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Review

Current Diagnostic Methods for Periprosthetic Joint Infection

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Total joint arthroplasty is a successful joint replacement treatment that improves joint function and overall quality of life and provides pain relief. However, the prevalence of periprosthetic joint infection (PJI) has become prevalent with the rise in the incidence of arthroplasty surgery. PJI occurs rarely following arthroplasty however presents with serious complications, including high morbidity. The identification of causative microorganisms is essential for the treatment of PJI. Managing PJI requires complex treatment strategies, including long-term antibacterial treatment, and significant medical costs can be incurred. The American Academy of Orthopedic Surgeons, the Centers for Disease Control and Prevention, and Surgical Care Improvement Project guidelines recommend that prophylactic antibiotics such as first-generation cephalosporins be infused completely 1 hour before surgical incision. However, these preventative antibiotics are very limited, therefore risk factors must be identified to diagnosis and treat patients effectively. Moreover, determining antimicrobial susceptibility during artificial joint surgery and choosing the most appropriate treatment strategy following an accurate diagnosis of microbial infections are essential. In the present review, we describe the management, including the etiology, diagnosis, and classification of PJI, and approaches to its diagnosis using the available novel molecular diagnostic methods.

Key Words: Periprosthetic joint infection (PJI), Diagnosis, Molecular diagnostic methods

INTRODUCTION

Definition of periprosthetic joint infection

Periprosthetic joint infection (PJI) is a terrible complication after total joint arthroplasty. It occurs in 0.8% to 1.9% of knee arthroplasties and 0.3% to 1.7% of hip arthroplasties (Frisch et al., 2017). PJI has a negative influence on joint function as it reduces quality of life and is associated with increased morbidity and mortality (Watanabe et al., 2021). In 2011, the Society for Musculoskeletal Infections and the Society for Infectious Diseases developed standardized criteria to define PJI. However, in 2018, a new definition was introduced for diagnostic purposes to address the limitations of the previous version (Parvizi et al., 2018). Although there is no universal definition of PJI, diagnostic accuracy

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Table 1. 2018 Evidence-based stepwise algorithm for diagnosis of PJI

	Score	Decision
Major criteria (at least one of the following)		
Two positive cultures of the same organism		Infected
Sinus tract with evidence of communication to the joint or visualization of the prosthesis		
Minor criteria (preoperative)		
Elevated CRP or D-dimer (serum)	2	
Elevated ESR (serum)	1	≥6 Infected
Elevated synovial WBC count or LE (synovial)	3	2~5 Possibly infected
Positive alpha-defensin (synovial)	3	
Elevated synovial PMN (%) (synovial)	2	0~1 Not infected
Elevated synovial CRP (synovial)	1	
Intraoperative diagnosis		
Preoperative score	−	≥6 Infected
Positive histology	3	4~5 Inconclusive
Positive purulence	3	
Single positive culture	2	≤3 Not infected

Data from the article of Parvizi et al. (J Arthroplasty. 2018. 33: 1309-1314.e2)
PJI: periprosthetic joint infection, CRP: C-reactive protein, ESR: erythrocyte sedimentation rate, WBC: white blood cell, LE: leukocyte esterase, PMN: polymorphonuclear

and collaborative research have improved with the introduction of the new criteria (Table 1).

Classification of periprosthetic joint infection

The classification of PJI is based on the time since the primary onset of symptoms. In order to identify PJI, one or more of the following criteria must be observed:

1. Growth of the same microorganism in two or more cultures obtained via joint aspiration or during surgery
2. Inflammation and/or open wounds at the implant site
3. Granulocytes in the tissue surrounding the implant site
4. Joint effusion, prosthetic loosening, and/or the presence of a sinus tract connection to the device

Microorganisms associated with periprosthetic joint infection

A wide range of pathogens can cause PJI, including aerobic and anaerobic bacteria and fungi (Peel et al., 2012; Tande and Patel, 2014). Microorganisms that cause PJI are divided into monomicrobial and polymicrobial species, and their distribution is different. Monomicrobial PJIs are primarily caused by *Staphylococcus epidermidis* and *S. aureus* followed by *Streptococcus* species, Gram-negative bacilli, *Enterococcus* species, non-epidermidis coagulase-negative Staphylococci (CoNS), *Corynebacterium* species, *Granulicatella adiacens*, and anaerobic Gram-positive bacteria, among others. Polymicrobial PJIs have a different species distribution compared to monomicrobial microorganisms (Table 2) (Flurin et al., 2019). The initial infection is predominantly caused by Staphylococci or Gram-negative bacillus. Low-virulence infections are characterized by subtle or absent symptoms. The most common type of infection is caused by microorganisms with low toxicity such as *S. aureus*, CoNS, and *Streptococci*. Late infection is caused by hematoma dissemination and characterized by a sudden increase in local joint pain due to inflammation.

Diagnosis of periprosthetic joint infection

Informations on the site for diagnose of PJI from the included diagnosis-related meta-analysis methods were found in papers (AlBuhairan et al., 2008). Histopathological examinations, molecular diagnostic methods, sonication of removed implants, alpha defensing, synovial fluid analysis, and imaging studies from different samples have been

Table 2. Pathogens isolated from the hip and knee PJIs, sorted by monomicrobial and polymicrobial infection cases

Microorganism	Monomicrobial infection	Polymicrobial infection	*P* value
Staphylococcus epidermidis	97 (35%)	19 (59%)	0.007
Staphylococcus aureus	58 (21%)	7 (22%)	0.9
Other coagulase-negative Staphylococci (CoNS)	17 (6%)	8 (25%)	0.0002
Enterococcus sp.	16 (6%)	9 (28%)	< 0.0001
Corynebacterium sp.	8 (3%)	5 (16%)	0.0007
Gram-negative bacilli	21 (8%)	3 (9%)	0.7
Streptococcus sp.	31 (11%)	2 (6%)	1
Granulicatella adiacens	6 (2%)	0 (0%)	−
Finegoldia magna	4 (1%)	6 (19%)	< 0.0001
Cutibacterium acnes	9 (3%)	3 (9%)	0.1
Others	11 (4%)	4 (12%)	−

proposed for the most accurate diagnosis of PJI (Trampuz, 2003). Among the most frequently used diagnostic methods are synovial fluid analysis (Balato et al., 2020), imaging (Aggarwal et al., 2016), and the histological examination of periprosthetic tissue cultures (Guilera et al., 2012).

1. Molecular diagnostic methods

An emerging PJI diagnostic approach is the molecular diagnostic method, which uses polymerase chain reaction (PCR) technology. Non-culturable PJI can be diagnosed and, theoretically, tested rapidly using the PCR technique. PCR analysis can be divided into two types, namely, a specific PCR and a broad-range PCR. In particular, a specific quantitative PCR (qPCR) assay can be used to perform a diagnostic test and identify a target using PCR primer pairs designed for laboratory and commercial use. These targets may include a single bacterial species (e.g., *S. aureus*), a group of closely related species (e.g., all staphylococcal species), or common resistance genes (e.g. the *mec*A gene for methicillin-resistant *S. aureus*) (Tarkin et al., 2003; Hartley and Harris, 2014; Lourtet-Hascoëtt et al., 2015). On the other hand, broad-range PCR assays targeting the 16S rRNA gene sequence are also an option. When the 16S rRNA gene is used, it is not possible to detect specific bacteria, therefore an additional analysis is required to identify specific bacteria. Additional diagnostic methods include cloning PCR amplicons and sequence analysis using next-generation sequencing (NGS) techniques (Cazanave et al., 2013).

PJI can also be diagnosed through cultures following the sonication of removed implants and periprosthetic tissues. In this method, bacterial biofilm samples present on, for example, the surfaces of implants in the hip, knee, or shoulder areas are used. In contrast, a standard specimen of periprosthetic tissue cultured during surgery cannot be used to sample the surface of the prosthesis where microorganisms attach and form a biofilm (Trampuz et al., 2006). Notably, sonication analysis using single specimens of a prosthesis is more sensitive to PJI diagnosis than periprosthetic tissue analysis, which requires multiple specimens (Piper et al., 2009; Gandhi et al., 2017). The sensitivity of sonication fluid cultures is 75% versus 54% for periprosthetic tissue, with specificities of 87% and 98%, respectively (Trampuz et al., 2006). A 2020 study demonstrated that sonication of removed implants provided better microbial identification in the diagnosis of PJI than conventional tissue cultures (Trampuz et al., 2006). Importantly, the sensitivity for PJI diagnosis was highest when both the sonication fluid cultures and periprosthetic tissue cultures were used together.

2. Biomarker

2-1. Serum biomarkers and erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP)

An ideal biomarker for rapid diagnosis of PJI should be

reliable and reproducible in a variety of environments. Although serological test results can improve diagnostic accuracy, there are difficulties in drawing final conclusions from a simply diagnostic method throughout the literature. Currently, it is impossible to early diagnose PJI with the level of WBC, ESR, CRP, and PCT, which are inflammatory markers (Dodson et al., 2010; Piper et al., 2010; Perez-Prieto et al., 2017). The sensitivity of synovial culture is still 45% to 75% and the specificity is 95%, making it a useful specimen for diagnosing PJI however synovial fluid should be taken by invasive sample collection procedure and it also could cause additional infection (Trampuz et al., 2004; Tande and Patel, 2014). It has the other limitation that it takes a long time for recovering pathogens that cause PJI by culturing, especially it takes about 14 days to have a final results and it could not detect some pathogen such as *Cutibacterium* species (Hughes et al., 2001).

2-2 Alpha-defensin test

The alpha-defensin (α-defensin) test is one of the new biomarkers for synovial fluid samples and can reportedly diagnose PJI more accurately (Deirmengian et al., 2015). Defensins are endogenous antimicrobial peptides released by polynuclear leukocytes in response to pathogens in synovial fluid. The α-defensin test can therefore be a suitable test method for diagnosing PJI caused by various organisms (Bingham et al., 2014; Deirmengian et al., 2014). In addition, the α-defensin test has shown consistent results for PJI diagnoses regardless of whether the type of organism is Gram-positive or Gram-negative bacteria, yeast, oral bacteria and virulent or less virulent organisms (Deirmengian et al., 2015).

2-3 Diagnosis using synovial fluid

Pathogen isolation can be achieved by inoculating synovial fluid into blood culture bottles and then culturing. Using this method, the appropriate antimicrobial treatment can be determined. Conventional inoculations were previously performed using agar and/or broth methods; however, inoculation into both aerobic and anaerobic blood culture bottles has since been used to accurately diagnose PJI (Hughes et al., 2001). Notwithstanding, synovial fluid samples have been found to be more positive in acute PJI than in chronic PJI (Font-Vizcarra et al., 2010).

3. Imaging techniques

In general, imaging techniques are not included among the various methods defined in the diagnostic guidelines for PJI (Diaz-Ledezma et al., 2015). Current approaches for patients with suspected PJI consist primarily of clinical and laboratory testing in addition to imaging studies. The clinical and laboratory tests include sampling by biopsy and joint aspiration, while the imaging techniques include radioactive material and nuclear medicine tests (Signore et al., 2019). The imaging techniques include X-rays and magnetic resonance imaging (MRI), among others. X-ray techniques are currently used as a general examination method for identifying patients with suspected PJI, while MRI and nuclear imaging techniques are more differentiated examination methods and can specifically identify PJI. Accordingly, although there are many imaging techniques for diagnosing PJI, MRI is considered a potential diagnostic method that can confirm the accuracy of a PJI diagnosis (Romanò et al., 2020).

4. Histological examination

Histological examinations are conducted by collecting a tissue samples from around the prosthesis that may have become infected during surgery (Shah et al., 2016). The examination criteria are based on the presence of neutrophil infiltration. The development of acute inflammation with neutrophil infiltration is strongly suggestive of PJI, and the number of neutrophils per high-power field (HPF), which is closely related to infection, varies from one to more than five neutrophils per HPF (Bémer et al., 2018).

5. Antibiotic treatment

Twelve weeks of antibiotic treatment is recommended for all surgical procedures. An effective antibiotic treatment for implant-related infections caused by Staphylococci and *Propionibacterium* sp. is rifampin, and ciprofloxacin, which has biofilm activity against Gram-negative bacteria, is also used. Table 3 summarizes the recommended antibiotic treatment targeting other microorganisms (Li et al., 2018).

Table 3. Antimicrobial treatment

Microorganisms	Antibiotics (dose)	Microorganisms	Antibiotics (dose)
Staphylococcus sp.		Gram-negative bacteria	
Oxacillin-/ methicillin-susceptible	Cefazolin(3×2 g, i.v.)* + Rifampin, (2×450 mg, p.o.), Duration 2 week	*Enterobacteriaceae* (*Escherichia coli*, *Klebsiella*, *Enterobacter*, etc.)	Ciprofloxacin (2×750 mg, p.o.)
Oxacillin-/ methicillin-resistant	Vancomycin (2×1 g, i.v.)† + Rifampin (2×450 mg. p.o.), Duration 2 week	Nonfermenters (*Pseudomonas aeruginosa*, *Acinetobacter* sp.)	Piperacillin/tazobactam (3×4.5 g, i.v.) or Meropenem (3×1 g, i.v.) or Ceftazidim (3×2 g, i.v.) + Gentamicin (1×240 mg, i.v.), Duration 2~3 week
Rifampicin-resistant§	Vancomycin (2×1 g, i.v.)†, Duration 2 week	Ciprofloxacin-resistant§	Depending on susceptibility: meropenem (3×1 g), colistin (3×3 million U) and/or fosfomycin (3×5 g), i.v.
Streptococcus sp.	Penicillin G (4×5 million U, i.v.)* or Ceftriaxon (1×2 g, i.v.), Duration 2 week	Anaerobes	
Enterococcus sp.		Gram-positive anaerobes (*Propionibacterium*, *Peptostreptococcus*, *Finegoldia magna*)	Penicillin G (4×5 million U, i.v.)* or Ceftriaxon (1×2 g, i.v.) + Rifampin (2×450 mg, p.o.), Duration 2 week
Penicillin-susceptible	Ampicillin (4×2 g, i.v.)* + Gentamicin (2×60~80 mg, i.v.)‡, Duration 2~3 week	Gram-negative anaerobes (*Bacteroides* sp.)	Clindamycin (3×600 mg, i.v.), Duration 2 week
Penicillin-resistant§	Vancomycin (2×1 g, i.v.)† or + Gentamicin (2×60~80 mg, i.v.)‡, Duration 2~4 week	*Candida* sp.	
		Fluconazole-susceptible§	Caspofungin (1×50 mg, 1st day: 70 mg; i.v.), Duration 2 week

Total treatment duration: usually 2 weeks intravenously followed by oral administration
Dose-adjustment according to renal function and body weight (< 40 kg or > 100 kg)
i.v.: intravenously; p.o.: per oral
Rifampin is administered only after the new prosthesis is implanted, wounds are dried and drains are removed; in patients aged >75 years, the rifampicin dose reduced to 2×300 mg, p.o.
*In case of anaphylaxis (such as Quincke's edema, bronchospasm, anaphylactic shock) or cephalosporin allergy: vancomycin (21 g, i.v.)
†Check vancomycin trough concentration (take blood before next dose) at least 1 time per week; therapeutic range, 15~20 μg/mL
‡Give only, if gentamicin high-level (HL) is tested susceptible. In gentamicin HL-resistant enterococci: gentamicin is exchanged with ceftriaxone (1×2 g, i.v.)

DISCUSSION AND CONCLUSION

A preoperative diagnosis of PJI is important when considering treatment outcomes. However, a definitive diagnostic method to identify the causative microorganisms or the optimal treatment strategy for PJI have not been clearly described in clinical studies.

Commercially available methods for diagnosis of PJI are the ELISA test targeting alpha defensin and Elastase enzyme released by neutrophil, the PCR test using universal 16S rRNA gene and pathogen-specific PCRs, and microbiological culture methods (Table 4). The diagnosis and proper management of PJI are challenging, and it is unclear which biomarker is the best for diagnosing PJI. Most PJI cases that have developed within the first year after surgery and they begin with a microbial infection at the time of surgery. These infections could be also occurred through direct contact with tissues surrounding the prosthesis or implant, or through aerosol contamination.

According to a recent report, main causative agents of PJI are *S. epidermidis* and *S. aureus*, followed by *Streptococcus* species, Gram-negative bacilli, *Enterococcus* species,

Table 4. Commercially available methods for diagnosis of PJI

Manufacturer	Target	Specimen	Diagnostic methods
ZIMMER BIOMET	Alpha defensin	Synovial fluid	ELISA test
ZIMMER BIOMET	Elastase enzyme released by neutrophil	Synovial fluid	ELISA test
ZIMMER BIOMET	Microbial antigen (*Staphylococcus* sp., *Enterococcus* sp. and *Cutibacterium acnes* (called *P. acnes*) in the synovial fluid	Synovial fluid	Bead-based method
ZIMMER BIOMET	Crystal analysis- CPPD (calcium pyrophosphate dehydrate) and/or MSU (monosodium urate) crystals.	Synovial fluid	Microscopic observation
Thermo-Fisher	Universal 16S rRNA gene and pathogen-specific PCRs	Synovial fluid	PCR assays
Calprest NG	Calprotectin	Synovial fluid	ELISA test
Laboratory manual	CoNS and *Candida* sp.	Synovial fluid	Microbiological culture

non-epidermidis CoNS, *Corynebacterium* species, *Granulicatella adiacens*, and anaerobic Gram-positive bacteria, including *C. acnes*, *Finegoldia magna*, and others (Flurin et al., 2019). It is expected that the rapid identification of these bacteria will reduce the incidence of PJI. According to molecular diagnostic assays should be developed as novel diagnostic approaches for more sensitive, specific, and accurate diagnosis of PJI. Molecular diagnostic assay is a highly sensitive and specific technology, and it could provide bacterial and fungal species identification results and molecular antimicrobial susceptibility test results such as methicillin and vancomycin resistance. Therefore, it is considered that it will be possible to reduce the abuse of antibiotics by diagnosing the pathogenic bacteria causing PJI at an early stage if the high cost of causing false-positive results and susceptibility to contamination are overcome. In this review, further research is needed to early and accurately bacterial identification in synovial fluid using molecular diagnostics. Therefore, it is necessary to develop in molecular diagnostics. Currently, after PJI has occurred, clinical samples are collected, causative pathogens of PJI are cultured to diagnose, and various antibiotics are being treated to prevent infection. Before PJI occurs, however, it is considered a very effective infection prevention method. If the causative agent of PJI can be diagnosed at an early stage using molecular diagnostics, early treatment through appropriate antibiotic treatment. This review covers molecular diagnostic tests for the diagnosis of PJI, several reports including immunodiagnostic assays, and effective infection prevention methods.

Further studies are therefore required to determine the standard diagnostic methods for identifying pathogens and their antibiotic resistance, and novel serum and synovial biomarkers, with a particular focus on molecular, protein, and metabolite biomarkers that can play an important role in PJI screening and treatment strategies.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

REFERENCES

Aggarwal A, Lewison G, Idir S, Peters M, Aldige C, Boerckel W, Boyle P, Trimble EL, Roe P, Sethi T, Fox J, Sullivan R. The state of lung cancer research: A global analysis. J Thorac Oncol. 2016. 11: 1040-1050.

AlBuhairan B, Hind D, Hutchinson A. Antibiotic prophylaxis for wound infections in total joint arthroplasty: A systematic review. J Bone Joint Surg Br. 2008. 90: 915-919.

Balato G, de Matteo V, Ascione T, Di Donato SL, De Franco C, Smeraglia F, Baldini A, Mariconda M. Laboratory-based versus qualitative assessment of α-defensin in periprosthetic hip and knee infections: A systematic review and meta-analysis. Arch Orthop Trauma Surg. 2020. 140: 293-301.

Bémer P, Léger J, Milin S, Plouzeau C, Valentin AS, Stock N, Jolivet-Gougeon A, Moreau A, Corvec S, Quintin-Roue I, Tandé D, Héry-Arnaud G, Rousselet MC, Lemarié C, Kempf M, Michenet P, Bret L, de Pinieux G, Burucoa C. Histopathological diagnosis of prosthetic joint infection: Does a threshold of 23 neutrophils do better than classification of the periprosthetic membrane in a prospective multicenter study? J Clin Microbiol. 2018. 56.

Bingham J, Clarke H, Spangehl M, Schwartz A, Beauchamp C, Goldberg B. The alpha defensin-1 biomarker assay can be used to evaluate the potentially infected total joint arthroplasty. Clin Orthop Relat Res. 2014. 472: 4006-4009.

Cazanave C, Greenwood-Quaintance KE, Hanssen AD, Karau MJ, Schmidt SM, Gomez Urena EO, Mandrekar JN, Osmon DR, Lough LE, Pritt BS, Steckelberg JM, Patel R. Rapid molecular microbiologic diagnosis of prosthetic joint infection. J Clin Microbiol. 2013. 51: 2280-2287.

Deirmengian C, Kardos K, Kilmartin P, Cameron A, Schiller K, Parvizi J. Combined measurement of synovial fluid α-defensin and c-reactive protein levels: Highly accurate for diagnosing periprosthetic joint infection. J Bone Joint Surg Am. 2014. 96: 1439-1445.

Deirmengian C, Kardos K, Kilmartin P, Gulati S, Citrano P, Booth RE, Jr. The alpha-defensin test for periprosthetic joint infection responds to a wide spectrum of organisms. Clin Orthop Relat Res. 2015. 473: 2229-2235.

Diaz-Ledezma C, Lamberton C, Lichstein P, Parvizi J. Diagnosis of periprosthetic joint infection: The role of nuclear medicine may be overestimated. J Arthroplasty. 2015. 30: 1044-1049.

Dodson CC, Craig EV, Cordasco FA, Dines DM, Dines JS, Dicarlo E, Brause BD, Warren RF. *Propionibacterium* acnes infection after shoulder arthroplasty: A diagnostic challenge. J Shoulder Elbow Surg. 2010. 19: 303-307.

Flurin L, Greenwood-Quaintance KE, Patel R. Microbiology of polymicrobial prosthetic joint infection. Diagn Microbiol Infect Dis. 2019. 94: 255-259.

Font-Vizcarra L, García S, Martínez-Pastor JC, Sierra JM, Soriano A. Blood culture flasks for culturing synovial fluid in prosthetic joint infections. Clin Orthop Relat Res. 2010. 468: 2238-2243.

Frisch NB, Kadri OM, Tenbrunsel T, Abdul-Hak A, Qatu M, Davis JJ. Intraoperative chlorhexidine irrigation to prevent infection in total hip and knee arthroplasty. Arthroplast Today. 2017. 3: 294-297.

Gandhi R, Silverman E, Courtney PM, Lee GC. How many cultures are necessary to identify pathogens in the management of total hip and knee arthroplasty infections? J Arthroplasty. 2017. 32: 2825-2828.

Guilera G, Barrios M, Gómez-Benito J. Meta-analysis in psychology: A bibliometric study. Scientometrics. 2012. 94: 943-954.

Hartley JC, Harris KA. Molecular techniques for diagnosing prosthetic joint infections. J Antimicrob Chemother. 2014. 69 Suppl 1: i21-24.

Hughes JG, Vetter EA, Patel R, Schleck CD, Harmsen S, Turgeant LT, Cockerill FR, 3rd. Culture with bactec peds plus/f bottle compared with conventional methods for detection of bacteria in synovial fluid. J Clin Microbiol. 2001. 39: 4468-4471.

Lourtet-Hascoët J, Bicart-See A, Félicé MP, Giordano G, Bonnet E. Is xpert mrsa/sa ssti real-time pcr a reliable tool for fast detection of methicillin-resistant coagulase-negative Staphylococci in periprosthetic joint infections? Diagn Microbiol Infect Dis. 2015. 83: 59-62.

Li C, Renz N, Trampuz A. Management of Periprosthetic Joint Infection. Hip Pelvis. 2018. 30: 138-146.

Parvizi J, Tan TL, Goswami K, Higuera C, Della Valle C, Chen AF, Shohat N. The 2018 definition of periprosthetic hip and knee infection: An evidence-based and validated criteria. J Arthroplasty. 2018. 33: 1309-1314.e1302.

Peel TN, Cheng AC, Buising KL, Choong PF. Microbiological aetiology, epidemiology, and clinical profile of prosthetic joint infections: Are current antibiotic prophylaxis guidelines effective? Antimicrob Agents Chemother. 2012. 56: 2386-2391.

Perez-Prieto D, Portillo ME, Puig-Verdie L, Alier A, Martinez S, Sorli L, Horcajada JP, Monllau JC. C-reactive protein may misdiagnose prosthetic joint infections, particularly chronic and low-grade infections. Int Orthop. 2017. 41: 1315-1319.

Piper KE, Fernandez-Sampedro M, Steckelberg KE, Mandrekar JN, Karau MJ, Steckelberg JM, Berbari EF, Osmon DR, Hanssen AD, Lewallen DG, Cofield RH, Sperling JW, Sanchez-Sotelo J, Huddleston PM, Dekutoski MB, Yaszemski M, Currier B, Patel R. C-reactive protein, erythrocyte sedimentation rate and orthopedic implant infection. PLoS One. 2010. 5: e9358.

Piper KE, Jacobson MJ, Cofield RH, Sperling JW, Sanchez-Sotelo J, Osmon DR, McDowell A, Patrick S, Steckelberg JM, Mandrekar JN, Fernandez Sampedro M, Patel R. Microbiologic diagnosis of prosthetic shoulder infection by use of implant sonication. J Clin Microbiol. 2009. 47: 1878-1884.

Romanò CL, Petrosillo N, Argento G, Sconfienza LM, Treglia G, Alavi A, Glaudemans A, Gheysens O, Maes A, Lauri C,

Palestro CJ, Signore A. The role of imaging techniques to define a peri-prosthetic hip and knee joint infection: Multi-disciplinary consensus statements. J Clin Med. 2020. 9.

Shah RP, Plummer DR, Moric M, Sporer SM, Levine BR, Della Valle CJ. Diagnosing infection in the setting of periprosthetic fractures. J Arthroplasty. 2016. 31: 140-143.

Signore A, Sconfienza LM, Borens O, Glaudemans A, Cassar-Pullicino V, Trampuz A, Winkler H, Gheysens O, Vanhoenacker F, Petrosillo N, Jutte PC. Consensus document for the diagnosis of prosthetic joint infections: A joint paper by the eanm, ebjis, and esr (with escmid endorsement). Eur J Nucl Med Mol Imaging. 2019. 46: 971-988.

Tande AJ, Patel R. Prosthetic joint infection. Clin Microbiol Rev. 2014. 27: 302-345.

Tarkin IS, Henry TJ, Fey PI, Iwen PC, Hinrichs SH, Garvin KL. Pcr rapidly detects methicillin-resistant Staphylococci periprosthetic infection. Clin Orthop Relat Res. 2003. 10.1097/01.blo.0000087323.60612.5d: 89-94.

Trampuz A, Hanssen AD, Osmon DR, Mandrekar J, Steckelberg JM, Patel R. Synovial fluid leukocyte count and differential for the diagnosis of prosthetic knee infection. Am J Med. 2004. 117: 556-562.

Trampuz A, Piper KE, Hanssen AD, Osmon DR, Cockerill FR, Steckelberg JM, Patel R. Sonication of explanted prosthetic components in bags for diagnosis of prosthetic joint infection is associated with risk of contamination. J Clin Microbiol. 2006. 44: 628-631.

Trampuz A SJ, Osmon DR, Cockerill FR, III, Hanssen AD, Patel R. Advances in the laboratory diagnosis of prosthetic joint infection. 2003. 2003. 14: 1-14.

Watanabe S, Kobayashi N, Tomoyama A, Choe H, Yamazaki E, Inaba Y. Clinical characteristics and risk factors for culture-negative periprosthetic joint infections. J Orthop Surg Res. 2021. 16: 292.

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