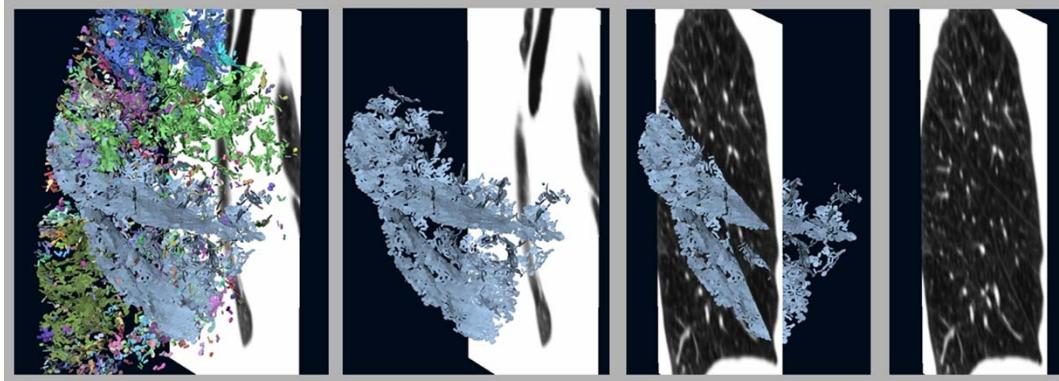


Practical Labor of Image Processing Challenges

Raúl San José Estépar, Ph.D.

Laboratory of Mathematics in Imaging
Applied Chest Imaging Laboratory

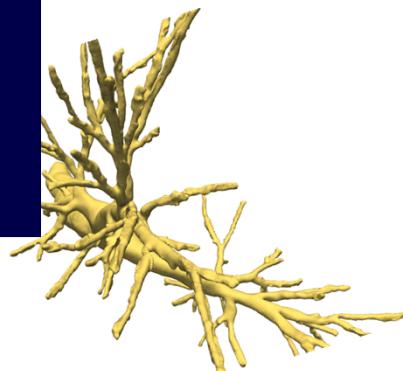
Brigham and Women's Hospital



Imaging Components



- Lung Mask
- Lung Fissures
- Airway Tree



- Parenchymal Damage Markers
 - Low Area Attenuation %
- Airway Inflammation Markers
 - Wall Thickening

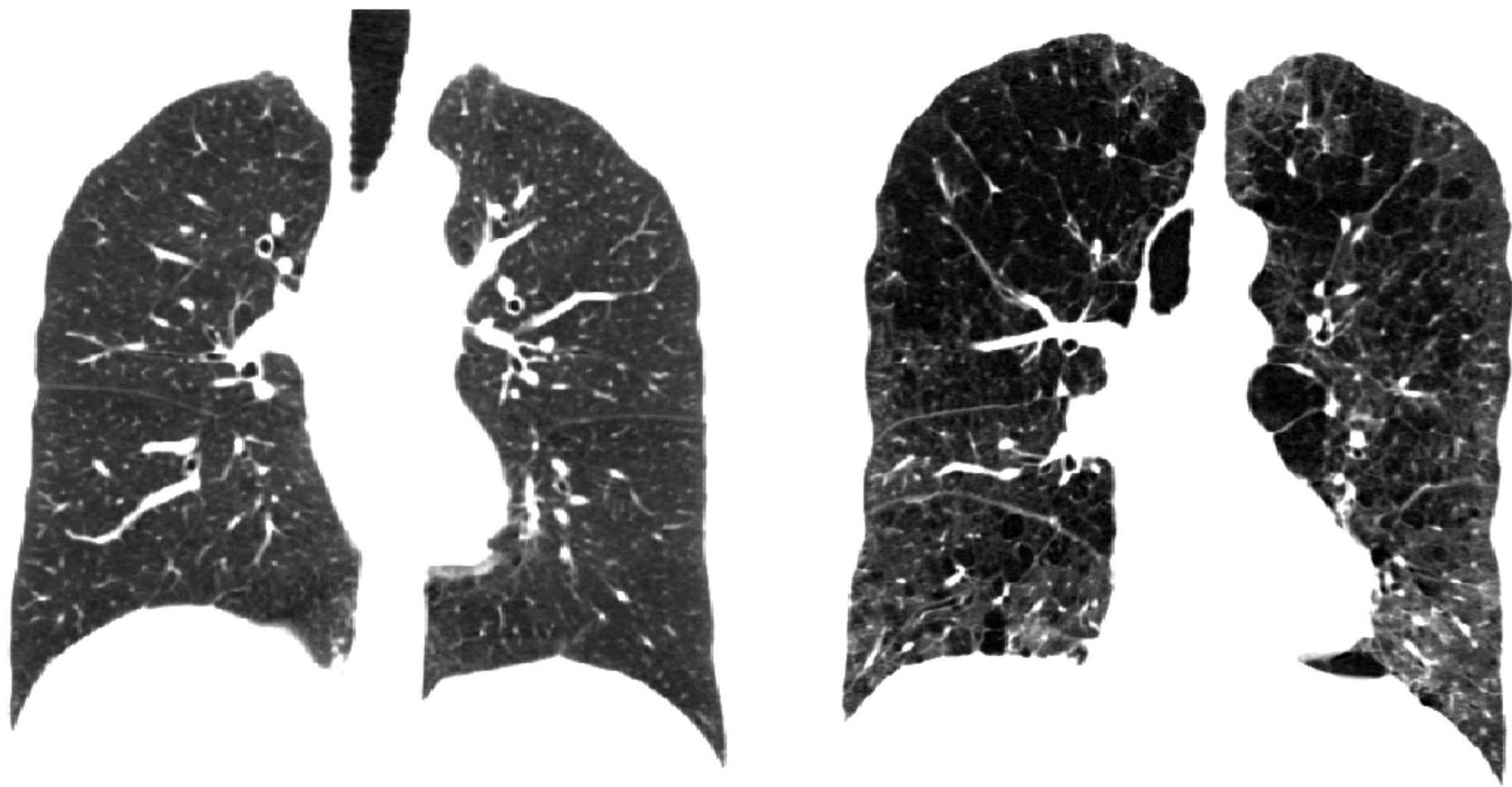


Image Processing Challenges

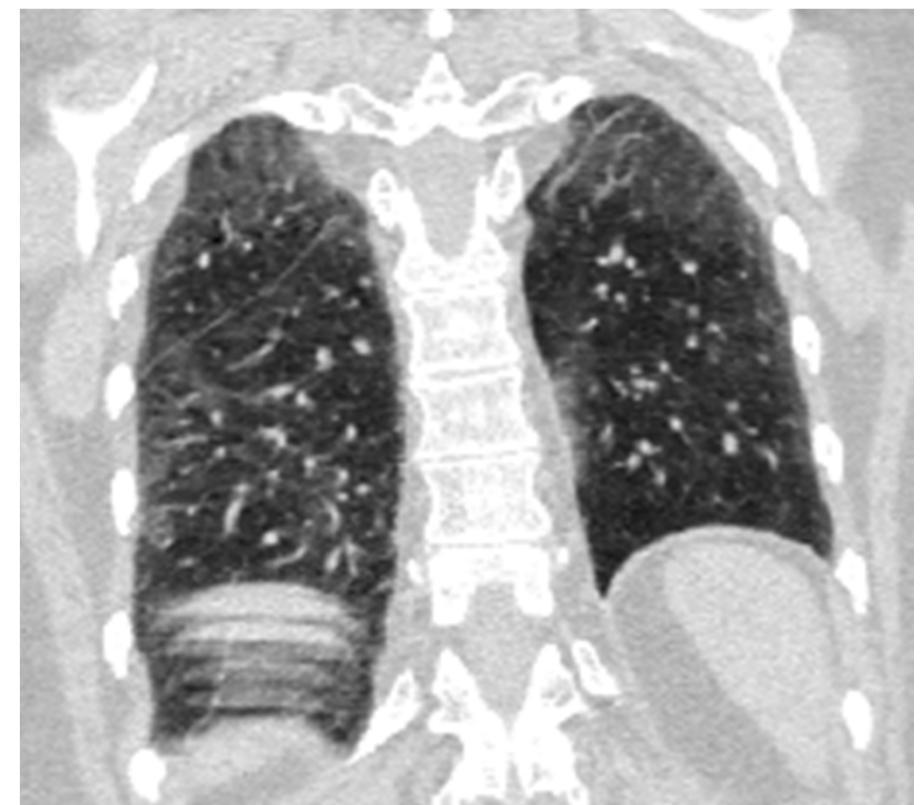
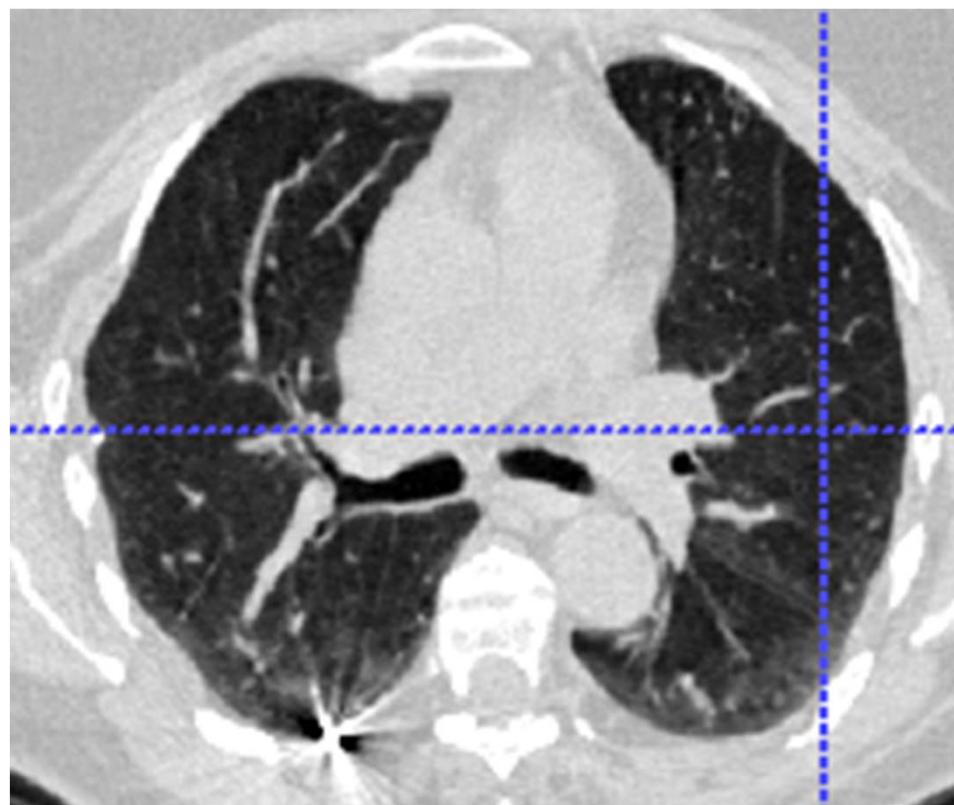
Issue	Lung Mask	Airway Detection	Fissure Detection	Emphysema Marker	Airway Marker
Subject dependent					
Advanced disease stage	X	X	X		
High density changes: IPF, ILD...	X		X	X	
Anatomic variability		X	X		
Respiratory motion	X				
Metal artifacts	X			X	
Stenosis, Mucus plugs		X			
Inspiratory level	X	X		X	
Scanner dependent					
Calibration				X	
Dose		X		X	
Reconstruction kernel		X		X	X



Variability in Images



Variability in Images



Community Validation Challenges

- Airways: EXACT '09

	Category	Branch count	Branch detected (cm)	Tree length (mm)	Tree length detected (%)	Leakage count	Leakage volume (mm ³)	False positive rate
ARTEMIS-TMSP	Automated	157.8	62.8	122.4	55.9	12.0	563.5	1.96
CADTB	Automated	91.1	43.5	64.6	36.4	2.5	152.3	1.27
UAVisionLab	Interactive	74.2	32.1	51.9	26.9	4.2	430.4	3.63
NagoyaLoopers	Automated	186.8	76.5	158.7	73.3	35.5	5138.2	15.56
DIKU	Automated	150.4	59.8	118.4	54.0	1.9	18.2	0.11
VOLCED	Interactive	77.5	36.7	54.4	31.3	2.3	116.3	0.92
TubeLink	Automated	146.8	57.9	125.2	55.2	6.5	576.6	2.44
Sevilla	Interactive	71.5	30.9	52.0	26.9	0.9	126.8	1.75
PhilipsResearchLabHamburg	Automated	139.0	56.0	100.6	47.1	13.5	368.9	1.58
VIA	Automated	79.3	32.4	57.8	28.1	0.4	14.3	0.11
ICCAS-VCM	Interactive	93.5	41.7	65.7	34.5	1.9	39.2	0.41
yactaTreeTracer	Automated	130.1	53.8	95.8	46.6	5.6	559.0	2.47
GVFTubeSeg	Automated	152.1	63.0	122.4	58.4	5.0	372.4	1.44
WEB2	Automated	161.4	67.2	115.4	57.0	44.1	1873.4	7.27
Iowa-1	Interactive	148.7	63.1	119.2	58.9	10.4	158.8	1.19

- Lung Registration: EMPIRE '10
- Fissure: LOLA'11



Lung Mask Extraction



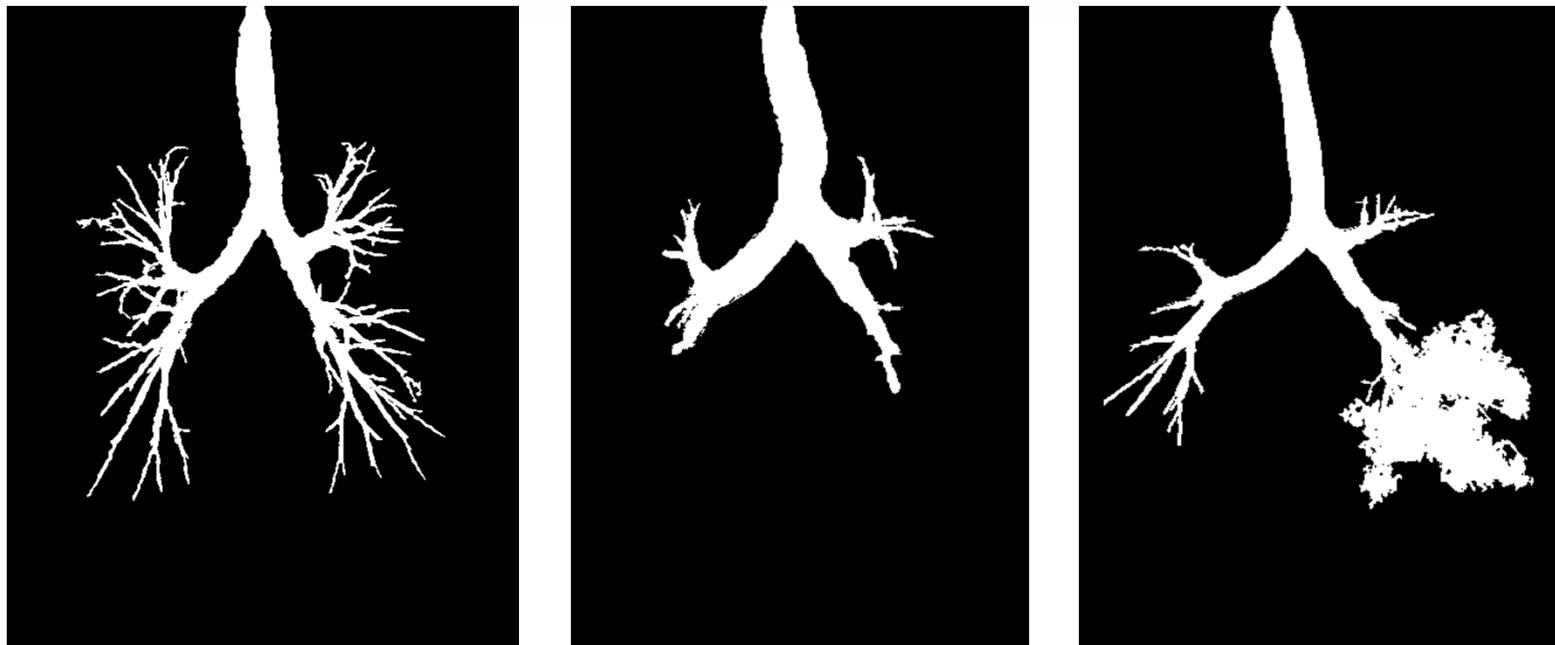
COPDGene: N = 6000 subjects

INSP	86.7 %	13.1 %	0.2 %
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EXP	68.2%	28.5%	3.3%
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Airway Extraction



COPDGene: N = 2500 subjects

5th Gen and up

25.7 %

4th - 3th Gen less 3th Gen

42.1 %

23.4 %

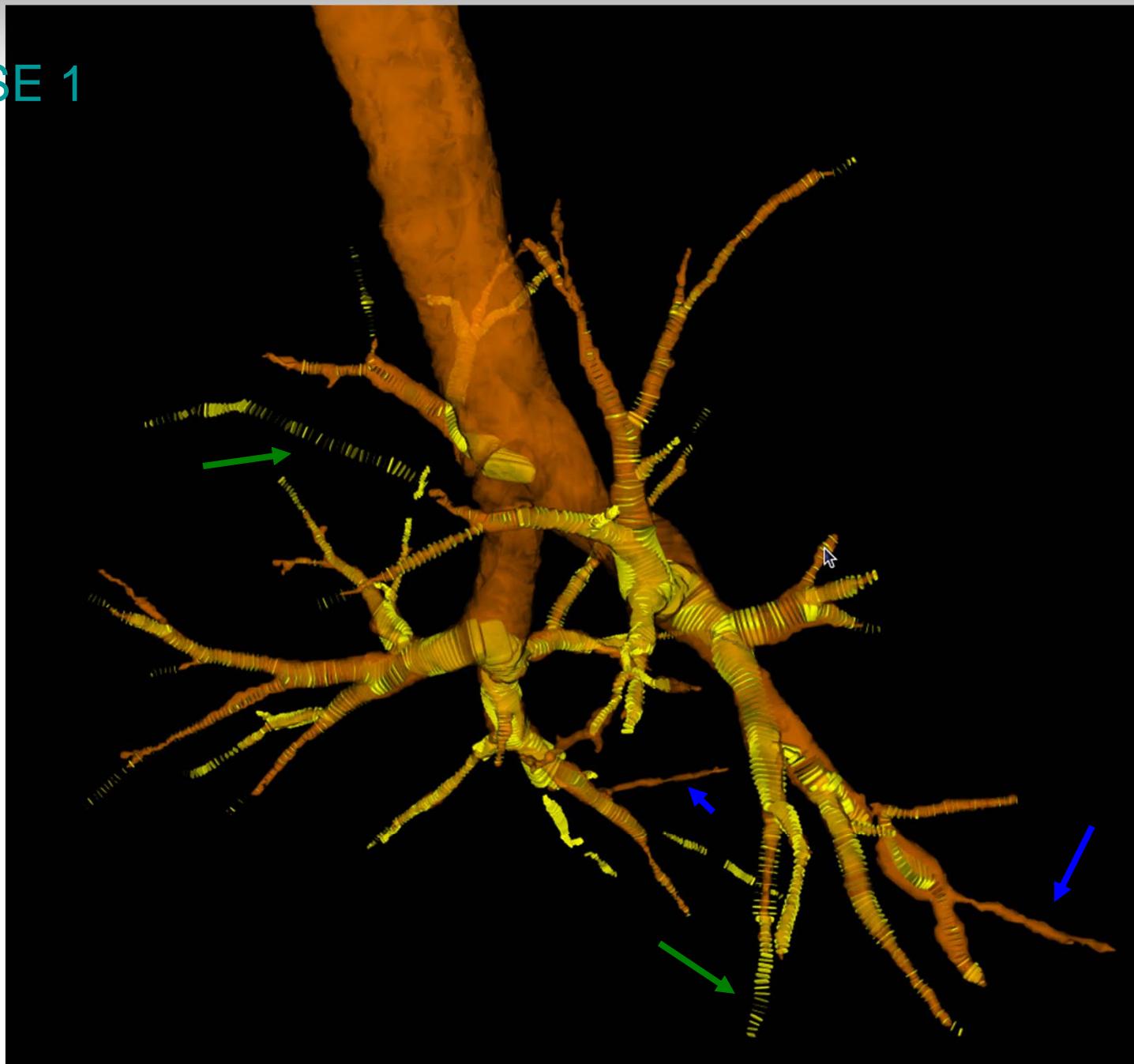
8.8%



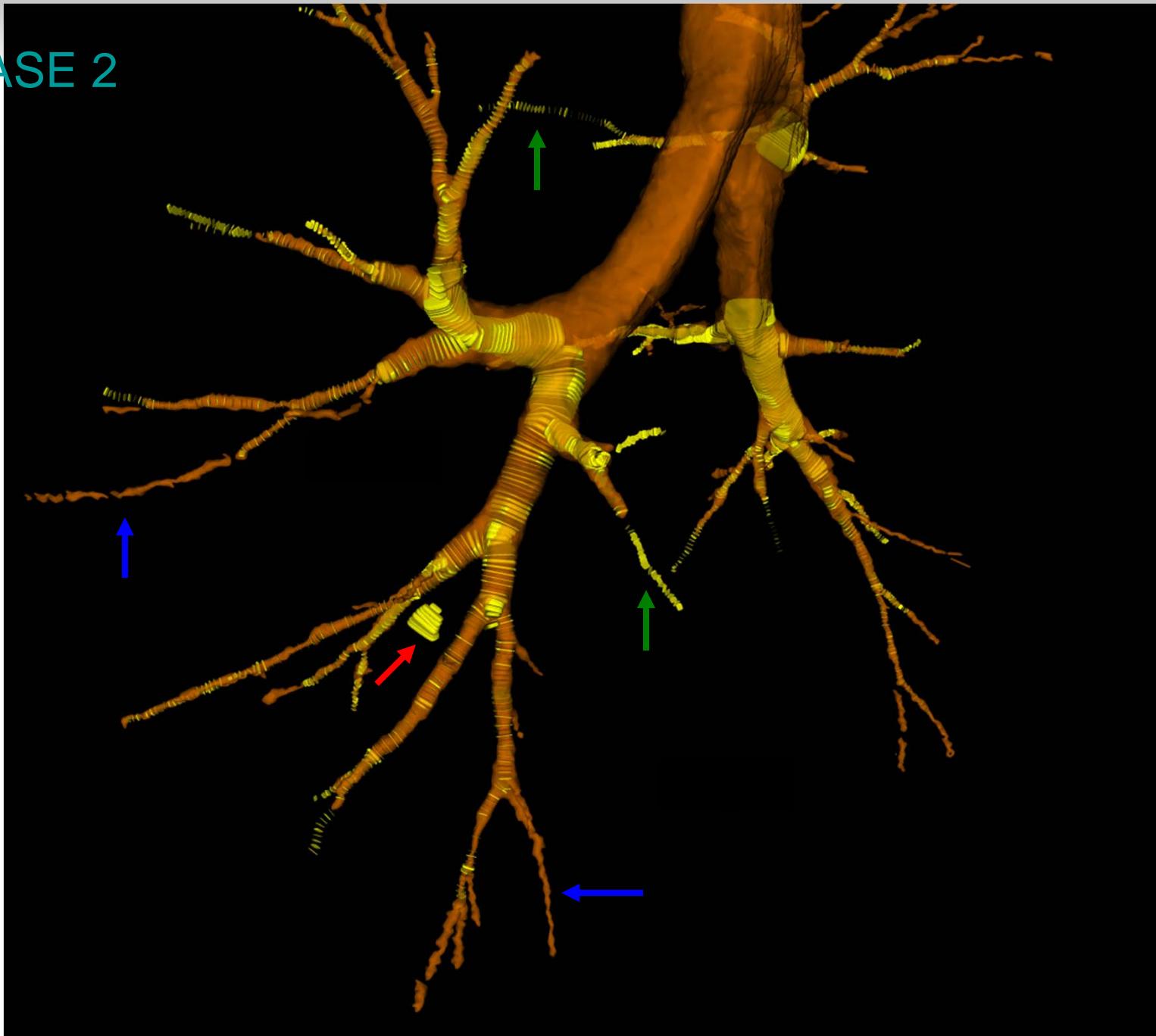
Advancing Airway Extraction



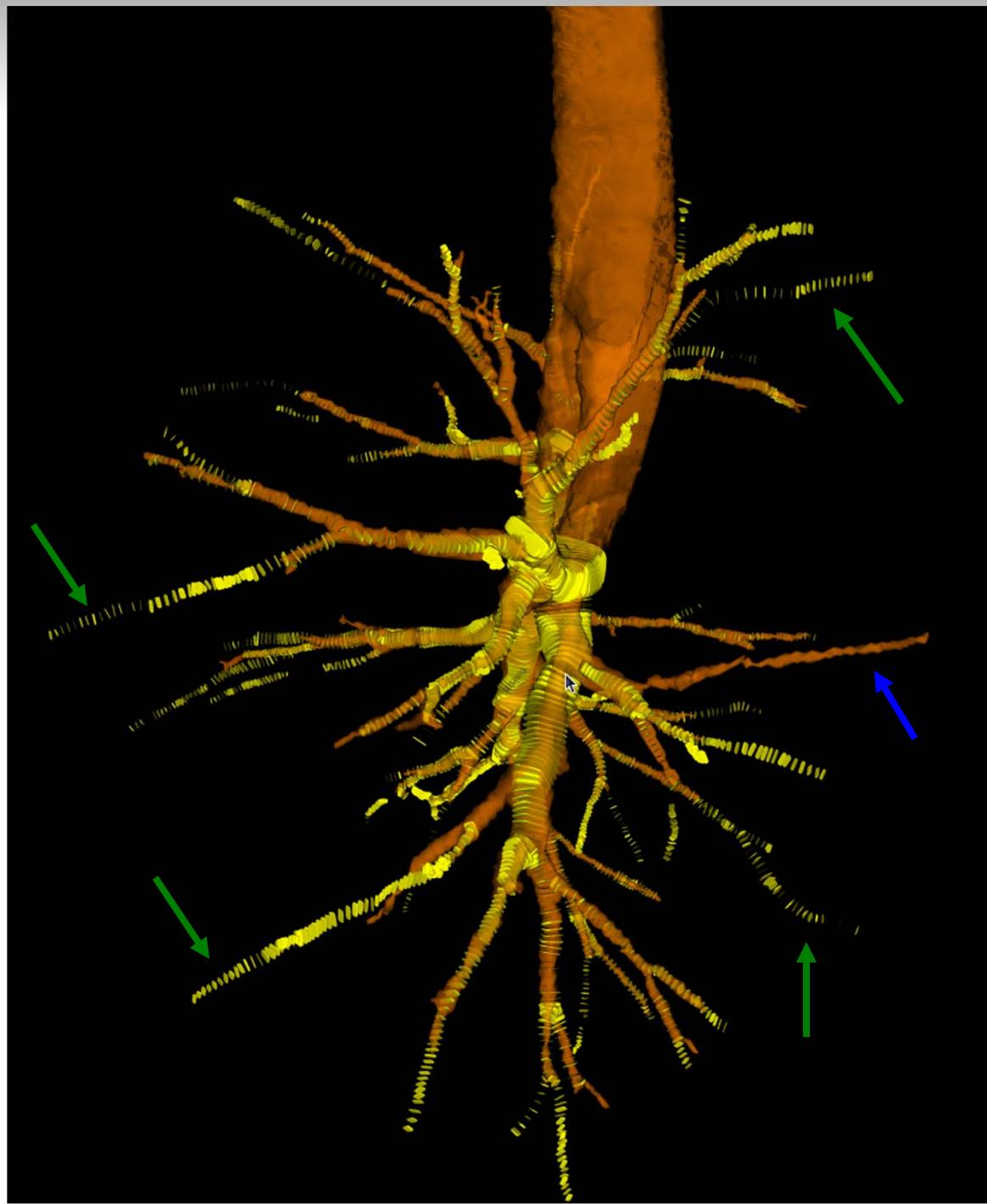
CASE 1

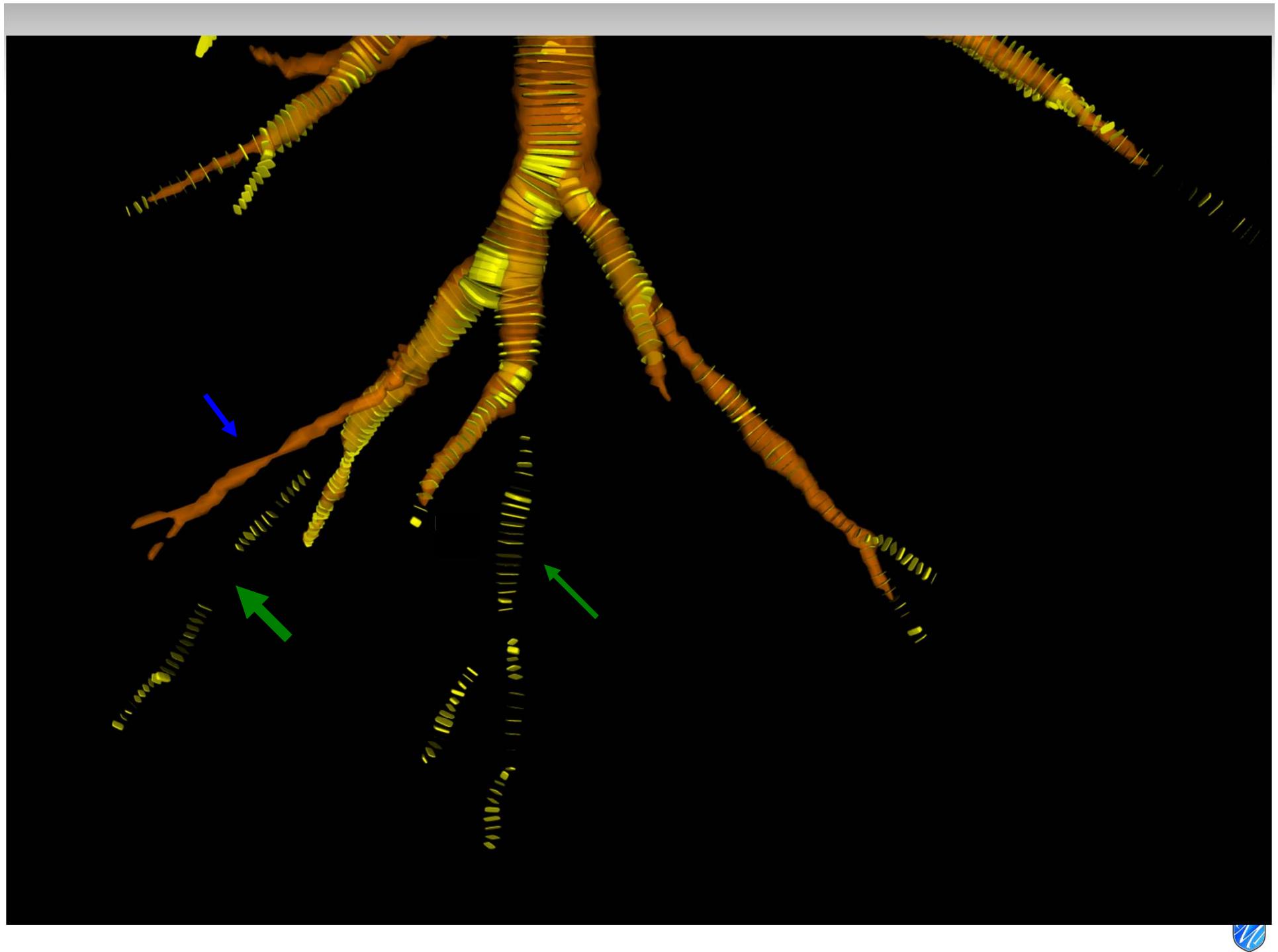


CASE 2



CASE 3

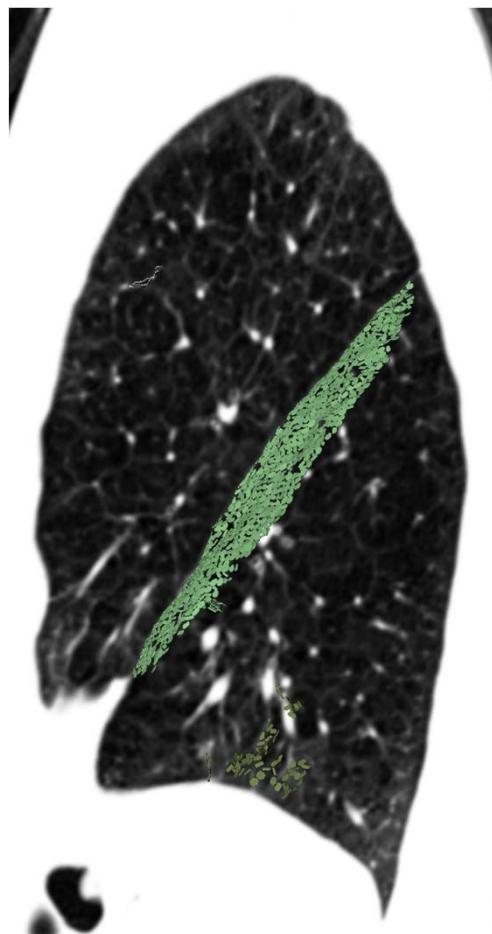




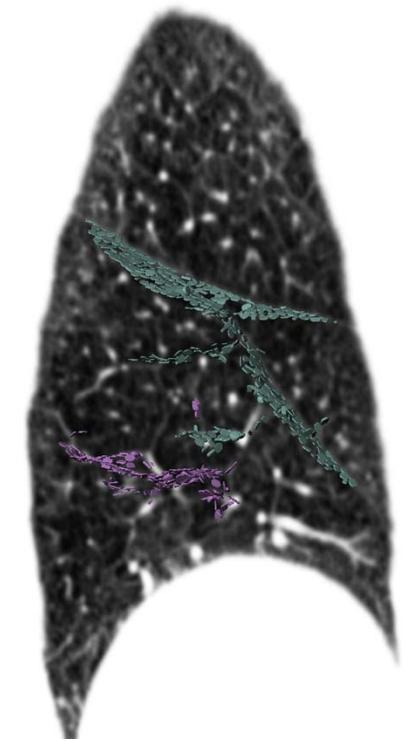
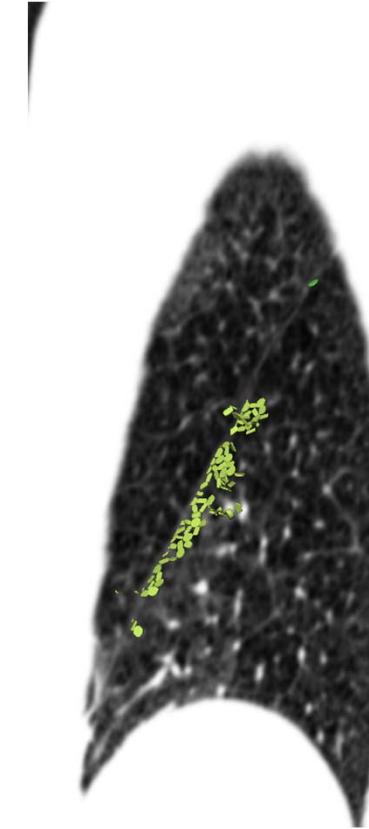
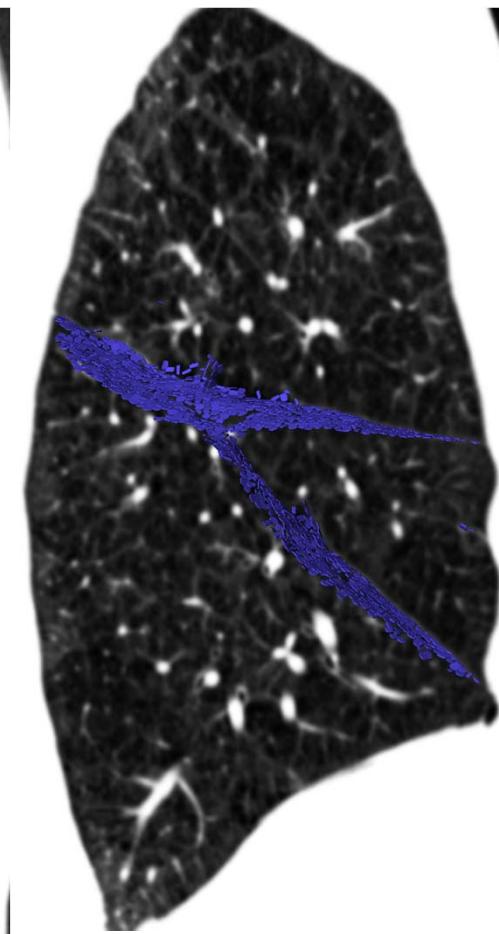


Fissure Extraction

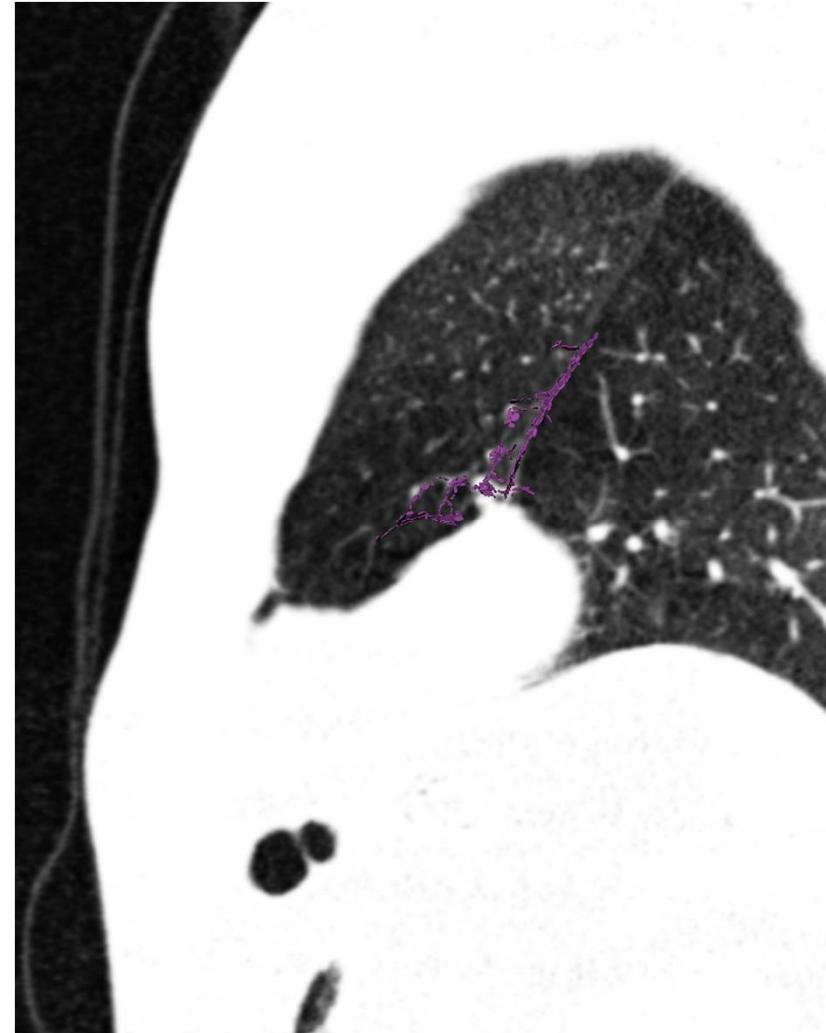
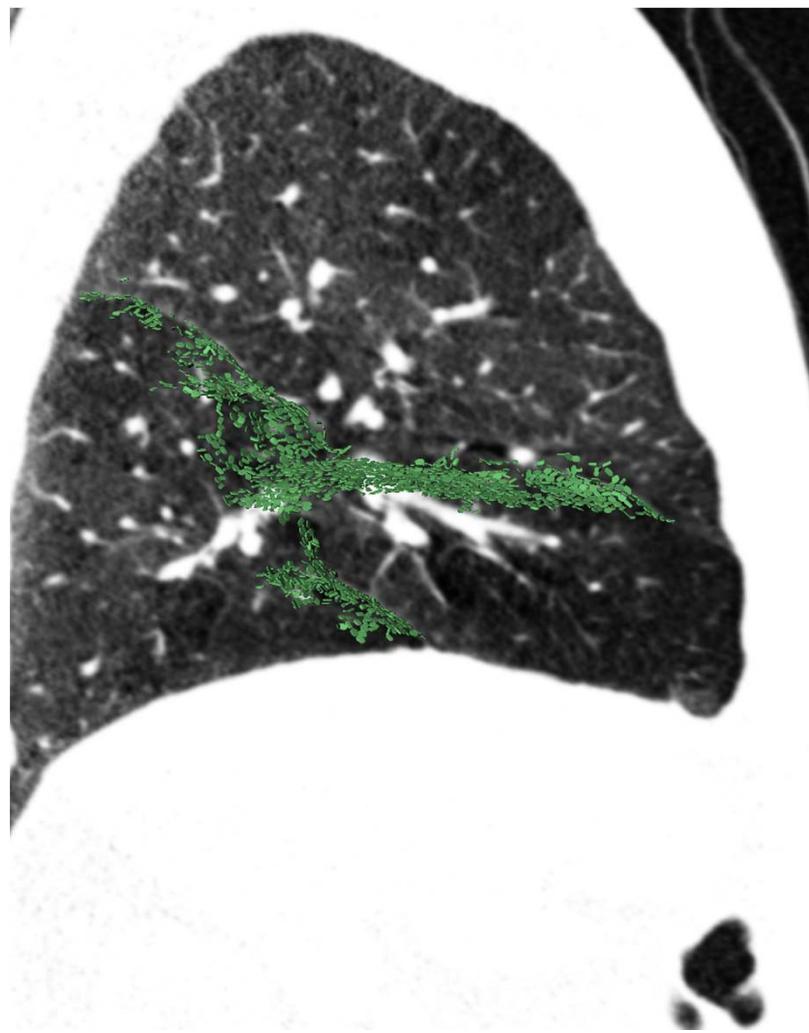
Inspiratory



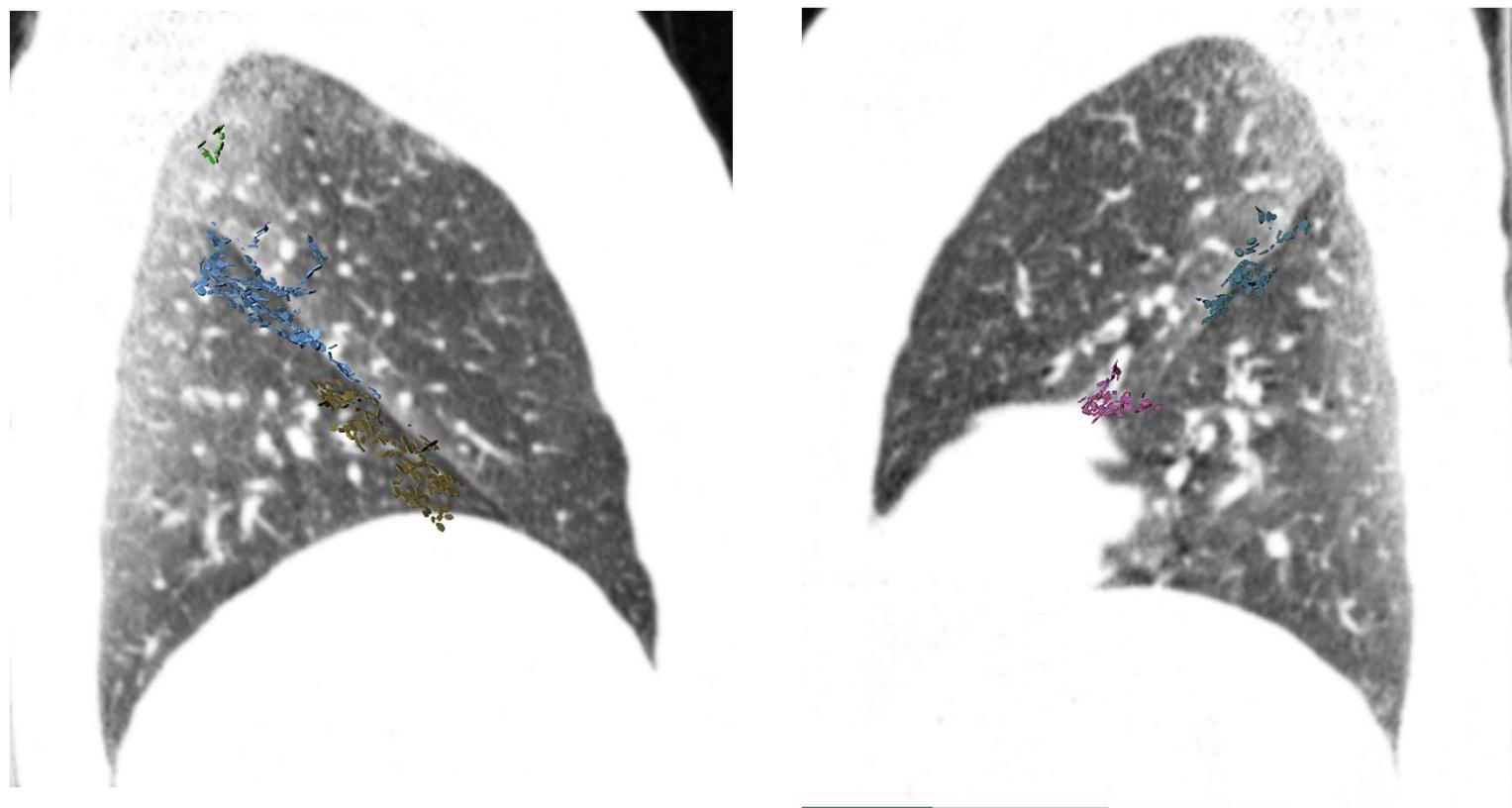
Expiratory



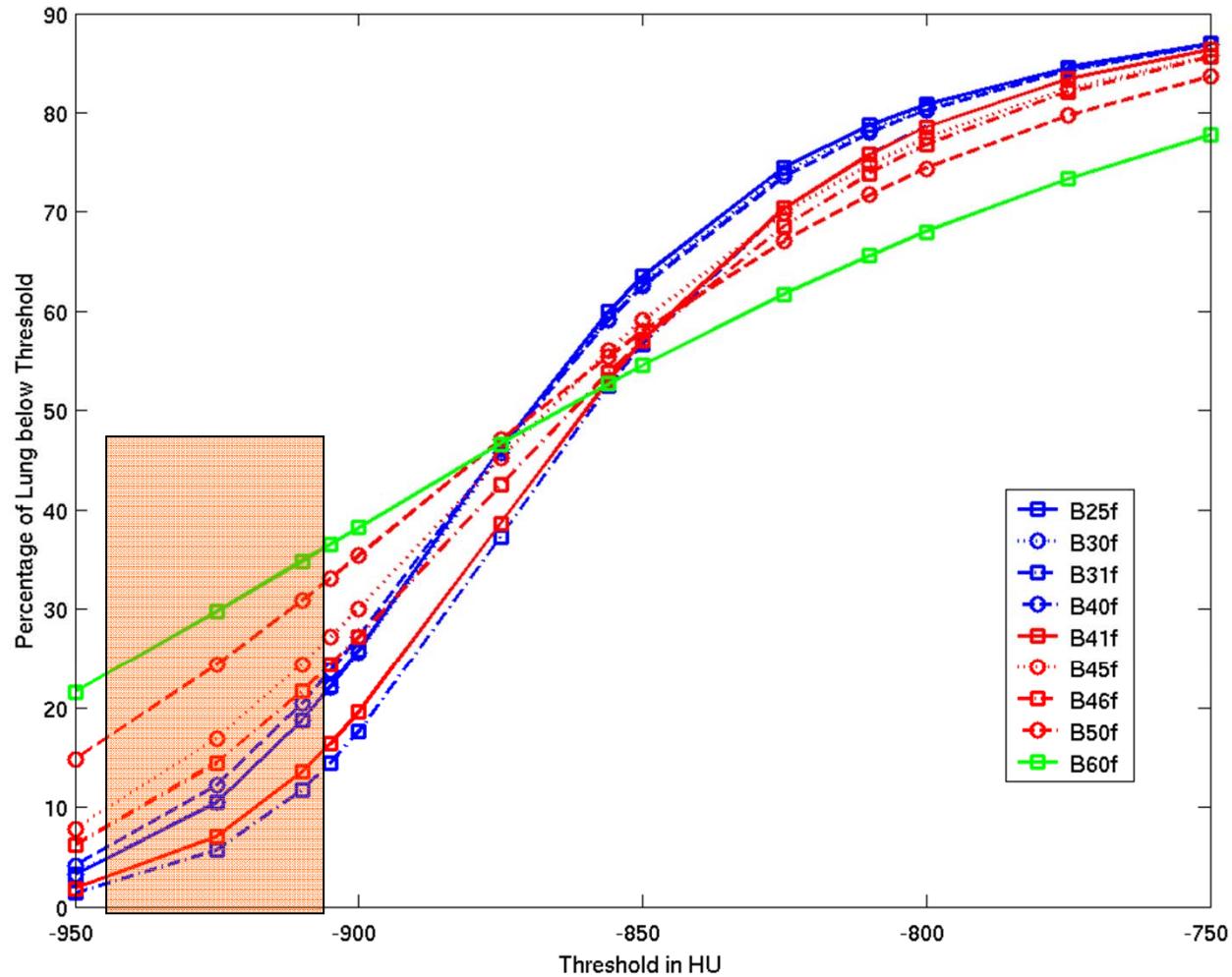
Fissure Extraction



Fissure Extraction



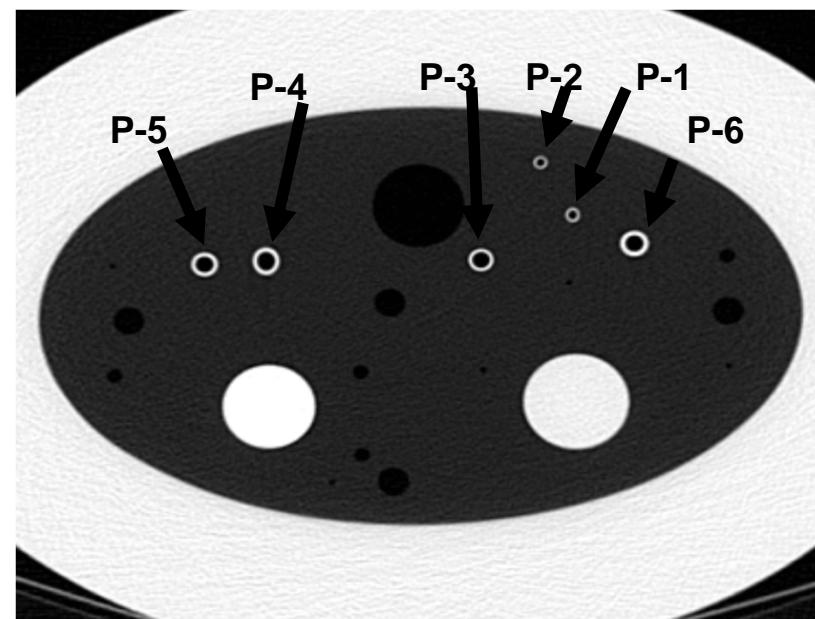
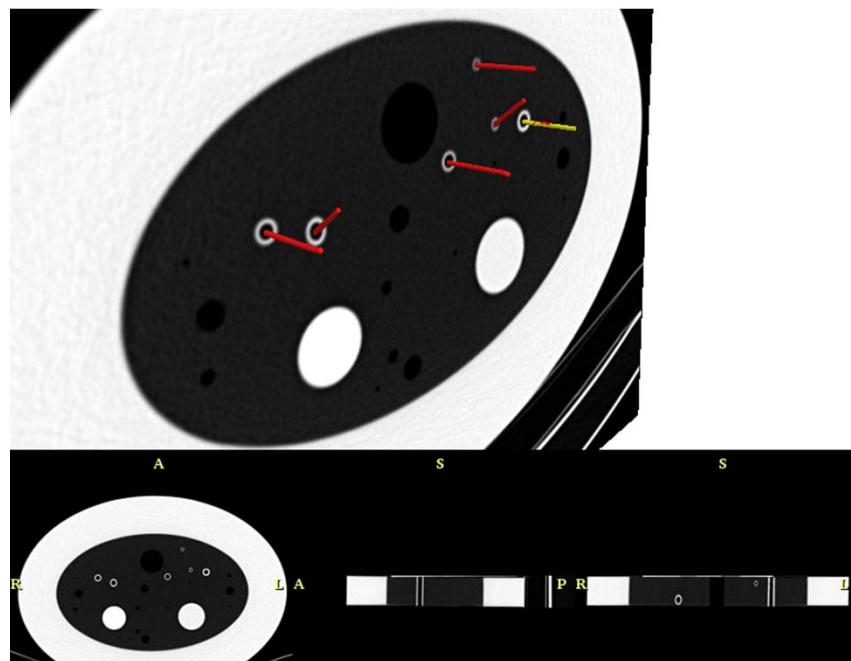
Toward Marker Qualification: Emphysema %



Toward Marker Qualification: Airway Thickness

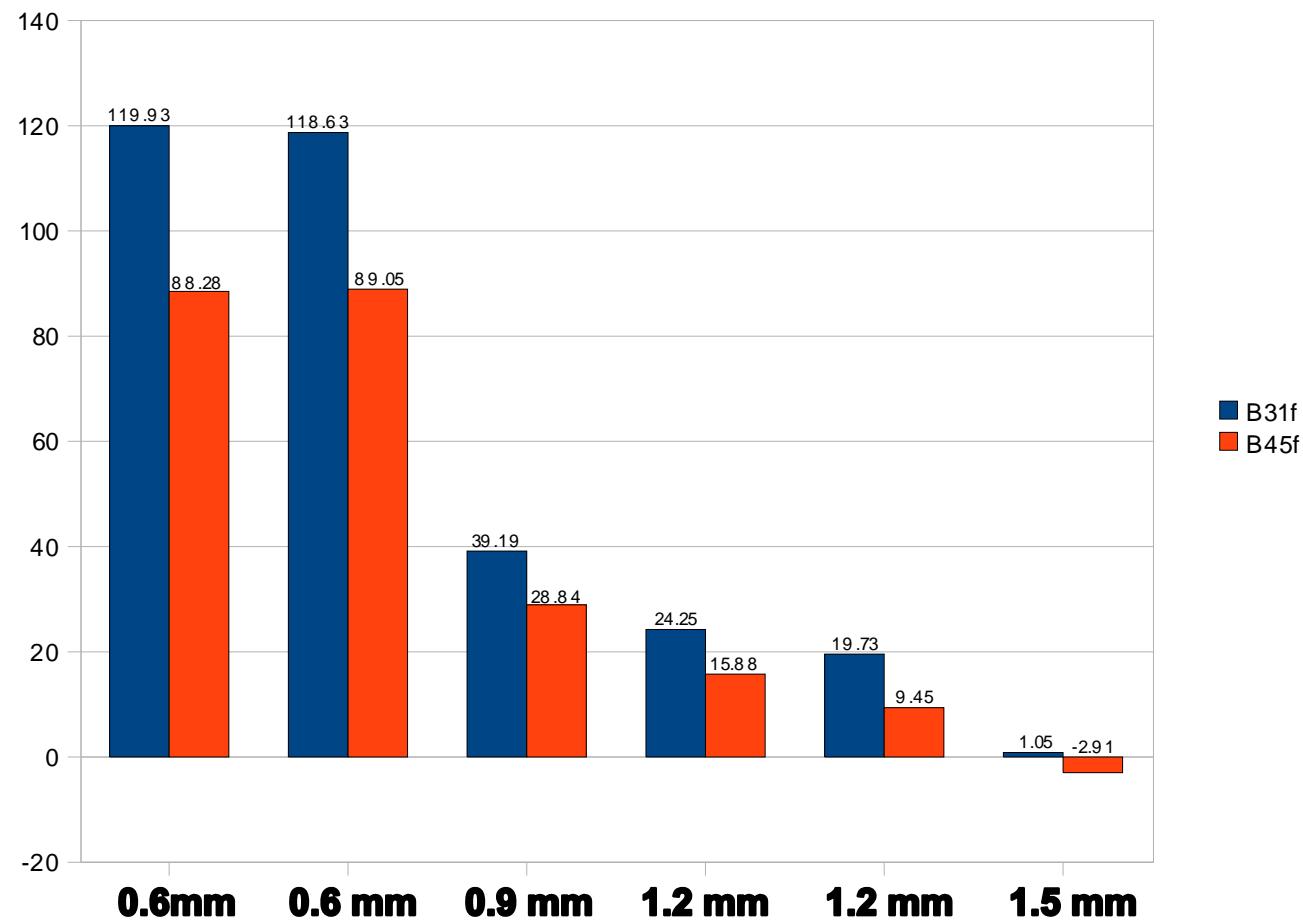
Tube	Spec-Di	Spec-Do	Spec-WT		
CTP666-1	3	4.2	0.6	←	30 degrees
CTP666-2	3	4.2	0.6		
CTP666-3	6	7.8	0.9		
CTP666-4	6	8.4	1.2	←	30 degrees
CTP666-5	6	8.4	1.2		
CTP666-6	6	9	1.5		

Pixel size: 0.713 x 0.713 x 0.75 mm



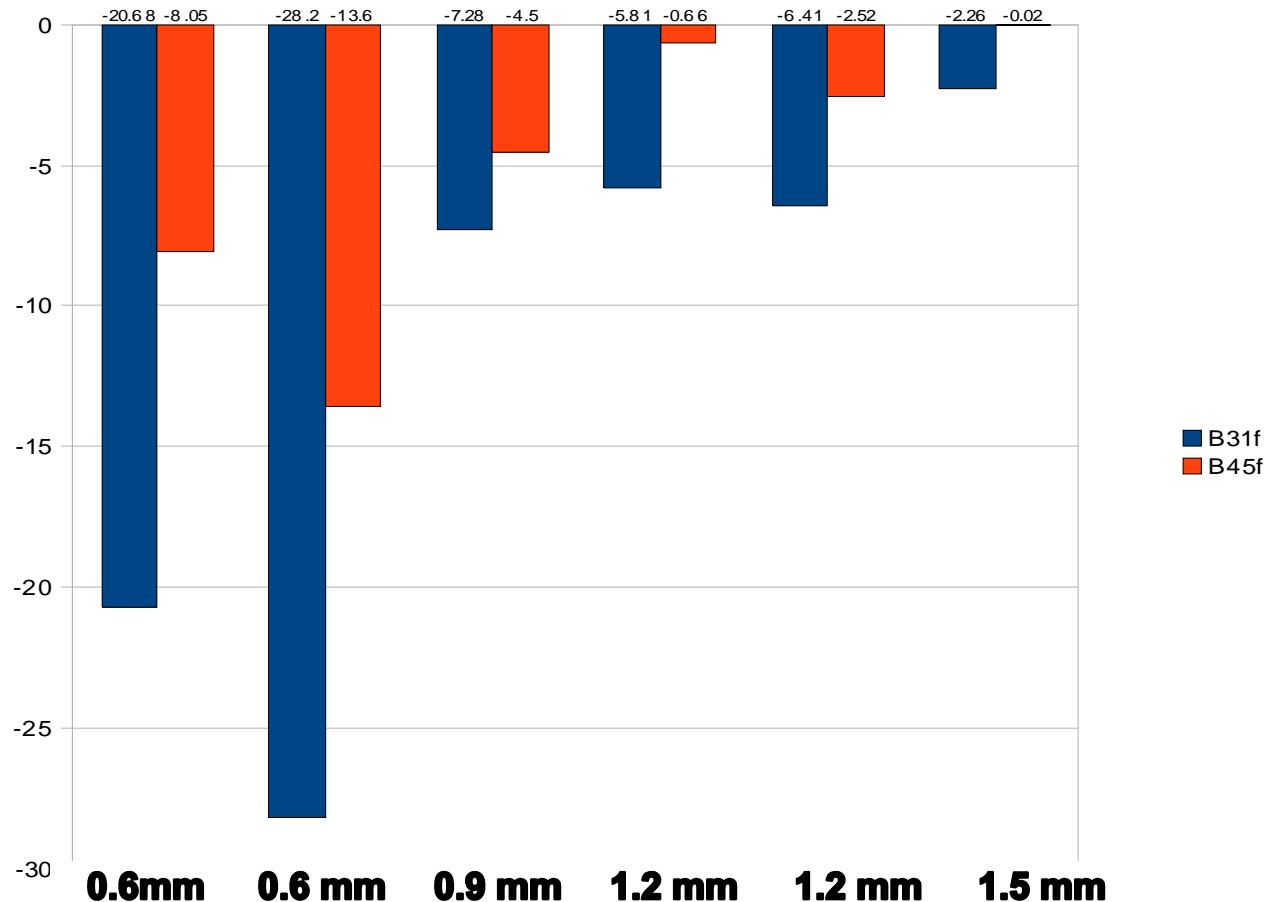
Wall Thickness Error

Wall Thickness Relative Error %



Inner Diameter Error

Inner Diameter Relative Error %



Conclusions

- CT is the primary imaging tool to characterize COPD
 - COPD phenotypes are still a moving target
- Shared quantitative challenges due to scanner variability
 - Reverse engineer scanner effects
 - Exploit signal invariant properties to define new metrics

