SPECIALTY UPDATE

What's New in Musculoskeletal Infection: Update Across Orthopaedic Subspecialties

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Every medical discipline includes the diagnosis and management of infection in some form, and orthopaedic surgery is no exception. The Centers for Disease Control and Prevention (CDC) instituted the National Healthcare Safety Network (NHSN) in 2004 to track procedure-associated infections, including surgical-site infections (SSIs)¹. In this regard, the goal was to identify infections and implement effective methods of prevention. The orthopaedic surgery and infectious disease communities have instituted their own initiatives to optimize the prevention of infection. Moreover, diagnostic criteria and methods have been developed, and treatment strategies have been implemented to manage infection and reduce the likelihood of reinfection².

Last year's Specialty Update on musculoskeletal infection focused on biofilms. While biofilm is 1 factor responsible for orthopaedic infections, different anatomic locations have diverse environments that lead to musculoskeletal infections. In each orthopaedic subspecialty, differences exist in the prevention and diagnosis of infection, and there may be variation in risk factors by anatomic area. Finally, treatment modalities can differ depending on the infection location.

The current update on musculoskeletal infection explores several orthopaedic subspecialties, including shoulder and elbow, total joint arthroplasty, foot and ankle, spine, trauma, and sports medicine.

Materials and Methods

Musculoskeletal infection was searched in a variety of orthopaedic surgery, infectious disease, and medical journals. Table 1 presents a list of the journals that were individually searched and the search terms utilized. We searched for the terms in the title, in the abstract, and among keywords, and papers with infection as a topic, focus, and critical finding were identified. Studies were excluded if they were not in English, and if they were not published in print or online in 2016. We used our editorial judgment to identify articles that were pertinent and relevant to the readership. Articles on the shoulder and elbow, total joint arthroplasty, foot and ankle, spine, trauma, and sports medicine were included. While other subspecialties, such as orthopaedic oncology, pediatric orthopaedics, and hand, are important, there were not sufficient citations in the musculoskeletal literature in 2016 to support inclusion in this update.

Shoulder and Elbow

Numerous studies sought to identify risks factors associated with infection after shoulder surgery. Of more than 3,000 arthroscopic rotator cuff repairs at a single institution, 0.85% were complicated by infection; male sex, an age of >60 years, and a longer surgical duration were all associated with increased infection risk³. Importantly, the receipt of surgical antibiotic prophylaxis was associated with a >5-fold reduction in infection risk. Smoking was associated with increased infection risk after labral repair (odds ratio [OR], 1.9)⁴; current and former smoking were also important risk factors for periprosthetic joint infection (PJI) after total shoulder arthroplasty (hazard ratio [HR], 7.27 and 4.56, respectively)⁵. Medicare databases were utilized to confirm that

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TABLE I Journals Searched, and Search Terms Used, to Identify Studies Related to Musculoskeletal Infection

Journals Searched	Search Terms
<i>The American Journal of Sports Medicine</i>	Biofilm
<i>Annals of Internal Medicine</i>	Biofilms
<i>Antimicrobial Agents and Chemotherapy</i>	Bone infection
<i>Archives of Orthopaedic Trauma and Surgery</i>	Diabetic foot infection
<i>Arthroscopy</i>	Implant infection
<i>The Bone & Joint Journal</i>	Periprosthetic joint infection
<i>Clinical Infectious Diseases</i>	Prosthetic joint infection
<i>Clinical Orthopaedics and Related Research</i>	Orthopaedic infection
<i>Diabetes/Metabolism Research and Reviews</i>	Orthopedic infection
<i>European Journal of Orthopaedic Surgery & Traumatology</i>	Osteomyelitis
<i>European Spine Journal</i>	Septic arthritis
<i>The Foot</i>	
<i>Foot & Ankle International</i>	
<i>Foot & Ankle Specialist</i>	
<i>Foot and Ankle Clinics</i>	
<i>Global Spine Journal</i>	
<i>Infection Control and Hospital Epidemiology</i>	
<i>International Journal of Shoulder Surgery</i>	
<i>International Journal of Spine Surgery</i>	
<i>JAMA</i>	
<i>The Journal of Arthroplasty</i>	
<i>The Journal of Bone & Joint Surgery</i>	
<i>The Journal of Foot & Ankle Surgery</i>	
<i>The Journal of Infectious Diseases</i>	
<i>Journal of Orthopaedic Surgery and Research</i>	
<i>Journal of Orthopaedic Trauma</i>	
<i>Journal of Orthopaedics and Traumatology</i>	
<i>Journal of Shoulder and Elbow Surgery</i>	
<i>The Knee</i>	
<i>Knee Surgery, Sports Traumatology, Arthroscopy</i>	
<i>The Lancet Infectious Diseases</i>	
<i>The New England Journal of Medicine</i>	
<i>Open Forum Infectious Diseases</i>	
<i>Orthopaedics and Trauma</i>	
<i>Shoulder & Elbow</i>	
<i>Spine</i>	
<i>The Spine Journal</i>	

patients with human immunodeficiency virus (HIV) and hepatitis C infection had a higher risk of PJI after total shoulder arthroplasty (OR, 1.36 and 1.7, respectively)^{6,7}. Reassuringly, PJI risk after total shoulder arthroplasty was not higher after treatment of lower-extremity PJI in a small case series⁸. However, the risk of infection after shoulder

arthroplasty and arthroscopy was heightened when performed <3 months after ipsilateral shoulder corticosteroid injection⁹, suggesting that shoulder surgery should be delayed after injection.

Research into *Propionibacterium acnes* infection again dominated the total shoulder arthroplasty infection literature

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in 2016. Regarding infection prevention, a cost-effectiveness study using various modeling assumptions found that vancomycin powder could be cost-effective for preventing infection after shoulder arthroplasty, even if the absolute risk reduction was low¹⁰. It is known that *P. acnes* infections are difficult to diagnose, as they may not be associated with inflammation. *P. acnes* also grows slowly and may contaminate cultures, including cultures of sterile materials and deep-tissue samples. Novel diagnostic strategies were reported, which may improve on the current approach if validated. A combination of synovial-fluid biomarkers (interleukin [IL]-6, tumor necrosis factor- α , and IL-2) demonstrated better-than-usual perioperative testing characteristics for diagnosing shoulder PJI, with a sensitivity of 80% and specificity of 93%¹¹. To improve on standard culture techniques, Holmes and colleagues developed a polymerase chain reaction-restriction fragment length polymorphism assay that rapidly identifies *P. acnes* in tissue biopsy specimens¹². One study shed light on the source of *P. acnes* in the surgical field¹³, where 33% of 40 patients (73% of 15 male patients) undergoing primary total shoulder arthroplasty without prior shoulder intervention had positive *P. acnes* cultures during surgery. The subdermal layer where *P. acnes* resides was the most common site of culture positivity, although positive results were also obtained from gloves and instruments. This study demonstrates how easily this organism can contaminate culture samples, but, as importantly, also provides a window into how the organism may be disseminated during surgery and lead to infection.

Several retrospective studies and 1 basic science study reported on the management of *P. acnes* shoulder PJI; overall, small sample sizes and cohort differences prevented useful conclusions from being drawn. One study compared antibiotic-only management to management with both antibiotic use and surgery and found similar rates of favorable outcomes¹⁴. A basic science study demonstrated that *P. acnes* biofilm formation on calcium sulfate and polymethylmethacrylate beads can be prevented when vancomycin and tobramycin are added to the beads¹⁵. Good outcomes from both 1-stage¹⁶ and 2-stage¹⁷ revision arthroplasties for shoulder PJI were reported, although high complication rates, including reinfection, were reported for the 2-stage revision arthroplasty patients. Nelson and colleagues systematically reviewed the shoulder PJI literature and found that both 1-stage and 2-stage approaches yielded pooled success rates of >90%¹⁸; however, they also noted that the retrospective nature of the data prevented robust conclusions.

Given the infrequent use of total elbow arthroplasty (TEA), the literature on infection after TEA remains in its infancy. A large database analysis of 189 primary and 53 revision TEAs showed an infection rate of 3.2% and 7.5%, respectively; smoking increased the risk of infection nearly 7-fold¹⁹. A small case series of 10 elbows demonstrated that resection elbow arthroplasty is a viable salvage technique for PJI, which adds to the literature on management options for infection following TEA²⁰.

Total Joint Arthroplasty; Hip and Knee

Similar to the shoulder and elbow, the literature on infection related to lower-extremity total joint arthroplasty has focused on PJI. With respect to infection prevention, recent studies highlighted factors that decreased or had no effect on the risk of infection and focused on preoperative, intraoperative, and implant factors. In the preoperative period, routine preoperative urine cultures were not effective as screening tools for the prevention of PJI^{21,22}. However, *Staphylococcus aureus* (methicillin-sensitive and methicillin-resistant *S. aureus*) screening and/or universal decolonization²³⁻²⁵ and preadmission chlorhexidine skin preparation were effective for reducing PJI after total joint arthroplasty^{26,27}. Intraoperatively, the reduction of airborne microorganisms resulted in decreased prosthesis-related infections in total hip arthroplasty and spinal surgeries, especially when utilized at the time of incision. Similarly, the use of antibiotic-loaded bone cement decreased PJI²⁸ as did gram-negative antibiotic prophylaxis using gentamicin or aztreonam in patients undergoing total hip arthroplasty²⁹. Instead of antibiotics, antimicrobial solutions, such as 0.19% vol/vol acetic acid, were shown to reduce the risk of reinfection when used in a 20-minute soak when treating PJI³⁰. After surgery was completed, patients undergoing total joint arthroplasty who were managed with use of silver-impregnated dressings had a lower PJI rate than did patients managed with use of xeroform dressings³¹. From an implant perspective, the use of all-polyethylene tibial components in total knee arthroplasty was associated with a lower PJI rate compared with the use of metal-backed tibial components³². Novel coatings, such as thermal-sprayed silver oxide-containing hydroxyapatite coating³³, titanium-copper oxide coating³⁴, and antibiotic implant coating using branched poly(ethylene glycol)-poly(propylene sulfide) (PEG-PPS) polymer³⁵, may reduce the likelihood of bacteria adhering to an implant surface. Finally, to prevent reinfection after treatment for PJI, a 3-month course of oral antibiotics may improve infection-free survival in the short term³⁶.

With regard to risk factors for infection, similar characteristics were found in lower-extremity total joint arthroplasty patients as in total shoulder arthroplasty patients. For example, a corticosteroid injection received within 3 months before surgery predisposed patients undergoing total hip arthroplasty³⁷ and total knee arthroplasty³⁸ to PJI. The patient comorbidities of obesity³⁹⁻⁴³ and psychiatric disorders⁴⁴ were associated with increased risk of PJI. Additionally, hypoalbuminemia was associated with increased PJI risk due to poor wound-healing^{45,46}, and improving nutritional parameters, such as albumin, iron, protein, transferrin, vitamin D, and zinc, can reduce the risk of infection⁴⁷. Finally, patient use of prophylactic anticoagulants, such as rivaroxaban, resulted in a 12.5-fold increased likelihood for infection, compared with other forms of chemoprophylaxis for venous thromboembolism prevention⁴⁸.

The diagnosis of PJI in total joint arthroplasty has been a well-studied topic, relying on traditional markers such as

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synovial-fluid white blood-cell (WBC) count, polymorphonuclear (PMN) percentage, and histologic and culture findings. Culture technique was improved by using blood culture bottles⁴⁹, and longer duration of culture growth led to higher detection of *P. acnes*⁵⁰. Over the past year, studies further evaluated other synovial fluid markers including procalcitonin, α -defensin, and leukocyte esterase⁵¹⁻⁵⁵. The α -defensin lateral flow test introduced in Europe demonstrated findings similar to those of intraoperative frozen sections, with a sensitivity of 67% and a specificity of 93%⁵⁶. Intraoperative frozen section histology was further validated in another study with the Musculoskeletal Infection Society (MSIS) criteria as the gold standard, demonstrating sensitivity of 73.7% and specificity of 98.9%⁵⁷. With regard to the use of imaging for diagnosing PJI, leukocyte scintigraphy had higher sensitivity (88%) and lower specificity (92%) compared with combined leukocyte and bone marrow scintigraphy (sensitivity 69%, specificity 96%)⁵⁸.

In terms of PJI treatment after lower-extremity total joint arthroplasty, the 2 main modalities include oral suppressive antibiotics and surgical management. As concluded by the authors of 1 study, if no surgical intervention was performed, oral antibiotics were recommended for 3 months, especially for gram-positive and sensitive organisms⁵⁹. The biggest trend in the literature regarding PJI treatment in total joint arthroplasty over the past year was the comparison of 1-stage and 2-stage exchange arthroplasty. The benefit of 1-stage exchange is that all arthroplasty materials are removed, decreasing the likelihood of persistent biofilm bacteria⁶⁰. One study found that female patients who underwent 2-stage exchange arthroplasty with static spacers had an increased risk of reinfection compared with patients who underwent 1-stage exchange or 2-stage exchange with a dynamic spacer⁶¹. A systematic review comparing the 2 procedures demonstrated that 1-stage exchange arthroplasty had significantly lower reinfection rates in studies published after 2000, with higher functional outcomes⁶². In both of the above studies, the importance of patient selection and of antibacterial regimens was noted; the criteria for patient selection have not yet been fully determined⁶³. Other authors found that when 1-stage exchange arthroplasty was performed in the knee or hip, catheter infusion with intra-articular antibiotics to which the organisms present were sensitive resulted in 95% infection-free survival^{64,65}.

For 2-stage exchange arthroplasty, infection control ranged from 71% to 91%⁶⁶⁻⁶⁹. In a case series of patients infected with *Mycobacterium tuberculosis* who underwent total hip arthroplasty, infection was controlled in 100% of the patients treated with 2-stage exchange arthroplasty⁷⁰. Articulating spacers continue to be used in the clinical setting, but debris from articulating spacers induce changes in CD3, CD20, CD11(c), and IL-17, raising the possibility of associated immune modulation⁷¹. Static spacers may result in good infection control (94%)⁷², but mechanical spacer-related complications were reported for 15% of 133 static spacers, including restricted range of motion and spacer fracture⁷³. Antibiotics used in cement

spacers vary, with some studies describing the use of ceftazidime and vancomycin⁶⁷, and others, vancomycin and tobramycin.

Foot and Ankle

Diabetes is a frequently encountered diagnosis in both medical and surgical specialties, and diabetic foot ulcers need to be addressed in a multidisciplinary fashion. In 1996, a group of experts interested in the care of patients with diabetes and foot problems formed the International Working Group on the Diabetic Foot (IWGDF; www.iwgdf.org). The IWGDF convened in 2015 and made 26 recommendations on the diagnosis and management of foot infections in persons with diabetes, which were then published in 2016⁷⁴. These recommendations were rated by the strength of the recommendation and the quality of evidence (Table II), and were listed by 6 general categories: classification/diagnosis, osteomyelitis, assessing severity, microbiological considerations, surgical treatment, and antimicrobial therapy. We sorted the recommendations from strong, with a high quality of evidence, to weak, with a low quality of evidence (Table III). Each recommendation will not be discussed individually, but key recommendations are discussed below.

Of the 26 recommendations, only 4 were listed as strong recommendations with a high quality of evidence and are listed in the categories of osteomyelitis, microbiological considerations, and antimicrobial therapy. The salient points were as follows: a probe-to-bone test in a high-risk patient is largely diagnostic, tissue cultures of infected wounds are preferred over swab cultures, most mild and moderate diabetic foot infections can be treated with 1 to 2 weeks of antibiotic therapy, and specific wound dressings could not be recommended to prevent an infection or to improve outcomes.

There were 7 recommendations that were strong with a moderate quality of evidence. Key points include the following: cultures of soft tissue or sinus tracts do not accurately reflect the pathogen causing osteomyelitis, use magnetic resonance imaging (MRI) when advanced imaging is needed to diagnose osteomyelitis, and only 1 week of antibiotics is needed for treatment if all infected bone is resected.

Eleven recommendations had a low quality of evidence, but the strength of the recommendation was nonetheless strong. Obtaining radiographs makes sense for any and all clinically suggested infections, yet the IWGDF found a low quality of evidence to support this recommendation. Clinical diagnosis seems to be a common thread among the recommendations considered strong with a low quality of evidence. From a diagnosis standpoint, clinical findings must be used to diagnose infected diabetic foot wounds, and these findings will help guide surgical recommendations and/or antimicrobial therapy.

Weak recommendations were noted for the categories of osteomyelitis and surgical treatment. For patients with osteomyelitis who cannot undergo MRI, a suggested recommendation was that a WBC-labeled radionuclide scan, single-photon emission computed tomography (SPECT) and computed tomography

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TABLE II IWGDF Guidance on the Diagnosis and Management of Foot Infections in Persons with Diabetes*

	Recommendations†
Classification/diagnosis	(1.) Diabetic foot infection must be diagnosed clinically, based on the presence of local or systemic signs or symptoms of inflammation (strong; low).
	(2.) Assess the severity of any diabetic foot infection using the Infectious Diseases Society of America/International Working Group on the Diabetic Foot classification scheme (strong; moderate).
Osteomyelitis	(3.) For an infected open wound, perform a probe-to-bone test; in a patient at low risk for osteomyelitis, a negative test largely rules out the diagnosis, while in a high-risk patient, a positive test is largely diagnostic (strong; high).
	(4.) Markedly elevated serum inflammatory markers, especially erythrocyte sedimentation rate, are suggestive of osteomyelitis in suspected cases (weak; moderate).
	(5.) A definite diagnosis of bone infection usually requires positive results on microbiological (and, optimally, histological) examinations of an aseptically obtained bone sample, but this is usually required only when the diagnosis is in doubt or determining the causative pathogen's antibiotic susceptibility is crucial (strong; moderate).
	(6.) A probable diagnosis of bone infection is reasonable if there are positive results on a combination of diagnostic tests, such as probe-to-bone, serum inflammatory markers, plain x-ray, magnetic resonance imaging (MRI), or radionuclide scanning (strong; low).
	(7.) Avoid using results of soft tissue or sinus tract specimens for selecting antibiotic therapy for osteomyelitis as they do not accurately reflect bone culture results (strong; moderate).
	(8.) Obtain plain x-rays of the foot in all cases of non-superficial diabetic foot infection (strong; low).
	(9.) Use MRI when an advanced imaging test is needed for diagnosing diabetic foot osteomyelitis (strong; moderate).
	(10.) When MRI is not available or contraindicated, consider a white blood cell-labeled radionuclide scan, or possibly single-photon emission computed tomography (SPECT) and computed tomography (CT) or fluorine-18-fluorodeoxyglucose positron emission tomography/CT scans (weak; moderate).
Assessing severity	(11.) At initial evaluation of any infected foot, obtain vital signs and appropriate blood tests, debride the wound, and probe and assess the depth and extent of the infection to establish its severity (strong; moderate).
	(12.) At initial evaluation, assess arterial perfusion and decide whether and when further vascular assessment or revascularization is needed (strong; low).
Microbiological considerations	(13.) Obtain cultures, preferably of a tissue specimen rather than a swab, of infected wounds to determine the causative microorganisms and their antibiotic sensitivity (strong; high).
	(14.) Do not obtain repeat cultures unless the patient is not clinically responding to treatment, or occasionally for infection control surveillance of resistant pathogens (strong; low).
	(15.) Send collected specimens to the microbiology laboratory promptly, in sterile transport containers, accompanied by clinical information on the type of specimen and location of the wound (strong; low).
Surgical treatment	(16.) Consult a surgical specialist in selected cases of moderate, and all cases of severe, diabetic foot infection (weak; low).
	(17.) Perform urgent surgical interventions in cases of deep abscesses, compartment syndrome, and virtually all necrotizing soft tissue infections (strong; low).
	(18.) Consider surgical intervention in cases of osteomyelitis accompanied by spreading soft tissue infection, destroyed soft tissue envelope, progressive bone destruction on x-ray, or bone protruding through the ulcer (strong; low).
Antimicrobial therapy	(19.) While virtually all clinically infected diabetic foot wounds require antimicrobial therapy, do not treat clinically uninfected wounds with antimicrobial therapy (strong; low).
	(20.) Select specific antibiotic agents for treatment based on the likely or proven causative pathogens, their antibiotic susceptibilities, the clinical severity of the infection, evidence of efficacy of the agent for diabetic foot infection, and costs (strong; moderate).
	(21.) A course of antibiotic therapy of 1–2 weeks is usually adequate for most mild and moderate infections (strong; high).

continued

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TABLE II (continued)

Recommendations†	
	<p>(22.) Administer parenteral therapy initially for most severe infections and some moderate infections, with a switch to oral therapy when the infection is responding (strong; low).</p> <p>(23.) Do not select a specific type of dressing for a diabetic foot infection with the aim of preventing an infection or improving its outcome (strong; high).</p> <p>(24.) For diabetic foot osteomyelitis, we recommend 6 weeks of antibiotic therapy for patients who do not undergo resection of infected bone and no more than a week of antibiotic treatment if all infected bone is resected (strong; moderate).</p> <p>(25.) We suggest not using any adjunctive treatments for diabetic foot infection (weak; low).</p> <p>(26.) When treating a diabetic foot infection, assess for use of traditional remedies and previous antibiotic use and consider local bacterial pathogens and their susceptibility profile (strong; low).</p>
<p>*Reproduced from: Lipsky BA, Aragón-Sánchez J, Diggle M, Embil J, Kono S, Lavery L, Senneville É, Urbančič-Rovan V, Van Asten S, Peters EJ; International Working Group on the Diabetic Foot. IWGDF guidance on the diagnosis and management of foot infections in persons with diabetes. <i>Diabetes Metab Res Rev</i>. 2016 Jan;32(Suppl 1):45-74. Used with permission. Copyright © 2015 John Wiley & Sons, Ltd. †The strength of the recommendation and the quality of evidence are presented in parentheses (e.g., "strong; low"). See Table III for a listing of the recommendations sorted by strength of recommendation and quality of evidence.</p>	

(CT) scan, or fluorine-18-fluorodeoxyglucose positron emission tomography/CT scan could be considered instead of MRI.

The IWGDF is planning for another systematic review and update of guidance recommendations in 2019, with the hope that additional scientific studies will help better define the diagnosis of, and treatment recommendations for, diabetic foot ulcers and diabetic foot infections. In the interim, current recommendations should be followed, and multidisciplinary approaches to these often complex patients should be promoted.

Spine

With respect to the spine, SSI was the dominant theme. SSI was reported as the leading cause of 30-day reoperation^{75,76} and late reoperations after 2 years^{77,78}. SSI rates and risk factors were reported for adults^{79,80} and children⁸¹. Anesthesia time⁸², obesity^{83,84}, coagulopathy⁸⁵, malnutrition^{86,87}, frailty⁸⁸, neurologic deficit⁸⁹, allogeneic transfusion⁹⁰, incidental durotomy⁹¹, epidural corticosteroids⁹²⁻⁹⁶, end-stage renal disease⁹⁷, and smoking⁹⁸ were all identified as being associated with higher spine SSI rates.

P. acnes was the pathogen studied in 9 spine-related studies, with 4 addressing the association of *P. acnes* with disc herniation. About half of the surgical specimens from discectomies were reported to be culture-positive with *P. acnes*^{99,100}; however, when the specimen collection and culturing protocol was rigorously aseptic to prevent contamination, the association was not found, with positive cultures in only 2 (0.5%) of 379¹⁰¹ and 0 (0%) of 22 disc protrusions¹⁰². Further drawing the association into question was an in vivo animal study in which hematogenous seeding of *P. acnes* to the disc was not achieved¹⁰².

There were 3 studies that reported on the delivery of vancomycin powder to surgical wounds¹⁰³⁻¹⁰⁵. Bone healing was reported to be unaffected¹⁰³. The authors of a Level-IV study reported an association between decreased infection rate

and the use of vancomycin powder in degenerative spine surgery (a rate of 1.3% without and 0.4% with the use of vancomycin)¹⁰⁴. Another observational study in 1 center reported SSI in 2 (4.9%) of 41 spine tumor procedures when vancomycin was used, but the rate without vancomycin use was not reported¹⁰⁵.

Trauma

A prospective cohort study of open fracture treatment reaffirmed the association between a higher grade of open fracture, infection, and smoking as risk factors for nonunion¹⁰⁶. Retrospective reviews added evidence that it is important to consider infection when managing "aseptic" nonunions; the authors of 1 study noted a 20% rate of culture-positive results¹⁰⁷. To reduce infection and nonunion, immediate, post-debridement closure of selected open fractures, with a severity of grade 3A or less, may be performed¹⁰⁸. For other open fractures, a Level-I study reported a 5-fold decrease in the rate of infection and a lower nonunion rate when using negative pressure wound therapy for open fractures¹⁰⁹. For patients with osteomyelitis, the implementation of a 1-stage protocol in optimized Type B hosts with osteomyelitis resulted in 96% infection-free outcomes in a 100-patient prospective cohort study¹¹⁰. Thus, the tenet of treating open fractures with open debridement to prevent reinfection and nonunion remain true, with the addition of wound-closure techniques and 1-stage treatment if osteomyelitis develops.

Sports Medicine

The rates of infection in arthroscopic sports-related procedures are low in the literature, but some studies reported notable findings. In a large claims-based analysis, higher rates of infection after anterior cruciate ligament (ACL) repair were identified on multivariate analysis when hamstring autografts were utilized compared with

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TABLE III IWGDF Guidance on the Diagnosis and Management of Foot Infections in Persons with Diabetes, by Strength of Recommendation and Quality of Evidence*

Strength of Recommendation; Quality of Evidence	Recommendation
Strong; high	<p>Osteomyelitis</p> <p>(i.) For an infected open wound, perform a probe-to-bone test; in a patient at low risk for osteomyelitis, a negative test largely rules out the diagnosis, while in a high-risk patient, a positive test is largely diagnostic.</p> <p>Microbiological considerations</p> <p>(i.) Obtain cultures, preferably of a tissue specimen rather than a swab, of infected wounds to determine the causative microorganisms and their antibiotic sensitivity.</p> <p>Antimicrobial therapy</p> <p>(i.) A course of antibiotic therapy of 1–2 weeks is usually adequate for most mild and moderate infections.</p> <p>(ii.) Do not select a specific type of dressing for a diabetic foot infection with the aim of preventing an infection or improving its outcome.</p>
Strong; moderate	<p>Classification/diagnosis</p> <p>(i.) Assess the severity of any diabetic foot infection using the Infectious Diseases Society of America/International Working Group on the Diabetic Foot classification scheme.</p> <p>Osteomyelitis</p> <p>(i.) A definite diagnosis of bone infection usually requires positive results on microbiological (and, optimally, histological) examinations of an aseptically obtained bone sample, but this is usually required only when the diagnosis is in doubt or determining the causative pathogen's antibiotic susceptibility is crucial.</p> <p>(ii.) Avoid using results of soft tissue or sinus tract specimens for selecting antibiotic therapy for osteomyelitis as they do not accurately reflect bone culture results.</p> <p>(iii.) Use MRI when an advanced imaging test is needed for diagnosing diabetic foot osteomyelitis.</p> <p>Assessing severity</p> <p>(i.) At initial evaluation of any infected foot, obtain vital signs and appropriate blood tests, debride the wound, and probe and assess the depth and extent of the infection to establish its severity.</p> <p>Antimicrobial therapy</p> <p>(i.) Select specific antibiotic agents for treatment based on the likely or proven causative pathogens, their antibiotic susceptibilities, the clinical severity of the infection, evidence of efficacy of the agent for diabetic foot infection, and costs.</p> <p>(ii.) For diabetic foot osteomyelitis, we recommend 6 weeks of antibiotic therapy for patients who do not undergo resection of infected bone and no more than a week of antibiotic treatment if all infected bone is resected.</p>
Strong; low	<p>Classification/diagnosis</p> <p>(i.) Diabetic foot infection must be diagnosed clinically, based on the presence of local or systemic signs or symptoms of inflammation.</p> <p>Osteomyelitis</p> <p>(i.) A probable diagnosis of bone infection is reasonable if there are positive results on a combination of diagnostic tests, such as probe-to-bone, serum inflammatory markers, plain x-ray, magnetic resonance imaging (MRI), or radionuclide scanning.</p> <p>(ii.) Obtain plain x-rays of the foot in all cases of non-superficial diabetic foot infection.</p> <p>Assessing severity</p> <p>(i.) At initial evaluation, assess arterial perfusion and decide whether and when further vascular assessment or revascularization is needed.</p> <p>Microbiological considerations</p> <p>(i.) Do not obtain repeat cultures unless the patient is not clinically responding to treatment, or occasionally for infection control surveillance of resistant pathogens.</p>

continued

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TABLE III (continued)

Strength of Recommendation; Quality of Evidence	Recommendation
	(ii.) Send collected specimens to the microbiology laboratory promptly, in sterile transport containers, accompanied by clinical information on the type of specimen and location of the wound.
	Surgical treatment
	(i.) Perform urgent surgical interventions in cases of deep abscesses, compartment syndrome, and virtually all necrotizing soft tissue infections.
	(ii.) Consider surgical intervention in cases of osteomyelitis accompanied by spreading soft tissue infection, destroyed soft tissue envelope, progressive bone destruction on x-ray, or bone protruding through the ulcer.
	Antimicrobial therapy
	(i.) While virtually all clinically infected diabetic foot wounds require antimicrobial therapy, do not treat clinically uninfected wounds with antimicrobial therapy.
	(ii.) Administer parenteral therapy initially for most severe infections and some moderate infections, with a switch to oral therapy when the infection is responding.
	(iii.) When treating a diabetic foot infection, assess for use of traditional remedies and previous antibiotic use and consider local bacterial pathogens and their susceptibility profile.
Weak; moderate	Osteomyelitis
	(i.) Markedly elevated serum inflammatory markers, especially erythrocyte sedimentation rate, are suggestive of osteomyelitis in suspected cases.
	(ii.) When MRI is not available or contraindicated, consider a white blood cell-labeled radionuclide scan, or possibly single-photon emission computed tomography (SPECT) and computed tomography (CT) or fluorine-18-fluorodeoxyglucose positron emission tomography/CT scans.
Weak; low	Surgical treatment
	(i.) Consult a surgical specialist in selected cases of moderate, and all cases of severe, diabetic foot infection.
	Antimicrobial therapy
	(i.) We suggest not using any adjunctive treatments for diabetic foot infection.
<p>*The recommendations shown in Table II are sorted in this table according to the strength of the recommendation and the quality of evidence. Reproduced, with modification, from: Lipsky BA, Aragón-Sánchez J, Diggle M, Embil J, Kono S, Lavery L, Senneville É, Urbančič-Rovan V, Van Asten S, Peters EJ; International Working Group on the Diabetic Foot. IWGDF guidance on the diagnosis and management of foot infections in persons with diabetes. <i>Diabetes Metab Res Rev</i>. 2016 Jan;32(Suppl 1):45-74. Used with permission. Copyright © 2015 John Wiley & Sons, Ltd.</p>	

both bone-patellar tendon-bone autografts and allografts (OR, 5.9)¹¹¹. In a separate study, football (soccer) players had a higher infection risk after ACL reconstruction than did winter athletes¹¹². In 1 retrospective case series using historical controls, autograft soaking using a vancomycin solution reduced the risk of infection after ACL repair¹¹³, providing an additional promising strategy for prevention, if the findings can be corroborated.

Conclusions

The 2016 literature on musculoskeletal infection spanned a variety of topics, and it highlighted the ongoing multidisciplinary work in the areas of infection prevention, diagnosis, and treatment. In fact, work in several subspecialties has progressed to influence other orthopaedic subspecialties. For example, the increase in studies of *P. acnes* in the literature regarding the shoulder has contributed to its diagnosis in patients undergoing spine surgery and lower-extremity total joint arthroplasty. The diagnostic methods from the

total joint arthroplasty literature have contributed to the development of synovial-fluid biomarkers for diagnosing infection after total shoulder arthroplasty. Research in the subspecialties of foot and ankle, trauma, and sports medicine has identified methods of infection prevention based on wound management and graft selection that can be practically applied to other subspecialties. Although musculoskeletal infections still occur, there is hope that there will be continued advancements in the field that will benefit all orthopaedic subspecialties.

Evidence-Based Orthopaedics

The editorial staff of *The Journal* reviewed a large number of recently published research studies related to the musculoskeletal system that received a higher Level of Evidence grade. In addition to articles cited already in the Update, 10 other articles with a higher Level of Evidence grade were identified

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that were relevant to musculoskeletal infection. A list of those titles is appended to this review after the standard bibliography. We have provided a brief commentary about each of the articles to help guide your further reading, in an evidence-based fashion, in this subspecialty area.

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WHAT'S NEW IN MUSCULOSKELETAL INFECTION: UPDATE ACROSS ORTHOPAEDIC SUBSPECIALTIES

Evidence-Based Articles Related to Musculoskeletal Infection

Böhler C, Dragana M, Puchner S, Windhager R, Holinka J. Treatment of septic arthritis of the knee: a comparison between arthroscopy and arthrotomy. *Knee Surg Sports Traumatol Arthrosc.* 2016 Oct;24(10):3147-54. Epub 2015 May 28.

This retrospective case series on arthrotomy versus arthroscopy for native knee septic arthritis found arthroscopy to be preferred. However, between-group differences limit the applicability of this finding.

Young SW, Zhu M, Shirley OC, Wu Q, Spangehl MJ. Do 'surgical helmet systems' or 'body exhaust suits' affect contamination and deep infection rates in arthroplasty? A systematic review. *J Arthroplasty.* 2016 Jan;31(1):225-33. Epub 2015 Aug 1.

This systematic review found that, in older studies, the use of body exhaust suits during total joint arthroplasty was associated with less air contamination and wound contamination and fewer deep infections. However, the use of modern surgical helmet systems did not significantly reduce deep infection or contamination during total joint arthroplasty.

Nickel BT, Klement MR, Penrose CT, Green CL, Seyler TM, Bolognesi MP. Lingering risk: bariatric surgery before total knee arthroplasty. *J Arthroplasty.* 2016 Sep;31(9)(Suppl):207-11. Epub 2016 Mar 15.

Patients who underwent bariatric surgery before total knee arthroplasty had a greater risk of medical and surgical complications (pneumonia, deep-vein thrombosis, heart failure, 2-year revision, infection, and manipulation rates) compared with nonobese patients and obese patients who did not undergo bariatric surgery.

Richardson AB, Bala A, Wellman SS, Attarian DE, Bolognesi MP, Grant SA. Perioperative dexamethasone administration does not increase the incidence of postoperative infection in total hip and knee arthroplasty: a retrospective analysis. *J Arthroplasty.* 2016 Aug;31(8):1784-7. Epub 2016 Jan 21.

Dexamethasone administration has been utilized in the perioperative management of patients undergoing total joint arthroplasty to reduce nausea and vomiting. This study demonstrated that patients who received intravenous dexamethasone (a single 4-mg to 10-mg intravenous dose) had a similar rate of periprosthetic joint infection (1.3%) compared with patients undergoing total joint arthroplasty who did not receive intravenous dexamethasone (1.2%).

Jahng KH, Bas MA, Rodriguez JA, Cooper HJ. Risk factors for wound complications after direct anterior approach hip arthroplasty. *J Arthroplasty.* 2016 Nov;31(11):2583-7. Epub 2016 May 6.

The risk of wound complications after direct anterior total hip arthroplasty was demonstrated to be greater in patients with a higher body mass

index (BMI) and diabetes mellitus, and patients with BMI of >28.0 kg/m² have a greater risk of wound complications and reoperation for wound complications.

De Vecchi E, Bortolin M, Signori V, Romanò CL, Drago L. Treatment with dithiothreitol improves bacterial recovery from tissue samples in osteoarthritic and joint infections. *J Arthroplasty.* 2016 Dec;31(12):2867-70. Epub 2016 May 11.

To increase the bacterial yield from periprosthetic tissue, dithiothreitol was applied to tissue samples to improve culture yield compared with that of saline-treated samples, which resulted in a sensitivity of 88.0% and a specificity of 97.8%.

Brimmo O, Ramanathan D, Schiltz NK, Pillai AL, Klika AK, Barsoum WK. Irrigation and debridement before a 2-stage revision total knee arthroplasty does not increase risk of failure. *J Arthroplasty.* 2016 Feb;31(2):461-4. Epub 2015 Sep 9.

Patients who underwent irrigation and debridement for PJI before 2-stage exchange arthroplasty did not have a higher failure rate than those who were directly treated with 2-stage exchange arthroplasty. When adjusted for race, sex, median household income, insurance, and comorbidities, patients who underwent irrigation and debridement had a lower risk of failure.

Allahabadi S, Haroun KB, Musher DM, Lipsky BA, Barshes NR. Consensus on surgical aspects of managing osteomyelitis in the diabetic foot. *Diabet Foot Ankle.* 2016 Jul 12;7:30079.

Fourteen panelists with an expertise in diabetic foot osteomyelitis used Delphi methodology to provide 38 consensus statements of best-practice guidelines on the perioperative management of diabetic foot osteomyelitis.

Yamada T, Yoshii T, Egawa S, Takada R, Hirai T, Inose H, Kato T, Jinno T, Okawa A. Drain tip culture is not prognostic for surgical site infection in spinal surgery under prophylactic use of antibiotics. *Spine (Phila Pa 1976).* 2016 Jul 15;41(14):1179-84.

In a retrospective review of 1,240 suction drain tips in spinal surgery, the infection rate was 1.5% and drain culture was positive in 4.4%. However, the organisms in the drain cultures were not the same as the SSI organism (sensitivity = 0%).

Kobayashi K, Imagama S, Ito Z, Ando K, Yagi H, Hida T, Ito K, Ishikawa Y, Tsushima M, Ishiguro N. Is a drain tip culture required after spinal surgery? *Clin Spine Surg.* 2016 Jul 14. Epub 2016 Jul 14.

In a retrospective review of 329 spinal procedures, the infection rate was 5.8% and drain culture was positive in 10.3%. The organisms in the drain cultures were associated with the SSI organism ($p < 0.05$; sensitivity = 52%; positive predictive value of 29%).