NAVIGATION ÉLECTROMAGNÉTIQUE: POSSIBILITÉS ET LIMITES

CC, DR. PAOLA GASCHE
LUNG TERRITORY REACHABLE BY CONVENTIONAL BRONCHOSCOPY
Peripheral nodule less than 2cm of diameter can be reached by conventional bronchoscopy only in 30% of cases (14% if in the outer ⅓ portion of lung parenchyma) Chest 2003;123:115S-128S.
CONVENTIONAL APPROACH

Ultra thin bronchoscope (2mm) and fluoroscopic guidance; 64.7% of sensitivity (Rooney CP, Respiration 2002;69:63-68)
BIOPSY & RADIOLOGICAL GUIDANCE

**Guidance & fluoroscopy** *(Chest 2006;129:147-150)*

- Irradiation
- Visibility? 40% (54/138) of < 2.2cm lesions are **not** visible

**CT-scan trans-thoracic bx**

- From 65 to 90% of sensitivity depending on the type of lesion
- Requires immobility of the patient during procedure
- Risk of hemorrhage *(10-20%)*
- Risk of pneumothorax *(>30%)*
PNEUMOTHORAX RISK OF TTNA

- **↑ with number of passes**
  37% one pass; 57% five passes

- **↑ with distance from pleura**
  15% 0 cm (pleura based); 50% 0-5 cm

- **↓ with lesion size**
  0-2 cm = 50%; 2-4 cm = 35%; >4 cm = 15%

- **↑ with presence of emphysema**
  With emphysema = 50% (chest tube 27%)
  Without emphysema = 35% (chest tube 9%)

Sources:
Cox et al. Radiology July 1999;212:165-168
<table>
<thead>
<tr>
<th>Procedure</th>
<th>Approx. #/year</th>
<th>Hospital Days</th>
<th>Reimbursement</th>
<th>Performed by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagnostic Bronchoscopy</td>
<td>3,500,000</td>
<td>1</td>
<td>$1,700</td>
<td>Interventional Pulmonologist</td>
</tr>
<tr>
<td>Therapeutic Bronchoscopy</td>
<td>200,000</td>
<td>1-4</td>
<td>Up to $5,000</td>
<td>Interventional Pulmonologist</td>
</tr>
<tr>
<td>CT-Guided Needle Biopsy</td>
<td>700,000</td>
<td>1</td>
<td>Up to $4,500</td>
<td>Interventional Radiologist</td>
</tr>
<tr>
<td>Open Surgery</td>
<td>1,000,000</td>
<td>6</td>
<td>Up to $70,000</td>
<td>Surgeon</td>
</tr>
</tbody>
</table>

Interventional Pulmonary procedures (Europe / N. America / Asia ~30% each)
ELECTROMAGNETIC NAVIGATION SYSTEM

Based on regular GPS system
COMPONENTS OF THE SYSTEM

1. Magnetic field; the board
COMPONENTS OF THE SYSTEM

2. Magnetic field: electrodes
COMPONENTS OF THE SYSTEM

3. Sensor

- Receptor of EM wave
- Position detected in 3 axes by software (X, Y, Z-axes, roll, pitch & yaw)
- Position shown on a monitor at a rate of 161 images/sec.
COMPONENTS OF THE SYSTEM

3. The guide

- 4 wires
- Rotating handle
- 8 positions
PROCEDURE

Pre-specified thoracic Ct-scan data (*Dicom CD*) ⇒ Upload of the images in the navigation system

⇒ Route planning
PROCEDURE

3-D reconstruction & virtual bronchoscopy \(\rightarrow\) Choice of the target (1 or more) \(+\) Choice of the pathway to the target
PROCEDURE

Synchronisation of the virtual with the real bronchoscopy Images (FB 2.8mm)

Navigation toward target
PROCEDURE

Navigation toward target(s) with steerable catheter inserted in a working channel
Procedure

Navigation toward target(s) with steerable catheter inserted in a working channel
PROCEDURE: TISSUE SAMPLING

Once the target is reached:
• Lock working channel
• Remove steerable navigation catheter
• Use instruments to remove tissue samples
ENB (ELECTROMAGNETIC NAVIGATION BRONCHOSCOPY)

ROSE: Rapid On Site Evaluation
### Table 5. Study-level characteristics associated with significant modification of ENB’s performance.

<table>
<thead>
<tr>
<th></th>
<th>Nb of studies</th>
<th>Pooled outcome [95% CI]</th>
<th>p-values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Diagnostic yield</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General anesthesia</td>
<td>Yes</td>
<td>9 69.2% [60.6 – 76.7]</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>7 57.5% [53.2 – 61.8]</td>
<td></td>
</tr>
<tr>
<td><strong>Sensitivity for malignancy</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROSE</td>
<td>Yes</td>
<td>4 80.2% [72.1 – 86.4]</td>
<td>0.006</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>10 66.3% [60.3 – 71.8]</td>
<td></td>
</tr>
<tr>
<td><strong>Diagnostic yield</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fluoroscopy</td>
<td>Yes</td>
<td>6 56.3% [51.5 – 60.9]</td>
<td>0.006</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>10 68.8% [61.3 – 75.4]</td>
<td></td>
</tr>
</tbody>
</table>
Electromagnetic Navigation Bronchoscopy Performed by Thoracic Surgeons: One Center’s Early Success

Daryl Phillip Pearlstein, MD, Curtis C. Quinn, MD, Charles C. Burtis, BS, Kwang Woo Ahn, PhD, and Aaron J. Katch, MS

Divisions of Cardiothoracic Surgery, and Biostatistics, Medical College of Wisconsin, Milwaukee; Division of Cardiothoracic Surgery, Waukesha Memorial Hospital, Waukesha; and Aurora Advanced Healthcare, Milwaukee, Wisconsin

Table 1. Negative Predictive Value and Sensitivity Based on Lesion Size

<table>
<thead>
<tr>
<th>Lesion Size (cm)</th>
<th>&lt;1.5</th>
<th>1.5–2</th>
<th>&gt;2</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative predictive value</td>
<td>78%</td>
<td>20%</td>
<td>55%</td>
<td>56%</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>78%</td>
<td>69%</td>
<td>85%</td>
<td>82%</td>
</tr>
</tbody>
</table>

Fisher exact test p value for negative predictive value: 0.141; Fisher exact test p value for sensitivity: 0.333.
SENSITIVITY FOR MALIGNANCY

<table>
<thead>
<tr>
<th>Studies</th>
<th>N/Total</th>
<th>Sensitivity [CI95%]</th>
<th>Forest plot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Becker 2005</td>
<td>15 / 24</td>
<td>62.5 [40.6;81.2]</td>
<td></td>
</tr>
<tr>
<td>Gildea 2006</td>
<td>27 / 40</td>
<td>67.5 [50.9;81.4]</td>
<td></td>
</tr>
<tr>
<td>Schwarz 2006</td>
<td>8 / 12</td>
<td>66.7 [34.9;90.1]</td>
<td></td>
</tr>
<tr>
<td>Makris 2007</td>
<td>20 / 33</td>
<td>60.6 [42.1;77.1]</td>
<td></td>
</tr>
<tr>
<td>Eberhardt 2007a</td>
<td>42 / 70</td>
<td>60.0 [47.6;71.5]</td>
<td></td>
</tr>
<tr>
<td>Eberhardt 2007b</td>
<td>16 / 29</td>
<td>55.2 [35.7;73.6]</td>
<td></td>
</tr>
<tr>
<td>Eberhardt 2007b EBUS</td>
<td>28 / 31</td>
<td>90.3 [74.2;98.0]</td>
<td></td>
</tr>
<tr>
<td>Bertoletti 2008</td>
<td>30 / 42</td>
<td>71.4 [55.4;84.3]</td>
<td></td>
</tr>
<tr>
<td>Eberhardt 2009</td>
<td>34 / 47</td>
<td>72.3 [57.4;84.4]</td>
<td></td>
</tr>
<tr>
<td>Lamprecht 2009</td>
<td>6 / 9</td>
<td>66.7 [29.9;92.5]</td>
<td></td>
</tr>
<tr>
<td>Seijo 2010</td>
<td>26 / 36</td>
<td>72.2 [54.8;85.8]</td>
<td></td>
</tr>
<tr>
<td>Mahajan 2011</td>
<td>18 / 27</td>
<td>66.7 [46.0;83.5]</td>
<td></td>
</tr>
<tr>
<td>Lamprecht 2012</td>
<td>82 / 95</td>
<td>86.3 [77.7;92.5]</td>
<td></td>
</tr>
<tr>
<td>Pearlstein 2012</td>
<td>67 / 82</td>
<td>81.7 [71.6;89.4]</td>
<td></td>
</tr>
</tbody>
</table>

Pooled (Random effects) 71.1 [64.6;76.8]  
I-squared = 57%
Electromagnetic Navigation Bronchoscopy: Diagnostic Yield by Year

ENB diagnostic yield has increased significantly from 68.3% to 85%.

- **2009**: 2 prospective studies, total N = 67
  - Diagnostic yield: 72.47% (range 71.4-76.9%)

- **2010**: 2 prospective studies, total N = 105
  - Diagnostic yield: 72% (range 67-75.5%)

- **2012**: 3 studies, total N = 271
  - 1 prospective, 2 retrospective
  - Diagnostic yield: 82.4% (range 74.5-85%)

- **2005-2008**: 8 studies, total N = 523
  - Diagnostic yield: 68.3% (range 50-75%)
  - Diagnostic yield for lymph nodes: 94-100%

- **2011**: 1 retrospective studies, total N = 48
  - Diagnostic yield: 77%

- **Multiple articles in review**
  - Diagnostic yield: 89%, N = 41
  - Diagnostic yield: 89.5%, N = 76
  - Diagnostic yield: 89%, N = 114
ELECTROMAGNETIC NAVIGATION BRONCHOSCOPY (ENB) ALLOWS YOU TO:

- **Navigate**
  - Navigate to distal lesions for biopsy

- **Stage**
  - Stage lymph nodes

- **Place**
  - Place fiducial markers for radiation treatment

- **Locate**
  - Place markers to facilitate VATS

- **Deliver**
  - Guide high dose radiation catheters
TRANSBRONCHIAL PLACEMENT OF FIDUCIAL MARKERS USING ENB
TRANSBRONCHIAL PLACEMENT OF FIDUCIAL MARKERS USING ENB

**superDimension® superLock® Bands**
(13-23mm: 3mm gold)

**superDimension® superLock® Coils**
(5-10-20mm, 0.9, gold)

**superDimension® superLock Cobra®**
Fiducial Marker
(7mm : Nitinol & gold seed 3.5x0.8)
Stereotactic Body Radiotherapy (SBRT/SRT)

- Uses a combination of precise patient positioning/immobilization to administer radiation with extreme accuracy

- Increasingly being used to treat patients with early-stage NSCLC who are not candidates for surgical resection or refuse surgery
• Studies show a 5-year survival rate of 50% for early stage lung cancer patients that are inoperable or refuse surgery\textsuperscript{1-4}

• Early data shows comparable results to surgery with \textbf{acceptable toxicity} and comparable local control and survival rates \textsuperscript{5-8}

\textbf{SOURCES:}
COMMON SBRT/SRT SYSTEMS

- Novalis Tx®
- TomoTherapy HiArt®
- Varian Trilogy®
- Varian TrueBeam®
- Elekta Synergy®
- Elekta Axesse®
- Siemens Primatom®
- Accuray CyberKnife®
• **Primary Treatment Modality – Curative**
  – Inoperable patients (COPD, ILD)
  – Patients who refuse surgery

• **(Neo) Adjuvant Treatment**
  – Pre-operative treatment for subsequent surgical curative intent (Stage IIIA disease)

• **Palliative Treatment**
Motion Management is Critical to SBRT

- Lung targets are dynamic
- Failure to manage motion may result in inaccurate dose delivery
- Preserves normal lung tissue
Problems of Respiratory Motion

- Causes artifact during imaging acquisitions
- Target shape and volume uncertainty due to CT artifact
- Dose uncertainty if motion is not accounted for

Motion varies markedly between patients, indicating that an individual approach to respiratory management is required in SBRT.
RESPIRATORY GATING

Defined as a specific window in the breathing cycle, much like a baseball strike zone, when it is optimal to turn on the radiation beam. Ideally, this "strike zone" is a period of time in the breathing cycle when the tumor moves the least.
RESPIRATORY TRACKING

Defined as delivering tightly contoured beams that move precisely with tumor motion throughout the respiratory cycle.
ABDOMINAL COMPRESSION

Defined as using a compression board to help minimize tumor motion during breathing cycles.
Localization with fiducial markers directly into and/or around a lung tumor is considered an accurate way to aid respiratory motion management when delivering SBRT/SRT.
IMPORTANCE OF FIDUCIAL MARKERS FOR AIDING MOTION MANAGEMENT

- Allows **synchronization** of patient’s anatomy from imaging to radiation delivery, accounting for respiratory motion

- Allows **smaller/conformal radiation fields**; less radiation to adjacent critical structures, higher doses to primary tumors and potentially better control

- Internal fiducial markers are a **better surrogate of tumor motion** compared to an external marker
**Planning Phase**
Target selected with planning software

**Navigation**
Using navigation catheter under electromagnetic guidance

**Marker Placement – Several Methods**

**Stereotactic Radiotherapy**
Procedure Proceeds
Six (6) articles published on transbronchial placement of fiducial markers using ENB ¹-⁶

- Fiducial markers successfully placed in over 80 patients
- 2-5 markers placed per tumor
- Lesion size varied from 0.8 cm to 6.5 cm in diameter
- Minimal migration and pneumothoracies reported

**SOURCES:**
CONCLUSIONS

1. **Effective diagnostic technique**
   - Successful diagnosis of peripheral lesions in 69-82% of cases
   - No association with size of nodule
   - Probable even higher success rates for lymph nodes

2. **Safe diagnostic technique**
   - Pneumothorax rate of 0-2.3%
   - No need for irradiation
   - Short learning curve

3. **New option for SBRT/SBT**