Joints

Reducing periprosthetic joint infection: what really counts?

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Abstract

Periprosthetic joint infection (PJI) remains one of the most challenging complications after joint arthroplasty. Despite improvements in surgical techniques and in the use of antibiotic prophylaxis, it remains a major cause of implant failure and need for revision. PJI is associated with both human host-related and bacterial agent-related factors that can interact in all the phases of the procedure (preoperative, intraoperative and postoperative). Prevention is the first strategy to implement in order to minimize this catastrophic complication.
The present review focuses on the preoperative period, and on what to do once risk factors are fully understood and have been identified.

Keywords: periprosthetic infection, risk factors, preoperative prevention.

Introduction

Total hip replacement (THR) and total knee replacement (TKR) are cost-effective procedures, found to be associated with a significant improvement in the quality of life of patients in whom conservative approaches to degenerative disease such as osteoarthritis (OA) had failed (1-3); the incidence of failure after joint replacement can be significantly reduced by improvements in surgical techniques and implant designs (4, 5).
However, periprosthetic joint infection (PJI) remains a major cause of implant failure and need for revision (6-8). The incidence of deep infection has certainly declined since the early years of joint replacement surgery, with infection rates after THR and TKR currently standing at around 0.3-0.6 and 1% respectively (9). Despite this decline, PJI is still one of the most challenging complications after joint arthroplasty, and it constitutes an economic burden, both on patients and on society (10).
PJI is associated with both host- and agent-related factors. Although improvements in medical care have led to longer life expectancy, the liberal prescription of antibiotics by physicians is increasing the emergence of antibiotic-resistant strains of bacteria, such as methicillin-resistant Staphylococcus aureus (MRSA) (11-13).
Numerous strategies are currently used to decrease the incidence of infection; some of these are supported by literature, whereas the validity of others still needs to be proven. Improving host response and decreasing the chances of bacterial contamination in all the phases of the joint replacement procedure (preoperative, intraoperative and postoperative) can certainly reduce the incidence of PJI.
Prevention is the first and best strategy to implement in order to minimize this catastrophic complication. A good understanding of the risk factors can make it easier to identify patients at high risk; similarly, proper screening for pre-existing medical comorbidities, and optimization of these conditions, is also crucial (14).
The present report reviews the available literature on the aspects to consider in the preoperative stage of planned joint replacement surgery.

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Patient-related risk factors

The early identification of periprosthetic infection is not straightforward, given that all diagnostic test

results have limitations; sensitivity, specificity and predictive values and positive and negative results are not completely reliable and PJI is thus diagnosed on the basis of a combination of tests. PJI should be considered an unknown enemy, and this explains why it is still hard to defeat (15).

Deep postoperative infection is traditionally classified as early (< 3 months postoperatively), delayed (3-24 months), or late (> 2 years postoperatively) infection. Almost one third of deep infections occur within three months and two-thirds within two years of the index operation. Hematogenous infection may occur at any time after the operation, but its proportion increases with increasing time since surgery. While the infectious pathogen is thought to contaminate the joint during surgery, most early and delayed infections are potentially preventable by minimizing the possibility of perioperative and early postoperative contamination of the prosthesis (9).

Prevention during the preoperative period is divided into the early measures that are usually started immediately after the initial consultation with the surgeon – mainly consisting of optimization of the patient's general health – and the measures performed preoperatively and on the day of the index operation, including preparation and decontamination of the surgical site (16).

In general, any comorbid condition that impairs the host's defense mechanism will prolong wound healing and/or predispose to wound-related complications, and should thus be considered a potential risk factor for deep infection (9).

Preoperative optimization of the patient's general health status is crucial to ensure a satisfactory outcome following a total joint arthroplasty (TJA) (16). Lai et al. (17) evaluated the single and cumulative effects of various comorbidities on the risk of developing PJI and showed that diabetes and the total number of medical comorbidities were factors associated with a higher risk of infection; each medical condition was associated with a 35% increased risk of PJI. Therefore, before undergoing surgery, all patients should be assessed and managed by a medical consultant in order to optimize their general health status (16).

In our Department, all patients undergo a preoperative evaluation that includes blood tests and cardiac and respiratory testing; urine analyses are required only in those patients who have a previous history of urinary tract infection. After an interview with an anesthesiologist and examination of the test results, patients may be referred for further evaluation (by a cardiologist, endocrinologist, pneumologist, etc.) in order to address any general health problems. We prefer to delay surgery until general health is optimized.

It is recommended that particular attention be paid to the following conditions:

Rheumatoid arthritis

Patients suffering from rheumatoid arthritis (RA), compared with the non-RA population, are at twice the risk of developing infection, regardless of the surgical site. These patients are under long-term treatment with a combination of medications including nonsteroidal anti-inflammatory drugs, glucocorticoids, disease-modifying antirheumatic drugs, and TNF-α inhibitors. Physicians generally stop these medicines before surgery; however the risk of infection remains quite high. At five-year follow-up after TKR, patients with RA had three times more infection than patients with OA (4.2 *vs* 1.4%) (18-20). It seems that drugs may differ in their effect on the healing process; both corticosteroids and methotrexate are given in small doses and usually have no influence on wound healing. The TNF-α inhibitor group has been shown to be associated with wound dehiscence; some Authors share the view that these drugs should be temporarily suspended in the perioperative period and restarted as soon as it is clear that there is no evidence of infection and the wound has healed satisfactorily (21, 22).

Diabetes

It has been shown that patients with diabetes mellitus have higher risk of infection (23, 24). Recent evidence suggests that hyperglycemia plays a significant role in the development of postoperative infection and it has also been reported to delay collagen synthesis and to impair phagocytosis (25-28). Accordingly, strict control of blood glucose levels in the perioperative setting was associated with decreased morbidity in both non-diabetic and diabetic patients (29, 30). Mraovic et al. (31), in a retrospective study in patients who underwent THR and TKR, showed that a perioperative fasting basal glycemia >200 mg/dl is associated with a more than twofold increased risk of infection compared to a normal perioperative basal glycemia value;

even patients without a diagnosis of diabetes mellitus were three times more likely to develop the infection if their fasting basal glycemia on the first postoperative day was >140 mg/dl (31). Han et al. (32) showed that poor preoperative glycemic control, defined as an HbA1c level of more than 8%, was associated with a substantially increased risk of a postoperative wound complication after TKR.

Obesity, malnutrition, smoking

The prevalence of obesity in industrialized and emerging countries is reaching epidemic proportions (33). Obesity is a well-documented risk factor for the development of OA (34-36). The literature provides no definitive proof of a correlation between obesity and incidence of complications after TJA (37); however, obese patients generally have more comorbidities than non-obese patients; coexisting diabetes and peripheral vascular disease may contribute to wound healing problems and wound infection. Kerkhoffs et al. (37), in a systematic review conducted to examine whether obesity leads to a worse outcome following TKR, showed that patients with a body mass index (BMI) $\geq$ 30 had more infections and a higher revision rate than patients with a BMI < 30. Therefore, in patients with a BMI $\geq$ 30, it is recommended to defer replacement surgery. These patients should then be referred to a specialist to receive a dietary program and to their general physician for monitoring of glycemic values and thyroid hormones. In a patient with arthritic pain in whom this approach has failed to result in weight loss, extensive information about the increased risks faced should be provided before proceeding with TJA surgery.

Malnutrition and smoking delay wound healing and increase the risk of infection, as does alcohol abuse. Malnutrition can be diagnosed in the presence of a serum transferrin level of less than 200 mg/dl, a serum albumin level of less than 3.4 mg/dl, and a total lymphocyte count of less than 1500 cells/mm^3 (38, 39). The levels of the above-mentioned parameters should be routinely ascertained from blood testing before TJA surgery; when malnutrition is diagnosed, arthroplasty should be delayed until the nutritional status improves and the medical conditions are optimized.

Singh et al. (40) found that preoperative smoking status was a significant predictor of postoperative complication rates at 30 days and of mortality at one year in patients undergoing elective TJA. Current smokers had significantly higher rates of surgical site infection (SSI), pneumonia, strokes and one-year mortality compared to never smokers; they also had a 41% increased risk of SSI compared with never smokers; however, no increase was found when they were compared with prior smokers (40). A smoking cessation program should be proposed to smokers wishing to undergo elective arthroplasty; alternatively, these patients should be invited to abstain smoking for at least 30 days before the index operation. To provide motivation, they should be reminded of all the other well-known health benefits of smoking cessation, and advised that the preoperative period might be seen as a golden opportunity for quitting.

Other comorbidities (renal disease and ASA score)

There is no agreement over whether or not patients with renal impairment have an increased risk of infection. McCleery et al. (41) reported higher rates of mortality, revision, infection and other complications when TJA is performed in patients with renal impairment, highlighting a direct relationship between disease severity and outcome of TKR. Miric et al. (42), whose study included patients with end-stage renal disease, demonstrated that complication rates were similar to those of the general population. However, both groups of Authors agree these patients present with a wide variety of medical problems and require close attention both during and well beyond the perioperative period (41, 42).

Preoperative risk can be calculated on the basis of various scores. Measures like the modified Charlson Comorbidity Index (CCI) or the ASA score are valuable for quantifying a patient's overall health. Patients with an ASA score of more than 2 or 3 are at significantly higher risk of developing infection after TJA. Also, patients with a CCI greater than 4 are at a 157 and 117% increased risk of developing infection after THR and TKR, respectively, compared with those with a score of 0 (43-45).

The above conditions are all important risk factors for developing PJI, and a multidisciplinary approach seems to be the only way to reduce these risks.

The Mayo Clinic recently presented a prosthetic joint infection risk score, which demonstrated a good capacity to discriminate subjects who will develop a PJI from those who will not (46).

Optimizing a patient's condition preoperatively

At the time of the operation current symptomatic infection must be excluded; the most common sources of hematogenous infection are the skin, the urinary tract and the respiratory tract (including the mouth and nose). With hip and knee replacement, the skin of the lower extremities should be completely intact; major dental procedures should be performed before joint replacement when possible (9).

Staphylococcus aureus (S. aureus) is recognized as the main pathogen responsible for SSI, and its contribution to this problem continues to increase (47). Nicholson et al. (48) conducted a molecular analysis of DNA of S. aureus causing SSI and showed that the majority of infecting strains were part of the patient's resident normal nasal flora (48). Although preoperative treatment using nasal mupirocin ointment reduces the risk of nosocomial S. aureus infections (in the lower respiratory tract, and in the urinary tract), it has not been proven to reduce the risk of SSI in patients with nasal S. aureus carriage (9, 49).

Urinary tract infection (UTI) is a common nosocomial infection associated with bacteria responsible for PJI (50, 51). The presence of an urinary catheter is the main risk factor for UTI and can precipitate bacteremia (51-54). There is no consensus among Authors over whether UTI is a cause of joint infection and over the question of whether urinary system examinations should be routinely carried out at a patient's first visit, given that asymptomatic bacteriuria does not need to be treated preoperatively, unlike symptomatic UTI, which does need to be treated and resolved before surgery (55-58).

A prior history of intra-articular steroid injection into the joint to be treated may be a risk factor for developing PJI; however, in a meta-analysis by Wang et al. (59), no increased risk of infection was identified among patients who received steroid injections prior to surgery. Nevertheless, in our Department we delay surgery in such patients for at least four weeks following the last steroid injection.

Perioperative management

The sterile technique and measures described by the Centers for Disease Control and Prevention (CDC) Hospital Infection Control Practices Advisory Committee (38) should be used in joint replacement surgery; however orthopaedic surgery and, in particular, replacement surgery has peculiar features that differentiate it from general surgery.

The duration of preoperative hospitalization should be minimized to reduce the risk of colonization of the patient's skin with possibly resistant hospital-acquired bacterial strains. It is preferable for the patient to be admitted on the actual day of the operation. Patients must be invited to have a shower the day before the surgery but no antiseptic agents are recommended. Hair removal, using clippers or depilatory agents, must also be performed immediately prior to surgery outside the operating room.

Zywiel et al. (60) recently proposed a protocol for skin disinfection: six washcloths (82% chlorexidine impregnated cloths) were used the evening before surgery (neck-chest-abdomen, arms, right leg, left leg, back, surgical site); the same procedure was then repeated the morning of surgery. The protocol was used in 136 of 912 total knee arthroplasties (15%). No SSIs occurred in the 136 patients who completed the protocol, whereas 21 infections occurred in the 711 procedures (3.0%) performed in patients who did not (60).

In our practice, we use chlorexidine for disinfection of the surgical site in the operating room and alcoholic povidone iodine solution is used just before draping the limb.

Strong evidence is available in favor of the use of plastic surgical adhesive tape and disposable paper drapes for surgical site draping (61-64). Iodine-impregnated drapes have been shown to slow down recolonization when compared with paper drapes and traditional plastic adhesive tape (62) and this is the procedure we currently use for covering the surgical site.

Even though we do not believe that arthroplasty must be performed only by dedicated and experienced surgeons, surgeon inexperience has been associated with increased operating time and increased infection rates (65). Furthermore, in TKR, Peersman et al. (66) found the duration of the procedure to be one of the key factors in the possible development of postoperative infection.

No consensus exists regarding the usefulness of mobile laminar air flow (LAF) units during joint replacement. Cost analysis shows that this technology

has become substantially less expensive over the years; Evans et al. (67), in a recent systematic review, showed LAF use to be associated with a lower incidence of PJI, notwithstanding the lack of high-level of evidence from randomized trials. They identified operating room traffic as the main concern during TJA: opening the operating room door disrupts the LAF, allowing pathogens to enter the space surrounding the surgical site. In order to mitigate this problem, careful planning and anticipation of instrument and implant needs is essential; proper education of operating room staff regarding the function of the LAF system and the relationship between traffic and infection may also increase awareness (67-69).

Although recent research (68) did not show a higher incidence of PJI when an arthroplasty was performed in an operating room just used for surgery on a patient with infection, the study may have been biased by the small sample size; therefore, until further studies are conducted, we prefer to avoid performing a clean case, such as a TJR, in a room in which an infected procedure has just taken place, and indeed recommend that this practice be avoided. We also believe that reserving an operating room exclusively for TJR procedures could be beneficial (69).

A recent review showed that antibiotic prophylaxis reduces the absolute risk of wound infection by 8% and the relative risk by 81% as compared with no antibiotic prophylaxis (70). Parenteral cefazolin and cefuroxime are the antibiotics of choice due to their excellent *in vivo* activity against Staphylococcus and Streptococcus, their long half-life and their good tissue penetration. The dose of cefazolin is based on patient's body mass: 1 g for individuals weighing < 80 kg and 2 g for those weighing >80 kg. Clindamycin and/or vancomycin may be considered for patients with a confirmed beta-lactam allergy. The American Academy of Orthopaedic Surgeons recommends prophylactic antibiotic infusion within one hour prior to skin incision; the duration of antibiotic administration should not exceed 24 hours (71).

Parenteral cefazolin for 24 hours is our standardized protocol: in fact the first dose is given at least 30 minutes before skin incision and, in knee replacements, antibiotic infusion is finished at least 10 minutes before application of a tourniquet (if used). Patients receive subsequent doses of cefazolin every 6 hours for the first 24 hours. In the event of a prolonged surgical procedure, an additional intraoperative dose is provided.

Even with careful observance of all these rules, PJI remains a major challenge for orthopaedic surgeons. Undoubtedly, some elements are still not well known and understood. Rodriguez-Merchan (72) conducted a systematic review and identified depression and psychoses as independent risk factors for postoperative infection. Depression may be associated with poor nutritional status, an important risk factor for the development of PJI; in addition, patient collaboration after a joint replacement is of essential importance to avoid complications.

Therefore, we recommend integrating evaluation of coexisting depression into the initial medical screening and delaying surgery in patients found to be affected; we strongly believe in the importance of dedicated preoperative programs targeting patients and including explanation of the surgical technique, of the recovery times, and of the risks and benefits of the index procedure. Finally, social interaction between people who have already had joint replacement surgery and patients who are awaiting it could also be useful.

Conclusions

Understanding of the risk factors presented by individual patients and careful application of the rules for the preoperative prevention of SSI are both essential aspects in order to reduce the overall incidence of PJI. All potentially modifiable risk factors should be optimized before surgery. The surgeon should clearly explain the procedure to the patient and, also his/her individual risk of infection. A multidisciplinary approach is essential to optimize the patient's general health. Although significant advances have been made in recent decades, there remain many questions regarding standardized practice to prevent PJI.

Additional randomized controlled trials are needed to better define the role of both modifiable and non-modifiable risk factors. Additionally, surgeons should consider the patient's compliance and mental status, given that the patient's behavior and compliance might be considered active elements in achieving a satisfactory outcome of TJR.

References

1. Laupacis A, Bourne R, Rorabeck C, et al. The effect of elective total hip replacement on health-related quality of life. J Bone Joint Surg Am. 1993;75 :1619-1626.
2. Robertsson O, Dunbar M, Pehrsson T, et al. Patient satisfaction after knee arthroplasty: a report on 27,372 knees operated on between 1981 and 1995 in Sweden. Acta Orthop Scand. 2000;71:262-267.
3. Lavernia CJ, Guzman JF, Gachupin-Garcia A. Cost effectiveness and quality of life in knee arthroplasty. Clin Orthop Relat Res. 1997;345:134-139.
4. Herberts P, Malchau H, Garellick G. Annual Report 2003-Swedish National Hip Arthroplasty Register Goteb: Department of Orthopedics Sahlgrenska University Hospital. 2004.
5. Lidgren L, Knutson K, Robbertsson O. Annual Report 2004-The Swedish Knee Arthroplasty Register. 2004.
6. Clohisy JC, Calvert G, Tull F, et al. Reasons for revision hip surgery: a retrospective review. Clin Orthop Relat Res. 2004;429:188-192.
7. Sharkey PF, Hozack WJ, Rothman RH, et al. Insall Award paper. Why are total knee arthroplasties failing today? Clin Orthop Relat Res. 2002;404:7-13.
8. Vessely MB, Whaley AL, Harmsen WS, et al. The Chitranjan Ranawat Award: Long-term survivorship and failure modes of 1000 cemented condylar total knee arthroplasties. Clin Orthop Relat Res. 2006;452:28-34.
9. Jämsen E, Furnes O, Engesæter LB, et al. Prevention of deep infection in joint replacement surgery. Acta Orthop. 2010;81:660-666.
10. Maderazo EG, Judson S, Pasternak H. Late infections of total joint prostheses. A review and recommendations for prevention. Clin Orthop Relat Res. 1988;229:131-142.
11. Parvizi J, Azzam K, Ghanem E, et al. Periprosthetic infection due to resistant staphylococci: serious problems on the horizon. Clin Orthop Relat Res. 2009;467:1732-1739.
12. Soulsby EJ. Resistance to antimicrobials in humans and animals. BMJ. 2005;331:1219-1220.
13. Arias CA, Murray BE. Antibiotic-resistant bugs in the 21st century-a clinical super-challenge. N Engl J Med. 2009; 360:439-443.
14. Baek SH. Identification and preoperative optimization of risk factors to prevent periprosthetic joint infection. World J Orthop. 2014;5:362-367.
15. Bauer TW, Parvizi J, Kobayashi N, et al. Diagnosis of periprosthetic infection. J Bone Joint Surg Am. 2006;88:869-882.
16. Matar WY, Jafari SM, Restrepo C, et al. Preventing infection in total joint arthroplasty. J Bone Joint Surg Am. 2010;92 Suppl 2:36-46.
17. Lai K, Bohm ER, Burnell C, et al. Presence of medical comorbidities in patients with infected primary hip or knee arthroplasties. J Arthroplasty. 2007;22:651-656.
18. Doran MF, Crowson CS, Pond GR, et al. Frequency of infection in patients with rheumatoid arthritis compared with controls: a population-based study. Arthritis Rheum. 2002; 46:2287-2293.
19. Bongartz T, Halligan CS, Osmon DR, et al. Incidence and risk factors of prosthetic joint infection after total hip or knee replacement in patients with rheumatoid arthritis. Arthritis Rheum. 2008;59:1713-1720.
20. Bernatsky S, Hudson M, Suissa S. Anti-rheumatic drug use and risk of serious infections in rheumatoid arthritis. Rheumatology (Oxford). 2007;46:1157-1160.
21. Grennan DM, Gray J, Loudon J, et al. Methotrexate and early postoperative complications in patients with rheumatoid arthritis undergoing elective orthopaedic surgery. Ann Rheum Dis. 2001;60:214-217.
22. Ledingham J, Deighton C; British Society for Rheumatology Standards, Guidelines and Audit Working Group. Update on the British Society for Rheumatology guidelines for prescribing TNFalpha blockers in adults with rheumatoid arthritis (update of previous guidelines of April 2001). Rheumatology (Oxford). 2005;44:157-163.
23. Meding JB, Reddleman K, Keating ME, et al. Total knee replacement in patients with diabetes mellitus. Clin Orthop Relat Res. 2003;416:208-216.
24. Muller LM, Gorter KJ, Hak E, et al. Increased risk of common infections in patients with type 1 and type 2 diabetes mellitus. Clin Infect Dis. 2005;41:281-288.
25. Golden SH, Peart-Vigilance C, Kao WH, et al. Perioperative glycemic control and the risk of infectious complications in a cohort of adults with diabetes. Diabetes Care. 1999;22:1408-1414.
26. Latham R, Lancaster AD, Covington JF, et al. The association of diabetes and glucose control with surgical-site infections among cardiothoracic surgery patients. Infect Control Hosp Epidemiol. 2001;22:607-612.
27. Brenner RE, Riemenschneider B, Blum W, et al. Defective stimulation of proliferation and collagen biosynthesis of human bone cells by serum from diabetic patients. Acta Endocrinol (Copenh). 1992;127:509-514.
28. Robertson HD, Polk HC Jr. The mechanism of infection in patients with diabetes mellitus: a review of leukocyte malfunction. Surgery. 1974;75:123-128.
29. van den Berghe G, Wouters P, Weekers F, et al. Intensive insulin therapy in critically ill patients. N Engl J Med. 2001; 345:1359-1367.
30. McMurry JF Jr. Wound healing with diabetes mellitus. Better glucose control for better wound healing in diabetes. Surg Clin North Am. 1984;64:769-778.
31. Mraovic B, Suh D, Jacovides C, et al. Perioperative hyperglycemia and postoperative infection after lower limb arthroplasty. J Diabetes Sci Technol. 2011;5:412-418.
32. Han HS, Kang SB. Relations between long-term glycemic control and postoperative wound and infectious complications after total knee arthroplasty in type 2 diabetics. Clin Orthop Surg. 2013;5:118-123.
33. Campos P, Saguy A, Ernsberger P, et al. The epidemiology of overweight and obesity: public health crisis or moral panic? Int J Epidemiol. 2006;35:55-60.
34. Stürmer T, Günther KP, Brenner H. Obesity, overweight and patterns of osteoarthritis: the Ulm Osteoarthritis Study. J Clin Epidemiol. 2000;53:307-313.
35. Flugsrud GB, Nordsletten L, Espehaug B, et al. Risk factors for total hip replacement due to primary osteoarthritis: a cohort study in 50,034 persons. Arthritis Rheum. 2002; 46:675-682.
36. Flugsrud GB, Nordsletten L, Espehaug B, et al. The impact of body mass index on later total hip arthroplasty for primary osteoarthritis: a cohort study in 1.2 million persons. Arthritis Rheum. 2006;54:802-807.
37. Kerkhoffs GM, Servien E, Dunn W, et al. The influence of obesity on the complication rate and outcome of total knee arthroplasty: a meta-analysis and systematic literature review. J Bone Joint Surg Am. 2012;94:1839-1844.
38. Mangram AJ, Horan TC, Pearson ML, et al. Guideline for Prevention of Surgical Site Infection, 1999. Centers for Disease Control and Prevention (CDC) Hospital Infection Control Practices Advisory Committee. Am J Infect Control. 1999;27:97-132.

39. Jensen JE, Jensen TG, Smith TK, et al. Nutrition in orthopaedic surgery. J Bone Joint Surg Am. 1982;64:1263-1272.
40. Singh JA, Houston TK, Ponce BA, et al. Smoking as a risk factor for short-term outcomes following primary total hip and total knee replacement in veterans. Arthritis Care Res (Hoboken). 2011;63:1365-1374.
41. McCleery MA, Leach WJ, Norwood T. Rates of infection and revision in patients with renal disease undergoing total knee replacement in Scotland. J Bone Joint Surg Br. 2012;92:1535-1539.
42. Miric A, Inacio MC, Namba RS. Can total knee arthroplasty be safely performed in patients with chronic renal disease? Acta Orthop. 2014;85:71-78.
43. Greene KA, Wilde AH, Stulberg BN. Preoperative nutritional status of total joint patients. Relationship to postoperative wound complications. J Arthroplasty. 1991;6:321-325.
44. Pulido L, Ghanem E, Joshi A, et al. Periprosthetic joint infection: the incidence, timing, and predisposing factors. Clin Orthop Relat Res. 2008;466:1710-1715.
45. Kurtz SM, Ong KL, Lau E, et al. Prosthetic joint infection risk after TKA in the Medicare population. Clin Orthop Relat Res. 2010;468:52-56.
46. Berbari EF, Osmon DR, Lahr B, et al. The Mayo prosthetic joint infection risk score: implication for surgical site infection reporting and risk stratification. Infect Control Hosp Epidemiol. 2012;33:774-781.
47. Beaujean DJ, Weersink AJ, Blok HE, et al. Determining risk factors for methicillin-resistant Staphylococcus aureus carriage after discharge from hospital. J Hosp Infect. 1999;42:213-218.
48. Nicholson MR, Huesman LA. Controlling the usage of intranasal mupirocin does impact the rate of Staphylococcus aureus deep sternal wound infections in cardiac surgery patients. Am J Infect Control. 2006;34:44-48.
49. Sankar B, Hopgood P, Bell KM. The role of MRSA screening in joint-replacement surgery. Int Orthop. 2005;29:160-163.
50. Burke JP. Infection control: a problem for patient safety. N Engl J Med. 2003;348:651-656.
51. Stéphan F, Sax H, Wachsmuth M, et al. Reduction of urinary tract infection and antibiotic use after surgery: a controlled, prospective, before-after intervention study. Clin Infect Dis. 2006;42:1544-1551.
52. Stamm WE. Catheter-associated urinary tract infections: epidemiology, pathogenesis, and prevention. Am J Med. 1991; 91:65S-71S.
53. Warren JW. The catheter and urinary tract infection. Med Clin North Am. 1991;75:481-493.
54. Olson ES, Cookson BD. Do antimicrobials have a role in preventing septicaemia following instrumentation of the urinary tract? J Hosp Infect. 2000;45:85-97.
55. David TS, Vrahas MS. Perioperative lower urinary tract infections and deep sepsis in patients undergoing total joint arthroplasty. J Am Acad Orthop Surg. 2000;8:66-74.
56. Ritter MA, Fechtman RW. Urinary tract sequelae: possible influence on joint infections following total joint replacement. Orthopedics. 1987;10:467-469.
57. American Urological Association; American Academy of Orthopaedic Surgeons. Antibiotic prophylaxis for urological patients with total joint replacements. J Urol. 2003;169:1796-1797.
58. Glynn MK, Sheehan JM. The significance of asymptomatic bacteriuria in patients undergoing hip/knee arthroplasty. Clin Orthop Relat Res. 1984;185:151-154.
59. Wang Q, Jiang X, Tian W. Does previous intra-articular steroid injection increase the risk of joint infection following total hip arthroplasty or total knee arthroplasty? A meta-analysis. Med Sci Monit. 2014;20:1878-1883.
60. Zywiel MG, Daley JA, Delanois RE, et al. Advance pre-operative chlorhexidine reduces the incidence of surgical site infections in knee arthroplasty. Int Orthop. 2011;35:1001-1006.
61. French ML, Eitzen HE, Ritter MA. The plastic surgical adhesive drape: an evaluation of its efficacy as a microbial barrier. Ann Surg. 1976;184:46-50.
62. Johnston DH, Fairclough JA, Brown EM, et al. Rate of bacterial recolonization of the skin after preparation: four methods compared. Br J Surg. 1987;74:64.
63. Blom A, Estela C, Bowker K, et al. The passage of bacteria through surgical drapes. Ann R Coll Surg Engl. 2000;82:405-407.
64. Blom AW, Gozzard C, Heal J, et al. Bacterial strike-through of reusable surgical drapes: the effect of different wetting agents. J Hosp Infect. 2002;52:52-55.
65. Jämsen E, Huhtala H, Puolakka T, et al. Risk factors for infection after knee arthroplasty. A register-based analysis of 43,149 cases. J Bone Joint Surg Am. 2009;91:38-47.
66. Peersman G, Laskin R, Davis J, et al. Prolonged operative time correlates with increased infection rate after total knee arthroplasty. HSS J. 2006;2:70-72.
67. Evans RP. Current concepts for clean air and total joint arthroplasty: laminar airflow and ultraviolet radiation: a systematic review. Clin Orthop Relat Res. 2011;469: 945-953.
68. Abolghasemian M, Sternheim A, Shakib A, et al. Is arthroplasty immediately after an infected case a risk factor for infection? Clin Orthop Relat Res. 2013;471:2253-2258.
69. Panahi P, Stroh M, Casper DS, et al. Operating room traffic is a major concern during total joint arthroplasty. Clin Orthop Relat Res. 2012;470:2690-2694.
70. AlBuhairan B, Hind D, Hutchinson AJ. Antibiotic prophylaxis for wound infections in total joint arthroplasty: a systematic review. Bone Joint Surg Br. 2008;90:915-919.
71. Recommendations for the Use of Intravenous Antibiotic Prophylaxis in Primary Total Joint Arthroplasty - AAOS information statement. http://www.aaos.org/about/papers/advistmt/1027.asp.
72. Rodriguez-Merchan EC. Review article: Risk factors of infection following total knee arthroplasty. J Orthop Surg (Hong Kong). 2012;20:236-238.