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Research article

The clinical value of second-opinion reporting by subspecialist musculoskeletal radiologists

Ajay Patel [a,*], Amanda Isaac [b]

[a] Kings College London GKT School of Medicine, United Kingdom
[b] Consultant Musculoskeletal and Interventional Radiologist, Guy's and St Thomas' Hospitals, King's College London, United Kingdom

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ABSTRACT

Introduction: This systematic review aims to evaluate the added clinical value of secondary interpretations produced by specialist musculoskeletal radiologists. Additional aims are to identify clinical settings producing more discrepant cases between the initial and secondary interpreters.

Methods: A systematic search of the MEDLINE and Scopus databases was performed for original research studies, which included a discrepancy rate or a number of discordant reports between a primary interpreter of any training level and a secondary subspecialist musculoskeletal radiologist. Full texts included were screened by two reviewers to determine inclusion. A modified version of the QUADAS-2 tool was used to evaluate the risk of bias for each study.

Results: Eight studies with 11,186 initial imaging examinations reinterpreted by a specialist musculoskeletal radiologist met the inclusion criteria. Across the studies, clinically significant discrepancies were generally defined as discrepant cases impacting a patient's management. Most initial reports were produced by radiologists of varying experience without musculoskeletal specialisation. The secondary reports were produced mainly by multiple experienced subspecialised musculoskeletal radiologists. The range of clinically significant discrepancies reported across the eight studies was between 1.4–27.9%. High discrepancy rates were seen in musculoskeletal oncologic cases, and lower discrepancy rates were seen in appendicular radiographs; however, it was concluded that both areas require greater awareness of the potential discrepancies.

Conclusion: Second opinion reports initially interpreted by a non-musculoskeletal radiologist and reinterpreted by a specialist musculoskeletal radiologist were established as beneficial for patients and impacted their management, especially in musculoskeletal oncology cases, fractures within the appendicular extremities and multiple myeloma focal lesion detection. Greater attention to these clinical settings can potentially advise policymaking to formalise second opinion reinterpretations, which could reduce the risk of misdiagnosis and enhance patient safety and survival. Findings highlight areas requiring greater focus in radiology education, guiding resource allocation to address knowledge gaps and enhance diagnostic accuracy.

1. Introduction

There has been significant growing demand for subspecialty reinterpretations of initial imaging reports completed by non-specialists and specialists [1]. These reports aim to increase the accuracy of patient diagnosis and follow-up. It is important to determine the clinical value of these reports to identify situations where patients would benefit most from a second opinion on their imaging report [2]. This can assist in policymaking to adapt guidelines for reinterpretations and ensure pathways are set in place for correct compensation and job planning for secondary reads. The additional workload due to second opinion reports is also increasing, at a time of workforce shortages and increasing backlogs. Therefore, it is necessary to establish whether this increase in workload provides extra value for patients [3,4]. A systematic review and *meta*-analysis of discrepancy rates between radiology residents and subspecialists for 58 studies of CT in adults resulted in a 2.4 % (95 % CI: 1.7 %, 3.2 %) major discrepancy rate [5]. In another similar study of 29 studies, 19 of which were in the oncologic setting, a major discrepancy rate of 20.4 % was calculated [6]. These studies included a range of secondary interpreters of different radiology subspecialties in various

* Corresponding author.
E-mail addresses: ajay.patel@kcl.ac.uk (A. Patel), Amanda.Isaac@gstt.nhs.uk (A. Isaac).

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clinical settings. However, musculoskeletal (MSK) imaging and secondary interpretation by MSK radiologists had minimal representation within these studies. Even though fractures are commonly misdiagnosed, and neoplastic MSK cases can be challenging to interpret for less experienced clinicians [7–9]. Therefore, this systematic review aims to evaluate the added clinical value of second-opinion reporting by MSK radiologists. Additional aims are to highlight the exact clinical settings, types of imaging studies, body regions and pathologies with more discrepant reports, which would benefit most from a second opinion or greater attention from the primary interpreter. Increasing awareness of more highly discrepant cases can influence time spent reading the report and maximise correct patient diagnosis and management whilst avoiding missed pathologies or incorrect further management steps.

2. Methodology

This systematic review will be reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA-2020) [10]. The study protocol was published in the International Prospective Register of Systematic Reviews (PROSPERO) on 23

Table 1
Study Characteristics.

Lead Author and Year of Publication	Study Design	Number of Imaging Examinations	Imaging Modality and Clinical Setting	Initial Interpreter of the Report	Secondary Interpreter of the Report	Definition of Clinically Significant Discrepancy Used in Study
A Rozenburg 2019 (12)	Retrospective, single centre	571	Cross-sectional imaging studies requested by an orthopaedic oncology service	Outside fellowship-trained MSK radiologist n = 184 Non-MSK fellowship-trained radiologist n = 387	1 of 7 fellowship-trained MSK radiologists with 25,22,15,9,7,4,2 years of experience respectively	A discrepant interpretation that resulted in a change in diagnosis, change in treatment or a change in follow-up
T York 2019 (13)	Retrospective	2947	Emergency department ankle X-rays	Doctors working in the emergency department with experience ranging from second year of practice to senior registrars and consultants	Consultant MSK radiologist	A disagreement with the initial report requiring intervention
M Bedoya 2020 (14)	Prospective	1037	MSK imaging studies requested by tertiary services, the majority of which of which were oncology (33.4 %) and orthopaedic surgery (24.3 %): MRI 71.6 % Radiographs 21.9 % CT 6.5 % Ultrasound 0.1 %	Radiologists of unknown speciality and training level	Subspecialty-trained MSK radiologists, with experience ranging from 1 to 40 years after MSK fellowship training	Discordance with the primary report likely to impact patient care and medical management by affecting the patient's prognosis, follow-up, treatment and/or referral to other specialists
J Kung 2013 (15)	Retrospective	2219	MSK radiographic reports (defined as radiographs of the appendicular and axial skeleton including cervical spinal and facial radiographs) of patients presenting with acute symptoms to the ED	On call radiology residents between 3–5 years of training and 4–12 weeks on the MSK service	6 board-certified MSK radiologists with 1–17 years of experience	A missed finding that caused a change in clinical management and required notification of the emergency care provider
J T.Huhtanen 2023 (16)	Retrospective cross-sectional study	1006	Appendicular radiographs	Radiology specialists and residents, unknown subspecialty and training level	Double reading by two subspecialty-level MSK radiologists with 20 and 25 years of experience	An interpretation error with clear clinical effect on patient treatment
M Chalian 2016 (17)	Retrospective	2326	MSK CT and MRI examinations	Radiologists of unknown subspecialty and training level	1 of 3 subspecialty MSK radiologists with 10–15 years of experience.	Discrepancies that caused a change in diagnosis, prognosis, treatment follow-up or referral
A Tagliafico 2020 (18)	Retrospective	70	Pre-transplant total-body CT examinations for patients with multiple myeloma	General radiologists with no known formal or informal specialised experience in MSK radiology.	2 MSK radiologists with a mean of 9.5 years' experience	Discrepancies likely to change patient care or diagnoses
A Rosskopf 2015 (19)	Retrospective, quality improvement study	1010	Knee MRI reports	Fellowship-trained MSK radiologist	5 board-certified and fellowship-trained MSK radiologist	A change in the report resulting in a change of diagnosis with an effect on the patient's treatment, prognosis, need for follow-up examinations or referral to other specialised clinicians.

MSK = musculoskeletal, CT = computed tomography, ED = emergency department, MRI = magnetic resonance imaging.

October 2024 (registration number CRD42024603600).

Eligibility Criteria.

Inclusion criteria:

1) Original research published in the English language
2) Initial imaging studies re-read by a musculoskeletal radiologist.
3) Studies must include data representing clinically significant discrepancies between initial and secondary reports in the form of clinically significant discrepancy rates or by including the number of discrepant reports.

Exclusion criteria:

1) Studies not published in the English language.
2) Secondary image reads performed by a non-musculoskeletal radiologist.
3) No inclusion of data regarding clinical significance.

2.1. Database search strategy

The electronic databases searched included MEDLINE through the Ovid platform and Scopus [Elsevier]. The search was conducted on 20th October 2024. A clinical librarian assisted with refining the search and the overall search strategy. The search was restricted to title, abstract, subject headings, and keyword fields. The search was limited to studies published in the English language. Three concepts were searched (second opinion, musculoskeletal, and discrepancy), and advanced searching tools were used, including proximity and truncation. The full database search strategy is included in Appendix 1. This search yielded 458 papers. All studies from the search were imported into the Zotero reference managing software. Duplicate studies were removed using the Zotero deduplication option. Any remaining duplicates were subsequently removed manually. A title and abstract screen were performed by A.P (a final year medical student) to remove any studies that did not meet the inclusion criteria. A.P and A.I (a specialist MSK radiologist) performed a full-text screen for studies whereby inclusion could not be determined by the title and abstract alone, any disagreements were resolved by consensus.

2.2. Data Extraction and Synthesis of results

The following data was extracted to an Excel spreadsheet as a table of study characteristics, and results. Data for Table 1 included: 1) lead author and year of publication, 2) study design, 3) clinical setting and imaging modality, 4) initial interpreter of the report, 5) secondary interpreter of the report, and 6) definition of clinically significant discrepancy. Data for Table 2 included: 1) author and year of publication, 2) number of imaging examinations, 3) the rate of clinically significant discrepancies, 4) list of clinically significant discrepancies, 5) overall study conclusion, and 6) overall risk of bias. Results were synthesised into two tables using the extracted study data. No methods of statistical analysis were performed due to significant study heterogeneity.

2.3. Methodological quality assessment

The risk of bias in each study was determined using a modified version of the Quality Assessment of Diagnostic Accuracy Studies 2 (QUADAS-2) tool. The original tool is used to assess the risk of bias in diagnostic accuracy studies. This review, however, includes studies with calculated discrepancy rates between the first reviewer and the second specialist reviewer. Therefore, a modified version was used, which was successfully created and implemented in the systematic review and *meta*-analysis by M Wu et al. [5] on discrepancy rates of CT in adults. This customised version allows a more focussed assessment of bias specific to studies evaluating discrepancy rates, ensuring appropriateness for evaluating this study's evidence quality. The tool is based on four domains: study selection, flow and timing, initial reading, and reference standard. Within each domain are questions to which the user will answer yes/no/unclear to determine the overall risk of bias. The nine questions and tools guidance are included in Appendix 2.

3. Results

The search strategy initially retrieved 458 papers. These were exported to the Zotero reference manager. 315 papers remained after duplicate copies were removed. A title and abstract screen were then performed by A.P. 298 records were deemed irrelevant and did not meet the inclusion criteria and were excluded at this stage. The remaining 17 studies underwent a full-text screen by A.P and A.I against the agreed inclusion and exclusion criteria. Nine studies were excluded after the full-text screening, with eight due to either the secondary reviewer not being a musculoskeletal radiologist or no inclusion of the subspecialty of the second interpreter. One study was excluded due to non-MSK and MSK radiologists generating the second opinion report. The full study characteristics are included in Table 1.

All eight included studies were conducted retrospectively, with at minimum one subspecialty MSK radiologist as a secondary interpreter, although the majority included several or more fellowship-trained MSK radiologists [11–18]. The studies had similar definitions for a clinically significant discrepancy, all included a statement that the discrepancy should impact the patient's management. Most studies included a change in diagnosis and follow-up within their definition. There was, however, significant variation in the initial interpreter, the clinical setting and the type of imaging study. All initial interpreters were radiologists, apart from one study, which included doctors in the emergency department [12]. The level of training of the radiologists varied with each study, although in comparison to the second interpreter, the initial interpreters were generally less experienced in MSK imaging. This was demonstrated by many of the studies, including imaging examinations sent as a referral to a specialist or generated by residents or general non-MSK radiologists. Several studies also included multiple MSK radiologists with over 10 years of experience post-fellowship as secondary interpreters [11,13–16].

Most imaging examinations included for a second opinion report were MSK; this varied by region, with studies focussing on individual areas of appendicular radiographs or a mixture of regions. One study focussed specifically on patients with multiple myeloma and lesion detection; two other studies also included imaging reports which were refereed mainly by oncologic services [11,13,17]. The type of imaging modality used for each study differed in each study, although in most, a mixture of imaging studies was used apart from three studies investigating ankle X-rays, knee MRI and total-body CT [12,17,18]. Emergency department and oncologic referrals were common clinical settings with second opinion report requests.

Across eight studies, a total of 11,186 initial imaging examinations were reinterpreted by a specialist MSK radiologist. Due to several studies including a mixture of imaging types, the number of examinations per modality could not be calculated. Of the imaging studies, 2947/11186 (26.35 %) were initially interpreted by non-radiologists and were solely ankle X-rays; the remaining 8239/11186 (73.65 %) images were initially interpreted by radiologists. Fellowship-trained MSK radiologists initially interpreted 1194/11186 (10.67 % of the total included imaging studies or 14.49 % of the studies reported by radiologists). A caveat is noted in that several studies did not mention details of the initial interpreter, so the results could be underreported [13,15,16]. Initial reports of specific body regions included 1010 knee MRI reports, 2947 ankle X-rays and 3225 appendicular radiographs. All studies reported a clinically significant discrepancy rate between the initial and secondary interpreter, defined in most studies as a discrepancy which resulted in a change in patient management, diagnosis or follow-up.

Table 2
Study Results.

Lead Author and Year of Publication	Number of Imaging Examinations	The Rate of Clinically Significant Discrepancies	Clinically Significant Discrepancies Recorded	Main Study Conclusions	Overall Risk of Bias
A Rozenburg 2019 (12)	571	9.2 % vs 27.9 % when initial interpretation was performed by an MSK and non-MSK radiologist respectively	Lower extremity mass consistent with hematoma; reinterpretation raised the suspicion of a soft-tissue malignancy, proven to be an undifferentiated pleomorphic sarcoma Failure to detect an incomplete fracture and incorrectly attributed the resultant bone marrow oedema to an infiltrative lesion	Fellowship-trained radiologists generate a lower discrepancy rate in an orthopaedic oncological patient population. Subspecialty radiologists can prevent unnecessary invasive interventions or be the first to suggest more aggressive therapeutic procedures.	Medium
T York 2019 (13)	2947	2.7 % 81/2947	False positives in 20 reports, missed findings in 61 reports of which included: Unreported soft tissue swelling 33 cases Missed fracture of lateral malleolus in 22 cases with 12/22 Weber C, 8/22 Weber B, 2/22 Weber A. Missed bimalleolar fracture in 2 cases and one case of missed trimalleolar fracture Missed medial malleolus fracture in 9 cases Missed navicular fracture in 5 cases, missed calcaneus fracture in 3 cases, missed talus fracture in 6 cases and one case of missed cuboid fracture. Missed 5th metatarsal fracture in 2 cases and joint dislocation in one case Missed osteomyelitis in one case	The most common discrepancies were Weber B ankle fractures of the lateral malleolus. 40.0 % of all navicular, 33.3 % of all cuboid and 21.9 % of all talus fractures were missed on the initial report. These should be a focus of increased awareness for initial reporters due to difficulty. A high standard of accuracy supports initial reporting to determine early clinical management, the presence of 166 reports with discrepancy indicates a continued need for timely senior review of ankle X-rays.	Medium
M Bedoya 2020 (14)	1037	17.5 %	A change in management in 63.3 % of 30 randomly selected discrepant cases. Examples included changing biopsy of an indeterminate lesion in the primary report to imaging follow-up for a nonaggressive lesion on the secondary interpretation, as well as changing the recommendation for surgery for a full-thickness tendon tear to physical therapy for a low-grade tendon tear. Recommending surgery or biopsy in suspicions/indeterminate lesions, meniscal tears, tendon tears, or calcaneal coalitions that were not identified or incorrectly interpreted in the primary report. One case of treatment initiation in a patient with multiple lytic lesions consistent with multiple myeloma rather than the initial recommendation for additional diagnostic sampling for a single lesion identified in the primary report	Oncologic studies were the most common indication for second-opinion interpretation. Original and second interpretations in the majority of cases were in agreement. However, subspecialty MSK interpretations were shown to be more accurate than primary interpretations and impacted clinical management in cases of discrepancy.	Medium
J Kung 2013 (15)	2219	1.8 %	Fractures accounted for 25/40 of the major discrepancies.In the upper extremity 7/14 of missed fractures involved the radius. 4 missed fractures of the distal radius on all 4 discrepant wrist radiographs. 3 missed fractures of the radial head on all 3 discrepant elbow radiographs. Missed fractures on hand radiographs included triquetral fractures in 2/5 cases Missed fracture of the lower extremity 9/40 and spine 1/40, a missed femoral head fracture 1/40 and a missed orbital floor fracture 1/40 Foreign bodies most of-ten glass 4/40 cases Tumorlike lesions 3/40	A high rate of agreement between resident and attending MSK radiologists in interpretation of emergency MSK radiographs Radiology residents should pay particular attention to upper extremity radiographs, particularly those of the wrist and hand, and should carefully evaluate the distal radius and radial head. Awareness of the findings on MSK radiographs most frequently missed by radiology residents is clinically important. In only two cases did a discrepant interpretation lead to a substantial change in clinical management, a missed femoral head fracture and a missed orbital floor fracture.	Medium
J T.Huhtanen 2023 (16)	1006	56/1006 radiographs 5.6 %	Missed findings n = 44 Overcalls in radiographs n = 12	No major differences between radiology specialists and residents in MSK radiograph interpretation. Certain MSK regions need	Low

(*continued on next page*)

Table 2 (*continued*)

Lead Author and Year of Publication	Number of Imaging Examinations	The Rate of Clinically Significant Discrepancies	Clinically Significant Discrepancies Recorded	Main Study Conclusions	Overall Risk of Bias
			Examples included a case of missed posterior dislocation and a case of a missed a Hill–Sachs lesion that resulted in delay in patient treatment	more attention in radiograph interpretation. Diagnostic accuracy in the wrist had the lowest sensitivity and specificity among MSK regions. Foot interpretation showed the lowest sensitivity and specificity in the lower extremity these should raise concerns and highlight the need for double reading and be taken into consideration in radiology education.	
M Chalian 2016 (17)	2326	26.2 % 610/2326	Clinically significant discrepant cases 331/911 neoplastic, 58/196 trauma, 15/69 vascular, 38/150 congenital and 17/70 inflammatory Examples included misidentifying a malignant tumour as benign and describing a bone cyst as a lytic metastatic lesion or myositis ossificans as a malignant osteosarcoma	Patients with MSK disorders benefit from second-opinion examinations due to a high rate of clinically important discrepancies, especially for oncologic cases such as bone and soft tissue tumours. The reports could be used as risk management, quality assurance and as a learning opportunity if feedback is provided to initial reporter. Referral services could implement internal policies for formal interpretation of outside imaging examinations. Policy makers and insurers could adjust reimbursement policies to create value for patient care by providing second-opinion consultations.	Medium
A Tagliafico 2020 (18)	70	21 %	All 14 discrepant cases included MSK specialists finding “new” focal lesions	Subspecialty second-opinion consultation in multiple myeloma CT could identify lytic lesions previously missed, amenable to influence patients’ care. The experience of MSK radiologists could be important to detect lytic lesions between 5–10 mm in diameter located in osteoporotic and degenerated vertebral body.	Low
A Rosskopf 2015 (19)	1010	1st round 500 Knee MRI reports − 3 % 2nd round 510 Knee MRI reports − 1.4 %	1st round: 114 total discrepancies classified as degenerative n = 66, traumatic n = 19, miscellaneous n = 13, and congenital n = 8 2nd round: 71 total discrepancies classified as degenerative n = 45 traumatic n = 11 and miscellaneous n = 8	Clinically relevant diagnostic errors occurred rarely and were mostly associated with the detection of lesions rather than their interpretation.	Medium

MSK = musculoskeletal, CT = computed tomography, MRI = magnetic resonance imaging.

The range of clinically significant discrepancies reported was between 1.4–27.9 %, with the lower value produced when knee MRI reports were read by an MSK radiologist then quality assessed by 5 fellowship-trained MSK radiologists – thereby demonstrating narrow interobserver variability. The highest value was produced when initial reports of orthopaedic oncological referrals were interpreted by non-MSK radiologists and reinterpreted by 1 of 7 fellowship-trained MSK radiologists [11]. Values in between this range calculated by the studies included clinically significant discrepancy rates of 1.8 %, 2.7 %, 3 %, 5.6 %, 5.8 %, 9.9 %, 17.5 %, 21 % and 26.2 % respectively – Table 1. Imaging studies associated with oncology through either oncologic second opinion referrals or patients with multiple myeloma generated the highest clinically significant rates with 27.9 % and 21 %, respectively. The M Chalian 2016 study, which had a 26.2 % clinically significant discrepancy rate, also had 331 discrepant neoplastic cases out of 610 clinically significant cases [16]. A lower rate was seen in the J Kung 2013 study with initial MSK appendicular reports produced by on-call residents with 3–5 years of experience, which produced a 1.8 % clinically significant discrepancy rate [14]. A clinically important discrepancy rate of 2.7 % was seen in the T York 2019 study when doctors in the emergency department reported ankle X-rays with secondary interpretation by the MSK radiologists [12].

Three studies documented the exact clinically significant discrepant cases produced [12,14,17]. The remaining studies either described several examples or categorised the discrepancies into subgroups. The full list of recorded clinically significant discrepancies and rates is included in Table 2. The three studies that recorded the exact discrepancies were by T York 2019, J Kung 2013, and A. Tagliafico 2020, the latter of which investigated pre-transplant total body CT for multiple myeloma patients [12,14,17]. Unreported soft tissue swelling and lateral malleolus fractures were the most commonly reported significant discrepancy in the study by T York 2019, with 33 and 22 cases out of 81, respectively [12]. Of the lateral malleolus fractures, 12 were Weber C, 8 were Weber B, and 2 were Weber A. Of the missed findings, the greatest percentage was osteomyelitis, where 2/3 of cases were initially missed. Fractures of the navicular, cuboid and talus bone were missed in 6/15, 2/6 and 7/32 cases, respectively. The J Kung 2013 study also reported 25/40 clinically significant cases due to missed fractures, 14 of which were upper extremity fractures, with 7/14 involving the radius [14]. Nine missed fractures were in the lower extremity. The study also

reported 4 cases of missed foreign bodies attributed to glass and 3 due to tumour-like lesions. A missed orbital fracture and femoral head fracture were reported to lead to the most impactful changes in clinical management. The study by A. Tagliafico 2020 reported all 14 clinically discrepant cases of 70 total pre-transplant total body CT scans due to unreported focal lytic lesions in the initial report [17]. Other clinically important discrepancies included an initial report of lower extremity haematoma for which secondary interpretation revealed a possible soft-tissue malignancy, which was then proven to be undifferentiated pleomorphic sarcoma. A case of missing an incomplete fracture and incorrectly attributing the resulting bone marrow oedema to an infiltrative lesion. A case of missed posterior shoulder dislocation and a missed Hill–Sachs lesion. A case of describing a bone cyst as a lytic metastatic lesion and describing myositis ossificans as a malignant osteosarcoma. Fig. 1

This review summarised the main conclusions of each study in Table 2**.** In general, most studies for which there was a relatively high discrepancy rate concluded that fellowship training and subspecialisation could generate a higher degree of accuracy for diagnosis and impact further patient management. This is most prevalent in oncologic patients with bone and soft tissue tumours and patients with multiple myeloma, where detecting small lytic lesions can immediately influence prognosis [19]. Two studies with a lower discrepancy rate, T York 2019 and J Kung 2013 highlight the accuracy and agreement of initial reports. However, they also mentioned that initial interpreters should be made aware of the presence of clinically significant reports and that contextual reporting with clinical relevance in mind is key to accurate image interpretation [12,14,20,21]. These two studies concluded that ankle X-rays need fast expert review, and radiology residents should pay particular attention to upper extremity radiographs, particularly those of the hand and wrist, and spend time carefully reviewing the distal radius and radial head. Further body regions of particular importance were mentioned in the conclusions of the J Huhtanen 2023 study [15]. These include that diagnostic accuracy in the wrist region had the lowest overall sensitivity and specificity, followed by the foot region. The study also concluded that there is a need for double reports to be included in radiology education and that there were no significant differences in the initial interpretation of MSK imaging studies by non-MSK subspecialty radiologists and radiology residents. The M Chalian 2016 study concluded that patients with MSK disease benefit from subspecialty second opinion reports due to high discrepancy rates and risk management [16]. The study mentioned that internal policies could be implemented by MSK referral services for formal reinterpretation of these studies and adjustment of reimbursement to create more value for these report types. Using the reports as a learning opportunity, if secondary reports were presented to the initial interpreter, was also suggested to help with quality assurance [22]. The A Rosskopf 2015 study concluded that there was a rarity of clinically significant discrepancies in knee MRI reports, although initial interpretation was performed by subspecialty MSK radiologists [18].

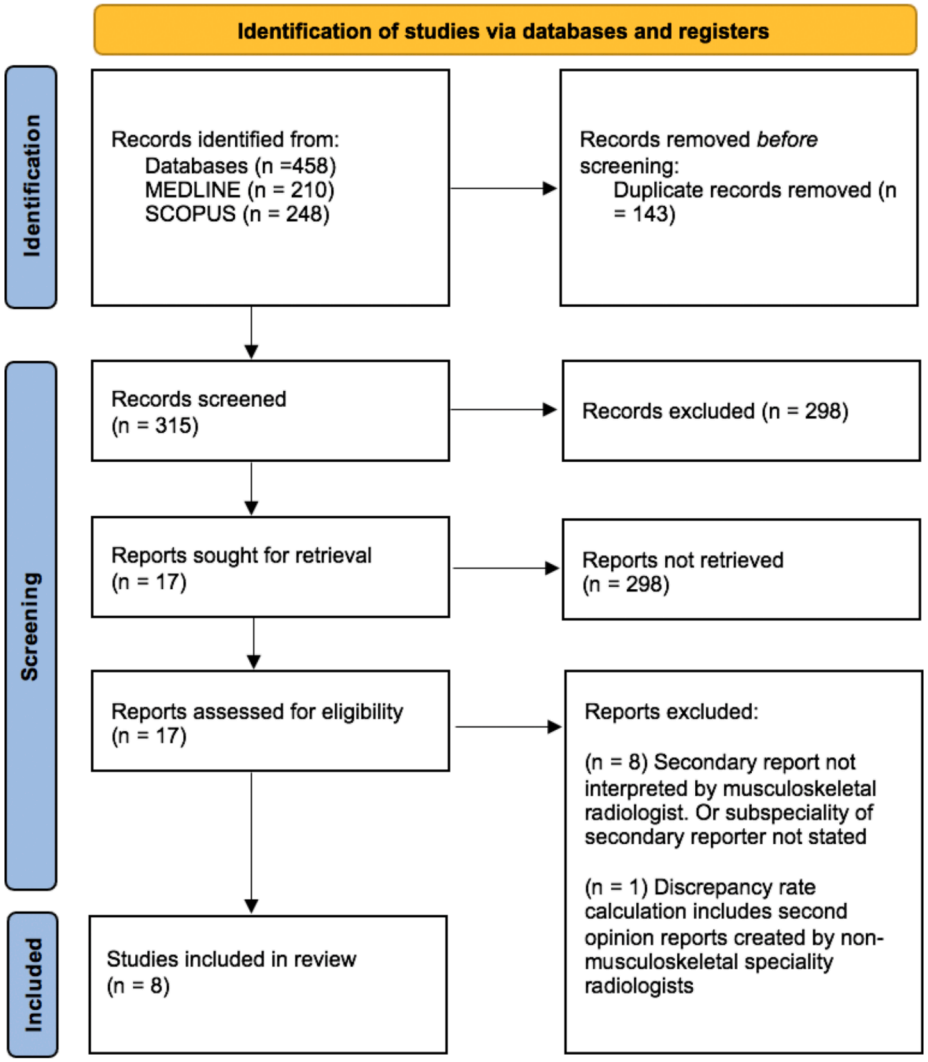

Fig. 1. PRISMA 2020 flowchart.

Therefore, this study evaluated the discrepancy rate between subspecialists.

The results of the methodological quality assessment using the QUADAS-2 modified risk of bias tool are demonstrated in Table 3. The overall risk of bias for each study generated using the tool is shown in Table 2**.** All studies were deemed at medium risk of bias apart from two studies, J T.Huhtanen 2023 and A Tagliafico 2020, which were thought to be at low risk of bias. Questions 8 and 6 have the highest number of unclear responses. Question 8 asked whether the secondary radiologist had access to the same data as the initial interpreter, and question 6 asked whether the secondary interpreter was blinded to the report produced by the initial interpreter. The two studies that blinded the secondary MSK radiologist to the initial report were deemed at low risk of bias as the primary interpretation would not have influenced the secondary interpretation [15,17]. All responses to question 8 yielded unclear responses as none of the studies included information on the level of information both interpreters received. The results of both questions caused the majority of studies to be assessed at a medium risk of bias. Several studies did not mention exclusion criteria, and whether they avoided inappropriate exclusions was unclear [11,13,14]. The number of studies answering yes, no or unclear for each question type are summarised in a traffic light plot in Fig. 2.

4. Discussion

Musculoskeletal imaging is an area with frequently missed pathologies and complex imaging, especially in the emergency department (ED) and oncologic setting [7–9,23]. This review aimed to evaluate the clinical benefit of reinterpretations by MSK radiologists by determining the clinically significant discrepancy rate of initial and secondary reports and identifying commonly misinterpreted pathologies which require attention. Eight studies met this review's inclusion criteria, and the range of clinically significant discrepancy rates reported was between 1.4–27.9 % [11–18]. The wide spread of discrepancy rates seen could be due to the heterogeneity of each study, which included different initial interpreters and clinical settings. However, within this review certain clinical settings and anatomical regions had notably higher discrepancy rates on further interpretation by a specialist MSK radiologist. There was also a noticeable number of cases for which patients had changes in management due to a second interpretation.

Our results highlighted that studies with more experienced clinicians as initial interpreters produced a lower discrepancy rate. The A Rosskopf 2015 study with subspecialty MSK radiologists as the initial interpreter for Knee MRI reports produced clinically significant discrepancy rates of 1.4 % and 3 %. The J Kung 2013 study involved radiology residents with 3–5 years of experience as the initial interpreter, this produced a lower clinically significant rate of 1.8 %. Hence increasing experience of the initial interpreter is likely to lower subsequent discrepancies, due to acquired expertise in reporting in radiological reporting. A lower rate of 2.7 % clinically significant discrepancies was also seen in the T York 2019 study when ankle-X rays in the ED were initially reported by doctors of varying experience. Significant exposure and experience reporting ankle pathologies may have contributed to the lower value. Although low discrepancies were seen, it was concluded that there should be more awareness of missed findings, such as lateral malleolus and upper extremity fractures involving the radius – highlighting the key anatomical review areas [12,24]. It is known that ankle fractures are common presentations in ED; missing the fracture can lead to prolonging of symptoms and social and psychological consequences for patients [8,23–25]. The T York 2019 study emphasised the need for fast secondary reviews of ankle X-rays, their study found 22 missed lateral malleolus fractures and 40.0 % of all navicular, 33.3 % of all cuboid and 21.9 % of all talus fractures being missed on the initial report. The J Kung 2013 study included 7/14 missed upper extremity fractures involving the radial head and several triquetral fractures on hand radiographs. Published studies have shown that fractures of the navicular and calcaneus bones are frequently missed; this review also showed that talus fractures were often missed [8,26,27]. The T York 2019 study identified 5 missed navicular fractures, 3 missed calcaneus fractures, and 6 missed talus fractures. The J Huhtanen 2023 study also concluded that diagnostic accuracy in the wrist region had the lowest sensitivity and specificity; the often superimposing uniquely shaped wrist bones can make fractures difficult to detect [7,8,28]. Other difficult-to-diagnoses cases in practice are fractures of the lateral process on the talus only seen on frontal ankle views, Lisfranc fractures and non-displaced radial styloid fractures [7,29].

The studies included in this review support the need for MSK subspecialty second opinion for distal extremity reports produced by non-MSK radiologists. The J Kung 2013 study also mentioned no major difference between non-MSK specialists and radiology residents for the initial interpretation of appendicular radiographs. This suggests that a subspecialty second opinion provides more value than a double review by an interpreter of similar training. This could be due to the greater experience of a subspecialist minimising potential sources of initial error such as 'lack of knowledge error', 'satisfaction of search error', and 'location-related error' [30,31]. This is concordant with recent studies reviewing the accuracy of automated or semiautomated reporting using artificial intelligence applications [32,33].

The studies with higher clinically significant discrepancy rates of 17.5 %. 21 %, 26.2 % and 27.6 % were related to oncologic referrals or neoplastic cases. The high impact on patient management and follow-up is expected with significant changes in diagnosis for cancer patients and can greatly impact mortality [34]. MSK oncological imaging can be difficult due to the complexity of cases, and many lesions can remain undetermined after imaging. For example, myxoid sarcoma, chondrosarcoma and other soft tissue tumours can be difficult to diagnose due to high water content, causing them to be misdiagnosed as benign cystic lesions [9]. All studies in this review, with a majority of oncologic cases, concluded that the secondary report of an MSK radiologist was beneficial. Across the studies, the reinterpretations were said to be of

Table 3
Results of Risk of Bias Assessment.

Lead Author and Year of Publication	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
A Rozenburg 2018 (12)	Yes	Unclear	Yes	Yes	Yes	Unclear	Yes	Unclear	Yes
T York 2019 (13)	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Unclear	Yes
M Bedoya 2020 (14)	Yes	Unclear	Yes	Yes	Yes	Unclear	Yes	Unclear	Yes
J Kung 2013 (15)	Yes	Unclear	Yes	Yes	Yes	Unclear	Yes	Unclear	Yes
J T.Huhtanen 2023 (16)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Unclear	Yes
M Chalian 2016 (17)	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Unclear	Yes
A Tagliafico 2020 (18)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Unclear	Yes
A Rosskopf 2015 (19)	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Unclear	Yes

Results of the modified QUADAS-2 risk of bias assessment for each study. Q1 – Consecutive or random imaging studies used. Q2 – Avoided inappropriate conclusions. Q3 – Imaging studies representative of clinical practice. Q4 – Initial interpreter provided clinical data. Q5 – Reference radiologist likely to correctly interpret image. Q6 – Reference radiologist blinded to the initial interpretation. Q7 – Discrepancy definition was clear and consistent. Q8 – Initial and reference radiologist have access to the same data. Q9 – All images receive the same reference standard.

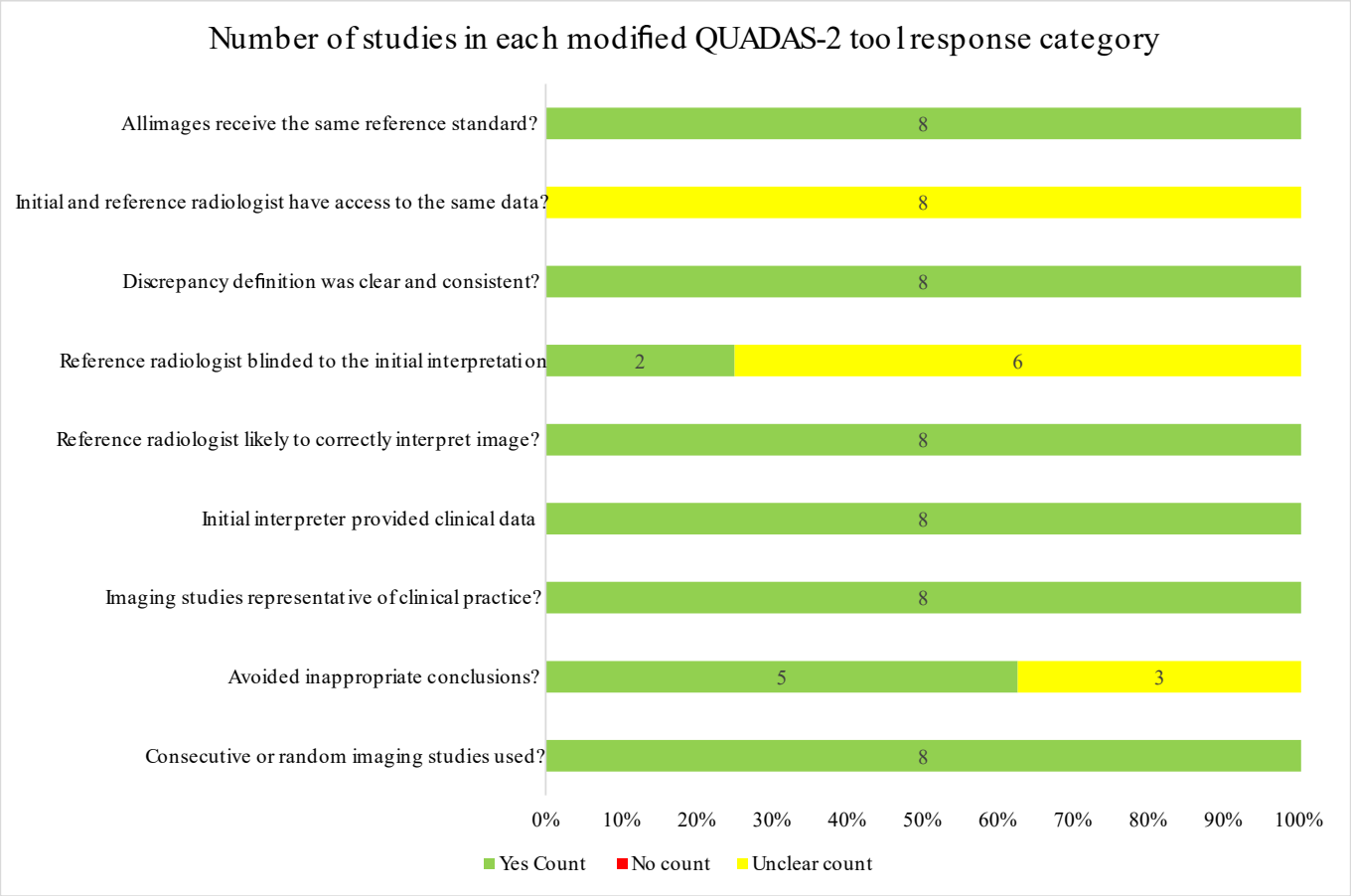

Fig. 2. Nine signalling questions within the modified QUADAS tool, alongside the total number of yes, no and unclear responses determined for each study during risk of bias assessment.

greater accuracy, lower the discrepancy rate and be of benefit in cases for which there could be a major effect on patients. In one study investigating the discrepancy rate of pre-transplant total-body CT for multiple myeloma patients, it was said subspecialty second opinion could identify missed lytic lesions, which could influence patient care. Of particular significance are lesions between 5–10 mm in diameter located in osteoporotic and degenerated vertebral bodies for which the experience of an MSK radiologist would help characterise the lesions. The presence of a lytic lesion impacts the time to disease progression; therefore, subspecialty review is of significant value, especially in focal lesion detection [19]. The M Chalian 2016 study, with mostly neoplastic cases, supported using second-opinion reporting in radiology education. Where feedback could be provided to the initial reporting radiologist in the form of the subspecialty second opinion report to raise awareness of misinterpretations and improve the accuracy of initial reports in the future. The J Huhtanen 2023 study also highlighted that low diagnostic accuracy in the wrist and foot region should be considered during radiology education. It has also been suggested that case conferences on missed findings could help improve the initial accuracy of the report. The M Chalian 2016 study also suggests that policymakers consider adjusting reimbursement to provide more value to these cases and implement formal standardisation of these secondary reports in clinical practice.

The risk of bias was assessed using the modified QUADAS-2 tool which is more specific for evaluating bias in studies including calculated discrepancy rates between initial and secondary reports. Bias was apparent across all of the studies due to the uncertainty of the secondary interpreters' blinding to the initial report or to other clinically relevant patient information. This, alongside the uncertainty of whether initial interpreters were aided in producing the report, could impact the calculated discrepancy rates. The sample size is also noted to produce heterogeneity in discrepancy rates, although most studies had a similar number of participants, apart from the A Tagliafico 2020 study, with a much smaller number of studies. Other limitations of this review include that the search was limited to two databases; therefore, other relevant studies were potentially omitted. The initial title and abstract screen were performed by a single reviewer; a more comprehensive screen would include two reviewers. No formal data analysis was used in this review either due to significant differences in the clinical setting, interpreters, and the varying definitions of a clinically significant discrepancy.

5. Conclusion

This review highlights a considerable variation in clinically significant discrepancy rates when imaging studies are initially interpreted by non-musculoskeletal (MSK) radiologists and subsequently re-evaluated by specialists in MSK radiology. These discrepancies underscore the potential value of a subspecialty second opinion, which can significantly enhance patient care and influence clinical management decisions. This is particularly evident in MSK oncological cases, such as the detection of lytic lesions in multiple myeloma, as well as in the assessment of appendicular fractures in both the distal upper and lower extremities. Misinterpretation of these conditions can have profound implications for patient outcomes, potentially leading to delayed or incorrect diagnoses that adversely affect treatment plans.

Given the clinical impact of these discrepancies, it is essential to raise awareness of areas with the highest rates of misinterpretation. This

awareness should inform policies surrounding second opinion interpretations, ensuring that more accurate diagnoses are made and reducing the risk of misdiagnosis. Such initiatives will, in turn, enhance patient safety and clinical efficacy.

Furthermore, the findings of this review have significant implications for radiology education. Identifying areas where knowledge gaps persist enables the strategic allocation of resources and the development of targeted educational interventions. By addressing these gaps, we can better equip radiologists with the necessary skills to recognise subtle yet critical pathologies, ultimately improving the quality of radiological practice and patient care.

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Ethics approval and consent to participate: Not applicable

Availability of data and material: No new data was created or analysed in this review.

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CRediT authorship contribution statement

Ajay Patel: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Data curation, Conceptualization. **Amanda Isaac:** Writing – review & editing, Visualization, Validation, Supervision, Resources, Project administration, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix 1

Search conducted 20th October 2024.

Ovid MEDLINE(R) ALL < 1946 to September 24, 2024>.

1 ((Second* adj2 opinion*) or (double adj2 report*) or (second adj2 report*) or (double adj2 review*) or (specialist adj2 review) or (second* adj2 interpretation*) or (final adj2 interpretation*) or (initial adj2 interpretation) or (double adj2 reading*) or reinterpretation* or (multiple adj2 reading*) or (subspecial* adj2 consultation) or (triple adj2 review*) or (triple adj2 report*) or (double adj2 interpretation*) or (dual adj2 interpretation) or (triple adj2 reading*) or (dual adj2 reading*) or peer review).tw,kw. 31,155.

2 discrep*.mp. 112,390.

3 exp Musculoskeletal System/ or exp Radiology/ or exp Musculoskeletal Diseases/ or exp Tomography, X-Ray Computed/ or exp Magnetic Resonance Imaging/ 3,261,239.

4 (musculo* or fract* or msk or orthop?ed* or radio*).tw,kw. 2,357,249.

5 3 or 4 5,003,729.

6 1 and 2 and 5 210.

SCOPUS, title abstract and keyword search:

((“Second* opinion*” or ”double report*” or “second report*” or ”double review*” or “specialist review” or “second* interpretation*” or “final interpretation*” or “initial interpretation” or “double reading*” or reinterpretation* or “multiple reading*” or “subspecial* consultation” or “triple review*” or “triple report*” or “double interpretation*” or “dual interpretation*” or “triple reading*” or “dual reading*” or “peer review”) and (“musculoskeletal radio*” or musculo* or “musculoskeletal imag*” or “fracture* detection” or “miss* adj2 fracture*” or fract* or msk or orthopaed* or radio* or “radiology resident”) and (discrepanc* or ”discrepanc* adj2 rate*” or “reporting adj2 discrepanc*” or “major discrepanc*” or “minor discrepanc*”)) 248.

Appendix 2

Customized Risk-of-Bias Tool based on QUADAS-2.

Domain	Risk of bias question	Question explanation
Domain 1: Study selection Risk of bias:	Q1: Was a consecutive or random sample of studies enrolled? (yes/no/unclear)	State no if the sample was not random or consecutive. State unclear if it is not stated or mentioned.
	Q2: Did the study avoid inappropriate exclusions? (yes/no/unclear)	• For example, in studies of resident discrepancy rates, some authors exclude images that were read by residents who had help from an attending. This would be an appropriate exclusion. Excluding technically inadequate or complex cases would not be an appropriate exclusion.
	Q3: Was the spectrum of studies representative of the types of studies that would be acquired for similar indications in practice? (yes/no/unclear)	• In other words, were the images realistic in the sense that they were acquired from real patients with real indications and with the appropriate technique.
Domain 2: initial reading Applicability:	Q4: Were the same clinical data available to the initial radiologists as would be available when the images are interpreted in practice? (yes/no/unclear)	For example, some studies have the initial radiologists interpret images without any clinical information–answer “no” in this case. If the initial read was done in “typical” clinical conditions, answer yes. If not specified, answer ‘unclear’.
Domain 3: reference standard Risk of bias:	Q5: Is the reference radiologist likely to correctly interpret the images? (yes/no/unclear)	Answer “yes” if a consensus panel of board certified radiologists formed the reference interpretation. Answer “yes” if a single reference radiologist has specialized training for interpreting the images of interest (ie subspecialty

(*continued on next page*)

(*continued*)

Domain	Risk of bias question	Question explanation
		trained neuroradiologist over-reading head CT).
	Q6: Did the reference radiologist interpret the images without knowledge of the interpretation of the initial radiologist? (yes/no/unclear)	For example, in some studies of resident discrepancy rates, the reference radiologist (the staff radiologist) has access to the initial resident interpretation–answer "no" in this case. If the reference radiologists were blinded to the initial report, answer 'yes'. If not stated = unclear.
	Q7: Was the definition of discrepancy clear and consistently applied? (yes/no/unclear)Q8: Did the reference radiologist have access to the same data (not more and not less) as the initial radiologist? (yes/no/unclear)	For example, some reference standards formed by consensus panels have access to histology/surgery results unavailable to the initial radiologist–answer "no" in this case.
Domain 4: flow and timing Risk of bias:	Q9: Did all images receive the same reference standard? (yes/no/unclear)	If some studies were reviewed by a subspecialty radiologist, and others by a non-subspecialty radiologist say "no." If multiple radiologists with equal training (ie several subspecialty neuroradiologists over-reading CT heads) then = yes. If not stated = unclear.
	Overall risk of bias for entire study (low/medium/high)	Here you should evaluate your overall impression of the risk of bias with respect to the accuracy of the data you are extracting. Essentially, do you think the methodology allows for accurate estimation of discrepancy rate? Low risk = likely accurate. Unsure = perhaps accurate. High risk = likely not accurate. An example of a study with a high risk of bias would be one where the probability that discrepancies are not reported in a voluntary error reporting system is high. Low risk would be a consecutive or random sample of cases over-read by a second sub specialty radiologist blinded to the initial report and without additional clinical or imaging information available who must provide a discrepancy report. CommentsOpen field for comments.

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