

# Advances in Image-Guided Thoracic Surgery

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## KEYWORDS

- Non-small-cell lung carcinoma • Pulmonary surgical procedures
- Minimally invasive surgical procedures • Neoplasm invasiveness

## KEY POINTS

- Different modalities of surgical excisional biopsy can be used when needle biopsy has failed to provide tissue diagnosis.
- These modalities include intraoperative localization techniques, such as ultrasonography, and pre-operative localization techniques, such as liquid dyes, radiolabeled aggregates, hook wires, and microcoils, as well as navigational bronchoscopy techniques.
- The highest level of evidence for efficacy currently appears to support microcoils, radiolabeling, and hook-wire localization techniques.
- Multiple methods have been used to help identify intersegmental planes in order to facilitate minimally invasive segmental resection.
- These methods include use of 3-dimensional multidetector computed tomographic rendering, administration of dyes such as indocyanine green, and virtual bronchoscopic techniques.

## INTRODUCTION

There has been increasing use of imaging technology to facilitate minimally invasive thoracic surgery techniques. This article reviews the use of imaging technology to facilitate minimally invasive excisional biopsy of small pulmonary nodules as well as the use of imaging technology to facilitate minimally invasive segmental lung resection.

## LOCALIZATION OF SMALL PULMONARY NODULES

Increasing use of low-dose computed tomographic (CT) screening for lung cancer has resulted in increased detection of small peripheral nodules or semisolid ground-glass opacities (GGOs). Although many of these may be amenable to percutaneous, image-guided needle biopsy, these lesions are challenging because of their

small size and risk of sampling error with needle biopsy. Semisolid GGOs are even more challenging given their semisolid state. Different modalities of surgical excisional biopsy have been used to address these challenges when needle biopsy has failed to provide tissue diagnosis.

Video-assisted thoracoscopic surgery (VATS) or open biopsy directed by intraoperative finger palpation or instrument sliding technique has been reported to have localization rates of approximately 30%.<sup>1</sup> The following is a review of image-guided pulmonary nodule localization.

### ***Intraoperative Localization with Ultrasonography***

Use of intraoperative ultrasonography has been reported to yield localization rates of up to 93%.<sup>1-3</sup> In their prospective nonrandomized study, Khereba and colleagues<sup>1</sup> found that

Conflicts of Interest: None to declare.

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intraoperative ultrasonography localized an additional 43% ( $n = 20/46$ ) of nodules that were not identified by palpation or visualization. Furthermore, intraoperative ultrasonography is not associated with complications related to its use. However, deflation of the lung is mandatory for visualization of the nodule, and therefore, its use in patients with emphysema is more challenging.<sup>2,3</sup> Moreover, ultrasonography is highly operator-dependent. Khoreba and colleagues<sup>1</sup> reported mean operative times of  $74 \pm 34$  minutes.<sup>1</sup> They also found however that the learning curve was quite steep and that the time required to identify a nodule sonographically decreased to an average of 4 minutes after the first few cases. The steepness of the learning curve is highlighted by the fact that 3 of 4 surgeons performing these procedures had no formal ultrasound training before the study.<sup>1</sup> The ultrasound probes that were used in these studies were mainly made for application in the abdominal cavity; thus, the settings may not be ideal for use in the lung. Currently, new thoracoscopic ultrasound probes are in development, which may enhance the localization capabilities within the lung.<sup>4</sup>

### **Preoperative Percutaneous Insertion of Hook Wire and Suture**

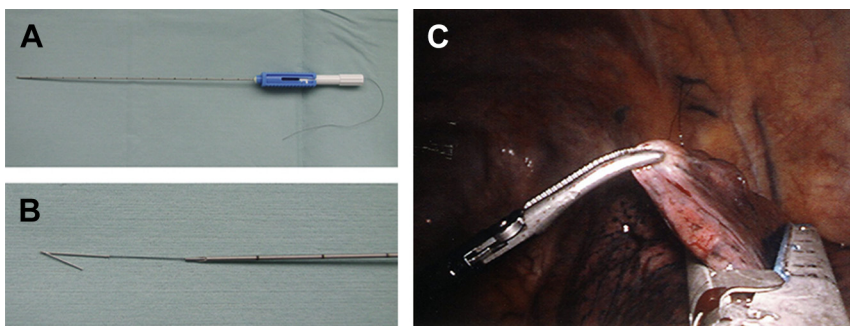
The hook-wire and suture technique involves preoperative insertion of a short 1-cm hook with an attached 30-cm monofilament suture that is exteriorized on the skin (Fig. 1).<sup>5</sup> Insertion is accomplished under CT guidance on the same day as VATS excisional biopsy.<sup>5</sup> Use of hook-wire localization has been reported to yield localization rates of up to 94% in retrospective studies.<sup>5</sup> Approximately 2% to 4% of patients experienced postinsertion pneumothoraces that required placement of chest tubes before proceeding to excisional biopsy.<sup>5,6</sup> Although a significant limitation reported

independently is a high rate of hook-wire dislodgement of up to 10%, recent data from the group that pioneered the hook-wire approach suggest that there is a low (1%–2%) rate of dislodgement of the hook wire between insertion and excisional biopsy.<sup>5,7,8</sup> A rare complication that has been reported is massive air embolism; it has mainly been described in case reports and 1 large case series at a rate of 0.6% ( $n = 1/161$ ).<sup>9</sup> Furthermore, Miyoshi and colleagues<sup>5</sup> suggest that this risk can be mitigated by limiting the length of time required to insert the hook-wire system.

### **Preoperative Percutaneous Injection of Radiolabeled Aggregates**

Preoperative injection of radiolabeled aggregates under CT guidance has been used to successfully localize nodules. Galetta and colleagues<sup>10</sup> reported a series of 123 nodules in 112 patients that they preoperatively localized using Technitium-99 radiolabeled macroaggregates. Intraoperatively, they used a handheld gamma probe to detect the area to resect.<sup>10</sup> Mean nodule size was 9 mm (with a range of 3–24 mm), and mean distance from the pleura was 12 mm (with a range of 0–39 mm).<sup>10</sup> They reported 62.5% ( $n = 30/44$ ) successful VATS biopsy with the rest requiring biopsy via thoracotomy. The gamma probe failed to localize the nodule entirely (either by VATS or thoracotomy) in only 2 patients (1.8%).<sup>10</sup> In terms of complications, they reported 29.4% ( $n = 33$ ) asymptomatic pneumothoraces with only 1 patient requiring chest tube insertion and 2 cases (1.8%) of significant radiotracer extravasation into the pleural cavity.<sup>10</sup>

A randomized controlled trial (RCT) comparing hook-wire localization to radio-guided localization in small 6- to 19-mm nodules showed that there was not a statistically significant difference between the 2 modalities with localization rates of



**Fig. 1.** Hook-wire localization. (A) Hook-wire device used for localization. (B) Hook wire with the suture deployed from the device. (C) Intraoperative findings of VATS wedge resection of a lung nodule with hook-wire localization.

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