Archives of Academic Emergency Medicine. 2023; 11(1): e30

OPEN ACCESS

REVIEW ARTICLE

Diagnostic Accuracy of Ottawa Knee Rule for Diagnosis of Fracture in Patients with Knee Trauma; a Systematic Review and Meta-analysis

Seyyed-Morteza Kazemi[1], Roya Khorram[2], Ehsan Fayyazishishavan[3], Reza Amani-Beni[4], Yas Haririan[5], Seyed Mehdi Hosseini Khameneh[1], Erfan Rahmani[6], Reza Minaei Noshahr[1], Mahshad Sarikhani[7], Rana Rahimi[7], Sara Saeidi[8], Diba Saeidi[8], Mehrdad Farrokhi[9]*

1. Bone Joint and Related Tissues Research Center, Akhtar Orthopedic Hospital, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

2. Department of Orthopedics, Shiraz University of Medical Sciences, Shiraz, Iran.

3. Department of Biostatistics and Data Science, School of Public Health, The University of Texas Health Science Center at Houston (UTHealth), Houston, TX 77030, USA.

4. Medical Student, School of Medicine, Isfahan University of Medical Sciences, Isfahan, Iran.

5. School of Medicine, Shiraz University of Medical Sciences, Shiraz, Iran.

6. School of Medicine, Tehran University of Medical Sciences, Tehran, Iran.

7. School of Medicine, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

8. Students Research Committee, Faculty of Pharmacy and Pharmaceutical Sciences, Isfahan University of Medical Sciences, Isfahan, Iran.

9. ERIS Research Institute, Tehran, Iran.

Received: January 2023; Accepted: February 2023; Published online: 3 April 2023

Abstract: **Introduction:** In order to improve the efficacy of requesting knee radiography and reduce unnecessary radiation exposure, some clinical decision rules have been proposed for the assessment of knee injuries. Among them, the Ottawa Knee Rule (OKR) was considered as one of the best guidelines with several validation studies. Therefore, in this meta-analysis, we aimed to investigate the accuracy of OKR for diagnosis of fracture in patients presenting with knee trauma. **Methods:** A systematic search was conducted in PubMed, Web of Science, Scopus, Google Scholar, and EBSCO from inception to September 2022. Quality assessment of the included studies was performed using QUADAS-2 tool. Diagnostic accuracy parameters were analyzed using random-effects model. Statistical analysis was performed using Meta-Disc and Stata softwares. **Results:** The meta-analysis of the 18 included studies (6702 patients) showed that the pooled sensitivity and specificity of OKR for diagnosis of fractures were 0.98 (95% CI: 0.96-0.99) and 0.43 (95% CI: 0.42-0.45), respectively. The pooled positive likelihood ratio (PLR) and negative likelihood ratio (NLR) were 1.56 (95% CI: 1.39-1.75) and 0.12 (95% CI: 0.05-0.26), respectively. The area under curve (AUC) of the hierarchical summary receiver operating characteristic (HSROC) curve was 0.54. **Conclusion:** This meta-analysis indicates that OKR has a high diagnostic performance for diagnosis of fracture, with a pooled sensitivity of 98% and a pooled specificity of 43%. These results propose potential effects of OKR on reduction of unnecessary radiography, time spent in emergency departments, and direct and indirect costs, which should be confirmed using high-quality studies in the future.

Keywords: Clinical decision rules; Knee injuries; Radiography

Cite this article as: Kazemi S-M, Khorram R, Fayyazishishavan E, Amani-Beni R, Haririan Y, et al. Diagnostic Accuracy of Ottawa Knee Rule for Diagnosis of Fracture in Patients with Knee Trauma; a Systematic Review and Meta-analysis. Arch Acad Emerg Med. 2023; 11(1): e30. https://doi.org/10.22037/aaem.v11i1.1934.

1. Introduction

Acute knee pain and trauma are known as prevalent complaints in emergency departments and account for a considerable number of plain radiography requests (1-4). Despite the high number of patients presenting with acute knee pain

***Corresponding Author:** Mehrdad Farrokhi; ERIS Research Institute, Tehran, Iran. Email: dr.mehrdad.farrokhi@gmail.com. Phone number: +989384226664, Fax: +989384226664, ORCID: https://orcid.org/0000-0002-1559-2323.

or trauma, less than 7% of these cases actually have a definite fracture (5, 6). Indeed, radiography is commonly requested as a standard diagnostic tool for more than 90% of these suspected cases. Therefore, the high rate of unnecessary radiography for detecting fractures in patients with acute knee trauma results in significantly increased medical costs along with extended hospital stay and also unnecessary radiation exposure (7, 8). In order to improve the efficacy of requesting radiography and reduce unnecessary radiation exposure, some clinical decision rules have been proposed for the assessment of knee injuries. Among them, the Ottawa Knee Rule (OKR) was considered as one of the best guidelines with several validation studies. The rules have been developed to improve the efficacy with which knee traumas are assessed and to reduce unnecessary radiography without an increase in the rate of missed fractures. The OKR was designed in 1995 by Stiell et al. (2) as a diagnostic tool to divide cases of acute knee injury into two groups including cases who are likely to have an important bony injury and need evaluation using radiography and cases who are not likely to have a significant fracture and do not require radiography. Suspected cases are highly likely to have a significant fracture and thus need a radiographic evaluation if at least one of the following criteria is positive: age at least 55 years old, isolated tenderness of patella, inability to flex the knee to 90 degrees, tenderness of fibular head, and inability to bear weight following the trauma and admission to the emergency department (2). Several studies have investigated the validation of OKR in patients with knee trauma, which showed high sensitivity and moderate specificity for application of this rule in emergency departments (9-12). The OKR can rule out fractures and reduce unnecessary exposure to ionizing radiation with high sensitivity. However, these validation studies reported a wide range of test sensitivities and specificities in adults. Therefore, in this systematic review and meta-analysis, we aimed to investigate the accuracy of OKR for diagnosis of fracture in patients with knee trauma.

2. Methods

2.1. Search strategy

This study was carried out according to the recommendations of Preferred Reporting Items for Systematic Reviews and Meta-Analyses of Diagnostic Test Accuracy Studies (PRISMA-DTA). A systematic search was conducted in PubMed, Web of Science, Scopus, Google Scholar, and EBSCO from their inception to September 2022. The search was carried out without limitations on language or the date of the published papers to ensure that all eligible studies were included in the meta-analysis. The following MeSH terms and keywords and also their combinations were used in English: “Ottawa” OR “Knee” OR “Rule” OR “Ottawa Knee Rule” AND “Knee Injury” OR “Knee Trauma” AND “Radiography” OR “Radiograph” OR “X-ray”.

2.2. Eligibility criteria

The specific inclusion criteria for the meta-analysis were as follows: (a) diagnostic accuracy parameters of OKR for diagnosis of fractures (true positive [TP], true negative [TN] and/or false positive [FP], and false negative [FN]) were reported; (b) the study population consisted of at least 10 cases with knee injury; (c) all fractures were confirmed using radiography; (d) the study has cross-sectional, case-control, or cohort design. The papers were excluded from the meta-analysis based on the following criteria: (a) solely the sensitivity and specificity of OKR were provided; (b) reviews, meta-analyses, poster presentations, editorials, case reports, and cases series with fewer than 10 cases with knee injury; (c) duplicate studies.

2.3. Data extraction and quality assessment

The following variables from the individual papers were extracted by two independent authors using an excel spreadsheet: diagnostic accuracy parameters including TP, TN, FP, and FN, first author, year of publication, country, study design, sample size, and reference standard. Disagreements between these two authors were resolved through a discussion with the third author. The quality assessment of the included studies was investigated using the Quality Assessment of Diagnostic Accuracy Studies (QUADAS)-2 tool.

2.4. Statistical analysis

Statistical analysis was performed using Meta-Disc software version 1.4. Heterogeneity between the included studies was assessed using I2. DerSimonian-Laird pooling method was used to estimate sensitivity, specificity, positive likelihood ratio (PLR), negative likelihood ratio (NLR), diagnostic odds ratio (DOR), and accuracy (summery receiver operating characteristic (SROC) curve). Begg’s test and funnel plot were used to investigate publication bias. Evaluation of the publication bias was carried out using Stata statistical software package (Stata Corp., College Station, TX, USA) (version 17.0).

3. Results

3.1. Study Selection

The systematic search identified a total of 245 studies, 58 of which were duplicates. We, then excluded 142 studies by screening their titles and abstracts. After reviewing the full texts and data integrity of the studies according to inclusion and exclusion criteria, 39 studies were excluded. Finally, 18 studies were included in this meta-analysis. The PRISMA flow diagram of the studies during retrieval process and reasons for exclusion are illustrated in Figure 1.

Table 1: Characteristics of the studies included in meta-analysis

First Author	Year	Country	Sample Size	Study Design	Gold Standard	TP	FP	FN	TN	Sensitivity (%)	Specificity (%)
Sims et al. (17)	2020	Australia	149	Retrospective	Radiography	17	68	7	57	71	46
Mohamed et al. (9)	2020	Ireland	110	Prospective	Radiography	12	60	0	38	100	39
Shams Vahdati et al. (18)	2019	Iran	220	Prospective	Radiography	164	44	0	12	100	21
Cheung et al. (19)	2013	Netherland	90	Prospective	Radiography	6	64	1	19	86	23
Beutel et al. (10)	2012	United States	260	Retrospective	Radiography	41	128	0	91	100	42
Konan et al. (20)	2012	England	106	Prospective	Radiography	6	73	0	27	100	27
Jalili et al. (21)	2010	Iran	283	Prospective	Radiography	21	146	1	115	95	44
Atkinson et al. (14)	2004	England	72	Prospective	Radiography	7	30	0	35	100	54
Kec et al. (22)	2003	United States	85	Prospective	Radiography	10	67	0	8	100	11
Matteucci et al. (23)	2003	United States	134	Prospective	Radiography	4	50	0	80	100	62
Ketelslegers et al. (12)	2002	Belgium	77	Prospective	Radiography	12	37	0	28	100	43
Szucs et al. (24)	2001	United States	96	Prospective	Radiography	8	47	0	41	100	47
Emparanza et al. (11)	2001	Spain	1522	Prospective	Radiography	89	688	0	745	100	52
Tigges et al. (25)	1999	United Sates	378	Prospective	Radiography	42	271	1	64	98	19
Seaberg et al. (8)	1998	United States	750	Prospective	Radiography	84	487	3	176	97	27
Stiell et al. (a) (1)	1997	Canada	987	Prospective	Radiography	58	483	0	446	100	48
Richman et al. (26)	1997	United States	287	Prospective	Radiography	22	143	4	118	85	45
Stiell et al. (b) (6)	1996	Canada	1096	Prospective	Radiography	63	522	0	511	100	49

TP: True positive; FP: False positive; FN: False negative; TN: True negative.

Table 2: Quality assessment of the included studies using QUADAS-2 tool

Study	Risk of bias				Applicability concerns		
	Patient selection	Index test	Reference standard	Flow and timing	Patient selection	Index test	Reference standard
Sims et al. (17)	☺	?	?	☺	☺	☺	☺
Mohamed et al. (9)	☺	?	?	☺	☺	☺	☺
Shams Vahdati et al. (18)	☺	☺	?	☺	☺	☺	☺
Cheung et al. (19)	☺	☺	☺	☺	☺	☺	☺
Beutel et al. (10)	☺	☺	☺	☺	☺	☺	☺
Konan et al. (20)	☺	?	?	☺	☺	☺	☺
Jalili et al. (21)	☺	☺	?	☺	☺	☺	☺
Atkinson et al. (14)	☺	☺	☺	☺	☺	☺	☺
Kec et al. (22)	☺	☺	☺	☺	☺	☺	☺
Matteucci et al. (23)	☺	☺	☺	☺	☺	☺	☺
Ketelslegers et al. (12)	?	☺	☺	☺	☺	☺	☺
Szucs et al. (24)	☺	☺	☺	☺	☺	☺	☺
Emparanza et al. (11)	☺	☺	?	☺	☺	☺	☺
Tigges et al. (25)	☺	☺	☺	☺	☺	☺	☺
Seaberg et al. (8)	☺	☺	☺	☺	☺	☺	☺
Stiell et al. (a) (1)	☹	☺	☺	☺	☺	☺	☺
Richman et al. (26)	☺	☺	☺	☺	☺	☺	☺
Stiell et al. (b) (6)	☺	☺	☺	☺	☺	☺	☺

☺: Low Risk; ☹: High Risk; ?: Unclear Risk. QUADAS: Quality Assessment of Diagnostic Accuracy Studies.

3.2. Study characteristics

Finally, 18 eligible studies involving a total of 6702 patients with knee injury were included from different geographical regions. In all included studies, radiography was used as a gold standard for diagnosis of fracture. The diagnostic sensitivity ranged from 71% to 100%, while the diagnostic specificity was 11% to 62%. All included studies were published in English. The main characteristics of the included studies are provided in Table 1.

3.3. Quality assessment and risk of bias

Quality assessment of the included studies was performed using QUADAS-2 tool. The included studies had a low risk of bias and moderate to high quality. Table 2 shows the results of quality assessment in detail. Evaluation of publication bias using Begg's test (P=1) showed no significant publication bias. Furthermore, investigation of publication bias using Funnel plot revealed the same result (figure 2).

3.4. Diagnostic accuracy of OKR

The heterogeneity was found to be significant for the pooled analysis of sensitivity (P=0.00, I2=70.9), specificity (P=0.00, I2=94.9%), PLR (P=0.00, I2=94.5%), NLR (P=0.00, I2=68.1%), and DOR (P=0.001, I2=57.6%). Therefore, these parameters were analyzed using random-effects model. The meta-analysis of the 18 included studies showed that the pooled sensitivity and specificity of OKR for diagnosis of fractures were 0.98 (95% CI: 0.96-0.99) and 0.43 (95% CI: 0.42-0.45), respectively (Figure 3 and Figure 4).

The pooled PLR and NLR were 1.56 (95% CI: 1.39-1.75) and 0.12 (95% CI: 0.05-0.26), respectively (Figure 5 and Figure 6).

Furthermore, the diagnostic odds ratio of OKR was 13.02 (95% CI: 5.99-28.32) (Figure 7). The area under curve (AUC) of the hierarchical summary receiver operating characteristic (HSROC) curve was 0.54, indicating that the accuracy of OKR for diagnosis of fractures in patients with knee trauma is 54% (Figure 8). Evaluation of threshold effect using spearman correlation revealed that there is no significant correlation between the sensitivity and specificity (r= 0.09, P=0.69).

4. Discussion

In this systematic review and meta-analysis of 18 studies investigating 6702 adult patients from nine countries, we demonstrated that the pooled sensitivity and specificity were 98% and 43% for OKR. These findings reveal that the sensitivity is high enough to be applied to rule out fractures in patients with knee trauma in emergency departments and it has an adequate specificity. The pooled PLR of 1.56 (95% CI, 1.39–1.75) and NLR of 0.12 (95% CI, 0.05–0.26) suggest that the odds of having a knee fracture in radiography increases by about 150% with a positive OKR, whereas the odds is reduced by 99.88% with a negative OKR.

In a similar meta-analysis, Bachman et al. (13) investigated the sensitivity, specificity, and NLR of OKR for diagnosis of knee trauma using 6 studies involving 4249 patients. Their analysis showed that the sensitivity and specificity of OKR were 98.5% and 48.6%, respectively. Furthermore, they found that NLR of OKR is 0.05. Although their sensitivity was similar to ours, their specificity was higher than the specificity that we found and their NLR was lower than what our analysis showed. These differences can be partially clarified by difference in the number of studies included in the meta-analysis. We included 18 studies, while they assessed 6 studies in their meta-analysis.

In a study by Atkinson et al. (14) the sensitivity and specificity of OKR for diagnosis of fractures were 1 (95% CI: 0.63-1) and 0.53 (0.41-0.65), respectively. These findings reveal the importance of the referrer being aware of the OKR. Moreover, accumulating lines of evidence have recently proposed that the main barriers to OKR usage were attributed to patients, and systematic and legal concerns rather than the efficacy of OKR. Therefore, in addition to increasing knowledge of evaluating doctors regarding OKR, addressing systematic and legal barriers is crucial to improve adherence to this rule (10).

OKR was designed to estimate the probability of fracture and aid physicians in deciding on the requirement of requesting radiography in the assessment of trauma. The designers of knee rules considered a sensitivity of about 100% in diagnosing fractures to reduce unnecessary radiographs. However, the data regarding rate of reduction in unnecessary radiography were limited in previous studies and could not be pooled in our meta-analysis. Additionally, we could not analyze data of time spent in emergency departments and direct and indirect costs saved due to reducing unnecessary radiography.

A systematic review and meta-analysis of observational studies was carried out by Vijayasankar et al. (15) to assess the diagnostic accuracy of OKR in children. They identified three eligible studies involving 1130 subjects for inclusion in meta-analysis. The analysis revealed that the pooled sensitivity, specificity, PLR, and NLR were 0.99 (95% CI: 0.94-0.99), 0.46 (95% CI: 0.43-0.49), 1.94 (95% CI: 1.60-2.36), and 0.07 (95% CI: 0.02-0.29), respectively. These findings show that sensitivity and specificity of OKR in children were higher than adults. Although the findings across these three studies were consistent, their quality was thought to be low, with little blinding, which affects the reliability of the meta-analysis.

In another meta-analysis by Sims et al. (16), the results of eight studies were pooled to indicate the diagnostic characteristics of OKR for diagnosis of knee fractures. Their pooled sensitivity and specificity of OKR were higher than those we found in our meta-analysis. These differences may be clarified by considerable difference in the number of included studies.

Patients' point of view and request may affect the efficacy of OKR for reduction of unnecessary radiographs in clinical practice. Some cases with knee trauma may request to be evaluated by radiography when they are evaluated in emergency department since they believe that an appropriate evaluation must include imaging. Therefore, in addition to introduction of a rule to evaluating physicians, education of the patients is also needed to reduce frequency of unnecessary radiographs. Our evaluation of the included studies indicates some limitations as most of them did not report need for further evaluation for patients without definite fracture in radiography and they did not investigate economic effects of the use of OKR in emergency departments.

5. Limitations

Despite valuable findings regarding pooled accuracy parameters of OKR for diagnosis of knee fractures in adults, this meta-analysis faced several limitations: evaluation of the heterogeneity using I2 revealed significant heterogeneity, particularly for specificity (I2=94.9%), which may be due to the threshold effect where different cut-offs are applied. However, since assessment of threshold effect using spearman correlation showed that there was no significant correlation between sensitivity and specificity, it seems that the detected heterogeneity may only slightly affect the findings. Another limitation of our meta-analysis is that we did not investigate the accuracy of OKR for children. Furthermore, evaluation of the economic effects of OKR and needs for further imaging in patients with no definite fracture were not carried out in our study. Few studies used both radiography and follow-up as reference standard for diagnosis of fracture suggesting risk of flow and timing bias in the results of QUADAS-2 evaluation.

6. Conclusion

This systematic review and meta-analysis of 6702 adult patients with acute knee trauma indicates that OKR has a high diagnostic performance for diagnosis of fracture, with a pooled sensitivity of 98% and a pooled specificity of 43%. Although our findings suggest applying the OKR as a sensitive rule in emergency departments, its widespread application still has some limitations. These results propose potential effects of OKR on reduction of unnecessary radiography, time spent in emergency departments, and direct and indirect costs, which should be confirmed using high-quality, large-scale, multicenter studies in the future.

7. Declarations

7.1. Acknowledgments

The authors thank all those who contributed to this study.

7.2. Conflict of interest

None.

7.3. Fundings and supports

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

7.4. Authors' contribution

All authors contributed to study design, data collection, writing the draft of the study and reading and approving the final version.

7.5. Data Availability

Not applicable.

7.6. Human and Animal Rights Statement

This meta-analysis does not contain any investigations with human or animal subjects.

References

1. Stiell IG, Wells GA, Hoag RH, Sivilotti ML, Cacciotti TF, Verbeek PR, et al. Implementation of the Ottawa Knee Rule for the use of radiography in acute knee injuries. JAMA. 1997;278(23):2075-9.
2. Stiell IG, Greenberg GH, Wells GA, McKnight RD, Cwinn AA, Cacciotti T, et al. Derivation of a decision rule for the use of radiography in acute knee injuries. Ann Emerg Med. 1995;26(4):405-13.
3. Keyhani S, Kazemi SM, Ahn JH, Verdonk R, Soleymanha M. Arthroscopic treatment of diffuse pigmented villonodular synovitis of the knee: complete synovectomy and septum removal—midterm results. J Knee Surg. 2019;32(05):427-33.
4. Kazemi SM, Minaei R, Safdari F, Keipourfard A, Forghani R, Mirzapourshafiei A. Supracondylar osteotomy in valgus knee: angle blade plate versus locking compression plate. Arch Bone Jt Surg. 2016;4(1):29.
5. Stiell IG, Wells GA, McDowell I, Greenberg GH, McKnight RD, Cwinn AA, et al. Use of radiography in acute knee injuries: need for clinical decision rules. Acad Emerg Med. 1995;2(11):966-73.
6. Stiell IG, Greenberg GH, Wells GA, McDowell I, Cwinn AA, Smith NA, et al. Prospective validation of a decision rule for the use of radiography in acute knee injuries. JAMA. 1996;275(8):611-5.
7. Seaberg DC, Jackson R. Clinical decision rule for knee radiographs. Am J Emerg Med. 1994;12(5):541-3.
8. Seaberg DC, Yealy DM, Lukens T, Auble T, Mathias S. Multicenter comparison of two clinical decision rules for the use of radiography in acute, high-risk knee injuries. Ann Emerg Med. 1998;32(1):8-13.

9. Mohamed A, Babikir E, Mustafa MKE. Ottawa Knee Rule: Investigating Use and Application in a Tertiary Teaching Hospital. Cureus. 2020;12(6):e8812.
10. Beutel BG, Trehan SK, Shalvoy RM, Mello MJ. The Ottawa knee rule: examining use in an academic emergency department. West J Emerg Med. 2012;13(4):366.
11. Emparanza JI, Aginaga JR. Validation of the Ottawa knee rules. Ann Emerg Med. 2001;38(4):364-8.
12. Ketelslegers E, Collard X, Vande Berg B, Danse E, El Gariani A, Poilvache P, et al. Validation of the Ottawa knee rules in an emergency teaching centre. Eur Radiol. 2002;12(5):1218-20.
13. Bachmann LM, Haberzeth S, Steurer J, ter Riet G. The accuracy of the Ottawa knee rule to rule out knee fractures: a systematic review. Ann Intern Med. 2004;140(2):121-4.
14. Atkinson P, Boyle A, Chisholm E. X-ray requesting patterns before and after introduction of the Ottawa Knee Rules in a UK emergency department. Eur J Emerg Med. 2004;11(4):204-7.
15. Vijayasankar D, Boyle A, Atkinson P. Can the Ottawa knee rule be applied to children? A systematic review and meta-analysis of observational studies. Emerg Med J. 2009;26(4):250-3.
16. Sims JI, Chau MT, Davies JR. Diagnostic accuracy of the Ottawa Knee Rule in adult acute knee injuries: a systematic review and meta-analysis. Eur Radiol. 2020;30:4438-46.
17. Sims JI, Chau M, Davies J. Validation of the Ottawa knee rule in adults: A single centre study. J Med Radiat Sci. 2020;67(3):193-8.
18. Vahdati SS, Ala A, Samani Z, Ahari SG, Mirza-Aghazadeh-Attari M. Screening of Trauma Patients in Need of Knee Radiography by Triage Nurses and Using Ottawa Knee Rule; a Letter to Editor. Arch Acad Emerg Med. 2019;7(1):e57.
19. Cheung TC, Tank Y, Breederveld RS, Tuinebreijer WE, de Lange-de Klerk ES, Derksen RJ. Diagnostic accuracy and reproducibility of the Ottawa Knee Rule vs the Pittsburgh Decision Rule. Am J Emerg Med. 2013;31(4):641-5.
20. Konan S, Zang T, Tamimi N, Haddad F. Can the Ottawa and Pittsburgh rules reduce requests for radiography in patients referred to acute knee clinics? Ann R Coll Surg Engl. 2013;95(3):188-91.
21. Jalili M, Gharebaghi H. Validation of the Ottawa knee rule in Iran: a prospective study. Emerg Med J. 2010;27(11):849-51.
22. Kec RM, Richman PB, Szucs PA, Mandell M, Eskin B. Can emergency department triage nurses appropriately utilize the Ottawa Knee Rules to order radiographs? An implementation trial. Acad Emerg Med. 2003;10(2):146-50.
23. Matteucci MJ, Roos JA. Ottawa Knee Rule: a comparison of physician and triage-nurse utilization of a decision rule for knee injury radiography. J Emerg Med. 2003;24(2):147-50.
24. Szucs PA, Richman PB, Mandell M. Triage nurse application of the Ottawa knee rule. Acad Emerg Med. 2001;8(2):112-6.
25. Tigges S, Pitts S, Mukundan Jr S, Morrison D, Olson M, Shahriara A. External validation of the Ottawa knee rules in an urban trauma center in the United States. AJR Am J Roentgenol. 1999;172(4):1069-71.
26. Richman PB, McCuskey CF, Nashed A, Fuchs S, Petrik R, Imperato M, et al. Performance of two clinical decision rules for knee radiography. J Emerg Med. 1997;15(4):459-63.

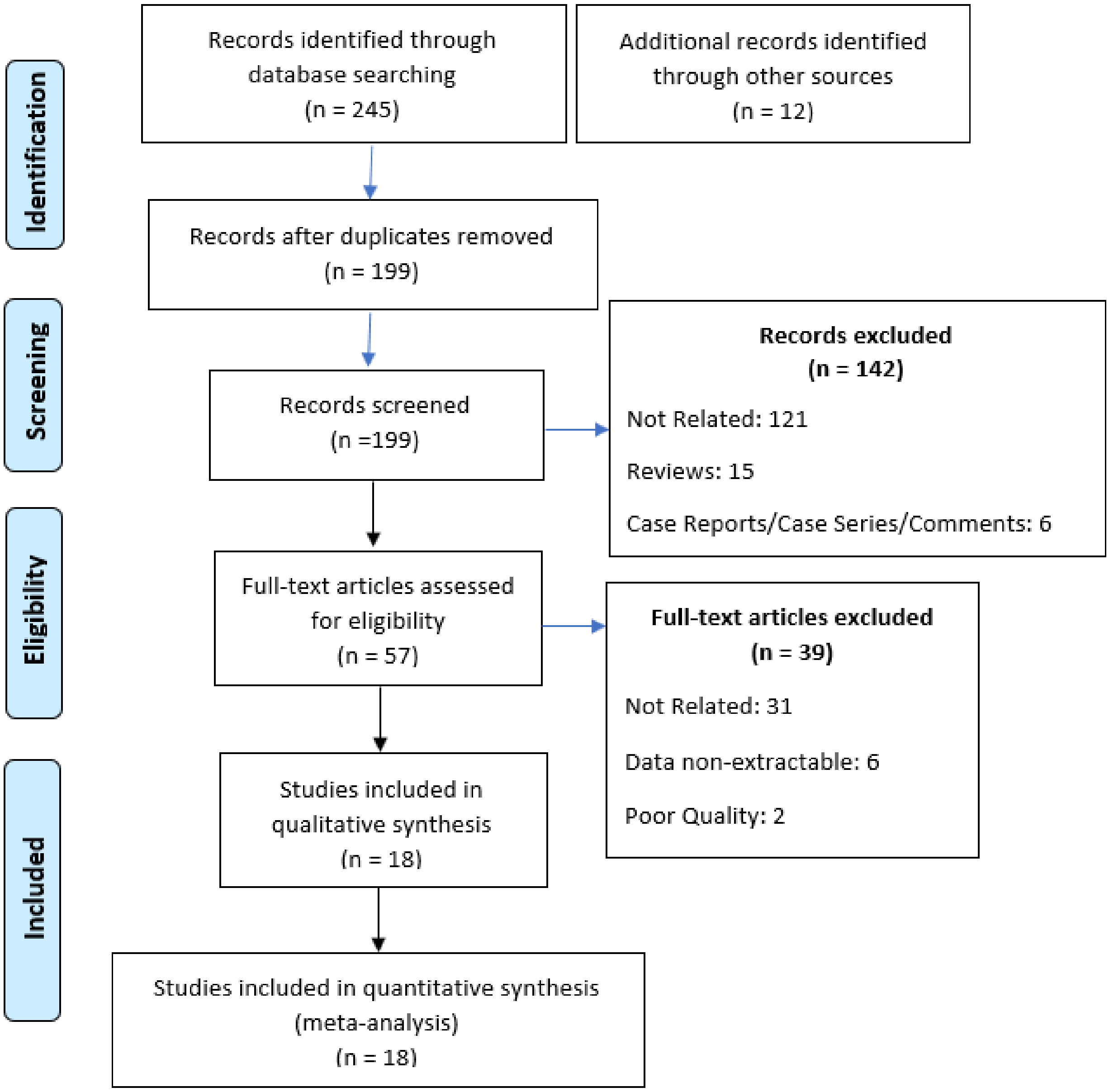

Figure 1: Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart of the literature search and selection of studies that reported accuracy of Ottawa Knee Rule (OKR) for diagnosis of fracture in patients with knee injury.

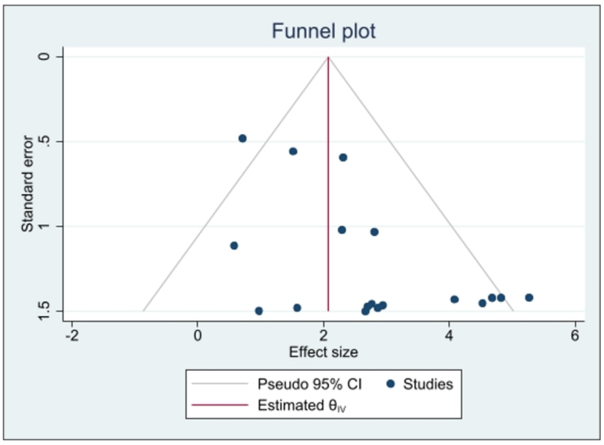

Figure 2: Funnel plot of publication bias on the pooled diagnostic odds ratio (DOR). CI: confidence interval.

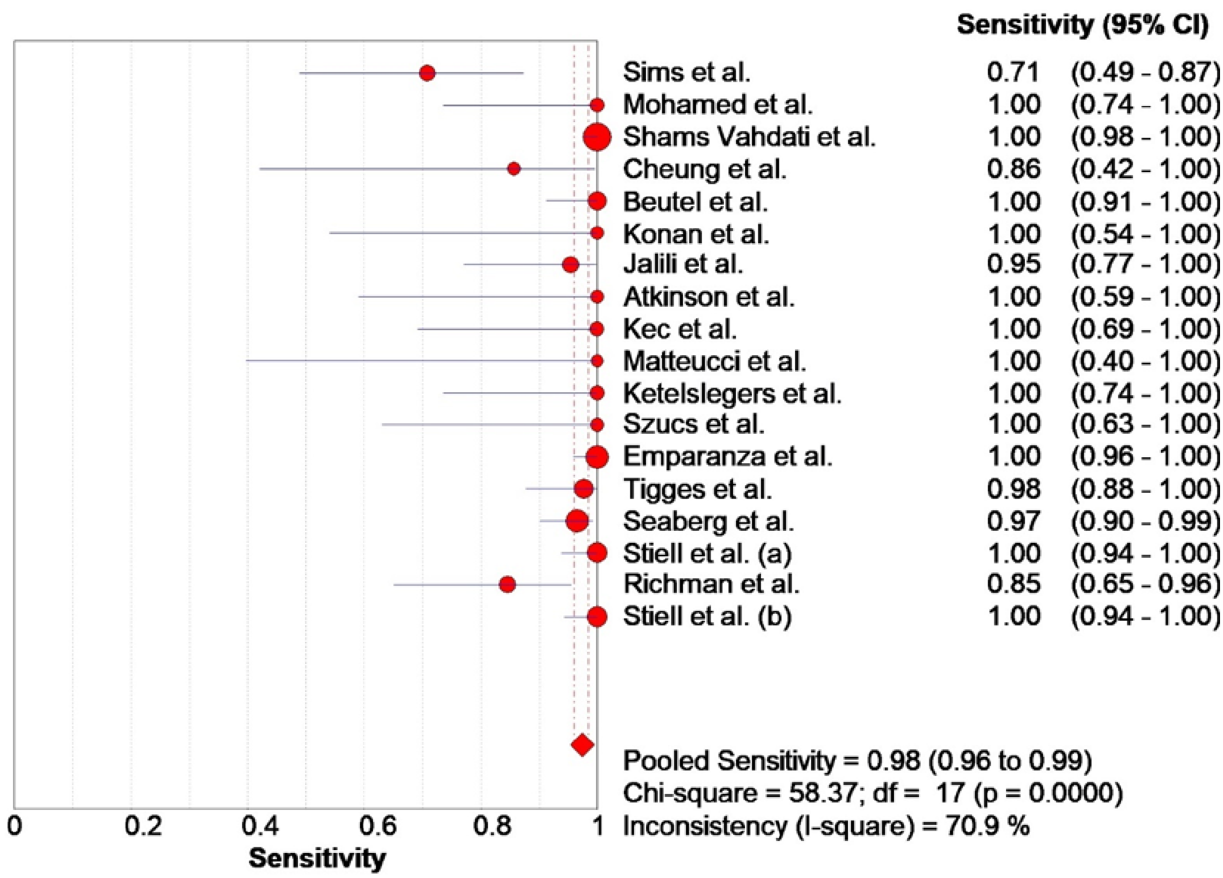

Figure 3: Forest plot of the pooled sensitivity of Ottawa Knee Rule (OKR) for diagnosis of fracture in patients with knee trauma. CI: confidence interval.

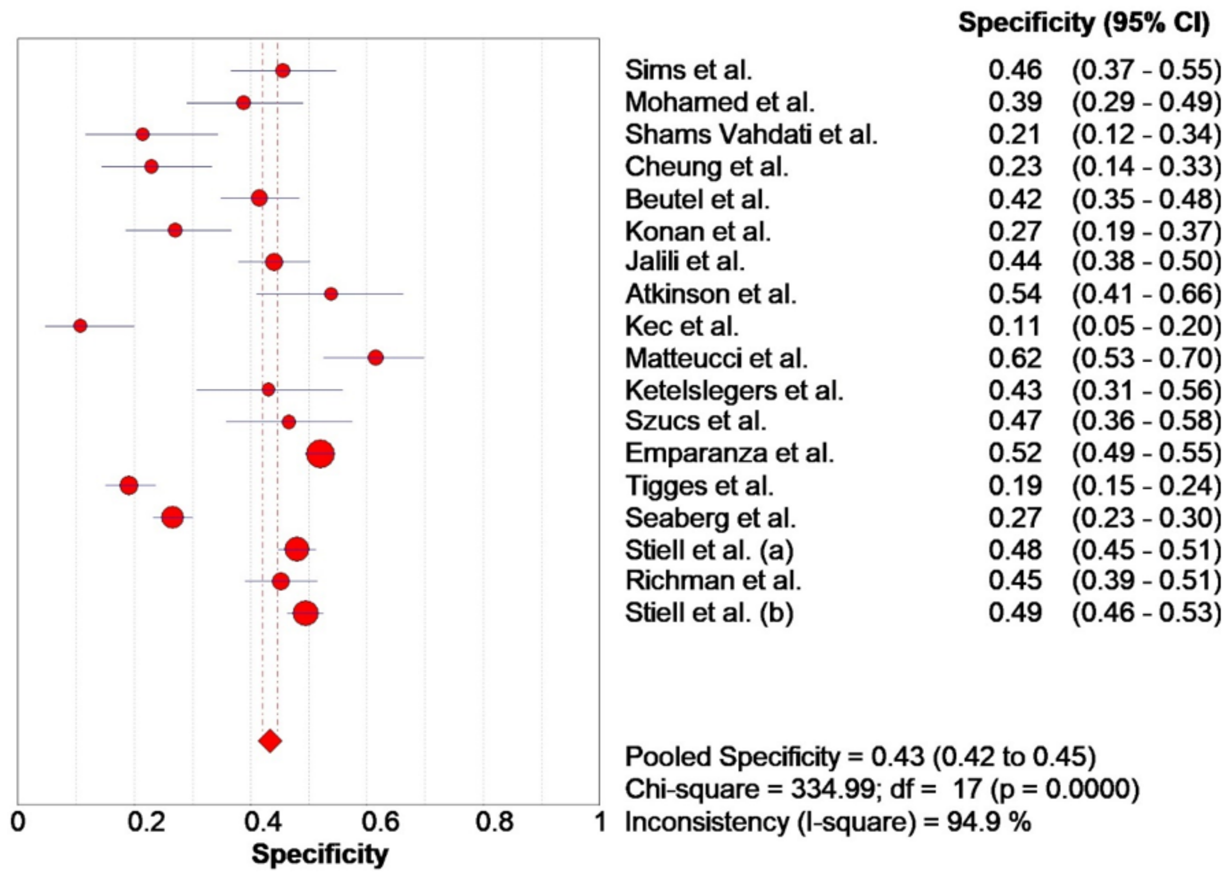

Figure 4: Forest plot of the pooled specificity of Ottawa Knee Rule (OKR) for diagnosis of fracture in patients with knee trauma. CI: confidence interval.

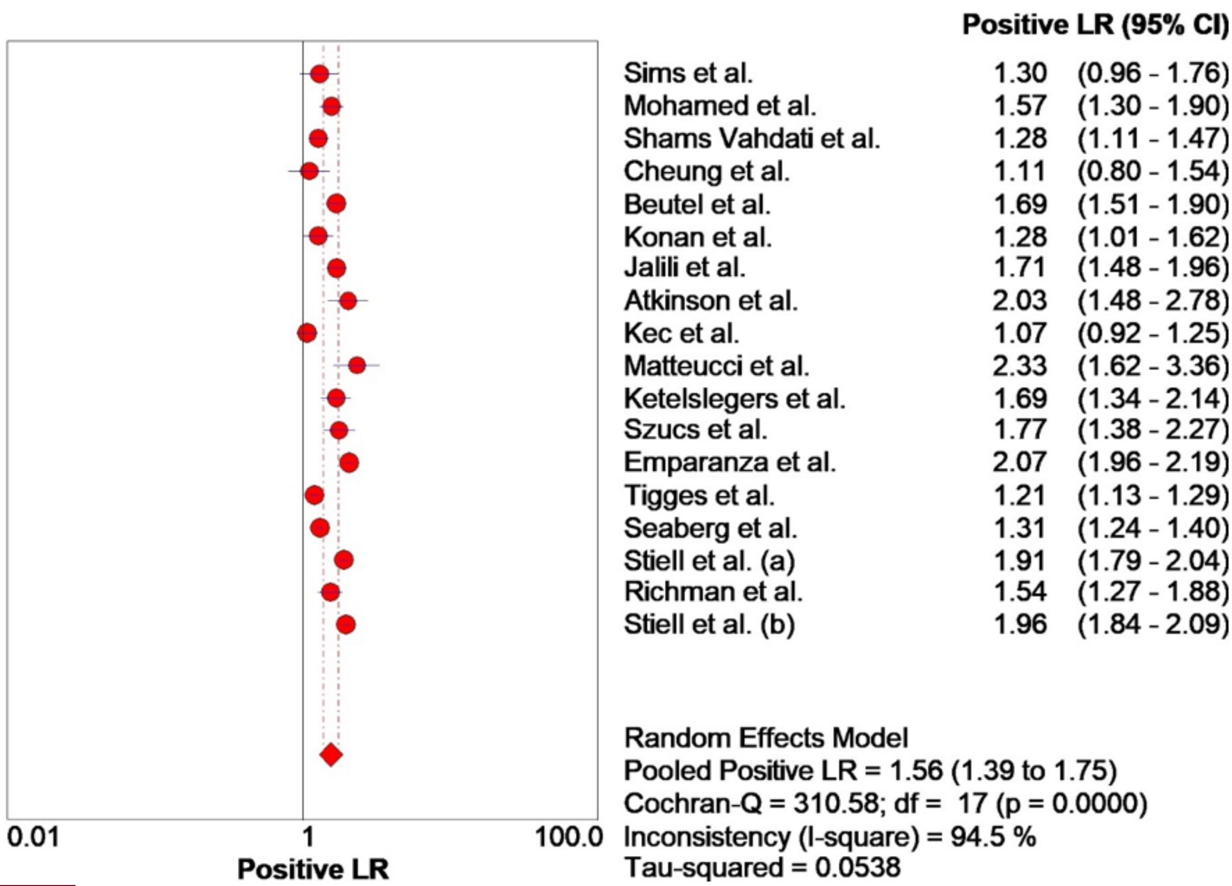

Figure 5: Forest plot of the pooled positive likelihood ratio (PLR) of Ottawa Knee Rule (OKR) for diagnosis of fracture in patients with knee trauma. CI: confidence interval.

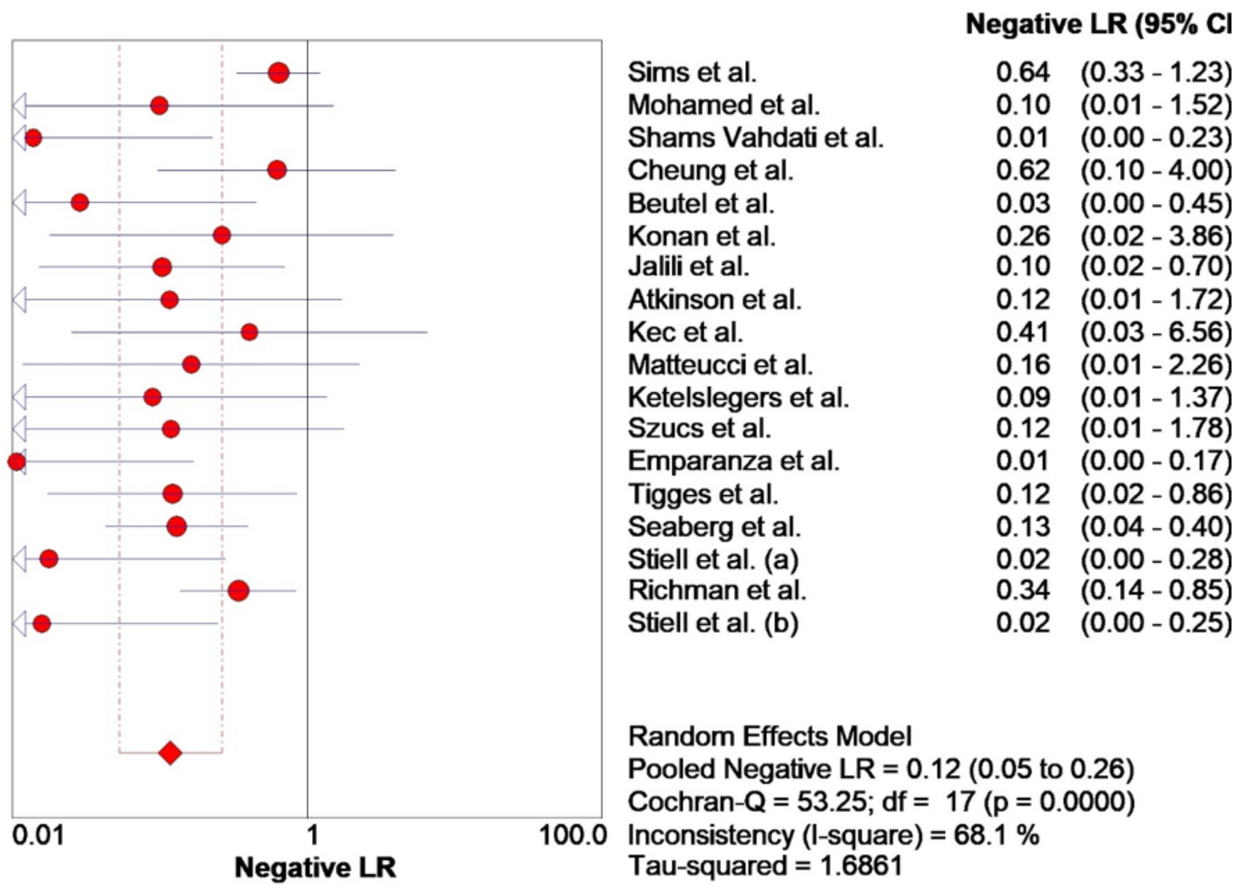

Figure 6: Forest plot of the pooled negative likelihood ratio (NLR) of Ottawa Knee Rule (OKR) for diagnosis of fracture in patients with knee trauma. CI: confidence interval.

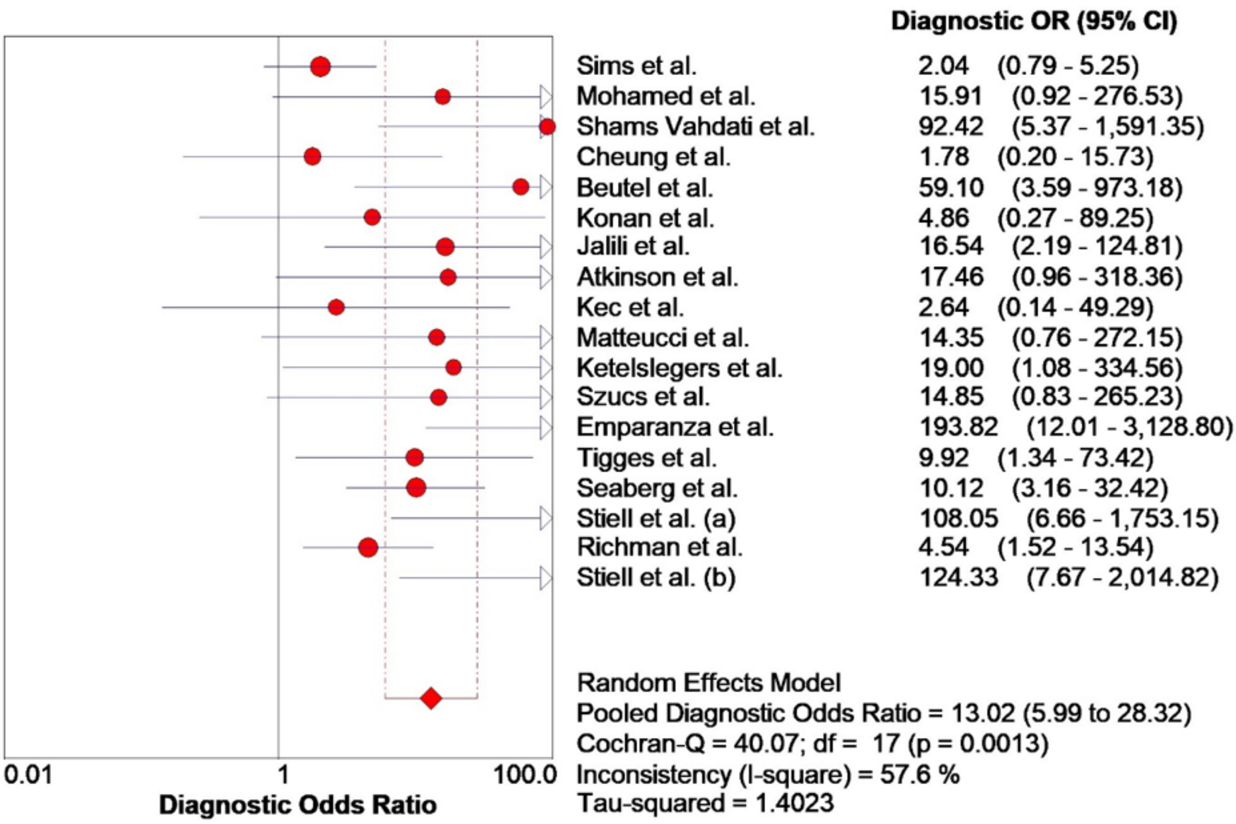

Figure 7: Forest plot of the pooled diagnostic odds ratio (DOR) of Ottawa Knee Rule (OKR) for diagnosis of fracture in patients with knee trauma. CI: confidence interval.

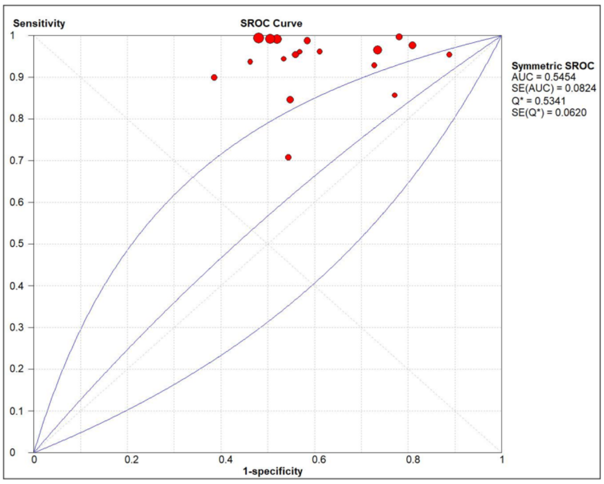

Figure 8: Hierarchical summary receiver-operating characteristic (HSROC) curve indicating accuracy of OKR for diagnosis of fracture in patients with knee trauma.