The purpose of this article is to provide the reader with a seven-step checklist that could help in minimising the risk of PJI. The check list includes strategies that can be implemented pre-operatively such as medical optimisation, and reduction of the bioburden by effective skin preparation or actions taking during surgery such as administration of timely and appropriate antibiotics or blood conservation, and finally implementation of post-operative protocols such as efforts to minimise wound drainage and haematoma formation.

Cite this article: Bone Joint J 2016;98-B(1 Suppl A):18–22.

Prosthetic joint infection (PJI) is one of the most devastating complications of total joint arthroplasty and continues to be a challenge to the orthopaedic community. One of the most important aspects of infection in orthopaedic surgery is prevention. While some of the risk factors for developing PJI are not modifiable, increasing efforts are being made to address those that are. There is increased interest in the prevention of infection, in particular surgical site infection (SSI), amongst international organisations, including the World Health Organisation (WHO) and the Center for Disease Control and Prevention (CDC). The CDC has recently completed the task of developing evidence-based guidelines for the prevention of SSI, and these are to be published shortly.1

There are numerous strategies for the prevention of infection, and the literature on this subject is enormous. However, the most efficient and effective strategies for prevention of PJI remain unknown. Recently the International Consensus meeting on PJI evaluated all literature pertinent to the subject and published a document that includes a section dedicated to the prevention of PJI.2 The purpose of this article is to provide the reader with a simple checklist of seven steps for the prevention of PJI, breaking it down into the pre-, intra-, and post-operative periods.

Pre-operative period

Step 1: Medical optimisation of the patient. Before elective arthroplasty, all patients should be worked up appropriately to identify issues and conditions that could predispose to an unacceptable risk of PJI. This includes the identification of any systemic or local infections such as those at the surgical site or in the distant organs, such as the genitourinary or the gastrointestinal tracts, nail and skin, or the oral cavity.

The presence of malnutrition, extreme obesity (> 40 Kg/m2), and vascular insufficiency should also be addressed before elective arthroplasty.3-5 Patients who are heavy smokers (> 25 cigarettes per day) should be encouraged and assisted to cease smoking for four to six weeks before arthroplasty.6-8 Intravenous drug abuse9 and excessive alcohol consumption (more than 400 g per week) are also strong risk factors for PJI and should be addressed.10,11

Hyperglycemia is associated with an increased risk of all complications, particularly infection, because of the impairment of several defence mechanisms of the host, including humoral and cell mediated immunity, decreased bactericidal activity of neutrophils, and impairment of collagen activity leading to delayed wound healing.12 The CDC and the International Consensus have both suggested a random blood glucose level greater than 200 mg/dL as indicator of poor glucose control.1 The guidelines from the American Diabetes Association and the Endocrine Society are more strict, recommending mean pre- and post-prandial glucose levels of between 90 and 130mg/dL and less than 180 mg/dL, respectively, and a glycosylated hemoglobin (Hb A1C) level below 7% as glycemic targets prior to elective surgery.13 For diabetic patients, an active ulcer in the extremity is a contraindication for elective surgery.14

Immunosuppression, especially biological, predisposes patients to infection. Although the CDC has produced no recommendation, the
should be based on the patient's weight. The antibiotic regimen should be continued no less than one hour before surgery and the dose or teicoplanin. Prophylactic antibiotics should be administered in patients who are known carriers of Methicillin-resistant *Staphylococcus aureus* (MRSA), institutionalised patients, and possibly healthcare workers. Patients who are allergic to cephalosporins should also be given vancomycin or teicoplanin. Prophylactic antibiotics should be considered for patients who are known carriers of Methicillin-resistant *Staphylococcus aureus* (MRSA), institutionalised patients, and possibly healthcare workers. Patients who are allergic to cephalosporins should also be given vancomycin or teicoplanin. Prophylactic antibiotics should be administered no less than one hour before surgery and the dose should be based on the patient's weight. The antibiotic administration should be repeated when the operative time extends beyond the half-life of the drug and in patients with intra-operative blood loss of greater than 3000 ml. Administration of prophylactic antibiotics for more than 24 hours should be avoided as it has no beneficial effect and may facilitate the emergence of resistant bacteria.

**Step 3: Skin preparation.** Pre-admission skin preparation is suggested in addition to the preparation performed prior to surgery. Patients should be encouraged to shower or bathe (full body) with either soap (antimicrobial or non-antimicrobial) or an antiseptic agent on at least the night before the operative day. There is no difference between any of the agents regarding efficacy, but alcohol must be part of the pre-operative skin preparation regimen as it acts rapidly and effectively to eradicate bacteria. Multiple randomised controlled trials (RCTs) have studied superiority of iodine based and chlorhexidine based solutions, with and without alcohol. A multiple treatment meta-analysis of ten RCTs concluded that alcohol-containing agents reduce the risk of SSI by 98% when compared with aqueous based preparations. In addition to pre-surgical skin preparation, the pre-operative whole body cleansing with chlorhexidine gluconate can reduce MRSA bioburden and subsequent risk of SSI.

Hair removal, when indicated, should be achieved by clipping rather than shaving, and should be performed as close to the time of the procedure as possible, but outside the operating theatre.

Patients who are carriers of *Staphylococcus aureus* are at higher risk for developing SSI. In the United States, in contrast to the United Kingdom, current guidelines do not recommend routine screening for *Staphylococcus aureus* and decolonisation owing to high rates of recolonisation with *Staphylococcus aureus* following decolonisation.

**Intra-operative period**

**Step 4: Particle-free operating environment.** Although the origin of contaminants causing SSI/PJI is not clear, the theoretical logic for provision of a particle free environment is well supported by numerous studies. Multiple strategies can be implemented to reduce the risk of exogenous infection. Reducing the number of particles that are shed in the operating theatre is an important goal as this number has been correlated with the incidence of SSI. Laminar air flow and body exhaust suits were designed to reduce the number of shed particles, but there is no conclusive evidence to prove or disprove that they are effective in reducing the rates of SSI. Increasing the number of people in the operating theatre leads to increased air contamination and, therefore, the number of theatre personnel should be kept to a minimum.

**Step 5: Respect for soft tissues.** The importance of a meticulous surgical technique and gentle handling of the soft tissues cannot be over-emphasised. Meticulous wound closure, by whatever method, is essential to reduce the risk of post-operative wound drainage, which has been associated with SSI.

Multiple studies have demonstrated an association between increased surgical time and development of subsequent SSI. While the cause–effect relationship is not clear and other factors including the surgeon’s experience, the complexity of the surgery, and other intra-operative

| International Consensus states that disease modifying agents (DMARs) should be stopped before elective arthroplasty at an interval of three to five times the half-life of the drug (Table I). The benefit of discontinuation of the drug should be weighted against the risk of rheumatoid flare for each patient. **Step 2: Administration of antibiotics.** Administration of prophylactic antibiotics is probably one of the most important steps in the prevention of infection. The most effective agents appear to be the first- and second-generation cephalosporins that are effective against most common bacteria, are cheap, and have good bioavailability. Adding an alternative antibiotic such as vancomycin or teicoplanin should be considered for patients who are known carriers of Methicillin-resistant *Staphylococcus aureus* (MRSA), institutionalised patients, and possibly healthcare workers. Patients who are allergic to cephalosporins should also be given vancomycin or teicoplanin. Prophylactic antibiotics should be administered no less than one hour before surgery and the dose should be based on the patient's weight. The antibiotic administration should be repeated when the operative time extends beyond the half-life of the drug and in patients with intra-operative blood loss of greater than 3000 ml. Administration of prophylactic antibiotics for more than 24 hours should be avoided as it has no beneficial effect and may facilitate the emergence of resistant bacteria. **Step 3: Skin preparation.** Pre-admission skin preparation is suggested in addition to the preparation performed prior to surgery. Patients should be encouraged to shower or bathe (full body) with either soap (antimicrobial or non-antimicrobial) or an antiseptic agent on at least the night before the operative day. There is no difference between any of the agents regarding efficacy, but alcohol must be part of the pre-operative skin preparation regimen as it acts rapidly and effectively to eradicate bacteria. Multiple randomised controlled trials (RCTs) have studied superiority of iodine based and chlorhexidine based solutions, with and without alcohol. A multiple treatment meta-analysis of ten RCTs concluded that alcohol-containing agents reduce the risk of SSI by 98% when compared with aqueous based preparations. In addition to pre-surgical skin preparation, the pre-operative whole body cleansing with chlorhexidine gluconate can reduce MRSA bioburden and subsequent risk of SSI. Hair removal, when indicated, should be achieved by clipping rather than shaving, and should be performed as close to the time of the procedure as possible, but outside the operating theatre.

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<th><strong>Table 1.</strong> Timing of cessation of immune modifying medications prior to elective arthroplasty</th>
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<td><strong>Non steroidal anti-inflammatory drugs</strong></td>
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<td><strong>Rituximab</strong></td>
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factors may contribute to the prolongation of the procedure, a co-ordinated effort should be made to minimise the duration of the surgery without compromising the integrity of the procedure.

Irrigation is an effective strategy to reduce the number of pathogens in the surgical wound. The optimal content of the irrigation solution is not clear, nor is its volume and the delivery system (low pressure or high pressure pulsatile lavage). High pressure pulsatile lavage effectively removes necrotic debris but concerns have been raised regarding mechanical damage to the soft-tissue and potential delivery of bacteria to deeper layers. Adding antibiotic to the irrigation solution is not recommended, based on non-arthroplasty literature. The use of dilute sodium chloride solution has been shown to reduce the bioburden and the use of this solution should be considered. Washing the wound with 500 ml of a solution of 17.5 mL of 10% povidone-iodine mixed with 500 mL of sodium chloride solution has been shown to reduce the rate of acute PJI significantly.

**Step 6: Minimising blood loss.** Allogeneic blood transfusion has a modulating effect on the immune system and has been associated with an increased risk of PJI. This risk also correlates with the number of transfused units. With this in mind, allogeneic transfusion should be avoided when possible, and the decision on transfusion should be based on clinical symptoms rather than haemoglobin levels. Effective strategies to reduce the rate of blood transfusion include treatment of pre-existing anaemia and the use of regional hypotensive anaesthesia rather than general anaesthesia. Recently, local or systemic administration of tranexamic acid has gained popularity as it has been shown to reduce operative blood loss and the need for subsequent blood transfusion after both knee and hip arthroplasty, without increasing the risk of venous thromboembolic events.

**Post-operative period**

**Step 7: Wound management.** There is a strong association between wound-related problems and subsequent infection. The purpose of wound management strategies is to isolate the wound environment from possible external contaminants while accelerating the healing process. Owing to the lack of conclusive evidence, the best skin closure technique after elective arthroplasty remains unknown. However, the International Consensus recommended the use of monofilament non-absorbable suture for patients who undergo re-operation for acute wound-related problems.

The optimal dressing for the wounds remains unknown. The wound dressing should be selected based on characteristics such as the rate of blister formation, the ease and the rate of dressing change, and more importantly, the rate of SSI.

Two recent prospective RCTs demonstrated a significant reduction in wound complications and a significant reduction in the number of dressing changes with the use of occlusive antimicrobial dressings compared with the standard dressings. In an *in vitro* study, dressings containing silver compounds had an antibactericidal effect against numerous skin pathogens, including resistant forms of *Staphylococcus aureus* and *Enterococcus*. However, *in vivo* studies were not as conclusive; a Cochrane review has failed to demonstrate a difference in time of wound healing or infection rates between silver-containing dressings and those that did not contain silver.

Persistent wound drainage is associated with an increased risk for development of SSI, so it must be treated aggressively. Persistent drainage for more than three days after the surgery may be initially treated with compression dressing or negative pressure wound therapy, as it has been shown to reduce the formation of seromas and wound drainage. When applied early, the majority of patients will not need further surgery. If drainage persists, early irrigation and debridement of the wound is necessary to reduce the risk of late PJI.

Haematoma formation is a serious complication following elective arthroplasty and is associated with increased risk for PJI. Therefore, every effort should be made to minimise haematoma formation. Important steps in its prevention includes meticulous haemostasis during surgery and, where possible, avoidance of the use of highly potent anticoagulants. Aspirin has been shown to be safe and cost effective form of thromboprophylaxis after hip and knee arthroplasty for patients at standard risk for venous thromboembolic events, and has been endorsed both by the American Academy of Orthopaedic Surgeons and the American College of Chest Physicians as an acceptable prophylactic regimen against thromboembolic events after hip and knee arthroplasty. Since January 2014, the Surgical Care Improvement Project, which is a regulatory organisation in the United States, also accepts aspirin as an effective prophylactic agent. The United Kingdom’s guidelines do not include aspirin as one of the recommended pharmacological methods.

PJI is a devastating complication of total joint arthroplasty that leads to increased morbidity and mortality. The first goal in its management should be prevention. While some of the risk factors for PJI are not modifiable, modifiable risk factors must be addressed before the surgery. Patients should be optimised before the surgery, and prophylactic antibiotics should be administered within one hour before the incision. Good skin preparation and maintaining a clean theatre environment are needed to reduce the number of inoculating pathogens. Performing a meticulous, expeditious surgery and minimising blood loss is invaluable. Post-operatively, any wound healing problem should be treated early and aggressively, and highly potent anticoagulants should only be used when necessary. If all of these recommendations are adhered to, the risk of PJI should be kept to a minimum.
Iguassu Falls, Brazil, 17th-20th September.

MINIMISING THE RISK OF INFECTION

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References


