Efficacy and Complications of Computed Tomography-Guided Hook Wire Localization

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Background. Video-assisted thoracic surgery offers a minimally invasive method for diagnosing and treating small pulmonary lesions, although the localization of these lesions is sometimes problematic. Various localization methods have been reported but few studies have described their efficacy and adverse events.

Methods. We performed computed tomography (CT)-guided localization using a hook wire in 417 patients with 500 lesions treated between January 2006 and December 2010.

Results. We located 178 lesions with a ground-glass opacity component and 322 solid lesions. The solid lesions had smaller tumor diameters and were located further from the pleura. Tumor depth to size ratio was 0.9 ± 0.9 for the lesions with a ground-glass opacity component and 1.8 ± 1.5 for the solid lesions (\(p < 0.001\)). Pneumothorax requiring aspiration was observed in 4.6% patients, and hemoptysis and pulmonary hematoma was observed in 10.3%. Systemic air embolism with no sequelae and spontaneous resolution occurred in a patient (0.24%). The morbidity rate was 15.1%. Male patients, patients who had undergone multiple localization, and heavy smokers were at a higher risk of pneumothorax requiring aspiration. Insertion distance more than 25 mm was a risk factor for pneumothorax and pulmonary hematoma (\(p < 0.001\)). Procedure duration per lesion was 14 ± 5 minutes. Dislodgement occurred in 2 patients (0.4%).

Conclusions. The safety, reliability, and convenience of CT-guided hook wire localization are acceptable. Localization for lesions with a ground-glass opacity component may be performed when the lesions are relatively large and shallow. Insertion distances greater than 25 mm are associated with a risk of pulmonary hematoma and hemoptysis.


The growing popularity and efficacy of computed tomography (CT) has led to an increase in the identification rate of small pulmonary lesions. Video-assisted thoracic surgery (VATS) offers a minimally invasive method for diagnosing and treating these lesions, although the localization of these lesions is sometimes problematic. Although it is possible to identify many small lesions by manual palpation or palpation using a metallic suction tube or forceps during VATS, identification of lesions with a ground-glass opacity (GGO) component, deep pleural lesions, and lesions surrounded by pleural adhesions remains difficult. Various localization methods have been reported, which can be classified into three types. First, there are noninvasive intraoperative methods using ultrasonography [1–4] or pressure sensors; however, these techniques struggle to identify lesions with a GGO component, deep lesions, and lesions in patients with emphysematous lungs or pleural adhesions. Second are methods wherein percutaneous localizers, including hook wires [5–8], dyes [9, 10], contrast media [11, 12], and radiotracers [13, 14] are inserted; however, the complications of these techniques include pneumothorax and pulmonary hemorrhage. Third are methods wherein localizers can be inserted transbronchially [15]. Although these methods are considered less invasive than percutaneous methods, they cause complications such as bronchoscopy-related pain and require specialized equipment and techniques such as CT-fluoroscopy for accuracy.

We introduced CT-guided hook wire localization in 1999, and since then we have used this technique for more than 900 patients. Here, we evaluate the safety, reliability, and convenience of the technique from the experience of 500 procedures after the digital imaging system was introduced in 2006.

Patients and Methods

We performed CT-guided localization using a hook wire in 417 patients with 500 lesions treated at Toranomon Hospital, Tokyo, Japan, between January 2006 and December 2010. Of 1,849 surgeries performed under general anesthesia during the period, 1,089 procedures (59%) were performed for undetermined lung nodules. Therefore, the rate of preoperative hook wire placement was 38% (417 of 1,089). Thoracic surgeons generally perform localization in the evening before the surgery.
because the CT room is busy with other patients undergoing ordinary CT scans during the day. In our study, puncture was performed in a direction perpendicular to the ground where possible, with patients in a suitable physical posture (lateral position in 254, supine position in 92, and prone position in 154). First, an initial CT image was obtained, puncture site determined, and distance between the skin and pleura calculated (Fig 1A). After local anesthesia, a second CT image was obtained to measure the distance between the needle tip and pleura, and the pleura was sufficiently anesthetized. The localizing needle (Guiding-Marker System; Hakko Medical Products, Tokyo, Japan) was inserted up to the pleura and a third image was obtained (Fig 1B). We then measured the distance from the needle tip to the lesion and inserted the localizing needle into the lung. A fourth image was obtained to confirm correct insertion of the localizer and check for pneumothorax, hemorrhage, or intravascular air (Fig 1C). We carefully confirmed the absence of neurologic symptoms. After 30 minutes of rest, a chest x-ray film was obtained to confirm the degree of pneumothorax.

We then evaluated the following items from patients’ medical records: tumor size, tumor depth, and insertion depth on CT; lesion type (with or without [solid] a GGO component); smoking index; forced expiratory volume in 1 minute; lung resection history; pleural adhesion; procedure time; time between localization and surgery; and complications. Continuous data are expressed as the mean ± SD. Lesions with a GGO component were defined as tumors with a less than 50% solid component. Pulmonary hematomas were defined as hematomas measuring more than 1 cm² on CT. The GGO lesions, which had no solid component, with diameters less than 10 mm were monitored by periodic chest CT until the lesions had grown by more than 10 mm in diameter or high-resolution CT revealed a core or pleural indentation. The general indication for preoperative localization is a tumor diameter of less than 1 cm or tumor depth to size ratio (D:S) greater than 1, but in certain cases, the surgeon may elect to perform preoperative localization on the basis of CT findings and medical history.

This study was conducted in accordance with the amended Declaration of Helsinki. The Toranomon Hospital Institutional Review Board of Clinical Research approved the protocol, and written informed consent was obtained from all patients.
Continuous data are expressed as mean ± SD. Categorical variables were analyzed using the \( \chi^2 \) test. All \( p \) values less than 0.05 were considered statistically significant.

**Results**

We treated 231 men and 186 women (mean age 64 ± 11 years). Target lesions occupied 500 locations; simultaneous localization was achieved in 53 patients with two lesions, 12 patients with three lesions, and 2 patients with four lesions. Pathologic diagnoses of the target lesions were as follows: lung cancer \( (n = 215) \), metastatic pulmonary tumors \( (n = 174) \), atypical adenomatous hyperplasia \( (n = 11) \), and benign lesions including intrapulmonary lymph nodes, granulomas, and scars \( (n = 100) \). In total, 127 of 500 lesions were resected because of the presence of another lesion that was larger and already diagnosed as or highly suspected of malignancy, although they were too small to indicate surgery by the lesion itself. A total of 11 adenomatous hyperplasia and 56 of 100 benign lesions were such concomitant tumors. Target lesions were resected by three-port VATS [16]: the diagnostic procedure was wedge resection in 460 patients, segmentectomy in 20, needle biopsy in 16, and enucleation in 4. On the basis of intraoperative frozen section histopathology findings, patients received additional resection such as lobectomy.

Of the target lesions, 178 had GGO components and 322 were solid (Table 1). The solid lesions had smaller tumor diameters and were located further from the pleura. The D:S ratio was 0.9 ± 0.9 for lesions with a GGO component and 1.8 ± 1.5 for solid lesions \( (p < 0.001) \). Pathologic diagnosis revealed that the lesions with a GGO component mostly comprised primary lung cancer, while solid lesions mostly comprised metastatic pulmonary tumors \( (p < 0.001) \). The solid lesions were further differentiated by the presence of pleural adhesions or a history of pulmonary resection. Forty-nine lesions in patients with pleural adhesions or a history of pulmonary resection exhibited smaller D:S ratios \( (1.5 ± 1.3) \). Pneumothorax was detected by CT in 206 patients \( (49\%) \) directly after the procedure and by chest x-ray film in 284 patients \( (68\%) \) 30 minutes after the procedure. Aspiration was performed when lung collapse was greater than 50% or symptoms such as dyspnea or chest pain were present, and 19 patients \( (4.6\%) \) required pleural puncture. Thirty-seven patients had pulmonary hematoma, 11 had hemoptysis, and 1 had systemic air embolism (SAE). We compared the 19 patients with pneumothorax requiring aspiration with the other patients and found that male patients \( (\text{odds ratio [OR]} 2.31) \), patients who had undergone multiple localization for several targets \( (\text{OR} 2.55) \), and smoking index greater than 400 \( \text{(OR} 2.09) \) were at a higher risk of having pneumothorax. Insertion depth on CT and forced expiratory

| Table 1. Comparison of Lesions With Ground-Glass Opacity Component and Solid Lesions |
|---------------------------------|-----------------|-----------------|------------------|
| Variable                        | GGO Lesions \( (n = 178) \) | Solid Lesions \( (n = 322) \) | \( p \) Value    |
| Tumor size, mm                  | 11.8 ± 5.3      | 9.1 ± 4.6       | <0.001           |
| 0–6                            | 8               | 75              |                  |
| 6–8                            | 33              | 73              |                  |
| 8–10                           | 24              | 62              |                  |
| 10–15                          | 68              | 67              |                  |
| >15                            | 45              | 45              |                  |
| Tumor depth, mm                | 9.9 ± 7.8       | 13.9 ± 11.0     | <0.001           |
| 0–4                            | 38              | 31              |                  |
| 4–7                            | 29              | 57              |                  |
| 7–10                           | 27              | 56              |                  |
| 10–15                          | 48              | 59              |                  |
| >15                            | 36              | 119             |                  |
| D:S ratio                      | 0.9 ± 0.9       | 1.8 ± 1.5       | <0.001           |
| 0–0.4                          | 40              | 21              |                  |
| 0.4–0.7                        | 34              | 40              |                  |
| 0.7–1.0                        | 40              | 50              |                  |
| 1.0–1.5                        | 32              | 69              |                  |
| >1.5                           | 32              | 142             |                  |
| Insertion depth, mm            | 18.4 ± 6.8      | 19.2 ± 8.2      | 0.23             |
| Pathology diagnosis            | Lung cancer/pulmonary metastasis/benign \( 144/6/28 71/168/83 <0.001 \) |
| Operative procedure            | Wedge resection/segmentectomy/needle biopsy/enucleation | 160/12/6/0 | 300/8/10/4 | 0.06 |

D:S ratio = tumor depth to size ratio, GGO = ground-glass opacity.
volume in 1 minute had little correlation with the risk of pneumothorax. We then compared the 43 patients with hemoptysis or pulmonary hematoma with the other patients and found that an insertion distance of greater than 25 mm was a risk factor for the development of these complications \( (p < 0.001; \text{OR} 6.94) \).

The patient who had SAE was a male nonsmoker in his fifties with a history of lung resection. He was placed in the left lateral position for localization, and the insertion distance was 22 mm. Mild pneumothorax was observed with no pulmonary hematoma. There was no coughing or body motion during puncture. Soon after localization, the patient exhibited yawning, dysarthria, and left upper and lower limb paralysis; brain CT showed a small amount of air suggestive of SAE. Immediately, the neurologic symptoms completely disappeared, and the patient was discharged the next day; he underwent uneventful surgery 25 days later.

Procedures were conducted in a CT room under local anesthesia by one physician and one radiology technician. The procedure duration was 14 ± 5 minutes per lesion. Time from localization to surgery initiation was 27 ± 20 hours (range, 5 to 138). Dislodgement was observed in 2 patients (0.4%), but in both it was possible to identify the lesion through the needle route.

**Comment**

At our institution, the decision to perform preoperative localization, selection of hook wire position, and actual needle placement are all undertaken by the thoracic surgeon. Investigations have been undertaken to determine the indications for preoperative localization \([17–21]\); however, the decision to perform localization is complex and difficult to make using a simple calculation formula. First, various palpation methods exist for patients in whom palpation is deemed impossible. In patients undergoing VATS with an incision length less than 3 cm, a metallic suction tube or forceps can be used or a single finger can be inserted to facilitate palpation. If the incision is 5 cm long, palpation with two fingers is possible, and this increases palpation ability. An incision of 10 cm is necessary to insert the entire hand for adequate palpation. Second, the lesions vary in firmness. Dense lesions with a GGO component are easy to palpate during VATS, although some extremely soft lesions elude palpation even when both hands are used. Among solid tumors, pulmonary metastases of hepatic cancer are comparatively soft and consequently difficult to palpate. Furthermore, the ease of palpation varies greatly, depending on the presence of pulmonary emphysema or pulmonary fibrosis, the degree of pleural adhesion, and proximity of lesions to the bronchi. Preoperative localization is commonly performed for lesions with a tumor diameter of less than 1 cm or a D:S ratio of greater than 1, but for individual cases, the operating surgeon may decide to perform preoperative localization on the basis of CT findings and medical history. In our study, patients having lesions with a GGO component and pleural adhesions tended to exhibit comparatively larger and more superficial lesions.

Although the finding that 111 of 500 lesions were benign or adenomatous hyperplasia is surprising, all of 11 adenomatous hyperplasia and 56 of 100 benign lesions were concomitant tumors, as previously mentioned. None of the adenomatous hyperplasia cases met our criteria for pathologic diagnosis described in the Methods section. From this result, we consider that this criterion is reasonable.

Problematic complications of percutaneous localization include pneumothorax, pulmonary hematoma, hemoptysis, and SAE. Pneumothorax was observed by CT immediately after the procedure in 49% of patients and on chest x-ray film 30 minutes after the procedure in 68% of patients. Therefore, studies that have conducted evaluations immediately after the procedure may have considerably underestimated the incidence of pneumothorax. In our study, pneumothorax requiring aspiration was observed in 4.6% patients, and hemoptysis and pulmonary hematoma in 10.3%. The rate of morbidities, including SAE, was 15.1%.

SAE was the most serious complication in this study, and it occurred in only 1 patient (0.24%), albeit without any sequelae and with spontaneous resolution. SAE arising as a complication of CT-guided needle biopsy and localization has been reported previously. Although the incidence of SAE during CT-guided needle biopsy has been reported to be 0.02% to 0.07% in large nationwide surveys \([22–24]\), recent institutional studies have reported a rate of 0.21% to 0.49% \([25–28]\). Freund and colleagues \([28]\) presented some alarming findings. Of 610 patients who underwent CT-guided needle biopsy, 0.49% had symptomatic SAE with a mortality rate of 0.16%, although intravascular air on CT immediately after the procedure was observed in no fewer than 3.8% of patients. The latent risk of SAE is clearly higher than generally believed. In addition, Freund and colleagues \([28]\) identified the following risk factors: depth of the needle in the lesion, endotracheal anesthesia, lesion location above the level of the left atrium, and a prone position during the procedure.

Extreme caution needs to be exercised to avoid puncturing the tumors and prevent dissemination; therefore, CT-guided localization may be associated with a higher risk of SAE compared with CT-guided needle biopsy. Our patient who had SAE underwent puncture in the left lateral position, and the lesion was above the level of the left atrium. The mechanism by which SAE occurs is thought to involve communication between the pulmonary vasculature and peripheral airways or between the pulmonary vasculature and the body’s external environment; however, the precise mechanism remains unclear and no known fundamental precautionary measures exist. Previously, we kept pulmonary puncture as brief as possible (1 s to 2 s), used puncture routes that avoided the pulmonary vasculature, and administered sufficient pleural anesthetics to prevent coughing and body movement during puncture. Despite these measures, we experienced a case of SAE and subsequently altered our
technique. First, to prevent the entry of atmospheric air through or around the needle, the aperture and puncture region are hermetically sealed with jelly. Second, we now perform puncture after exhalation rather than after inhalation. Third, as detailed by Kuo and colleagues [27], we perform puncture after exhalation rather than after inhalation. Fourth, as detailed by Kuo and colleagues [27], we perform puncture after exhalation rather than after inhalation. Fifth, we now perform puncture after exhalation rather than after inhalation. Sixth, we now perform puncture after exhalation rather than after inhalation. Seventh, we now perform puncture after exhalation rather than after inhalation. Eighth, we now perform puncture after exhalation rather than after inhalation. Ninth, we now perform puncture after exhalation rather than after inhalation.

With regard to reliability, gradual scattering is an issue with the dye method, and identification becomes difficult in patients with pleural adhesion and anthracosis. Dislodgement is reportedly a problem of the hook wire method, but in this study, it only occurred in 2 patients (0.4%) in whom identification of lesion location was possible through the puncture route. In a study by Seo and colleagues [29] localization failure occurred in 8 of 174 patients (5%); in that study, insertion distance from the pleura was significantly shorter (8.3 ± 5.3 mm) in the failed cases. On the basis of our experience, we conclude that failure can be avoided if insertion distances are maintained at greater than 1 cm.

The convenience of the hook wire method is exceptional. Procedure duration per lesion is 14 ± 5 minutes, only one physician and one radiology technician are required, and no specialized equipment such as that required for CT fluoroscopy, gamma probe, and radio-tracer is necessary. While the contrast method necessitates intraoperative fluoroscopy, the hook wire method does not. Furthermore, this method is convenient for patients. Our marker comprises a short hook wire and thread. After the insertion of the hook wire, the metallic part of the marker is completely under the pleura. We cut the thread at skin level so that no part of the marker is protruding. Almost all of the patients showed no symptoms after the procedures. They could sleep well, go out, work, and leave the hospital.

In conclusion, the safety, reliability, and convenience of CT-guided hook wire localization are acceptable. Localization for lesions with a GGO component may be performed when the lesion is relatively large and shallow. Insertion distances greater than 25 mm are associated with a risk of pulmonary hematoma and hemoptysis. Finally, the SAE incidence rate is low, as observed in this study (0.24%), if sufficient caution is exercised.

References

INVITED COMMENTARY

Changes in characteristics of lung cancer and improvements in computed tomography imaging frequently raise the question of optimal approach to tissue characterization of solid or ground-glass small pulmonary lesions. The association in the same patient of different lesions, with similar or different radiologic patterns, may be at the origin of diagnostic or management dilemmas. Widespread diffusion of video-assisted thoracoscopic surgery (VATS), and relative reticence in proposing limited thoracotomy for small lesions with a diagnostic and even with a therapeutic intent, led to development of different techniques for thoracoscopic visualization of small and deep lesions. Thus, digital or instrumental palpation, dyes or radio- nuclides injection, opacification with radiopaque substances, and computed tomography-guided hook wire insertion have been proposed. All these techniques have advantages and limitations, as well as costs and side effects.

The article by Ichinose and associates [1] focuses on preoperative computed tomography-guided hook wire localization of single or multiple lung abnormalities. The surgical team acquired a very important experience with this technique, which was, in their practice, very reliable. In particular, lesions could be always found at VATS, even after displacement of the hook, an occurrence exceptionally encountered (only 2 cases of 500) in the authors’ practice. In spite of this great experience, morbidity was not negligible, with a figure of 15%, probably related to the technique itself and thus incompressible.

In the authors’ experience, among 1,849 surgical procedures performed under general anesthesia during the study period, 1,089 (59%) were performed for undetermined lung nodules, and 38% of them (417 of 1,089) were VATS retrieval of nodules after hook wire placement. These figures reflect the interest of the team in the technique, as well as the specific epidemiology of lung abnormalities encountered in the authors’ activity. The particular interest in the technique probably explains the high rate of success in terms of low rate of hook displacement and high reliability in abnormalities identification and VATS retrieval, but raises the question of reproducibility of results of a relatively morbid technique by less-experienced teams. In fact, most surgeons are less frequently challenged with lung abnormalities not accessible to direct visualization or digital/instrumental palpation at VATS. Thus, imaging-guided segmental resections or manual palpation through a limited open approach, especially in the case of multiple lesions, probably remain largely acceptable therapeutic approaches for most surgical teams.

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