Video-assisted thoracoscopic surgery for pulmonary nodules: rationale for preoperative computed tomography-guided hookwire localization

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Received 8 July 2003; received in revised form 20 November 2003; accepted 24 November 2003

Abstract

Objectives: Video-assisted thoracic surgery (VATS) provides a minimally invasive means to resect pulmonary nodules (PN). Deep localization of PN may jeopardize VATS lung resection. The aim of this study was to establish the utility of preoperative computed tomography (CT)-guided hookwire localization of PN. Methods: Between January 1993 and September 2001, we performed 151 VATS resections for PN. Preoperative CT-guided hookwire localization was not performed in 98 patients (group I); it was done just before surgery in 53 patients (group II) when, at CT scan, the distance of PN from the lung surface was >15 and/or when the size was <10 mm. Results: Pneumothorax occurred in four patients (7.5%). Hookwire dislodged in four patients, but the hematoma left on the visceral pleura made thoracoscopic localization possible in three of these. Seventeen patients (17%) in group I and 4 (7.5%) in group II required conversion to thoracotomy (P<0.05). The most common reason for conversion was impossibility to localize PN in group I (nine cases) and deep localization requiring local enucleation in group II (two cases). In 31 group II patients (58%) hookwire positioning led to successful VATS resection that would otherwise have been impossible because PN were neither visible nor palpable. Conclusions: Preoperative CT-guided hookwire localization for pulmonary nodules is an effective technique which allows VATS resection of PN located >15 mm from the pleural surface. Even when PN are subpleural but <10 mm, hookwire localization makes VATS resection faster. Apical and diaphragmatic localization of PN are limitations to the procedure.

Keywords: Video-assisted thoracic surgery; Pulmonary nodules; Hookwire

1. Introduction

Developments in thoracic surgery over the last 10 years have broadened the application spectrum of thoracoscopy. Video-assisted thorascoscopic surgery (VATS) is nowadays routinely used both to diagnose and to treat specific lung diseases [1,2].

Pulmonary nodules (PN) represent the most common reason for the use of VATS. Most lesions can be easily detected by inspection and tactile evaluation with an instrumental probe. However, some lung nodules are difficult to identify thorascopically. The small size of the nodule and/or distance from the pleural surface might be limiting factors for a successful thorascoscopic resection [3].

Preoperative marking of a pulmonary nodule is sometimes necessary prior to thoracoscopy. Among the various methods proposed for identifying PN [4–6] is the preoperative placement of a localization wire into the nodule under computed tomography (CT) scan control.

This study was aimed at investigating the effectiveness of hookwires for CT-guided localization of peripheral pulmonary lesions requiring thorascoscopic resection.

2. Materials and methods

Between January 1993 and September 2001, 151 patients who underwent VATS resections for PN at our institution were retrospectively analyzed. There were 89 men and 62 women, mean age was 63 ± 8 years (range 27–74 years). All patients underwent preoperative spiral CT scan that was
always reviewed by the same radiologists (RN; ADM). The size of the PN at the CT scan ranged between 5 and 28 mm (mean size 16 ± 6 mm); they were all located peripherally at a distance from the pleural surface that ranged between 0 and 35 mm (mean 17 ± 7 mm).

Preoperative diagnosis of the nature of PN was not available in 130 patients for the following reasons: CT-guided transthoracic needle aspiration biopsy was either non-diagnostic or could not be performed because of the unfavorable localization and/or small size of the PN; clinical history of malignancy and radiological features were consistent with metastatic disease; there were radiological features of benign disease. The remaining 21 patients, for whom preoperative diagnosis was obtained, still required VATS resection because of metastatic lesions or primary lung cancer in impaired pulmonary function. Fiberoptic bronchoscopy was negative in all patients.

Preoperative CT-guided hookwire localization was not performed in 98 patients (group I) because the position of the PN was apical or diaphragmatic, the size was >10 mm or distance from the pleural surface evaluated at the CT scan was <15 mm. In 53 patients (group II) CT-guided hookwire localization was done just before surgery since the size of PN was <10 mm and/or the distance from the lung surface was >15 mm.

Patients in group II were taken to the radiology unit on the day of surgery just before their operation and were placed on the CT scan table possibly in a posterolateral thoracotomy position. After local anesthesia with lidocaine, a 20-gauge needle, 15 cm in length, was placed percutaneously through the chest wall and through the pulmonary parenchyma near the PN under CT scan guidance. A hookwire, 32 cm in length (Breast Localization Needle, Manan Medical Product, Northbrook, IL, USA), was then placed through the localizing needle into the nodule (Fig. 1). When it was not possible to place the hookwire directly into the nodule, localization within 1 cm of the target lesion was considered sufficient. The 20-gauge needle was then removed and the proximal end of the hookwire positioned on the skin under gauze dressing. The wire was left free to follow the collapse of the lung during subsequent surgery. At the end of the localization procedure patients were transferred to the operating room.

Thoracoscopic surgery was performed under general anesthesia using single lung ventilation through a double-lumen endobronchial tube. The thoracoscope was inserted through a thoracic port in the seventh intercostal space on the midaxillary line in most cases. Additional intercostal incisions were made to visualize and handle the nodule as necessary. Thoracoscopic wedge resections were performed whenever feasible (Fig. 2) and all specimens underwent frozen section. When the diagnosis was a benign nodule, metastatic disease and/or primary lung cancer in impaired pulmonary function, the operation did not go further and a chest tube was inserted. When the finding was primitive lung cancer the incision was converted to a thoracotomy and a major resection was performed. Conversion to standard thoracotomy in such patients was considered a necessary therapeutic procedure and not a failure of thoracoscopic resection. Consequently it was not taken into account in the statistical analysis.

3. Statistical analysis

Data are presented as mean ± SD, unless otherwise indicated. Categorical variables were analyzed using the χ²-test. Multivariate analysis was performed by logistic regression to determine the impact of size and/or distance from the pleural surface of the nodules on conversion to...
thoracotomy. *P*-values less than 0.05 were considered statistically significant.

4. Results

Hookwire positioning was accomplished successfully by radiologists whenever it was required. Pneumothorax occurred in four patients (7.5%) but it did not require chest tube insertion. At thoracoscopy the hookwire became dislodged in four patients (7.5%) but the hematomas at the entry site of the wire made it possible to localize the nodule in three of these patients, the remaining one required a thoracotomy. Dislodgement occurred either at transport to the operating room or during the positioning of the patient on the operating table.

At the time of thoracoscopy 74 lesions in group I and 11 in group II were located between 0 and 15 mm beneath the pleural surface, 19 PN in group I and 21 PN in group II were smaller than 10 mm. Table 1 shows the characteristics of the PN at surgery in all patients.

Seventeen patients (17%) in group I required conversion to a standard thoracotomy. Conversion was necessary because of the impossibility to localize PN (nine patients), strong pleural adhesions (seven patients) and bleeding at the site of stapler suture in one patient. The nine PNs in group I that were impossible to localize were <10 mm in size. In group II thorascopic resection was not possible in four patients (7.5%); two patients had local enucleation due to deep intraparenchymal localization of the PN, in one patient the hookwire became dislodged, and in the remaining patient a standard thoracotomy was necessary because of strong pleural adhesions. Thus PNs were localized thoracoscopically in 81 patients (82%) in group I and in 49 patients (92%) in group II (*P* = 0.07). The reasons for the failure of thorascopic resections are listed in Table 2. A definitive histological diagnosis was obtained in all patients. Seventy-seven patients had a malignant disease, 55 in group I and 22 in group II. Of these, 9 patients (6%) (group I, 7; group II, 2) had primary lung cancer; 61 patients (40%) (group I, 45; group II, 16) had metastatic cancer and 7 patients (4%) (group I, 3; group II, 4) had a lymphoma. The other patients had benign diseases (62 patients) (group I, 39; group II, 23) or other diseases (12 patients) (group I, 4; group II, 8) (Table 3).

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<td>Characteristics of pulmonary nodules at surgery</td>
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ps, pleural surface.

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<td>Conversion to thoracotomy</td>
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<td>Histology of all pulmonary nodules</td>
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PLC, primary lung cancer; MC, metastatic cancer; Lymph, lymphoma.

The average time of operation was 75 ± 12 min in group I and 40 ± 7 in group II (*P* < 0.001). Time of CT hookwire positioning was 20 ± 10 min.

In 31 out of the 53 group II patients (58%) hookwire positioning enabled a VATS resection to be performed, which would not have been feasible otherwise since the PN was not visible and/or palpable on the pleural surface. Two of these patients were found to have primary lung cancer and had a lobectomy through a standard thoracotomy. Hookwire positioning was found to be redundant at thoracoscopy in 15 group II patients (28%) as the PN was subpleural or palpable with an instrumental probe. In the remaining seven patients hookwire positioning expedited the surgical procedure.

Conversion to standard thoracotomy was significantly correlated to the size of PN < 10 mm (*P* = 0.01).

Hospital stay for patients who had a standard thoracotomy was 7 ± 2 vs. 3 ± 1 days for patients who had a VATS resection (*p* < 0.001).

Thirty-two group II patients were discharged from hospital without a thoracotomy incision (60%). Of these, 29 patients (54%) fully benefited from hookwire positioning since it permitted a VATS resection that otherwise would not have been possible due to the size of the PN and/or the distance from pleural surface.

5. Discussion

When a peripheral solitary PN or multiple nodules are discovered radiologically a histological differentiation between malignant and benign disease becomes necessary. The conventional procedures currently available for the diagnosis of PN are either CT-guided percutaneous transthoracic needle aspiration or transbronchial biopsy. The effectiveness of both procedures can at times be limited by the unfavorable position or the small size of the PN.
and the cytological examination often fails to diagnose the nodule as benign.

In the last decade VATS has become a useful minimally invasive tool in the diagnosis and treatment of PN [1,2,7], since it enables the entire nodule to be resected and histological analysis to be performed. Moreover, a VATS wedge resection is an acceptable surgical option in patients with primary lung cancer and impaired pulmonary function. The benefits of VATS might, however, be offset by the inability to locate nodules at the time of the procedure, which some authors report as occurring in 7.5–11% of cases [8–10].

Techniques to localize PN vary from preoperative injection of methylene blue [5] or colored collagen [6] at the site of the PN to intraoperative ultrasound detection and CT-guided positioning of a metal wire [4,11–13]. A failure rate of around 13% for methylene blue injection has been reported due to either an excess of liquid injected or an error in nodule localization [5]. Intraoperative ultrasound detection requires a special flexible probe and it can be limited by the presence of air in the lung when complete collapse is not feasible [12]. Moreover, despite the lack of complications and the high sensitivity and specificity found with the use of ultrasound [13] only a few cases are reported in the literature and it is known to present limitations in localizing inflammatory nodules [14]. Probe and/or digital palpation could also be useful methods for localizing PNs, although in our experience they were effective only when the nodule was superficial or > 20 mm in size.

Our approach to small indeterminate PN also includes transbronchial lung biopsy and/or CT-guided transthoracic needle biopsy. VATS biopsy was performed only when less invasive conventional procedures failed to provide a diagnosis or when they were not indicated. We chose to localize difficult peripheral nodules by CT-guided positioning of a hookwire. The vicinity of the radiology unit and the possibility to perform the procedure just before surgery has made this technique safe and fast in our hands. The incidence of complications such as pneumothorax occurred in 7.5% of the patients, symptoms were minor and chest tube insertion was not required.

The chance of dislodgement was reduced by positioning the patients on the operating table and maintaining an adequate length of the hookwire outside the chest, thus allowing the wire to follow the deflated lung during single-lung ventilation. Moreover, the hook at the distal end of the wire ensured a more reliable insertion in the PN. Despite these precautions we had a 7.5% rate of hookwire dislodgement. This percentage is acceptable and consistent with the percentage of 8% reported in the literature [4] and much lower than the failure rate of 47% reported by Bernard in a multicenter study due to hookwire dislodgement, mistaken nodule localization or significant subpleural hematoma [2]. In three of our cases thoracoscopic resection was still possible despite hookwire dislodgement because the small hematoma left on the pleural surface enabled the nodule to be localized. For this reason we do not think injection of methylene blue is required in addition to hookwire positioning.

Pulmonary venous air embolism during pulmonary nodule hookwire localization has been reported in the literature [15]. We ourselves never experienced this complication, which can have a lethal outcome. As suggested by the authors a short trajectory for the hookwire and the absence of prolonged lung inflation may decrease the possibility of air embolism.

At times the hookwire might not be placed exactly inside the PN but this does not in itself constitute a problem. In our series surgeons were always present at the moment of the CT-guided positioning of the hookwire and considered location within 1 cm of the PN acceptable. The hook at the far end of the wire may also be positioned beyond the PN, especially when a soft nodule is present. This may be avoided by instructing patients to hold their breath while the guide-needle is extracted.

Nodule size and distance from the pleural surface are reported as being important parameters for successful identification at thoracoscopy [3]. Difficulties reported by authors regarded nodules with size < 10 mm and/or a distance from the pleural surface of between 5 and 15 mm [1,3,4]. We found it difficult to locate the PN in nine patients in group I and two patients in group II and conversion to standard thoracotomy was necessary. All of them had either PN < 10 mm in size and/or a distance from the pleural surface > 15 mm. The PN in group II that were not detected at thoracoscopy were too deep for a thoracoscopic resection despite hookwire positioning and required local enucleation; diagnosis at frozen section was a benign lesion. In 28% of the group II patients, localization of PN would have been possible even without hookwire positioning because of their subpleural or palpable position. Yet the presence of the hookwire expedited thoracoscopic resection.

Although CT hookwire positioning is a fairly expensive procedure, costing almost 200$, this is entirely compensated for by the saving in hospital costs when nodules do not require thoracotomy. It expedites surgical resection and avoids thoracotomy, which shortens the operative time and patients’ hospital stay. A further saving in operative room occupation and costs is ensured by preparing the patient in the Radiology Unit while the previous operation is still in progress.

Nowadays spiral CT scan makes it possible to detect PN which are otherwise not visible with the traditional CT scan, leading to a more frequent finding of PN. Whenever diagnosis cannot be achieved with low-invasive techniques such as transbronchial biopsy and/or CT-guided transthoracic needle biopsy, VATS should be considered as both a diagnostic and therapeutic tool. Preoperative evaluation of the PN at CT scan is important to define the indications for surgical resection and to select those patients who might benefit from preoperative localization. CT-guided hookwire localization may be a useful preoperative marker with minor
complications and a high rate of success in expert hands. The procedure should be performed just before surgery and requires the close cooperation of radiologists and surgeons.

We conclude that preoperative hookwire marking appears to be a safe procedure, it may be beneficial when the PN size is < 10 mm and/or the distance from the pleural surface is > 15 mm, and advisable when PN size is > 10 mm and/or the distance from the pleural surface is between 15 and 25 mm. In the latter case preoperative marking nevertheless expedites thoracoscopic wedge resection. Positioning of preoperative marking may be unnecessary in all other cases.

Acknowledgements

The authors wish to thank Dr G. Cremona for his statistical analysis.

References