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SYSTEMATIC REVIEW

A Systematic Review and Meta-Analysis of Surgical Site Infections in Older Adults Undergoing Total Knee Arthroplasty: Incidence Rate and Risk Factors

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ABSTRACT

Background. Total knee arthroplasty (TKA) effectively improves joint function and quality of life, but carries the risk of surgical site infection (SSI). SSIs most affect older adult patients with comorbidities. Thus, we evaluated the incidence of SSIs following TKA in older adult populations (≥ 65 years) and explored the association of SSIs with male sex, morbid obesity, and other comorbidities.

Methodology. A systematic review and meta-analysis were conducted according to PRISMA guidelines. Data were extracted from prospective and retrospective studies evaluating the incidence and risk factors for SSIs following TKA in older adults aged ≥ 65 years. Studies were found through MEDLINE/PubMed, Cochrane Library, and other databases up to 31 July 2024. Risk factors included male sex, morbid obesity, type 2 diabetes, rheumatologic disease, peripheral vascular disease, heart failure, and anaemia. Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated using a random-effects model. Heterogeneity was assessed using the I^2 statistic.

Results. Twenty studies with a total population of 29,20,681 patients were included. The pooled prevalence of SSIs following TKA was estimated at 1.19% (95% CI: 0.84–1.68%). Male sex was associated with a higher SSI risk (OR: 1.79, 95% CI: 1.45–2.21%). Morbid obesity showed the strongest association with SSIs (OR: 1.47, 95% CI: 1.16–1.86%), followed by type 2 diabetes (OR: 1.28, 95% CI: 1.05–1.56%), and rheumatologic disease (OR: 1.72, 95% CI: 1.09–2.69%). Significant heterogeneity was observed across studies (I^2 > 50%).

Conclusion. This meta-analysis highlights the burden of SSIs among older adult patients following TKA, particularly male patients and those with comorbidities. These results indicate the need for individualized risk assessment and preventive strategies to optimize surgical outcomes in this population. Future research should focus on developing tailored interventions for this vulnerable population.

Keywords. anemia, heart failure, males, morbid obesity, peripheral vascular disease, rheumatologic disease, surgical site infection, total knee arthroplasty, type 2 diabetes

INTRODUCTION

Total knee arthroplasty (TKA) is one of the most effective, economical, and consistently successful surgeries indicated for treating patients with severe osteoarthritis of the knee. TKA improves joint function, relieves pain, and corrects deformities, thereby improving patients' quality of life.[1,2] The global demand for TKA is rising rapidly due to the growing prevalence of knee arthritis. It is estimated that the number of primary TKA procedures will increase by 85%, i.e., 1.26 million procedures, by 2030.[3,4]

Despite these promising trends, challenges remain, as 11% to 20.8% of patients develop perioperative complications.

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The most common complications include thromboembolic disease, infection, periprosthetic fracture, extensor mechanism injury, surgical wounds, joint stiffness, and neurovascular lesions.[2] Among these, infections pose a particularly significant challenge. Recent data suggest that peri-prosthetic joint infection, in particular, occurs in 0.8% and 1.9% of all TKAs.[5]

Early surgical site infections (SSIs) are more common than late (≥ 3 months post-TKA) SSIs.[6,7] Wilson et al. concluded that patients who were morbidly obese (BMI ≥ 40 kg/m^2) were at the highest risk of SSIs after knee surgeries.[8] Werner et al. categorized 891,567 patients who underwent total hip arthroplasty into four BMI-based cohorts: non-obese (BMI < 30 kg/m^2), obese (BMI 30–39.9 kg/m^2), morbidly obese (BMI 40–49.9 kg/m^2), and super-obese (BMI ≥ 50 kg/m^2). The study demonstrated a progressive increase in the risk of SSIs with rising BMI, with SSI rates reported as 0.8% in non-obese patients, 2.6% in obese patients, 5.2% in morbidly obese patients, and 12.4% in super-obese patients.[9,10] Fu et al. demonstrated the same trend in 71,599 patients,[9,11] emphasizing the need to address BMI.

The impact of age on TKA outcomes remains a contentious topic of discussion. In clinical research, individuals aged 65 years and above are commonly classified as older adults, a group prone to comorbidities, physiological decline, and increased vulnerability to postoperative complications.[2] While some studies suggest that age alone is not a risk factor for SSI after total joint arthroplasty (citing 65 years old as the cut-off),[12] other studies indicate a significantly higher risk in patients aged 76 to 80 years as compared to those aged ≤ 50 years.[13] Numerous studies support the use of primary TKA in appropriately selected elderly patients, but these studies often suffer from limitations such as incomplete datasets, diverse patient populations, and inconsistent outcome measures.[14]

In addition, comorbidities such as type 2 diabetes, rheumatologic disease, peripheral vascular disease, heart failure, and anemia also influence TKA outcomes. Baseline comorbidities increase the risk of postsurgical mortality and SSIs in the older adult population undergoing TKA. Congestive heart failure, chronic pulmonary disease, preoperative anemia, depression, diabetes, renal disease, pulmonary circulation disorders, rheumatologic disease, psychoses, metastatic tumour, valvular disease, and peripheral vascular disease were associated with increased risk of SSIs.[14,15] With regard to timing, early SSIs were associated with hypertension, heart failure, coagulopathies, depression, and peripheral vascular disease, while delayed and late SSIs were associated with alcohol abuse, congestive heart failure, depression, diabetes, renal failure, and iron-deficiency anemia.[7,16]

While recent studies demonstrated age and other comorbidities as risk factors in TKA, no single study has evaluated the risk of post-TKA SSIs in the older adult population and its association with gender and comorbidities. Elucidating these relationships will help prevent SSIs and achieve better surgical outcomes after TKA in this high-risk population.

METHODOLOGY

Study design

The objectives of this study were to evaluate the risk factors for SSI after TKA in the older adult population (≥ 65 years old) and to assess the association of SSI with male sex, morbid obesity, type 2 diabetes, rheumatologic disease, peripheral vascular disease, heart failure, and anemia. We included published prospective and retrospective observational studies, cohort studies, surveillance studies, and database analyses that evaluated the incidence rate of infection after TKA and/or evaluated the risk factors including male sex, morbid obesity, type 2 diabetes, rheumatologic disease, peripheral vascular disease, heart failure, and anemia associated with SSIs in patients aged ≥ 65 years of either sex. We excluded non-English publications, case reports, and studies lacking SSI data in the relevant population (Figure 1).

Search strategy

This systematic review and meta-analysis followed the 2020 PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines.[17] A comprehensive search was conducted across MEDLINE/PubMed, WHO International Clinical Trials Registry Platform, IndMED, ClinicalTrials.gov, and the Cochrane Library [Cochrane Central Register of Controlled Trials (CENTRAL), Cochrane Database of Systematic Reviews, and Cochrane Methodology Register] from study inception to 31 July 2024. The search terms used in different combinations were: "incidence," "infection," "total," "knee," "arthroplasty," "postoperative," "rates," "surgical," "site," "replacement," "periprosthetic," "joint," "risk," "factors," "epidemiology," "prevalence," "deep," "statistics," "trends," "management," "complications," "antibiotic," "prophylaxis," and "revision." We refined our search by adapting the search terms and filtering the results. Two authors independently screened the found abstracts and subsequently retrieved the full texts, if necessary. Disagreements were settled by a third author.

Data extraction and management

Data were extracted independently by the two authors and tabulated in a custom spreadsheet, making no assumptions or simplifications to ensure accuracy and reproducibility.

Both authors independently evaluated the studies' risk of bias. Observational studies were assessed using the Newcastle–Ottawa Scale. Discrepancies were resolved by a third author when necessary.

A random-effects model accounted for variability among studies and ensured robustness against potential outliers. The primary outcome, "incidence rate of SSI following TKA", and the secondary outcome "association of SSI following TKA with male sex, morbid obesity, type 2 diabetes, rheumatologic disease, peripheral vascular disease, heart failure, and

anemia" were assessed by calculating odds ratios (ORs) with corresponding 95% confidence intervals (CIs). Heterogeneity was analyzed with the $\chi 2$ test on n−1 degrees of freedom (with an α error of 5% for statistical significance) and the test. The values of 25% corresponded to low, 50% to medium, and 75% to high levels of heterogeneity.

Attrition rates, such as losses to follow-up, withdrawals, and dropouts, were documented. We critically assessed the studies' methods for handling missing data.

All statistical analyses were performed using MetaXL v 4.0.

RESULTS

A total of 127 studies were retrieved. After removing 32 duplicate records, we screened the titles and abstracts of 95 unique studies. During this screening phase, 18 studies were excluded. After evaluating the full-text articles of the remaining 37 studies, 20 studies were deemed eligible for inclusion in the analysis.[2,7,14-16,18-32] Data from 19 studies were used for quantitative analysis (one study lacked pooled prevalence data). A detailed overview of the search and selection process is provided in Figure 1.

Characteristics of the included studies

A total of 29,20,681 patients were included in our meta-analysis (range 38 to 12,27,244 patients). The percentage of males ranged from 16% to 94.8% (Table 1).

Incidence rate of surgical site infections following TKA

Data from 28,37,670 patients in 19 studies were included for quantitative analysis of data to estimate the pooled prevalence rate of SSI following TKA (Figure 2).[2,7,14,16,18-32] We excluded one study since it lacked data to estimate the pooled prevalence.[15] This was estimated to be 1.19% (95% CI: 0.84%-1.68%).

Incidence rate of surgical site infections following TKA in male patients

Data from seven studies were included for quantitative analysis to estimate the pooled prevalence rate of SSI following TKA in male patients (Figure 3). This was estimated to be 1.79% (95% CI: 1.45%-2.21%).[14,16,21,22,27,28,30]

Incidence rate of surgical site infections in patients with comorbidities

Data from seven studies were included for quantitative analysis to estimate the pooled prevalence rate of SSI following TKA in patients with morbid obesity (Figure 4A). This was estimated to be 1.47% (95% CI: 1.16%-1.86%).[7,15,16,20-22,31]

Data from five studies were included for quantitative analysis to estimate the pooled prevalence of SSI following TKA in patients with type 2 diabetes (Figure 4B). This was estimated to be 1.28% (95% CI: 1.05%-1.56%).[15,16,21,27,31]

Data from three studies were included for quantitative analysis to estimate the pooled prevalence of SSI following TKA in patients with rheumatologic disease (Figure 4C). This was estimated to be 1.72% (95% CI: 1.09%-2.69%).[7,15,30]

Table 1. Characteristics of the included studies

Study	Design	Country	Total population	Males	Mean age	Newcastle-Ottawa Scale
Souza GGA,[2] 2020	Prospective	Brazil	70	23.6%	73.0	6
Weinstein EJ,[7] 2023	Retrospective	USA	61701	94.8%	Median: 65	7
Bischoff P,[14] 2023	Retrospective	Germany	286074	27%	Median: 70	7
Bozic KJ,[15] 2012	Retrospective	USA	83011	NA	NA	5
Sodhi N,[16] 2020	Retrospective	USA	275717	35%	NA	6
Babkin Y,[18] 2007	Retrospective	Israel	180	34%	72.4	6
Chesney D,[19] 2008	Prospective	UK	1509	42.68%	NA	6
Pulido L,[20] 2008	Retrospective	USA	4185	NA	NA	5
Dowsey MM,[21] 2009	Retrospective analysis of prospectively collected data	Australia	1214	36.99%	Median: 72	7
Suzuki G,[22] 2011	Retrospective	Japan	1146	NA	Median: 72	5
Belmont PJ Jr,[23] 2014	Prospective	USA	15321	35.5% (n = 15,287)	67.3	7
Yun ST,[24] 2018	Retrospective	Korea	79	16%	82.8	5
Kodaira S,[25] 2019	Retrospective	Japan	679	23%	82	6
Sezgin EA,[26] 2019	Retrospective	Sweden	329	31%	92	6
Ravi B,[27] 2019	Retrospective	Canada	92343	38.5%	Median: 68	7
Baier C,[28] 2019	Retrospective	Germany	2439	32.1%	Median: 69	7
Yang QF,[29] 2021	Retrospective	China	1227244	NA	NA	6
Fricka KB,[30] 2023	Retrospective	USA	525887	37.9%	73.0	7
Li H,[31] 2024	Retrospective	China	650	34.46%	NA	5
Lenguerrand,[32] 2019	Prospective	UK	340903	43.15%	Median: 70	8

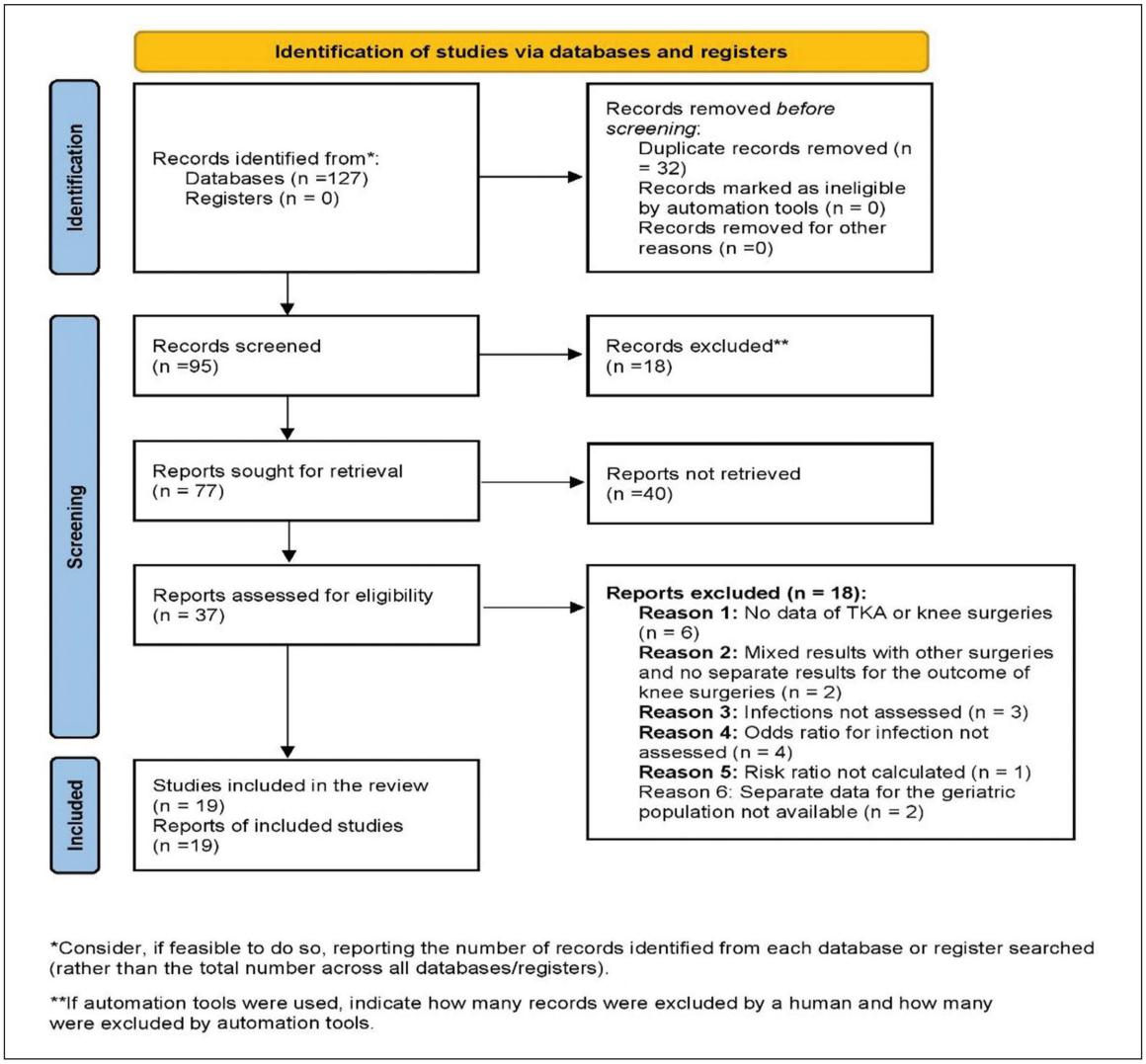

Figure 1. PRISMA 2020 flow diagram for study selection.

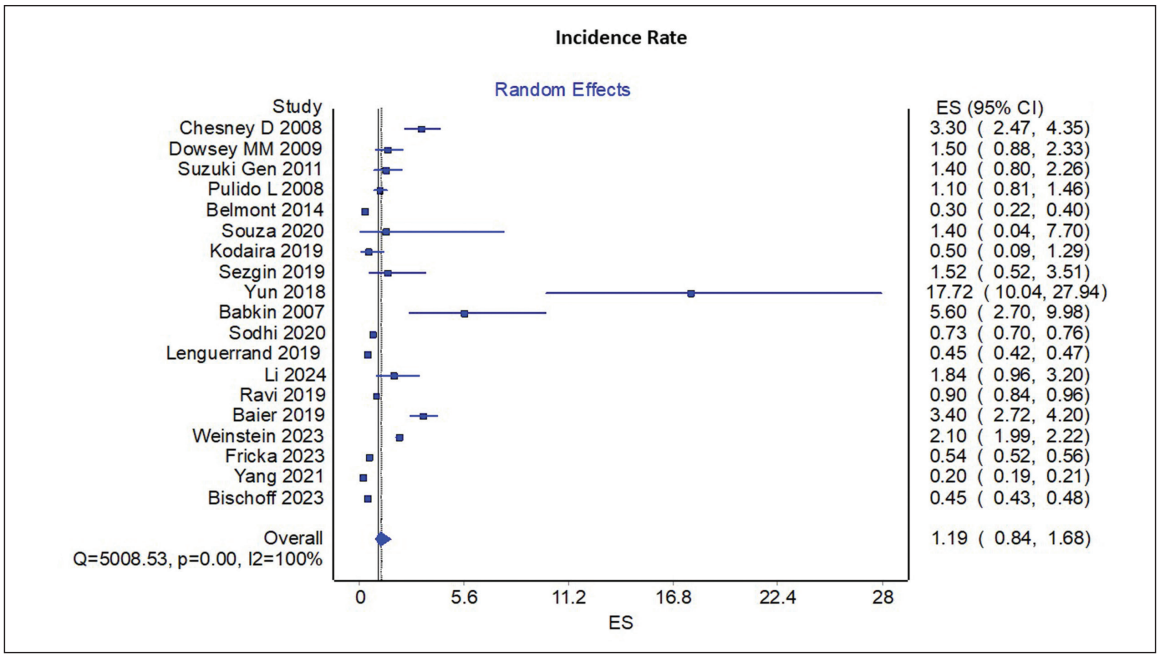

Figure 2. Forest plot showing pooled prevalence of surgical site infections (SSIs) in older adult patients post-total knee arthroplasty (TKA).

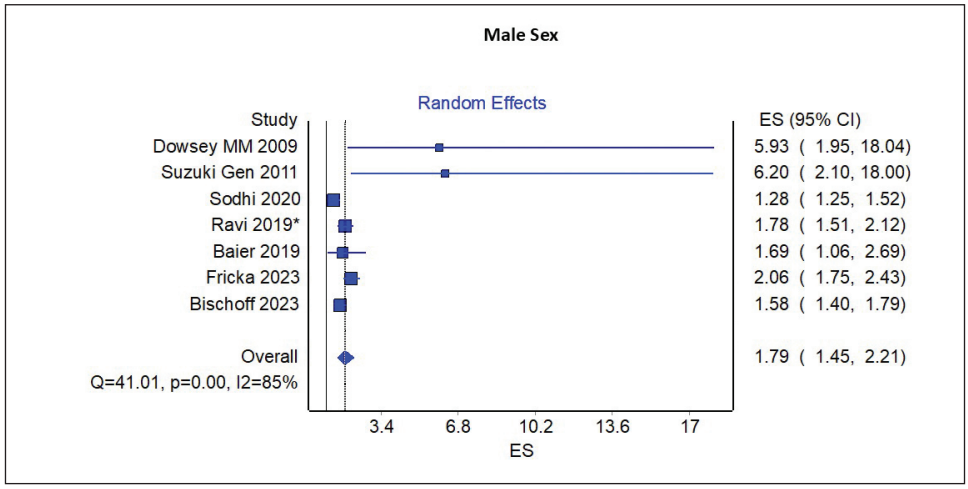

Figure 3. Forest plot of odds ratios estimating SSI risk associated with male sex post-TKA.

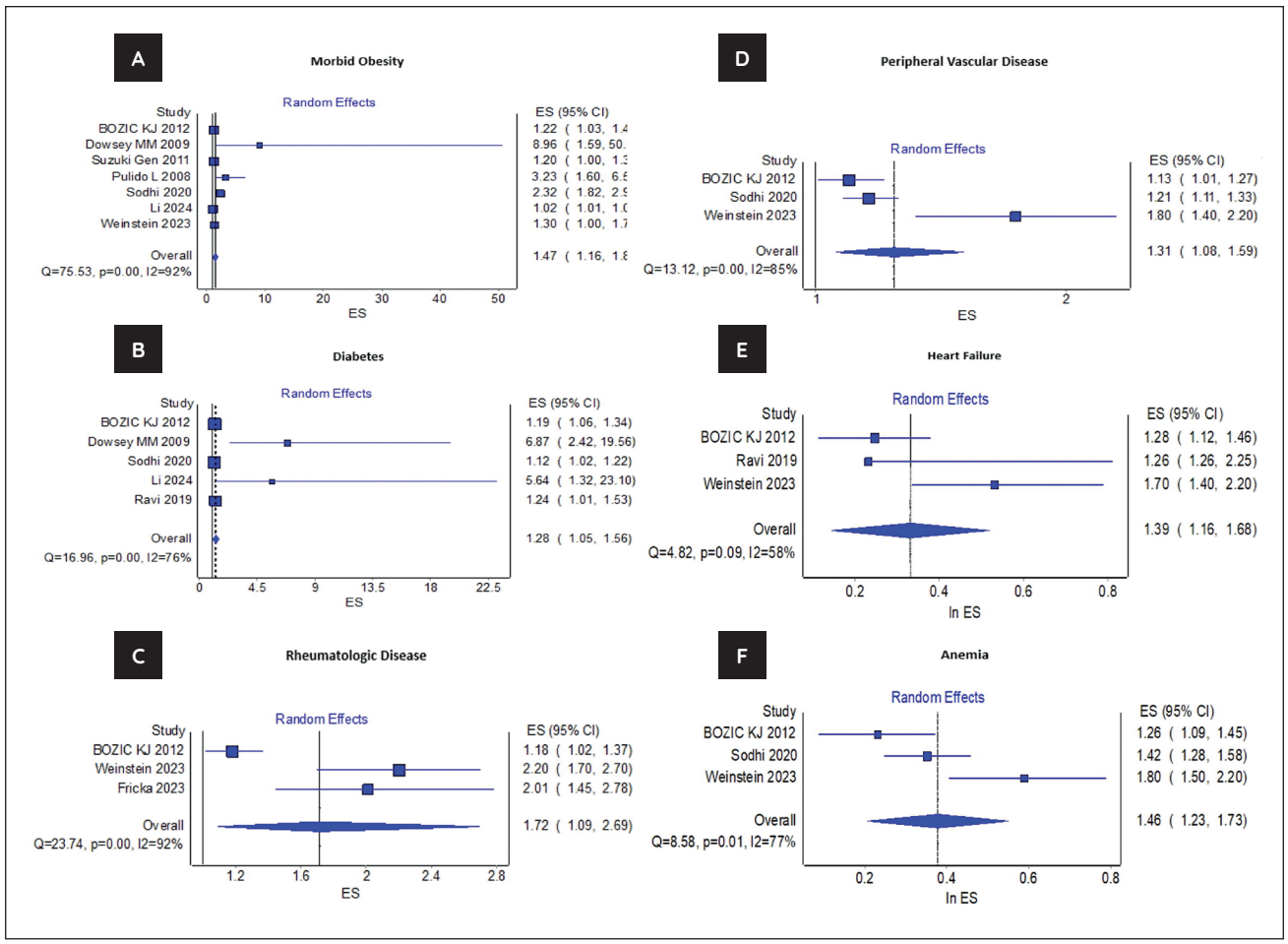

Figure 4. (A) Forest plot estimating SSI risk in older adult patients with morbid obesity. (n = 7 studies; random-effects model; I^2 = 92%). **(B)** Forest plot estimating SSI risk in older adult patients with type 2 diabetes. (n = 5 studies; random-effects model; I^2 = 76%). **(C)** Forest plot estimating SSI risk in older adult patients with rheumatologic disease. (n = 3 studies; random-effects model; I^2 = 92%). **(D)** Forest plot estimating SSI risk in older adult patients with peripheral vascular disease. (n = 3 studies; random-effects model; I^2 = 85%). **(E)** Forest plot estimating SSI risk in older adult patients with heart failure. (n = 3 studies; random-effects model; I^2 = 58%). **(F)** Forest plot estimating SSI risk in older adult patients with anemia. (n = 3 studies; random-effects model; I^2 = 77%).

Data from three studies were included for quantitative analysis to estimate the pooled prevalence rate of SSI following TKA in patients with peripheral vascular disease (Figure 4D). This was estimated to be 1.31% (95% CI: 1.08%-1.59%).[7,15,16]

Data from three studies were included for quantitative analysis to estimate the pooled prevalence of SSI post-TKA in patients with heart failure (Figure 4E). This was estimated to be 1.39% (95% CI: 1.16%-1.68%).[7,15,27]

Data from three studies were included for quantitative analysis to estimate the pooled prevalence of SSI following TKA in patients with anemia (Figure 4F). This was estimated to be 1.46% (95% CI: 1.23%-1.73%).[7,15,16]

Test for heterogeneity

There was significant heterogeneity (> 50%) in all analyses conducted in this study.

DISCUSSION

We intended to estimate the prevalence rate of SSI following TKA by systematically reviewing recent publications with relevant data. Our findings demonstrated a significant incidence rate of SSIs in older adult patients undergoing TKA. Additionally, various modifiable and non-modifiable risk factors, such as male sex and comorbidities, were found to independently contribute to the increased risk of SSIs. Following a comprehensive screening process, 20 studies were included in our meta-analysis, with an overall population of 29,20,681 patients. The pooled prevalence of SSIs post-TKA in the older adult population was estimated to be 1.19% (95%, CI: 0.84%-1.68%), and in older adult men was 1.79% (95%, CI: 1.45%-2.21%. The incidence was also high in patients with comorbidities. However, these results remain non-definitive due to the studies' heterogeneity and our analysis's low power.

To our knowledge, this meta-analysis is the first to assess the incidence rate of surgical site infections (SSIs) following total knee arthroplasty (TKA) in the older adult population with various comorbidities, while also evaluating the outcomes specifically in males. The strengths of our study include its large cohort, a diverse age range within the older adult population, various comorbidities, and the variety of participants' ethnic origins. The major drawback of this meta-analysis is the dearth of high-quality and sufficiently powered data. We also did not account for the different postoperative wound management methods used, which could have affected the outcome.

Sezgin et al. found that in 329 nonagenarians (mean age = 92 years) who underwent TKA, 8 (2.4%) patients experienced knee complications requiring revision surgery. After 5 and 10 years, over 50% and 10% of patients, respectively, did not need revision.[26] Our incidence rate aligns with previously reported data, indicating that older adult patients undergoing TKA are at risk of developing SSIs. Factors include a weakened immune system, organ failure, and other comorbidities.[25,26,31]

Sodhi et al. reported a higher risk of 90-day SSIs in men (OR 1.28 [95% CI 1.25 to 1.52]; $p < 0.001$), patients with comorbidities, and overweight patients (BMI > 25 kg/m^2, $p < 0.001$). Our results were similar, suggesting a sex difference in immune response.[16]

Among the comorbidities, morbid obesity has emerged as one of the most significant risk factors for deep and superficial SSIs following TKA. Excess adipose impacts tissue vascularity, potentially delaying wound healing and increasing the risk of infection.[21] Type 2 diabetes also inhibits wound healing by reducing collagen synthesis, impairing angiogenesis, and attenuating neutrophil and macrophage functions, thereby raising the risk of infection and microvascular complications.[31]

Recent studies indicate that patients with autoimmune rheumatic diseases (including systemic lupus erythematosus and rheumatoid arthritis) face a higher risk of infection following surgery. Factors contributing to the risk of post-operative infections include immunosuppression, disease activity, comorbidities, patient demographics, surgeon experience, and the volume of surgeries performed at the hospital.[32]

Peripheral vascular disease (OR 1.21 [95% CI 1.11 to 1.33]; $p < 0.001$) increased the risk of SSIs post-TKAs.[16]

Heart failure and anemia also significantly increase SSI risk following TKA. Reduced tissue perfusion and tissue hypoxia both compromise wound healing.[33,34]

Patient selection and comorbidity control could help reduce SSI incidence rates in the older adult population. Male patients and those with rheumatologic disease or cardiovascular comorbidities may benefit from individualized wound management therapies.

CONCLUSION

This meta-analysis highlights a significant incidence of SSIs following TKA in older adult patients and identifies risk factors. The results should guide clinical practice and help develop targeted interventions aimed at minimizing infection risks for this vulnerable population.

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STATEMENT OF AUTHORSHIP

All authors certified fulfillment of ICMJE authorship criteria.

CREDIT AUTHOR STATEMENT

CH: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data Curation, Writing – original draft preparation, Writing – review and editing, Supervision, Project administration; **BS:** Conceptualization, Software, Validation, Formal analysis, Investigation, Resources, Data Curation, Writing – original draft preparation, Writing – review and editing, Visualization, Funding acquisition; **PS:** Methodology, Software, Validation, Formal analysis, Data Curation, Writing – review and editing, Visualization, Project administration.

DATA AVAILABILITY STATEMENT

The datasets generated and analyzed are included in the published article.

AUTHOR DISCLOSURE

The authors declared no conflict of interest related to the research, authorship, or publication of this manuscript.

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