Electromagnetic tracking based navigation for robot-assisted lung brachytherapy

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Introduction

Brachytherapy is a form of radiation therapy that is delivered by directly placing a radioactive source (seed) near or inside a tumour. Compared to external-beam radiation, it offers a more precise delivery of radiation so that the effect on cancerous tissue may be maximized while damage outside of the tumour may be minimized. The radiation is delivered in low dose through the injection of permanent radioactive seeds into cancerous tissue using long hollow needles.

Traditionally each needle is inserted manually. The main drawback is the inaccuracies in dose distribution caused by difficult accurate placement of the seeds within the tumour.

System description

An integrated surgical guidance system for lung brachytherapy procedures was developed. This system localizes lesions using real-time ultrasound images and interactively guides the brachytherapy needle to a target with an intuitive user-interface. Electromagnetic trackers were placed on the needle and on the ultrasound probe to provide real-time position and orientation feedback to the software. The software, dubbed InterNAV™, calculates the trajectory of the needle and displays it relative to the ultrasound image thereby recreating a virtual workspace that provides intuitive guidance. The user can then select a target on the ultrasound image and determine if the needle position needs to be adjusted in order to hit the target. Furthermore, a robotic brachytherapy seed injector was developed using the ZEUS™ platform, enabling the surgeon to precisely manipulate the brachytherapy needle at a safe distance and in a comfortable position.

Methodology

Opaque agar gelatine was used to simulate lung tissue. Randomly positioned 1.6 mm steel balls served as targets for seed injection. Using various experimental setups, seeds were injected as close as possible to the target.

The completion time, number of attempts, and the accuracy of seed deployment were compared among open-manual, video-assisted thoracoscopic surgery (VATS), and robot systems, with or without InterNAV™ guidance.

Hypothesis: Adding electromagnetic (EM) guidance and robot assistance to minimally invasive lung brachytherapy will result in same or improved performance when compared to open surgery with considerably less trauma.

The reduction in number of attempts through the use of InterNAV™ and robot assistance is especially encouraging because it represents decreased likelihood of surgical trauma that might lead to injury to proximal mediastinal structures, bleeding, and lung collapse.

Results

Blue bars represent setups with only ultrasound guidance, whereas red bars represent setups with both ultrasound and InterNAV™ guidance.

InterNAV™ reduced the average amount of time that was required to complete the task by 52 seconds for the VATS and 34 seconds for the ZEUS™ techniques respectively.

The median number of attempts was reduced to 1 for all three setups when the InterNAV™ was used. Robot-assistance reduced attempts by 1 compared to VATS in ultrasound-only setups.

The accuracies of seed insertion were comparable among all of the setups.

Conclusions

The InterNAV™ electromagnetic navigation system and the ZEUS™ robot for minimally invasive robot-assisted lung brachytherapy offer improvements over an ultrasound guided VATS technique in the placement of seeds beside a target. The resulting enhancement in speed and reduction in surgical trauma are important clinically.

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