ELSEVIER

Seminars in
ROENTGENOLOGY

Septic Arthritis and Joint Aspiration: The Radiologist's Role in Image-Guided Aspiration for Suspected Septic Arthritis

Jack Porrino, MD,[*] Michael L. Richardson, MD,[†] Erin Flaherty, MD,[‡] Mahmood Albahhar, MD,[§] Alice S. Ha, MD,[†] Hyojeong Mulcahy, MD,[†] and Felix S. Chew, MD[†]

Introduction

Septic arthritis must be considered in the setting of an acute hot and swollen joint. This disease entity is disabling and potentially life-threatening, destroying cartilage within days of onset, and with a reported mortality rate of 5%-50%.[1-8] A delay in diagnosis has been described as a major contributor to poor outcome.[2,4,7-9]

The radiologist often plays an important role in the diagnostic work-up of patients presenting with suspected septic arthritis, providing image-guided joint aspiration. Although this practice is common, there are several factors that influence the decision of the radiologist to either proceed with the procedure or defer, without an obvious consensus in the literature regarding these often-encountered obstacles.

The purpose of our study was to poll those practicing musculoskeletal (MSK) radiology in both the private practice and academic realm with regards to the decision-making process related to joint aspiration for suspected septic arthritis. We sought to identify any potential trends in variables that serve as relative or absolute contraindications, as well as identify any glaring inconsistencies, with a particular interest in the following:

(1) The influence of clinical or systemic, serum laboratory, or imaging findings on the decision to aspirate.
(2) The influence of preprocedure specialty consultation on the decision to aspirate.
(3) The influence of preprocedure antibiotic therapy on the decision to aspirate.
(4) The influence of preprocedure coagulopathy on the decision to aspirate.
(5) The influence of superficial soft tissue changes along the course of the needle track on the decision to aspirate.
(6) Variability in procedural technique.

Methods

Investigational review board approval was not required for this study, in accordance with the University of Washington Investigational Review Board guidelines.

A 17-question survey, comprised of 16 questions and 1 free comment option, (Appendix 1) was devised by 2 MSK-trained attending radiologists addressing multiple scenarios that may be encountered during the process of being consulted for and subsequently performing a joint aspirate for suspected septic arthritis. The questions were formulated based upon practice inconsistencies among MSK radiology attendings at the University of Washington, as well as within the literature, pertaining to guidelines and contraindications of performing the procedure.

Following permission, the survey was distributed to 2017 members of the Society of Skeletal Radiology (SSR) through the use of an e-mail listserv containing 1412 member addresses. The responses were collected by SurveyMonkey and remain anonymous to the authors. An initial e-mail was sent to SSR members on August 28, 2017, inviting members to partake in a short survey (Appendix 2). A second, reminder e-mail was sent to SSR members on September 5, 2017. The survey was subsequently closed on September 11, 2017. No identifiable information about the respondents was solicited or obtained during the survey process, and there was no contact between authors and respondents.

[*]Yale School of Medicine Radiology and Biomedical Imaging, 20 York Street, New Haven, CT 06510.
[†]Department of Radiology, University of Washington, Seattle, WA.
[‡]Kaiser Permanente Washington Medical Group, Tacoma, WA.
[§]Niagara Health—St Catharines Hospital, McMaster university, St Catharines, ON, Canada.
Address reprint requests to Jack Porrino, MD, Yale School of Medicine Radiology and Biomedical Imaging, 20 York Street, New Haven, CT 06510. Phone: (203) 688-1010 E-mail: rhees27@yahoo.com

https://doi.org/10.1053/j.ro.2018.04.005

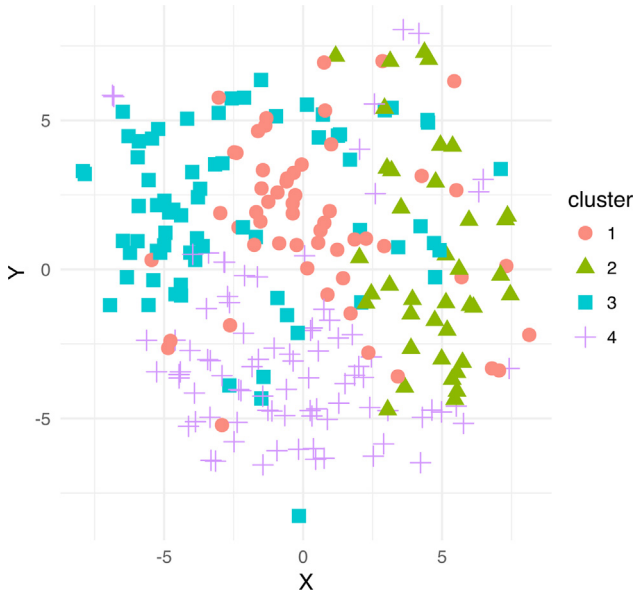

Figure Two-dimensional cluster plot of our survey data demonstrated 4 distinct groups among our respondents. Clusters 1 and 2 represent largely private practice radiologists, whereas clusters 3 and 4 represent largely academic radiologists.

Statistical Analysis

The data from this survey was analyzed using cluster analysis with the R environment for statistical computing.[10] A Gower distance matrix was calculated for the 16 categorical variables collected in this survey.[11] Cluster analysis was then performed on this distance matrix using the partitioning around medoid algorithm. The silhouette width metric suggested that 4 was the optimal number of clusters to extract with the partitioning around medoid algorithm.[12] We used the t-distributed stochastic neighbor embedding dimension reduction technique to display these clusters on a 2-dimensional plot[13] (Fig. 1).

Results

A total of 249 SSR members performed the survey before its closure. Not all respondents answered every question. There were 46 free comments.

Practice Demographic (Question 14)

Out of 248, 149 (60.08%) members identified themselves as working in an academic practice, 99 of 248 (39.92%) members identified themselves as working in private practice, and 1 respondent skipped this demographic question.

One free comment reported that answers provided were based on a former academic job, and that he or she does not aspirate joints in private practice.

Clinical or Systemic Manifestations (Question 2)

Out of 249, 25 (10.04%) respondents believe clinical systemic manifestations of infection are required before performing a joint aspiration for suspected septic arthritis. Out of 249, 175 (70.28%) respondents believe clinical manifestations are not required. Out of 249, 49 (19.68%) answered that sometimes clinical manifestations are required before performing the aspiration.

Laboratory Evidence and Influence of Bacteremia (Questions 1 and 5)

Out of 249, 33 (13.25%) respondents believe that laboratory evidence of septic arthritis is required prior to performing an aspiration, such as an elevated erythrocyte sedimentation rate (ESR), C-reactive protein (CRP), or peripheral white blood cell (WBC) count. Out of 249, 153 (61.45%) feel laboratory evidence is not required. Out of 249, 63 (25.30%) respondents feel that sometimes laboratory evidence is required.

Out of 249, 3 (1.20%) respondents believe that the presence of bacteremia is an absolute contraindication to performing an aspiration that has been requested. Another 78 of 249 (31.33%) respondents believe that bacteremia represents a contraindication to joint aspiration, but not in an absolute fashion, and that decisions are made on a case by case basis. Out of 249, 168 (67.47%) respondents believe bacteremia does not reflect a contraindication to joint aspiration.

Consultation Requirements (Question 4)

As a whole, 133 of 249 (53.41%) respondents believe that a consultation service, either infectious disease or orthopedic surgery or both, must first see the patient prior to a joint aspiration being performed. Specifically, 60 of 249 (24.10%) respondents believe orthopedic surgery must first see the patient and agree with the plan to aspirate, 71 of 249 (28.51%) respondents believe either infectious disease OR orthopedic surgery must first see the patient and agree with the plan, and 2 of 249 (0.80%) respondents believe that both infectious disease AND orthopedic surgery must first see the patient and agree with the plan.

Out of 249, 116 (46.59%) respondents believe that specialized consultation is not required before a joint aspiration for suspected septic arthritis.

Imaging Before Procedure (Question 3)

Out of 249, 91 (36.55%) respondents believe that imaging is not required before agreeing to a joint aspiration, with an understanding that some form of imaging will be performed at the time of the procedure.

Out of 249, 82 (32.93%) respondents believe that radiographs are required before agreeing to a joint aspiration, whereas 76 of 249 (30.52%) respondents believe that one of either ultrasound (US), computed tomography (CT), or magnetic resonance imaging (MRI) is a requirement before agreeing to a joint aspiration.

There were no respondents who believe that 2 or more of US, CT, or MRI is necessary before agreeing to perform a joint aspiration.

Coagulopathy (Question 11)

There were 247 responses to the survey question regarding the management of coagulopathy before joint aspiration for suspected septic arthritis. As a whole, 96 of 247 (38.55%) respondents report that coagulopathy (abnormally elevated INR or abnormally low platelet count) should be addressed prior to a joint aspiration for suspected septic arthritis. Out of 247, 58 (23.48%) respondents feel that coagulopathy should be corrected before performing the procedure, WITH specific criteria used in their practice. Out of 247, 38 (15.38%) respondents believe that coagulopathy should be corrected before performing the procedure, but WITHOUT the use of specific criteria.

Out of 247, 151 (61.13%) respondents do not believe that coagulopathy influences their decision to perform the procedure.

One free comment added that correcting a coagulopathy could be considered in the prosthetic joint, as this demographic is nonemergent or semiurgent, as the infection is commonly indolent and long standing, and may not cause toxic symptoms. Alternatively, the same respondent reported correcting coagulopathy for native joints is not routinely performed due to the urgent need for diagnosis, unless the coagulopathy is profound.

Influence of Antibiotics (Question 6)

Out of 249, 6 (2.41%) respondents report deferring the joint aspiration if the patient is on antibiotics at the time of the request. Out of 249, 157 (63.05%) respondents do not defer the procedure if the patient is on antibiotics at the time of joint aspiration. Out of 249, 86 (34.54%) respondents will sometimes defer the joint aspiration if the patient is on antibiotics at the time of the request.

Influence of Soft Tissue Changes (Questions 7-9, and 13)

There were 247 responses to the survey question regarding the influence of red or inflamed soft tissues overlying the needle path at the time of aspiration. Out of 247, 20 (8.10%) respondents report that they would proceed with the joint aspiration if the soft tissues of the patient overlying the projected needle path at the time of aspiration appeared red or inflamed. Out of 247, 124 (50.20%) respondents report that they would not proceed with the joint aspiration if the soft tissues of the patient overlying the projected needle path at the time of aspiration appeared red or inflamed. Out of 247, 103 (41.70%) respondents report that they would sometimes proceed with the joint aspiration if the soft tissue of the patient overlying the projected needle path at the time of aspiration appeared red or inflamed.

There were 247 responses to the survey question regarding the influence of edematous changes within the soft tissues suggestive of cellulitis apparent on MRI overlying the projected needle path. Out of 247, 35 (14.17%) respondents report that they would proceed with the joint aspiration if MRI showed edema in the soft tissues suggestive of cellulitis overlying the projected needle path. Out of 247, 95 (38.46%) respondents report that they would not proceed with the joint aspiration if MRI showed edema in the soft tissues suggestive of cellulitis overlying the projected needle path. Out of 247, 117 (47.37%) respondents report that they would sometimes proceed with the joint aspiration if MRI showed edema in the soft tissues suggestive of cellulitis overlying the projected needle path.

There were 248 responses to the survey question regarding the influence of an abscess within the soft tissues apparent on MRI overlying the projected needle path. Out of 248, 6 (2.42%) respondents report that they would proceed with the joint aspiration if MRI showed an abscess within the soft tissues overlying the projected needle path. Out of 248, 222 (89.52%) respondents report that they would not proceed with the joint aspiration if MRI showed an abscess within the soft tissues overlying the projected needle path. Out of 248, 20 (8.06%) respondents report that they would sometimes proceed with the joint aspiration if MRI showed an abscess within the soft tissues overlying the projected needle path.

Numerous respondents reported via free comment that if there is evidence of soft tissue infection along the projected needle path, he or she change their approach. Another respondent added that if there is soft tissue inflammation and minimal effusion in the joint, the effusion is reported as reactive, and the joint is not aspirated for fear of infecting a potentially sterile joint.

Out of 249, 10 (4.02%) respondents reported that they have personally been involved with a case in which a patient developed a DOCUMENTED joint infection after a negative joint aspiration, such that the negative joint aspiration procedure was suspected of causing the subsequent joint infection. Out of 249, 239 (95.98%) respondents reported that they have not personally been involved with such a case.

Needle Gauge (Question 12)

There were 245 responses to the survey question regarding the preferred needle gauge used for aspiration of a joint for suspected septic arthritis.

Out of 245, 129 (52.65%) respondents report using an 18-gauge needle, 37 of 245 (15.10%) respondents report using a 22-gauge needle, and 2 of 245 (0.82%) respondents report using a 25-gauge needle.

Out of 245, 3 (1.22%) respondents report using whatever needle is available, whereas 74 of 245 (30.20%) respondents report the needle gauge chosen is dependent upon the joint being aspirated.

Out of 46, 9 free comments state that a 20-gauge needle is preferred for the aspiration of a suspected septic joint, a choice not provided in question 12.

Dry Tap and the Influence of Lidocaine and Iodinated Contrast (Questions 10, 15, and 16)

There were 247 responses to the survey question regarding next steps when a "dry tap" is encountered. When encountering a "dry tap" (one in which no fluid can be aspirated), 134 of 247 (54.25%) respondents report always following with a

nonbacteriostatic saline lavage. Out of 247, 15 (6.07%) respondents report always following with a contrast lavage. Out of 247, 72 (29.15%) respondents sometimes perform some form of unspecified lavage, whereas 26 of 247 (10.53%) respondents never perform a lavage. One respondent reported via free text comment that he or she performs a synovial biopsy with either a 20-gauge core or "vacu-cut" if encountering a dry tap. One free text comment stated that a lavage is used dependent on the joint; the hip always being lavaged following a dry tap scenario.

There were 248 responses to the survey question regarding the use of lidocaine during the aspiration. Out of 248, 209 (84.27%) respondents attempt to avoid injecting lidocaine into the joint before collecting the aspirate. Out of 248, 30 (12.10%) respondents do not attempt to avoid injecting lidocaine into the joint before collecting the aspirate. Out of 248, 9 (3.63%) respondents sometimes attempt to avoid injecting lidocaine into the joint before collecting the aspirate.

There were 248 responses to the survey question regarding the use of iodinated contrast media during the aspiration. Out of 248, 127 (51.21%) respondents attempt to avoid using iodinated contrast media during the procedure. Out of 248, 90 (36.29%) respondents do not attempt to avoid using iodinated contrast media during the procedure. Out of 248, 31 (12.50%) respondents sometimes attempt to avoid using iodinated contrast media during the procedure. Numerous respondents added via free text comment that contrast is injected after the aspiration, but not prior, to confirm the needle is in the appropriate position, assess for sinus tracts or abscess, while avoiding the bacteriostatic effects of contrast. One free comment stated that iodinated contrast is not bacteriostatic, and that this is proven. One free comment reported that he or she performs all joint aspiration under US, and as such iodinated contrast has no influence. One free comment reported that he or she uses air to confirm needle position under fluoroscopy.

Additional Free Comments

Several free comments reported that a suspected septic arthritis in the native joint vs that in a joint prosthesis will alter the decision-making process with regards to aspiration.

Statistical Analysis

Cluster analysis identified 4 groups from the survey data (Tables 1-4). Tables 1 and 2 are comprised mostly of private practice radiologists. When focusing on the radiologist's decision to either proceed or defer a requested joint aspiration, Cluster 1 represents a more flexible and less discriminatory group, whereas Cluster 2 represents a less flexible and more discriminatory group.

Tables 3 and 4 are comprised mostly of academic radiologists. Similarly, when focusing on the radiologist's decision to either proceed or defer a requested joint aspiration, Cluster 3 represents a more flexible and less discriminatory group, whereas Cluster 4 represents a less flexible and more discriminatory group.

Table 1 Cluster 1 Questions and Answers

Is laboratory evidence required?	No (39/55)	Is bacteremia a contraindication?	No (36/55)	Would you proceed if the MRI shows abscess?	No (44/55)	Joint aspiration caused infection?	No (54/55)
Are clinical manifestations required?	No (41/55)	Does active antibiotic therapy defer procedure?	No (39/55)	Do you lavage following dry tap?	Always saline (42/55)	Do you attempt to avoid lidocaine in joint?	Yes (48/55)
What imaging is required?	Radiographs or cross sectional (21/55; 21/55)	Would you proceed if there are abnormal soft tissues?	Sometimes (37/55)	Does coagulopathy influence decision?	No (31/55)	Do you attempt to avoid iodinated contrast?	Yes (44/55)
Is consult required?	Ortho or ID (32/55)	Would you proceed if the MRI shows cellulitis?	Sometimes (41/55)	Gauge needle?	Depends on the joint (33/55)		

Most in Cluster 1 are private practice radiologists (36/55). This cluster uses a more flexible and less discriminatory approach to aspiration.

Table 2 Cluster 2 Questions and Answers

Is laboratory evidence required?	Sometimes (26/38)	Is bacteremia a contraindication?	Yes (25/38)	Would you proceed if the MRI shows abscess?	No (37/38)	Joint aspiration caused infection?	No (36/38)
Are clinical manifestations required?	Sometimes (21/38)	Does active antibiotic therapy defer procedure?	Sometimes (25/38)	Do you lavage following dry tap?	Always saline (24/38)	Do you attempt to avoid lidocaine in joint?	Yes (32/38)
What imaging is required?	Cross sectional (28/38)	Would you proceed if there are abnormal soft tissues?	No (28/38)	Does coagulopathy influence decision?	Yes with criteria (17/38)	Do you attempt to avoid iodinated contrast?	Yes (17/38)
Is consult required?	Ortho only (17/38)	Would you proceed if the MRI shows cellulitis?	No (23/38)	Gauge needle?	Depends on the joint (20/38)		

Most in Cluster 2 are private practice radiologists (21/38). This cluster uses a less flexible and more discriminatory approach to aspiration.

Table 3 Cluster 3 Questions and Answers

Is laboratory evidence required?	No (45/71)	Is bacteremia a contraindication?	No (58/71)	Would you proceed if the MRI shows abscess?	No (60/71)	Joint aspiration caused infection?	No (68/71)
Are clinical manifestations required?	No (54/71)	Does active antibiotic therapy defer procedure?	No (49/71)	Do you lavage following dry tap?	Sometimes (39/71)	Do you attempt to avoid lidocaine in joint?	Yes (57/71)
What imaging is required?	Radiographs (32/71)	Would you proceed if there are abnormal soft tissues?	Sometimes (51/71)	Does coagulopathy influence decision?	No (47/71)	Do you attempt to avoid iodinated contrast?	No (45/71)
Is consult required?	No (42/71)	Would you proceed if the MRI shows cellulitis?	Sometimes (53/71)	Gauge needle?	18 (53/71)		

Most in Cluster 3 are academic radiologists (53/71). This cluster uses a more flexible and less discriminatory approach to aspiration.

Table 4 Cluster 4 Questions and Answers

Is laboratory evidence required?	No (66/85)	Is bacteremia a contraindication?	No (61/85)	Would you proceed if the MRI shows abscess?	No (81/85)	Joint aspiration caused infection?	No (81/85)
Are clinical manifestations required?	No (68/85)	Does active antibiotic therapy defer procedure?	No (57/85)	Do you lavage following dry tap?	Always saline (53/85)	Do you attempt to avoid lidocaine in joint?	Yes (72/85)
What imaging is required?	None (52/85)	Would you proceed if there are abnormal soft tissues?	No (71/85)	Does coagulopathy influence decision?	No (60/85)	Do you attempt to avoid iodinated contrast?	Yes (51/85)
Is consult required?	No (50/85)	Would you proceed if the MRI shows cellulitis?	No (58/85)	Gauge needle?	18 (49/83)		

Most in Cluster 4 are academic radiologists (60/85). This cluster uses a less flexible and more discriminatory approach to aspiration.

Discussion

Septic arthritis is a disabling and potentially life-threatening process, with rapid destruction of joint cartilage. Interestingly, once the process of articular cartilage destruction has begun, the presence of viable organisms is not necessary for ongoing joint damage to occur due to the release of proteolytic enzymes and acute inflammatory cells that result in synovial necrosis.[2,14] Irreversible loss of joint function develops in 25%-50% of patients with bacterial arthritis, and reportedly up to 75% of survivors develop a significant functional disability of the involved joint.[2,3,7]

Septic arthritis may be the result of direct inoculation (including iatrogenic—joint aspiration or corticosteroid injection), hematogenous spread, or spread of a local infection such as an adjacent ulcer, cellulitis, osteomyelitis, or bursitis.[2,14-16] Most cases of septic arthritis are the result of hematogenous seeding.[2-4,14,17]

The most common pathogens involved in septic arthritis include *Staphylococcus aureus* and group B Streptococcus, as well as gonococcal arthritis.[1,3,5,6,8,9,14,15,17-19] Coagulase-negative Staphylococcus is common in patients with recent joint replacement.[4,5,15,20]

Risk factors include advanced age, malignancy, diabetes mellitus, rheumatoid arthritis, immunosuppression, chronic liver disease, chronic renal disease, history of joint replacement, skin infection or cutaneous ulcers, intravenous drug use, alcoholism, those with preexisting systemic connective tissue disease, prior intraarticular steroid injection, or chronic arthritis with resultant joint damage that may lead to chronic synovitis and bloody effusion serving as a nidus for bacterial infection.[1-5,8,14-18]

The early and aggressive management of septic arthritis has been advocated repeatedly in the literature in effort to avoid cartilage loss and joint destruction. At many institutions this has resulted in the MSK radiologist playing an integral role in the diagnosis of this disease, performing the image-guided joint aspiration that frequently determines definitive courses of management.

One would presume that a procedure performed so often for a relatively routine clinical question would have a standardized series of indications, contraindications, and technique independent of institution, without much confusion. However, the nature of the literature and the disease entity presents various obstacles for the radiologist and may generate ambiguity at various levels of the procedure. Our survey focused on the following factors involved in the joint aspiration procedure for suspected septic arthritis.

Clinical or Systemic Manifestations (Question 2)

Patients typically present with a painful, swollen joint (although disease may be polyarticular), and less commonly with systemic symptoms such as fever, sweats, and rigors or chills.[2,7,8,15,16] In addition to poor sensitivity, the presence of fever, sweats, and rigors or chills is nonspecific, and may be present in patients with crystal-induced arthritis.[2,7] Reduced

range of motion with pain upon movement of the joint may be present.[2,8,15]

The differentiation of septic arthritis from other causes of monoarticular arthritis, such as crystal-induced arthropathy, osteoarthritis, trauma, and a variety of systemic diseases, is difficult based on clinical history and physical examination, as these entities all can present as a painful swollen joint.[1,2,4,5,7,14,16,18,21,22]

Notably, Carpenter et al found that no finding from the history significantly decreases the probability of septic arthritis. Conversely, the authors reported that only recent joint surgery or a joint prosthesis with overlying skin infection significantly increases the probability of septic arthritis.[4]

The knee reflects the most common joint involved with septic arthritis, followed by the hip.[1-4,8,14,15,18]

Results of question 2 indicate that the majority, 175 of 249 (70.28%), of radiologists do not require the presence of clinical systemic manifestations of infection, such as fever or chills or rigors, before performing a requested joint aspiration for suspected septic arthritis. However, despite the fact that systemic symptoms of infection are neither sensitive or specific for septic joint, 74 of 249 (29.72%) respondents reported either requiring or sometimes requiring documentation of these systemic manifestations before performing a joint aspiration.

Laboratory Evidence and Influence of Bacteremia (Questions 1 and 5)

The American Rheumatologic Association provides the following guidelines for synovial fluid cell count interpretation: noninflammatory >200 to 2000 WBC/mm^3; inflammatory $=$ 2000 to 50,000 WBC/mm^3; and infectious $=$ $>50{,}000$ WBC/mm^3.[15]

Serum and Joint WBC Count

The upper limit threshold for joint WBC (jWBC) count in the diagnosis of septic arthritis has never been clearly established, with medical folklore and texts suggesting variable cut-off values of 2000, 10,000, or 50,000.[21] Both an elevated serum WBC count and jWBC count (using a threshold of $>50{,}000$ cells/mm^3) have proven insensitive in the detection of septic arthritis in prior studies, with sensitivities of 19%-77% and 0%-92% reported, respectively.[18,21]

Mathews et al[8] concluded that the jWBC count is not sufficiently reliable a measure to exclude or confirm a diagnosis of septic arthritis. Conversely, Carpenter et al demonstrated that a jWBC count $>50 \times 10^9$/L does in fact increase the probability of septic arthritis.[4] Margaretten et al[1] advocated the analysis of jWBC count, despite variable reports in the literature. Finally, Li et al reported a jWBC count of $>17{,}500$ cells/mm^3 provides the most optimal sensitivity (83%) and specificity (67%).[21]

Joint Polymorphonuclear Cell Percentage

Margaretten et al[1] recommended arthrocentesis with evaluation of synovial fluid WBC count and percentage of polymorphonuclear (PMN) cells as the best diagnostic tool available for detecting bacterial arthritis while waiting for synovial culture test results, with a threshold of $>90\%$ PMNs within the synovial fluid increasing the likelihood of septic arthritis. Kung et al[5] reported an elevated percentage of synovial fluid PMN cells also as a significant association with septic arthritis.

Joint Glucose, Protein, and Lactate Dehydrogenase

Markers such as synovial glucose, protein, and lactate dehydrogenase (LDH) exhibit variable sensitivities and specificities with respect to the detection of septic arthritis.[1] Carpenter et al[4] concluded that while a synovial LDH $>$ 10 mmol/L consistently "ruled-in" septic arthritis, synovial glucose, and protein values do not effectively discriminate between septic arthritis and alternative causes of acute arthritis. Conversely, Mathews et al[8] concluded that LDH levels in the synovial fluid did not have any discriminate value in the setting of suspected septic arthritis.

Joint Aspirate Gram Stain

The Gram stain has also been shown to have a poor sensitivity (29%-70%), or high false-negative rate (45%-71%), in particular with gonococcal disease.[1,4,6,8,9,14,15] The specificity remains undefined.[4]

Joint Aspirate Culture

A positive culture from fluid aspirate remains the reference standard in the diagnosis of septic arthritis. Increasing turbidity of the fluid aspirate has been demonstrated to reflect a strong positive predictor for septic arthritis by Kung et al. In this same study, the authors noted that amount of fluid aspirated and whether the fluid analyzed was aspirated on the first attempt or reaspirated after lavage were not significantly associated with a positive culture.[5] That said, the literature also reports that up to 40% of cases of septic arthritis will have negative aspirate cultures.[3,15]

Polymerase Chain Reaction

Recently, universal microbe nucleic acid amplification and sequencing by polymerase chain reaction (universal polymerase chain reaction [PCR]) has been used for diagnosis or confirmation of septic arthritis. Universal PCR is especially useful in the context of negative synovial culture or preprocedure antibiotic administration, however, is limited by slow turnaround time, lack of a gold standard, and high rates of false positives or contamination.[17]

Serum ESR and CRP

Values such as the ESR and CRP have a high sensitivity in the detection of septic arthritis (71%-96% reported in the literature for ESR per Li et al[18]), however, these tests have demonstrated a poor specificity, and therefore limited diagnostic power for changing the probability of septic arthritis.[1,7,18,21] Additionally, the absence of a raised serum ESR or CRP does not exclude the diagnosis of septic arthritis.[8]

Blood Cultures

Blood cultures are also obtained during the evaluation of septic arthritis, and on occasion have reflected the only source of microbiologic diagnosis in some prior reports.[7,8,14,17,19] Interestingly, established bacteremia has been considered a relative contraindication with a theoretical risk of infection spreading to the joint.[16]

Question 1 focuses on the radiologists' interpretation of serum laboratory markers of infection, and how they influence his or her willingness to perform a requested aspiration. 153 of 249 (61.45%) respondents do not require laboratory evidence of septic arthritis (elevated ESR, CRP, or peripheral WBC count) before performing a joint aspiration for suspected septic arthritis. However, despite limited diagnostic power for changing the probability of septic arthritis, 96 of 249 (38.55%) respondents reported either requiring or sometimes requiring laboratory evidence of septic arthritis before performing the aspiration.

Although the literature reports bacteremia as the most likely avenue by which a joint may become infected, and in some reports, the only laboratory evidence of septic arthritis, Hansford et al considered established bacteremia a relative contraindication for joint aspiration due to a theoretical risk of infecting a sterile joint during the procedure.[16] The literature is confusing, and the results of question 5 indicate that radiologists are equally confused. Although 168 of 249 (67.47%) respondents do not consider bacteremia a contraindication to performing a joint aspiration for suspected septic arthritis, 81 of 249 (32.53%) respondents reported that bacteremia is either an absolute or relative contraindication to performing a joint aspiration.

Consultation Requirements (Question 4)

UK guidelines recommend specialist referral and consideration of synovial aspiration early in the management of the hot, swollen joint.[7]

To optimize management of the patient with suspected septic arthritis, the radiologist requesting input from experienced clinicians such as orthopedic surgery or infectious disease would seem reasonable. However, the results of question 4 suggest that the majority of respondents, 116 of 249 (46.59%), do not require specialized consultation prior to joint aspiration.

Imaging Before Procedure (Question 3)

Imaging often begins with conventional radiography; however, radiographs are usually normal early in the disease or are nonspecific.[1,2,16] The presence of synovial inflammation and effusion manifest as soft tissue swelling, with defined effusion apparent at the elbow, knee, and ankle, but not readily visible at alternative joints. Diffuse cartilage destruction results in uniform joint space narrowing. Demineralization of the bone adjacent to the joint may be present, with marginal erosions occurring at sites of joint capsule attachment, where the cartilage is thinnest.[2,16]

US may be used to identify joint fluid and synovial thickening.[16]

MRI features of septic arthritis include joint effusion, synovial thickening, surrounding soft tissue edema, diffuse joint space narrowing, and adjacent bone marrow edema with bare area erosions.[2,16] However, other forms of inflammatory arthritis should also be considered, such as rheumatoid arthritis, seronegative spondyloarthropathies, and crystal disease, all of which have considerable overlap with regards to MRI findings.[1,2]

In summary, radiography, US, MRI, as well as nuclear medicine studies, can be helpful in the workup of septic arthritis, but may be nonspecific and are not considered to be definitive for the diagnosis of infection.[5,8,14] In many cases, imaging alone cannot accurately distinguish infected from noninfected joints, and aspiration and culture are often necessary to confirm the diagnosis of septic arthritis.[16]

Question 3 suggests that radiologists are varied as to their image preference before joint aspiration. Notably, 76 of 249 (30.52%) require one of either US, CT, or MRI before agreeing to a joint aspiration. Although there is no way to understand the respondents' justification by way of a quantitative, survey-based, research study, one could reasonably conclude that this imaging is considered necessary for 1 of 2 reasons: (1) to determine the presence or absence of a joint effusion; (2) to evaluate the overlying soft tissues along the course of the needle path; those who do not require such imaging will not have an understanding of the soft tissue planes along the course of the needle.

Coagulopathy (Question 11)

Hansford et al[16] stated that there is little consensus regarding the handling of oral anticoagulant therapy before percutaneous interventions; however, studies have reported that arthrocentesis is safe in patients receiving chronic warfarin therapy at therapeutic levels.

Question 11 indicates that the majority of respondents (151 of 247; 61.13%) feel that coagulopathy has no influence on performing a joint aspiration for suspected septic arthritis. However, 96 of 247 (38.87%) respondents reported that coagulopathy should be corrected prior to performing the procedure.

Influence of Antibiotics (Question 6)

Management of septic arthritis includes a combination of antibiotics, without a standardized agent profile or duration yet defined, and removal of any purulent material (arthroscopy versus arthrotomy vs repeated needle aspiration).[3,8,14,15,17] Surgical drainage vs repeated needle aspiration has been debated in the literature, with definitive management often dependent on the specific consultant.[8,15,17]

Prompt microscopic analysis and culture of synovial fluid are fundamental diagnostic tools in the evaluation of possible septic joint, enabling the diagnosis of septic joint and crystal-induced arthritis.[8]

To facilitate standardized care, a multidisciplinary working party set up by the British Society for Rheumatology formulated standardized guidelines to manage hot swollen joints. Recommendations included aspiration with synovial fluid sent for analysis, to include crystals and culture, before commencing antibiotics. The British Society for Rheumatology recommend that aspiration be followed by antibiotic administration, and complete drainage of pus by means of arthroscopic washout or closed needle aspiration is regarded essential. Notably, the working party acknowledged insufficient evidence in the literature to suggest any additional benefit of surgical drainage over closed needle aspiration (repeated as required) in the majority of cases. However, in cases of unsatisfactory response to medical management, the presence of thick inspissated pus, or hip involvement, surgical intervention is required. Regardless of these guidelines, the management of suspected septic arthritis varies in practice with respect to antibiotic coverage or duration and the need for surgical intervention.[6]

Joint aspiration should be performed in a targeted fashion, and with knowledge of the low sensitivity rate, the latter exacerbated by those receiving antibiotics. Withholding antibiotics until joint aspiration should be performed, as antibiotics reduce the possibility of isolating an organism on both Gram stain and culture, preventing tailored management, findings corroborated by Hindle et al.[9]

If the clinician suspects septic arthritis, and is planning urgent surgical lavage, samples can be obtained at the time of surgery, and preoperative aspiration may not be indicated. If the clinical presentation is equivocal, a positive aspiration may be helpful, however, clinicians should not be falsely reassured by a negative result. An aspirate with crystals helps to identify a crystal arthropathy, but does not exclude concomitant infection.[9]

Despite the impact of antibiotic administration on the diagnostic efficacy of joint aspiration, the results of question 6 demonstrate that the majority of respondents (157 of 249; 63.05%) do not defer a joint aspiration if a patient is on antibiotics at the time of joint aspiration.

Influence of Soft Tissue Changes (Questions 7-9, and 13)

The risk of iatrogenic "infection" from arthrocentesis has been estimated to be 0.0001%-0.037% in the general population, and as high as 0.05% in immunocompromised patients.[4,22]

It has been reported in the literature that an absolute contraindication to aspiration of a suspected septic joint is the inability to access the joint without traversing inflamed or infected superficial tissues because the needle could infect a previously sterile joint.[16] According to Lin et al,[2] the needle tract to the joint should not transect a soft tissue abscess, if one is identified on preceding MRI, and needle approaches should never traverse an area of inflammation or a skin lesion such as psoriasis or acne, because the needle may introduce an infectious agent into a joint that was not initially infected.

Margaretten et al stated that when septic arthritis is suspected, arthrocentesis is mandatory. When overlying cellulitis is present, the physician should perform arthrocentesis while attempting to avoid percutaneous puncture of infected skin. The authors also stated that some clinicians favor proceeding with arthrocentesis through a cellulitis area when no other approach is possible.[1]

According to Dooley, when performing a review of the English-language literature (MEDLINE) from 1966-2002, cross-indexing "cellulitis," "skin infection," "septic arthritis," "arthrocentesis," and "joint aspiration," not a single case report was found, nor is there documentation in the form of a large case series, of the inoculation of a previously sterile joint through cellulitis, resulting in a subsequent septic arthritis. Dooley explained that demonstrating this occurrence would be very challenging. At a minimum, 2 arthrocenteses would be necessary: the first an aspiration through cellulitis yielding sterile joint fluid, and the second an aspiration through normal skin then demonstrating infected joint fluid. Dooley conceded that such inoculations through cellulitis must have occurred at some point in time in the past, but the lack of report in the literature is likely the result of its exceedingly rare occurrence. Additionally, he stated that the use of antibiotics to treat the presumptive cellulitis will probably sterilize the scant inoculum of bacteria being introduced into the newly penetrated joint. Finally, he concluded that the cost of delay in the appropriate therapy of septic arthritis outweighs the decision to defer aspiration due to a risk of iatrogenic inoculation.[23]

Dooley's scenario in which proving such an occurrence of iatrogenic arthrocentesis-induced septic arthritis related to overlying cellulitis fails to address that even in his situation, if the follow-up aspiration were to yield infected joint fluid, while the initial did not, this finding could be explained by one of many errors in the test. These errors would include, but are not limited to, sampling error on the first attempt, a false-negative result on the first attempt despite adequate sampling, such as that seen in the context of those on preprocedural antibiotics, or false-positive result or contaminate on the second attempt if only relying upon Gram stain or culture growth.

Questions 7-9, and 13 are tailored to investigate the radiologists' beliefs with regards to inflamed soft tissue overlying the projected aspiration path on physical examination and imaging, the presence of soft tissue abscess along the projected path of the needle on imaging, and finally, whether such a scenario of contaminating once, sterile joint by placing a needle through infected superficial soft tissue has ever been documented in his or her practice.

Out of 247, 124 (50.20%) respondents would not proceed with a joint aspiration if the overlying soft tissue appears red or inflamed clinically. Out of 247, 95 (38.46%) respondents would not proceed with a joint aspiration if MRI demonstrated edema in the soft tissues suggesting cellulitis along the needle path. Out of 248, 222 (89.52%) respondents would not proceed with the joint aspiration if MRI showed an abscess in the soft tissue overlying the projected needle path.

Notably, Carpenter et al[4] reported that only recent joint surgery or a joint prosthesis with overlying skin infection significantly increases the probability of septic arthritis. Although overlying skin infection is reportedly a marker of septic arthritis, the literature simultaneously suggests infected

soft tissue is a contraindication to joint aspiration. As numerous respondents reported via free text comments, the most logical resolution would be to find an alternative approach to the joint, devoid of potential soft tissue infection. However, how does one proceed when there is no approach free from soft tissue changes? Although the literature reports that even in the immunocompromised population the risk of iatrogenic "infection" from arthrocentesis has been estimated to be 0.05%, 10 of 249 (4.02%) radiologists in our study reported having been personally involved with a case in which a patient developed a documented joint infection after a negative joint aspiration, such that the negative joint aspiration procedure was suspected of causing the subsequent joint infection. As Dooley noted, simply demonstrating this occurrence would be challenging at best.

Needle Gauge (Question 12)

Hansford et al stated that the choice of needle used for joint access depends on the specific target, the patient's body habitus, and the consistency of the fluid to be aspirated. For deep joints such as the shoulder or hip, 3.5-in spinal needles are preferred, as the trocar prevents the needle from becoming clogged. Superficial joints can be accessed with a 1.5-in needle. An 18-gauge needle may be necessary to aspirate thick joint fluid. When pus is encountered, as much should be aspirated as possible to decompress the joint.[16]

According to Kung et al,[5] 18, 20, or 22-gauge needles are used depending on the size and location of the joint. If the aspiration contains pus, as much fluid as possible should be aspirated to achieve decompression. Contrast material can be injected to confirm intraarticular needle location, but not universally performed if fluid is successfully aspirated and the needle resides on the bony landmark targeted.[2,5]

Question 12 indicates that radiologists prefer an 18-guage needle for aspiration of the suspected septic joint (129 of 245; 52.65%), but with a large number of radiologists changing needle size based on the joint (74 of 245; 30.20%).

Dry Tap and the Influence of Lidocaine and Iodinated Contrast (Questions 10, 15, and 16)

Rotation and repositioning of the needle is recommended if there is an insufficient amount of fluid aspirated. If still insufficient, some advocate that the joint be irrigated with nonbacteriostatic saline and then aspirated.[2,16] In this scenario, contrast has been advocated to confirm intraarticular injection of the saline solution.[5,16]

However, contrast injection is controversial, with some reporting a risk of hematogenous propagation of infection, or a potential bactericidal effect, whereas others feel it is a necessary component of the procedure, potentially demonstrating sinus tracks, abscesses, or bursae that may be infected.

Bruins et al explained that although arthrography is not necessary in order to perform a joint aspiration, it helps to confirm the position of the needle. Iodinated contrast media has been considered a major cause of the frequent false-negative cultures from intraarticular samples in the past, likely because free iodine is bactericidal and used as a disinfectant. As such, the authors investigated the antimicrobial effects of numerous older and modern iodinated contrast agents on numerous microorganisms, the latter chosen based on species that have been isolated from infected hip prostheses. The authors found no inhibiting effects with disc diffusion testing, a qualitative method applied for classic antimicrobial susceptibility. Using undiluted contrast media, quantitative testing showed only a bactericidal effect of ioxithalamate on *Escherichia coli* and on *Pseudomonas aeruginosa*. Notably, ioxithalamate reflects an older, high osmolar, allegedly more toxic media. The authors noted that the evidence linking contrast media false-negative cultures of joint fluid is mixed and sometimes contradictory, likely due to inconsistencies in the sizes of the bacterial inoculum and dilutions of the medium. The authors concluded that false-negative results found in cultures currently are still not explained, but are not caused by the tested modern contrast agents.[24]

A variety of factors may play a role in a false-negative culture, and include autolysis of the microorganisms or delayed arrival of the sample in the microbiology laboratory with suboptimal transport conditions, antibiotic treatment of the patient before aspiration, or the bactericidal effects of a local anesthetic injected before aspiration.[24]

Amine-type anesthetics, such as lidocaine, have an antimicrobial effect typically at the membrane level.[25,26] In a review by Johnson et al, the authors concluded that caution should be taken when administering local anesthetics before diagnostic procedures in which culture specimens are to be obtained, as the antimicrobial activity of the local anesthetic could lead to false-negative results or suboptimal culture yields. They recommend that if use of a local anesthetic cannot be avoided, the lowest concentration possible of a mildly antimicrobial agent, such as cocaine or ropivicaine, should be used.[26]

However, Schweitzer et al[25] demonstrated that at body temperature, the clinically used concentration of lidocaine has no effect on the growth of the usual types of organism that cause skeletal infections.

Question 10, 15, and 16 suggest that radiologists most frequently follow a dry tap with a nonbacteriostatic saline lavage (134 of 247; 54.25%). However, not all radiologists subscribe to this protocol, despite its potential utility of identifying a septic joint in an otherwise negative procedure. Although there are reports demonstrating that false-negative culture results appear unrelated to the presence of iodinated contrast administered during joint aspiration, most radiologists surveyed (127 of 248; 51.21%) reported that they make an attempt to avoid using iodinated contrast media. Numerous comments provided via free text also reported that contrast was used only after successful aspiration to confirm needle location, whereas avoiding the bacteriostatic effects of the contrast media. The literature is varied as to the effects lidocaine may have on the growth of microorganisms aspirated from a septic joint, but the majority of radiologists report attempting to avoid injecting lidocaine into the joint prior to sample collection (209 of 248; 84.27%).

Conclusion

Clinical systemic manifestations and serum laboratory markers of infection are neither sensitive or specific for a septic joint, however, appear to influence the radiologist's decision to perform a requested joint aspiration. Although bacteremia is the most likely avenue by which a joint may become infected, a substantial number of radiologists consider it to be a contraindication to joint aspiration.

There is no clear consensus among those surveyed regarding specialized consultation requirements, preprocedural imaging, or the management of coagulopathy before aspiration.

The administration of antibiotics before the procedure, which has shown to reduce the possibility of isolating an organism on both Gram stain and culture, does not deter the majority of respondents from performing a requested aspiration. This in turn may have the untoward effect of enabling poor practice habits from the referring provider.

Most radiologists will not put a needle through an abscess to access a joint. However, how to approach the request of a joint aspiration when there are features of inflamed soft tissue overlying the needle path are not as clear in the literature or clinical practice.

The size of the needle used is not universal, and for many, joint dependent. The use of a lavage following a dry tap appears to be unclear to the respondents based on the mixed results of its use in practice. As a whole, the group is also unclear as to what bacteriostatic effects, if any, lidocaine and iodinated contrast have on joint aspiration growth results.

Appendix 1. Septic arthritis and joint aspiration

The Radiologist's Role in Image-Guided Aspiration for Suspected Septic Arthritis

The following questions pertain to the management of suspected septic arthritis, and your personal experiences and opinions:

(1) Is laboratory evidence of septic arthritis required prior to performing the aspiration (such as elevated ESR, CRP, or peripheral WBC count)?

Yes

No

Sometimes

(2) Are clinical systemic manifestations of infection required (such as fever or chills or rigors) before performing the aspiration?

Yes

No

Sometimes

(3) What imaging is required prior to agreeing to a joint aspiration request?

None (some form of imaging is done at the time of the procedure)

Radiographs only

One of US, CT, or MRI

Two or more of US, CT, or MRI

(4) Is specialized consultation required prior to aspiration?

Yes, infectious disease must first see the patient and agree with the plan

Yes, orthopedic surgery must first see the patient and agree with the plan

Yes, either infectious disease OR orthopedic surgery must first see the patient and agree with the plan

Yes, both infectious disease AND orthopedic surgery must first see the patient and agree with the plan

No

(5) Is bacteremia a contraindication to performing an aspiration that has been requested?

Yes, absolute

Yes, but not absolute, and decisions are made on a case by case basis

No

(6) If a patient is on antibiotics at the time of joint aspiration request, do you defer the procedure?

Yes

No

Sometimes

(7) If the soft tissue of the patient overlying your projected needle path at the time of aspiration appears red or inflamed, would you proceed with the joint aspiration that has been requested?

Yes

No

Sometimes

(8) Suppose MRI shows edema in the soft tissues suggestive of cellulitis overlying your projected needle path. Would you proceed with the joint aspiration that has been requested?

Yes

No

Sometimes

(9) Suppose MRI shows an abscess in the soft tissues overlying your projected needle path. Would you proceed with the joint aspiration that has been requested?

Yes

No

Sometimes

(10) If you encounter a "dry tap" (one in which no fluid can be aspirated), do you perform a lavage maneuver in which you administer nonbacteriostatic saline or contrast followed by aspiration that has been requested?

Always, nonbacteriostatic saline lavage

Always, contrast lavage

Sometimes

Never

(11) Does coagulopathy (abnormally elevated INR or abnormally low platelet count) influence your decision to perform the procedure?

Yes, coagulopathy should be corrected before performing the procedure, WITH specific criteria used

Yes, coagulopathy should be corrected prior to performing the procedure, but WITHOUT specific criteria used

No

(12) What gauge needle do you use to aspirate a joint for suspected septic arthritis?

18 gauge
22 gauge
25 gauge
Whatever is available
Depends on the joint

(13) Have you personally been involved with a case in which a patient developed a DOCUMENTED joint infection after a negative joint aspiration, such that the negative joint aspiration procedure was suspected of causing the subsequent joint infection?

Yes
No (cannot remember such a case)

(14) Which of the following best describes your practice setting?

Academic
Private practice
Teleradiology

(15) When performing a joint aspiration for suspected septic arthritis, do you attempt to avoid injecting lidocaine into the joint before collecting the aspirate?

Yes
No
Sometimes

(16) When performing a fluoroscopic-guided joint aspiration for suspected septic arthritis, do you make an attempt to avoid using iodinated contrast media?

Yes
No
Sometimes

(17) Free comments:

Appendix 2

Dear SSR Member,

I'd like to invite you to participate in a very brief survey about your personal experience with joint aspiration procedures for suspected septic arthritis. The radiologist often plays an important role in the diagnostic work-up of patients presenting with suspected septic arthritis by providing image-guided joint aspiration. Although this practice is common, there are several factors that influence the decision of the radiologist to either proceed with the procedure or defer, without an obvious consensus in the literature regarding these often-encountered obstacles.

Our purpose is to poll those practicing musculoskeletal (MSK) radiology in both the private practice and academic realm with regards to the decision-making process related to joint aspiration for suspected septic arthritis. We are attempting to identify any potential trends in variables that serve as relative or absolute contraindications, as well as identify any glaring inconsistencies. Thank you in advance for your time.

Link to the survey (copy and paste in browser if link is not active).

Sincerely,
Jack Porrino, MD
Diagnostic Radiology
University of Washington

References

1. Margaretten ME, Kohlwes J, Moore D, Bent S: Does this adult patient have septic arthritis? J Am Med Assoc 297(13):1478-1488, 2007. http://dx.doi.org/10.1001/jama.297.13.1478
2. Lin HM, Learch TJ, White EA, Gottsegen CJ: Emergency joint aspiration: a guide for radiologists on call. Radiographics 29(4):1139-1158, 2009. http://dx.doi.org/10.1148/rg.294085032
3. Sammer DM, Shin AY: Comparison of arthroscopic and open treatment of septic arthritis of the wrist. J Bone Joint Surg Am 91(6):1387-1393, 2009. http://dx.doi.org/10.2106/JBJS.H.00630
4. Carpenter CR, Schuur JD, Everett WW, Pines JM: Evidence-based diagnostics: adult septic arthritis. Acad Emerg Med 18(8):781-796, 2011. http://dx.doi.org/10.1111/j.1553-2712.2011.01121.x
5. Kung JW, Yablon C, Huang ES, Hennessey H, Wu JS: Clinical and radiologic predictive factors of septic hip arthritis. AJR Am J Roentgenol 199(4):868-872, 2012. http://dx.doi.org/10.2214/AJR.10.6273
6. Butt U, Amissah-Arthur M, Khattak F, Elsworth CF: What are we doing about septic arthritis? A survey of UK-based rheumatologists and orthopedic surgeons. Clin Rheumatol 30(5):707-710, 2011. http://dx.doi.org/10.1007/s10067-010-1672-3
7. Farah Z, Reddy V, Matthews W, Giles I: Poor adherence to guidelines on early management of acute hot swollen joint(s): an evaluation of clinical practice and implications for training. Int J Clin Pract 69(5):618-622, 2015. http://dx.doi.org/10.1111/ijcp.12580
8. Mathews CJ, Kingsley G, Field M, et al: Management of septic arthritis: a systematic review. Postgrad Med J 84(991):265-270, 2008. http://dx.doi.org/10.1136/ard.2006.058909
9. Hindle P, Davidson E, Biant LC: Septic arthritis of the knee: the use and effect of antibiotics prior to diagnostic aspiration. Ann R Coll Surg Engl 94(5):351-355, 2012. http://dx.doi.org/10.1308/003588412X13171221591015
10. Core Team R: A Language and Environment for Statistical Computing. Vienna, Austria: R Foundation for Statistical Computing, 2017. Available from: https://www.R-project.org/
11. Gower J: A general coefficient of similarity and some of its properties. Biometrics 27:857-874, 1971.
12. Rousseeuw P: Silhouettes: a graphical aid to the interpretation and validation of cluster analysis. Comput Appl Math 20:53-65, 1987.
13. van der Maaten L, Hinton G: Visualizing high-dimensional data using t-SNE. J Mach Learn Res 9:2579-2605, 2008.
14. Shirtliff ME, Mader JT: Acute septic arthritis. Clin Microbiol Rev 15(4):527-544, 2002.
15. McGillicuddy DC, Shah KH, Friedberg RP, Nathanson LA, Edlow JA: How sensitive is the synovial fluid white blood cell count in diagnosing septic arthritis? Am J Emerg Med 25(7):749-752, 2007. http://dx.doi.org/10.1016/j.ajem.2006.12.001
16. Hansford BG, Stacy GS: Musculoskeletal aspiration procedures. Semin Interv Radiol 29(4):270-285, 2012. http://dx.doi.org/10.1055/s-0032-1330061
17. Sharff KA, Richards EP, Townes JM: Clinical management of septic arthritis. Curr Rheumatol Rep 15(6):332, 2013. http://dx.doi.org/10.1007/s11926-013-0332-4
18. Li SF, Henderson J, Dickman E, Darzynkiewicz R: Laboratory tests in adults with monoarticular arthritis: can they rule out a septic joint? Acad Emerg Med 11(3):276-280, 2004.
19. Kang S-N, Sanghera T, Mangwani J, Paterson JMH, Ramachandran M: The management of septic arthritis in children: systematic review of the English language literature. J Bone Joint Surg Br 91(9):1127-1133, 2009. http://dx.doi.org/10.1302/0301-620X.91B9.22530
20. Cipriano CA, Brown NM, Michael AM, Moric M, Sporer SM, Della Valle CJ: Serum and synovial fluid analysis for diagnosing chronic periprosthetic infection in patients with inflammatory arthritis. J Bone Joint Surg Am 94(7):594-600, 2012. http://dx.doi.org/10.2106/JBJS.J.01318

21. Li SF, Cassidy C, Chang C, Gharib S, Torres J: Diagnostic utility of laboratory tests in septic arthritis. Emerg Med J 24(2):75-77, 2007. http://dx.doi.org/10.1136/emj.2006.037929
22. Chong YY, Fong KY, Thumboo J: The value of joint aspirations in the diagnosis and management of arthritis in a hospital-based rheumatology service. Ann Acad Med Singapore 36(2):106-109, 2007.
23. Dooley DP: Aspiration of the possibly septic joint through potential cellulitis: just do it! J Emerg Med 23(2):210, 2002.
24. Bruins MJ, Zwiers JH, Verheyen CCPM, Wolfhagen MJHM: In vitro study of the antimicrobial effects of radiological contrast agents used in arthrography. J Bone Joint Surg Br 93(1):126-130, 2011. http://dx.doi.org/10.1302/0301-620X.93B1.24968
25. Schweitzer ME, Deely DM, Beavis K, Gannon F: Does the use of lidocaine affect the culture of percutaneous bone biopsy specimens obtained to diagnose osteomyelitis? An in vitro and in vivo study. AJR Am J Roentgenol 164(5):1201-1203, 1995. http://dx.doi.org/10.2214/ajr.164.5.7717232
26. Johnson SM, Saint John BE, Dine AP: Local anesthetics as antimicrobial agents: a review. Surg Infect 9(2):205-213, 2008. http://dx.doi.org/10.1089/sur.2007.036