Factors determining successful computed tomography–guided localization of lung nodules

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Objectives: To investigate the factors related to the successful computed tomography–guided nodule localization for subsequent nodule excision.

Methods: We retrospectively reviewed the medical records for 181 patients who had undergone computed tomography–guided nodule localization using hook wire and subsequent video-assisted thoracic surgery resection for lung nodules. The demographic factors, nodule factors, and technical factors were reviewed to determine what affects effective nodule localization for video-assisted thoracic surgery resection using both univariate and multivariate models.

Results: A total of 174 patients were included in our study. Successful localization was accomplished in 166 patients (95%). Univariate analysis implicated patient age, nodule solidity, zonal location, and a sufficient distance between the hook wire tip and pleural surface as significant factors for successful localization. Multivariate analysis focused on the distance between the wire tip and pleural surface as the sole independent factor for successful localization ($P = .012$).

Conclusions: The distance between the hook wire tip and pleural surface was the major significant factor for successful computed tomography–guided nodule localization for subsequent video-assisted thoracic surgery resection. Thus, the localization of a hook wire adjacent to a target nodule with sufficient depth from the pleural surface is crucial to the success of the procedure. (J Thorac Cardiovasc Surg 2012;143:809-14)

Lung cancer is the most common cause of cancer death for both men and women in developed countries.[1] The overall 5-year survival rate of lung cancer is only 15%. However, the 5-year survival rates can reach ≤60–80% when lung cancer is detected at an early stage (eg, at stage I when the tumor dimension is ≤3 cm in diameter).[2,3] Thus, early detection is the only method of increasing patient survival in lung cancer.

With the application of computed tomography (CT) imaging techniques to lung cancer screening, small subcentimeter lung nodules are frequently detected.[4-7] However, at the moment, it is difficult to characterize subcentimeter lung nodules with noninvasive imaging techniques alone.[6,8] Furthermore, the detection of ground-glass opacity nodules (GGNs), known to exhibit high malignancy potential, has increased, posing an additional burden on clinicians for tissue confirmation.[9]

The other condition necessitating tissue confirmation is the presence of small lung nodules in a patient with a known extrathoracic malignancy. Small lung nodules in patients with such a malignancy need tissue confirmation for additional treatment planning. A significant improvement in survival rates has been reported after resection of metastatic lung nodules from certain types of extrathoracic malignancies such as colorectal cancer or renal cell carcinoma.[10-12] Thus, it is expected that cases necessitating surgical tissue confirmation for lung nodules will increase in number.

Because fine needle aspiration or transbronchial biopsy for small lung nodules is difficult and often leads to sampling errors, excisional biopsy using video-assisted thoracoscopic surgery (VATS) is often performed. The VATS procedure has been known to be ideal for nodule resection, because it results in minimal lung volume loss and little postoperative morbidity and mortality.[3,13,14] However, for GGNs of substantial size or small nodules located in the deep lung parenchyma, localizing them visually or even by palpation during VATS is difficult.[15,16] Inadequate nodule localization might lead to a prolonged operative time because of a nodule search or conversion to an unplanned open thoracotomy.[13,15,16] Preoperative localization techniques have been introduced as a method of improving the success rates of VATS and to prevent

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GTS

Abbreviations and Acronyms
CT = computed tomography
GGN = ground-glass opacity nodule
VATS = video-assisted thoracoscopic surgery

unwanted thoracotomy.[15,16] To accomplish successful VATS nodule resection, various factors (eg, nodule-related factors on the CT scans, patient demographics, or procedure-related factors) might be related. However, few studies have presented empirical evidence of the factors necessary for success in nodule localization.[17] Thus, the purpose of our study was to investigate the factors related to successful CT nodule localization for subsequent VATS lung nodule excision.

MATERIALS AND METHODS

Our institutional review board approved the present retrospective study and waived the requirement for informed consent for the use of medical data from all the patients.

Patients

From August 2003 through February 2010, a total of 181 patents underwent CT-guided nodule localization by hook wire and subsequent VATS resection for lung nodules detected on chest CT scans. In our institute, preoperative nodule localization was performed for patients with the following criteria: patients without extrathoracic malignancy (those with a suspected primary lung lesion) and nodules less than 3 cm that were persistent or growing on the follow-up CT images, and patients with an extrathoracic malignancy and any lung nodules less than 3 cm that had newly appeared on follow-up CT images or persistent or growing lesions. The exclusion criteria were as follows: unavailability of preoperative CT images or the images during nodule localization, the use of a device other than the hook wire for nodule localization, the use of multiple hook wires for the localization of a single nodule, and the absence of VATS resection. For these patients, the demographic information, including the age and gender of patients, and the medical history of having an extrathoracic malignancy were recorded.

CT-Guided Localization

In a CT room, the chest CT scans were taken before the localization procedure to formulate an entire plan for the procedure. The CT scan covered a range limited to the area in which a target nodule could be visualized. The scans were obtained using a 4-slice multidetector CT scanner (LightSpeed QX/i; GE Healthcare, Waukesha, Wis) or a 16-slice multidetector (LightSpeed Ultra or Ultra16, GE Healthcare; or Aquilion, Toshiba Medical Systems, Tustin, Calif). The scan parameters were as follows: 125 mA, 120 kVp, beam width of 10 to 20 mm, and beam pitch of 1.375 to 1.5. The scan data were reformatted with a 2.0-, 2.5-, or 5.0-mm section thickness for the transverse images.

A 10-cm-long, 21-gauge-needle/wire and breast lesion localization system (Homer Mammlok Plus; Mitek Surgical Products, Inc, Glen Falls, NY) was used for nodule localization. The needle/wire was inserted into the lung using a percutaneous route. Under CT guidance, the wire was advanced toward the lung parenchyma just lateral to the nodule. Immediate postprocedural CT scans were obtained to assess the relative location of the wire tip to the target nodule and to the pleural surface and to assess the presence of possible complications such as hemorrhage, pneumothorax, or subcutaneous emphysema.

VATS Procedure

After moving to an operation room, each patient was intubated with a double lumen endobronchial tube to achieve single-lung ventilation during general anesthesia. The patients were positioned in either the left or right lateral decubitus depending on the nodule location. Skin preparation and draping were done. In most patients, 3 VATS trocars (Cabot Medical Corp, Langhorne, Pa) were inserted at the anterior, middle, and posterior axillary lines or subscapular points at a level between the fourth and eighth intercostal space with a minimal skin incision. A 10-mm, 30° videotelescope (Karl Storz, Tuttlingen, Germany) was inserted to explore the pleural cavity. Two other ports were used for an endoscopic grasper and endoscopic stapling device. If nodule localization with a hook wire was confirmed by the thoracic surgeon, wedge resection with a sufficient resection margin was performed using several staplers (Multifire EndoGIA 30; Auto Suture, US Surgical Corp, Norwalk, Conn). If the wire was not identified or a nodule was not visualized or palpated, blind wedge resection, considering the location of a nodule on the CT scans, was conducted in the VATS procedure. The thoracic surgeon confirmed that each wire was removed from the pleural cavity, along with the surgical specimens. All resected specimens were sent for immediate histopathologic examination. If a nodule was confirmed to be primary lung cancer by histopathologic examination, additional lobectomy and mediastinal lymph node dissection were performed.

CT Analysis

The analyzed factors are schematically presented in Figures 1 and 2. The preoperative CT images were reviewed by 2 thoracic radiologists who had chest imaging interpretation experience of 3 and 8 years, respectively. The location and characteristics of each nodule were recorded. The nodule location was subclassified into 3 different lung zones: upper (right upper lobe and left upper lobe, other than lingular division), middle (right middle lobe and lingular division of the left upper lobe), and lower (right lower lobe and left lower lobe) lung zones. The characteristics (solidity) of a nodule were subclassified into GGNs or solid nodules. The maximum diameter of the nodule, distance from the nodule to the pleural surface, angle between the hook wire and the pleural surface (in degrees), distance between the wire tip and the pleural surface (in millimeters), and wire depth within the thoracic wall (in millimeters) were measured using electronic calipers on the picture archiving and communication system (Centricity, GE Healthcare) and recorded.

Statistical Analysis

Wire localization was considered technically successful when the wire could be identified visually by a surgeon during the VATS resection procedure. Specifically, if the surgeon identified a localized needle in the segment of the lesion that correlated with the postprocedural CT scans, we considered it a technical success. The nodule factors evaluated included nodule size (maximum diameter), zone location, nodule solidity, and distance from a nodule to the pleural surface. The technical factors evaluated were the angle between the nodule and the pleural surface, distance between the wire tip and pleural surface (in millimeters), and wire depth within the thoracic wall (in millimeters).

The descriptive analysis results are expressed in terms of the frequency, mean, and standard error. Frequencies were compared using Fisher's exact test for categorical variables to compare the differences between the success and failure groups for nodule localization. The Mann–Whitney U test was used to compare continuous variables. Linear regression analysis was performed for multivariate analysis. Statistical analysis was performed using the Statistical Package for Social Sciences, version 15, statistical software for Windows (SPSS, Chicago, Ill). The values are expressed as the mean $\pm$ standard deviation. $P \leq .05$ was considered statistically significant.