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Results of a Prospective Trial to Evaluate Novel Lung Function Imaging for Lung Cancer Surgery

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Results of a Prospective Trial to Evaluate Novel Lung Function Imaging for Lung Cancer Surgery

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Background

- Surgery is the primary form of definitive treatment for early-stage lung cancer.
- Poor lung function before surgery places patients at high risk of pulmonary complications after resection.
- Surgeons evaluate patient fitness for surgery using pulmonary function tests (PFTs) to calculate the predicted postoperative PFT (ppoPFT).
- Conventional ppoPFT calculations assume homogeneous lung function, which can be inaccurate.
- 4DCT-ventilation is a novel lung function imaging modality developed in radiation oncology that uses 4DCT data to calculate high-resolution ventilation maps.

Objective

The purpose of this study was to report the first pilot clinical trial to prospectively investigate the suitability of 4DCT-ventilation for lung cancer surgical evaluation.

Approach

- **Cohort:**
  - Patients enrolled in the clinical trial titled 'A Novel Lung Function Imaging Modality as a Preoperative Evaluation Tool (LIME)' (NCT03426306)
  - Inclusion Criteria:
    - Patients being considered for:
      - Pneumonectomy
      - Lobectomy
      - Segmentectomy
- **Data:**

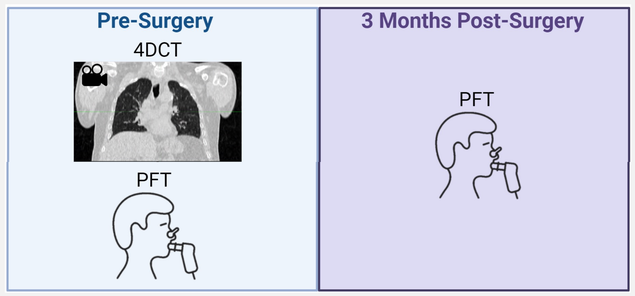

Figure 1. Diagram of data included in this study: 4 dimensional computed tomographic (4DCT) images prior to surgery and pulmonary function test (PFT) scores before and after surgery.

- **4DCT-Ventilation Calculation:** Validated algorithms [1] used deformable image registration to map lung voxels from the inhale to exhale phase of the 4DCT dataset for each patient and approximated the 4DCT-ventilation by capturing the changes in air content between the two phases. (Figure 2)

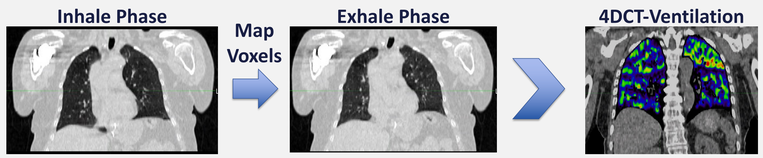

Figure 2. Schematic diagram of 4DCT-Ventilation calculation.

Results

- **Cohort:**

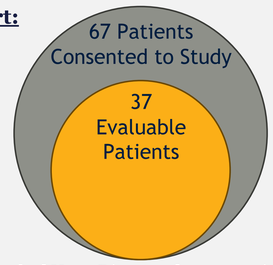

Figure 4. Stacked Venn Diagram demonstrating the clinical trial enrolment and evaluable cohort who completed all evaluations (i.e., pre-surgical 4DCT, pre- and post-surgical PFT evaluation) to be included in this study.

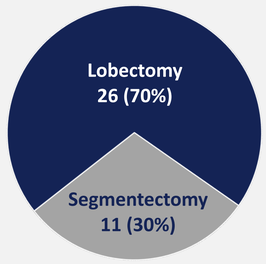

Figure 5. Pie chart depicting the distribution of surgical procedures represented among the 37 evaluable patients in this study.

- **Statistical Analysis:**

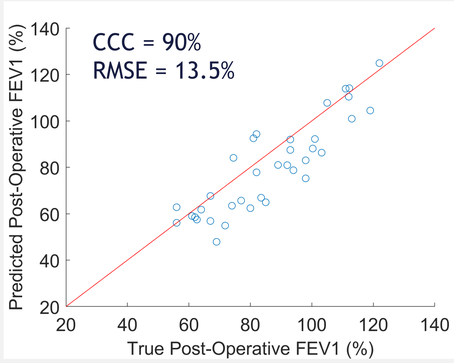

Figure 6. Scatter plot of the true post-surgery pulmonary function test measure of forced expiratory volume in 1 second (FEV1) versus the predicted post-operative value. The red line indicates the X=Y identity line, representing a perfect prediction. The overlaid text indicates the concordance correlation coefficient (CCC) and root-mean-squared error (RMSE).

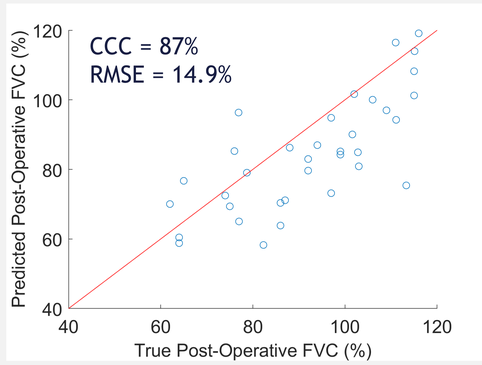

Figure 7. Scatter plot of the true post-surgery pulmonary function test measure of forced vital capacity (FVC) versus the predicted post-operative value. The red line indicates the X=Y identity line, representing a perfect prediction. The overlaid text indicates the concordance correlation coefficient (CCC) and root-mean-squared error (RMSE).

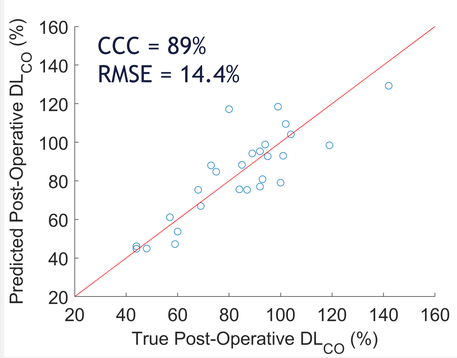

Figure 8. Scatter plot of the true post-surgery pulmonary function test measure of diffusing capacity of the lungs for carbon monoxide (DL_{CO}) versus the predicted post-operative value. The red line indicates the X=Y identity line, representing a perfect prediction. The overlaid text indicates the concordance correlation coefficient (CCC) and root-mean-squared error (RMSE).

Conclusion

- This was the first pilot study to prospectively evaluate the accuracy of 4DCT-ventilation imaging for calculating ppoPFTs.
- The study met the primary CCC criteria for the 3 most common PFT measures with variations observed in individual patients.
- 4DCT-ventilation methods developed in radiation oncology can be innovatively applied to improve the ability of surgeons to quantitatively evaluate patient appropriateness and safety for lung cancer resection.

Future Directions

- Future work will evaluate correlations between clinical factors and individual patient differences in ppoPFT accuracy.
- Comparing 4DCT-ventilation with conventional ppoPFT calculations will inform cost-benefit analyses for clinical integration of 4DCT-ventilation-based methods.
- Novel techniques like voxel-based analysis and machine learning could be adopted to develop more sophisticated algorithms predicting surgical outcomes.

Methods

- **Predicted Post-Operative PFT (ppoPFT) Calculation:** We weighted the pre-surgery PFT by the proportion of lung function left over once you remove the function in the planned surgical volume. (Figure 3)

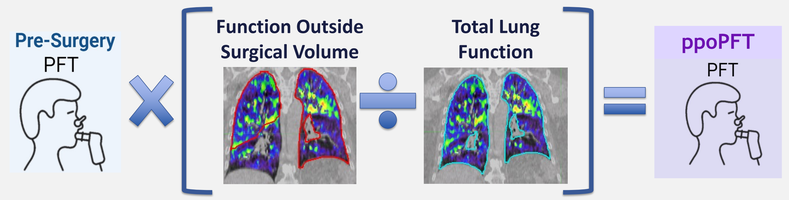

Figure 3. Schematic diagram of predicted post-operative pulmonary function test (ppoPFT) score calculation.

- **Statistical Analysis:** We compared our ppoPFT to the true post-surgery PFT measures for 3 common PFT measures:
  - Forced Expiratory Volume in 1 second (FEV1)
  - Forced Vital Capacity (FVC)
  - Diffusing Capacity of the Lungs for Carbon Monoxide (DL_{CO})
  - Root-Mean-Squared (RMS) Error
    - Evaluates accuracy
    - Neglects the sign of errors (overestimation and underestimation lumped together)
    - Sensitive to outliers
  - Concordance Correlation Coefficient (CCC)
    - Evaluates accuracy and precision simultaneously
    - CCC→100% indicates a better prediction
- **Hypothesis:** ppoPFT based on 4DCT-Ventilation could achieve CCC ≥ 85%.

[1] Guerrero T. et al. (2006) "Dynamic ventilation imaging from four-dimensional computed tomography." Phys Med and Biol

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