Periprosthetic joint infection in total hip arthroplasty: prevention and management

Periprosthetic joint infection is a devastating complication. Orthopaedic surgeons must prevent, anticipate, rapidly diagnose and effectively manage such patients in the multidisciplinary setting. This review discusses current strategies in the management of these patients following total hip arthroplasty.

Total hip arthroplasty is a cost-effective solution for patients with end-stage hip arthritis, with the primary aim of improving symptoms, function and quality of life. Periprosthetic joint infection is among the most severe complications of total hip arthroplasty with an estimated incidence of 1–2% (Oussedik et al, 2012). Despite the relatively low incidence, the associated clinical, socioeconomic and financial encumbrance is vast and projected to increase (Vanhegan et al, 2012; Aggarwal et al, 2013). It is a perpetual challenge for clinicians to continually improve the ability to prevent, diagnosis and successfully manage periprosthetic joint infection within an ageing population afflicted with multiple comorbidities and multi-resistant organisms.

This review discusses measures to promote periprosthetic joint infection prevention, and enable prompt diagnosis and effective management in a multidisciplinary setting. Although this review concentrates on infected total hip arthroplasty, the principles of recognition, prevention and management are applicable to all total joint arthroplasties.

Prevention

Preoperative interventions

Preoperative interventions can be undertaken by the clinician to prevent or reduce the risk of periprosthetic joint infection in the postoperative period. Patients at increased risk of developing postoperative periprosthetic joint infection must first be identified.

Literature has shown a correlation with specific patient characteristics (advanced age, male gender, super-obesity (body mass index > 40 kg/m^2) and malnutrition), comorbidities (depression, cardiac arrhythmia, skin disorders, chronic renal failure, immunocompromised), systemic sources of infections (recurrent urinary tract infections), local factors to the specific joint (previous native joint infection, inflammatory arthritis) and a history of prior surgical site infection (Dumville et al, 2013; Ibrahim et al, 2013; Parvizi et al, 2013; Bozic et al, 2014). Poorly controlled diabetes mellitus has been repeatedly shown to be related to periprosthetic joint infection, but it is unclear if acute perioperative or chronic glycaemic control (as measured haemoglobin A_{1c} level) is more important in preventing periprosthetic joint infection (Dumville et al, 2013).

Patients with these risk factors should be investigated preoperatively, and surgery delayed until the patient is optimized. This may involve a multidisciplinary approach to improve glycaemic control, eradicate urinary tract infections, improve nutrition, allow weight loss or perform cardiac investigations, which should coincide with patient education. In very high-risk patients the risks of the surgery and subsequent development of a periprosthetic joint infection may outweigh the benefits of elective arthroplasty, so patients need to be fully informed before gaining consent for the index procedure.

In addition, preoperative screening and subsequent treatment of meticillin-resistant *Staphylococcus aureus* in joint arthroplasty patients has dramatically reduced surgical site infection and periprosthetic joint infection rates (Nixon et al, 2006; Pofahl et al, 2009). Swabs are typically obtained from the nose, axilla or groin regions, and patients diagnosed with meticillin-resistant *S. aureus* undergo a daily 2% chlorhexidine shower for 5 days before their operation, with or without the application of 2% mupirocin intranasal ointment, with additional contact precautions during their hospital stay (Sporer et al, 2011).

Perioperative interventions

Administration of perioperative antibiotics is an important prophylactic measure in reducing periprosthetic joint infection, as recognized by the International Consensus Meeting on Periprosthetic Joint Infection (Parvizi et al, 2013). It is recommended that antibiotics are administered within 1 hour before the surgical incision. This ensures adequate antibiotic tissue concentrations at the time of incision. The use of first or second-generation cephalosporin antibiotics is recommended for routine procedures, as these give broad-spectrum cover of anaerobic gram-positive organisms and aerobic gram-negative bacilli. In patients with known cephalosporin allergies clindamycin may be used. Vancomycin remains an alternative but is

Mr David A George *is Clinical and Research Registrar, Trauma and Orthopaedic Surgery, University College Hospital London, London NW1 2BU,* **Mr Mohsin Khan** *is Clinical and Research Registrar, Trauma and Orthopaedic Surgery, University College Hospital London, and* **Professor Fares S Haddad** *is Consultant Orthopaedic Surgeon, University College London and Princess Grace Hospitals, and Director, Institute of Sport, Exercise and Health, UCL, London*

Correspondence to: Mr DA George (davidgeorge@doctors.org.uk)

usually recommended for patients with known meticillin-resistant *S. aureus* colonization, health-care workers and preoperative inpatients to negate the risk of developing vancomycin-resistant infections (Bozic et al, 2014).

As soon as the patient arrives in theatre the surgical site should be meticulously prepared before incision. Hair should be removed immediately before the procedure using electric clippers and skin prepared with an alcohol-based solution. Both methods have been proven to reduce surgical site infections (Vanhegan et al, 2012; Dumville et al, 2013). A Cochrane review suggests preoperative skin preparation with 0.5% chlorhexidine in methylated spirits is associated with lower rates of surgical site infections than alcohol-based povidone iodine preparations (Dumville et al, 2013).

A strict sterile field must be maintained throughout the operation. Following correct patient positioning on the operating table, the ipsilateral limb is prepared with a sterile antimicrobial solution from pelvis to ankle, and the foot isolated within a separate sterile drape. Further surgical drapes surround the operative field and an antimicrobial incision drape is placed over the patient's exposed skin, isolating the incision site. The surgeon will take further precautions during the operation by frequently changing his/her surgical gloves to prevent bacterial contamination from perforations (Parvizi et al, 2013). In addition wound pulsatile lavage with 0.9% sodium chloride solution, and irrigation with dilute betadine before closure reduces the bacterial load and consequently reduces periprosthetic joint infection risk (Parvizi et al, 2013).

Diagnosis

No single standard test can accurately diagnose periprosthetic joint infection, and diagnosis often depends upon a combination of clinical suspicion, clinical features, serological investigations, diagnostic imaging and microbiological analysis. Tsukayama et al (2003) proposed a classification system dividing periprosthetic joint infection into four categories, dependant on timing of presentation from index procedure (*Table 1*), to help the clinician manage such patients.

Clinical features

Clinical features vary depending upon the time of onset. Patients with identifiable risk factors should be monitored for continuous wound discharge, delayed healing, persistence of pain and dehiscence in the postoperative period. Any postoperative wound which causes concern should prompt the clinician to suspect periprosthetic joint infection and warrant an early senior orthopaedic review.

However, a patient may present in a number of ways, as there is a spectrum of clinical features associated with periprosthetic joint infection which will dictate the operative urgency. This includes non-specific pain on weight bearing of insidious onset, an acutely painful joint that is warm, erythematous and oedematous, or septic shock with multi-organ dysfunction.

Serological investigations

The suspicion of periprosthetic joint infection is heightened in the presence of raised inflammatory markers, specifically erythrocyte sedimentation rate and C-reactive protein. An erythrocyte sedimentation rate >30 mm/hr and C-reactive protein level >10 mg/litre have sensitivity of 94.4% and 91.1% respectively, but combining both erythrocyte sedimentation rate and C-reactive protein level increased the sensitivity to 97.6% (Dumville et al, 2013). A systematic review and meta-analysis including 30 eligible studies observed the highest sensitivity and specificity for diagnosing periprosthetic joint infection with serum interleukin-6 (IL-6), followed by C-reactive protein, erythrocyte sedimentation rate and the white blood cell count (Beldame et al, 2012). However, serum erythrocyte sedimentation rate and C-reactive protein level can be raised with concomitant infection, inflammation and neoplasm, but when both markers are not elevated infection is doubtful (*Table 2*) (Brown et al, 2012).

Following uncomplicated joint surgery serum IL-6 levels peak at postoperative day 2 and rapidly return to normal, whereas C-reactive protein levels can take 3 weeks and erythrocyte sedimentation rate 3 months to 1 year to return to normal parameters (Berbari et al, 2010). Measurement of serum IL-6 levels appears invaluable, but detection requires specialized enzyme-linked immunosorbent assay kits, which are expensive, time-consuming and not readily accessible on the NHS.

Table 1. Modified classification of periprosthetic joint infection

Type	Timing of diagnosis
1	Positive intraoperative culture
2	Early postoperative period (within 1 month), subcategorised as a superficial or deep infection
3	Secondary to an acute haematogenous source
4	Late chronic period as a result of inoculation at the time of surgery

From Tsukayama et al (2003)

Table 2. Mean serological and synovial values comparing infected and non-infected total hip arthroplasty

	Infected (*n*=9)		Not infected (*n*=23)		*P* value
	Mean	Range	Mean	Range	
Erythrocyte sedimentation rate (mm/hr)	69	6–140	46	8–80	0.02
C-reactive protein (mg/litre)	192	5–395	30	5–68	<0.01
Synovial white blood count	84 954	1400–455 322	2391	260–12 680	<0.01
Differential (% percentage polymorphonuclear cells)	91%	64–99%	63%	19–96%	<0.01

From Kwee et al (2008)

Diagnostic imaging

All patients investigated for periprosthetic joint infection must undergo baseline orthogonal view radiographs. This includes an anterio-posterior view of the pelvis and lateral views of the symptomatic hip. Although not immediately useful in an acute setting they convey important information about the implant, bone–cement–implant interface and surrounding soft tissue. Plain radiographs cannot differentiate between infection and aseptic prosthetic loosening in the presence of periostitis, endosteal reaction, periprosthetic lucency, osteolysis, and migration seen on X-ray.

Ultrasound scanning remains a non-invasive diagnostic investigation which can confirm an effusion and facilitate aseptic aspiration. Computed tomography and magnetic resonance imaging are often used in more complex cases and provide information on the surrounding soft tissue. However, images are commonly hampered by implant-induced artifact, even in non-ferromagnetic prostheses such as titanium (Tsukayama et al, 2003).

Nuclear medicine has a pivotal role in helping to differentiate between aseptic loosening and periprosthetic joint infection. Isotope bone scans and positron emission tomography (PET) are not affected by the presence of underlying metallic joint implants. Technetium-99m isotope bone scans have very high sensitivity for detecting implant failure but remain non-specific for infection, which limits their use (Brown et al, 2012). Indium-111-labelled white cell scans are time consuming and expensive but yield higher sensitivity (77%), specificity (86%) and negative predictive value (95%) for infection (Brown et al, 2012). A review concluded that an indium-111-labelled white cell scan, combined with bone marrow imaging using technetium-99m sulphur colloid, approaches 90% accuracy in detecting periprosthetic joint infection and should be the imaging test of choice (Toms et al, 2006).

Fluorine-19-fluoro-2-deoxy-D-glucose (FDG)-PET scanning enables areas of increased metabolic activity to be visualized, which suggests infection. A review and meta-analysis comprising 11 eligible studies found pooled sensitivity and specificity of FDG-PET to be 82.1% and 86.6% respectively (Della Valle et al, 2010). However, the results of the individual studies were heterogeneous which the authors were unable to fully explore. The diagnostic potential of FDG-PET is evident but further studies are needed.

Microbiological analysis

The organisms most commonly isolated in periprosthetic joint infection are *S. aureus* and *S. epidermidis*, followed by gram-negative bacteria (Toms et al, 2006). A variety of sources can be used for microbiological analysis.

Synovial fluid aspirate is submitted for cell count and differential, gram stain, and aerobic and anaerobic culture and is warranted in the majority of patients suspected of having a periprosthetic joint infection. These tests have a high specificity (88–97%) but variable sensitivity (50–92%), attributable to variability in technique and criteria for positive findings used in different studies (Brown et al, 2012).

The gram-stain technique is a rapid universally exploited laboratory test to distinguish between gram-positive and gram-negative bacteria. These tests have a low sensitivity but high specificity, so a negative gram stain implies that no infection is present (Del Arco and Bertrand, 2013).

Polymerase chain reaction and enzyme-linked immunosorbent assay techniques are extremely sensitive in detecting periprosthetic joint infections. However, polymerase chain reaction is unable to distinguish between active and eradicated infections, and is an expensive investigation not available for routine clinical use (Toms et al, 2006).

Synovial fluid culture has a sensitivity of 56–75% and specificity of 95–100% (Berbari et al, 2010). A leucocyte count of 4200 cells/μl has a sensitivity of 84% and a specificity of 93% (Del Pozo and Patel, 2009). The presence of leucocyte esterase, an enzyme secreted by neutrophils, in addition to an elevated leucocyte count improves the sensitivity to 92.9% with a leucocyte count of > 3000 cells/μl (Parvizi et al, 2011; Gemmel et al, 2012). A single positive microbiological sample may be the result of contaminant organisms and should be evaluated in the context of other available results. The International Consensus on Periprosthetic Joint Infection (Parvizi et al, 2013) defines a positive test as bacterial growth in two or more separate samples, and therefore a repeat aspirate may be required, depending on the patient's clinical state and serological parameters.

Empirical antimicrobial treatment of patients suspected of periprosthetic joint infection is not advised as it may mask the underlying pathogen, unless the patient is systemically compromised and life-saving broad-spectrum antibiotics are indicated. Withholding antimicrobial therapy for a minimum of 2 weeks before hip aspiration or intraoperative tissue collection increases the likelihood of recovering the organism (Del Pozo and Patel, 2009). This allows the clinician to begin an appropriate antibiotic regimen without compromising future antibiotic resistance. Aseptic aspiration should never be performed over overlying cellulitis because of the risk of introducing infection into the hip joint, and may require imaging guidance to improve yield.

However, the results of a joint aspiration may remain negative despite high clinical suspicion and clinical features. Arthroscopy or arthrotomy may be required for tissue biopsy, as this improves sensitivity and accuracy (Meermans and Haddad, 2010).

Intraoperative microbiology sampling

In all surgical options, multiple intraoperative tissue samples should be sent for microbiology and histopathological analysis (Del Pozo and Patel, 2009). Atkins et al (1998) recommend that five or six specimens be sent intraopera-

tively, as they showed that the isolation of an indistinguishable microorganism from three or more independent specimens was highly predictive of infection (sensitivity 65%, specificity 99.6%, likelihood ratio 168.6).

Perioperative gram staining has a wide range of reported sensitivity and should be interpreted with caution (Brown et al, 2012).

The explanted prostheses or components can be submitted for culture and sonification (a process which enhances the isolation of organisms from the prostheses). Trampuz et al (2007) found the sensitivity of periprosthetic sonicate-fluid culture in diagnosing hip periprosthetic joint infection was higher at 78.5% than a single periprosthetic tissue culture at 60.8% ($P<0.001$) (Wetters et al, 2012).

Perioperative frozen sections have a sensitivity of 43–100% and specificity of 94–100% in confirming periprosthetic joint infection (Brown et al, 2012). They may have a role in confirming the eradication of infection during the second part of the two-stage exchange before re-implantation.

Diagnosis in the early postoperative period

Within the first 6 weeks postoperatively the diagnosis of periprosthetic joint infection can be exceptionally difficult. The wound is understandably tender, oedematous and may be erythematous secondary to trauma to the surrounding tissue from surgery. In addition, serological markers such as erythrocyte sedimentation rate and C-reactive protein level are likely to be raised.

In a retrospective review of revision total hip arthroplasty, a large variation in biochemical parameters was identified between infected and non-infected cases. Yi et al (2014) suggested the following cut-off values in predicting periprosthetic joint infection in the early postoperative period: synovial fluid white blood cell count of >12 800 cells/μl, C-reactive protein level >93 mg/litre, and synovial fluid differential of >89% polymorphonuclear cells. This enables an algorithmic approach to treatment; if the C-reactive protein level is raised greater than 93 mg/litre, a hip aspiration is indicated, and if the aspirate yields a white blood cell count greater than 12 800 cells/μl in combination with greater than 89% differential, operative management is indicated (Yi et al, 2014). In cases where the diagnosis is uncertain the clinician can wait for culture results before proceeding.

Management

Patients diagnosed with periprosthetic joint infection will invariably require definitive operative surgery. Conservative management may only be advocated if the risk of surgery outweighs its benefits depending on the patient's comorbidities and his/her systemic physiological state (*Figure 1*). Definitive surgical management involves open irrigation and debridement, with options for either implant retention or exchange arthroplasty in a single or two-stage approach.

Irrigation and debridement

Debridement, antibiotics and implant retention with exchange of modular bearing surface is the least invasive of all surgical options and traditionally advocated in the early postoperative period (Sukeik et al, 2012). Eligibility for this approach includes healthy patients, presenting within the first 4–6 weeks postoperatively with a stable implant, no sinus tract and an organism of low virulence (Del Pozo and Patel, 2009). The success of the debridement, antibiotics and implant retention approach varies dramatically between institutions, ranging from 14–100% (Kwee et al, 2008; Osmon et al, 2013).

Single-stage exchange arthroplasty

Exchange arthroplasty is increasingly used, especially when debridement, antibiotics and implant retention is contraindicated or has failed, or when the patient presents late with an established infection. A single-stage exchange protocol has been used and advocated by European centres. It has inherent advantages of being a single procedure associated with reduced costs, decreased morbidity, improved patient satisfaction and quality of life when compared to a two-stage exchange (Del Pozo and Patel, 2009). The procedure involves meticulous removal of the prosthesis and associated cement, a thorough debridement, and reimplantation of a new prosthesis typically with antibiotic-impregnated cement (Hansen et al, 2013). This is combined with a 6-week course of culture-specific oral antibiotics.

Indications for single-stage exchange arthroplasty are varied, and should be avoided when the organism is unknown or culture-negative, multi-drug resistant, significant soft tissue loss is expected, and the patient is immunosuppressed or systemically unwell (Del Pozo and Patel, 2009; Del Arco and Bertrand, 2013). In such scenarios a two- or multi-stage exchange arthroplasty should be planned in a multidisciplinary setting (e.g. involving plastic surgeons in cases of significant tissue loss) (Parvizi et al, 2011). Success at eradicating periprosthetic joint infection with single-stage exchange procedure ranges from 56–100% (Aggarwal et al, 2013; Hansen et al, 2013). The presence of a cutaneous sinus or fistula may contaminate operative cultures and hinder antimicrobial treatment, but a success rate of 86% has been demonstrated following single-stage exchange for deep infections with associated sinuses at an average of 7 years of follow up (Raut et al, 1994).

Two-stage exchange arthroplasty

This approach encompasses a period of localized antibiotic treatment via an antibiotic-impregnated acrylic spacer left in situ following initial irrigation, debridement, and implant (with associated cement) removal. The antibiotic-impregnated spacer allows a localized field of high concentration antibiotic that is not achievable with systemic treatment (Yi et al, 2014). Intravenous antibiotics are continued for 6 weeks postoperatively after the first stage.

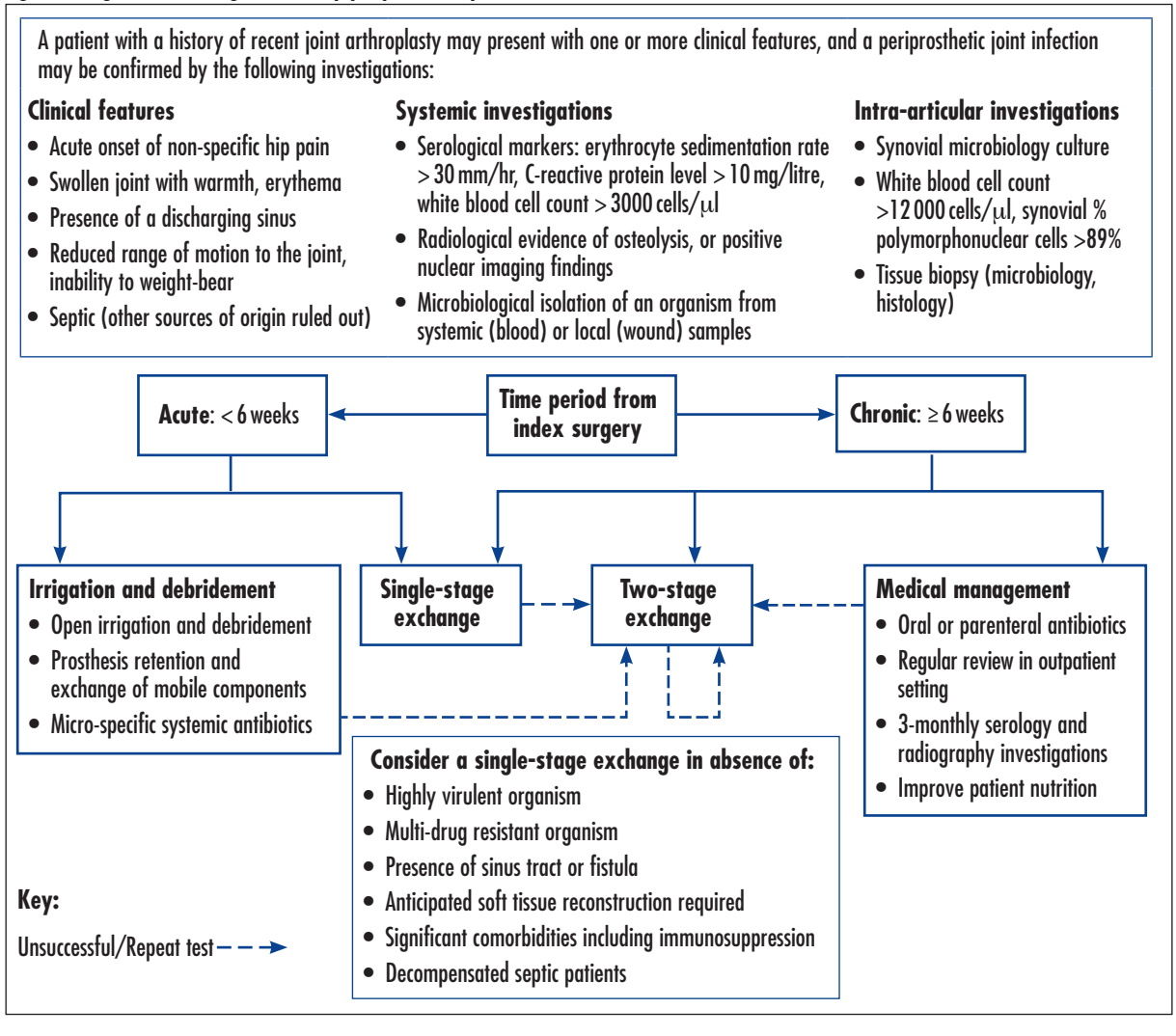
Within the literature there is little evidence to suggest an optimal time for undertaking the second stage (Joseph et al, 2003). Several factors must be taken into consideration when deciding to exchange the spacer for the permanent prosthesis. This includes the quality and healing of the soft tissue, the patient's general wellbeing, quality of bone stock, and the haematological and serological response to antibiotics (although the erythrocyte sedimentation rate and C-reactive protein level may not normalize) (Haddad et al, 2000). The second stage may take place within 2–6 weeks of initial resection (Osmon et al, 2013), or after several months when significant healing has occurred. During re-implantation antibiotic-impregnated cement or local antibiotic-eluting substances are used where possible (Youngman et al, 2003).

Despite the prolonged hospital stay, duration of treatment and economic implications, a two-stage exchange is currently the gold standard of care especially if a single-stage exchange procedure is contraindicated (*Figure 1*). The interval between the two stages allows time to address the most life-threatening complications, and enables a combination of systemic and local antibiotic release. The perceived recurrence rate from a single-stage exchange procedure may persuade surgeons to opt for a two-stage exchange despite the absence of contraindications. Differences in success rates between single-stage and two-stage procedures have not been clearly demonstrated. Reported success rates of a two-stage procedure range from 74% to 96% (Haddad et al, 2000; Parvizi et al, 2008).

Conclusions

The occurrence of a periprosthetic joint infection is a devastating complication associated with significant clinical and socioeconomic hardship for both patient and institution. The patient is subjected to a multitude of invasive investigations, long-term antibiotics and further surgical procedures. This has an incredibly negative effect on patient morbidity, function and outcome. Surgeon and patient education are vital in increasing efforts to prevent or reduce periprosthetic joint infection risk through meticulous preoperative planning, patient optimization and patient compliance. If periprosthetic joint infection is suspected the clinician has an array of inves-

Figure 1. Algorithmic management of hip periprosthetic joint infection at the authors' institution.



tigations using an algorithmic approach to allow rapid diagnosis and facilitate appropriate management.

The indication and patient characteristics determine which treatment modality is undertaken. Both the single- and two-stage exchange protocols have advantages and disadvantages. Neither a single- nor a two-stage exchange can guarantee infection eradication, so patient education regarding the complexity of the condition is key. **BJHM**

Conflict of interest: none.

Aggarwal VK, Rasouli MR, Parvizi J (2013) Periprosthetic joint infection: Current concept. *Indian J Orthop* **47**(1): 10–17 (doi: 10.4103/0019-5413.106884)

Atkins BL, Athanasou N, Deeks JJ et al (1998) Prospective evaluation of criteria for microbiological diagnosis of prosthetic-joint infection at revision arthroplasty. The OSIRIS Collaborative Study Group. *J Clin Microbiol* **36**(10): 2932–9

Beldame J, Lagrave B, Lievain L, Lefebvre B, Frebourg N, Dujardin F (2012) Surgical glove bacterial contamination and perforation during total hip arthroplasty implantation: when gloves should be changed. *Orthop Traumatol Surg Res* **98**(4): 432–40 (doi: 10.1016/j.otsr.2011.10.015)

Berbari E, Mabry T, Tsaras G et al (2010) Inflammatory blood laboratory levels as markers of prosthetic joint infection: a systematic review and meta-analysis. *J Bone Joint Surg Am* **92**(11): 2102–9 (doi: 10.2106/JBJS.I.01199)

Bozic KJ, Ward DT, Lau EC et al (2014) Risk factors for periprosthetic joint infection following primary total hip arthroplasty: a case control study. *J Arthroplasty* **29**(1): 154–6 (doi: 10.1016/j.arth.2013.04.015)

Brown NM, Cipriano CA, Moric M, Sporer SM, Della Valle CJ (2012) Dilute betadine lavage before closure for the prevention of acute postoperative deep periprosthetic joint infection. *J Arthroplasty* **27**(1): 27–30 (doi: 10.1016/j.arth.2011.03.034)

Del Arco A, Bertrand ML (2013) The diagnosis of periprosthetic infection. *Open Orthop J* **7**: 178–83 (doi: 10.2174/1874325001307010178)

Del Pozo JL, Patel R (2009) Clinical practice. Infection associated with prosthetic joints. *N Engl J Med* **361**(8): 787–94 (doi: 10.1056/NEJMcp0905029)

Della Valle C, Parvizi J, Bauer TW et al (2010) Diagnosis of periprosthetic joint infections of the hip and knee. *J Am Acad Orthop Surg* **18**(12): 760–70

Dumville JC, McFarlane E, Edwards P, Lipp A, Holmes A (2013) Preoperative skin antiseptics for preventing surgical wound infections after clean surgery. *Cochrane Database Syst Rev* **3**: CD003949 (doi: 10.1002/14651858.CD003949.pub3)

Gemmel F, Van den Wyngaert H, Love C, Welling MM, Gemmel P, Palestro CJ (2012) Prosthetic joint infections: radionuclide state-of-the-art imaging. *Eur J Nucl Med Mol Imaging* **39**(5): 892–909 (doi: 10.1007/s00259-012-2062-7)

Haddad FS, Muirhead-Allwood SK, Manktelow AR, Bacarese-Hamilton I (2000) Two-stage uncemented revision hip arthroplasty for infection. *J Bone Joint Surg Br* **82**(5): 689–94

Hansen E, Tetreault M, Zmistowski B et al (2013) Outcome of one-stage cementless exchange for acute postoperative periprosthetic hip infection. *Clin Orthop Relat Res* **471**(10): 3214–22 (doi: 10.1007/s11999-013-3079-3)

Ibrahim MS, Khan MA, Nizam I, Haddad FS (2013) Peri-operative interventions producing better functional outcomes and enhanced recovery following total hip and knee arthroplasty: an evidence-based review. *BMC Med* **11**: 37 (doi: 10.1186/1741-7015-11-37)

Joseph J, Raman R, Macdonald DA (2003) Time interval between first and second stage revision hip arthroplasty for infection, the effect on outcome. *J Bone Joint Surg Br* **85-B**(suppl I): 58

Kwee TC, Kwee RM, Alavi A (2008) FDG-PET for diagnosing prosthetic joint infection: systematic review and metaanalysis. *Eur J Nucl Med Mol Imaging* **35**(11): 2122–32 (doi: 10.1007/s00259-008-0887-x)

Meermans G, Haddad FS (2010) Is there a role for tissue biopsy in the diagnosis of periprosthetic infection? *Clin Orthop Rel Res* **468**(5): 1410–17 (doi: 10.1007/s11999-010-1245-4)

Nixon MB, Jackson B, Varghese P, Jenkins D, Taylor G (2006) Methicillin-resistant *Staphylococcus aureus* on orthopaedic wards. Incidence, spread, mortality, cost and control. *J Bone Joint Surg Br* **88**(6): 812–17

Osmon DR, Berbari EF, Berendt AR et al (2013) Executive summary: Diagnosis and management of prosthetic joint infection: clinical practice guidelines by the Infectious Diseases Society of America. *Clin Infect Dis* **56**(1): e1–e25 (doi: 10.1093/cid/cis966)

Oussedik S, Gould K, Stockley I, Haddad FS (2012) Defining peri-prosthetic infection: do we have a workable gold standard? *J Bone Joint Surg Br* **94**(11): 1455–6 (doi: 10.1302/0301-620X.94B11.30244)

Parvizi J, Ghanem E, Azzam K, Davis E, Jaberi F, Hozack W (2008) Periprosthetic infection: are current treatment strategies adequate? *Acta Orthop Belg* **74**(6): 793–800

Parvizi J, Jacovides C, Antoci V, Ghanem E (2011) Diagnosis of periprosthetic joint infection: the utility of a simple yet unappreciated enzyme. *J Bone Joint Surg Am* **93**(24): 2242–8 (doi: 10.2106/JBJS.J.01413)

Parvizi J, Gehrke T, Chen AF (2013) Proceedings of the International Consensus on Periprosthetic Joint Infection. *Bone Joint J* **95-B**(11): 1450–2 (doi: 10.1302/0301-620X.95B11.33135)

Pofahl WE, Goettler CE, Ramsey KM, Cochran MK, Nobles DL, Rotondo MF (2009) Active surveillance screening of MRSA and eradication of the carrier state decreases surgical-site infections caused by MRSA. *J Am Coll Surg* **208**(5): 981–6 (doi: 10.1016/j.jamcollsurg.2008.12.025)

Raut VV, Siney PD, Wroblewski BM (1994) One-stage revision of infected total hip replacements with discharging sinuses. *J Bone Joint Surg Br* **76-B**(5): 721–4

Sporer S, Hjerstedt K, Coleman J et al (2011) Preoperative *Staphylococcus aureus* screening to reduce surgical site infection. Presented at the American Academy Orthopaedic Surgeons Annual Meeting, San Diego, CA

Sukeik M, Patel S, Haddad FS (2012) Aggressive early debridement for treatment of acutely infected cemented total hip arthroplasty. *Clin Orthop Relat Res* **470**(11): 3164–70 (doi: 10.1007/s11999-012-2500-7)

Toms AD, Davidson D, Masri BA, Duncan CP (2006) The management of peri-prosthetic infection in total joint arthroplasty. *J Bone Joint Surg Br* **88**(2): 149–55

Trampuz A, Piper KE, Jacobson MJ et al (2007) Sonication of removed hip and knee prostheses for diagnosis of infection. *N Engl J Med* **357**(7): 654–63

Tsukayama DT, Goldberg VM, Kyle R (2003) Diagnosis and management of infection after total knee arthroplasty. *J Bone Joint Surg Am* **85-A**(Suppl 1): S75–80

Vanhegan IS, Malik AK, Jayakumar P, Ul Islam S, Haddad FS (2012) A financial analysis of revision hip arthroplasty: the economic burden in relation to the national tariff. *J Bone Joint Surg Br* **94**(5): 619–23 (doi: 10.1302/0301-620X.94B5.27073)

Wetters NG, Berend KR, Lombardi AV, Morris MJ, Tucker TL, Della Valle CJ (2012) Leukocyte esterase reagent strips for the rapid diagnosis of periprosthetic joint infection. *J Arthroplasty* **27**(8 Suppl): 8–11 (doi: 10.1016/j.arth.2012.03.037)

Yi PH, Cross MB, Moric M, Sporer SM, Berger RA, Della Valle CJ (2014) The 2013 Frank Stinchfield Award: Diagnosis of infection in the early postoperative period after total hip arthroplasty. *Clin Orthop Relat Res* **472**(2): 424–9 (doi: 10.1007/s11999-013-3089-1)

Youngman JR, Ridgway GL, Haddad FS (2003) Antibiotic-loaded cement in revision joint replacement. *Hosp Med* **64**(10): 613–16 (doi: 10.12968/hosp.2003.64.10.2330)

KEY POINTS

- The management of periprosthetic joint infections is complex, requiring a multidisciplinary approach.
- Multiple methods of prevention and management are available, with varying degrees of sensitivity.
- Pathogen-specific antibiotic therapy combined with surgical debridement and revision arthroplasty is key to successful eradication of infection.