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LungVis Family: an AI-powered organ imaging technology enables quantitative and interactive exploration of lung morphometry and aerosol inhalation

Inhalation therapy is essential for targeted and rapid treatment of respiratory diseases; however, unbiased disease assessment and precise drug delivery and dosimetry within the lungs remain significant challenges. To address this, we developed the **LungVis Family**, a suite of organ imaging and AI-driven computational tools for quantitative and interactive exploration of 3D histopathological features and pulmonary drug distribution in preclinical murine models.

We have recently developed the **LungVis 1.0** platform, which combines holistic organ imaging using tissue-cleared light sheet fluorescence microscopy (LSFM) with an active learning-based nnU-Net model for accurate airway segmentation. This enables spatially resolved quantification of drug/nanoparticle dose distribution in both airway and acinar regions for bulk-liquid and aerosol-based delivery routes over a two-week timeline1. Building upon this foundation, LungVis 2.0 is exploiting pulmonary blood vessel segmentation. This extension allows unbiased evaluation of lung anatomical alterations by integrating insights from both **LungVis 1.0** and **2.0** in mouse models of emphysema and fibrosis. To support in situ, user-driven analysis, **LungVis-Interactive**, a Python-Napari-based application is being developed for interactive 3D exploration of lung morphometry and deposition patterns. It uses skeletonization and graph modeling to extract and determine airway and vascular anatomical features such as generation, length, diameter, and surface area, and supports generation-specific quantification of therapeutic deposition.

We envision the full LungVis family (**LungVis 1.0**, **2.0**, and **Interactive**) as a transformative technology suite, poised to uncover 3D holistic histopathological alterations across multiple lung networks and enhance the precision of inhalation therapy in preclinical models of pulmonary disorders such as lung fibrosis, emphysema, and cancer.

1. Yang, L., Liu, Q., Kumar, P., Sengupta, A., Farnoud, A., Shen, R., ... & Schmid, O. (2024). LungVis 1.0: an automatic AI-powered 3D imaging ecosystem unveils spatial profiling of nanoparticle delivery and acinar migration of lung macrophages. Nature Communications, 15(1), 10138.

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