

Analysis of factors that drives arthrocentesis for suspected septic joint

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Abstract

Introduction: This study aims to develop a simple diagnostic criterion that could be used to justify arthrocentesis in adults with suspected septic arthritis. Our hypothesis is that no single factor will be predictive for a decision to aspirate a questionable septic joint.

Methods: A prospective observational cohort study was performed at a Level 1 Trauma institution including all patients over the age of 18 years referred to Orthopaedics through the Emergency Department or inpatient orthopaedic consultations for a suspected septic joint. Patient information recorded was age, laboratory markers (white blood cell count, erythrocyte sedimentation rate, C-reactive protein, physical exam findings (fever, pain with range-of-motion), and presence of smoking, diabetes, end-stage renal disease (ESRD) on dialysis, and body mass index > 30. Continuous data was analyzed using logistic regression, and nominal data was analyzed using a two-tailed Fisher's exact test.

Results: A total of 128 patients met inclusion criteria for this study; 71 patients underwent arthrocentesis for suspected septic joint. On analysis of risk factors, the demographics, laboratory markers, physical exam and comorbidities were not significant between the two groups. On subset analysis of the septic joints, we found the only risk factor to be significantly predictive of whether a joint was septic was the presence of ESRD on dialysis ($p=0.042$).

Conclusion: Past data have looked solely at predictive risk factors for septic arthritis; however, this study aims to predict what drives physicians towards aspirating a joint even before it is determined to be septic. We found no single factor was predictive of joint aspiration. Only ESRD on dialysis is predictive of whether a joint with concern for septic arthritis would ultimately be septic in our institution. The decision to aspirate continues to be best determined by clinician judgment in light of experience and available clinical information.

Keywords: clinical decision making, diagnosis, septic arthritis

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Introduction

The diagnosis of septic arthritis is a true orthopedic emergency requiring timely detection in order to minimize joint damage and reduce associated morbidity and mortality. Septic arthritis most often presents as a monoarticular joint infection, commonly affecting the knee and less often the wrist, ankles, and hips.¹ Once the infectious agent has effectively seeded the joint, the onset of symptoms is typically rapid, progressive and usually presents with some combination of erythema, heat, stiffness, pain, reduced range of motion, fever, weakness, and headache.² The mechanisms

of infection include: hematogenous seeding of the joint, such as intravenous (IV) drug use, or direct inoculation of bacteria *via* trauma or surgery.³ Proposed risk factors for acute joint infection include advanced age, artificial joint, recent joint surgery or injection, diabetes, immunosuppression, and IV drug use.⁴ Causative agents differ based on underlying patient characteristics; however, infection is usually monomicrobial and treatment consists of arthroscopic or open surgical debridement with adjuvant antimicrobials directed at *Staphylococci* or *Streptococci*.³ Gonococcal arthritis can result from sexually transmitted bacteria

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Neisseria gonorrhoeae in sexually active young adults.⁵

Recent research suggests an increasing incidence and cost burden of septic arthritis in the United States (US). In 2012, over 13,000 hospitalizations in the US were attributed to septic arthritis, leading to over \$759 million in hospital costs. This cost burden has risen in recent years, with inpatient charges from septic arthritis in the US increasing by 24% from 2009 to 2012.⁶ Unlike in pediatric populations, where criteria exist to guide providers in the decision to perform diagnostic arthrocentesis,^{7–9} no validated criteria exist in adult populations. Arthrocentesis indications in adults have been largely extrapolated from pediatric criteria without sufficient study on the merit of these indications. This potentially leads to unnecessary joint aspiration, delays in diagnosis, and increased costs associated with related complications. Currently, diagnosis of septic arthritis in adults is generally based on joint aspiration.² Synovial fluid analysis with synovial white blood cell counts greater than 50,000 mm³ or positive gram stain suggests a potential joint infection.¹⁰

However, ultimate diagnosis and treatment depends on clinical judgment. Other joint diseases that mimic septic arthritis include gout, pseudogout, inflammatory bowel disease (IBD)-associated arthritis, reactive arthritis, and rheumatoid arthritis. Synovial fluid analysis, specifically cell count, can help differentiate between such entities. While the gold standard for diagnosis is positive synovial fluid culture, this may take days for growth, and thus is not useful for making a prompt diagnosis.

Recent studies have attempted to identify combinations of patient history, physical exam, or laboratory data that could serve as useful criteria in diagnosing septic arthritis; however studied patient predictor values differ greatly across studies.^{1,11–14} Furthermore, many of these studies depend on joint aspiration data for definitive diagnosis. Thus, in order to prevent unnecessary joint aspiration and minimize the number of missed diagnosis, this study aims to develop a simple diagnostic criterion to justify arthrocentesis in adults with suspected septic arthritis. Our hypothesis is that no single factor will be predictive for a decision to aspirate a suspected septic joint.

Patients and methods

A retrospective observational cohort study was performed at a single Level 1 Trauma institution from January 2018 to March 2020. All patients over the age of 18 years old referred to Orthopedics through the Emergency Department or inpatient orthopedic consultations for a suspected septic joint were included. Exclusion criteria included; patients <18 years old, and/or those with history of prosthetic joint, those unable or unwilling to consent to participate. Patients were assessed by physicians blinded to the patients' participation in the study. All the physicians involved in patient assessment were orthopaedic surgeons, including one staff attending surgeons and two senior residents.

Patient information recorded in the chart was:

- Demographic
 - Age (years)
- Laboratory serum laboratory values
 - White blood cells (WBC) 10³/μl (normal 3.5–11.0 10³/μl)
 - Erythrocyte sedimentation rate (ESR) mm/h (normal 1–47 mm/h)
 - C-reactive protein (CRP) mg/l (normal <5 mg/l)
- Physical exam findings
 - Fever (temperature >38°C)
 - Pain with range-of-motion (ROM) as documented by consulting physician
- Presence of risk factors
 - History of smoking, diabetes (DM), end-stage renal disease (ESRD) on dialysis, body mass index (BMI) > 30

The treating physician's decision to aspirate or not aspirate the joint was recorded. The presence or absence of a septic joint was then recorded based on available data. Patients who were not aspirated were followed clinically for the development of septic arthritis, while those patients who underwent aspiration had synovial fluid analysis performed. Non-aspirated patients were followed closely as inpatients for any acute changes that may necessitate joint aspiration. A diagnosis of infection was determined if synovial WBC count was over 50,000/μl and/or if the patient was taken to the operating room for irrigation and debridement based on a positive culture or high clinical concern for septic joint. The presence of physical examination findings and laboratory markers at the time of the arthrocentesis were evaluated as

potential guiding factors in the decision tree. Additionally, subset analysis of the arthrocentesis group was evaluated for predictive risk factors for a positive aspirate.

Statistical analysis was performed using Stata Software (StataCorp LLC, College Station, TX, USA). Continuous data was analyzed using logistic regression, with a 95% confidence interval (CI) and an alpha-value of 0.05. Nominal data was analyzed using a two-tailed Fisher's exact test with an alpha value of 0.05.

Results

A total of 128 patients met inclusion criteria for this study (Appendix). Patients were separated into two groups based on whether their joint in question was aspirated or not. Joints in question included: knee, shoulder, elbow, ankle, hip, and wrist. All aspirations were performed without image guidance with the exception of hip aspiration, which was done in the radiology suite. "Dry taps", or arthrocentesis without fluid, were not included in the analysis. The first group included 57 patients (44.6%) who were not aspirated, and the second group included 71 patients (55.4%) who were aspirated. There were four patients in the first group who we were reconsulted about for concern of another suspected joint infection. Three of these patients were aspirated on the second consult, yielding two aspirations positive for gout, and one aspiration negative for infection, gout, and/or pseudogout. None of these aspirations were determined to be septic. The remainder of the patients in the first group who were not aspirated did not develop an eventual septic arthritis.

Of 57 joints that were not aspirated, the average age was 57.33 years old, ESR 65.14 mm/h, CRP 128.03 mg/l, and WBC 10.67 $10^3/\mu\text{l}$, 13 (22.8%) were smokers, 40 (70.2%) had pain with ROM of the joint on physical exam, 19 (33.3%) had diabetes, 6 (11.0%) had ESRD on dialysis, 6 (11.0%) had a fever $>38^\circ$, and 17 (30.0%) had a BMI >30 (Table 1).

Of the 71 joint aspiration cases, the average age was 59.34 years old, ESR 74.37 mm/h, CRP 126.70 mg/l, and WBC 11.55 $10^3/\mu\text{l}$, 16 (22.5%) were smokers, 58 (81.7%) had pain with ROM of the joint on physical exam, 23 (32.4%) had diabetes, 7 (9.86%) had ESRD on dialysis, 7 (9.86%) had a fever $>38^\circ$, and 19 (26.8%) had a BMI

>30 . On analysis of risk factors, no single risk factor was predictive of whether a joint was aspirated. The ages, laboratory markers and physical exam and comorbidities were not significant between the two groups on multivariate analysis (Tables 1 and 2).

The patients who were aspirated were then separated into two subgroups: whether or not the joint was determined to be infected through aspiration. Of the 71 aspirated patients, 18 (25.4%) were found to have a septic joint, determined by synovial fluid analysis of $>50,000$ cells/ μl and/or if they were taken to the operating room for irrigation and debridement.

Of the 18 septic joints, the average age was 58.78 years old, ESR 65.65 mm/h, CRP 140.29 mg/l, and WBC 10.70 $10^3/\mu\text{l}$ (Table 2); 4 (22.2%) were smokers, 14 (77.8%) had pain with ROM of the joint on physical exam, 6 (33.3%) had diabetes, 4 (22.2%) had ESRD on dialysis, 3 (16.7%) had a fever $>38^\circ$, and 3 (16.7%) had a BMI >30 .

Of the 53 non-septic joints, the average age was 59.21 years old, ESR 73.43 mm/h, CRP 119.25 mg/l, and WBC 10.67 $10^3/\mu\text{l}$ (Table 2); 12 (22.6%) were smokers, 44 (83%) had pain with ROM of the joint on physical exam, 17 (32.1%) had diabetes, 3 (5.7%) had ESRD, 4 (7.5%) had a fever $>38^\circ$, and 16 (30.2%) had a BMI >30 .

On subset analysis of the septic joints, we found that the only risk factor that was found to be significantly predictive of whether a joint was septic was the presence of ESRD on dialysis ($p=0.042$) with Fisher's exact testing. All other risk factors, age, and laboratory markers were not significantly predictive of whether an aspirated joint would be determined to be septic (Table 2).

Discussion

Past data have focused on predictive risk factors for septic arthritis; here, we aimed to evaluate what drives physicians towards aspirating a joint. Although a potential surrogate for septic arthritis, the decision to aspirate a joint is complex, multifactorial, and may not mirror the risk factors for septic arthritis. Our decision to aspirate usually hinges on the physical examination and the laboratory markers. Our institution tends to err on the side of caution, aspirating more patients with equivocal exam findings and slightly elevated markers, to avoid missing an occult septic

Table 1. Patient age, laboratory markers, comorbidities and physical examination findings in patients with joint not aspirated *versus* aspirated.

Age and laboratory markers		
	Joint not aspirated (mean)	Joint aspirated (mean, <i>p</i> value) ^a
Age (years)	57.33	59.34, <i>p</i> =0.567
ESR (mm/h)	65.14	74.37, <i>p</i> =0.158
CRP (mg/l)	128.03	126.70, <i>p</i> =0.539
WBC (10 ³ /μl)	10.67	11.55, <i>p</i> =0.730
Risk factors		
	Joint not aspirated (%)	Joint aspirated (%), <i>p</i> value)
Smoking	13/57 (22.8)	16/71 (22.5), <i>p</i> =0.971
Pain with ROM	40/57 (70.2)	58/71 (81.7), <i>p</i> =0.126
Diabetes	19/57 (33.3)	23/71 (32.4), <i>p</i> =0.910
ESRD	6/57 (11.0)	7/71 (9.86), <i>p</i> =0.901
Fever	6/57 (11.0)	7/71 (9.86), <i>p</i> =0.901
BMI > 30	17/57 (30.0)	19/71 (26.8), <i>p</i> =0.843

^aAlpha value set at 0.05.
 BMI, body mass index; CRP, C-reactive protein; ESR, erythrocyte sedimentation rate; ESRD, end-stage renal disease on dialysis; ROM, range-of-motion; WBC, white blood cell count.

arthritis. Given the possibility of a negative tap and the implications of “over investigation”, evaluating the risk factors that may tighten the indications for an aspiration of a joint is beneficial. In the following analysis, we found no single factor (age, comorbidity, laboratory value) to be predictive for the decision to aspirate a joint. Our secondary aim, identifying predictors of positive arthrocentesis, demonstrated that only ESRD on dialysis is predictive of whether a joint with concern for septic arthritis would ultimately be septic in our institution.

Data is mixed with both small focused studies and large meta-analyses evaluating what is predictive of septic arthritis in adults. Roberts looked at 17 patients who underwent operative joint irrigation-and-debridement and found that a serum CRP of > 105 mg/l was predictive of infection.¹⁵ A meta-analysis to assess the pretest probability and diagnostic test characteristics (sensitivity, specificity, likelihood ratios) for septic arthritis showed that CRP values of 100 mg/l have a reported sensitivity of 82–83% for septic arthritis but specificities range from 27% to 70%.¹² The absence of

fever does not rule out a diagnosis of septic arthritis, with only 30–50% of cases of *S. aureus* culture-confirmed septic arthritis patients having fever upon initial presentation.¹⁶ The sensitivity of elevated serum WBCs > 50,000/μl in the diagnosis of septic arthritis in adults has been analyzed in a meta-analysis, involving 6242 patients, and ranges from 50% to 70%. In the same meta-analysis, risk factors that increased the likelihood of septic arthritis were age older than 80 years, DM, rheumatoid arthritis, recent joint surgery, hip or knee prosthesis and/or skin infection, and HIV-1 infection.¹ Unfortunately, no single study or meta-analysis has evaluated all risk factors or generated a sensitive or specific predictive model in adults.

The *American Family Physician Journal*, in their algorithm for the diagnosis of acute septic monoarthritis in adults, suggests arthrocentesis in patients with joint effusion in absence of traumatic mechanism, based on history and physical examination, even without laboratory markers.^{2,17} Kocher’s classic study on pediatric septic hip arthritis illustrates the difficulty in creating

Table 2. Patient age, laboratory markers, co-morbidities and physical examination findings in patients with and without a septic joint.

Age and laboratory markers		
	Joint aspirated and non-septic (mean)	Septic joint (mean, <i>p</i> value)
Age (years)	59.21	58.78, <i>p</i> =0.919
ESR (mm/h)	74.43	65.65, <i>p</i> =0.300
CRP (mg/l)	119.25	140.29, <i>p</i> =0.685
WBC (10 ³ /μl)	10.67	10.70, <i>p</i> =0.430
Risk factors		
	Joint aspirated and non-septic (%)	Septic joint (%), <i>p</i> value)
Smoking	12/53 (22.6)	4/18 (22.2), <i>p</i> =0.971
Pain with ROM	44/53 (83)	14/18 (77.8), <i>p</i> =0.619
Diabetes	17/53 (32.1)	6/18 (33.3), <i>p</i> =0.922
ESRD	3/53 (5.67)	4/18 (22.2), <i>p</i> =0.042 ^a
Fever	4/53 (7.5)	3/18 (16.7), <i>p</i> =0.262
BMI > 30	16/53 (30.2)	3/18 (16.7), <i>p</i> =0.362

^aAlpha value set at 0.05.
 BMI, body mass index; CRP, C-reactive protein; ESR, erythrocyte *sedimentation rate*; ESRD, end-stage renal disease on dialysis; ROM, range-of-motion; WBC, white blood cell count.

a formula or algorithm for diagnosing septic arthritis. The “Kocher criteria” is a tool used to differentiate septic arthritis from transient synovitis in a child with a painful hip. In the original 1999 paper, the authors showed that the presence of four clinical predictors determines a 99.6% positive predictive value of pediatric septic hip arthritis *versus* transient synovitis.⁷ A point is given for each of the following: non-weight bearing, ESR > 40, fever > 38.5°, WBC > 12.0 10³/μl.¹⁸ However, the follow-up validation study in 2004 using the same four clinical predictors yielded only an 93% chance of septic arthritis diagnosis in a similar population.⁸ Additionally, a 2019 retrospective review of 104 pediatric patients determined that the “Kocher Criteria” for pediatric septic hip diagnosis do not apply to concern for pediatric septic knee. The researchers collected the modified Kocher criteria: serum WBC, non-weight bearing, ESR, fever, and CRP. Their data suggested four clinical predictors a sensitivity of 0.3, and five predictors a sensitivity of 0.11, demonstrating the complexity of the diagnosis. Furthermore, to our knowledge, no study has validated these values in the adult population.

Additionally, it may be hard to apply in critically ill adult patients in Level 1 trauma centers, especially when they are unable to stand. Finally, even with successful aspiration, synovial fluid Gram staining and microscopy gives a positive result in only 50% of cases of septic arthritis, which further muddies the waters.^{19,20}

The variety of available evidence, with the addition of our analysis, demonstrates that there are multiple factors at play in the decision who to aspirate and predict, of those aspirated, who will have a true “positive” septic arthritis. No patient can be fit into a rigid diagnostic algorithm. With regards to the decision to aspirate a joint, the clinician must use their own judgment, along with the available history, physical examination, and laboratory data to make the decision to attempt an invasive and painful arthrocentesis. It does not appear that any one factor can specifically steer the clinician towards this decision. We feel that, given the lack of a gold standard predictive algorithm, clinical acumen proves to be the most accurate. We had hoped to improve this clinical acumen by identifying specific factors that would

make the decision to aspirate more accurate. However, in this study, none of the patients that were not aspirated ended up becoming subsequently infected, demonstrating that our clinical judgment may be better than we initially thought.

Limitations

This study has a number of limitations, including the inherent limitations of a retrospective review, limited sample size, and range of risk factors examined. Although a large single-center study, the total number of patients limits the generalizability and power of the conclusions. We are also inferring that the decision to aspirate is based solely on clinical, laboratory, and comorbidity risk factors of the patient population, excluding variations in specific physician practice, and hospital-based algorithms. Furthermore, we are assuming that all those who did not receive an aspiration did not develop septic arthritis.

Conclusion

In conclusion, this study demonstrates that no single factor drove a clinician decision to aspirate a potentially septic joint. However, subgroup analysis suggested that the presence of ESRD on dialysis may be predictive of positive joint aspiration. Based on previous literature and our own findings, at this time we do not believe there is a single or algorithmic approach to risk-factor-based predictive modeling for arthrocentesis and septic arthritis. Thus, the decision to aspirate continues to be best determined by clinician judgment in light of experience and available clinical information.

Research ethics and patient consent

The study was approved by the Institutional Review Board (IRB 18-1348). All patients provided written informed consent for their data to be used in the study. The consent form was included and approved by the IRB.

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Conflict of interest statement

The authors declare that there is no conflict of interest.

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Supplemental material

Supplemental material for this article is available online.

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