RESEARCH ARTICLE

Accuracy of Preoperative Hip Aspiration in Diagnosing Infection before Conversion to Total Hip Arthroplasty after Failed Fixation for Hip Fracture: A Retrospective Study

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Abstract

Objectives: 1.What is the accuracy of preoperative hip aspiration in diagnosing infections in patients scheduled for conversion of failed hip fixation to total hip arthroplasty (cTHA)? 2. What is the clinically significant cutoff value for inflammatory markers that may assist in diagnosing hip infections before cTHA? 3. What is the concordance between preoperative hip aspiration and intraoperative cultures?

Methods: A retrospective study was conducted at Imam Khomeini Hospital Complex, Tehran (2017–2021), including candidates for cTHA following failed open reduction and internal fixation (ORIF). Exclusions were dry tap (failed aspiration), recent antibiotic therapy, or insufficient synovial fluid. Patients underwent erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) testing, joint aspiration, and intraoperative cultures, with the latter serving as the gold standard for diagnosis.

Results: The study involved 38 patients (mean age 50 ± 16.4 years). Preoperative hip aspiration demonstrated low sensitivity (17.7%) but high specificity (81.0%). C-reactive protein (CRP) demonstrated moderate diagnostic value (AUC = 0.643) with an optimal cutoff of 8.8 mg/L (sensitivity, 64.3%; specificity, 64.7%). Erythrocyte sedimentation rate (ESR) had limited diagnostic value (AUC = 0.577).

Conclusion: Preoperative hip aspiration for diagnosing infection in patients with total hip arthroplasties (THA) demonstrated poor sensitivity but high specificity. C-reactive protein (CRP) demonstrated moderate potential, whereas erythrocyte sedimentation rate (ESR) had limited value. These findings underscore the need for improved diagnostic methods, potentially combining multiple tests. Future research should focus on developing more accurate diagnostic approaches for infections in patients with chronic total hip arthroplasty (cTHA).

Level of evidence: II

Keywords: Conversion, Joint aspiration, Periprosthetic joint infection, Proximal femur fixation, Total hip arthroplasty

Introduction

Proximal femoral fractures, which are particularly prevalent in individuals aged 65 and older, are commonly treated with open reduction and internal fixation (ORIF).[1,2] However, up to 45% of these fixations fail in elderly patients, often necessitating conversion to total hip arthroplasty (THA).[3-6] The choice of initial procedure may influence the rate of conversion from failed fixation to THA (cTHA), with conversion rates varying significantly based on the fixation method employed.[7-9]

In these cases, diagnosing infection before conversion to total hip arthroplasty (cTHA) is essential. Pre-existing infections or positive intraoperative cultures significantly

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increase the risk of THA failure and subsequent periprosthetic joint infections (PJI).[10,11] However, no diagnostic method is completely reliable in detecting these infections.[12]

Accurately diagnosing hip infection before proceeding with conversion to total hip arthroplasty (cTHA) is essential, yet it remains a challenging task. Although preoperative hip aspiration is validated for diagnosing periprosthetic joint infection (PJI) in total hip arthroplasty (THA) according to the Musculoskeletal Infection Society (MSIS) criteria, there is a gap in the literature regarding its efficacy in diagnosing infections before cTHA.[13,14] This gap serves as the impetus for our study. We aim to investigate the accuracy of preoperative hip aspiration in diagnosing infections in patients scheduled for total hip arthroplasty (THA). Additionally, our study seeks to establish a clinically significant cutoff value for inflammatory markers, which could serve as a valuable tool for clinicians. Through this research, we aim to provide the medical community with critical data that could help optimize decision-making in selecting the most appropriate approach—whether single-stage or two-stage—for cTHA, potentially reducing the risk of THA failure.

The questions that guide the study are:

1. How accurate is preoperative hip aspiration in diagnosing infections in patients scheduled for cTHA?
2. What is the clinically significant cutoff value for inflammatory markers that could assist in diagnosing hip infections before cTHA?
3. What is the concordance rate between preoperative hip aspiration and intraoperative cultures?

Materials and Methods

Study Design and Population

This retrospective, single-center study included consecutive patients treated at the Orthopedic Department of Imam Khomeini Hospital Complex in Tehran, Iran, from 2017 to 2021. Eligible patients had experienced failed proximal femoral fixation and were scheduled for conversion to total hip arthroplasty (cTHA). Exclusion criteria included failed aspiration (dry tap), insufficient synovial fluid for testing (less than 1 mL), concurrent hip infections, and antibiotic use within two weeks before hip aspiration. The study was approved by the Ethics Committee of Tehran University of Medical Sciences, and all participants provided informed consent.

Data Collection

Medical records provided data on sex, age, body mass index (BMI), and medical comorbidities. All patients underwent a standard workup, including preoperative erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) testing, joint fluid aspiration and culture, and intraoperative cultures. Intraoperative cultures were considered the gold standard for diagnosing infection.

Joint Aspiration Procedure

Experienced orthopedic surgeons performed joint aspirations under fluoroscopic guidance to ensure precise placement of the aspiration needle into the joint space. Strict aseptic techniques were adhered to throughout the procedure.

Patients were changed into clean hospital gowns. In a designated sterile operating room, the surgeon, wearing a sterile surgical hood, mask, gown, and gloves, prepped the patient's skin around the joint four times with an alcohol-based disinfectant. After draping, the surgeon inserted a 21-gauge needle into the hip joint under C-arm fluoroscopic guidance.

An appropriate volume of synovial fluid, typically between 2 and 10 mL, was aspirated without the addition of local anesthetics or saline to avoid contamination or dilution of the sample. Due to its potential bacteriostatic properties, contrast media was not used during the aspiration.

Synovial fluid samples were divided for various analyses. For microbiological culture, samples were directly inoculated into two blood culture flasks—one containing an aerobic and the other an anaerobic liquid enrichment medium. The samples were subsequently processed using standard microbiological techniques. An infectious disease specialist reviewed the results of the synovial culture to prevent misinterpretation of contamination.

Intraoperative Cultures

During the surgical procedure, the surgical team collected six to seven samples from various locations, including the surgical site, the native joint, and the fixation screw or plate, to cover potential infection sites. These samples were handled and processed using sterile techniques to avoid contamination.

In the laboratory, the samples were incubated for up to ten days to facilitate the growth of slow-growing bacteria or those present in low numbers. Each sample was cultured under both aerobic and anaerobic conditions to ensure the detection of a broad range of potential pathogens.

The criteria for a positive culture were based on the type of organism isolated. For virulent organisms, such as *Staphylococcus* aureus or *Streptococcus* species, a positive culture was defined as at least two specimens showing the same organism associated with purulence. In contrast, for pathogens with low virulence, such as coagulase-negative Staphylococcus species or Propionibacterium species, at least three positive specimens with identical bacterial phenotypic profiles were required.

The study aimed to assess the effectiveness of preoperative hip aspiration in accurately diagnosing infection by comparing the results of cultures obtained from hip aspiration with those from intraoperative samples. Intraoperative cultures, due to their broader and more direct sampling, were considered the gold standard for comparison.

Statistical Analysis

Frequencies and percentages were used for categorical variables, and the mean, standard deviation, and range were used for continuous variables. To evaluate the performance of synovial fluid culture, we calculated specificity, sensitivity, positive and negative predictive values, positive and negative likelihood ratios, and accuracy. Receiver operating characteristic (ROC) curves were used to assess the diagnostic performance of synovial fluid erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP). The

area under the curve (AUC) was determined with a 95% confidence interval, and receiver operating characteristic (ROC) analysis was used to identify the optimal cutoff value. Chi-square tests were applied to compare the results of hip aspiration and synovial fluid cultures, with a P-value of less than 0.05 considered statistically significant. All analyses were performed using IBM SPSS Statistics, version 26.

Results

This retrospective study included 38 consecutive patients (22 males and 16 females) with a mean age of 50 ± 16.4 years (range: 29–69 years). The majority of patients (n = 31) underwent cementless total hip arthroplasties (THAs), while the remaining patients (n = 7) received cemented THAs. The cohort had a mean C-reactive protein (CRP) value of 20.37 ± 30 mg/L (range: 0.5–136 mg/L) and a mean erythrocyte sedimentation rate (ESR) value of 33.48 ± 28 mm/h (range: 5–110 mm/h) [Table 1].

Question #1

Among all patients, seven had positive joint aspiration cultures, with the identified pathogens including Staphylococcus aureus (n = 3), Staphylococcus epidermidis (n = 1), Escherichia coli (n = 1), Bacillus cereus (n = 1), and gram-positive cocci (n = 1). These seven cases underwent a two-stage conversion. Intraoperative cultures were positive for 17 patients, with the most common pathogens identified as Staphylococcus aureus (n = 7) and Enterobacter species (n = 3) [Table 2].

Table 1. Patient Demographics and Clinical Data

Characteristics	Values
Age (years)	50 ± 16.4 (Range: 29-69)
Sex	
Male	20 (57.9%)
Female	18 (42.1%)
Fixation	
Cementless	31 (81.6%)
Cemented	7 (18.4%)
Preoperative CRP (mg/l)	20.4 ± 30 (Range: 0.5–136)
Preoperative ESR (mg/l)	33.48 ± 28 (Range: 5-110)

Values are presented as mean ± standard deviation (minimum-maximum) or n (%)

Table 2. Identification of Microorganisms in Preoperative Hip Aspiration and Intraoperative Cultures

Type of Culture	Positive Cultures (Patients)	Detected Pathogens
Preoperative Hip Aspiration	7	S. Aureus (n=3), S. Epidermidis (n=1), E. Coli (n=1), Bacillus cereus (n=1), Gram-positive cocci (n=1)
Intraoperative Culture	17	S. Aureus (n=7), Enterobacter sp. (n=3), S. Maltophilia (n=2), Coagulase-negative staphylococci (n=1), Serratia sp. (n=1), Bacillus sp. (n=1), Bacillus cereus (n=2), Pseudomonas aeruginosa (n=1), SCN (n=1)

The preoperative hip aspiration screening test demonstrated a sensitivity of 17.7%, a specificity of 81.0%, a positive predictive value of 42.9%, a negative predictive value of 54.9%, and an overall accuracy of 52.6% [Tables 3 and 4].

Of all cases, one developed periprosthetic joint infection (PJI) during early follow-up (5 months). The remaining cases were not revised during the follow-up period (range: 5–7 years).

Table 3. Diagnostic Classification Table

	Aspiration Positive	Aspiration Negative
Culture Positive	3	14
Culture Negative	4	17

Table 4. Diagnostic Accuracy of Joint Aspiration Cultures Compared to Intraoperative Culture (Gold Standard)

Metric	Value (%)	95% Confidence Interval
Sensitivity	17.65	0 - 35.8
Specificity	80.95	64.2 - 97.7
Positive Predictive Value (PPV)	42.86	6.2 - 79.5
Negative Predictive Value (NPV)	54.84	37.3 - 72.3
Positive Likelihood Ratio	0.93	0.24 - 3.59
Negative Likelihood Ratio	1.02	0.75 - 1.38
Accuracy (%)	52.6	41.4 - 65.7
Pearson Chi-Square	0.912	N/A

Question #2

In the serological tests, C-reactive protein (CRP) was able to distinguish between infected and non-infected cases, with an area under the curve (AUC) of 0.643 (95% confidence interval [CI], 0.44–0.84; P-value to be included). A CRP cutoff of 8.8 mg/L resulted in a sensitivity of 64.3%, specificity of 64.7%, positive predictive value of 88.2%, negative predictive value of 76.2%, and an accuracy rate to be included [Figure 1]. In contrast, erythrocyte sedimentation rate (ESR) did not show predictive potential for infection, with an AUC of 0.577 [Figure 2].

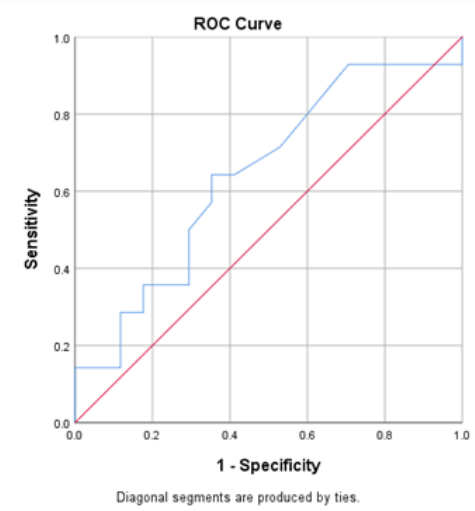

Figure 1. ROC curves for preoperative CRP, AUC = 0.643 representing 64.3% sensitivity, 64.7% specificity, 88.23% PPV, and 76.19% NPV at an optimal cutoff value of 8.8 mg/L

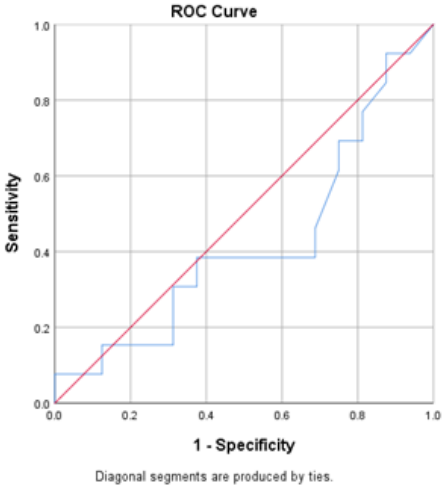

Figure 2. ESR AUC= 0.577 representing 38.5% sensitivity, 62.5% specificity, 70.6% PPV, and 85.7% NPV at an optimal cutoff value of 30 mm/h

Question #3

Among the cases studied, 17 were negative for both culture and aspiration. Four cases were positive on aspiration but negative on culture, while 14 cases were positive on culture but negative on aspiration. Only three cases were positive for both culture and aspiration. However, none of these cases showed concordance in the identified species, resulting in a concordance rate of 0% between aspiration and culture.

Discussion

This retrospective study of 38 patients who underwent conversion to total hip arthroplasty (cTHA) for failed fixation of proximal femoral fractures investigated the effectiveness of preoperative hip joint aspiration in diagnosing infections. Despite its widespread use in diagnostic procedures, a knowledge gap remains regarding its efficacy in detecting infections before cTHA. This gap is particularly concerning, given the critical importance of accurately diagnosing infection before this surgical procedure.

The study aimed to evaluate the sensitivity and specificity of preoperative hip aspiration. However, our findings raise

concerns about the reliability of this technique. The sensitivity of preoperative hip aspiration was only 17.7%, indicating that a significant number of patients with true infections were not correctly diagnosed. This could result in missed infection cases, potentially leading to poorer surgical outcomes. Conversely, the specificity of preoperative hip aspiration was 81.0%. Although this method is widely used in revision total hip arthroplasty (THA), to the best of our knowledge, this is the first study to evaluate preoperative hip aspiration for the detection of infection in conversion THA (cTHA) following failed fixation of proximal femoral fractures. Kanthawang et al., in a study of 202 total hip arthroplasties (THAs), found that hip aspiration (AUC = 0.78) and intraoperative parameters (AUC = 0.80) outperformed serum-based tests (AUC = 0.64) and clinical parameters (AUC = 0.68) in detecting periprosthetic joint infection (PJI).[15] Hip aspiration demonstrated a sensitivity of 64.0% and an accuracy of 78.5%. In a review of 186 hip aspirations, Li et al. reported a significant re-aspiration rate of 45.3% due to dry taps. Despite this, the sensitivity, specificity, positive predictive value, and negative predictive value were generally high, suggesting that the procedure provides a satisfactory detection of periprosthetic joint infection (PJI).[16] Kebschull et al. evaluated the accuracy of CT-guided joint aspiration in predicting periprosthetic joint infection (PJI). The study reported an accuracy of 86.5% and identified significant predictors, including high aspirate volume, accumulation of soft tissue exceeding the joint margin, and enlarged iliac lymph nodes.[17] In a study of 349 hip aspirations, Duck et al. found that the procedure had an accuracy of 87%, a sensitivity of 83%, a specificity of 89%, a positive predictive value of 79%, and a negative predictive value of 91%.[18] They concluded that ultrasound-guided aspirations help diagnose periprosthetic joint infection (PJI), although caution should be exercised with bloody aspirates and those obtained after lavage due to decreased accuracy. Christensen et al. reported that, in a group of 335 total hip arthroplasty (THA) patients, those with successful aspirations had higher rates of meeting the MSIS criteria preoperatively and were more likely to undergo revision for PJI.[19] They recommended that surgeons apply extra scrutiny when interpreting negative results in patients who require saline lavage for hip joint aspiration.

Despite the recognized importance of accurately diagnosing infections before conversion to total hip arthroplasty (cTHA), a significant knowledge gap remains in this area. Few studies have specifically assessed diagnostic approaches for latent infections in cTHA patients.[12,20-29] A recent systematic review by Poursalehian et al. evaluated various diagnostic tests for latent infections in chronic total hip arthroplasty (cTHA). The reviewed studies utilized C-reactive protein (CRP), erythrocyte sedimentation rate (ESR), fibrinogen, and platelet counts.[26] According to this review, CRP emerged as the most reliable marker for diagnosing latent infection.

In the clinical setting, suspicion of infection should be raised when patients present with specific symptoms, such as localized pain, swelling, redness, warmth around the joint, unexplained persistent joint discomfort, or systemic symptoms like fever.[30] Elevated levels of inflammatory markers, such as C-reactive protein (CRP) and erythrocyte sedimentation rate (ESR), may also suggest an infection, although these markers are not entirely specific to infection.[31,32] Interestingly, our results demonstrated that CRP could be a significant serological marker in distinguishing between infected and non-infected cases. With an area under the curve (AUC) of 0.643, CRP appears to be moderately helpful in diagnosing hip infections. Notably, a CRP cutoff of 8.8 mg/L exhibited relatively balanced sensitivity and specificity (64.3% and 64.7%, respectively), which may provide a potential threshold for identifying infections.

The results indicated a complete lack of concordance between aspiration and culture results in cTHA, as evidenced by a 0% concordance rate. While a subset of cases showed positivity in either ambition or culture, no cases exhibited agreement between the two methods regarding the specific species identified. This discrepancy raises essential questions about the reliability and diagnostic utility of aspiration versus culture in identifying the causative organisms in similar clinical settings. A systematic review of 886 primary total hip arthroplasties (THAs) reported concordance rates between aspiration and culture ranging from 52% to 79%.[33] In contrast, our study demonstrated a markedly lower concordance rate, suggesting that aspiration before cTHA may not be as valuable as it is in primary THA.

Joint aspiration is particularly valuable when patients present with ambiguous clinical symptoms or conflicting laboratory test results, as it provides direct evidence of intra-articular infection. Additionally, preoperative joint aspiration can guide the selection of appropriate antibiotics for perioperative prophylaxis if a pathogen is identified.[14] However, our study revealed a complete lack of concordance (0%) between aspiration and intraoperative culture results in patients undergoing total hip arthroplasty (THA). This discrepancy raises essential questions and warrants further investigation into both biological and procedural factors.[34]

Aspiration is susceptible to contamination from skin or soft tissue, which can inadvertently affect the sample.[35] In cases of hardware-associated infections, mixed flora are commonly observed.[36] Additionally, when bacteria form a biofilm on hardware, some organisms may be intermittently released, often in low quantities, into the joint fluid, while the principal organism within the biofilm may remain undetected by aspiration.[37] During surgery, removing hardware or sampling periprosthetic tissue or bone may help identify the predominant organism in biofilm form.

A plausible explanation for the observed low accuracy of joint aspiration in cTHA may be related to the nature of infections associated with failed open reduction and internal fixation (ORIF). Pathogens responsible for latent or deep-seated infections often adhere to hardware rather than infiltrating the synovial fluid.[38] As a result, they may remain extra-articular and fail to contaminate the joint space. This scenario helps explain the reduced sensitivity of aspiration in detecting infection, as the synovial fluid may not contain the pathogen responsible for the infection. Clinically, this

highlights the importance of recognizing that negative aspiration findings do not necessarily exclude infection in cases of failed open reduction and internal fixation (ORIF).

Several studies have investigated the accuracy of C-reactive protein (CRP) as a diagnostic marker for infections in patients undergoing conversion total hip arthroplasty (cTHA). For example, a retrospective cohort study by Gittings in 2017 reported a high sensitivity of 100% and a specificity of 81% using a CRP threshold of 7 mg/L.[12] Similarly, Cichos et al. (2020) reported a sensitivity of 75% and a specificity of 84% for CRP at a threshold of 12 mg/L.[21] However, Anderson's 2022 study showed lower sensitivity and specificity values of 66.6% and 60.5%, respectively, although the CRP threshold was not specified.[23] Hemmann's study in the same year reported even lower sensitivity and specificity (50% and 43%, respectively), again without specifying the CRP threshold (24). Most recently, Xu et al. (2022) used a CRP threshold of 10 mg/L and found a sensitivity of 66.7% and a high specificity of 92.5%.[25]

Nevertheless, while these biomarkers can provide helpful information, they lack specificity for infections and can be elevated in many other conditions, such as malignancies, trauma, or systemic infections.[31] Furthermore, their values can be influenced by various factors, including age, comorbidities, and medication use, which can further reduce their specificity.[32] Therefore, while inflammatory markers, such as C-reactive protein (CRP), can play a crucial supporting role in diagnosing infections, they should not be used in isolation, and their results should be interpreted within the broader clinical and diagnostic context.

Another significant aspect of our findings was the wide range of pathogens identified from joint aspiration and intraoperative cultures, with Staphylococcus aureus (S. aureus) being the most commonly detected pathogen. This finding reinforces previous studies that have identified S. aureus as a common cause of orthopedic infections.[38] The diversity of detected pathogens further underscores the need for comprehensive diagnostic measures that can identify a wide range of potential infectious agents.

Limitations

As a single-center, retrospective study, our findings may not be generalizable to other settings. Furthermore, the small sample size may limit the statistical power of the results. As indicated by our study, the sensitivity and overall accuracy of this technique may not be optimal in cTHA, potentially leading to false-negative results.

Conclusion

This study highlighted the significant limitations of preoperative hip joint aspiration as a diagnostic tool for detecting infections before conversion to total hip arthroplasty (THA). Despite its widespread use, the findings revealed a strikingly low sensitivity of 17.7% and a complete lack of concordance between aspiration and culture results, with a concordance rate of 0%. These results suggested that preoperative hip aspiration may be inadequate for accurately diagnosing infections in the context of cTHA. Additionally, while inflammatory markers, such as C-reactive protein (CRP), showed moderate diagnostic value, they were insufficient when used in isolation and must be interpreted in conjunction with other clinical findings.

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Authors Contribution:

Alireza Moharrami conceived and designed the study and contributed to drafting the manuscript. Mohammad Poursalehian and Mohammadreza Razzaghof designed the analysis, performed the statistical evaluation, and contributed data. Mohammadreza Razzaghof assisted in manuscript writing and final revision. Mir Mansour Moazen Jamshidi collected the clinical data. Iman Menbari Oskuei assisted in manuscript preparation. Peyman Mirghaderi contributed analysis tools and methodological support. Nima Hosseini Zare collected and verified the data. Moein Khoori contributed to data collection. SM Javad Mortazavi supervised the study design and approved the final version of the manuscript.

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Declaration of Informed Consent:

Written informed consent was obtained from all participants prior to data collection, and all identifying information was anonymized to maintain confidentiality.

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