Extraction and Visualization of the Central Chest Lymph Node Stations

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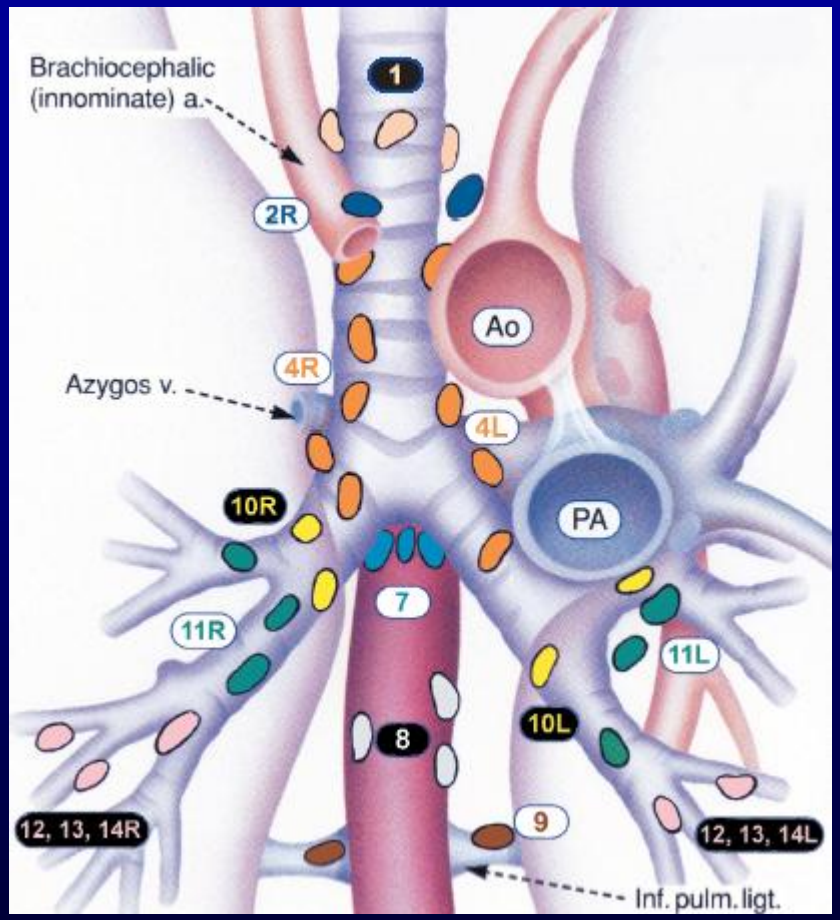
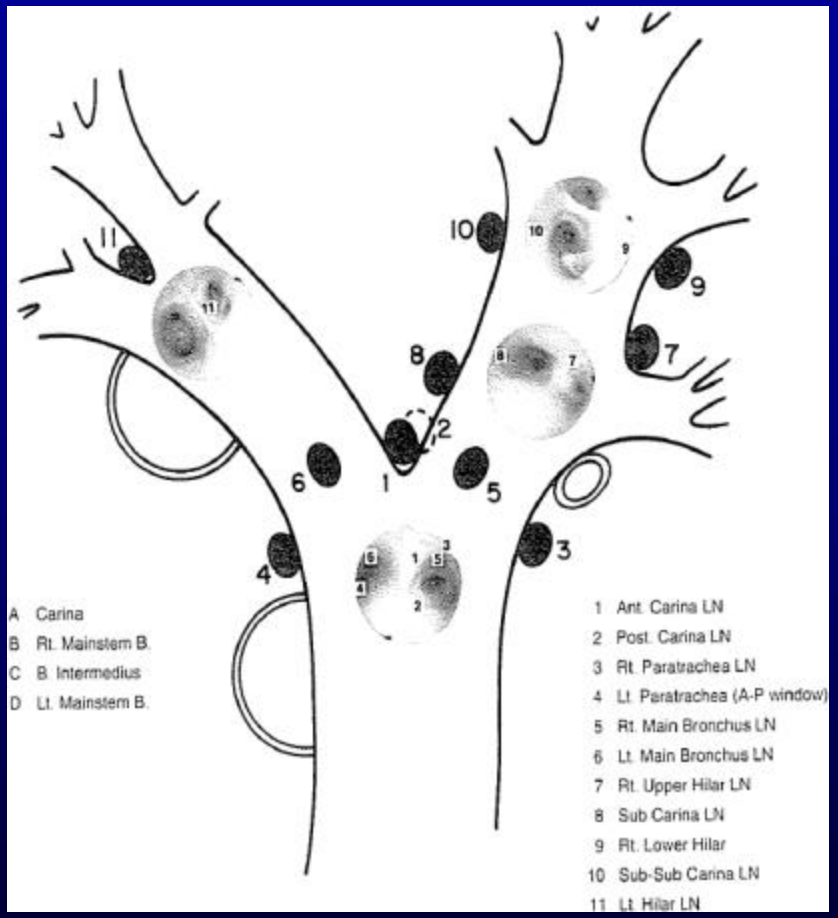
Motivation

- Central chest lymph node sampling
  - Vital for lung cancer staging
- Two systems — Lymph node stations
  1. Mountain: Anatomical
  2. Wang: Bronchoscopy
- This paper's focus: Mountain
  1. Automatic station definition
  2. Interactive lymph node examination / definition

Aids for Lymph-Node Assessment



Mountain System (C. F. Mountain, Chest, 1997; J. P. Ko, AJR, 2000)



Wang System (K. P. Wang, Chest, 1994)

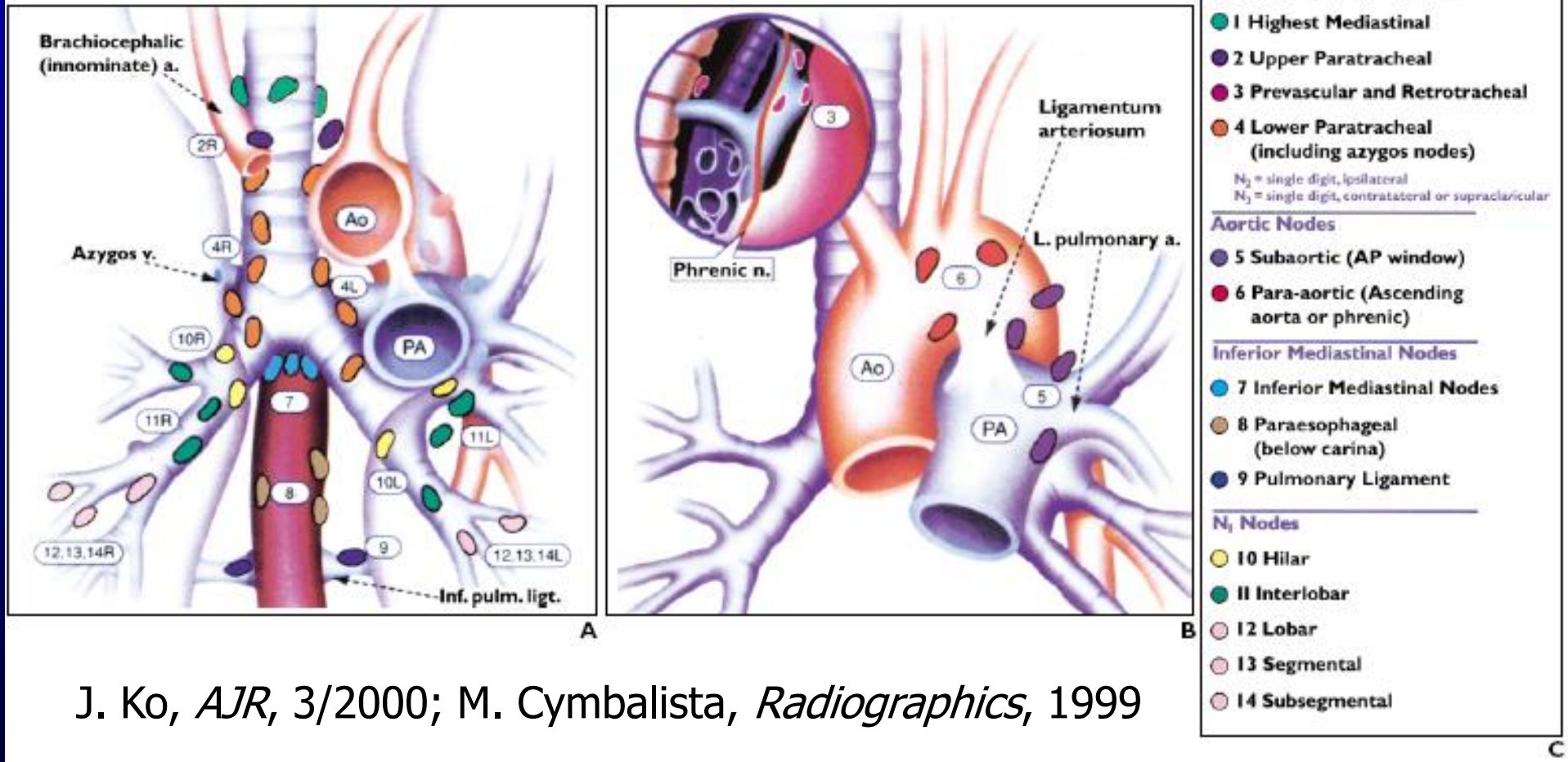
Central Chest Lymph Nodes and Nodal Stations

- Play a vital role in lung cancer staging
- TNM Staging System:

(C. Mountain, *Chest* 6/1997, 2 papers; J. Wynants, *Radiol Clin N Am*, 7/2007)

  - T – primary tumor
  - N – regional lymph-node involvement: Nx, x=0,...3
    - N3 – Mountain 1-9, ipsilateral
    - N2 – Mountain 1-9, contralateral or supraclavicular
    - N1 – Mountain 10-14
  - M – distant metastasis

Mountain System: AJCC Lymph Node Classification

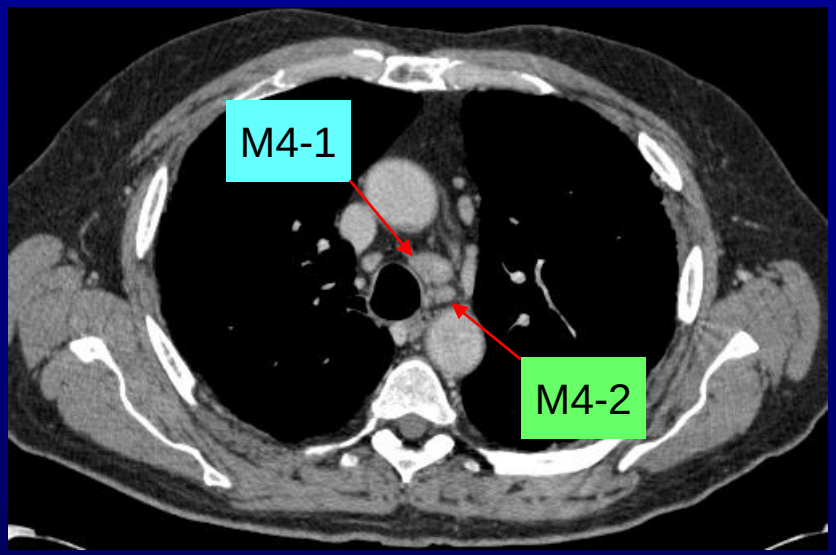


J. Ko, *AJR*, 3/2000; M. Cymbalista, *Radiographics*, 1999

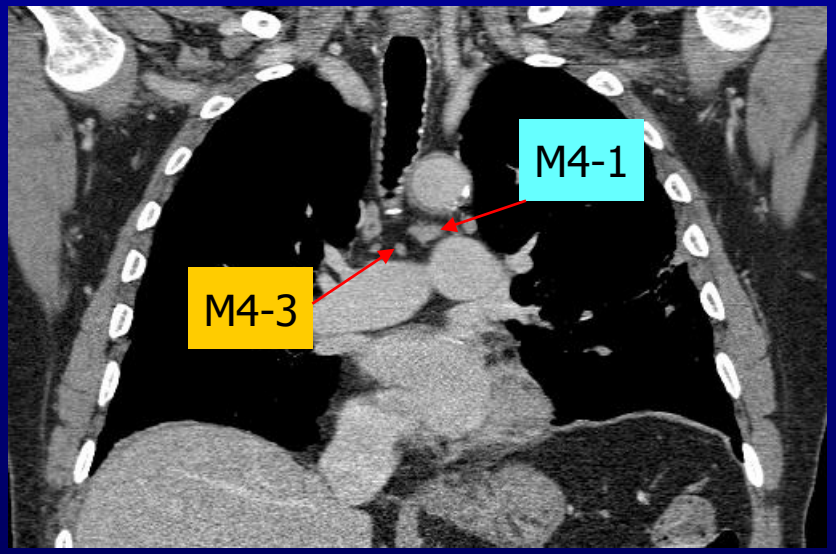
→ Stations 4, 7, 10 – most important (bronchoscopy)

Lymph Nodes (LNs) in 3D Multi-Detector CT (MDCT)

Transverse Section



Coronal Section



Mountain 4 - Lower paratracheal lymph nodes

(case IRB20349.3.3, mediastinal window)

→Lymph nodes vary greatly in size, shape, gray scale; cluster

→ Very tedious to go through an entire MDCT scan!

Previous Work

C. F. Mountain, *Chest*, 6/1997

M. Cymbalista, *Radiographics*, 1999

J. P. Ko, *AJR*, 3/2000 – CT rendition of stations

3D lymph-node definition — Open problem!

O. Chapet, *Int J Rad Oncol Biol Phys*, 1/2005

- CT Atlas of Mountain stations
- Mountain 1-2, 10-11 merged; skip 9, 12-14

J. Yan, *CMIG*, 2004; G. Unal, *IEEE-ICIP*, 2006

- attempts at semi-auto CT LN extraction

A. Kiraly, *SPIE Med Imag 2007*

- automatically label predefined LNs

Our Computer-Based System

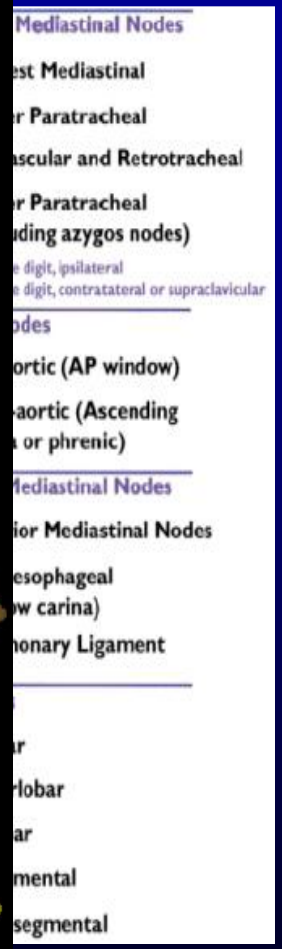
1. Extract and process key chest structures (automatic)
2. Landmark and station definition (automatic)
   i. Extract landmarks from key structures
   ii. Define stations
3. Visualization and interaction
   i. Station visualization and interaction
   ii. Lymph-node segmentation and labeling

Extract and Process Key Chest Structures

(*M. Cymbalista, Radiographics, 1999; J. P. Ko, AJR J, 2000; O. Chapet, Int. J Rad Oncol Biol Phys, 2005*)

Airway t
center

Aorta



Anatomical definition

Pulmonary Artery

Lungs

Vertebra

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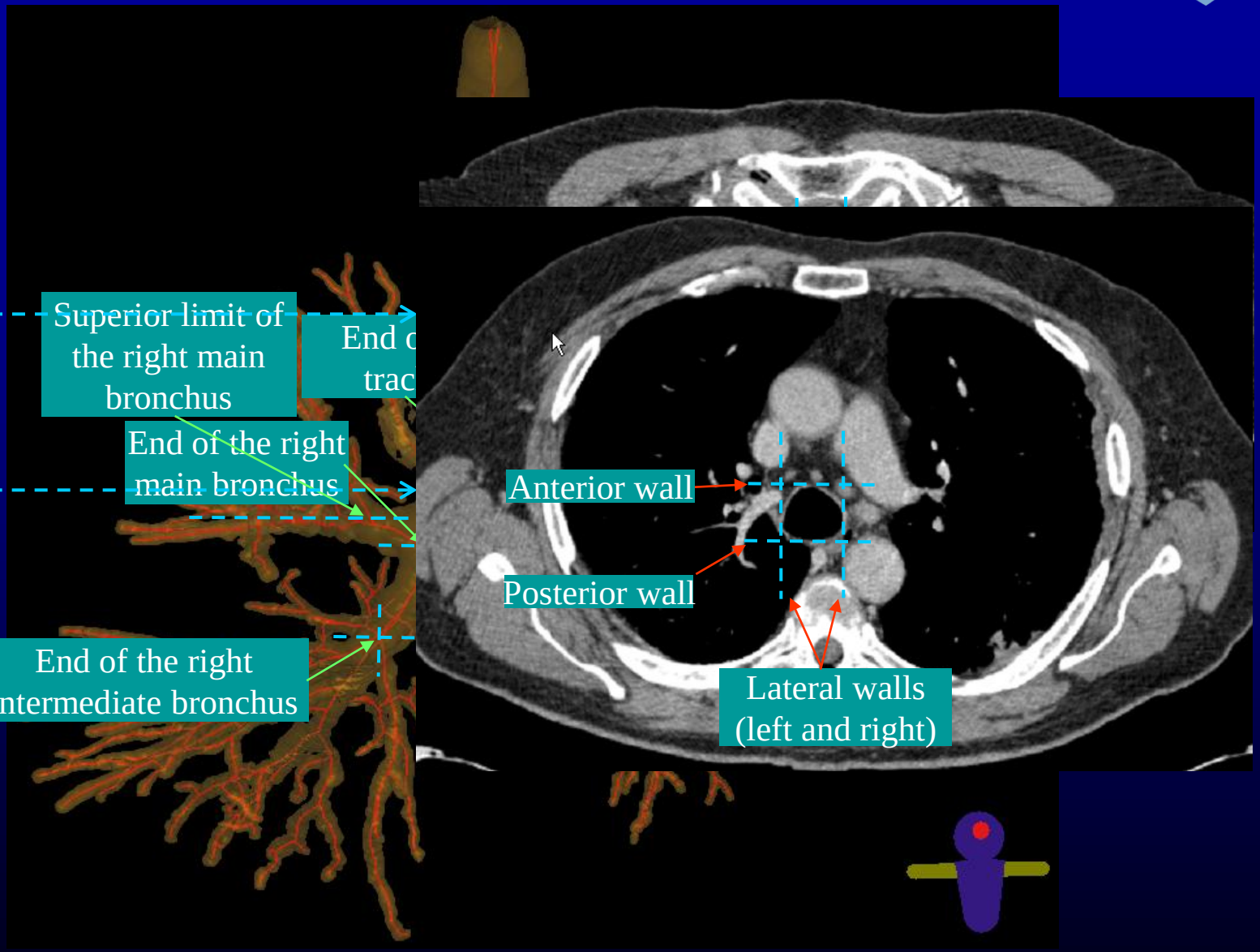
Landmark and Station Definition



Airway Tree

Landmark and Station Definition

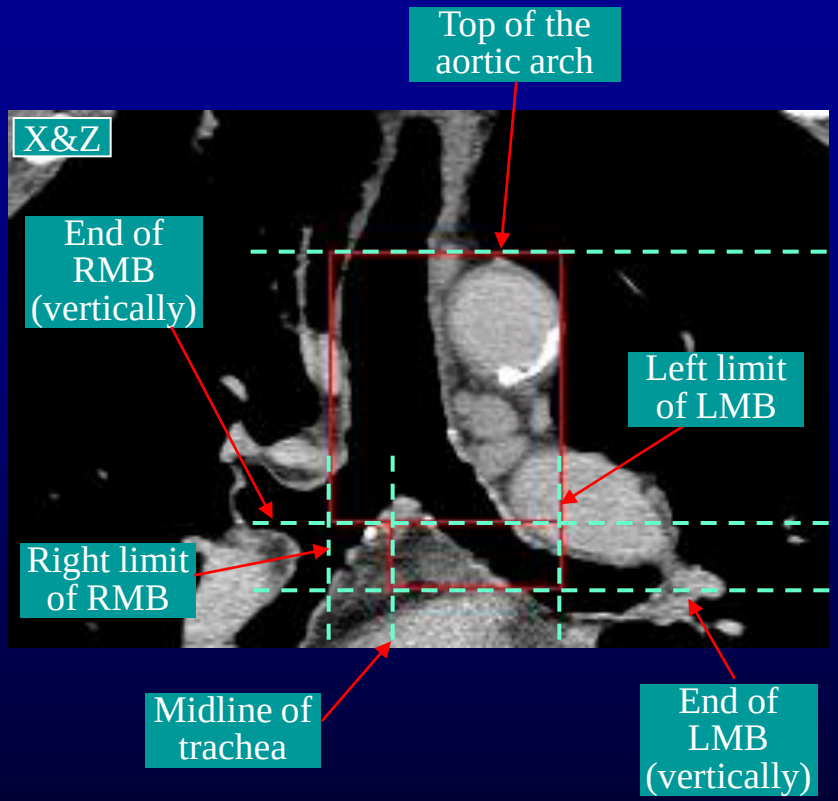
List of nodal stations derived from the Mountain system

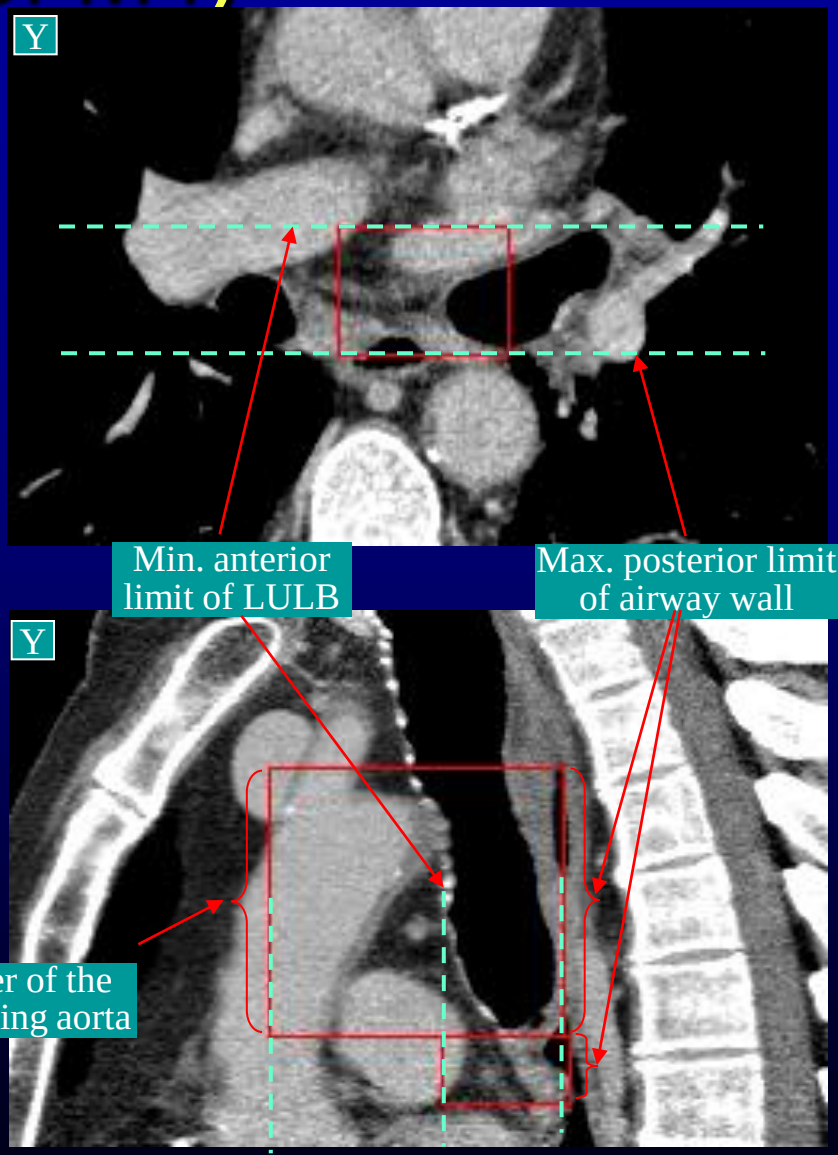
Mountain Stations	Description
M1-2	Highest mediastinal and upper paratracheal
M3	Prevascular and retrotracheal
M4	Lower paratracheal
M5	Subaortic (AP window)
M6	Para-aortic
M7	Inferior mediastinal
M8	Paraesophageal (below carina)
M9	Pulmonary ligament
M10-11	Hilar and interlobar
M12-14	Lobar, segmental, and subsegmental

C. F. Mountain, Chest, 1997;
J. P. Ko, ARJ, 2000;

M. Cymbalista, Radiographics, 1999;
O. Chapet, Int J Rad Oncol Biol Phys, 2005

Landmark and Station Definition (Example of M4)





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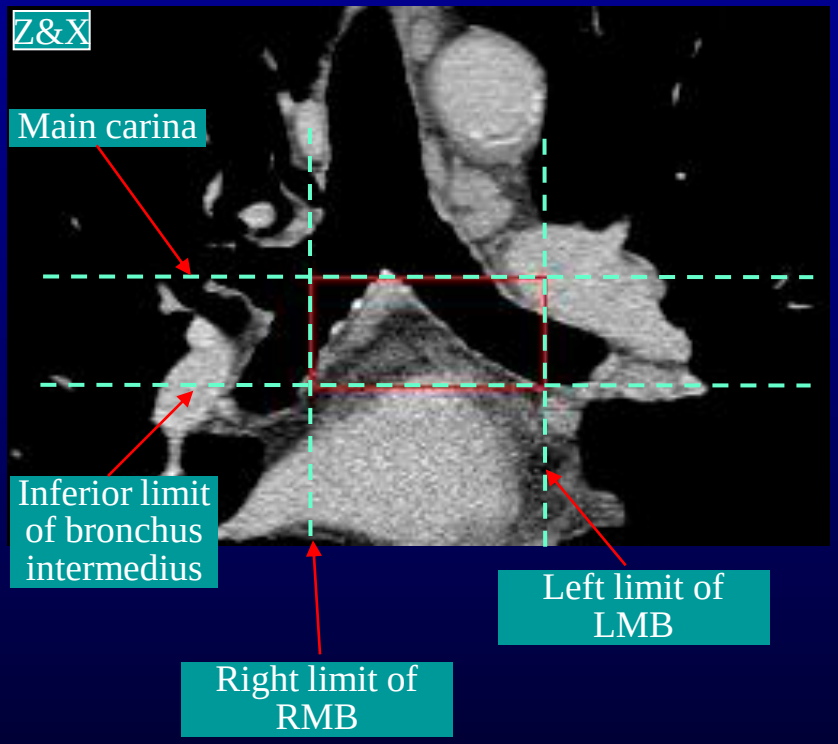
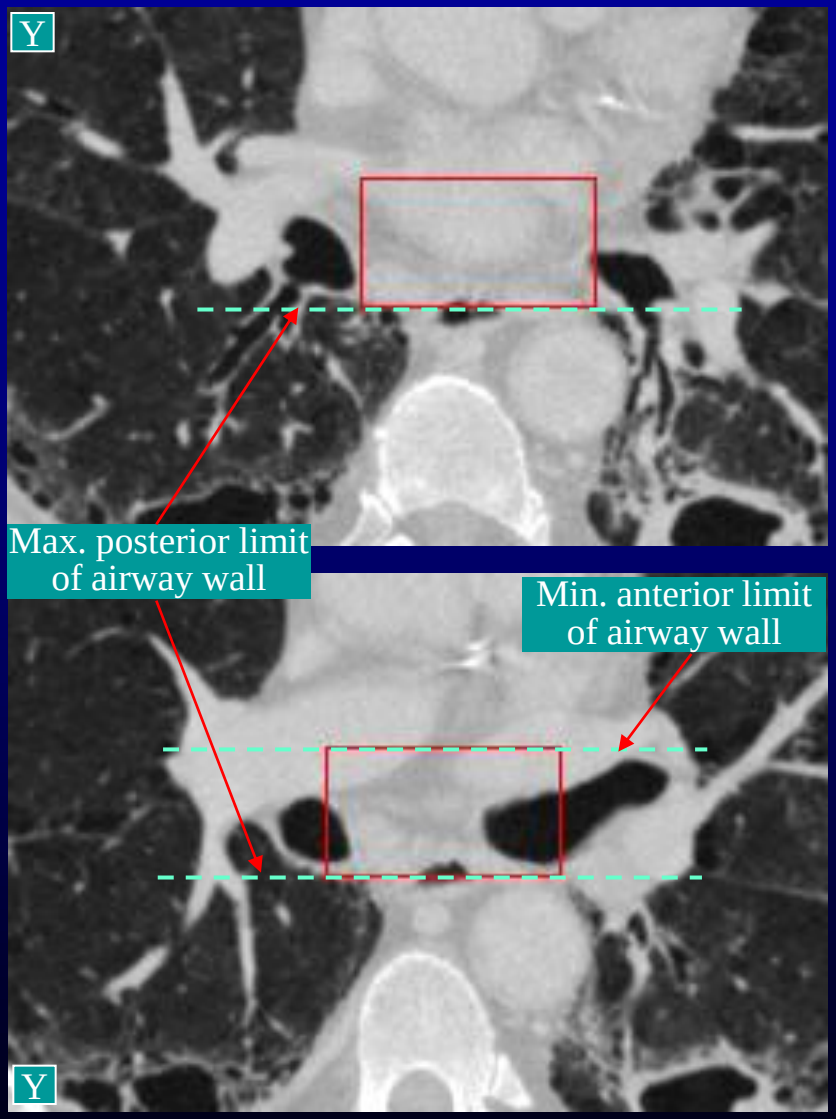
RMB-Right Main Bronchus; LMB-Left Main Bronchus; LULB-Left Upper Lobe Bronchus. Mediastinal window is used.

Landmark and Station Definition (Example of M7)





RMB-Right Main Bronchus; LMB-Left Main Bronchus. Left - Mediastinal Window; Right - Lung Window.

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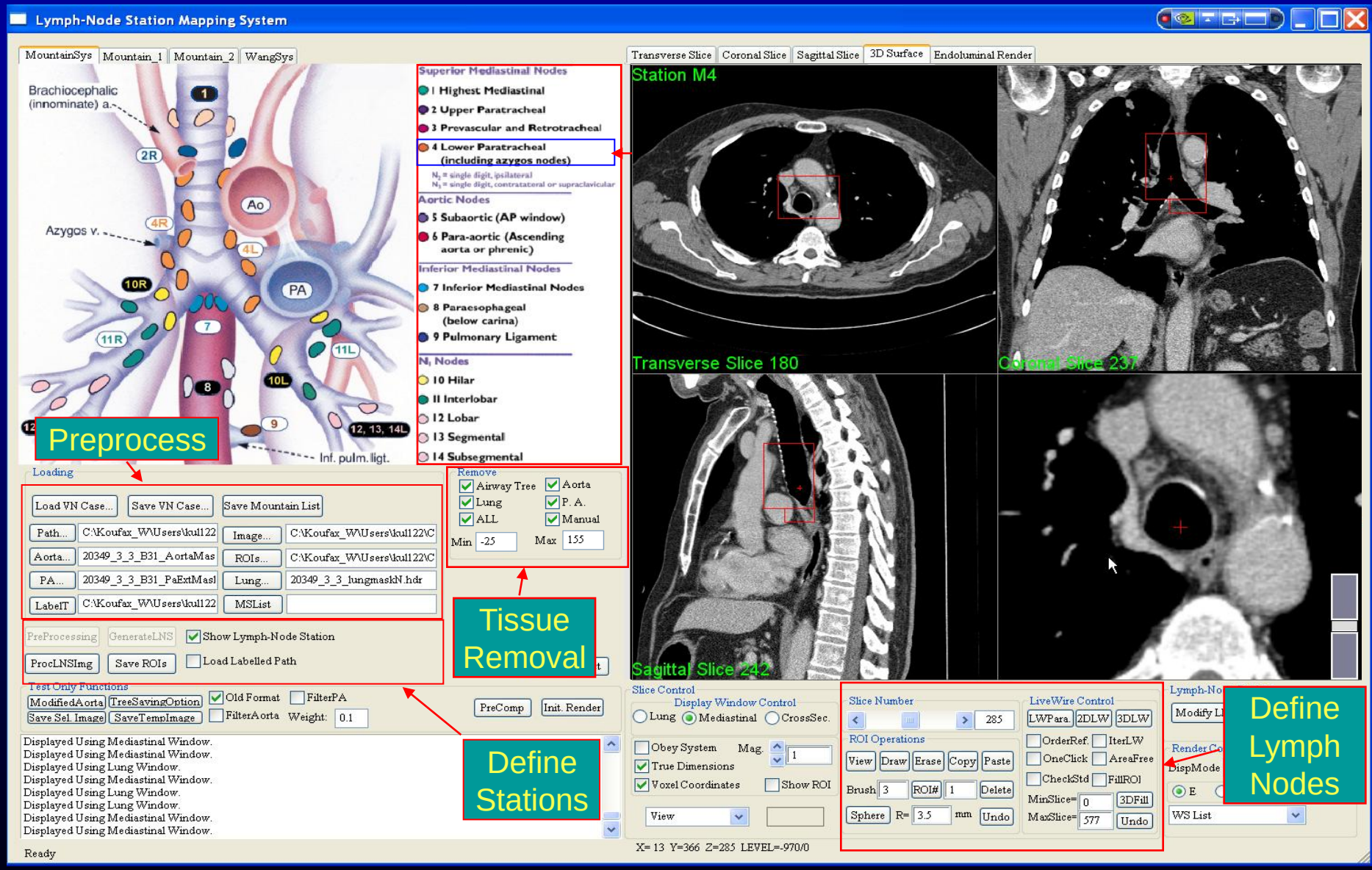
System Snapshots: Visualization and Interaction



Results: 21 MDCT Case Summary

Series	# of Scans	ΔZ (mm)	ΔX, ΔY (mm)		Contrast Agent Applied?	
			0.52-0.65	0.65-0.86	Yes	No
IRB21405	8	0.5	5	3	3	5
IRB20349.3	13	0.5	7	6	6	7

- Total # of nodes: 574
- Ave # of nodes per case: 27
- # of nodes per case
  - Min: 1 Median: 22 Max: 63
- Ave # of nodes by station:
  - M3: 5 M4: 8 M5: 2
  - M7: 2 M10-11: 2 M12-14: <1

Results: 21 MDCT Cases Summary

- Success in getting stations:
  - % of nodes in a station: 96%
  - % of stations without missing nodes: 92.4%
    - M3 90.5%
    - M6 90.5%

- Preprocessing time: 15-20 min
- Time to get stations: <1 sec
- Interaction time to detect nodes: 33 min

Results: M7 - Inferior Mediastinal

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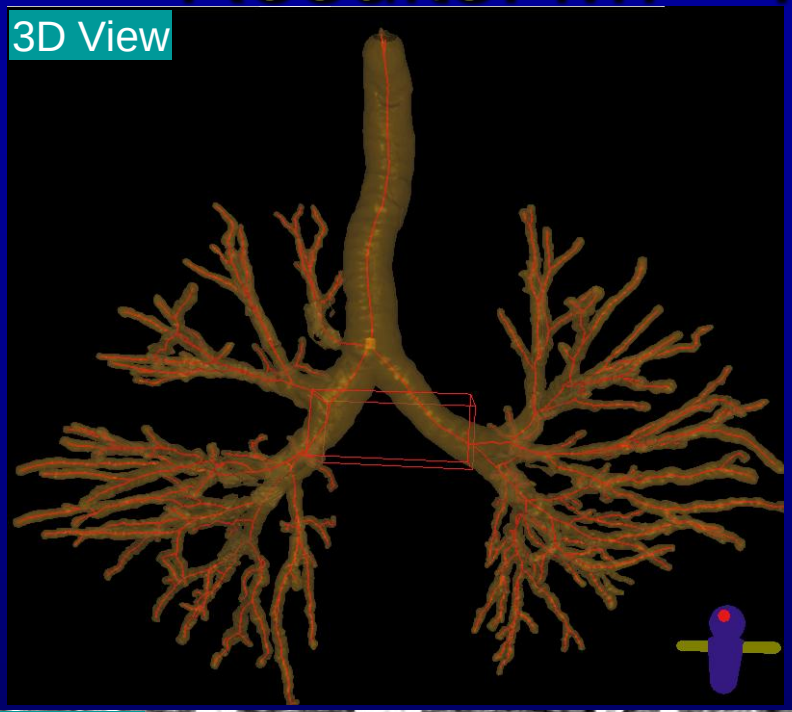
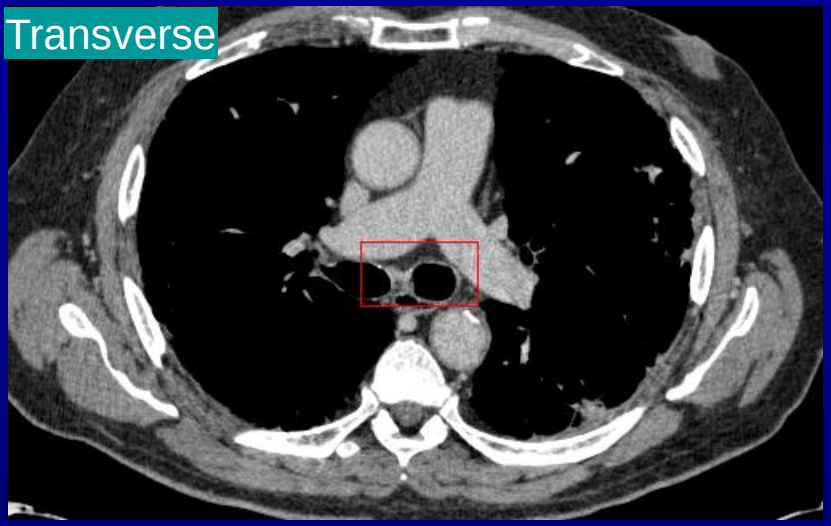
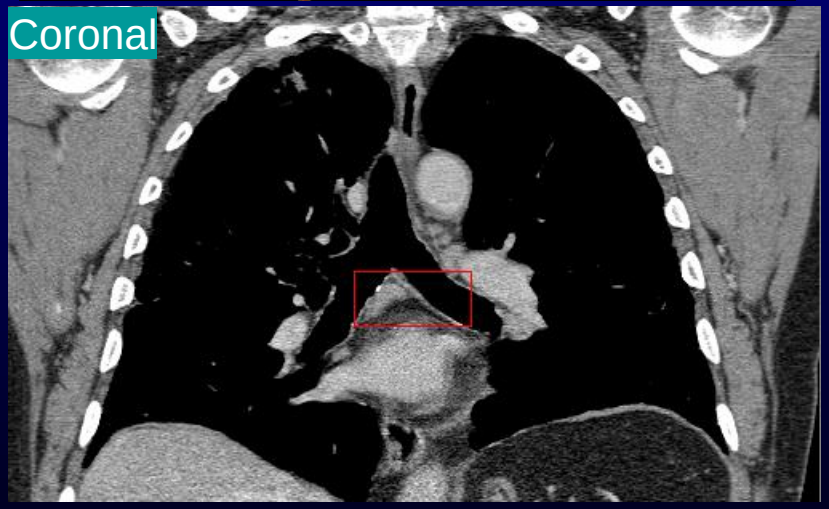
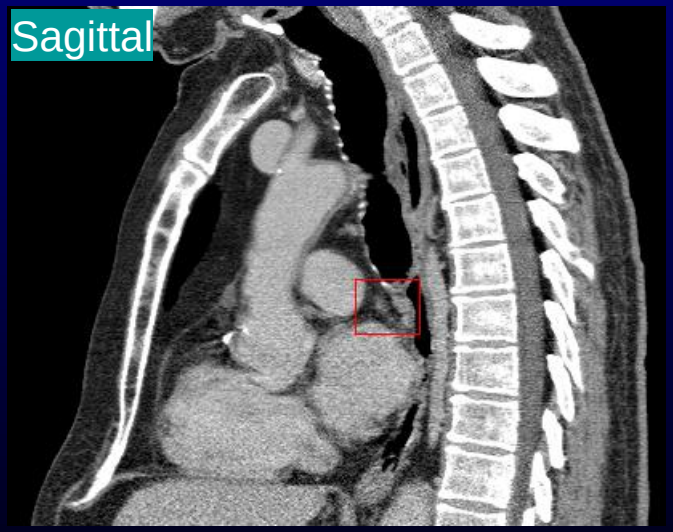
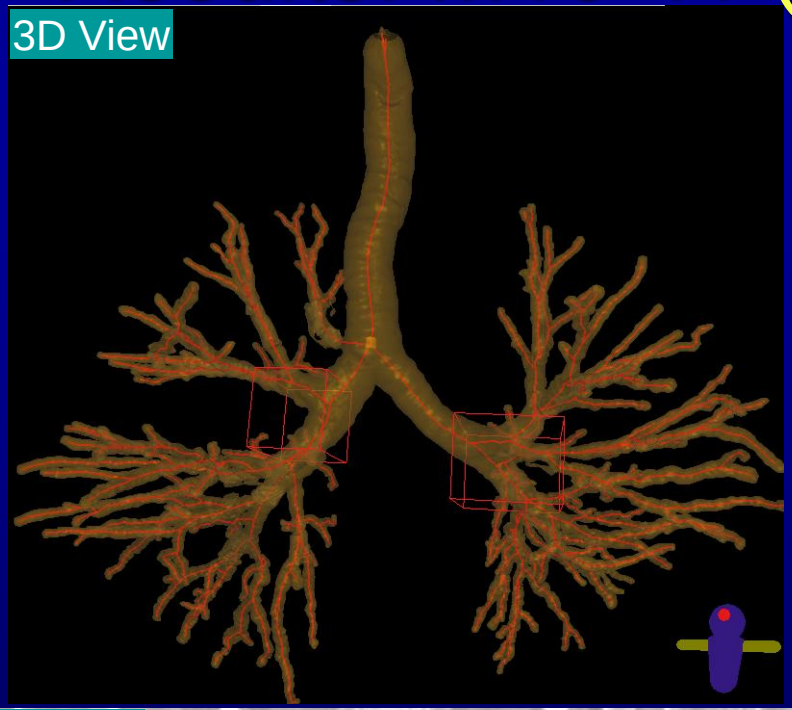


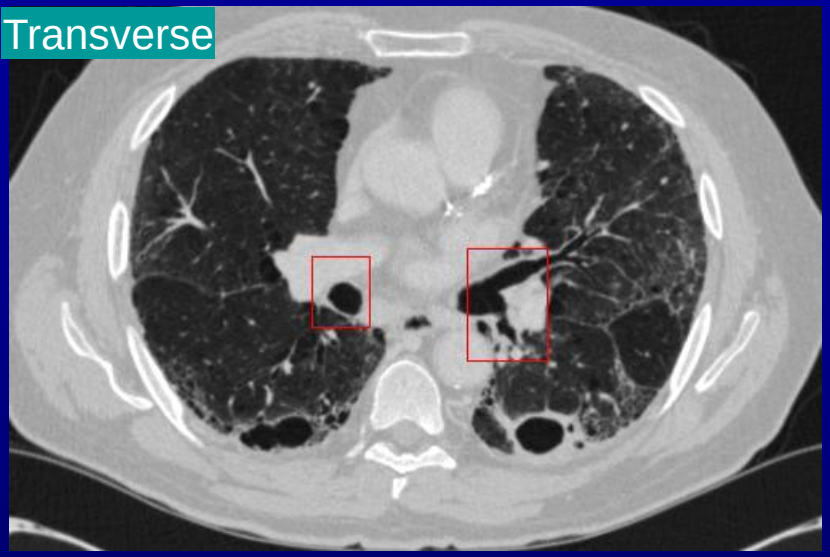


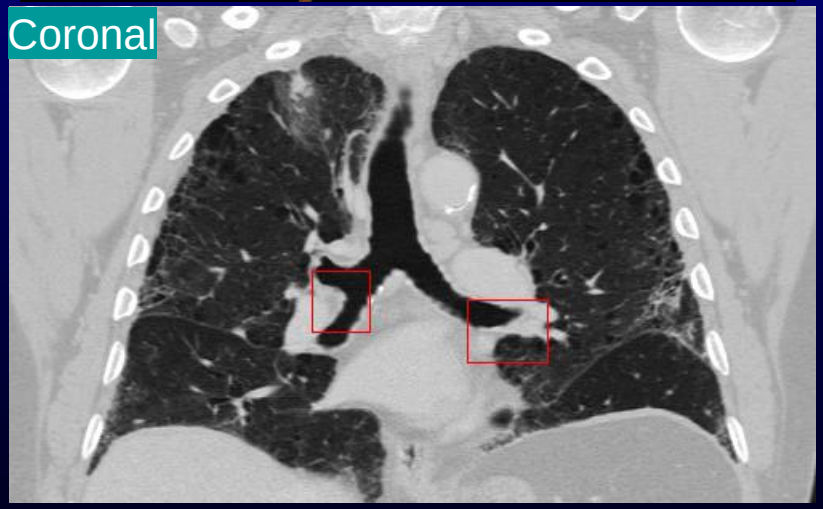


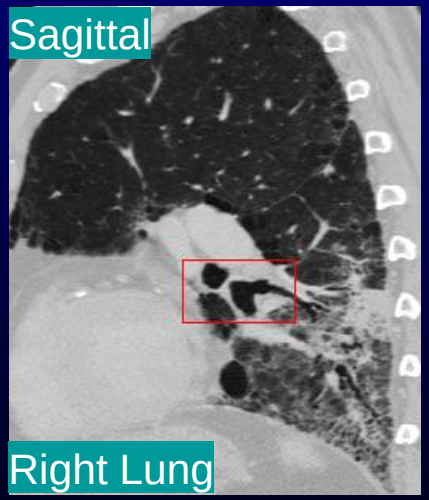


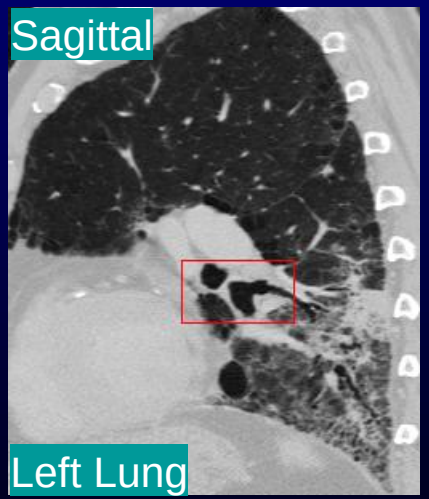
Results: M10-11 (Hilar and Interlobar)











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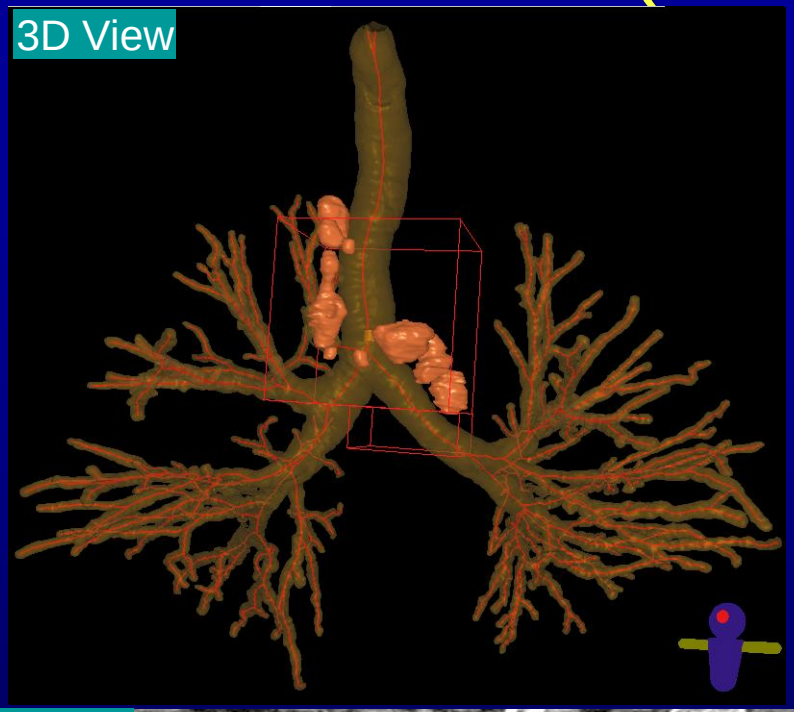
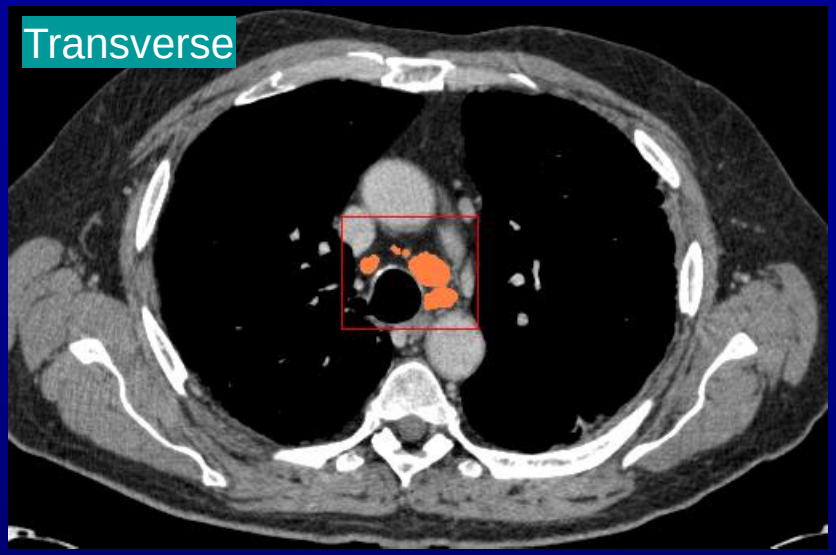
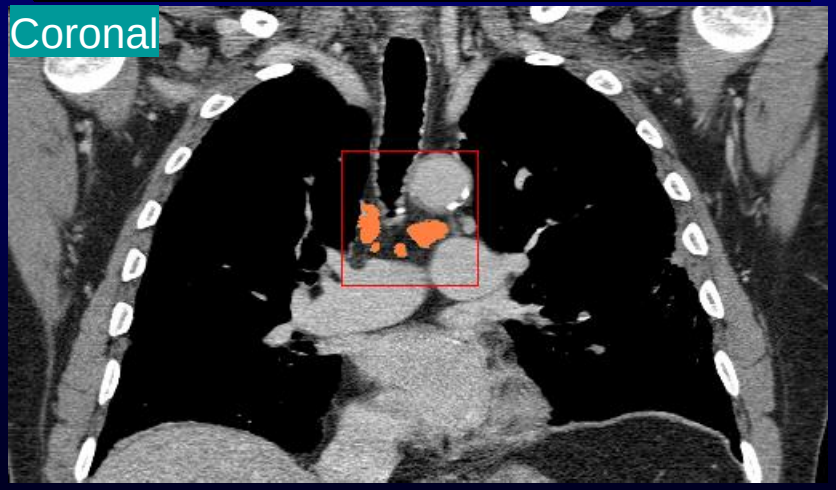
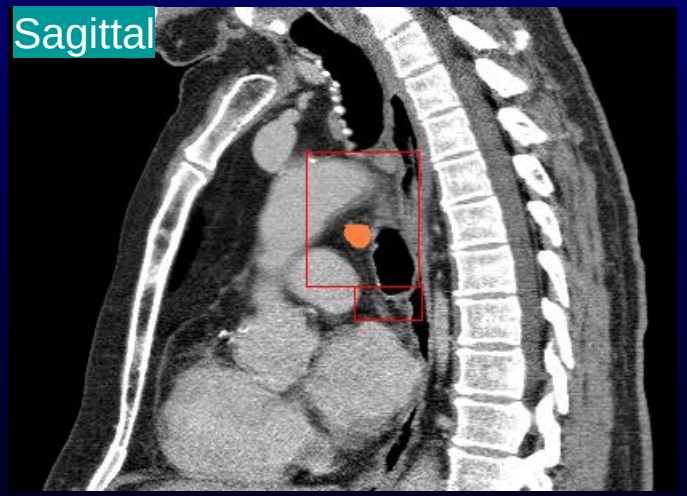
Results: M4 (Lower Paratracheal)

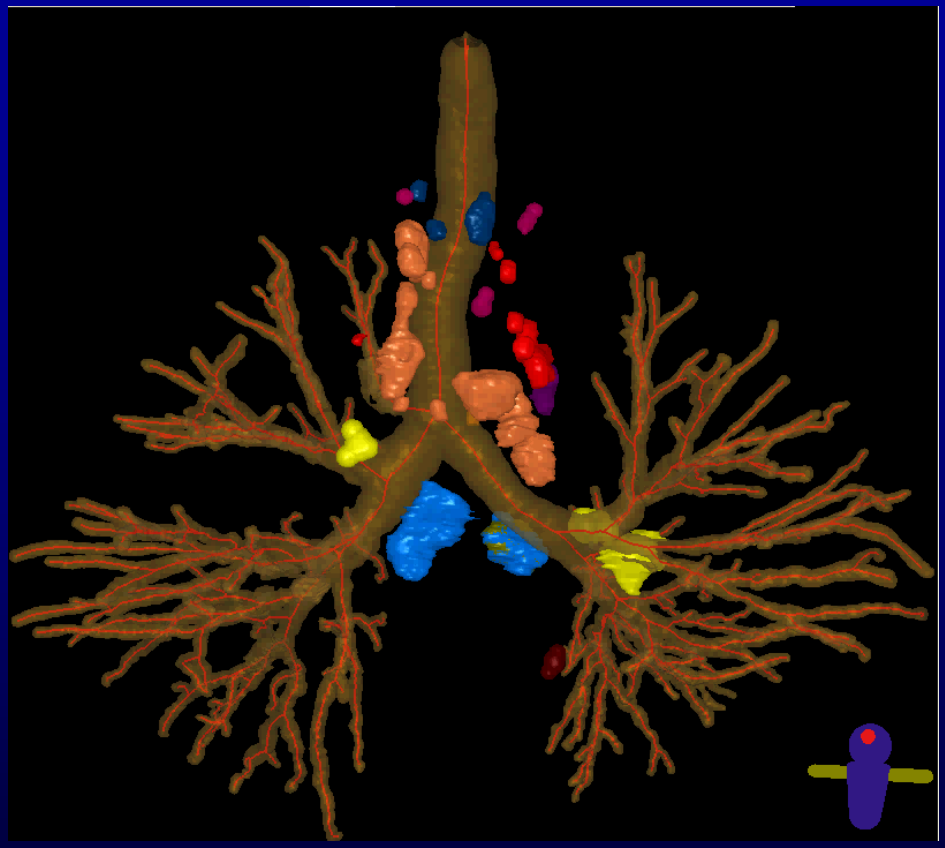






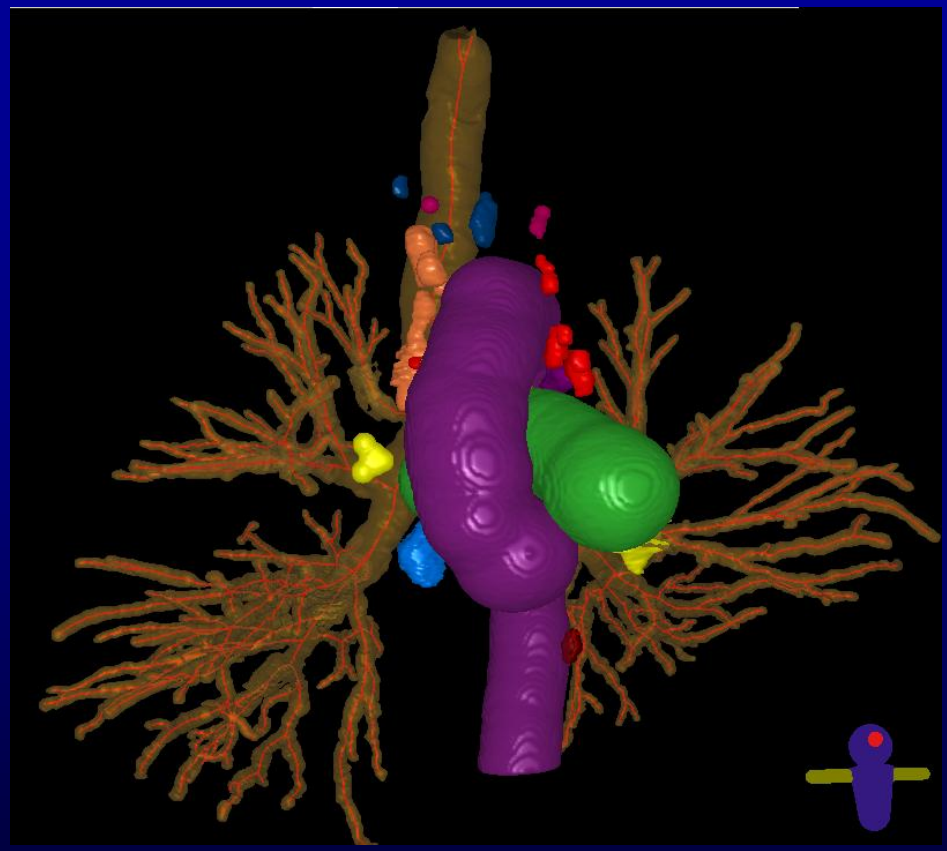


Results: Pulmonary Lymph Nodes



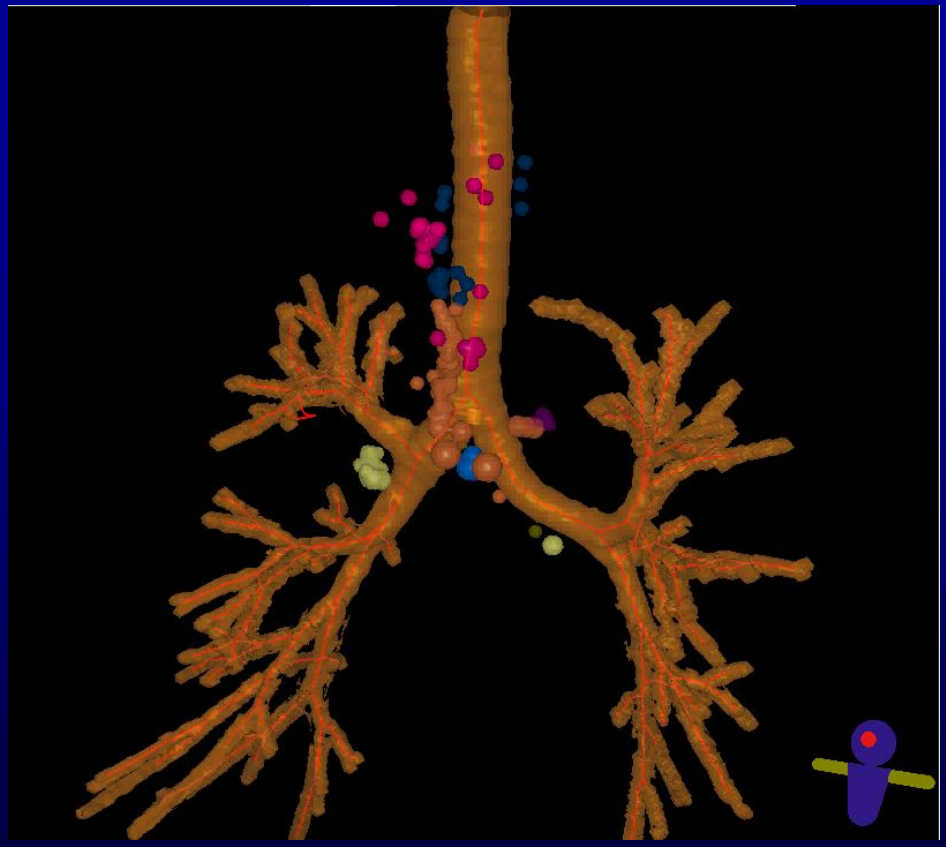
Lymph Nodes and Airway Tree

(30 nodes)



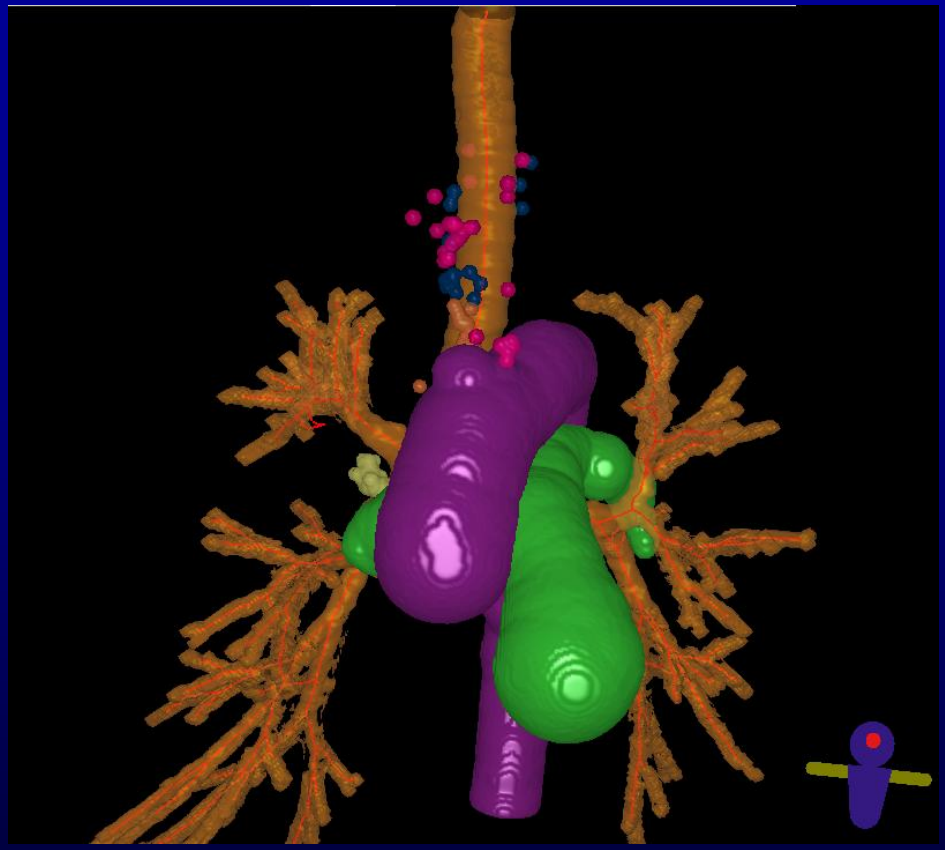
Lymph Nodes, Aorta,
Pulmonary Artery, Airway Tree

Results: Pulmonary Lymph Nodes



Lymph Nodes and Airway Tree

(39 nodes)



Lymph Nodes, Aorta,
Pulmonary Artery, Airway Tree

IRB21405.17

Conclusions

- Systematic definition of Mountain Stations
  - Fast automated analysis
  - Custom visualization and interaction
- Segmentation of lymph nodes
  - Live-wire-based interactive segmentation
- Further quantitative studies in progress

Acknowledgments

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Thanks!