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Review Article

# Do urinary tract infections affect the rate of periprosthetic joint infections in patients who underwent arthroplasty surgery? A systematic review and meta-analysis

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## Abstract

Periprosthetic joint infection (PJI) is a significant issue in orthopedic surgery. Urinary tract infections (UTIs) and asymptomatic bacteriuria (ASB) have been identified as potential causes of PJI; however, evidence is inconclusive. Understanding these relationships is critical for improving therapy and patient outcomes. A systematic review was performed by conducting searches from PubMed, EBSCO, ProQuest, and manual searching with adherence to the Preferred Reporting Items for Systematic Review and Meta-Analysis 2020 guideline. Studies that reported UTI/ASB and PJI were included. Meta-analysis was conducted using a random-effects model using RevMan 5.4 software. A total of 14 studies were included with UTIs and ASB showed an overall association with increased risk of PJI (odds ratio [OR]: 1.84, 95% confidence interval [CI]: 1.14–2.99, $P = 0.01$). However, subgroup analysis for UTIs and ASB was not significant. Further analysis of UTIs in total hip arthroplasty (THA) surgery showed a significant association (OR: 1.76, 95% CI: 1.57-1.96) with PJI. Preoperative UTIs timing between 0 and 2 weeks before surgery showed an increased risk of PJI (OR: 1.45, 95% CI: 1.35–1.55). Antibiotic treatment in ASB did not significantly impact PJI rates. Urine and PJI sample cultures in four studies showed no correlation of microorganisms between the two sites. According to recent evidence, a statistically significant association was found between UTIs and PJI in patients who underwent THA surgery. However, ASB did not yield significant results in relation to PJI. These results should be supported by larger and well-designed studies to make proper clinical suggestion in future. For further research, it is recommended to adopt standardized criteria for outcome measurement and to involve larger sample sizes to enhance the reliability and generalizability of findings.

**Keywords:** *Arthroplasty, Asymptomatic bacteriuria, Periprosthetic joint infection, Urinary tract infection*

## Introduction

Periprosthetic joint infection (PJI) is a serious challenge in the field of orthopedic surgery, providing significant morbidity, increased health-care costs, and potential implant failure [1]. Projections suggest that the financial burden of PJI in the United States will reach approximately $1.85 billion each year by 2030 [2].

Throughout their entire indwelling period, all prosthetic joints are fundamentally susceptible to hematogeneous seeding from a distant primary focus. Because of the increased vascularity of periprosthetic tissue in the first few years following implantation, the prosthesis is at the highest risk of hematogeneous infection. A detailed assessment of the hematogenous infection pathway becomes necessary in cases of acute PJI occurring after an asymptomatic period, necessitating active exploration of suspected primary infectious sources. The common sources of infecting organisms include the skin and soft tissues, oral cavity, respiratory tract, and gastrointestinal system.

The urinary system, which is known to be home to a wide variety of bacteria and other microorganisms, may also play a

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role in the pathogenesis of PJI. Because of the proximity of the urine system to prosthetic joints, as well as cases of bacteriuria and the prevalence of biofilm-forming bacteria inside the urinary tract, microbial seeding of prosthetic implants and subsequent infection is a possible possibility [3]. However, conflicting evidence exists regarding the association between the presence of bacteria in the urinary tract, as seen in urinary tract infections (UTIs) and asymptomatic bacteriuria (ASB) and the occurrence of PJI [4-7].

While urology and orthopedics have traditionally been considered different areas, new data reveal that UTIs or ASB and the development of PJIs may be linked. Understanding these relationships is critical for optimizing treatment tactics and increasing patient outcomes. As a result, the purpose of this systematic review is to thoroughly examine the current literature, uncover potential linkages between UTIs and PJI, and explain their potential therapeutic consequences.

## Methods

This systematic review was carried out according to Preferred Reporting Items for Systematic Review and Meta-Analysis and registered on PROSPERO (CRD42023449922) [8].

### Inclusion criteria

Research studies could be considered for inclusion if they met the following criteria.

1. Designs: Randomized controlled trial (RCT), prospective and retrospective studies, case–control, or nested case–control studies. However, we excluded cross-sectional studies, case series, and case reports from our analysis
2. Population: General population that undergoes joint arthroplasty
3. Exposure: UTIs or ASB
4. Control: Patient without existing diseases
5. Outcome: The rates of PJI.

### Information sources and search strategy

We employed medical subject headings and free text terms related to the rates of PJI due to UTIs or ASB to develop search strategies for identifying related studies. Our search encompassed various databases, including PubMed, EBSCO, and ProQuest. To ensure thoroughness, we manually examined the reference lists of the included research and relevant reviews, in addition to conducting a search on Google Scholar, to identify any potentially overlooked relevant articles. Our search encompassed synonyms and variations of the terms "urinary tract infection," "asymptomatic bacteriuria," and "periprosthetic joint infection" limited to the years 2013–2023 [Supplementary Table 1]. All the studies of any language were included in the early search and screening, however, only articles in English and Indonesia were included in the final selection.

### Data selection, collection, and extraction

We managed identified studies using the Zotero reference manager. Initially, the studies will undergo a process of deduplication, and then they will be screened based on their titles and abstracts to assess their eligibility criteria. Two co-authors (AH and MT) will independently carry out this screening. If any studies are deemed potentially relevant during the initial screening, a full-text assessment will be conducted. In the event of any disagreements during the selection process or quality assessment, these issues will be discussed with the other co-authors (KGP and PP) to reach a consensus. Data from the selected studies will be extracted and cross-checked to facilitate qualitative synthesis. Extracted data including author, year of study, country, study design, sampling method, number of participants, follow-up duration, inclusion, and exclusion criteria, PJI diagnosis criteria, UTIs or ASB, type of joint prostheses, and incidence of PJI.

### Quality assessment

The quality of each study will be evaluated using the ROBINS-E tool for cohort studies and the RoB 2 tool for RCT [9,10].

### Data analysis and synthesis

A comprehensive qualitative synthesis will be conducted, incorporating information from both the text and tables to provide a summary and explanation of the characteristics and findings of the included studies. In addition, this synthesis will explore the relationships among the studies. If the studies exhibit sufficient homogeneity concerning their design and comparator, we will perform meta-analyses using the random effects model. To measure the overall effect, dichotomous data will be analyzed using an odds ratio (OR) with a 95% confidence interval (CI). To assess statistical heterogeneity, we will utilize the $I^2$ statistic. In the case of high levels of heterogeneity ($P < 0.1$ or $I^2 \geq 50$). Subgroup analysis for each type of urological disease will be conducted. Relevant information will be merged and calculated using the statistical software RevMan 5.4 (Review Manager, Cochrane Collaboration, 2020).

## Results

### Study characteristics

A total of 2188 studies were identified through database searches and manual exploration [Figure 1]. After removing duplicates, 2092 studies underwent initial screening based on their titles and abstracts. Out of these, 37 studies were further assessed to determine their eligibility criteria, all in English, none was in other languages, leading to the inclusion of a total of 14 studies in the final review [3-7,11-24].

Among the included studies, the majority followed a retrospective design, while one was prospective studies, and the other was a RCT [Table 1]. The topics covered in these studies were as follows: 8 examined UTIs and 6 investigated ASB or asymptomatic leukocyturia [Table 2]. The surgical procedures analyzed in these studies encompassed reverse shoulder arthroplasty, total knee arthroplasty (TKA), total hip arthroplasty (THA), and hemi-hip arthroplasty (HHA).

### Overall effect of urinary tract infections or asymptomatic bacteriuria on periprosthetic joint infection

Overall UTIs-ASB composites were measured to have an OR of 1.84 (95% CI: 1.14–2.99, $P = 0.01$) indicating that they are associated with increased risk of PJI with significantly high heterogeneity [$I^2 = 94\%$, $P < 0.01$, Figure 2]. However, subsequent subgroup analyses based on type of disease (UTIs

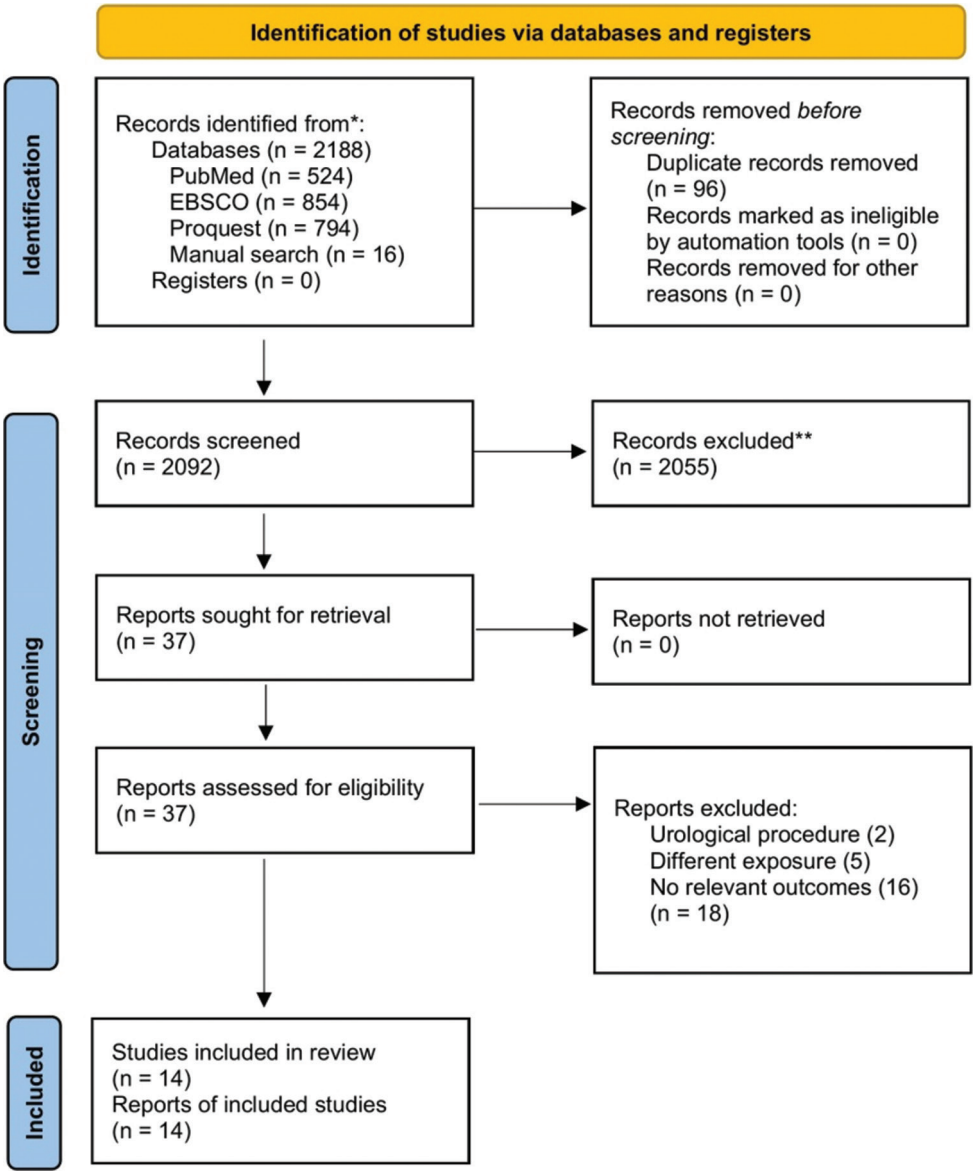


**Figure 1:**Preferred Reporting Items for Systematic Review and Meta-Analysis flow diagram 2020

and ASB) showed no significant results. In the UTIs subgroup, the OR was 1.58 (95% CI: 0.85–2.95, $P = 0.15$) with high heterogeneity ($I^2 = 96\%$, $P < 0.01$). In the ASB subgroup, the OR was 2.30 (95% CI: 0.86–6.17, $P = 0.10$) with high heterogeneity ($I^2 = 80\%$, $P < 0.01$).

Further analyses for the effects of UTIs in THA surgery resulted in a significant OR of 1.76 [95% CI: 1.57-1.96, Figure 3]. Analysis of the risk PJI that only included preoperative UTIs timing between 0 and 2 weeks before surgery showed increased risk in this group with OR of 1.45 [95% CI: 1.35–1.55, Figure 4].

Out of the six studies examining ASB, only three of them compared the use of antibiotics and found no significant difference in the rates of PJI between the group that received treatment and the group that did not [Table 3]. In addition, five of the studies conducted urine and PJI sample cultures, revealing no correlation of microorganisms between the two sites.

### Risk of bias

The risk of bias assessment is presented in Supplementary Tables 2 and 3. Out of 14 studies included, we found that 6 studies had potentially high or very high risk of bias. Funnel plots are presented in Figure 5, with Egger's $P > 0.05$ for both exposures.

### Urinary tract infections and periprosthetic joint infections

Research examining the relationship between UTIs and the risk of PJI has yielded conflicting findings. While six studies indicated a significant connection, two studies did not find any such association. A meta-analysis was eventually conducted, which encompassed THA, TKA, and all surgeries combined. When combining TKA and THA surgeries, the overall effects of UTIs on the rates of PJI did not demonstrate any significant associations. However, on conducting subsequent analysis exclusively on patients undergoing THA, a significant result

**Table 1: Characteristics of included studies**

| Author | Year | Country | Design | Sampling methods | Number of participants | Follow-up duration | Inclusion | Exclusion | PJI criteria |
|---|---|---|---|---|---|---|---|---|---|
| Westberg *et al*., [13] | 2013 | Norway | Prospective | Consecutive | 184 | 1.5 years | Patients with femoral neck fracture | Patient from outside hospital catchment area or with pathological fracture | Tsukayama criteria |
| Gou *et al*., [14] | 2014 | China | Retrospective | Consecutive | 771 | 3 years | Primary THA/ TKA | Unspecified | Tsukayama criteria |
| Sousa *et al*., [3] | 2014 | United Kingdom, Portugal, Spain | Retrospective | Consecutive | 2497 | 1 year | Patients undergoing THA or TKA | Unspecified | Unspecified |
| Radtke *et al*., [15] | 2016 | Germany | Retrospective | Consecutive | 498 | 1 year | Primary THA | Unspecified | Unspecified |
| Rark *et al*., [16] | 2017 | South Korea | Retrospective | Consecutive | 527 | 1 year | Elective primary THA | Nonelective THA | Unspecified |
| Poultsides *et al*., [6] | 2018 | US | Retrospective | Consecutive | 17,959 | 2 years | Primary TKA | Revision TKA | PICM criteria |
| Punjani *et al*., [17] | 2018 | Canada | Retrospective | Consecutive | 113,061 | 2.25 years | Patients were required to have both an OHIP and CCI code for either a THA or TKA | 1. Were missing data on age or sex, were not a resident of Ontario, or had died on or before the index date; 2. Were <66 years old; 3. Had had a THA or TKA within the prior 10 years; 4. Had a possible PJI in the prior 10 years; 5. Had simultaneous or bilateral THA or TKA | CIHI-DAD/ SDS coding |
| Weale *et al*., [5] | 2019 | UK | Retrospective | Consecutive | 5542 | 2 years | Patient with prothetic joint operations with microbial cultures | Unspecified | MSIS criteria |
| Honkanen *et al*.,[4] | 2018 | Finland | Retrospective | Consecutive | 20,226 | 1 year | Primary TKA/ THA | Unspecified | CDC criteria |
| Schmitt *et al*,.[7] | 2020 | US | Retrospective | Ratio matching (1:1) | 796 | 1 months | Primary TKA/ THA | Unspecified | NSQIP coding |
| Maharaj *et al*., [18] | 2021 | South Africa | Retrospective | Consecutive | 179 | 2.45 years | Adults >18 years, Primary and elective TKA or THA | Revision THA, revision TKA | Modified MSIS criteria |
| Rodríguez-Pardo *et al*., [19] | 2021 | Spain | RCT | Randomization with 1:1 ratio | 594 | 3 months | ≥18 years requiring HHA for fracture | Any concomitant infection requiring antibiotis and hip fractures treated with screws of THA | IDSA criteria |
| Cancienne *et al*., [24] | 2022 | US | Retrospective | Ratio matching (1:5) | 6781 | 2 years | Primary TSA/ RSA | Revision shoulder arthroplasty and <1 year follow-up | ICD-10 coding |
| Blanchard *et al*., [21] | 2022 | US | Retrospective | Ratio matching (1:8) | 256,056 | 2 years | Primary TKA/ THA | Unspecified | ICD-10 coding |

THA: Total hip arthroplasty, TKA: Total knee arthroplasty, PICM: Philadelphia International Consensus Meeting, OHIP: Ontario Health Insurance Plan, CCI: Canadian Classification of Intervention, CIHI: Canadian Institute for Health Information, DAD: Discharge abstract database, SDS: Same-day surgery, US: United States, PJI: Prosthetic joint infection, HHA: Hemi-hip arthroplasty, ICD-10: International Classification of Diseases 10, MSIS: Musculoskeletal infection society, NSQIP: National Surgical Quality Improvement Program, IDSA: Infectious Diseases Society of America, RSA: Reverse shoulder arthroplasty, RCT: Randomized controlled trial, TSA: Total shoulder arthroplasty

was observed, indicating a potential relationship between UTIs and PJI in this specific group.

It is important to note that three of the included UTIs studies exhibited a high risk of bias. Three studies utilized matching

ratios for sampling to enhance the comparability of the groups. All the studies used different criteria for PJIs, however, UTIs diagnosis was made based on the clinical examination and urine culture which is the gold standard for the diagnosis.

**Table 2: Summary of urological diseases and prosthetic joint infection rates among included studies**

| Author, year | Type of surgery | Exposure | PJI rates | Other related complications |
|---|---|---|---|---|
| | | **UTIs** | | |
| Westberg *et al*., 2013 [13] | THA | UTIs | 2/12 | Not reported |
| | | Control | 15/172 | |
| Radtke *et al*., 2016 [15] | THA | UTIs | 2/22 | Not reported |
| | | Control | 11/476 | |
| Park *et al*., 2017 [16] | THA | UTIs | 0/13 | Not reported |
| | | Control | 0/514 | |
| Punjani *et al*., 2018 [17] | TKA and THA | UTIs | 140/28,256 | Not reported |
| | | Control | 889/84,805 | |
| Poultsides *et al*., 2018 [6] | TKA | UTIs | 21/761 | Not reported |
| | | Control | 169/17,198 | |
| Schmitt *et al*., 2020 [7] | TKA and THA | UTIs | 3/398 | Not reported |
| | | Control | 1/398 | |
| Blanchard *et al*., 2022 [21] | TKA | UTIs | 678/31,578 | Not reported |
| | | Control | 2142/127,032 | |
| | THA | UTIs | 470/18,142 | |
| | | Control | 1184/79,304 | |
| Cancienne *et al*., 2022 [24] | TSA and RSA | UTIs | 40/1771 | Not reported |
| | | Control | 72/5010 | |
| | | **ASB** | | |
| Gou *et al*., 2014 [14] | TKA and THA | ASL | 1/131 | Not reported |
| | | Control | 6/608 | |
| Sousa *et al*., 2014 [3] | TKA and THA | ASB | 13/303 | Not reported |
| | | Control | 30/2193 | |
| Weale *et al*., 2019 [5] | TKA and THA | ASB | 7/140 | Not reported |
| | | Control | 26/4228 | |
| Honkanen *et al*., 2018 [4] | TKA and THA | ASB | 7/1378 | Not reported |
| | | Control | 133/18,848 | |
| Maharaj *et al*., 2021 [18] | TKA and THA | ASB | 4/39 | Not reported |
| | | Control | 1/140 | |
| Rodríguez-Pardo *et al*., 2021 [19] | HHA | ASB | 4/152 | Not reported |
| | | Control | 11/442 | |

BPH: Benign prostatic hyperplasia, sBPH: Symptomatic BPH, AUR: Acute urinary retention, RSA: Reverse shoulder arthroplasty, TSA: Total shoulder arthroplasty, THA: Total hip arthroplasty, TKA: Total knee arthroplasty, UTIs: Urinary tract infections, ASB: Asymptomatic bacteriuria, ASL: Aymptomatic leukocyturia, PJI: Prosthetic joint infection, HHA: Hemi-hip arthroplasty

UTI is a potential risk factor for PJI in patients undergoing joint replacement surgeries. The prosthesis may get infected through several routes: First, during the perioperative period, most commonly through inoculation, in some cases, UTIs may be present at the time of arthroplasty surgery, if proper precautions are not taken to prevent contamination, microorganisms from the urinary tract may contaminate the surgical site [25,26]. Second, through hematogeneous spread which may occur at any time after implantation, with pathogens originating from various sources such as respiratory or UTIs, skin infections, and pneumonia; UTIs can lead to bacteremia, which allows bacteria to travel to the surgical site where a joint prosthesis has been implanted. Most of the participants included in these studies are of the population of the elderly and more frail patient groups, both trauma and surgery may have contributed to immune dysfunction, which may predispose to septic complications. UTIs can adversely affect the immune system, compromising its ability to combat infections. Subsequently, a weakened immune response may increase the susceptibility of PJI in patients with UTIs [13].

Coagulase-negative staphylococci and *Staphylococcus aureus* are the most common microorganisms in hip and knee PJI [13,25,26]. Both are skin-colonizing microorganisms and interventions to reduce the risk of PJIs should focus on reducing the bio-burden of these organisms instead of Gram-negative (GN) organisms from the urine [5]. There is a suggestion from a study done by Koulouvaris *et al*. that prior antibiotic exposure and changes in colonized bacterial resistance may indicate a general susceptibility to bacterial infections [27]. Nonetheless, the intriguing finding from multivariate analysis by Punjani *et al*. is that prior antibiotic exposure or a previous UTI at baseline did not show an independent association with the risk of PJI [17]. This suggests that symptomatic UTIs occurring after the placement of a prosthetic joint are of greater importance in this context.

In 2019, the General Assembly International Consensus on Musculoskeletal Infection reached multiple conclusions [28]. Among them, it was determined that addressing preoperative UTI is essential and should be treated before proceeding with surgery, however, this perspective may differ from various individual studies. Blanchard *et al*. is the first study to recognize the importance of timing of UTI diagnosis before surgery in primary hip and knee arthroplasty [21]. A study done by Blanchard *et al*. shows that they establish

**Table 3: Comparisons of prosthetic joint infection rates of asymptomatic bacteriuria patients treated with antibiotics and not treated patients, and correlation between microorganism in asymptomatic bacteriuria and prosthetic joint infection**

| Author, year | ASB patients | | Control | Antibiotics used | Microorganism correlation between ASB and PJI |
|---|---|---|---|---|---|
| | Treated with antibiotics | Not treated with antibiotics | | | |
| Gou *et al*., 2014 [14] | N/A | 1/131 | 6/608 | None | N/A |
| Sousa *et al*., 2014 [3] | 6/154 | 7/149 | 30/2193 | Based on physician discretion | No correlation |
| Weale *et al*., 2019 [5] | 7/140 | N/A | 26/4228 | Based on sensitivity | No correlation |
| Honkanen *et al*., 2018 [4] | 1/344 | 6/1085 | 133/18,848 | Unspecified | No correlation |
| Maharaj *et al*., 2021 [18] | 4/39 | N/A | 1/140 | Based on sensitivity | No correlation |
| Rodríguez-Pardo *et al*., 2021 [19] | 2/75 | 2/77 | 11/442 | Fosfomycin | No correlation |

ASB: Asymptomatic bacteriuria, PJI: Perirosthetic joint infections, N/A: Not applicable

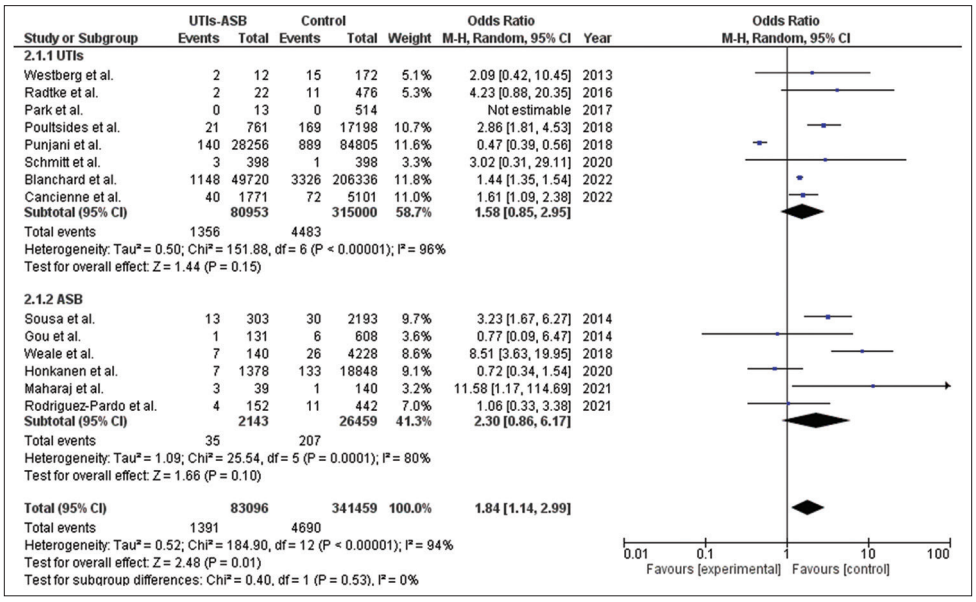


**Figure 2:** Forest plot of risk of periprosthetic joint infection based on the presence of urinary tract infections or asymptomatic bacteriuria. CI: Confidence interval, OR: Odds ratio, ASB: Asymptomatic bacteriuria, UTI: Urinary tract infection

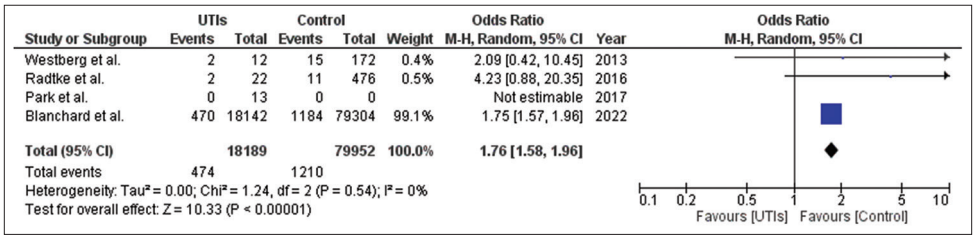


**Figure 3:** Forest plot of risk of periprosthetic joint infection based on the presence of urinary tract infections in total hip arthroplasty surgery. CI: Confidence interval, OR: Odds ratio, UTI: Urinary tract infection

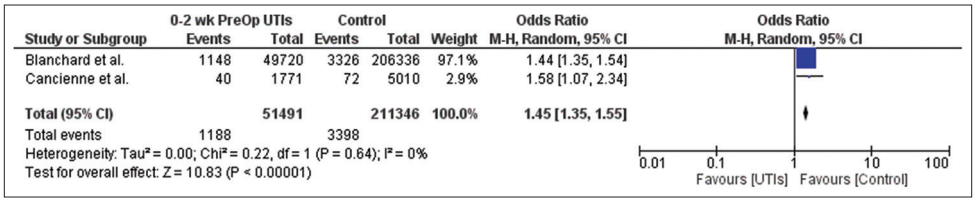


**Figure 4:** Forest plot of risk of periprosthetic joint infection based on the presence of preoperative urinary tract infections (0–2 weeks) in total joint arthroplasty. CI: Confidence interval, OR: Odds ratio, UTI: Urinary tract infection

a critical period before total joint arthroplasty (TJA) specifically showing that there was a significant association between PJI and UTI diagnosis preoperatively within 1 week of TKA, within 2 weeks of THA, as well as during the 2 weeks preceding total shoulder arthroplasty in Cancienne *et al*. [21,24]. Antibiotic prescription for UTIs in Blanchard *et al*. did not show decreased PJI rates compared to patients who did not receive treatment [21]. This suggests that it might be more prudent to consider delaying surgery rather than proceeding with antibiotic treatment before surgery.

Preoperative factors linked to a heightened risk of PJI also encompass inadequate nutrition, uncontrolled diabetes mellitus, obesity (body mass index >40 kg/m$^2$), male gender, extended surgical duration, and rheumatoid arthritis [29]. Current smokers represent another noteworthy risk factor that could contribute to both acute and chronic PJI, whereas postoperative UTI is linked to acute PJI [30].

The prolonged duration of surgery raises the likelihood of PJI, which might explain why the risk of PJI was increased in THA patients with UTIs. Surgical procedures lasting more than 90 min were connected to a 1.6 times higher risk of PJI compared to surgeries lasting <60 min [31]. Previous studies done by Ridgeway *et al*. and Dale *et al*. reported similar findings, indicating that longer surgical durations have been associated with an increased risk of PJI after THA [32,33]. Unfortunately, the duration of the procedure was not recorded nor mentioned in our included studies enabling them to act as a variable that may influence the results of the research. Several factors influence the surgical duration of joint arthroplasty, such as the proficiency and expertise of the surgeon, the

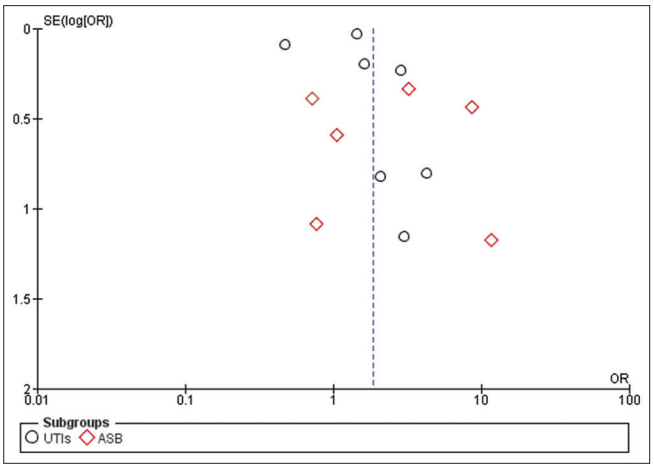


**Figure 5:** Funnel plot of risk of periprosthetic joint infection and urinary tract infections. CI: Confidence interval, OR: Odds ratio

complexity of the case, the efficiency in the operating room, and hospital factors [34,35]. Previous studies also suggest that prolonged surgical duration is a cause of postoperative complications leading to extended length of stay and additional surgeries [31,36,37]. A study performed by Orland *et al*. determined that patients who underwent THA or TKA with a surgical duration exceeding 87 min faced significantly greater risks of experiencing wound complications [36]. The risk of sepsis significantly rose with longer procedure times in THA. Hence, the length of the surgical procedure may play a role in the overall significant results observed in our subgroup analysis of the studies focusing on THA, even though the specific mechanism remains uncertain.

Several infection risk mitigation strategies should be considered, including administering intravenous antibiotics perioperatively, ensuring proper skin preparation, using gowns, and gloves appropriately, using antibiotic-impregnated cement, limiting operating room traffic, and selecting the most suitable method of wound closure [29]. Identifying patients that have the risk of UTIs is also important, such as diseases causing urinary obstruction/retention (benign prostatic hyperplasia or urinary stones), underlying chronic diseases (diabetes mellitus or other immunocompromised conditions), using an indwelling catheter, and had a history of UTIs [38,39]. Patients who undergo urological procedures should also be considered to get prophylactic antibiotics [40]. Before having arthroplasty, history taking and physical examination should include screening for UTIs symptoms and signs, such as lower urinary tract symptoms or fever. Although dipstick urinalysis is not a gold standard diagnostic tool, it is an affordable and easy examination to screen patients for UTIs and increase/decrease the pretest probability of UTIs [39,41]. Patients with a high probability of UTIs will most likely benefit from empiric treatment and may not be urine culture. In patients with moderate probability, urine culture might be beneficial, while for low probability, further testing might not be necessary [41]. Patients who undergo culture should also have antimicrobial sensitivity testing to ensure choosing the appropriate antibiotics based on the results and local resistance patterns. Urinary catheterization should follow the best practices for catheter care including aseptic technique, optimizing the duration of the catheterization as short as possible, and ensuring adequate hydration. Patients and their caregivers should also receive proper education on the prevention and management of UTIs.

### Asymptomatic bacteriuria and periprosthetic joint infections

Six studies regarding ASB were included in this study, with three out of six showed significant results. In the meta-analysis, the study did not find a significant association between ASB and the risk of PJI. Most studies included combined TKA and THA/HHA participants. These studies, three of them might pose a high risk of bias, due to the possibility of confounding and selection of participants due to undetailed methods.

ASB is commonly caused by *Escherichia coli*, with other bacterial species such as *Proteus mirabilis*, *Klebsiella pneumoniae*, *Enterobacter* spp., *Providencia stuartii*, *Morganella morganii*, *Pseudomonas aeruginosa*, *Enterococcus* spp., *S. aureus*, and coagulase-negative staphylococci (mainly *Staphylococcus saprophyticus*) also contributing to its occurrence [42]. Notably, all of these bacterial species can also cause acute uncomplicated UTIs, characterized by symptomatic bladder infections with frequency, urgency, dysuria, and/or suprapubic pain in individuals with normal genitourinary tract function.

In addition to no significant association between ASB and PJI, findings from studies investigating the bacterial isolates in ASB and PJI also reveal distinct profiles [3,19]. PJIs primarily demonstrate bacterial isolates of coagulase-negative staphylococci, such as *Staphylococcus epidermidis* [43,44]. While there have been reports of *E. coli* and other enterobacteria as isolates in PJI cases, their occurrence is less common compared to coagulase-negative staphylococci. This divergence in bacterial profiles may partially explain why ASB is not significantly associated with PJI.

In addition, it is crucial to consider other possibilities contributing to the presence of PJI in ASB cases. Rather than one condition causing the other, both ASB and PJI may share similar risk factors, particularly in the elderly population. For instance, a history of diabetes, rheumatoid arthritis, depression, steroid use, and previous joint surgery have been associated with an increased risk of PJI [45]. Advance age itself is a risk factor for ASB, potentially influenced by factors such as increasing rates of urinary incontinence and urinary retention, hospitalizations and accompanying urinary catheterizations, long-term medical institutionalization, and immune senescence [46]. Potentially modifiable factors contributing to UTIs include anatomic abnormalities of the urinary tract, particularly those causing incontinence or urinary retention, uncontrolled diabetes mellitus) and, most critically in the elderly population, urinary catheterization [47,48]. The possibility of coexistence between both conditions because they share the same risk factors might be possible, hence the results were insignificant.

In addition, three studies compared the administration of antibiotics and found no significant difference in the rates

of PJI between the group that received treatment and the group that did not even though 2 studies treated ASB based on culture sensitivity [3,4,19]. This lack of difference could be attributed to the fact that the microorganisms isolated from PJI cases differed from those identified in preoperative urine cultures [3]. Therefore, the use of antibiotics in patients with ASB does not have an influence on the occurrence of PJI. Sousa *et al*. observed that microorganisms found in PJI have no direct correspondence with the species found in the urine cultures [3]. Although it is suspected that the underlying mechanism of lack of correspondence between ASB/UTIs and PJI microorganisms may possibly caused by the perioperative treatment with antibiotics might risk patients for recurrence with a different organism. However, the short interval between preoperative antibiotic treatment and surgery makes recurrent ASB/UTI with a different organism and subsequent hematogeneous seeding of the new organism unlikely to justify most GN infections found. A plausible explanation could be the skin flora of patients with ASB.

This review has several limitations, including the presence of some included studies with a high risk of bias and the possibility of publication bias. Moreover, there is a considerable discrepancy in the total sample sizes among the studies. In addition, the criteria used to diagnose PJI and UTIs or ASB varied across the studies, which could impact the estimation of outcome effects. Future research should consider adopting standardized criteria for outcome measurement and should involve larger sample sizes.

### Suggestion for clinical practice

Older adults with UTIs usually show atypical symptoms, including confusion, dizziness, drowsiness, urinary incontinence, or poor appetite [49]. This population is also at risk of UTIs due to malnutrition, uncontrolled diabetes, poor bladder control, benign prostatic hyperplasia, or unhygienic living conditions. Considering the harm and benefits, patients who are at risk of UTIs and have an increased risk of falls or degenerative diseases resulting in the need for arthroplasty, such as the older adult population, should be screened for UTIs and promptly treated before undergoing elective THA surgery to prevent the risk of PJI. Diagnosed UTIs should be carefully treated according to prospective guidelines, and arthroplasty should be delayed. Antimicrobial susceptibility testing is encouraged. Nonantibiotic measures designed to reduce the risk of SSI, including proper instrument sterilization and environmental disinfection, effective hand washing, appropriate protective clothing, minimizing operating room traffic, and the use of appropriate ventilation systems [50]. These measures, combined with ongoing research in orthopedic surgery aimed at optimizing patient treatment, hold promise for reducing the incidence of prosthetic joint infections in the future. Preoperative evaluations, guided by the ASA physical status scale, help assess perioperative risks and functional limitations, ensuring patient safety. Despite orthopedic surgeons' emphasis on musculoskeletal care, comprehensive preoperative evaluations are essential to ensure patient safety and optimize surgical outcomes, ultimately aiming to reduce the incidence of PJIs in the future [51].

## Conclusion

According to recent evidence, a statistically significant association was found between UTIs and PJI in patients who underwent THA surgery. However, ASB did not yield significant results in relation to PJI. These results should be supported by larger and well-designed studies to make stronger clinical suggestions in the future. For further research, it is recommended to adopt standardized criteria for outcome measurement and to involve larger sample sizes to enhance the reliability and generalizability of findings.

### Data availability statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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### Conflicts of interest

There are no conflicts of interest.

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**Supplementary Table 1: Search strategy**

| Key concepts | Concept 1 - urologic diseases | Concept 2 - PJI |
|---|---|---|
| Controlled vocabulary terms/ subject terms | "Urinary Tract Infections" [MeSH Term] OR "Bacteriuria" [MeSH Term] | "Arthroplasty" [MeSH Term] OR "Joint Prosthesis" [MeSH Term] OR "Prosthesis-related infections" [MeSH Term] |
| Free text terms/ natural language terms | "UTI*" [Text Word] OR "Cystitis" [Text Word] OR "Urethritis" [Text Word] OR "Urological Infection" [Text Word] OR "Urinary Infection" [Text Word] OR "Lower Urinary Tract Infection" [Text Word] OR "Kidney Infection" [Text Word] OR "Upper Urinary Tract Infection" [Text Word] OR "Asymptomatic Bacteriuria" [Text Word] OR "ASB" [Text Word] | "Total Knee Replacement" [Text Word] OR "Total Knee Arthroplasty" [Text Word] OR "Total Hip Replacement" [Text Word] OR "Total Hip Arthroplasty" [Text Word] OR "Hemiarthroplasty" [Text Word] OR "Prosthesis Infection" [Text Word] |

| Serial number | Entry | Filter | Total findings |
|---|---|---|---|
| | **Draft entry EBSCO search (identified articles: 854); July 28, 2023** | | |
| 1 | SU (MM "Urinary Tract Infections") OR SU (MM "Bacteriuria") OR TX UTI* OR TX Cystitis OR TX Urethritis OR TX Urological Infection OR TX Urinary Infection OR TX Lower Urinary Tract Infection OR TX Kidney Infection OR TX Upper Urinary Tract Infection OR TX Asymptomatic Bacteriuria OR TX ASB | None | 25,240 |
| 2 | SU (MM "Joint Prosthesis") OR SU (MM "Arthroplasty") OR SU (MM "Prosthesis-related infections") OR TX Total Knee Replacement OR TX Total Knee Arthroplasty OR TX Total Hip Replacement OR TX Total Hip Arthroplasty OR TX Hemiarthroplasty OR TX Prosthesis Infection | None | 24,607 |
| 3 | S1 AND S2 | None | 1319 |
| 4 | S1 AND S2 | Year 2013–2023 | 854 |
| | **Draft entry ProQuest search (identified articles: 763) July 29, 2023** | | |
| 1 | MAINSUBJECT.EXACT("Urinary Tract Infections") OR MAINSUBJECT.EXACT("Bacteriuria") OR fulltext("UTI*") OR fulltext("Cystitis") OR fulltext("Urethritis") OR fulltext("Urological Infection") OR fulltext("Urinary Infection") OR fulltext("Lower Urinary Tract Infection") OR fulltext("Kidney Infection") OR fulltext("Upper Urinary Tract Infection") OR fulltext("Asymptomatic Bacteriuria") OR fulltext("ASB ") | None | 196,691 |
| 2 | MAINSUBJECT.EXACT("Joint surgery") OR (MAINSUBJECT.EXACT("Prostheses") OR MAINSUBJECT.EXACT("Joint replacement surgery") OR MAINSUBJECT.EXACT("Joint surgery")) OR fulltext("Total Knee Replacement") OR fulltext("Total Knee Arthroplasty") OR fulltext("Total Hip Replacement") OR fulltext("Total Hip Arthroplasty") OR fulltext("Hemiarthroplasty") OR fulltext("Prothesis Infection") | None | 204,750 |
| 3 | S1 AND S2 | | 5473 |
| 4 | S1 AND S2 | Scholarly journals and last 10 years | 794 |
| | **Draft entry PubMed search (identified articles: 522); July 30, 2023** | | |
| 1 | ((((((((((Urinary Tract Infections[MeSH Terms]) OR (Bacteriuria[Text Word])) OR (UTI* [Text Word])) OR (Cystitis [Text Word])) OR (Urethritis [Text Word])) OR (Urological Infection[Text Word])) OR (Urinary Infection [MeSH Terms])) OR (Lower Urinary Tract Infection[Text Word])) OR (Kidney Infection[Text Word])) OR (Upper Urinary Tract Infection[Text Word])) OR (Asymptomatic Bacteriuria[Text Word])) OR (ASB[Text Word]) | None | 873,190 |
| 2 | (((((((Arthroplasty[MeSH Terms]) OR (Joint Prosthesis[MeSH Terms])) OR (Prosthesis-related infections[MeSH Terms])) OR (Total Knee Replacement[Text Word])) OR (Total Knee Arthroplasty[Text Word])) OR (Total Hip Replacement[Text Word])) OR (Total Hip Arthroplasty[Text Word])) OR (Hemiarthroplasty[Text Word])) OR (Prothesis Infection[Text Word]) | None | 135,133 |
| 3 | S1 AND S2 | None | 1065 |
| 4 | S1 AND S2 | Year 2013–2023 | 524 |

PJI: Periprosthetic joint infection

**Supplementary Table 2: Risk of bias assessment using risk of bias in nonrandomized studies - of exposure tool**

| Author, year | Bias due to confounding | Bias arising from measurement of the exposure | Bias in selection of participants into the study | Bias due to postexposure interventions | Bias due to missing data | Bias arising from measurement of outcomes | Bias in selection of the reported results | Overall |
|---|---|---|---|---|---|---|---|---|
| Westberg *et al*., [13] | Some concerns | Low risk | High risk | Low risk | Low risk | High risk | Low risk | High risk |
| Gou *et al*., [14] | Low risk | Low risk | Low risk | Low risk | Low risk | Low risk | Low risk | Low risk |
| Sousa *et al*., [3] | High risk | Low risk | Low risk | Some concern | Low risk | Low risk | Low risk | High risk |
| Radtke *et al*., [15] | High risk | Some concerns | High risk | Some concerns | High risk | Some concerns | Low risk | Very high risk |
| Park *et al*., [16] | Very high risk | Low risk | Some concerns | High risk | Some concerns | Low risk | Low risk | Very high risk |
| Poultsides *et al*., [6] | Some concerns | Some concerns | Low risk | Low risk | Some concerns | Low risk | Low risk | Some concerns |
| Punjani *et al*., [17] | Low risk | Some concerns | Low risk | Low risk | Some concerns | Low risk | Low risk | Some concerns |
| Weale *et al*., [5] | High risk | Low risk | Low risk | Low risk | Some concerns | Low risk | Low risk | High risk |
| Honkanen *et al*., [4] | Low risk | Low risk | Low risk | Low risk | Low risk | Low risk | Low risk | Low risk |
| Schmitt, *et al*., [7] | Low risk | Low risk | Low risk | Low risk | Low risk | Low risk | Low risk | Low risk |
| Maharaj *et al*., [18] | Low risk | Low risk | Low risk | Some concerns | Low risk | Low risk | Low risk | Some concerns |
| Cancienne *et al*., [24] | Low risk | Some concerns | Low risk | Some concerns | Low risk | Some concerns | Low risk | Some concerns |
| Blanchard *et al*., [21] | Low risk | Some concerns | Low risk | Some concerns | Low risk | Some concerns | Low risk | Some concerns |

**Supplementary Table 3: Risk of bias assessment using risk of bias tool**

| Author, year | Random sequence generation (selection bias) | Allocation concealment (selection bias) | Blinding of participants and personnel (performance bias) | Blinding of outcome assessment (detection bias) | Incomplete outcome data (attrition bias) | Selective reporting (reporting bias) | Overall |
|---|---|---|---|---|---|---|---|
| Rodriguez-Pardo *et al*, .[19] | Low risk | Low risk | High risk | Low risk | Low risk | Low risk | High risk |