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Research Article

ACR Bone-Rads in MRI: Decoding Benign to Aggressive Bone Tumours

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ABSTRACT

Background: Magnetic resonance imaging (MRI) evaluation of bone tumors can be challenging because of the wide spectrum of benign, indeterminate, and malignant lesions with overlapping imaging appearances. The American College of Radiology (ACR) Bone Reporting and Data System (Bone-RADS) provides a standardized framework for characterization and management of bone lesions.
Purpose: To demonstrate the application of ACR Bone-RADS in MRI evaluation of bone tumors through a pictorial case series and to highlight its role in guiding diagnosis and management.
Materials and Methods: This retrospective descriptive study was conducted in the Department of Radiodiagnosis, Belagavi Institute of Medical Sciences, Belagavi. Twenty MRI-evaluated bone lesions studied between March and July were categorized according to the ACR MRI Bone-RADS classification system based on lesion signal characteristics, morphology, enhancement pattern, and ancillary imaging features.
Results: Of the 20 lesions evaluated, the majority were benign (Bone-RADS 1 and 2), including osteochondroma, non-ossifying fibroma, simple bone cyst, aneurysmal bone cyst, and fibrous dysplasia. Two lesions were categorized as Bone-RADS 3 due to indeterminate imaging features requiring short-interval follow-up. Six lesions were classified as Bone-RADS 4 and demonstrated aggressive characteristics such as cortical destruction, soft tissue extension, periosteal reaction, and pathological fracture. These included osteosarcoma, giant cell tumor, multiple myeloma, and complicated simple bone cysts. Bone-RADS classification improved lesion stratification and aided appropriate management recommendations.
Conclusion: ACR Bone-RADS is a valuable MRI-based standardized reporting system for characterization of bone lesions. It improves consistency in reporting, enhances diagnostic confidence, facilitates multidisciplinary communication, and assists in differentiating benign, indeterminate, and aggressive bone tumors, thereby supporting optimal patient management.

Keywords*: ACR Bone-RADS; Bone lesions; Bone tumors; Magnetic resonance imaging; MRI; Musculoskeletal imaging; Structured reporting; Pictorial essay.*

INTRODUCTION

Bone lesions are more frequently detected with the increasing number of radiological examinations. However, the diagnosis of bone lesions can be difficult due to the broad spectrum of differential diagnoses and overlapping imaging features [1–5,10]. Focal bone lesions may be related to benign or malignant tumors, metabolic or infectious disorders, degenerative changes, and tumor-like conditions [4,5,10,20]. Thus, an accurate differentiation between benign and potentially malignant lesions is crucial to avoid underestimation of disease or overtreatment of benign lesions and to address critical aspects of patient management, such as determining if the lesion can be monitored over time or if the patient should be referred to a specialized oncology center [1,19].

There is a need for multidisciplinary communication on bone lesions, and consensus regarding systematic and standardized approaches for bone lesion evaluation is desirable [1,19]. The clinical presentations of bone tumors are usually nonspecific,

such as pain, discomfort, and palpable mass [5,8]. Radiologists, pathologists, and clinicians should collaborate to reach an accurate diagnosis for appropriate treatment selection [2,5,20].

Following the success of the Breast Imaging Reporting and Data System (BI-RADS), a series of RADS classification systems have been proposed, including systems for colon, liver, lung, head and neck, ovarian-adnexal, prostate, and thyroid imaging [1]. RADS systems facilitate structured reporting and standardized communication, thereby enhancing collaboration among healthcare professionals from different specialties [1,19]. Currently, several RADS classifications for bone lesions have been proposed. The Radiological Evaluation Score for Bone Tumors (REST) on radiography was developed using cohorts of patients with primary bone tumors. Subsequently, Bone-RADS on radiography for tumor risk stratification and management was established through expert consensus by the Committee of the American College of Radiology (ACR) [1].

The Bone Tumor Imaging Reporting and Data System (BTI-RADS) was later developed using histologically confirmed bone tumors, although it required both CT and MRI evaluation [3,10]. The Society of Skeletal Radiology (SSR) Bone-RADS system for CT and MRI includes four diagnostic algorithms for CT lucent lesions, CT sclerotic/mixed lesions, MRI T1 hyperintense lesions, and MRI T1 hypointense lesions, respectively [1]. Bone-RADS is presented in a decision-tree approach to simplify interpretation and management recommendations, primarily relying on lesion imaging characteristics [1,3].

MRI evaluation of bone tumors remains challenging because of overlapping appearances between benign, indeterminate, and aggressive lesions [2,3,11,18]. Bone-RADS provides a standardized scoring system that helps classify lesions as benign, indeterminate, or aggressive based on imaging morphology, signal characteristics, enhancement patterns, and ancillary imaging features [1,3,19]. Such a structured approach may improve diagnostic confidence, reduce variability in reporting, and guide appropriate patient management [1,18,19].

OBJECTIVES

- To demonstrate Bone-RADS application in MRI.
- To present a pictorial case series.
- To highlight the role of Bone-RADS in guiding management decisions.

MATERIALS & METHODS

- **Study design:** Retrospective descriptive study.
- **Place of study:** Department of Radiodiagnosis, BIMS Belagavi.
- **Sample size**: 20 MRI-evaluated bone lesions (March to July).
- Categorized using MRI ACR BONE-RADS classification.
- Classification was based on signal characteristics, morphology, enhancement pattern, and ancillary imaging features.

Table 1: ACR Bone-RADS Classification Categories, Imaging Interpretation, and Recommended Management

Bone-RADS Category	Description	Recommendation
Bone-RADS I	Definitely benign	No further imaging
Bone-RADS II	Likely benign, other imaging is required	other imaging modalities correlation
Bone-RADS III	Indeterminate	Short-interval follow-up
Bone-RADS IV	Suspicious for malignancy	Urgent orthopedic oncology referral

Table 2: Demographic Profile, Bone-RADS Classification and diagnosis of Bone Lesions Evaluated on MRI.

S.No	Age	Sex	Bone-RADS	Diagnosis
1	22	Male	4	GCT
2	9	Female	4	Osteosarcoma
3	59	Male	4	Osteosarcoma
4	12	Male	1	NOF
5	26	Female	2	Chondromyxoid fibroma
6	11	Female	2	SBC
7	40	Male	2	SBC
8	25	Male	4	SBC

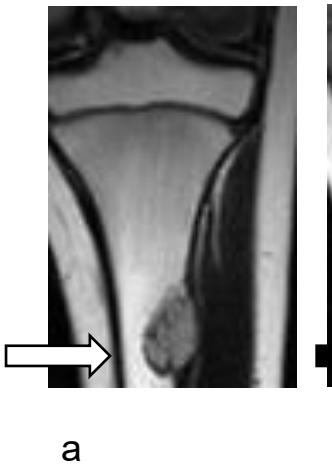
9	12	Male	2	SBC
10	14	Male	2	SBC
11	27	Male	2	ABC
12	15	Female	1	Osteochondroma
13	16	Male	1	Osteochondroma
14	12	Male	1	Osteochondroma
15	37	Male	1	Osteochondroma
16	32	Male	3	Fibrous dysplasia
17	38	Female	2	Fibrous dysplasia
18	21	Male	3	Fibrous dysplasia
19	50	Male	4	GCT
20	48	Female	4	Multiple myeloma

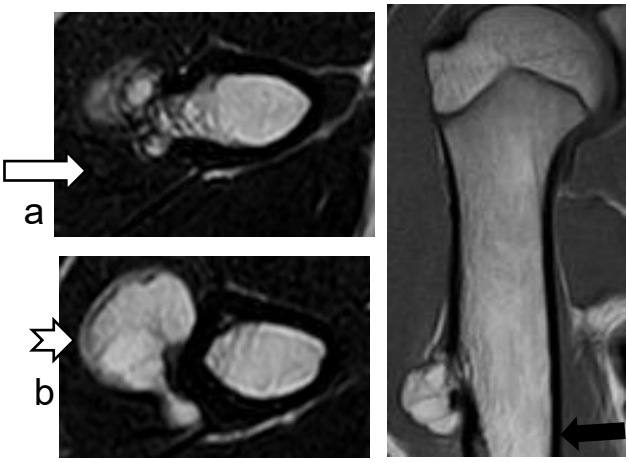
PICTORIAL PRESENTATION OF CASES
BONE RADS 1

Total 5 cases of bone rads 1 were there out of which 2 cases are shown below as representation images.

Case 1:
A 12 year old male patient with complaints of pain in the knee, ccoronal MRI images demonstrating a well-defined eccentric cortically based metaphyseal lesion in the proximal tibia, showing a narrow zone of transition and lobulated margins. The lesion appears isointense on T1-weighted images with peripheral T2 hypointense sclerosis and no associated cortical breach, periosteal reaction, soft tissue component, or surrounding marrow edema (arrows). Imaging findings are characteristic of non-ossifying fibroma (NOF), a benign fibrous cortical lesion, categorized as Bone-RADS 1.

Case 2:
A 16 year old male patient Coronal T1-weighted and fluid-sensitive sequences show well-defined exophytic osseous lesions with continuity of the cortex and medullary cavity with the parent bone. The lesiondemonstrate a cartilage cap appearing hyperintense on T2-weighted images. No associated cortical destruction, marrow edema, soft tissue mass, or aggressive periosteal reaction is seen. Imaging features are characteristic of benign osteochondroma (Bone-RADS 1)





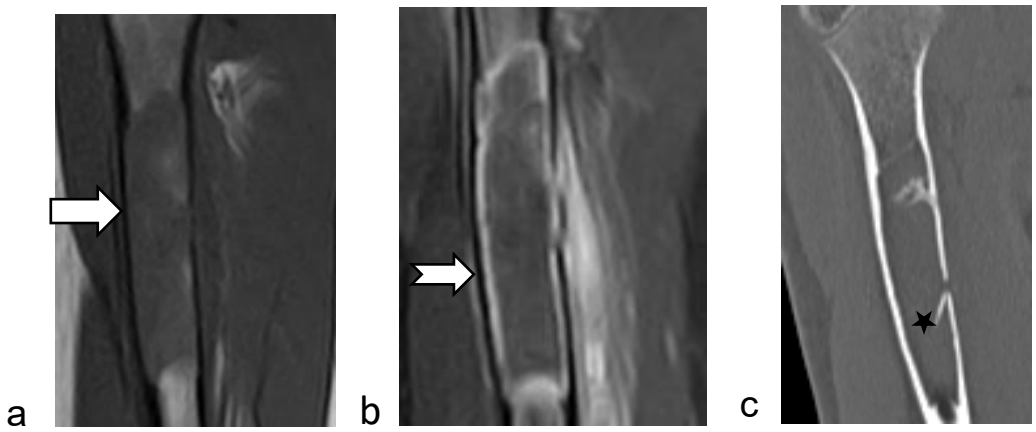
Case 1: NOF in 12 year old male patient with well defined eccentric lesion **a)**T1 iso to hyperintense (open arrow) and**b)** T2 hyperintense lesion (block arrow).

Case 2: Osteochondroma in 16 year old male patient with focal bony outgrowth appearing **a)&c)**T1/ T2 iso to hyperintense (open& closed arrow) and **b)** T2 hyperintense cartilage cap (notched arrow).

BONE RADS 2

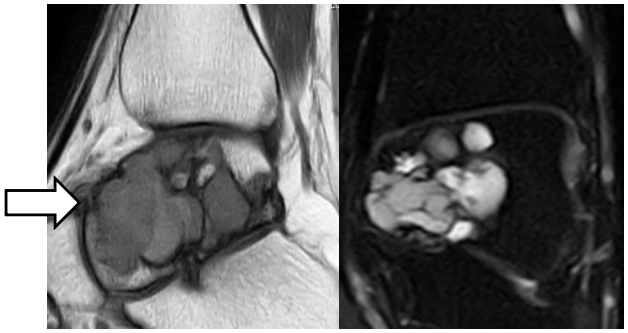
CASE 3:
Coronal MRI and CT images demonstrating a well-defined expansile intramedullary cystic lesion involving the proximal humeral shaft (arrows). The lesion shows fluid signal intensity with cortical thinning and mild osseous expansion without cortical destruction, aggressive periosteal reaction, or soft tissue component. CT image demonstrates a dependent cortical

fragment within the cystic cavity (star), representing the classic "fallen fragment sign," characteristic of a simple bone cyst. Imaging findings are consistent with simple bone cyst (SBC) (Bone-RADS 2).



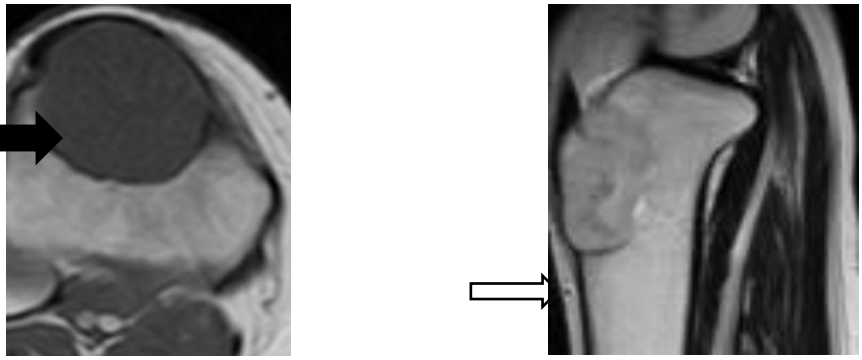
CASE 3 :Simple bone cyst in 12 year old male patient with **a)**T1 hypointense with peripheral hyperintense rim (open arrow) **b)**T1C+ non enhancing hyperintense (notched arrow) **c)** CT shows fallen fragment sign (black star).

CASE 4 :
MRI images of the talus in a 27-year-old male demonstrating a multiloculated expansile lesion consistent with aneurysmal bone cyst. The lesion appears hyperintense on (a) T1-weighted images (block arrow) and markedly hyperintense on (b) T2-weighted images with internal fluid-fluid levels/T2 shading (open arrow). Associated cortical expansion and thinning are noted without significant soft tissue component. Imaging findings are characteristic of aneurysmal bone cyst (ABC) (Bone-RADS 2).



Case 4 :Aneurysmal bone cyst of talus in 27 year old male patient with multiloculated **a)**T1 hyperintense (block arrow) and **b)** T2 hyperintense lesion with T2 shading (open arrow).

CASE 5 : MRI images of the proximal tibia in a 26-year-old female demonstrating a well-defined eccentric metaphyseal lesion consistent with chondromyxoid fibroma. The lesion appears iso- to hypointense on (a) T1-weighted images (open arrow) and markedly hyperintense on (b) T2-weighted images (block arrow), with associated cortical thinning and mild expansile remodelling. No aggressive periosteal reaction or soft tissue component is identified. Imaging findings are characteristic of chondromyxoid fibroma.

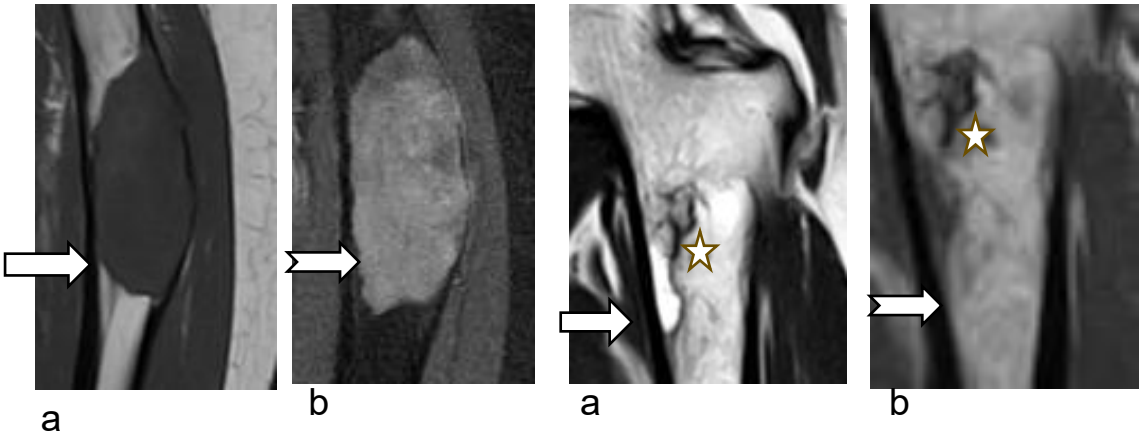


Case 5: Chondromyxoid fibroma of tibia in 26 year old female patient with **a)**T1 iso to hypointense (open arrow) and **b)** T2 hyperintense lesion (block arrow).

BONE RADS 3

CASE 6: Coronal MRI images of 21year old male patient demonstrating a well-defined expansile intramedullary lesion involving the proximal femur. The lesion appears isointense on T1-weighted images and heterogeneously enhancing on T1 post contrast images s with cortical thinning and mild osseous expansion. No cortical destruction, periosteal reaction, or associated soft tissue component is identified. Imaging findings are consistent with fibrous dysplasia. BONE RADS 3.

CASE 7: RI images of the involved bone in a 32-year-old male demonstrating fibrous dysplasia with secondary cystic changes. Coronal T2-weighted and T1-weighted images show hyperintense cystic components on T2-weighted imaging with corresponding hypo intensity on T1-weighted images. Associated T1/T2 hypointense sclerotic areas are also noted. Mild expansile remodelling is present without cortical destruction or soft tissue extension. Imaging findings are consistent with fibrous dysplasia with secondary cystic degeneration. BONE RADS 3.

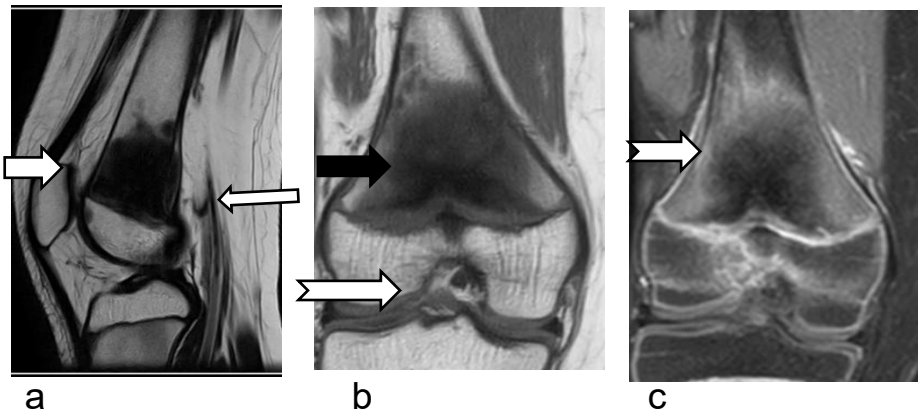


CASE 6: Fibrous dysplasia in 21 year old male patient with a) T1iso intense (open arrow) b) T1C+ heterogeneously enhancing (notched arrow).

Case 7: Fibrous dysplasia with secondary changes in 32year old male patient with a)T2 & b)T1W coronal view shows T2 hyperintense (open arrow) & T1 hypointense (notched arrow) cystic components and T1/T2 hypointense sclerotic area (star).

BONE RADS 4

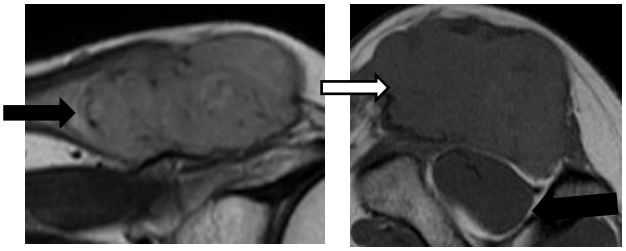
CASE 8 : MRI images of the right distal femur in a 9-year-old female demonstrating features of osteosarcoma.Coronal T2-weighted and T1-weighted images show a heterogeneous intramedullary lesion with predominantly T2/T1 hypointense matrix mineralization (open and block arrows) and associated aggressive periosteal elevation (long arrow). T1-weighted images also demonstrate hypointense tumor extension across the physis into the epiphysis (notched arrow). Post-contrast T1-weighted fat-suppressed image reveals central non-enhancing hypointense necrotic/calcified areas with peripheral heterogeneous enhancement (notched arrow). Imaging findings are consistent with conventional osteosarcoma. Diagnosis was confirmed on biopsy.



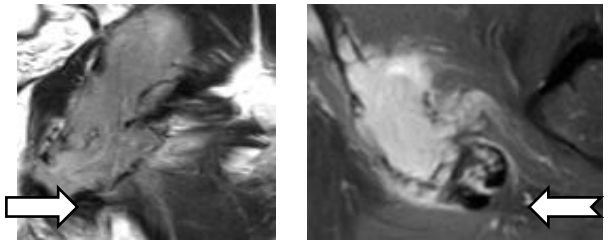
Case 8: Conventional Osteosarcoma in 9 yearold female patient with **a) &b)**T2/T1 hypointense (open & block arrow) and periosteal elevation (long arrow) , T1 hypointense focus extension to the epiphysis (notched arrow) **c)**T1C+ non enhancing central hypo intensity & peripheral enhancement (notched arrow).

CASE 9 : Multiple myeloma involving the left clavicle in a 48-year-old female patient demonstrates a lobulated marrow-replacing expansile lesion centred within the left clavicle. On MRI, the lesion appears isointense to skeletal muscle on T1-weighted images and heterogeneously hyperintense on T2-weighted images, reflecting high cellularity and increased water content. There is associated cortical destruction with extension into the adjacent soft tissues, indicating aggressive osseous involvement. The lesion exhibits aggressive features, including medullary expansion, cortical breach, and extraosseous soft tissue component. On biopsy it was confirmed as multiple myeloma.

CASE 10 : Giant cell tumour involving the left acetabulum in a 50-year-old male patient demonstrates an expansile osteolytic lesion centred in the periacetabular region with aggressive imaging characteristics. On MRI, the lesion appears heterogeneously hyperintense on T2-weighted imagesand shows avid post-contrast enhancement on T1-weighted contrast-enhanced sequences, reflecting its hypervascular solid nature. There is associated cortical destruction with extension into the adjacent soft tissues, indicative of locally aggressive behaviour. Giant cell tumours typically occur in skeletally mature individuals and characteristically demonstrate expansile eccentric lytic morphology with cortical thinning or breach. MRI is valuable in delineating marrow involvement, articular extension, cortical integrity, and extraosseous soft tissue components BONERADS 4. On biopsy the lesion was found to be giant cell tumour.

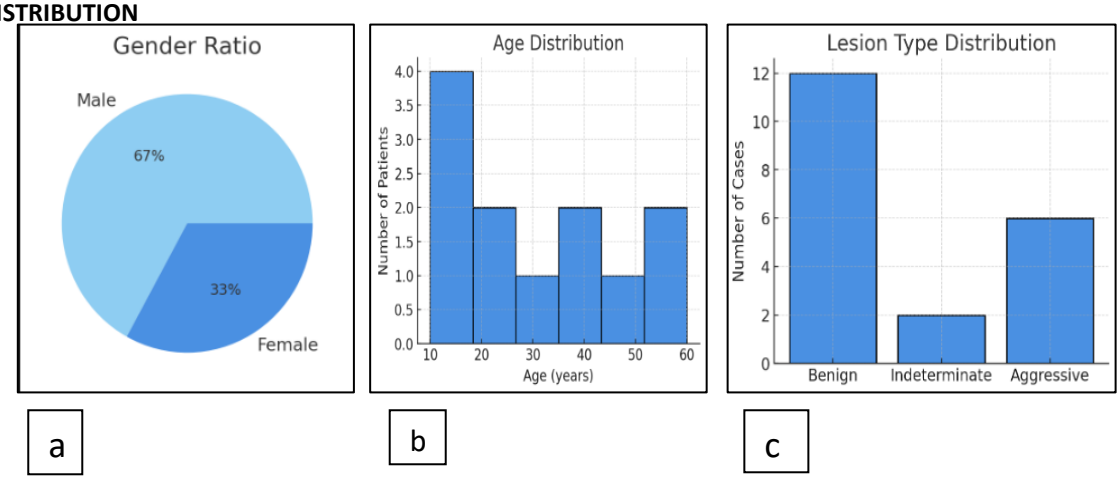


Case 9 :Multiple myeloma involving the left clavicle in 48 year old female patient with lobulated a)T1 isointense (block arrow) and b) T2 hyperintense lesion (open arrow) and shows extension to surrounding soft tissue and cortical destruction.



Case 10 : Giant cell tumour involving the left acetabulum in 50 year old male patient with a) T2 hyperintense (block arrow) and b) T1C+ enhancing lesion (open arrow) and shows extension to surrounding soft tissue and cortical destruction (notched arrow).

DISTRIBUTION



Figures a-c: Graphical representation of demographic and lesion distribution in the study population, demonstrating male predominance, majority of cases in younger age groups, and predominance of benign bone lesions over indeterminate and aggressive lesions.

RESULTS

A total of 20 bone lesions were evaluated using the ACR Bone-RADS classification system on MRI. The demographic analysis demonstrated a male predominance, accounting for 67% of cases, while females constituted 33% of the study population. The age distribution ranged from the first to sixth decades, with the majority of patients presenting in the second and third decades of life.

The lesion distribution revealed that benign lesions formed the largest category, comprising 12 cases. These included osteochondroma, non-ossifying fibroma, simple bone cyst, aneurysmal bone cyst, and fibrous dysplasia. Indeterminate lesions accounted for 2 cases and consisted of fibrous dysplasia lesions demonstrating heterogeneous post-contrast enhancement, warranting interval imaging follow-up. Aggressive lesions constituted 6 cases and included osteosarcoma, giant cell tumour with cortical destruction and soft tissue extension, simple bone cyst with pathological displaced fracture, and multiple myeloma.

The application of Bone-RADS enabled systematic lesion characterization and facilitated stratification into benign, indeterminate, and aggressive categories, thereby assisting in appropriate management recommendations and reducing diagnostic ambiguity.

DISCUSSION

The evaluation of bone lesions on MRI remains a diagnostic challenge because of the overlapping imaging features between benign, indeterminate, and malignant entities. The recently introduced American College of Radiology (ACR) Bone Reporting and Data System (Bone-RADS) provides a structured framework for characterization and management of incidental solitary bone lesions, thereby improving reporting uniformity and reducing variability among radiologists [1]. In the present study, Bone-RADS demonstrated practical utility in categorizing lesions into benign, indeterminate, and aggressive groups with corresponding management recommendations.

In our study, benign lesions constituted the majority of cases (60%). Common benign entities included osteochondroma, non-ossifying fibroma, simple bone cyst, aneurysmal bone cyst, and fibrous dysplasia. These lesions demonstrated characteristic MRI features such as well-defined margins, narrow zones of transition, absence of aggressive periosteal reaction, preserved cortical integrity, and lack of significant soft tissue extension. Similar findings have been extensively described in previous musculoskeletal imaging studies emphasizing that benign lesions typically exhibit non-aggressive imaging characteristics and geographic patterns of bone destruction [2,3]. The predominance of benign lesions in our study is also consistent with prior reports evaluating incidental bone lesions detected on MRI examinations [1,8].

Fibrous dysplasia represented both benign and indeterminate categories in our series. Although usually benign, fibrous dysplasia may occasionally demonstrate atypical imaging appearances including heterogeneous enhancement, cystic degeneration, haemorrhage, or secondary aneurysmal bone cyst formation, making differentiation from aggressive lesions challenging [4,9]. In our study, two cases with heterogeneous post-contrast enhancement were categorized as indeterminate and required interval imaging follow-up. This highlights the value of Bone-RADS in appropriately stratifying lesions that do not exhibit overt malignant features but cannot be confidently labelled benign.

Aggressive lesions accounted for 30% of the study population and included osteosarcoma, giant cell tumour with cortical destruction and soft tissue extension, pathological fracture associated with simple bone cyst, and multiple myeloma. MRI findings suggestive of aggressive behaviour included cortical breach, marrow replacement, periosteal reaction,

heterogeneous enhancement, surrounding marrow oedema, and soft tissue extension. These imaging features are recognized indicators of malignancy or locally aggressive behaviour in musculoskeletal radiology literature [5,10].

Osteosarcoma in our series demonstrated classical aggressive MRI features including marrow replacement, cortical destruction, periosteal reaction, and extraosseous soft tissue extension. MRI plays a crucial role in local staging, assessment of neurovascular involvement, and surgical planning in osteosarcoma [11]. Giant cell tumour showed expansile osteolytic morphology with cortical thinning, cortical breach, and soft tissue extension, findings which correlate with previous studies describing the locally aggressive behaviour of giant cell tumours despite their benign histology [6]. Similarly, multiple myeloma demonstrated infiltrative marrow lesions with cortical destruction and associated soft tissue components, which are characteristic MRI hallmarks of plasma cell neoplasms [7].

The use of MRI in conjunction with Bone-RADS provides several advantages in lesion characterization. MRI offers superior marrow contrast resolution and improved evaluation of soft tissue extension, internal matrix, neurovascular involvement, and pathological fractures compared with conventional radiography and CT [12]. Structured reporting systems such as Bone-RADS also improve communication between radiologists and referring clinicians, assist in risk stratification, and guide recommendations regarding follow-up imaging, biopsy, or oncologic referral [1]. Additionally, standardized reporting may improve diagnostic confidence and reduce interobserver variability, particularly among less experienced radiologists.

Previous studies have emphasized the importance of combining imaging morphology, enhancement characteristics, lesion margins, and clinical features in differentiating benign from malignant bone tumors [13,14]. Bone-RADS integrates these principles into a practical and reproducible framework for routine clinical use. Our findings support its utility in daily musculoskeletal MRI practice and demonstrate its applicability across a spectrum of benign, indeterminate, and aggressive lesions.

The present study has certain limitations. The sample size was relatively small, and histopathological confirmation was not available for all benign lesions. Some diagnoses relied on characteristic imaging findings and clinical follow-up. Additionally, this was a single-center observational study, which may limit generalizability. Larger multicentric studies with long-term follow-up are required to validate the reproducibility and diagnostic accuracy of Bone-RADS in diverse patient populations.

Overall, our findings support the usefulness of the ACR Bone-RADS system as an effective standardized MRI-based classification tool for bone lesions. Its application assists in differentiating benign from aggressive lesions, guides management decisions, reduces diagnostic ambiguity, and may contribute to improved patient care in musculoskeletal imaging practice.

CONCLUSION

The ACR Bone-RADS classification system provides a practical and standardized approach for the evaluation of bone lesions on MRI. In our study, Bone-RADS effectively differentiated benign, indeterminate, and aggressive lesions based on imaging characteristics, thereby aiding in appropriate risk stratification and management planning. Benign lesions constituted the majority of cases, while aggressive lesions demonstrated characteristic features such as cortical destruction, periosteal reaction, marrow replacement, and soft tissue extension. The structured reporting framework improved diagnostic confidence and facilitated clear communication between radiologists and clinicians. Overall, Bone-RADS serves as a valuable tool in musculoskeletal imaging practice by reducing diagnostic ambiguity, guiding follow-up recommendations, and assisting in timely identification of lesions requiring biopsy or oncologic referral. Further large-scale multicentric studies are recommended to validate its diagnostic accuracy and reproducibility.

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