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Original Research Article

Bone Tumours and Tumour-Like Lesions: Comparing the Diagnostic Efficacy of Different Imaging Modalities

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Conflict of interest: Nil

Abstract:

Objective: This retro-prospective study was performed to evaluate the diagnostic accuracy of various imaging modalities as compared to histopathological findings in tumours and tumour-like lesions of bone.

Materials and Methods: Imaging findings of 70 patients in the age group of 2 to 75 years were evaluated. The findings on Radiographs, Computed Tomography (CT), and Magnetic Resonance Imaging (MRI) were correlated with histopathological findings.

Results: 70% of the bone lesions were benign on histopathology and 30% were malignant. Plain radiographs showed a sensitivity of 80.95%, and 95.92% specificity, with a PPV of 89.47%. NPV of 92.16%, and diagnostic accuracy of 91.43% were seen. CT showed a sensitivity of 95.0%, specificity of 91.67%, PPV of 86.36%, NPV of 97.06%, and diagnostic accuracy of 92.86%. On MRI 100% sensitivity, 93.8% specificity, a PPV of 91.3%, a NPV of 100%, and diagnostic accuracy of 96.23% were found. On comparing findings on radiographs, CT, and MRI with histopathological findings, Cohen Kappa values (K-values) of 0.8, 0.84, and 0.92 respectively were obtained.

Conclusion: This study shows high accuracy of all imaging modalities, more so MRI with a good correlation between radiological and histological diagnosis.

Keywords: Bone Tumours, Tumour-Like Lesions, Imaging, Radiology, Histopathology, Correlation, Diagnostic Accuracy.

Introduction

The phrase "bone tumour and tumour-like lesions" encompasses a wide range of disorders including reactive, focal, or metabolic abnormalities, and benign and malignant neoplasms. Primary bone tumours are comparatively scarce, accounting for fewer than 1% of all neoplasms [1]. A study done by Gulia et al. to determine the occurrence of bone and soft-tissue tumors in India demonstrated approximately 60% of all musculoskeletal lesions were bone tumours and tumor-like lesions and 36% were of soft-tissue origin. In bony lesions, 15% were benign, 66% were malignant and 19% represented the non-neoplastic aetiology [2].

The true incidence of each bone tumour is difficult to determine, as many of these lesions are incidentally found on imaging and histologic diagnosis is not always available. Certain benign bony lesions may even go undetected. Accurate diagnosis and appropriate management of these lesions is essential as they are an important cause of morbidity and mortality in children and adolescents. The diagnosis of bone tumours entails clinical examination, radiologic imaging, and histology.

Radiographs are used as the initial modality in the diagnosis of bone tumours as they are inexpensive and less time-consuming. They help in evaluating the site, characterizing the lesion, and evaluating the aggressiveness of the lesion. However, characterization of the bone matrix, periosteal reaction, detection of mineralization, tumour growth extension into the bone marrow, overlying adjacent soft tissue involvement and adjacent joint involvement is better seen on cross-sectional imaging like CT and MRI. Skip lesions and metastasis, which are important for staging and treatment of the bony lesions, can also be evaluated

with these modalities [3]. Advanced MRI imaging techniques like diffusion imaging, in-phase/out-of-phase imaging, spectroscopy, and dynamic contrast perfusion help in increasing the diagnostic accuracy and evaluation of response to the treatment [4]. Bone biopsy – image-guided needle aspiration or open incisional biopsy is considered the gold standard in the diagnosis of bone tumours but may not be performed in every patient [5].

Materials and Methods:

This study was done after approval by the institutional research ethical committee. 70 patients were included in our retro-prospective study which covered a period of 5 years. All consecutive patients referred with clinical features and radiographic findings suggestive of bone tumours and tumor like lesions were included in the study.

The imaging for all the prospective cases was done after obtaining written, informed consent from the patient/parent/guardian. In retrospective cases, records were acquired from the hospital archives. Radiographs were performed on the Konica Minolta DR), CT was done on (Phillips Brilliance 16 Slice, Phillips Incisive 128 slice) and MRI on a Phillips Achieva 1.5 Tesla, Phillips Ingenia Elition 3.0 Tesla systems. Radiographs were available for all 70 patients.

CT imaging was available for 56 patients and 53 patients had undergone MRI. 14 patients had only radiographs done, as the radiological features were suggestive of a benign etiology and they directly underwent surgical intervention/biopsy. Bone biopsy and histopathology were performed for all the patients. The data was entered into the Microsoft Excel Worksheet and analyzed using SPSS (Statistical Package for social sciences) version 25.0 software. The results were presented in a tabular format. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and Cohen kappa statistics were calculated for each imaging modality.

Results:

We enrolled 70 patients with ages ranging from 2 to 75 years, out of which, 42 were male (60%) and 28 were female (40%). The patients were divided into three age groups: < 20 years, 20 - 40 years, and > 40 years. The mean age in each group was 13.3 years, 28.6 years, and 56 years respectively. The mean age of patients in our study was 27.5 years. The frequency of bone tumours and tumour-like lesions according to the age group and gender are described in Table 1.

The correlation of radiographs, CT, and MRI with histopathology was done to calculate the diagnostic accuracy of the imaging modalities. On plain radiographs, four of the 70 patients with malignant tumours had been wrongly diagnosed as tumours of benign origin. Two benign tumours were classified as malignant. The diagnostic accuracy of radiographs in our study was 91.43% with Cohen's kappa value of 0.8.

CT imaging was available for 56 patients. On CT, one case of a malignant bone tumour was wrongly labelled as a benign aetiology. Three benign tumours were classified as malignant on CT. The diagnostic accuracy of CT in our study was 92.86% with Cohen's kappa value of 0.84. Out of 53 patients with MR imaging, two cases of benign neoplasms were wrongly diagnosed as malignant neoplasms. No patient who had a malignancy was wrongly diagnosed to have a benign pathology indicating a very high sensitivity of MRI in detecting subtle findings due to its higher spatial resolution and better soft tissue contrast. The diagnostic accuracy of MRI in our study was 96.23 % with Cohen's kappa value of 0.92. The sensitivity, specificity, PPV, and NPV of Radiographs, CT and MRI in our study are tabulated in Table 2.

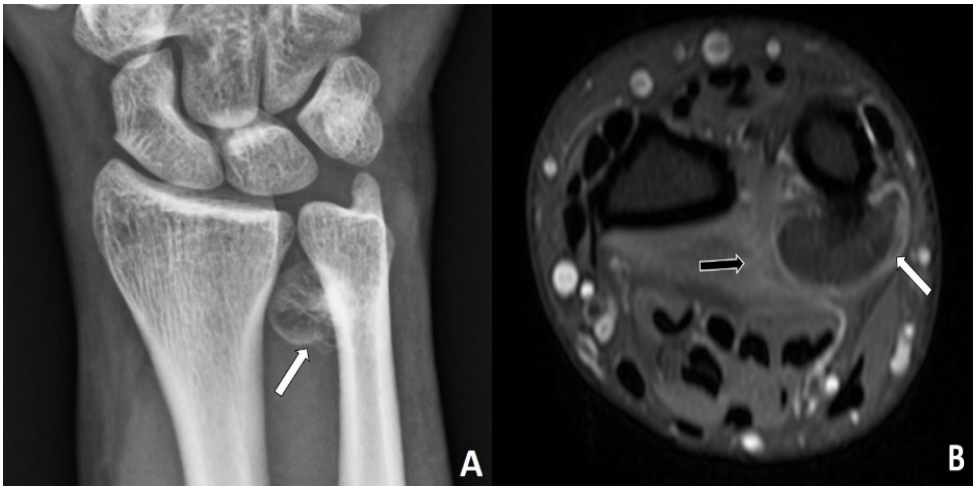

Figure 1A: **Figure 1B:**

An anteroposterior radiograph of the left wrist (Figure 1) shows a well-defined, osseous excrescence arising from the metaphysis of the distal ulna (white arrow). Corresponding axial proton-density fat suppressed PD-FS MRI image (Figure 1B), at the level of distal ulna show an osteochondroma with a very thin cartilage cap (white arrow). Minimal surrounding soft tissue oedema is also noted (black arrow). These findings are consistent with a bizarre parosteal osteochondromatous proliferation (Nora lesion).

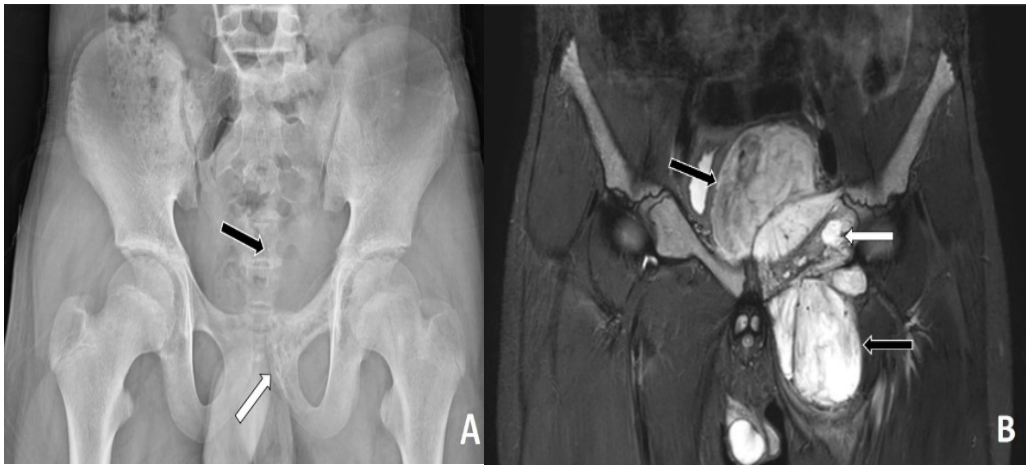

Figure 2A: **Figure 2B:**

13 years old boy diagnosed with Ewing sarcoma of pelvis presenting with suprapubic region pain and left proximal thigh swelling. An anteroposterior radiograph of the pelvis with both hips (Figure 2A) shows an ill-defined lesion with mixed lytic & sclerotic areas and a wide zone of transition involving the left superior pubic ramus, left acetabulum, and superior half of the inferior pubic ramus (white arrow). Mild periosteal reaction along the left superior ischio-pubic ramus is also noted. A soft tissue opacity was seen in the pelvis on the left with obliteration of left obturator fat pad (black arrow). MRI coronal STIR image (Figure 2B) shows a hyperintense lesion in the region of the pelvis on the left and medial compartment of the left thigh causing compression of the urinary bladder and pelvic soft tissues extending into the left thigh via obturator foramen (black arrow). The bony component of lesion shows areas of necrosis within (white arrow).

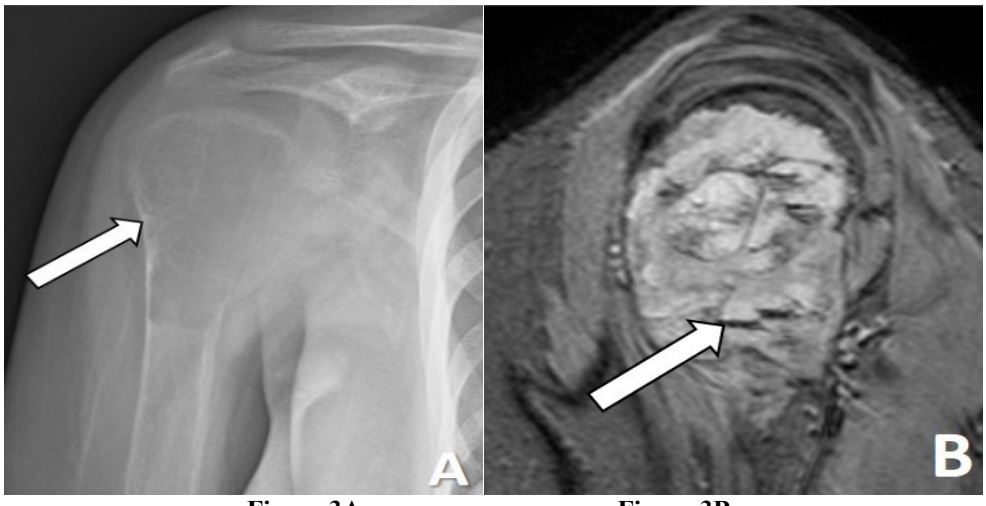

Figure 3A: **Figure 3B:**

22 years old female coming with complains of right shoulder swelling and pain. An anteroposterior radiograph of the right shoulder (Figure 3A) shows a well-defined, expansile, lytic lesion involving the epi-metaphysis and proximal diaphysis of the humerus. The lesion shows a narrow zone of transition and fine bony trabeculations within. No periosteal reaction is seen. The medial cortex of the proximal humerus appears eroded. MRI sagittal FFE image (Figure 3B) shows an expansile, multiloculated hyperintense lesion in the proximal humerus. The lesion shows multiple fluid-fluid levels with areas of blooming within (white arrow). This is a case of aneurysmal bone cyst of the humerus.

Table 1: Incidence of bone tumour and tumour-like lesions according to age group and sex

Bone Tumours	< 20 Years		20 - 40 Years		> 40 Years		Total	Percentage
	Male	Female	Male	Female	Male	Female	Frequency	
Aneurysmal Bone Cyst	0	0	1	2	0	0	**3**	4.3
Bone Lymphoma	0	0	0	0	1	0	**1**	1.4
Bone Metastasis	0	0	0	0	1	2	**3**	4.3
Chondroblastoma	0	1	1	0	0	0	**2**	2.9
Chondrosarcoma	0	0	1	0	0	2	**3**	4.3
Enchondroma	0	0	0	1	0	0	**1**	1.4
Ewing Sarcoma	2	2	1	0	0	0	**5**	7.1
Giant Cell Tumour	1	1	4	2	4	2	**14**	20
Multiple myeloma	0	0	0	0	2	2	**4**	5.7
Non-ossifying Fibroma	2	0	0	0	0	0	**2**	2.9
Osteochondroma	11	2	3	0	0	1	**17**	24.3
Osteoid osteoma	3	2	0	1	0	0	**6**	8.6
Osteoma	1	0	0	2	0	0	**3**	4.3
Osteosarcoma	3	1	0	1	0	0	**5**	7.1
Simple Bone Cyst	0	1	0	0	0	0	**1**	1.4
Total	**23**	**10**	**11**	**9**	**8**	**9**	**70**	100

Table 2: Sensitivity, specificity, PPV, and NPV of Radiographs, CT and MRI in our study

Statistical Parameters	Radiographs	CT	MRI
Sensitivity	80.95%	95.00%	100%
Specificity	95.92%	91.67%	93.80%
Positive Predictive Value	89.47%	86.36%	91.30%
Negative Predictive Value	92.16%	97.06%	100%
Diagnostic accuracy	91.43%	92.86%	96.23%

Discussion

We correlated the imaging findings on plain radiographs, CT, and MRI with histopathology as the gold standard to calculate the diagnostic accuracy of each imaging modality as well as to evaluate the spectrum of bone tumours and tumour-like lesions and classify the lesions according to the age, gender, type, and site of the lesion. Salazar et al. [6] documented 92.9% sensitivity, 87.5% specificity, 90% diagnostic accuracy, 86.7% PPV, and 93.3% NPV of radiographs in the assessment of bone tumours [6]. Our study was comparable to his study and showed a sensitivity of 80.95%, specificity of 95.92%, diagnostic accuracy of 91.43%, PPV of 89.47%, and NPV of 92.16%. The Kappa value of radiographs in his study was 0.8, similar to ours being 0.8. Negash et al. [7] documented the diagnostic accuracy of 84% by radiographs with a Kappa value of 0.82 [7]. The study done by Naz et al. [8] documented 83.3% sensitivity, 100% specificity, and 93.3% diagnostic accuracy with a 100% PPV and 93.3% NPV [8]. Correlation between CT and histopathology was only documented in a study by Salazar et al 6. The sensitivity of CT in our study was 95% compared to 84.6% by Salazar et al, with a specificity of 91.67% vs 68.8%, compared to Salazar et al [6]. We had a diagnostic accuracy of 92.86% as compared to 75.9% by Salazar et al [6] with a PPV of 86.36% vs 68.8% by Salazar et al [6] and an NPV of 97.06% vs 84.6%. The Cohen Kappa value for CT was 0.84 compared to 0.5 by Salazar et al. [6]. Our study showed a good correlation between CT and histology compared to Salazar et al. 6 with higher diagnostic accuracy. Azad et al. [9] and Salazar et al. [6] documented the analysis of MRI with histology with a sensitivity of 92.5% and 94.4%, specificity of 71.42% and 95.7%, diagnostic accuracy of 87% and 95.1%, a PPV of 97.3% and 94.4% and the NPV of 54.5% and 95.7% respectively. Our study showed similar data with a sensitivity of 100%, specificity of 93.8%, and diagnostic accuracy of 96.23%, a PPV of 91.3% and a NPV of 100%. The Cohen kappa score in our study was 0.92 similar to the 0.9 seen with Salazar et al. The Cohen kappa statistics value above 0.75 suggests great inter-rater reliability. Our study found good diagnostic capability of radiographs (0.8) and CT (0.84) and great performance of MRI (0.94).

Based on the imaging features and histopathology, the lesions were defined as either benign or malignant. Our study showed the most common benign tumour being osteochondroma, which was seen in 17 out of 70 cases (24.3%). Salazar et al. [6] documented a 20.3% incidence of osteochondroma. This was reported by them as the most common benign bone tumour and was similar to our findings. The second most benign bone tumour in our study was a giant cell tumour, seen in 14 cases (20%). The incidence was similar to a study done by Naz et al.

[8], who found an incidence of 20% of GCT in their study. A study by Settakorn et al. [10] with 1001 patients showed the most common benign tumour being GCT in 3.7% of cases. The most common malignant tumour reported by Salazar et al. was metastasis in 17.2% of cases. We had only 3 cases of metastatic bone malignancy accounting for 4.3% of total cases. Negash et al. [7] documented only 5.5% of cases of metastatic malignancies. Similarly, Settakorn et al. [10] showed 10.4% of cases being metastatic. The low incidence of bony metastasis reported was probably because histopathology was not available from the bony lesion in a majority of the studies; as the need for performing a biopsy from a metastatic bone lesion in a known primary malignancy is less as compared to a suspected primary bone malignancy [6]. The most common primary malignant tumour in our study was Ewing sarcoma and osteosarcoma, seen in 5 cases each (7.1%). Salazar et al. [6] documented an incidence of only 0.9% cases of Ewing sarcoma and 0.5% osteosarcoma.

The patients were divided into three age groups with the largest number of patients being under 20 years of age (47.1%). Similar findings were observed in a study conducted by Salazar et al. [6] who recorded 50% of their cases being < 25 years of age. Naz et al. documented bone tumours with a peak incidence in the age group of 10 – 20 years with 50% of patients being < 20 years of age. Negash et al. [7] and Settakorn et al. [10] documented 77.1% and 60% of their patients being under the age of 30 years respectively. Salazar et al. [6] also documented a second peak of incidence in the > 50 years of age group (26.6% cases). Negash et al. [7] and Naz et al. [8] did not find an incidence with a second peak in the older age group. Our study data was similar to that of Negash et al. [7] and Naz et al. [8] since the incidence did not show a second peak in the older age group. There was a male predominance in our study with 60% (42 cases) of the patients being male. Similar findings were seen by Salazar et al. [6] with 64.1% of patients being male in their study. 54.9% and 66.7% of the study population were male in a study done by Settakorn et al. [10] and Naz et al. [8] respectively. Negash et al. [7] also had a male-to-female ratio of 1.08:1 in their study.

The type of lesion whether lytic or sclerotic, helps in differentiating the types of tumors as the differential diagnoses are different. Our study showed 33 cases (47.14%) of sclerotic lesions, 29 cases (41.4%) of lytic lesions and 8 cases (11.42%) of mixed-density lesions. A study done by Ghadiali et al. 11 showed 46.7% of lesions being lytic in their study, 43.3% of lesions being mixed and 10% of lesions being sclerotic. This difference could be because of a smaller sample size in their study as only 30 cases were included in the study. The most common lesion in our study was osteochondroma, which was included in the sclerotic type of lesion. Azad et al. [9] documented 54% of lesions being lytic, 37% of lesions being sclerotic and 7.7% being mixed type. Other studies done by Salazar et al. [6], Naz et al. [8], Settakorn et al. [10] and Negash et al. [7] did not reveal any data on the type of the lesion.

The location of the lesion helps in narrowing down the differentials as different bone tumours have the propensity to occur at different locations in the long bone. Out of 70 cases in our study, the most common site involved was the metaphysis, seen in 18 patients (25.7%). A study done by Ghadiali et al. [11] showed the most common site of origin was epi-metaphysis in 30% of cases, followed by metaphysis and diaphysis in 26.7% of cases each. The second most common site affected in long bones in our study was the epi-metaphysis, seen in 18.6% of cases followed by meta-diaphysis in 17.1% of cases. In a study done by Azad et al. [9], the most common site of the lesion was the epi-metaphysis in 34.8% of cases, followed by diaphysis in 27.2%. Metaphyseal involvement was noted in 20.7% of cases. Salazar et al. [6] did not reveal any data on the location of the lesion.

Defining a lesion wrongly as benign or malignant may have serious repercussions as the treating physician may ask for unnecessary investigations to find out the occult primary lesion, subjecting the patient to futile investigations. Which may lead to delay in the treatment or administration of completely wrong treatment. A bone biopsy can help in resolving this issue and let the physician make use of the best treatment modality available for the particular lesion in the younger patient population [12,13]. Even though the majority of the cases are managed correctly with the application of appropriate imaging modalities evading the need for invasive bone biopsy, it is very critical to carry out the risks vs benefits analysis in each individual patient [6].

Conclusion

Bone tumours have a very low incidence compared to other cancers worldwide [12]. However, they are one of the major causes of morbidity and mortality in the young population [14]. Imaging plays a crucial role in making an accurate diagnosis in such cases. Imaging is a relatively faster and non-invasive method compared to invasive bone biopsy. Our study showed high accuracy and good correlation of various imaging modalities compared to histopathology. This study reiterates the importance of radiographs in the evaluation of bone tumours. The initial diagnosis on radiographs was altered in only eight out of seventy cases taking into account the additional findings detected on CT and MR imaging. Plain radiographs are therefore of paramount importance in the diagnosis of bone tumours with cross-sectional imaging playing a

supplementary role in evaluating additional tumour characteristics. Histopathology remains the gold standard in all patients. Hence a multimodality imaging approach should be used in the evaluation of bone tumours with radiographs remaining indispensable.

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