REFERENCES

[1] Virolainen P, Lahteenmaki H, Hiltunen A, Sipola E, Meurman O, Nelimarkka O. The reliability of diagnosis of infection during revision arthroplasties. Scand J Surg. 2002;91:178–181.
[2] Trampuz A, Piper KE, Hanssen AD, Osmon DR, Cockerill FR, Steckelberg JM, et al. 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.
[3] Pons M, Angles F, Sanchez C, Matamala A, Cuchi E, Salavert M, et al. Infected total hip arthroplasty – the value of intraoperative histology. Int Orthop. 1999;23:34–36.
[4] Muller M, Morawietz L, Hasart O, Strube P, Perka C, Tohtz S. Diagnosis of periprosthetic infection following total hip arthroplasty – evaluation of the diagnostic values of pre- and intraoperative parameters and the associated strategy to preoperatively select patients with a high probability of joint infection. J Orthop Surg Res. 2008;3:31.
[5] Roberts P, Walters AJ, McMinn DJ. Diagnosing infection in hip replacements. The use of fine-needle aspiration and radiometric culture. J Bone Joint Surg Br. 1992;74:265–269.
[6] Kraemer WJ, Saplys R, Waddell JP, Morton J. Bone scan, gallium scan, and hip aspiration in the diagnosis of infected total hip arthroplasty. J Arthroplasty. 1993;8:611–616.
[7] Fehring TK, Cohen B. Aspiration as a guide to sepsis in revision total hip arthroplasty. J Arthroplasty. 1996;11:543–547.
[8] Mulcahy DM, Fenelon GC, McInerney DP. Aspiration arthrography of the hip joint. Its uses and limitations in revision hip surgery. J Arthroplasty. 1996;11:64–68.
[9] Ali F, Wilkinson JM, Cooper JR, Kerry RM, Hamer AJ, Norman P, et al. Accuracy of joint aspiration for the preoperative diagnosis of infection in total hip arthroplasty. J Arthroplasty. 2006;21:221–226.
[10] Somme D, Ziza JM, Desplaces N, Chicheportiche V, Chazerain P, Leonard P, et al. Contribution of routine joint aspiration to the diagnosis of infection before hip revision surgery. Joint Bone Spine. 2003;70:489–495.
[11] Bicart-See A, Lourtet J, Delpierre C, Livideanu C, Pollon T, Remi J, et al. Preoperative joint aspiration in the diagnosis of non-acute hip and knee prosthetic joint infections. Med Mal Infect. 2017;47:364–369.
[12] Claassen L, Radtke K, Ettinger M, Plaass C, von Lewinski G. Preoperative diagnostic for periprosthetic joint infection prior to total knee revision arthroplasty. Orthop Rev (Pavia). 2014;6:5437.
[13] Cross MC, Kransdorf MJ, Chivers FS, Lorans R, Roberts CC, Schwartz AJ, et al. Utility of percutaneous joint aspiration and synovial biopsy in identifying culture-positive infected hip arthroplasty. Skeletal Radiol. 2014;43:165–168.
[14] Shanmugasundaram S, Ricciardi BF, Briggs TW, Sussmann PS, Bostrom MP. Evaluation and management of periprosthetic joint infection – an international, multicenter study. HSS J. 2014;10:36–44.
[15] Williams JL, Norman P, Stockley I. The value of hip aspiration versus tissue biopsy in diagnosing infection before exchange hip arthroplasty surgery. J Arthroplasty. 2004;19:582–586.
[16] Battaglia M, Vannini F, Guaraldi F, Rossi G, Biondi F, Sudanese A. Validity of preoperative ultrasound-guided aspiration in the revision of hip prosthesis. Ultrasound Med Biol. 2011;37:1977–1983.
[17] Eisler T, Svensson O, Engstrom CF, Reinholt FP, Lundberg C, Wejkner B, et al. Ultrasound for diagnosis of infection in revision total hip arthroplasty. J Arthroplasty. 2001;16:1010–1017.
[18] Fink B, Makowiak C, Fuerst M, Berger I, Schafer P, Frommelt L. The value of synovial biopsy, joint aspiration and C-reactive protein in the diagnosis of late peri-prosthetic infection of total knee replacements. J Bone Joint Surg Br. 2008;90:874–878.
[19] Zimmerli W, Trampuz A, Ochsner PE. Prosthetic-joint infections. N Engl J Med. 2004;351:1645–1654.
[20] Font-Vizcarra L, Garcia S, Martinez-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.
[21] Morgenstern C, Cabric S, Perka C, Trampuz A, Renz N. Synovial fluid multiplex PCR is superior to culture for detection of low-virulent pathogens causing periprosthetic joint infection. Diagn Microbiol Infect Dis. 2018;90:115–119.

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QUESTION 3: Do bone cultures provide additional diagnostic accuracy in the diagnosis of periprosthetic joint infections (PJIs)?

RECOMMENDATION: Inconclusive. We cannot recommend for or against bone biopsy to provide additional diagnostic accuracy in the diagnosis of PJIs.

LEVEL OF EVIDENCE: Limited

DELEGATE VOTE: Agree: 90%, Disagree: 5%, Abstain: 5% (Super Majority, Strong Consensus)

RATIONALE

Use of traditional culture remains the preferred method for isolation of the infecting organism(s) in PJIs. It is reasonable to assume that increasing the number of samples and taking culture from "representative areas of infection" enhances the yield of culture in isolating the infective organism. Current data supports obtaining synovial fluid and tissue samples for culture, with studies showing tissue to have a better yield than synovial fluid and is preferred over swabs [1,2]. Whether the tissue culture should include bone also has not been well studied. In general, multiple samples improve diagnostic accuracy [3]. Most data supports obtaining at least three distinct and as many as six intraoperative samples for culture [2,4]. The site of specimen retrieval includes the synovium, as well as tissue from the femur and tibia in the knee or the femur and the acetabulum in the hip. In addition to traditional cultures, sonication of implants has been shown to possibly increase chance of identifying the organism [5-7].

Only one study addresses the role of utilizing bone biopsy in the detection of infection in joint arthroplasty. In a prospective cohort study, Larsen et al. [8] assess the contribution of different specimen types in detecting PJI. It was found that bone biopsy did not provide any additional information and did not contribute independently to the diagnosis of infection. The bone biopsy was obtained from bone in contact with the prosthesis. Only 9 of 32 samples (28%) resulted in a positive culture after 6 days. This increased to 13 of 32 at 14 days. This was considerably less than soft tissue biopsies which resulted in 37 of 42 (88%) positive cultures. There were no cases where bone biopsy yielded a positive culture independent of soft tissue biopsy. This resulted in a negative likelihood ratio of 0.6 (95% confidence interval (CI), 0.5-0.8) which only slightly decreases the probability of infection with a negative result. This study found the optimal specimen set for diagnosis of periprosthetic joint infection included joint fluid, prosthetic component and five soft tissue biopsies [8].

Other studies have assessed the role of bone biopsy in detecting osteomyelitis and septic arthritis. Bone biopsy in osteomyelitis was found to have significantly improved sensitivity, specificity and predictive value in determining the etiological organism when compared to sinus tract biopsy [9] and soft-tissue and deep wound biopsy [10]. In the setting of septic arthritis, sampling of the ileum

and proximal femur resulted in significantly increased positive culture rates when compared to aspiration of synovial fluid alone [11]. However, it is difficult to extrapolate these findings to assume that obtaining a bone sample in a patient with PJI is likely to increase the yield of culture. In the absence of adequate data, we have refrained from recommending that bone samples for culture should be taken routinely in patients with PJIs.

REFERENCES

[1] Aggarwal VK, Higuera C, Deirmengian G, Parvizi J, Austin MS. Swab cultures are not as effective as tissue cultures for diagnosis of periprosthetic joint infection. Clin Orthop Relat Res. 2013;471:3196–3203.

[2] Spangehl MJ, Masri BA, O'Connell JX, Duncan CP. Prospective analysis of preoperative and intraoperative investigations for the diagnosis of infection at the sites of two hundred and two revision total hip arthroplasties. J Bone Joint Surg Am. 1999;81:672–683.

[3] Atkins BL, Athanasou N, Deeks JJ, Crook DW, Simpson H, Peto TE, McLardy-Smith P, Berendt AR. Prospective evaluation of criteria for microbiological diagnosis of prosthetic-joint infection at revision arthroplasty. The OSIRIS Collaborative Study Group. J Clin Microbiol. 1998;36:2932.

[4] Mikkelsen DB, Pedersen C, Højbjerg T, Schønheyder HC. Culture of multiple peroperative biopsies and diagnosis of infected knee arthroplasties. APMIS. 2006;114:449–452.

[5] Trampuz A, Piper KE, Jacobson MJ, Hanssen AD, et al. Sonication of removed hip and knee prostheses for diagnosis of infection. N Engl J Med. 2007;357:654–663.

[6] Gomez E, Cazanave C, Cunningham SA, Greenwood-Quaintance KE, et al. Prosthetic joint infection diagnosis using broad-range PCR of biofilms dislodged from knee and hip arthroplasty surfaces using sonication. J Clin Microbiol. 2012;5011:3501–3508.

[7] Achermann Y, Vogt M, Leunig M, Wüst J, Trampuz A. Improved diagnosis of periprosthetic joint infection by multiplex PCR of sonication fluid from removed implants. J Clin Microbiol. 2010;48:1208–1214.

[8] Larsen LH, Khalid V, Xu Y, Thomsen TR, Schønheyder HC, the PRIS Study Group. Differential contributions of specimen types, culturing, and 16S rRNA sequencing in diagnosis of prosthetic joint infections. J Clin Microbiol. 2018;56:pii:e01351–17.

[9] Akinyoola AL, Adegbehingbe OO, Aboderin AO. Therapeutic decision in chronic osteomyelitis: sinus track culture versus intraoperative bone culture. Arch Orthop Trauma Surg. 2009;129:449.

[10] Chadayammuri V, Herbert B, Hao J, Mavrogenis A, Quispe JC, Kim JW, Young H, Hake M, Mauffrey C. Diagnostic accuracy of various modalities relative to open bone biopsy for detection of long bone posttraumatic osteomyelitis. Eur J Orthop Surg Traumatol. 2017;27:871–875.

[11] Schmale GA, Bompadre V. Aspirations of the ilium and proximal femur increase the likelihood of culturing an organism in patients with presumed septic arthritis of the hip. J Child Orthop. 2015;9:313.

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QUESTION 4: Is there a role for obtaining cultures before, and at the time of, insertion of prosthesis during second stage (reimplantation) of a two-stage exchange arthroplasty?

RECOMMENDATION: Preoperative aspiration of a joint should be determined based on the index of suspicion for persistent infection. During reimplantation, however, multiple fluid and tissue samples should be sent for culture. There is a direct correlation between the outcome of two-stage exchange arthroplasty and culture results during reimplantation.

LEVEL OF EVIDENCE: Moderate

DELEGATE VOTE: Agree: 95%, Disagree: 4%, Abstain: 1% (Unanimous, Strongest Consensus)

RATIONALE

Two-stage exchange arthroplasty consists of removal of the infected prosthesis in the first stage, usually replacing it by an antibiotic-loaded cement spacer and treatment with systemic antibiotics. Once the infection is thought to be under control, the second-stage of reimplantation is performed. The metrics that determine the optimal timing of reimplantation are not known. However, many surgeons rely on a combination of metrics that may include aspiration of the joint prior to reimplantation. The exact role of preoperative joint aspiration prior to reimplantation remains undefined. Furthermore, there is also no specific test to determine if the infection has or has not been controlled.

Although aspiration of a joint is critical for the diagnosis of periprosthetic joint infections (PJIs) [1], it is not obvious if culture of synovial fluid with a polymethyl methacrylate (PMMA) spacer in place before reimplantation is helpful for the diagnosis of persistent infection [2]. In fact, it has been demonstrated that aspiration for microbial culture before the second stage has a low sensitivity for predicting infection [3–6]. Lonner et al. investigated the role of knee aspiration for detection of persistent infection before reimplantation and after cessation of a four- to eight- week course of antibiotics. They found that knee aspiration performed after resection arthroplasty had a sensitivity of zero, a positive predictive value (PPV) of zero, a negative predictive value (NPV) of 75% and a specificity of 92% [6]. Janz et al. studied the diagnostic performance of synovial aspiration in resected hips without a PMMA spacer, for detection of infection persistence prior to total hip arthroplasty (THA) reimplantation. They found a sensitivity of only 13% and specificity of 98% and concluded that aspiration of a resected hip neither reliably confirmed nor excluded the persistence of infection [5]. Hoell et al. investigated 115 patients with two-stage hip or knee arthroplasty and found that the sensitivity of the aspiration culture before replantation was 5% (95 % confidence interval (CI), 0.13–24.87) and the specificity was 99% (95 % CI, 94.27–99.97). The NPV was 83% and the PPV was 50 % [4]. Preininger et al. investigated the diagnostic validity of synovial PMMA spacer aspiration after two weeks of antibiotic holiday for detection of persistent infection. They included 73 patients who underwent two-stage revision for infection and found only 21% sensitivity for synovial PMMA space aspiration. They concluded that synovial PMMA aspiration cannot be recommended for exclusion of persistent infection [7].

There are some potential explanations for this finding. First of all, it is possible for bacteria to be in a biofilm and remain adherent to cement spacer, which in turn leads to uncertain predictability of culture from aspirations before reimplantation [8–10]. Secondly, the