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# Sonographic characteristics of local soft tissue recurrence in primary bone tumor and diagnostic efficacy versus MRI

Ping Yu<sup>1†</sup>, Junxue Gao<sup>2†</sup>, Yue Hu<sup>1</sup>, Jiaan Zhu<sup>1</sup> and Yu Wang<sup>1\*</sup>

## Abstract

**Background** The accurate diagnosis of local soft tissue recurrence (LR) in primary bone tumors is crucial for guiding clinical management and predicting patient outcomes. However, standardized postoperative surveillance protocols remain undefined. This study aims to compare the diagnostic efficacy of ultrasound (US) versus magnetic resonance imaging (MRI) in detecting LR following primary bone tumor surgery and to characterize the sonographic features of osteosarcoma recurrence.

**Methods** We conducted a retrospective review of medical records from patients who underwent postoperative surveillance for primary bone tumors at our institution between 01/06/2016 to 01/09/2023. Diagnostic performance was compared using McNemar's test for paired variables. Sonographic characteristics were analyzed using logistic regression analysis, with statistical significance set at  $p < 0.05$ .

**Results** Comparative analysis revealed no statistically significant differences ( $p > 0.05$ ) in sensitivity, specificity, or accuracy between MRI and US, and the exact values for these parameters are provided in Table 1. Key sonographic features predictive of osteosarcoma recurrence included tumor size and anatomical location. The diagnostic model demonstrated excellent discriminative ability, with an area under the receiver operating characteristic (ROC) curve of 0.973. The diagnostic parameters were as follows: sensitivity (96.6%), specificity (90.9%), accuracy (94.6%), positive predictive value (95.0%), and negative predictive value (93.8%).

**Conclusion** The findings from this study support the role of ultrasonography as a valuable tool in tumor surveillance paradigms, providing a scientific rationale for optimizing integrated management strategies in bone oncology.

**Keywords** Ultrasound, Magnetic resonance imaging, Local recurrence, Primary bone tumors, Limb salvage, Logistic regression analysis

## Background

Primary malignant bone tumors represent a rare and histologically diverse group of neoplasms originating in bone tissue, encompassing distinct pathological entities such as osteosarcoma (OS), Ewing sarcoma (ES), and chondrosarcoma (CS) [1, 2]. These malignancies demonstrate a higher incidence among adolescents and young adults compared to other cancers, often resulting in significant limb dysfunction and substantial reduction in life expectancy [3]. Recent advances in tumor biology, enhanced preoperative diagnostic imaging, effective neoadjuvant

<sup>†</sup>Ping Yu and Junxue Gao joint first authors.

\*Correspondence:

Yu Wang

wangyu.vivian@outlook.com

<sup>1</sup> Department of Ultrasound, Peking University People's Hospital, Beijing 100044, China

<sup>2</sup> Department of Ultrasound, Xiang'an Hospital of Xiamen University, Xiamen 361101, China



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chemotherapy protocols, and refined surgical techniques have established limb-salvage surgery as the preferred approach for local control of aggressive bone tumors [3]. Limb-salvage surgery, defined as a surgical intervention aimed at preserving and restoring bone and joint function following extensive resection of malignant bone tumors in the extremities [4], offers superior functional, psychological, and cosmetic outcomes compared to amputation. However, it carries comparable risks of metastasis and local recurrence (LR) as amputation procedures. Notably, LR serves as a significant prognostic indicator for reduced survival in patients with operable primary osteosarcoma [5], with recurrent lesions exceeding 5 cm and concurrent metastases representing independent predictors of poor prognosis [6]. Early detection of LR through vigilant surveillance may theoretically improve survival outcomes in patients with primary bone tumors [7].

Imaging plays a crucial role in postoperative follow-up; however, there remains a lack of consensus regarding the optimal follow-up protocol after surgery [8, 9]. Each imaging modality possesses its own strengths and limitations. For instance, MRI excels in soft tissue imaging and offers valuable insights for tumor detection, characterization, staging, and post-treatment monitoring [10]. Nevertheless, its imaging quality can be significantly compromised by artifacts caused by metallic prostheses. While ultrasound (US) has inherent limitations in evaluating bone tumors, it demonstrates utility in assessing LR postoperatively and is unaffected by prosthetic artifacts. Currently, there is a paucity of literature on the imaging features of LR following bone tumor surgery. Notably, the ESMO Guidelines Committee's 2021 Clinical Practice Guidelines for the diagnosis, treatment, and follow-up of bone tumors did not establish definitive recommendations for postoperative surveillance of bone tumors, owing to divergent expert opinions and the lack of formal prospective studies [11]. Therefore, this study aims to evaluate the diagnostic performance of MRI and US in detecting local recurrence (LR) of primary malignant bone tumors and to characterize the US imaging features of postoperative soft tissue recurrence in bone tumors.

## Materials and methods

### Study subjects

This study was a retrospective analysis of routinely acquired imaging and clinical data. First, we screened patients from the ultrasound system for postoperative follow-up of bone tumors. The MRI follow-up data and pathological data of the patients were then obtained from the relevant databases. The analysis was performed on the data of patients who were received MRI and US surveillance in Peking University People's Hospital after

surgery for primary bone tumors from 01/06/2016 to 01/09/2023.

### Diagnostic criteria of LR

Two experienced radiologists (Yu Wang and Ping Yu), blinded to pathological data, independently reviewed all images. Discrepancies were resolved through consensus. Multiple recurrences in a single patient were counted as separate cases. Inclusion Criteria for US vs. MRI Comparison: 1) Pathologically confirmed recurrence or non-recurrence; 2) Non-recurrence confirmed by  $\geq 6$  months of clinical and imaging follow-up; 3) Availability of both US and MRI imaging; 4) Inclusion of diverse bone tumor types (OS, ES, CS). Inclusion Criteria for US Imaging Analysis: 1) Pathologically confirmed recurrence or non-recurrence; 2) Non-recurrence confirmed by  $\geq 6$  months of clinical and imaging follow-up; 3) Largest lesion selected for patients with multiple lesions; (4) Pathologically confirmed osteosarcoma (OS) cases only. Exclusion criteria: 1) Isolated calcifications; 2) Suspected recurrence without pathological confirmation; 3) Suspected non-recurrence without pathological or  $\geq 6$ -month clinical/imaging follow-up.

### Diagnostic value of MRI and US

MRI and US were used to detect local tumor recurrence after primary bone tumor surgery. The diagnostic performance of each modality was evaluated based on sensitivity, specificity, and accuracy. The following definitions were applied to calculate sensitivity, specificity, and diagnostic accuracy [12]:

1. True positive (TP): Pathologically confirmed LR.
2. False positive (FP): Imaging-suspected LR without pathological confirmation.
3. True negative (TN): Pathologically confirmed absence of LR or  $\geq 6$  months of recurrence-free clinical follow-up.
4. False negative (FN): Imaging-negative cases with pathologically confirmed LR.

### Sonographic characteristics of LR

Two radiologists—an attending physician (8 years of superficial US experience) and an associate chief physician (14 years of superficial US experience)—conducted double-blind image interpretation. Discrepancies were resolved through consensus. The following sonographic features of LR were evaluated: nodule number (single vs. multiple), maximum lesion diameter, shape (regular vs. irregular), margin (well-defined vs. ill-defined), depth (superficial vs. deep fascia), calcification (present vs. absent), cortical contour (smooth vs. irregular), and vascularity (detectable vs. undetectable).

**Table 1** Diagnostic performance of surveillance US and MRI scans for detection of local recurrent primary bone tumor

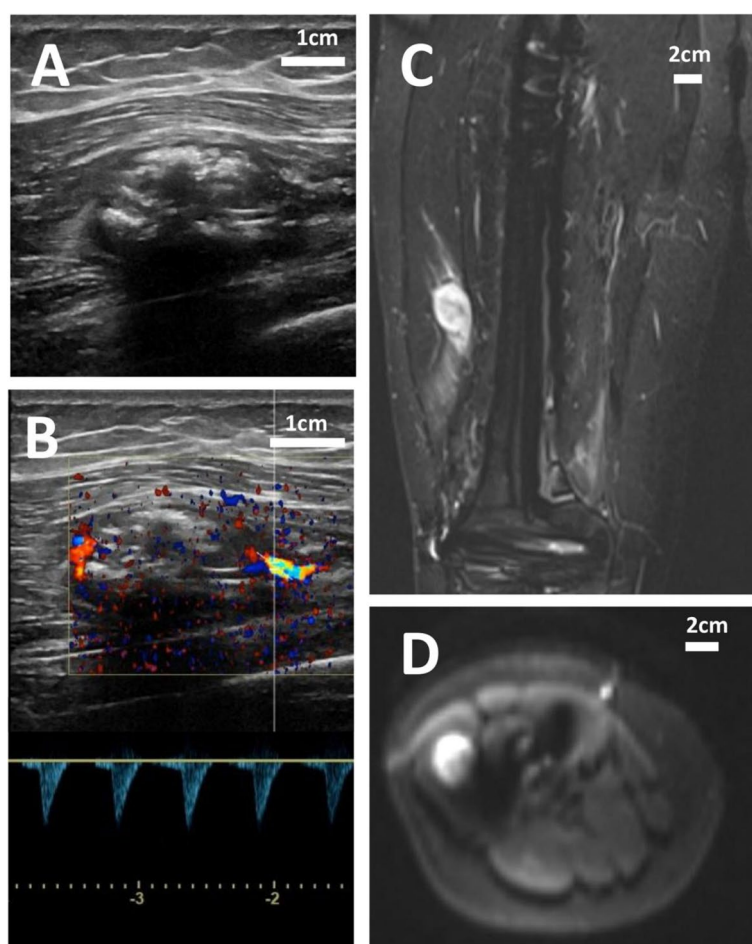
Variables	Pathology		Sensitivity	Specificity	Accuracy	PPV	NPV
	Positive	Negative					
US (n = 56)							
Positive	26	2	89.66%	92.59%	91.07%	92.86%	89.29%
Negative	3	25					
MRI (n = 56)							
Positive	23	2	79.31%	92.59%	85.71%	92.00%	80.65%
Negative	6	25					

US Ultrasound, MRI Magnetic resonance imaging, NPV Negative predictive value, PPV Positive predictive value

### Statistical analyses

The McNemar's Chi-squared test was employed for US-MRI comparisons. Continuous variables (age, lesion diameter) were analyzed using independent sample t-tests, while categorical variables were assessed with McNemar's test. Statistically significant sonographic features were included as independent variables in

binary logistic regression analysis. A regression model was constructed, and diagnostic performance was evaluated using receiver operating characteristic (ROC) curve analysis with area under the curve (AUC) calculation. All analyses were conducted using R (v3.5.1) or SPSS® (v24.0), with  $p < 0.05$  considered statistically significant.



**Fig. 1** Representative imaging findings of the lesion on US and MRI. **A** Longitudinal US image demonstrating a heterogeneous echogenic mass. **B** Corresponding US image showing intramuscular localization with vascularity and calcifications. **C** MRI STIR sequence revealing perioperative high signal intensity. **D** Diffusion-weighted MRI exhibiting restricted diffusion within the nodule

## Results

### Results of the US versus MRI comparison study

#### Characteristics of study subjects

Fifty-six cases were involved. The mean age was  $20.38 \pm 1.60$  years, and there were 32 (57.63%) males. Osteosarcoma ( $n = 43$ ) was accounted for 76.79% of all cases, Ewing's sarcoma 12.50% ( $n = 7$ ), and Chondrosarcoma 10.71% ( $n = 6$ ).

#### Diagnostic performance of US and MRI

Regardless of lesion size and position, there was no significant difference ( $P > 0.05$ ) in the sensitivity, specificity and accuracy of the two examination methods (Table 1).

#### Diagnostic performance and imaging features of the cases with erroneous US/MRI findings

Figure 1 demonstrates the capability of both US and MRI in detecting LR, though false-positive and false-negative results remain inherent limitations. Two false-positive cases were identified by both modalities, involving lower extremity osteosarcoma. In one case, misdiagnosis likely resulted from sampling error due to limited tissue acquisition via needle biopsy. In the other, diagnostic uncertainty arose from the imaging overlap between inflammatory changes and tumor recurrence.

Three false-negative US findings were identified, all involving thigh osteosarcoma. One case was misdiagnosed due to misinterpretation of recurrence as synovial hyperplasia, while the other two cases resulted from osseous rather than soft tissue recurrence. Six false-positive

MRI findings were observed, all in osteosarcoma patients (1 lower extremity, 5 thigh). As illustrated in Fig. 2, all six cases demonstrated significant prosthesis-related artifacts on MRI. Additionally, one case may have been misclassified due to osseous recurrence.

### Results of ultrasonographic feature analysis

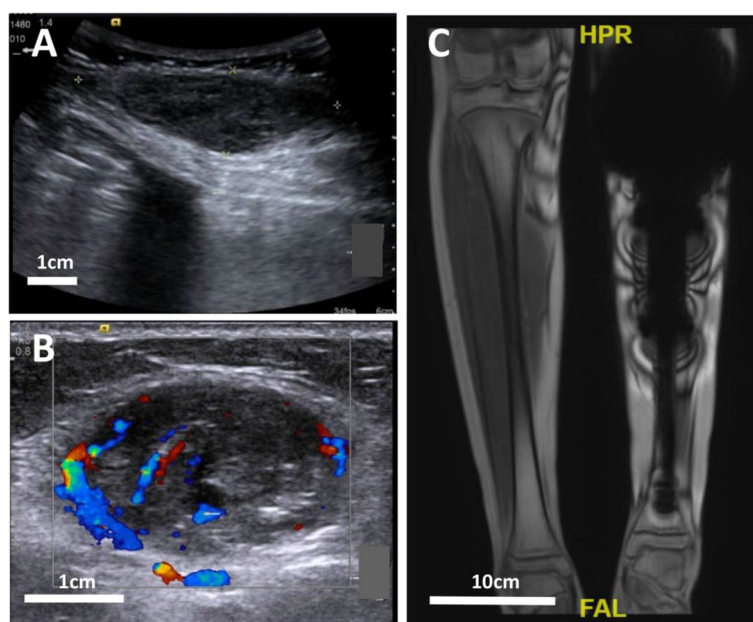
#### Results of single-factor analysis

Pathological examination confirmed 59 recurrent and 2 non-recurrent cases, while 31 non-recurrent cases were verified through  $\geq 6$  months of clinical and imaging follow-up. Compared to the non-LR group, LR cases predominantly exhibited single nodules, larger tumor diameters, and deep fascial involvement (all  $P < 0.05$ ). The non-LR group demonstrated higher rates of calcification and cortical smoothness (both  $P < 0.05$ ). Both groups showed similar characteristics of irregular nodule morphology, well-defined margins, and detectable vascularity, with no significant differences (all  $P > 0.05$ ) (Table 2).

#### Results of multi-factor analysis

Binary logistic regression analysis identified tumor size and growth location as independent predictive factors for distinguishing LR from postoperative changes (Table 3).

The diagnostic performance of the logistic regression model for distinguishing LR from non-LR was assessed using ROC curve analysis. The model was defined as:  $\text{Logistic}(Y) = -7.178 + 5.064X_1 + 1.266X_2$ . The area under the ROC curve (AUC) was 0.973, with a maximum



**Fig. 2** Comparative imaging findings demonstrating lesion visibility on US but not MRI. **A** US image revealing a hypoechoic mass in the left leg's postoperative soft tissue. **B** Additional US image showing a vascularized mass within the lateral gastrocnemius. **C** MRI T1-weighted image obscured by metal prosthesis artifacts, preventing lesion visualization

**Table 2** Clinical data for the patients and single factor analysis of ultrasonographic features

	Definition	Total	no-recurrence	recurrence	p Value
<b>Characteristics</b>					
Sex					0.898
Women	0	33	15	18	
Man	1	59	26	33	
Age					0.058
Mean ± SD			18.03 ± 1.51	21.83 ± 1.82	
<b>Imaging features</b>					
Number of nodules					0.014
Multiple	1	40	18	22	
Single	0	52	15	37	
Size (CM)					< 0.001*
Mean ± SD			1.85 ± 0.14	5.68 ± 0.36	
Shape					0.743
Regular	0	30	13	17	
Irregular	1	62	20	42	
Margin					0.296
Well-defined	1	66	20	46	
Ill-defined	0	26	13	13	
Location					0.039*
Shallow fascia	0	26	25	1	
Deep fascia	1	66	8	58	
Calcification					< 0.001*
Presence	1	24	10	14	
Absence	0	68	23	45	
Cortical smoothness					< 0.001*
Smooth	1	7	2	5	1
Non-smooth	0	92	31	54	
Vascularity					0.665
Detectable	1	55	22	33	
Undetectable	0	37	11	26	

The asterisk designates the statistically significant features if *p* value is less than 0.05

Youden's index of 0.875 (Fig. 3). The model demonstrated sensitivity of 96.6%, specificity of 90.9%, and accuracy of 94.6%, with positive and negative predictive values of 95.0% and 93.8%, respectively.

**Table 3** Clinical data for the patients and single factor analysis of ultrasonographic features

Variables	OR	95% C.I		P Value
		lower limit	upper limit	
Location	158.231	3.672	6817.813	0.008*
Size	3.547	1.699	7.404	0.001*
Calcification	0.475	0.059	3.837	0.485
Cortical smoothness	2.416	0.002	2624.342	0.805

The asterisk designates the statistically significant features if *p* value is less than 0.05

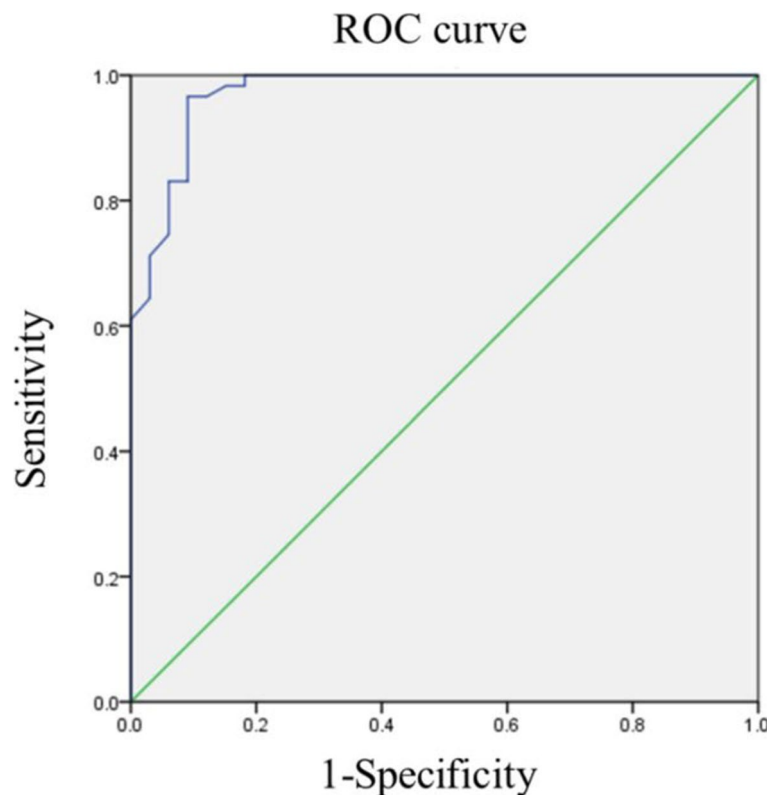
OR odds ratio, C.I. Confidence interval

## Discussion

Limb salvage surgery demonstrates comparable post-operative survival rates to radical resection [4], making it the preferred choice for patients with malignant bone tumors [13]. Prosthetic reconstruction remains the most widely utilized and effective limb salvage technique. Recent surveys have shown that the clinical 10-year satisfaction rate of a good quality prosthesis can reach 90% [14]. However, metal implants generate significant artifacts on MRI [15, 16], limiting its utility despite excellent soft tissue contrast for evaluating musculoskeletal structures, neurovascular relationships, and tumor extent [17–19]. As demonstrated in Fig. 2, US enables better lesion visualization compared to MRI in these cases due to its immunity to metallic artifacts.

Akihiko et al. demonstrated a 30% 5-year overall survival rate following osteosarcoma LR, identifying recurrent tumor size as a key prognostic indicator [20]. Early





**Fig. 3** The ROC curve of logistic regression

LR detection is therefore critical for improving patient outcomes [12]. However, small LR lesions are often non-palpable and challenging to differentiate from post-radiotherapy fibrosis or scar tissue. These recurrences may occur at various sites, including the primary tumor location, resection margins, or periprosthetic regions. Conventional radiographs and bone scans frequently fail to detect soft tissue recurrences lacking mineralized osteoid [21]. Our previous work established US as a non-invasive first-line imaging modality for detecting LR in primary bone tumors: the sensitivity and accuracy of US was higher than that of x-ray, and there is demonstrated no statistically significant differences in the sensitivity, specificity and accuracy among US, CT and 99 mTc-MDP bone scan [12]. The current study further demonstrates comparable efficacy between US and MRI for postoperative surveillance. Notably, this investigation represents one of the first comprehensive analyses of sonographic predictors for postoperative osteosarcoma LR. Logistic regression identified lesion size and deep fascial location as significant diagnostic indicators. Future research should use advanced ultrasonographic techniques to enhance postoperative surveillance strategies for bone tumors, addressing current limitations and optimizing diagnostic accuracy in clinical practice.

Several limitations should be acknowledged in this study. First, a sample size of less than 100 cases is a relatively small cohort that makes it difficult to draw definitive conclusions. Second, the retrospective nature of this study limits the generalizability of these findings, and a prospective study is needed in the future. Third, Interobserver variability in image interpretation among radiologists could affect diagnostic consistency as ultrasound interpretation depends on the operator-dependent variability. Finally, while MRI provides comprehensive evaluation of both osseous and soft tissue structures throughout the entire limb, US is limited to targeted soft tissue assessment. Our study focused specifically on comparing these modalities for detecting soft tissue recurrence following bone tumor surgery, rather than evaluating their complete diagnostic capabilities.

### Conclusions

While MRI demonstrates high sensitivity for musculoskeletal evaluation, its utility in postoperative surveillance of prosthetic reconstruction is significantly limited by metal-induced artifacts that compromise soft tissue assessment. In such cases with metal artifacts, US is complementary to MRI. Our logistic regression

analysis identified lesion size and deep fascial location as key sonographic predictors of osteosarcoma recurrence. The robust evidence derived from this investigation underscores the pivotal role of ultrasonography in contemporary tumor surveillance paradigms, providing a scientific rationale for optimizing integrated management strategies in bone oncology.

#### Abbreviations

US	Ultrasound
MRI	Magnetic resonance imaging
OS	Osteosarcoma
ES	Ewing sarcoma
CS	Chondrosarcoma
PPV	Positive predictive value
NPV	Negative predictive value
TP	True positive
FP	False positive
TN	True negative
FN	False negative
LR	Local soft tissue recurrence

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Not applicable.

#### Authors' contributions

YW: Funding acquisition, Supervision and critical revision of the manuscript. PY: Resources, Data curation, formal analysis, and visualization. JG: Funding acquisition, validation, and manuscript drafting. YH: Investigation and Data curation. JZ: Conceptualization and Methodology. All authors read and approved the final manuscript.

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#### Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

#### Declarations

##### Ethics approval and consent to participate

The retrospective analysis of available patient data was performed in accordance with the declaration of Helsinki. This study was approved by the ethics committee at Ethics Committee of Peking University People's Hospital. (Approval No.2021PHB061 -001). This retrospective study was conducted in accordance with "Ethical Review Measures for Biomedical Research Involving Human Subjects" promulgated by the Chinese government. The need for written informed consent was waived by ethics committee of Peking University People's Hospital due to the retrospective nature of the study.

##### Consent for publication

Not applicable.

##### Competing interests

The authors declare no competing interests.

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