Infection Prevention in Total Knee and Total Hip Arthroplasties

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Abstract

Infection after primary joint arthroplasty is responsible for severe morbidity to the patients and staggering costs to society. Understanding the patient population undergoing these procedures and the use of appropriate prophylactic regiments and precautions in the perioperative and postoperative periods is crucial for the ultimate success of the procedures. In this article, we review the current related literature and our techniques for reducing the likelihood of infection after total knee and total hip arthroplasties.

Despite advances in aseptic technique and modifications within the operating suite, the incidence of infection after primary joint arthroplasty is 0.3% to 2%. The annual cost of total joint infections in the United States is estimated to be $250 million.[1] Bozic and colleagues[1] found that the direct medical costs associated with revising total hip arthroplasty (THA) because of infection was 2.8 times higher than the costs associated with revising THA because of aseptic loosening and 4.8 times higher than the direct medical costs associated with primary THA. The authors also found that patients undergoing revision THAs because of infection had significantly more hospitalizations, total days in hospital, number of operations, outpatient visits, outpatient charges, and further complications. Hebert and colleagues[2] showed that such infection equates to a net loss to the hospital of roughly $15,000 to $30,000 per patient. It is crucial to understand the population of patients who undergo these procedures and to be mindful of prophylactic regiments and precautions in the perioperative and postoperative periods in order to reduce the likelihood of infection.

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Patient Selection

Certain populations have a much higher risk for infection after primary joint arthroplasty. Patients with diabetes, psoriasis, rheumatoid arthritis, recent prolonged hospitalizations, recent infection, malnutrition, sickle-cell disease, previous solid organ transplant, oral steroid use, immune system compromise, and a history of surgery on the affected joint are at much higher risk than the general population for the development of a joint infection after primary joint arthroplasty.[3,4] Infection after primary total joint arthroplasty (TJA) was also associated with obesity and recurrent urinary tract infections, though the correlation was not statistically significant.[5] It is imperative that these high-risk patients be placed in a subgroup that requires careful attention and optimization before surgery.

General guidelines for optimizing nutrition include a lymphocyte count of more than 1500 cells/mm^3 and an albumin level of more than 3.5 g/dL. For patients who receive methotrexate, discontinuation 2 weeks before surgery is sufficient. Smoking cessation 30 days before surgery and autologous blood donation was also postulated to reduce infection.[5]

Preoperative Period

Patient preparation before surgery is essential in preventing infection.

Hair Removal

Considerable debate remains, however, regarding removal of hair from the surgical site. Surgeons who remove hair from the operative region should do so immediately before surgery, as there are reports of rapid colonization of the small nicks left by the razor being associated with an increased infection rate.[5]

A recent meta-analysis demonstrated that, when hair removal was necessary, chemical depilation or electric clipping instead of shaving was preferable immediately before surgery to prevent infection.[6] In contrast, clipping in comparison to shaving was associated with fewer skin nicks, but no difference in infection was observed.[7] A prospective, randomized study comparing the effects of preoperative shaving versus chemical depilation on wound infection in 253 patients found no statistical difference. The depilatory cream was used the night before, which may save time between surgeries.[6]

Disinfectants

Next, the surgeon must decide which surgical disinfectants to use to remove bacteria from the skin. Several studies have demonstrated the potential of using chlorhexidine or iodine showers the night before surgery to reduce skin flora, but the results from these studies have not been conclusive. Surgical scrub options vary from single-agent scrubs to combination agents. Convincing data from a prospective randomized trial involving 177 patients undergoing surgery of the foot or ankle demonstrated that chlorhexidine and alcohol provide better reduction in bacterial carriage than povidone-iodine.[8] Furthermore, chlorhexidine in detergent/alcohol regimens was superior to povidone-iodine.[9] In a randomized, prospective study, Jacobson and colleagues[10] demonstrated that 0.7% iodine plus 74% isopropyl alcohol (DuraPrep™ Surgical Solution; 3M, St. Paul, Minn) in combination with Ioban™ 2 Antimicrobial Incise Drapes (3M) had a lower infection rate in TJA compared with povidone-iodine scrub and paint plus Ioban 2 drapes. The authors found that the reduced infection rate was related to a reduction of drape lift, the incident whereby the drape lifts, exposes underlying skin, and thereby allows remaining or regenerating skin bacteria to be carried into the wound during surgery. Although DuraPrep reduces drape lift, a prospective study demonstrated that a combination of 2% chlorhexidine gluconate and 70% isopropyl alcohol (ChloraPrep, Enturia, Inc. Leawood, Kansas) was most effective for eliminating bacteria from the forefoot before surgery when compared with 3.0% chloroxylenol or DuraPrep.[8]

Antibiotic Use

Despite advances in surgical preparation, the single most important factor in reducing infection is routine use of antibiotic prophylaxis.[3] Most studies, however, fail to define the appropriate timing and duration of antimicrobial prophylaxis. Moreover, there is disagreement as to which antimicrobial agent is optimal. The ideal agent would have excellent in vitro activity against staphylococci and streptococci, penetrate tissue well, and have a relatively long serum half-life for the duration of the procedure.

At this time, cefazolin qualifies as an attractive choice for prophylaxis. Routine use of this drug, however, causes concern regarding resistance. Current guidelines for antimicrobial prophylaxis for surgery recommend cefazolin or cefuroxime for patients undergoing THA. Vancomycin is recommended as an alternative agent for patients who have a true type I β-lactam allergy. The goal of antimicrobial prophylaxis is to achieve serum and tissue drug levels that exceed the minimum inhibitory concentrations for the organism likely to be encountered. According to recommendations, cefazolin should be administered 30 to 60 minutes before skin cut and at least 5 to 10 minutes before tourniquet inflation. For prolonged procedures exceeding 1 to 2 times the half-life of the antibiotic or for procedures associated with extensive blood loss, an additional intraoperative dose of antibiotic is recommended.[5] Hanssen[11] found that dosing every 3 hours is appropriate during surgery, especially when blood loss is heavy. The transient increase in blood flow to the extremity immediately after tourniquet deflation facilitates delivery of the antibiotic to the operative site.

Postoperative Antibiotic Period. Several studies have shown no additional benefit to continuing prophylaxis past 24 hours.[2,11] A significant number of orthopedic surgeons choose to continue postoperative prophylactic antibiotics until all indwelling catheters are removed, usually at 48 hours. We were unable to identify any reports indicating an increase in toxicity and/or antimicrobial resistance when the postoperative antibiotic period was increased from 24 to 48 hours. Cost of the additional 1 day of antibiotics is negligible in comparison with the staggering cost of treating postoperative infections.

Intraoperative Period

Over the past 50 years of joint arthroplasty, significant advances in infection reduction have been made.

Airflow Systems

In 1969, Charnley and Eftekhar[12] reported a revolutionary reduction in post-THA infections, from 9% (17/190) to 1% (9/708), with implementation of a clean-air operating room—a combination of laminar airflow, a room-air-exchange turnover rate of more than 300 times an hour, use of a vertical airflow system, and use of personnel isolator suits.[13]

Whereas early studies demonstrated the efficacy of laminar flow, later scrutiny cast doubt on it as an independent variable in infection reduction. Further research revealed that the single most important factor in infection reduction is use of preoperative antibiotics. Infection rates were 2.8%, when only laminar flow was used, and 0.5%, when preoperative antibiotics were used with or without laminar flow.[4] Salvati and colleagues[5] further demonstrated a paradoxically increased infection rate when total knee arthroplasty (TKA) was performed with laminar airflow but minus exhaust suites. The large exposed surgical area and the subsequent entrainment of air containing particulate matter and bacteria from operating-room personnel into the operative wound were blamed for its increase in infection rate. Usually, however, vertical laminar airflow units reduce airborne contamination better than horizontal airflow units do, especially in the absence of personnel isolator suits.[4]

Additional Means of Reducing Contamination

Intraoperative contamination remains a disturbing problem. Hanssen[11] noticed alarmingly high rates of contamination of suction tips in prolonged surgeries and recommended changing tips every 30 minutes and turning the suction system on only before its actual use in order to minimize this source of bacterial contamination.

Contamination resulting from glove perforation was predicted in 100% of patients in which surgery lasted longer than 3 hours.[9] Changing gloves periodically during surgery should be made routine practice. Seventy-four percent of splash basins were contaminated at the end of the orthopedic procedure, and 59% of positive cultures yielded multiple organisms, the most common being coagulase-negative *Staphylococcus*. Contrary to usual practice, instruments placed in the splash basin should not be returned to the operative wound.

Wound Irrigation

Wound irrigation with a physiologic solution during surgery keeps the tissue moist, removes debris and blood clots, and reduces the concentration of bacteria. Adding various antibiotics to the solution is common practice, but whether this preventive measure reduces the infection rate is difficult to prove. No study has demonstrated tissue penetration or duration of action of the antibiotic within the tissue. The main factor repeatedly proven to increase efficiency of wound irrigation is volume. Detergents, antibiotics, and pulsatile flow, however, have not been proved effective in reducing the bacterial bioload in TJA.

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Extrapolating data from spine surgery shows promise with use of dilute povidone-iodine irrigation. A recent prospective, single-blinded, randomized study demonstrated the clinical effectiveness of dilute povidone-iodine solution irrigation for prevention of wound infection after spinal surgery.[14] All patients undergoing spinal surgery were randomized into a group who received dilute povidone-iodine solution irrigation before closure (n = 208) and a group who did not receive povidone-iodine in the irrigant (n = 206). There were no infections when dilute povidone-iodine was used and 1 superficial infection and 2 deep infections when it was not used.

Antibiotic-Cement Combinations

In 1981, Buchholz and colleagues[15] introduced impregnating acrylic cone cement with antibiotics as a possible means of preventing infection in patients undergoing TJA. Today, several types of acrylic bone cement incorporate antibiotics. Antibiotic cements available in the United States include Palacos G (Zimmer, Warsaw, Ind), which contains 0.85 g gentamicin; Simplex® P (Stryker Howmedica Osteonics, Mahwah, NJ), which contains 1 g tobramycin; SmartSet GHV and MHV (DePuy Orthopaedics, Warsaw, Ind), which contain 1 g gentamicin; and the PROSTALAC® prosthesis (DePuy) used with 1 g of vancomycin and 3.6 g of tobramycin in 40 g of cement powder.

Once mixed, the heat-stable antibiotics elute from antibiotic-impregnated bone cement at rates dependent on their specific chemical characteristics. The cement-to-antibiotic ratio is crucial. Laboratory studies have shown no notable influence on the compressive strength of bone cement when the antibiotics are used in appropriate amounts.

The main advantage of the antibiotic-cement combinations is in the ability to elute antibiotic at the inhibitory concentration for common infecting organisms for weeks. Once microorganisms attach to cement, bone, or other biomaterials, the bacteria become metabolically less active and concomitantly cover themselves with biofilm, rendering them unresponsive to antibiotics at usually therapeutic levels. Biofilm is an extracellular polymeric glycocalyx; once formed, it protects the organism from antimicrobials, opsonization, and phagocytosis. To achieve a pharmacologic kill of bacteria in a biofilm, antibiotic concentrations must be 10 to 100 times the usual bactericidal concentration, which often cannot be achieved with safe doses of parenteral antibiotics; therefore, systemic antibiotic treatment of sessile bacterial infections often is not possible. In North America, use of antibiotic bone cement has become the gold standard of treatment for recognized, established joint arthroplasty infections.[16-18] In Europe, antibiotic bone cement is used in treating established infections in joint arthroplasty and is commonly used in preventing infection during joint arthroplasty. Impregnating acrylic bone cement with antibiotic holds promise as a possible means of preventing infection in high-risk patients undergoing TJA. The US Food and Drug Administration has approved antibiotic-impregnated bone cements, which may be beneficial in lowering infection rates in primary TJA.[17]

Postoperative Prophylaxis

The reconstructed joint is at risk for infection during episodes of bacteremia. The risk of hematogenous spread from dental, gastrointestinal, and genitourinary procedures is well known, and prophylaxis is warranted.[10,19,20]

Consensus statements[19,20] emphasize that the most critical period for hematogenous seeding is up to 2 years after joint arthroplasty. Patients deemed high risk include those with inflammatory arthroplasties, drug- or radiation-induced suppression, and multiple medical comorbidities, such as insulin-dependent diabetes and malignancy. Examples of dental procedures considered high risk are dental extractions, periodontal surgery, endodontic instrumentation, and cleaning where bleeding is anticipated. For patients without a penicillin allergy, the recommended treatment is use of cephalexin or amoxicillin 2 g orally 1 hour before the procedure. For high-risk patients with a penicillin allergy and for patients who cannot take oral medications, the recommendation is clindamycin 600 mg intravenously 1 hour before the procedure.[19]

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Hematologic seeding risk factors are similar for patients with gastrointestinal and genitourinary conditions. As the bacteremia risk is dramatically increased in the presence of bacteriuria, the advisory statement recommends preoperative treatment of any bacteriuria before manipulation of the urinary tract. For patients without a penicillin allergy, ampicillin plus gentamicin is recommended. For patients with a penicillin allergy, the recommendation is vancomycin plus gentamicin or levofloxacin, ciprofloxacin, or ofloxacin.[20] Gastrointestinal disorders are also associated with bacteremia, but, because of their extremely low rate of infection, prophylaxis is not recommended.[21]

Conclusions

We recommend that all patients receive preoperative antibiotics in the form of cefazolin, unless they are allergic to penicillin. If patient has a history of penicillin allergy, clindamycin or vancomycin should be used. Preoperative patient optimization is crucial. No data favor clipping, shaving, or use of dipilatory cream in the immediate preoperative setting. Our preference still is to shave the surgical site immediately before application of the surgical scrub. Given the evidence, we prefer chlorhexidine-alcohol combinations for the surgical scrub. Chemical showers may be helpful, but we have no conclusive evidence to encourage this practice.

We routinely administer the first dose of the prophylactic IV antibiotic less than 30 minutes before incision; during TKA, the second dose is delivered immediately after tourniquet deflation. With TKAs, we also prefer to use vertical flow with exhaust suites because of the large exposed surgical area and the high potential for contamination from bone debris. We do not use exhaust suites with primary, uncomplicated THAs. Use of prophylactic antibiotics for more than 24 hours after a routine primary TJA is not usually recommended. However, use of prophylactic antibiotics may be justified during the 48 hours after surgery for immunocompromised patients or to cover the retained drains. Antibiotic-impregnated cement may provide extra protection in primary TJAs and may help prevent postoperative infections, which are often devastating for patients and costly for both patients and society.

Authors' Disclosure Statement

The authors report no actual or potential conflict of interest in relation to this article.

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This paper will be judged for the Resident Writer's Award.