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Risk factors for surgical site infections after orthopaedic surgery: A meta-analysis and systematic review

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Abstract

The objective of this meta-analysis was to investigate the occurrence and determinants of surgical site infections (SSIs) in individuals following orthopaedic surgical procedures. A systematic exploration of articles concerning factors predisposing individuals to SSIs after orthopaedic surgery was conducted across multiple databases, including PubMed, Embase, Cochrane Library and Web of Science, up to March 20, 2024. The Stata 15.0 software was employed to estimate combined odds ratios (ORs) utilizing either a random-effects model or a fixed-effects model based on the degree of heterogeneity among the included studies. Egger's test was used to assess publication bias. Among the 1248 records retrieved, 45 articles were deemed eligible after screening for studies incorporating multivariate analyses of risk factors associated with SSIs. These comprised four case–control studies and 41 cohort studies, collectively involving 1 572 160 patients, among whom 43 971 cases of SSIs were reported postoperatively. Meta-analysis outcomes indicated significant associations between SSIs and the following factors: low Albumin levels (<35 g/L; OR = 2.29, 95% confidence interval [CI]: 1.45–3.62, $p = 0.0001$), ASA score >2 (OR = 2.32, 95% CI: 1.86–2.89, $p = 0.0001$), elevated body mass index (BMI) (>24 kg/m^2) (OR = 2.15, 95% CI: 1.60–2.90, $p = 0.0001$), diabetes (OR = 2.25, 95% CI: 1.66–3.05, $p = 0.0001$), prolonged surgical duration (>60 min) (OR = 2.06, 95% CI: 1.52–2.80, $p = 0.001$), undergoing multiple surgeries/procedures (OR = 2.38, 95% CI: 1.29–4.41, $p = 0.006$), presence of an open fracture (OR = 3.35, 95% CI: 2.51–4.46, $p = 0.001$), current smoking (OR = 2.87, 95% CI: 1.88–4.37, $p = 0.0001$), higher wound class (>2; OR = 3.59, 95% CI: 1.68–7.66, $p = 0.001$) and utilization of implants (OR = 1.89, 95% CI: 1.15–3.11, $p = 0.0012$). The

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present study identified a number of risk factors for the development of SSIs following orthopaedic surgery. It is therefore recommended that clinicians closely monitor these indicators in order to prevent the development of postoperative SSIs. Furthermore, our interpretation of diabetes mellitus was not adequate. It is therefore recommended that future studies refine the effect of diabetes mellitus on SSIs in different situations.

KEYWORDS

orthopaedics, infection, orthopaedic surgery, risk factors, surgical site infection

Key Messages

- The impact of diabetes on surgical site infections needs further discussion.
- The utilization of drainage in the postoperative period does not represent a risk factor.
- Further investigation is required to elucidate the potential association between the duration of postoperative drainage, subcutaneous fat thickness and surgical site infection.

1 | INTRODUCTION

Orthopaedic surgeons have long faced challenges due to postoperative surgical site infections (SSIs), which pose significant problems for both patients and healthcare providers in the field of orthopaedics.[1] Within the realm of orthopaedic surgery, SSIs are defined as infections that manifest within 30 days post-surgery, in cases where no fixation device is implanted, or within 1-year post-surgery if a metal device remains implanted.[2] SSIs can be categorized based on the location of infection, including superficial, deep and interstitial classifications.[3] Superficial SSIs encompass infections limited to the skin or subcutaneous tissues adjoining the incision. Deep SSIs extend beyond the fascia or muscle layers, while interstitial SSIs encompass infections extending beyond the skin, fascia and muscle layers at the surgical site.[3] Despite advancements in surgical techniques, intraoperative practices and numerous advanced wound therapies, the burden of SSIs persists for both patients and healthcare institutions.[4] Patients afflicted with SSIs encounter escalated hospital expenses, extended hospitalizations, diminished physical and social functionality and, in severe cases, necessitate internal fixation removal or may face mortality.[5] According to the American College of Surgeons, SSIs have emerged as the most prevalent hospital-acquired infection and the most financially burdensome to manage. The collective incidence of SSIs across all inpatient surgeries ranges from 2% to 5%, with an estimated cost averaging around $20 000 per occurrence.[6] Another study reported that approximately 1%–3% of all orthopaedic surgeries in all age groups are complicated by SSIs, with a corresponding 300% increase in healthcare costs.[7] The high hospitalization costs associated with SSIs place a heavy financial burden on patients, while the prolonged treatment is a huge physical and psychological blow, all of which are destroying patients' daily lives and families. Hence, it is imperative to deepen our comprehension of the prevalence and risk elements linked to SSIs. This knowledge is crucial for informing prevention approaches and enhancing patient outcomes.

Literature has delved into meta-analyses and systematic evaluations across diverse orthopaedic surgeries, aiming to scrutinize their respective risk factors for postoperative SSIs. Risk factors found in studies often include elderly age,[8] diabetes,[9] smoking,[10] obesity[11] and poor nutrition.[12] However, these studies tend to be limited to a single area, such as spinal,[13] joint,[2] traumatic injuries[14] and bone tumours.[15] Our review of the literature has not identified any studies that performed meta-analysis and systematic evaluation of postoperative SSIs throughout orthopaedic surgery. To deepen our comprehension of the occurrence and risk elements associated with SSIs, this study conducted a meta-analysis and systematic evaluation focusing on the incidence and risk factors of postoperative SSIs in orthopaedic surgery. The aim is to alleviate the strain on medical resources and enhance patient prognoses.

2 | INFORMATION AND METHODS

The program's foundation lies in the guidelines outlined by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocol. The review shall adhere meticulously to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines throughout its execution.[16]

2.1 | Literature search

Information was retrieved from PubMed, Embase, Cochrane Library and Web of Science, focusing on cohort studies and case–control studies analysing risk factors for orthopaedic SSIs with multivariate analyses. The search, conducted up to March 20, 2024, utilized a combination of subject terms and free words, including 'orthopedics', 'surgical site infections' and 'risk factors', supplemented by a detailed search strategy outlined in the Supplementary Material.

2.2 | Inclusion and exclusion criteria

Inclusion criteria: (1) meeting the diagnostic criteria for SSIs.[17] (2) research articles comprising case–control and cohort studies investigating risk factors associated with SSIs in orthopaedic patients post-surgery. These studies are required to incorporate multivariate analyses examining SSI risk factors. The primary focus was on conducting multivariate analysis of risk factors. The secondary emphasis was on determining the occurrence of SSIs following orthopaedic surgery.

Exclusion criteria included: Conference abstracts, meta-analyses, study protocols, correspondence, duplicate publications, systematic reviews, incomplete access to full-text articles, insufficiency of usable data and studies involving experimentation on animals.

2.3 | Data extraction

Two independent evaluators conducted data extraction by screening the literature for relevant information. They reviewed titles, abstracts and full texts to identify eligible articles, resolving any discrepancies through consultation with relevant experts. Adherence to inclusion and exclusion criteria was paramount during screening. Extracted data underwent cross-validation to ensure consistency. Key elements extracted included the first author's name, publication year, country, study design, sample size, gender distribution and age demographics.

2.4 | Quality evaluation

The Newcastle-Ottawa Scale[18] was employed for assessing case–control and cohort studies, covering three key aspects: the selection of the study population (worth four points), comparability between groups (worth two points) and exposure factors or outcome measures (worth three points). This scale utilizes a nine-point system, where a score of ≤4 indicates low quality, 5–6 denotes moderate quality, and ≥7 signifies high quality. In cases of disagreement between the two assessors during the evaluation, a discussion will take place, and if needed, a third party will make the final decision.

2.5 | Statistical analyses

Statistical analysis was performed utilizing Stata 15.0 software. Risk estimates in each study were presented as odds ratios (OR) without distinguishing between OR, relative risks or hazard ratios. Pooled OR values and 95% confidence intervals were computed. The selection of the appropriate model for combining OR values was based on the results of the heterogeneity test (*Q*-test method) and the I^2 statistic. A random-effects model was employed if I^2 exceeded 50%, while a fixed-effects model was utilized if I^2 was 50% or less. A sensitivity analysis of the literature was conducted for $I^2 > 50\%$ using the one-by-one exclusion test. Publication bias was assessed using Egger's test with a significance level set at $\alpha = 0.05$. Statistical significance was defined as $p < 0.05$.

3 | RESULTS

3.1 | Literature search and process

From PubMed, Embase, Cochrane Library, Web of Science and other sources, cohort studies and case–control studies with multivariate analyses focusing on risk factors for orthopaedic SSIs were collected. EndNote 21 facilitated literature management throughout the process. Initially, 1248 documents were retrieved, with 201 duplicates removed, resulting in 1047 unique documents. Based on the exclusion criteria, 180 articles were initially screened after a review of the titles and abstracts. Following a full-text review and the exclusion of two studies that were inaccessible, a total of 45 eligible articles were ultimately included.

3.2 | Basic characteristics of the included literature

A total of 45 studies were included,[15,19–62] four case–control studies, and 41 cohort investigations were conducted, encompassing 1 572 160 patients, among whom 43 662 individuals experienced SSIs following their operations. Table S1 outlines detailed characteristics of the literature. Utilizing the Newcastle-Ottawa Scale quality rating, 45 articles underwent assessment, achieving scores between 7 and 9, indicative of elevated study quality. Table S2 provides a breakdown of the precise quality evaluation.

4 | MULTIVARIATE META-ANALYSIS

4.1 | Albumin <35 g/L

Seven studies mentioned Albumin <35 g/L, and the heterogeneity test ($I^2 = 58.7$, $p = 0.018$) was analysed using a random-effects model, and the results of the analyses suggested that Albumin <35 g/L was a risk factor for the development of SSIs in postoperative-orthopaedic-patients, and the difference was statistically significant (OR = 2.29, 95% confidence interval [CI] [1.45, 3.62], $p = 0.0001$). Detailed results are available in Figure S2 and Table S3.

4.2 | ASA >2

Eight studies addressed ASA >2, with heterogeneity analysis conducted using a fixed-effects model ($I^2 = 0$, $p = 0.887$). The results indicated that ASA >2 significantly increased the risk of SSIs among postoperative orthopaedic patients, with a statistically significant difference observed (OR = 2.30, 95% CI [1.86, 2.89], $p = 0.0001$). Detailed results are available in Figure S2 and Table S3.

4.3 | BMI >24 kg/m^2

Ten studies examined body mass index (BMI) levels exceeding 24 kg/m^2, with a heterogeneity test conducted utilizing a random-effects model ($I^2 = 64.1$, $p = 0.0001$). The analyses revealed that BMI >24 kg/m^2 significantly increased the risk of SSIs among postoperative orthopaedic patients, with a statistically significant difference noted (OR = 2.15, 95% CI [1.60, 2.90], $p = 0.0001$). Refer to Figure S3 and Table S3 for further details.

4.4 | Diabetes

Eighteen studies addressed the presence of diabetes, with heterogeneity analysis conducted using a random-effects model ($I^2 = 70.8$, $p = 0.0001$). The results indicated that diabetes significantly elevated the risk of SSIs among postoperative orthopaedic patients, with a statistically significant difference observed (OR = 2.25, 95% CI [1.66, 3.05], $p = 0.0001$). Detailed results are available in Figure S4 and Table S3.

4.5 | Prolonged surgical duration >60 min

Ten studies investigated prolonged surgical durations exceeding 60 min, with a heterogeneity test conducted using a random-effects model ($I^2 = 64.5$, $p = 0.0001$). The findings indicated that prolonged surgical duration >60 min significantly increased the risk of SSIs in postoperative orthopaedic patients, with statistically significant differences observed (OR = 2.06, 95% CI [1.52, 2.80], $p = 0.001$). Further details can be found in Figure S5 and Table S3.

4.6 | Multiple surgeries/procedures

Six studies examined the occurrence of multiple surgeries or procedures, with a heterogeneity test conducted using a random-effects model ($I^2 = 84.7$, $p = 0.0001$). The analysis results indicated that multiple surgeries/procedures were a significant risk factor for SSIs in post-orthopaedic surgery patients, with a statistically significant difference observed (OR = 2.38, 95% CI [1.29, 4.41], $p = 0.006$). For more detailed insights, please refer to Figure S6 and Table S3.

4.7 | Open fracture

Nine studies investigated open fractures, with a heterogeneity test conducted using a fixed-effects model ($I^2 = 45.8$, $p = 0.064$). The analysis indicated that open fractures were a significant risk factor for SSIs in postoperative orthopaedic patients, with a statistically significant difference observed (OR = 3.35, 95% CI [2.51, 4.46], $p = 0.001$). Detailed findings can be found in Figure S7 and Table S3.

4.8 | Current smoking

Seventeen studies examined the association between current smoking and SSIs, with a heterogeneity test conducted using a random-effects model ($I^2 = 87.6$, $p = 0.0001$). The analysis indicated that current smoking was a significant risk factor for SSIs in postoperative orthopaedic patients, with a statistically significant difference observed (OR = 2.87, 95% CI [1.88, 4.37], $p = 0.0001$). For more detailed information, please refer to Figure S8 and Table S3.

4.9 | Wound class >2

Six studies investigated wound class greater than 2, with a heterogeneity test conducted using a random-effects model ($I^2 = 76.4$, $p = 0.0001$). The analysis revealed that wound class greater than 2 was a significant risk factor for the development of SSIs in postoperative orthopaedic patients, with a statistically significant difference observed (OR = 3.59, 95% CI [1.68, 7.66], $p = 0.001$). Further details can be found in Figure S9 and Table S3. Please refer to Table S4 for the specific criteria used to grade wounds.[46]

4.10 | Utilization of implants

Three studies examined the utilization of implants, with a heterogeneity test conducted using a random-effects model ($I^2 = 62.1$, $p = 0.048$). The analysis indicated that the utilization of implants was a significant risk factor for the development of SSIs in postoperative orthopaedic patients, with a statistically significant difference observed (OR = 1.89, 95% CI [1.15, 3.11], $p = 0.0012$). For more detailed insights, please refer to Figure S10 and Table S3.

4.11 | Results of other multivariate meta-analysis

The difference in correlation between gender, age, intraoperative Blood loss >400 mL and hypertension, and the occurrence of SSIs in postoperative orthopaedic patients was not statistically different.

5 | SENSITIVITY ANALYSES

To evaluate the influence of each study on the collective findings, sensitivity analyses were conducted by omitting one study at a time. The analysis revealed that the pooled effect sizes and 95% confidence intervals remained unaltered by the single-study exclusion. This indicates that the meta-analysis's overall conclusions are robust and reliable.

6 | PUBLICATION BIAS

The Egger test was applied to each risk factor to assess publication bias. Among the 10 risk factors that were statistically different, diabetes ($p = 0.001$), current smoking ($p = 0.001$), prolonged surgical duration >60 min ($p = 0.034$), utilization of implants ($p = 0.042$) and BMI >24 kg/m^2 ($p = 0.008$) as risk factors for SSIs in postoperative orthopaedic patients with publication bias. The remaining five risk factors included Albumin <35 g/L ($p = 0.280$), ASA >2 ($p = 0.285$), Multiple surgeries/procedures ($p = 0.703$), open fracture ($p = 0.191$) and WoundClass >2 ($p = 0.552$), $p > 0.05$ for each risk factor suggesting that none of them had publication bias.

7 | DISCUSSION

This meta-analysis investigated the factors linked to the occurrence of SSIs in individuals post orthopaedic surgery. SSI prevalence across the studies analysed varied from 0.3% to 29%. Albumin <35 g/L, ASA >2, BMI >24 kg/m^2, diabetes, prolonged surgical duration >60 min, multiple surgeries/procedures, open fracture, current smoking, Wound Class >2 and utilization of implants increased the incidence of SSIs in post orthopaedic patients. Age >60, Hypertension, and Blood loss >400 mL also did not show any significant difference. The utilization of drainage did not emerge as a contributing factor to the risk of SSIs.

Regarding the demographic characteristics of the patients, out of a total of 45 publications, 10 involved males[15,29–31,33,46,54,56,59] and one involved females[20] in the multivariate analysis. In our examination, gender did not demonstrate a notable distinction (OR = 1.30, 95% CI [0.79, 1.42], $p = 0.688$). Age is commonly acknowledged as an autonomous risk determinant for postoperative orthopaedic SSIs, with an increased likelihood of SSIs with advancing age.[27,39] Nevertheless, in our investigation, age over 60 years failed to exhibit a substantial variation (OR = 1.06, 95% CI [0.93, 1.83], $p = 0.130$), but this must be interpreted with care because only five papers[19,20,39,46,54] gave age-specific thresholds or stratified analyses of age, and we chose 60 years as the threshold as a way of including the findings of the five papers. Subsequent researchers conducting similar analyses of risk factors might consider applying the ROS (Receiver operating characteristic) to determine a highly sensitive threshold, which could provide a larger sample for similar meta-analyses. In addition, we focused on the association between postoperative drainage and SSIs, whether the use of postoperative drainage is a risk factor for SSIs has been controversial, regarding postoperative drainage five studies[15,25,39,41,47] were included for analysis, and the results of two of these studies showed the use of drainage to be a protective factor for SSIs and were significantly different. One study indicated that the utilization of drainage posed a risk for SSIs and exhibited a noteworthy disparity, whereas our findings indicated that the utilization of drainage as a risk factor for SSIs did not manifest significant differentiation (OR = 1.00, 95% CI [0.47, 2.15], $p = 0.992$). Postoperative drainage can draw fluid out of the surgical site, which can be beneficial as it will reduce the number of patients experiencing fever; however, when drainage is reversed, it may increase the incidence of SSIs in patients, which may be the reason for the controversy that has arisen. In addition, the relationship between the duration of postoperative drainage and SSIs is not clear and few studies have analysed this.

Albumin, as a negative acute-phase reactant, experiences a decrease in levels during inflammatory and pathological conditions, thereby serving as an indicator of disease severity and malnutrition.[23] By delivering crucial nutrients, regulating fluid equilibrium, mitigating inflammation, serving as an antioxidant and bolstering immune responses, Albumin assumes a pivotal function in wound healing and immune modulation. Diminished albumin levels can impede these processes, compromising wound healing and immune functionality.[58] Therefore, close observation of the patient's albumin level during the perioperative period to maintain it at a normal level is important for the prevention of SSIs and improvement of the patient's prognosis.

Obesity is widely acknowledged as a risk factor for SSIs due to its impact on immune function, vascular perfusion and surgical outcomes, potentially elevating the occurrence of SSIs. Morbid obesity can lead to a pro-inflammatory state and disrupt the normal immune state by secreting adipokines, such as leptin and lipocalin. Also, poor vascularization of adipose tissue may lead to local hypoxia in the incision and affect the ability of neutrophils to phagocytose bacteria.[22,54] In addition, obesity leads to increased skin folds and decreased vascular perfusion, increasing the risk of skin infections and abscesses.[54] During surgery, patients with a higher BMI encounter challenges related to thicker subcutaneous tissue, including heightened soft tissue cutting, increased tissue tension, challenges in implant placement and the potential for dead space formation. These factors collectively escalate surgical risks.[23,40] Therefore, it is imperative to exercise caution when adjusting the dosage of prophylactic antibiotics in obese patients to guarantee sufficient antibiotic serum levels, thereby mitigating the risk of infection. Moreover, while some researchers have suggested a potential association between subcutaneous fat thickness and SSIs, this connection has been minimally explored. Further studies are warranted to elucidate the relationship between the two variables comprehensively.

Diabetes and current smoking affect the immune function and vascular function of patients, which increases the incidence of SSIs. Diabetes mellitus is also widely acknowledged as a risk factor for SSIs, possibly due to the impairment of immune response and vascular function associated with hyperglycaemia.[28] In diabetic patients, neutrophil chemotaxis and phagocytosis are impaired, which may lead to reduced antimicrobial defences and delayed wound healing.[26] In addition, diabetes brings with it damage to the vascular endothelium, vascular sclerosis, microangiopathy, etc.[63] These factors collectively contribute to the heightened susceptibility to SSIs in diabetic individuals. Peripheral vascular disease, a comorbidity affecting 9.5% of diabetic patients, exacerbates the movement of immune cells and nutrients towards the infection site. This impairment stems from the thickening of the capillary basement membrane induced by prolonged inflammation. Consequently, inadequate tissue perfusion may compromise antibiotic efficacy and exacerbate underlying immunodeficiencies, culminating in a poorer prognosis for SSIs in diabetic patients with peripheral vascular disease.[64] Current smoking significantly impairs wound healing through various mechanisms, including reduced tissue perfusion and oxygenation, hindered inflammatory response and compromised oxidative bactericidal mechanisms.[40]

In this investigation, prolonged surgical duration exceeding 60 min, undergoing multiple surgeries or procedures and experiencing open fractures were recognized as predisposing factors for SSIs among orthopaedic patients during the postoperative period. Increased length of surgery, multiple surgeries, or a single surgery that includes multiple procedures, and open fracture are all indicative of a complex condition that requires more surgical skill, more trauma to the patient and longer exposure to surgical wounds, which makes them more susceptible to infections.[38,40] Remarkably, in certain instances, SSIs may stem from nosocomial infections like urinary tract and upper respiratory tract infections, which exhibit a twofold prevalence among trauma patients, particularly those with spinal, thoracic or limb injuries.[21] Extended preoperative hospitalizations theoretically elevate the likelihood of nosocomial infections among patients, compounded by the influence of the intricate hospital milieu on patients' daily activities, consequently impinging on their physical capabilities. These combined factors intensify the susceptibility to SSIs during the postoperative phase. Therefore, after the patient is admitted to the hospital, complete the examination and exclude contraindications to surgery should be arranged as soon as possible, to reduce the occurrence of SSIs.

The presence of an implant makes nearby tissues more susceptible to infection. Granulocyte deficiencies, alongside locally acquired hematomas surrounding the implant, foster an optimal setting for bacterial proliferation. Bacteria adhere readily to the implant surface, forming resilient biofilms. Penetrating these regions proves challenging for antibiotics, hindering the establishment of effective local antimicrobial concentrations.[52,55] Therefore, the covering and sterilization of surgical devices and implants, as well as optimizing nutrition, antibiotic use and postoperative wound care, should be properly monitored.

8 | LIMITATION

Certain limitations are present within this meta-analysis. Firstly, the types of surgery and surgical techniques were different in different studies; secondly, the selection of patients and inclusion criteria were different in different studies, and the measurement of risk factors was different; thirdly, the role of diabetes mellitus as a risk factor is not sufficiently clarified. This is due to the broad spectrum of diabetes, which ranges from well-controlled to poorly controlled cases, includes both those with and without comorbidities (such as nephropathy, peripheral artery disease and neuropathy) and varies between ideal and poor perioperative glycemic management. Consequently, our analyses might not fully reflect the influence of these varying conditions, potentially impacting the interpretation of the study outcomes; finally, most of the included studies were retrospective studies, with different follow-up periods, and there was interviewer bias.

9 | CONCLUSION

The present study identified a number of risk factors for the development of SSIs following orthopaedic surgery. It is therefore recommended that clinicians closely monitor these indicators in order to prevent the development of postoperative SSIs. Furthermore, our interpretation of diabetes mellitus was not adequate. It is therefore recommended that future studies refine the effect of diabetes mellitus on SSIs in different situations. Moreover, there is a need to explore the influence of subcutaneous fat thickness and the duration of postoperative drainage on the risk of SSIs in orthopaedic patients. In addition, more investigations are necessary to elucidate whether age acts as a risk factor for SSIs.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare that are relevant to the content of this article.

DATA AVAILABILITY STATEMENT

Data available in supplementary material.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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