

Augsburg University

Idun

Theses and Graduate Projects

8-6-2024

The Efficacy of Common Prosthetic Joint Infection Prevention Strategies: A Systematic Review

Cameron Jennings

Follow this and additional works at: <https://idun.augsburg.edu/etd>



Part of the [Musculoskeletal System Commons](#), and the [Preventive Medicine Commons](#)

The Efficacy of Common Prosthetic Joint Infection Prevention Strategies:

A Systemic Review

Cameron Jennings, PA-S

Augsburg University: Department of PA Studies

Abstract

Background: Thousands of total hip and knee arthroplasty patients suffer from prosthetic joint infections every year, making them a leading cause of arthroplasty failure. As the number of these procedures continues to grow, so will the healthcare and socio-economic burden of prosthetic joint infections.

Objective: The aim of this systematic review is to evaluate the efficacy of commonly used prosthetic joint infection prevention strategies for patients undergoing total hip and knee arthroplasty. Strategies include tobacco use cessation, prior intra-articular injections, prophylactic antibiotics, and glycemic control.

Methods: A comprehensive search for up-to-date literature was completed via the PubMed database, identifying eighteen retrospective and prospective cohort studies that focused on the four prosthetic joint infection prevention methods of interest.

Results: Three of four studies discussing tobacco use recommended cessation. Four of five studies discussing prior intra-articular injections recommended withholding injections within a certain time from surgery. All five studies discussing prophylactic antibiotics recommended using single dose cephalosporins. Three of four studies discussing glycemic control recommended using HbA1c as a marker.

Conclusions: Tobacco use cessation of all forms is an efficacious prosthetic joint infection prevention strategy. The common practices of withholding intra-articular injections prior to surgery, using prophylactic single dose cephalosporins, and using the glycemic marker of HbA1c were found to be partially efficacious but require further considerations. Surgeons should be aware of the various considerations involved in validating or discrediting their preferred prevention strategies in order to prevent prosthetic joint infection.

Key Words: prosthetic joint infection, total hip arthroplasty, total knee arthroplasty

Introduction

Total joint arthroplasty has quickly become one of the fastest growing and commonly performed procedures across both the United States and the world, with primary hip and knee arthroplasty accounting for the majority.¹ The frequency of these two procedures is continuing to increase, with a projected 572,000 hips and 3.48 million knees replaced yearly in the United States by 2030.² Total joint arthroplasty is used to cure various conditions including rheumatologic diseases, certain fractures, and most commonly, osteoarthritis.^{2,3} These procedures can be life-altering for patients, as they can provide a wide range of benefits including decreased pain, improved range of motion, increased strength, and restoration of independence.² Health-related quality of life was found to be improved in total joint arthroplasty patients, especially in the total hip population.⁴

While these beneficial elective procedures are generally considered safe, they do not come without risk. Prosthetic joint infection occurs in up to 2.5% of all total arthroplasty patients, and 2.18% of total hip and knee arthroplasty patients.³ With the sizable and still growing number of total hip and knee arthroplasty procedures done every year, 2.18% of patients suffering from an infection has led to a serious healthcare and socio-economic issue for thousands of patients.³ Prosthetic joint infection is defined as “infection involving the joint prosthesis and adjacent tissue.”² These infections account for the leading cause of total knee arthroplasty failure, and third leading cause of total hip arthroplasty failure. They also account for 3-4 times more hospital charges when compared to an uninfected total joint arthroplasty, and this does not include the cost of possible lengthened antibiotic therapy.³

Like all surgical procedures, strategies are put in place to prevent infections in total hip and knee arthroplasties. However, a national database study spanning from 2005 to 2019 found

that even with the use of prevention strategies, postoperative infections in total hip arthroplasties only showed a small decline, while they instead showed an increase over time in total knee arthroplasties.⁵ This poses the research question of which this systematic review seeks to answer, “Are commonly used prosthetic joint infection prevention strategies efficacious for patients undergoing total hip and knee arthroplasty?” While a wide range of strategies are practiced based on the surgeon, the following commonly used prevention strategies will be reviewed: tobacco use cessation, prior intra-articular injections, prophylactic antibiotics, and glycemic control.

Tobacco use and smoking have long been considered risk factors for post-operative infection due to their decreasing effects on tissue oxygenation and immune responses. Past studies have shown that former tobacco users have a higher risk of prosthetic joint infection than non-tobacco users, and current tobacco users have an even higher risk.⁶ While no definitive optimal timeframe has been identified and it varies depending on the surgeon, multiple reports have stated four weeks of tobacco cessation prior to total joint arthroplasty can reduce risk of infection and other complications.⁷

Prior intra-articular injections before total joint arthroplasty have also been considered a risk factor for infection due to their impairment of the immune response. Both hyaluronic acid and corticosteroid injections given within three months of arthroplasty are believed to increase the risk of prosthetic joint infection, and some believe the risk may be raised until six months post-injection.⁶

The typical antibiotic prophylaxis regimen for total hip and knee arthroplasty has been a single preoperative dose of a first- or second-generation cephalosporin, with cefazolin being a popular choice. These antibiotics are considered first-line due to minimal side effects and proper coverage against common prosthetic joint infection pathogens. This strategy is often debated and

therefore varies, as some surgeons may want to add vancomycin for MRSA coverage or extend antibiotic prophylaxis, but the Center for Disease Control still recommends one single dose.⁷

Uncontrolled diabetes has been viewed as a major factor for increased risk of prosthetic joint infection after total joint arthroplasty due to the decrease in immune response and possible poor tissue oxygenation. While this still is the case, preoperative hyperglycemia has now been shown to significantly increase prosthetic joint infection risk in all patients, not just in diabetics. For this reason, acute glycemic control has recently become a critical infection prevention strategy. While it varies depending on the surgeon, a hemoglobin A1c less than 7.5-8% and a non-fasting glucose value less than 200 mg/dL are commonly used glycemic markers believed to be sufficient prior to total joint arthroplasty.⁷

Methods

Data Sources and Searches

This systematic review was conducted according to the most recent Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A comprehensive search for up-to-date literature was completed via the PubMed database, occurring from inception in October 2023 until March 2024. Fundamental search terminology used to identify literature included: total joint arthroplasty, total knee arthroplasty, total hip arthroplasty, prosthetic joint infection, periprosthetic joint infection, tobacco, smoking, intra-articular injection, corticosteroid injection, hyaluronic acid injection, antibiotic prophylaxis, cephalosporin, cefazolin, vancomycin, glycemic control, diabetes control, and HbA1c. Reference lists of original and review studies were also manually screened to identify appropriate literature that met inclusion criteria.

Study Selection

Inclusion criteria comprised of studies published within five years of systematic review inception and studies that focused on information regarding tobacco use cessation, prior intra-articular injections, prophylactic antibiotics, and glycemic control as prevention strategies for prosthetic joint infection. Observational studies, both retrospective and prospective cohort, were included. One analysis using a break-even economic model to provide information on an infection prevention strategy was also included. Exclusion criteria involved studies that were systematic reviews, did not target the hip or knee joint, focused on infections that were not prosthetic joint infections, and were published before 2018. Studies that were not in the English language were also excluded.

Data Extraction and Synthesis

The single author of this systematic review independently screened studies by initially assessing their titles and abstracts for applicable information. No automation tools were used. Inclusion and exclusion criteria were then assessed through full text versions of relevant studies. Data extracted included publication year, dates the study spanned, location of the study, study design, study population, prevention strategy, joint of interest, outcome variable, results, and *P*-values if applicable. The data extracted from the studies that met inclusion criteria did not require any methods such as data conversion to prepare findings for presentation or synthesis.

Results

After accounting for duplicate studies, 506 potential records were identified and were reviewed based on their titles and abstracts. Through this screening process, 482 records were excluded due to not being relevant to the systematic review and/or meeting exclusion criteria. This left twenty-four remaining studies sought for full text retrieval. These studies were thoroughly analyzed for systematic review eligibility, but ultimately four were excluded due to not including prosthetic joint infection in the type of infection that was being studied, and two were excluded due to targeting joints that were not the hip or knee. The remaining eighteen studies met the inclusion criteria and were included in this systematic review. Four studies discuss prosthetic joint infection prevention through tobacco use cessation, five studies through prior intra-articular injections, five studies through prophylactic antibiotics, and four studies through glycemic control. This entire study selection process can be viewed in Figure 1.

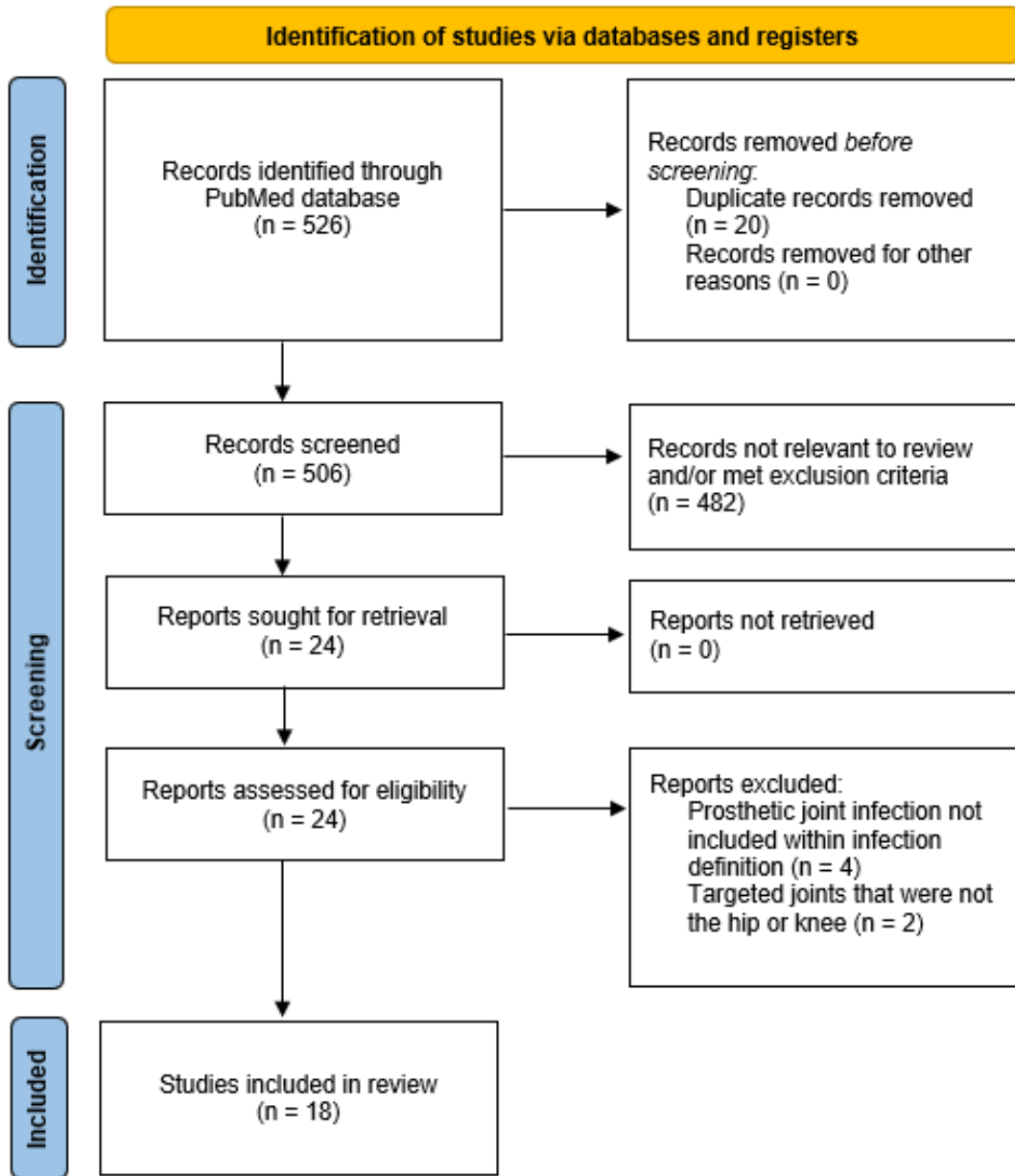


Figure 1. PRISMA flow diagram of study selection

Tobacco Use Cessation

In order to determine the role smoking status has on prosthetic joint infection, Gonzalez et al. conducted a prospective hospital registry-based cohort study that included total hip and total knee arthroplasties from March 1996 to December 2013. At the time of surgery, all patients who underwent one of the procedures were sorted by smoking status which included three groups: never, former, and current smoker. The operating surgeon and an infectious disease specialist made the determination of a prosthetic joint infection. A total of 8559 total joint arthroplasties were included, with 108 prosthetic joint infections occurring within that population. The former and current smoker groups had similar infection risks within one year of the procedure, but both of those groups had a risk for infection 1.8 times higher than the never smoker group. The three groups had the same risk for prosthetic joint infection after one-year post-surgery. There was no significant difference in the outcome between total hip and knee arthroplasties.⁸ This study emphasizes that smoking increases the risk of prosthetic joint infection, but smoking cessation may not have any benefit in reducing the risk, as current and former smokers had the same risk for infection.

In a similar study to analyze smoking's relationship with post-arthroplasty complications, Sahota et al. performed a retrospective propensity score-matched statistical analysis that included total hip and total knee arthroplasties performed in 2011 and 2012.⁹ Patient data during this time frame was selected from the American College of Surgeon's National Quality Improvement Program (ACS-NSQIP), which includes hundreds of surgery centers within the United States. Due to restrictions placed by the ACS-NSQIP, the study was only able to define non-smokers as those who had not smoked cigarettes one year prior to their surgery. They were also not able to assess for cigar or chewing tobacco usage. 12,588 patients were included in the study, and 1251

were identified as current smokers. While there was no significant difference between smokers and non-smokers for overall surgical complications, there was a statistically significant higher rate in smokers for thirty day deep surgical site infections and prosthetic joint infections. ($P = 0.007$). While there was a slightly greater rate of deep surgical site infections in total hip arthroplasty compared to total knee, the overall surgical complications for both were generally the same.⁹ The findings in this study suggest that current smokers have an increased risk of prosthetic joint infection compared to non-smokers.

Similarly to the two previous studies, Bedard et al. conducted a retrospective analysis that included total hip arthroplasty revisions between 2006 and 2014 to examine the effect of smoking on total joint arthroplasty. The American College of Surgeon's National Quality Improvement Program (ACS-NSQIP) was again utilized in this study, and patients were divided into a current smokers group and a non-smokers group. 8237 patients were included in the study, and 14.7% were identified as current smokers. There was found to be a statistically significant higher rate in smokers for any post-arthroplasty complication, specifically deep wound and prosthetic joint infections within thirty days. ($P < 0.001$).¹⁰ The findings in this study further emphasize that current smokers have an increased risk of prosthetic joint infection compared to non-smokers.

Unlike the previous three studies, Waters et al. conducted a retrospective cohort study to assess the association between smokeless tobacco and worse outcomes following total hip arthroplasty. Patient data between 2010 and 2021 was selected from the PearlDiver Mariner Database, which includes deidentified patient records from across the United States. 250,026 patients within the database met the study criteria, and 950 of those patients were identified as smokeless tobacco users who did not smoke. A reference group was also created that was

comprised of 24,448 patients who smoked cigarettes but did not use smokeless tobacco products. When compared to the control group, it was found that smokeless tobacco users have higher rates of overall joint complications and prosthetic joint infections, while people who smoke have statistically significant higher rates. There was not found to be a statistically significant difference between people who smoke and smokeless tobacco users for prosthetic joint infections. The study also found that smokeless tobacco use was significantly underdiagnosed in its study population, with a 3.22% decrease in males and 0.21% decrease in females when compared to the Center for Disease Control's recent estimates.¹¹ This study accentuates that although smoking remains the greater cause for increased risk of prosthetic joint infection, smokeless tobacco use also has risk concerns.

Overall, all four studies concluded that current smokers have an increased risk of prosthetic joint infection when compared to non-smokers. While three of the study's findings encourage smoking cessation to help avoid prosthetic joint infection post-arthroplasty, Gonzalez et al. found that smoking cessation may not have any added benefit as current smokers and former smokers have similar infection rates.⁸ Waters et al. also emphasized that smokeless tobacco use cessation needs to be considered as well prior to total joint arthroplasty.¹¹

Characteristics of the studies can be viewed in Table 1.

Author	Year	Joint of Interest	Tobacco Type	Prevention Strategy Efficacy
Gonzalez et al. ⁸	2018	Hip & Knee	Smoking Only	Negative
Sahota et al. ⁹	2018	Hip & Knee	Smoking Only	Positive
Bedard et al. ¹⁰	2018	Hip Only	Smoking Only	Positive
Waters et al. ¹¹	2024	Hip Only	Smoking & Smokeless	Positive

Table 1. Characteristics of included studies discussing tobacco use and prosthetic joint infection

Prior Intra-articular Injections

Khan et al. performed a retrospective study that included patients who underwent total knee arthroplasty between 2015 and 2020 in order to determine the connection between post-operative prosthetic joint infection and cumulative intra-articular injections, as well as the time from surgery the injections were given. Patient records were used from Rothman Orthopedic Institute at Thomas Jefferson University and included both corticosteroid and hyaluronic acid injection data. Of the patients that met the study criteria and underwent total knee arthroplasty, 672 had a history of knee injections not within ninety days of surgery and 648 did not have a history of injections. Of the history of knee injections group, 278 patients received both corticosteroid and hyaluronic injections, 151 patients received only hyaluronic injections, and 243 patients received only corticosteroid injections. Among patients who had received injections and patients who had not, there was no significant difference in prosthetic joint infection rate at both ninety days and one-year post-arthroplasty. Even though the patient group who had received both corticosteroid and hyaluronic injections were found to have a much higher total injections count, no significant difference was found in the development of prosthetic joint infection among the three groups that had a history of intra-articular joint injections.¹² The findings in this study express that numerous intra-articular injections will not increase a patient's risk for prosthetic joint infection, as long as it is not within ninety days of surgery.

For the purpose of determining the safety of intra-articular hyaluronic acid injections within six months of total hip arthroplasty, Colen et al. performed a retrospective cohort study on 565 patients from 2005 to 2009. All 565 patients were treated by the same medical doctor, the senior author of the study, through intra-articular hyaluronic injections and total hip arthroplasty with identical conditions in all instances. The patients were split up into two groups, those who

had received a hyaluronic acid injection within six months of total hip arthroplasty, and those who had total hip arthroplasty without a prior injection. A statistically significant higher rate of prosthetic joint infection was found in the injection group when compared to the control group who did not receive an injection ($P < 0.001$). Five prosthetic joint infections occurred in the injection group, with zero in the control group. Two of the five prosthetic joint infections received their hyaluronic acid injection within three months of their arthroplasty. The other three patients received their hyaluronic acid injection three to six months before their arthroplasty.¹³ This study highlights the increased risk of prosthetic joint infection when a patient receives an intra-articular hyaluronic acid injection within six months of total hip arthroplasty.

Differing from the previous study, Tang et al. conducted a retrospective study to determine if intra-articular corticosteroid or hyaluronic acid injections delayed time to surgery for patients undergoing total joint arthroplasty, as well as if they lead to more complications when compared to patients that did not receive an injection. 3340 total hip and total knee arthroplasties that took place throughout 2018 at NYU Langone Health, New York were included in the study. Patient data was split into two groups, those who had received intra-articular injections at least three months before total joint arthroplasty and those who did not receive an injection. The study found a statistically significant average delay in receiving both a total hip arthroplasty and a total knee arthroplasty for those who received a prior intra-articular injection. The average total hip arthroplasty delay was 5.1 months ($P < 0.001$) and the average total knee arthroplasty delay was 8.4 months ($P < 0.001$) when compared with those who did not receive a prior injection.¹⁴ These findings show that total hip and knee arthroplasty patients who received a prior injection could have had their arthroplasty 5.1-8.4 months sooner if not for the short-term pain relief and increased infection risk from intra-articular injections. No

statistically significant difference was found for prosthetic joint infections in patients who received a prior injection when compared to patients who did not ($P = 0.190$).¹⁴ The findings in this study suggest that while intra-articular joint injections can lead to delayed time to surgery for those who meet arthroplasty criteria, they are safe to give as long as they come at least three months prior to total joint arthroplasty.

In an effort to find the connection between intra-articular corticosteroid injections and prosthetic joint infection, Forlenza et al. performed a retrospective analysis in patients who underwent total hip arthroplasty between 2010 and 2018. Patient records were selected from the PearlDiver Mariner Database and included 29,058 total hip arthroplasty patients. Six groups were formed, with one for every month out from surgery the patient had their last intra-articular corticosteroid injection. A control group was created and encompassed all total hip arthroplasty patients who did not receive an injection within six months of their surgery date. Three separate sub-groups were also created based on how many injections they received in the three months leading up to their total hip arthroplasty. 14,430 patients received one injection in the three months leading to their total hip arthroplasty, 1203 received two injections, and 151 received three or more injections.¹⁵

There was a statistically significant increase in risk of prosthetic joint infection for patients who received a corticosteroid injection within four months of total hip arthroplasty: 1 month prior ($P < 0.001$), 2 months prior ($P < 0.001$), 3 months prior ($P < 0.001$), 4 months prior ($P = 0.040$). There was no increased risk of prosthetic joint infection for patients who received a corticosteroid injection five months ($P = 0.507$) or six months ($P = 0.276$) prior to total hip arthroplasty. Cumulative corticosteroid administration within three months of total hip arthroplasty exhibited a dose-dependent relationship, as two injections in that time period

doubled prosthetic joint infection risk compared to one injection, and three or more injections increased infection risk times 3.5.¹⁵ This study suggests that intra-articular corticosteroid injections within four months of total hip arthroplasty may increase the risk of prosthetic joint infection. It also emphasizes that more than one injection within three months of total hip arthroplasty significantly increases risk of prosthetic joint infection.

The findings of the previously listed studies are contradicted by Grondin et al. in their prospective cohort study of 279 patients between 2016 and 2019. To find the connection between prosthetic joint infection and intra-articular corticosteroid and hyaluronic acid injections, total knee arthroplasty patients were included who fit the study criteria and received the surgery at University Hospital of Nantes in France. Patients were split into two groups, those who received an intra-articular injection within six months of their total knee arthroplasty, and those who did not. No statistically significant difference was found for increased prosthetic joint infection risk in the injection group when compared to the non-injection group, although there was a small sample size and a trend toward an increased risk for the injection group was present ($P = 0.08$).¹⁶ The findings in this study suggest intra-articular corticosteroid and hyaluronic acid injections do not increase the risk of prosthetic joint infection, even if administered within six months prior to total knee arthroplasty.

Overall, four of the five studies found an increased risk of prosthetic joint infection post-arthroplasty if an intra-articular injection was given within a certain period of time prior to surgery. However, those time periods varied. Khan et al. and Tang et al. emphasized that there was no increased risk outside of three months prior to surgery.^{12,14} Forlenza et al. found that there is an increased risk for prosthetic joint infection if it is given within four months of surgery.¹⁵ Lastly, Colen et al. found that there is an increased risk of prosthetic joint infection if an intra-

articular injection is given within six months of surgery.¹³ The only study that did not find an increased risk of prosthetic joint infection due to prior intra-articular injections was done by Grondin et al., who highlighted that injections do not increase infection risk even if given within six months of arthroplasty.¹⁶ Khan et al. also pointed out that numerous intra-articular injections will not increase prosthetic joint infection risk if given at the appropriate timing.¹² Characteristics of the studies can be viewed in Table 2.

Author	Year	Joint of Interest	Injection Type	Prevention Strategy Efficacy
Khan et al. ¹²	2022	Knee Only	Corticosteroid & Hyaluronic	Positive
Colen et al. ¹³	2021	Hip Only	Hyaluronic Only	Neutral
Tang et al. ¹⁴	2021	Hip & Knee	Corticosteroid & Hyaluronic	Positive
Forlenza et al. ¹⁵	2021	Hip Only	Corticosteroid Only	Neutral
Grondin et al. ¹⁶	2021	Knee Only	Corticosteroid & Hyaluronic	Negative

Table 2. Characteristics of included studies discussing intra-articular injections and prosthetic joint infection

Prophylactic Antibiotics

While cefazolin is a widely used prophylactic antibiotic in total joint arthroplasty, some surgeons use a set dose for every patient when weight-based dosing may have more benefits. Rondon et al. conducted a retrospective study of 17,393 total knee arthroplasties that received cefazolin sixty minutes prior to surgery for the purpose of determining how many patients were underdosed and if those that were had an increased risk of prosthetic joint infection. Patient records between 2005 and 2017 were obtained from the Rothman Institute at Thomas Jefferson University. At this institution, the recommended prophylactic antibiotic dose was two grams of cefazolin intravenously but varied depending on the surgeon. Patients were divided into three

groups based off the generalized dosing protocol of three grams intravenously for patients weighing 120 kilograms or more, two grams for patients weighing between 60 and 120 kilograms, and one gram for patients weighing under 60 kilograms. It was found that 95.9% of the patients weighing 120 kilograms or more were underdosed, while only 11.7% of patients weighing less than 120 kilograms were underdosed. There was a statistically significant increased rate of prosthetic joint infection in underdosed patients when compared to properly dosed patients ($P = 0.002$), as well as in patients weighing 120 kilograms or more compared to patients weighing under 120 kilograms ($P < 0.001$).¹⁷ This study emphasizes the increased risk of prosthetic joint infection in cefazolin underdosed patients, who often are obese.

Similarly, Badge et al. performed a prospective multicenter cohort study to determine the connection between increased infection risk after total joint arthroplasty and the timing, duration, and dose of cephalosporin prophylaxis. 1838 patients who received cephalosporin prophylaxis prior to undergoing total hip or total knee arthroplasty between 2013 and 2015 were included in the study. The patients were followed across nineteen different sites in Australia and included 118 different surgeons. A statistically significant increase in deep surgical site infection or prosthetic joint infection risk was found in patients who were not properly dosed for their weight ($P = 0.013$). When compared to patients receiving intraoperative or postoperative antibiotics, a statistically significant decrease in infection risk was found in patients receiving preoperative cephalosporins, specifically within sixty minutes of surgery ($P < 0.001$), but also longer than sixty minutes prior to surgery ($P = 0.002$).¹⁸ The findings in this study indicate that proper weight-based cephalosporin dosing that is given preoperatively may decrease the risk of prosthetic joint infection post total hip or total knee arthroplasty.

Due to the possibility of patients with a penicillin allergy receiving less-effective prophylactic antibiotics prior to total joint arthroplasty, Wu et al. conducted a retrospective comparative study to determine if patients with a self-reported penicillin allergy led to an increased prosthetic joint infection risk. Patient records were selected from the PearlDiver Mariner Database and included 397,214 patients who underwent total hip arthroplasty and 800,660 patients who underwent total knee arthroplasty from 2010 to 2017. 9755 total hip patients and 19,669 total knee patients had a self-reported penicillin allergy. Both total hip and total knee arthroplasty populations were split into two groups, those with an allergy and those without. A statistically significant increase in prosthetic joint infection risk was found in patients who underwent total knee arthroplasty and had a self-reported penicillin allergy when compared to those without an allergy ($P < 0.010$). On the other hand, a slight increase in prosthetic joint infection risk was found in patients who underwent total hip arthroplasty and had a self-reported penicillin allergy when compared to those without an allergy, but it was not statistically significant ($P = 0.360$).¹⁹ The findings in this study suggest that patients undergoing total knee arthroplasty may be at an increased risk of prosthetic joint infection if they have a self-reported penicillin allergy and receive a different prophylactic antibiotic.

With the majority of 10% of the United States population falsely self-reporting a penicillin allergy, Pagani et al. performed a break-even analysis to ascertain if routine preoperative penicillin and cephalosporin allergy testing prior to total joint arthroplasty is cost-effective. Patients with a penicillin allergy receive second- or third-line antibiotics that may increase their risk of prosthetic joint infection, and testing to determine if they have a true allergy or not could mitigate this risk. The average cost of preoperative allergy consultations was found to be \$225.71, while treatment of prosthetic joint infection was \$27,870 after total knee

arthroplasty and \$34,445 after total hip arthroplasty. Routine allergy consultation before total joint arthroplasty was found to be cost effective, as only one prevented infection would be needed out of 123 total knee arthroplasties or 153 total hip arthroplasties.²⁰ This study suggests that routine penicillin allergy testing prior to total joint arthroplasty is cost-effective and should be adopted into practice by many surgeons.

To determine if dual-antibiotic prophylaxis by adding vancomycin was effective at lowering risk of prosthetic joint infection, Burger et al. performed a retrospective study that included 1997 total hip and total knee arthroplasty patients from 2012 to 2016. The study also set out to find any adverse effects of adding vancomycin, specifically renal impairment. The patient population was split into two groups, 1044 who received cefazolin alone and 953 who received cefazolin with a single dose of vancomycin. The dual-antibiotic group was then split into two more groups, 476 who received the vancomycin more than 45 minutes prior to surgery and 477 who received the vancomycin less than 45 minutes prior to surgery. The decrease in prosthetic joint infection risk with the addition of vancomycin when compared to cefazolin alone was not statistically significant ($P = 0.320$), but there was a statistically significant decrease in prosthetic joint infection risk when vancomycin was given 45 minutes or more prior to surgery when compared to vancomycin given 45 minutes or less prior to surgery ($P < 0.010$) or cefazolin alone ($P < 0.010$). No significant differences in post-arthroplasty hemoglobin or creatinine levels were found when comparing dual-antibiotic prophylaxis with vancomycin and cefazolin alone.²¹ The findings in this study indicate that adding vancomycin to the prophylactic antibiotic regimen prior to total joint arthroplasty is a safe and effective way to decrease prosthetic joint infection risk as long as it is administered 45 minutes or more prior to surgery.

Overall, there was unanimous support for cephalosporins amongst the studies included. However, there were other factors that differed between the studies. Rondon et al. and Badge et al. found that a single dose cephalosporin preoperatively is an efficient strategy for decreasing prosthetic joint infection risk for total hip and knee arthroplasty patients, but it had to be properly dosed. The two studies found that many patients, especially if they were obese, were susceptible to increased infection risk because weight-based dosing was not used.^{17,18} Wu et al. found that patients who were not able to receive a cephalosporin preoperatively due to a self-reported penicillin allergy were at an increased risk for prosthetic joint infection.¹⁹ Pagani et al. supported this finding and also found that routine penicillin allergy testing prior to total hip or knee arthroplasty is cost-effective.²⁰ Lastly, Burger et al. emphasized that while single dose cephalosporin preoperatively was effective at decreasing prosthetic joint infection risk, adding vancomycin at least forty-five minutes prior to surgery is safe and even more effective at decreasing risk.²¹ Characteristics of the studies can be viewed in Table 3.

Author	Year	Joint of Interest	Antibiotic Type	Prevention Strategy Efficacy
Rondon et al. ¹⁷	2018	Knee Only	Cefazolin	Neutral
Badge et al. ¹⁸	2022	Hip & Knee	Cephalosporin	Neutral
Wu et al. ¹⁹	2020	Hip & Knee	Non-Cephalosporin	Neutral
Pagani et al. ²⁰	2021	Hip & Knee	N/A	N/A
Burger et al. ²¹	2018	Hip & Knee	Cephalosporin & Vancomycin	Neutral

Table 3. Characteristics of included studies discussing prophylactic antibiotics and prosthetic joint infection

Glycemic Control

For the purpose of finding the ideal glycemic marker that predicts complications from total joint arthroplasty, Cetik et al. conducted a prospective study that included 304 patients that underwent total hip or total knee arthroplasty between 2018 and 2021. Patients were followed

across three different institutions in Istanbul. Patients with HbA1c over 6.5% were labeled as diabetic, and this included 51% of the study population. All patients underwent the same pre-arthroplasty laboratory tests, which included hemoglobin A1c (HbA1c), fructosamine, and albumin corrected fructosamine. Thirty-nine patients experienced complications, five of which had a prosthetic joint infection. Four of those five patients had elevated fructosamine and HbA1c levels. There was a statistically significant increase in overall complication risk for diabetic patients and elevated HbA1c patients ($P = 0.001$), and a significant increase in prosthetic joint infection risk for elevated fructosamine patients ($P = 0.025$). The results of albumin corrected fructosamine did not provide any more information and were comparative to fructosamine levels.²² This study suggests that while multiple markers are needed to assess glycemic control prior to total joint arthroplasty, fructosamine is the ideal predictor of prosthetic joint infection.

In a similar fructosamine involving study, Shohat et al. performed a prospective multi-center study to determine fructosamine's ability to predict negative outcomes after total joint arthroplasty such as prosthetic joint infection. From 2017 to 2018, 1212 total hip arthroplasty patients of eight separately trained fellowship surgeons were followed. Fructosamine, fasting plasma glucose, and HbA1c were obtained from each patient. During the screening stage, 303 patients had HbA1c levels in the prediabetic range, even though only forty-five of the patients were aware of this status prior to screening. Also, eighty-eight patients had HbA1c levels in the diabetic range, and only fifty-one patients were aware of this status prior to screening. The average fructosamine level was found to be 241.91 $\mu\text{mol/L}$, with greater than 293 $\mu\text{mol/L}$ being an indicator of poor glycemic control.²³ Fifty-four patients were found to have a fructosamine over 293 $\mu\text{mol/L}$, but only twenty-one of these patients were known diabetics. For these patients with elevated fructosamine, a statistically significant increased risk of prosthetic joint infection

was found at a rate of 6.64 times higher than patients with normal fructosamine levels ($P = 0.002$). In a separate group of patients with a fasting plasma glucose over 100 mg/dL, there was also a statistically significant increased risk of prosthetic joint infection in patients with elevated fructosamine ($P = 0.004$).²³ The findings in this study emphasize that elevated fructosamine is predictive of prosthetic joint infection post total hip arthroplasty, in both patients with normal and elevated fasting plasma glucose. It also suggests that diabetes may be going underdiagnosed as many patients are unknowingly hyperglycemic prior to total joint arthroplasty procedures, which may further be contributing to post-arthroplasty infection.

In a related effort to find the ideal glycemic marker that predicts prosthetic joint infection after total joint arthroplasty, Yiğit et al. conducted a retrospective study that included 264 diabetic patients who underwent total hip or total knee arthroplasty between 2012 and 2020. Labs that were included in the study were HbA1c, albumin, and HbA1c/albumin ratio. The patients were split into two groups, forty patients that developed prosthetic joint infection, and 224 patients that did not. A statistically significant difference in HbA1c ($P = 0.02$) and HbA1c/albumin ratio ($P = 0.00$) was found between the prosthetic joint infection group and the non-infection group. It was also found that the risk for prosthetic joint infection was 14.6 times higher in patients with a HbA1c/albumin ratio over 2.37 mg/dL ($P = 0.01$).²⁴ This study highlights the ability of HbA1c/albumin ratio to predict an increased risk of prosthetic joint infection after total hip or total knee arthroplasty.

With multiple sources emphasizing the predictive benefits of HbA1c, Citak et al. conducted a prospective single-center study to determine the connection between elevated HbA1c in patients undergoing total joint arthroplasty and their risk for surgical site infection and prosthetic joint infection. The study also aimed to identify how often patients with unknown or

uncontrolled diabetes were undergoing total joint arthroplasty. From 2017 to 2018, 1488 patients who underwent either total hip or total knee arthroplasty were followed. During the screening stage, 312 patients were found to be diabetic through fasting blood glucose and HbA1c levels. Of these 312, 165 patients were not aware they were diabetic. Of the known diabetic patients, ninety-eight were labeled as uncontrolled diabetics as they were found to have extremely elevated levels of fasting blood glucose and HbA1c.²⁵ There was no statistically significant difference in average HbA1c levels for patients without prosthetic joint infection (5.75%) when compared to those with infection (5.84%). When comparing the increased risk of prosthetic joint infection in patients with HbA1c above 6.5% and those below 6.5%, again there was no statistically significant difference ($P = 0.092$).²⁵ The findings in this study show that uncontrolled or unknown diabetic patients are often undergoing total joint arthroplasty, as well as that HbA1c being utilized as a preoperative predictive marker may not be reliable.

Overall, three of the four studies found benefit in using HbA1c in the screening process prior to total hip or knee arthroplasty in order to decrease prosthetic joint infection risk. However, none of the three found HbA1c to be the ideal glycemic marker at predicting infection. Cetik et al. and Shohat et al. determined fructosamine to be the best glycemic marker, although other markers such as HbA1c and fasting plasma glucose can be beneficial when utilized with fructosamine.^{22,23} Shohat et al. also emphasized that patients with both normal and elevated fasting plasma glucose but elevated fructosamine were at an increased risk for infection, meaning many patients were unknowingly having surgery when they had poor glycemic control.²³ Yiğit et al. found that while HbA1c was beneficial to use, combining it with albumin and using the HbA1c/albumin ratio was the preferred predictor of increased prosthetic joint infection risk.²⁴

One study by Citak et al. found that HbA1c was not a reliable glycemic marker in predicting increased prosthetic joint infection risk.²⁵ Characteristics of the studies can be viewed in Table 4.

Author	Year	Joint of Interest	Glycemic Marker	Prevention Strategy Efficacy
Cetik et al. ²²	2023	Hip & Knee	HbA1c & Fructosamine	Neutral
Shohat et al. ²³	2021	Hip Only	HbA1c, FPG, & Fructosamine	Neutral
Yiğit et al. ²⁴	2023	Hip & Knee	HbA1c & Albumin	Neutral
Citak et al. ²⁵	2020	Hip & Knee	HbA1c & FPG	Negative

Table 4. Characteristics of included studies discussing glycemic control and prosthetic joint infection

Discussion

The present systematic review revealed that each of the four included common prosthetic joint infection prevention strategies – tobacco use cessation, prior intra-articular injections, prophylactic antibiotics, and glycemic control – ranged from partially efficacious to efficacious for patients undergoing total hip and knee arthroplasty. While a few of these results were consistent with previous literature,^{6,7} it is important for surgeons as well as all healthcare professionals to be aware of findings that differ from historically used common prevention strategies.

Tobacco Use Cessation

Tobacco use cessation, primarily smoking cessation, has been a widely used prosthetic joint infection prevention strategy by surgeons.^{6,7} All four of the included studies acknowledged that current smokers have an increased risk of infection when compared to non-smokers, and three of the studies encouraged smoking cessation to reduce that risk.^{9,10,11} While one study found that smoking cessation may not be beneficial as current and former smokers have similar

infection rates,⁸ the overall consensus was that smoking is harmful to a patient's recovery post-arthroplasty and smoking cessation will lead to more benefits than harm. Another study emphasized that smokeless tobacco use cessation is also needed due to increased infection risk, and that surgeons often neglect this aspect of infection prevention.¹¹

The optimal timeframe for current smokers to cease tobacco use prior to arthroplasty still requires further studies, but ideally cessation begins as far out from surgery as the patient is able to tolerate. Overall, tobacco use cessation of all forms is an efficacious prosthetic joint infection prevention strategy for patients undergoing total hip or knee arthroplasty.

Prior Intra-articular Injections

Prior intra-articular injections of both corticosteroid and hyaluronic acid form have been considered by surgeons to increase prosthetic joint infection risk post-arthroplasty if given within a certain time from surgery. Three months prior to surgery has been the widely used cut-off date for many surgeons, but up to six months prior is also practiced by some.⁶ Four of the five included studies emphasized increased prosthetic joint infection risk when an intra-articular joint injection is given within a certain time from surgery. These timeframes varied however, with two studies stating three months,^{12,14} one study stating four months,¹⁵ and one study stating six months prior to surgery.¹³ One study stated that intra-articular injections do not increase prosthetic joint infection risk at any time from surgery, even if given within six months of arthroplasty.¹⁶

With these findings, common practice of withholding injections three months prior to arthroplasty is partially efficacious. As some surgeons practice, withholding intra-articular injections up to six months prior to arthroplasty is the most efficacious for preventing prosthetic

joint infection. Further research is warranted to continue to find the ideal timeframe prior to surgery, but six months has been identified as the most efficacious in preventing prosthetic joint infection as it covers the three-, four-, and six-month recommendations identified in this review.

Prophylactic Antibiotics

Although some surgeons prefer to add vancomycin or extend antibiotic prophylaxis, the most commonly used prophylactic antibiotic regimen used by surgeons is the Center for Disease Control's recommendation of a single preoperative dose of a first- or second-generation cephalosporin.⁷ Unanimous support for cephalosporins was seen amongst the included studies, however there were factors that made the current most commonly used regimen only partially efficacious. Two studies found that while a single dose cephalosporin preoperatively was efficacious at reducing prosthetic joint infection risk post-arthroplasty, it was often not properly dosed. Many patients, especially if they were obese, were found to be at increased risk for infection due to weight-based dosing not being used.^{17,18} One study emphasized that patients who were not able to receive a cephalosporin preoperatively due to a self-reported penicillin allergy were at an increased risk for prosthetic joint infection. This is due to the fact that the majority of self-reported penicillin allergies are not accurate, and with routine allergy testing not a part of most surgeon's screening process, many patients are at an increased risk of infection.¹⁹ Another study supported this finding and determined that routine penicillin allergy testing prior to total hip or knee arthroplasty is cost-effective and should be integrated into the preoperative process of surgeons.²⁰ Additionally, one study found that while single dose cephalosporin preoperatively was effective at decreasing prosthetic joint infection risk, adding vancomycin at least forty-five minutes prior to surgery is safe and even more effective at decreasing risk.²¹

Due to these findings, the current most commonly used prophylactic antibiotic regimen of a single preoperative cephalosporin dose is partially efficacious but requires further attention and adjustment. It is crucial that surgeons are aware of and practice weight-based dosing for cephalosporins, integrate penicillin allergy testing prior to surgery to ensure proper antibiotic coverage, and consider the addition of vancomycin to a cephalosporin, especially if a history of MRSA is present.

Glycemic Control

Uncontrolled diabetes has been a historical risk factor for prosthetic joint infection post-arthroplasty, but acute glycemic control has recently become a more commonly used infection prevention strategy due to findings showing a connection between infection and preoperative hyperglycemia in all patients, not just diabetics. Hemoglobin A1c less than 7.5-8% is a commonly used glycemic marker for acute glycemic control.⁷ Three of the four included studies found benefit in utilizing HbA1c in some part of the preoperative total hip or knee arthroplasty process, but none found it to be the ideal glycemic marker at predicting prosthetic joint infection. Two studies concluded that fructosamine was the ideal glycemic marker,^{22,23} while one study found the HbA1c/albumin ratio to be the finest predictor of increased prosthetic joint infection risk post-arthroplasty.²⁴ One study determined that HbA1c was not a reliable glycemic marker at all in assisting with increased prosthetic joint infection risk.²⁵

Based on the findings of the included studies, the current commonly used glycemic marker of HbA1c is only partially efficacious in preventing prosthetic joint infection post-arthroplasty. While it is still appropriate to utilize this marker, it is valuable for surgeons to include other markers in the screening process as well, such as fructosamine and albumin. It is also crucial for surgeons to check these labs in all patients, not just diabetics, as many patients

are unknowingly having total joint replacements at an increased risk of prosthetic joint infection due to poor glycemic control.

Future Research

While tobacco use cessation prior to total hip or knee arthroplasty is an efficacious prosthetic joint infection prevention strategy, further studies are needed to determine the optimal timeframe for current tobacco users to cease use prior to arthroplasty. While ideally surgeons could advise a patient to cease tobacco use months to years in advance, the reality is few patients are able to tolerate this and their quality of life will be affected. For this reason, the ideal amount of time prior to surgery that will reduce infection risk while a patient is still able to maintain their ideal lifestyle for as long as possible needs to be identified.

Withholding intra-articular injections six months prior to surgery has been identified as the most efficacious timeframe in preventing prosthetic joint infection, however this can lead to patient quality of life concerns. Implementing a timeframe of six months can lead to a prolonged period of time that patients are in pain, and this may not be tolerable for some. Patients may require an injection three months prior to surgery in order to manage their pain leading up to total hip or knee arthroplasty, and in this case they will need to discuss the risks and benefits of doing so with their surgeon. For this reason, the ideal timeframe prior to surgery should be further studied and confirmed in order for surgeons to provide the best recommendations to this patient population.

Limitations

The limitations of this systematic review include the omission of all other commonly used prosthetic joint infection prevention strategies outside of the four included, making findings

in this review not generalizable to other prevention strategies. Another limitation is the variability between all of the studies. Not every included study focused on both the hip and the knee, as well as had the exact same criteria for factors such as patient history knowledge and hospital policy on post-operative care. This led to difficulties directly comparing studies and determining similar results. Furthermore, the small sample sizes within some of the included studies, as well as a moderately limited number of studies available for each prevention strategy could cause issues with generalizability of the review findings. Additionally, as total hip and total knee arthroplasty is performed around the world, the restriction of included studies within the English language only may lead to bias towards countries that are primarily English speaking.

Conclusion

In the attempt to answer the research question “Are commonly used prosthetic joint infection prevention strategies efficacious for patients undergoing total hip and knee arthroplasty?” it was concluded that each of the four included common prosthetic joint infection prevention strategies ranged from partially efficacious to efficacious for patients undergoing total hip and knee arthroplasty. Tobacco use cessation of all forms was found to be an efficacious prosthetic joint infection prevention strategy. The common practice of withholding intra-articular injections within three months of arthroplasty was found to be partially efficacious, with a six-month window proving to be more favorable. The current most commonly used prophylactic antibiotic regimen of a single preoperative cephalosporin dose is partially efficacious, but other factors such as weight-based dosing, penicillin allergy testing, and addition of vancomycin must be considered along with it. The current commonly used glycemic marker of HbA1c is only partially efficacious for monitoring glycemic control with the intention of preventing prosthetic

joint infection post-arthroplasty. Other markers, such as fructosamine and albumin, are considered to be more ideal and should be used in tandem with HbA1c. Further research must still be done to obtain the optimal timeframe for current tobacco users to cease use prior to surgery, as well as to confirm the optimal timeframe prior to surgery that intra-articular injections should be withheld. As this research is waiting to be conducted, surgeons should consider optimizing the four infection prevention strategies included in some form as the current research has shown positive outcomes in reducing prosthetic joint infection post-arthroplasty. Overall, surgeons should be aware of the current research that validates or discredits their preferred prevention strategies, common or not, in order to avoid the healthcare and socio-economic burden that is prosthetic joint infections.

References

1. Schwartz AM, Farley KX, Guild GN, Bradbury TL. Projections and Epidemiology of Revision Hip and Knee Arthroplasty in the United States to 2030. *The Journal of Arthroplasty*. 2020;35(6, Supplement):S79-S85. doi:10.1016/j.arth.2020.02.030
2. Tande AJ, Patel R. Prosthetic Joint Infection. *Clin Microbiol Rev*. 2014;27(2):302-345. doi:10.1128/CMR.00111-13
3. Zardi EM, Franceschi F. Prosthetic joint infection. A relevant public health issue. *Journal of Infection and Public Health*. 2020;13(12):1888-1891. doi:10.1016/j.jiph.2020.09.006
4. Miettinen HJA, Mäkirinne-Kallio N, Kröger H, Miettinen SSA. Health-Related Quality of Life after Hip and Knee Arthroplasty Operations. *Scand J Surg*. 2021;110(3):427-433. doi:10.1177/1457496920952232
5. Murphy MP, MacConnell AE, Killen CJ, et al. Prevention Techniques Have Had Minimal Impact on the Population Rate of Prosthetic Joint Infection for Primary Total Hip and Knee Arthroplasty: A National Database Study. *The Journal of Arthroplasty*. 2023;38(6):1131-1140. doi:10.1016/j.arth.2023.02.059
6. Batty LM, Lanting B. Contemporary Strategies to Prevent Infection in Hip and Knee Arthroplasty. *Curr Rev Musculoskelet Med*. 2020;13(4):400-408. doi:10.1007/s12178-020-09653-9
7. Iannotti F, Prati P, Fidanza A, et al. Prevention of Periprosthetic Joint Infection (PJI): A Clinical Practice Protocol in High-Risk Patients. *Trop Med Infect Dis*. 2020;5(4):186. doi:10.3390/tropicalmed5040186
8. Gonzalez AI, Luime JJ, Uçkay I, Hannouche D, Hoffmeyer P, Lübbecke A. Is There an Association Between Smoking Status and Prosthetic Joint Infection After Primary Total Joint Arthroplasty? *The Journal of Arthroplasty*. 2018;33(7):2218-2224. doi:10.1016/j.arth.2018.02.069
9. Sahota S, Lovecchio F, Harold RE, Beal MD, Manning DW. The Effect of Smoking on Thirty-Day Postoperative Complications After Total Joint Arthroplasty: A Propensity Score-Matched Analysis. *The Journal of Arthroplasty*. 2018;33(1):30-35. doi:10.1016/j.arth.2017.07.037
10. Bedard NA, Dowdle SB, Owens JM, Duchman KR, Gao Y, Callaghan JJ. What is the Impact of Smoking on Revision Total Hip Arthroplasty? *The Journal of Arthroplasty*. 2018;33(7, Supplement):S182-S185. doi:10.1016/j.arth.2017.12.041
11. Waters TL, Collins LK, Cole MW, Springer BD, Salas Z, Sherman WF. Smokeless Tobacco Use is Associated With Worse Medical and Surgical Outcomes Following Total Hip Arthroplasty. *The Journal of Arthroplasty*. 2024;39(2):441-447. doi:10.1016/j.arth.2023.05.041

12. Khan IA, Small I, Sutton RM, et al. Cumulative Intraarticular Injections Are Not a Risk Factor for Periprosthetic Joint Infection Following total Knee Arthroplasty. *The Journal of Arthroplasty*. 2022;37(6):1059-1063.e1. doi:10.1016/j.arth.2022.02.027
13. Colen S, Hoorntje A, Maeckelbergh L, et al. Intra-Articular Hyaluronic Acid Injections Less Than 6 Months Before Total Hip Arthroplasty: Is It Safe? A Retrospective Cohort Study in 565 Patients. *The Journal of Arthroplasty*. 2021;36(3):1003-1008. doi:10.1016/j.arth.2020.09.024
14. Tang A, Almetwali O, Zak SG, Bernstein JA, Schwarzkopf R, Aggarwal VK. Do preoperative intra-articular corticosteroid and hyaluronic acid injections affect time to total joint arthroplasty? *Journal of Clinical Orthopaedics and Trauma*. 2021;16:49-57. doi:10.1016/j.jcot.2020.12.016
15. Forlenza EM, Burnett RA, Korrapati A, Yang J, Forsythe B, Della Valle CJ. Preoperative Corticosteroid Injections Demonstrate a Temporal and Dose-Dependent Relationship with the Rate of Postoperative Infection Following Total Hip Arthroplasty. *The Journal of Arthroplasty*. 2021;36(6):2033-2037.e1. doi:10.1016/j.arth.2021.01.076
16. Grondin J, Menu P, Métayer B, Crenn V, Dauty M, Fouasson-Chailloux A. Intra-Articular Injections Prior to Total Knee Arthroplasty Do Not Increase the Risk of Periprosthetic Joint Infection: A Prospective Cohort Study. *Antibiotics*. 2021;10(3):330. doi:10.3390/antibiotics10030330
17. Rondon AJ, Kheir MM, Tan TL, Shohat N, Greenky MR, Parvizi J. Cefazolin Prophylaxis for Total Joint Arthroplasty: Obese Patients Are Frequently Underdosed and at Increased Risk of Periprosthetic Joint Infection. *The Journal of Arthroplasty*. 2018;33(11):3551-3554. doi:10.1016/j.arth.2018.06.037
18. Badge H, Churches T, Xuan W, Naylor JM, Harris IA. Timing and duration of antibiotic prophylaxis is associated with the risk of infection after hip and knee arthroplasty. *Bone Jt Open*. 2022;3(3):252-260. doi:10.1302/2633-1462.33.BJO-2021-0181.R1
19. Wu VJ, Iloanya MC, Sanchez FL, et al. Is Patient-reported Penicillin Allergy Independently Associated with Increased Risk of Prosthetic Joint Infection After Total Joint Arthroplasty of the Hip, Knee, and Shoulder? *Clin Orthop Relat Res*. 2020;478(12):2699-2709. doi:10.1097/CORR.0000000000001497
20. Pagani NR, Moverman MA, Puzzitiello RN, Menendez ME, Barnes CL, Kavolus JJ. Preoperative Allergy Testing for Patients Reporting Penicillin and Cephalosporin Allergies is Cost-Effective in Preventing Infection after Total Knee and Hip Arthroplasty. *The Journal of Arthroplasty*. 2021;36(2):700-704. doi:10.1016/j.arth.2020.08.045
21. Burger JR, Hansen BJ, Leary EV, Aggarwal A, Keeney JA. Dual-Agent Antibiotic Prophylaxis Using a Single Preoperative Vancomycin Dose Effectively Reduces Prosthetic Joint Infection Rates With Minimal Renal Toxicity Risk. *The Journal of Arthroplasty*. 2018;33(7, Supplement):S213-S218. doi:10.1016/j.arth.2018.03.009

22. Cetik RM, Azboy I, Birinci M, Ozturkmen Y, Kalyenci AS, Atilla B. Predictive value of different glycemic control markers in total hip or knee arthroplasty: A prospective study. *Acta Orthop Traumatol Turc.* 2023;57(5):289-293. doi:10.5152/j.aott.2023.23037
23. Shohat N, Goswami K, Breckenridge L, et al. Fructosamine is a valuable marker for glycemic control and predicting adverse outcomes following total hip arthroplasty: a prospective multi-institutional investigation. *Sci Rep.* 2021;11:2227. doi:10.1038/s41598-021-81803-6
24. Yiğit Ş, Akar MS. Periprosthetic infection risks and predictive value of HbA1c/albumin ratio for total joint arthroplasty in patients with diabetes mellitus. *Eur Rev Med Pharmacol Sci.* 2023;27(5):1869-1874. doi:10.26355/eurrev_202303_31551
25. Citak M, Toussaint B, Abdelaziz H, et al. Elevated HbA1c is not a risk factor for wound complications following total joint arthroplasty: a prospective study. *HIP International.* 2020;30(1_suppl):19-25. doi:10.1177/1120700020926986