Infection After Primary Total Hip Arthroplasty

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Educational Objectives

As a result of reading this article, physicians should be able to:

1. Understand contemporary postoperative infection rates for primary total hip arthroplasty (THA).
2. Understand the epidemiology of bacterial species responsible for postoperative primary THA infections.
3. Review current interventions to decrease the primary THA infection rate.
4. Assess the volume and quality of data in the current orthopedics literature regarding primary THA infections.

Abstract

The number of primary total hip arthroplasties (THAs) performed in the United States each year continues to climb, as does the incidence of infectious complications. The changing profile of antibiotic-resistant bacteria has made preventing and treating primary THA infections increasingly complex. The goal of this review was to summarize (1) the published data concerning the risk of surgical site infection (SSI) after primary THA by type of bacteria and (2) the effect of potentially modifying factors.

The Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Reviews, Database of Abstracts of...
Reviews of Effects, EMBASE, Web of Science, and PubMed were searched. Studies dated between 2001 and 2011 examining primary THA in adults were included. Meta-analysis of the collected data was performed. The pooled SSI rate was 2.5% (95% confidence interval [CI], 1.4%-4.4%; P<.001; n=28,883). The pooled deep prosthetic joint infection (PJI) rate was 0.9% (95% CI, 0.4%-2.2%; P<.001; n=28,883). The pooled rate of methicillin-resistant Staphylococcus aureus SSI was 0.5% (95% CI, 0.2%-1.5%; P<.001; n=26,703). This is approximately 20% of all SSI cases. The pooled rate of intraoperative bacterial wound contamination was 16.9% (95% CI, 6.6%-36.8%; P=.003; n=2180). All these results had significant heterogeneity. The postoperative risk of SSI was significantly associated with intraoperative bacterial surgical wound contamination (pooled rate ratio, 2.5; 95% CI, 1.4%-4.6%; P=.001; n=19,049). [Orthopedics. 2013; 37(4):257-265.]

**Total hip arthroplasty (THA) has been widely recognized as one of the most successful orthopedic surgeries since its introduction in the early 1960s.**

Approximately 220,000 THAs were performed in the United States annually between 1998 and 2008. Despite advances in surgical techniques and devices, the rate of revision increased from 9/100,000 in 1990 to 15/100,000 in 2002, with a mean revision burden of 17.5%. The infection burden as a proportion of the total number of primary and revision THAs performed increased from 0.66% in 1990 to 2.18% in 2009. The estimated nationwide total hospital cost for treatment of hip PJI was approximately $200 million in 2009.

There are 3 main types of postoperative surgical site infection (SSI) after THA: (1) acute postoperative (early onset), appearing within 3 months postoperatively; (2) delayed deep, appearing 3 to 12 months postoperatively; and (3) late hematogenous, appearing more than 1 year postoperatively.

**DESCRIPTION OF INTERVENTION**

Ultra-clean-air systems, limiting the number of personnel in the operating room, improved barrier draping, and the use of sterile suction systems reduced the risk of exogenous wound contamination, decreasing the infection rate from 7% to 10% in the 1960s to 1.5% to 3% in the 1990s. Bacteriological tests suggested that skin-concomitant bacteria, in particular *Staphylococcus aureus*, were the most typical isolates in cases of both early and late infection. Preoperative application of an iodophor plastic adhesive drape decreased the risk of perioperative bacterial wound contamination to 1.6%. The association of postoperative infection with intraoperative bacterial wound contamination was not evaluated. However, it was shown in the 1980s that a combination of aseptic measures, such as ultra-clean-air systems with perioperative antibiotic prophylaxis, decreased the postoperative infection rate to 0.6%. Meta-analysis showed that the rate of deep infection after THA varied from 1.2% to 2.3% and was lower if antibiotic-loaded cement was used. A Cochrane review demonstrated that application of closed suction surgical wound drainage did not decrease the risk of SSI after THA.

The most significant risk factors of SSI and PJI can be classified into 3 groups: (1) preoperative: prior rheumatoid or septic arthritis (odds ratio [OR]=2.2), other prior infectious diseases (OR=1.8-2.3), malignancy (OR=2.4), prior THA (OR=2.2), or nasal carrier of *S aureus* (relative risk=8.9); (2) perioperative: contaminated wound (OR=4.3); and (3) postoperative: SSI (OR=27.5), wound dehiscence (OR=21.5), or hematoma (OR=2.7). The risk of PJI was associated with intraoperative surgical wound contamination by skin-concomitant bacteria (OR=2.1); however, this finding was not statistically significant due to the small number of cases with intraoperative surgical wound contamination.

**HOW THE INTERVENTION MIGHT WORK**

Studies from the early 2000s showed that strains of methicillin-resistant *S aureus* (MRSA), which had previously been observed in hospitals and patients with chronic diseases, were emerging in the community and in an increasing number of healthy carriers.

Currently, cefazolin and cefuroxime are recommended for patients undergoing orthopedic procedures, and clindamycin or vancomycin is recommended for patients with known MRSA colonization. However, pre- or perioperative administration of cefazolin and methicillin did not decrease the risk of PJI significantly. Preoperative selective decolonization by intranasal administration of mupirocin and chlorhexidine baths decreased the risk of postoperative infection to 1.2%; however, 27% of MRSA isolates causing hip and knee PJI were resistant to mupirocin. Use of at-home chlorhexidine decreased the risk of deep infection after THA; however, this effect was not significant due to the low rate of infectious cases.

A Cochrane review with meta-analysis revealed no significant decrease in postoperative SSI associated with hair removal, regardless of method.

The use of ultra-clean laminar airflow ventilation systems was associated with a higher rate of SSI after THA (OR=1.71). This may suggest that in contemporary operating rooms, skin-concomitant bacteria determine intraoperative surgical wound contamination and risk of postoperative SSI/PJI rather than exogenous infection.

**WHY THIS REVIEW IS IMPORTANT**

The change in proportion of antibiotic-resistant surgical wound pathogens influences THA infection prophylaxis and treatment. Thus, assessment of postoperative infection rate, taking into consideration pathogenic microorganisms such as MRSA and other methicillin-resistant...
microorganisms, is an important task. Taking into consideration contemporary rates of postoperative SSI (approximately 2.5%) and PJI (approximately 1%) after primary THA and that rates of different microorganisms varied from 40% to 60% (*S. aureus*) to 1% (*Propionibacterium* species), more than 4200 cases of primary THA should be included in the analysis to obtain statistically significant results with 95% statistical power. To obtain statistically significant results concerning the association between intraoperative bacterial surgical wound contamination and postoperative infection, 125 cases or more of intraoperative wound contamination and a corresponding number of uncontaminated cases should be analyzed. It is difficult to collect this number of cases in 1 study, so pooling data with a meta-analysis offers a solution. Moreover, pooling data from different independent studies provides more representative results than data obtained from a single study.

**Materials and Methods**

**Objectives**

This review assessed the risk of SSI after primary THA while taking into consideration the type of complication; the bacterial types, including methicillin-resistant strains; the effect of potentially modifying factors; and the heterogeneity of the results obtained by different studies.

**Inclusion Criteria**

Randomized controlled trials; prospective cohort studies; case series; and retrospective comparative and noncomparative studies with a follow-up greater than 2 months focusing on the evaluation of postoperative SSI and intraoperative surgical wound contamination by type of bacteria were sought. Participants were skeletally mature adults (male and female) 18 years and older undergoing primary THA.

**Outcome Measures**

Primary outcomes included:

1. Rate of postoperative SSI by type of bacteria, including MRSA
2. Rate of postoperative deep PJI by type of bacteria, including MRSA
3. Rate of intraoperative bacterial surgical wound contamination by type of bacteria, including MRSA
4. Association of postoperative SSI with intraoperative bacterial surgical wound contamination

Secondary outcomes included:

1. Perioperative antibiotic prophylaxis (yes/no/nonspecified)
2. Air-cleaning system in the operating room (yes/no/nonspecified)
3. Type of implantation (cemented/noncemented/nonspecified)
4. Postoperative follow-up (less than 12 months/12 months or more/nonspecified)

**Search Methods**

The following databases were searched: Cochrane Central Register of Controlled Trials (CENTRAL), Cochrane Database of Systematic Reviews (CDSR), Database of Abstracts of Reviews of Effects (DARE), EMBASE, Web of Science, and PubMed. The search strategy was developed in Ovid Medline and translated to PubMed, EMBASE, Web of Science, CENTRAL, CDSR, and DARE. Medline, Embase, and Web of Science strategies are shown in Appendix A (available at the end of the PDF of this article). A sensitive search was performed to identify as many relevant trials as possible. Only studies published between 2001 and 2011 were included. No language limits were applied. The search was performed by a University of Colorado Health Sciences Library Professional Research Librarian.

Reference lists of review articles, in particular Cochrane systematic reviews, were also reviewed to identify eligible studies.

**Data Collection, Analysis, Extraction, and Management**

One reviewer (Z.H.) screened the titles, abstracts, and, when necessary, full texts to determine potentially eligible studies. Full-text reports of selected studies were then analyzed by 2 reviewers (A.N., Z.H.). Disagreements regarding inclusion were resolved by discussion. Excluded studies were listed with reason for exclusion.

Data were extracted from the included studies by 1 reviewer (A.N.) and checked by another (B.L.). The following data were collected: (1) general information: authors, title, publication status, year of publication, country, study design, sponsorship, and study objectives; (2) participants: inclusion and exclusion criteria, number in intervention groups, ages, sexes, baseline comparability, dropouts; (3) trial characteristics: design, length of follow-up, randomization, allocation concealment, and blinding of assessors if applicable; (4) interventions: cemented or noncemented, perioperative antibiotic prophylaxis, preoperative skin treatment, air-cleaning system in the operating room, and postoperative follow-up period; and (5) intra- and postoperative outcomes.

Only groups within a study that used the same surgical technique and device were included in the analysis. Studies with a dropout rate of more than 30% at 24-month follow-up were excluded.

**Assessment of Risk of Bias**

The risk of bias for each study included in the review was defined independently by 2 reviewers (A.N., Z.H.) using Cowley’s score.24 The items were scored with yes or no. Studies were selected for analysis if at least 6 of the 16 criteria were met, and risk of bias was defined using Review Manager 5.1 (The Nordic Cochrane Center, Copenhagen, Denmark). Agreement between the 2 independent assessments was defined by kappa test. Disagreements were resolved by discussion.

**Measures of Studied Effects**

The studied effects were binary data and were assessed as a ratio of studied evidence to sample size at follow-up. An
inverse-variance method was used for combining data across studies. Pooled rates with 95% confidence intervals (CIs) were calculated. To evaluate the influence of modifying factors, grouping analysis was applied. A random-effects model was used for pooling data in each group.

Assessment of Heterogeneity
Statistical heterogeneity of pooled data was defined by chi-square test ($P<.05$ represented heterogeneity) and $I^2$ test with the following interpretation of heterogeneity: less than 30% = low; 30% to 60% = moderate; greater than 60% = high.

Assessment of Publication Bias
Funnel plots were used to evaluate the risk of publication bias.

Data Synthesis
A meta-analysis of studied effects was performed by defining pooled rates in each group of interest with 95% CIs. To summarize data, a random-effects model was applied. The GRADE approach was applied to evaluate the quality of the revealed evidence.

Sensitivity Analysis
Sensitivity analysis was performed by extracting studies that showed results significantly different from the pooled result.

RESULTS
Description of Studies
Electronic searches provided a total of 1024 citations, and 67 were identified from other sources. After adjusting for duplicates, 918 remained and were screened. Of these, 904 were discarded because they did not meet the study criteria. The remaining 14 citations were examined in more detail. A further 6 studies did not meet all of the inclusion criteria, leaving 8 studies that were included in the systematic review and meta-analysis (Figure 1).

Included Studies
Eight studies selected for the review were published as full-text articles in English and were conducted in the following countries: United States, Canada, United Kingdom, Ireland, Greece, Hong Kong, and Poland (Table A, available at the end of the PDF of this article). Six studies were prospective, including 5 case series, 1 was a nonrandomized cohort study, and 2 were retrospective case series. The search revealed no randomized controlled clinical trials meeting the inclusion criteria. The postoperative follow-up period ranged from 2 to 120 months. Dropout was reported by 6 studies and did not exceed 20%.

The included studies involved 28,883 participants after THA, including 23,729 primary THAs, 2587 revision THAs, and 2567 combined primary and revision THAs. Mean age in the study groups was reported by 6 studies and ranged from 40 to 72 years (Table A, available at the end of the PDF of this article). The male:female ratio was reported by 5 studies.

Figure 1: Flow chart of study inclusion in the meta-analysis.
and ranged from 0.5 to 0.7. Two studies reported results of cemented THAs, 28,30 and 1 study reported results of uncemented THAs. 27, 3 studies reported results of combined (cemented, uncemented, or hybrid) THAs, 29,31,33 and 2 studies did not specify the type of implant fixation. 32,34 Pre operative infection status of enrolled patients was reported in 3 studies. 31-33 Antibiotic prophylaxis was reported by 7 studies (Table B, available at the end of the PDF of this article), 27,28,30-34 Antibiotic prophylaxis was applied as a standard procedure for all patients in 5 studies, 27,30-32,34 was partially used in 2 studies, 28,33 and was not specified in 1 study. 29 Pre operative wound site preparation was reported in 3 studies (Table B, available at the end of the PDF of this article). 27,30-31 Seven studies reported testing of surgical wound bacterial contamination. 27-33 All studies reported data concerning postoperative infection, including deep PJI. Five studies reported that an air-cleaning system was used in the operating room during THA. 27,28,30-32 Three studies did not specify this. 29,33,34

**Risk of Bias in Included Studies**

The 2 independent bias evaluations demonstrated good agreement (kappa coefficient, 0.95; standard error, 0.027; P=.56). All studies were nonrandomized, including 7 case series 27,28,30-34 and 1 cohort study. 29 None of the studies reported the type of hip prosthesis. Three studies did not report the number of enrolled men and women. 28,30,32 Seven studies did not report preoperative diagnosis. 27,31,33,34 Only 2 studies reported patient weight and body mass index. 27,28 This suggests a risk of selection bias in all included studies (Figure 2). A high risk of performance bias was found for all 8 studies. This bias is attributed to the fact that personnel and participants could not be blinded to the type of complications associated with infection. Only 1 study reported that the evaluation of clinical and radiologic outcomes, including statistical analysis, was independent of operating surgeon. 34 This suggests a high risk of detection bias in the other 7 studies (Figure 2). 27,33 Two studies did not report the number of patients lost to follow-up, leaving them vulnerable to attrition bias. 32,34

In summary, 100% of included studies were at risk of selection and performance bias, 87.5% were at risk of detection bias, and 25% were at risk of attrition bias (Figure 3).

**Primary Outcomes**

**Rate of Postoperative Surgical Site Infection**

In the 8 included studies, the rate of postoperative SSI ranged from 0.3% to 63.6%. The pooled SSI rate was 2.5% (95% CI, 1.4%-4.4%; P<.001; n=28,883; high heterogeneity: I²=95.7%; P<.001).

**Rate of Postoperative Deep Prosthetic Joint Infection**

In the 8 included studies, the rate of postoperative deep PJI ranged from 0.1% to 11.1%. The pooled deep PJI rate was 0.9% (95% CI, 0.4%-2.2%; P<.001; n=28,883; high heterogeneity: I²=94.4%; P<.001). This is approximately 36% of all SSI cases.

**Rate of Bacteria Types Associated With Surgical Site Infection**

*Staphylococcus aureus* was found to be a cause of SSI in 6 studies. 27-29,31,33,34 Rates of SSI with isolated *S aureus* ranged from 0.2% to 27.3%. The pooled rate of SSI with *S aureus* was 1.3% (95% CI, 0.6%-2.5%; P<.001; n=28,185; high heterogeneity: I²=95.3%; P<.001). This is approximately 52% of all SSI cases. *Staphylococcus epidermidis* was cultured in 6 studies, with rates ranging from 0% to 13.6%. 27,29,32,34 The pooled rate was 0.5% (95% CI, 0.2%-1.3%; P<.001; n=26,505; high heterogeneity: I²=98.9%; P<.001). This is approximately 20% of all SSI cases. Streptococci were reported in 2 studies, with a pooled rate of 0.2% (95% CI, 0.1%-0.3%; P<.001; n=20,834; low heterogeneity: I²=0%; P=.784). 28,29 This is approximately 8% of all SSI cases. Gram-negative bacilli were
reported by 2 studies, with rates of 0.04%\(^{-29}\) and 1%.\(^{-29}\) The pooled rate was 0.2% (95% CI, 0%-4.4%; \(P<.001\); \(n=16,770\)); high heterogeneity: \(I^2=93.8\%\); \(P<.001\). This is approximately 8% of all SSI cases.

Other and mixed bacteria isolates, including Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa, Proteus mirabilis, and others, were reported by 5 studies, with rates ranging from 0.04% to 4.5%\(^{-27,29,32,33}\). The pooled rate was 0.4% (95% CI, 0.2%-1.0%; \(P<.001\); \(n=26,026\)); high heterogeneity: \(I^2=85.8\%\); \(P<.001\). This is approximately 16% of all SSI cases.

**Rate of Methicillin-resistant Bacteria Associated With Postoperative Surgical Site Infection.** Antibiotic-resistant bacteria reported included MRSA and methicillin-resistant *S. epidermidis* (MRSE). Methicillin-resistant *S. aureus* was reported by 5 studies, with rates varying from 0.1% to 1.9%\(^{-27,29,31,33,34}\). The pooled rate was 0.5% (95% CI, 0.2%-1.5%; \(P<.001\); \(n=26,703\)); high heterogeneity: \(I^2=95.7\%\); \(P<.001\). This is approximately 20% of all SSI cases. Methicillin-resistant *S. epidermidis* was cultured in 1 study, with a rate of 0.1% (95% CI, 0%-0.2%; \(P<.001\); \(n=5060\)).\(^{27}\)

**Rate of Intraoperative Bacterial Surgical Wound Contamination.** Four studies reported cases of intraoperative surgical wound bacterial contamination, with rates ranging from 2.7% to 59%\(^{-28,30,32,33}\). The pooled rate was 16.9% (95% CI, 6.6%-36.8%; \(P=0.003\); \(n=2180\)); high heterogeneity: \(I^2=92.8\%\); \(P<.001\).

**Rate of Bacteria Types Associated With Intraoperative Surgical Wound Contamination.** Three studies reported that *S. aureus* was cultured from swabs taken from the surgical wound, with rates ranging from 0.5% to 27.3%\(^{-28,32,33}\). The pooled rate was 3.5% (95% CI, 0.2%-36.5%; \(P=0.019\); \(n=2125\)); high heterogeneity: \(I^2=96.5\%\); \(P<.001\). Four studies reported *S. epidermidis*, with rates ranging from 0.3% to 18.2%\(^{-28,30,32,33}\). The pooled rate was 3.5% (95% CI, 0.3%-7.3%; \(P=0.005\); \(n=2180\)); high heterogeneity: \(I^2=95.6\%\); \(P<.001\).

Streptococci were reported by 2 studies, including *Streptococcus pyogenes*, *Streptococcus viridans*, and *Streptococcus salvarius*, with rates of 0.3\(^{-28}\) and 1.8%\(^{-30}\). The pooled rate was 0.6% (95% CI, 0.1%-3.6%; \(P<.001\); \(n=2048\)); high heterogeneity: \(I^2=69.4\%\); \(P=0.071\). *Escherichia coli* was reported in 3 studies, with rates ranging from 0.1% to 13.6%\(^{-28,32,33}\). The pooled rate was 1.1% (95% CI, 0%-23.5%; \(P=0.008\); \(n=2125\)); high heterogeneity: \(I^2=93.8\%\); \(P<.001\). Gram-negative bacteria were reported in 1 study, with a rate of 1.8% (95% CI, 0.3%-11.8%; \(P<.001\); \(n=55\)).\(^{30}\) Other bacteria and mixed bacterial wound contamination were reported in 4 studies, with rates ranging from 0.4% to 4.6%\(^{-28,30,32,33}\). The pooled rate was 1.6% (95% CI, 0.4%-5.9%; \(P<.001\); \(n=2180\)); high heterogeneity: \(I^2=76.5\%\); \(P<.001\).

**Secondary Outcomes**

**Perioperative Antibiotic Prophylaxis.** Perioperative antibiotic prophylaxis was given to all patients in 2 studies, with a pooled risk of SSI of 1% (95% CI, 0.7%-1.6%; \(P<.001\); \(n=1845\)); low heterogeneity: \(I^2=0\%\); \(P=0.562\).\(^{30,31}\) Three studies showed a risk of SSI after partially used (not in all patients) perioperative antibiotic prophylaxis for primary THA, with a pooled SSI risk of 1.4% (95% CI, 0.5%-4.4%; \(P<.001\); \(n=21,884\)); high heterogeneity: \(I^2=97.1\%\); \(P<.001\).\(^{27,29,33}\) This difference is not significant, but higher heterogeneity in the second group suggests that nonregular use of perioperative antibiotic prophylaxis may lead to less certain outcomes after primary THA.

**Air-cleaning System in the Operating Room.** Three studies reported that air-cleaning systems were used in the operating room during primary THA, with rates of SSI ranging from 0.3% to 1.8%\(^{-27,30,31}\). The pooled risk of SSI was 0.7% (95% CI, 0.2%-1.9%; \(P<.001\); \(n=6905\)); high heterogeneity: \(I^2=85.3\%\); \(P=0.001\). Use of an air-cleaning system was not specified in 2 studies, with SSI rates of 2.2%\(^{-29}\) and 4.4%\(^{-33}\) and a pooled rate of 2.9% (95% CI, 1.6%-5.3%; \(P<.001\); \(n=16,824\)); high heterogeneity: \(I^2=87.6\%\); \(P=0.005\). This is significantly (\(P=0.018\)) higher than in studies using air-cleaning systems.

**Type of Implantation (Cemented/Non-cemented).** Primary cemented THA was performed in 1 study, with a risk of SSI of 1.8% (95% CI, 0.3%-11.8%; \(P<.001\); \(n=55\)).\(^{30}\) Primary noncemented THA was performed in 1 study, with a risk of SSI of 0.3% (95% CI, 0.2%-0.5%; \(P<.001\); \(n=5060\)).\(^{23}\) This difference is not statistically significant.

**Postoperative Follow-up.** Two studies had less than 12 months of follow-up, with a pooled risk of SSI of 2.7% (95% CI, 1.8%-4.1%; \(P<.001\); \(n=19,320\)); high heterogeneity: \(I^2=90.2\%\); \(P<.001\).\(^{29,34}\) Twelve or more months of postoperative follow-up was reported in 6 studies.\(^{27,28,30,33}\) The pooled risk of SSI was...
3.8% (95% CI, 1.9%-4.1%; \( P < .001 \); \( n = 9578 \); high heterogeneity: \( I^2 = 97.1\% \); \( P < .001 \)). The difference between these 2 groups was not significant.

Deep PJI with less than 12 months of postoperative follow-up was reported in 2 studies, with a pooled risk of 0.3% (95% CI, 0.1%-0.9%; \( P < .001 \); \( n = 19,320 \); high heterogeneity: \( I^2 = 84.6\% \); \( P < .001 \)).

Six studies reported 12 or more months of postoperative follow-up, with a pooled risk of deep PJI of 1.4% (95% CI, 0.5%-3.7%; \( P < .001 \); \( n = 9578 \); high heterogeneity: \( I^2 = 91.6\% \); \( P < .001 \)). The difference was statistically significant (\( P = .037 \)), suggesting that more than 12 months of follow-up revealed a higher rate of deep PJI than did fewer than 12 months of follow-up.

**DISCUSSION**

**Summary of Main Results**

Eight nonrandomized clinical studies (7 case series and 1 cohort study) involving 28,883 participants were included to assess the risk of SSI after THA. Information concerning sponsorship of these publications was not provided.

All studies reported rate and number of SSIs after THA, with a pooled rate of 2.5% (95% CI, 1.4%-4.4%; \( P < .001 \)). Despite statistical significance of the pooled result, the level of evidence is low due to the serious limitations in the design of the studies, high risk of bias, and high heterogeneity of the combined data.

Deep PJI was also reported by all included studies, with a pooled rate of 0.9% (95% CI, 0.4%-2.2%; \( P < .001 \)). Despite statistical significance, the level of this evidence is also low, due to the same problems.

Pooling data concerning bacteria cultured in SSI cases demonstrated the prevalence of skin concomitants such as *S aureus* (1.3%; 95% CI, 0.6%-2.5%), and *S epidermidis* (0.5%; 95% CI, 0.2%-1.3%), reported by 6 studies.

In addition, 5 studies revealed the following species sometimes found in combination with *S aureus* and *S epidermidis*: *E coli, K pneumoniae, P aeruginosa, P mirabilis*, and others, with a pooled rate of 0.4% (95% CI, 0.2%-1.0%).

Streptococci and gram-negative bacteria were reported by 2 studies, with a pooled rate of 0.2%. The most common antibiotic-resistant strain was MRSA, reported by 5 studies and with a pooled rate of 0.5% (95% CI, 0.2%-1.5%).

One study cultured MRSE in 0.1% (95% CI, 0%-0.2%) of cases. All of these results are statistically significant, but the level of evidence is low due to the methodological limitations of the studies, high heterogeneity of the results, and small number of studies reporting several findings.

Intraoperative bacterial wound contamination was reported by 4 studies, with a pooled rate of 16.9% (95% CI, 6.6%-36.8%). Despite statistical significance (\( P = .003 \)), the level of evidence is low due to the methodological limitations of the studies and high heterogeneity of the results. Skin concomitants were the most typical isolates from the surgical wound, including *S aureus* (3.5%; 95% CI, 0.2%-36.5%), *S epidermidis* (3.5%; 95% CI, 0.3%-27.3%), streptococci (0.6%; 95% CI, 0.1%-3.6%), and gram-negative bacilli (1.8%; 95% CI, 0.3%-11.8%).

*R E coli* and other bacteria were reported with pooled rates of 1.1% (95% CI, 0%-23.5%) and 1.6% (95% CI, 0.4%-5.9%), respectively. Pooled data concerning bacterial contamination of the surgical wound are statistically significant, but the level of evidence is low due to high heterogeneity, methodological limitations, and a small number of studies reporting several results.

Combining the results of 5 studies showed that intraoperative bacterial wound contamination resulted in a more than 2-fold increased risk of SSI after THA (Figure A, available at the end of the PDF of this article). This result was statistically significant with low heterogeneity, suggesting that the results of different studies were relatively consistent. However, the level of evidence is low because of methodological limitations of the studies and a high risk of bias.

Collected data and pooled results do not allow a conclusion concerning efficacy of antibiotic prophylaxis, air-cleaning systems in the operating room, and type of implantation (cemented or noncemented) for prevention of SSI and PJI after THA.

Duration of follow-up less than 12 months after primary THA may significantly underestimate the risk of PJI. Despite the statistical significance of this finding, the level of evidence is low.

**Overall Completeness and Applicability of Evidence**

The included studies provide the most complete information available concerning rates of SSI and deep PJI after primary THA; however, methods of diagnosis were different, adding heterogeneity to the pooled results. Information concerning bacteriologic analysis of SSI and surgical wound swab isolates was presented partially. Rates of SSI associated with MRSA were presented partially. Information concerning surgical wound intraoperative bacterial contamination—in particular by MRSA and other antibiotic-resistant strains—and its association with postoperative SSI and PJI was limited. Data concerning potential confounding factors, such as preoperative diagnosis, type of hip prosthesis, type of prosthesis fixation, use of antibiotic-loaded cement, preoperative skin treatment, antibiotic prophylaxis, and air-cleaning system in the operating room, were incomplete.

**Quality of the Evidence**

The overall quality of included studies is poor. All are nonrandomized observational studies with serious limitations. Overall sample size allows obtaining several statistically significant results. However, the level of evidence of these findings is low or very low due to heterogeneity of the pooled data and the risk of bias caused by the studies’ design.
Potential Biases in the Review Process

The review was conducted following contemporary requirements for systematic reviews and meta-analysis of studies that evaluate health care interventions. Comprehensive searches were performed to identify relevant studies. Unfortunately, no randomized controlled clinical trials met the inclusion criteria. Therefore, the authors had to include nonrandomized studies while taking into consideration the risk of corresponding biases. The results of the meta-analysis are limited by the quality of the studies identified in the review. Theoretically, studies relevant to the review may have been missed by the search. However, the authors’ analysis demonstrated that this potential loss would not change the results significantly. This review was conducted independent of industry.

Agreement and Disagreement With Other Studies or Reviews

Pooled data concerning postoperative SSI after primary THA obtained in this study were similar to previously published results. A 2008 Cochrane review summarized outcomes of 12 randomized or quasi-randomized clinical trials studying risk of postoperative infection after THA in 1415 participants. Rates of postoperative infection varied from 0% to 32%. The pooled rate was 3.6% (95% CI, 1.8%-7.4%). This is slightly higher than that of the current study, but the difference is not statistically significant. Another review summarized data of 6 randomized or quasi-randomized clinical trials examining the risk of deep PJI after primary cemented (with or without antibiotics) THA in 15,137 hips. Studies included in that review were published between 1987 and 1997. Rates of postoperative infection varied from 0.4% to 8.6%. The pooled rate of deep infection was 1.5% (95% CI, 0.7%-3.0%). This is slightly higher than the pooled rate obtained in the current review, but the difference is not significant. The current authors found no reviews that met their inclusion criteria summarizing data concerning the risk of SSI and/or PJI associated with different bacterial species, in particular antibiotic-resistant strains. Since the 1970s, it has been well-known that skin flora are the most common isolate from surgical wounds and postoperative infections. Data concerning the association between intraoperative surgical wound bacterial contamination and the risk of postoperative infection after THA were published but did not reach statistical significance due to the relatively small number of cases. The current review showed a statistically significant association by pooling data from different studies.

Data concerning the appearance of methicillin-resistant strains of Staphylococcus aureus and other bacteria in SSI and PJI after THA have been published during the past decade. Risks associated with methicillin-resistant infection are likely high but not well evaluated, which is shown in the current review. No significant disagreements with previously published data were revealed.

CONCLUSION

This study clarifies primary THA infection rates by type of bacteria, shows an increased risk of SSI given positive intraoperative cultures, and establishes a need for future research.

During the past decade, the most significant likelihood of SSI rate after primary THA was approximately 2.5% (95% CI, 1.4%-4.4%), and the most significant likelihood rate of deep PJI after primary THA was approximately 0.9% (95% CI, 0.4%-2.2%). Skin flora is the most typical isolate in cases of postoperative infection. Approximately 20% of SSIs are associated with methicillin-resistant strains.

In current clinical conditions, the risk of intraoperative bacterial wound contamination is approximately 16.9% (95% CI, 6.6%-36.8%). The skin flora determines the risk of intraoperative wound contamination, increasing the risk of postoperative infection after THA approximately 2-fold despite contemporary measures of aseptic and antiseptic prophylaxis.

This review highlights the paucity of high-quality studies on the risk of complications associated with type of bacteria, especially methicillin-resistant infections after THA. Well-designed randomized, controlled trials and economic studies are needed to assess the clinical effectiveness and cost-effectiveness of methods to decrease infection and risk of reoperation after primary THA.

REFERENCES

Appendix A Search Strategies and Strings

Medline strategy + first 100 results:

- .mp = keyword in any field
- .tw = title words
- $ = truncation device (right end “catch all”)
- .fs = “floating subheading” (not used yet, although it might be incorporated later)
- #36 is larger set bcs it includes the broad terms, postoperative complication$ and all prosthesis related infections (not just bacterial ones)
- #38 is the set without those 2 terms (much more focused on your question)

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Note: pCS – prospective case series or cohort study, rCS – retrospective case series or cohort study
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Note: MRSA - Methicillin-resistant Staphylococcus aureus
Association of surgical site infection after total hip arthroplasty with intraoperative surgical wound bacterial contamination

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Heterogeneity: $\tau^2 = 0\%$; $p = 0.685$

Random effect model