Modeling Respiratory Motion for Cancer Radiation Therapy Based on Patient-specific 4DCT Data

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Abstract. Prediction of respiratory motion has the potential to substantially improve cancer radiation therapy. A nonlinear finite element (FE) model of respiratory motion during full breathing cycle has been developed based on patient specific pressure-volume relationship and 4D Computed Tomography (CT) data. For geometric modeling of lungs and ribcage we have constructed intermediate CAD surface which avoids multiple geometric smoothing procedures. For physiologically relevant respiratory motion modeling we have used pressure-volume (PV) relationship to apply pressure loading on the surface of the model. A hyperelastic soft tissue model, developed from experimental observations, has been used. Additionally, pleural sliding has been considered which results in accurate deformations in the superior-inferior (SI) direction. The finite element model has been validated using 51 landmarks from the CT data. The average differences in position is seen to be 0.07 cm (SD = 0.20 cm), 0.07 cm (0.15 cm), and 0.22 cm (0.18 cm) in the left-right, anterior-posterior, and superior-inferior directions, respectively.

1 Introduction

Respiratory motions have a profound impact on the radiation treatment planning of cancer in the lung and adjacent tissues. In external beam radiation treatment, for example, a lethal radiation dose is delivered through precisely conformed radiation to the target. The current radiation treatment paradigm, however, is largely based on an assumption that both tumor location and shape are well known and remain unchanged during the course of radiation delivery. Such a favorable rigid-body relationship does not exist in anatomical sites such as the thoracic cavity and the abdomen, owing predominantly to respiratory motions. When the tumor-bearing normal organs move during radiation therapy, discrepancies between planned and actually delivered radiation doses can be quite significant. As a result, although higher radiation doses have shown better local tumor control, organ motions have sometimes required less