Multiplanar reconstruction technique for difficult computed tomography-guided lung biopsy: Improved accuracy and safety

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Abstract
We assessed the value of the multiplanar reconstruction technique (MRT) for computed tomography-guided lung biopsy. We evaluated 72 difficult biopsy cases (traditional method = 44; MRT = 28) to compare patient and lesion characteristics, diagnostic accuracy, complications, radiation dose, and procedure duration. Diagnostic accuracy was significantly higher using MRT than the traditional method (100% vs. 84.1%, respectively; \( P = 0.038 \)). There were no severe complications in the MRT group, but one case each of severe pneumothorax and fatal hemothorax in the traditional method group. The dose-length product rate was lower and the procedure duration slightly higher in the MRT than in the traditional group (336.83 vs. 479.64 and 33.39 vs. 25.93 minutes, respectively). MRT using computed tomography-guided lung biopsy could improve diagnostic accuracy and avoid severe complications compared to the traditional method.

Introduction
Computed tomography (CT)-guided lung tumor biopsy is widely used to diagnose pulmonary nodules. Although it is a relatively accurate and safe method, technically difficult cases can lead to inadequate diagnoses or severe complications. Diagnostic accuracy is limited by small lesion size or subpleural location. Other factors create difficulties for the procedure, such as long biopsy routes, routes obstructed by ribs or scapula, and dangerous routes in proximity to large blood vessels or the diaphragm.

The most common complication of CT-guided lung biopsy is pneumothorax, followed by pulmonary hemorrhage. Hemothorax is rare, but sometimes causes rapid hemodynamic change and death. Avoiding puncture of systemic arteries, such as the subclavian, axillary, internal mammary, and intercostal arteries can limit this complication. Use of the axial CT view alone can be ambiguous or less accurate to safely confirm the biopsy. Tumor seeding is also rare and is likely to arise from direct biopsy of a subpleural lesion; indirectly approaching the subpleural tumor through the normal pulmonary parenchyma can reduce the risk of pleural seeding.

The multiplanar reconstruction technique (MRT) offers an additional image plane to the axial view to ensure a supracostal needle path and avoid intercostal artery puncture. It also helps with the approach to the lesion when obstructed by bone or other structures, such as cartilage, breasts, and implants. This method can guide the biopsy route through a small part of the lung to approach the subpleural lesions and prevent pleural seeding.

To our knowledge, no study has compared the diagnostic accuracy and post procedure complications between MRT and the traditional method. This study applied MRT to CT-guided lung tumor biopsy to enhance diagnostic accuracy and safety, particularly in difficult cases.
Methods

Study population

Data of patients with suspected malignant or uncertain lung tumors that underwent CT-guided biopsy using the traditional method (44 cases) or MRT (28 cases) were collected from Mackay Memorial Hospital and its branch from January 2015 to July 2016. Each case had at least one difficult condition. Patient and lesion characteristics, including age, gender, biopsy position, tumor location, tumor size, and distance of intrapulmonary biopsy path, were collected. The difficulty of biopsy, biopsy result, and post procedure complications were investigated separately.

Difficulty of biopsy

We identified difficulties for each biopsy procedure, including small lesion size, subpleural lesions, lesions obstructed by bone, needle insertion site near the spine, long biopsy route, and dangerous biopsy route (Table 1).

Procedure

Multiple detector CT scanners (Somatom Definition AS and Somatom Definition Flash, Siemens, Munich, Germany; Aquilion One and Aquilion, Toshiba, Tokyo, Japan) were used for all CT-guided lung biopsies. The biopsy route was determined as the shortest route between the tumor margin and supracostal edge, including extension to the skin (Fig 1c). All patient biopsies were performed using a 17-gauge coaxial needle and an 18-gauge biopsy instrument (Argon, Frisco, TX, USA).

All patients underwent CT scanning immediately after biopsy to detect procedural complications, such as pneumothorax, pulmonary hemorrhage, or hemothorax. Complications were graded as mild, moderate, or severe.

Table 1 Difficulties of biopsy

| Difficulties                                | Traditional method (n = 44) | MRT (n = 28) |
|---------------------------------------------|----------------------------|-------------|
| Small size†                                 | 9 (20.5)                   | 8 (28.6)    |
| Subpleural lesion‡                          | 30 (68.2)                  | 19 (67.9)   |
| Obstructed by bone                         | 19 (43.2)                  | 19 (67.9)   |
| Insertion site near spine§                  | 20 (45.5)                  | 9 (32.1)    |
| Long biopsy route‡                          | 0 (0)                      | 1 (3.6)     |
| Dangerous biopsy route†                     | 17 (38.6)                  | 5 (17.9)    |

†Maximal lesion diameter ≤ 2 cm. ‡Shortest distance between the lesion and visceral pleural ≤ 1 cm. §In prone position biopsy, the shortest distance between the lesion and spinous process ≤ 6 cm. ¶Transpulmonary needle path > 5 cm. ††The lesion adjacent to great vessel or above the diaphragm. MRT, multiplanar reconstruction technique.

Multiplanar reconstruction technique (MRT)

We reconstructed the multiplanar image from axial image data after initially determining the biopsy route with a radiopaque marker on the skin (Fig 1a,b). For each axial scan, we created a reconstructed image along the biopsy route (Fig 1d-f). Needle direction was adjusted based on axial and reconstructed views to ensure the biopsy route was correct and safe when close to the biopsy target (Fig 2).

Statistical analysis

Statistical analysis was performed using SPSS version 22 (IBM Corp., Armonk, NY, USA). We conducted chi-square and Fisher’s exact tests to compare the difference in diagnostic accuracy and lesion characteristics between MRT and traditional methods. The threshold for statistical significance was P < 0.05.

Results

We found no statistically significant differences in age, gender, biopsy position, tumor location, tumor size, or distance of biopsy path between MRT and the traditional method (Table 2). The dose-length product (DLP) rate was lower using MRT (336.86) than the traditional method (479.64), representing a lower radiation dose in the MRT group. The procedure duration of MRT (33.39 minutes) was slightly higher than the traditional method (25.93 minutes). Diagnostic accuracy was 100% in 28 cases using MRT and 84.1% in 44 cases using the traditional method (P = 0.038) (Table 3). Pneumothorax occurred in 20 cases (45.5%) in the traditional method group, with one case severe enough to require chest tube insertion. In the MRT group, 18 patients had pneumothorax (64.3%), but none were severe cases. Twenty-one cases in the traditional method group showed hemorrhagic complications and one patient died from massive hemothorax. In the MRT group, 26 cases showed mild to moderate hemorrhagic complications, with no severe cases or death (Table 4).

Discussion

Although CT-guided lung biopsy is a relatively accurate and safe method, there are still difficult cases leading to inadequate diagnosis or severe complications. In this study, we used MRT for 28 difficult biopsy cases and the results show a 100% diagnosis rate without severe post-biopsy complications. Conversely, the traditional method had significantly lower diagnostic accuracy (84.1%) among difficult biopsy cases, and often caused severe complications.
Several factors impact diagnostic accuracy, including lesion size and small subpleural lesions. Using the traditional short-needle-path method for a small subpleural lesion biopsy requires more needle punctures, which causes more frequent incidence of pneumothorax, but has lower diagnostic accuracy compared to the long-needle-path method.

Figure 1: Computed tomography-guided lung tumor biopsy using the multiplanar reconstruction technique: (a) pre-biopsy scan; (b) localization with radiopaque marker on the skin; (c) biopsy route confirmed via supracostal edge; (d–f) step-by-step to approach to the lesion. The white arrow represents the biopsy target.

Figure 2: Final biopsy image: (a) axial view; (b) sagittal view; (c) coronal view; and (d) three-dimensional reconstruction image. The white arrow represents the biopsy target.
method. In our study, 26 cases of subpleural lesions were detected using the traditional method, including three failed diagnoses, and one moderate and one severe pneumothorax post-procedure. All 10 cases diagnosed with subpleural lesions using MRT were accurate, with no incidence of moderate or severe pneumothorax.

Many difficulties are encountered during a biopsy procedure, including bone obstruction. MRT offers another image view to improve the biopsy plane and tissue access. MRT ensures the needle approaches the target tissue and safely avoids the aorta or diaphragm when the lesion is adjacent to these structures. Our results show that MRT has higher diagnostic accuracy than the traditional method, revealing the importance of using this method in difficult biopsy cases.

Although severe complications of CT-guided lung biopsy are rare, they can be fatal. Rapid hemothorax with hemodynamic change is a severe complication, and death can occur if the complication is not detected and managed early. Hemothorax is often caused by injury to the intercostal artery or internal mammary artery. The intercostal artery is shielded in the intercostal groove of the superior rib, but there is variability to the arterial course (Fig. 3). The intercostal artery is exposed within the intercostal space and safely aid the procedure.

Pleural seeding after CT-guided lung biopsy is rare, but can induce advanced lung cancer if occurring in the early stages. Direct biopsy of subpleural lesions leads to a higher risk of pleural seeding than non-subpleural lesions. Inoue et al. suggest approaching the subpleural tumor through the pulmonary parenchyma to reduce the risk of pleural seeding. MRT offers a biopsy plan for subpleural lesions through the pulmonary parenchyma to alleviate the risk of post-biopsy pleural seeding.

MRT is the reconstructed image from the axial CT image, thus the radiation dose does not increase. In our data, the DLP in MRT was much lower than the traditional method, possibly because of the use of a lower dose scan protocol and scan frequency for MRT. MRT takes longer than the traditional method, possibly because more time is taken for image reconstruction and planning. Generally,
30 minutes per biopsy is reasonable and MRT is completed within this time.9 There are some limitations with this technique. The operator needs sufficient biopsy experience and spatial perception. Our small sample size limits the value of this study, but analysis of more cases in the future may validate the benefit of MRT.

MRT using CT-guided lung biopsy can improve diagnostic accuracy and avoid severe complications compared to the traditional method. We encourage applying this technique for difficult cases.

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Disclosure

No authors report any conflict of interest.

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