



Prevalence of Surgical Site Infections in Total Knee Arthroplasty Surgeries: A Systematic Review and Meta-Analysis

Ali Mohammad Mokhtari ¹, Ashkan Karimi ², Reza Feizi ³, Armin Salavatian ⁴, Mehrdad Rohaninasab ⁵, Jalal Mardaneh ⁶, Naseh Pahlavani ^{7,*}, Reza Tavakkol ⁸

¹ Department of Epidemiology, School of Health, Gonabad University of Medical Sciences, Gonabad, Iran

² Department of Operating Room, School of Paramedical, Hamadan University of Medical Sciences, Hamadan, Iran

³ Department of Operating Room, School of Allied Medical Sciences, Kermanshah University of Medical Sciences, Kermanshah, Iran

⁴ Department of Operating Room, School of Paramedical, Qazvin University of Medical Sciences, Qazvin, Iran

⁵ Department of Operating Room, School of Nursing and Midwifery, Neyshabur University of Medical Sciences, Neyshabur, Iran

⁶ Department of Microbiology, Infectious Diseases Research Center, School of Medicine, Gonabad University of Medical Sciences, Gonabad, Iran

⁷ Health Sciences Research Center, Torbat Heydariyeh University of Medical Sciences, Torbat Heydarieh, Iran

⁸ Department of Operating Room, School of Nursing and Midwifery, Torbat Heydariyeh University of Medical Sciences, Torbat Heydarieh, Iran

*Corresponding Author: Health Sciences Research Center, Torbat Heydariyeh University of Medical Sciences, Torbat Heydarieh, Iran. Email: nasehpahlavani91@yahoo.com

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Abstract

Context: Total knee arthroplasty (TKA) surgeries are among the most significant orthopedic procedures. The high sensitivity of these surgeries makes surgical site infections (SSIs) a critical concern worldwide.

Objectives: This study aims to determine the prevalence of SSIs following TKA procedures.

Evidence Acquisition: This systematic review and meta-analysis were conducted up to November 2024. Searches were performed in PubMed, Scopus, and Embase to identify relevant studies. The Joanna Briggs Institute Critical Appraisal Checklist was applied for quality assessment. A total of 375 articles were identified through database and hand searches, with 44 articles included in the statistical analysis. The results from the forest plot studies indicated heterogeneity among the studies.

Results: The study found a low prevalence of SSIs in TKA surgeries, with a rate of 1.59% (95% CI: 1.44 - 1.73). Controlling the occurrence of SSIs is crucial due to the significance of these conditions, particularly in high-risk procedures like TKA.

Conclusions: Given the importance of SSIs, hospital managers should design training courses for patients and healthcare workers to improve awareness of risk factors and preventive measures. Efforts should be made to control the factors that contribute to SSIs as much as possible.

Keywords: Surgical Wound Infection, Arthroplasty, Prevalence, Orthopedic Procedures

1. Context

Surgical site infections (SSIs) are complications that may affect the incision site or deep tissues, occurring up to 30 days post-surgery or up to a year later in patients with implants (1). The SSIs rank as the second most common nosocomial infection, accounting for 15 - 30% of all such infections (2, 3). Among surgical patients, SSIs are the most prevalent, comprising approximately 38% of all surgical infections. These infections are either confined to superficial and deep tissues or occur in

involved organs or spaces, in two-thirds and one-third of cases, respectively (3-5).

The causal pathogens in most SSIs are derived from the patient's natural flora, with *Staphylococcus aureus*, coagulase-negative staphylococci, enterococci, and *Escherichia coli* being the most common microorganisms (1). Beyond increased morbidity and occasional mortality, SSIs lead to hospital readmissions, increased medical costs, and sometimes necessitate repeat surgeries (6). According to the Centers for Disease Control and Prevention (CDC), there are 500,000 cases of SSIs annually in the United States, with an average

hospital stay of 7.5 days and an annual cost of approximately 130 - 145\$ million (6). An estimated 188,000 - 398,000 cases of SSIs are reported annually in the United States (7).

The prevalence of SSIs is higher in orthopedic surgeries compared to other surgical procedures (8). Approximately 28% of nosocomial infections in orthopedic departments are due to SSIs (9), which can extend hospital stays to 28 days and increase treatment costs by more than 188%. Patients with orthopedic SSIs experience greater physical limitations and a reduced quality of life (10). While success after orthopedic surgery depends on several factors, complications such as periprosthetic joint infection (PJI) remain a major concern. The PJI significantly contributes to inefficiency and the need for implant reuse (11). In the USA, hospitals were projected to spend over \$1.62 billion on re-surgeries for orthopedic prosthesis infections in 2021 (12). Infections are the third most frequent reason for knee surgery (11).

The SSIs account for 13 - 88% of simple tibia fractures, 2 - 17% of femoral fractures, 2 - 10% of patellar fractures, and 3 - 45% of varied proximal tibia fractures following orthopedic procedures (13). In Europe, the prevalence of SSIs in total knee arthroplasty (TKA) surgeries ranges from 0.5% in France to 2.2% in the Netherlands (14-18), and in the United States, it is reported at 0.9 - 2.3% (18). Given the increasing prevalence of total joint arthroplasty surgeries and the status of SSIs as the most common infection in surgical patients, maintaining hygiene and sterility during and after surgery to mitigate the risk of SSIs should be a priority for surgical teams.

Preventing and controlling SSIs in TKA surgeries is essential as it reduces mortality, rehospitalization, shortens recovery periods, and decreases costs for both patients and the healthcare system. To effectively prevent such complications, accurate information about these infections is crucial.

2. Objectives

This review and meta-analysis aim to assess the prevalence of SSIs in TKA surgeries among surgical patients.

3. Evidence Acquisition

3.1. Study Aim and Quality Assessment

This study aimed to investigate the prevalence of SSIs in TKA surgeries among surgical patients through a systematic review and meta-analysis, adhering to the

Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist.

3.2. Search Strategy

The researchers of the present study explored three international databases—PubMed, Scopus, and Embase—in November 2024. The keywords selected for the database searches included: ["Surgical Wound," "Surgical site," "Postoperative wound," "SSIs"] AND ["Infect*," "Infestation"] AND ["Knee surgery," "Knee replacement," "Knee arthroplasty"] AND ["prevalence," "frequency," "incidence," "epidemiology"]. The collected data were entered into EndNote X8 software, and duplicate articles were automatically removed. Subsequently, the articles were independently evaluated by two researchers.

3.3. Study Selection

To screen the eligibility of the articles, a primary screening was conducted based on the title and abstract by two independent researchers. A secondary screening was then performed on the remaining articles from the first step by reading the full text. Conflicts at each of these steps were resolved by a third researcher. All human studies that assessed SSIs in TKA surgeries were included in the study, while animal studies and unrelated articles were excluded.

3.4. Statistical Analysis

Cochran's test (with a significance level of less than 0.1) and the I^2 statistic (with a significance level greater than 50%) were performed to assess heterogeneity between the studies. In addition to Cochran's test and the I^2 statistic, subgroup analysis and meta-regression were also employed to examine study heterogeneity. In cases of heterogeneity, a random-effects model was used with the inverse-variance method, whereas a fixed-effects model was applied in the absence of heterogeneity. Given the significant heterogeneity between the studies ($I^2 = 99.3\%$, $P < 0.001$), the random-effects model was utilized. All analyses were conducted using STATA statistical software, version 12.

4. Results

4.1. Description of Searching for Articles

A total of 375 articles were identified after searching all specified databases. Fifty-four papers proceeded to the next step, where the full text of the articles was assessed. After eliminating duplicate and irrelevant

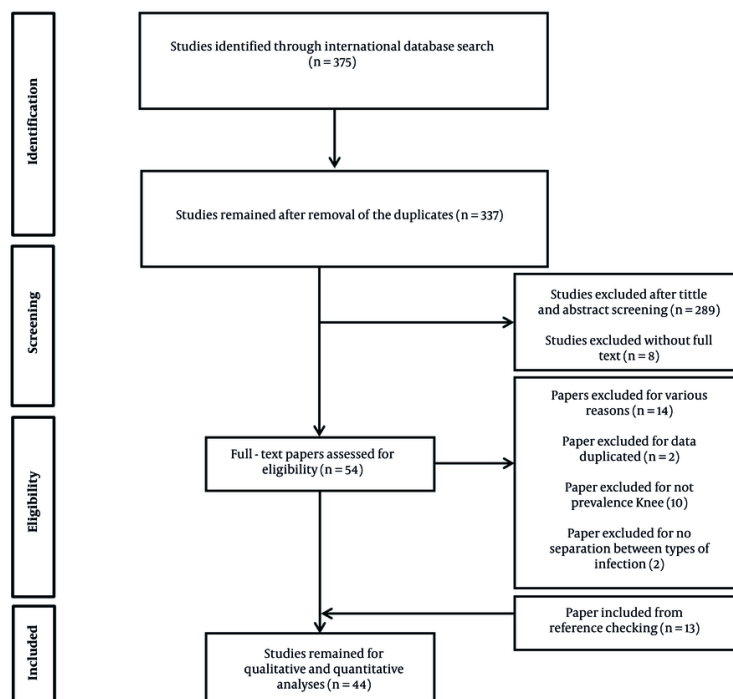


Figure 1. Flowchart of the studies included in systematic review

studies during the title and abstract screening stage, 31 articles were included in the final analysis. Additionally, by reviewing the references of the selected articles, 13 studies were added, resulting in a total of 44 studies being reviewed (Figure 1).

4.2. Description of the Included Studies

Table 1 presents the characteristics of the evaluated studies. Among the selected studies, fifteen were conducted in the United States (19-33), five in Canada (34-38), three in Spain (39-41), and two each in Brazil (42, 43), Finland (44, 45), Germany (15, 46), Korea (47, 48), and Poland (49, 50). Additionally, one study was conducted in each of the following countries: Australia (51), the United Kingdom (52), France (2, 53), India (54), the Netherlands (55), Israel (56), Italy (57), Japan (58), Scotland (59), and Taiwan (60). In one study, the country of origin was not specified (37). The highest prevalence of SSIs was reported in Brazil, at approximately 25%, while the lowest prevalence was observed in the United States, at 0.22%.

4.3. Evaluation of the Articles Quality

The Joanna Briggs Institute Checklist was utilized to evaluate and regulate the quality of the content. The objectives of this tool are to assess the methodological quality of research and to identify and prevent errors in study design, execution, and data analysis (Table 1).

4.4. Results from Meta-Analysis of the Studies

Based on the random-effects model, the prevalence of SSIs was 1.59% with a 95% confidence interval of 1.44 - 1.73. The results related to the forest plot studies are shown in Figure 2. The findings also indicated heterogeneity among the studies ($I^2 = 99.3\%$, $\chi^2 = 5940.64$, $\tau^2 = 0.1604$, $P < 0.001$). Sensitivity analysis and subgroup analysis were conducted to determine the causes of heterogeneity in the study findings. According to the subgroup analysis, although the prevalence rate varied depending on the data collection instruments, heterogeneity persisted across all subgroups (Figure 3).

To further explain the heterogeneity, meta-regression was performed on the sample size of the studies. The meta-regression findings indicated that sample size was a potential cause of heterogeneity, accounting for

Table 1. Characteristics of the Evaluated Studies

First Authors (Year)	Country	Sample Size	Gender	Mean Age	Tools	Prevalence (%)	Quality	Ref.
Anderson (2008)	USA	9658	-	-	Electronic data	0.76	Good	(19)
Mannien (2008)	Netherland	15176	Both	72	Questionnaire	1.2	Good	(20)
Miletic (2014)	USA	76289	Both	64.3	Observation	0.87	Good	(21)
Miner (2007)	USA	8,288	-	-	Observation	0.34	Satisfactory	(22)
Von Dolinger (2010)	Brazil	12	-	-	Observation	25	Good	(23)
Perdiz (2016)	Brazil	102	-	-	Observation	12.74	Good	(24)
Reilly (2006)	Scotland	1298	Both	-	Observation	1.46	Good	(25)
Rennert-May (2016)	Canada	160	Both	66.7	Electronic review	1.26	Good	(26)
Rennert-May (2018)	Canada	10736	-	-	Observation	1.05	Good	(27)
Singh (2015)	India	3280	-	-	Check list	1.7	Good	(28)
Song (2011)	Korea	1323	male	-	Check list	1.06	Good	(29)
Song (2012)	Korea	3426	Both	66	Check list	2.82	Good	(30)
Rusk (2016)	Canada	7135	-	-	Check list	1.1	Good	(31)
Calderwood (2012)	USA	724	Both	65	Observation	1	Good	(32)
Curtis (2004)	Australia	122	-	-	Observation	1.68	Good	(33)
Arduino (2015)	USA	8446	-	60	Electronic data	0.52	Good	(34)
Baier (2019)	Germany	2439	Both	69	Electronic data	3.4	Good	(35)
Castella (2011)	Italy	645	Both	70.8	Electronic data	1.86	Good	(36)
Debarge (2007)		923	Both	71	Electronic data	2.1	Good	(37)
Dicks (2015)	USA	42187	-	67	Electronic data	1.03	Good	(38)
Dyck (2019)	Canada	7737	-	67	-	1.38	Good	(39)
Grammatico-Guillon (2015)	France	11045	-	72	Electronic data	2	Good	(40)
Guirro (2015)	Spain	3000	Both	70	Electronic data	1.5	Good	(41)
Huenger (2005)	Germany	248	Both	68.1	Electronic data	0.4	Good	(15)
Houtari (2006)	Finland	3706	-	71	Electronic data	2.3	Good	(42)
Inacio (2011)	USA	27539	-	-	Electronic data	1.06	Satisfactory	(43)
Jean (2012)	Spain	2088	Both	71	Electronic data	2.1	Good	(44)
Jenks (2014)	England	970	-	-	Electronic data	3.2	Good	(45)
Kadota (2016)	Japan	196	-	64	Electronic data	2.04	Good	(46)
Kolpa (2020)	Poland	847	-	-	-	1.53	Good	(47)
Lewallen (2014)	USA	11072	Both	67.5	Electronic data	1.94	Good	(48)
Lopez-Contreras (2012)	Spain	16781	-	68	-	3.3	Good	(49)
Babkin (2007)	Israel	180	Both	72.4	Electronic data	5.6	Good	(50)
Jamsen (2010)	Finland	2647	Both	70	Electronic data	2.9	Good	(51)
Kurtz (2010)	USA	69633	-	-	Electronic data	2	Good	(52)
Peersman (2001)	USA	6489	-	-	-	1.74	Good	(53)
Poultides (2013)	USA	784335	Both	66.36	Electronic data	0.31	Good	(2)
Pugely (2015)	USA	16291	Both	67.3	Electronic data	1.22	Good	(54)
Pulido (2008)	USA	4185	-	65	Electronic data	1.1	Good	(55)
Wu (2016)	Taiwan	3152	Both	69.7	Electronic data	1.52	Good	(56)
Yokoe (2013)	USA	121640	Both	67.7	Electronic data	2.02	Good	(57)
Canadian Nosocomial Infection Surveillance Program (2020)	Canada	3904	Both	67	Check list	8.73	Good	(58)
Slowik (2020)	Poland	584	Both	70	Check list	1.9	Good	(59)
Zastrow (2020)	USA	862918	-	-	Check list	0.22	Good	(60)

approximately one-third of it ($R^2 = 32.23\%$, $P < 0.001$). Therefore, with increasing sample sizes, the reported prevalence of infection was lower (Figure 4).

5. Discussion

This systematic review and meta-analysis investigated the prevalence of SSIs in TKA surgeries.

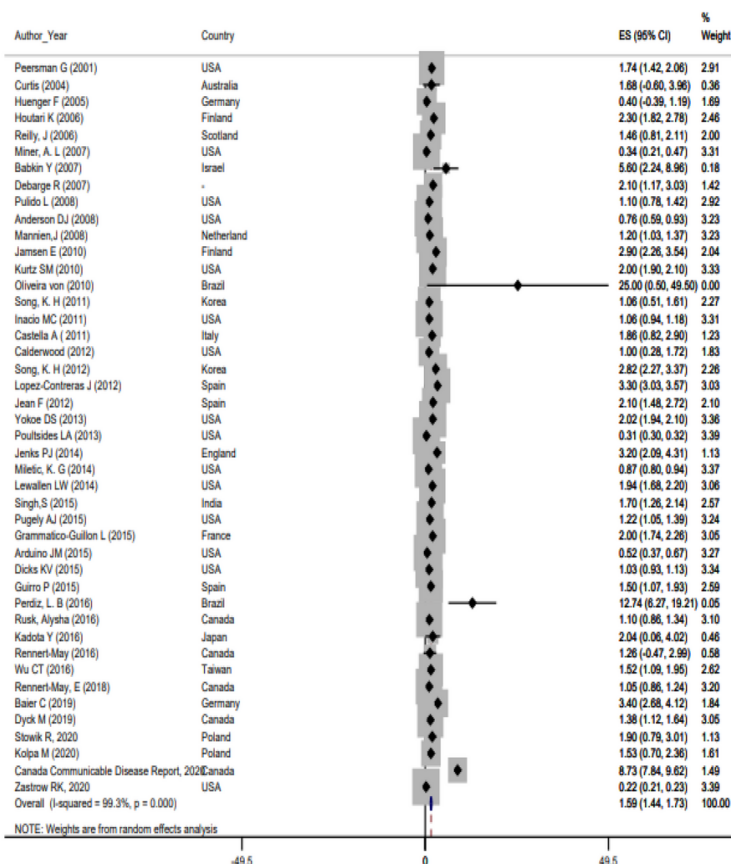


Figure 2. Forest plot of the prevalence of surgical site infection based on the model of random effects

After reviewing 44 studies, the results indicated that the prevalence of SSIs was 1.59% in patients undergoing TKA surgeries, which is considered low and acceptable. The SSIs following TKAs are often a significant issue for the healthcare system, resulting in substantial expenses for both patients and the system (39).

Among the evaluated studies, some (e.g., those conducted in Brazil by von Dolinger et al. and Perdiz et al.) reported infection rates exceeding 10% in TKA surgeries. Possible causes for the high prevalence in these studies include small sample sizes, environmental factors, and the lifestyle of the evaluated patients. Generally, characteristics such as risk factors for infection and underlying illnesses can be used to identify a lower incidence of SSIs. Additionally, factors like antibiotic prophylaxis, preoperative skin preparation procedures, and shorter surgery durations

can directly reduce the prevalence of SSIs after TKA surgeries (23, 24, 34, 61, 62).

Furthermore, the results of this study demonstrated heterogeneity among the studies. One possible reason for this heterogeneity was the variation in sample sizes. Meta-regression findings accounted for approximately one-third of the heterogeneity, indicating that increased sample sizes are associated with a lower prevalence of infection. Another factor contributing to this variability could be the differing average ages of the samples across various studies. Younger individuals, due to their robust immune systems and lower frequency of underlying illnesses, naturally have reduced infection rates after surgery (36, 60).

Additionally, the populations studied varied in terms of surgical procedures. The TKA surgeries can be performed alone or in combination with other surgeries, such as total hip arthroplasty, femoral

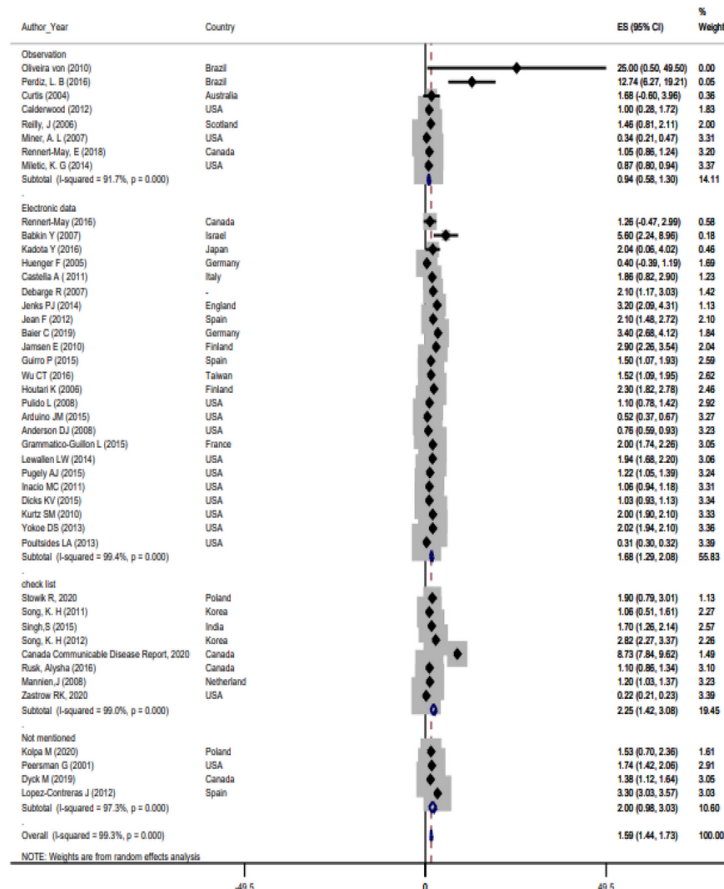


Figure 3. Forest plot sub of the prevalence of surgical site infection based on collection tools

fractures, and tibia procedures. Generally, when two or more surgeries are performed simultaneously, the risk of infection may increase due to excessive bleeding and involvement of adjacent areas (63). Moreover, in several of the reviewed studies, the study population consisted solely of males undergoing TKA operations. According to research by Cohen et al., gender impacts postoperative infection rates (64). Consequently, the variety of outcomes may also be related to differences in individual gender.

Other factors associated with SSIs in TKA surgeries include the duration of the surgeries. Peersman et al. found that patients undergoing longer TKA surgeries had higher levels of SSIs (65). In another study, Poultsides et al. demonstrated that alcohol consumption increases the incidence of SSIs in TKAs, and individuals with alcoholism were determined to be

at higher risk for infection (2). The findings of this research suggest that variations in any of the aforementioned scenarios might contribute to the heterogeneity of the results.

Additional factors associated with SSIs in TKA surgeries include the causes of surgery, obesity, malnutrition (66), race (67), reoperation of TKAs (54), penicillin allergy (68), smoking (69), use of closed drainage systems (70), and underlying diseases such as hypertension, electrolyte imbalances, respiratory problems, and blood disorders (54).

One limitation of the present study is the use of different methods for evaluating SSIs in patients, as varying tools can reduce the accuracy of the evaluation. In the analyzed studies, patients were assessed using questionnaires, checklists, observations, and electronic data. Therefore, it is advised that future research employ

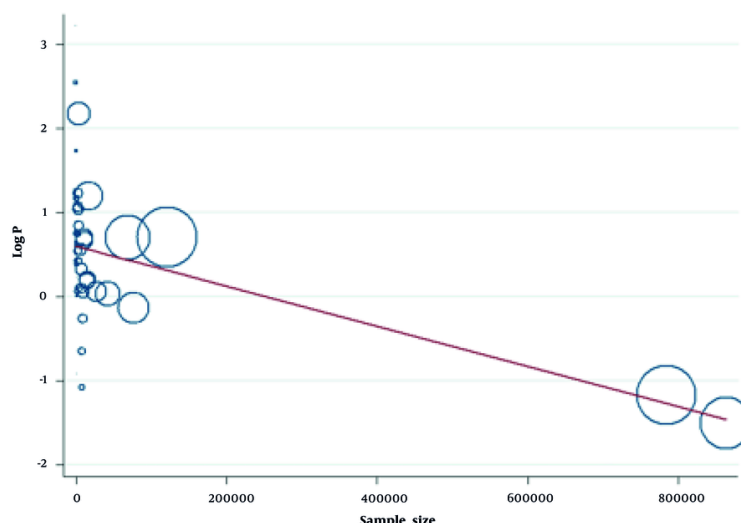


Figure 4. Meta-regression of the prevalence of surgical site infection based on sample size

more methodologically comparable studies using the same instruments to achieve more accurate findings.

This study is the first systematic review and meta-analysis to separately assess SSI rates in TKAs and investigate the details and conditions of each study. It is recommended that future studies conduct more detailed classifications and measure the prevalence of infection based on age groups and gender. This approach would allow for a more precise determination of prevalence and the development of preventive solutions.

5.1. Conclusions

The results of the present study showed that the prevalence of SSIs in TKA surgeries was low, despite the heterogeneity among the evaluated studies. Given the significance of SSIs, particularly in high-risk surgeries such as TKAs, it is crucial to monitor their rates. These infections pose numerous challenges and incur expenses for both patients and the healthcare system. Considering the variation in SSI prevalence across different countries and conditions, standard and uniform protocols should be implemented to effectively reduce these infections in various regions.

In light of this, hospital managers should design training courses for patients and healthcare workers to enhance awareness of risk factors and preventive

measures. Efforts should be made to control the factors that contribute to SSIs as much as possible.

Footnotes

Authors' Contribution: R. T. and A. K. cooperated in design and concept of the study. A. M. M., R. T. and N. P. developed the search strategy and assessed the risk of bias of the meta-analyses. A. K., R. F., and A. S., and A. M. M. extracted the data and conducted the analyses. R. T., A. S., and N. P. drafted the manuscript. R. T., N. P., and A. M. M. interpreted the results. A. M. M., N. P., and R. T. revised manuscript. All authors read and approved the final manuscript.

Conflict of Interests Statement: The authors declared no conflict of interests.

Data Availability: The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

Ethical Approval: The present study was conducted in accordance with the recommendations of ethical guidelines, [IR.GMU.REC.1400.210](https://doi.org/10.2196/1400210).

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References

- Owens CD, Stoessel K. Surgical site infections: epidemiology, microbiology and prevention. *J Hosp Infect.* 2008;**70 Suppl** 2:3-10. [PubMed ID: 19022115]. [https://doi.org/10.1016/S0195-6701\(08\)60017-1](https://doi.org/10.1016/S0195-6701(08)60017-1).
- Poultides LA, Ma Y, Della Valle AG, Chiu YL, Sculco TP, Memtsoudis SG. In-hospital surgical site infections after primary hip and knee arthroplasty—incidence and risk factors. *J Arthroplasty.* 2013;**28**(3):385-9. [PubMed ID: 23142444]. <https://doi.org/10.1016/j.arth.2012.06.027>.
- Townsend CM, Beauchamp RD, Evers BM, Mattox KL. *Sabiston textbook of surgery: the biological basis of modern surgical practice.* Netherlands, New York: Elsevier Health Sciences; 2016.
- Valdes M, de Pablo J, Campos R, Farre JM, Giron M, Lozano M, et al. [Multinational European project and multicenter Spanish study of quality improvement of assistance on consultation-liaison psychiatry in general hospital: clinical profile in Spain]. *Med Clin (Barc).* 2000;**115**(18):690-4. [PubMed ID: 11141428]. [https://doi.org/10.1016/S0025-7753\(00\)71665-4](https://doi.org/10.1016/S0025-7753(00)71665-4).
- Ramo BA, Roberts DW, Tuason D, McClung A, Paraison LE, Moore H, et al. Surgical site infections after posterior spinal fusion for neuromuscular scoliosis: a thirty-year experience at a single institution. *J Bone Joint Surg Am.* 2014;**96**(24):2038-48. [PubMed ID: 25520337]. <https://doi.org/10.2106/JBJS.N.00277>.
- Gibson A, Tevis S, Kennedy G. Readmission after delayed diagnosis of surgical site infection: a focus on prevention using the American College of Surgeons National Surgical Quality Improvement Program. *Am J Surg.* 2014;**207**(6):832-9. [PubMed ID: 24119885]. [PubMed Central ID: PMC4811594]. <https://doi.org/10.1016/j.amjsurg.2013.05.017>.
- Anderson DJ, Podgorny K, Berrios-Torres SI, Bratzler DW, Dellinger EP, Greene L, et al. Strategies to prevent surgical site infections in acute care hospitals: 2014 update. *Infect Control Hosp Epidemiol.* 2014;**35 Suppl** 2:S66-88. [PubMed ID: 25376070]. <https://doi.org/10.1017/S0899823X00193869>.
- Greene LR. Guide to the elimination of orthopedic surgery surgical site infections: an executive summary of the Association for Professionals in Infection Control and Epidemiology elimination guide. *Am J Infect Control.* 2012;**40**(4):384-6. [PubMed ID: 21868132]. <https://doi.org/10.1016/j.ajic.2011.05.011>.
- Saadatian-Elahi M, Teyssou R, Vanhems P. Staphylococcus aureus, the major pathogen in orthopaedic and cardiac surgical site infections: a literature review. *Int J Surg.* 2008;**6**(3):238-45. [PubMed ID: 17561463]. <https://doi.org/10.1016/j.ijsu.2007.05.001>.
- Hasanjani Roushan MD MR. [Orthopedic (Osteoarticular) Manifestations of Brucellosis]. *J Babol Univ Med Sci.* 2014;**16**(3):65-74. FA.
- Bozic KJ, Kurtz SM, Lau E, Ong K, Chiu V, Vail TP, et al. The epidemiology of revision total knee arthroplasty in the United States. *Clin Orthop Relat Res.* 2010;**468**(1):45-51. [PubMed ID: 19554385]. [PubMed Central ID: PMC2795838]. <https://doi.org/10.1007/s11999-009-0945-0>.
- Kurtz SM, Lau E, Watson H, Schmier JK, Parvizi J. Economic burden of periprosthetic joint infection in the United States. *J Arthroplasty.* 2012;**27**(8 Suppl):61-5. [PubMed ID: 22554729]. <https://doi.org/10.1016/j.arth.2012.02.022>.
- Norris GR, Checketts JX, Scott JT, Vassar M, Norris BL, Giannoudis PV. Prevalence of Deep Surgical Site Infection After Repair of Periarticular Knee Fractures: A Systematic Review and Meta-analysis. *JAMA Netw Open.* 2019;**2**(8). e199951. [PubMed ID: 31441940]. [PubMed Central ID: PMC6714463]. <https://doi.org/10.1001/jamanetworkopen.2019.9951>.
- Coello R, Charlett A, Wilson J, Ward V, Pearson A, Borriello P. Adverse impact of surgical site infections in English hospitals. *J Hosp Infect.* 2005;**60**(2):93-103. [PubMed ID: 15866006]. <https://doi.org/10.1016/j.jhin.2004.10.019>.
- Huenger F, Schmachtenberg A, Haefner H, Zolldann D, Nowicki K, Wirtz DC, et al. Evaluation of postdischarge surveillance of surgical site infections after total hip and knee arthroplasty. *Am J Infect Control.* 2005;**33**(8):455-62. [PubMed ID: 16216659]. <https://doi.org/10.1016/j.ajic.2005.05.008>.
- Muiliwijk J, Walenkamp GH, Voss A, Wille JC, van den Hof S. Random effect modelling of patient-related risk factors in orthopaedic procedures: results from the Dutch nosocomial infection surveillance network 'PREZIES'. *J Hosp Infect.* 2006;**62**(3):319-26. [PubMed ID: 16406851]. <https://doi.org/10.1016/j.jhin.2005.08.006>.
- Wilson J, Ramboer I, Suetens C, Helics-Ssi working group. Hospitals in Europe Link for Infection Control through Surveillance (HELICS). Inter-country comparison of rates of surgical site infection—opportunities and limitations. *J Hosp Infect.* 2007;**65 Suppl** 2:165-70. [PubMed ID: 17540264]. [https://doi.org/10.1016/S0195-6701\(07\)60037-1](https://doi.org/10.1016/S0195-6701(07)60037-1).
- NNIS System. National Nosocomial Infections Surveillance (NNIS) System Report, data summary from January 1992 through June 2004, issued October 2004. *American J Inf Control.* 2004;**32**(8):470-85. <https://doi.org/10.1016/j.ajic.2004.10.001>.
- Arduino JM, Kaye KS, Reed SD, Peter SA, Sexton DJ, Chen LF, et al. Staphylococcus aureus infections following knee and hip prosthesis insertion procedures. *Antimicrob Resist Infect Control.* 2015;**4**:13. [PubMed ID: 28428876]. [PubMed Central ID: PMC5395892]. <https://doi.org/10.1186/s13756-015-0057-4>.
- Baier C, Adelmund S, Schwab F, Lassahn C, Chaberny IF, Gosse F, et al. Incidence and risk factors of surgical site infection after total knee arthroplasty: Results of a retrospective cohort study. *Am J Infect Control.* 2019;**47**(10):1270-2. [PubMed ID: 31153712]. <https://doi.org/10.1016/j.ajic.2019.04.010>.
- Castella A, Argentero PA, Farina EC, Charrier L, Del Prever EM, Zotti CM, et al. Incidence of surgical-site infections in orthopaedic surgery: a northern Italian experience. *Epidemiol Infect.* 2011;**139**(5):777-82. [PubMed ID: 20619080]. <https://doi.org/10.1017/S0950268810001627>.
- Debargue R, Nicolle MC, Pinaroli A, Ait Si Selmi T, Neyret P. [Surgical site infection after total knee arthroplasty: a monocenter analysis of 923 first-intention implantations]. *Rev Chir Orthop Reparatrice Appar Mot.* 2007;**93**(6):582-7. [PubMed ID: 18065867]. [https://doi.org/10.1016/S0035-1040\(07\)92680-x](https://doi.org/10.1016/S0035-1040(07)92680-x).
- Dicks KV, Baker AW, Durkin MJ, Anderson DJ, Moehring RW, Chen LF, et al. Short Operative Duration and Surgical Site Infection Risk in Hip and Knee Arthroplasty Procedures. *Infect Control Hosp Epidemiol.* 2015;**36**(12):1431-6. [PubMed ID: 26391277]. [PubMed Central ID: PMC4748707]. <https://doi.org/10.1017/ice.2015.222>.
- Dyck M, Embil JM, Trepman E, Bohm E. Surgical site infection surveillance for elective primary total hip and knee arthroplasty in Winnipeg, Manitoba, Canada. *Am J Infect Control.* 2019;**47**(2):157-63. [PubMed ID: 30274885]. <https://doi.org/10.1016/j.ajic.2018.07.017>.
- Grammatico-Guillon L, Baron S, Rosset P, Gaborit C, Bernard L, Rusch E, et al. Surgical site infection after primary hip and knee arthroplasty: a cohort study using a hospital database. *Infect Control Hosp Epidemiol.* 2015;**36**(10):1198-207. [PubMed ID: 26154882]. <https://doi.org/10.1017/ice.2015.148>.
- Guirro P, Hinarejos P, Pelfort X, Leal-Blanquet J, Torres-Claramunt R, Puig-Verdie L. Long term follow-up of successfully treated superficial wound infections following TKA. *J Arthroplasty.* 2015;**30**(1):101-3. [PubMed ID: 25282072]. <https://doi.org/10.1016/j.arth.2014.08.019>.
- Huotari K, Lyytikäinen O, Hospital Infection Surveillance T. Impact of postdischarge surveillance on the rate of surgical site infection after

- orthopedic surgery. *Infect Control Hosp Epidemiol.* 2006;**27**(12):1324-9. [PubMed ID: 1752030]. <https://doi.org/10.1086/509840>.
28. Inacio MC, Paxton EW, Chen Y, Harris J, Eck E, Barnes S, et al. Leveraging electronic medical records for surveillance of surgical site infection in a total joint replacement population. *Infect Control Hosp Epidemiol.* 2011;**32**(4):351-9. [PubMed ID: 21460486]. <https://doi.org/10.1086/658942>.
 29. Jaen F, Sanz-Gallardo MI, Arrazola MP, Garcia de Codes A, de Juanes A, Resines C, et al. [Multicentre study of infection incidence in knee prosthesis]. *Rev Esp Cir Ortop Traumatol.* 2012;**56**(1):38-45. [PubMed ID: 23177941]. <https://doi.org/10.1016/j.recot.2011.08.001>.
 30. Jenks PJ, Laurent M, McQuarry S, Watkins R. Clinical and economic burden of surgical site infection (SSI) and predicted financial consequences of elimination of SSI from an English hospital. *J Hosp Infect.* 2014;**86**(1):24-33. [PubMed ID: 24268456]. <https://doi.org/10.1016/j.jhin.2013.09.012>.
 31. Kadota Y, Nishida K, Hashizume K, Nasu Y, Nakahara R, Kanazawa T, et al. Risk factors for surgical site infection and delayed wound healing after orthopedic surgery in rheumatoid arthritis patients. *Mod Rheumatol.* 2016;**26**(1):68-74. [PubMed ID: 26357931]. <https://doi.org/10.3109/14397595.2015.1073133>.
 32. Kolpa M, Slowik R, Walaszek M, Wolak Z, Rozanska A, Wojkowska-Mach J. Multimodal strategy in surgical site infections control and prevention in orthopaedic patients - a 10-year retrospective observational study at a Polish hospital. *Antimicrob Resist Infect Control.* 2020;**9**(1):20. [PubMed ID: 31998475]. [PubMed Central ID: PMC6979063]. <https://doi.org/10.1186/s13756-020-0680-6>.
 33. Lewallen LW, Maradit Kremers H, Lahr BD, Mabry TM, Steckelberg JM, Berry DJ, et al. External validation of the national healthcare safety network risk models for surgical site infections in total hip and knee replacements. *Infect Control Hosp Epidemiol.* 2014;**35**(11):1323-9. [PubMed ID: 25333425]. <https://doi.org/10.1086/678412>.
 34. Lopez-Contreras J, Limon E, Matas L, Olona M, Salles M, Pujol M, et al. Epidemiology of surgical site infections after total hip and knee joint replacement during 2007-2009: a report from the VNCat Program. *Enferm Infecc Microbiol Clin.* 2012;**30** Suppl 3:26-32. [PubMed ID: 22776151]. [https://doi.org/10.1016/S0213-005X\(12\)70093-9](https://doi.org/10.1016/S0213-005X(12)70093-9).
 35. Babkin Y, Raveh D, Lifschitz M, Itzhaki M, Wiener-Well Y, Kopuit P, et al. Incidence and risk factors for surgical infection after total knee replacement. *Scand J Infect Dis.* 2007;**39**(10):890-5. [PubMed ID: 17852911]. <https://doi.org/10.1080/00365540701387056>.
 36. Jansen E, Varonen M, Huhtala H, Lehto MU, Lumio J, Kontinen YT, et al. Incidence of prosthetic joint infections after primary knee arthroplasty. *J Arthroplasty.* 2010;**25**(1):87-92. [PubMed ID: 19056210]. <https://doi.org/10.1016/j.arth.2008.10.013>.
 37. Kurtz SM, Ong KL, Lau E, Bozic KJ, Berry D, Parvizi J. Prosthetic joint infection risk after TKA in the Medicare population. *Clin Orthop Relat Res.* 2010;**468**(1):52-6. [PubMed ID: 19669386]. [PubMed Central ID: PMC2795807]. <https://doi.org/10.1007/s11999-009-1013-5>.
 38. Peersman G, Laskin R, Davis J, Peterson M. Infection in Total Knee Replacement. *Clinical Orthopaedics and Related Research.* 2001;**392**:15-23. <https://doi.org/10.1097/00003086-200110000-00003>.
 39. Pugely AJ, Martin CT, Gao Y, Schweizer ML, Callaghan JJ. The Incidence of and Risk Factors for 30-Day Surgical Site Infections Following Primary and Revision Total Joint Arthroplasty. *J Arthroplasty.* 2015;**30**(9 Suppl):47-50. [PubMed ID: 26071247]. <https://doi.org/10.1016/j.arth.2015.01.063>.
 40. Pulido L, Ghanem E, Joshi A, Purtill JJ, Parvizi J. Periprosthetic joint infection: the incidence, timing, and predisposing factors. *Clin Orthop Relat Res.* 2008;**466**(7):1710-5. [PubMed ID: 18421542]. [PubMed Central ID: PMC2505241]. <https://doi.org/10.1007/s11999-008-0209-4>.
 41. Wu CT, Chen IL, Wang JW, Ko JY, Wang CJ, Lee CH. Surgical Site Infection After Total Knee Arthroplasty: Risk Factors in Patients With Timely Administration of Systemic Prophylactic Antibiotics. *J Arthroplasty.* 2016;**31**(7):1568-73. [PubMed ID: 26869065]. <https://doi.org/10.1016/j.arth.2016.01.017>.
 42. Yokoe DS, Avery TR, Platt R, Huang SS. Reporting surgical site infections following total hip and knee arthroplasty: impact of limiting surveillance to the operative hospital. *Clin Infect Dis.* 2013;**57**(9):1282-8. [PubMed ID: 23912846]. <https://doi.org/10.1093/cid/cit516>.
 43. Canadian Nosocomial Infection Surveillance Program. Device-associated infections in Canadian acute-care hospitals from 2009 to 2018. *Can Commun Dis Rep.* 2020;**46**(1112):387-97. [PubMed ID: 33447160]. [PubMed Central ID: PMC7799883]. <https://doi.org/10.14745/ccdr.v46i1112a05>.
 44. Slowik R, Kolpa M, Walaszek M, Rozanska A, Jagiencarz-Starzec B, Zienczuk W, et al. Epidemiology of Surgical Site Infections Considering the NHSN Standardized Infection Ratio in Hip and Knee Arthroplasties. *Int J Environ Res Public Health.* 2020;**17**(9). [PubMed ID: 32370125]. [PubMed Central ID: PMC7246776]. <https://doi.org/10.3390/ijerph17093167>.
 45. Zastrow RK, Huang HH, Galatz LM, Saunders-Hao P, Poeran J, Mouchar CS. Characteristics of Antibiotic Prophylaxis and Risk of Surgical Site Infections in Primary Total Hip and Knee Arthroplasty. *J Arthroplasty.* 2020;**35**(9):2581-9. [PubMed ID: 32402578]. <https://doi.org/10.1016/j.arth.2020.04.025>.
 46. Anderson DJ, Chen IF, Sexton DJ, Kaye KS. Complex surgical site infections and the devilish details of risk adjustment: important implications for public reporting. *Infect Control Hosp Epidemiol.* 2008;**29**(10):941-6. [PubMed ID: 18808342]. <https://doi.org/10.1086/591457>.
 47. Mannien J, van den Hof S, Mulwijk J, van den Broek PJ, van Benthem B, Wille JC. Trends in the incidence of surgical site infection in the Netherlands. *Infect Control Hosp Epidemiol.* 2008;**29**(12):1132-8. [PubMed ID: 18991504]. <https://doi.org/10.1086/592094>.
 48. Miletic KG, Taylor TN, Martin ET, Vaidya R, Kaye KS. Readmissions after diagnosis of surgical site infection following knee and hip arthroplasty. *Infect Control Hosp Epidemiol.* 2014;**35**(2):152-7. [PubMed ID: 24442077]. <https://doi.org/10.1086/674854>.
 49. Miner AL, Losina E, Katz JN, Fossel AH, Platt R. Deep infection after total knee replacement: impact of laminar airflow systems and body exhaust suits in the modern operating room. *Infect Control Hosp Epidemiol.* 2007;**28**(2):222-6. [PubMed ID: 17265409]. <https://doi.org/10.1086/509852>.
 50. von Dolinger EJ, de Souza GM, de Melo GB, Filho PP. Surgical site infections in primary total hip and knee replacement surgeries, hemiarthroplasties, and osteosyntheses at a Brazilian university hospital. *Am J Infect Control.* 2010;**38**(3):246-8. [PubMed ID: 20347637]. <https://doi.org/10.1016/j.ajic.2009.06.004>.
 51. Perdiz LB, Yokoe DS, Furtado GH, Medeiros EAS. Impact of an Automated Surveillance to Detect Surgical-Site Infections in Patients Undergoing Total Hip and Knee Arthroplasty in Brazil. *Infect Control Hosp Epidemiol.* 2016;**37**(8):991-3. [PubMed ID: 27072598]. <https://doi.org/10.1017/ice.2016.86>.
 52. Reilly J, Allardice G, Bruce J, Hill R, McCoubrey J. Procedure-specific surgical site infection rates and postdischarge surveillance in Scotland. *Infect Control Hosp Epidemiol.* 2006;**27**(12):1318-23. [PubMed ID: 17152029]. <https://doi.org/10.1086/509839>.
 53. Rennert-May E, Bush K, Vickers D, Smith S. Use of a provincial surveillance system to characterize postoperative surgical site infections after primary hip and knee arthroplasty in Alberta, Canada. *Am J Infect Control.* 2016;**44**(11):1310-4. [PubMed ID: 27158089]. <https://doi.org/10.1016/j.ajic.2016.03.021>.
 54. Rennert-May E, Manns B, Smith S, Puloski S, Henderson E, Au F, et al. Validity of administrative data in identifying complex surgical site infections from a population-based cohort after primary hip and

- knee arthroplasty in Alberta, Canada. *Am J Infect Control*. 2018;**46**(10):1123-6. [PubMed ID: 29709393]. <https://doi.org/10.1016/j.ajic.2018.03.018>.
55. Singh S, Chakravarthy M, Rosenthal VD, Myatra SN, Dwivedy A, Bagasrawala I, et al. Surgical site infection rates in six cities of India: findings of the International Nosocomial Infection Control Consortium (INICC). *Int Health*. 2015;**7**(5):354-9. [PubMed ID: 25487724]. <https://doi.org/10.1093/inthealth/ihu089>.
 56. Song KH, Kang YM, Sin HY, Yoon SW, Seo HK, Kwon S, et al. Outcome of cefazolin prophylaxis for total knee arthroplasty at an institution with high prevalence of methicillin-resistant *Staphylococcus aureus* infection. *Int J Infect Dis*. 2011;**15**(12):e867-70. [PubMed ID: 22019197]. <https://doi.org/10.1016/j.ijid.2011.09.009>.
 57. Song KH, Kim ES, Kim YK, Jin HY, Jeong SY, Kwak YG, et al. Differences in the risk factors for surgical site infection between total hip arthroplasty and total knee arthroplasty in the Korean Nosocomial Infections Surveillance System (KONIS). *Infect Control Hosp Epidemiol*. 2012;**33**(11):1086-93. [PubMed ID: 23041805]. <https://doi.org/10.1086/668020>.
 58. Rusk A, Bush K, Brandt M, Smith C, Howatt A, Chow B, et al. Improving Surveillance for Surgical Site Infections Following Total Hip and Knee Arthroplasty Using Diagnosis and Procedure Codes in a Provincial Surveillance Network. *Infect Control Hosp Epidemiol*. 2016;**37**(6):699-703. [PubMed ID: 27018968]. <https://doi.org/10.1017/ice.2016.53>.
 59. Calderwood MS, Ma A, Khan YM, Olsen MA, Bratzler DW, Yokoe DS, et al. Use of Medicare diagnosis and procedure codes to improve detection of surgical site infections following hip arthroplasty, knee arthroplasty, and vascular surgery. *Infect Control Hosp Epidemiol*. 2012;**33**(1):40-9. [PubMed ID: 22173521]. <https://doi.org/10.1086/663207>.
 60. Curtis M, Graves N, Birrell F, Walker S, Henderson B, Shaw M, et al. A comparison of competing methods for the detection of surgical-site infections in patients undergoing total arthroplasty of the knee, partial and total arthroplasty of hip and femoral or similar vascular bypass. *J Hosp Infect*. 2004;**57**(3):189-93. [PubMed ID: 15236846]. <https://doi.org/10.1016/j.jhin.2004.03.020>.
 61. Alijanipour P, Heller S, Parvizi J. Prevention of periprosthetic joint infection: what are the effective strategies? *J Knee Surg*. 2014;**27**(4):251-8. [PubMed ID: 24792971]. <https://doi.org/10.1055/s-0034-1376332>.
 62. Merollini KM, Zheng H, Graves N. Most relevant strategies for preventing surgical site infection after total hip arthroplasty: guideline recommendations and expert opinion. *Am J Infect Control*. 2013;**41**(3):221-6. [PubMed ID: 22999770]. <https://doi.org/10.1016/j.ajic.2012.03.027>.
 63. Rasouli MR, Restrepo C, Maltenfort MG, Purtill JJ, Parvizi J. Risk factors for surgical site infection following total joint arthroplasty. *J Bone Joint Surg Am*. 2014;**96**(18):e158. [PubMed ID: 25232088]. <https://doi.org/10.2106/JBJS.M.01363>.
 64. Cohen B, Choi YJ, Hyman S, Furuya EY, Neidell M, Larson E. Gender differences in risk of bloodstream and surgical site infections. *J Gen Intern Med*. 2013;**28**(10):1318-25. [PubMed ID: 23605308]. [PubMed Central ID: PMC3785652]. <https://doi.org/10.1007/s11606-013-2421-5>.
 65. Peersman G, Laskin R, Davis J, Peterson MG, Richart T. Prolonged operative time correlates with increased infection rate after total knee arthroplasty. *HSS J*. 2006;**2**(1):70-2. [PubMed ID: 18751850]. [PubMed Central ID: PMC2504110]. <https://doi.org/10.1007/s11420-005-0130-2>.
 66. Pruzansky JS, Bronson MJ, Grelsamer RP, Strauss E, Moucha CS. Prevalence of modifiable surgical site infection risk factors in hip and knee joint arthroplasty patients at an urban academic hospital. *J Arthroplasty*. 2014;**29**(2):272-6. [PubMed ID: 23890832]. <https://doi.org/10.1016/j.arth.2013.06.019>.
 67. Namba RS, Inacio MC, Paxton EW. Risk factors associated with deep surgical site infections after primary total knee arthroplasty: an analysis of 56,216 knees. *J Bone Joint Surg Am*. 2013;**95**(9):775-82. [PubMed ID: 23636183]. <https://doi.org/10.2106/JBJS.L.00211>.
 68. Blumenthal KG, Ryan EE, Li Y, Lee H, Kuhlen JL, Shenoy ES. The Impact of a Reported Penicillin Allergy on Surgical Site Infection Risk. *Clin Infect Dis*. 2018;**66**(3):329-36. [PubMed ID: 29361015]. [PubMed Central ID: PMC5850334]. <https://doi.org/10.1093/cid/cix794>.
 69. Singh JA, Houston TK, Ponce BA, Maddox G, Bishop MJ, Richman J, et al. Smoking as a risk factor for short-term outcomes following primary total hip and total knee replacement in veterans. *Arthritis Care Res (Hoboken)*. 2011;**63**(10):1365-74. [PubMed ID: 21770042]. <https://doi.org/10.1002/acr.20555>.
 70. Minnema B, Vearncombe M, Augustin A, Gollish J, Simor AE. Risk factors for surgical-site infection following primary total knee arthroplasty. *Infect Control Hosp Epidemiol*. 2004;**25**(6):477-80. [PubMed ID: 15242195]. <https://doi.org/10.1086/502425>.