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Validation of a deformable image registration method to assess lung ventilation from 4DCT

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INTRODUCTION

- Implementing pulmonary functionality in treatment planning could limit medical complications associated with radiotherapy treatments of lung cancer. It could help preserve high-functioning areas of lung tissue.
- The current community standard for measuring the lung ventilation is SPECT imaging. However, this method requires performing additional image acquisitions on patients.
- Using 4DCT scans retrospectively, it is possible to assess lung ventilation.

AIM

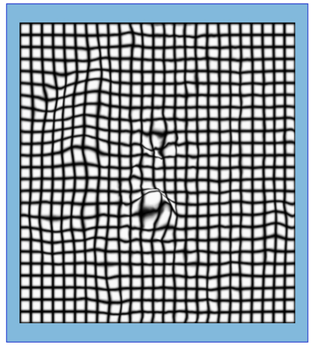
- To validate a DIR (Deformable Image Registration) technique for assessing lung ventilation using 4DCT.

METHODS & VALIDATION

METHODS

- Deformation of the lung has a localized impact on air flow, which is correlated with ventilation, one of the two aspects of the pulmonary functionality.
- 4DCT scans of a patient cohort (n=31), taken for treatment planning purposes, were processed retrospectively with a program called ANTs (Advanced Normalization Tools).
- To assess lung ventilation with a DIR technique, the deformation is evaluated between respiratory maxima. A DVF (Displacement Vector Field) is generated using this technique[1].
- Local behavior ascribed to each voxel is estimated by the Jacobian of those vector fields at corresponding locations for the peak exhale and inhale respiratory phases[2].

Stack of images from a 4DCT scan



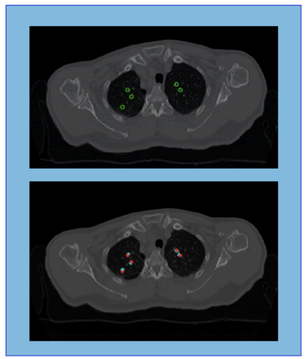
Example of registration grid after the DIR between two images of the same 4DCT scan

VALIDATION

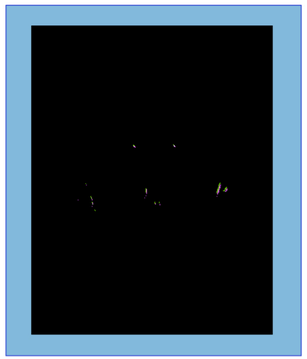
- A validation of the DIR technique is performed using several metrics.
- The target registration error (TRE) uses anatomical markers such as airway bifurcations. The registration is computed on both the images and the landmarks, and the distance between the computed LM and the registered LM is used for comparison.
- The Dice coefficient (DC) and the Hausdorff distance (HD) between the deformed lung contours and aimed contours were used as well.

RESULTS

- The distance between five corresponding anatomical landmarks was calculated for six patients. The mean TRE was (1.44 ± 0.79) mm for those six.
- Additionally, the similarity between the registered and targeted lung contours showed a mean DC of (0.91 ± 0.03) and a mean HD of (8.0 ± 0.9) mm for all 31 patients.



Top: fixed image with landmarks
Bottom: resulting image with expected landmark positions (in red) and resulting landmark positions (in blue)



Difference between the fixed image and computed image for a Dice of 0.92.

DISCUSSION

- The overall performance of the registration technique will allow us to determine the robustness of our methods in extracting ventilation data from 4DCT scans.
- Single-photon emission computed tomography (SPECT) datas, the current standard to estimate lung ventilation, will be used as ground truth for comparison with our proposed methods.
- A good accuracy with the DIR technique means that less scans need to be taken, and less healthy tissues will be irradiated.
- Future work will focus on lung functionality based on both ventilation and perfusion data derived from 4DCT and dual-energy CT with iodine contrast, respectively.

REFERENCES

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