



Ultrasound-guided percutaneous rib biopsy: a safe procedure with high diagnostic yield[☆]



J.W. Huang^{a,b}, C. Souza^{a,b}, Z. Jibri^{a,b}, K.S. Rakhra^{a,b,*}

^aDepartment of Medical Imaging, The Ottawa Hospital, Ottawa, Ontario, Canada

^bThe Ottawa Hospital Research Institute, Ottawa, Ontario, Canada

ARTICLE INFORMATION

Article history:

Received 4 October 2018

Accepted 9 April 2019

AIM: To assess the diagnostic yield and complication rate of image-guided percutaneous rib biopsy, comparing ultrasonography (US) to fluoroscopy and computed tomography (CT)-guided biopsy techniques.

MATERIALS AND METHODS: A retrospective review was conducted of patients who underwent image-guided percutaneous rib biopsy at a single tertiary-care academic centre between January 2007 and June 2017. The diagnostic yield and complication rates were calculated and compared between the three imaging methods.

RESULTS: A total of 70 consecutive, image-guided percutaneous rib biopsies were performed in 67 patients (48 in males, 22 in females, mean age of 68.2 years, age range 31–92 years). The image guidance method utilised for biopsy was US in 64.3% (45/70), CT in 18.6% (13/70), and fluoroscopy in 17.1% (12/70). The diagnostic yield for all cases combined was 97.1% (68/70) and 97.8% (44/45) for US-guided biopsies specifically. A complication of pneumothorax was encountered in 4.3% (3/70) of all cases combined and in 4.4% (2/45) of US-guided biopsies specifically.

DISCUSSION: US-guided percutaneous rib biopsy has a high diagnostic yield and low complication rate, comparable to fluoroscopy or CT-guided biopsy.

© 2019 The Royal College of Radiologists. Published by Elsevier Ltd. All rights reserved.

Introduction

The diagnosis of rib lesions is often a clinical dilemma and may be indeterminate even after multimodality imaging investigation. Rib lesions can be assessed by plain radiography, computed tomography (CT), ultrasound (US), nuclear medicine studies and magnetic resonance imaging

[☆] The data in this paper were presented in poster form at the Radiology Society of North America, 30 November 2017, Chicago, Illinois, USA.

* Guarantor and correspondent: K. Rakhra, Department of Medical Imaging, The Ottawa Hospital, 501 Smyth Road, Ottawa, Ontario, K1H 8L6, Canada. Tel.: 613-737-8751.

E-mail address: krakhra@toh.ca (K.S. Rakhra).

(MRI), each with its unique advantages for lesion characterisation.^{1,2} Solitary rib lesions can be benign or malignant, either primary or metastatic with each diagnosis implying different prognosis and management. In patients with known malignancy, a definite diagnosis is pivotal as the presence of osseous metastasis affects the disease stage and prognosis.² Although a presumptive diagnosis can, on occasion, be made based on imaging findings alone, tissue sampling is often required for confirmation.¹ Surgical biopsy is traditionally considered the reference standard in the diagnosis of rib lesions; however, it is often not feasible due to associated risks, increased morbidity, and greater cost.^{3–6} A safe and reliable minimally invasive diagnostic procedure is therefore desired particularly for lesions that

do not require surgical resection such as metastasis.⁵ Conversely, for lesions for which surgical resection is the treatment of choice, pre-treatment diagnosis may be advised either for neoadjuvant therapy or surgical planning.⁷

Image-guided percutaneous needle biopsy of bone lesions has been established as a technique with high diagnostic yield and accuracy, and low complication rates^{1,5,8,9}; however, specific to rib lesions, there is limited information in the literature¹ and previous studies have focussed mainly on CT guidance with few data available on US-guided rib biopsy.^{1,7} US is a well-established technique used to guide biopsy of various body sites, including musculoskeletal structures, with several benefits when compared to CT. Advantages include lower cost, wider availability, and lack of ionising radiation. From a technical perspective, US allows for greater flexibility and tolerance of patient positioning, lesion characterisation to target viable tissue and real-time visualisation of the needle facilitating avoidance of neurovascular structures, all of which potentially increase diagnostic yield and decrease complication rate.^{6,10,11}

The goal of this project was to assess the diagnostic yield and complication rate of image-guided percutaneous rib biopsy, comparing US-guided to fluoroscopy and CT-guided biopsies. Additionally, the imaging appearance and pathological diagnosis profile of rib lesions referred for biopsy was analysed.

Material and methods

Study cohort

Institutional research ethics approval was obtained for this retrospective review of a prospectively maintained thoracic biopsy database. The database included all image-guided thoracic procedures performed between 1 January 2007 and 30 June 2017 at a single academic tertiary-care centre. From this database, consecutive patients who underwent image-guided percutaneous rib biopsy were identified.

Image-guided percutaneous rib biopsy

Percutaneous rib biopsies were performed under US, CT, or fluoroscopy image guidance. In The Ottawa Hospital, the choice of imaging technique to guide biopsy is generally based on the CT characteristics of the lesion. Lesions with an extra-osseous soft-tissue component and without overlying bone are performed under US guidance. If the lesion is completely intra-osseous or if it is grossly sclerotic then either fluoroscopy or CT is employed. For fluoroscopy to be selected, the lesion would have to be clearly visualised on pre-procedure chest radiograph. CT would be the technique for all other lesions.

Biopsies, either fine-needle aspiration (FNA) or core needle biopsy (CNB), were performed according to standardised institutional protocol, using sterile technique and local anaesthetic, with patients in prone or supine position, depending on the location of the rib lesion. Neither

conscious sedation nor general anaesthesia was used. FNA was performed with a 25 or 22 G spinal needle attached to 10 ml syringe; all FNA samples were prepared immediately on slides by a cytotechnologist for assessment of sample adequacy using rapid on-site evaluation (ROSE). Once sample adequacy was confirmed on the smears, additional samples were obtained for cell block, submitted in formalin, or in saline solution if lymphoma was suspected. CNB was performed if three or more consecutive FNA samples were inadequate by ROSE (insufficient cellularity), if the FNA did not reveal neoplastic cells, or if there was a pre-test diagnostic possibility of a primary rib neoplasm (benign or malignant) or non-neoplastic pathology. CNB was performed with coaxial technique using 18 or 20 G cutting needle advanced through a 17 or 19 G introducer, respectively. CNB samples were submitted in formalin or in saline solution if lymphoma was suspected. If infection was suspected, further aspirates were submitted for microbiological analysis, including acid fast bacilli.

As per institutional protocol, patients' vital signs were monitored and a chest radiograph was obtained 30 minutes after the procedure to assess for the presence of pneumothorax. In the absence of complications, patients were discharged from the radiology department after 1 hour of observation.

Data collection and analysis

The age, gender, final histology, and cytology results were obtained from the patients' institutional electronic medical records. Information regarding the biopsy, including imaging technique of guidance (US, CT, or fluoroscopy), type of biopsy (FNA or CNB), and presence of post-procedural complication (haemoptysis, pneumothorax, or acute respiratory distress) were obtained from biopsy reports in the institutional radiology reports database. Rib lesions were evaluated on pre-procedural CT by a fellowship trained musculoskeletal radiologist. The parameters of location (anterior, lateral, or posterior third), size (long axis), internal characteristics (lytic, sclerotic, mixed, calcification), bone expansion, cortical destruction, presence of soft-tissue mass, and overall aggressive radiological appearance were tabulated.

Diagnostic yield was defined as the proportion of diagnostic procedures with the tissue sample adequate for a definitive histopathological diagnosis. A needle biopsy sample was considered to have a positive yield when the FNA or CNB provided a final diagnosis of malignancy or of a benign entity. Samples with insufficient cells or demonstrating cellular atypia alone were considered non-diagnostic (negative yield).

The complication rate was defined as the proportion of procedures with pneumothorax, haemoptysis, and acute respiratory distress over the total number of biopsies.

Fisher's exact test was used to determine if there was any difference in the yield or complication rate dependent on the technique for biopsy guidance, the type of biopsy performed and for each of the various lesion characteristics. Statistical significance was defined as $p < 0.05$.

Results

A total of 70 consecutive image-guided percutaneous rib biopsies were performed in 67 patients, 22 (31.4%) in females and 48 (68.6%) in males, mean age of 68.2 years (range 31–92). Of the three patients with more than one procedure, two had biopsy at two different anatomical ribs and one had a biopsy repeated at the same rib due to a non-yielding initial result. The imaging technique used to guide biopsy was US in 64.3% (45/70), CT in 18.6% (13/70), and fluoroscopy in 17.1% (12/70). FNA was performed in 71.4% (50/70) and CNB in 28.6% (20/70) of cases. Representative radiological images of biopsy performed under each the three imaging techniques are presented in Figs 1–3.

As shown in Table 1, 97.1% (68/70) of the biopsies yielded a diagnostic sample. When stratified by imaging technique, US-guided biopsies had a yield of 97.8% (44/45), which was similar to the yield of 92.3% (12/13) for CT and 100% (12/12) for fluoroscopy. When stratified by type of biopsy, the yield of FNA was 98% (49/50) and of CNB 95% (19/20). There was no significant difference in the yield based on the imaging technique ($p=0.590$) or type of biopsy ($p=0.493$).

The final results of diagnostic biopsies are summarised in Table 2. The large majority of cases were metastases of lung origin (37), although there were several other origins including breast ($n=4$), renal ($n=4$), prostate ($n=2$), melanoma ($n=2$), gastrointestinal ($n=1$), neuroendocrine ($n=1$), and sarcoma ($n=1$). Of the nine primary bone malignancies, five were myeloma, two chondrosarcoma, and two sarcoma. Of the seven benign lesions, three were tuberculosis, one Langerhans cell histiocytosis, one simple fracture, one aneurysmal bone cyst, and one benign schwannoma. Of the two (2.9%) non-diagnostic biopsies, one was in a patient with biopsy-proven non-small cell lung carcinoma in whom FNA of rib lesion was insufficient. A presumptive clinical diagnosis of metastasis was made supported by positive bone scintigraphy, with the patient subsequently receiving radiation therapy for local control. The second case was a non-diagnostic CNB in a patient with no history of

malignancy and CT appearance and clinical follow-up suggestive of fibrous dysplasia.

The complication rates are summarised in Table 3. Three cases (4.3%, 3/70) had a small post-procedure pneumothorax diagnosed on chest radiograph, none requiring chest tube drainage. Two of these cases occurred after FNA, one with US and one with CT-guidance, and the third case occurred after CNB under US guidance. These three biopsies yielded a positive result. There were no cases of post-biopsy haemoptysis or acute respiratory distress. There was no significant difference in the complication rate based on the imaging technique ($p=0.741$) or type of biopsy ($p=1.000$).

The characteristics of the lesions as seen on pre-biopsy CT are summarised in Table 4. The lesion size, laterality, location within the rib, lesion internal characteristics, and morphological features of the rib including bone expansion, endosteal scalloping, cortical disruption, extra-osseous mass, soft-tissue invasion, and aggressive radiologic appearance were not associated with any significant difference in the yield or complication rates.

Discussion

Image-guided rib biopsy was diagnostic in 97.1% of cases and the yield of US-guided biopsy (97.7%) was slightly higher to that obtained with CT guidance (91.7%). Two previous studies reported a diagnostic yield of 70% and 88% and accuracy >90% for percutaneous rib biopsies, with most cases performed under CT or fluoroscopy.^{1,7} The advantages of US as a biopsy-guidance technique are well established⁷ for musculoskeletal lesions but not specifically for rib lesions, with only one study specifically assessing that in a small number of patients.¹

Rib lesions can be technically difficult to biopsy due to compounding factors, including the oblique orientation of the ribs, small bone diameter, breathing motion, and proximity to the pleura and intercostal vessels.⁷ In comparison to CT, US allows more flexibility for patient positioning and provides real-time multiplanar imaging

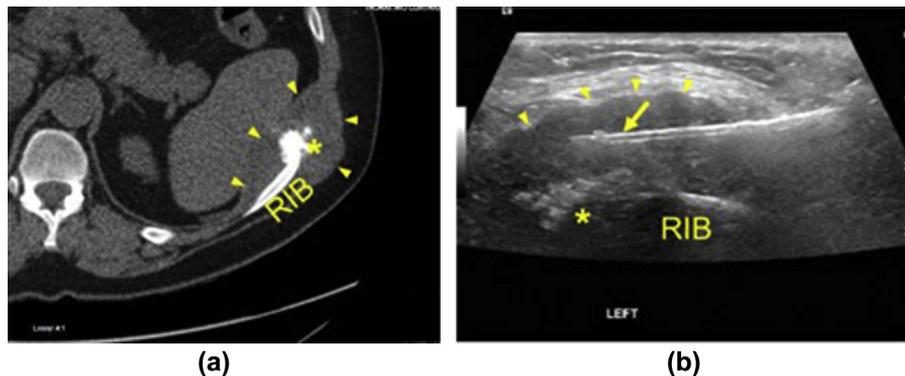


Figure 1 A 53-year-old woman presenting with abdominal pain. (a) CT image shows an incidental posterolateral left 10th rib lesion detected with dense, spiculate mineralisation (asterisk) and a circumferential, large soft-tissue mass (arrowheads). (b) Ultrasound image showing the core needle biopsy needle (arrow) through a solid soft-tissue mass superficial to the rib (arrowheads). Deep to the soft-tissue component is an irregular, echogenic focus (asterisk) with shadowing corresponding to the mineralisation seen on CT. The final histopathological diagnosis was high-grade chondrosarcoma.

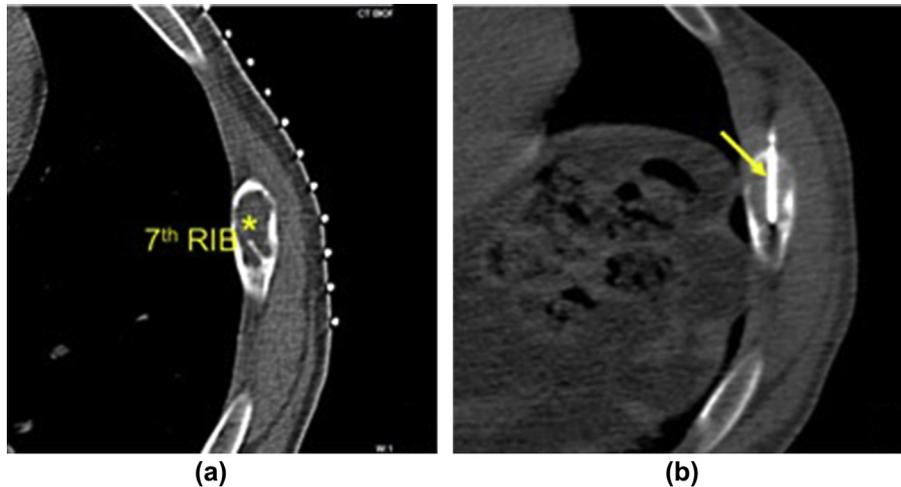


Figure 2 A 64-year-old man with a history of prior cardiac leiomyosarcoma. (a) CT shows a left lateral seventh rib, lytic, expansile lesion with cortical thinning and minimal intermittent full-thickness breach (asterisk). (b) CT-guided biopsy image demonstrates core needle biopsy centred within the lesion (arrow). Final histopathological diagnosis was metastatic leiomyosarcoma.

facilitating needle placement within the lesion, potentially decreasing procedure time and improving yield and patient comfort. The real-time visualisation of the needle tip may avoid inadvertent puncture of the pleura and intercostal vessels, thus increasing safety.¹¹ US is widely available and can be performed at the bedside in hospitalised patients. In the series of 51 rib biopsies reported by Jakanani *et al.*, 43 used CT guidance under general anaesthesia and required hospitalisation. Of note, all 70 procedures in the present series were performed in an ambulatory basis and under local anaesthetic. Moreover, US procedures as compared to CT are generally less time-consuming, less expensive, and more widely available, thus implying a more cost-effective biopsy technique.¹¹ It is acknowledged that US is operator-dependent and that success rates can be affected by experience of the physician performing the procedure.

Previous studies have suggested that a large extra-osseous component is required for US biopsy of rib lesions with the absent soft-tissue component correlated with lower success rate.¹ In the current study, 18% (8/45) of US-guided biopsied rib lesions did not have extra-osseous soft tissue, yet all were diagnostic. It is noted that all had cortical thinning, and seven of these eight had cortical disruption. Thus, alterations in the cortical integrity may alone allow for successful biopsy, as they facilitate needle penetration into the bone. Hwang *et al.* showed that there is greater likelihood of a diagnostic result when cortical destruction is present.⁷ Although a soft-tissue component may facilitate US-guided biopsy, the present results suggest it may not be essential. Overall, combining all techniques, a considerable proportion of lesions (24/70, 30.3%) did not have any extra-osseous soft tissue, and this did not

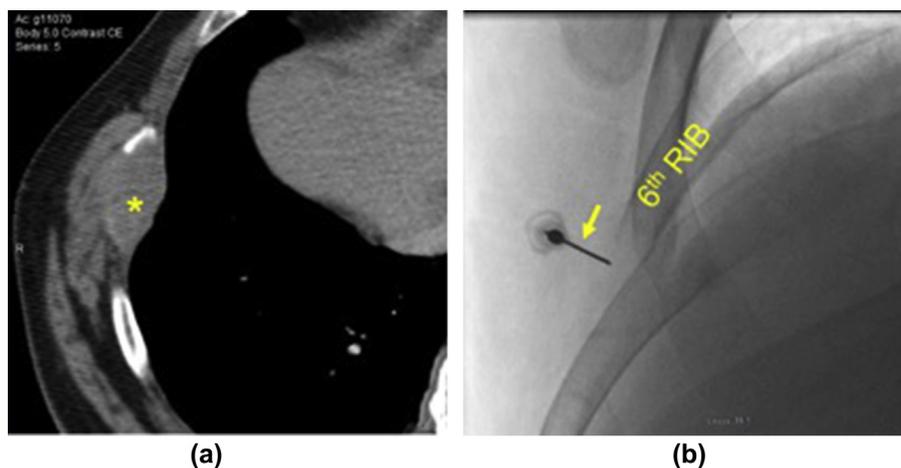


Figure 3 A 55-year old male patient presented with decreased appetite, weight loss, fatigue, and spiculate lesion in right upper lobe. (a) CT demonstrates a large lytic, expansile, bone resorptive lesion with severe cortical thinning and areas of full-thickness breach, involving the lateral right sixth rib (asterisk). (b) Fluoroscopic image demonstrates abrupt loss of the cortical margin of the rib, with FNA needle (arrow) within the destructive lytic component of the lesion. Final histopathological diagnosis was metastatic squamous cell carcinoma of the lung.

Table 1
Diagnostic yield of image-guided percutaneous rib biopsy.

Variables	Diagnostic yield % (/)
Overall	97.1 (68/70)
Imaging technique	
Ultrasound	97.8 (44/45)
Computed tomography	92.3 (12/13)
Fluoroscopy	100 (12/12)
Type of biopsy	
FNA	98 (49/50)
CNB	95 (19/20)

FNA, fine-needle aspiration; CNB, core needle biopsy.

negatively affect biopsy success nor increase rate of complication.

In the present study, biopsy type (FNA or CNB) did not significantly affect diagnostic yield or rate of complications. The role of FNA in the diagnosis of rib lesions has not been assessed in previous studies.¹ Results of studies of osseous biopsy of various sites, however, suggest a complimentary role of FNA and CNB leading to the belief by some that both should be obtained whenever possible.^{12,13} The strong performance of FNA in the present series may partly be due to the predominance of metastases and relative small number of benign lesions and primary rib neoplasms. Malignant lesions with greater cellularity and higher histological grade relative to benign entities are easier to diagnose especially with small samples.⁷ This may have also been influenced by routine FNA sample adequacy assessment available in The Ottawa Hospital. Although these values may have been overestimated, FNA plays an important role in the diagnosis of rib lesions. Notably, FNA is valuable for microbiological analysis when infection is suspected as well as for diagnosis of intra-osseous cystic lesions with no solid tissue and those containing purely fluid such as aneurysmal bone cyst.¹ The use of FNA may be affected by institutional preference, as it requires a strong, experienced cytology service.³ In contrast, if a primary rib neoplasm is suspected, CNB should be considered to avoid a non-diagnostic result and repeat biopsy.

Compared to the study of Jakanani *et al.*, in which all cases had CNB using larger needles (11–14 G), the CNB were performed with smaller needles (18 or 20 G) needles with no negative impact on yield.¹ Thus centres should consider

Table 2
Final histology results of image-guided percutaneous rib biopsy.

Final diagnosis	No.
<i>Malignant lesion</i>	61
Metastasis from primary lung cancer	37
Metastasis from extra-thoracic cancer	15
Primary bone malignancy	9
<i>Benign lesion</i>	7
Tuberculosis	3
Langerhans cell histiocytosis	1
Fracture	1
Aneurysmal bone cyst	1
Benign schwannoma	1
<i>Non-diagnostic</i>	2

Table 3
Complication rate of image-guided percutaneous rib biopsy by imaging technique and biopsy type.

Parameters	Complication rate %(/)
Overall	4.3 (3/70)
Imaging technique	
Ultrasound	4.4 (2/45)
Computed tomography	7.7 (1/13)
Fluoroscopy	0 (0/12)
Type of biopsy	
FNA	4.0 (2/50)
CNB	5.0 (1/20)

FNA, fine-needle aspiration; CNB, core needle biopsy.

performing these rib biopsies with smaller gauge needles, which may potentially further reduce complication rates.

The majority of rib lesions in the present series (61/70,90%) were malignant, mostly metastases (52/61). It is well known that metastasis are the most common malignant lesions affecting the ribs.^{1,14,15} Baxter *et al.* showed that in patients with malignancy, solitary rib lesions were metastatic in 41% of cases.¹⁶ The relatively higher number of malignant rib lesions in the present study as compared to the reported 15–81% rate likely reflects selection bias from the present tertiary oncology referral centre where lesions are often detected during staging investigation.

Complications of imaging-guided rib biopsy occurred in only three patients (4.3%), consisting of small pneumothorax that did not require drainage nor hospital admission. To the authors' knowledge, the complication rate of percutaneous rib biopsy has not been described in the literature.

This study has limitations, including the small sample size to perform multivariate analysis for diagnostic success and occurrence of complications, namely for the fluoroscopy and CT groups. Given the retrospective design, it is not known exactly what decision-making process was used to determine which technique the radiologists chose to biopsy the rib lesions with, thus introducing potential selection bias for each of the three groups. Radiologist personal preference and availability of certain techniques may have additionally contributed to the non-random assignment of cases to the three different techniques. Most cases had no surgical biopsy (reference standard), thus not allowing calculation of accuracy. All biopsy diagnoses, however, were concordant with subsequent clinical diagnoses, treatment, and follow-up. The imaging profile of biopsied lesions must be acknowledged to provide context to the rates of yield and complication. CT evaluation of rib lesions in the current study found that 91% were lytic, 81% had bone expansion, 93% had cortical thinning, 96% had cortical disruption, 76% had an extra-osseous soft-tissue component with 91% having an overall aggressive radiological appearance. This profile may not be similar to other studies thus making direct comparison challenging and may not be applicable to centres with different prevalence of various pathologies. Although this study included a broad spectrum of pathologies, the histological distribution of lesions and the attenuation distribution (lytic, mixed, or sclerotic) may not match the profile of their incidence in the general

Table 4
Rib lesion characteristics on pre-biopsy computed tomography.

Lesion characteristics		n	Percent of Total	Yield % (/)	Complication Rate % (/)
Size (long axis)	0–3 cm	22	31.4	95.5 (21/22)	0 (0/22)
	3.1–6 cm	25	35.7	100.0 (25/25)	8.0 (2/25)
	6.1–9 cm	20	28.6	100.0 (20/20)	5.0 (1/20)
	>9 cm	3	4.3	66.7 (2/3)	0 (0/3)
Location	Right	37	52.9	97.3 (36/37)	5.4 (2/37)
	Left	33	47.1	97.0 (32/33)	3.0 (1/33)
Location	Anterior	22	31.4	100.0 (22/22)	0 (0/22)
	Lateral	19	27.1	94.7 (18/19)	10.5 (2/19)
	Posterior	29	41.4	96.6 (28/29)	3.4 (1/29)
Lesion internal characteristics	Lytic	64	91.4	98.4 (63/64)	4.7 (3/64)
	Sclerotic	2	2.9	50.0 (1/2)	0 (0/2)
	Mixed	4	5.7	100.0 (4/4)	0 (0/4)
	Calcification	0	0	0 (0)	0 (0)
Presence of morphological features	Bone expansion	57	81.4	96.5 (55/57)	3.5 (2/57)
	Endosteal scalloping	65	92.9	98.5 (64/65)	4.6 (3/65)
	Cortical disruption	67	95.7	98.5 (66/67)	4.5 (3/67)
	Extra-osseous soft-tissue mass	53	75.7	98.1 (52/53)	1.9 (1/53)
	Invasion of adjacent soft tissues	30	42.9	100.0 (30/30)	0 (0/30)
	Aggressive radiological appearance	66	94.2	97.0 (64/66)	4.5 (3/66)

population. The selection bias of performing this study at a tertiary care centre with heavy oncology load, along with the culture of not undertaking biopsy of benign-appearing lesions is acknowledged. Lastly, it is unknown if there were any cases of rib lesions that may have proceeded directly to open, surgical biopsy, or resection, and thus would not have undergone image-guided biopsy and not have been included in the present study.

In conclusion, the present results demonstrate that US-guided biopsy has an excellent yield for the diagnosis of rib lesions with very low complication rate. Considering the advantages when compared to traditional guidance techniques, US-guided biopsy should be considered and incorporated into clinical practice when tissue diagnosis is required.

Conflict of interest

The authors declare no conflict of interest.

References

- Jakanani GC, Saifuddin A. Percutaneous image-guided needle biopsy of rib lesions: a retrospective study of diagnostic outcome in 51 cases. *Skeletal Radiol* 2013;**42**:85–90.
- Zarqane H, Viala P, Dallaudiere B, et al. Tumors of the rib. *Diagn Interv Imaging* 2013;**94**:1095–108.
- Rimondi E, Rossi G, Bartalena T, et al. Percutaneous CT-guided biopsy of the musculoskeletal system: results of 2027 cases. *Eur J Radiol* 2011;**77**:34–42.
- Skrzynski MC, Biermann JS, Montag A, et al. Diagnostic accuracy and charge-savings of outpatient core needle biopsy compared with open biopsy of musculoskeletal tumors. *J Bone Joint Surg Am* 1996;**78**:644–9.
- Datir A, Pechon P, Saifuddin A. Imaging-guided percutaneous biopsy of pathologic fractures: a retrospective analysis of 129 cases. *AJR Am J Roentgenol* 2009;**193**:504–8.
- Saifuddin A, Mitchell R, Burnett SJ, et al. Ultrasound-guided needle biopsy of primary bone tumours. *J Bone Joint Surg Br* 2000;**82**:50–4.
- Hwang S, Lefkowitz RA, Landa J, et al. Percutaneous CT-guided bone biopsy: diagnosis of malignancy in lesions with initially indeterminate biopsy results and CT features associated with diagnostic or indeterminate results. *AJR Am J Roentgenol* 2011;**197**:1417–25.
- Hau A, Kim I, Kattapuram S, et al. Accuracy of CT-guided biopsies in 359 patients with musculoskeletal lesions. *Skeletal Radiol* 2002;**31**:349–53.
- Nouh MR, Abu Shady HM. Initial CT-guided needle biopsy of extremity skeletal lesions: diagnostic performance and experience of a tertiary musculoskeletal center. *Eur J Radiol* 2014;**83**:360–5.
- Gil-Sanchez S, Marco-Domenech SF, Irurzun-Lopez J, et al. Ultrasound-guided skeletal biopsies. *Skeletal Radiol* 2001;**30**:615–9.
- Torriani M, Etchebehere M, Amstalden E. Sonographically guided core needle biopsy of bone and soft tissue tumors. *J Ultrasound Med* 2002;**21**:275–81.
- Ng CS, Salisbury JR, Darby AJ, et al. Radiologically guided bone biopsy: results of 502 biopsies. *Cardiovasc Intervent Radiol* 1998;**21**:122–8.
- Schweitzer ME, Gannon FH, Deely DM, et al. Percutaneous skeletal aspiration and core biopsy: complementary techniques. *AJR Am J Roentgenol* 1996;**166**:415–8.
- Guttentag AR, Salwen JK. Keep your eyes on the ribs: the spectrum of normal variants and diseases that involve the ribs. *RadioGraphics* 1999;**19**:1125–42.
- De Maeseneer M, De Mey J, Lenchik L, et al. Helical CT of rib lesions: a pattern-based approach. *AJR Am J Roentgenol* 2004;**182**:173–9.
- Baxter AD, Coakley FV, Finlay DB, et al. The aetiology of solitary hot spots in the ribs on planar bone scans. *Nucl Med Commun* 1995;**16**:834–7.