Ultrasound imaging tracking technique for tumor motion tracking based on a 4DCT respiratory motion model

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Background, Motivation and Objective

The movement of organs during radiotherapy often has considerable negative impacts on the clinical diagnosis, the efficacy of radiation therapy, and the extent of radiation exposure. This expansion of the irradiated area results in normal organ tissues around the tumor also receiving radiation doses. The purpose of this study was to develop a method for the indirect positioning of lung tumors based on ultrasound imaging. An ultrasound image tracking algorithm (UITA) was developed and combined with four-dimensional computed tomography (4DCT) to create a real-time tumor motion-conversion model. The real-time position of a lung tumor phantom based on the real-time diaphragm motion trajectories detected by ultrasound imaging in the superior–inferior (SI) and medial–lateral (ML) directions were obtained.

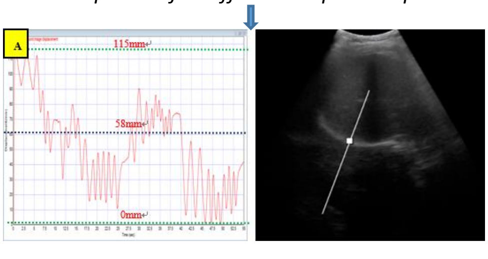
Statement of Contribution/Methods

Three different tumor motion-conversion models were created using a respiratory motion simulation system (RMSS) combined with 4DCT. The tumor tracking error was verified using cone-beam computed tomography (CBCT). The tumor motion-conversion model was produced by using the UITA to monitor the motion trajectories of the diaphragm phantom in the SI direction, and using 4DCT to monitor the motion trajectories of the tumor phantom in the SI and ML directions over the same time period, to obtain parameters for the motion-conversion model such as the tumor center position and the amplitude and phase ratios.

Results/Discussion

The tumor movement was monitored for 90 seconds using CBCT to determine the real motion trajectories of the tumor phantom and using ultrasound imaging to simultaneously record the diaphragm movement. The absolute error of the motion trajectories of the real and estimated tumor varied between 0.5 mm and 2.1 mm in the two directions. This study has demonstrated the feasibility of using ultrasound imaging to track diaphragmatic motion combined with a 4DCT tumor motion-conversion model to track tumor motion in the SI and ML directions. The proposed method makes tracking a lung tumor feasible in real time, including under different breathing conditions.

Fig. 1 (A) Real-time ultrasound images and displacement signals of the diaphragms of one patient for different respiration patterns.



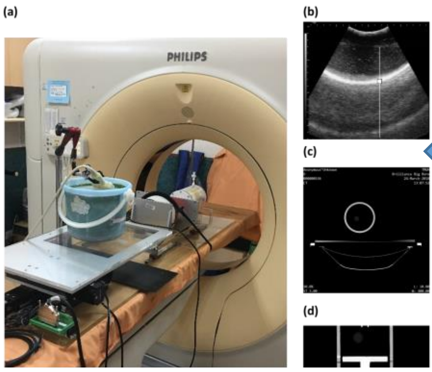


Fig. 2 (a) Photograph of the RMSS and three phantoms mounted on the Cine-CT machine. (b) Ultrasound image of the diaphragm phantom. (c) 4DCT axial section. (d) Photograph of the tumor position for a phase of 50% under 4DCT.

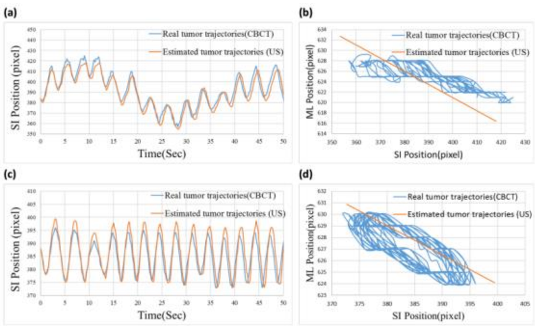


Fig. 3 Comparison of real tumor phantom trajectories (obtained using CBCT) and estimated tumor phantom trajectories (obtained using ultrasound).