Electromagnetic Navigation Bronchoscopy-Guided Fiducial Placement for Robotic Stereotactic Radiosurgery of Lung Tumors*

A Feasibility Study

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Background: **Stereotactic radiosurgery (Cyberknife; Accuray Incorporated; Sunnyvale, CA) is a treatment option for patients who are medically unfit to undergo lung tumor resection. For precise tumor ablation, the Cyberknife requires fiducial marker placement in or near the target tumor. Fiducial placement under transthoracic CT guidance is associated with a high risk of iatrogenic pneumothorax. Electromagnetic navigation bronchoscopy (ENB) may offer a less morbid alternative to accurately deploy fiducials to bronchoscopically invisible peripheral lung lesions.**

Objective: **Open-label, feasibility study to assess fiducial placement in peripheral lung tumors by ENB.**

Method: **Consecutive patients with peripheral lung tumors and who were evaluated to be nonsurgical candidates underwent fiducial placement under ENB. This procedure was considered successful if fiducials were placed in or near the tumors and remained in place without migration for radiosurgery to proceed. The need for alternative or additional intrathoracic fiducial placement was documented as procedure failure.**

Results: **A total of 39 fiducials markers were successfully deployed in eight of nine patients (89%). Of these eight successful cases, seven had fiducials placed directly within the tumor (88%). At Cyberknife planning, 7 to 10 days after fiducial placement, 35 of 39 fiducial markers (90%) were still in place and were adequate to allow radiosurgery to proceed. No immediate bronchoscopic complications were observed. One patient had a COPD exacerbation. Another patient returned within 1 day with transient, self-limiting fever.**

Conclusions: **ENB can be used to deploy fiducial markers for Cyberknife radiosurgery of lung tumors safely and accurately without the complications associated with transthoracic placement.**

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Key words: Cyberknife; electromagnetic navigation bronchoscopy; fiducial; lung cancer; robotic stereotactic radiosurgery

Abbreviations: ENB = electromagnetic navigation bronchoscopy; EWC = extended working channel

Patients who have potentially resectable lung tumors may be considered inoperable because of advanced age, comorbidities, or poor pulmonary function. Stereotactic radiosurgery (Cyberknife; Accuray Incorporated; Sunnyvale, CA) is an alternative to external beam radiotherapy in such patients. The Cyberknife is a frameless and image-guided device that has a 6-megavolt linear accelerator mounted on a robotic arm (Fig 1), Consequently, the Cyberknife can administer radiation to a tumor from different trajectories while minimizing dosage to adjacent normal tissue. When used with the Synchrony Sys-

FIGURE 1. Cyberknife device with a linear accelerator mounted on a robotic arm.

tem (Accuray Incorporated), the Cyberknife avoids the need for breath holding because it compensates for changes in tumor position during the normal respiratory cycle. However, this system requires the insertion of fiducials in or near the tumors to enable accurate tracking. Fiducials are radiographically visible markers that precisely identify the location of a tumor during Cyberknife therapy.

Fiducials can be inserted into intrathoracic tumors via three modalities: transthoracic, intravascular, and bronchoscopic.[1–3] Bronchoscopic insertion has an excellent side effect profile compared to the other modalities.[1–3] A particular disadvantage of bronchoscopic placement of fiducials into a peripheral lung lesion is the location of the tumor and its relationship to an accessible bronchus. As peripheral tumors are rarely visualized directly, this is essentially a "blind" procedure. The reported sensitivity for the diagnosis of peripheral bronchogenic carcinoma by bronchoscopy ranges from 36 to 86% and is primarily dependent on lesion size.[4,5] Extrapolation of these data to bronchoscopic fiducial placement suggests that this method of fiducial deployment may be inaccurate.

Electromagnetic navigation bronchoscopy (ENB) is designed to guide bronchoscopic tools to predetermined locations within the periphery of the bronchial tree. ENB consists of four components: an electromagnetic location board, a locatable sensor probe with an eight-way steering mechanism that is able to navigate the bronchial tree, an extended working channel (EWC) that can carry either the sensor probe or a flexible forceps/brush/needle, and computer software that converts CT scans into multiplanar images with three-dimensional virtual bronchoscopy reconstruction. This system enables real-time navigation guidance within the lungs to endobronchially invisible targets. The diagnostic yield from ENB-guided biopsies of peripheral lung lesions ranges from 69 to 74% and is independent of target size.[6–8] Therefore, ENB-guided fiducial placement is likely to be more accurate than standard bronchoscopy.

We hypothesized that ENB could be used as a vehicle to precisely place fiducials into peripheral lung tumors. An open-label, feasibility study was conducted to test this hypothesis.

Materials and Methods

Nine consecutive patients who were referred for bronchoscopic fiducial placement were recruited between September 2005 and April 2006. All patients had peripheral lung tumors and no CT evidence of endobronchial pathology. The cases were reviewed at a multidisciplinary thoracic oncology clinic, and seven were deemed inoperable. Two additional patients declined surgery when informed of the potential surgical risks and complications due to their medical comorbidities. The indications for all nine patients for Cyberknife radiosurgery are listed in Table 1. Patients with implantable pacemakers or defibrillators were excluded from ENB. The Institutional Review Board of Beth Israel Deaconess Medical Center approved the data collection and analysis.

ENB Procedure

The superDimension/Bronchus (superDimension Incorporated; Plymouth, MN) system was used for ENB. All patients had noncontrast CT scans of the chest with slice thickness of 2 to 3.5

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The locatable sensor probes for electromagnetic navigation bronchoscopy were provided free of charge by superDimension. superDimension has supported continuing medical education courses at Harvard University through unrestricted educational grants. Dr. Ernst was a member of the Scientific Advisory Board of superDimension and has been reimbursed for time and travel expenses related to that function. Dr. Ernst also had stock options in superDimension, which have been returned in the past. Dr. DeCamp is a member of the Scientific Advisory Board of superDimension and Accuray and has been reimbursed for time and travel expenses related to that function. Neither Dr. Ernst nor Dr. DeCamp were involved in the consenting process. Drs. Anantham, Feller-Kopman, Shanmugham, Berman, Gangadharan, Eberhardt, and Herth have no conflict of interest to report. A portion of this data was presented as an abstract at the European Respiratory Society Congress, Munich, Germany, 2006.
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