Hiroshima J. Med. Sci.
Vol. 70, No. 2·3·4, 35~38, December, 2021
HIMJ 70–6

Computed Tomography Fluoroscopy-guided Biopsy of Lung Nodules: Comparison of the Step-wise and Real-time Techniques

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ABSTRACT

The present study aimed to compare the step-wise and real-time techniques for computed tomography (CT) fluoroscopy-guided biopsy of lung nodules. It included 72 consecutive patients (50 men, 22 women; mean age: 71.8 years; range: 45–89 years) with lung nodules. Between March 2017 and April 2019, 72 CT fluoroscopy-guided biopsy procedures were performed using either the step-wise (n = 34) or real-time technique (n = 38). The diagnostic accuracy was 97.1% for biopsies performed using the step-wise technique and 94.7% for those performed using the real-time technique ($p = 0.39$). The mean CT dose index was 48.8 ± 16.9 mGy/s for the step-wise method and 59.9 ± 25.6 mGy/s for the real-time method; the dose length product was 1956 ± 729 mGy and 2613 ± 1300 mGy for the two techniques, respectively ($p < 0.05$). There was a significant difference in mean exposure time (81 ± 43 s for the step-wise technique and 162 ± 120 s for the real-time technique; $p < 0.05$). The mean lung nodule size was also significantly different (29.9 ± 17.6 mm for the step-wise method and 17.8 ± 12.2 mm for the real-time method; $p < 0.01$). Of the 34 step-wise procedures, 11 (32.4%) resulted in pneumothorax, as did 24 of 38 (63.2%) real-time procedures ($p < 0.01$). The real-time technique is particularly useful in patients with small nodules. The CT dose, exposure time, and incidence of pneumothorax were significantly lower when the step-wise technique was applied to CT fluoroscopy-guided biopsy of lung nodules.

Key words: *Non-vascular intervention, Lung biopsy, CT fluoroscopy, Step-wise technique*

INTRODUCTION

Percutaneous computed tomography (CT)-guided biopsy of pulmonary nodules is an accurate and safe procedure for the pathological diagnosis of lung lesions[2,6,9,11,13]. Although CT fluoroscopy yields immediate feedback images throughout the procedure[2], the needle position must be confirmed throughout the procedure and personnel must be present during X-ray delivery to ensure accurate biopsy results[4]. Some clinicians have suggested that CT fluoroscopy-guided biopsy be performed using the step-wise technique to shorten the exposure time and prevent direct exposure of the operator's hand[3,5,6,8]. However, unlike the ultrasound and fluoroscopy examinations, CT fluoroscopy guidance using the step-wise technique does not present images in real time, and the imaging steps required to monitor and document needle placement can be time-consuming[1]. Lung lesions move when a patient breathes, so it can be difficult to biopsy small nodules using the step-wise technique, which is faster and requires fewer needle passes.

We compared factors such as usefulness, safety, and radiation dose between the step-wise and real-time techniques for CT fluoroscopy-guided biopsy of lung nodules.

MATERIALS AND METHODS

Approval of this research was obtained from our institutional ethics committee. The principles of the Declaration of Helsinki were followed. Written informed consent to undergo the procedure was obtained from all patients.

Patients

Our study included 72 consecutive patients with lung nodules (50 men, 22 women; mean age: 71.8 years; range: 45–89 years). Between March 2017 and April 2019, we performed 72 CT fluoroscopy-guided biopsy procedures using either the step-wise (n = 34) or real-time technique (n = 38). The final diagnosis was confirmed based on pathological findings or clinical follow-up. The choice of technique depended on the size

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of the nodules, the patient's breathing status, or the operator's preference. When the nodule size was less than 2 cm, the real-time technique was preferred.

Biopsy procedures

Preliminary helical CT images were obtained using a skin marker in place. We imaged 5-mm-thick sections of each lesion. Based on these images, we determined the appropriate patient position (supine, prone, or lateral), the level of the needle entry site, and the direction of approach that would yield the best direct route for biopsy. We avoided bullae and fissures, major blood vessels, and other important organs. The procedure was performed by one of six interventional radiologists who undertook CT-fluoroscopy-guided biopsy. Pulmonary nodule biopsies were performed using an interventional CT system featuring a unified, 16-row, multidetector CT scanner (Aquilion LB; Canon Medical Systems, Tokyo, Japan). During CT-fluoroscopy-guided biopsy, the exposure parameters were 120 kV, 50 mA, 4-mm slice thickness, 0.5-s scanning speed per rotation. The operator in the CT suite controlled the CT fluoroscopic exposure using a foot pedal, assisted in moving the gantry, and directed the laser light beam via a control panel. To reduce overall radiation exposure, the radiologist wore a lead-covered apron, gloves, glasses, and neck protectors; a body dosimeter was located at the upper chest level under the lead apron.

Biopsies were performed using a Monopty needle (Bard, Covington, GA, USA) or a Temno needle (Bauer Medical, Clearwater, FL, USA). In 66 procedures, we used the Monopty, while in eight we used the Temno needle. During two procedures, we used both needles. The Monopty needle is a fully automated biopsy device that automatically triggers a rapidly firing, side notch, Tru-Cut-type biopsy needle. The Temno needle is a semiautomated biopsy device that requires manual advancement of the trocar to expose the side notch.

To identify possible early complications, a low-dose CT scan of the biopsy site was acquired immediately after the guide needle was removed. Expiratory chest radiographs with the patient in the upright position were obtained 2 hr after the procedure and again on the day after.

Using the step-wise technique, CT fluoroscopy images were acquired to confirm the position of the puncture needle, without advancing or adjusting the puncture angle. Using the intermittent real-time technique, the biopsy needle was advanced using an I-I device (Hakko, Tokyo, Japan), which was developed to assist in precisely advancing the needle while avoiding irradiation of the operator's hands. The puncture needle was advanced in true real-time mode using an I-I device (Figure 1). A part of the biopsy needle was grasped using surgical forceps to prevent direct radiation exposure of the operator's hand[12].

Investigated parameters

We retrospectively investigated the following parameters: diagnostic accuracy, lesion size and depth (skin to nodule), puncture time, procedure-related complications, exposure dose (CT dose index [CTDI], dose length product [DLP], and exposure time).

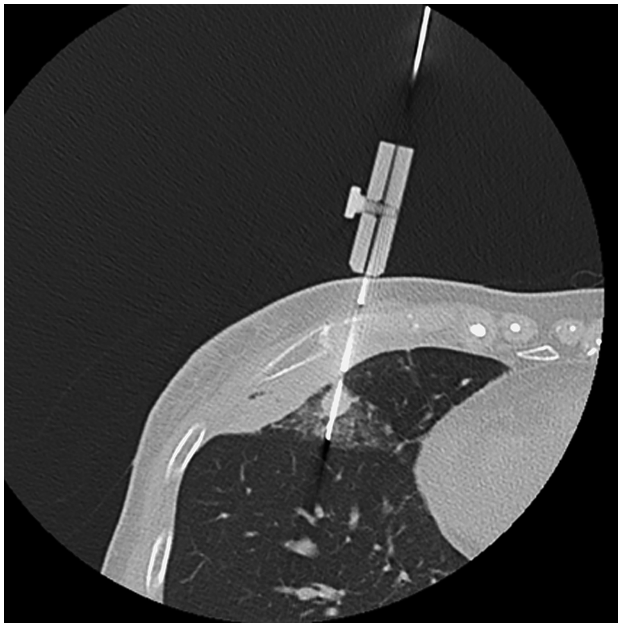

Figure 1 CT images of 76-year-old woman. Application of real-time technique using an I-I device. Note the small lung nodules. The patient was diagnosed with granuloma.

Histological findings were compared with the final diagnosis rendered by members of the surgical pathology department, or with findings made during clinical follow-up visits. A final diagnosis of malignant lesion was accepted when the patient was treated for malignancy and the subsequent clinical course and response to therapy were in line with the diagnosis. A final diagnosis of benign lesion was recorded when there was spontaneous resolution, resolution after treatment for conditions other than cancer (e.g., treatment with antibiotics), or no change in lesion size for more than 12 months. The two techniques were compared with respect to the incidence of pneumothorax, hemoptysis, and hemothorax. Hemothorax was defined as a new post-biopsy pleural effusion confirmed on CT scans acquired immediately after the procedure. In patients with pneumothorax, we recorded the number of patients requiring manual aspiration and tube placement[10].

Statistical analysis

The Mann–Whitney *U*-test was used to assess statistical differences in the mean values, while Fisher's exact test was used to evaluate significant differences in categorical data. Statistical significance was set at p-values < 0.05.

RESULTS

We performed 72 CT-fluoroscopy-guided lung biopsies in 72 patients (step-wise technique, n = 34; real-time technique, n = 38).

Table 1 Comparison between the step-wise and real-time techniques

	Step-wise n = 34	Real-time n = 38	p-values
Men	28	22	< 0.01
Women	6	16	
Age (years)	71 ± 10.9	72 ± 8.4	0.76
Benign	9	10	0.48
Malignant	25	28	

Table 2 Comparison of the investigated parameters

Characteristics	Step-wise	Real-time	p-values
Lesion size (mm)	29.9 ± 17.6	17.8 ± 12.2	< 0.01
Lesion depth (mm)	45.7 ± 17.5	41.6 ± 17.2	0.30
Sufficient samples	100% (34/34)	100% (38/38)	1
Accuracy	97.1% (33/34)	94.7% (36/38)	0.386
Number of punctures	2.4 ± 0.8	2.5 ± 1.0	0.8619
CT dose index (mGy/s)	48.8 ± 16.9	59.9 ± 25.6	0.0255
Dose length product (mGy/s)	1956 ± 729	2613 ± 1300	0.0119
Exposure time (sec)	81 ± 43	162 ± 120	< 0.01
Pneumothorax	32.4% (11/34)	63.2% (24/38)	< 0.01
Hemoptysis	47.1% (16/34)	50.0% (19/38)	0.46816
Hemothorax	5.9% (2/34)	13.2% (5/38)	0.1760

Step-wise technique

With the 34 step-wise techniques, we diagnosed eight lung nodules as benign (organizing pneumonia, n = 3; inflammatory lesions, n = 2; no malignancy, n = 3); 26 nodules were malignant (lung cancer, n = 24; malignant lymphoma, n = 1; spindle and pleomorphic cell tumor, n = 1). All biopsy samples were sufficient for histopathological evaluation. Two lesions were undiagnosed; the pathological diagnosis of one lesion was eventually confirmed by surgery; in another lesion, it was confirmed in a 2-year follow-up. No instances of seeding, air embolism, nerve injury, or infection were observed.

Real-time technique

With the 38 procedures performed using the real-time technique, 10 lung nodules were diagnosed as benign (organizing pneumonia, n = 2; inflammatory lesions, n = 2; granuloma, n = 1; no malignancy, n = 5); 28 nodules were malignant (lung cancer, n = 24; metastatic carcinoma, n = 3; malignant lymphoma, n = 1; Table 1). All samples were sufficient for histopathological evaluation. Two lesions were undiagnosed, and the pathological diagnosis was confirmed by surgery. No instances of seeding, air embolism, nerve injury, or infection were observed.

Comparison of the two techniques

As shown in Table 1, the lung nodule size was significantly larger when using the step-wise technique than when using the real-time method ($p < 0.01$), but the mean depth of the nodules was not significantly different between the two groups ($p = 0.30$). The mean CTDI and DLP were significantly higher in the real-time group than in the step-wise group ($p < 0.05$). Moreover, exposure time was significantly longer when using the real-time technique than when using the step-wise technique ($p < 0.01$). The rate of pneumothorax was significantly higher using the real-time technique ($p < 0.01$), but there were no inter-group differences with respect to the incidence rates of hemoptysis and hemothorax (Table 2). No step-wise procedures required chest tube placement; however, a chest tube was necessary in one of the 38 real-time procedures (2.6%; $p = 0.24$). In eight of the 23 real-time procedures resulting in pneumothorax, manual aspiration was required, but tube placement was not; manual aspiration was only performed in two of 34 step-wise procedures.

DISCUSSION

Imaging modalities, such as ultrasonography, fluoroscopy, CT, CT fluoroscopy, and magnetic resonance imaging, are used for guidance during percutaneous biopsies. CT fluoroscopy offers good reproducibility, variable field of view, easy access, and high spatial resolution and precision. To detect pulmonary targets, CT guidance may be superior to other imaging modalities because it is specifically applicable in air-containing body regions. In the presence of extensive respiratory movement, nodules can shift and disappear from the scan plane during percutaneous, CT-guided biopsy instruments[1]. This problem is greater when the lesions are small, so repeat punctures may be required and diagnostic accuracy reduced in such cases.

CT-fluoroscopy systems have been developed to address the lack of real-time imaging during CT procedures. They facilitate real-time image reconstruction and display cross-sectional CT images on a monitor[2,6].

Although CT-fluoroscopy-guided biopsy using the step-wise technique shortens exposure time and protects the operator's hand from direct radiation exposure, it is not a true real-time procedure, in which needle targeting and advancement are imaged synchronously. Our comparison between the two techniques revealed differences.

In CT-fluoroscopy-guided interventions, both the patient and the operator are exposed to ionizing radiation[2)]. The degree of risk associated with low-dose ionizing radiation remains under discussion; nonetheless, researchers agree that the radiation dose applied in diagnostic procedures should be as low as reasonably achievable. The two techniques differed significantly in terms of degree of radiation exposure.

While the diagnostic abilities of the two techniques were similar, the mean CTDI and DLP were significantly lower with the step-wise technique than with the real-time technique. In contrast, the real-time technique was superior in the identification of small lung nodules and in the detection of nodules subject to respiratory motion[5)]. The rate of pneumothorax of the step-wise technique was twice that of the real-time technique, possibly because nodule size differed between the groups; small lesions raise the risk of pneumothorax[7)]. We postulate that, with small lesions, frequent needle adjustment destroys bronchoalveolar structures and increases the risk of pneumothorax. However, the need for chest tube implantation did not differ significantly between the two groups.

Our study had some limitations. Its design was retrospective and observational. The two patient groups were not strictly randomized using a computerized randomization program, and their demographic backgrounds were dissimilar. Effective dose is the most significant parameter when identifying potential radiation-associated risks, and applying conversion factors allows clinicians to approximate the optimal effective dose as a function of CTDI or DLP.

CONCLUSION

The diagnostic ability of CT-fluoroscopy-guided biopsy of lung nodules was similar between the real-time and step-wise techniques. However, the CT dose and exposure time were significantly lower when the step-wise technique was used. Based on our findings, we suggest that the real-time technique be performed in selected patients with small lung nodules.

(Received May 13, 2021)
(Accepted June 18, 2021)

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