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An Automated, Open-Source Pipeline for Quantitative Pulmonary Vascular Phenotyping from Chest CT: Detection of Vascular Remodeling in Dermatomyositis

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Introduction/Background
Caliber-stratified quantitative CT vascular biomarkers—most notably the small-vessel blood volume fraction (e.g., BV5) and vascular "pruning"—are validated markers of pulmonary vascular remodeling across COPD, pulmonary hypertension, and interstitial lung disease. Their clinical and research adoption is limited by reliance on specialized, non-reproducible segmentation tools. We developed a fully automated, open-source pipeline built on TotalSegmentator that quantifies whole-lung vascular volumetrics and caliber-stratified vessel fractions from routine chest CT, and validated it in dermatomyositis (DM), where inflammatory ILD drives peripheral vascular remodeling.

Methods/Intervention
Retrospective chest CTs from 414 patients (171 DM-positive, 243 without DM) were processed. TotalSegmentator generated pulmonary vessel and lung masks; an automated pipeline extracted total pulmonary vessel volume, vessel-to-lung volume ratio, and skeletonization-derived binning of vessels by caliber (< 5, 5–10, >10 mm^3). Analysis was restricted to a 6-cm peripheral lung shell to isolate small distal vessels most affected by inflammatory remodeling. Ground-glass opacity and consolidation were quantified to assess the degree of active inflammation. Cohorts were compared.

Results/Outcome
DM-positive patients showed a significantly higher peripheral vessel-to-lung volume ratio (0.0218 vs 0.0184; $p < 0.001$), a significantly lower small-vessel (< 5 mm^3) volume fraction (0.281 vs 0.321; $p < 0.001$), and a significantly higher large-vessel (>10 mm^3) fraction (0.536 vs 0.491; $p < 0.001$) than controls, consistent with redistribution of blood volume from small distal vessels toward larger calibers (pruning physiology). Quantified ground-glass opacity and consolidation correlated with the degree of peripheral vascular remodeling ($p < 0.001$), supporting active inflammation as the underlying driver. The pipeline processed all 414 studies without manual segmentation.

Conclusion
A fully automated, open-source, TotalSegmentator-based pipeline reproducibly quantifies pulmonary vascular phenotype from routine CT and distinguishes DM-associated peripheral remodeling. The framework is modality- and cohort-agnostic and supports interchangeable segmentation strategies (lobar, iterative peripheral "peel"), enabling extension to other pulmonary vascular diseases.

Statement of Impact
This work delivers an accessible, reproducible tool for extracting quantitative pulmonary vascular biomarkers

from existing CT data, lowering the barrier to large-scale imaging-biomarker research and clinical deployment beyond specialized laboratories.

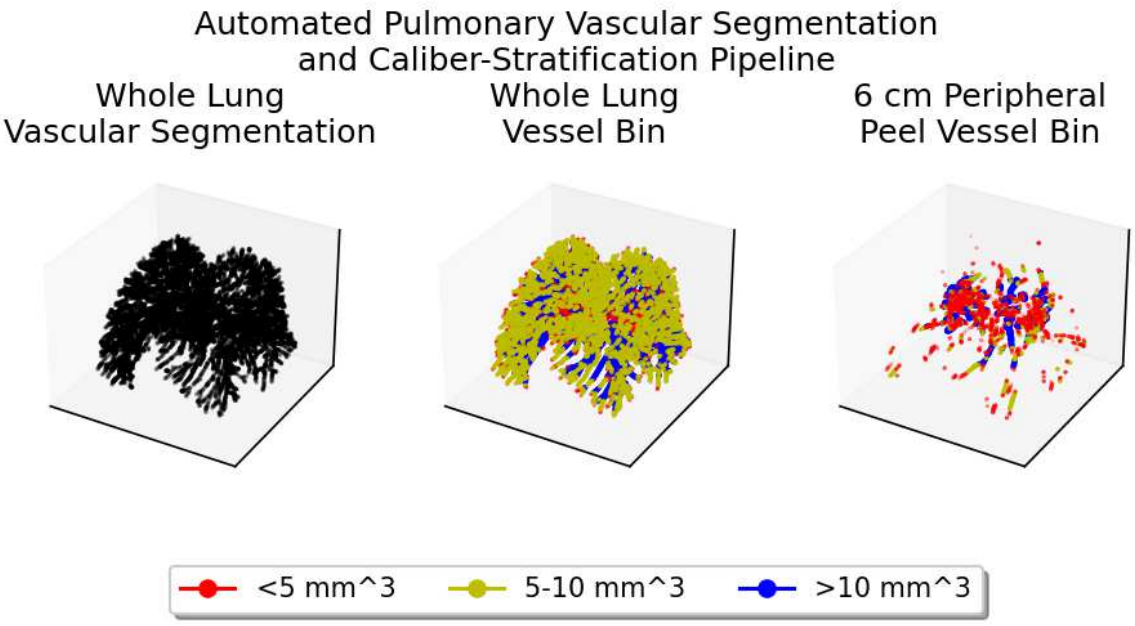

Figure 1. Automated pulmonary vascular segmentation and caliber-stratification pipeline. TotalSegmentator-derived vessel masks (left) are skeletonized and classified by caliber into small (10 mm³, blue) bins (center), then restricted to a 6-cm peripheral lung shell to isolate small distal vessels for remodeling analysis (right).

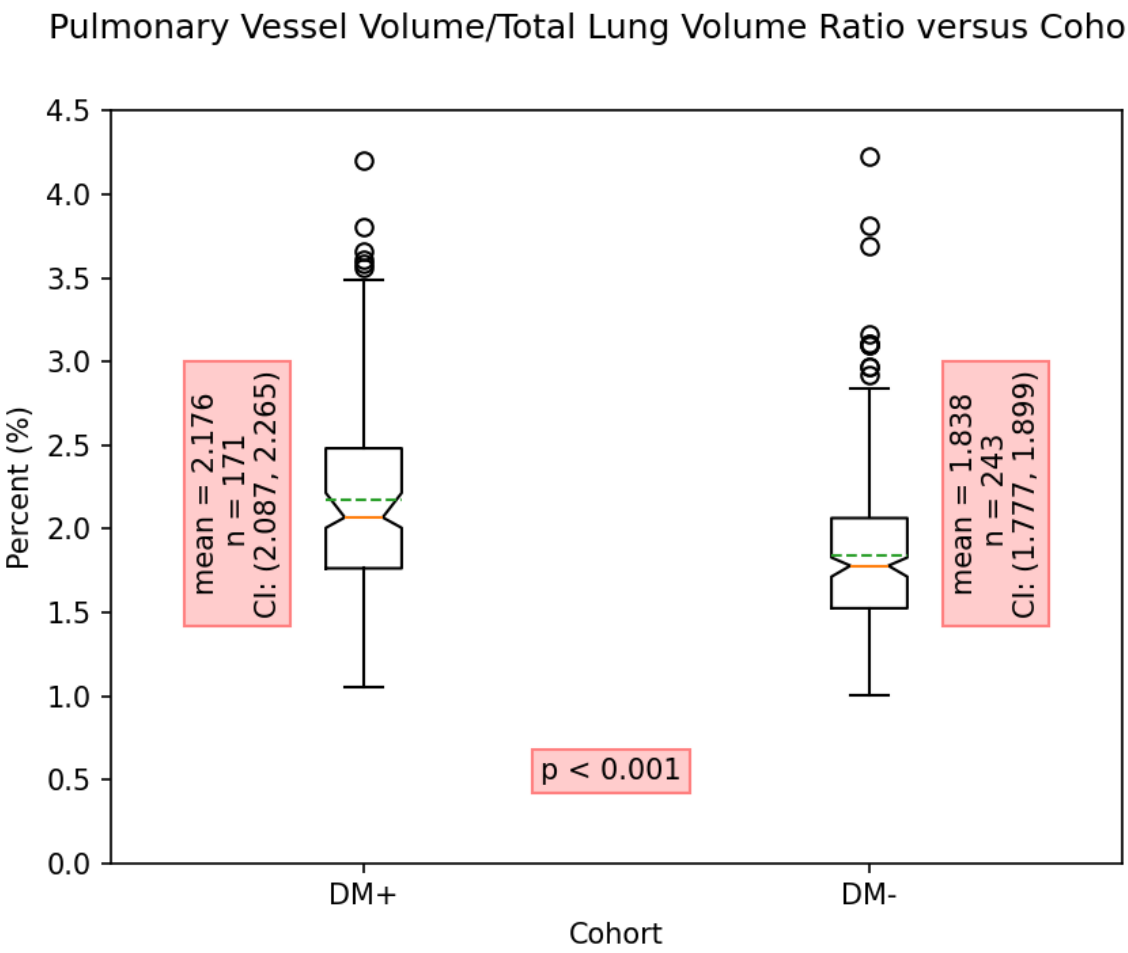

Figure 2. Pulmonary vessel volume fraction by dermatomyositis status. Notched box plots comparing the ratio of total pulmonary vessel volume to total lung volume (PVV/TLV, %) between DM+ (n = 171) and DM− (n = 243) cohorts. DM+ patients showed a significantly higher mean PVV/TLV (2.176%, 95% CI 2.087–2.265) than DM− patients (1.838%, 95% CI 1.777–1.899; $p < 0.001$). Boxes span the interquartile range; orange line denotes the median, green dashed line the mean, whiskers extend to 1.5× IQR, and open circles represent outliers.

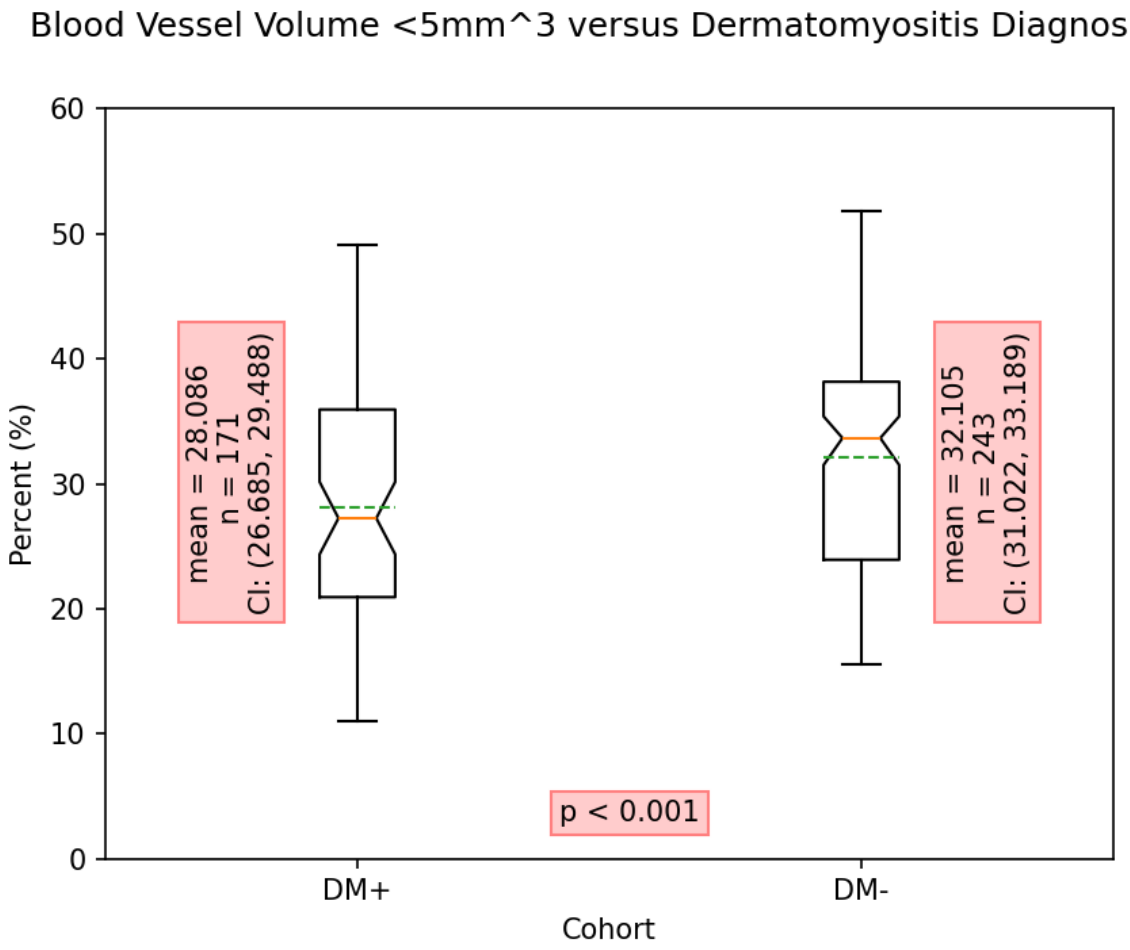

Figure 3. Small-vessel blood volume fraction (BV5) by dermatomyositis status. Notched box plots comparing the proportion of blood volume contained in vessels < 5 mm³ (percent of total pulmonary vessel volume) between DM+ (n = 171) and DM− (n = 243) cohorts. DM+ patients showed a significantly lower mean small-vessel fraction (28.086%, 95% CI 26.685–29.488) than DM− patients (32.105%, 95% CI 31.022–33.189; p < 0.001), indicating a relative shift of blood volume toward larger vessels. Orange line denotes the median, green dashed line the mean, whiskers extend to 1.5× IQR, and open circles represent outliers.

Keywords

pulmonary vascular volume; quantitative CT biomarker; TotalSegmentator; vessel segmentation; vascular pruning; open-source pipeline