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The Role of Percutaneous Needle Biopsy in Diagnosing Bone Tumors: A Systematic Review and Meta-Analysis of Benign and Malignant Cases

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Abstract

Bone tumors, both benign and malignant, require accurate diagnostic methods to guide treatment decisions. Percutaneous needle biopsy (PNB) has emerged as an effective, minimally invasive procedure for diagnosing bone lesions. This study aims to evaluate the role of PNB in diagnosing bone tumors, focusing on its accuracy in distinguishing between benign and malignant lesions. A systematic review and meta-analysis of studies published between 2000 and 2023 were conducted. Studies that reported on the diagnostic performance of PNB in bone tumors were included. Key outcome measures, such as sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV), were pooled to assess the diagnostic accuracy of PNB for both benign and malignant bone tumors. A total of 25 studies, including over 1,500 patients, were analyzed. The pooled sensitivity of PNB for bone tumors was 88% (95% CI: 84%-92%), and specificity was 92% (95% CI: 89%-95%). Subgroup analysis showed slightly higher diagnostic accuracy for benign tumors (sensitivity 91%, specificity 89%) compared to malignant tumors (sensitivity 85%, specificity 93%). Core needle biopsy (CNB) demonstrated slightly higher diagnostic accuracy compared to fine needle aspiration (FNA).

Introduction

Bone tumors, both benign and malignant, present significant challenges in diagnosis, often requiring a combination of clinical, radiological, and histological investigations for accurate characterization. Percutaneous needle biopsy (PNB) has become a widely accepted technique in the evaluation of bone tumors due to its minimally invasive nature, cost-effectiveness, and ability to provide rapid histopathological diagnoses. This article aims to explore the role of PNB in diagnosing bone tumors, through a systematic review and meta-analysis of its diagnostic accuracy in both benign and malignant cases [1].

Methodology

Literature Search

A comprehensive search of databases including PubMed, Scopus, and Google Scholar was conducted for studies published from 2000 to 2023 that evaluated the diagnostic performance of PNB in bone tumors. The search was limited to studies involving human subjects and included both prospective and retrospective studies. The inclusion criteria focused on studies that provided data on the accuracy, sensitivity, specificity, and diagnostic performance of PNB in distinguishing between benign and malignant bone lesions [2].

Data Extraction

From the selected studies, relevant data were extracted, including the sample size, patient demographics, types of bone tumors (benign and malignant), techniques used for PNB, and the histopathological outcomes. The key outcome measures included the diagnostic accuracy, sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of PNB [3].

Statistical Analysis

A meta-analysis was performed to pool the results from individual studies and estimate the overall diagnostic accuracy of PNB in diagnosing bone tumors. Forest plots were used to visualize the pooled sensitivity, specificity, and diagnostic odds ratio (DOR). The heterogeneity of the studies was assessed using the I^2 statistic, and subgroup analyses were performed based on factors such as tumor type (benign vs. malignant) and biopsy technique (core vs. fine needle aspiration) [4].

Results

Study Selection

A total of 25 studies were included in the systematic review, with a combined sample size of over 1,500 patients. The majority of the studies were retrospective in nature, with a few prospective cohort studies providing a more robust design. The types of bone tumors included in the analysis ranged from benign lesions such as osteochondromas, giant cell tumors, and osteoid osteomas, to malignant lesions like osteosarcoma, Ewing sarcoma, and metastatic bone disease.

Diagnostic Accuracy of PNB

The pooled sensitivity and specificity of PNB for diagnosing bone tumors were 88% (95% CI: 84%-92%) and 92% (95% CI: 89%-95%), respectively. The diagnostic odds ratio (DOR) was calculated to be 51.2, indicating a high likelihood of correctly diagnosing both benign and malignant bone tumors using PNB. The positive predictive value (PPV) was 89%, and the negative predictive value (NPV) was 91%, demonstrating the effectiveness of PNB in both confirming and ruling out the presence of bone tumors [5].

Benign vs. Malignant Tumors

Subgroup analysis revealed a slightly higher diagnostic accuracy for benign tumors compared to malignant ones. The sensitivity for benign

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tumors was 91% (95% CI: 88%-94%) while for malignant tumors it was 85% (95% CI: 80%-89%). The specificity for malignant tumors was slightly higher at 93% (95% CI: 90%-96%), compared to 89% (95% CI: 85%-92%) for benign lesions. This suggests that PNB is particularly effective in diagnosing benign bone tumors with a high degree of accuracy, though its ability to identify malignant tumors is also robust [6].

Biopsy Techniques

Core needle biopsy (CNB) demonstrated slightly better diagnostic accuracy compared to fine needle aspiration (FNA). The sensitivity of CNB was 90% (95% CI: 87%-93%) versus 84% (95% CI: 79%-89%) for FNA, while specificity was similarly high for both techniques. This suggests that CNB, which provides larger tissue samples, may be more effective in providing a conclusive diagnosis, particularly for more complex or heterogeneous bone lesions [7].

Discussion

Percutaneous needle biopsy plays a critical role in the diagnostic workup of bone tumors. This systematic review and meta-analysis have highlighted the high diagnostic accuracy of PNB, with pooled sensitivity and specificity values indicating that it is a reliable technique for differentiating benign from malignant bone lesions. The relatively high sensitivity and specificity for both tumor types suggest that PNB is particularly useful in guiding clinical decisions, avoiding the need for more invasive procedures like open biopsy or surgery in many cases [8]. The higher sensitivity for benign tumors indicates that PNB is more likely to identify these lesions correctly. For malignant tumors, while the sensitivity is slightly lower, the specificity remains high, making PNB an excellent tool for confirming or ruling out malignancy. This finding is consistent with previous studies that emphasize the importance of histological confirmation in suspected malignant cases, particularly in determining the appropriate treatment approach. The preference for core needle biopsy over fine needle aspiration aligns with the current literature suggesting that larger tissue samples are more likely to provide accurate diagnostic results, particularly in bone tumors that may be histologically heterogeneous [9].

Limitations

Despite its promising findings, this review is not without limitations. The included studies varied in their sample sizes, biopsy techniques, and reporting of outcomes, which could introduce some degree of bias. Additionally, the lack of a standardized protocol for PNB across studies may affect the generalizability of the results. Future studies should aim to standardize biopsy techniques and report on outcomes in a more uniform manner to improve the robustness of the findings [10].

Conclusion

Percutaneous needle biopsy is a valuable and reliable tool in the diagnosis of bone tumors, with high diagnostic accuracy for both benign and malignant lesions. Its minimally invasive nature, coupled with its ability to provide rapid histopathological results, makes it an essential part of the diagnostic algorithm for bone tumors. Although core needle biopsy is slightly more accurate than fine needle aspiration, both techniques demonstrate strong diagnostic performance. This review supports the use of PNB in clinical practice, emphasizing its role in improving patient management and reducing the need for more invasive procedures.

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