The Journal of Arthroplasty 29 Suppl. 1 (2014) 119–128

Workgroup 15:

Prevention of Late PJI

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Note:

This workgroup overlaps with other groups. For more detailed and/or alternative views on specific concepts, please refer to the other workgroups indicated:

Risk factors for infection	Workgroup 1: Mitigation and Education
Diagnostic procedures and thresholds	Workgroup 7: Diagnosis of Periprosthetic Joint Infection

QUESTION 1: What is the definition of a late periprosthetic joint infection (PJI)?

Consensus: Late PJI can be defined as a PJI that develops at a variable length of time after an index arthroplasty procedure. The late PJI occurs after an initially successful index procedure with no clinical or radiographic signs of PJI. Risk factors for late PJI are similar to those described for PJI (Workgroup 1).

Delegate Vote: Agree 56%, Disagree 39%, Abstain 5% (Weak Consensus)

Justification:

The definition of late PJI is variable in literature. Majority of the members of the consensus felt that any infection occurring after one year should be considered as late. Coventry defined stages of PJI, where Stage I is an acute infection that occurred within 3 months of the index procedure, Stage II is a delayed infection that occurred between 3 months and 2 years after the index procedure where there was no pain-free interval, and Stage III is a hematogenous infection where there is a pain-free stage [1]. Garvin and Hanssen defined a late chronic PJI as one that occurred 4 weeks after the index procedure with an insidious clinical onset [2]. McPherson et al defined a chronic infection as one that had symptoms for 4 weeks or longer [3]. In Sweden, a late PJI is defined as one that occurs 2 years after the index procedure. Due to the huge variation in time frames, we did not find consensus in defining a timeframe for a late PJI. However, we classified late PJI as late hematogenous PJI, where there was an asymptomatic period followed by clinical and/or radiographical signs of infection. The workgroup feels that late PJI arises as a result of bacteremia at a later stage [4] and should be distinguished with infections arising as a result of intraoperative contamination.

Risk factors for late PJI are similar to those described for PJI in Workgroup 1 (Please see Question 1, Workgroup 1).

QUESTION 2: Which diagnostic procedures have to be done to verify late PJI?

Consensus: The workup of patients with painful joint and suspected (late) PJI should follow the algorithm provided in Workgroup 7.

Delegate Vote: Agree 89%, Disagree 9%, Abstain 2% (Strong Consensus)

Justification:

Late PJI can present as pain and may not be obvious in all circumstances. For the preoperative diagnosis of late PJI, a systematic approach for workup of these patients must be considered. This workgroup proposes the following workup for patients suspected of having late PJI. The diagnostic workup includes ordering laboratory tests followed by aspiration of the joint with the patient not on antibiotics for two weeks if serology is abnormal or for patients at high index of suspicion for PJI. The serological test should include ESR and CRP. An ESR >30 mm/hour and a CRP >13.5 mg/dL are concerning for PJI affecting total hip arthroplasty (THA) and an ESR >46.5 mm/hour and a CRP >23.5 mg/DL are concerning for PJI affecting total knee arthroplasty (TKA) [5]. A synovial fluid sample should be drawn from the joint prior to the initiation of antibiotics or when the patient is off antibiotics for 2 weeks. A diagnosis of late PJI should be based on synovial fluid leukocyte counts that are greater than 3,000 cells/μl with a neutrophil differential greater than 80%. In the light of systemic manifestation, blood cultures can be considered. Nuclear medicine imaging techniques may be used as an adjunct for diagnosing late PJI [6–18]. Tissue biopsies can be performed preoperatively to obtain a diagnosis.

For intraoperative diagnosis of PJI, microbiology culture is still the gold standard. We recommend that a minimum of 3 tissue samples should be obtained [19]. Histology should be considered as part of the diagnostic criteria [20]. Gram stains should not be used for diagnosing late PJIs [21]. Adjunct diagnostic methods, including sonication of implants, polymerase chain reaction (PCR), reverse transcriptase polymerase chain reaction (RT-PCR), mass spectrometry, microarray identification, and fluorescence in situ hybridization, may assist with determining the organism present if available, especially in culture-negative patients. Removed implants should be transported under low-oxygen conditions to the microbiology laboratory where they can be immediately processed. The interpretation of cultures for late PJIs is the same as for early PJI.

0883-5403/2902-0022$36.00/0 – see front matter
http://dx.doi.org/10.1016/j.arth.2013.09.051

Multiple studies have determined that elevated inflammatory serum laboratory tests such as ESR and CRP are highly sensitive for detecting PJIs [22–25]. CRP is a more specific laboratory test than ESR, although both can be elevated in light of other infectious/inflammatory processes. There is also some evidence that serum IL-6 can be useful in the diagnosis of PJI [5,26]. Synovial fluid can be tested for multiple factors to determine if there is a late PJI. The most common method is to measure the leukocyte cell count and the neutrophil differential. Besides that, synovial fluid can be tested for culture, CRP, leukocyte esterase, and other molecular markers. The threshold for the leukocyte cell count and neutrophil differential from synovial fluid has varied with time. A study conducted by Kersey et al determined thresholds to rule out infection and demonstrated that a leukocyte cell count of less than 2,000 cells/μL and less than 50% polymorphonuclear leukocytes had a 98% negative predictive value [27]. Mason et al conducted one of the first studies to determine a cut-off value suggestive of PJI in TKA patients. They determined that a leukocyte count greater than 2,500 cells/μL and greater than 60% polymorphonuclear leukocytes were suggestive for infection [28]. A study examining revision TKA determined that leukocyte counts greater than 1,700 cells/μl and neutrophil differentials greater than 65% were highly sensitive and specific for PJI [29]. For revision TKA, a synovial fluid white count greater than 3,000 cells/μL with elevated ESR and CRP had 100% sensitivity, 98% specificity, and 99% accuracy [30].

In the setting of revision THA for infection, greater than 3,000 white blood cells/ μL provided the greatest combined sensitivity, specificity, and positive and negative predictive value in patients with elevated ESR and CRP [23,31,32]. CRP is a commonly-tested inflammatory marker in serum that can also be found in synovial fluid.

Recent studies have evaluated the role of synovial molecular markers for the diagnosis of PJI [5,33]. The leukocyte esterase test that is used for detecting bacteria in urine was found to be 80.6% sensitive and 100% specific for detecting infection in prosthetic joints [34]. These values also correlate with elevated polymorphonuclear leukocytes, total white blood cell count, ESR, and CRP. Some other markers that have been found to be elevated in patients with PJI include synovial IL-6, Interleukin-8, α (2)-macroglobulin, CRP, and vascular endothelial growth factor. One study demonstrated that measuring CRP in synovial fluid using a multiple assay was a more sensitive marker than serum CRP (84 vs 76%) [5,33].

The diagnosis of late PJI can be confounded by culture-negative results. Extending the incubation of culture (7–14 days) can help minimize this situation. In one study the detection rate of infecting organisms after 7 days of incubation was 73.6% and this increased greatly when cultures were incubated for 13 days [35]. Additionally, if a synovial fluid aspirate yields a culture-negative result, taking synovial tissue for testing instead of an aspirate yields a sensitivity of 82% and a specificity of 98% [36].

Advanced diagnostic methods can also be employed to identify organisms responsible for infection [37]. The use of sonication to remove bacteria from explanted prostheses has been shown to increase the sensitivity of detecting bacteria (60.8% sensitivity with tissue culture and 78.5% sensitivity with sonicated fluid culture), but both tests have similar specificities [38]. Additionally, there were 14 patients whose bacteria were detected by sonicated fluid culture but not by tissue culture.

Other advanced diagnostic methods can be used to amplify bacteria that are present within the tissue or from sonicated samples. PCR [39–42] amplifies existing bacteria DNA, while RT-PCR [43,44] amplifies RNA. This increases the sensitivity of detection if there is a small amount of bacteria present [45].

QUESTION 3: Does the type, dose, and length of anticoagulation for prophylaxis influence the incidence of surgical site infection (SSI) following total joint arthroplasty (TJA)?

Consensus: Yes. The type, dose, and length of administration of anticoagulation drugs for prophylaxis against venous thromboembolism influence the incidence of SSI following TJA.

Delegate Vote: Agree 76%, Disagree 9%, Abstain 15% (Strong Consensus)

Justification:

Multiple high-level studies have compared different methods of anticoagulation for prophylaxis after TJA. Most studies concluded that there were no differences between different anticoagulation methods and SSI, or parameters associated with surgical infections (eg wound infection, wound dehiscence, and wound hematoma). However, not many of these studies were powered to detect a difference in SSI and they were conducted mostly for the assessment of the efficacy of anticoagulation. The more effective an anticoagulation agent is the more likely it is for the patient to develop a hematoma or have excess wound drainage, both of which are associated with SSI.

The risk for these adverse events could be based on the type, dose, and length of administration of anticoagulation. An extensive search of the literature was performed to identify studies that evaluated hematoma formation, wound drainage, SSI, and/or PJI formation with administration of anticoagulation. There is a wide variability in the incidence of later adverse events in all of these studies. Some studies show no difference in the incidence of hematoma formation when Dextran-70, warfarin (15 mg loading, 5 mg subsequent, for 3 weeks), and low-dose heparin (5000 IU twice a day (BID) for 3 weeks) were utilized [46]. Another study did not find a difference in the incidence of deep wound infections when aspirin, warfarin, or injectable anticoagulation was utilized [47]. The dose of prophylactic injectables and the length of administration were variable in the latter study. Another study comparing enoxaparin versus control/graduated compression stockings/intermittent pneumatic compression did not find a difference in the incidence of superficial infections [48]. In one study earlier administration of low molecular-weight heparin (LMWH) was found to have no correlation with SSI when compared to a control group of uninfected patients [49]. On the other hand, anticoagulation resulting in an INR greater than 1.5 was found to result in a higher likelihood of wound-related problems that had a greater chance of developing into an infection. All patients received deep vein thrombosis prophylaxis with warfarin for 6 weeks [50]. Another study showed that administration of LMWH resulted in a high incidence of hematoma formation and return to the operating room [51].

One consideration with regard to the amount of anticoagulation is the ability to reverse these agents. Drugs such as warfarin can be reversed with vitamins and LMWH can be reversed with protamine. Unfortunately, there are no direct agents to reverse fondaparinux, rivaroxaban, or dabigatran. Administration of Factor VII is the only available modality to deal with the excessive bleeding that may occur as a result of using the latter anticoagulation agents.

QUESTION 4: Should a patient with TJA be given routine dental antibiotic prophylaxis?

Consensus: The use of dental antibiotic prophylaxis in patients with TJA should be individualized based on patient risk factors and the complexity of the dental procedure to be performed.

Delegate Vote: Agree 81%, Disagree 16%, Abstain 3% (Strong Consensus)

Justification:

Based on the available literature, within which there is no consensus, there is increased bacteremia after dental procedures, and providing antibiotic prophylaxis before dental work can reduce the burden of the bacteria load. Additionally, most PJIs occur within the first 2 years after surgery [52–54]. One study found that the use of antibiotic prophylaxis did not reduce the risk of infection, independent of the dental procedure performed in a 2-year period [55]. Dental procedures may not be associated with the development of PJIs [56]. However, many studies demonstrate that there is increased bacteremia after dental procedures, as the incidence of bacteremia from oral procedures ranged from 5 to 65% [57–98]. Thus, we conclude that using antibiotic prophylaxis for dental procedures after TJA to decrease the risk of bacteremia following dental procedures is justifiable to decrease the risk of sustaining a PJI within the first 2 years after surgery.

Consensus: We recommend that high-risk patients receive lifetime dental antibiotic prophylaxis after TJA.

Justification:

The risk factors for PJI after dental procedures are patient-dependent and the risk for infection is higher in patients who receive dental work.

The orthopaedic and dental literature both detail groups of patients that are at higher risk for developing a PJI after dental procedures and who could benefit from the use of antibiotic prophylaxis. The patients that could receive the greatest benefits include those with:

- Inflammatory arthropathies (eg rheumatoid arthritis) [53,99–101].
- Immunosuppression (drug- or radiation-induced immunosuppression—including oncology or transplant patients and HIV patients) [102,103].
- Insulin-dependent diabetes [103].
- A major systemic infection [104].
- Hemophilia [105].
- The following factors are to be determined by a dental care provider:
  - High gingival score and gingival index [72,106,107].
  - High plaque score and plaque index [72,106,108].
  - Gum probing depth [72,106].
  - Periodontitis [72].

Consensus: We recommend that an oral antibiotic be given at the following dosages for only one dose prior to dental procedures.

Justification:

Using oral antibiotics can reduce the burden of bacteria that is released during dental procedures. The following oral antibiotics are recommended as prophylaxis prior to dental procedures:

- Amoxicillin 2 gm, 1 hour prior to procedure [81,109–114].
- Azithromycin 500 mg, 30 minutes to 1 hour prior to procedure [115].
- Cefaclor 1 gm 1 hour prior to procedure [116].
- Cefalexin 2 gm, 30 minutes to 1 hour prior to procedure [115].
- Clindamycin 600 mg, 1–1.5 hours prior to procedure [109,115,117,118].
- Erythromycin 1.5 gm, 1–1.5 hours prior to procedure [119,120].
- Moxifloxicin 400 mg 1–2 hours prior to procedure [109].
- Penicillin 2 gm, 1 hour prior to procedure [62,113,121,122].

Consensus: We recommend that one of the following IV or intramuscular antibiotics be given at the following dosages for only one dose prior to dental procedures.

Justification:

Using IV antibiotics can reduce the burden of bacteria that is released during dental procedures. The following IV antibiotics are recommended as prophylaxis prior to dental procedures:

- IV Ampicillin 2 gm, 30 minutes to 1 hour prior to procedure.
- IV Cefazolin 1 gm, 30 minutes to 1 hour prior to procedure [115].
- IV Cefuroxime 1.5 gm, 10 minutes before procedure [123].
- IV Ceftriaxone 1 gm, 30 minutes to 1 hour prior to procedure [115].
- IV Teicoplanin 400 mg, immediately before procedure [111,124].

QUESTION 5: Should patients at high risk of late PJI be given prophylactic antibiotics during viral illnesses?

Consensus: There is no role for the administration of oral antibiotics to patients with TJA who develop viral illnesses.

Delegate Vote: Agree 98%, Disagree 2%, Abstain 0% (Strong Consensus)

Justification:

Patients with late risk factors for bacterial infections, such as those undergoing an invasive procedure that produce bacteremia, may benefit from prophylactic antibiotic administration. However, preventative antibiotics for conditions such as viral infections only contribute to emerging antibiotic-resistant organisms and should be avoided in clinical practice.

Patients with late risk factors for bacterial infections are those who are susceptible to infection. These risk factors include but are not limited to the following:

- Immunocompromization or immunosuppression (drug-induced, radiation-induced, diabetes, hepatitis, HIV, malignancy) [125–127].
- Social habits (smoking and drinking alcohol) [126,128] and inflammatory arthritis [128,129].
- Obesity [126,129–131].
- Malnourishment [126].
- Previous joint infection (not currently on suppression antibiotics).

Often, antibiotics are unnecessarily prescribed, especially in conditions such as rhinosinusitis [132]. One study demonstrated that antibiotics were only prescribed in a justified manner in 13.5% of upper respiratory infection cases [133].

Finally, taking antibiotics for conditions such as viral infections can result in increased antibiotic resistance [134]. This reduces the effectiveness of treatment for potential PJIs.

QUESTION 6: Can transient bacteremia be minimized during endoscopic procedures such as colonoscopy to prevent late PJI?

Consensus: The influence of transient bacteremia can be minimized during minor surgical procedures by administering prophylactic antibiotics to individualized patients and especially to high-risk patients.

Delegate Vote: Agree 85%, Disagree 13%, Abstain 2% (Strong Consensus)

Justification:

Transient bacteremia can result from gastrointestinal (GI) and genitourinary (GU) procedures, and this bacterial burden can be

decreased by administering prophylactic antibiotics. However, GI societies recommend against giving prophylactic antibiotics for minor surgical procedures such as upper endoscopies, sigmoidoscopies, or colonoscopies, while GU societies are mixed on their stance on antibiotic prophylaxis.

GI procedures such as upper endoscopy, sigmoidoscopy, or colonoscopy can produce transient bacteremia. Studies throughout the literature have demonstrated mixed results, but they predominantly support the idea that GI procedures result in increased bacteremia. Prophylactic administration of antibiotics before these procedures can decrease transient bacteremia, especially in high-risk patients. One of the earliest published studies found that there was transient bacteremia when rigid sigmoidoscopies were performed as measured by blood cultures 5 minutes, 10 minutes, 15 minutes, and 30 minutes after the procedure [135]. Three older studies evaluating bacteremia in colonoscopies found the burden of bacteria in the blood to be very low, except in immunocompromised patients, such as those with severe liver disease or carcinomatosis [136–138]. During the same time frame, other studies demonstrated up to 15% bacteremia after colonoscopies [139,140]. Of note, these studies varied at the time points at which they collected the blood samples and not every study collected blood at the peak of bacteremia (5 minutes after the end of the procedure).

A subsequent study by Kumar et al demonstrated that there was limited bacteremia from colonoscopies in low-risk patients, even when polypectomies or biopsies were performed [141]. This was also found to be true in proctosigmoidoscopies [142]. Based on these studies, GI endoscopic societies such as the American Society for Gastrointestinal Endoscopy and The American Society of Colon and Rectal Surgeons recommend against the use of prophylactic antibiotics prior to colonoscopies and other lower GI endoscopies [143,144]. In a survey of infectious disease program directors, 50% stated that they would not give prophylactic antibiotics before colonoscopies and polypectomies [145]. However, other studies have demonstrated that there is increased bacteremia from colonoscopies (10%) and the highest rate of bacteremia came from endoscopic retrograde cholangiopancreatography (39%) [146]. A review paper by Nelson [147] demonstrated that postprocedure bacteremia differed depending on the procedure, including 0.5% for flexible sigmoidoscopies, 2.2% for colonoscopies, 4.2% for esophagogastroduodenoscopies, 8.9% for variceal ligation, 11% for endoscopic retrograde cholangiopancreatography, 15.4% for variceal sclerotherapy, and 22.8% for esophageal dilation.

Bacteremia can also result from exogenous sources such as the equipment being used in the procedure. One systematic review evaluated GI endoscopy and found that salmonella, mycobacterium, and pseudomonas are common organisms that are transmitted by these procedures [148]. Another systematic review demonstrated that esophagogastroduodenoscopy can also be responsible for transmission of serious organisms, such as HIV, *Salmonella*, *Pseudomonas*, *Helicobacter pylori*, and hepatitis [149].

In the orthopaedic literature, there have been some reports of PJI that presented after GI procedures. One case report described a patient who developed a *Listeria monocytogenes* PJI after a routine colonoscopy without receiving prophylactic antibiotics [150]. One study reported a 1.9% infection rate in prosthetic joints [151] and another reported that one patient with a prosthetic knee and cirrhosis out of 16 patients developed a serious infection after an endoscopic procedure [152]. Coelho-Prabhu et al reported that there is an increased risk of PJI associated with esophago-gastro-duodenoscopies performed with biopsies [153].

Thus antibiotic prophylaxis may be administered to high-risk patients undergoing GI procedures or peritoneal dialysis [154,155]. In addition, high-risk cardiac patients, such as those who have artificial heart valves, acquired valvular dysfunction, vascular grafts, surgical pulmonary shunts, complex congenital cardiac disease, and a history of endocarditis, have a higher likelihood for developing endocarditis and may benefit from antibiotic prophylaxis prior to GI procedures [156]. Immunocompromised patients may also benefit from routine prophylaxis [157].

GU procedures are similar to GI procedures; prostatic biopsies and cystoscopies can produce bacteremia and/or bacteriuria. Studies have demonstrated that bacteriuria correlates with bacteremia [158,159]. Most of the studies on GU procedures encourage the use of prophylactic antibiotics without exacerbating bacterial resistance [160]. However, in contrast to the GI literature, professional GU societies encourage the use of routine antibiotic prophylaxis.

An early study by Sullivan et al demonstrated the following rates of bacteremia for certain procedures: 31% for transurethral resection of the prostate, 17% for cystoscopy, 24% for urethral dilation, and 8% for urethral catheterization [161]. Enterococci and *Klebsiella pneumonia* were the two most common organisms. These anaerobes were also found to be present after transrectal prostatic biopsies [162], as well as *Escherichia coli* [163]. *Candida albicans* has also been found in bloodstream infections in patients who have undergone ureteroscopy and ureteral stenting [164]. When evaluating transrectal prostate biopsies, it is recommended that patients receive antibiotic prophylaxis. Ultrasound-guided transrectal biopsies were found to have a rate of 43% *E. coli* bacteremia post-procedure [165]. A study by Thompson et al demonstrated that when a transrectal prostate biopsy was combined with cystoscopy, the incidence of bacteremia was very high at 73% compared to 13% for cystoscopy alone [166]. The highest rate of bacteremia after transrectal prostate biopsy was reported as 100% by the same group [167], of which 87% had a postoperative urinary tract infection and 27% were symptomatic. There was a significant reduction in bacteremia when cefamandole, a second generation cephalosporin, was administered as antibiotic prophylaxis. A Cochrane review on the use of antibiotic prophylaxis for transrectal prostate biopsies found that the use of antibiotics for at least 3 days could prevent infectious complications after the procedure [168]. One report described a case of *Klebsiella pneumoniae* periprosthetic knee infection secondary to a prostatectomy for prostatic carcinoma [169].

Patients who underwent transurethral surgery of the prostate developed subsequent bacteremia that was shown to lead to a 6%–60% incidence of urinary tract infections in patients who did not receive antibiotic prophylaxis [170,171].

Patients who underwent extracorporeal shock wave lithotripsy had a 5% incidence of bacteremia [172] and a case report described a patient who developed enterococcal endocarditis after this procedure [173]. For women, there is increased bacteremia during labor [174] and with placement of intrauterine devices [175]. Patients who undergo chorionic villus sampling, especially transcervically, have increased rates of bacteremia [176]. Based on these studies, the American Urological Association determined that antibiotic prophylaxis should be administered in specific situations depending on the patient population [177]. For example, patients who undergo cystography should only receive a fluoroquinolone or trimethoprim-sulfamethoxazole if they are at high risk, but all patients who undergo transrectal prostate biopsy should receive fluoroquinolone antibiotic prophylaxis. Alternatively, the American College of Obstetricians and Gynecologists recommends against antibiotic prophylaxis [178].

QUESTION 7: What is the role of herbal supplements, probiotics, and alternative medicine in decreasing translocation of bacteria across the intestinal wall?

Consensus: There is insufficient evidence that supports the use of herbal supplements, probiotics, and alternative medicine to decrease translocation of bacteria across the intestinal wall to prevent late PJIs.

Delegate Vote: Agree 95%, Disagree 3%, Abstain 2% (Strong Consensus)

Justification:

While certain herbal supplements, probiotics, and alternative medications have demonstrated decreasing translocation of bacteria across the intestinal wall, most of the studies are animal studies and none have level I evidence. Thus, we do not recommend using any of the alternative medicine products for preventing bacteremia from entering the gut to prevent late PJIs, but these products may be considered for general health purposes.

Herbal supplements: vitamin C (ascorbic acid) and vitamin E (alpha-tocopherol) have been shown to reduce bacterial translocation from the intestine and decrease mucosal lipid peroxidation in common bile duct ligation and chronic portal hypertension in rats [179]. Glutamine has been shown to be an effective amino acid for reducing the translocation of bacterial across intestinal walls in animal models [180,181]. The mechanism of action is proposed to be an increase of secretory IgA (sIgA), an increase of villous height, and an increase in mucosal thickness to improve the intestinal barrier and decrease bacterial translocation and adherence. An older study by White et al demonstrated that the enteral administration of glutamine resulted in decreased bacterial translocation to extra-intestinal sites and that glutamine can reduce intestinal permeability [182]. The protective effects of glutamine also include reduced bacterial translocation in blood. This study supported a murine acute graft vs. host disease model that demonstrated the use of oral glutamine reduced gastrointestinal permeability, reduced TNF-α expression, increased occluding, and resulted in less apoptotic cells in the crypt of the intestine [183]. Arginine is another amino acid that has also been shown to decrease bacterial translocation, as measured by the decreased level of bacteria in mesenteric lymph nodes in rats [184]. Curcumin is a member of the ginger family that is related to turmeric spice. A study by Karatepe et al demonstrated that curcumin was able to reduce the amount of intestinal bacterial translocation into blood in a rat model [185].

Chinese herbal supplements have demonstrated positive effects on gut flora and enhance the immune system. One study by Huang et al demonstrated that the use of Chinese medicine herbs such as Panax ginseng, Dioscoreaceae opposite, Atractylodes macrocephala, Glycyrrhiza uralensis, Ziziphus jujube, and Platycodon grandiflorum can increase lactobacilli counts in the ileum and decrease coliform counts in the colon. The immune activities of polymorphonuclear leucocytes were also enhanced, including enhancement of the respiratory burst, in weanling pigs [186]. Fermented dietary herbs, such as Rhizoma Atractylodis Macrocephalae, Massa Medicata Fermentata, and Dolichoris Semen, have been shown to protect against lipopolysaccharide, an endotoxin that triggers the systemic inflammatory response [187]. Phosphatidylcholine is a phospholipid that is a component of biological membranes. Studies have shown that the use of phosphatidylcholine supplementation can protect against bacterial translocation in a colitis rat model [188,189].

Probiotics: Lactobacillus is a naturally-occurring bacterium that resides in human digestive and GU tracts [184]. It is also present in fermented foods such as yogurt and dietary supplements. *Lactobacillus plantarum* has been shown to be effective at adhering to gut mucosa and reducing endotoxin and microbacterial translocation out of the digestive tract [190]. *L. plantarum* and *Lactobacillus reuteri* reduced bacterial translocation, recreated intestinal microbiology, and decreased enzyme myeloperoxidase in the intestine [191]. *Saccharomyces boulardii*, a beneficial baker's yeast, stimulates host defense mechanisms and increases IgA, which has been shown to decrease the translocation of *Candida* from the gut to the mesenteric lymph nodes in animal models [192–194].

Alternative medicine: Growth hormone, when combined with glutamine, improved the intestinal barrier in portal hypertension patients by decreasing intestinal permeability and improving mucosal integrity [195]. Cellulose fiber has been demonstrated to decrease bacterial translocation, but did not prevent bacterial overgrowth [196–198].

QUESTION 8: Is there a role for post-surgical monitoring of methicillin-resistant *Staphylococcus aureus* (MRSA) colonization in the asymptomatic patient?

Consensus: We recommend against post-surgical monitoring of MRSA colonization in the asymptomatic patient.

Delegate Vote: Agree 98%, Disagree 2%, Abstain 0% (Strong Consensus)

Justification:

Post-surgical monitoring of MRSA colonization has not been shown to lead to reduced SSIs. The rate of *S. aureus* colonization has been reported as high as 33% in the 3–30 month postoperative period after total joint arthroplasty (TJA) [199] and most of the bacteria have unchanged antibiotic sensitivity. Although these organisms may persist, *S. aureus* colonization in the postoperative period has not been correlated with increased risk of SSI. Thus, monitoring and decolonizing patients who are *Staphylococcus aureus*-colonized may not prove an efficacious method for infection prevention and should not be encouraged until further studies are performed.

Consensus: We recommend that patients undergo repeat screening for *S, aureus* and decolonization prior to additional arthroplasty.

Justification:

Because decolonization does not persist in the postoperative phase, we recommend that patients be rescreened and decolonized for subsequent arthroplasty procedures after the index procedure. One study demonstrated that there was 70% persistent decolonization of MRSA and methicillin-sensitive *S. aureus* (MSSA) at an average of 156 days after the index procedure [200]. However, at 213 days, 30% of the patients were no longer decolonized. Repeat testing indicated that two new patients developed MRSA and 35 new patients developed MSSA. Thus, rescreening and decolonization of *S. aureus*-colonized patients are recommended prior to any repeat arthroplasty procedures.

QUESTION 9: What are the methods to identify extra-articular sources of late PJI?

Consensus: Extra-articular sources that contribute to late PJI should be identified by obtaining history, performing a thorough physical exam, laboratory testing, and imaging of suspected areas of infection.

Delegate Vote: Agree 92%, Disagree 3%, Abstain 5% (Strong Consensus)

Justification:

To identify the source of infection, performing a proper history and physical examination can narrow down the region of interest. Once the area of suspected infection is identified, laboratory testing, imaging, and examination by specialists can further refine the source and provide a solution for eradicating the infection. The strongest evidence for an extra-articular source of PJI is cultures of the same pathogen that are found intra-articularly and from the extra-articular source of infection.

The most common method of acquiring a late PJI is by hematogenous spread [201,202]. Thus, most organs that are infected in the body can become an extra-articular source of a late PJI. The

main sources of extra-articular PJIs by body systems are as follows: dental, cardiac, lungs, GI, GU, integumentary, and blood stream.

Dental abscesses can also be sources of extra-articular infection. *Actinomyces israelii* is an organism responsible for dental carriers and this organism has been isolated in PJI [203]. *Actinomyces naeslundii* is another organism that has been identified in late PJI secondary to routine dental work on a molar tooth [204]. Patients who have a high suspicion for dental infection should be seen by a dentist and appropriate repairs (eg dental extraction) should be performed.

For cardiac issues such as infective endocarditis [205,206], an echocardiogram can identify vegetations. Patients who are IV drug users have a higher likelihood of developing infective endocarditis that can produce septic emboli. IV antibiotics are the treatment of choice.

For the lungs, infectious conditions such as pneumonia can be an extra-articular source of infection [207]. Pneumonia can also be superimposed on chronic conditions such as chronic obstructive pulmonary disease and asthma. The use of imaging such as a chest x-ray or computed tomography (CT) scan can identify pneumonia, or pulmonary testing can diagnose chronic obstructive pulmonary disease. Sputum cultures can be used to identify the appropriate organisms to treat with IV antibiotics.

Inflammatory conditions in the GI system [208] such as cholecystitis and cholangitis can seed the prosthesis with bacteria [209]. Other diseases such as diverticulitis can also predispose patients to PJIs, as well as chronic conditions such as liver disease (eg hepatitis) [210]. Imaging modalities, such as CT scans with oral contrast, can elucidate GI pathology, in addition to direct visualization using endoscopy. However, endoscopy is not benign, as the performance of health maintenance tests, such as routine colonoscopies, can result in PJIs. One case report described a patient who developed a *Listeria monocytogenes* infection in a total knee arthroplasty [150].

There are multiple conditions within the GU system that can provide an extra-articular source for a PJI. Systemic bacteremia is increased with routine procedures such as a transrectal prostate biopsy [167]. Performing a prostatectomy for prostatic carcinoma leads to the development of a *K. pneumoniae* periprosthetic knee infection in one patient [169]. The bacteria from sexually transmitted diseases, such as gonorrhea [211], can also infect TJA implants. Infections of the urinary tract, including cystitis and pyuria, are extra-articular sources of infection that are associated with increased risk of PJI [212,213]. If a urinary tract infection is suspected, a urine sample should be sent for urinalysis and culture. However, treatment of asymptomatic bacteriuria is controversial [214]. Advance imaging using ultrasound or CT can be preformed to identify the source of infection. Microbiology testing of discharged bodily fluids may also provide cultures by which to guide antibiotic management.

Skin lesions from immunocompromised skin such as with psoriasis [215] or chronic venous ulcers can be a source of extra-articular bacteria leading to PJI; however, some studies have demonstrated that there is no association [216,217]. Thorough checks for breaks in the skin can identify wounds that can be treated by wound care specialists and dermatology consultations.

Direct seeding of the bloodstream with bacteria, as in the use of IV drugs, can result in hematogenous spread to the prosthesis [218]. Catheters can become colonized by skin flora and can directly seed the blood stream [219,220]. Removal of catheters can reduce the risk of infection and culturing the catheter tips can provide an organism to treat.

QUESTION 10: When should further workup for postoperative fevers be performed after TJA?

Consensus: We recommend against the routine workup of fevers greater than 38.5 °C in the immediate postoperative period. However, the workup of persistent fevers after postoperative day 3 may be warranted.

Delegate Vote: Agree 81%, Disagree 15%, Abstain 4% (Strong Consensus)

Justification:

Fevers in the immediate postoperative period are common after TJA. However, when patients present with temperatures greater than 39.0 °C, especially for multiple days and after postoperative day 3, a workup that includes urinalysis, urine culture, blood culture, and chest x-ray is warranted. Additionally, examination for deep vein thrombosis, infected IV lines, and drug-related fevers should be included in the workup if there is high clinical suspicion. Treating these infections may reduce the risk of causing a late PJI.

In the immediate postoperative period after TJA, patients commonly sustain elevated body temperatures due to the invasion of surgery [221–223]. This associated with increased tissue, joint fluid, and serum concentrations of inflammatory molecules, including IL-1β from drain fluid and IL-6, which can be detected in serum and joint fluid [224]. Postoperative fevers may be routine in the postoperative period or can be caused by a multitude of factors, including urinary tract infections, blood borne infections, pneumonia, deep vein thrombosis, pulmonary emboli, SSIs, IV line infections, or drug fevers. These are often evaluated by urinalysis, urine culture, blood cultures, chest x-rays, Doppler ultrasounds, wound or joint cultures, IV line cultures, or ceasing the administration of certain drugs. However, multiple studies within the orthopaedic literature have demonstrated that a postoperative fever, especially within the first 3 days, has a low association with the development of PJI. Kennedy et al demonstrated that none of the patients that exhibited a temperature greater than 39 °C developed a PJI and that postoperative fevers were correlated with a drop in hematocrit or a subsequent transfusion within 5 days after surgery [225]. Guinn et al demonstrated that 14/158 (8.9%) TKAs developed a postoperative fever that could be attributed to laboratory findings. Their study demonstrated that unilateral TKA patients were more likely to sustain a complication and that urinalysis, aggressive pulmonary toilet, and repeat physical exams were helpful with diagnosis [226]. Shaw and Chung demonstrated that out of 100 TKAs and 100 THAs none developed a PJI and that positive urine cultures did not correlate with a febrile response [227]. Postoperative temperatures were greatest on postoperative day 1. When using fever (≤38 °C) as a diagnostic test for developing PJI, the sensitivity was 0.286 (95% confidence interval (CI) = 0.084–0.581), the specificity was 0.628 (95% CI = 0.548–0.704) and the positive predictive value was 0.065 (95% CI = 0.018–0.157) [228].

Blood cultures have low utility when working up postoperative fevers. In a study by Bindelglass and Pellegrino, blood cultures were drawn on 40/240 TKAs and 31/124 THAs, of which only 2 patients came back with positive results. Both of these results were thought to be contaminants. Performing routine blood cultures to work up postoperative fevers was not found to be cost-effective [229]. A study conducted by Tai et al demonstrated that patients who were diagnosed with PJIs had peak body temperatures reported on postoperative day 4 and these fevers were often sustained for 3–4 days [230]. Thus, postoperative fever workups were recommended in patients who sustained later and prolonged fevers. Additionally, working up all postoperative fevers can be expensive and the cost may not be warranted. A study by Ward et al demonstrated that the routine evaluation of postoperative fever (>38.5 °C) over a 2-year period was $73,878, which amounted to a charge of $959.45 for a fever evaluation per patient [231]. However, fevers that occurred after postoperative day 3 were sustained for multiple events (<1) and had a temperature >39.0 °C were more likely to be associated with a positive workup. Thus, in this patient population, a febrile workup after TJA may be warranted.

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