A retrospective comparison of the diagnostic accuracy of CT-guided percutaneous core needle and open biopsy for musculoskeletal tumours

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Abstract

Background

An accurate histological diagnosis is imperative for directed management of musculoskeletal tumours. Globally there has been a shift from open biopsies to less invasive computerised tomography (CT)-guided percutaneous core needle biopsies for diagnosis. Literature suggests comparable diagnostic accuracy with the two modalities. This investigation aimed to evaluate the diagnostic accuracy of CT-guided percutaneous core needle biopsy (CTNB) compared to open biopsy (OB) in musculoskeletal tumours at a South African training hospital.

Methods

A retrospective review of patients' histological records was conducted for patients who underwent either CTNB or OB for a primary musculoskeletal tumour, followed by definitive surgical resection. Patients of any age who had a biopsy between January 2017 and December 2021, whose biopsy was not excisional nor performed during a definitive procedure for a pathological or impending fracture, were eligible for inclusion. Biopsies of metastatic lesions were excluded. Biopsy results were compared to final histopathological diagnoses to determine diagnostic accuracy. Sensitivity, specificity and predictive values were calculated. Logistic regression was conducted to determine if significant differences in accuracy were present between the biopsy techniques.

Results

Forty-eight patients met inclusion criteria, of which 33 had a CTNB (69%) and 15 an OB (31%). Patients had a median age of 26 years, and 54% were female. There were 33 malignant lesions (69%) and 15 benign lesions (31%). Most were primary bone lesions (27, 56%) of the lower limb (40, 83%). Diagnostic accuracy was 73% for CTNB and 87% for OB. Statistical significance could not be determined due to the limited sample size. The ability to distinguish between benign and malignant lesions was 91% for CTNB and 100% for OB. The sensitivity and specificity for detecting malignancy utilising CTNB were 92% and 89%, respectively, whereas for OB, both sensitivity and specificity were 100%.

Conclusion

CTNB and OB in this setting have acceptable sensitivity and specificity profiles for distinguishing benign from malignant lesions. Although this study could not confirm equivalence due to limited power, the results suggest CTNB is a viable alternative to incisional biopsy. Larger local prospective studies are needed to determine if both biopsy types are equivalent for future diagnostic practices.

Level of evidence: 4

Keywords: biopsy, musculoskeletal tumour, CT-guided percutaneous core needle biopsy, open biopsy, histopathological diagnostic accuracy

Introduction

An accurate histological diagnosis is imperative for directed management of musculoskeletal tumours.[1] Tissue biopsy is the cornerstone of tumour identification when clinical or radiological examination is not diagnostic.[1] The presently unrealised ideal biopsy technique would cause minimal soft tissue injury, consider the future surgical excision tract, and be highly accurate.[1] Open biopsies have been considered the gold standard for obtaining representative diagnostic samples.[1] They provide larger volumes of tissue which facilitate accurate histological analyses.[2] However, they carry certain disadvantages. Compared to percutaneous biopsies, open biopsies are typically performed in an operating theatre, require a general anaesthetic, are more costly, cause greater patient discomfort, and have higher complication rates.[2,3] Performing open biopsies in an operating theatre burdens the established South African theatre access limitations.[4] Potential complications of open biopsy (OB) include fractures, biopsy-site haematoma formation, wound breakdown, and subsequent infection.[3] These complications may preclude endoprosthetic limb-salvage surgery options, ultimately compromising functional outcomes.[5-7] Percutaneous core needle biopsy has gained popularity due to several advantages over the OB technique.[8] Investigation has found that for similar diagnostic accuracy, percutaneous core needle biopsies can be performed in an outpatient setting, under local anaesthesia, are more cost-effective, result in fewer complications, and histological diagnosis can be obtained earlier in some cases.[5,8-11] Complication rates as low as 1% have been reported.[7] Imaging-guided percutaneous core needle biopsy improves the accuracy of percutaneous sampling for tumours that are not readily palpated.[12] Puri et al. reported that computerised tomography (CT) guidance can improve the accuracy of sampling by localising tumour and consequently the histological yield.[12]

Internationally, results of investigation of the diagnostic accuracy of OB as compared to CT-guided percutaneous core needle biopsy (CTNB) in bone and soft tissue sarcomas have been mixed.[6,13] A 2018 meta-analysis of five studies directly comparing CTNB and OB found that OB was 6.1 times more likely to yield an accurate result.[6] The authors conducted a sub-group analysis, evaluating the difference between the diagnostic accuracy of CTNB conducted by either a surgeon or a radiologist.[6] CTNB conducted by a radiologist further improved the accuracy.[6] Criticism of previous comparative studies has arisen regarding the definition of an accurate result, with some reports not utilising the final histopathological diagnosis of the resected tumour matched as the reference gold standard. A more recent meta-analysis, quality checked against this reference standard, found the accuracy of CTNB to be at least comparable to OB.[13] Presently, CTNB is accepted as a safe and efficacious method of biopsy in musculoskeletal oncology and is advocated by the National Comprehensive Cancer Network.[14,15]

Limited investigation has been conducted in the South African context to assess the accuracy of CTNB,[16] and the authors are unaware of a local investigation that compares CTNB and OB diagnostic accuracy. Previous epidemiological investigations have determined that the region serviced by the training hospital has a higher incidence of osteosarcoma than comparative international investigations.[17] This may affect the accuracy of CTNB as evidence suggests that failure to obtain an accurate CTNB result is more likely with bone tumours than with soft tissue tumours.[18] This study aimed to compare the diagnostic accuracy of CTNB and OB for musculoskeletal tumours in a South African clinical setting, to better inform the future local diagnostic practices.

Methods

Patients

This retrospective comparative study investigated the CTNB and OB histological result accuracy for consecutive patients with bone and soft tissue tumours (that required biopsy for diagnostic purposes) who presented to the orthopaedic oncology unit at a training hospital in South Africa between January 2017 and December 2021. The report was compiled following the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.[19]

Patients of all ages who underwent either a CTNB or an OB (between 1 January 2017 and 31 December 2021) and had a subsequent definitive tumour resection histopathological diagnosis for a primary bone or soft tissue tumour were eligible for inclusion. This meant that biopsies performed at the time of definitive surgery (nail insertion or arthroplasty) for pathological fracture or impending fracture were not eligible for inclusion. Also ineligible were cases where the diagnosis was evident based on history, clinical examination and imaging, that had a biopsy as part of the definitive surgery, or an excisional biopsy to complete the management. Patient selection for CTNB or OB was case-based, dependent on radiologist availability, accessibility of lesion (intramedullary lesions and lesions deeper than 14–16 cm are not easily accessible with 14G coaxial needle), and patient preference. Theatre records and the procedural CT register were used to identify all biopsy cases within the inclusion period. Basic demographic details, including name, age, sex, date of birth, hospital number, biopsy site and date of biopsy were captured. The patients' histopathological records were traced using the sourced names, dates of birth, and hospital numbers. The demographic and histopathological details were captured on a Microsoft® Excel (version 16.94) spreadsheet to summarise and prepare for statistical analysis. Biopsies of all metastatic lesions were excluded.

Biopsy techniques

CTNBs were performed by an experienced consultant radiologist. They were performed following gadolinium-enhanced magnetic resonance imaging (MRI). MRI was used to delineate the peritumoral reactive zone and to identify a location for sourcing a representative sample, avoiding areas of necrosis (*Figure 1a*).[20] The MRI and CT images were then correlated to identify the optimal CT-guided trajectory to target biopsy of an area of contrast enhancement identified on MRI, indicative of biological activity.[21] Biopsy planning was conducted with the orthopaedic oncological surgeon, considering the resection surgery. The optimal entry point and biopsy tract location were planned for ease of biopsy tract excision at the time of definitive surgery. An aseptic technique with a 14G coaxial needle was used through a single-entry site. The entry location of the needle was confirmed with CT imaging, and seven to nine core needle biopsy samples were obtained (*Figure 1b*). Typically, five samples were sent for histological analysis, one or two samples for tuberculosis (TB) polymerase chain reaction (PCR), and another one or two for microscopy, culture, and sensitivity (MC&S). The biopsy site was marked with a non-absorbable single skin suture to facilitate future biopsy-site excision at the time of definitive surgery. CT images with the biopsy needle in situ were saved on the picture-archiving system for future reference.

Open biopsies were similarly performed after MRI imaging was completed. Analysis of the MRI study formed part of the preoperative planning conducted by the operating orthopaedic oncology surgeon. Biopsy sites were selected after considering imaging and planning future tumour resection surgery. Open biopsies were conducted in an operating theatre under general or

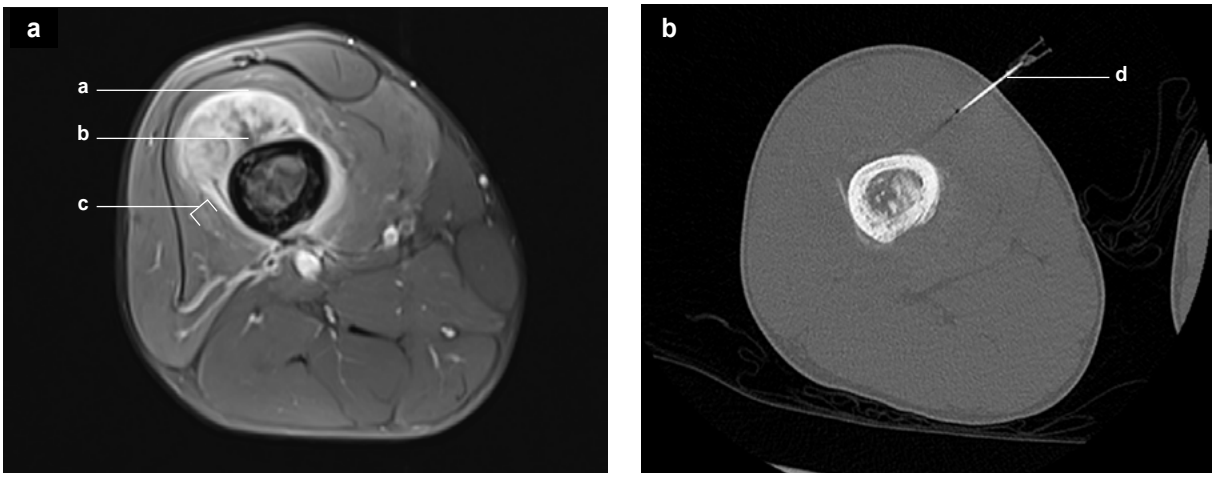

Figure 1: a) T1 post-gadolinium contrast MRI axial view of midshaft thigh showing a bone tumour encapsulating the femur with solidly enhancing extra-osseous component identified as the target area for biopsy; b) matched axial view CT scan with the coaxial needle in-situ within in the target biopsy area

a: high signal area of enhancing tumour; b: low signal areas within the enhancing tumour representative of necrotic tumour tissue; c: intermediate signal band surrounding the tumour representing the reactive zone; d: 14-gauge coaxial needle in-situ

regional anaesthesia (dependent on tumour location). OB surgical principles outlined by Abeysekera & Punchihewa were followed during each procedure.[22] Representative samples were sent for histological, TB PCR and MC&S analyses.

Definitions and analysis

Following the methods of the systematic review and meta-analysis of Birgin et al., accuracy was determined with reference to the final surgical resection histopathological diagnosis.[13] Two variations of accuracy were recorded. The term 'accurate' was assigned for results where the biopsy histology matched the resection histology (e.g. biopsy result - osteosarcoma and resection result - telangiectatic osteosarcoma). The terms 'accurate' or 'diagnostic' or 'accurate in determining exact diagnosis' have been previously used in this context.[13,23,24] For results where the biopsy histology was concordant with the resection histology regarding the nature of the lesion (benign or malignant), we preferentially used the term 'effectively accurate' (other previously utilised terms include: 'dignity of lesion' and 'accurate').[13,23,25] Cases that did not fulfil either of these criteria were termed inaccurate. In practice, in cases where the biopsy result (CTNB or OB) was discordant with the patient's presentation, examination and imaging findings, a repeat biopsy (always OB) was performed; the results of these OBs were not included in this investigation.

Statistical analysis comprised descriptive and analytical components. The Microsoft® Excel (version 16.94) spreadsheet data was exported to jamovi (version 2.6.44.0) for analysis. Categorical variables were summarised with counts and percentages, and continuous variables (age) summarised with median, interquartile range (IQR) and range. A sensitivity analysis was conducted utilising the 'effective accuracy' to determine sensitivity, specificity, positive, and negative predictive values of CTNB and OB with reference to the nature of the final histological specimen as malignant (test positive) or benign (test negative). Both accuracy and effective accuracy were calculated for CTNB and OB. The area under the curve (AUC) was reported using effective accuracy results for CTNB and OB. Binomial logistic regression was conducted to assess for significant differences in demographic variables and effective accuracy between CTNB and OB for various variables (location of lesion, bony or soft tissue lesion and final histological finding of malignant or benign lesion). Where appropriate, these results are reported as odds ratios (OR) with 95% confidence intervals. Statistical significance was accepted for p values of < 0.05.

Results

A total of 48 patients were included in the study. *Figure 2* depicts the case enrolment, detailing cases not meeting inclusion criteria (n = 77) and exclusions (n = 5). The study population consisted of 26 (54%) female and 22 (46%) male patients, with a median age of 26 years (IQR 31, range of 8–75). Thirty-three malignant lesions (69%) and 15 benign lesions (31%) were identified. Most

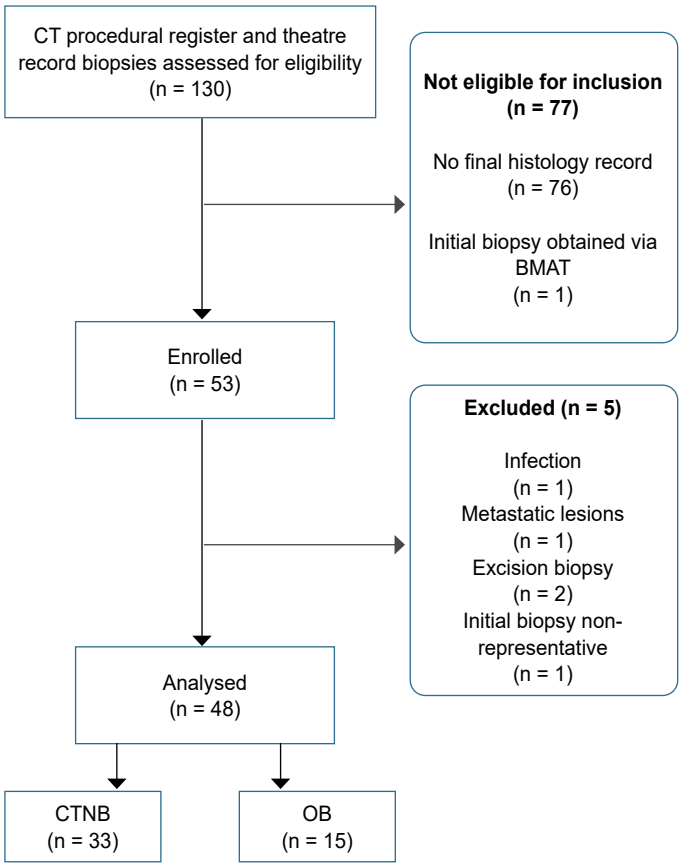

Figure 2. Flow diagram indicating the process of patient record selection for inclusion in the analysis

CT: computerised tomography; CTNB: CT-guided core needle biopsy; OB: open biopsy; BMAT: bone marrow aspiration and trephine biopsy

Table I: Patient and biopsy characteristics compared by biopsy modality, assessed for significant differences with binomial logistic regression

Characteristic	CTNB (n = 33)	OB (n = 15)				
	Median (IQR)	Median (IQR)	p-value*	Odds ratio	95% CI	Power (%)
Age (years)	26 (25)	29 (32)	0.201	0.98	0.95–1.01	5
	Count (%)	Count (%)	p-value*	Odds ratio	95% CI	
Sex			0.585	1.41	0.41–4.87	69
Female	17 (36)	9 (18)				
Male	16 (33)	6 (13)				
Biopsy site			0.677	1.44	0.26–8.16	69
Upper limb	6 (13)	2 (4)				
Lower limb	27 (56)	13 (27)				
Biopsy tissue type			0.784	1.19	0.35–4.05	69
Bone lesion	19 (40)	8 (16)				
Soft tissue lesion	14 (29)	7 (15)				
Nature of tumour			0.381	1.78	0.49–6.43	69
Malignant	24 (50)	9 (19)				
Benign	9 (19)	6 (13)				

CTNB: CT-guided percutaneous core needle biopsy; OB: open biopsy; IQR: interquartile range; * binomial logistic regression; 95% CI: 95% confidence interval; power: for alpha 0.05

were primary bone lesions (27, 56%) in the lower limb (40, 83%). Thirty-three (69%) biopsies were performed as CTNBs and 15 (31%) as OBs. For variables that were sufficiently powered, there were no significant demographic, biopsy location or biopsy tissue type differences between the biopsy modalities. *Table I* compares the patient and tumour characteristics in the CTNB and OB groups.

In comparison of the two biopsy modalities, the accuracy for CTNB was 73% and for OB 87%. The samples were inadequately powered to determine if this difference was significant. The effective accuracy, or ability to distinguish between benign and malignant lesions, was 91% for CTNB and 100% for OB. The sensitivity and specificity for detecting malignancy utilising CTNB were 92% and 89%, respectively, whereas for OB, both sensitivity and specificity were 100%. In CTNB cases, a result positive for malignancy was correct in 96% of cases, and a negative result was correct in 80% of cases. For OB, both positive and negative results were correct for the detection of or absence of malignancy in 100% of cases *(Table II)*. The sample was underpowered to detect a difference in effective accuracy of CTNB and OB for tumour location, origin of tumour (bony or soft tissue), or nature of tumour (benign or malignant). CTNB and OB showed good discrimination, with AUC values of 0.878 and 1.000, respectively.

In the CTNB group, three of the biopsy (3 of 33, 9%) samples were inaccurate. Two of the three inaccurate results in the CTNB group were false negatives, samples initially assessed as benign lesions but later confirmed to be malignant. This was evident by the negative predictive value (80%), the CTNB group's lowest-scoring sensitivity parameter. The final inaccurate sample was initially assessed as malignant, but the final histological specimen confirmed a benign lesion (a false positive). *Table III* provides the specific histological findings of the inaccurate results.

Upon final histological analyses, 27 of the 48 lesions biopsied were of bony origin, most of which were malignant (18 of 27, 67%). Osteosarcoma was the most prevalent diagnosis of all histological diagnoses (17 of 48, 35%), followed by chondrosarcoma, both skeletal and extraskeletal variants (4 of 48, 8%). Giant cell tumour of bone was the most common benign bony lesion identified (3 of 48, 6%), and lipoma was the most common benign soft tissue lesion (3 of 48, 6%). *Table IV* summarises the final histological results comparing CTNB and OB samples.

Table II: Comparison of sensitivity parameters and accuracy rates of CTNB and OB, assessed for significant differences with binomial logistic regression

Sensitivity analysis	CTNB (n = 33)	OB (n = 15)	p-value*
Sensitivity	92%	100%	0.995
Specificity	89%	100%	0.997
Positive predictive value	96%	100%	0.995
Negative predictive value	80%	100%	0.995
Area under the curve (AUC)	0.878	1.000	
Diagnostic accuracy rates (%)	**(n) %**	**(n) %**	
Accuracy	(24/33) 73	(13/15) 87	0.297
Effective accuracy	(30/33) 91	(15/15) 100	0.994
Limb location			
Upper limb (n = 8)	(5/6) 83	(2/2) 100	0.997
Lower limb (n = 40)	(25/27) 93	(13/13) 100	0.993
Tumour origin			
Bony lesion (n = 27)	(17/19) 90	(8/8) 100	0.995
Soft tissue lesion (n = 21)	(13/14) 93	(7/7) 100	0.995
Nature of lesion			
Benign lesion (n = 15)	(7/8) 88	(6/6) 100	0.997
Malignant lesion (n = 33)	(22/24) 92	(9/9) 100	0.995

CTNB: CT-guided percutaneous core needle biopsy; OB: open biopsy; n: count; * binomial logistic regression; %: percentage

Table III: Depiction of the inaccurate CTNB (n = 3) histology as compared to the final histological specimen

Biopsy histology	Final histology
Nodular hidradenoma	Extraskeletal mesenchymal chondrosarcoma
GCT/ABC/NOF	High grade osteosarcoma
Osteosarcoma	Osteoid osteoma

CTNB: CT-guided percutaneous core needle biopsy; GCT: giant cell tumour; ABC: aneurysmal bone cyst; NOF: non-ossifying fibroma

Table IV. Final histological diagnoses of all biopsied lesions

Final histology	CTNB (n = 33)	OB (n = 15)
Bony lesions	**19**	**8**
Malignant bony lesions	**15**	**3**
Osteosarcoma	14	3
Chondrosarcoma	1	
Benign bony lesions	**4**	**5**
Giant cell tumour of bone	1	2
Aneurysmal bone cyst		1
Chondroblastoma		1
Enchondroma		1
Osteoid osteoma	1	
Myositis ossificans	1	
Metaphyseal fibrous defect	1	
Soft tissue lesions	**14**	**7**
Malignant soft tissue lesions	**9**	**6**
Sarcomatoid carcinoma	1	
Liposarcoma	1	
Extraskeletal chondrosarcoma	2	1
Malignant peripheral nerve sheath tumour	1	1
Synovial sarcoma	2	
Fibrosarcoma	1	
Dermatofibrosarcoma protuberans	1	
Soft tissue melanoma		1
Leiomyosarcoma		1
Rhabdomyosarcoma		2
Benign soft tissue lesions	**5**	**1**
Fibromatosis	2	
Lipoma (including atypical lipomatous tumour)	3	
Scar tissue		1

CTNB: CT-guided percutaneous core needle biopsy; OB: open biopsy

Discussion

This investigation aimed to compare the diagnostic accuracy of CTNB and OB for musculoskeletal tumours at an oncology unit at a South African training hospital. While the sample was underpowered to detect significant differences in the accuracy rates, the sensitivity analyses determined good discrimination for both modalities to identify malignancy successfully. Similar findings have been documented in international investigations comparing percutaneous and open biopsies,[1,3,6,13,24] which is the likely driver for the global increase in popularity of percutaneous biopsy methods.[26] For a similar accuracy, percutaneous biopsy is the less invasive alternative.[3] Burke et al. showed in a large multicentre investigation in 2023 that core needle biopsy was the most utilised modality, accounting for 58% of biopsies across 12 centres investigated.[26] The addition of CT guidance to percutaneous core needle biopsies further increases diagnostic accuracy and safety by enabling visualisation of the target biopsy location (cross-referenced with MRI findings to avoid areas of necrosis) for sampling.[12,20] This is particularly pertinent when the lesions are small, deep-seated, have large areas of necrosis or are located in difficult to access areas like the pelvis, spine, sacrum or scapula.[7,12,15,20] Literature has shown diagnostic accuracy rates of CTNB to be favourable, ranging from 80 to 100%.[6,7,11,25,27] These accuracy rates evaluated critically, however, represent a mix of both accurate and effectively accurate results as defined in this investigation. So, while the accuracy of CTNBs undertaken at our institution (73%) at first appears to be on the lower end of the accuracy range, it is, in fact, similar, if effective accuracy is considered (91%). However, these findings are not necessarily generalisable to other contexts. The study was conducted in an experienced centre with a radiologist proficient in taking CTNBs and musculoskeletal oncology surgeons. Pohlig et al. suggested that the surgeon's experience and training in performing the biopsy affected their investigation's overall diagnostic yield and accuracy.[1] Similarly, Issakov et al. demonstrated improved diagnostic accuracy over time, as the radiologist performing their biopsies gained more experience,[11] and Kubo et al. identified a significant difference in diagnostic accuracy when the CT-guided biopsy was performed by a radiologist as compared to a surgeon.[6]

Nevertheless, inaccurate results offer the opportunity to refine the biopsy technique and evaluate opportunities for improvement. A close review of the histological analyses shows that CTNB was effectively accurate for a broad spectrum of bony and soft tissue lesions. A substantial number of these were malignant cases, including 14 osteosarcomas. This is interesting in light of Taupin et al's. finding that CTNB inaccuracy is more likely with bone tumours than soft tissue tumours.[18] While our sample could not detect a difference in accuracy between bone and soft tissue biopsies comparing CTNB and OB, two of the three inaccurate CTNB results were biopsies of bone origin, and one was of soft tissue origin. For the biopsies of bone origin that were inaccurate, one osteoid osteoma was inaccurately reported as an osteosarcoma, and one osteosarcoma was inaccurately reported with a wide differential (non-ossifying fibroma - NOF, giant cell tumour of bone - GCT, or aneurysmal bone cyst - ABC). Histologically, both osteoid osteoma and osteosarcoma produce osteoid matrix, the distinguishing feature being increased cellularity, disorganisation and cellular atypia present in osteosarcoma.[28] Giant cells and fibroblasts are commonly visualised in NOFs, ABCs and GCTs, which are also found in fibroblastic and telangiectatic osteosarcomas. In the single case of inaccuracy of soft tissue biopsy, extraskeletal chondrosarcoma was inaccurately reported as a nodular hidradenoma. Arthi et al. expounded on the histological profile of hidradenoma in their investigation, identifying that both chondrosarcoma and nodular hidradenoma can have myxoid or chondroid differentiation.[29] Shared among all the inaccurate diagnoses is the overlap in histological features, which makes distinguishing tumours from each other challenging with small-volume samples. Klein et al. additionally attributed the most common reason for diagnostic failures to non-representative tissue samples taken from the periphery of lesions.[30]

The retrospective nature of the study, reliant on incomplete patient records, resulted in a small number of included cases. This limited the determination of significant differences in accuracy between the modalities. Furthermore, patient selection for CTNB or OB was based on the availability of the radiologist, patient preference and lesion location, all of which have the potential to introduce a selection bias. A larger randomised and prospective investigation would be better suited to compare the accuracy of the two modalities. However, for the purpose of assessing the accuracy of the individual modalities, both modalities show acceptable sensitivity profiles for use in practice.

Conclusion

CTNB and OB in this setting have acceptable sensitivity and specificity profiles for distinguishing benign from malignant lesions. While this study was underpowered to confirm equivalence, the findings support that CTNB is a viable alternative to incisional biopsy. Larger, local, prospective studies are needed to determine equivalence of the two biopsy modalities to guide future local diagnostic practices.

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Ethics statement

The author/s declare that this submission is in accordance with the principles laid down by the Responsible Research Publication Position Statements as developed at the 2nd World Conference on Research Integrity in Singapore, 2010. The study complied with the South African Department of Health ethics guidelines (2015), and the University of KwaZulu-Natal policy on research ethics. Prior to commencement of this research the appropriate ethical approval was obtained from the Biomedical Research Ethics Committee of UKZN (BREC/00006829/2024).

All procedures were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008. Informed written consent was not obtained from patients included in the study as the work represents a retrospective review of patient charts.

Declaration

The authors declare authorship of this article and that they have followed sound scientific research practice. This research is original and does not transgress plagiarism policies.

Author contributions

ZJCS: conceptualisation; investigation; data curation; writing of original draft, review and editing; visualisation

LN: conceptualisation; investigation (data collection); writing of review and editing; supervision

MOC: methodology; formal analysis; writing of review and editing; supervision

LCM: conceptualisation; writing of review and editing

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