1. Background

The standard unguided approach to navigating the bronchoscope through the airway tree is very challenging, resulting in navigation errors as early as the 2nd-generation airways. While image-guided intervention (IGI) systems have proven to be effective for bronchoscope navigation, they typically require two people to operate: the bronchoscopist and an attending technician. This limits the practicality of such systems for more routine use. We present an IGI system that enables direct control by the bronchoscopist.

2. Materials and Methods

The system operates over two stages, as summarized by Figures 1-2.

Stage 1: Procedure planning

The bronchoscopist identifies lesions of interest using the patient’s 3D multidetector computed-tomography (MDCT) chest scan. Automatic computer-based methods drawing upon the MDCT scan then derive navigation routes through the airways leading to each lesion. Given these data, follow-on automatic processing computes a set of navigation directions for each route, where the directions suggest how to navigate the bronchoscope toward a lesion along its preplanned navigation route. With reference to Figure 2, CCW = rotate the bronchoscope counterclockwise; CW = rotate the bronchoscope clockwise. After these preplanning operations, the bronchoscope previews the navigation routes and directions on a tablet computer.

Stage 2: Image-guided bronchoscopy

Before bronchoscopy, we channel the bronchoscope’s video output into the IGI system and initialize the system’s guidance display as shown in Figure 3. During bronchoscopy, the bronchoscopist controls the system through a 3-pedal foot switch. Switch commands (advance, freeze, back) trigger updates to the system’s guidance display. For example, activation of the advance command moves the guidance display distally one bifurcation as the bronchoscopist follows along directly, referring to the navigation directions as needed.

3. Results and Discussion

We first tested the system using two MDCT-based human airway-tree phantoms with lesions as summarized below. Using the IGI system, we successfully guided the bronchoscope to all sites, with no assistance from a technician, using the precomputed bronchoscope maneuvers associated with the planned routes. Figure 4 shows final sampling sites for two of the lesions in the two phantoms.

We next performed a human study to test system safety and feasibility in clinical conditions. Image guidance was successful in all cases, with the terminal route branching reached for 5 of 8 sites; for 3 sites, the bronchoscope’s diameter exceeded more distal airway diameters. A summary of the results is presented below. Sample IGI system views along one of the lesion routes are shown in Figure 3. A preliminary pilot study involving four additional human subjects indicated that the system performed smoothly in all cases.

4. Conclusion

The self-guided IGI system has considerable potential for bronchoscope navigation and proved to be safe and feasible in a clinical environment. We believe this development could greatly improve the practicality of such systems for more routine use. The system’s navigation directions could also help coach novice bronchoscopists and adapt to the preferences of a bronchoscopist.

References


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