

Extraction and Visualization of the Central Chest Lymph Node Stations

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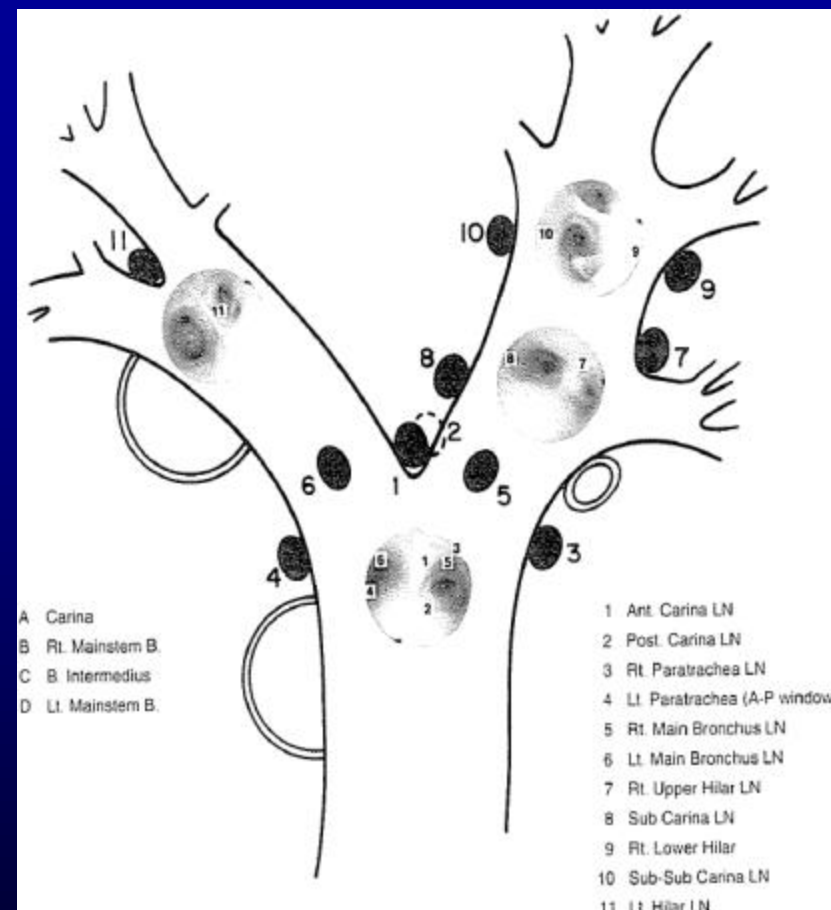
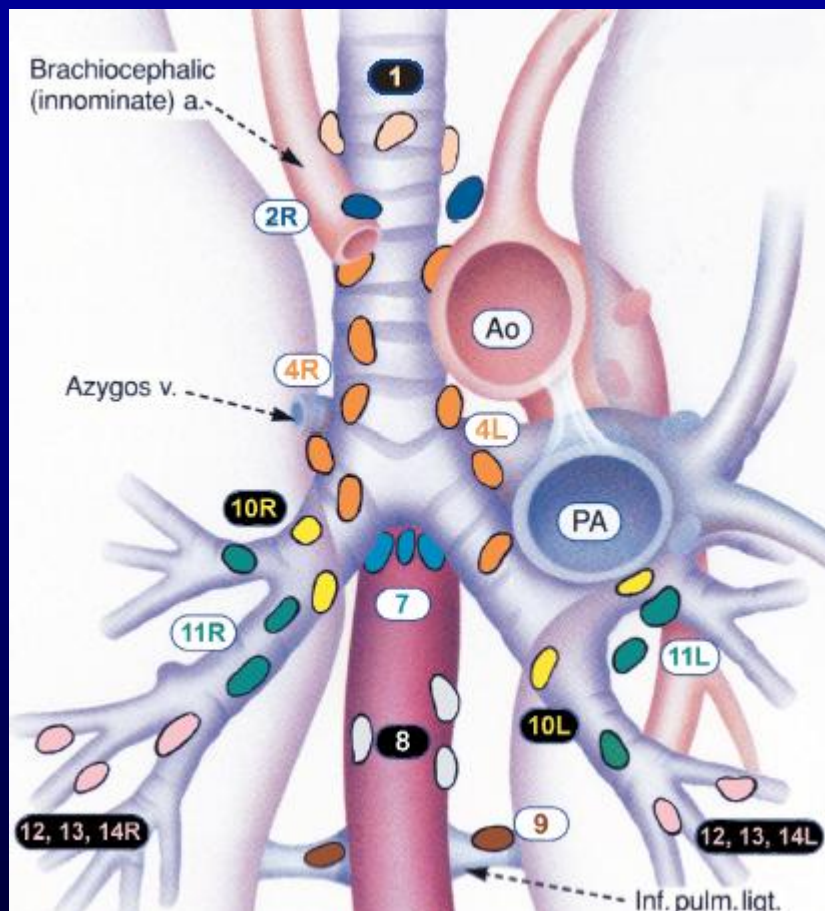


SPIE Medical Imaging 2008: Computer-Aided Diagnosis, San Diego, CA, 21 Feb. 2008

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

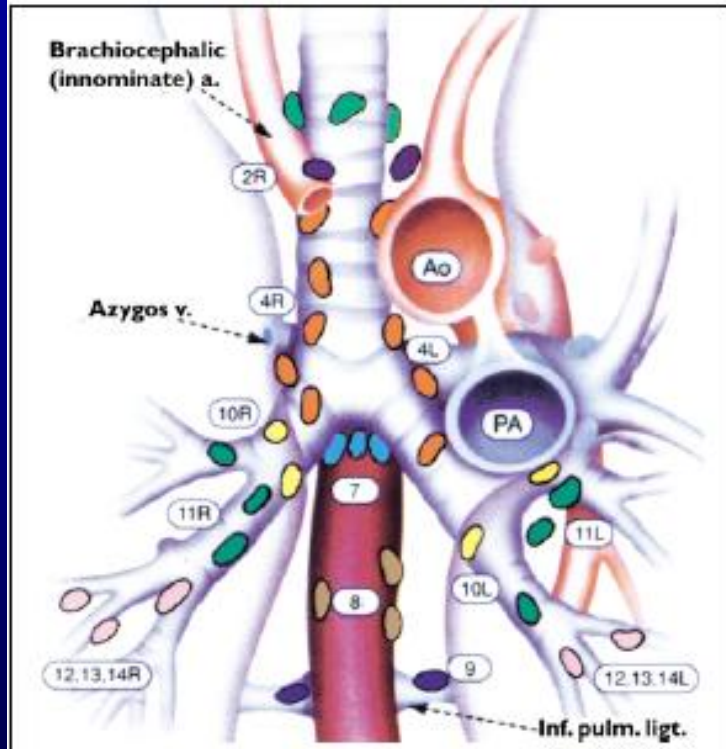
- Play a vital role in lung cancer staging
- TNM Staging System:

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

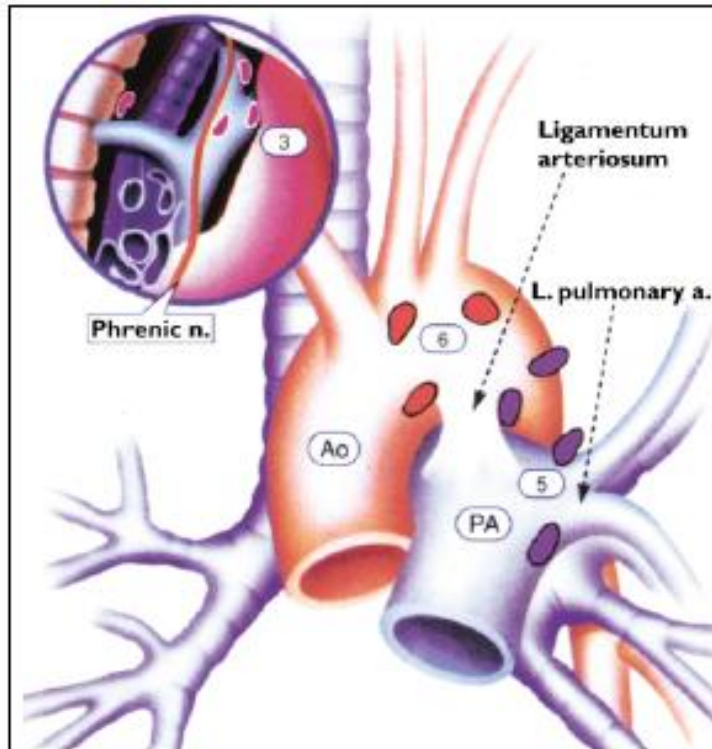
- T – primary tumor
- N – regional lymph-node involvement: Nx, x=0,...3
 - ❖ N3 – Mountain 1-9, ipsilateral
 - ❖ N2 – Mountain 1-9, contralateral or supraclavicular
 - ❖ N1 – Mountain 10-14
- M – distant metastasis



Mountain System: AJCC Lymph Node Classification



A



B

Superior Mediastinal Nodes	
● 1	Highest Mediastinal
● 2	Upper Paratracheal
● 3	Prevascular and Retrotracheal
● 4	Lower Paratracheal (including azygos nodes)
<small>N₂ = single digit, ipsilateral N₂ = single digit, contralateral or supraclavicular</small>	
Aortic Nodes	
● 5	Subaortic (AP window)
● 6	Para-aortic (Ascending aorta or phrenic)
Inferior Mediastinal Nodes	
● 7	Inferior Mediastinal Nodes
● 8	Paraesophageal (below carina)
● 9	Pulmonary Ligament
N ₁ Nodes	
● 10	Hilar
● 11	Interlobar
● 12	Lobar
● 13	Segmental
● 14	Subsegmental

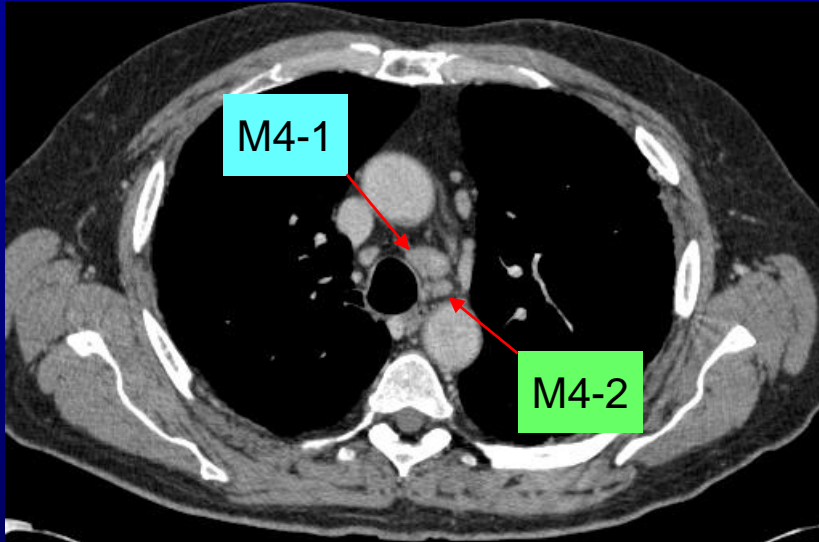
C

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

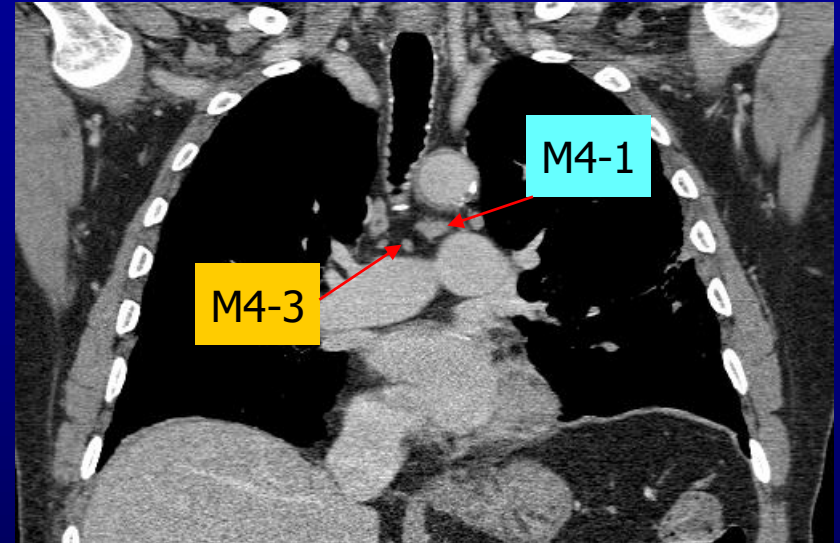
→ Stations 4, 7, 10 – most important (bronchoscopy)

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!

U. 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

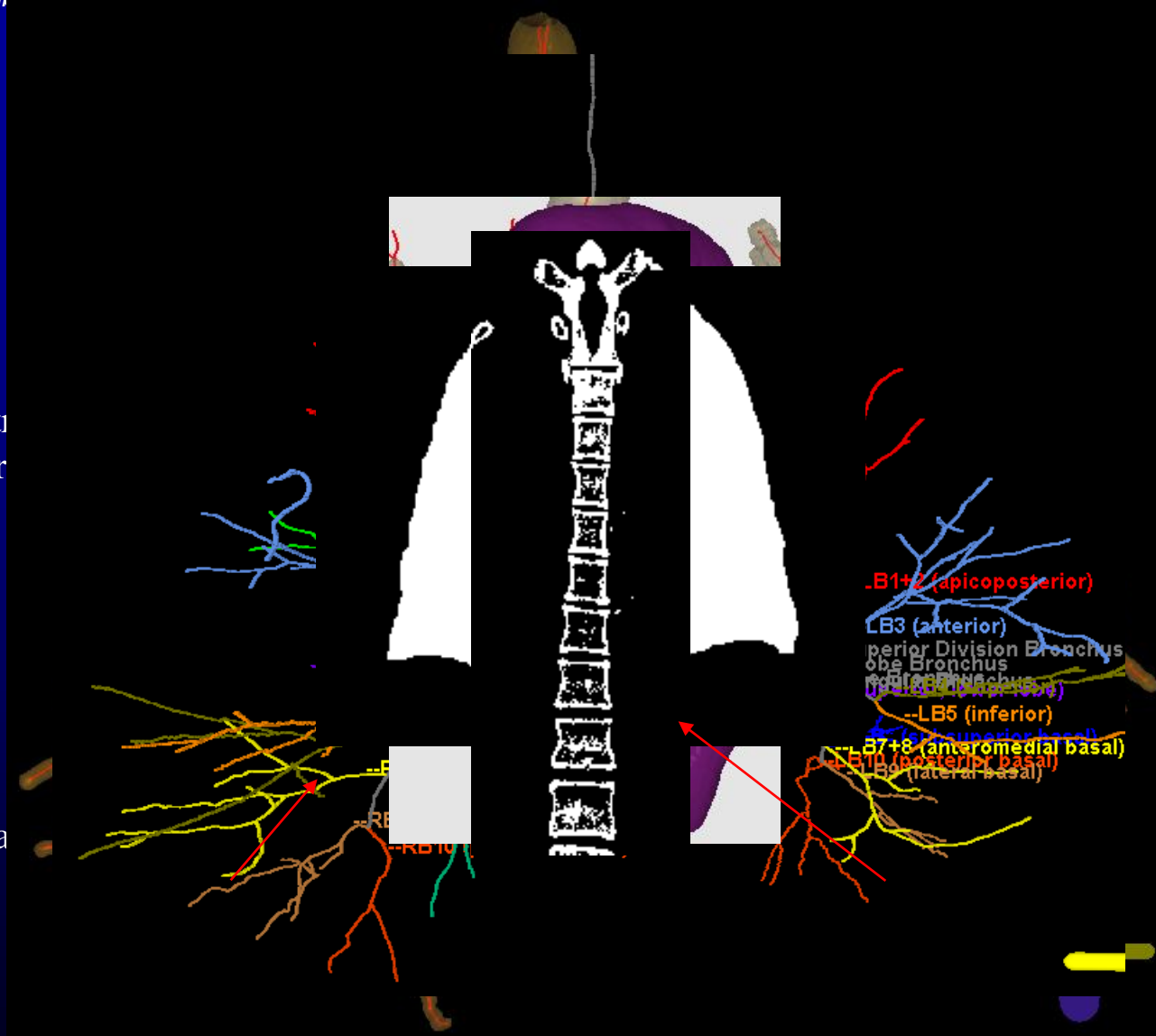
1. Extract and process key chest structures (automatic)
2. Landmark and station definition (automatic)
 - i. Extract landmarks from key structures
 - ii. Define stations
3. Visualization and interaction
 - i. Station visualization and interaction
 - ii. Lymph-node segmentation and labeling

Extract and Process Key Chest Structures

(M. Cymhalista, Radiographics, 1999; L.P. Ko, ARL 2000; O. Chanet, Int J Rad Oncol Biol Phys, 2005)

Airway to
center

Aorta



Mediastinal Nodes
Anterior Mediastinal
Pretracheal
Paratracheal
Subcarinal
Esophageal
Aortic (AP window)
Aortic (Ascending)
Subcarinal or phrenic
Mediastinal Nodes
Anterior Mediastinal Nodes
Esophageal
Subcarinal
Bronchovascular Ligament
Subcarinal
Hilar
Subcarinal
Segmental
Anatomical definition

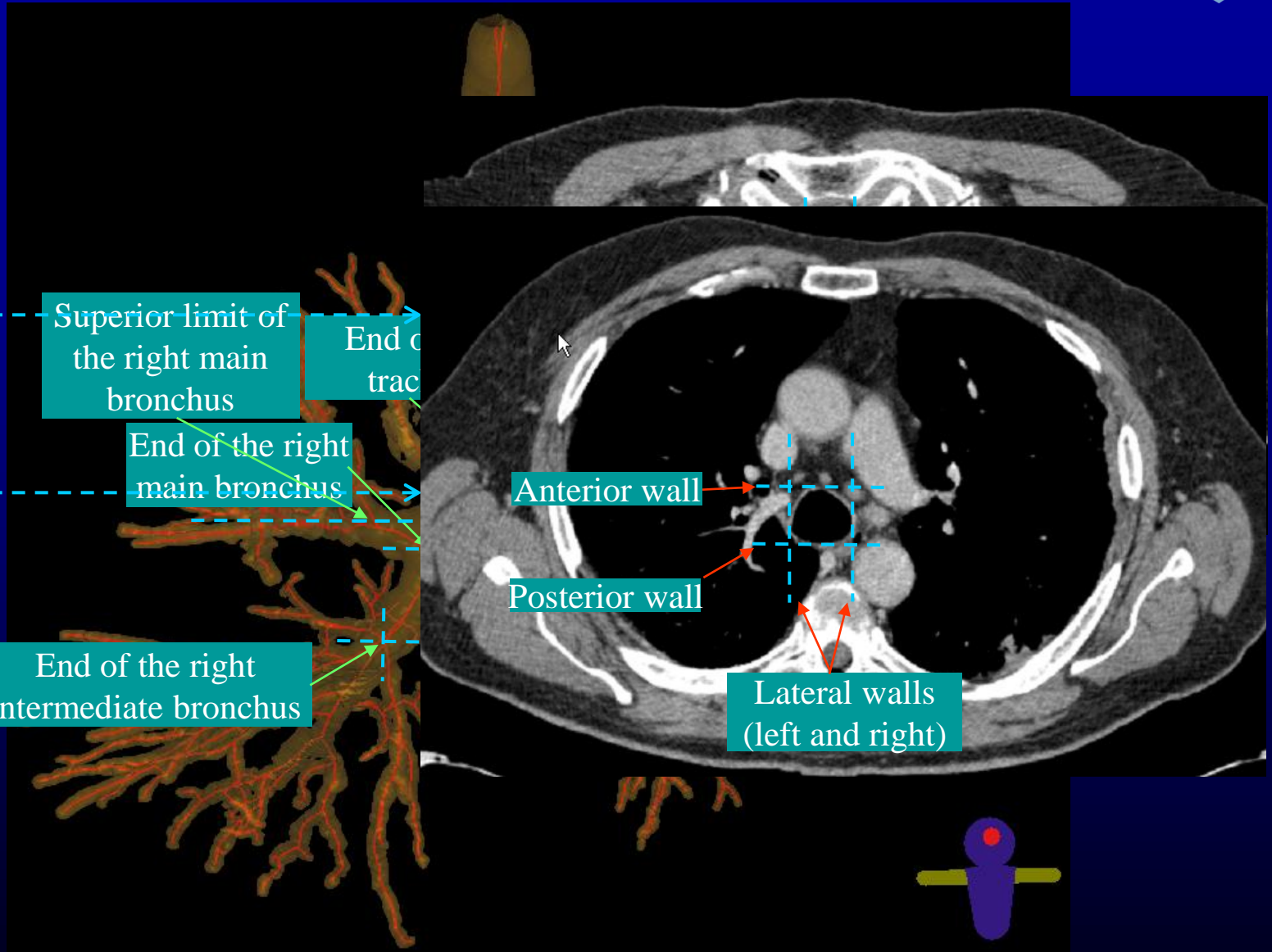
Pulmonary Artery

Lungs

Vertebra

IRB20349.3.3

Landmark and Station Definition



Airway Tree

Landmark and Station Definition

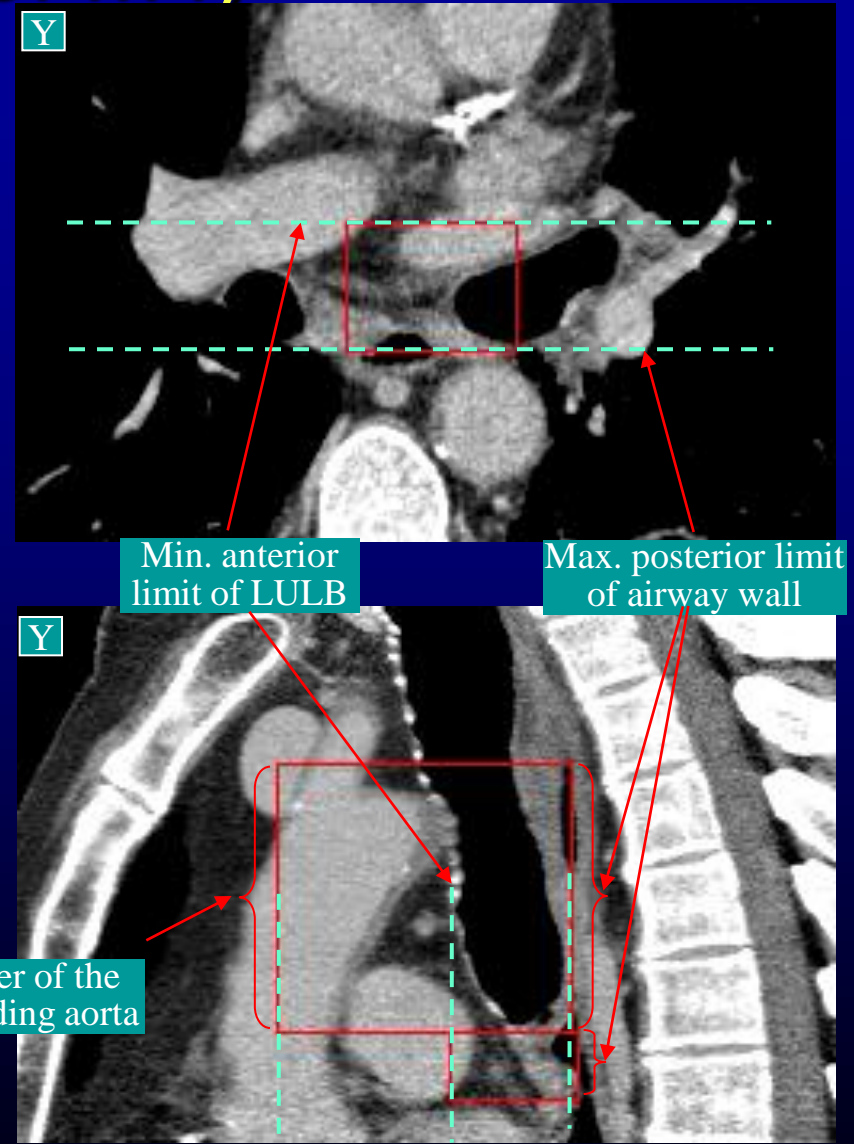
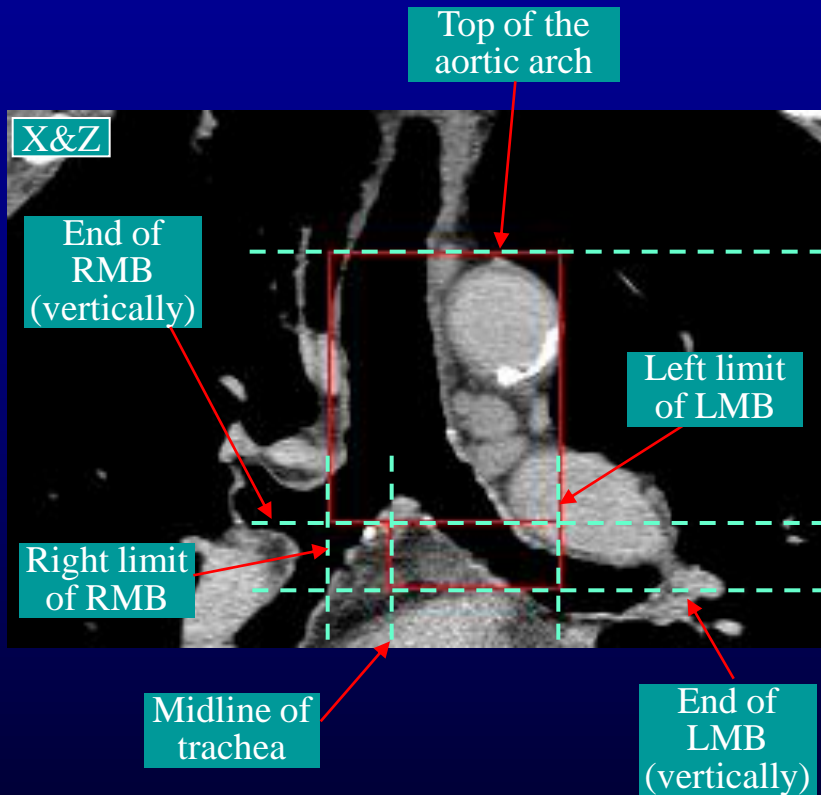
List of nodal stations derived from the Mountain system

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

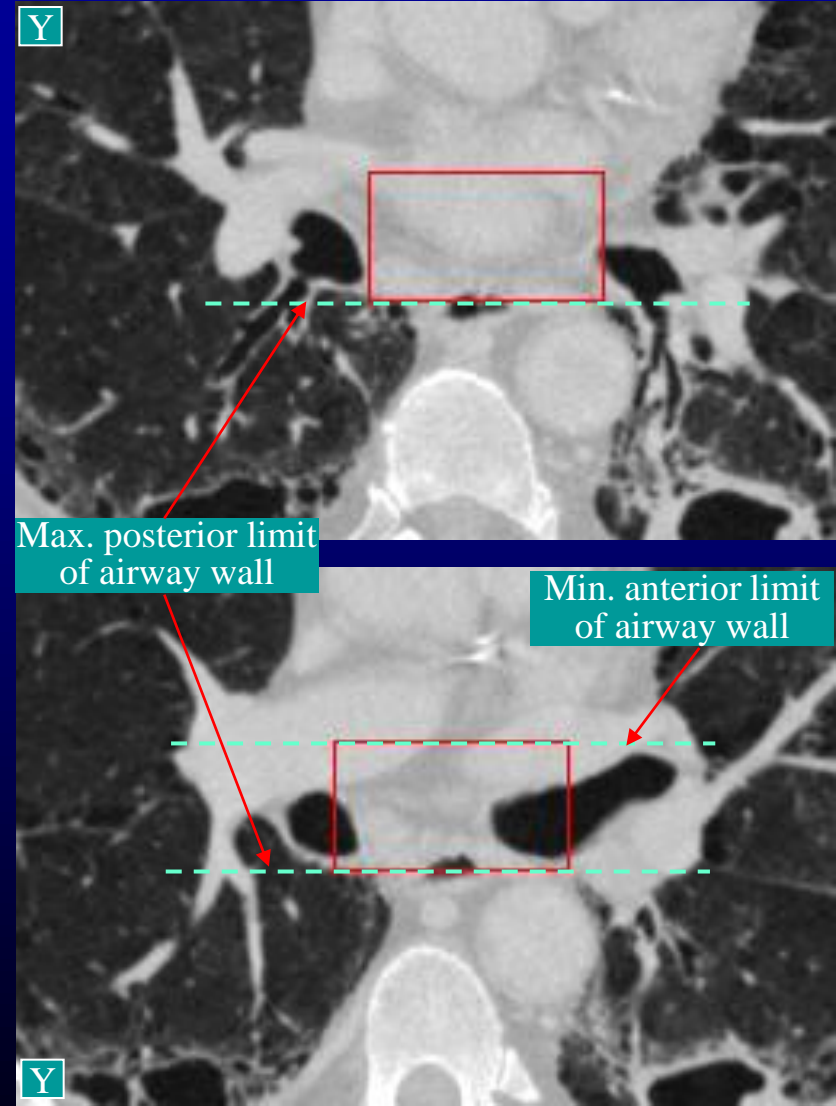
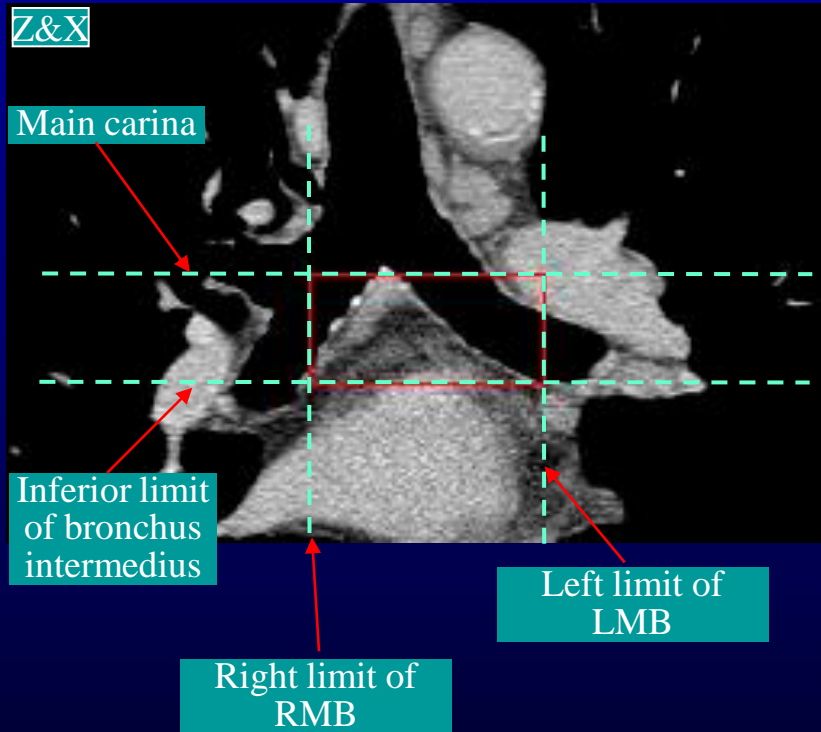
C. F. Mountain, Chest, 1997;
J. P. Ko, ARJ, 2000;

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

Landmark and Station Definition (Example of M4)



Landmark and Station Definition (Example of M7)



System Snapshot: Visualization and Interaction

Lymph-Node Station Mapping System

MountainSys Mountain_1 Mountain_2 WangSys

Brachiocephalic (innominate) a. 1 2R 4R 10R 11R 11L 12 12, 13, 14L

Ao PA

Azygos v.

Inf. pulm. lig.

Preprocess

Superior Mediastinal Nodes
 1 Highest Mediastinal
 2 Upper Paratracheal
 3 Prevascular and Retrotracheal
 4 Lower Paratracheal (including azygos nodes)
N₁ = single digit, ipsilateral
 N₂ = single digit, contralateral or supraclavicular
Aortic Nodes
 5 Subaortic (AP window)
 6 Para-aortic (Ascending aorta or phrenic)
Inferior Mediastinal Nodes
 7 Inferior Mediastinal Nodes
 8 Paraesophageal (below carina)
 9 Pulmonary Ligament
N₁₀ Nodes
 10 Hilar
 11 Interlobar
 12 Lobar
 13 Segmental
 14 Subsegmental

Remove
 Airway Tree Aorta
 Lung P. A.
 ALL Manual
 Min -25 Max 155

Tissue Removal

Load VN Case... Save VN Case... Save Mountain List
 Path... C:\Koufax_WAUsers\skull22 Image... C:\Koufax_WAUsers\skull22\C
 Aorta... 20349_3_3_B31_AortaMas ROIs... C:\Koufax_WAUsers\skull22\C
 PA... 20349_3_3_B31_PaExtMasL Lung... 20349_3_3_lungmaskN.hdr
 LabelIT C:\Koufax_WAUsers\skull22 MSList

PreProcessing GenerateLNS Show Lymph-Node Station
 ProcLNSimg Save ROIs Load Labelled Path

Define Stations
 Test Only Functions
 ModifiedAorta TreeSavingOption Old Format FilterPA
 Save Sel. Image Save Template FilterAorta Weight: 0.1
 PreComp Init. Render

Transverse Slice Coronal Slice Sagittal Slice 3D Surface Endoluminal Render
Station M4
Transverse Slice 180
Coronal Slice 237
Sagittal Slice 242

Slice Control Display Window Control
 Lung Mediastinal CrossSec.
 Obey System Mag. 1
 True Dimensions Show ROI
 Voxel Coordinates
 View

Slice Number < 285 >
 LiveWire Control
 LWP para. 2DLW 3DLW
 OrderRef IterLW
 OneClick AreaFree
 CheckStd FillROI
 ROI Operations View Draw Erase Copy Paste
 Brush 3 ROI# 1 Delete
 Sphere R= 3.5 mm Undo
 MinSlice= 0 3DFill
 MaxSlice= 577 Undo

Lymph-Node Station
 Modify L...
 Render Co...
 DispMode
 E
 WS List

Define Lymph Nodes

Ready

X= 13 Y=366 Z=285 LEVEL=-970/0

Results: 21 MDCT Case Summary

Series	# of Scans	ΔZ (mm)	$\Delta X, \Delta Y$ (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

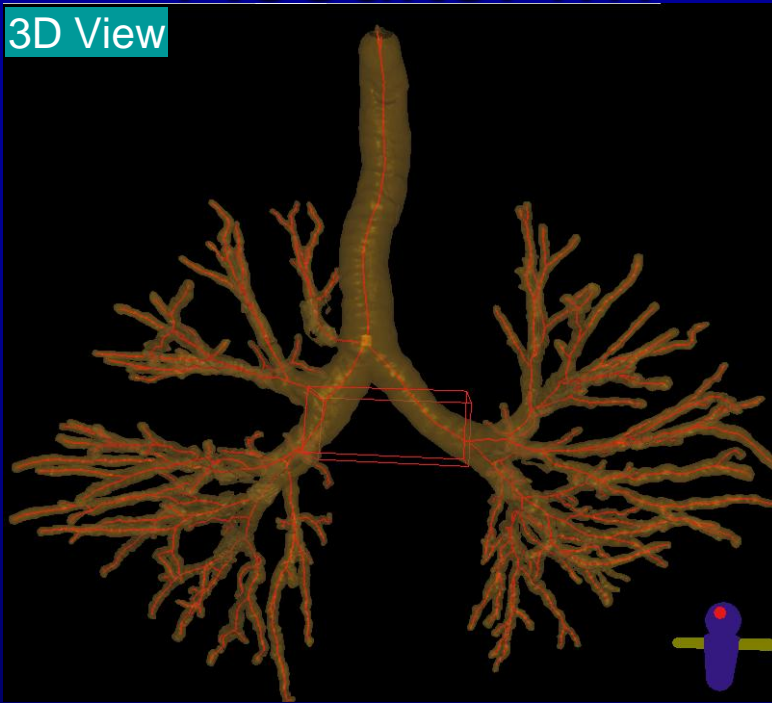
Results: 21 MDCT Cases Summary

- 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

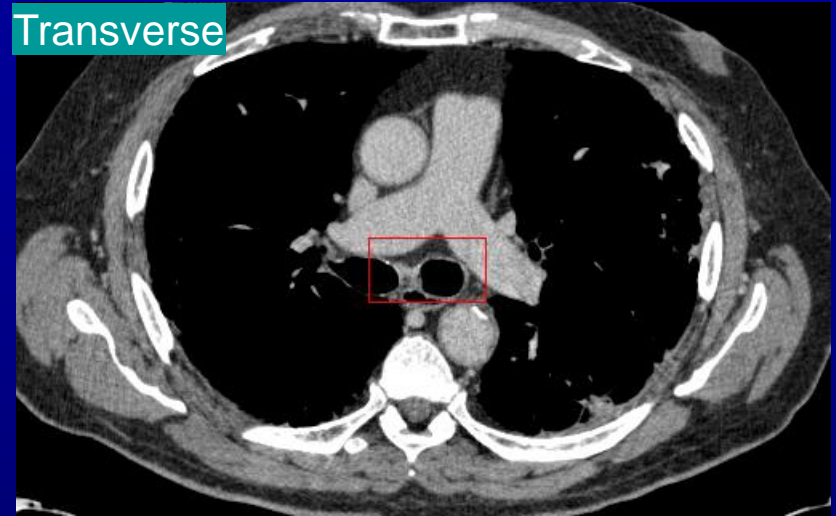
Results: M7 - Inferior Mediastinal



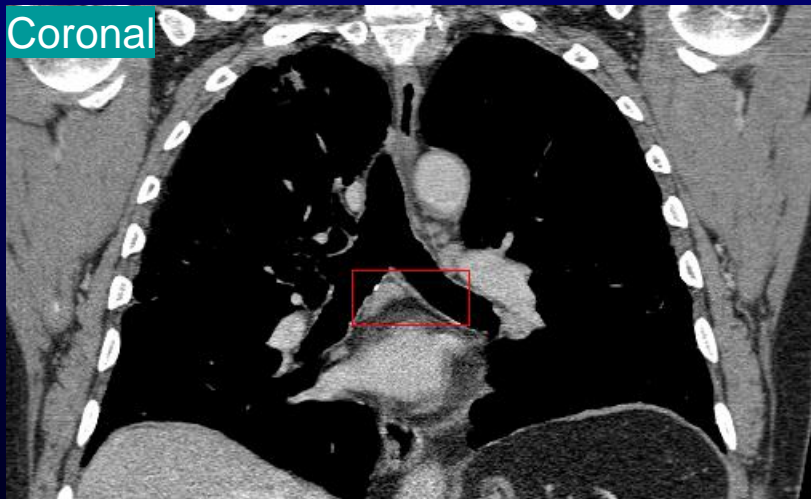
3D View



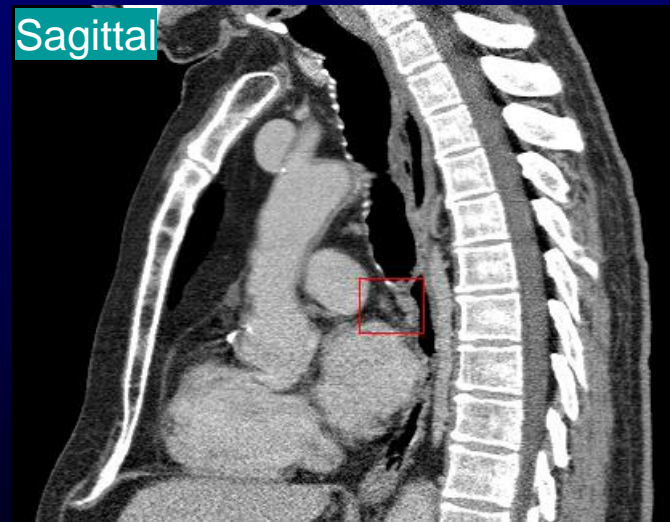
Transverse



Coronal

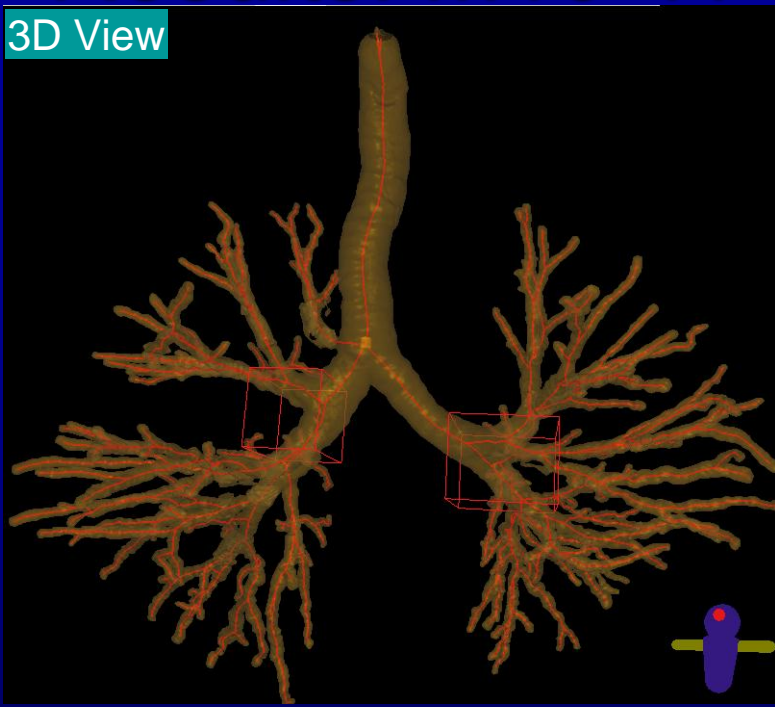


Sagittal

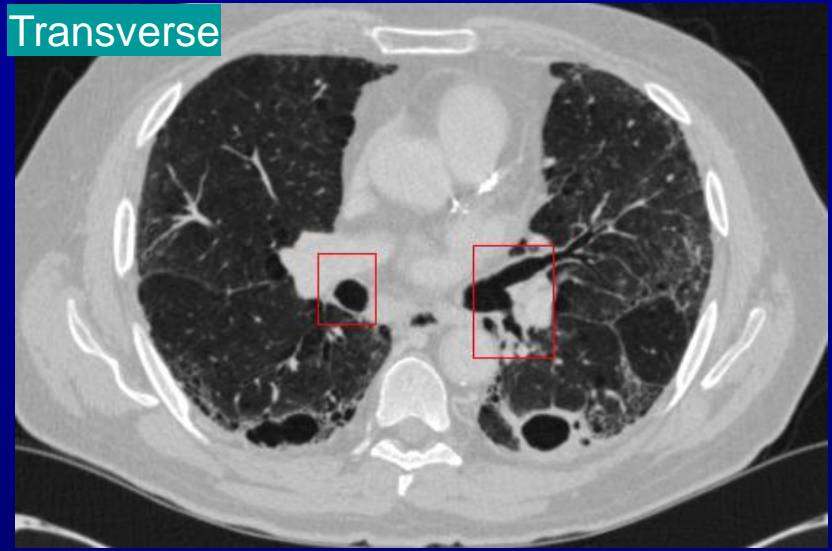


Results: M10-11 (Hilar and Interlobar)

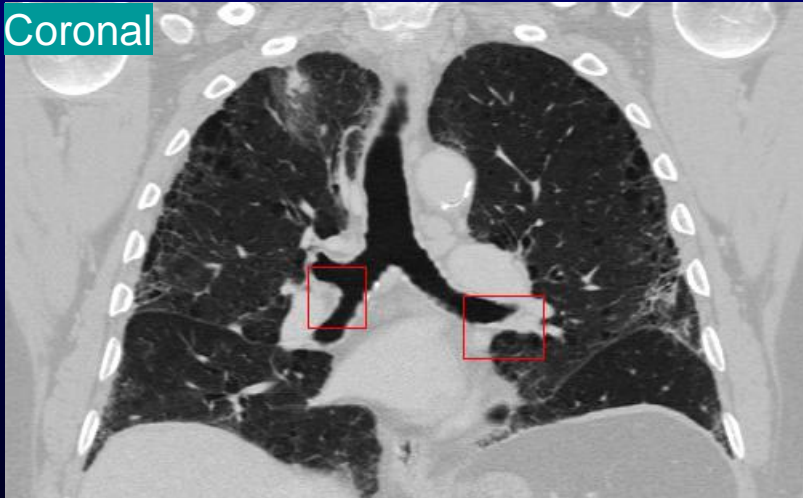
3D View



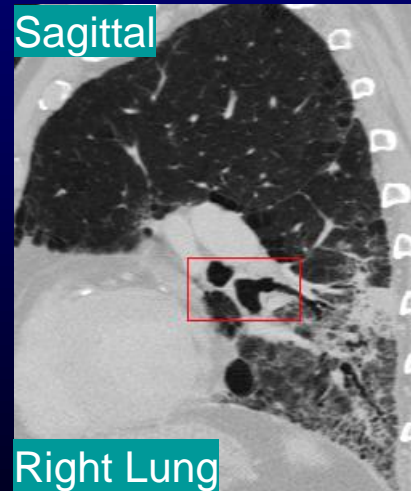
Transverse



Coronal



Sagittal



Right Lung

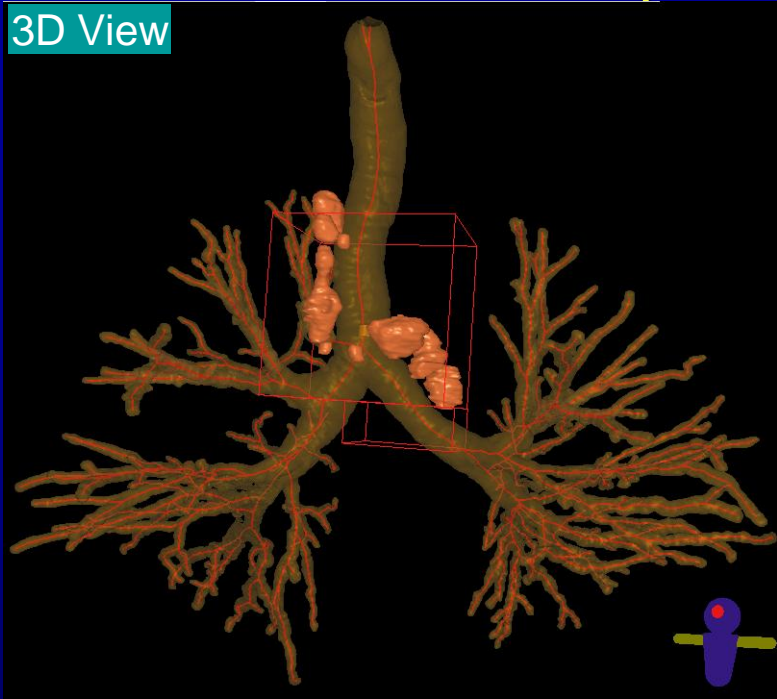
Sagittal



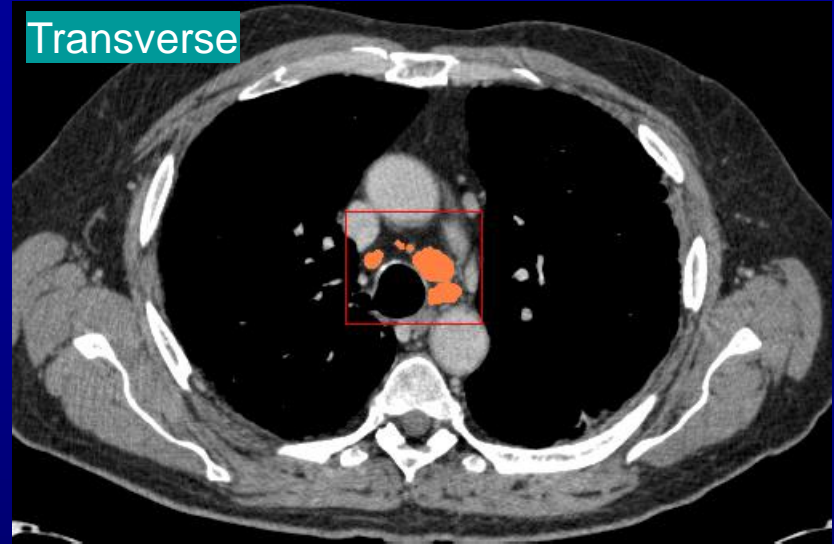
Left Lung

Results: M4 (Lower Paratracheal)

3D View



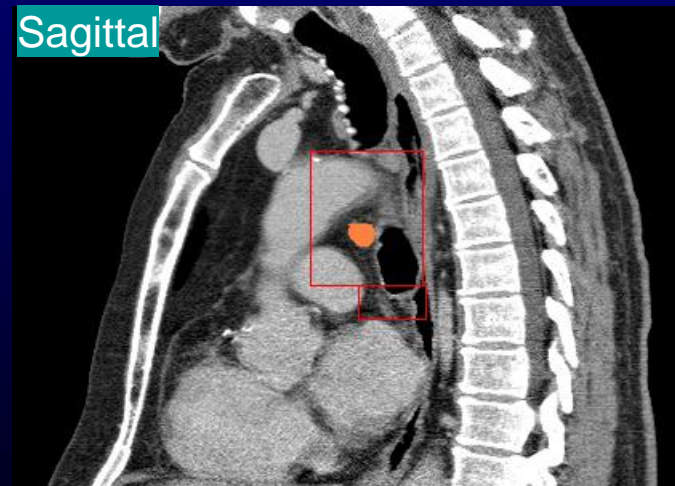
Transverse



Coronal



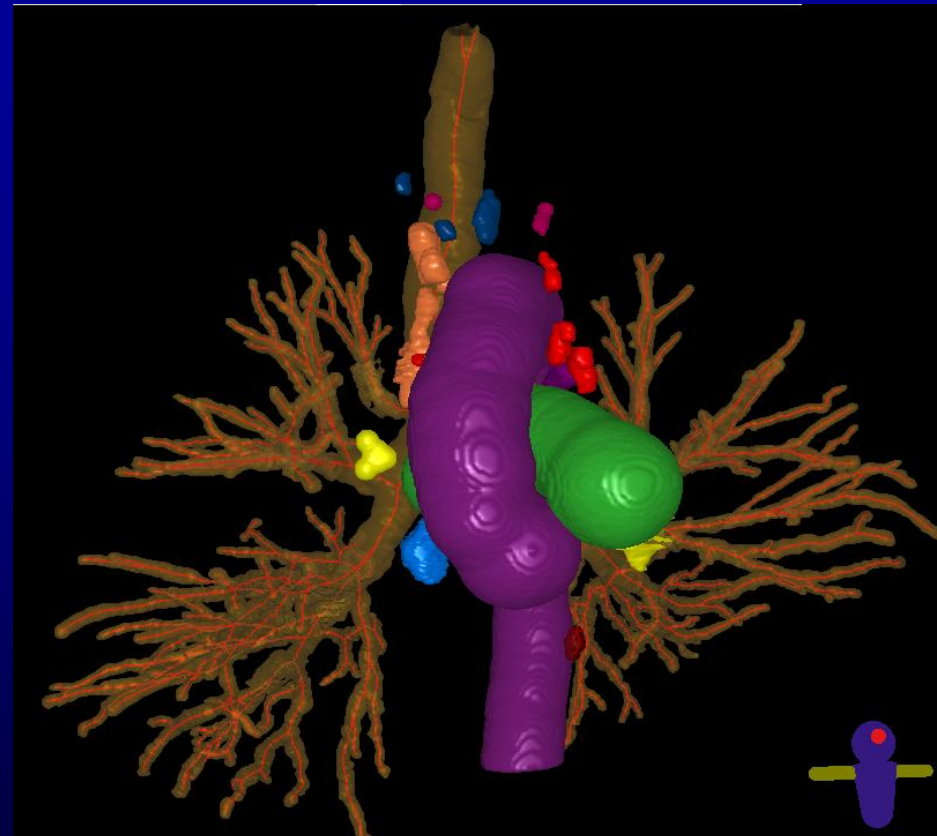
Sagittal



Results: Pulmonary Lymph Nodes

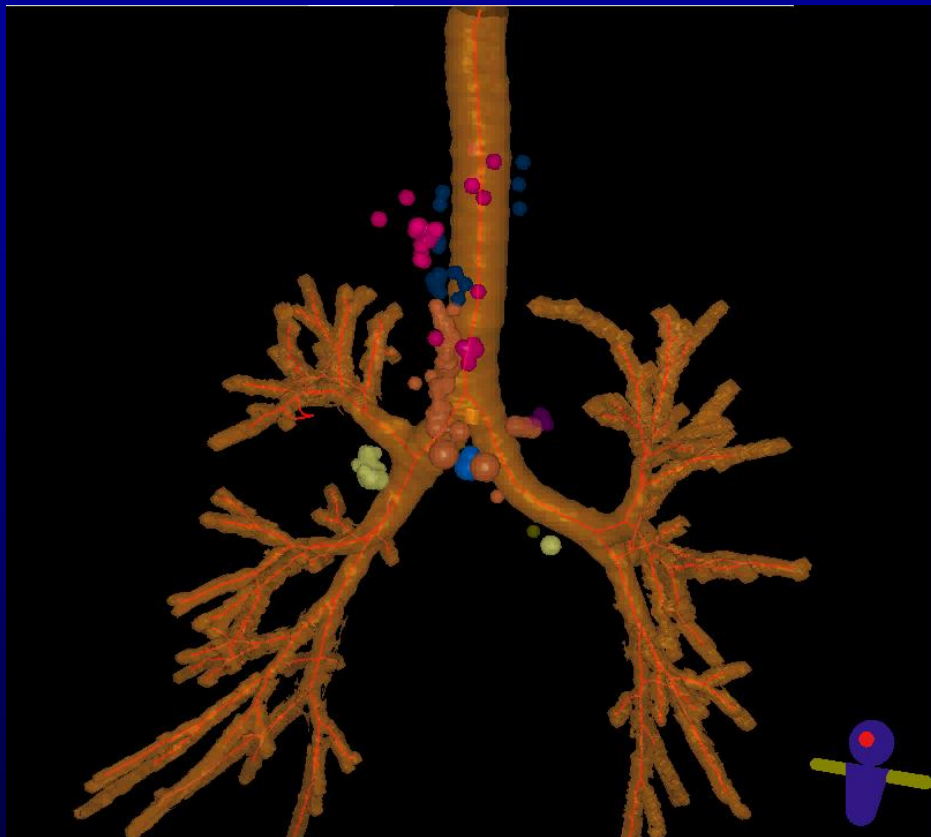


Lymph Nodes and Airway Tree
(30 nodes)

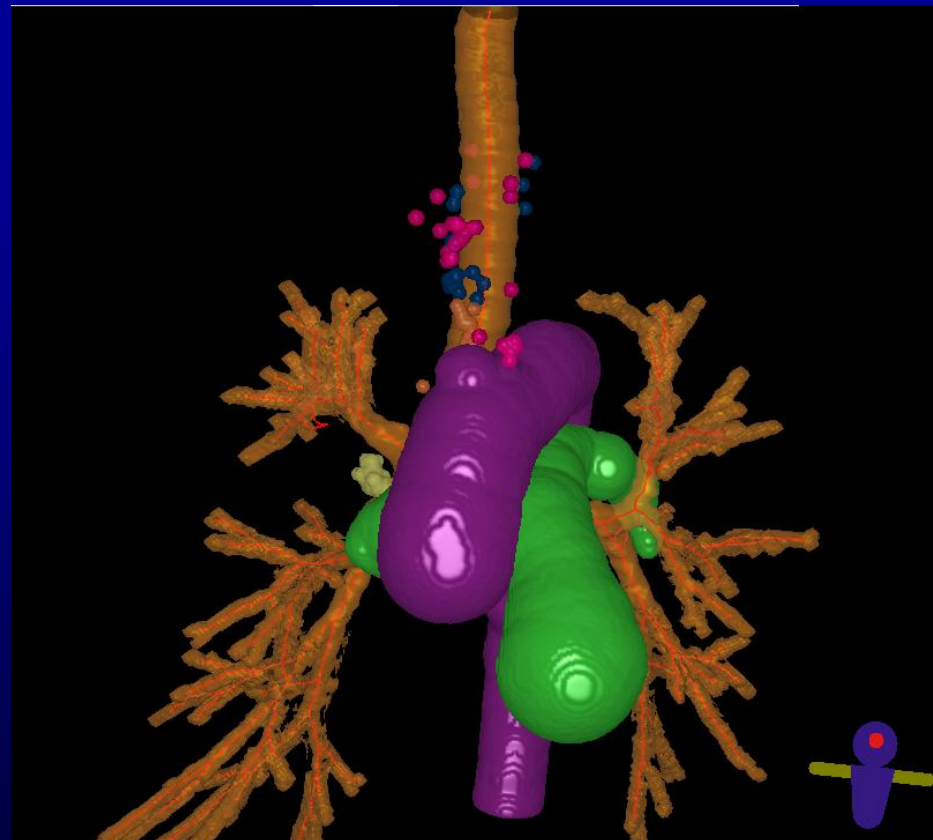


Lymph Nodes, Aorta,
Pulmonary Artery, Airway Tree

Results: Pulmonary Lymph Nodes



Lymph Nodes and Airway Tree
(39 nodes)



Lymph Nodes, Aorta,
Pulmonary Artery, Airway Tree

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!