Original Clinical Article

JOURNAL OF CHILDREN'S ORTHOPAEDICS

Journal of Children's Orthopaedics
2022, Vol. 16(3) 233–237

DOI: 10.1177/18632521221106383
journals.sagepub.com/home/cho

The modified Kocher criteria for septic hip: Does it apply to the knee?

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Abstract

Background: Pediatric septic arthritis is a surgical emergency and timely diagnosis prevents serious complications. To differentiate between septic hip and transient synovitis, the predictive value of four original Kocher criteria (fever, inability to bear weight, elevated serum white blood cell count, and elevated erythrocyte sedimentation rate) plus Caird's addition of elevated C-reactive protein have been studied, termed the modified Kocher criteria. These criteria have not been tested extensively on septic knee. This study tested the utility of the modified Kocher criteria in predicting septic knee while validating it for septic hip.

Methods: A retrospective chart review was conducted of pediatric patients evaluated at a single institution for irritable hip or knee between 2009 and 2018. Patients who underwent arthrocentesis were included and the modified Kocher criteria were applied to all.

Results: One hundred fifty-five patients (96 hips and 59 knees) were identified. One hundred four (67.1%) patients had septic arthritis with 44/59 (74.6%) of knees and 60/96 (62.5%) of hips. The strongest predictors for septic hip and knee were elevated C-reactive protein (odds ratio = 26.9, $p < 0.0001$) and refusal to bear weight (odds ratio = 14.5, $p < 0.0001$), respectively. For hips, 5/5 criteria produced a 100% positive predictive value for septic arthritis. For knees, the combination of inability to bear weight and elevated C-reactive protein had a positive predictive value of 89.7%.

Conclusion: While all five of the modified Kocher criteria are not predictive of pediatric septic knee, the combination of two specific factors (inability to bear weight and elevated C-reactive protein) is strongly predictive. This study validates previous work that the modified Kocher criteria are predictive of septic hip.

Level of evidence: level III

Keywords: Septic arthritis, knee, hip, Kocher criteria (four original and five modified criteria)

Introduction

Septic arthritis is an orthopedic emergency and necessitates operative debridement to avoid growth disturbance and cartilage destruction.[1–3] Long-term complications of delayed diagnosis or inadequate treatment include early osteoarthritis, avascular necrosis, joint dislocation, pathologic fracture, and premature physeal closure, which can cause deformity, instability, or limb-length discrepancy.[4,5] Ultrasonography and magnetic resonance imaging (MRI) with contrast both have strong diagnostic utility in detecting joint effusions and, most important, synovial enhancement present in septic arthritis and can assist clinicians in the early stages.[6] Many conditions have a similar clinical presentation to pediatric septic arthritis, including Lyme arthritis, crystal-induced arthritis, inflammatory arthritis, and transient synovitis, which is self-limiting.[7,8] Transient synovitis of the hip (in German "Hüftschnupfen"—"sniffles of the hip") is a well-known entity with a typical history, typical clinical findings, and typical changes in

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Date Received: 5 February 2022; accepted: 11 May 2022

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ultrasound and MRI. Most important, it can be the forerunner of Perthes' disease. Subacute epimetaphyseal osteomyelitis must also be considered.[9]

In 1999, Kocher et al.[10] identified four predictive factors that can aid in differentiating septic arthritis of the hip from transient synovitis. Fever >38.5 C, inability to bear weight, serum white blood cell count (WBC) >12,000/mm^3, and an erythrocyte sedimentation rate (ESR) ≥40 mm/h were found to be associated with septic arthritis of the hip. The presence of all four factors was 99.6% predictive of septic hip in the initial retrospective study. In 2006, Caird et al.[11] evaluated C-reactive protein (CRP), as a fifth criteria. This prospective study found that the presence of all five factors predicted septic arthritis in 98% of cases and that CRP level >2.0 mg/dL (>20 mg/L) was a strong independent risk factor for diagnosing children with septic arthritis of the hip.[11] A subsequent prospective study by Kocher et al.[12] to validate the original four criteria was less predictive of septic arthritis of the hip. Other studies have been unable to replicate that same predictive level, with one study reporting a predictive value of only 59% for children with septic hip for the four original criteria.[13]

There have not been many studies validating the predictive value of all five factors for septic arthritis of the hip and very few studies that have tested the predictive value of these factors for septic arthritis of the knee.[14–16] The purpose of this study was to evaluate the utility of the modified Kocher criteria for septic arthritis of the knee and validate its application in predicting septic hip.

Methods

This is a retrospective cross-sectional case series of pediatric patients who were evaluated for an irritable hip or knee with arthrocentesis at a single institution between January 2009 and January 2018. This institution is not located in a Lyme endemic area. This study was approved by the Institutional Review Board (IRB) (IRB #15-058). The modified Kocher criteria and demographic information were collected for all patients. Septic arthritis was defined as a positive synovial fluid or positive blood culture and a synovial fluid WBC count >50,000 cells/mm^3. Patients were diagnosed with presumed septic arthritis if they had a negative blood or synovial fluid culture but had a synovial fluid WBC count >50,000 cells/mm^3. Transient synovitis was defined as synovial fluid WBC count <50,000 cells/mm^3, a negative blood or synovial fluid culture, and improvement without the use of antibiotics or surgery.[12] Lyme disease was identified by positive Lyme serology, but it should be noted that there were no Lyme cases in this study. During this study period, polymerase chain reaction (PCR), next-generation sequencing (NGS), and whole-genome sequencing (WGS) were not used. However, this institution is starting to use PCR and NGS for selected cases, although not universally.

Patient demographics and clinical characteristics were reported as mean values, with standard deviations for continuous variables and frequencies, or percentages for categorical variables. The Kruskal–Wallis test compared continuous variables among the three diagnostic categories (transient synovitis, presumed septic arthritis, and confirmed septic arthritis). Chi-square/Fisher's exact was used to compare categorical variables. Multiple logistic regression analysis was used to ascertain how well, selected risk factors were associated with confirmed septic arthritis status and presumed/confirmed septic arthritis status, respectively. Subsequent backwards variable selection was utilized to ascertain which risk factors best predicted septic arthritis status. Area under the curve of >0.70 indicated good fit of the statistical model. Diagnostic characteristics (sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV)) for the total number of risk factors were calculated using the receiver operating characteristic (ROC) curve. All p-values were two-sided and $p < 0.05$ was considered statistically significant. All data analyses were conducted using STATA version 15 (STATA Corp; College Station, TX, USA).

Results

A total of 155 patients, comprising 59 knee and 96 hip patients were included in this study. Of these patients, 51 had transient synovitis or other etiology for atraumatic irritable joint, 59 had culture negative septic arthritis, and 45 had culture positive septic arthritis. In total, 44/59 (74.6%) of the knees and 60/96 (62.5%) of the hips had confirmed or presumed septic arthritis. Of the 60 septic hip patients, 24 were culture positive and of the 44 septic knee patients, 21 were culture positive. The average age of the patients was 5.75 ± 4.0 years and 57.4% were male. There were significant differences in the presenting clinical factors between groups (Table 1). The organism most commonly identified in positive synovial fluid cultures was *Staphylococcus aureus* (80.0% of positive cultures). Additional positive cultures included Group A streptococcus, which was identified on multiple occasions, and *Neisseria gonorrhoeae* and *Pseudomonas aeruginosa*, which were both identified once.

Using Multivariate Logistic Regression, inability to bear weight in knee patients was the only independent risk factor in differentiating septic arthritis from aseptic knee odds ratio (OR) = 7.16 (1.27, 40.5) ($p = 0.026$), which was stronger than for hip patients OR = 5.87 (0.99, 34.9) ($p = 0.051$). In hip patients, elevated CRP (OR = 21.6, $p < 0.0001$), WBC count (OR = 13.3, $p = 0.002$), and elevated ESR (OR = 10.5, $p = 0.005$) were all independently predictive for septic arthritis. In knee patients, elevated WBC count was not included in the multivariate analysis as this risk factor exhibited multicollinearity with inability to bear weight (Table 2).

Table 1. Demographic and clinical characteristics.

Predictors	Knee		*p*-value[a]	Hip		*p*-value[a]
	Septic arthritis (*n* = 44)	Other etiology (*n* = 15)		Septic arthritis (*n* = 60)	Transient synovitis (*n* = 36)	
Age, years (mean, SD)	6.77 (5.53)	6.98 (5.37)	0.89	5.03 (3.42)	5.20 (2.84)	0.80
Sex (male) (*N*, %)	26 (59.1)	9 (60.0)	1.0	31 (51.7)	23 (63.9)	0.29
Race (Caucasian) (*N*, %)	10 (22.7)	4 (26.7)	0.74	19 (31.7)	21 (58.3)	0.018*
Body temperature >38.5 C (*N*, %)	19 (43.2)	3 (20.0)	0.13	19 (31.7)	2 (5.56)	0.002*
Inability to bear weight (*N*, %)	37 (84.1)	4 (26.7)	<0.001*	53 (88.3)	18 (50.0)	<0.001*
WBC count (>12,000/mm^3) (*N*, %)	20 (45.5)	7 (46.7)	1.0	39 (65.0)	5 (13.9)	<0.001*
ESR (>40 mm/h) (*N*, %)	26 (52.3)	5 (33.3)	0.24	34 (56.7)	5 (13.9)	<0.001*
C-reactive protein (>2.0 mg/dL) (*N*, %)	40 (90.9)	6 (40.0)	<0.001*	51 (85.0)	7 (19.4)	<0.001*

SD: standard deviation; WBC: white blood cell count; ESR: erythrocyte sedimentation rate.
Kruskal–Wallis test to compare continuous variables, and chi-square to compare categorical variables.
*A *p*-value < 0.05 was considered statistically significant.

Table 2. Multivariate analysis.

	Hip and knee SA vs other	*p*-value[a]	Knee SA vs other	*p*-value[a]	Hip SA vs TS	*p*-value[a]
	OR (95% CI)		OR (95% CI)		OR (95% CI)	
Temperature >38.5 C	2.88 (0.83, 9.94)	0.09	1.53 (0.29, 8.05)	0.61	3.71 (0.42, 33.3)	0.24
Unable to bear weight	4.49 (1.58, 12.7)	0.005*	7.16 (1.27, 40.5)	0.026*	5.87 (0.99, 34.9)	0.051
WBC >12,000/mm^3	1.61 (0.59, 4.38)	0.35	N/A	N/A	3.3 (2.57, 68.5)	0.002*
ESR >40 mm/h	2.06 (0.77, 5.51)	0.15	0.43 (0.06, 2.86)	0.38	10.5 (2.05, 53.5)	0.005*
CRP >2.0 mg/dL	10.7 (4.09, 27.9)	<0.0001*	7.06 (0.88, 56.2)	0.064	21.6 (4.38, 106.9)	<0.0001*
AUC	0.87		0.92		0.94	

SA: septic arthritis; TS: transient synovitis; OR: odds ratio; CI: confidence interval; WBC: white blood cell count; N/A: not applicable; ESR: erythrocyte sedimentation rate; CRP: C-reactive protein; AUC: area under curve.
[a]Odds ratios and 95% CI calculated using the Multiple Logistic Regression.
*Statistically significant.

Stepwise variable selection was utilized to determine the impact of each individual variable. In knee patients, the only variable that demonstrated significance when isolated was inability to bear weight (OR = 14.5, $p < 0.0001$). In hip patients, four variables were statistically significant: inability to bear weight (OR = 5.9, $p = 0.046$), elevated WBC count (OR = 14.6, $p = 0.001$), elevated ESR (OR = 11.0, $p = 0.003$), and elevated CRP (OR = 26.9, $p < 0.0001$). When knee and hip patients were examined together, inability to bear weight (OR = 5.72, $p < 0.0001$) and elevated CRP (OR = 16.1, $p < 0.0001$) were statistically significant (Table 3).

In hip patients, as the number of risk factors progressively increased, there was a corresponding increase in the PPV from 0% to 100% and in the specificity from 36.1% to 100%, this trend was also seen in patients with presumed septic hip. In knee patients, the PPV did not correlate consistently with an increasing number of risk factors (Table 4); this trend was also seen in patients with presumed septic knee. When the only two risk factors analyzed in knee patients were inability to bear weight and elevated CRP, patients with 0/2 risk factors,1/2 risk factors, and 2/2 risk factors, had PPVs of 18.1%, 77.8%, and 89.7% in predicting septic arthritis of the knee, respectively (Table 5).

Discussion

Transient synovitis may be rare in the knee, but there are other self-limiting causes for atraumatic unilateral irritable knee, including Lyme arthritis, viral infection, autoimmune arthritis, and crystal arthropathy that must be distinguished from a septic joint. Applying the modified Kocher criteria to identify septic knee had reduced predictability compared to septic hip in this study, which had been reported by previous studies. Obey et al.[14] studied 102 pediatric patients with septic knee and found the original Kocher criteria to be less reliable for knee than it would be for the hip, with 3/4 criteria 48.5% sensitive for septic knee compared to 84% for septic hip patients as found by Kocher et al.[10,14] While the study performed by Obey et al. had more patients with septic knee than this current analysis, there was no comparison to other causes of irritable knee or to septic hip at the same institution. Similarly,

Table 3. Stepwise variable selection of multivariate analysis.

	All SA vs TS	*p*-value[a]	Knee SA vs TS	*p*-value[a]	Hip SA vs TS	*p*-value[a]
	OR (95% CI)		OR (95% CI)		OR (95% CI)	
Temperature >38.5 C	N/A	N/A	N/A	N/A	N/A	N/A
Unable to bear weight	5.72 (2.19, 14.9)	<0.0001*	14.50 (3.58, 58.90)	<0.0001*	5.90 (1.03, 33.80)	0.046*
WBC >12,000/mm^3	N/A	N/A	N/A	N/A	14.60 (2.84, 75.40)	0.001*
ESR >40 mm/h	N/A	N/A	N/A	N/A	11.00 (2.22, 54.40)	0.003*
CRP >2.0 mg/dL	16.10 (6.47, 39.80)	<0.0001*	N/A	N/A	26.90 (5.48, 131.60)	<0.0001*

SA: septic arthritis; TS: transient synovitis; OR: odds ratio; CI: confidence interval; N/A: not applicable; WBC: white blood cell count; ESR: erythrocyte sedimentation rate; CRP: C-reactive protein.
[a]Odds ratios and 95% CI calculated using the Multiple Logistic Regression following backwards stepwise variable selection.
*A *p*-value < 0.05 was considered statistically significant.

Table 4. Impact of number of risk factors for hip patients and knee patients.

Number of risk factors	Other (*N* = 15)	Knee	Positive predictive value	Transient synovitis (*N* = 36)	Hip	Positive predictive value
		Septic arthritis (*N* = 44)			Septic arthritis (*N* = 60)	
0	7 (46.7)	0 (0.0)	0.0	13 (36.1)	0 (0.0)	0.0
1	2 (13.3)	5 (11.4)	71.4	13 (36.1)	0 (0.0)	0.0
2	1 (6.67)	7 (15.9)	87.5	7 (19.4)	12 (20.0)	63.2
3	1 (6.67)	15 (34.1)	93.4	2 (5.56)	25 (41.7)	92.6
4	2 (13.3)	10 (22.7)	83.3	1 (2.78)	18 (30.0)	94.7
5	2 (13.3)	7 (15.9)	77.8	0 (0.0)	5 (8.33)	100.0

Table 5. Utility of only using elevated CRP and inability to bear weight to predict septic knee.

Number of risk factors	Transient synovitis (*N* = 15)	Knee	Positive predictive value
		Septic arthritis (*N* = 44)	
0	9 (60.0)	2 (4.6)	18.1
1	2 (13.3)	7 (15.9)	77.8
2	4 (26.7)	35 (79.5)	89.7

Joshy et al. [15] compared 37 pediatric knee patients to 29 with hip patients who underwent arthrotomy for suspected septic joint. Culture positive synovial fluid was not only more common in the hip group, but also had a stronger correlation with the original four Kocher criteria. That study is limited by small patient sizes as it included only culture positive cases.

As an alternative to the traditional Kocher criteria, Baldwin et al.[17] evaluated subjective history of fever, pain with <30 degrees of motion (referred to as short arc motion), CRP ≥4.0 mg/L, and age <2 years old as predictive factors to help differentiate septic arthritis from Lyme arthritis and found that with increasing number of criteria, there was a higher predictive value. Correlative to this study, pain with short arc motion had the greatest adjusted odds ratio at 67.3 ($p < 0.001$). This study evaluated a unique geographic area with relatively high rates of Lyme, which does not apply broadly or to the patient population in this study. This study did not measure pain with short arc motion, rather, the inability to bear weight was documented.

For patients with hip disease, having an elevated CRP was the strongest independent prognostic factor for septic arthritis and has been reported previously as such.[11,18] In knee patients, the inability to bear weight was the strongest predictor. This suggests that the location of the disease in the body may impact how the local or systemic symptoms present in pediatric patients.

This study has several limitations. It is a retrospective study including only patients who underwent arthrocentesis, leading to a higher prevalence of septic joint than that of all patients presenting with atraumatic unilateral knee pain. This can lead to higher specificity of the criteria, limiting the applicability of its findings to a boarder population. The criteria used to define a septic joint in this study may have some inaccuracies. There were culture negative patients with synovial fluid WBC <50,000 who were clinically diagnosed and treated as having septic arthritis but

did not meet that definition by study criteria. This study definition may lead to incorrect categorization of patients with true septic arthritis; examples of diseases that could fall into this category include rheumatoid arthritis and Lyme disease. Furthermore, this is a relatively small sample size at a single institution. Future studies evaluating the applicability of the modified Kocher criteria to septic knee should include prospectively gathered data with larger sample sizes.

Conclusion

This is the first known study to apply the modified Kocher criteria by comparing septic arthritis to other etiologies of both the hip and knee in the same population of pediatric patients. In hip patients, the PPV increased as the number of risk factors increased, with 5/5 criteria producing a 100% PPV in this patient population. Elevated CRP was the strongest independent risk factor for septic arthritis of the hip. The modified Kocher criteria have limited utility in predicting septic arthritis of the knee. Instead, inability to bear weight combined with elevated CRP had an 89.7% PPV for septic knee, with inability to bear weight as the strongest independent risk factor for septic knee.

The modified Kocher criteria have reduced applicability to the evaluation of pediatric septic knee than for septic hip. The combination of inability to bear weight and elevated CRP have significant association with septic knee, which can be used as an adjunct to evaluate pediatric patients presenting with unilateral atraumatic irritable knee.

Declaration of conflicting interests

Dr M.W.S. is an Associate Editor for Journal of POSNA and is a Board Member for the National Advisor Board on Medical Rehabilitation Research at the Eunice Kennedy National Institute of Child Health and Human Development (NICHD). Dr M.W.S. has no conflicts of interest. The other authors have no disclosures or conflicts of interest.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Informed consent

Patient consent was waived during IRB approval as this was a retrospective chart review.

Institutional review board/ethics committee approval

This study was approved by the institutional IRB (IRB #15-058).

Research involving human participants and/or animals

This was a retrospective chart review involving pediatric patients evaluated for irritable hip/knee with arthrocentesis.

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References

1. Funk SS and Copley LAB. Acute hematogenous osteomyelitis in children: pathogenesis, diagnosis, and treatment. *Orthop Clin North Am* 2017; 48: 199–208.
2. Arkader A, Brusalis C, Warner WC, et al. Update in pediatric musculoskeletal infections: when it is, when it isn't, and what to do. *J Am Acad Orthop Surg* 2016; 24: e112–e121.
3. Brown DW and Sheffer BW. Pediatric septic arthritis: an update. *Orthop Clin North Am* 2019; 50: 461–470.
4. Nade S. Septic arthritis. *Best Pract Res Clin Rheumatol* 2003; 17: 183–200.
5. Belthur MV, Palazzi DL, Miller JA, et al. A clinical analysis of shoulder and hip joint infections in children. *J Pediatr Orthop* 2009; 29: 828–833.
6. Buchmann RF and Jaramillo D. Imaging of articular disorders in children. *Radiol Clin North Am* 2004; 42: 151–168, vii.
7. Long B, Koyfman A and Gottlieb M. Evaluation and management of septic arthritis and its mimics in the emergency department. *West J Emerg Med* 2019; 20: 331–341.
8. Mataika R, Carapetis JR, Kado J, et al. Acute rheumatic fever: an important differential diagnosis of septic arthritis. *J Trop Pediatr* 2008; 54: 205–207.
9. Hempfing A, Placzek R, Göttsche T, et al. Primary subacute epiphyseal and metaepiphyseal osteomyelitis in children. diagnosis and treatment guided by MRI. *J Bone Joint Surg Br* 2003; 85: 559–564.
10. Kocher MS, Zurakowski D and Kasser JR. Differentiating between septic arthritis and transient synovitis of the hip in children: an evidence-based clinical prediction algorithm. *J Bone Joint Surg Am* 1999; 81(12): 1662–1670.
11. Caird MS, Flynn JM, Leung YL, et al. Factors distinguishing septic arthritis from transient synovitis of the hip in children. *J Bone Joint Surg Am* 2006; 88(6): 1251–1257.
12. Kocher MS, Mandiga R, Zurakowski D, et al. Validation of a clinical prediction rule for the differentiation between septic arthritis and transient synovitis of the hip in children. *J Bone Joint Surg Am* 2004; 86(8): 1629–1635.
13. Luhmann SJ, Jones A, Schootman M, et al. Differentiation between septic arthritis and transient synovitis of the hip in children with clinical prediction algorithms. *J Bone Joint Surg Am* 2004; 86: 956–962.
14. Obey MR, Minaie A, Schipper JA, et al. Pediatric septic arthritis of the knee: predictors of septic hip do not apply. *J Pediatr Orthop* 2019; 39: e769–e772.
15. Joshy S, Choudry Q, Akbar N, et al. Comparison of bacteriologically proven septic arthritis of the hip and knee in children, a preliminary study. *J Pediatr Orthop* 2010; 30: 208–211.
16. Gage MJ, Twomey KD, Sala DA, et al. Identifying predictive factors of pediatric septic arthritis of the knee in a Lyme endemic area. *Bull Hosp Jt Dis* 2018; 76: 161–164.
17. Baldwin KD, Brusalis CM, Nduaguba AM, et al. Predictive factors for differentiating between septic arthritis and Lyme disease of the knee in children. *J Bone Joint Surg Am* 2016; 98: 721–728.
18. Levine MJ, McGuire KJ, McGowan KL, et al. Assessment of the test characteristics of C-reactive protein for septic arthritis in children. *J Pediatr Orthop* 2003; 23: 373–377.