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ORIGINAL ARTICLE

Systematic Imaging Evaluation and Reporting of Primary Bone Tumor using BTI-RADS

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ABSTRACT

Background: The goal is to identify the key imaging characteristics that distinguish benign from malignant primary bone tumors, as well as the effectiveness of the novel systemic approach (BTI-RADS) in bone tumor stratification and its function in facilitating radiologists' ability to clearly and consistently convey results to the referring physician.

Methods: A cross-sectional study that included 36 individuals were referred from the Orthopedics Department to the Radio Diagnosis Department Starting by the IRB approval number IRB number 9077 on November 2021 till December 2023 to analyze a primary focal bone lesion that had been tentatively diagnosed. All these patients underwent evaluation using X-ray, CT, and MRI.

Results: We applied our study on 36 patients (23 men and 13 women; age range, 10 - 70 years).

Conclusions: We found a good agreement between BTI-RADS and gold standard results (K=0.658). The value (P value <0.001) was highly significant. While there were 25% of false negative cases (BTI-RADS-diagnosed as benign lesions but histopathology showed them to be malignant) and 10% of false positive cases (BTI-RADS-diagnosed as malignant masses but histopathology showed them to be benign), BTI-RADS agreed with gold standard results in 90% of true malignant cases and 75% of true benign cases.

Keywords: Bone Tumors ;BTI-RADS;MRI

INTRODUCTION

The rarity of primary bone tumors has undoubtedly led to a lack of information regarding their relative incidence as well as a lack of knowledge regarding the risk factors. Overall, bone sarcomas make up 0.2% of all cancers. The 5-year overall survival rate is 67.9%, and the adjusted incidence rate for all bone and joint cancers is 0.9 per 100,000 people annually. Benign bone tumors are more common than original malignant tumors, but because they are frequently asymptomatic and not clinically identifiable, benign lesions are probably underreported. Furthermore, metastases from melanoma, carcinomas, or hematologic malignancies such plasmacytoma exceed primary bone tumors [1].

It can be difficult to characterize bone lesions with imaging. The differential diagnosis of focal bone lesions is extensive and includes tumor-like illnesses, metabolic abnormalities, degenerative alterations, and benign and malignant neoplasms. With a significant influence on prognosis and survival rates, it is critical to accurately distinguish between benign and malignant bone tumors for the best

possible patient care. When sarcoma patients receive treatment under the direction of a multidisciplinary committee, their relapse-free survival is noticeably higher [2].

Certain imaging characteristics of bone tumors have been thoroughly studied in the past, and a methodical approach to bone tumor assessment has been suggested. The patient's age and the tumor's location are the two most crucial factors in assessing a bone tumor. Without even examining any pictures, this information alone can be used to restrict the differential diagnosis [3].

The single right diagnosis will frequently result from the radiographic appearance, which should then aid in further narrowing the list. To diagnose bone tumors using radiography, the lesion must be analyzed methodically, paying close attention to several distinct radiographic characteristics [4].

Margin and zone of transition, periosteal reaction, mineralization, tumor location, lesion size and quantity, and the existence of a soft-tissue component are the characteristics that require evaluation [4].

MRI is the preferred modality for staging and evaluating post-treatment response. These features were first described in plain radiography and computed tomography (CT), but MRI is better than CT for assessing the extent of tumor in the medullary cavity and extra-osseous tumor volume, including relationship with surrounding neurovascular structures [5]

On the other hand, nothing is known about how to combine various imaging results, and which ones are most relevant for characterizing lesions. According to the theory put by BTIRADS (bone tumor imaging reporting and data system), a methodical multimodality analysis of focal bone lesions would enable the determination of the most appropriate criteria for the distinction between aggressive (malignant) and non-aggressive (benign) lesions, potentially affecting patient care [6].

Regardless of the reader's level of experience, we assess the reproductivity of the new classification system (BTI-RADS) in this study. It may assist standardize the assessment of bone tumors by classifying bone lesions into four groups with rising malignancy frequencies.

METHODS

Study design and patients

Thirty-six patients (23 men and 13 women, ages 10 to 70) who were sent from our institution's orthopedics department to the radiodiagnosis department were gathered for this study between November 2021 and December 2023. Ethical approval no. 9077 issued on November 2021

Patient inclusion criteria include patients with any age and any sex , and patients with focal bone lesions.

Patient exclusion criteria include patients who declined to participate in the research , individuals with osseous metastatic deposits and extra-skeletal original tumors , Pregnant females , patients have contraindications for MRI, those with implanted hearing aids, electronic devices, cardiac pacemakers, insulin pumps, and intracranial metal clips which are not eligible for MRIs and obese patients > 120Kg (MRI tables have specific weight limitations).

Patients were subjected to the following

A-Clinical assessment

1) Clinical history: including patients' name, age, sex, family history, complaints and history of bone pain, pathological fractures, and any palpable masses.
2) Clinical examination:

- General examination: For vital sign and body built.
- Patients assessed by our colleagues in the orthopedics department then redirected to the radiology unit.

B-Examining every prior imaging study that is accessible

X-ray The first imaging method used to assess patients experiencing bone discomfort is radiography.

All patients in this study underwent computed tomography (CT) exams, which were

performed using a 128 multidetector row CT scanner (PHILIPS ingenuity core 128 TM slice CT scanner) with the following settings: detector row configuration: 128 x 1 mm, 300 mAs, 120 kVp, reconstruction interval 1 mm, slice thickness 1.25 mm, pitch 1.375, and collimation 1 mm.

Patient preparation

No specific patient preparation was required apart from quiet breathing.

Patient position

-Patients were scanned in a supine position with their heads tilted towards the gantry to get direct axial slices; patient motion should be avoided during the research.

-Protocols were modified to account for the unique anatomy and location of the tumor. When scanning a limb, the patient should be positioned so that the only part of the body in the scanner aperture is the diseased limb. This will produce scans with a greater signal-to-noise ratio at lower mA and less radiation exposure for the patient.

Image reconstruction (post processing technique)

- High quality post-processing coronal and sagittal reformatted images with thin cuts <1.25 mm thickness was obtained using the multi-planer reconstruction (MPR) technique from volumetric and isotropic axial CT data by the machine software after thin axial images were reviewed, analyzed, and then reconstructed.

-The thin axial images obtained were sent directly from the MDCT scanner to the workstation via the picture archiving and communication system (PACS) for coronal and sagittal reconstruction and 3D images.

Magnetic Resonance Imaging (MRI); using closed MRI 1.5 Tesla (Achieva-class IIa, PHILIPS Medical Systems, and Optima 450 GEM, GE Healthcare) using the most optimal surface coil accommodates each lesion.

Patient preparation:

Patients were told to take away any metallic items before entering the examining room. Additionally, they were frequently questioned if they had any iron surgical clips or cardiac pacemakers. After that, the patient was given a brief explanation of the assessment. During the examination and patient reassurance, it was necessary to remain still.

Protocol and pulse sequences

-The following sequences are advised as a minimum, and acquisition techniques were modified to fit the anatomy at the tumor site. Local preferences were taken into consideration when creating additional sequences.

1. T1-WI without fat saturation (TR/TE = 800/40; FOV, 20-35).
2. T2-WI in axial, sagittal, and coronal without fat saturation (TR/TE = 3000/120; FOV, 20-35).
3. A minimum of one short inversion recovery (STIR) or fat saturated sequence (TR/TE=4000-5600/18-40; FOV, 20-35).
4. Patients received post-IV contrast sequences utilizing gadolinium D.T.P.A. at a dose of approximately 0.1 mmol/kg body weight.

-Body parts to be examined were immobilized to prevent motion artifact, interslice gap of 2-3mm ,slice thickness ranged from 4 to10 mm, , the matrix used for all sequences was 512 x 256.

C) Classification of bone tumors

BTI-RADS classification for focal bone lesions. We categorize solitary bone lesion as follows based on the number of benign and malignant indicators which are listed by Ribeiro in 2021.

Benign indicators	Minor malignant indicators	Major malignant indicators
Lesion size < 15 mm	Size ≥ 60 mm	Lodwick-Madewell grade III
Round/oval shape	Age > 50 years old	Aggressive periosteal reaction
No contrast enhancement on MRI	Irregular shape	Suspicion for metastases
No soft tissue infiltration or invasion on MRI	Soft tissue infiltration or invasion on MRI	
Cortical/subperiosteal transverse bone location	Intramedullary centered transverse bone location	
Lodwick-Madewell grade I	Anatomical region (pelvic bones)	
Anatomical region (hand and foot)		

Modified classification of Lodwick-Madewell

- **1A:** well-defined, geographic with sclerotic rim
- **1B:** well-defined, geographic, sharp margin, no sclerotic rim
- **2:** geographic, ill-defined margin (partial or circumferential)
- **3A:** change of margin, or progressive endosteal scalloping over time
- **3B:** moth-eaten or permeative
- **3C:** radiographically occult

We gave each bony lesion a score from I to IV

- BTI-RADS I: imaging findings and characteristics of a typical "do not touch" lesion with ≥2 benign and ≤ 1 minor malignant indicator.
- BTI-RADS II: ≥ 2 benign & ≤1 minor malignant indicator without imaging findings and characteristics of a typical "do not touch" lesion.
- BTI-RADS III: ≤ 1 benign indicator or < 3 minor malignant indicators.
- BTI-RADS IV: ≥ 3 minor malignant indicators or any major malignant indicator.

D) Gold standard

According to the histological technique, the diagnosis was confirmed by histologic biopsies in many of the included patients. patients with benign radiological criteria were followed up for six months.

Statistica1 design & analysis

A software program IBM SPSS 23.0 for Windows (SPSS Inc., Chicago, IL, USA) was used to code, enter, and analyze the gathered data.

Data summarization:

Qualitative data:

- (n) Number of each observation at each category or order.
- (%) percentage of the observation to all categories or order.

Quantitative data:

• Mean: calculated by dividing the total number of observations by the sum of the observed values.

• Median: It is the middle observation in a set of observations arranged in ascending or descending order and magnitude. It's used for summarization of skewed data because it is insensitive to extreme values

- Standard deviation (SD): The square root of variance and a measure of dispersion. Standard deviation (SD): It is a measure of dispersion and square root of the variance.
- Inter-quartile range (IQR): It is the range of values that resides in the middle of the scores.
- Range: the difference between the largest and smallest values.

At level of significance value (P value): P > 0.05 = non-significant and P ≤ 0.05 =Significant

RESULTS

This cross-section study included 36 patients with suspected bone abnormalities, all of them were evaluated with X-ray, CT and MRI.

The mean age was (31.4 ±16) years. 10 patients (27.8%) were younger than 20 years, 5 patients (13.9%) were older than 50 years. More than 50% of the patients were males as we had 23 male patients (63.9%) and only 13 female patients (36.1%) (Table 1)

Histopathological, there were 22 masses (61.1%) that were malignant and 14 masses (38.9%) that were benign. Regarding the number of masses, 3 masses (8.3%) were multiple, and 33 masses (91.7%) were solitary.

The most frequent benign lesion detected was osteochondroma in (21.4%), followed by chondroblastoma, eosinophilic granuloma, hemangioma in (14.3%), while osteoid osteoma, giant cell tumor, non-ossifying & ossifying fibroma and simple bone cyst were detected in (7.1%). (Table 2).

The most frequent malignant tumor detected was osteosarcoma in (22.7%), followed by chondrosarcoma in (13.6%), then adamantinoma, Ewing, leiomyosarcoma, osteoblastic osteosarcoma, plasmacytoma and osteochondroma with malignant transfusion in (9.1%), while intracortical osteosarcoma and round cell tumor were the least frequent malignant tumors detected in (4.5%) (Table 2).

As regards signal intensity, 7 masses (19.4%) showed hypo-intensity, 14 masses (38.9%)

showed hyper-intensity, and 15 masses (41.7%) showed intermediate intensity, as regards the BTI-RADS classification; 6 masses (16.7%) took BTI-RADS I, while 5 masses (13.9%) were grade II, 5 masses (13.9%) were grade III and 20 masses (55.6%) were grade VI, and regarding T staging, 14 masses (38.9%) were T1, while 13 masses (36.1%) were T2, 4 masses (11.1%) were T3, and 5 masses (13.9%) were T4.(Table 3).

In terms of shape and soft tissue invasion, there was a highly statistically significant difference between benign and malignant lesions; most malignant lesions had irregular shapes (77.3%), whereas the majority of benign lesions were rounded (35.7%). Additionally, 90.9% of malignant lesions displayed soft tissue invasion, whereas none of the benign lesions did. (P value <0.001).

In terms of lesion size, pain, periosteal reaction and cortical lysis ,there was a statistically significant difference (P value <0.05) between benign and malignant lesions as lesion size ranged from 15 to 59 mm in 11 benign lesions (78.6%) in comparison to only 3 malignant lesions (13.6%), while (100%) of malignant lesions were accompanied by pain, only (50%) of benign lesions were accompanied by pain, also (31.8%) of malignant lesions showed periosteal reaction while none of the benign lesions showed periosteal reaction, regarding cortical lysis; (81.8%) of malignant lesions showed cortical lysis, while only (21.4%) of benign masses showed cortical lysis.

There was a statistically significant difference (P value <0.05) between benign and malignant lesions in respect to lesion size, shape, aggressive periosteal reaction and metastasis , the lesion size was more than 60 mm in 19 malignant lesions (86.4%) compared to only one benign lesion (7.1%), while (86.4%) of malignant lesions were irregular in shape, only (35.7%) of benign lesions were irregular in shape, also (31.8%) of malignant lesions showed aggressive periosteal reaction while none of the benign lesions showed periosteal reaction, as regard metastasis 9 malignant lesions (40.9%) showed metastasis, while none of the benign lesions showed metastasis.

Regarding X-ray and CT results, most malignant masses (77.3%) displayed a wide zone of transition, whereas the majority of benign masses (42.9%) displayed a narrow zone of transition. This difference was highly statistically significant (P value <0.001). In terms of periosteal reaction, there was also a statistically significant difference between benign and malignant masses; 40.9% of malignant masses displayed periosteal reactivity, but none of the benign masses did. (Table 4)

The MRI (T2WI) T staging and the pathological T staging of the cases showed a good agreement in this study (K=0.766), and the value was highly significant (P value <0.001). The staging of 30 cases (83.3%) was agreed upon by both. Only one case (2.8%) was overestimated, while five cases (13.9%) were underestimated. (Table 5)

This study showed 25% of false negative cases (BTI-RADS-diagnosed as benign lesions but histopathology showed them to be malignant) and 10% of false positive cases (BTI-RADS-diagnosed as malignant masses but histopathology showed them to be benign), BTI-RADS agreed with gold standard results in 90% of true malignant cases and 75% of true benign cases. The BTI-RADS and gold standard results showed good agreement (K=0.658). The value (P value <0.001) was highly significant (Table 6).

The Sensitivity of BTI-RADS was 81.8%, its specificity was 85.7%, PPV was 90%, NPV was 75% and accuracy was 83.3%.

Following multivariate regression analysis, BTI-RADS, lesion size, irregular form, and cortical lysis were found to be very significant factors that may be employed in discrimination between benign and malignant lesions based on MRI (P value < 0.001).

Table 1: Demographic data among studied patients

Variable	All patients (n=36)
Age (years) Mean ± SD	 31.4 ± 16
Age groups *(N.%)* – <20 – 20 - 30 – 30 – 40 – 40 – 50 – >50	 10 (27.8%) 11 (30.6%) 4 (11.1%) 6 (16.7%) 5 (13.9%)
Sex *(N.%)* – Male – Female	 23 (63.9%) 13 (36.1%)

Table 2 Benign and Malignant lesions detected by histopathology among studied patients

Variable	Benign lesions (n=14)	Variable	Malignant lesions (n=22)
Osteoid osteoma	1 (7.1%)	Adamantinoma	2 (9.1%)
Chondroblastoma	2 (14.3%)	Chondrosarcoma	3 (13.6%)
Eosinophilic granuloma	2 (14.3%)	Ewing sarcoma	2 (9.1%)
Giant cell tumor	1 (7.1%)	Intracortical osteosarcoma	1 (4.5%)
Hemangioma	2 (14.3%)	Leiomyosarcoma	2 (9.1)
Non-ossifying fibroma	1 (7.1%)	Osteoblastic osteosarcoma	2 (9.1%)
Ossifying fibroma	1 (7.1%)	Telangiectatic & small cell osteosarcoma	5 (22.7%)
Osteochondroma	3 (21.4%)		
Simple bone cyst	1 (7.1%)	Plasmacytoma	2 (9.1%)
		Round cell tumor	1 (4.5%)
		Osteochondroma with malignant transformation	2 (9.1%)

Table 3: MRI (T2W1), BTI-RADS and T- Staging findings among studied patients

Variable	All patients (n=36)
Signal intensity – Hypo – Hyper – Intermediate	 7 (19.4%) 14 (38.9%) 15 (41.7%)
BTI-RADS – I – II – III – VI	 6 (16.7%) 5 (13.9%) 5 (13.9%) 20 (55.6%)
T staging – T1 – T2 – T3 – T4	 14 (38.9%) 13 (36.1%) 4 (11.1%) 5 (13.9%)

Table 4: X-ray & Ct findings among studied patients

Variable *(N.%)*	Benign masses (n=14)	Malignant masses (n=22)	P Value
Zone of transition – Narrow – Intermediate – Wide – Variant – Continuous	 6 (42.9%) 3 (21.4%) 0 (0%) 2 (14.3%) 3 (21.4%)	 0 (0%) 5 (22.7%) 17 (77.3%) 0 (0%) 0 (0%)	<0.001
Periosteal reaction – Absent – Present – Medullary with exophytic comp.	 14 (100%) 0 (0%) 0 (0%)	 13 (59.1%) 7 (31.8%) 2 (9.1%)	0.02
Chondroid matrix	0 (0%)	5 (22.7%)	0.13

Table 5: Agreement between T2W1 diagnostic data and pathological T staging among studied cases

T2W1 T staging	Pathological T staging			Total	K test	P value
	T1	T2	T3			
T1	13	0	0	13	0.766	<0.001
T2	1	9	0	10		
T3	0	0	6	5		
T4	0	4	4	8		
Total	14	13	9	36		

Table 6: Agreement between BTI-RADS and gold standard results:

BTI-RADS	Histopathology		Total	K test	P value
	Malignant	Benign			
Malignant	18 (90%)	2 (10%)	20	0.658	<0.001
Benign	4 (25%)	12 (75%)	16		
Total	22	14	36		

Illustrative cases Fig. 1 and 2

Fig. 1

A male patient (45 y) presented with history of lower abdominal and pelvic pain, more at the right side, referred to radiodiagnosis department.

- X-Ray and CT reveal a well-defined right pubic exophytic pedunculated lesion seen in continuity with the related medullary cavity, it measures about 80 mm at maximum dimension, it shows heterogenous attenuation with predominant sclerotic components.
- MRI reveals a well-defined bony outgrowth from the inferior aspect of the RT pubic bone with no evidence of cortical disruption or soft tissue, overlying cartilaginous cap less than 1.5 cm displaying iso to low at T1WI, iso to high signal at T2w and at STIR consequent abnormal signal intensity and edema of the compressed muscles of the RT upper thigh.
- No significant post contrast enhancement (H).

The lesion shows 2 benign criteria, 3 minor malignant criteria and 0 major malignant criteria

Benign criteria	Minor malignant criteria	Major malignant criteria
1- Cortical bone location. 2- No post contrast enhancement on MRI	1- Lesion size> 60 mm 2- Pelvic location 3- Irregular shape	

Final diagnosis based on the radiological findings and BTI -RADS: the mass takes BITRADS IV (Likely malignant)
Histopathological correlation after the excisional biopsy of the right pubic bony lesion revealed osteochondroma.

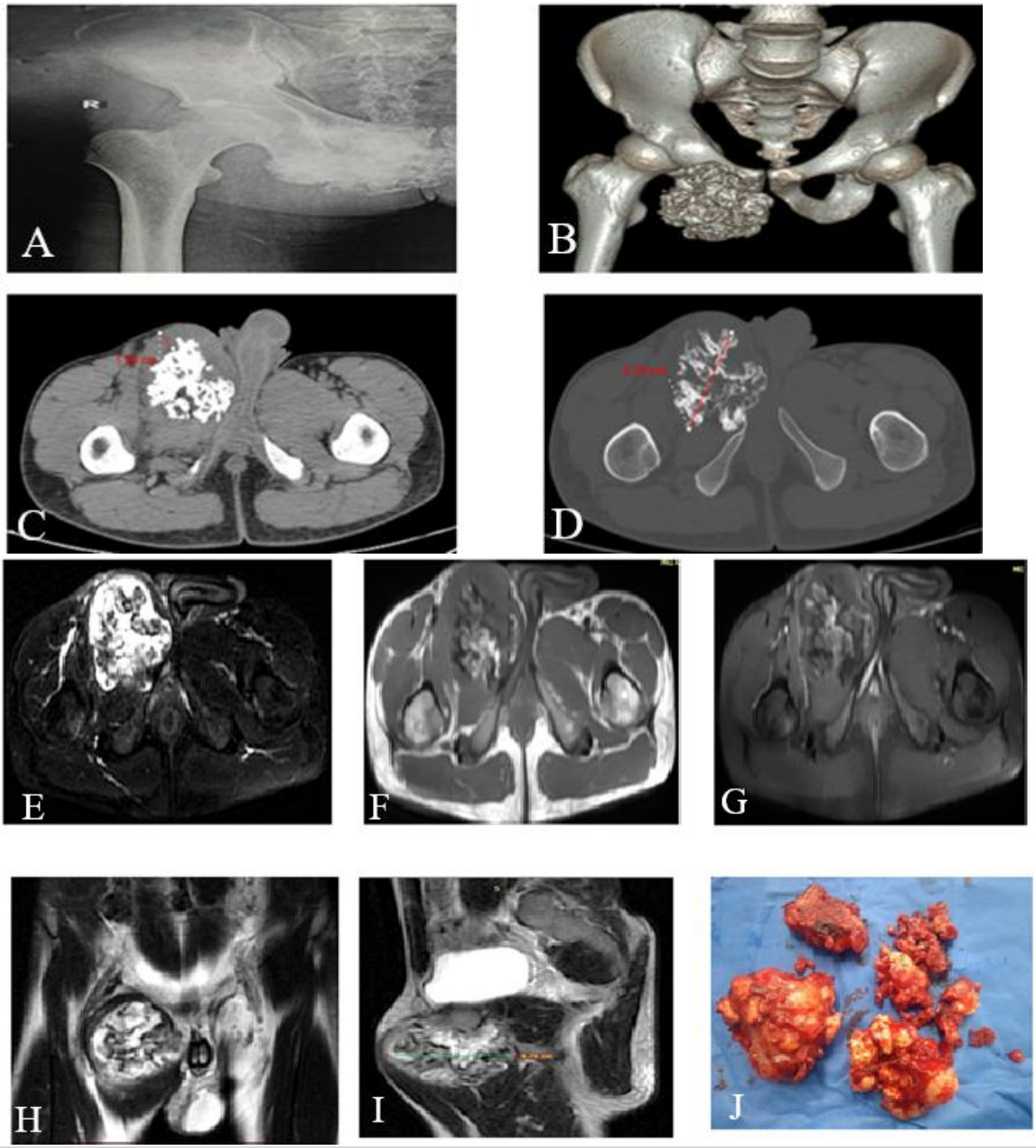


Fig.1 A case of BTI RADS IV right pubic bone osteochondroma

Fig. 2

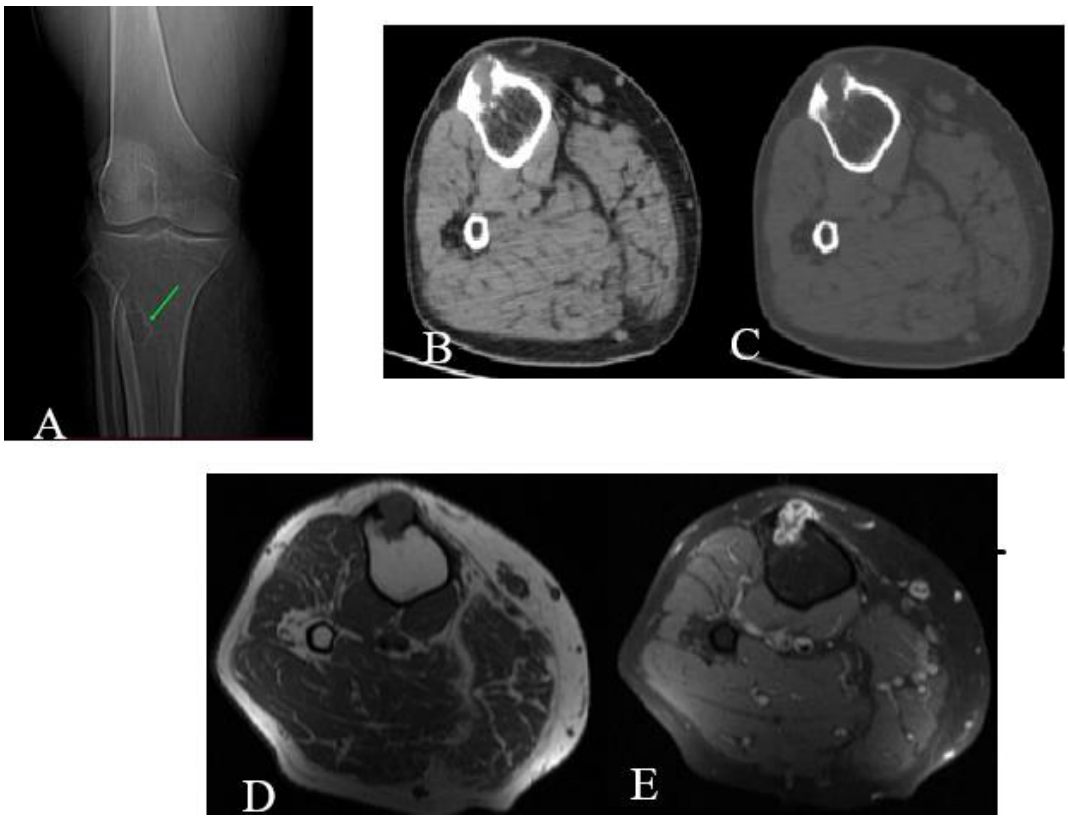
A male patient (40 y) presented with history of right leg pain and limitation of movement. Plain X-Ray (A): show a well-defined lytic lesion with sclerotic margin at the tibial metaphyseal region, with narrow zone of transition, no fracture lines
CT (B) Axial view soft tissue window – (C) Axial view bone window reveals right tibial metaphyseal cortical based lobulated lytic lesion with cortical defect and soft tissue component, minimal intramedullary extension. MRI (D) Axial T1 WI (E) Axial STIR (F) Coronal STIR (G) Axial T1 Post contrast Shows a single well-defined oval (oblong) shaped exophytic osseous lesion seen at the anterior border of the upper third of the tibia measuring about 20mm displaying mixed signal intensity being iso-to low signal intensities at T1w and of intermediate high signal intensity at STIR with multiple small internal signal voids. The mass shows homogenous enhancement at the post contrast image.

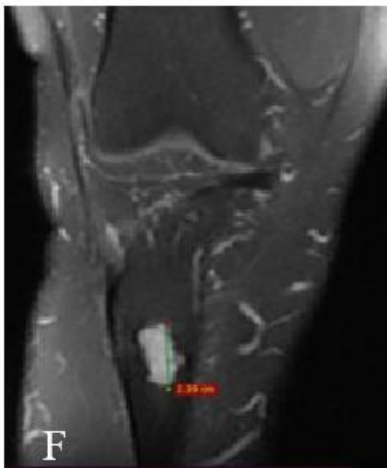
- The lesion shows 3 benign criteria, 1 minor malignant criterion and 0 major malignant criteria

Benign criteria	Minor malignant criteria	Major malignant criteria
Oval shape Cortical location Lytic lesion with sclerotic ring (Ludwick madewell grade I)	Soft tissue invasion	

Final diagnosis based on the radiological findings and BTI -RADS: the mass takes BITRADS I (Benign)

Histopathological correlation after CT guided biopsy of the right tibial bony lesion revealed Enchondroma.





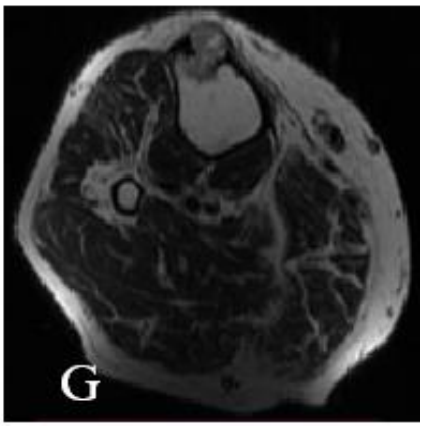


Fig. 2 A case of BT RADS I Enchondroma

DISCUSSION

Primary bone and joint cancers are the third most prevalent cause of death among cancer patients under the age of twenty, even though primary bone tumors are rare, with incidence rates of 4–7% among children and adolescents in the United States. [7].

A thorough medical history that includes the patient's age, gender, kind and duration of symptoms, mass location, and history of trauma is the first step in evaluating patients with bone tumors. Osteochondromas are the most prevalent benign bone tumor in children, accounting for 10–15% of all bone tumors and 20–50% of all benign bone tumors [8].

One could contend that applying a RADS technique to focal bone lesions is beneficial and could enhance the quality and relevance of imaging findings given the existing experience with RADS for other organs. [9].

The categorization of bone lesions into four categories with increasing rates of malignancy was made possible by the evidence-based systematic approach to solitary bone tumor characterization known as BTI-RADS. This could assist standardize the evaluation of bone tumors and perhaps influence patient management [6].

Of the 36 patients that were part of our study, we discovered that 23 (63.9%) of them were men and 13 (36.1%) were women. The male to female ratio was 16:9; Ryan's (2022) &Pullan, (2024) research found similar results. & found that male patients had a greater overall incidence of bone tumors across all age categories than female patients [10,11].

Regarding the age in our study, the most frequent age groups were from (< 20 and from 20 to 30 years) representing (27.8 and 30.6%) respectively of the total with mean age about (31.4 ± 16) years and the least frequent age group was from (30-40 years) representing only (11.1%) of the total; this was nearly in agreement with Kumar 2016. who reported that bone tumors showed a stable incidence trend below 39 years, whereas the 40 to 79 years age group demonstrated a declining trend and disagreed with them, claiming that the age of 80 years is when the incidence peaks again [12].

In terms of the aggressiveness of the bone tumors in our study, 14 patients (38.9%) had benign bone lesions, and 22 patients (61.1%) had malignant tumors. These results are inconsistent with those of Ribeiro et al., 2021, whose study comprised 32.7% of patients with malignant tumors and 67.3% of patients with benign tumors and don't touch lesions [6].

Regarding the number of bone lesions identified in our investigation, 33 patients (91.7%) had a single bone lesion, whereas 3 patients (8.3%) had several. This appears to be another discrepancy with Ribeiro et al., 2021, who only included patients with single bone lesion [6].

The following is the distribution of benign lesions found in the patients in our study: Osteoid osteoma (7.1%), two chondroblastoma patients (14.3%), two eosinophilic granuloma patients (14.3%), one giant cell tumor patient (7.1%), two hemangioma patients (14.3%), one non-ossifying fibroma patient (7.1%), one ossifying fibroma patient (7.1%), three osteochondroma patients (21.4%), and one simple bone cyst patient (7.1%) , the most common benign bone lesion in our study was osteochondroma , this is keeping with De Salvo, et al ., 2022 studies who reported that these cartilaginous tumors represent most of the benign bone tumors [13].

Twenty two patients of the total cases in our study were pathologically proven to have malignant lesions as follow , 2 patients with adamantinoma (9.1%) , 3 patients with chondrosarcoma (13.6%) , 2 patients with Ewing sarcoma (9.1%) , 1 patient with intracortical osteosarcoma (4.5%), 2 patients with leiomyosarcoma (9.1%) , 2 patients with osteoblastic osteosarcoma (9.1%) , 5 patients with telangiectatic and small cell osteosarcoma (22.7%) , 2 patients with plasmacytoma (9.1%) , 1 patient with round cell tumor (4.5%) , 2 patients with osteochondroma with malignant transformation (9.1%) , In line with research by Kumar (2016) and Cole et al. (2022), which indicated that osteosarcoma is the most prevalent primary malignant bone tumor across all age categories, we discovered that osteosarcoma accounted for 36.3% of all primary malignant bone tumors in our study [12,14].

Regarding the size of the focal bone lesions included in our study, out of 16 cases, 80.25% had benign lesions measuring less than 15 mm and between 15 and 59 mm, while the remaining 20 cases had lesions measuring more than 60 mm, 95% had malignant tumors. This was in line with the findings of Ramadan et al., 2025, who discovered that primary malignant bone tumors are generally larger than benign tumors. Generally speaking, lesions greater than 6 cm have a statistically higher chance of being malignant [15].

Regarding the morphology of the bone tumors in our study, we discovered that 18 out of the 21 cases with lobulated irregular margins (approximately 85% of them) were malignant. This is in good agreement with Gemescu's 2019 study, which found that the margin's shape can also provide extra information, reducing the number of differential diagnoses. For instance, malignant situations may exhibit a lobulated shape [16].

According to Gemescu et al. (2019) and Ramadan et al. (2025), nonaggressive lesion presents a narrow zone of transition, leaving the cortex intact. As for the zone of transition of the bone tumors included in this study, 16 patients had a narrow zone of transition, all of which were benign, and 17 patients had a wide zone of transition, accounting for 77.3% of the total cases with malignant bone tumors aggressive lesion, on the other hand, causes cortical damage and a broad zone of transition [15,16].

Seven cases in our study had aggressive periosteal reaction on CT, and all of them were found to be malignant tumors (representing 31.8% of the total malignant cases), which is in line with Ramadan et al., 2025, and Gemescu et al., 2019 who reported that when assessing periosteal reaction, the radiologist should describe it as aggressive or nonaggressive because the more interrupted and complex pattern is suggestive of greater biologic activity and a more aggressive lesion [15,16].

Characterizing the matrix of the bone tumors included in this study, we found that 12 patients had bone lesions with mineralized and chondroid matrix on CT examination, and that 20 of the 30 patients with solid (bone and soft tissue) matrix on MRI examination were malignant, accounting for 90.9% of the total included malignant cases. The remaining patients displayed cystic and mixed heterogenous matrix, four of which were benign. However, of the 19 patients who had non-mineralized bone lesions, 63.1% also had malignant ones. This was in line with Ladd et al. (2017), who claimed that while matrix is present in both benign and malignant tumors and does not directly correlate to malignant

potential, it is useful to accurately characterize a tumor by determining its matrix or composition, which is frequently more sensitive by CT and MR imaging [17].

According to the MRI criteria of the bone lesions that were included in our study, osteochondroma, osteoid osteoma, ossifying fibroma, and sclerotic osteosarcoma are among the 29 cases (80.6%) that exhibit intermediate to high signal intensity at T2WI, while 7 cases (19.4%) exhibit iso to low signal intensity at T2WI. The majority of musculoskeletal tumors are hyperintense on T2-weighted sequences, according to a 2019 study by Gemescu. However, there are certain outliers, such as osteoid osteoma, osteoblastoma, osteoblastic metastasis, lymphoma, and osteosarcoma [16].

We agreed with James et al. (2008) that bone marrow edema may be found adjacent to a variety of neoplastic and non-neoplastic lesions, but extensive marrow oedema relative to a small lesion is typically benign seen, for example in benign tumors, inflammatory lesions, and stress fractures. In our study, 16 patients had minimal perilesional bone marrow oedema on MRI examination, and the majority of them (12 cases) were diagnosed with malignant bone tumors. On the other hand, a big lesion with little oedema surrounding it is more likely to be malignant [18].

A group of radiologists in Nancy, France, led by Brazilian radiologist Guilherme Jaquet Ribeiro, developed and clinically tested the bone tumor imaging reporting and data system. It was published in the Journal of European Radiology in 2021 as the first reporting and data system for bone lesions [6].

The BTI-RADS system was clinically tested by the study group with a fair interobserver agreement. It is based on various CT and MR imaging aspects as well as fundamental clinical data. Based on clinical and imaging characteristics categorized as designated benign indicators, minor malignant indicators, and significant malignant indicators, the assessment categories run from 1 to 4.

According to the criteria for benign and malignant focal bone lesions outlined by Ribeiro et al. (2021), we found a statistically significant difference (P value <0.05) between benign and malignant lesions in terms of lesion size, shape, aggressive periosteal reaction, and metastasis. For example, 19 malignant lesions (86.4%) had a lesion size greater than 60 mm, whereas only one benign lesion (7.1%) had an irregular shape. Additionally, 86.4 percent of malignant lesions were irregular in shape, whereas only 35.7% of benign lesions did the same. In terms of metastasis, nine malignant lesions (40.9%) had metastasis, while none of the benign lesions did [6].

Additionally, there was a statistically significant difference (P value <0.05) between benign and malignant lesions in terms of lesion size, pain, and cortical lysis. For example, 11 benign lesions (78.6%) had lesion sizes ranging from 15 to 59 mm, whereas only three malignant lesions (13.6%) had lesion sizes between 15 and 59 mm. Also, while 100% of malignant lesions had pain, only 50% of benign lesions had pain. Finally, in terms of cortical lysis, 81.8 percent of malignant lesions displayed cortical lysis, whereas only 21.4% of benign masses displayed cortical lysis.

Summary and explanation of the results

The BTI-RADS and gold standard results in our study showed good agreement (K=0.658). The value (P value <0.001) was highly significant. While there were 25% of false negative cases (BTI-RADS-diagnosed as benign lesions but histopathology showed them to be malignant) and 10% of false positive cases (BTI-RADS-diagnosed as malignant masses but histopathology showed them to be benign), BTI-RADS agreed with gold standard results in 90% of true malignant cases and 75% of true benign cases.

CONCLUSIONS

Bone lesions can be categorized into four groups with increasing rates of malignancy using the Bone Tumor Imaging-Reporting and Data System (BTI-RADS), an efficient comprehensive scoring system with good diagnostic value.

Limitations

1) The number of benign, minor, and major malignant indicators on which BTIRADS depends is quite large. So, it can be time-consuming for radiologists
2) BTI-RADS does not account for scenarios where only one modality or incomplete imaging is available.
3) BTIRADS considers the presence of contrast-enhancement on MRI as a minor malignant indicator , which could result in increased expenses for patients with bone tumors that display typical benign characteristics on non-enhanced CT and MRI
4) BTIRADS considers the presence of distant metastatic lesions as a major malignant indicator, so previous body imaging such as PET-CT or contrast-enhanced CT of the chest, abdomen, and pelvis is required to provide an accurate score. This information is often unavailable to the radiologist.

Recommendations

We recommend more studies with larger datasets as this study was a single institute experience with a small sample size so it was difficult to generalize the results.

Conflict of Interest:

There is no any financial or personal relationships with other people or organizations that could inappropriately influence (bias) the authors' actions.

Financial Disclosures:

None .

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