Localization of pulmonary nodules

Lung cancer screening has lead to frequent diagnosis of indeterminate pulmonary nodules

Widespread use of minimally invasive thoracic surgery (thoracoscopy and robot assisted) for pulmonary lesions

Lack of tactile / haptic feedback with robot

Pulmonary lesions that are difficult to visualize or palpate during surgery:
- Small nodules / sub-centimeter nodules
- Centrally located nodules
- Partially solid / mixed ground glass and solid nodules
- Ground-glass opacity (GGO)
Localization techniques

Preoperative
Intraoperative

Image guided techniques
• CT
• Bronchoscopy / navigational bronchoscopy

Localization materials
• Coils
• Dyes
• Fiducials
• Hook wires
• Radiotracers
• Fluorescence tracers
Preoperative CT guided percutaneous hook wire localization

**Technique**
- 20-gauge breast localization needles
- Hook wires traverse pulmonary nodule and the tips were placed just deep to the nodule (i.e., the hook was wrapped around the nodule)
- Excess wire is trimmed and the hook wire was fixed in position externally with tape
- Same-day surgery

**Advantages**
- High successful localization (93.6–97.6%)
- Intraoperatively easy to identify the needle and localized area
- Short localization procedure time
Disadvantages
Hook wire dislodgement is major disadvantage
- Reported dislodgment rate (2.4–13%)
- Dislodgement occurs during:
  - Patient transport and positioning
  - Intraoperative atelectasis/single lung ventilation
  - Surgeon manipulation of lung during surgery

Other complications:
- Pneumothorax (7.5–40%)
- Lung parenchyma hemorrhage (13.9–36%)
- Subcutaneous emphysema (5%)

Limitations in certain locations:
- Apex of lung
- Near diaphragm
- Near mediastinum / great vessels
Dye localization

**Technique**
- 20-25 gauge spinal needles
- CT fluoroscopic guidance to place needle into the superficial aspect of pulmonary nodule
- Methylene blue is injected as the needle is removed, with the majority of the stain injected into the subpleural parenchyma directly overlying the nodule
- Half a milliliter was the most commonly injected volume
- Same day surgery

**Advantages**
- Short localization procedure time
- No anatomical limitation
- Dye injection can be CT or bronchoscopic guidance
- Methylene blue is cost effective
Dye localization

Disadvantages
• Rapid diffusion of dye into surrounding lung parenchyma
• Requires immediate surgery after dye injection
• Rapid dye diffusion between time of injection and surgery
• Difficulty in dye visualization during operation
• Anthracotic pigmentation may make the dye difficult to see
• Limited information on lesion depth

Complications
• Pneumothorax
• Intrapulmonary hemorrhage
• Anaphylaxis to dye is a lethal complication (rare)
• Risk of air embolism and cerebrovascular accident

Microcoil or fiducial placement

Technique
- Microcoil or fiducial placement
- Percutaneous / CT guided placement of coil or fiducial is administered through coaxial needle (19 gauge) and deployed into lung parenchyma
- Multi-delivery system allow multiple markers to be placed with single needle
- Markers can also be placed with electromagnetic navigational bronchoscopy
- Success rate of 93-98%

Disadvantage
- Requires intraoperative fluoroscopy to visualize the marker

Complications
- Marker migration may lead to localization failure in 3-10% of patients
- Air embolism
- Marker embolism
- Intraparenchymal pulmonary hemorrhage
- Pneumothorax
- Hemothorax

Fluorescence tracer

**Technique**
- Percutaneous CT guided indocyanine green (ICG) injection
- 22 guage needle positioned into nodule
- 0.4 cc ICG injected and inner stylet withdrawn
- Illumination system (near infrared; NIR)
- Nodule illuminates in fluorescence green color

**Disadvantage**
- Highly operator and facility dependent
- Most important predictor of in vivo fluorescence was distance from pleural surface
- Limitation of suboptimal depth of penetration with the use of visible spectrum dyes
- False positive and false negative fluorescence

**Complications**
- Same as CT guided percutaneous marking procedures

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*In Vivo*

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Radiotracer

**Technique**
- Utilizes radioisotopes (technetium 99) attached to albumin
- CT guided injection of radiotracer into lung
- Intraoperative probe to detect gamma ray emission translated into digital counts and audio signals
- Strongest signal identifies the lesion
- Radiotracer remains stable for 24 hours

**Disadvantage**
- Highly operator and facility dependent due to radiotracer, probe, and protective equipment
- Radiation exposure

**Complications**
- Same as CT guided percutaneous marking procedures
• Understanding and mastering the pulmonary segmental anatomy is critical to nodule localization

• Segmentectomy (-ies) may be the best intraoperative localization in many cases
Preoperative, percutaneous CT guided placement of microcoil
Self expanding hydrogel plug

- Placed during CT guided core needle biopsy
- Needle tract sealant to prevent air leak / pneumothorax
- Visible intraoperatively during Robot assisted LUL apical posterior segmentomy
Intraoperative visualization of hydrogel plug and microcoil

Hydrogel plug

Microcoil

Robot assisted RUL apical wedge resection

Intraoperative x-ray of specimen to assess margin
Pulmonary Nodule Localization

Summary

• Lung cancer screening has led to frequent diagnosis of indeterminate pulmonary nodules which are often small or ground glass lesions

• Widespread use of minimally invasive thoracic surgery (thoracoscopy and robot assisted) pose limitations in identifying pulmonary lesions

• Difficulty in intraoperative localization of small or ground glass lung lesions

• There are many preoperative localization techniques with distinctive advantages and disadvantages

• These localization modalities may aid in intraoperative margin assessment

• Operator and facility limitations should be considered in choosing a localization technique (ex. CT guided vs. bronchoscopic; type of tracer or marker)

• Consider utilization of more than one localization technique

• Consider segmentomy (-ies) as a localization and therapeutic option