UCLA Health | David Geffen School of Medicine

2026 JULY 19–22 VANCOUVER, BC
JOINT AAPM | COMP MEETING

Pre-Implantation Peri-Valve Jacobian Texture Radiomics As a Biomarker of Endobronchial Valve Treatment Success

Minji Victoria Kim[1], Jack Neylon, PhD[2], Michael Vincent Lauria, PhD[2], Michael F. McNitt-Gray, PhD[3] , Dallas Tada[1] and Grace Hyun Kim, PhD[3]
[1]University of California, Los Angeles, [2]Department of Radiation Oncology, University of California, Los Angeles,
[3]David Geffen School of Medicine at UCLA, Los Angeles, CA, [4]Department of Radiological Sciences, University of California, Los Angeles

ABSTRACT

Purpose: Endobronchial Valves (EBV) are one of the few treatment options for patients with moderate to severe emphysema. Eligibility is typically assessed from CT image data analysis including Emphysema Score (Relative Area, RA950) and Fissure Integrity Score (FIS). However not all EBV candidates are responders. The purpose of this work was to develop an approach to quantify CT texture of biomechanical lung expansion and contraction during lung inspiration and expiration using Jacobian-derived texture-based radiomics features, and to investigate the association of localized peri-valve biomechanical lung texture in pre-implantation scans in identifying candidates who will benefit from EBV treatment.

Methods: We performed a retrospective study using data from 24 patients with moderate to severe emphysema who underwent EBV treatment. Each patient underwent baseline (pre-treatment) CT scanning at both Total Lung Capacity (TLC) and Residual Volume (RV) breath-holds. Lung lobe segmentations were performed on CT image data was automatically identify lobar regions. RA950 were extracted for each lobe. Using the deformation vector field from deformable registered in RV-TLC images, Jacobian determinant was calculated to quantify lung expansion and contraction and discretized for second-order texture-based radiomics. 72 features from first-order and 3 texture-radiomic feature sets were extracted. Peri-valve regions of interest (ROIs) were generated using a valve detection method. Linear mixed effect (random intercept) models were used to evaluate improvements in model prediction with inclusion of radiomic features.

Results: In unadjusted $_{Spearman}$ analysis, 8 of 72 original metrics were significantly associated with target-lobe volume reduction. The strongest correlations were observed for first-order Energy and Total Energy, both (ρ =0.287, p = 0.0046). Additional significant metrics included GLRLM Run Length Non Uniformity, GLSZM Gray Level Non Uniformity, GLCM Imc1, GLRLM Gray Level Non Uniformity, GLCM Imc2, and GLSZM Size Zone Non Uniformity. Mixed-effects model comparison suggested that several metrics may improve overall model fit beyond Fissure Integrity score (FIS) alone. The strongest model-fit improvements were seen for first-order Total Energy, first-order Energy, and GLSZM Size Zone Non Uniformity.

Conclusion: A fully automated pipeline for peri-valve biomechanical texture analysis is feasible and shows proof-of-concept signal for EBV response stratification. Individual radiomic fixed-effect estimates being not statistically significant shows the need for further investigation and larger sample size.

CONTACT

Minji Kim
Physics and Biology in Medicine,
University of California,
Los Angeles, CA
mkim3@mednet.ucla.edu

INTRODUCTION

Endobronchial Valves (EBV) are one of the few treatment options for patients with moderate to severe emphysema. Eligibility is typically assessed from CT image data analysis including Emphysema Score (Relative Area, RA950) and Fissure Integrity Score (FIS). However not all EBV candidates are responders.

The **purpose** of this work was to develop an approach to quantify CT texture of **biomechanical** lung expansion and contraction during lung inspiration and expiration **using Jacobian determinant (detJ) derived texture-based radiomics** features, and to investigate the association of localized peri-valve biomechanical lung texture in pre-implantation scans in identifying candidates who will benefit from EBV treatment.

Register RV TLC to create Deformation Vector Field (DVF)

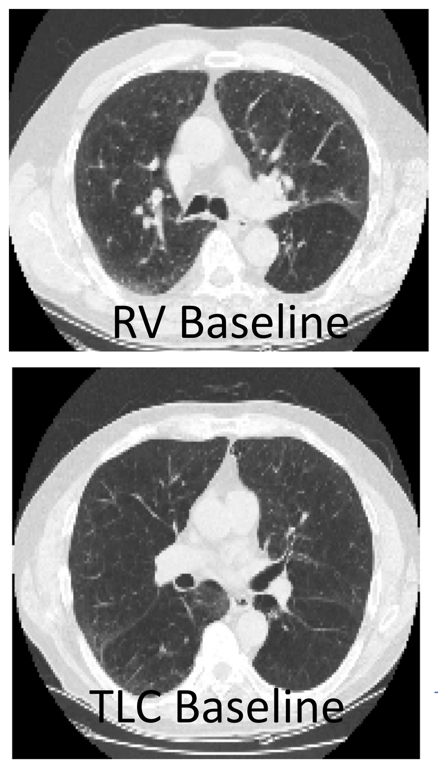
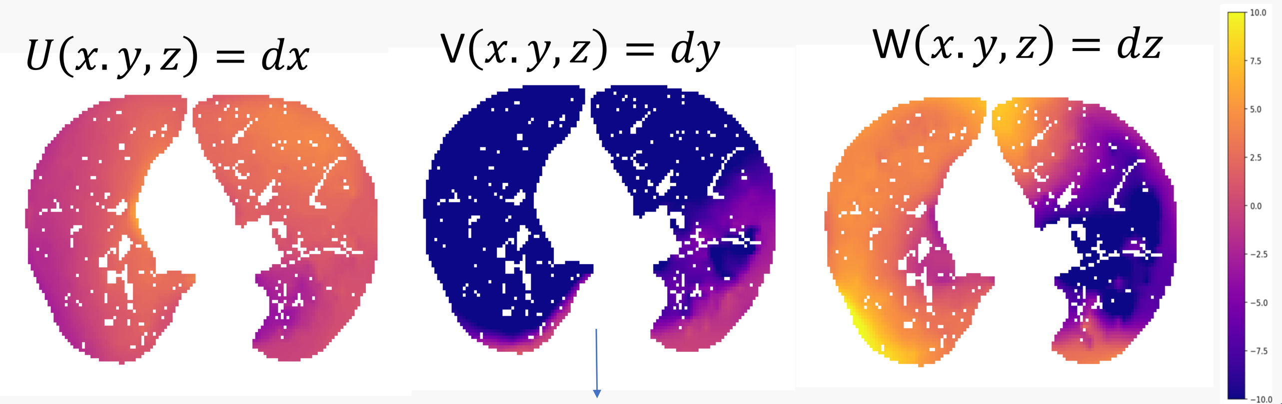


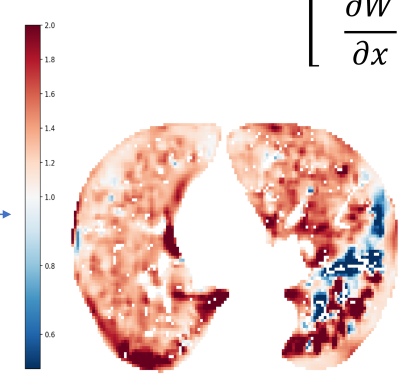
Fig 1. Workflow including Registration and Calculation of Jacobian Determinant

$U(x.y,z) = dx$ $\quad$ $V(x.y,z) = dy$ $\quad$ $W(x.y,z) = dz$



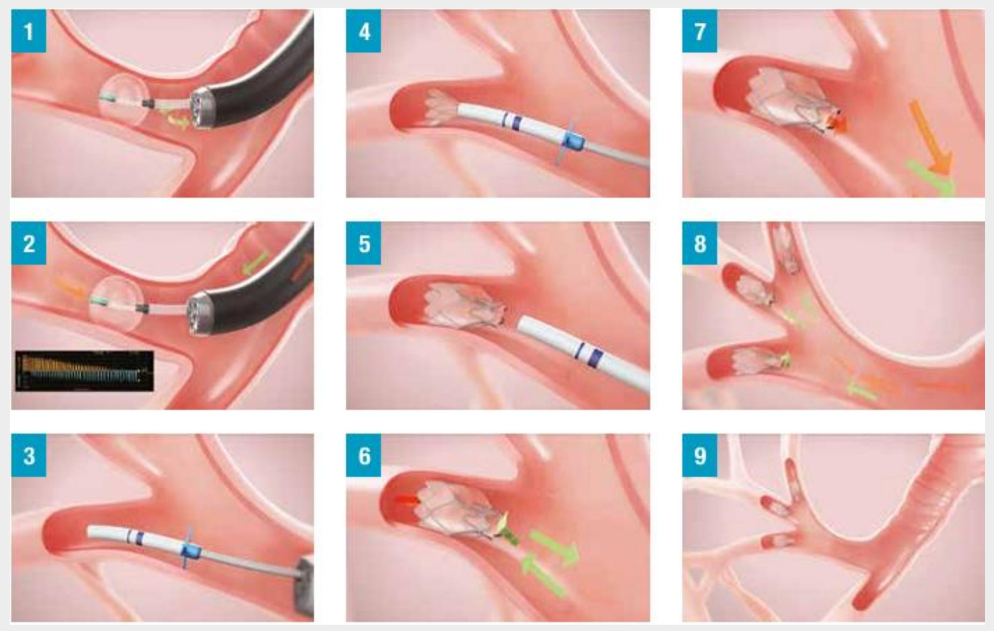
$$\phi(x,y,z) = \begin{bmatrix} x + U(x,y,z) \\ y + V(x,y,z) \\ z + W(x,y,z) \end{bmatrix}$$

$$J = \frac{\partial \phi}{\partial(x,y,z)} = \begin{bmatrix} 1+\frac{\partial U}{\partial x} & \frac{\partial U}{\partial y} & \frac{\partial U}{dz} \\ \frac{\partial V}{\partial x} & 1+\frac{\partial V}{\partial y} & \frac{\partial V}{dz} \\ \frac{\partial W}{\partial x} & \frac{\partial W}{\partial y} & 1+\frac{\partial W}{\partial z} \end{bmatrix}$$



$$\det(J) = (1+\frac{\partial U}{\partial x})((1+\frac{\partial V}{\partial y}) - (1+\frac{\partial W}{\partial z})) - \frac{\partial U}{\partial y}(\frac{\partial V}{\partial x}\cdot(1+\frac{\partial W}{\partial z}) - \frac{\partial V}{dz}\cdot\frac{\partial W}{\partial x}) + \frac{\partial U}{dz}((\frac{\partial V}{\partial x}\cdot\frac{\partial W}{\partial y}) - (1+\frac{\partial V}{\partial y})(\frac{\partial W}{\partial x}))$$

Fig 2. Valves implanted using bronchoscope. Multiple valves placed in segmental airways to completely occlude entire lobe with goal of target lobe volume reduction (TLVR).

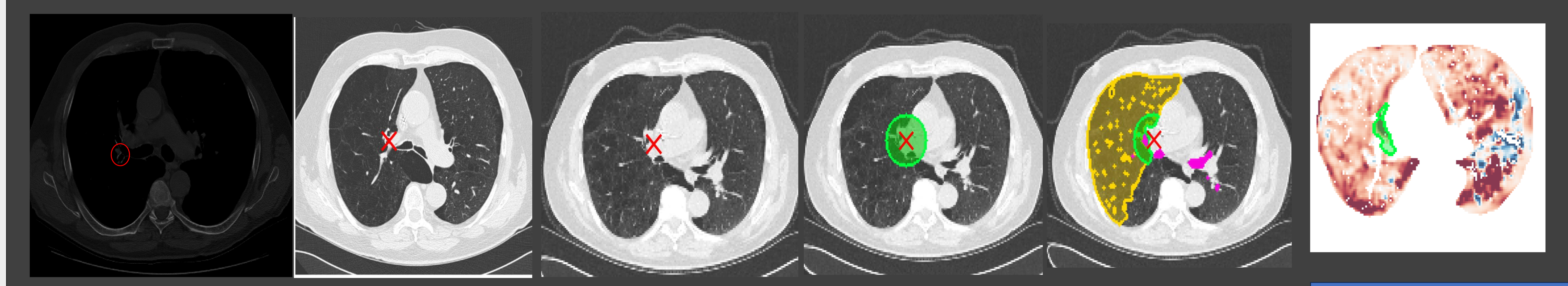


METHODS AND MATERIALS

We performed a retrospective study using data from 24 patients with moderate to severe emphysema who underwent EBV treatment. Each patient underwent baseline (pre-treatment) CT scanning at both Total Lung Capacity (TLC)and Residual Volume (RV) breath-holds. Lung lobe segmentations were performed on CT image data to automatically identify lobar regions. RA910 and RA950 were extracted for each lobe. Using the deformation vector field from deformable registered in RV-TLC images, Jacobian determinant was calculated to quantify lung expansion and contraction and discretized for second-order texture-based radiomics. 72 features from 3 texture-radiomic feature sets were extracted. Peri-valve regions of interest (ROIs) were generated using a novel valve detection method on follow-up CT and rigid mapping to baseline RV geometry.

Feature selection was performed using significant associations with **target lobe volume reduction** (**TLVR**). Linear mixed effect models (random intercept) compared baseline (Fissure predictor only) and including jacobian feature. Model improvement was calculated by assessing Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC).

Fig. 3. Peri-Valve Region of Interest (ROI) Generation Step-by-Step



TLC post-implantation: Valve (red marker)	TLC baseline: Valve (red) location from radiologist annotation	RV: Valve (red marker) mapped from TLC baseline using DVF	Spherical ROI (green) surrounding valve	Spherical ROI (green) within parenchymal target lobe (yellow) excluding airway (magenta)	Peri-valve ROI (green) on detJ map

RESULTS

Several radiomic features including Total energy, energy, and GLSZM Size Zone Non-Uniformity showed improved model fit when added to FIS based on AIC/BIC improvement. However, the individual radiomic fixed-effect estimates were not statistically significant.

CONCLUSIONS

First order and Texture-based radiomics derived from Jacobian ventilation maps can help provide improvements prediction models for endobronchial valve therapy when using localized parenchymal regions of interest surrounding the valve location.

Table 1. Linear Mixed Effect Model (Random Intercept) Improvements Including Jacobian Feature

Baseline Random Intercept Linear Mixed Effect Model	$TLVR_{ij} = \beta_0 + \beta_1(FIS\ Comp_{ij}) + b_i + \epsilon_{ij}$
Expanded Random Intercept Linear Mixed Effect Model	$TLVR_{ij} = \beta_0 + \beta_1(FIS\ Comp_{ij}) + \beta_2(Radiomic\ Feature_{ij}) + b_i + \epsilon_{ij}$

The baseline model includes Fissure completeness, measured as fissure integrity score (FIS), as a fixed effect and a patient-level random intercept to account for multiple valve observations within the same patient. The expanded model adds one Jacobian determinant derived radiomic feature at a time to evaluate whether biomechanical texture improved prediction beyond FIS. The term i, indexes patient, j indexes valve observation, β_0 is constant, β_1 and β_2 are fixed-effect coefficients, b_{ij} is patient-specific random intercept, and ϵ_{ij} is residual error. Predictors were z-scored, so coefficients represent the expected change in TLVR per 1 standard deviation increase in the predictor.

Metric	Log-Ratio Test p-value	ΔAIC	ΔBIC	β coefficient	95% CI
First order Total Energy	0.0089	-4.85	-2.28	1.69E-08	[-0.000785, 0.000785]
First order Energy	0.0089	-4.85	-2.28	1.69E-08	[-0.000785, 0.000785]
GLSZM Size Zone Non-Uniformity	0.0093	-4.77	-2.21	2.87E-08	[-0.000765, 0.000765]

REFERENCES

1. Tada DK, et al. Quantifying lung fissure integrity using a three-dimensional patch-based convolutional neural network on CT images for emphysema treatment planning. J Med Imaging (Bellingham). 2024 May;11(3):034502. doi: 10.1117/1.JMI.11.3.034502.
2. Cohen J, et al. Computed Tomography Registration-Derived Regional Ventilation Indices Compared to Global Lung Function Parameters in Patients With COPD. Front Physiol. 2022 May 26;13:862186. doi: 10.3389/fphys.2022.862186.
3. Pulmonx. "The Zephyr® Endobronchial Valve System". 2024.
4. PyRadiomics documentation nhttps://pyradiomics.readthedocs.io/en/latest/features.html

Special acknowledgements to Dr. Fereidoun Abtin, M.D. [4] for valve annotations.