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Original Research

Retrospective Review of 80 Patients with Chronic Recurrent Multifocal Osteomyelitis Evaluated by Pediatric Orthopaedic Surgeons

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Abstract

Background: Chronic Recurrent Multifocal Osteomyelitis (CRMO) is a rare aseptic autoinflammatory disease with a wide and vague clinical presentation that often mimics infection, malignancy, or benign conditions, leading to a delayed diagnosis. We aimed to evaluate the clinical characteristics, differential diagnoses from evaluating pediatric orthopaedic surgeons, and compared the number of patients that could have avoided a biopsy in 80 patients with CRMO.

Methods: Children diagnosed with CRMO at a single tertiary pediatric hospital in the United States between 2012 and 2022 who were evaluated by a pediatric orthopaedic surgeon were retrospectively reviewed. The differential diagnoses from the surgeons were recorded from their initial presentation. The Jansson criteria and Bristol Criteria were retrospectively applied to evaluate patients who could have been spared a biopsy.

Results: 80 children (65% female) with CRMO were identified. The mean age at diagnosis was 10.28 ± 3.52 years, follow-up of 37.13 ± 27.67 months, and delay in diagnosis of 6.21 ± 9.75 months. Common presenting symptoms were antalgic gait (45%), local inflammation (30%), and fever/fatigue (26.25%). 58% presented clinically with unifocal symptoms, but 81% had multifocal disease on imaging. Radiographs were unremarkable in 35%, had periosteal reaction/sclerosis (23%), or a lytic lesion (22%). On MRI, 72% of patients had marrow edema, periosteal reaction (23%), and/or osteitis (19%). 69% of patients received a whole-body MRI, and 75% received a bone biopsy. The femur, tibia, pelvis, and spine were involved in >30% of patients. The most common initial differential diagnoses were

related to infection (34%) and neoplasm (21%). The Jansson criteria was found to be more sensitive than the Bristol criteria for diagnosing CRMO (OR 3.94, $P < 0.001$) and identified 80% that could have been spared biopsy.

Conclusions: This cohort of 80 patients with CRMO in the U.S. displayed an ambiguous presentation. Whole-body MRI was useful for identifying multifocal lesions. In conjunction with clinical reasoning, the Jansson criteria may be useful in the diagnosis of CRMO and perhaps avoid an unnecessary bone biopsy.

Levels of Evidence: Level IV

Key Concepts

- Chronic Recurrent Multifocal Osteomyelitis is a rare condition in children with a delay in definitive diagnosis of approximately 6 months after initial presentation.
- Chronic Recurrent Multifocal Osteomyelitis often has unremarkable radiographs and MRI findings similar to a neoplasm or infectious osteomyelitis.
- The most common lesions were found in the femur, tibia, pelvis, and spine.
- Pediatric orthopaedic surgeons evaluating these patients placed neoplasm/malignancy and infection on their differential most frequently.
- The Jansson criteria may be used in some patients to possibly prevent unnecessary bone biopsies.

Introduction

Chronic recurrent multifocal osteomyelitis (CRMO), also known as chronic nonbacterial osteomyelitis (CNO), is an aseptic autoinflammatory disorder primarily affecting 1/250,000-1,000,000 children per year.[1] CRMO is characterized by multiple and recurrent osteolytic or sclerotic lesions in the metaphysis of the long tubular bones, clavicle, spine, pelvis, and mandible.[1] However unifocal, non-recurrent, and radiographically undetectable lesions are also common.[2,3] CRMO typically presents with insidious bone pain with or without fever, swelling, and limited mobility. Extraosseous involvement like psoriasis, acne, or palmoplantar pustulosis (PPP) may also be present, but the absence of skin findings does not rule out the possibility of CRMO.[2,4,5]

CRMO is a diagnosis of exclusion and is aided by whole-body MRI (WB-MRI) to identify multiple bone involvement.[6–8] Traditionally, patients will have normal white blood counts (WBC), negative bacterial and blood cultures, and elevated erythrocyte sediment rate (ESR) and C reactive protein (CRP), though in many cases, these may be normal.[3] Bone biopsies are used to rule out malignancy, especially in unifocal disease. The variable clinical and radiographic presentation will often lead it to be mistaken for infectious osteomyelitis, malignancy, trauma, metabolic or autoinflammatory conditions, or other benign conditions.[2,4,9]

Due to its rarity and misleading presentation, diagnosis of CRMO is often difficult and delayed. Previous studies reported average time from symptom onset to diagnosis of 12-24 months.[3,4,9] Delayed diagnosis often leads to ineffective treatments like antibiotics, receiving multiple bone biopsies, progressive skeletal damage, and patient frustration.[1,3,5,10] Most commonly, rheumatologists will ultimately manage CRMO long term and are responsible for producing most of the current literature and awareness of this disease. However, more than half of all patients will present to an orthopaedic surgeon prior

to diagnosis; due to the occult presentation of CRMO, few patients may be referred to rheumatologists when it is appropriate.[10–12] As the bone biopsy would be the last step in the diagnostic work-up for patients suspected to have CRMO, the use of a criteria capable of diagnosing it prior to the procedure, and therefore identifying patients that could be spared a biopsy, would be valuable. The Jansson criteria and Bristol criteria are two independently created clinical scoring systems for CRMO that include biopsy as a criterion but do not necessitate it for diagnosis.[11,13]

The current literature of CRMO in the United States patient population is sparse. Most of the current literature describing CRMO patients are small case series based in Europe, were performed more than 10 years ago, or had fewer patients.[4,5,9,11,12,14] Therefore, we conducted a retrospective study to evaluate the clinical characteristics, differential diagnoses from evaluating pediatric orthopaedic surgeons, and compared the number of patients that could have avoided a biopsy using the Jansson or Bristol criteria in 80 patients with CRMO evaluated at one tertiary pediatric center in the United States.

Materials and Methods

After institutional review board approval (H-49332), we conducted a retrospective analysis of data collected on patients aged 18 years or younger who were diagnosed with CRMO identified via ICD code (Chronic multifocal osteomyelitis: M86.38) from a single, large tertiary care children's hospital system between January 1, 2012, and May 1, 2022. Inclusion criteria included patients seen by orthopaedic surgeons prior to diagnosis who were definitively diagnosed with CRMO by a physician within our institution before 18 years of age and had radiographic evidence of at least one lesion consistent with osteomyelitis without detectable infection. Exclusion criteria included patients with no follow-up or were incorrectly coded as being diagnosed with CRMO. One hundred thirty-four patients were initially collected for chart review and after inclusion and exclusion criteria were applied, 80 patients were included for final study.

Collected data included patient demographics (age, race, gender, follow-up), clinical data (symptoms, date of symptom onset and diagnosis, distribution of painful osseous sites, dermatologic symptoms, family history, past medical history, and the initial orthopaedic surgeon's differential diagnoses from the first encounter's assessment), radiologic data (x-ray, MRI, bone scintigraphy, and PET-CT findings), laboratory data (CRP, ESR, hemoglobin, white blood count, blood cultures, and biopsy pathology), status of clinical remission (resolution of pain, normal ESR/CRP, and no active lesions on MRI for >6 months) at last follow-up and length of symptoms.

All data analysis was performed using RStudio version 2022.07.0 (R Core Team, 2014). Descriptive statistics were estimated and reported as means ± standard deviation and range, median with the interquartile range or range, and number (percent) for categorical variables. The Student's *t*-test was used to compare differences between normally distributed, continuous data. The Mann-Whitney U-test or Wilcoxon sign rank test was used for comparing differences of non-parametric data. The Chi-square tests or Fisher exact test was used for comparing differences in categorical variables. P-values less than 0.05 were considered significant.

The decision to pursue bone biopsy was based on individual surgeon judgement. Jansson criteria[13] and the Bristol criteria[11] (Table 1) were both applied retrospectively to evaluate if their respective scores would have aided in confirmation of a CRMO diagnosis before bone biopsy and how they differ.

Results

There were 52 female and 28 male patients with CRMO (ratio 1.85:1) (Table 2). The mean ± SD age of the patients at time of data collection was 15.15 ± 4.57 years (range 3.5 – 25.6). The mean ± SD age of symptom onset was 9.76 ± 3.66 years (range 2.0 – 16.8). Patients were diagnosed 6.21 ± 9.75 months (range 0 – 50) after symptom onset. The follow-up time was 37.13 ± 27.67 months (range 1 – 117). Forty-six percent of patients had a close family history of autoimmune disease.

Table 1. Jansson and Bristol Criteria for the Diagnosis of CRMO

<table>
<tr><th colspan="2">Jansson Criteria</th><th colspan="2">Bristol Criteria</th></tr>
<tr><th>Major Criteria</th><th>Minor Criteria</th><th>Required Criteria</th><th>Plus, One Criterion</th></tr>
<tr><td rowspan="2">1. Radiologically proven osteolytic/-sclerotic bone lesion

2. Multifocal bone lesions

3. PPP or psoriasis

4. Sterile bone biopsy with signs of inflammation and/or fibrosis, sclerosis</td><td rowspan="2">A. Normal blood count and good general state of health
B. CRP and ESR mild-to-moderately elevated
C. Observation time >6 months
D. Hyperostosis
E. Associated with other autoimmune diseases apart from PPP or psoriasis
F. Grade I or II relatives with autoimmune or autoinflammatory disease</td><td>Typical clinical findings: bone pain ± localized swelling without significant local or systemic features of inflammation or infection</td><td>Criterion 1: >1 bone (or clavicle alone*) without significantly raised CRP (<30 mg/L)</td></tr>
<tr><td>Typical radiological findings: Plain x-ray (lytic areas, sclerosis, and new bone formation) or STIR MRI (bone marrow edema ± bone expansion; lytic areas, periosteal reaction)</td><td>Criterion 2: If unifocal disease (other than clavicle), or CRP >30 mg/L: bone biopsy showing inflammatory changes with no bacterial growth while not on antibiotic therapy</td></tr>
<tr><td colspan="2">Diagnostic Threshold: 2 major or 1 major + 3 minor criteria. Diagnosis not possible with major criteria #3 + minor criteria A, B, and C alone</td><td colspan="2">Diagnostic Threshold: Both required criteria, plus either criterion 1 or criterion 2</td></tr>
</table>

**Even though the clavicle is a typical site of involvement, the findings may also be due to malignancy, so caution should be taken in these patients. PPP = Palmoplantar pustulosis; CRP = c-reactive protein; ESR = erythrocyte sediment rate; STIR MRI = short tau inversion recovery magnetic resonance imaging.*

Antalgic gait (45%), localized inflammation (30%), fever/fatigue (26.25%), nocturnal bone pain (13%), and arthritis (8.75%) were common presenting symptoms. Fifty-eight percent of patients presented with a single painful osseous location, and 42% had multiple painful localizations. The median number of painful localizations was 1 (range 1 – 6). Dermatologic manifestations were present in 37.5% of patients. Fifty-four percent experienced a recurrence of symptoms after a median of 13 (5 – 28) months. Fifty-three percent were referred to a rheumatologist after a bone biopsy was performed, 23% before their biopsy occurred, and 23% were referred without ever receiving a biopsy.

At last follow-up, 45% of patients achieved clinical remission. These patients had a median length of symptoms of 1.68 (0.72 – 3.05) years. Of the total cohort, 74% of patients had residual symptoms, including recurrent pain (48%), vertebral flattening/height loss (4%), bone deformity (2.5%), and immobility (2.5%).

At diagnosis, 44% had an elevated CRP and 50% of patients had an elevated ESR (Table 3). The hemoglobin concentration was decreased[15] in 14% of patients, and the white blood count was elevated (>12.0 × 10^9 WBC/L) in only 6% of patients. Thirty percent of patients had blood cultures drawn upon initial presentation, which were all negative. A bone biopsy was performed on 75% of patients, which revealed normal tissue in 37% of samples, chronic inflammation with lymphocytic infiltrate (43%), bone marrow fibrosis (28%), bone remodeling (18%), and osteosclerosis (3%).

Plain radiographs were initially ordered in 74 patients, which were normal in 35% or revealed periosteal reaction/sclerosis (23%) or a lytic lesion (22%). Seventy-nine patients received an MRI and 55 received

Table 2. Demographics, Clinical, and Outcome Data of Patients with CRMO (n=80)

Variables	Values
Demographics	
Sex, F:M (ratio)	52:28 (1.86:1)
Mean age, years, mean ± SD (range)	15.15 ± 4.57 (3.5 - 25.6)
Age at onset, years, mean ± SD (range)	9.764 ± 3.66 (2.0 - 16.8)
Age at diagnosis, years, mean ± SD (range)	10.28 ± 3.52 (2.0 - 16.9)
Follow-up, months, mean ± SD (range)	37.13 ± 27.67 (1 - 117)
Delay in diagnosis, months, mean ± SD (range)	6.21 ± 9.75 (0 - 50)
Ethnicity	
White	46 (57.5%)
Hispanic	15 (18.75%)
Black	12 (15%)
Asian	5 (6.25%)
Native American	1 (1.25%)
Medical History of Autoimmune Disease	8 (10%)
Family History of Autoimmune Disease	37 (46%)
Dermatologic Symptoms	
Other	12 (15%)
Psoriasis	10 (12.5%)
Eczema	6 (7.5%)
Palmoplantar pustulosis	2 (2.5%)
Symptoms	
Antalgic gait	36 (45%)
Local inflammation	24 (30%)
Fever/Fatigue	21 (26.25%)
Nocturnal pain	11 (13.75%)
Arthritis	7 (8.75%)
Clinical Course	
Clinical localizations per patient, median (IQR)	1 (1 - 2)
Clinically unifocal	46 (57.5%)
Recurrence	43 (53.75%)
Time from diagnosis to first recurrence, months, median (IQR)	13 (5 - 28)
Rheumatology Referral	
None	2 (2.5%)
Before biopsy	18 (22.5%)
After biopsy	42 (52.5%)
Without biopsy	18 (22.5%)
Remission	
Clinical remission*	36 (45%)
Length of symptoms, years, median (IQR)	1.68 (0.72 - 3.05)
Subsequently diagnosed with additional condition	6 (7.5%)

**Absence of pain/swelling, no biochemical inflammation, and no active lesions on MRI for >6 months. CRMO = chronic recurrent multifocal osteomyelitis; TNF = tumor necrosis factor; NSAID = non-steroidal anti-inflammatory drug; MRI = Magnetic Resonance Imaging.*

Table 3. Imaging and Laboratory Data (n = 80)*

Variables	Values
Plain Films †	
Normal	26 (35.14%)
Periosteal reaction/sclerosis	17 (22.97%)
Lytic lesion	16 (21.62%)
Mixed findings (Osteolysis and hyperostosis)	9 (12.16%)
Abnormal structure (dysplasia, scoliosis, ruptured disc)	5 (6.76%)
Hyperostosis	2 (2.7%)
MRI	
Received MRI	79 (98.75%)
Received Whole-Body MRI	55 (69.62%) ‡
Received bone scintigraphy	25 (31.25%)
Received PET-CT	4 (5%)
Bones involved on imaging at diagnosis, median (IQR)	3 (1 - 5)
Bones involved on imaging at last follow up, median (IQR)	1 (0.75 - 3) §
Symmetric lesions	33 (44.59%)
Unifocal	15 (18.75%)
Progressed to multifocal	4 (26.67%) ¶
Findings at Diagnosis ‡	
Marrow edema	57 (72.15%)
Periosteal reaction	18 (22.78%)
Osteitis	15 (18.99%)
Soft tissue involvement	14 (17.72%)
Hyperostosis	6 (7.59%)
Lytic lesion	5 (6.33%)
Sclerosis	4 (5.06%)
Labs	
Hgb at diagnosis, g/dL, median (IQR)	12.3 (11.8 - 12.9)
WBC at diagnosis, WBC/µL, mean ± SD	8.48 ± 2
CRP at diagnosis, mg/L, median (IQR)	8.8 (1.55 - 15.6)
ESR at diagnosis, mm/hr, median (IQR)	21 (9 - 38)
CRP at last follow up, mg/L, median (IQR)	0.5 (0.5 - 3.85) §
ESR at last follow up, mm/hr, median (IQR)	7 (2 - 14) §
HLA +	6 (23.08%) #
ANA +	9 (40.91%) **
Received Bone Biopsy	60 (75%)
Normal	22 (36.67%) ††
Inflammation	28 (46.67%) ††
Fibrosis	10 (16.67%) ††

**Unless specified, values represent the number (%) of patients; MRI = Magnetic Resonance Imaging; PET-CT = Positron Emission Tomography-Computed Tomography; CRP = C-reactive Protein; ESR = Erythrocyte Sediment Rate; Hgb = Hemoglobin; WBC = White Blood Count; HLA = Human Leukocyte Antigen; ANA = Antinuclear Antibody; † n = 74; ‡ n = 79; § P < 0.001 by Wilcoxon signed rank test; ¶ n = 15; ** n = 22; †† n = 60; # n = 26.*

a whole-body MRI. Multifocal disease was present in 81% and symmetric lesions in 45% of patients for a median of three bones (IQR 1 – 5) affected per patient. The distribution of lesions (Figure 1) included both the appendicular and axial skeleton. Pelvic and vertebral involvement occurred in >30% of patients, and femoral or tibia lesions affected almost half of the patients each.

The most common findings on MRI were marrow edema (72% of patients) followed by periosteal reaction (23%) and osteitis (specifically cortical inflammation) in 19% of patients. By the last follow-up, 39 patients (49%) had shown improvement in lesion progression on imaging, 20 of whom achieved complete resolution of lesions.

After the initial workup, 141 differentials were collected from the assessment portion of the patient's HPI (Table 4). The most common differentials were infection (34% of reported differentials), consisting of "infection" broadly (14.89%) followed by osteomyelitis (12%) and synovitis (6%). Neoplasm accounted for 21% of differentials, with 14% of total differentials being "Neoplasm/Malignancy." Eleven percent of differentials included CRMO, most often after MRI characterization.

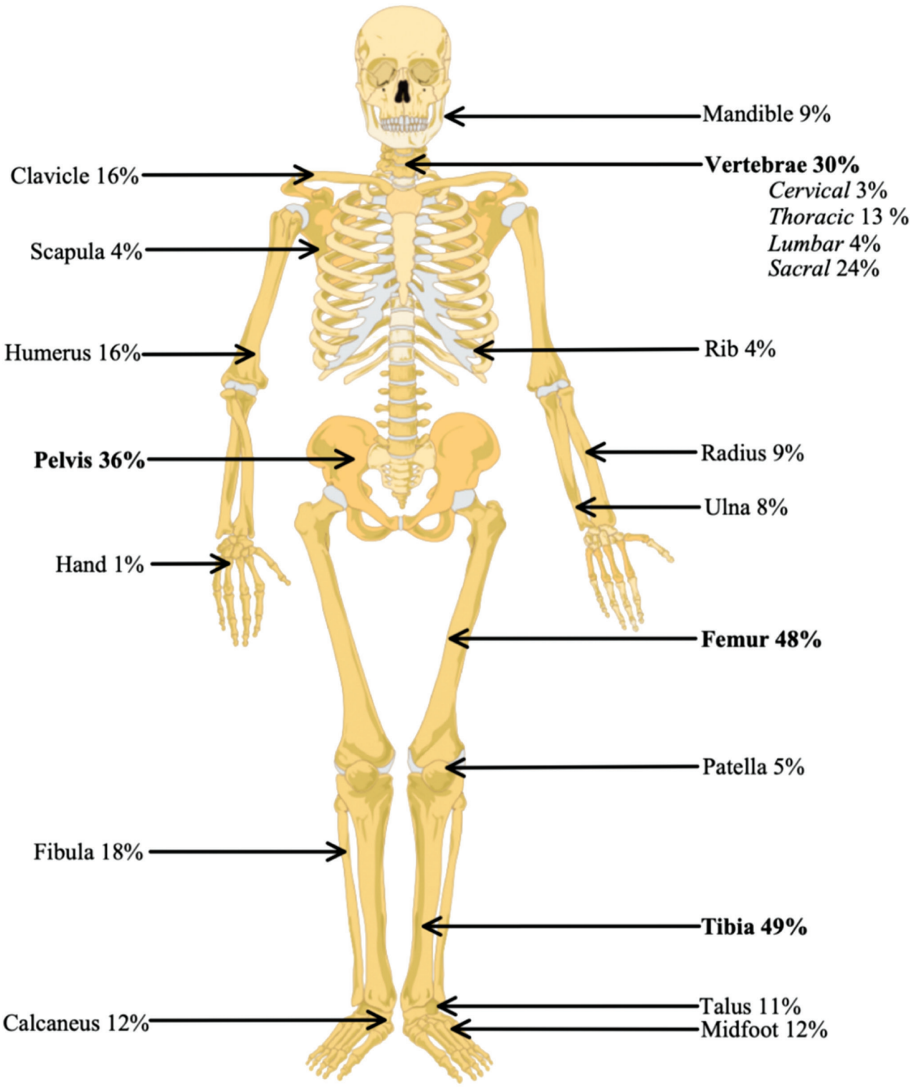

Figure 1. *Frequency of bone lesions in patients. n = 80. Bolded sites are present in >30% of patients.*

Table 4. Surgeon Differential of Patients with CRMO (n = 141)

Differential	Count (%)
Neoplasm/Malignancy	20 (14)
Osteosarcoma	4 (2.8)
Langerhans	3 (2.1)
Osteoid osteoma	2 (1.4)
Osteoblastoma	1 (0.7)
Ewing Sarcoma	1 (0.7)
Cartilage tumor	1 (0.7)
Infection	21 (14.9)
Brodie's abscess	2 (1.4)
Synovitis	6 (4.3)
Septic joint/arthritis	2 (1.4)
Osteomyelitis	17 (12)
Abscess	1 (0.7)
Cyst	1 (0.7)
Parotitis	1 (0.7)
Inflammation	
CRMO	16 (11.3)
Crohn's Disease	2 (1.4)
Vasculitis/Vascular malformation	2 (1.4)
Dermatomyositis	1 (0.7)
Reactive arthritis	1 (0.7)
JIA	1 (0.7)
Neurologic	1 (0.7)
Other	
Fracture/Trauma	9 (6.4)
Imbalance/Strain/Overuse/Tendinitis/ Sprain	13 (9.2)
Growing pains	1 (0.7)
Osteochondral defect	1 (0.7)
Osgood-Schlatter	1 (0.7)
Perthes	1 (0.7)
SCFE	1 (0.7)
Van-Neck Disease	1 (0.7)
Unsure	1 (0.7)

CRMO = Chronic Recurrent Multifocal Osteomyelitis; JIA = Juvenile Idiopathic Arthritis; SCFE = Slipped Capital Femoral Epiphysis.

Other benign differentials like fractures, muscular imbalances, sprains, growing pain, etc., were included 20% of the time.

The Jansson criteria was overall more sensitive than the Bristol criteria for diagnosing CRMO (85% vs. 58.75%, OR 3.94 CI 1.77-9.30 $P < 0.001$ by Fisher exact test). The Jansson criteria also identified a greater proportion of patients who had positive criteria but still received a bone biopsy (80% vs. 55%, OR 3.24, CI 1.36-8.09).

Discussion

We report the findings of 80 patients from a single institution over a span of 10 years who were initially evaluated by pediatric orthopaedic surgeons and subsequently diagnosed with CRMO. Our cohort was similar to prior studies, with a ~2:1 female/ ratio, symptom onset about 10 years of age, and family history of autoimmune disease of 46%.[4,5,9,11,12] Only 10% of the patients had a comorbid autoimmune and/or inflammatory condition which was much lower than previous reports of approximately 33%.[5,13] This may be due to the demographic heterogeneity of our population, as most studies were of European patient populations and ours had a greater distribution of Hispanic and other non-European ethnicities. This is further evidenced by a Chilean study by Concha et al. where none of their patients had concurrent inflammatory disease.[16]

CRMO is a painful condition with a highly variable presentation that often requires a thorough evaluation to exclude infectious osteomyelitis, Langerhans cell histiocytosis, osteosarcoma, neuroblastoma metastasis, fibrous dysplasia, etc.[3,6,7] In this study, 21% of differential diagnoses were related to neoplasia, which demonstrates how CRMO may present like aggressive or malignant tumors. Osteosarcomas are the most common primary bone malignancy among adolescents and present in the metaphyseal distal femur, proximal tibia, or proximal humerus with a mixed lytic and osteoblastic radiographic lesion.[17] Langerhans cell histiocytosis can also present with single or multiple osteolytic

bone lesions as well, but spinal lesions are located in the cervical vertebrae unlike CRMO.[18] In cases where radiographic findings mimic malignancy, like with unifocal CRMO lesions, bone biopsy is essential for definitive diagnosis. Furthermore, deferral of a thorough diagnostic workup in cases where the main differential diagnosis is a benign etiology (such as muscular strain, Osgood-Schlatter, etc.) may also account for the lengthy period between symptom onset and diagnosis. This highlights the importance of correlating clinical evaluation with prompt imaging and multidisciplinary collaboration.[3,8,14,19]

Because plain radiographs were frequently unremarkable, diagnosis was often delayed. MRI typically generates a T1 hypointensity or T2 hyperintensity reflecting marrow edema. Gadolinium enhancement and MRI sequences with fat suppression techniques like short tau inversion recovery (STIR) can be used to provide a better view of the lesion and study surrounding tissues, which may help rule out malignancy and osteomyelitis.[8,20] However, WB-MRI,[21] is the most sensitive exam for detecting multifocal lesions and simultaneously characterizing them.[22,23] In our study, most patients were clinically unifocal, but extensive imaging revealed a median of three lesions per patient. Other common modalities included PET-CT and ^{99m}Tc bone scintigraphy which may be obtained for patients and hospitals with limited resources; however, these modalities expose patients to high amounts of radiation.

In this study, the highest distribution of lesions were found in the tibia, femur, pelvis, or spine. This was similar to prior reports that highlighted the tibia as the most common site of involvement.[2,8,12,14,20] Our cohort also demonstrated multifocal involvement in 81% of patients, similar to studies by Andronikou et al. (89%),[8] Wipff et al. (70%),[4] and Roderick et al. (76%).[11] We also reported a median of 3 lesions per patient, which is equal to Walsh et al.[12] and Jansson et al.[13] and slightly less than Wipff et al. (3.5)[4] and Borzutzky et al. (3.5).[5] Symmetrical lesions are common in patients with multifocal involvement and can aid in diagnosis when present.[9] Symmetrical lesions were lower compared to Fritz (44% vs. 85%)[20] and greater than Roderick (12%)[11] though their sample sizes were 13 and 41, respectively. While the distribution of lesions remains consistent in literature, different frequencies of multifocality and lesions per patient may be due to population differences or variation in the number of patients who received WB-MRI.

The clavicle and spine are classic locations for lesions in CRMO.[8] Nine percent of our cohort had clavicular lesions which was relatively low compared to previous studies, which reported involvement in 5-38% of patients.[5,8,11,14] The clavicle is an unusual location for infectious osteomyelitis and is therefore very specific for inflammatory lesions, such that unifocal clavicular lesions are considered positive Bristol criteria.[11]

Spinal lesions were present in 30% of our patients, which was one of the highest proportions reported.[3,4,11,13,14] Prior studies reported thoracic involvement as the most frequent,[3,24] but our cohort's highest frequency was of the sacral spine. Regardless, our report was still similar to Hospach et al. (19%),[24] suggesting that thoracic lesions may be underrepresented due to asymptomatic involvement and proportionally less patients receiving dedicated spine imaging compared to pelvis or hip imaging. Furthermore, two patients in this study presented with scoliosis, and two patients had a vertebral compression fracture. Hospach reported two of the eight patients with asymptomatic spinal lesions also had vertebral deformity.[24] Because vertebral compression fractures are the most common pathological fracture in CRMO and treatment does not reverse height loss,[3,24] early detection is imperative to prevent deformity.

We found the Jansson criteria was significantly more sensitive in detecting patients with CRMO. Although bone biopsy was often necessary for ruling out other diagnoses, in retrospect, some patients could have avoided this invasive procedure. After excluding the portions that require biopsy data, we found that of the 60 patients who received a bone biopsy, 55% of patients with the Bristol criteria and 80% of patients with the Jansson criteria, could have avoided the procedure. These

results may suggest a superiority of the Jansson criteria and indicate use in practice to avoid bone biopsy in select patients.

Our study is not without limitations. It was performed at a single large tertiary children's hospital, as more severe cases or trends specific to our region may be overrepresented. As a retrospective study, it is limited to reporting outcomes and characteristics only available in patient charts. Not every patient received a whole-body MRI, so asymptomatic lesions might have been missed in some patients. Ideally, large multi-institutional retrospective cohorts or prospective studies with randomized imaging protocols would be performed to distinguish management differences.

Despite these limitations, our data aligns well with prior reports worldwide. It has a large cohort that reflects the demographic distribution of the United States, whereas most reports are European or have homogenous populations. Our sample also had a mean follow up around 3 years, which indicates the validity of our results and ensures against misdiagnoses.

Variable presentation and imaging create a unique challenge for orthopaedic surgeons and other clinicians managing these patients prior to diagnosis of CRMO. Our results highlight the importance of ordering WB-MRI to uncover multifocal lesions early in the disease process due to the various differential diagnoses presented by evaluating clinicians. In conjunction with clinical reasoning, the Jansson criteria may be useful to diagnose CRMO and perhaps avoid an unnecessary biopsy. Further studies are necessary to validate these criteria, further characterize CRMO patients, and develop standardized management protocol.

Additional Links

- POSNA Study Guide: CRMO (Chronic Recurrent Multifocal Osteomyelitis)
- POSNAcademy: Think Tumour? Think Infection? Think CRMO . . ., Deborah M. Eastwood, MD

Disclaimer

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