Predictive Factors Influencing Diagnostic Yield in Image-Guided Bone Biopsies: A Retrospective Analysis

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Abstract

Aim: To evaluate the factors that influence the diagnostic yield of image-guided percutaneous core needle biopsy (CNB) for bone lesions.

Method: A retrospective analysis was conducted on 211 patients who underwent 226 image-guided percutaneous core needle biopsies for bone lesions between June 2020 and June 2024. The variables evaluated included patient age, lesion location, the modality used for biopsy guidance (ultrasound vs. CT), and pre-biopsy imaging techniques (PET/CT, MRI).

Results: Diagnostic adequacy was achieved in 70.1% of cases. Key findings revealed that patients with adequate diagnostic yield were significantly older than those with inadequate yield (p=0.001). Lesions located in the lower extremity were more frequently associated with inadequate diagnostic yield (p=0.029), and the use of CT guidance was more common in this group (p<0.001). Additionally, pre-biopsy MRI use was higher in the inadequate yield group (p=0.005), while pre-biopsy PET scan use was lower (p=0.034). Among patients who underwent pre-biopsy PET scans, those with adequate diagnostic yield had significantly higher SUV values compared to those with inadequate yield (p=0.004)

Conclusion: This study highlights key factors influencing diagnostic yield in bone biopsies, providing insights that can guide clinical decision-making. Understanding these factors may help improve diagnostic yield, aiding in appropriate treatment planning for patients with bone lesions.

Keywords: Bone neoplasms, image-guided biopsy, computed tomography, ultrasonography.

Görüntüleme Eşliğinde Yapılan Kemik Biyopsilerinde Tanı Yeterliliğini Etkileyen Faktörler: Retrospektif Bir Analiz Çalışması

Öz

Amaç: Kemik lezyonları için görüntüleme eşliğinde yapılan perkütan kor iğne biyopsisinin tanı yeterliliğini etkileyen faktörleri değerlendirmek.

Yöntem: Haziran 2020 ile Haziran 2024 arasında kemik lezyonları için 226 görüntüleme eşliğinde perkütan kor iğne biyopsisi uygulanan 211 hasta retrospektif olarak değerlendirildi. Hasta yaşı, lezyon lokalizasyonu, biyopsi rehberliğinde kullanılan modalite (ultrason vs. BT) ve biyopsi öncesi görüntüleme yöntemleri (PET/CT, MRI) gibi çeşitli değişkenlerin biyopsi yeterliliği üzerindeki etkisi araştırıldı.

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ETHICAL STATEMENT: Before the start of the research, a written decision No: 237 was taken from the Ethics Committee of University of Health Sciences, Istanbul Training and Research Hospital. Ethics committee was taken on 15.09.2023.

Bulgular: Olguların %70,1'inde (148/211) biyopsi sonucu tanısal açıdan yeterli bulundu. Daha ileri yaş grubunda tanısal yeterlilik oranı anlamlı olarak daha yüksek saptandı (p=0,001). Üst ekstremite ve aksiyal iskelet yerleşimli lezyonlarda tanısal yeterlilik daha yüksek bulundu. US rehberliğinde biyopsi yapılan olgularda, BT rehberliğine göre daha yüksek oranda yeterlilik sağlandı (p<0,001). Ayrıca, biyopsi öncesi MRI kullanımı yetersiz tanı gruplarında daha yüksekken (p=0,005), biyopsi öncesi PET/CT kullanımı daha düşük bulundu (p=0,034). Biyopsi öncesi PET/CT yapılan hastalarda, yeterli tanı sağlananların SUV değerlerinin, yetersiz tanı sağlananlara göre anlamlı derecede yüksek olduğu görüldü (p=0,004).

Sonuç: Çalışma, kemik biyopsilerinde tanı yeterliliğini etkileyen faktörleri ortaya koymakta ve klinik karar verme sürecinde yol gösterici olabilecek önemli bilgiler sunmaktadır. Bu faktörlerin anlaşılması, tanı yeterliliğini artırarak kemik lezyonları olan hastaların tedavi planlamasına katkıda bulunabilir.

Anahtar Sözcükler: Kemik neoplazmları, görüntüleme eşliğinde biyopsi, bilgisayarlı tomografi, ultrasonografi, iğne biyopsisi.

Introduction

Although advanced medical imaging techniques offer valuable insights for characterizing bone lesions, histopathological examination is often required for subsequent treatment planning[1]. While open surgical biopsies are considered the gold standard for obtaining tissue for diagnosis, image-guided percutaneous core needle biopsy has become the initial method of choice for diagnosing musculoskeletal lesions at many institutions. This preference is due to its less invasive nature, reduced sedation time, lower cost, shorter recovery time, and fewer complications[2]. Image-guided core needle biopsies are usually performed using ultrasound or CT guidance and have a high diagnostic accuracy, ranging from 66% to 98%[2-11].

The diagnostic yield of percutaneous image-guided bone biopsies is influenced by numerous factors. However, there are several studies that examine the predictive factors affecting the diagnostic yield of image-guided percutaneous core needle biopsy (CNB) for bone lesions[1,2,11-20].

This retrospective single-center study aimed to identify the factors influencing the diagnostic yield of image-guided percutaneous CNB for bone lesions by examining variables related to patient demographics, bone lesion characteristics, biopsy procedures, and imaging techniques.

Material and Methods

Ethics Approval

The study received approval from the Cam and Sakura City Hospital Ethics Committee (approval date: June 22, 2023, approval number: 2023-275).

Patient Cohort

Between June 2020 and June 2024, 225 patients referred for percutaneous image-guided biopsy of bone lesions were retrospectively evaluated. Fourteen patients with incomplete clinical data or inaccessible pre-procedure imaging were excluded, resulting in 211 patients with complete records, accessible pre-procedure imaging, and pathology results. Sixteen of these patients underwent two biopsies, bringing the total to 226 procedures evaluated. Biopsies were conducted on musculoskeletal lesions of uncertain origin or suspected malignancy, with decisions made collaboratively by orthopedic surgeons and radiologists based on clinical data and imaging findings.

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Pre-Biopsy Evaluation

Each patient's biopsy indication, lesion location, and suitability for the procedure (including hemogram, coagulation profiles, and medication use) were assessed. Previous imaging studies (CT, MRI, PET) were reviewed. Informed consent was obtained from all patients, who were informed about the procedure and potential complications.

Modality Selection

The choice of imaging modality was based on lesion location, size, type, and cortical involvement. Ultrasound was preferred for lesions visible by this method; otherwise, CT guidance was used. The biopsy approach was decided jointly by the orthopedic surgeon and radiologist to ensure the biopsy tract could be excised during surgery to prevent recurrence. Radiography, CT, MRI, or PET CT was used to assess lesion spread and assist in planning. In cases with multiple lesions, the most accessible lesion was selected for biopsy.

Biopsy Procedure

Each biopsy was conducted by the same interventional radiologist with eight years of experience in image-guided biopsies.

CT-Guided Biopsy

CT-guided biopsies were performed under local anesthesia with a Tru-Cut needle (Geotek, Ankara, Turkey). Depending on the lesion, either an 11-gauge bone biopsy needle or a 14-gauge core biopsy needle was used. Patients were positioned to optimize access and comfort. A scanogram was obtained to identify the target, and after local anesthesia, the needle was inserted with CT confirmation (Figure 1,2). Specimens were sent to pathology in 10% formalin.

Ultrasound-Guided Biopsy

Ultrasound-guided biopsies were conducted using a linear or convex probe (Hitachi Arietta 65, Tokyo, Japan). Real-time sonographic guidance and color Doppler were used to position the needle, avoid vascular structures, and target viable tissue. After local anesthesia, the biopsy needle was introduced under continuous ultrasound monitoring. A single core was collected and preserved in formalin for histopathological examination.

Data Collection and Definitions

Patient data were retrospectively reviewed, including demographics, biopsy details (date, site, approach, number of cores, complications), histopathology reports, additional biopsy sessions for inconclusive results, and any subsequent surgeries or follow-ups. Pre-biopsy imaging data (CT, MRI, PET) were collected, focusing on lesion size, location, type (lytic, sclerotic, mixed), and SUV max on PET CT. Lesions were categorized as lytic (bone destruction), sclerotic (increased bone density), or mixed (containing both dense and lucent components), based on radiological appearance. Measurements were taken along the maximum long-axis diameter. A musculoskeletal radiologist, blinded to pathology results, assessed all imaging features.

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Figure 1. A) A 45-year-old female patient with a history of breast cancer presents with a lytic lesion in the left iliac bone on CT imaging (indicated by a solid white arrow). B) A CT-guided core needle biopsy was performed (indicated by an open white arrow), confirming the diagnosis of breast cancer metastasis.

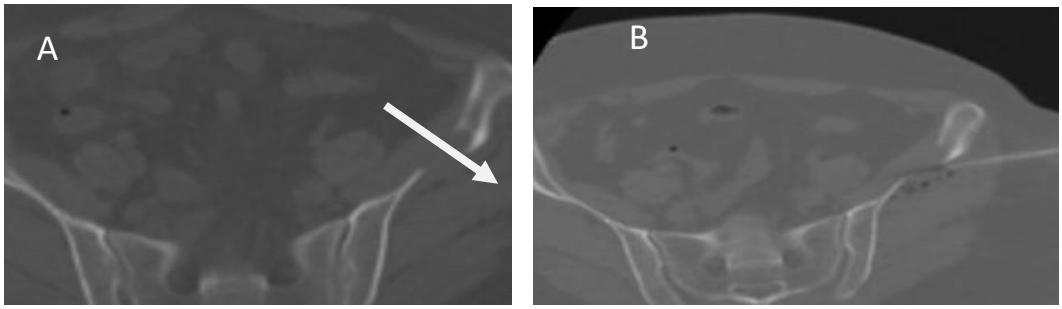
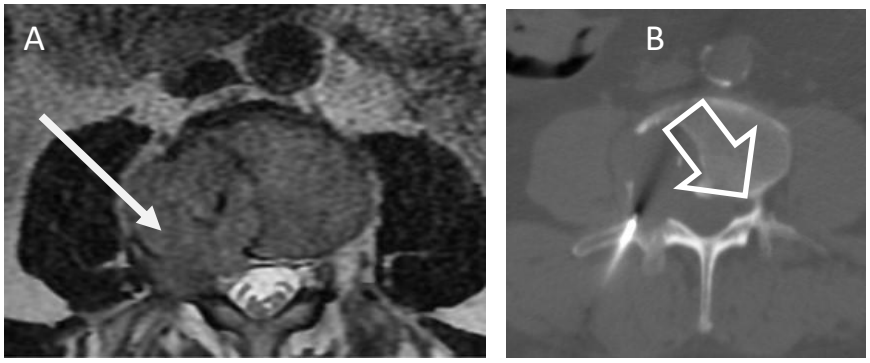


Figure 2. A) A 70-year-old male patient with a lytic lesion in the right pedicle of the L3 vertebral body, as indicated by the solid white arrow. B) CT-guided biopsy of the lesion confirmed a diagnosis of plasma cell neoplasm.



Diagnostic Yield Definition

Diagnostic yield was considered positive if the biopsy results matched post-surgical findings or provided a definitive pathological diagnosis consistent with stable imaging over six months. A negative yield was defined by discordance with post-surgical findings or insufficient specimen volume for diagnosis.

Statistical Analysis

Data analysis was performed using SPSS for Windows version 18.0 (SPSS Inc., Chicago, IL, USA). The normality of data distribution was assessed using the Shapiro-Wilk test. Numerical data were summarized with means, standard deviations, and medians, while categorical data were summarized with frequencies and percentages. The Mann-Whitney U test was used to analyze non-normally distributed numerical data, and chi-square tests were employed for categorical comparisons. Statistical significance was defined as $p<0.05$.

Results

This retrospective study included 211 patients who underwent biopsies for suspected bone lesions. The median age was 53 years (range 35-63 years), with 50.2% (n=106) being female. Diagnostic adequacy was achieved in 148 patients (70.1%), while 63

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patients (29.9%) had non-diagnostic biopsies. The most common diagnosis was metastasis, identified in 50 cases (33.8%). Detailed demographic and biopsy results are presented in Table 1.

Table 1. Patient demographics and disease characteristics

Characteristic	**All Patients (n=211) n (%)**
Diagnostic Adequacy	
Inadequate	63 (29.9)
Adequate	148 (70.1)
Diagnosis (n=148)	
Plasma Cell Neoplasm	21 (14.2)
Metastasis	50 (33.8)
Soft Tissue Sarcoma	31 (20.9)
Chondroma	5 (3.4)
Lymphoma	8 (5.4)
Ewing Sarcoma	4 (2.7)
Rhabdomyosarcoma	1 (0.7)
Giant Cell Tumor	2 (1.4)
Paget's Disease	2 (1.4)
Fibrous Dysplasia	5 (3.4)
Langerhans Cell Histiocytosis	2 (1.4)
Hemangioma	2 (1.4)
Rosai-Dorfman Disease	1 (0.7)
Pseudogout	1 (0.7)
Chondrosarcoma	2 (1.4)
Foreign Body Granuloma	1 (0.7)
Aneurysmal Bone Cyst	1 (0.7)
Osteosarcoma	2 (1.4)
Osteoblastoma	2 (1.4)
Myositis Ossificans	1 (0.7)
Sarcoidosis	1 (0.7)
Ganglion Cyst	1 (0.7)
Pleomorphic Sarcoma	1 (0.7)
Plasmacytoma	1 (0.7)

Among the 63 non-diagnostic cases, the reasons for non-diagnosis included necrosis in 27 cases, fragments of reactive bone tissue in 11 cases, and insufficient tissue for diagnosis in 25 cases. Of the 148 diagnostic biopsy cases, 12 were followed by surgical resection. In 11 of these cases (91.6%), the biopsy diagnosis matched the final surgical

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findings. However, one case initially diagnosed as osteosarcoma via biopsy was later identified as chondrosarcoma after surgical resection.

In 4 of the 63 non-diagnostic cases, the final diagnosis was confirmed through surgery, which revealed one case of plasma cell neoplasm, one case of osteosarcoma, and two cases of diffuse B-cell lymphoma. A total of 16 cases required repeat biopsy due to non-diagnostic results from the first biopsy. Among these repeat biopsies, 7 yielded a definitive diagnosis: three cases of carcinoma metastasis, two cases of plasma cell neoplasm, and two cases of osteosarcoma.

Lesion characteristics included: location in the lower extremity (n=125, 59.2%), CT-guided biopsy (n=160, 75.8%), lytic lesion type (n=140, 66.4%), a mean lesion long axis of 35.0 mm, and the use of an 11G needle gauge (n=131, 62.1%). Additionally, 48 patients (22.7%) had a pre-biopsy diagnosis of malignancy (Table 2).

Statistical analysis identified several predictors of diagnostic yield. Patients with adequate diagnostic yield were significantly older than those with inadequate yield (p=0.001). Biopsies in the lower extremity were more commonly associated with inadequate yield (p=0.029), and CT guidance was more prevalent in this group (p<0.001). Pre-biopsy MRI use was higher, while pre-biopsy PET scan use was lower in the inadequate yield group (p=0.005 and p=0.034, respectively). Additionally, among patients who underwent PET scans, those with adequate diagnostic yield had higher SUV values compared to those with inadequate yield (p=0.004) (Table 2).

Table 2. Comparison of Patient Demographics and Diagnostic Method Characteristics with Diagnostic Adequacy

Characteristic	All Patients (n=211)	Diagnostic Adequacy		**p**
		Inadequate (n=63)	Adequate (n=148)	
Age / Median (1st-3rd Quartile)	53.0 (35.0-63.0)	42.0 (26.0-56.0)	56.0 (39.2-65.0)	**0.001**[a]
Gender, n (%)				
Female	106 (50.2)	35 (55.6)	71 (48.0)	0.313[b]
Male	105 (49.8)	28 (44.4)	77 (52.0)	
Second biopsy, n (%)				
No	195 (92.4)	54 (85.7)	141 (95.3)	**0.020** [b]
Yes	16 (7.6)	9 (14.3)	7 (4.7)	
Lesion location, n (%)				
Upper extremity	16 (7.6)	3 (4.8)	13 (8.8)	**0.029** [b]
Lower extremity	125 (59.2)	46 (73.0)	79 (53.4)	
Axial	70 (33.2)	14 (22.2)	56 (37.8)	
Imaging guidance method, n (%)				
USG	51 (24.2)	4 (6.3)	47 (31.8)	**<0.001** [b]
CT	160 (75.8)	59 (93.7)	101 (68.2)	
Lesion characteristics, n (%)				
Lytic	140 (66.4)	38 (60.3)	102 (68.9)	0.481[b]
Sclerotic	37 (17.5)	13 (20.6)	24 (16.2)	

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Mixed type	34 (16.1)	12 (19.0)	22 (14.9)	
Lesion long axis (mm) Median (1st-3rd Quartile)	35.0 (22.0-54.0)	40.8 (21.0-55.0)	42.1 (22.0-54.0)	0.815[a]
Prebiyopsi, n (%)				
CT	112 (53.1)	30 (47.6)	82 (55.4)	0.300 [b]
MRI	134 (63.5)	49 (77.8)	85 (57.4)	**0.005 [b]**
PET/CT	69 (32.7)	14 (22.2)	55 (37.2)	**0.034 [b]**
PET SUV max (n=68) Median (1st-3rd Quartile)	5.7 (3.5-10.3)	3.5 (1.4-5.7)	6.4 (4.5-10.5)	**0.004[a]**
Needle gauge, n (%)				
11 G	131 (62.1)	48 (76.2)	83 (56.1)	-
13 G	28 (13.3)	10 (15.9)	18 (12.2)	
14 G	23 (10.9)	-	23 (15.5)	
16 G	25 (11.8)	5 (7.9)	20 (13.5)	
18 G	4 (1.9)	-	4 (2.7)	
Previous known malignancy, n (%)				
No	163 (77.3)	54 (85.7)	109 (73.6)	0.056 [b]
Yes	48 (22.7)	9 (14.3)	39 (26.4)	
Surgical definitive diagnosis, n (%)				
No	195 (92.4)	59 (93.7)	136 (91.9)	0.451 [b]
Yes	16 (.,6)	4 (6.3)	12 (8.1)	

[a]Mann-Whitney U test; [b] Chi- square test

Using the Society of Interventional Radiology Complication Classification System, no major complications were reported. Minor complications included hematomas at the entry site in two patients, which resolved spontaneously.

Discussion

In our retrospective study of 211 patients who underwent image-guided bone biopsies, we achieved a diagnostic adequacy rate of 70.1%. This result aligns well with previously reported diagnostic adequacy rates in the literature, which range from 66% to 98%[1,2,14]. This study identified several key factors associated with a higher likelihood of obtaining sufficient diagnostic information, including older age, the use of ultrasound for biopsy guidance, the presence of pre-biopsy PET/CT, higher SUV values, and lesions located in the upper extremity and axial skeleton.

Despite advancements in imaging techniques, accurately diagnosing bone lesions remains challenging. The primary clinical concern is differentiating between benign and malignant lesions, which directly impacts treatment decisions. PET/CT is particularly effective in identifying metabolically active regions, while MRI provides high-resolution visualization of both bone and soft tissue. Recent improvements in MRI technology have enhanced its role as a radiation-free alternative in select cases. Though unlikely to replace CT in emergency settings, MRI's expanding applications in diagnosis, treatment planning, and surgical guidance offer new possibilities for optimizing biopsy strategies.

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However, despite these advances, imaging alone often falls short of providing a definitive diagnosis, necessitating histopathological confirmation through biopsy[1,11,14,15].

Image-guided biopsy has become an indispensable tool in the diagnosis of bone lesions due to its minimally invasive nature, cost-effectiveness, and low complication rates. The diagnostic adequacy observed in our study (70.1%) aligns with previous findings, further reinforcing the reliability of this approach in clinical practice[1,2,14,21]. While percutaneous image-guided biopsy is the preferred method, other techniques such as fluoroscopic, MRI-guided, or open biopsy may be necessary in specific cases. Fluoroscopic-guided biopsy is primarily used for spinal lesions but has limited soft tissue resolution, making it less effective for heterogeneous bone lesions[22]. Open biopsy is sometimes required when percutaneous sampling fails, offering a diagnostic accuracy of 91%-96%, albeit at the cost of increased morbidity. Complications such as seroma, hematoma, infection, wound dehiscence with tumor fungation, and fractures occur more frequently after open or excisional biopsies. In contrast, percutaneous biopsy techniques have a significantly lower complication rate (0%-1%), whereas open surgical biopsies report higher rates, ranging from 4% to 19%[23,24]. MRI-guided biopsy is an alternative when CT fails to provide adequate visualization, offering superior accuracy but at a higher cost[25].

This study found that older age was significantly associated with a higher diagnostic yield in bone biopsies. Previous research has indicated that older patients are more likely to have malignant bone lesions, which typically yield better diagnostic results compared to benign lesions[4,9,17]. However, there is limited data directly correlating older age with improved diagnostic outcomes in bone lesions. This association may be due to age-related changes in bone density and composition, which could make lesions more distinct on imaging, thereby enhancing biopsy accuracy. Alternatively, the increased prevalence of malignancy in older patients may inherently result in a higher diagnostic yield[4,9]. These hypotheses underscore the need for further studies to explore the mechanisms by which age influences diagnostic success in bone biopsies.

Ultrasound guidance was identified as an effective predictor of diagnostic yield in our study and is the preferred method for musculoskeletal biopsies in our clinic, particularly for lesions visible on ultrasound, such as those with cortical thinning or destruction and extraosseous soft tissue involvement. The benefits of ultrasound—real-time imaging, absence of ionizing radiation, lower cost, and effectiveness in visualizing soft tissues—contribute to its higher diagnostic success[16,26]. In contrast, CT guidance was more often associated with inadequate yield, likely due to its use in deeper, less accessible lesions. Ultrasound is particularly useful for lytic bone lesions with cortical disruption, especially in the extremities or pelvis with soft tissue components, making it an excellent choice in these cases[26]. However, CT remains essential and most commonly used for biopsies of deep or non-cortical destruction lesions where ultrasound is not feasible[27].

This study also demonstrated that pre-biopsy imaging is a significant predictor of diagnostic yield. The presence of pre-biopsy PET/CT, particularly with higher SUV values, was associated with a higher diagnostic yield. PET/CT is highly effective in identifying metabolically active lesions, which allows for the targeting of the most suitable biopsy sites. It can also reveal occult lesions, highlight necrotic or inhomogeneous areas, and, in cases with multiple lesions, identify the most

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metabolically active lesion, ensuring that the biopsy is taken from the area most likely to yield diagnostic information[28]. This targeted approach increases the likelihood of obtaining a diagnostic sample.

Lesion location was another significant factor in diagnostic yield, with higher success rates observed in upper extremity and axial skeleton lesions. This may be due to the accessibility and distinct pathological features of lesions in these areas, which often lead to better imaging and biopsy outcomes. Studies have shown that diagnostic yield is generally higher in axial lesions compared to appendicular ones, likely because axial bone pathology tends to be more aggressive or advanced at diagnosis[27]. These anatomical and pathological differences between axial and appendicular regions likely account for the observed disparities in diagnostic yields.

Studies findings highlight the importance of carefully considering patient demographics, lesion characteristics, and imaging modalities when planning bone biopsies. By aligning the biopsy approach with these factors, diagnostic yield can be enhanced, the need for repeat procedures reduced, and patient outcomes ultimately improved.

Despite the valuable insights gained from this study, there are some limitations to consider. First, the retrospective nature of the study introduces the potential for selection bias. Second, the single-center and single-operator design may limit the generalizability of the findings. Third, not all patients had surgical pathology results or follow-up data, which could affect the accuracy of the conclusions. To address these limitations, future prospective studies with larger, multicenter cohorts could provide more robust and generalizable data, helping to refine predictive models for diagnostic yield in bone biopsies. Additionally, exploring newer imaging techniques, such as MRI-guided biopsies or fusion imaging, could further improve diagnostic outcomes and should be a focus of future research.

Conclusion

In conclusion, this study highlights the complexity of achieving optimal diagnostic yield in bone biopsies and identifies key predictive factors that can guide clinical decision-making. By understanding these factors, clinicians can enhance the likelihood of obtaining sufficient diagnostic information, which in turn facilitates accurate diagnosis and appropriate treatment planning for patients with bone lesions.

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