their association with infection incidence. No significant correlation was found between intraoperative blood loss of 500 mL or more and the occurrence of PWIs ($p=0.771$), nor between hospital stay duration and infection ($p=0.686$). Conversely, prolonged operation time (≥ 5 h) was significantly associated with an increased rate of PWIs ($p=0.002$). Other factors significantly associated with PWIs included anemia ($p=0.001$), drainage time exceeding 7 days ($p<0.001$), diabetes mellitus ($p<0.001$), smoking ($p<0.001$), and patient age of 60 years or older

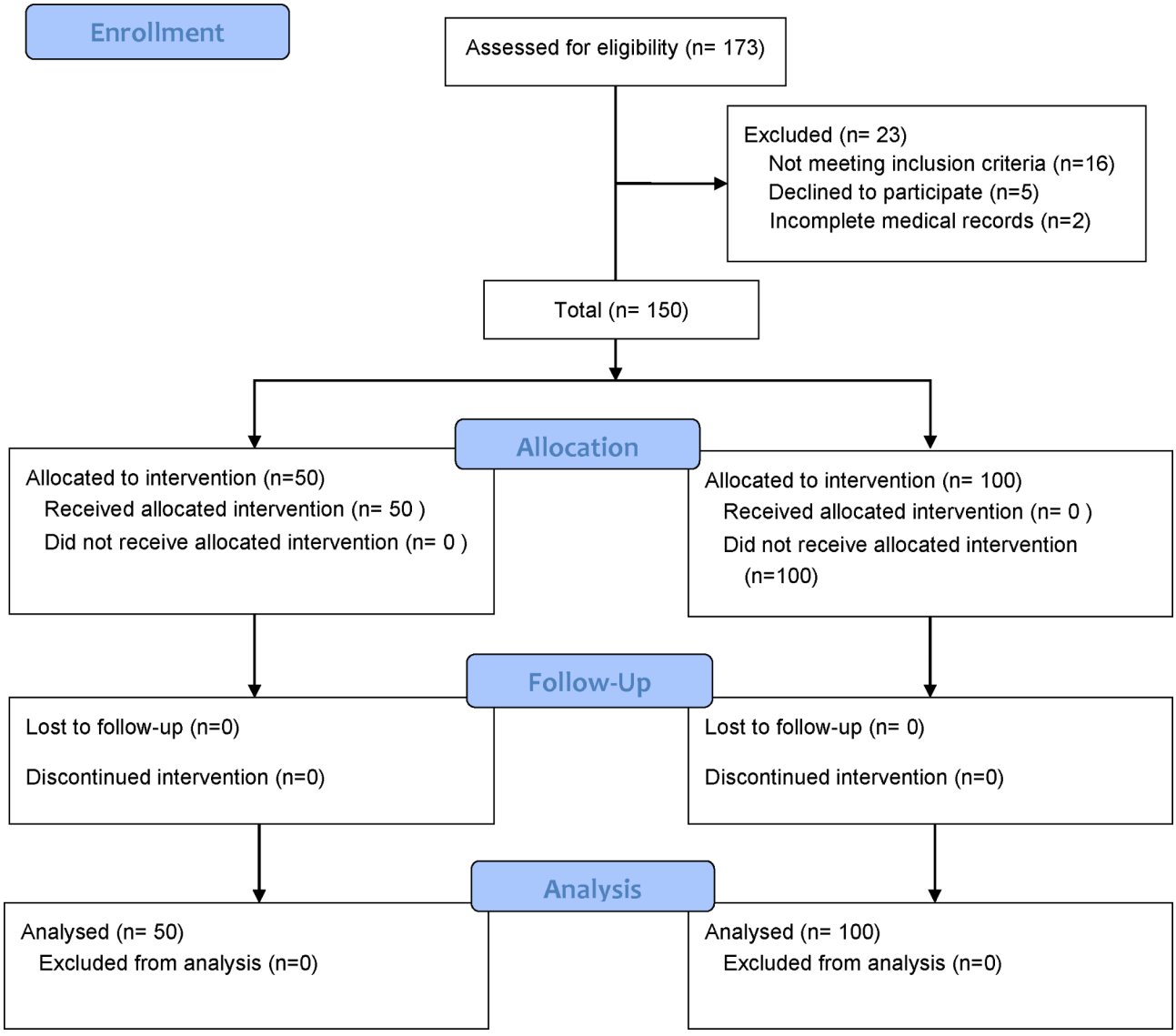

Fig. 1 Flow diagram of the study design and population

($p<0.001$). These findings suggest that while some factors, such as intraoperative blood loss and hospital stay duration, are not independent predictors of PWIs, others—including prolonged operation time, comorbid conditions, and patient habits—substantially increase the risk of developing infections after ORIF (Table 1).

Multivariate logistic regression analysis of factors associated with postoperative wound infections

In the advanced phase of our investigation, a multivariate logistic regression was utilized to identify the intricate relationships among diverse risk factors and their impact on the occurrence of PWIs following ORIF for rib fractures. The regression model was modified for confounders, indicating many variables significantly influenced the probability of acquiring PWIs. The length of surgical procedures was identified as a significant predictor, with surgeries over 5 h correlating with a greater than fourfold elevation in infection risk (OR 4.46, $p=0.007$). Additionally, the presence of anemia was identified as a significant predictor of PWIs, nearly quadrupling the risk (OR 3.69, $p=0.046$). Prolonged drainage time of 7 days or more, diabetes mellitus, and smoking were also significantly associated with the development of PWIs, exhibiting odds ratios of 2.55, 3.94, and 3.52, respectively, and p-values indicating statistical significance. Notably, patient age of 60 years or older was correlated with a near tripling in infection risk (OR 2.89, $p=0.013$). These findings underscore the multifactorial nature of PWIs, highlighting the importance of a nuanced approach to perioperative patient management to mitigate infection risks (Table 2).

Table 1 Univariate analysis of factors associated with postoperative wound infections in patients undergoing orif for rib fractures

Factors	Infected ($n=50$)	Non-Infected ($n=100$)	Chi-Squared (χ^2)	*p*-value
Intraoperative Blood Loss (≥ 500 mL)	29 (58%)	54 (54%)	0.084	0.771
Hospital Stay (> 10 days)	24 (48%)	53 (53%)	0.163	0.686
Body Mass Index (≥ 25 kg/m^2)	33 (66%)	48 (48%)	3.653	0.056
Operation Time (≥ 5 h)	28 (56%)	29 (29%)	9.2	0.002
Anemia	22 (44%)	18 (18%)	10.232	0.001
Drainage Time ≥ 7 Days	35 (70%)	35 (35%)	15.03	< 0.001
Diabetes Mellitus	33 (66%)	18 (18%)	32.119	< 0.001
Smoking	34 (68%)	20 (20%)	31.283	< 0.001
Age (≥ 60 years)	41 (82%)	29 (29%)	35.521	< 0.001

PWI: Postoperative Wound Infection

ORIF: Open Reduction and Internal Fixation

Discussion

Postoperative wound infections are a significant concern in thoracic surgery, especially after the open reduction and internal fixation of rib fractures. These infections can significantly worsen patient outcomes, prolong hospitalizations, and increase healthcare expenses, ultimately straining both patients and the healthcare system. Comprehending the risk variables linked to PWIs following ORIF is essential for formulating appropriate preventive measures, surgical methodologies, and postoperative care protocols. Rib fractures, typically caused by blunt trauma, require open reduction and internal fixation (ORIF) to reestablish chest wall stability and functionality. The technique is crucial for patient recovery but carries an inherent risk of infection due to its invasive nature and the possibility of significant tissue manipulation. The interaction of individual patient characteristics, such as comorbidities and lifestyle decisions, with procedural variables, including operational duration and technical methodology, establishes a complicated risk environment for PWIs [10, 11]. Our thorough analysis aims to examine these complex risk factors, offering a systematic assessment of their individual and collective effects. This analysis seeks to enhance patient care by finding modifiable and non-modifiable risk factors, allowing surgeons and healthcare providers to stratify patients by risk and implement focused therapies.

The findings of our study clarify the complex causes of PWIs after ORIF of rib fractures. The lack of a substantial correlation between intraoperative blood loss or prolonged hospital stays and the occurrence of PWIs undermines many traditional notions concerning infection risks. This may indicate that the extent of blood loss and length of hospitalization are not as pivotal to infection control as previously believed, or that other, more significant factors diminish their influence in the setting of ORIF for rib fractures [12, 13]. In contrast, the significant correlation between extended surgical duration and the occurrence of PWIs is notably revealing. Extended surgical procedures may elevate exposure to infectious agents, compromise physiological barriers to infection, and result in more tissue trauma, hence increasing the risk of infection. This discovery necessitates measures to reduce operational duration without sacrificing surgical quality, potentially through preoperative planning, intraoperative efficiency, and the implementation of advanced technology that may accelerate the surgical procedure. Anemia's importance as a predictor of PWIs aligns with its established effects on wound healing and immunological function. Anemia, by hindering oxygen transport to tissues, may weaken the immune response and create a favorable environment for bacterial growth at the surgery site. Consequently, managing preoperative anemia may serve as an effective strategy for mitigating infection risks [14, 15]. Our data clearly highlight the influence of prolonged drainage duration on PWI risk. Extended utilization of drains may facilitate bacterial entry into the wound, impede the standard healing process, and prolong exposure to possible infections. Therefore, reassessing the protocols for postoperative draining and investigating the feasibility of early drain removal without elevating the risk of complications such as seroma formation may prove advantageous.

The correlations among diabetic mellitus, smoking, and advanced age with increased occurrences of PWIs can be understood as a result of compromised immune function. Diabetes mellitus adversely impacts microvascular circulation and diminishes leukocyte activity, both

Table 2 Multivariate logistic regression of factors associated with postoperative wound infections in patients undergoing ORIF for rib fractures

Factors	β Value	Standard Error	Wald Value	OR Value	95% CI for OR	*P*-Value
Operation Time (≥ 5 h)	0.33	1.54	4.43	4.46	[1.28, 14.34]	0.007
Anemia	0.35	1.16	3.97	3.69	[1.12, 12.77]	0.046
Drainage Time ≥ 7 Days	0.26	1.12	2.90	2.55	[0.56, 11.02]	0.015
Diabetes Mellitus	0.36	1.37	4.08	3.94	[1.3, 13.3]	0.032
Smoking	0.31	0.92	3.39	3.52	[1.39, 9.58]	0.045
Age (≥ 60 years)	0.32	1.24	3.71	2.89	[0.64, 15.74]	0.013

of which are essential for efficient wound healing and infection prevention. Smoking impairs oxygenation and tissue perfusion, whereas aging typically results in a loss in physiological resilience, including a reduced immunological response [16, 17]. The heightened infection risk in those with diabetes mellitus, smokers, and the elderly may also be associated with the cumulative load of comorbid illnesses that frequently accompany these conditions. Therefore, optimizing blood glucose levels preoperatively, promoting smoking cessation, and doing thorough geriatric assessments may be essential elements of preoperative preparation [18, 19]. The logistic regression analysis has elucidated the interaction of these risk factors, providing a more refined comprehension of their combined impact on PWI rates. The odds ratios remained significant after correcting for potential confounders, indicating that these characteristics independently contribute to the likelihood of PWIs.

Prolonged surgical duration and comorbidities are well-established risk factors for PWIs [20]. In our study, surgeries lasting 5 h or more significantly increased the risk of PWIs, likely due to extended tissue exposure and bacterial contamination. Comorbidities such as diabetes mellitus, anemia, and smoking, which impair wound healing, were also identified as significant risk factors. Patients aged 60 years or older were nearly three times more likely to develop PWIs, likely due to reduced immune function and tissue recovery. While repeated interventions were not directly analyzed, they are known to increase infection risk by introducing microbial contamination. Endogenous microbial flora, including resistant organisms, often complicate recovery. PWIs delay healing, extend hospital stays, and increase healthcare costs, highlighting the importance of addressing these risk factors in perioperative management.

To further validate the robustness of our findings, a post-hoc power analysis was conducted. Given the sample size of 150 patients and the significant effect sizes observed, the statistical power for detecting associations between key risk factors and postoperative wound infections (PWIs) was exceptionally high, approaching 100% for most variables. For example, the power to detect the association between prolonged operation time (≥5 h) and PWIs was nearly 100% (OR 4.46, $p=0.007$), underscoring the reliability of this finding. Similarly, anemia (OR 3.69, $p=0.046$), prolonged drainage time (≥7 days, OR 2.55, $p=0.015$), diabetes mellitus (OR 3.94, $p=0.032$), smoking (OR 3.52, $p=0.045$), and advanced age (≥60 years, OR 2.89, $p=0.013$) all exhibited high power, supporting the robustness of these associations. Overall, the post-hoc power analysis confirms that the study was sufficiently powered to detect meaningful differences, minimizing the risk of Type II errors. These findings are statistically reliable and provide a strong basis for understanding the critical risk factors associated with PWIs following ORIF for rib fractures.

Compared to existing literature, our findings offer a more nuanced analysis of risk factors for PWIs following ORIF of rib fractures. Feng et al. [6]identified surgical site as an independent risk factor for SSI in trauma surgeries, while our study provides a broader analysis, incorporating multifactorial risks like diabetes, anemia, prolonged operation time, and smoking. Similarly, Cheng et al. [21] showed that longer surgeries increase complication rates. We confirm this by identifying operation time≥5 h as a significant predictor of PWIs, but focus specifically on rib fractures, offering more targeted recommendations. Nishimuta et al. [22] reviewed general SSI prevention strategies, including chlorhexidine, normothermia, and glycemic control, while our study emphasizes the importance of preoperative optimization of diabetes and anemia, as well as minimizing operative time in the context of rib fracture surgeries. Overall, our study adds a focused, multifactorial perspective to PWI risk management in ORIF for rib fractures, enhancing prevention strategies within this surgical context.

One limitation of our study is its retrospective design, which risks selection and information bias due to reliance on historical records, potentially omitting key lifestyle factors. Conducted at a single institution, the findings may not generalize to other populations. Additionally, microbial identification and infection severity classification were not included, limiting insights into pathogen-specific risks and antibiotic resistance. To reduce the risk of PWIs, strategies include optimizing modifiable factors like anemia, diabetes, and smoking cessation, minimizing operative time, and adhering to strict aseptic techniques. High-efficiency masks and appropriate attire can further reduce airborne contamination [23]. Early drain removal and limiting unnecessary interventions are also key to improving outcomes.

Conclusions

In conclusion, operation duration surpassing 5 h, anemia, extended drainage, diabetes mellitus, smoking, and advanced age are recognized as critical risk factors for postoperative wound infection after rib ORIF. It is essential to quickly identify these factors and adopt proactive preventative strategies to reduce the occurrence of surgical site infections, hence improving patient outcomes and recovery.

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Author contributions
Conceptualization: Hong Li. Data curation: Xufeng Zheng. Formal analysis: Xufeng Zheng. Methodology: Hong Li. Resources: Xufeng Zheng. Software: Hong Li. Writing – original draft: Hong Li. Writing – review & editing: Jie Gao.

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Data availability
The data sets generated and analyzed during this study are not public, but under reasonable requirements, the correspondence author can provide.

Declarations

Ethics approval and consent to participate
This study was approved by the Ethics Committee of Qionghai People's Hospital (L-2023067, December 17, 2023). The techniques conducted in studies involving human subjects adhered to the ethical criteria set by the institutional and/or national research committee, as well as the 1964 Helsinki statement and its subsequent revisions or similar ethical standards. Consent was gained from all participants or their legal guardians after providing them with relevant information.

Consent for publication
Written informed consent for publication was obtained from all patients and their families included in this retrospective analysis.

Competing interests
The authors declare that they have no competing interests.

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