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ORIGINAL ARTICLE

Quick-check Computed Tomography Versus Traditional Multi-slice Computed Tomography–guided Lung Biopsies: Comparison on Radiation Dose, Accuracy, Procedure Time, and Complications

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ABSTRACT

Objective: *To compare the diagnostic accuracy, complications, duration, and radiation dose of a quick-check computed tomography (CT)–guided percutaneous lung biopsy with the traditional multi-slice CT (MSCT)-guided method.*

Methods: *This was a retrospective study of 157 consecutive patients undergoing either a quick-check CT-guided or traditional MSCT-guided lung biopsy. The radiation dose (volume CT dose index and dose–length product), procedural time, technical success, and complications were compared.*

Results: *Quick-check CT-guided biopsy had a shorter procedural time (5 min vs. 12 min) without a significant difference in diagnostic yield (88% vs. 90%) or complication rate (post-procedural pulmonary haemorrhage or pneumothorax) when compared with traditional MSCT-guided biopsy. Quick-check CT biopsy also showed a reduced dose–length product (26 ± 12 mGy·cm vs. 178 ± 109 mGy·cm) across various lesion sizes and depths from pleura.*

Conclusion: *Quick-check CT-guided biopsy afforded a shorter procedural time and a reduction in dose–length product compared with the traditional MSCT-guided biopsy. Such reduced radiation dose was likely due to the reduced scanned length of the target lesion. Quick-check CT did not negatively impact patient safety or diagnostic yield in pulmonary lesion biopsies. Quick-check CT is a potentially viable option for CT-guided biopsy that can lower radiation dose and shorten procedural time.*

Key Words: *Lung neoplasms; Radiation dosage; Tomography, X-ray computed/methods*

中文摘要

快檢電腦斷層和傳統多層電腦斷層引導肺活檢：輻射劑量、準確性、手術時間和併發症的比較

羅嘉齊、王先民、朱卓文

目的：比較快檢電腦斷層（CT）引導與傳統多層電腦斷層（MSCT）引導進行經皮肺活檢的診斷準確性、併發症、持續時間和輻射劑量。

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方法：對連續157名接受快檢CT或MSCT引導下肺活檢的患者進行回顧研究，以比較兩者的輻射劑量（電腦斷層劑量指數和劑量長度乘積）、手術時間、技術成功率和併發症。

結果：與傳統MSCT引導比較，快檢CT引導的活檢手術時間較短（5分鐘比12分鐘）；診斷率（88%比90%）或併發症率（術後肺出血或氣胸）則無顯著差異。與傳統MSCT引導相比，快檢CT在不同大小和胸膜深度的病變時達到劑量長度乘積均減少（26 ± 12 mGy·cm比178 ± 109 mGy·cm）。

結論：與傳統MSCT引導活檢相比，快檢CT引導活檢可縮短手術時間和減少劑量長度乘積。輻射劑量減少或因靶病變的掃描長度減少。快檢CT肺病變活檢對於患者安全性或診斷價值沒有負面影響。快檢CT是CT引導活檢的潛在可行選擇，可減低輻射劑量並縮短手術時間。

INTRODUCTION

Percutaneous computed tomography (CT)–guided biopsy is an established procedure for evaluating solitary pulmonary nodule, mass, or persistent infiltrate.[1] Its success relies on accurate verification of the needle position throughout the intervention. Since the 1970s, traditional multi-slice CT (MSCT) has been the modality of choice.[2] However, MSCT-guided biopsy requires repeated scanning of the target lesion during the procedure with the interventional radiologist repeatedly entering and leaving the CT suite after each needle adjustment (Figure 1).[2] Conversely, continuous CT fluoroscopy is an alternative method[3,4] which allows for real-time scanning and needle adjustment but at the expense of a higher radiation dose to the patient and the operators.[2-4]

A quick-check CT method using SmartStep™ software (General Electric, Milwaukee [WI], US) could offer a potential third option in CT-guided procedures.[5] In this method, the examiner operates the CT machine within the CT suite with a foot pedal. When activated, three static axial slices (with a choice of collimation of 0.625 mm, 1.25 mm, 2.5 mm, or 5 mm) are immediately displayed on a monitor (Figure 2). This is in contrast to scanning the entire length of the lesion using the traditional MSCT-guided method. The acquisition and simultaneous display of three axial slices per step can potentially reduce procedure time and radiation dose compared with scanning the entire length of thorax harbouring the lesion. The radiation dose should also be reduced when compared with continuous CT fluoroscopy method, owing to the absence of real-time CT fluoroscopic screening.

Using the quick-check CT method, the operator can also use a remote control to automatically pull the patient out of the gantry to allow for biopsy needle manipulation and then automatically move the patient back to the last position. This process can potentially be valuable in reducing the procedural time. To our knowledge, no dedicated studies have compared the radiation dose, diagnostic accuracy, complication rate using the quick-check CT method with the traditional MSCT-

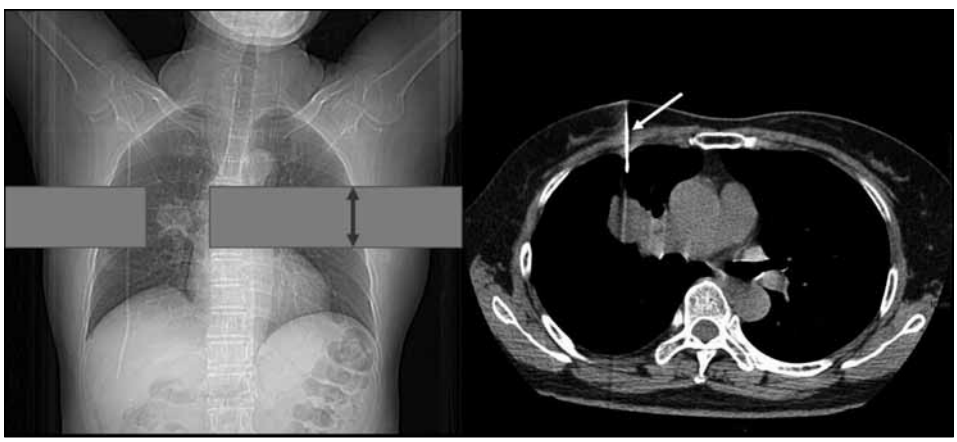

Figure 1. Scanogram and selected axial computed tomography slice during traditional multi-slice computed tomography-guided lung biopsy. This traditional method requires repeated scanning of the entire length of the lesion (height of the grey bar) after each needle adjustment (arrow) while advancing to the lesion.

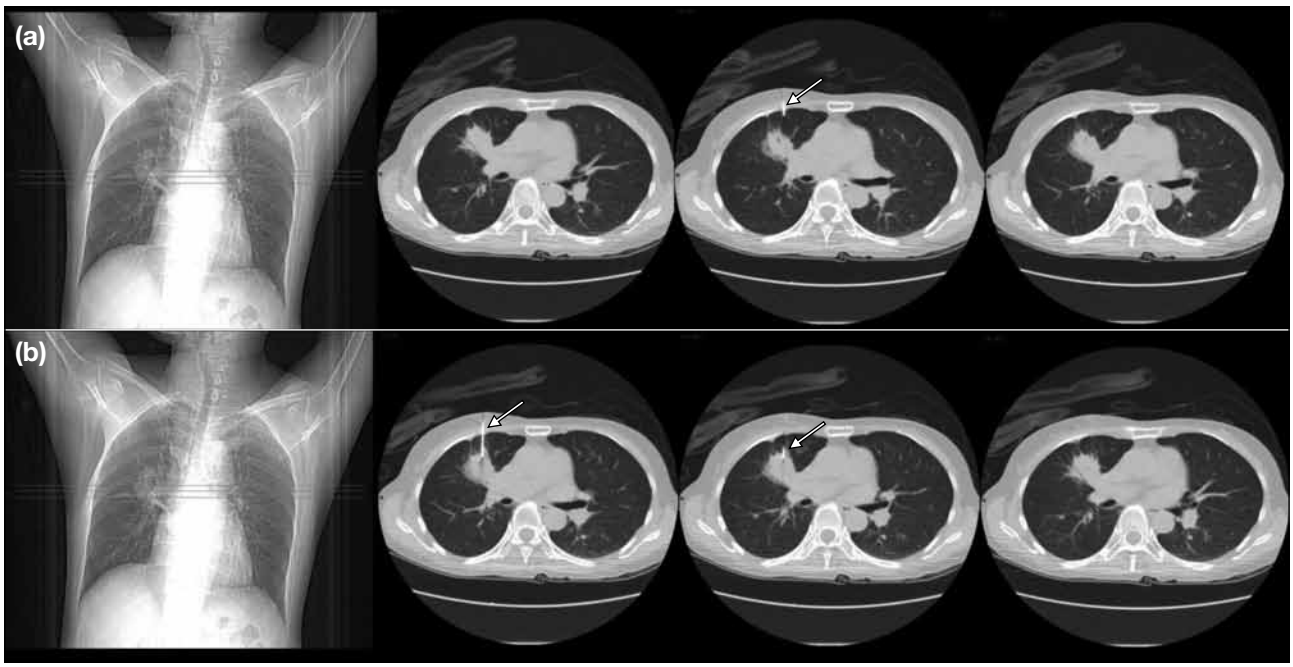

Figure 2. (a) Scanogram and selected axial computed tomography slices during quick-check computed tomography lung biopsy. This method only scans and displays three axial slices after stepping on the foot pedal. Needle adjustment (arrows) is made after assessing the initial images and additional foot pedal is activated (b) until the needle advances to target. In contrast to the multi-slice computed tomography, scanning three axial slices for each step reduces the scan length and radiation dose delivered to the patient.

guided method in pulmonary lesion biopsy.[5] Herein, we retrospectively reviewed patients who underwent lung lesion biopsy and compared the diagnostic accuracy, radiation dose, procedural time, and complications of the quick-check CT method with those of the traditional MSCT-guided method.

METHODS

The institutional review board of Prince of Wales Hospital, Shatin, Hong Kong, waived the need for ethics approval for this retrospective study. We reviewed the data of lung biopsies performed between January 2014 and December 2016 using a 64-slice CT scanner (Lightspeed 64 VCT; GE Healthcare, Uppsala, Sweden). In this period, 157 patients underwent 157 fine needle aspiration cytology (FNAC) and/or core biopsies of a pulmonary mass or nodule using either the traditional MSCT-guided method or the quick-check CT method. Biopsies were performed by four interventional radiologists with or without trainees under their direct supervision.

Scanning Protocol and Biopsy

Each patient was first positioned on the scanning table in supine, prone or decubitus positions, depending on the site of the lesion. A preliminary plain CT [tube voltage of 120 kV and automated tube current, usually 40-80 mA (0.6-s rotation time, 2.5-mm collimation, standard and lung algorithm)] was acquired covering the entire target lesion with a skin marker, and the interventional radiologist would then decide on the skin puncture site and the needle pathway. The skin puncture site was infiltrated with local anaesthetic (2% lignocaine). Then, a co-axial needle (19G, Bard Peripheral Vascular Inc., Tempe [AZ], US) was gradually inserted to the desired position at full expiration. The need to perform a progress CT (either quick-check or MSCT) was determined by the radiologist; for example, a single progress CT was performed for a large superficial lesion, whereas several progress CTs were performed for small deep lesions close to vital structures. Once the needle tip reached the target, the mandrel of the coaxial needle was removed, and an initial specimen was taken using a 22G Franseen needle (CareFusion, Waukegan [IL], US). At least three contiguous tissue cylinders were obtained for each target lesion. The specimen was immediately processed by an on-site cytology technician and a cytopathologist to determine the adequacy of the obtained specimen. If the specimen was considered inadequate for diagnosis, a trucut biopsy using a 20G Temno needle (CareFusion,

San Diego [CA], US) was performed. Immediately after removing the needle and applying a sterile adhesive dressing, a post-procedural CT scan was made to detect pneumothorax or pulmonary haemorrhage [tube voltage of 120 kV and automated tube current, usually 40-80 mA (0.6-s rotation time, 2.5-mm collimation, standard and lung algorithm)]. Of note, the progress CT during needle placement employed a reduced tube current of 10 to 20 mA, and further adjustment of the tube voltage and current was occasionally made if the same image quality could be achieved in slender patients at a lower dose or if a higher dose was required for obese patients. All images were archived in the picture archiving and communication system.

Procedural Time, Radiation Dose, Diagnosis, and Complications

Procedural time was calculated from the time when the biopsy needle was inserted to the time when the final specimen was obtained. With the needle in situ, two specific radiation dose metrics—the volume CT dose index ($CTDI_{vol}$) and the dose–length product (DLP)—were retrieved from the picture archiving and communication system and recorded. The thermoluminescence dosimeters of the radiologists and radiographers involved were also collected and the radiation doses received documented. The size, location, and depth of the pulmonary lesion, and any post-procedural complications including pneumothorax and pulmonary haemorrhage were recorded. The diagnostic yield (adequacy of sample) was calculated based on whether the samples were adequate in the final histopathological reports. Sensitivity, specificity, accuracy, and positive and negative predictive values were calculated using the methods proposed by Prosch et al.[2] More specifically, a lesion was considered truly malignant if the specimen or surgical histology confirmed it, whereas a lesion was considered truly benign if the result was confirmed by histology or stable or decreasing size over 1 year. A biopsy was considered non-diagnostic if histology revealed inadequate specimen, necrotic material, or normal lung parenchyma.

Statistical Analysis

Numerical variables were expressed as arithmetic mean ± one standard deviation. Parametric tests (Student's *t* test, Pearson's correlation), and non-parametric tests (Pearson Chi-square test) were performed using the SPSS (Windows version 19.0; IBM Corp, Armonk [NY], US). A p value of <0.05 was considered statistically significant.

RESULTS

Patient Demographics, Diagnostic Yield, and Complications

From January 2014 to December 2016, there were 157 FNAC and/or core biopsies of pulmonary nodule/mass/infiltrate performed in 157 patients using either the traditional MSCT-guided method (n = 73) or the quick-check CT method (n = 84). The demographic data of each subgroup and lesion characteristics are summarised in Table 1. The two groups were comparable in age, sex, and lesion characteristics including the size and the depth from the pleura.

The diagnostic yield was similar between the two groups, as the on-site histocytologist was able to confirm sufficient material for histological diagnosis based on FNAC in 74/84 quick-check biopsies (88%) and 66/73 (90%) MSCT-guided biopsies (Chi-square test; p = 0.8). The final diagnosis was malignant in 115/157 patients (73%), benign in 25/157 (16%), and the biopsy was considered non-diagnostic in 17/157 (11%). The overall accuracy, sensitivity, specificity, negative predictive value, or positive predictive value were all similar between the two groups (Table 2).

The quick-check CT method was quicker to perform than the MSCT-guided method (4.5 min vs. 12.6 min; Student's *t* test; p = 0.04 [Table 3]). The numbers of post-

Table 1. Patient demographics (n=157).*

	Quick-check (n=84)	Multi-slice computed tomography (n=73)	p Value
Age (years)	67 ± 14	69 ± 10	0.5†
Sex (male:female)	50:34	52:21	0.13‡
Final diagnosis			0.80‡
Benign	17	8	
Malignant	57	58	
Non-diagnostic	10	7	
Size (mm)	28 ± 12	30 ± 16	0.91†
Lesion depth (mm)	41 ± 28	39 ± 24	0.96†
Location			0.49‡
Upper	27	26	
Mid	28	18	
Lower	29	29	
Position			0.10‡
Supine	39	24	
Prone	45	49	

* Data are shown as mean ± standard deviation or No. of patients, unless otherwise specified.
† Student's *t* test.
‡ Chi-square test.

Table 2. Performance characteristics of quick-check and MSCT-guided biopsies.

	Quick-check*	MSCT*	p Value†
Sensitivity	88.3% (77.4%-95.1%)	93.5% (84.3%-98.2%)	0.98
Specificity	85.0% (62.1%-96.8%)	72.7% (39.0%-94.0%)	0.67
Accuracy	88.0%	90.4%	1
PPV	94.6% (86.1%-98.0%)	94.6% (88.0%-98.1%)	1
NPV	70.8% (54.1%-83.3%)	66.7% (42.0%-84.7%)	0.82

Abbreviations: MSCT = multi-slice computed tomography; NPV = negative predictive value; PPV = negative predictive value.
* Data are shown as % (95% confidence interval).
† Chi-square test.

Table 3. Comparison of procedural time and radiation dosage between groups receiving quick-check or MSCT-guided biopsy.

	Quick-check	MSCT	p Value*
Procedural time	4 min 32 s ± 3 min 36 s	12 min 41 s ± 4 min 59 s	0.04
DLP (mGy·cm)	26 ± 12	178 ± 109	0.02
$CTDI_{vol}$ (mGy)	27 ± 14	25 ± 21	0.42

Abbreviations: $CTDI_{vol}$ = volume computed tomography dose index; DLP = dose–length product; MSCT = multi-slice computed tomography.
* Student's *t* test.

procedural perilesional haemorrhage in the quick-check group (39/84; 46%) and in the MSCT group (40/73; 55%) were similar (Chi-square test; p = 0.42), with no emergency embolization or blood transfusion required. The pneumothorax rates in the quick-check group (33/84; 39%) and in the MSCT group (30/73; 41%) were also similar (Chi-square test; p = 0.68). One patient in the quick-check group required chest drain insertion, whereas 12 patients in the MSCT group required chest drain insertion (Chi-square test; p = 0.023). The rate of chest drain insertion was also lower in the quick-check group.

Radiation Dose

We investigated the effect on radiation dose by comparing the $CTDI_{vol}$ and DLP of the quick-check CT method with those of the MSCT-guided method. The quick-check group had a lower DLP than the MSCT group (26 ± 12 mGy·cm vs. 178 ± 109 mGy·cm; Student's *t* test, p = 0.02), whereas the $CTDI_{vol}$ values were similar for the two groups (27 ± 14 mGy vs. 25 ± 21 mGy; Student's *t* test, p = 0.42).

The depth of the pulmonary lesion showed a positive correlation with the DLP in both the MSCT group (Pearson's correlation; $r = 0.72$) and in the quick-check group (Pearson's correlation; $r = 0.34$), suggesting that deeper lesions required more radiation to complete. We further investigated the relationship between lesion depth and radiation dose by categorising the lesions into superficial (<3 cm), medium (3-6 cm), and deep lesions (>6 cm). In the deep category, DLP was lower in the quick-check group than in the MSCT group (Figure 3). Conversely, there was a negative correlation between the size of the lesion and DLP in the MSCT group (Pearson's correlation; $r = –0.75$) and in the quick-check group (Pearson's correlation; $r = –0.3$), suggesting that a larger lesion required a lower dose of radiation. We divided the lesions into small (<2 cm), medium (2-4 cm), and large (>4 cm) categories. In the small category, DLP was lower in the quick-check CT method than in the MSCT group, regardless of lesion size (Figure 4). Finally, the thermoluminescence dosimeters of the radiologists and radiographers involved in either biopsy method indicated that radiation doses remained below the local government regulated dose limits (<20 mSv per year).

DISCUSSION

The goal of dose reduction in any CT-guided interventional procedure is to minimise the stochastic effects of radiation without sacrificing the diagnostic accuracy.[1,6-8] Here, we showed that with the quick-check CT method, lung biopsy can be performed to a high standard with an 80% reduction in DLP and shorter procedure time, while achieving a similar diagnostic yield and complication rate as compared with the traditional MSCT-guided method. Lung biopsy using the quick-check CT method also had a lower chest drain insertion rate than that using the MSCT-guided method. The decision for chest drain insertion was based on assessment of the pneumothorax size and clinical symptoms immediately after the biopsy in the radiology department, or by the clinicians based on the aforementioned factors and possible resolution of the pneumothorax on serial radiographs. The observation

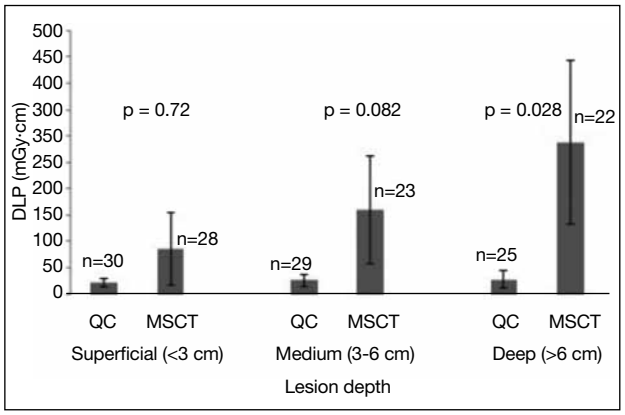

Figure 3. Relationship between lesion depth and DLP.
Abbreviations: DLP = dose–length product; QC = quick-check computed tomography; MSCT = multi-slice computed tomography.

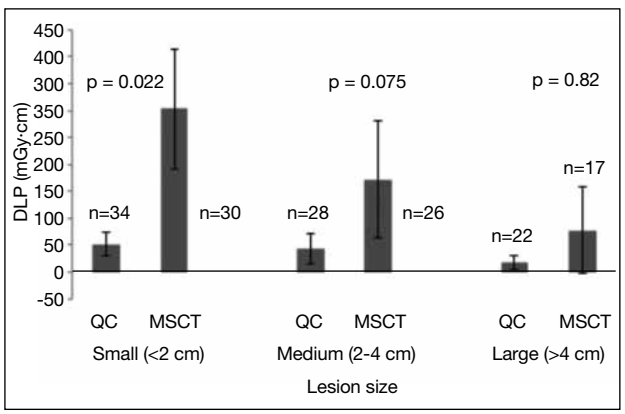

Figure 4. Relationship between lesion size and DLP.
Abbreviations: DLP = dose–length product; QC = quick-check computed tomography; MSCT = multi-slice computed tomography.

of fewer chest drain insertions in the quick-check group was probably multi-factorial but could be related to the shorter procedure time. Both the quick-check and MSCT data met the quality guidelines published by the Society of Interventional Radiology Standards of Practice Committee.[1] At our institution, quick-check CT method has been employed in biopsy of mediastinal or intra-abdominal mass (data not shown). A previous study has also shown that the quick-check CT method is useful in biopsy of paediatric bone tumours.[9]

In the present study, we used CT-specific dose measurements ($CTDI_{vol}$ and DLP) to quantify radiation dosage. CTDI is calculated based on radiation dose absorbed by acrylic phantoms.[10-12] $CTDI_{vol}$ includes the absorbed radiation dose from the primary beam plus that scattered from surrounding tissues in adjacent contiguous sections and incorporates variables such as collimation, pitch factor, and the position of the irradiated tissue in the scanning plane.[12] From this information, the DLP can be calculated, which estimates the total dose delivered over a specific scan length. Thus, the DLP relates to the total energy imparted in the patient and has a linear relationship with the effective dose.[12] Current debate is ongoing about the best quantitative assessment on radiation dose.[10,11] Some authors argue that these indices do not measure the dose the patient absorbs and do not account for variation in patient size.[10] Conversely, others have argued that radiation dose is primarily determined by the machine and the region imaged, and that the patient size is only a minor contributing factor.[11] Here, we used DLP as an index for the radiation dose and found that the quick-check CT method had an approximate six-fold decrease in DLP when compared with the traditional MSCT-guided method, whereas the $CTDI_{vol}$ values were similar for the two groups. This suggests that the dose reduction was due to the shortened scan length of the quick-check CT method, as only three axial slices were acquired during each scan, rather than the entire length of the lesion using the traditional MSCT-guided method. When using the quick-check CT method, care must be taken to align the needle in the same plane as the scanning plane, so that the entire needle path can be visualised. This is particularly challenging for small lesions, as the position varies with respiration and may not be consistently captured in the same manner in successive steps.[13] However, the lower DLP achieved by the quick-check CT method in small and deep lesions demonstrated that such a limitation could be overcome by careful technique and procedure planning.

The main limitation of this study was its retrospective nature. The lack of randomisation may also have led to selection bias. However, we found no difference between the quick-check CT and MDCT-guided methods in terms of patients' demographics, lesion size, depth, or nature (benign vs. malignant). There was also a lack of a standard radiation dosage adjustment protocol. More specifically, a pre-and post-procedural CT scan of the entire thorax was used but with a variable tube currency of 20-100 mA (0.6-s rotation time, 2.5-mm collimation, standard and lung algorithm) and a usual tube voltage of 120 kV. This variability depended on patient size and the preferences of the radiologist. Thus, adherence to a standard, low-dose protocol in the future would be helpful to achieve further radiation dose reduction.

With advances in dosimeters that can measure skin entry dose, further studies are required to assess the radiation dose delivered to the operators. Although the thermoluminescence dosimeters of the radiologists and radiographers involved in either biopsy method remained below the local government regulated dose limits (<20 mSv per year), the exact dosage specific to the procedure was not recorded.

CONCLUSION

We demonstrated that, for lung biopsy, the quick-check CT method can lower radiation dose and shorten procedure time by 33% without sacrificing diagnostic accuracy or increasing complication rate, compared with the traditional MDCT-guided method. The quick-check CT method is a viable option in CT-guided biopsy for pulmonary lesions.

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