Modeling change of patient position during thoracoscopic surgery

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Introduction

The lung deforms considerably during video-assisted thoracoscopic surgery (VATS), hindering the localization of nodules, and therefore, their resection. Modeling such deformation may provide useful intraoperative guidance. Two important factors should be considered: a change of patient position from supine (before surgery) to lateral (during surgery), and a pneumothorax (lung deflation). In our previous work, we have estimated proposed to account for these two factors using a hybrid approach mixing image-based registration and biomechanical modeling [1]. In this study, we focus on modeling lung deformation after a change of patient position, with a special attention to the sliding motion behavior.

Methods

Data and image registration

We used retrospective clinical data from a patient undergoing nodule resection through VATS. Two image acquisitions were performed: a preoperative CT (supine position) and an intraoperative CBCT (lateral position) with only a partial view of the lung.

We estimated the deformation of the lung lobes and thoracic wall between the two images using image registration [1]. Displacement and sliding motion measurements were used for evaluation and for computation of boundary conditions (BCs).

Step-1: Thoracic wall deformation

The hyperelastic Yeoh model was used for simulating the thoracic wall deformation. The model parameters were taken from the literature [2]. A second-order-tetrahedral mesh was computed from the lung segmentation in the CT. Displacements from image registration were prescribed as BCs to surface nodes inside the FOV of the CBCT.

Step-2: Lung lobes deformation

A poroelastic model with a Yeoh hyperelastic solid matrix was used for simulating lobe deformation. The material properties were taken from the literature [1,2]. Second-order tetrahedral meshes were generated from lobe segmentations in the CT.

The surface of the thoracic wall was fully constrained with displacements after step one. The lobes were constrained through frictionless contact both against the thoracic wall and between themselves. Displacements from image registration were prescribed at the airway inlet and zero-pressure was imposed at the lobes' surfaces.

Results

The attached figure depicts the resulting deformation after our two-step simulation process. We measured large sliding motion against the thoracic wall (up to 14mm) and between the two lobes (up to 15.1mm).

Discussion and conclusion

We proposed a two-step process for simulating lung deformation after the change of patient position during VATS. The first step simulated the thoracic wall deformation using BCs from partial intraoperative data. The second step simulated lobar deformation with a poroelastic model and was formulated as a contact problem. Although prestress, diaphragm, and gravity effects were not considered, the simulated amount of sliding motion was coherent with our observations from image registration, including a qualitatively similar spatial distribution for the sliding motion between lobes.

Acknowledgments

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References

[1] Alvarez et al., “A hybrid, image-based and biomechanics-based registration approach to markerless intraoperative nodule localization during video-assisted thoracoscopic surgery,” MedIA, 2021, doi:10.1016/j.media.2021.101983.

[2] Jafari et al., “In-vivo lung biomechanical modeling for effective tumor motion tracking in external beam radiation therapy,” Comp. Bio. Med., 2021, doi:10.1016/j.compbiomed.2021.104231.