Lesion Segmentation and CT Biomarkers Definition for Tuberculosis Assessment and Follow-up

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Context & Objectives

TB survivors suffer from multiple life-long risks and morbidities:

Risk of Recurrence & Transmission: e.g. in South Africa: >30% cases are recurrences.

Post-TB Lung Disease (PTLD): 75% of survivors show abnormal lung function (mild-severe disability). Major cause of TB-related disability; mechanisms unknown, no treatments available.

Reduced Life Expectancy: TB survivors show 3–6× higher mortality from lung/cardiovascular disease; causes poorly defined.

Cardiovascular Risk: increased via shared factors/chronic inflammation and directly causes complications (pericardial effusion, pulmonary hypertension).

<u>**Objective:**</u> Define CT biomarkers of TB lesions, inflammation, and vascular remodeling to evaluate progression, sequelae, and risk.
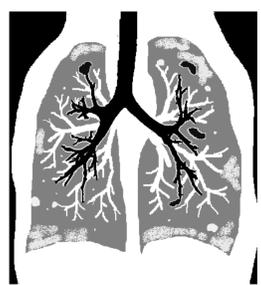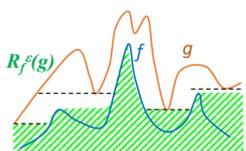
Materials & Methods

56 follow-up TB cases (Avicenne Hospital, Bobigny, France)

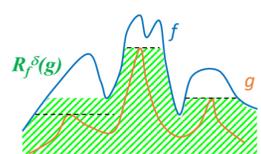**Target:** Airways, vessels, cavities, nodules, dense opacities
Segmentation approach: Topographical mathematical morphology leveraging spatial connectivity between structures

- Lung mask – uses R231 AI model [1]
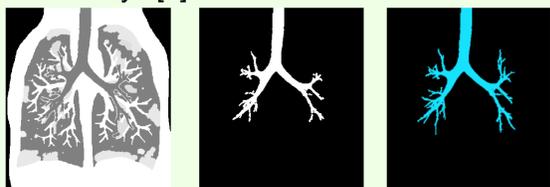
Reconstruction by erosion: valleys "flooding"

$R_f^\varepsilon(g)$

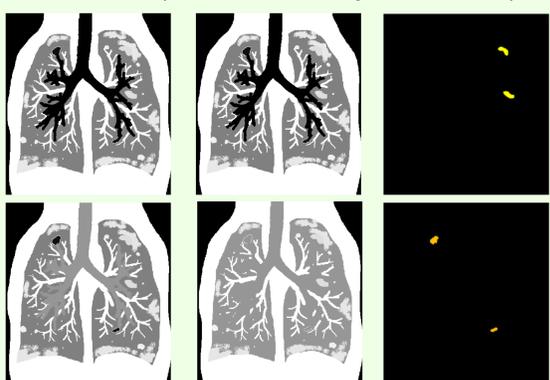CT image = f topographical relief

Reconstruction by dilation: ridge "truncation"

$R_f^\delta(g)$

- Airways [2]
- Cavities (isolated / airway-connected)
- Vessels [3] & nodules: multiscale filtering
- Dense opacities (*h-domes* based selection)

TB biomarkers:
- Airways: stenosis, bronchiectasis, tortuosity [6]
- Vessels: global and peripheral remodeling scores and maps [7]
- Cavities and nodules: distribution and size
- Dense opacities: volume

References

[1] Hofmanninger, *Eur Rad* 2020; [2] Fetita, *MICCAI WS* 2009;
[3] Kouvahe, *IRBM* 2020; [4] Latrasse, *SPIE MI 2021*; [5] Fetita, *SPIE MI 2022*;
[6] Lo, *EXACT'09*; [7] Rudyanto, *VESSEL12*;
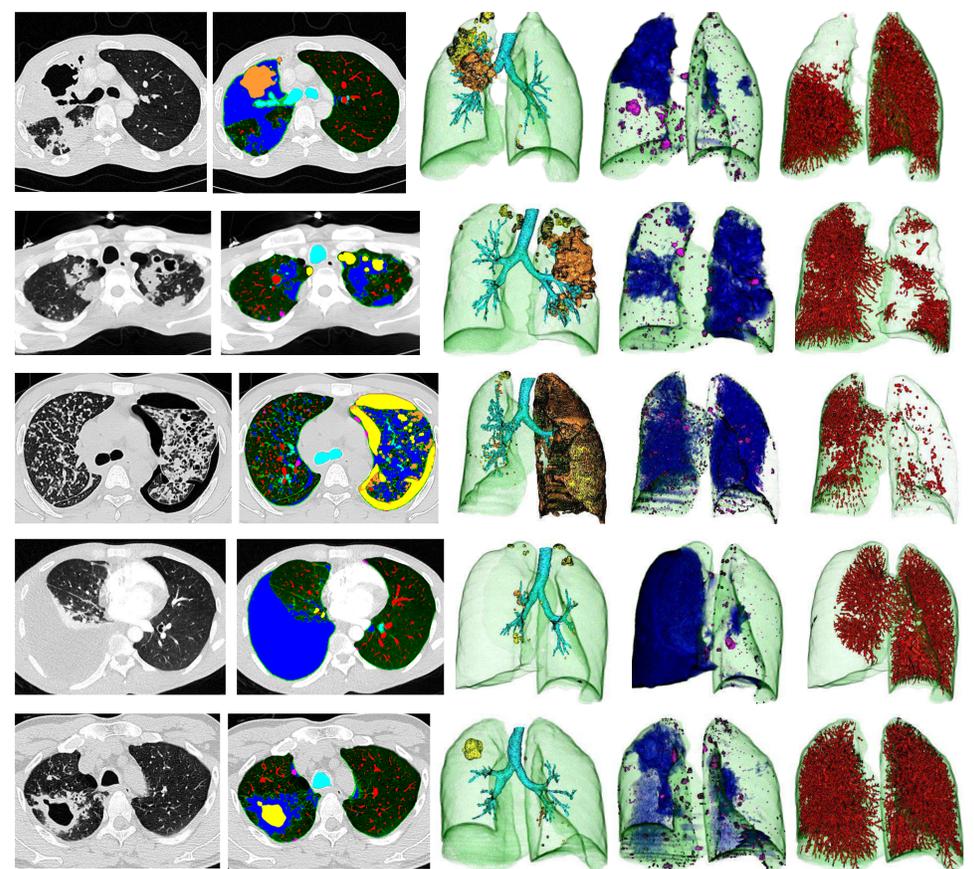[8] DeepPulmoTB https://doi.org/10.1016/j.heliyon.2024.e25490

Results

Segmentation validation:
- Previously achieved for airways [4], vessels [5]
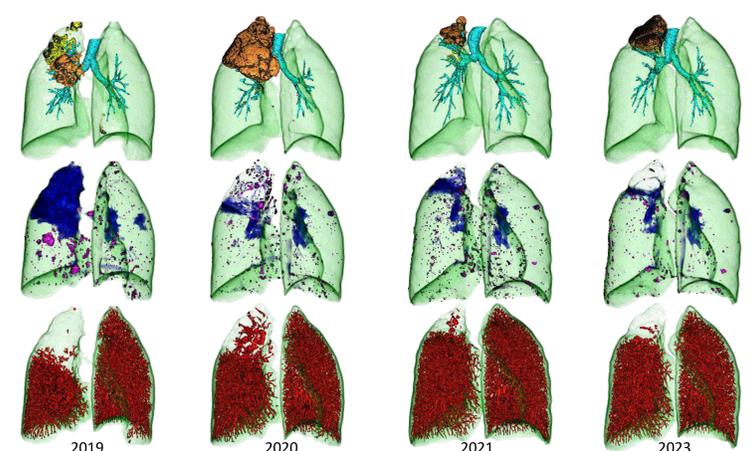- Cavities, nodules – expecting access to [8] database

Cavity detection validation (56 cases):
- Small-medium (<20 mm): Recall = 0.86; Precision = 0.71
- Large ($\geq$ 20 mm): Recall = 1; Precision = 1
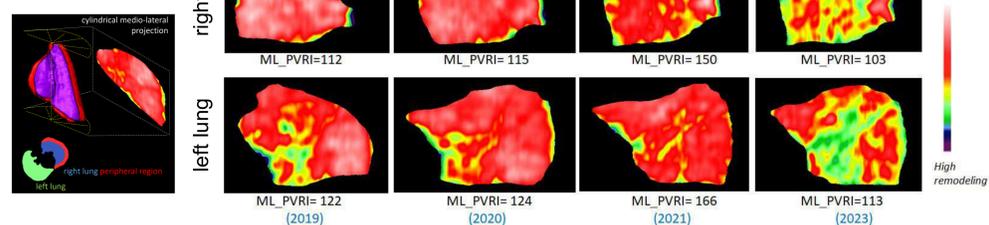- Global: Recall = 0.88; Precision = 0.75

Showcase

Follow-up example

Peripheral vascular remodeling maps and scores

right lung

ML_PVRI= 112 | ML_PVRI= 115 | ML_PVRI= 150 | ML_PVRI= 103

Low remodeling

left lung

ML_PVRI= 122 (2019) | ML_PVRI= 124 (2020) | ML_PVRI= 166 (2021) | ML_PVRI= 113 (2023)

High remodeling

2019   2020   2021   2023

Conclusion & Perspectives

A unified approach for CT image biomarkers extraction in the context of tuberculosis assessment and follow-up:

- Combines AI and conventional approaches ensuring robustness and full explainability of results for future large-scale clinical investigation (France - South Africa collaboration)
- Enables high-quality data annotation for the development of a multi-target, fully AI-driven framework for post-TB patient follow-up