

Atlases for Organs at Risk (OARs) in Thoracic Radiation Therapy

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Outline of Content

- Atlas for lung, esophagus, and spinal cord
- Atlas for brachial plexus
- Atlas for proximal bronchial tree
- Atlas for chest wall
- Atlas for pericardium, heart and great vessels (including normal pericardial recesses)

RTOG 1106 Required OARs

Structure	Description	Structure definition and contouring instructions
Lung	Lungs – PreGTV (composite of CT1GTV and PETMTV)	Both lungs should be contoured using pulmonary windows. The right and left lungs can be contoured separately, but they should be considered as one structure for lung dosimetry. All inflated and collapsed, fibrotic and emphysematic lungs should be contoured, small vessels extending beyond the hilar regions should be included; however, pre GTV, hilars and trachea/main bronchus should not be included in this structure.
Heart	Heart & Pericardium	The heart will be contoured along with the pericardial sac. The superior aspect (or base) will begin at the level of the inferior aspect of the pulmonary artery passing the midline and extend inferiorly to the apex of the heart.
Esophagus	Esophagus	The esophagus should be contoured from the beginning at the level just below the cricoid to its entrance to the stomach at GE junction. The esophagus will be contoured using mediastinal window/level on CT to correspond to the mucosal, submucosa, and all muscular layers out to the fatty adventitia.
Spinalcord	Spinal Canal	The spinal cord will be contoured based on the bony limits of the spinal canal. The spinal cord should be contoured starting at the level just below cricoid (base of skull for apex tumors) and continuing on every CT slice to the bottom of L2. Neuroforamines should not be included.
Brachialplex	Brachial Plexus	This is only required for patients with tumors of upper lobes. Only the ipsilateral brachialplex is required. This will include the spinal nerves exiting the neuroforamine from top of C5 to top of T2. In contrast to prior RTOG lung studies of contouring the major trunks of the brachial plexus with inclusion of subclavian and axillary vessels, this trial requests contouring the nerves according to the CT anatomy on every other CT slice. The structure should extend at least 3 cm above the PTV.

RTOG 1106 Optional OARs

Structure	Description	Structure definition and contouring instructions
Pericard	Pericardium	The structure of pericardium includes pericardial fatty tissue, part of great vessels, normal recesses, pericardial effusion (if applicable) and heart chambers. Pericardium starts at one slice above the top of aortic arch, ends at the last slice of heart apex at diaphragm. Pericardium includes the heart.
Greatvess Aorta SVC IVC PV PA	Great vessels Aorta Superior vena cava Inferior vena cava pulmonary vein pulmonary artery	The great vessels should be contoured separately from the heart, using mediastinal windowing to correspond to the vascular wall and all muscular layers out to the fatty adventitia (5 mm from the contrast enhanced vascular wall). The great vessel should be contoured starting at least 3 cm above the superior extent of the PTV and continuing on every CT slice to at least 3 cm below the inferior extent of the PTV. For right sided tumors, SVC will be contoured, and for left sided tumors, the aorta will be contoured. The ipsilateral PA will be delineated for tumor of either side.
Pbtree	Proximal Bronchial Tree	This structure includes the distal 2 cm of the trachea, the carina, the right and left mainstem bronchi, the right and left upper lobe bronchi, the intermedius bronchus, the right middle lobe bronchus, the lingular bronchus, and the right and left lower lobe bronchi.
CW2cm	Chest wall 2 cm outside of lung	Chest wall can be autosegmented from the ipsilateral lung with a 2-cm expansion in the lateral, anterior, and posterior directions. Anteriorly and medially, it ends at the edge of the sternum. Posteriorly and medially, it stops at the edge of the vertebral body with inclusion of the spinal nerve root exit site. CW2cm which include intercostal muscles, nerves exclude vertebrate bodies, sternum and skin. This can be accomplished through auto-expansion of the ipsilateral lung (within 3 cm range of PTV).

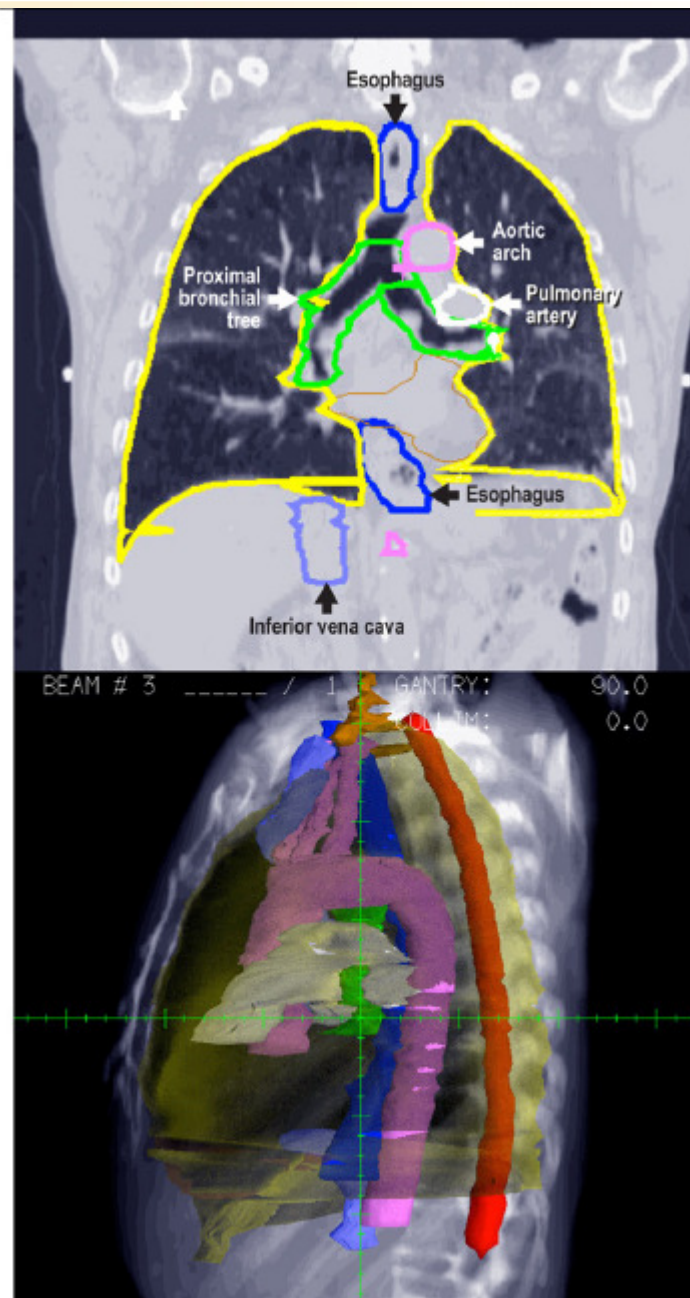
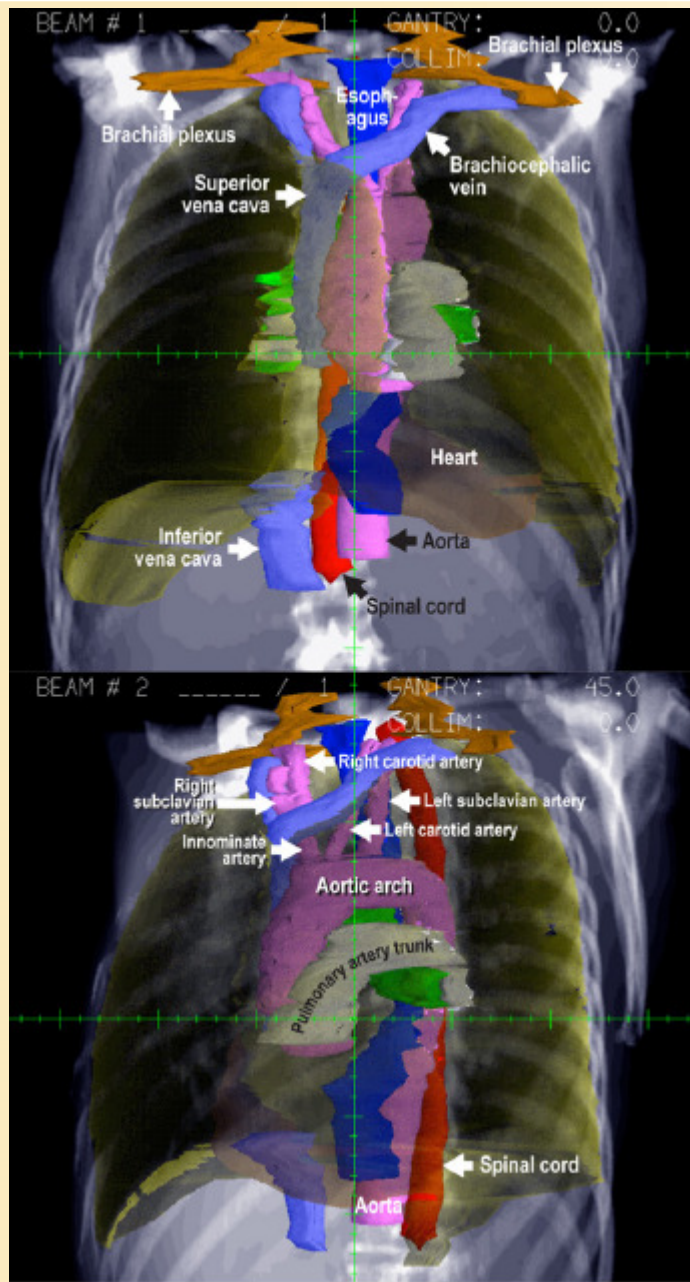
Atlas of lung, esophagus, and spinal cord

CLINICAL INVESTIGATION

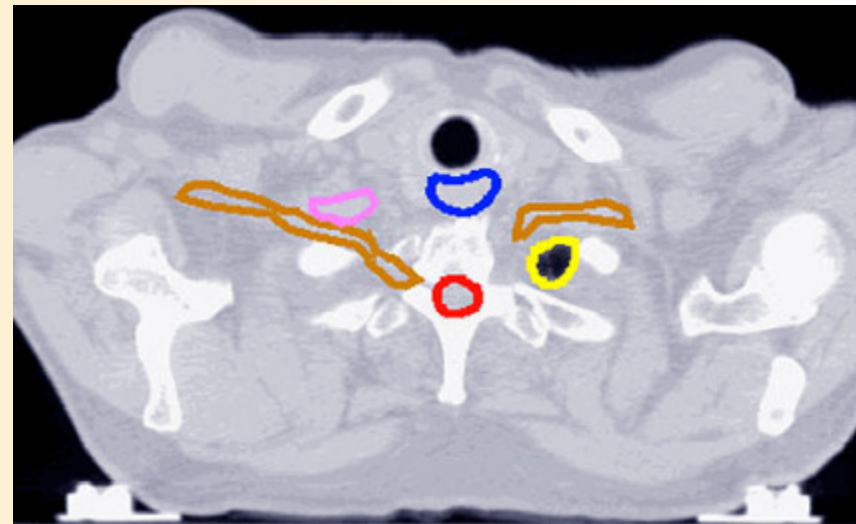
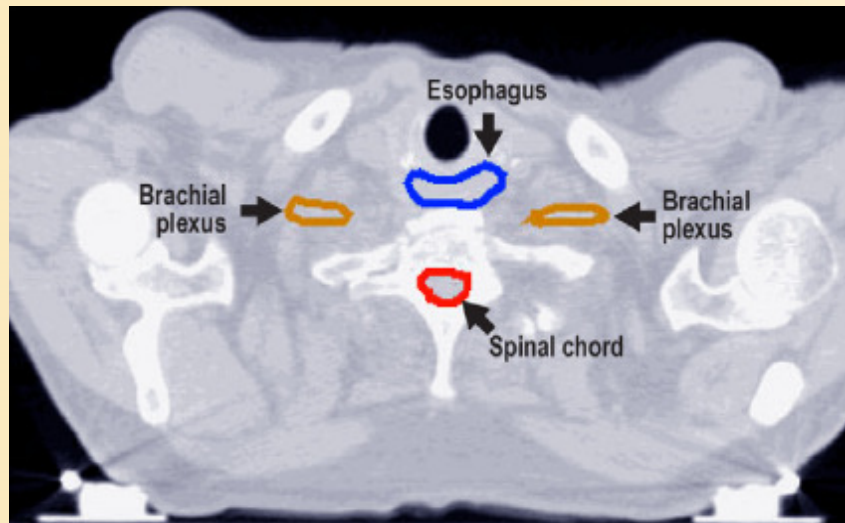
CONSIDERATION OF DOSE LIMITS FOR ORGANS AT RISK OF THORACIC RADIOTHERAPY: ATLAS FOR LUNG, PROXIMAL BRONCHIAL TREE, ESOPHAGUS, SPINAL CORD, RIBS, AND BRACHIAL PLEXUS

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HAK CHOY, M.D.,[#] AND WALTER J. CURRAN, JR., M.D.^{¶¶}

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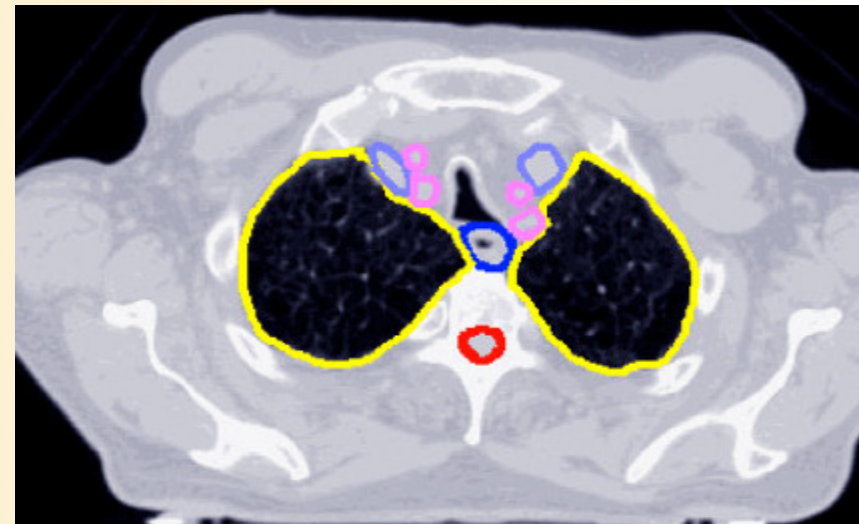
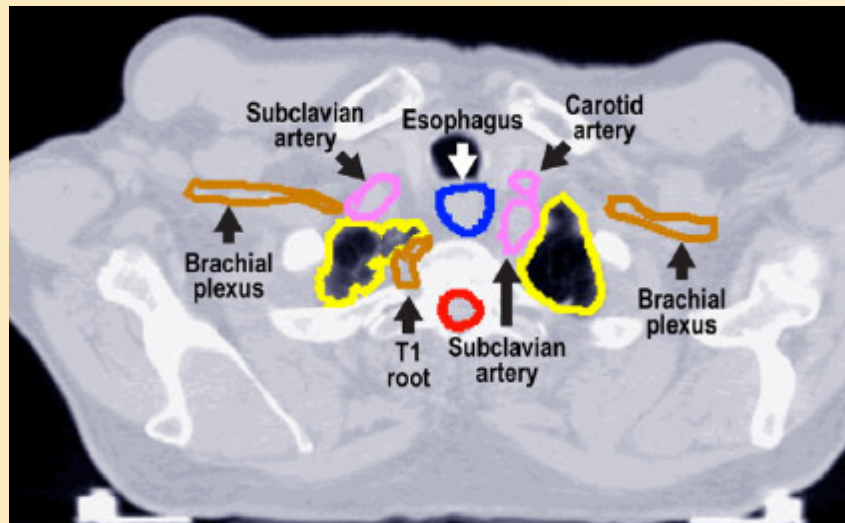


Esophagus starts at the level of cricoid
Lung is visible now of the left apex



Spinal cord should also start at this level just below the cricoid or from the base of skull C1 if scan is available, particularly when the tumors involve neck or apex.

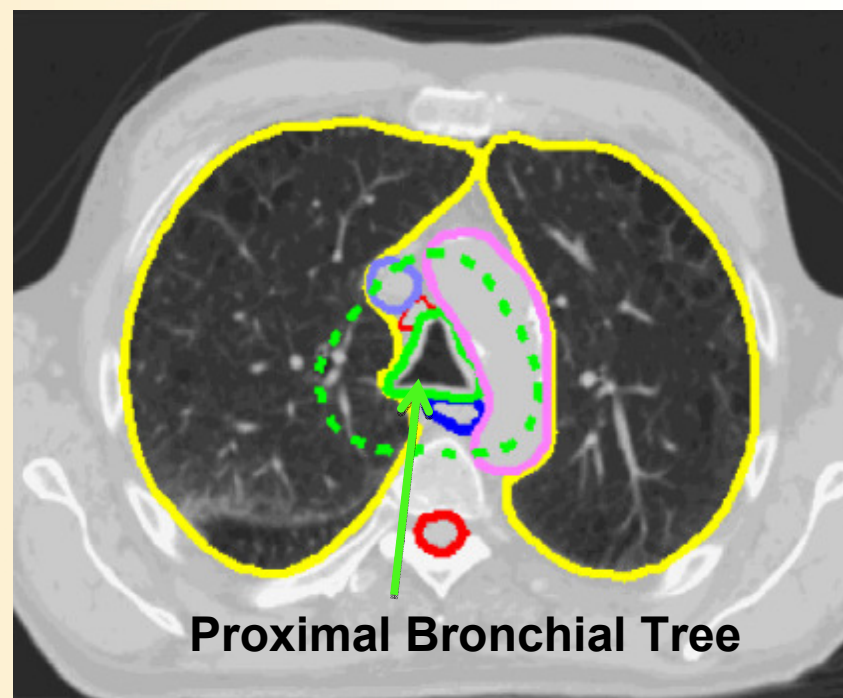
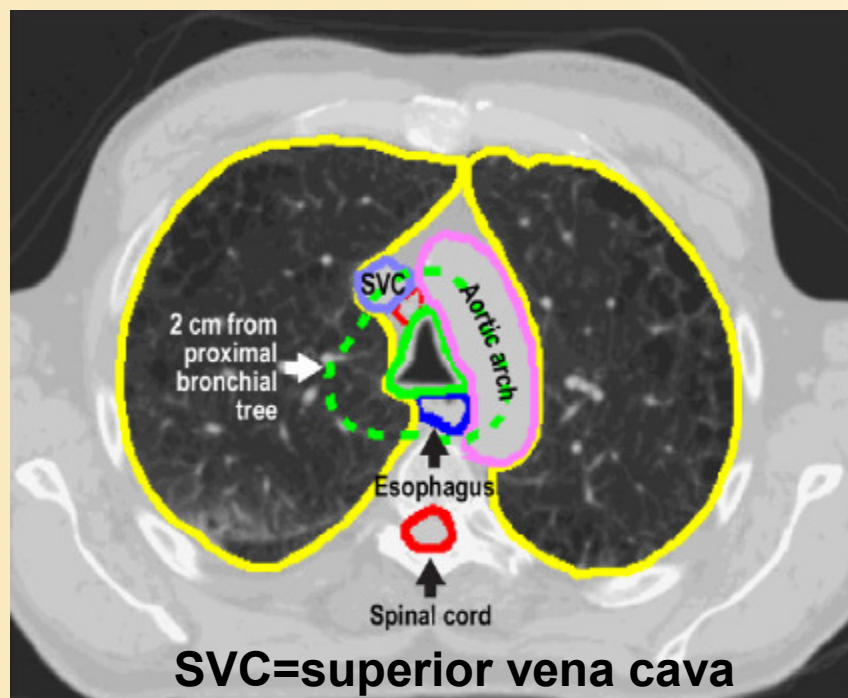
Esophagus and lung continue...



The structure of spinal cord should include the entire spinal canal to decrease contouring variations .

Esophagus, lung and cord continue...

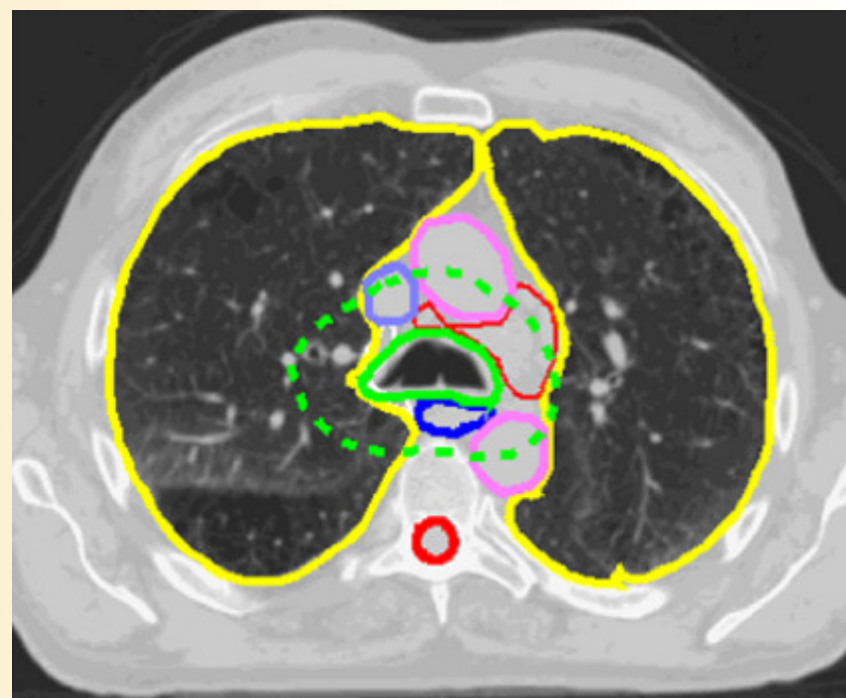
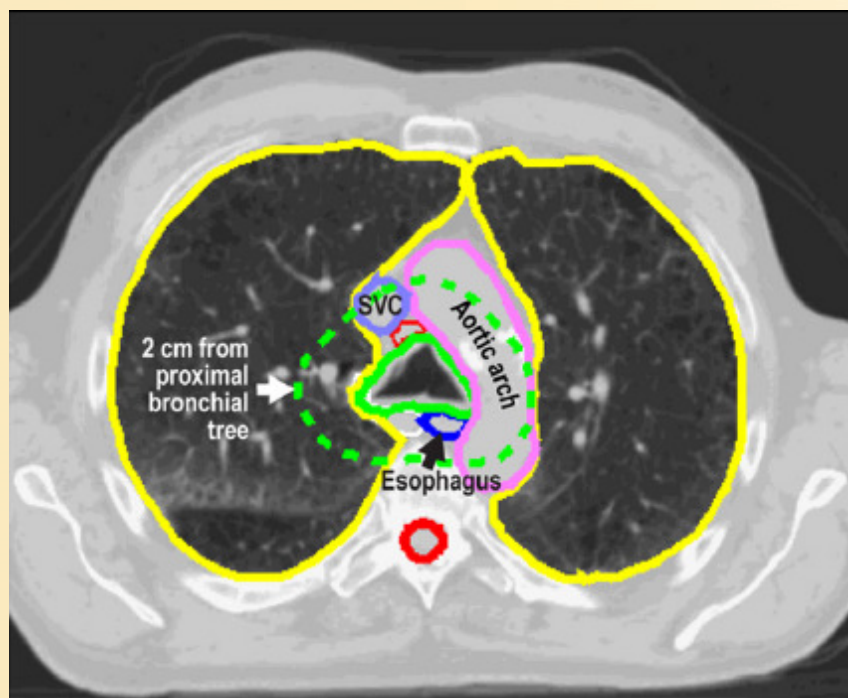
Great vessels delineation is recommended, but not mandated.



Proximal bronchial tree delineation is recommended, but not mandated.

Esophagus, lung and cord continue...

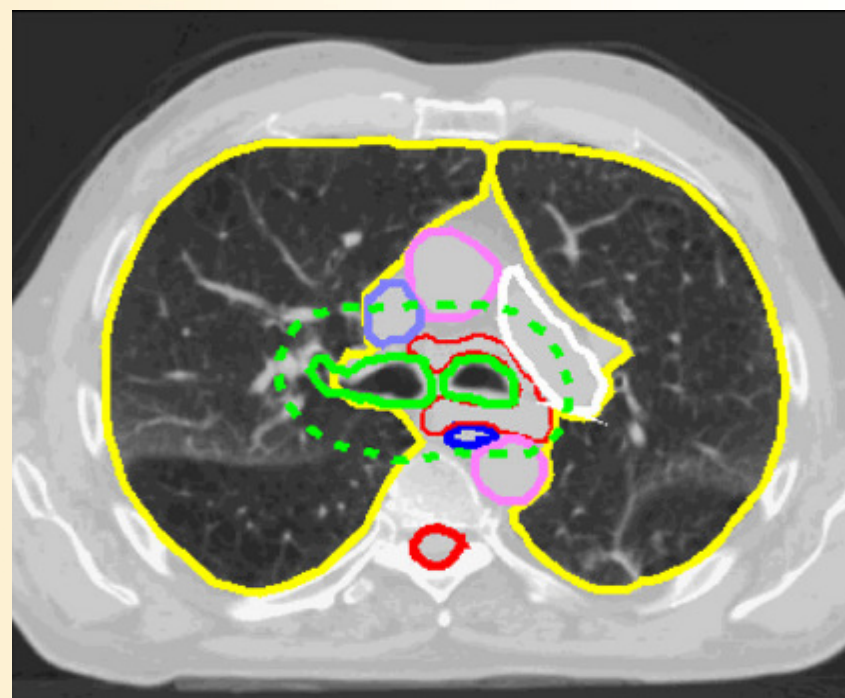
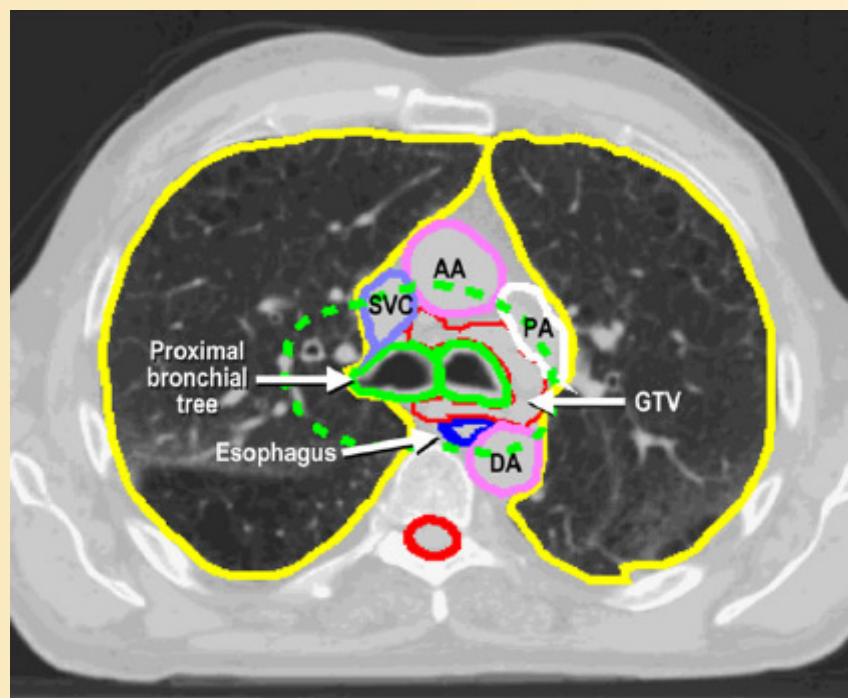
great vessels start from the level of aortic arch



Proximal bronchial tree starts at 2 cm above carina

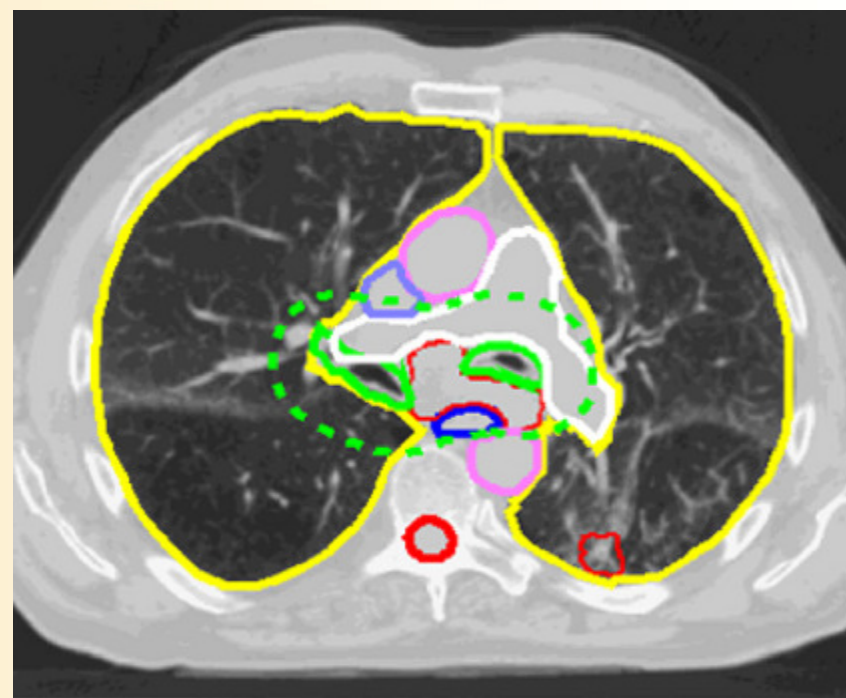
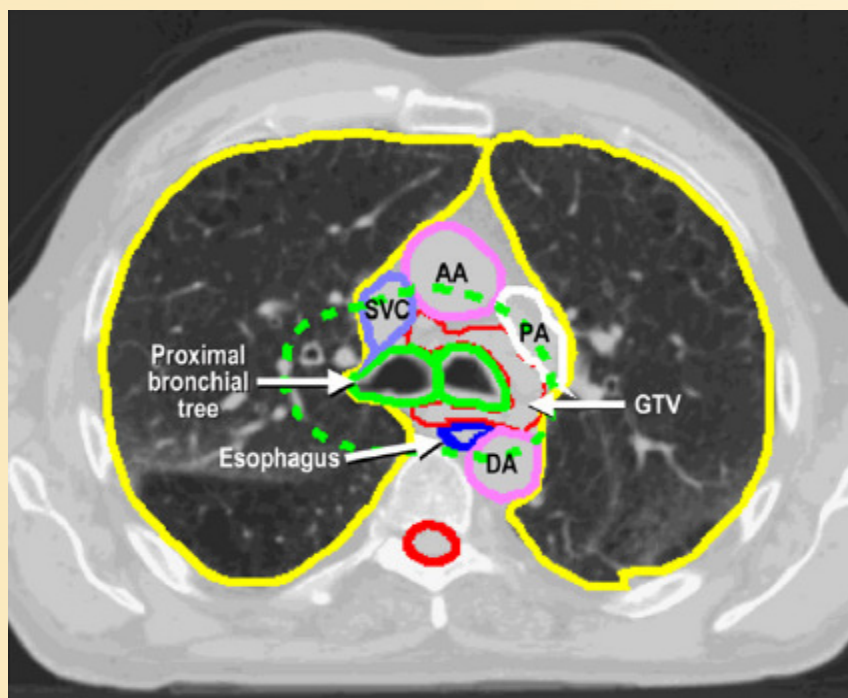
Esophagus, lung and cord continue...

and great vessels, proximal bronchial tree



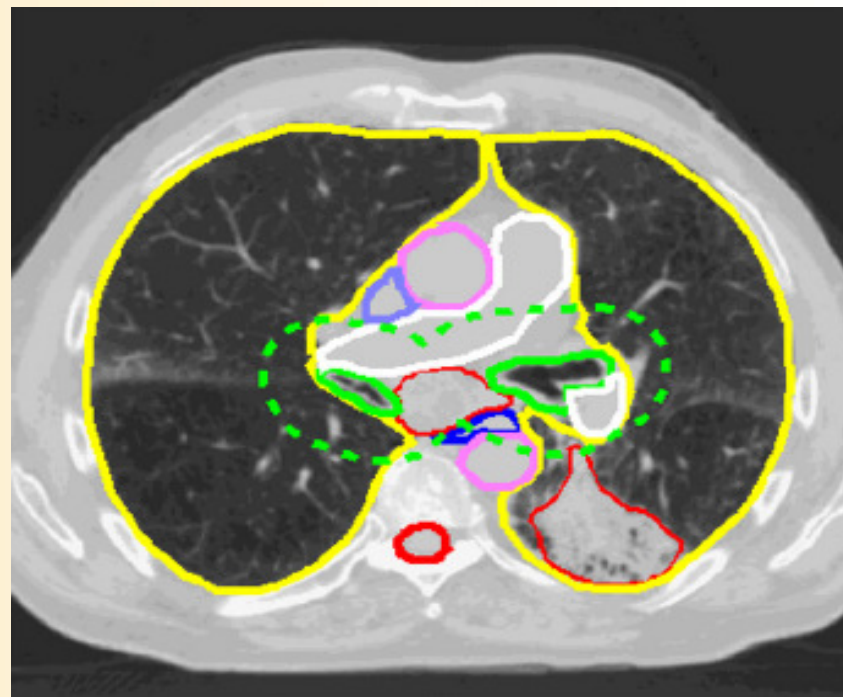
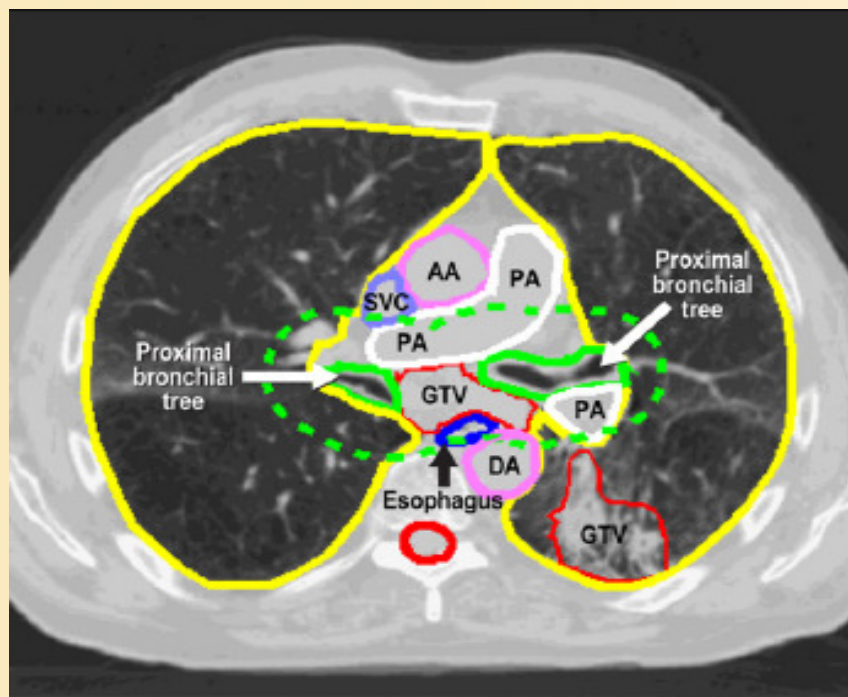
AA=ascending aorta, PA=pulmonary artery, DA=descending aorta,
SVC=superior vena cava

Esophagus, lung, cord, great vessels and proximal bronchial tree



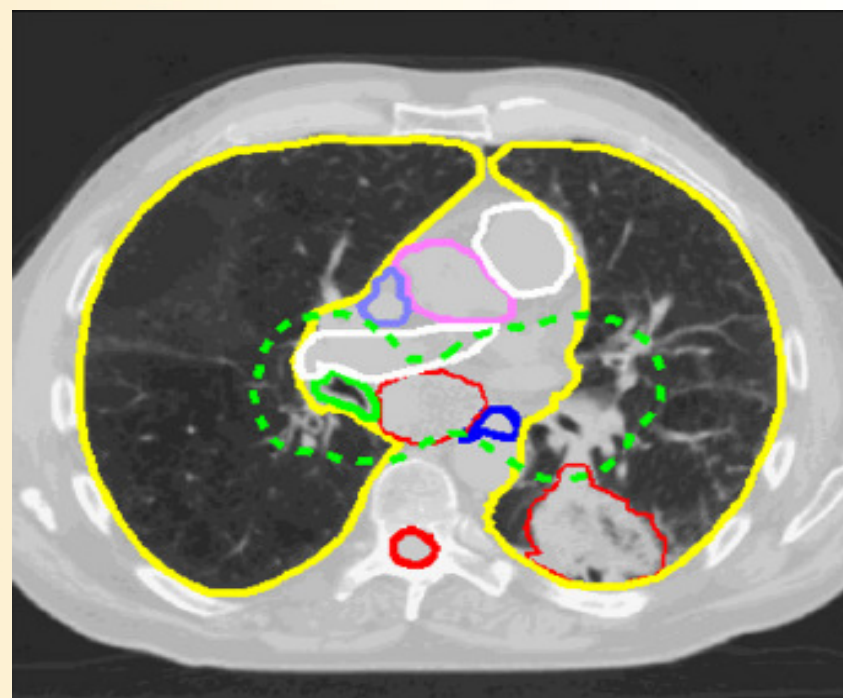
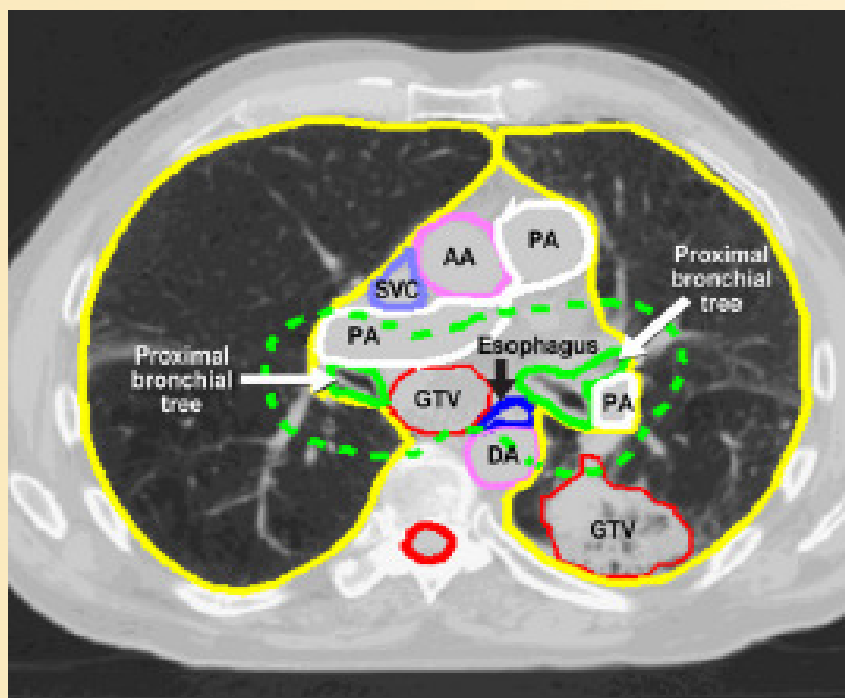
AA=ascending aorta, PA=pulmonary artery,
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Esophagus, lung, cord, great vessels and proximal bronchial tree



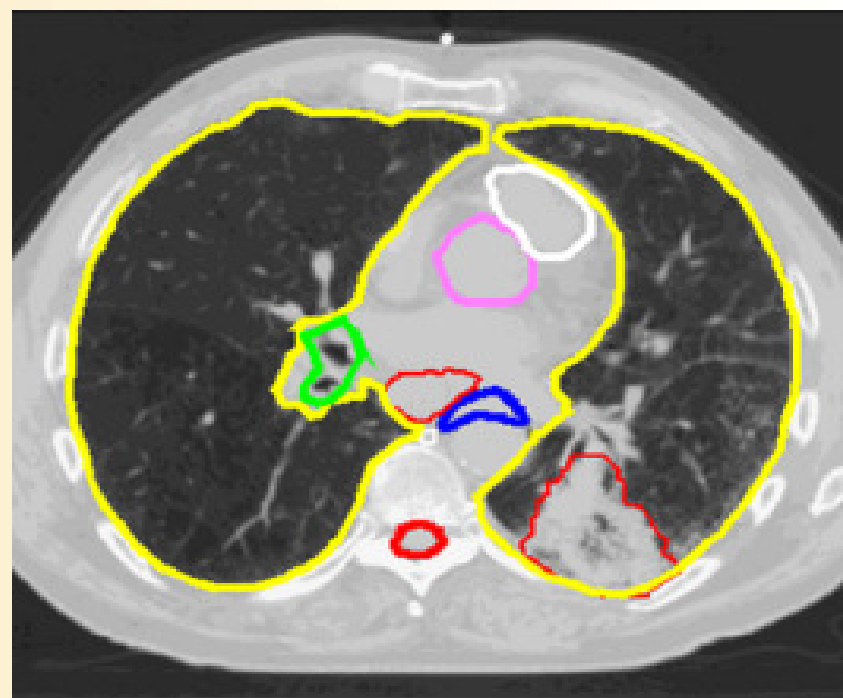
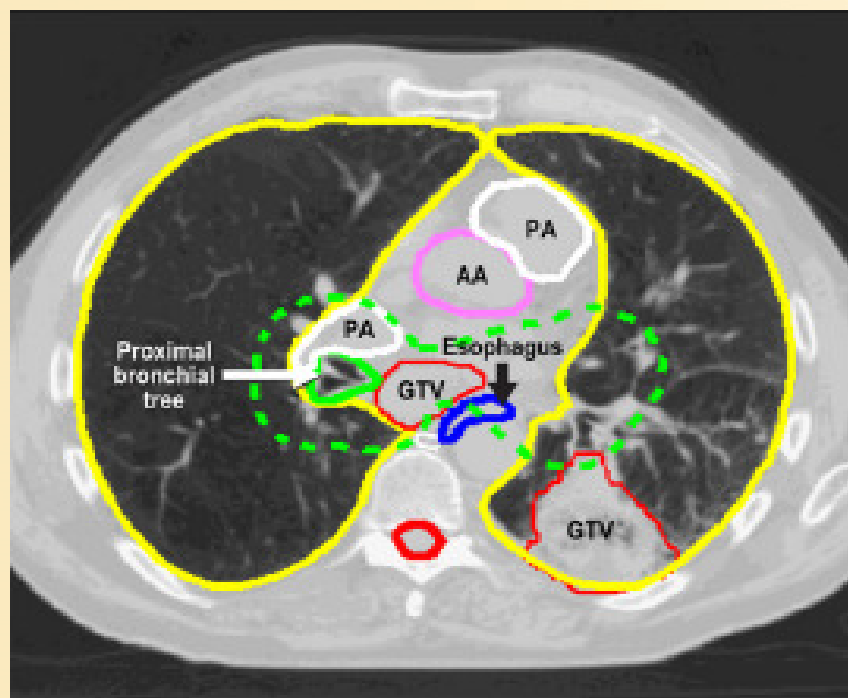
AA=ascending aorta, PA=pulmonary artery,
DA=descending aorta, SVC=superior vena cava

Esophagus, lung, cord, great vessels and proximal bronchial tree continue...



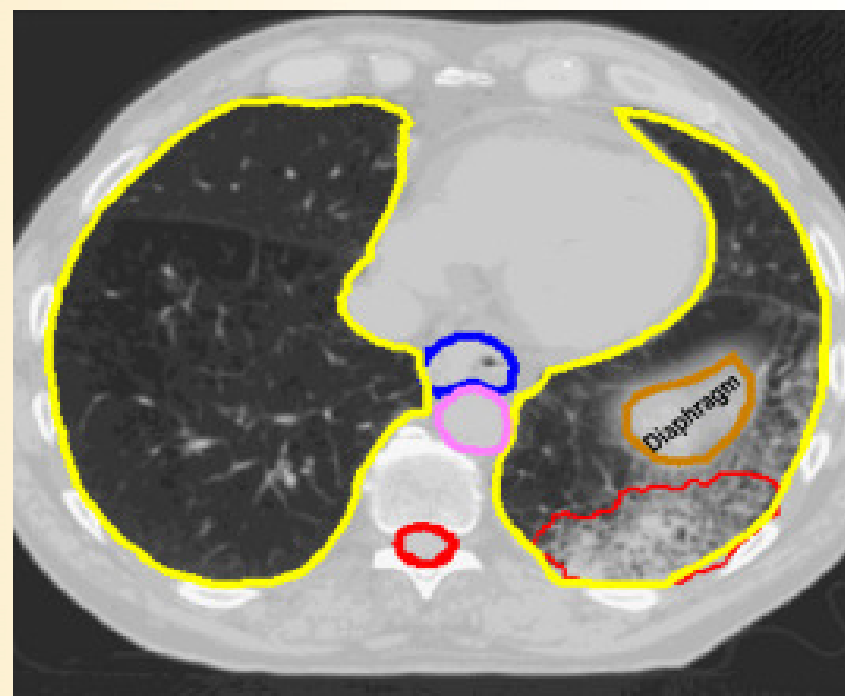
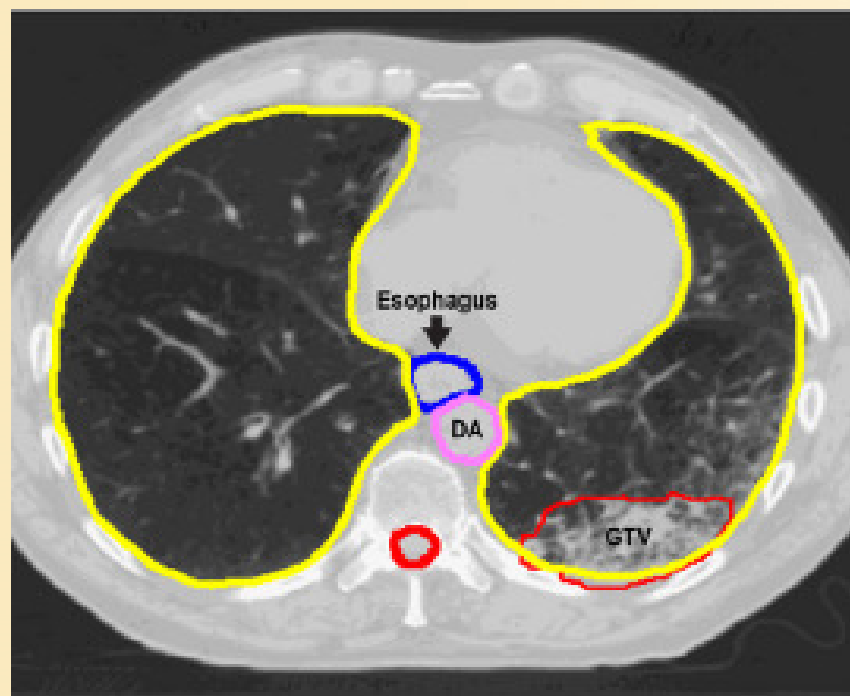
AA=ascending aorta, PA=pulmonary artery,
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Esophagus, lung, cord, great vessels and proximal bronchial tree



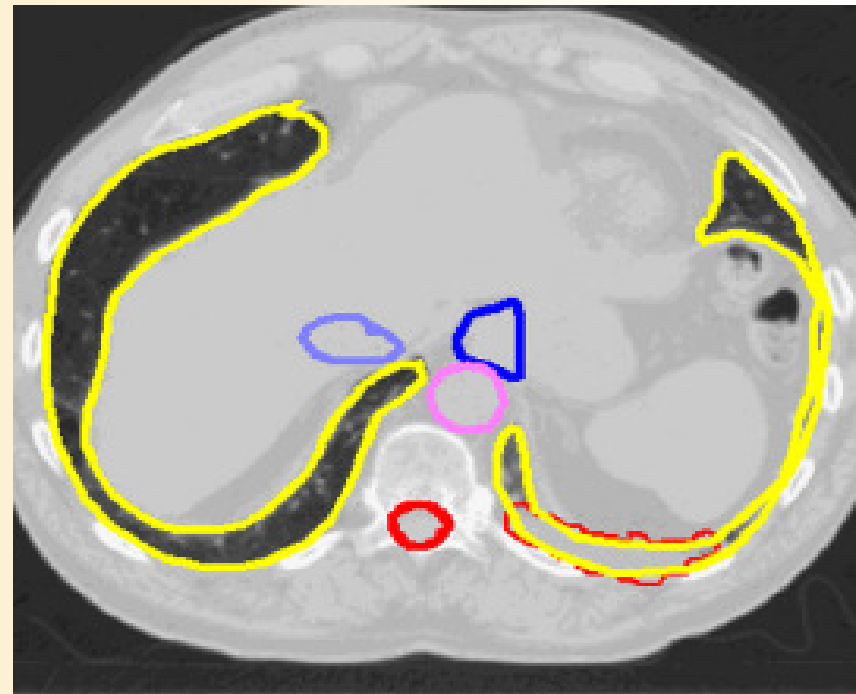
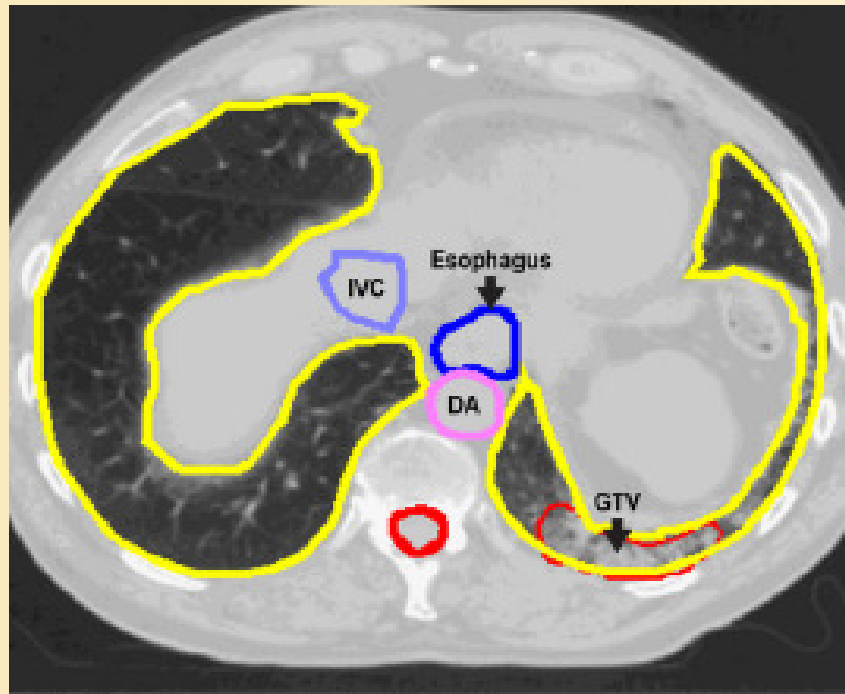
AA=ascending aorta, PA=pulmonary artery,
DA=descending aorta, SVC=superior vena cava

Esophagus, lung, cord continue...



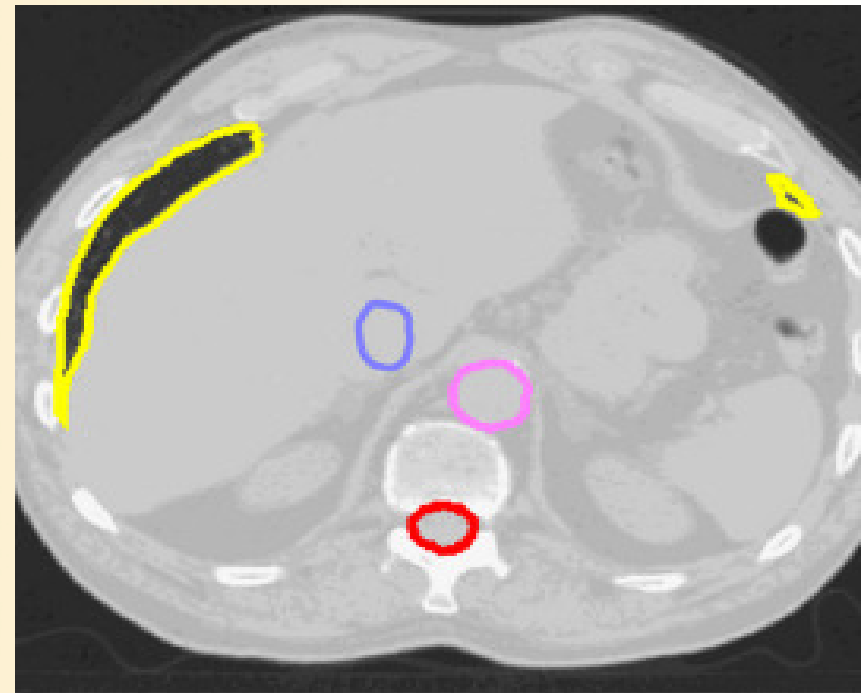
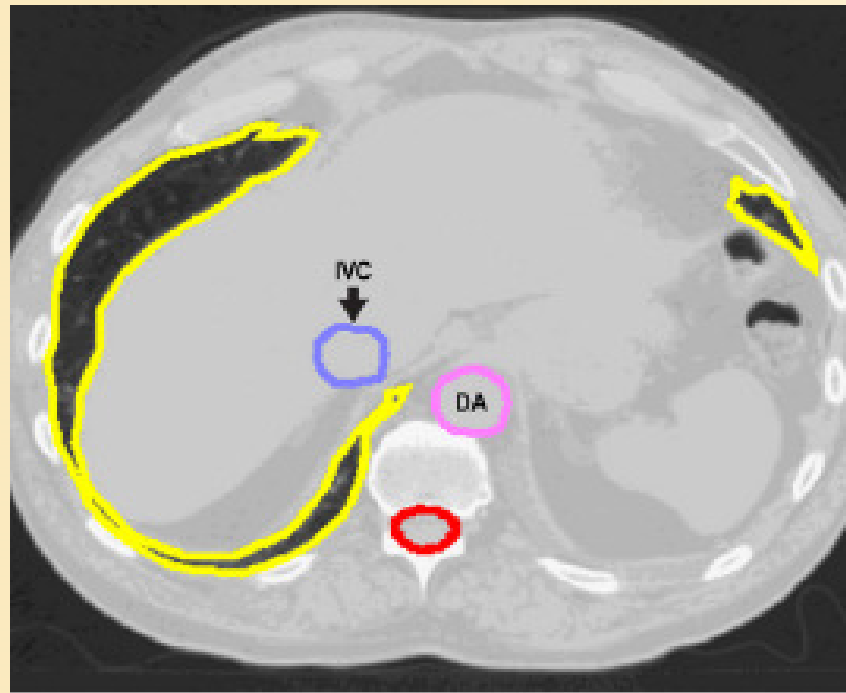
DA=descending aorta

**Esophagus ends at gastric-esophageal junction,
Lung and cord continue...**



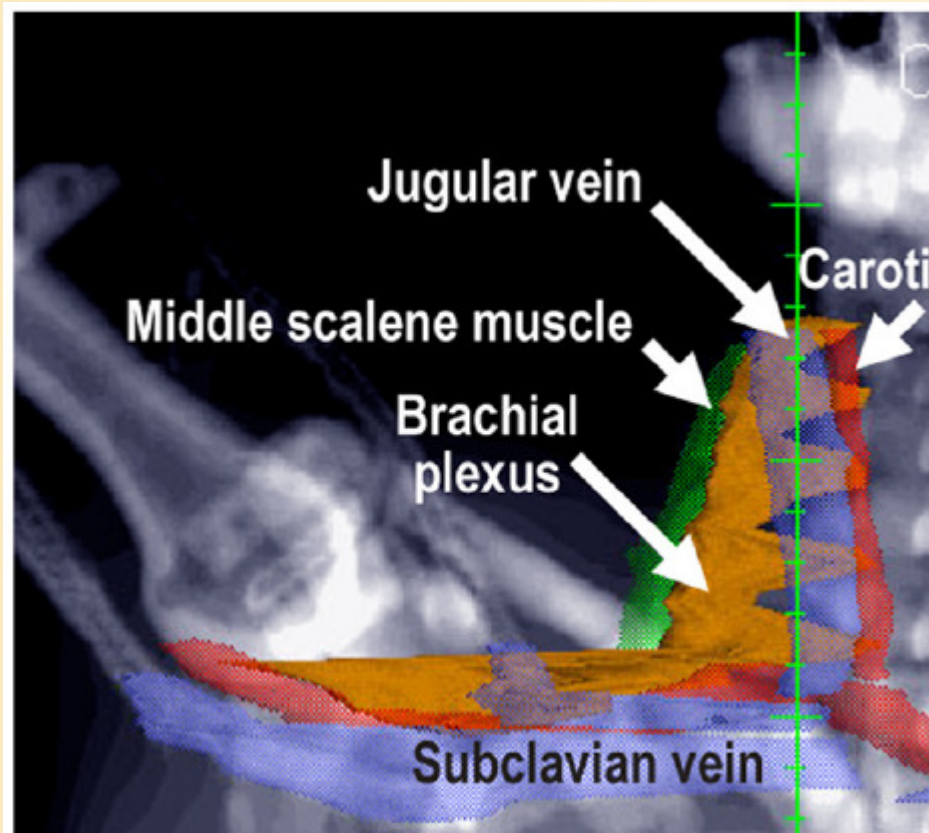
IVC=inferior vena cava, DA=descending aorta

Lung ends, cord continues until the bottom of L2 Vertebral body

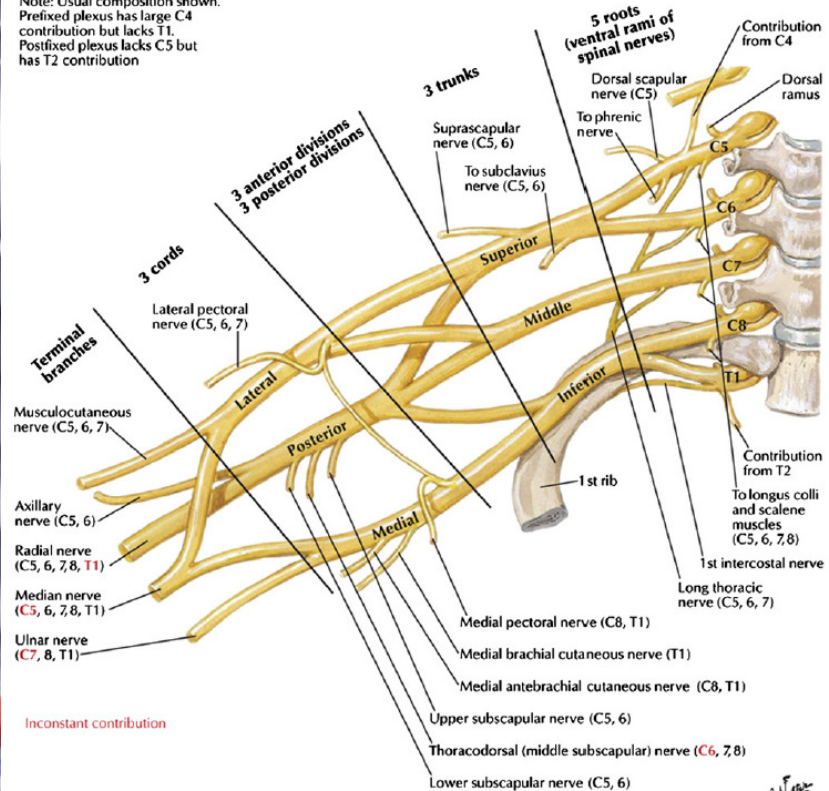


IVC=inferior vena cava, DA=descending aorta

Atlas for Brachial Plexus



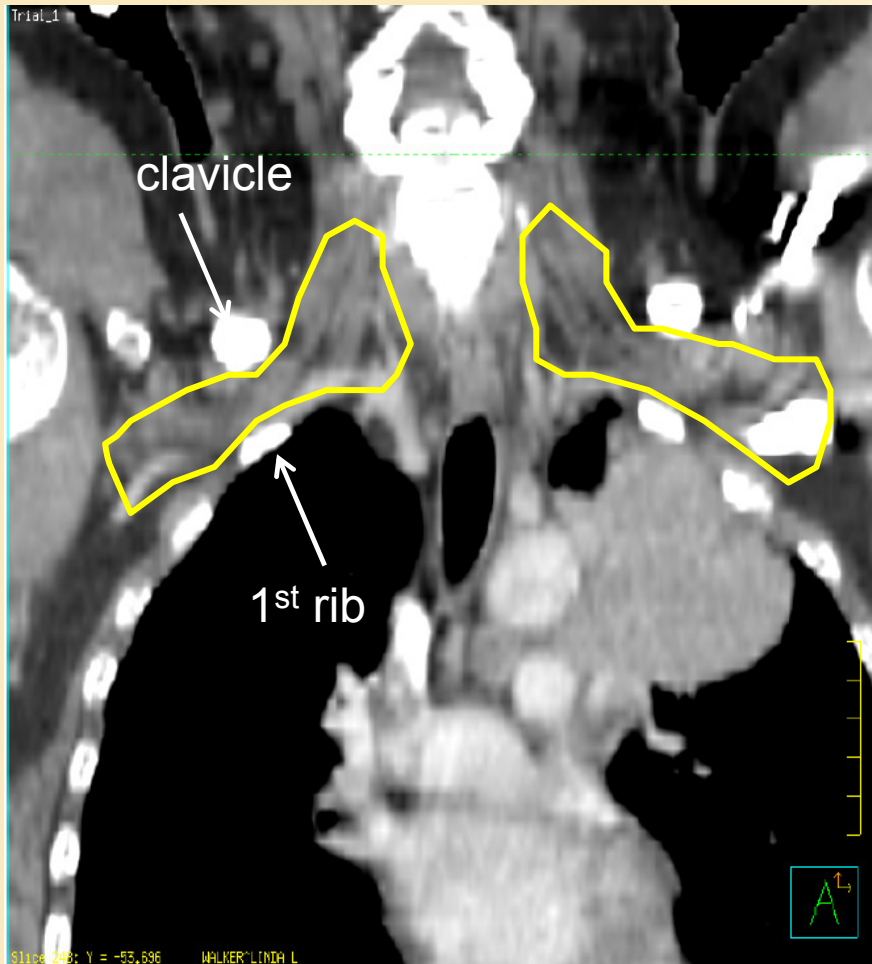
Note: Usual composition shown.
Prefixed plexus has large C4 contribution but lacks T1.
Postfixed plexus lacks C5 but has T2 contribution



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Locating the Brachial Plexus

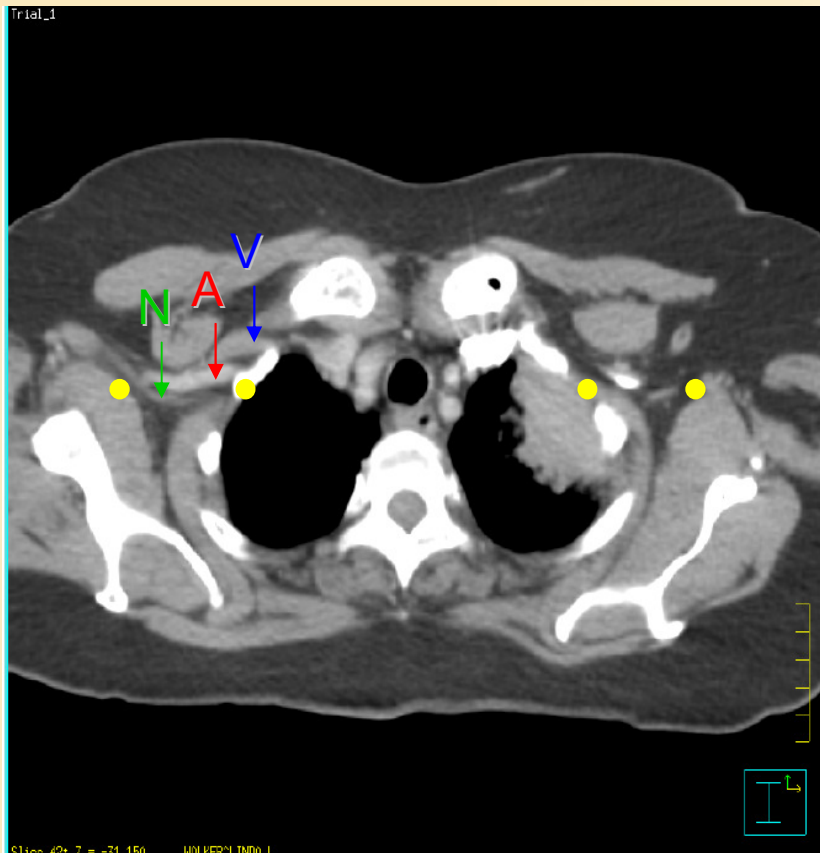
Timmerman's Trick-1



- Vein, artery, and nerve (VAN, anterior to posterior) will go over the 1st rib and under the clavicle
- Using coronal images, find the plane where vascular/nerve structures (tubes and wires) pass between the 1st rib and clavicle
- Roughly contour these neuro-vascular tissues in this coronal plane (as shown in yellow)
- You will use these rough contours in the next step

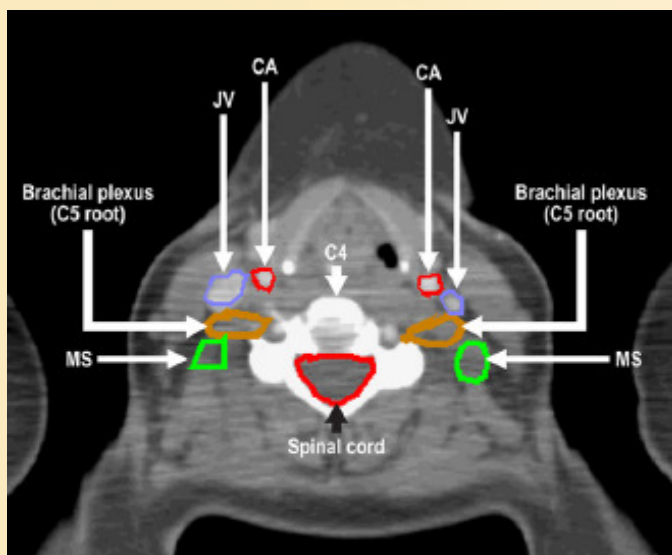
Locating the Brachial Plexus

Timmerman's Trick-1

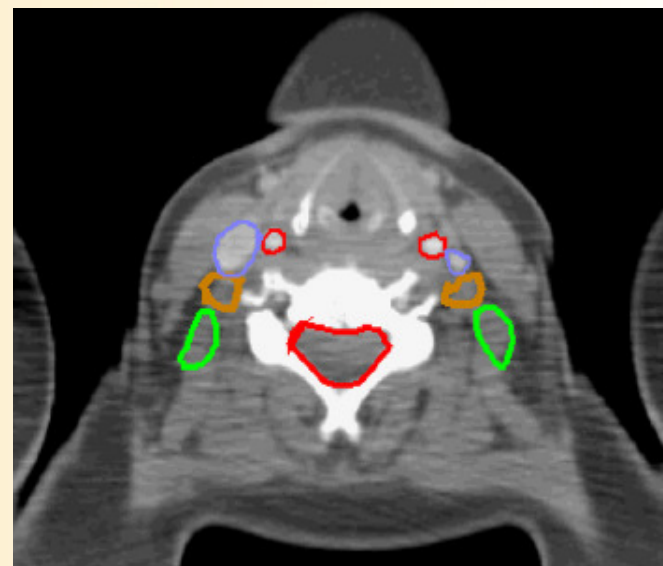


- Project coronal contours onto axial images (yellow points shown on axial image)
- In the region between the projected points, identify the VAN on either side. Contour the “N” as the root(s) of the brachial plexus
- Note: Finding the brachial plexus on the uninvolved side will help in finding it on the involved side
- Note: IV contrast greatly facilitates this task (see contrast in artery)

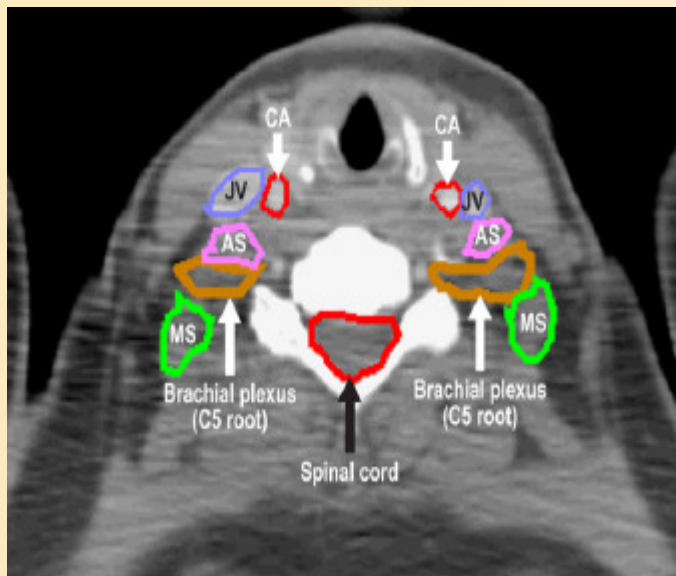
Brachial plexus starts between C4 C5



C5 root, C4 VB



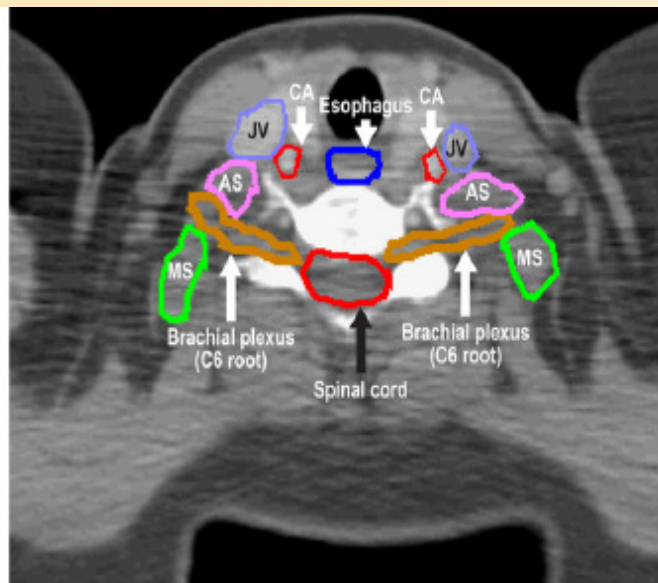
C5 root, C4-C5 disk



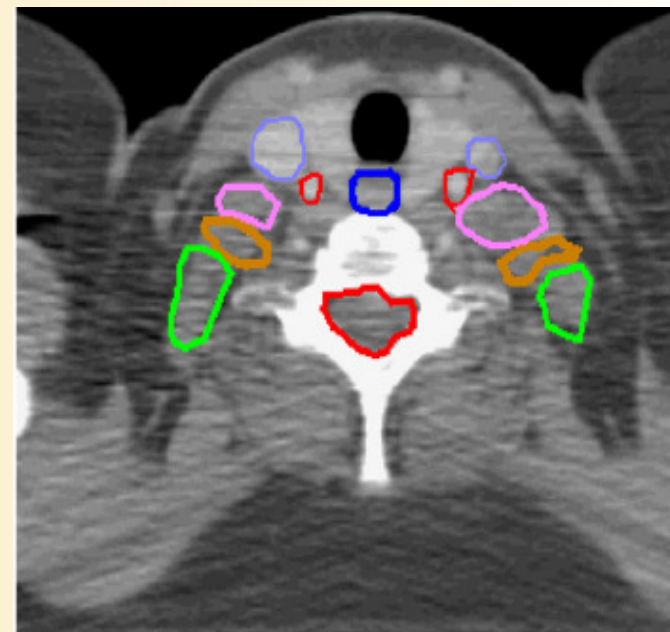
C5 root, C5VB



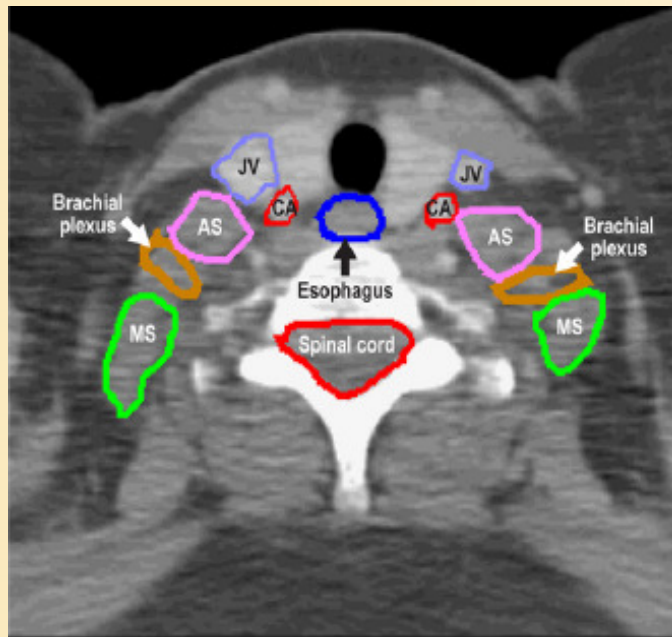
C5 root, C5VB



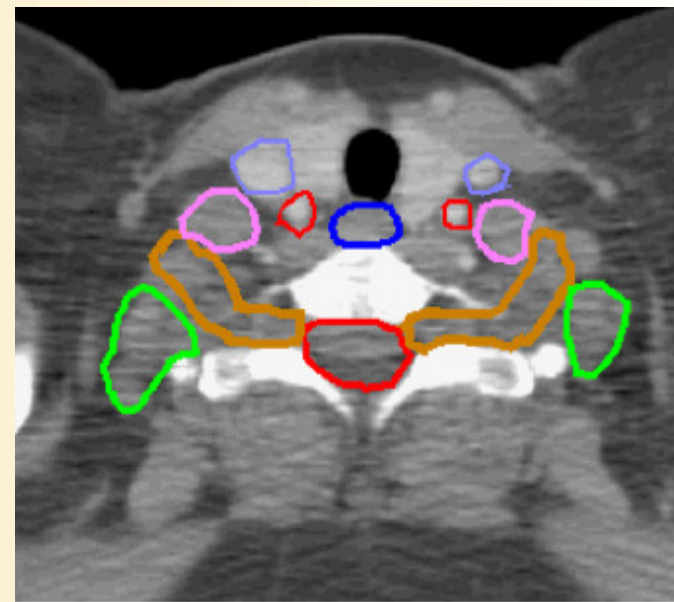
Superior (C5,C6) trunk, C6 root, C5 /C6 disk



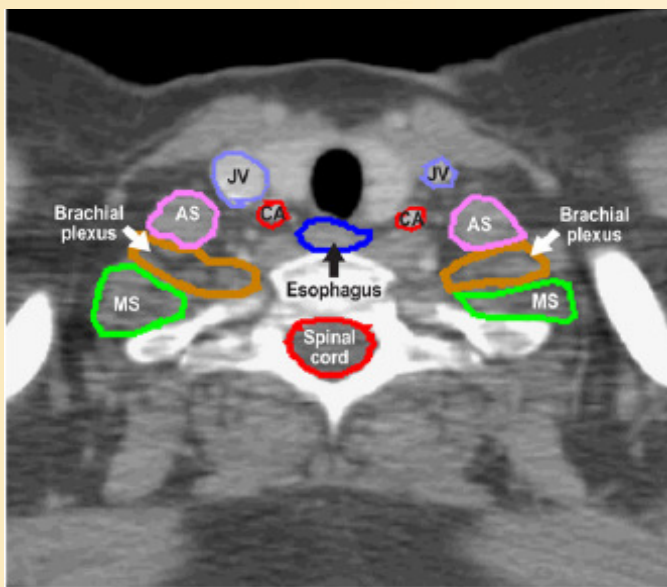
Superior (C5,C6) trunk, C6 VB



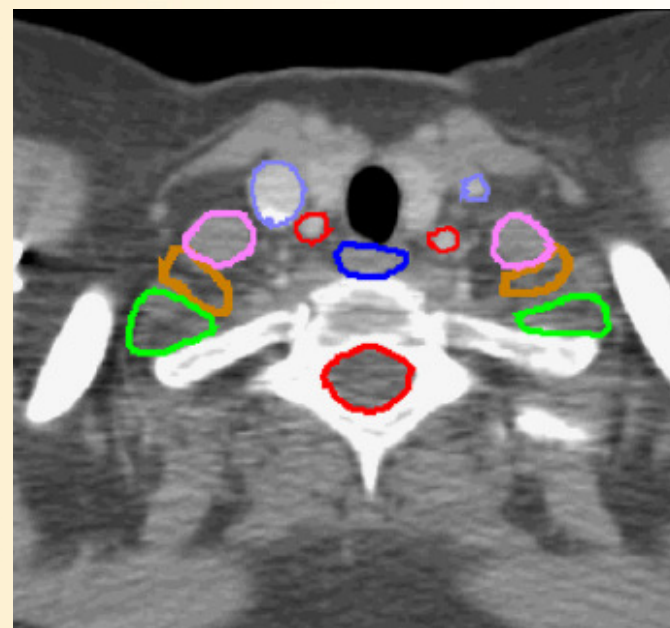
Superior (C5,C6)trunk, C6VB



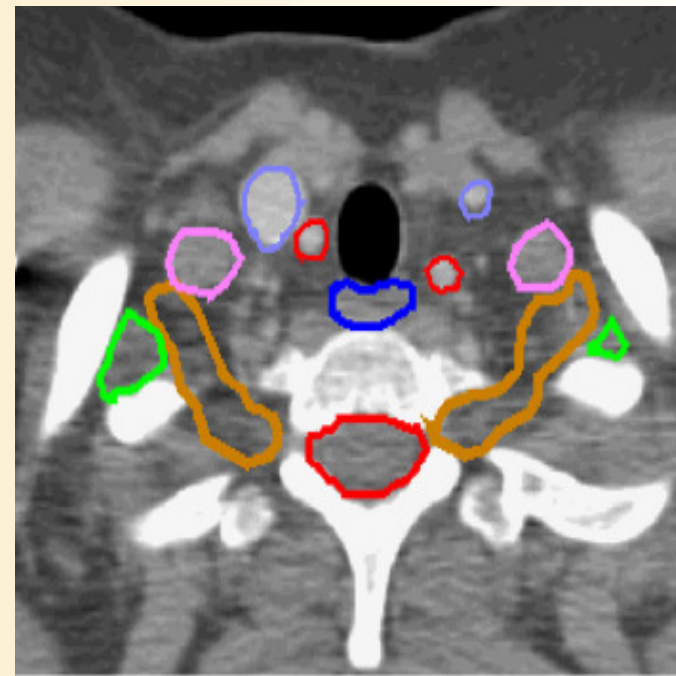
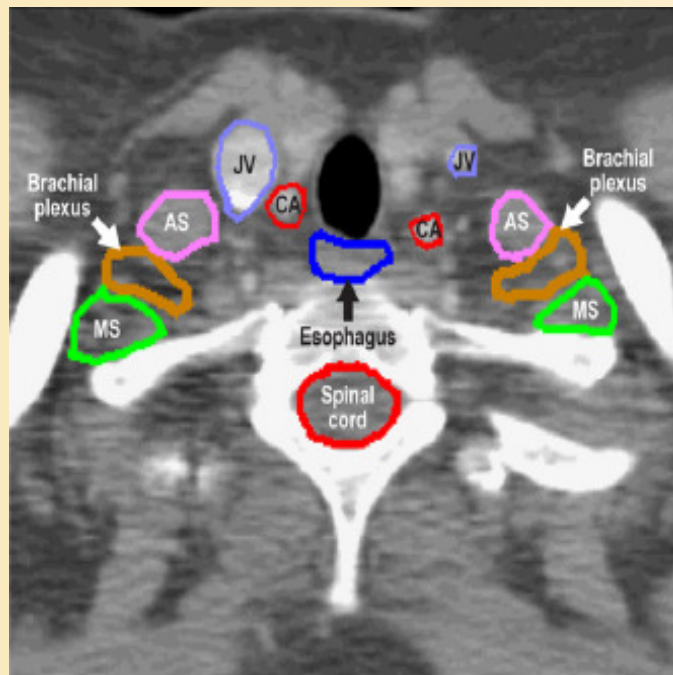
Superior (C5,C6) trunk, C7 root, C6/C7 disk

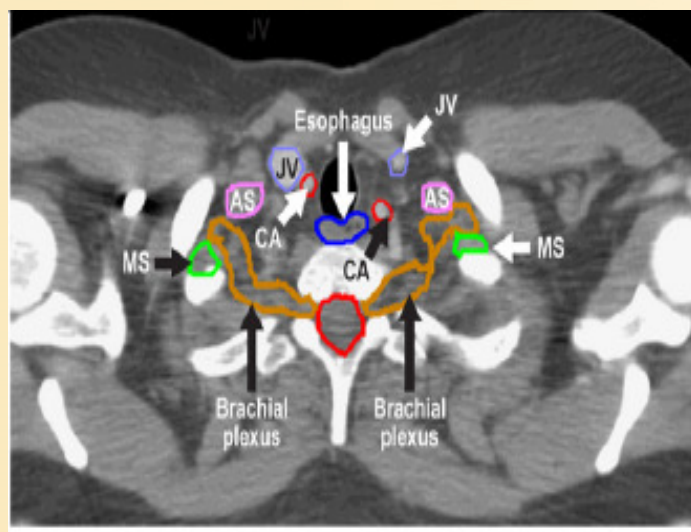


Superior (C5, C6) and middle (C7) trunks C7
VB

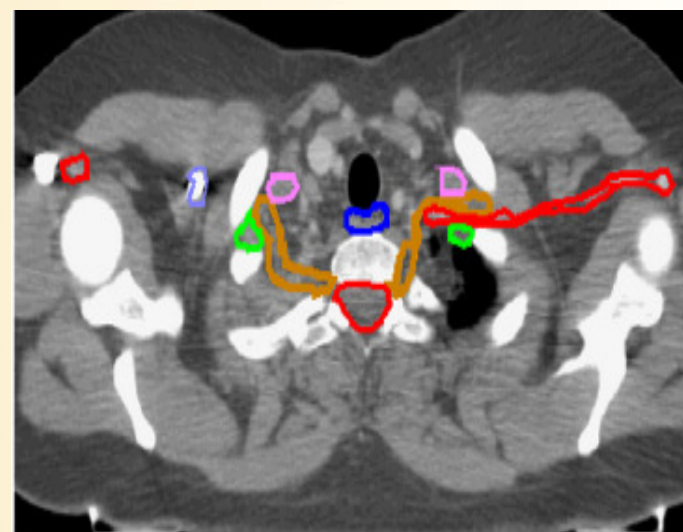


Superior (C5, C6) & C 7 trunks, C7 VB

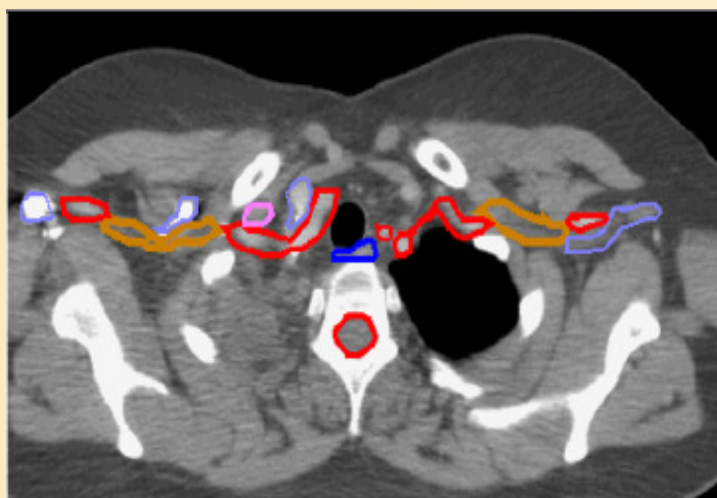




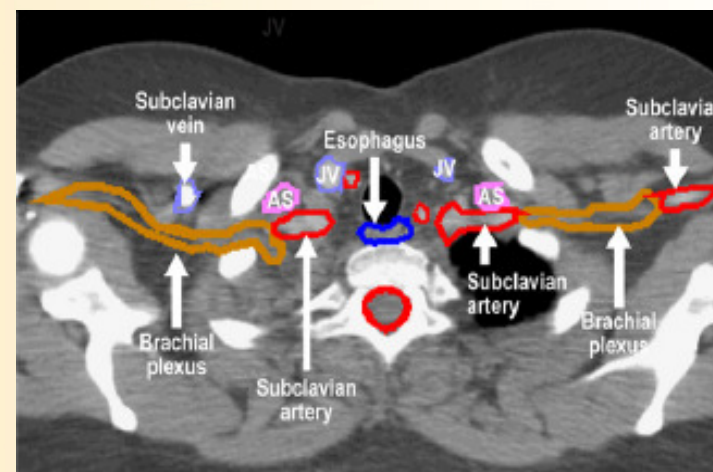
C5, C6, C7, C8 trunks, T1 root, T1VB



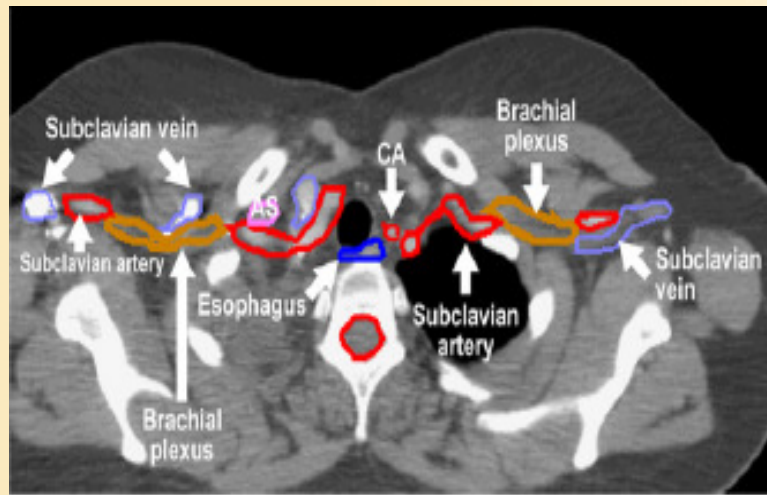
C5, C6, C7, C8 trunks, T1 root, T1/T2 disk



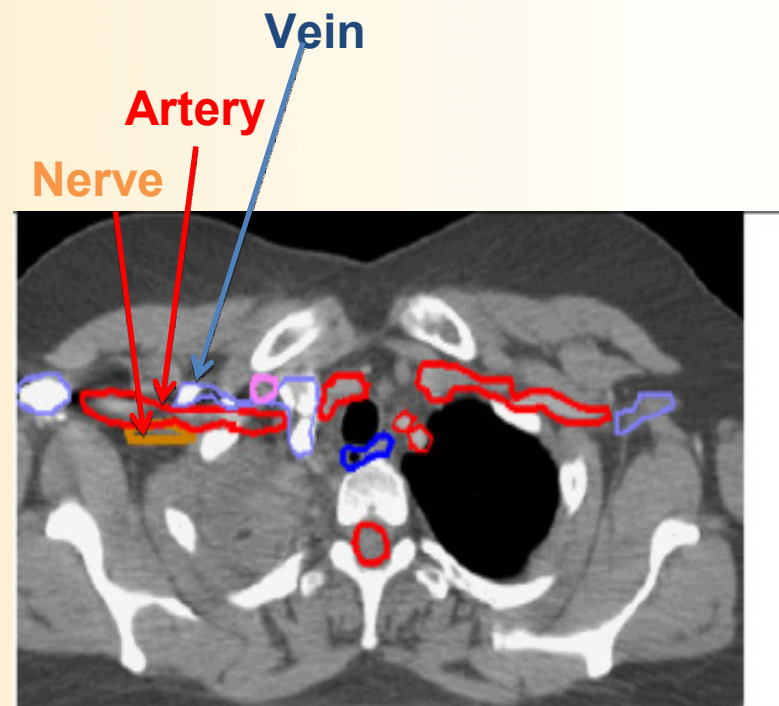
Superior (C5, C6), middle (C7), and inferior (C8 & T1) trunks, T2VB



Superior (C5, C6), middle (C7), and inferior (C8 & T1) trunks, T2VB

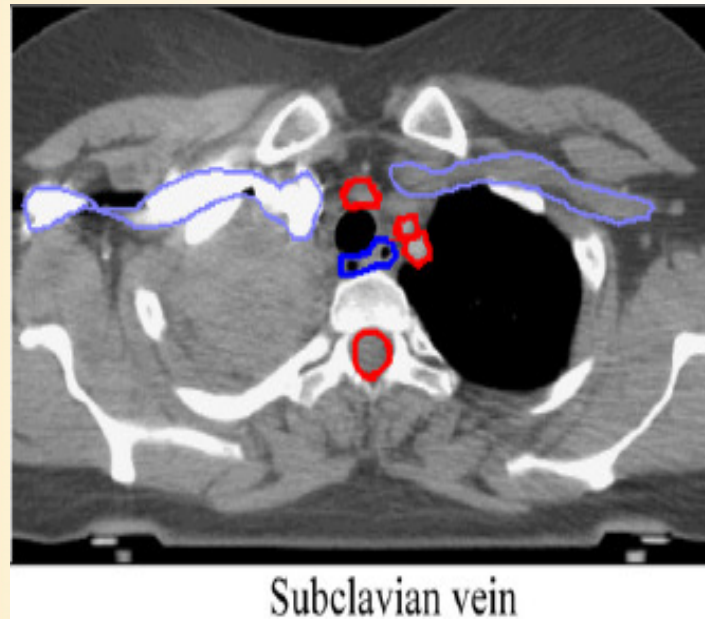
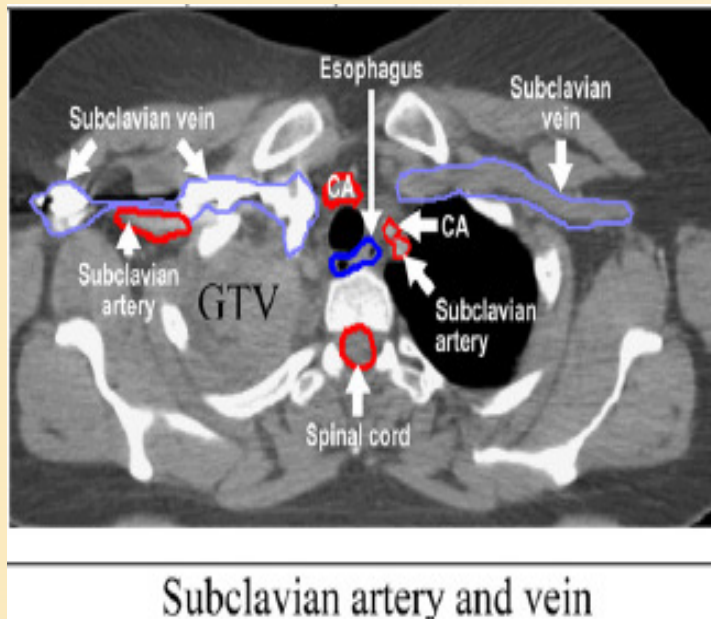


Superior (C5, C6), middle (C7), and inferior (C8 & T1) trunks, T2VB



The most inferior right trunk and vessels, T2/T3 disk

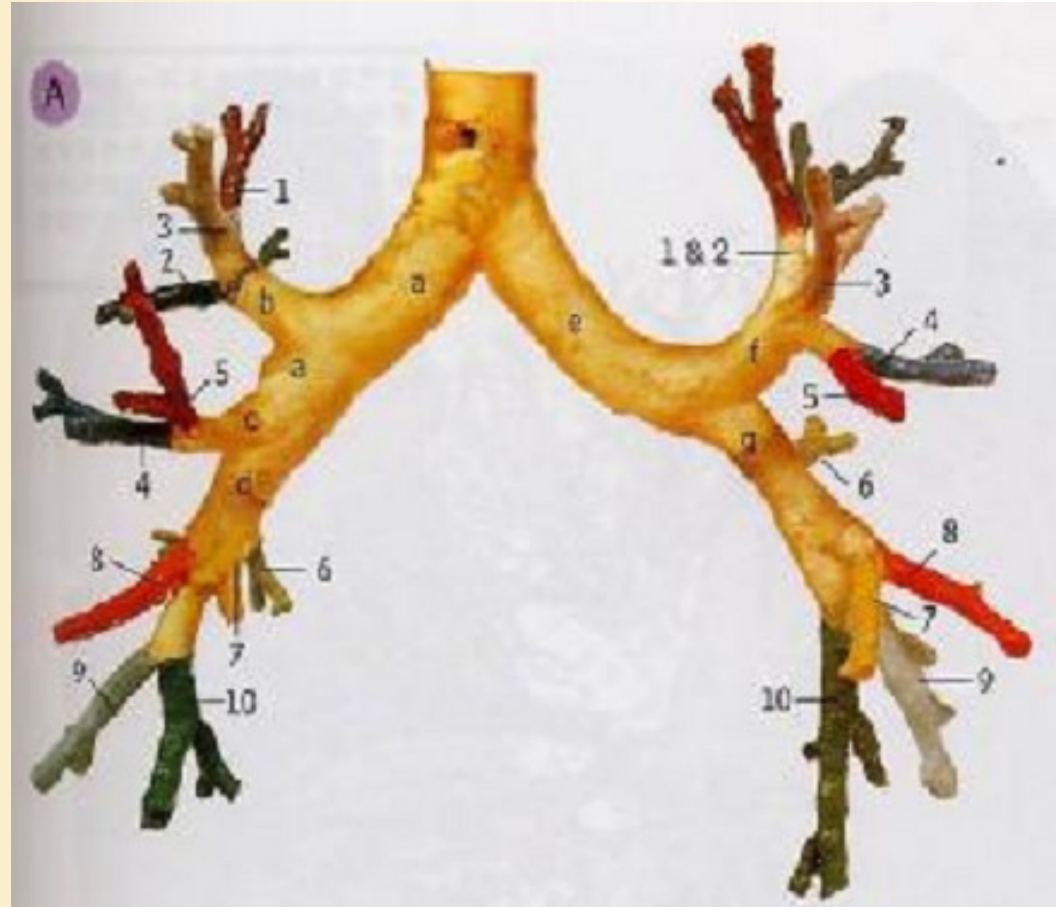
Brachial plexus not visible any more



Proximal Bronchial Tree (PBT)

PBT should include the distal 2 cm of the trachea, the carina, the right and left mainstem bronchi, the right and left upper lobe bronchi, the intermedius bronchus, the right middle lobe bronchus, the lingular bronchus, and the right and left lower lobe bronchi (a, b, c, d, e, f, g in the figure)

PBT can be contoured by autosegmenting the airspace of the central airway with 3 mm expansion (2 mm for lobar bronchus, 3 mm for main bronchus, 4 mm for trachea)



Proximal Bronchial Tree

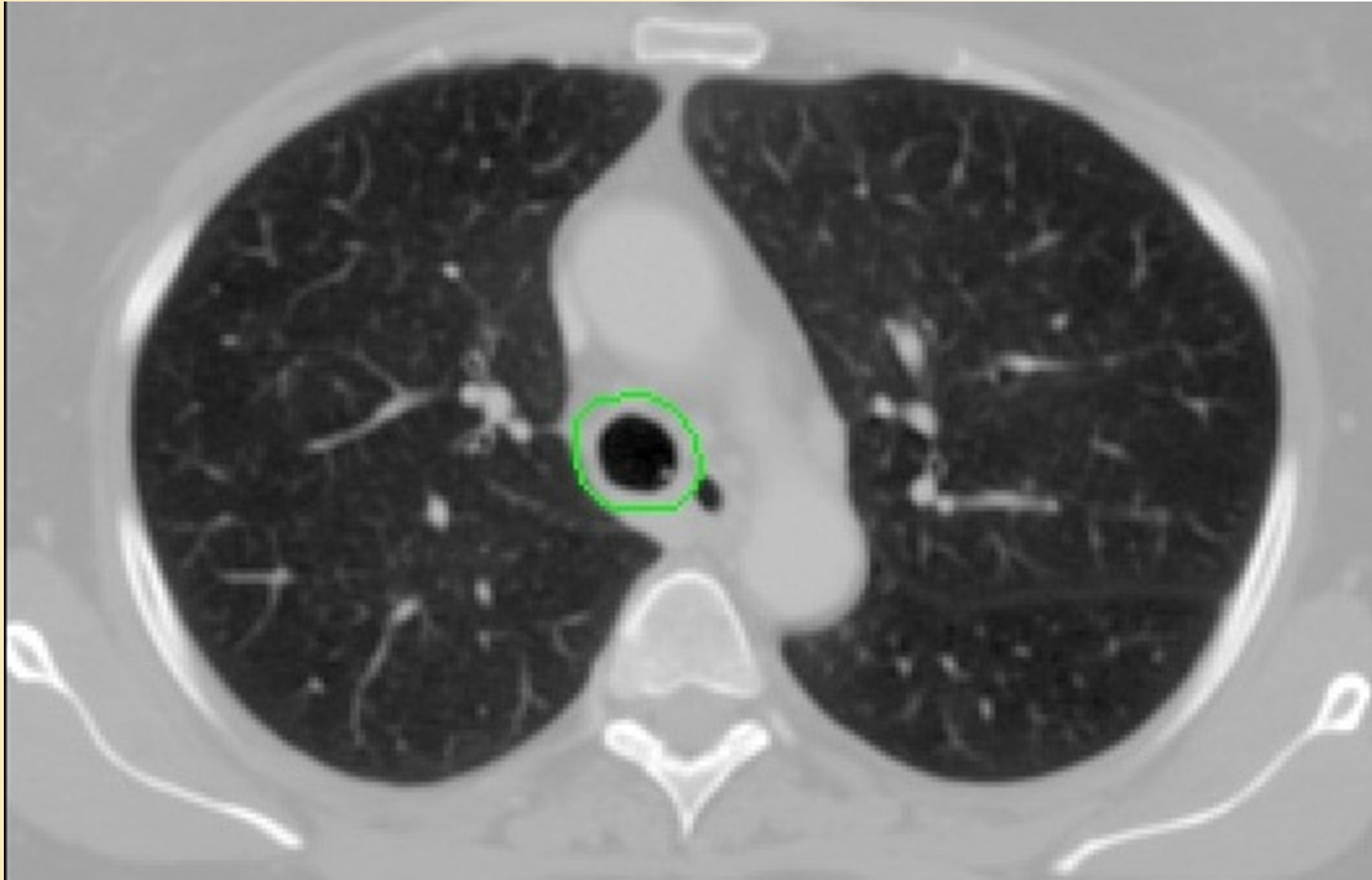
- The proximal bronchial tree can be contoured using mediastinal windows on the CT scan to correspond to the mucosal, submucosa, and cartilage rings and airway channels associated with these structures. It can be contoured as one structure, including the most inferior 2 cm of distal trachea and the proximal airways of both sides. Contouring the lobar bronchi should end immediately at the level of a segmental bifurcation.

Recommendation based on Timmerman et al for RTOG 0236 and RTOG 0618, Bezjak et al for RTOG 0813

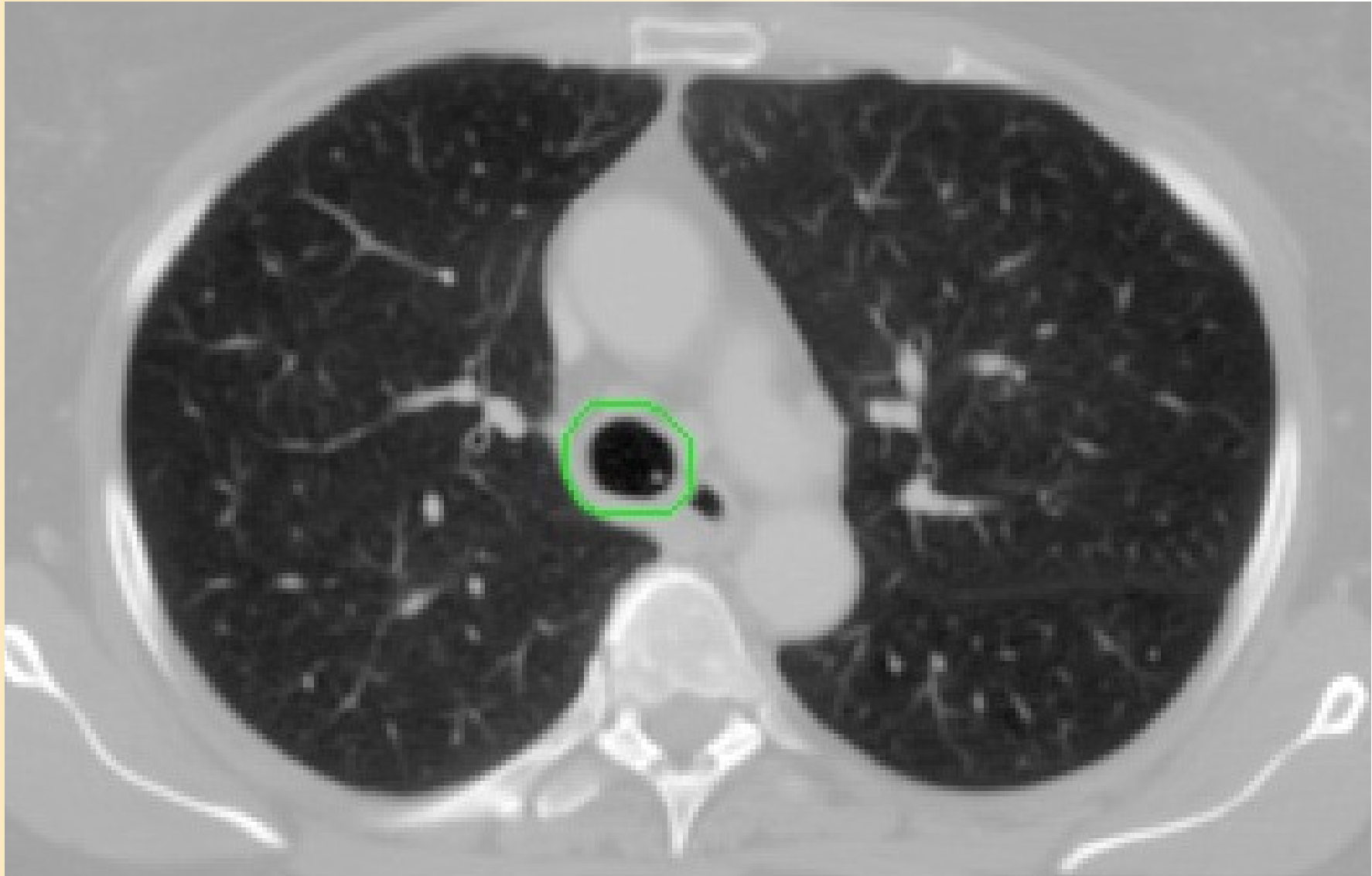
PBT starts at 2 cm above carina



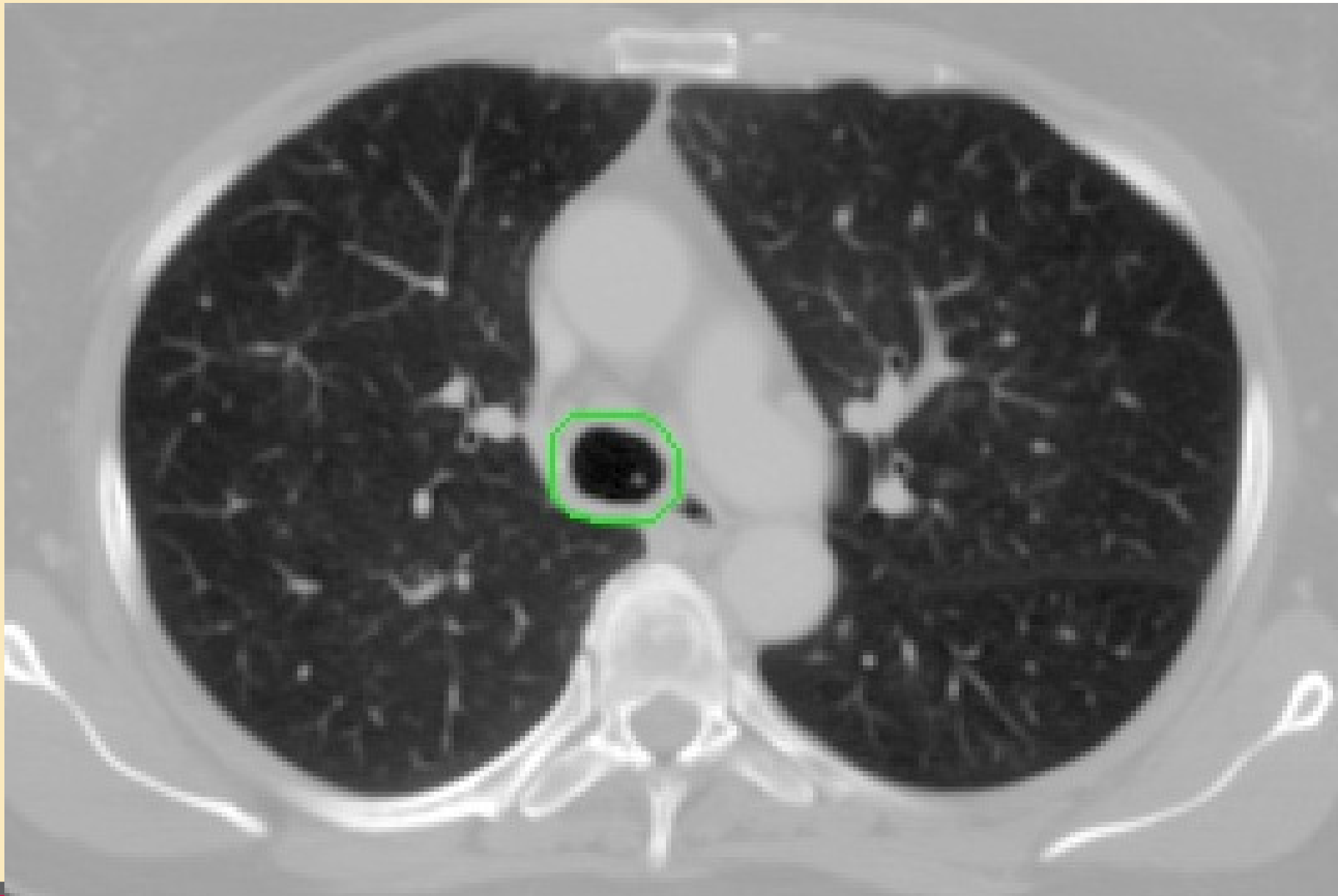
Proximal Bronchus Tree continues...



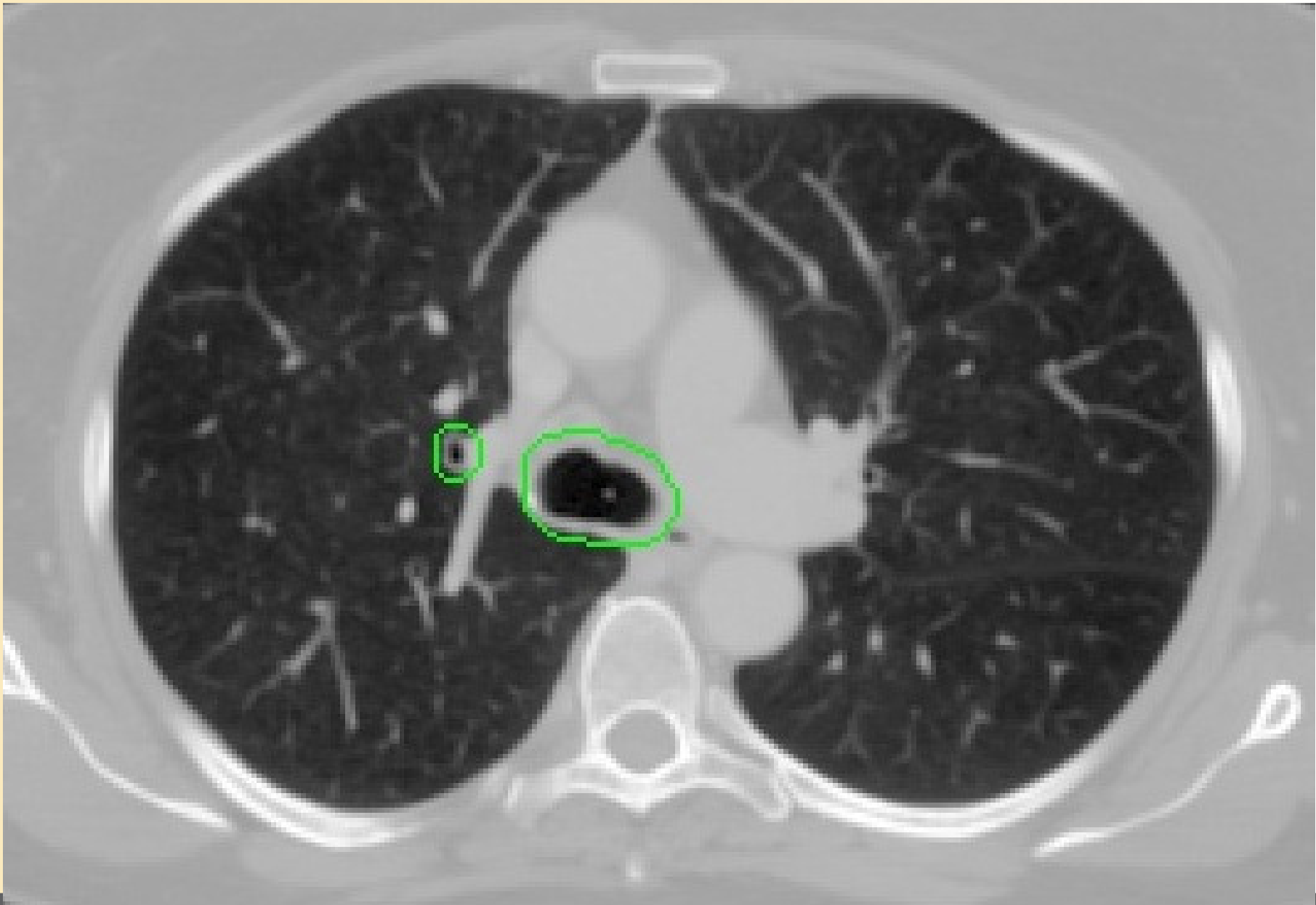
Proximal Bronchus Tree continues...

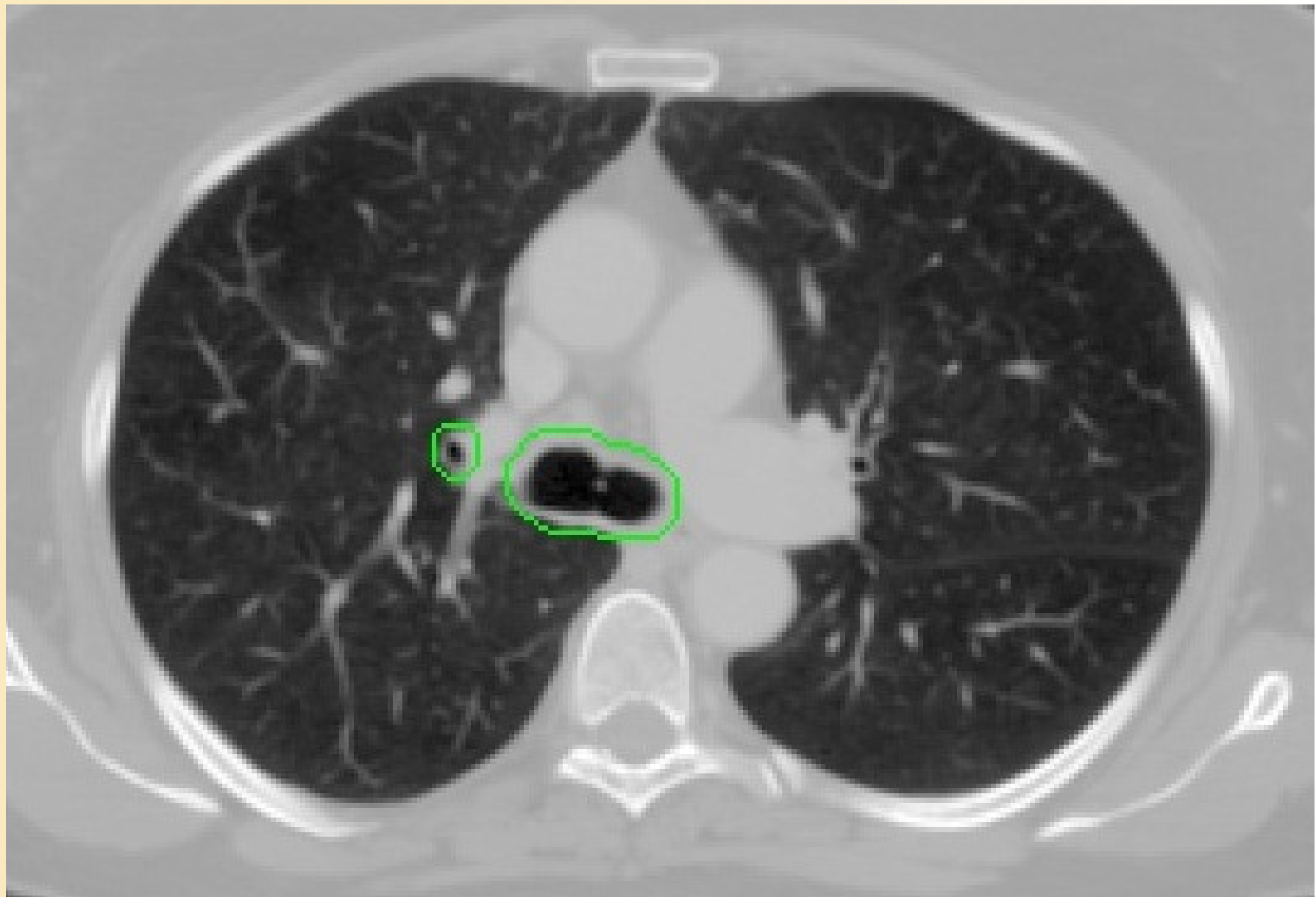


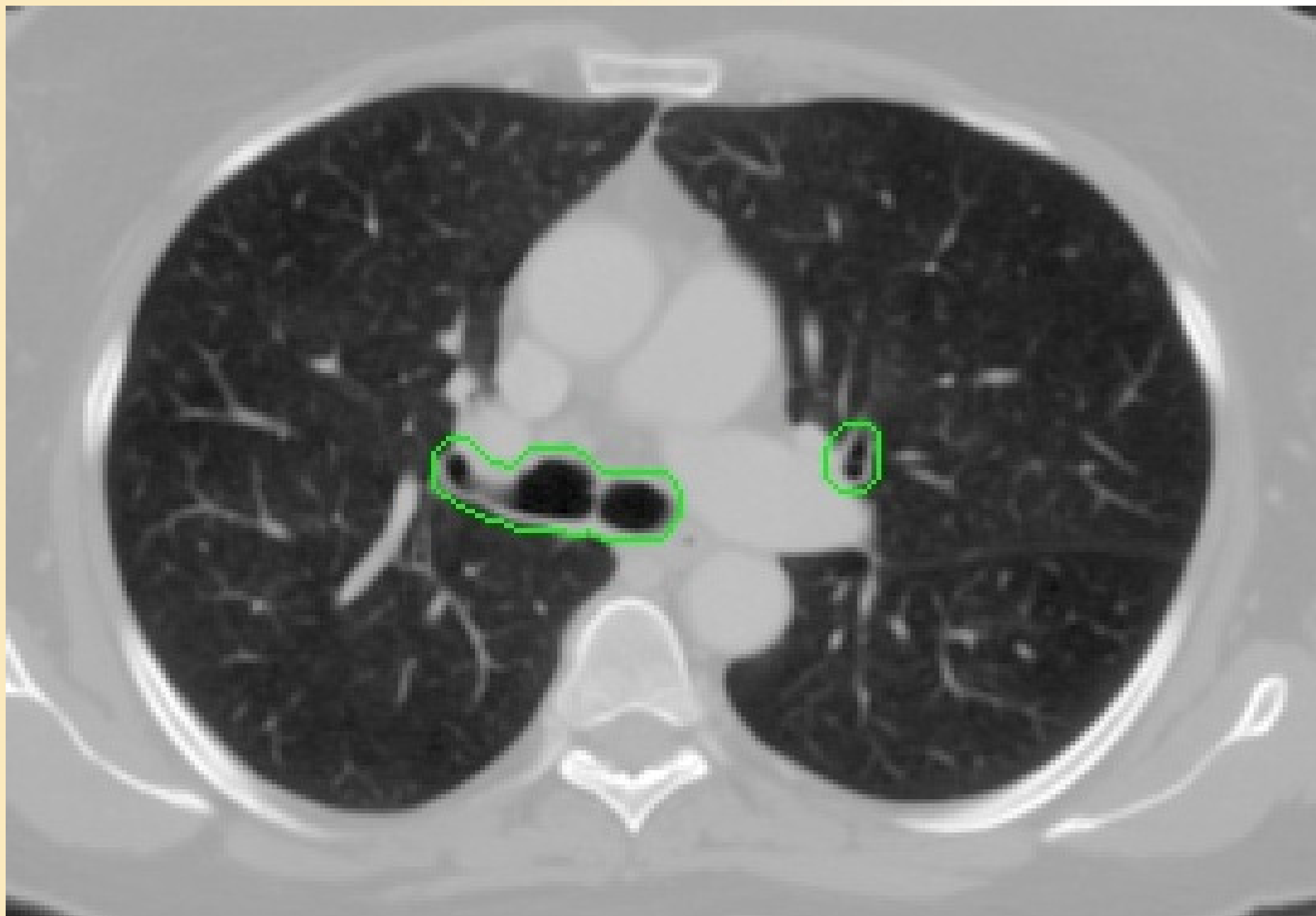
Proximal Bronchus Tree Continues...



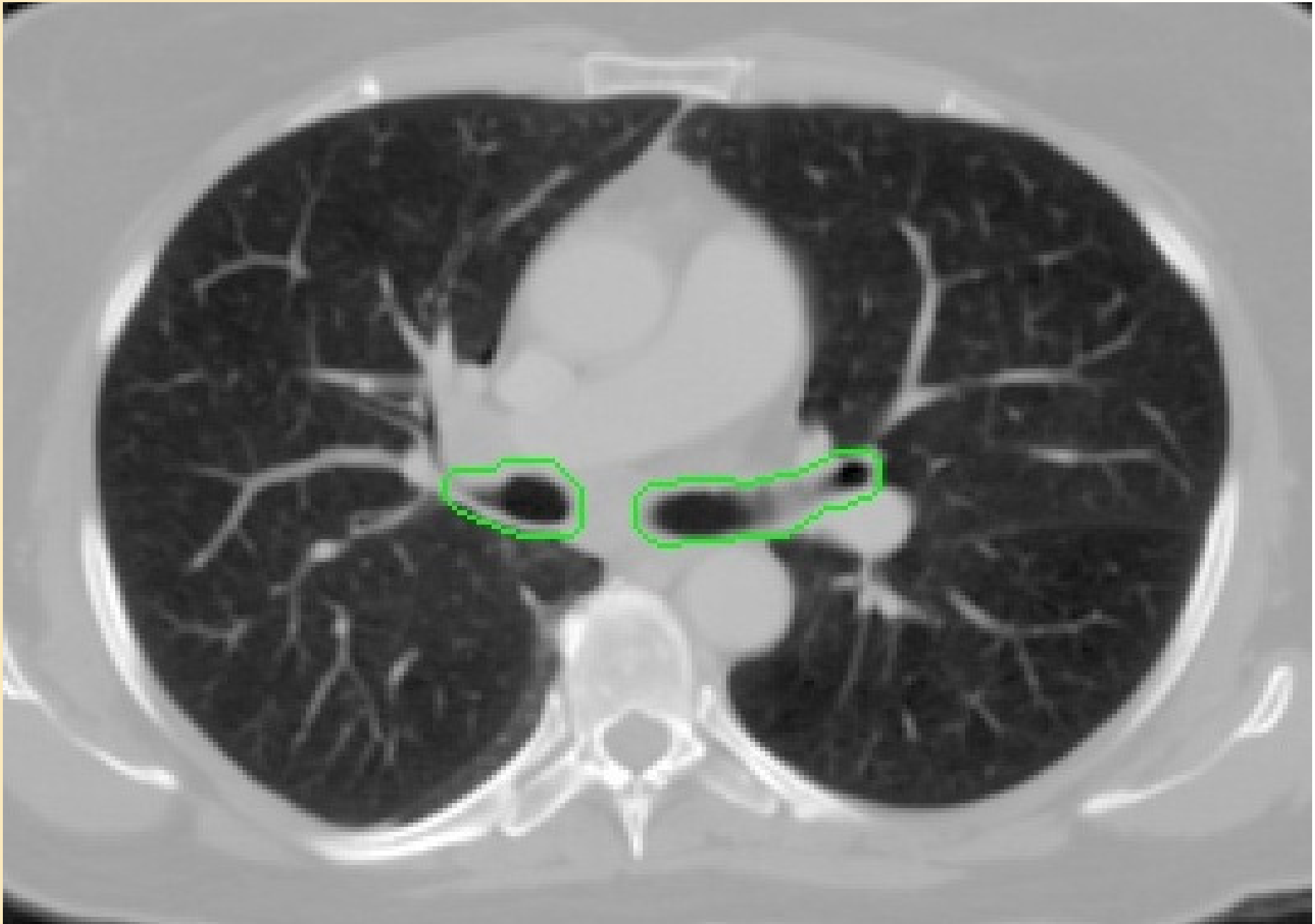
Proximal Bronchus Tree continues...

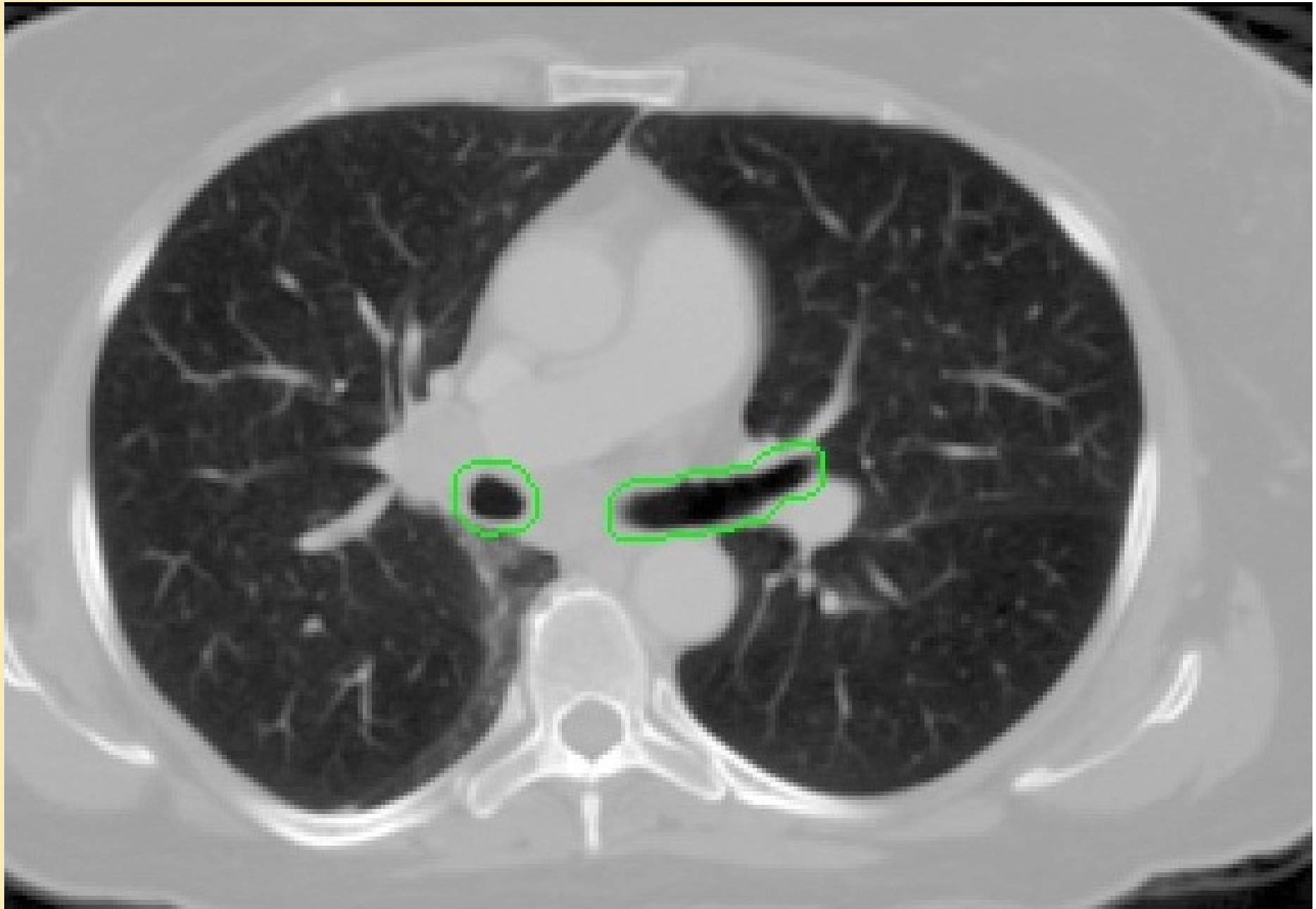


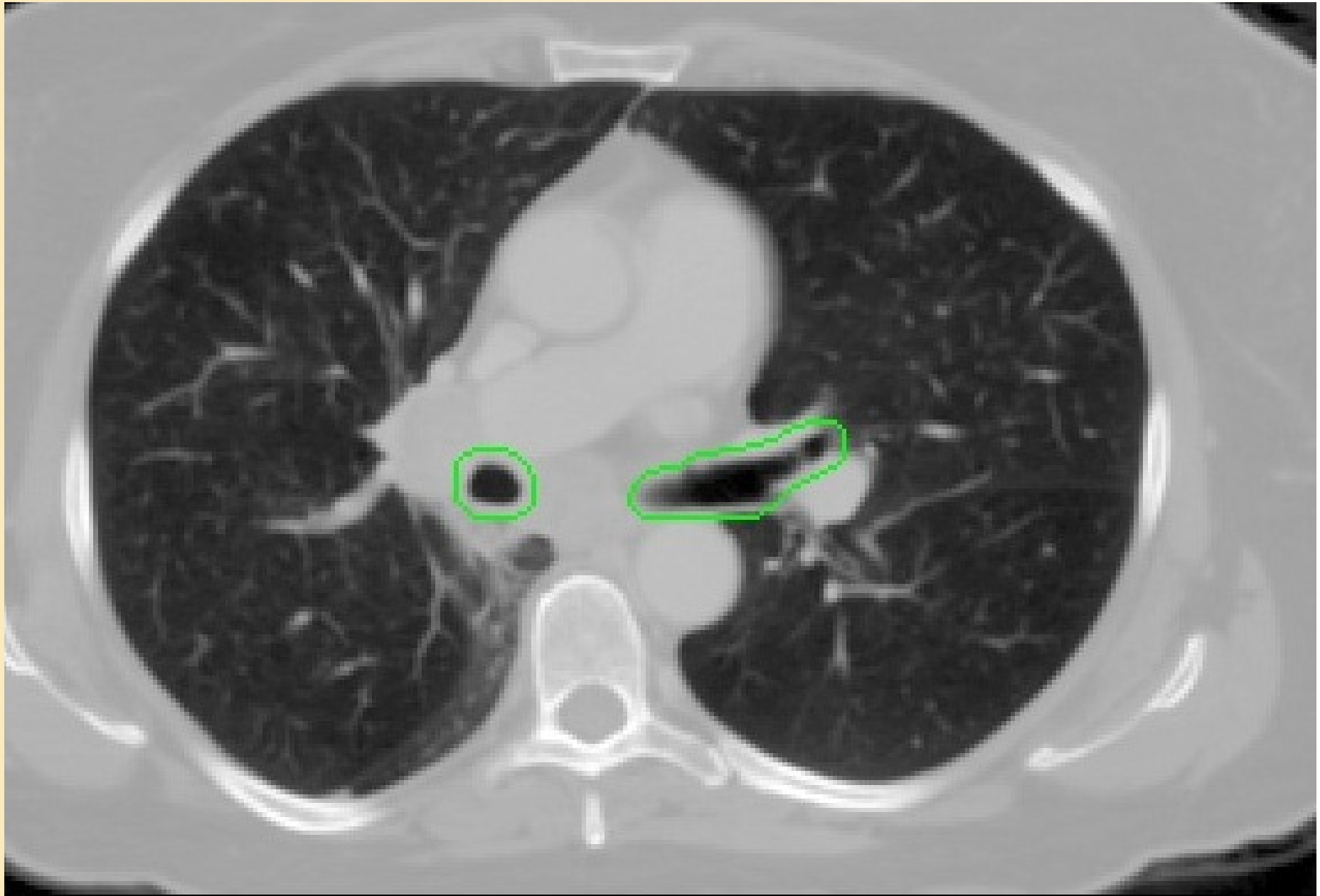


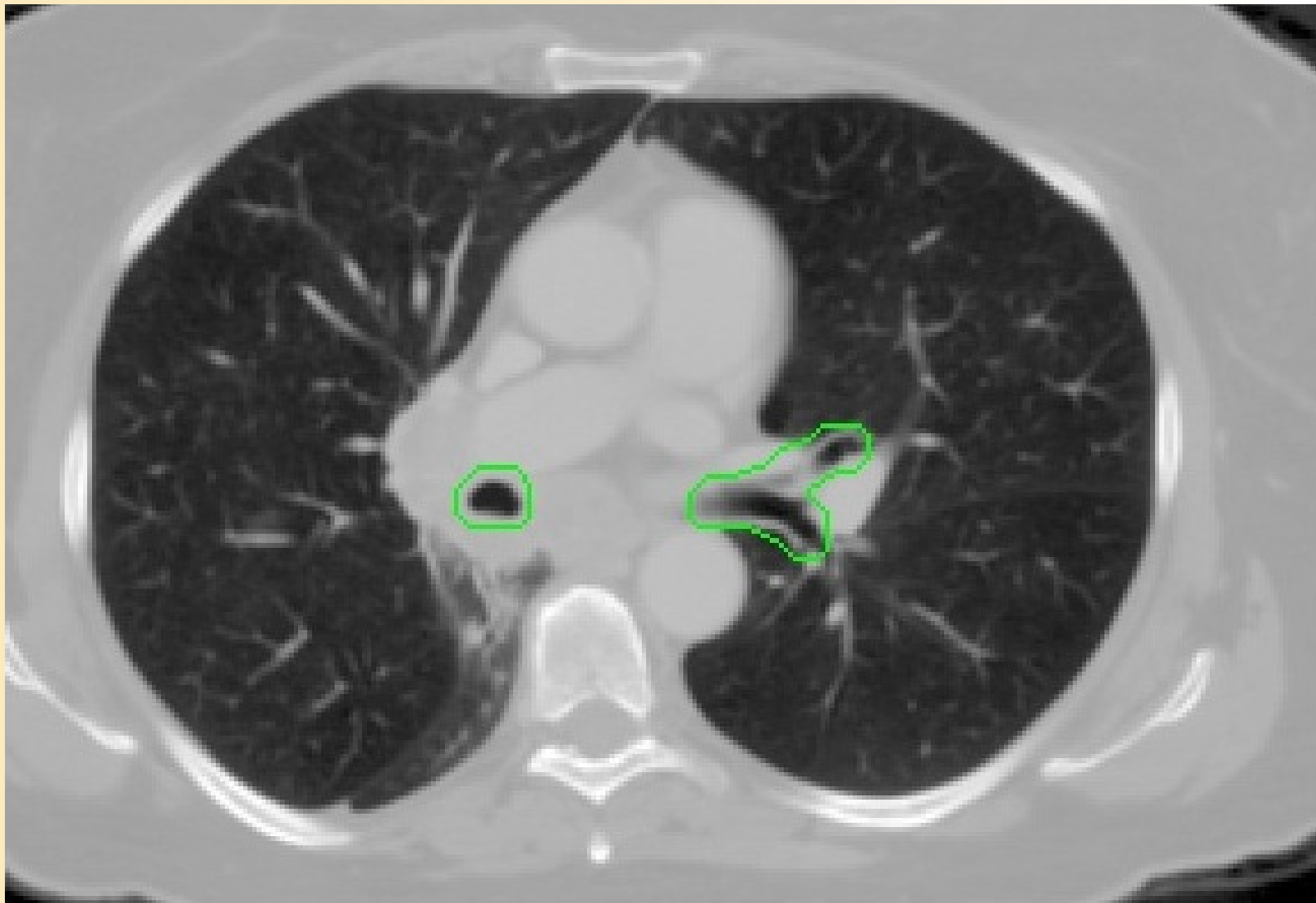


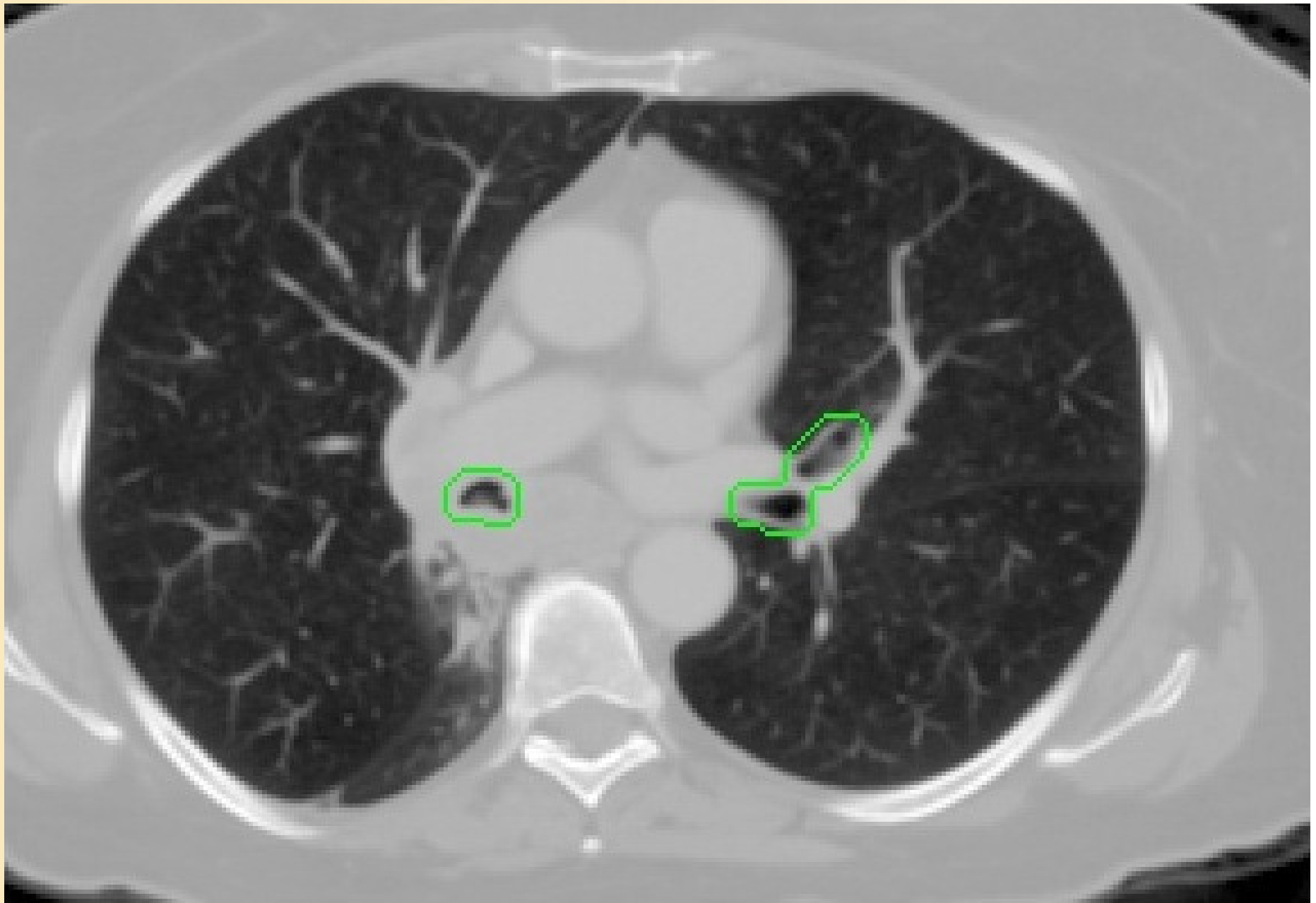


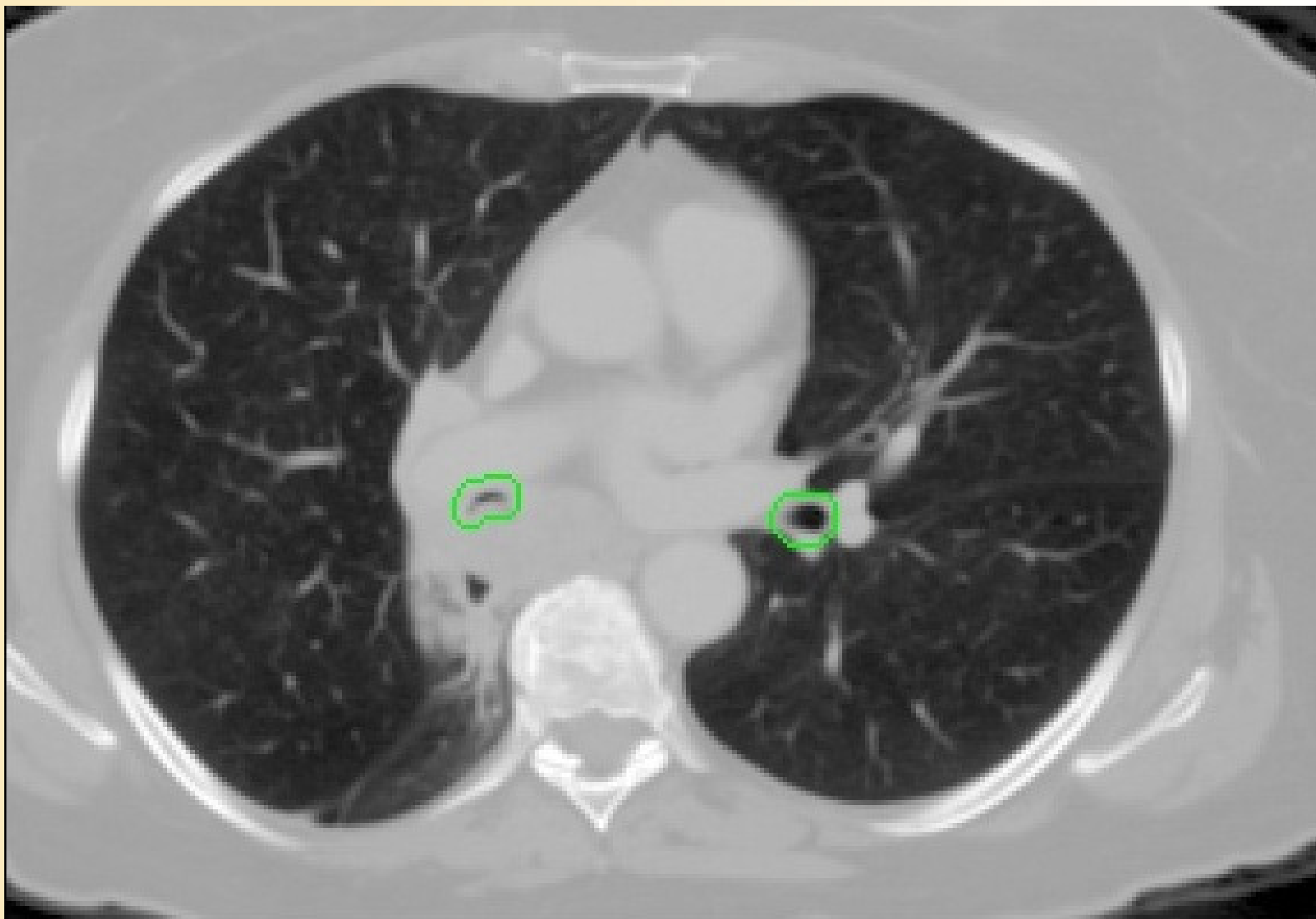


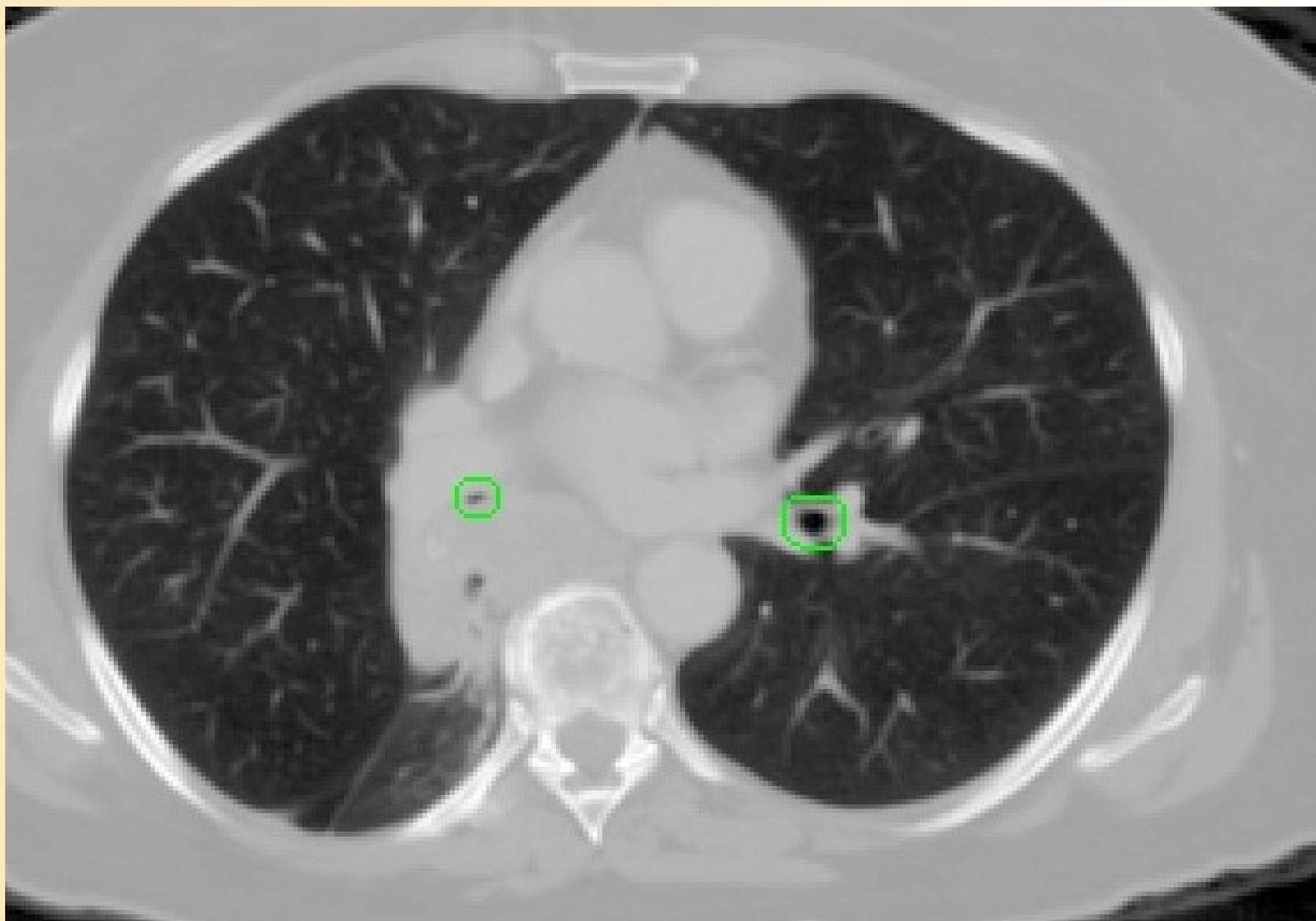


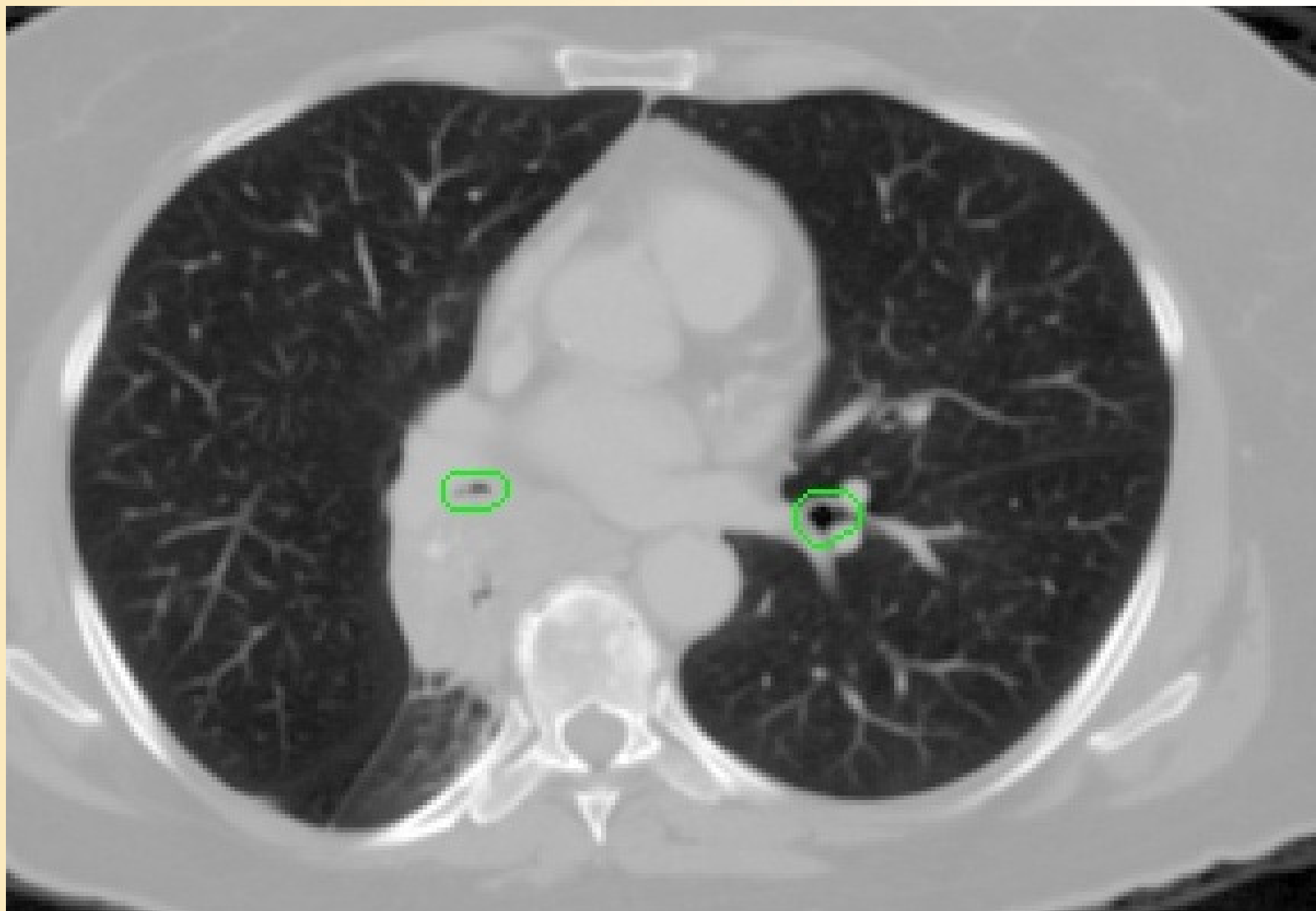












Proximal Bronchus Tree Ends

at the level of lobar bronchus bifurcating
into segmental bronchus

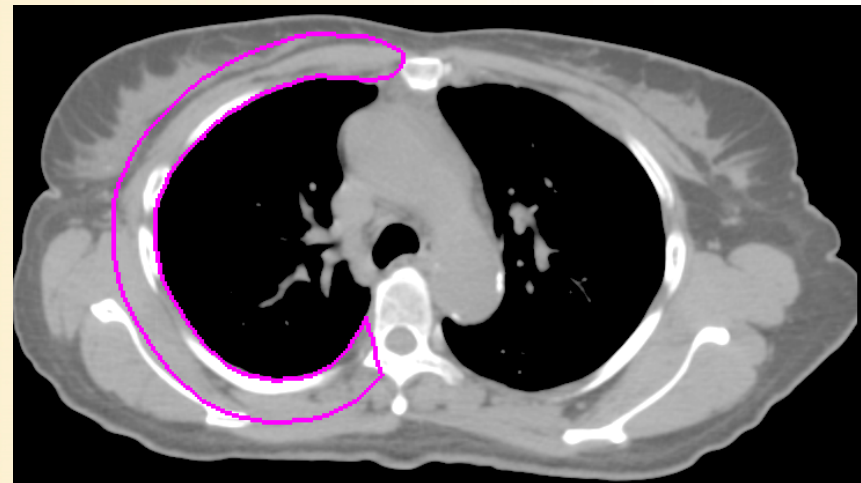
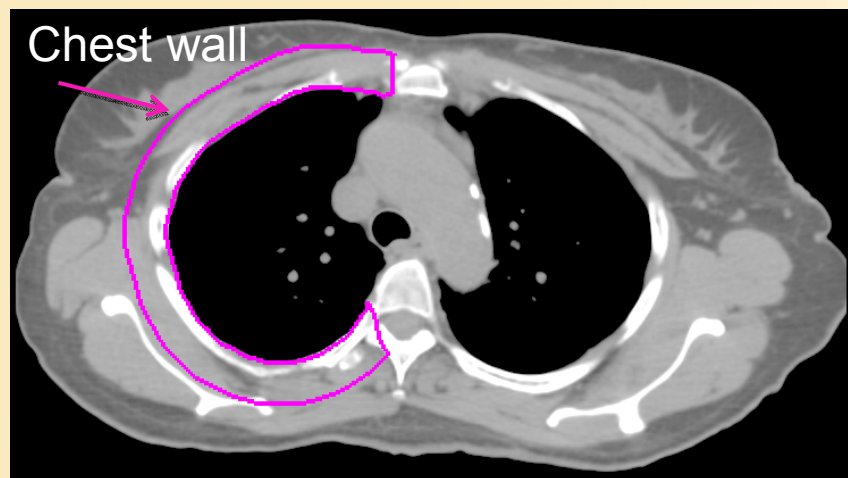


Chest Wall Contours

- Chest wall can be autosegmented from the ipsilateral lung with a 2-cm expansion in the lateral, anterior, and posterior directions. Anteriorly and medially, it ends at the edge of the sternum. Posteriorly and medially, it stops at the edge of the vertebral body with inclusion of the spinal nerve root exit site.
- This recommendation was:
 - based on Kong et al, Int J Radiat Oncol Biol Phys. 2010 Oct 7. [Epub ahead of print]
 - Supported by “CW2cm consistently enabled better prediction of CW toxicity than CW3cm” in Mutter et al, Int J Radiat Oncol Biol Phys. 2011 Aug 23. [Epub ahead of print]

Chest Wall (CW)

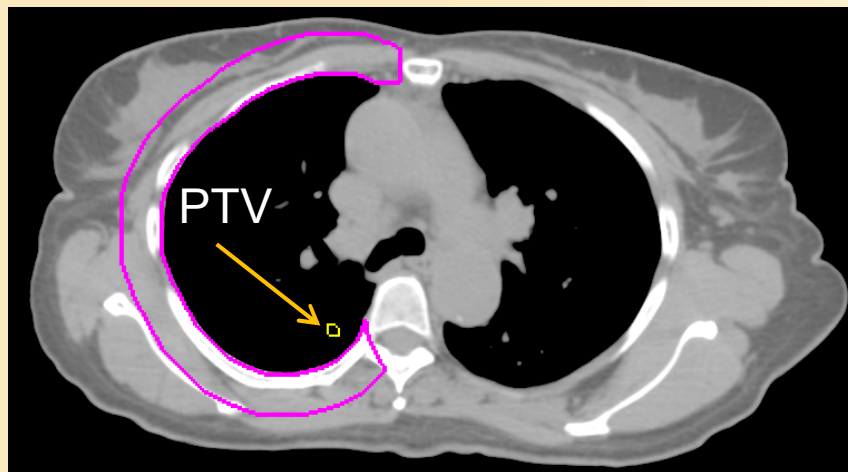
CW refers to CW2cm which include intercostal muscles, nerves exclude vertebral bodies, sternum and skin. This can be accomplished through auto-expansion of the ipsilateral lung (within 3 cm range of PTV).



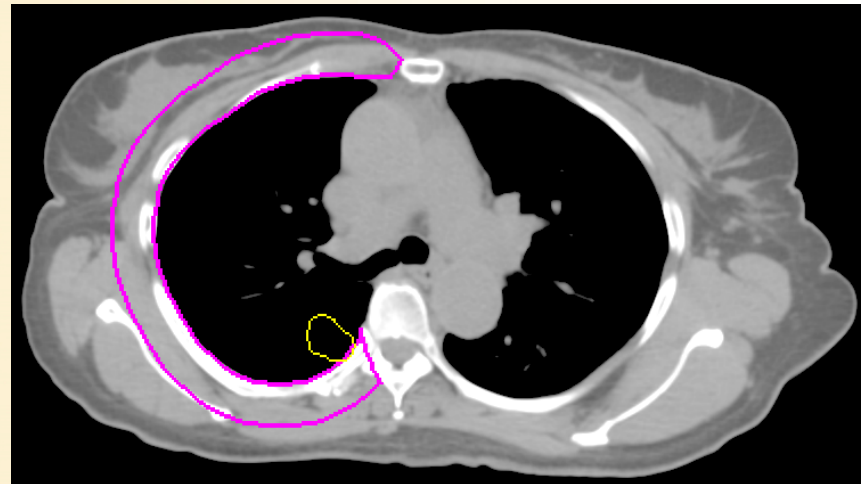
CW contouring starts at 3 cm above the PTV

Chest Wall

CW refers to CW2cm which include intercostal muscles, nerves
exclude vertebral bodies, sternum and skin.

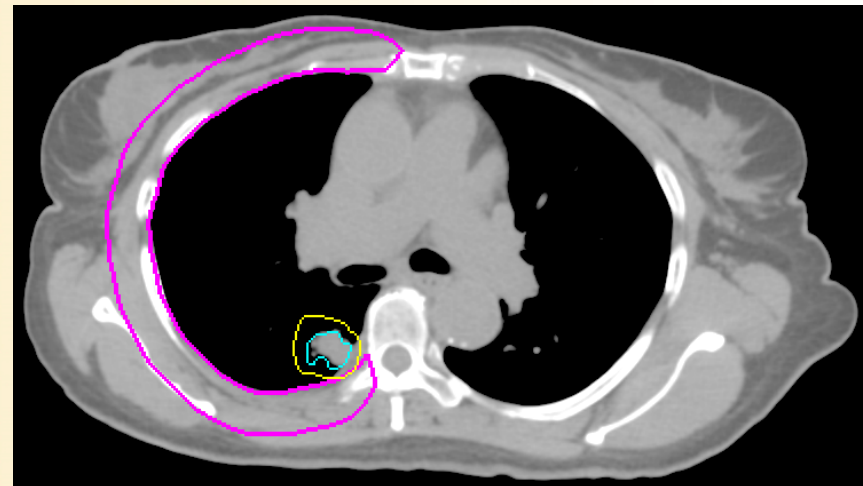
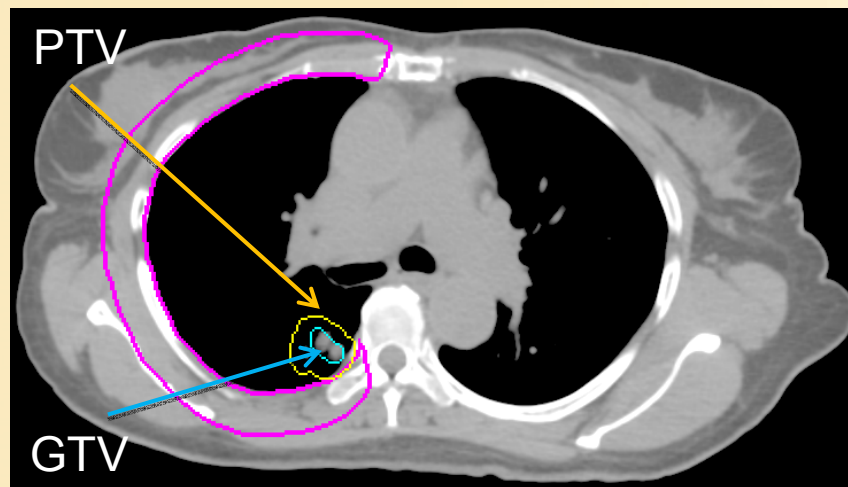


The superior end of PTV



Chest Wall

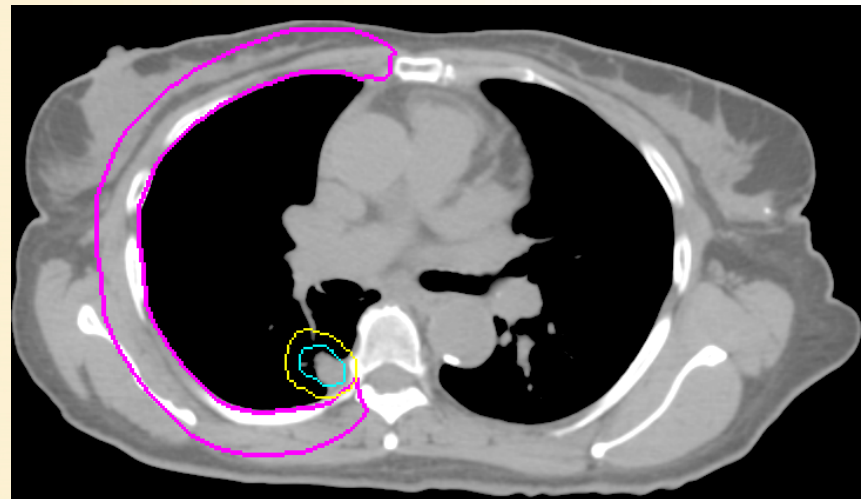
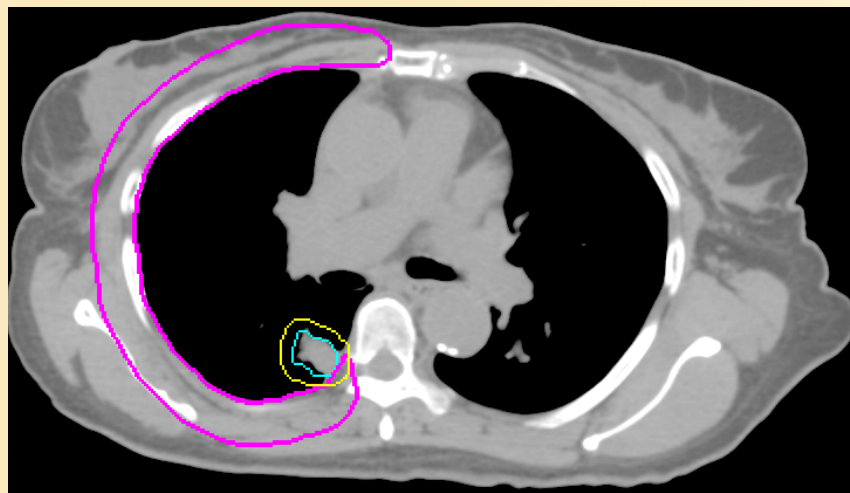
CW refers to CW2cm which include intercostal muscles, nerves
exclude vertebral bodies, sternum and skin.



The superior end of GTV

Chest Wall

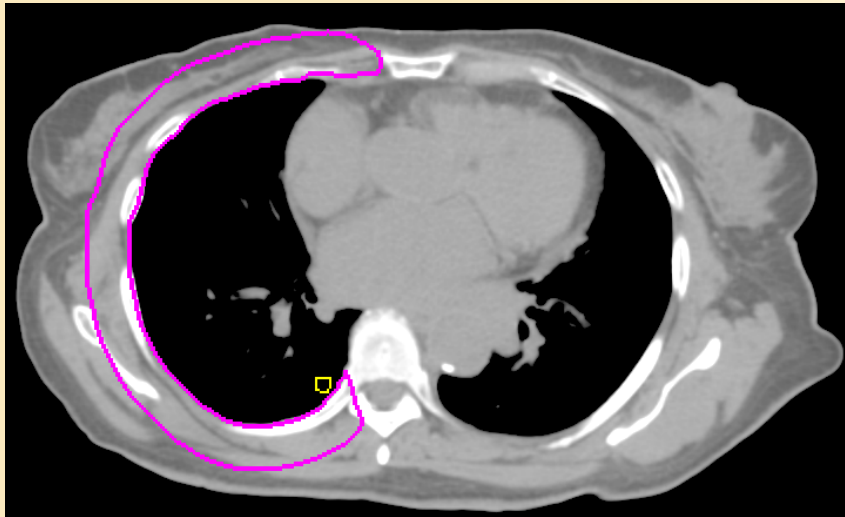
CW refers to CW2cm which include intercostal muscles, nerves
exclude vertebral bodies, sternum and skin.



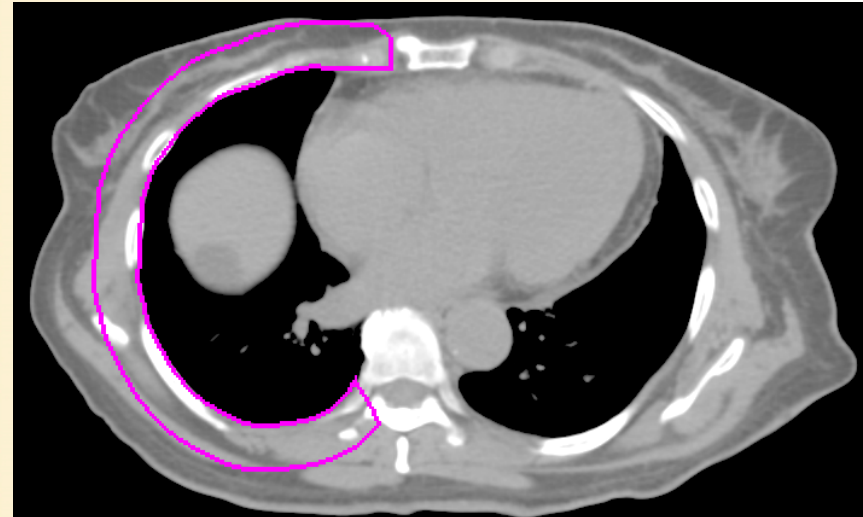
Chest wall contours around GTV.

Chest Wall

CW refers to CW2cm which include intercostal muscles, nerves exclude vertebral bodies, sternum and skin.



The inferior end of PTV



3 cm below PTV

CW ends at 3cm from the inferior edge of PTV.

Pericardium/Heart, Great Vessels, Heart Chambers, and Normal Pericardial Recesses

Feng-Ming (Spring) Kong (RTOG), Leslie Quint (ACRIN), Jeffrey Bradley (RTOG), Suresh Senan (EORTC), Ritsuko Komaki (RTOG), Laurie Gaspar (SWOG), Luying Xu (UM), Chengbo Han (UM), Jun Liu (UM), Weili Wang (UM), Robin Marsh (UM), Randall Ten Haken (UM), Charles Thomas (SWOG), Jeffrey Bogart (CALGB), Mitchell Machtay (RTOG)

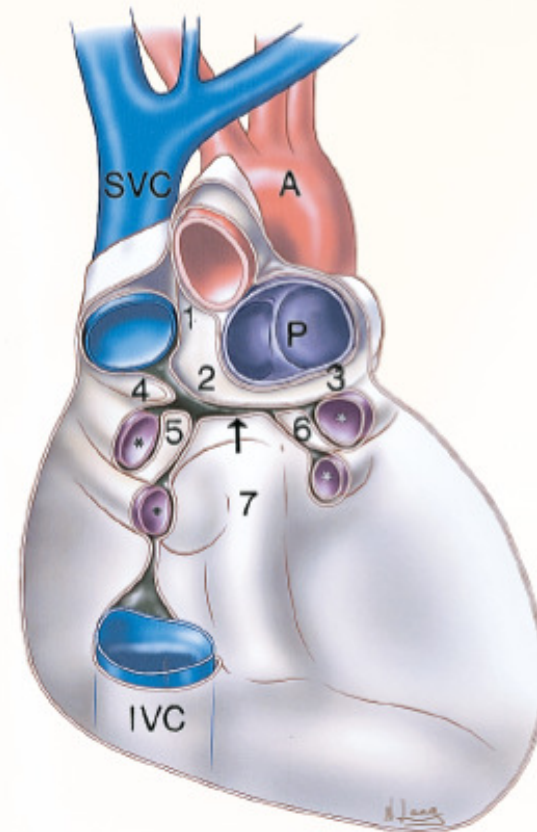
Pericardium, normal recesses and heart chambers

The structure of pericardium includes pericardial fatty tissue, part of great vessels, normal recesses, pericardial effusion (if applicable) and heart chambers.

Anatomy of Pericardium

Pericardial sac and normal recesses

Fig. 1.—Drawing of interior of serosal pericardial sac seen from front after section of large vessels at their cardiac origin and removal of heart. Aorta (A) and pulmonary trunk (P) are enclosed in one tube. Superior vena cava (SVC), inferior vena cava (IVC), and pulmonary veins (*asterisks*) are enclosed in other tube forming inverted J. Cul-de-sac within curve of J is oblique sinus located behind left atrium. Transverse sinus is complex interconnecting passage between these two tubes. Double layer of serous pericardium (*arrow*) separates transverse sinus and oblique sinus. 1 = superior aortic recess of transverse sinus, 2 = right pulmonic recess of transverse sinus, 3 = left pulmonic recess of transverse sinus, 4 = postcaval recess, 5 = right pulmonary venous recess, 6 = left pulmonary venous recess, 7 = oblique sinus. (Drawing by Lang N; printed with permission from Department of Visual Arts, M. D. Anderson Cancer Center)

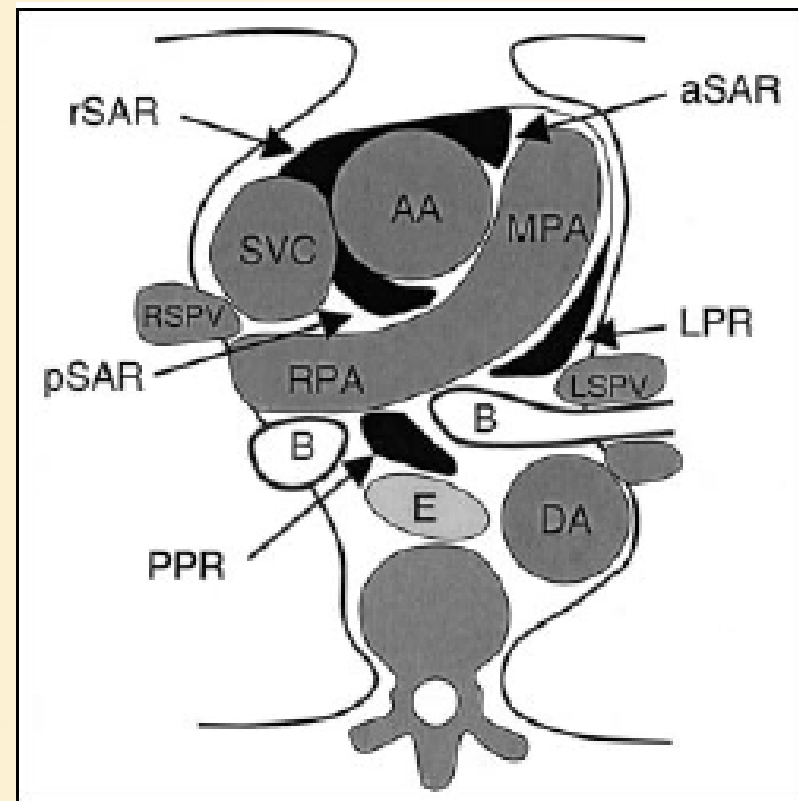


©2003 THE UNIVERSITY OF TEXAS
MD ANDERSON CANCER CENTER

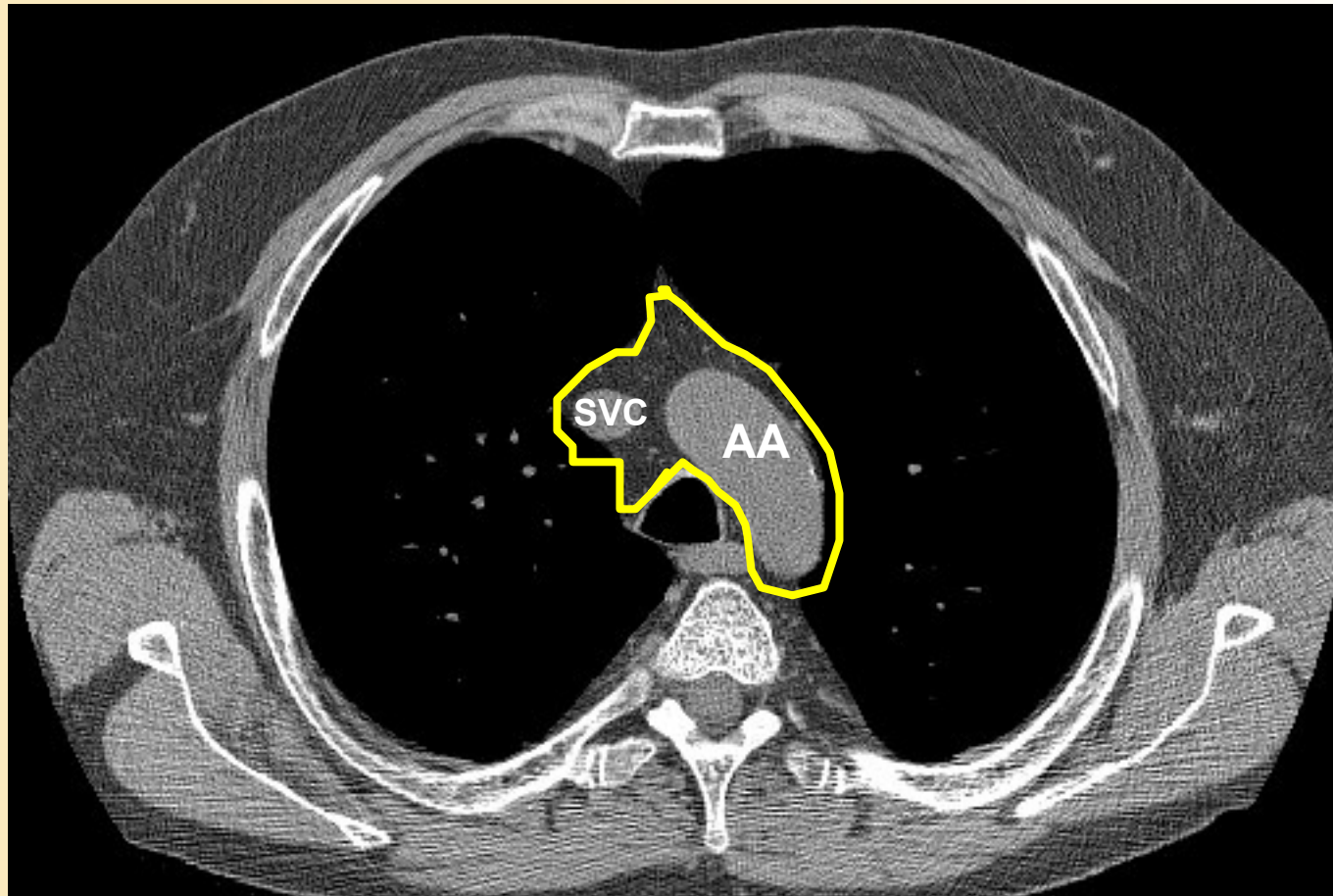
Pericardial Normal Recesses

Nomenclature of the Pericardial Cavity	Abbreviation
Pericardial cavity proper	...
Postcaval recess	PCR
Right pulmonic vein recess	RPVR
Left pulmonic vein recess	LPVR
Transverse sinus	TS
Superior aortic recess	SAR
Anterior portion	aSAR
Posterior portion	pSAR
Right lateral portion	rSAR
Inferior aortic recess	IAR
Right pulmonic recess	RPR
Left pulmonic recess	LPR
Oblique sinus	OS
Posterior pericardial recess	PPR

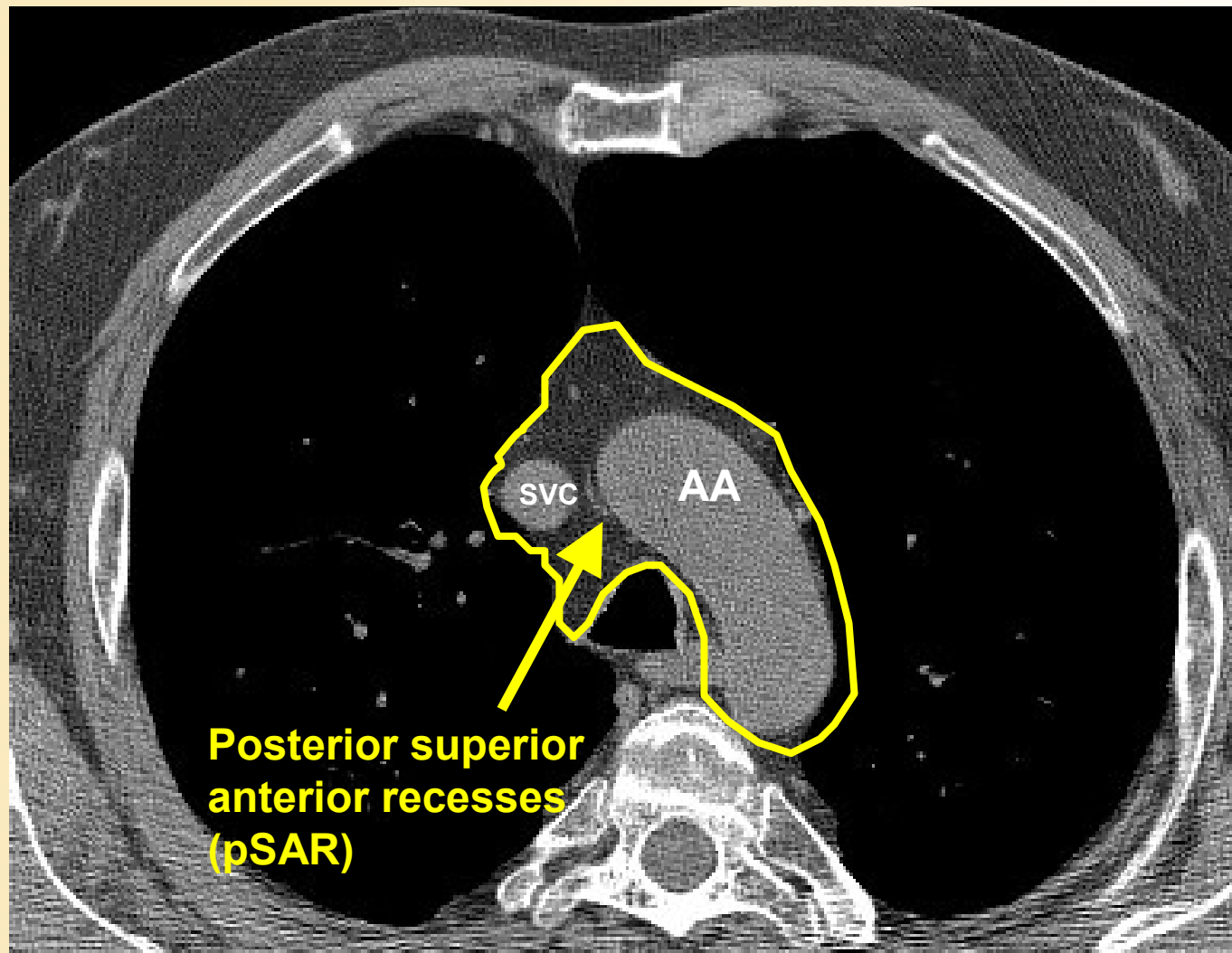
Vesely et al, 1986



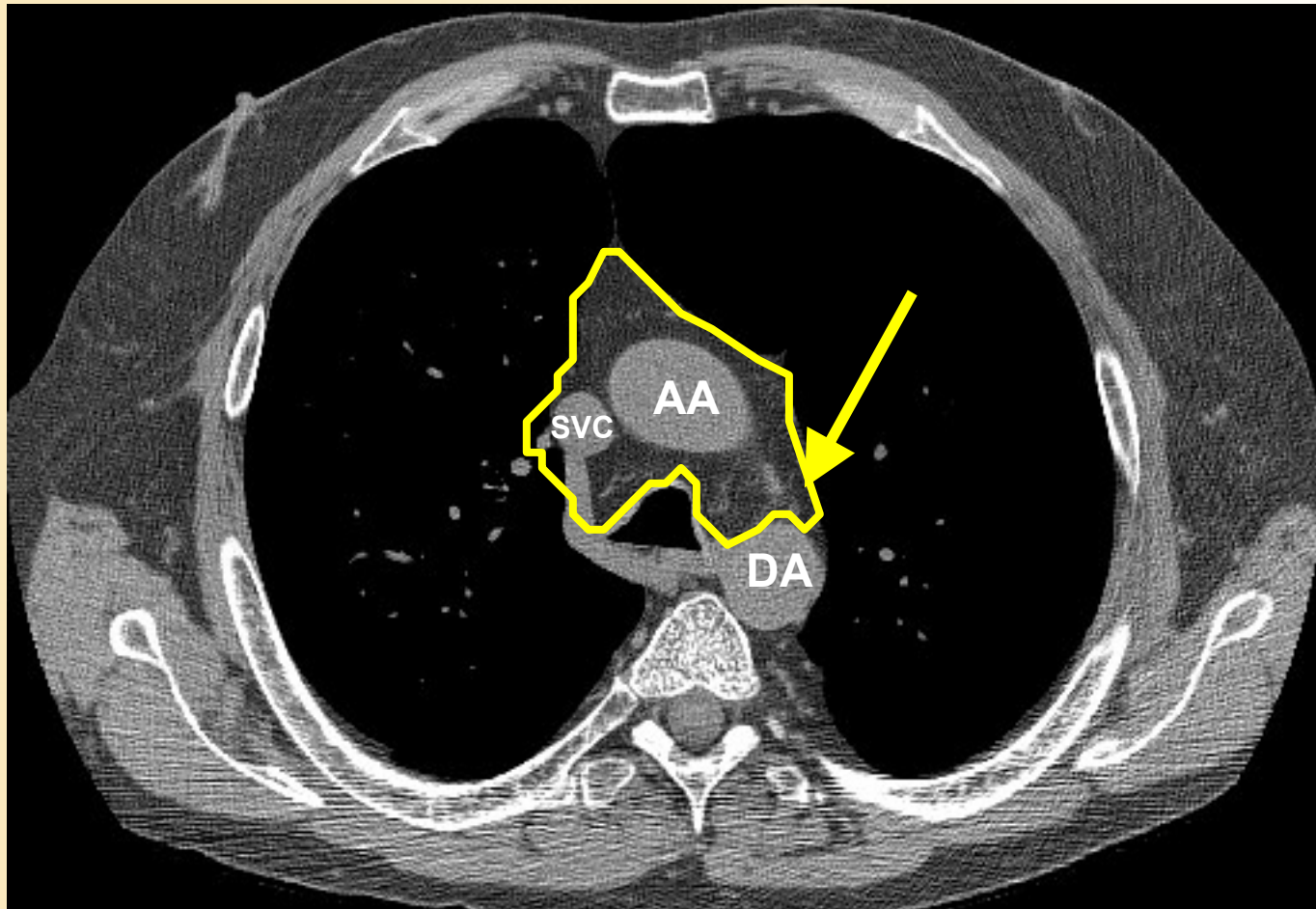
Groell et al, Radiology, 1999



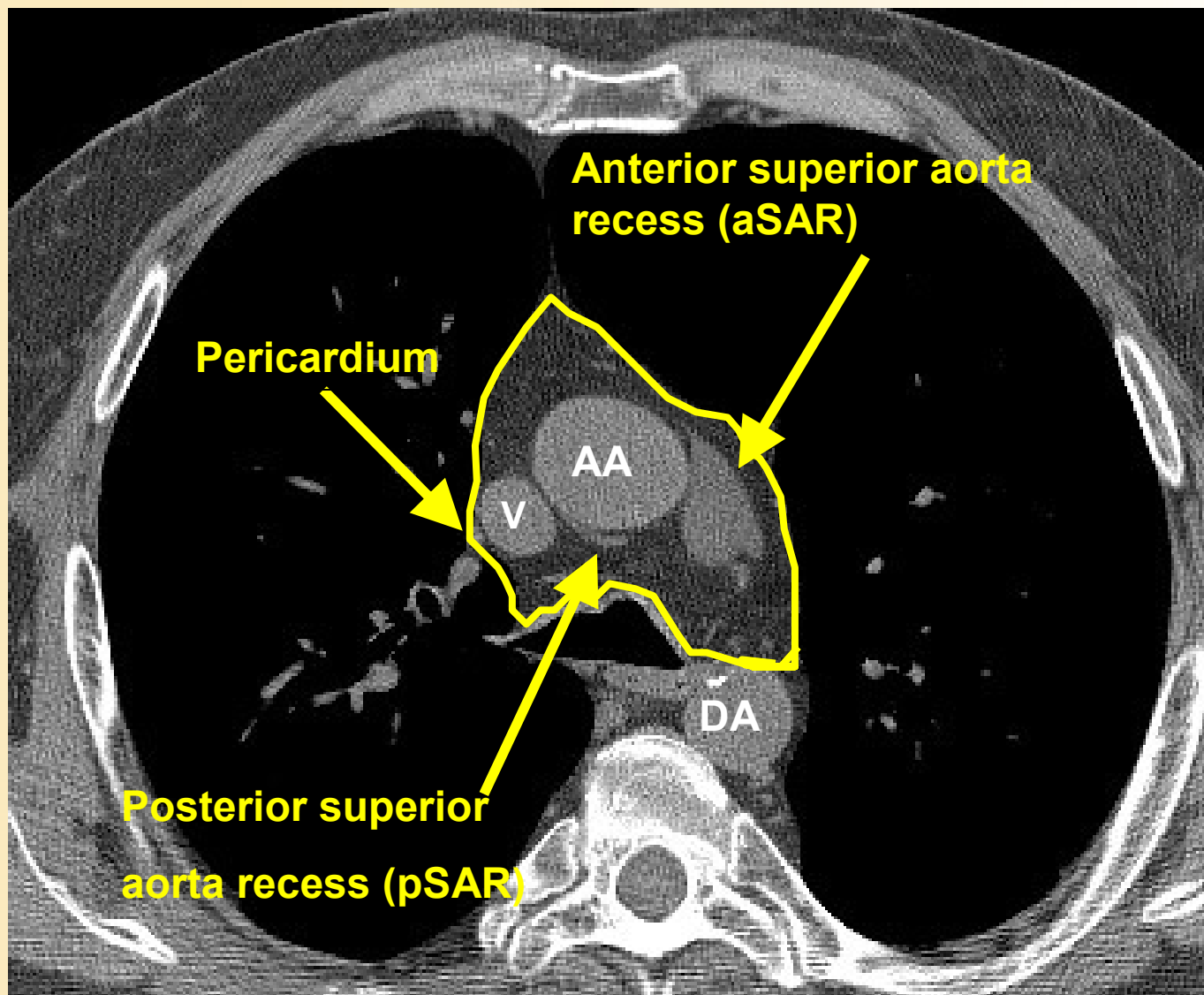
AA=ascending aorta, SVC=superior vena cava



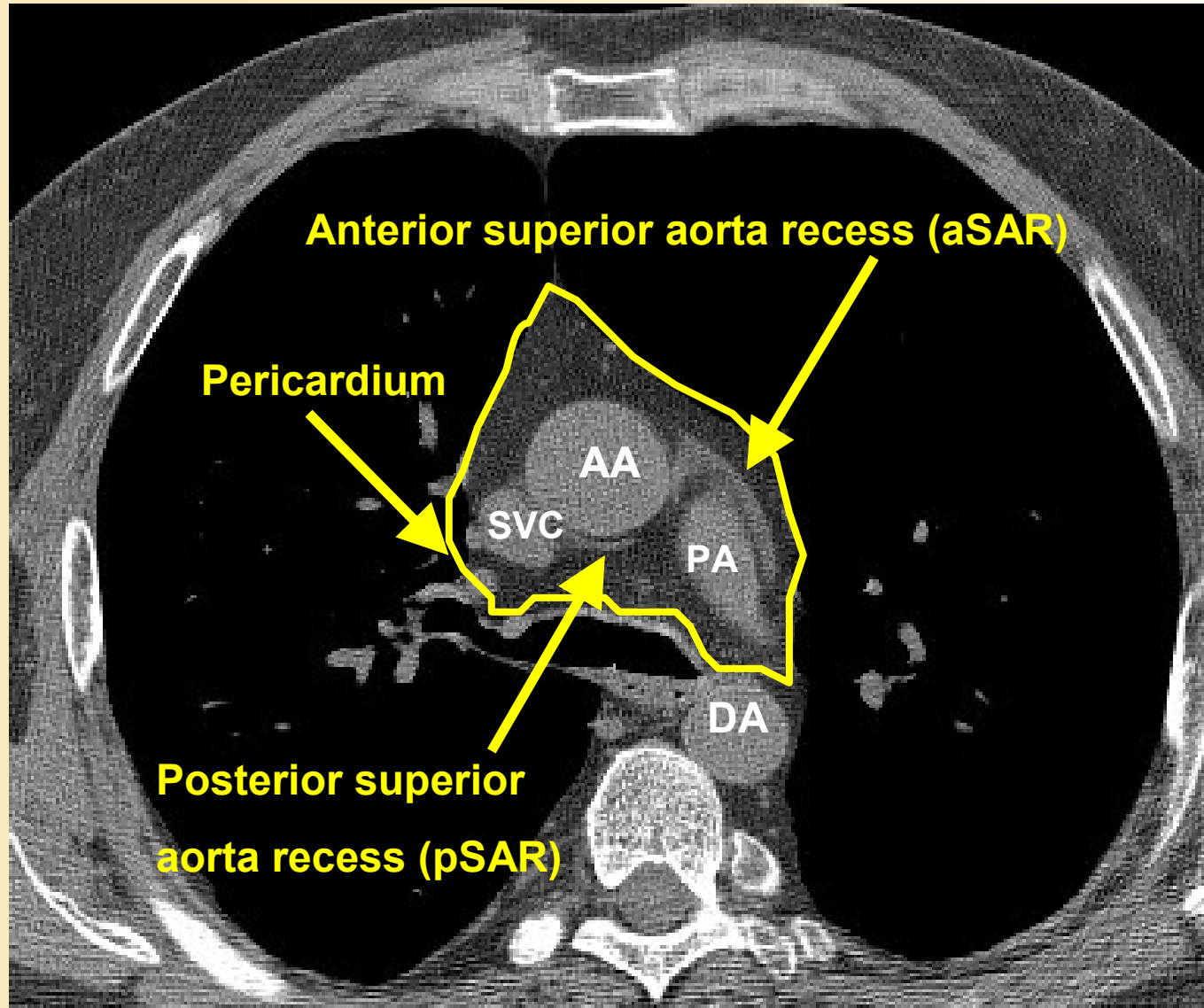
AA=ascending aorta, V=superior vena cava



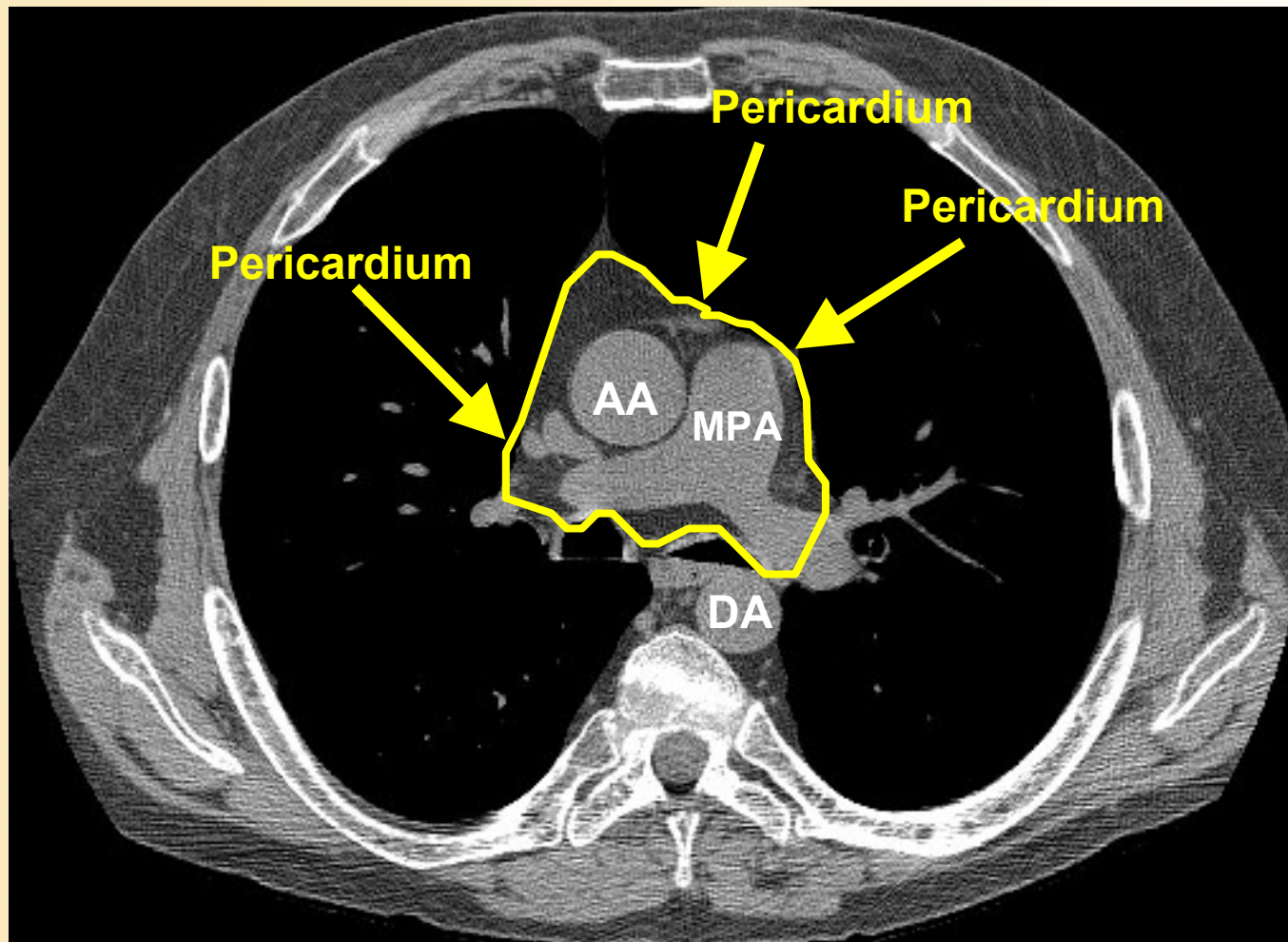
AA=ascending aorta, DA=descending aorta, SVC=superior vena cava



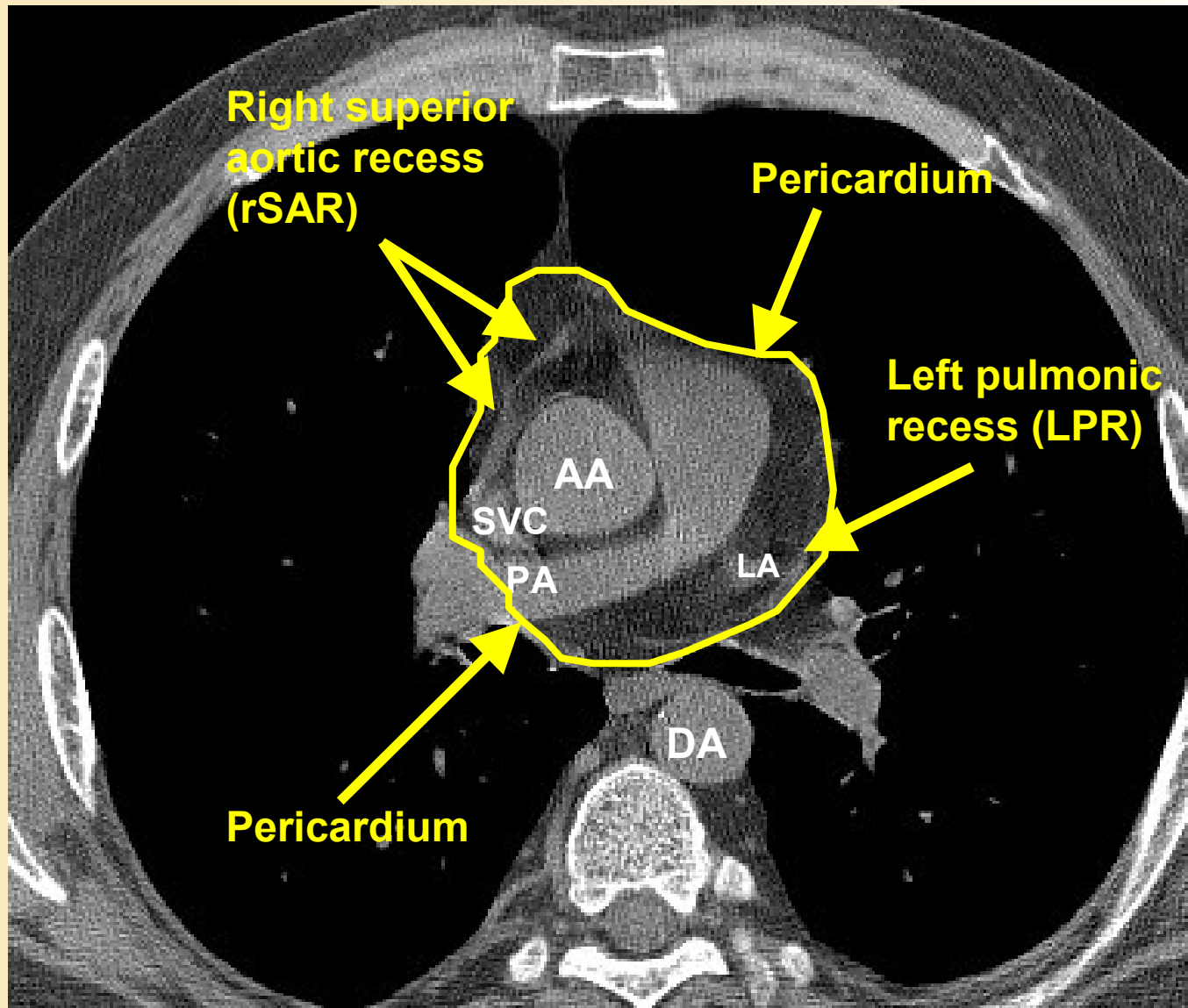
AA=ascending aorta, DA=descending aorta, SVC=superior vena cava



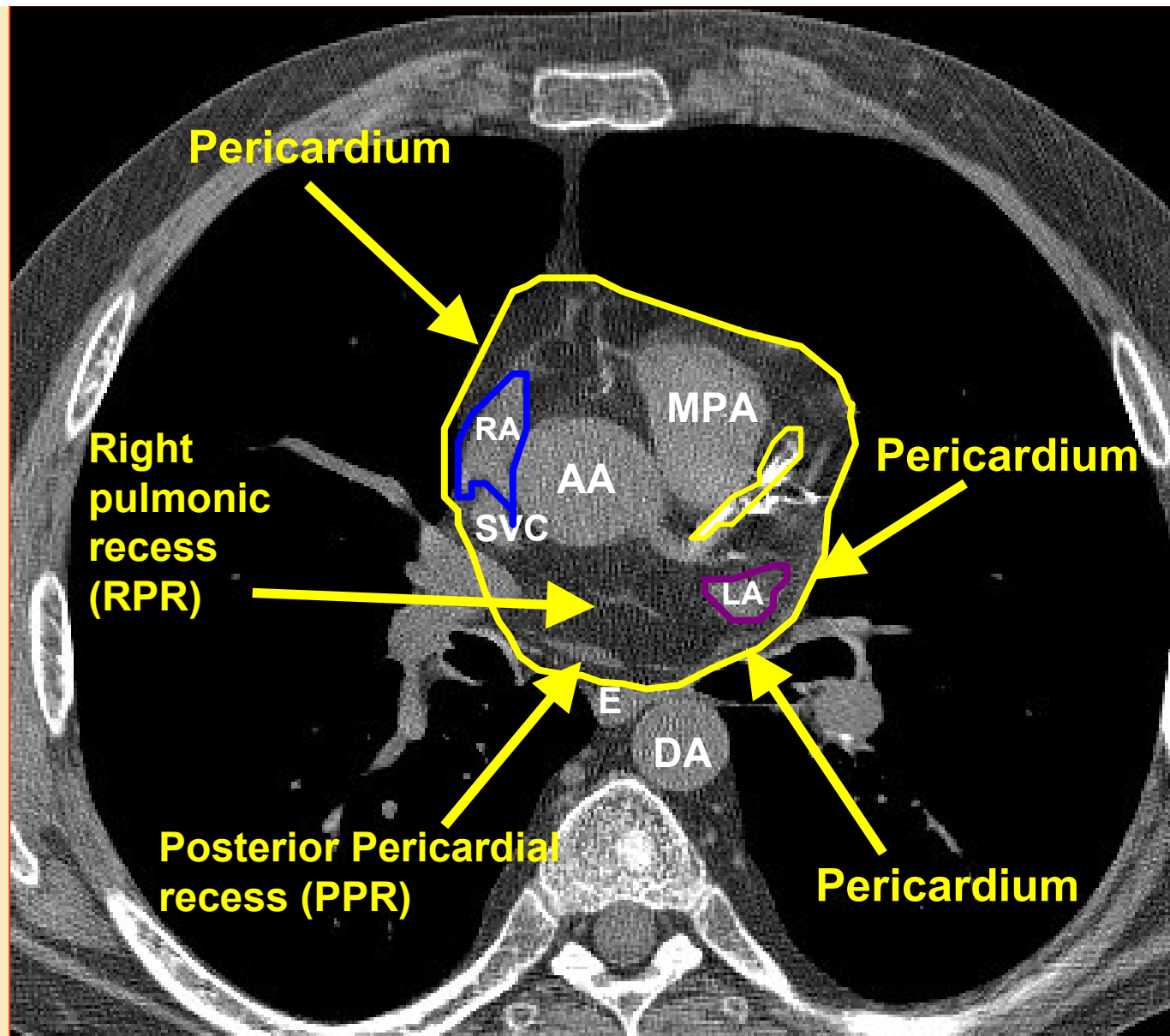
AA=ascending aorta, DA=descending aorta, SVC=superior vena cava,
PA= pulmonary artery



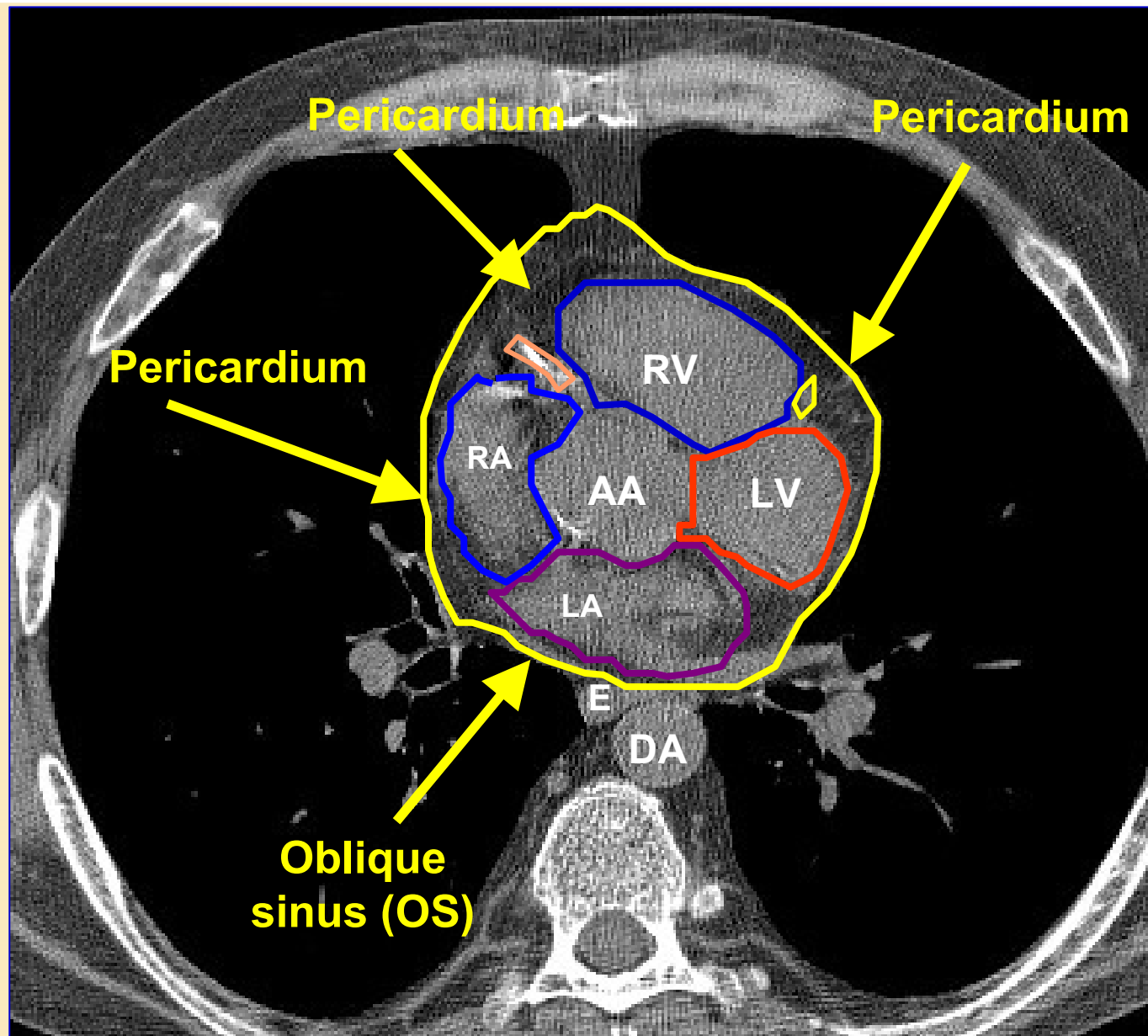
AA=ascending aorta, DA=descending aorta, MPA=main pulmonary artery



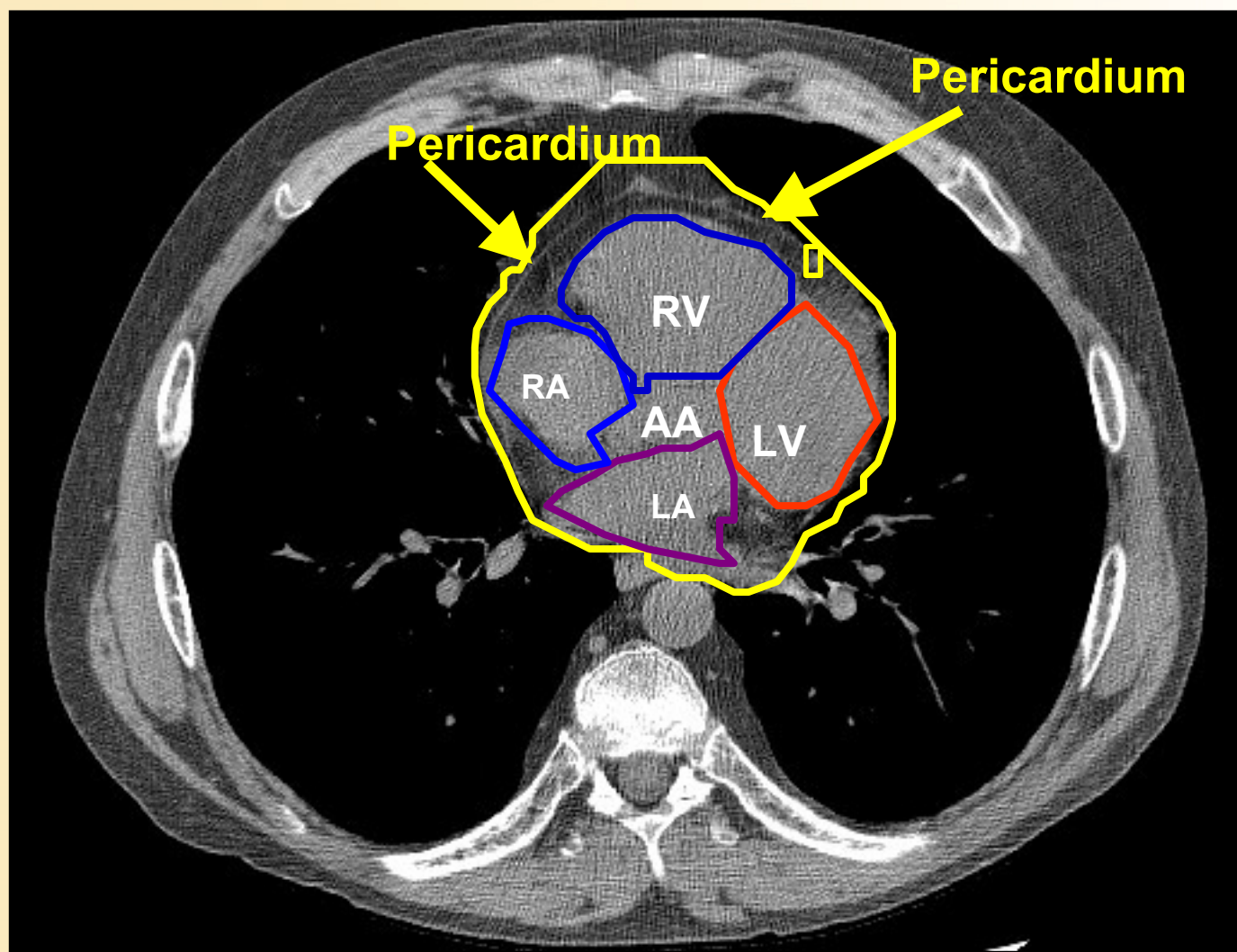
AA=ascending aorta, DA=descending aorta, V=superior vena cava,
PA=main pulmonary artery, PA=right pulmonary artery, LA=left atrium



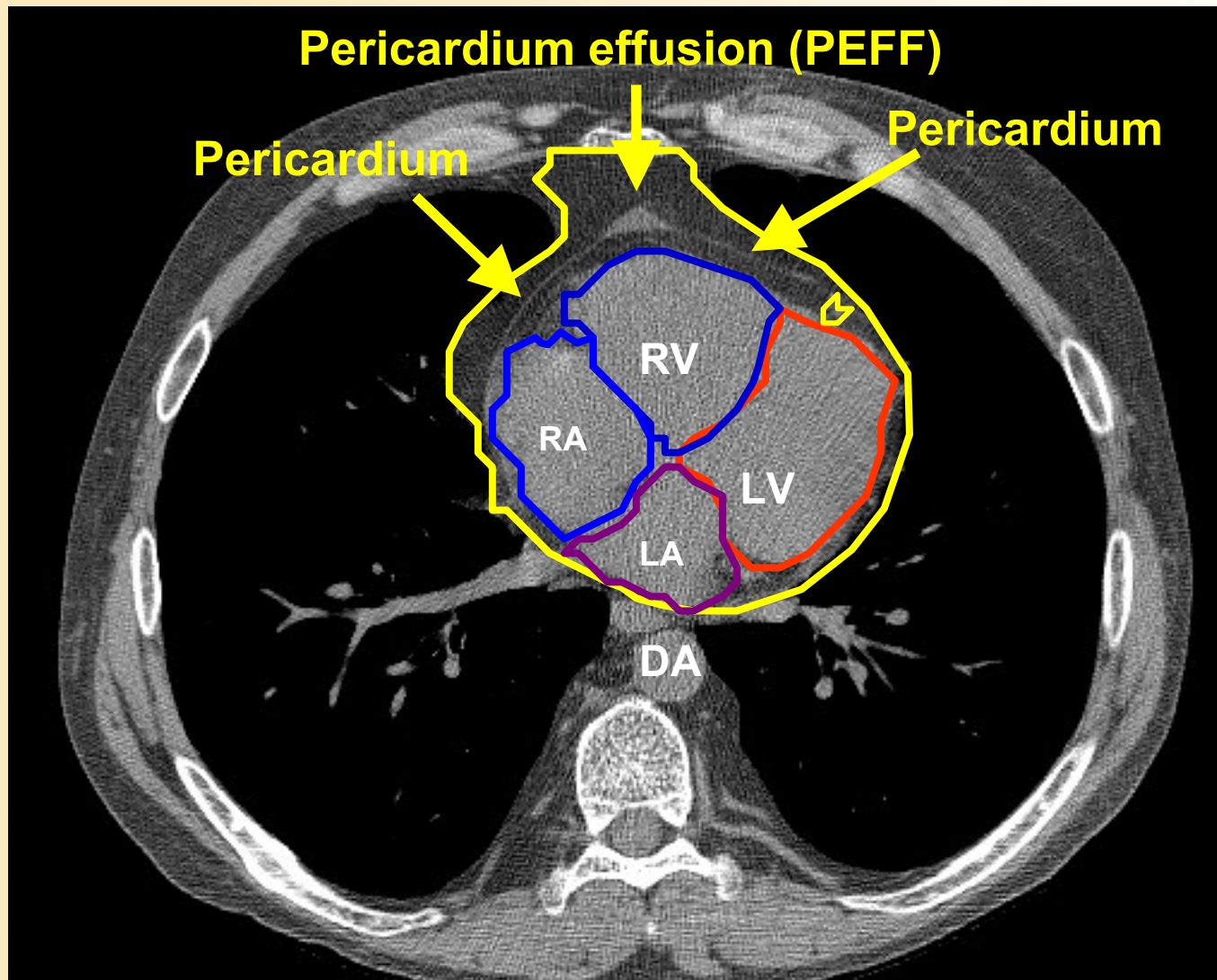
RA=right atrium, AA=aortic arch, LV=left ventricle, LA=Left atrium, MPA=main pulmonary artery, DA=descending aorta, E=esophagus



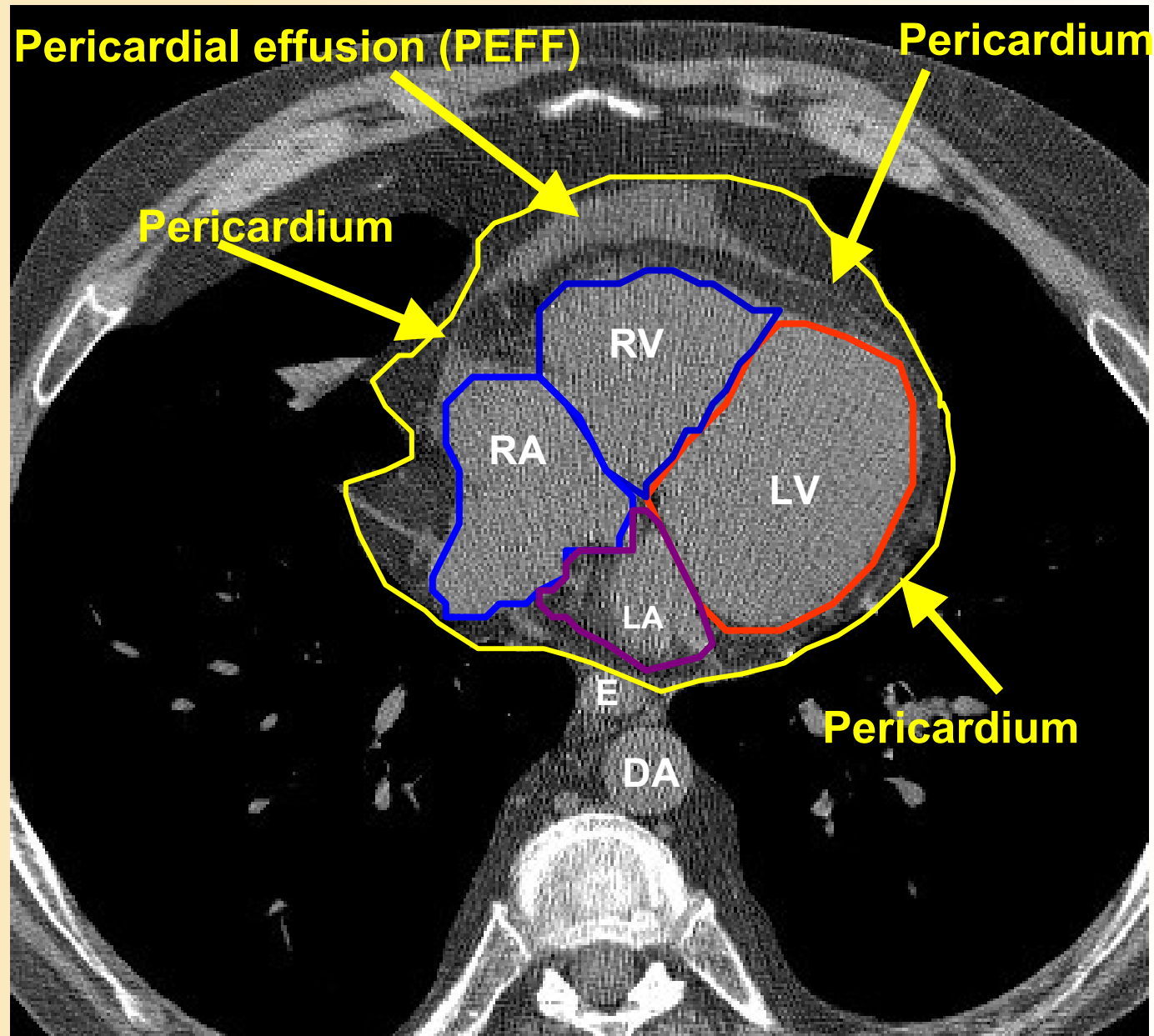
RA=right atrium, RV=right ventricle, LV=left ventricle, LA=Left atrium,
AA=aortic arch, DA=descending aorta, E=esophagus



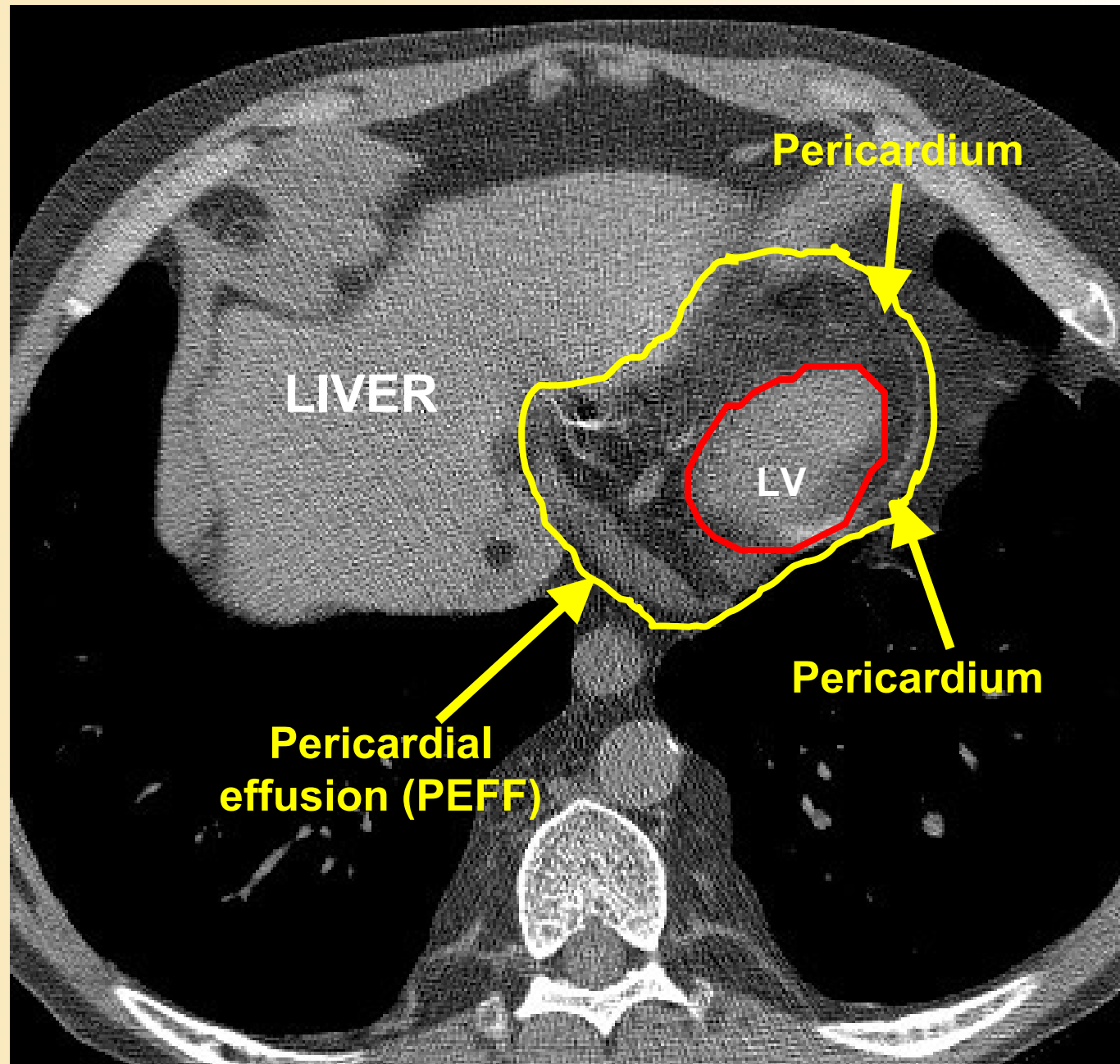
RA=right atrium, RV=right ventricle, LV=left ventricle, LA=Left atrium, AA=Ascending Aorta



RA=right atrium, RV=right ventricle, LV=left ventricle, LA=Left atrium, AA=aortic arch

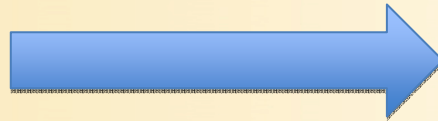


RA=right atrium, RV=right ventricle, LV=left ventricle, LA=Left atrium

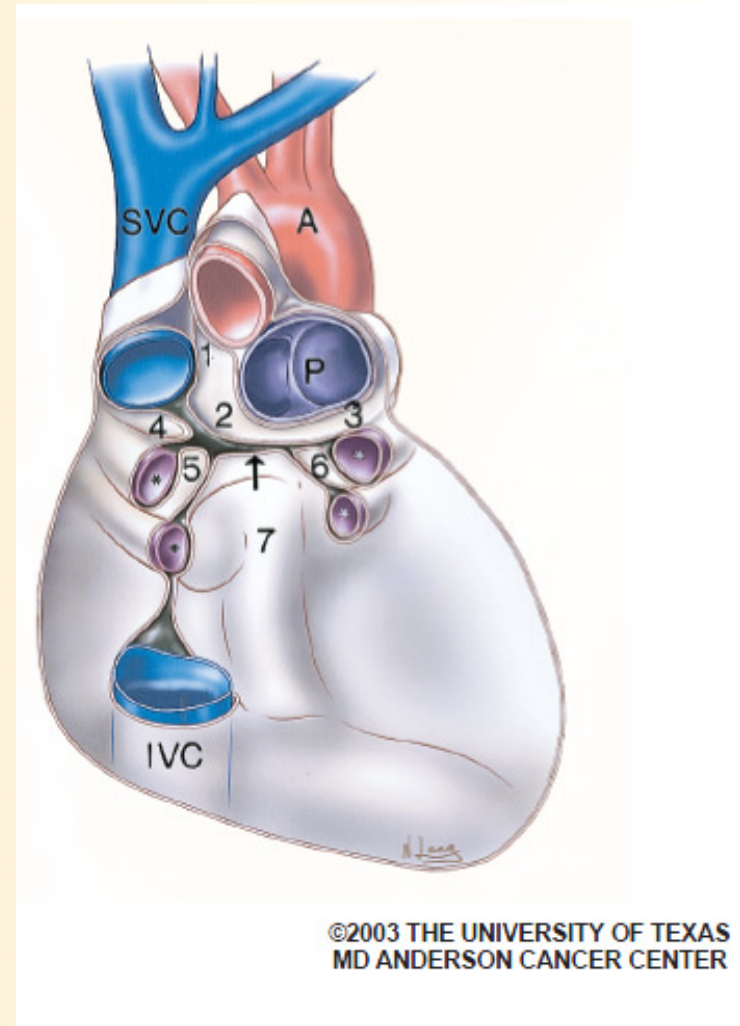


Atlas for Heart and Pericardium

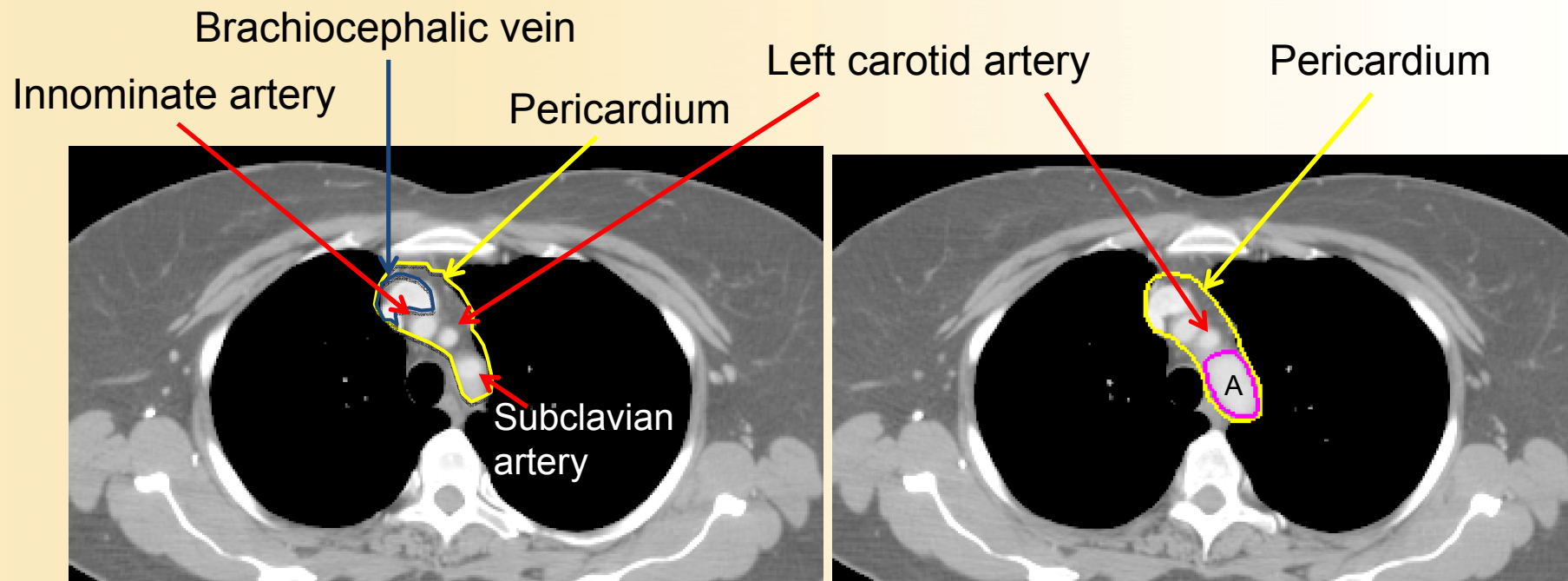
Pericardium: based on anatomy



Heart: based on consensus contours of most RTOG centers/previous trials, actually including part of pericardium

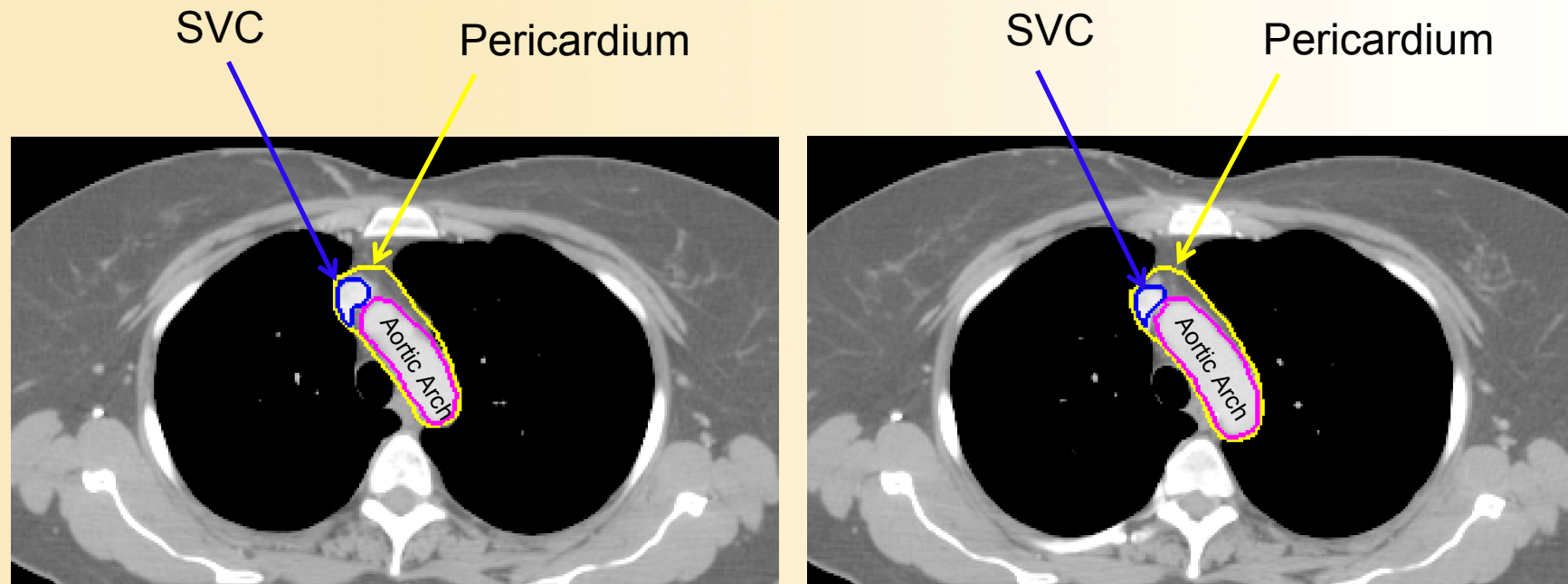


Pericardium starts



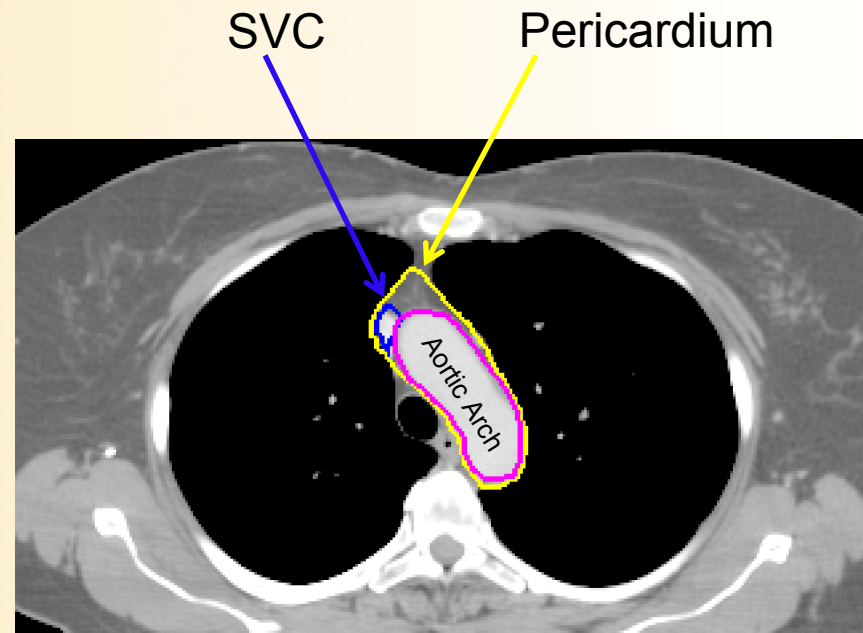
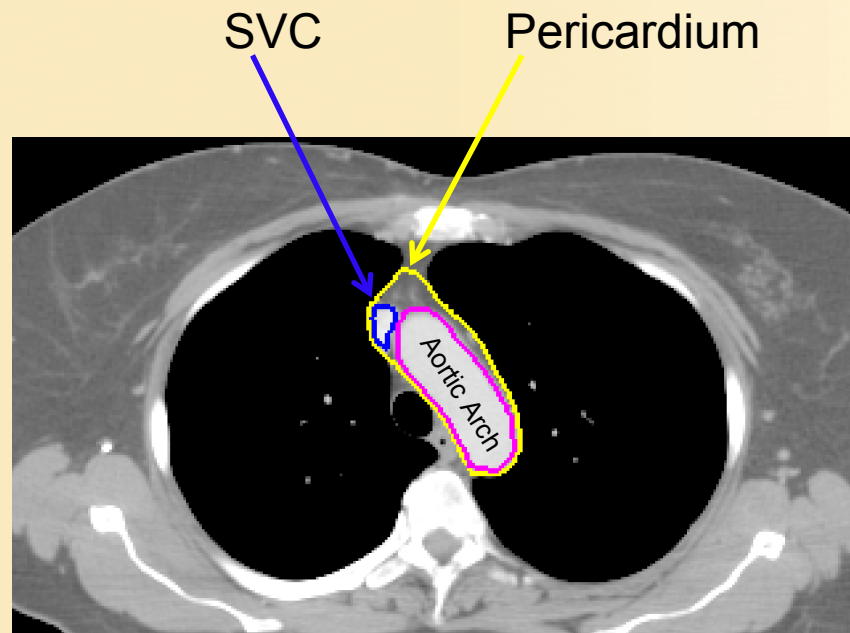
Pericardium starts at 1-2 slices (5-6 mm) above the superior end of the aortic arch

Pericardium continues...



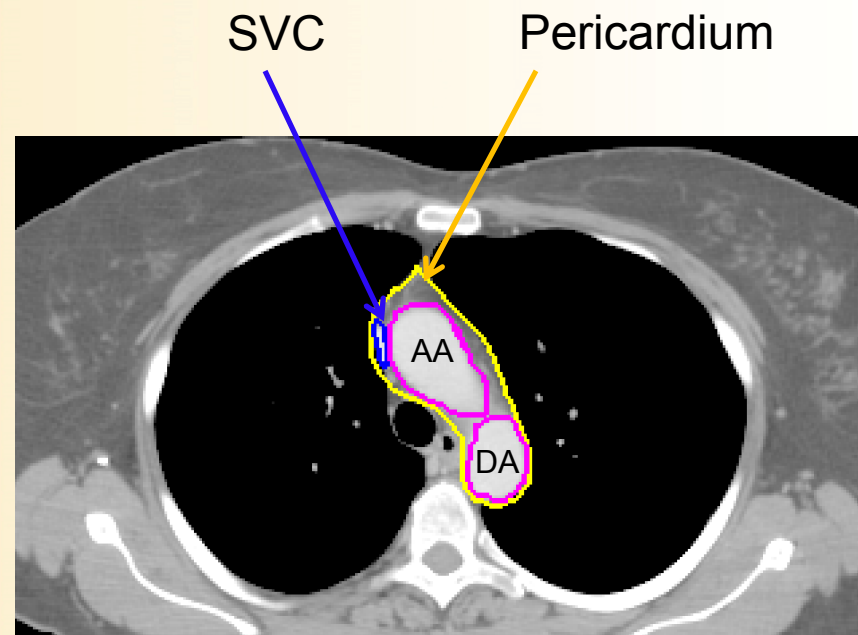
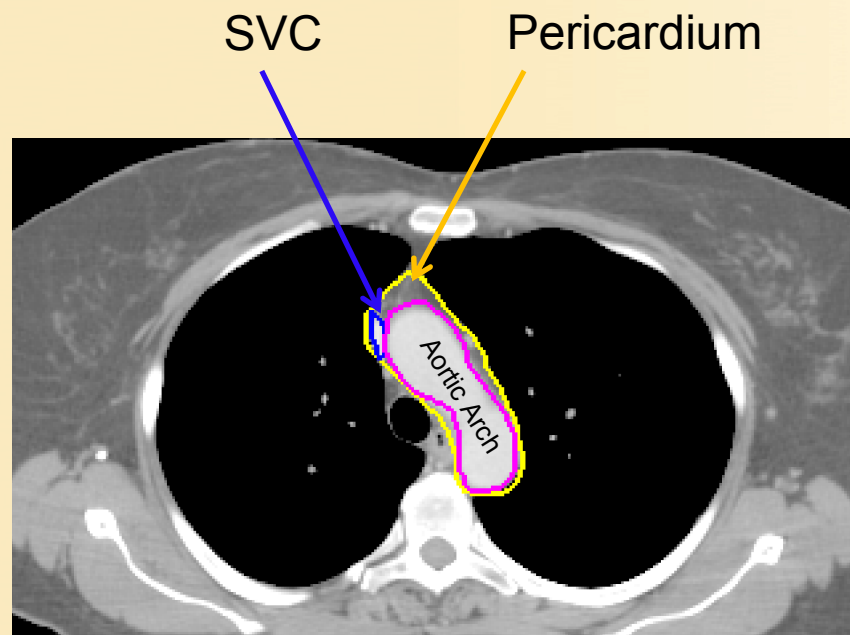
SVC=superior vena cava

Pericardium continues...



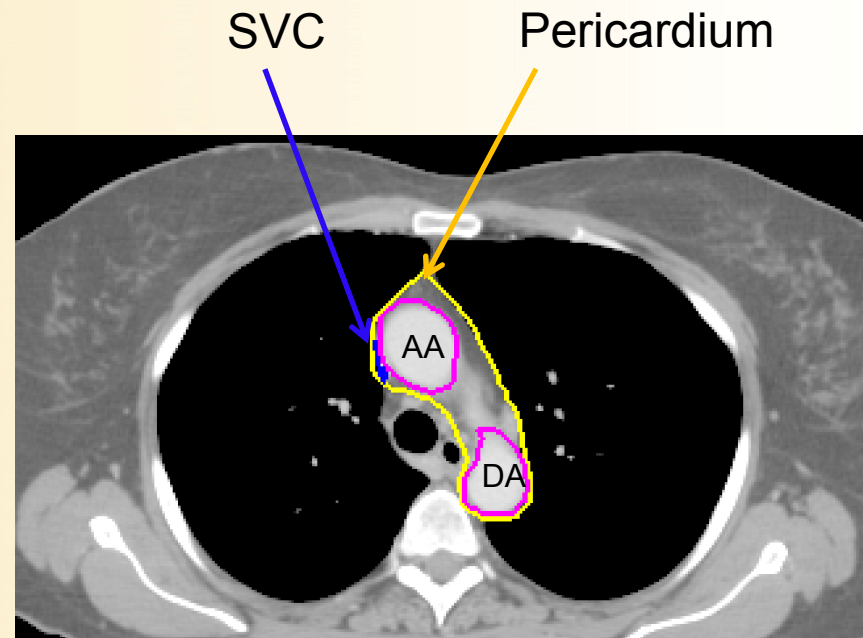
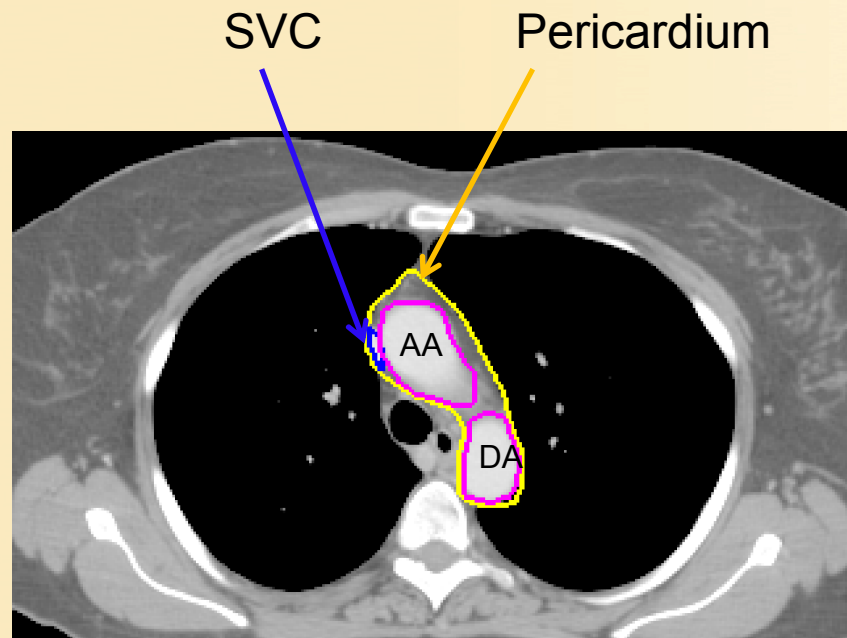
SVC=superior vena cava

Pericardium continues...



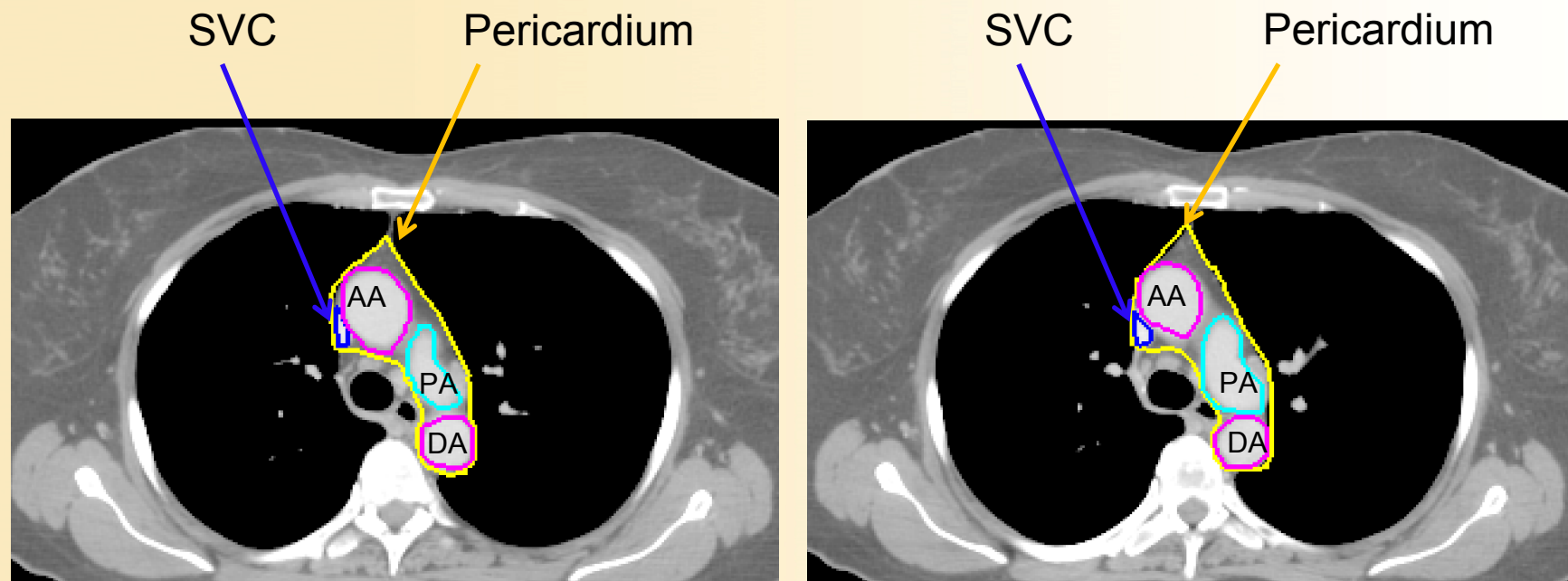
SVC=superior vena cava

Pericardium continues...

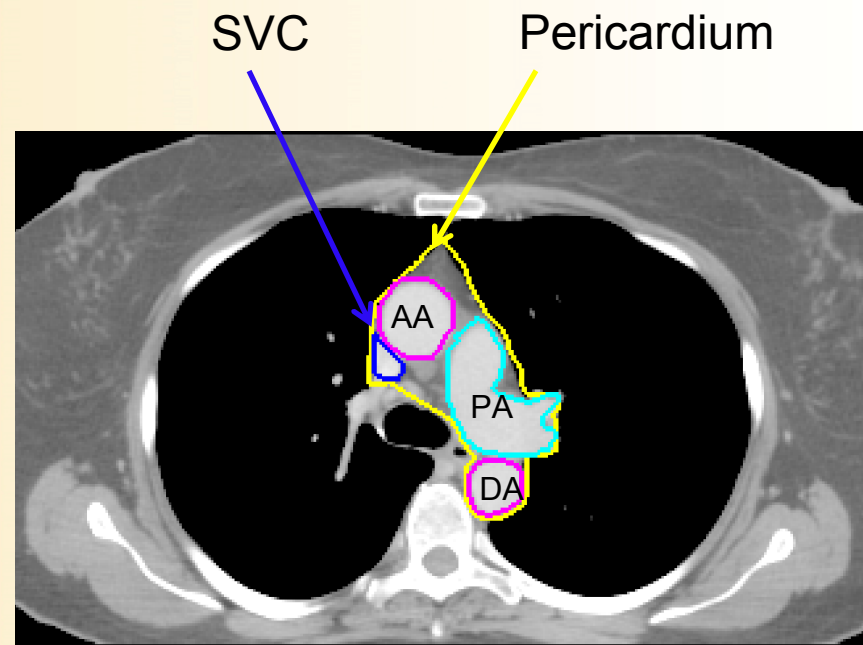
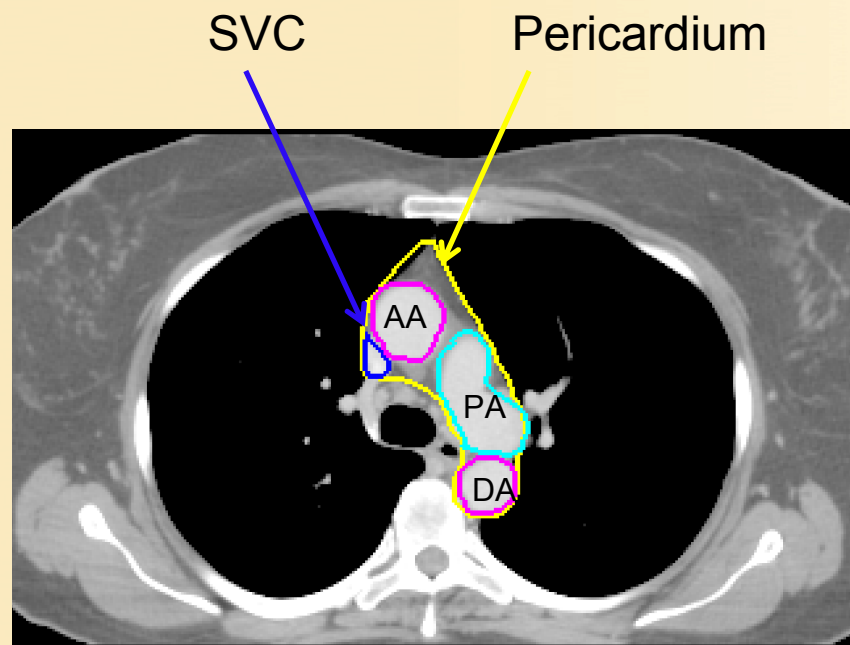


SVC=superior vena cava
AA=Ascending aorta
DA=Descending aorta

Pericardium continues...

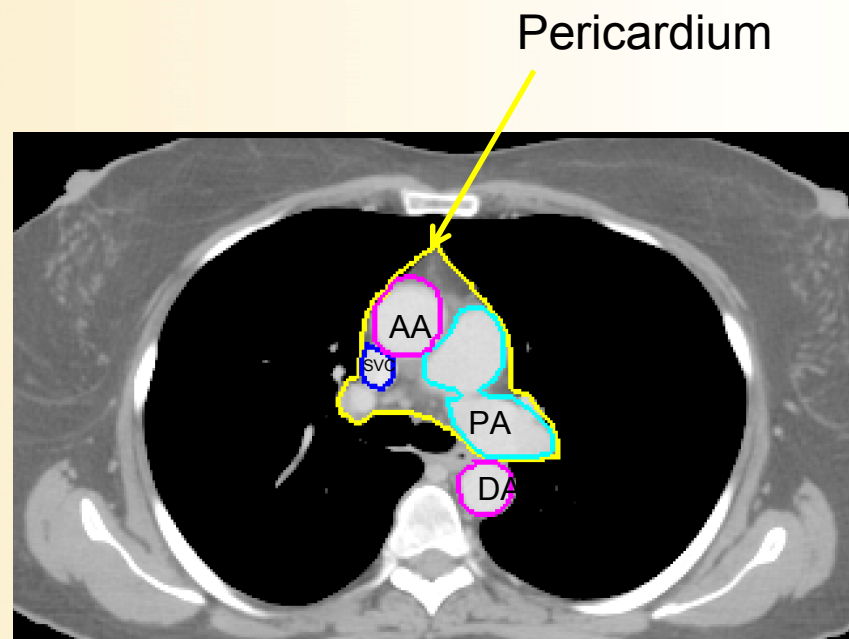
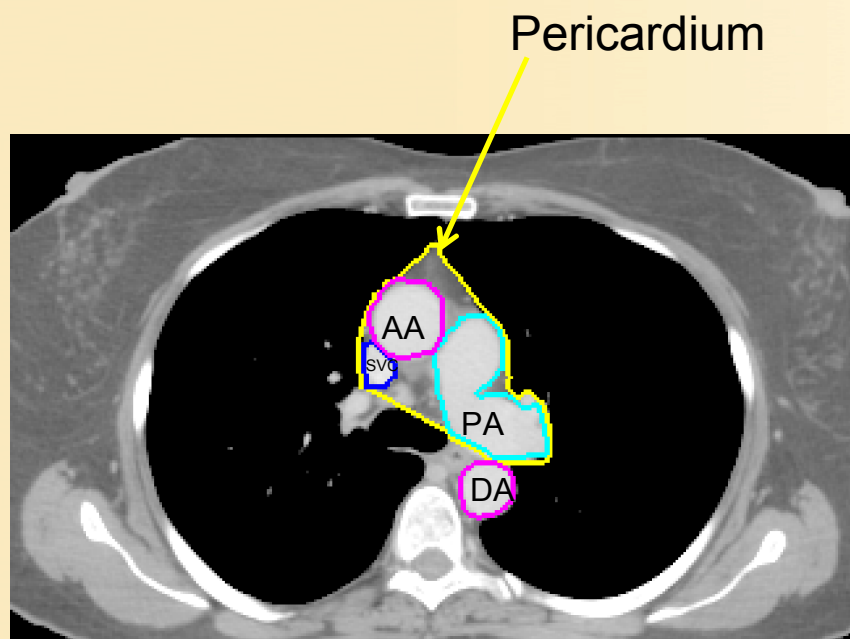


SVC=superior vena cava
PA=Pulmonary artery
AA=Ascending aorta
DA=Descending aorta



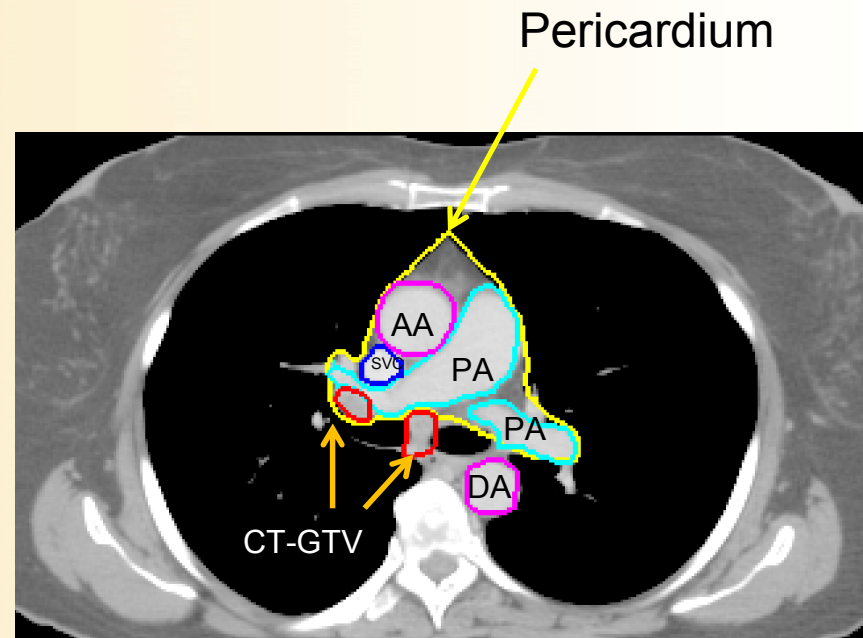
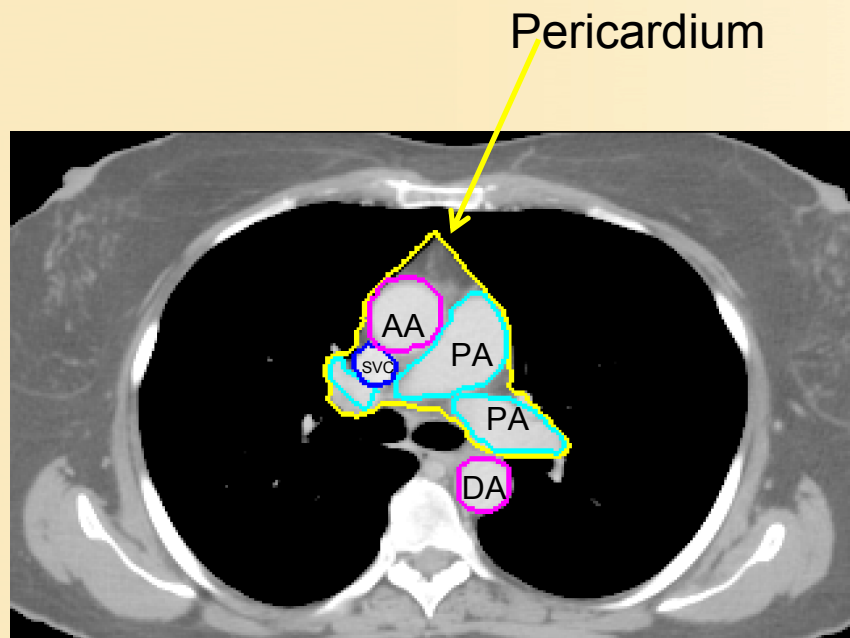
SVC=Superior vena cava
PA=Pulmonary artery
AA=Ascending aorta
DA=Descending aorta

Pericardium Continues...



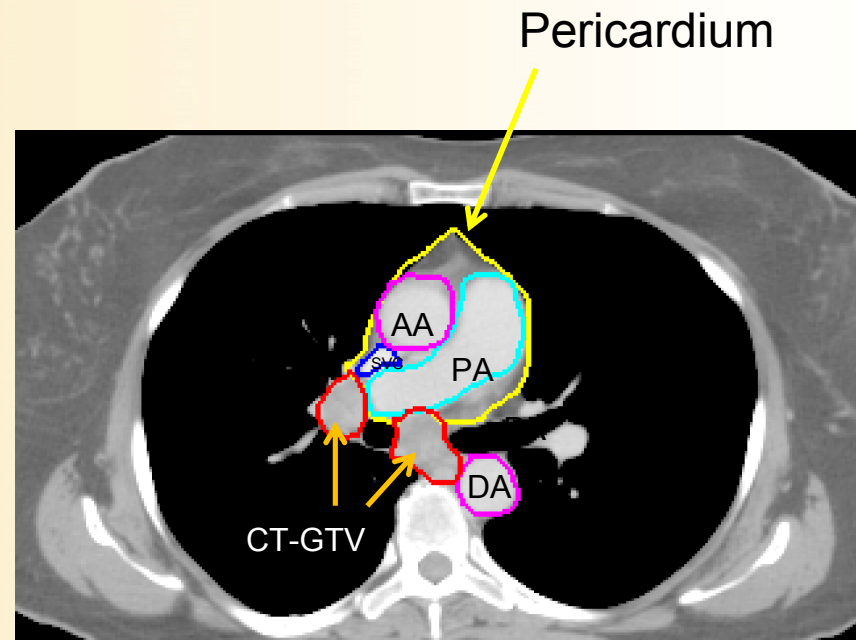
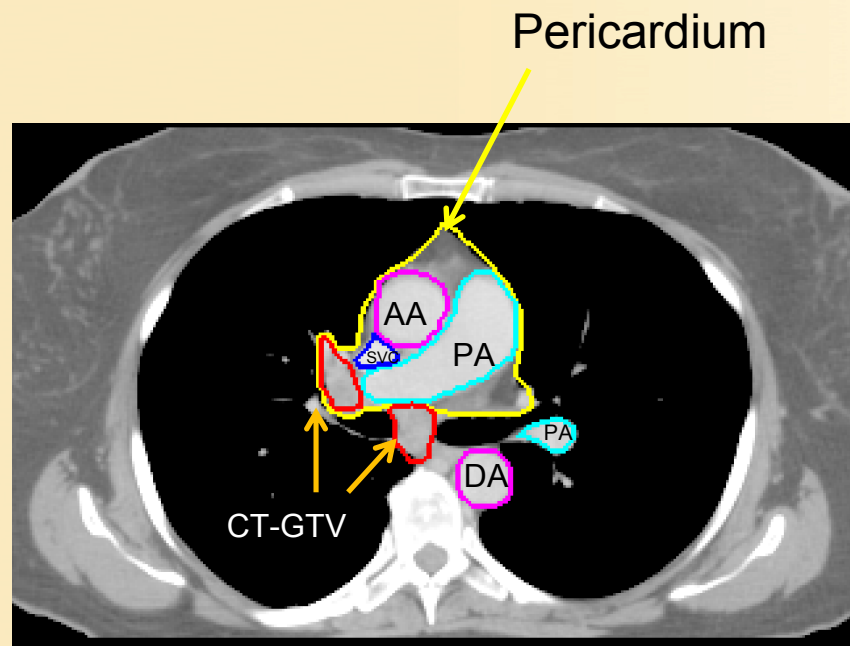
SVC=Superior vena cava
PA=Pulmonary artery
AA=Ascending aorta
DA=Descending aorta

Pericardium Continues...



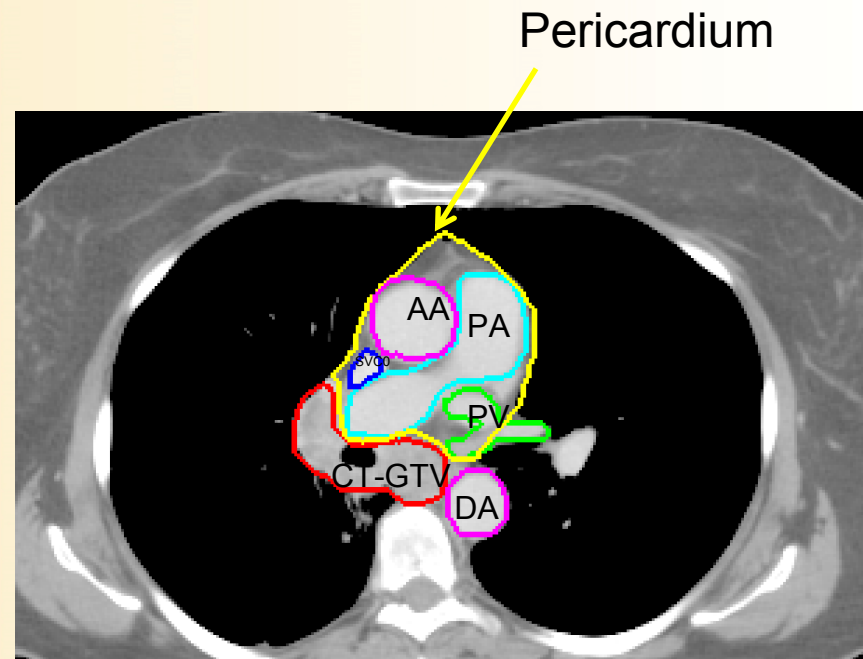
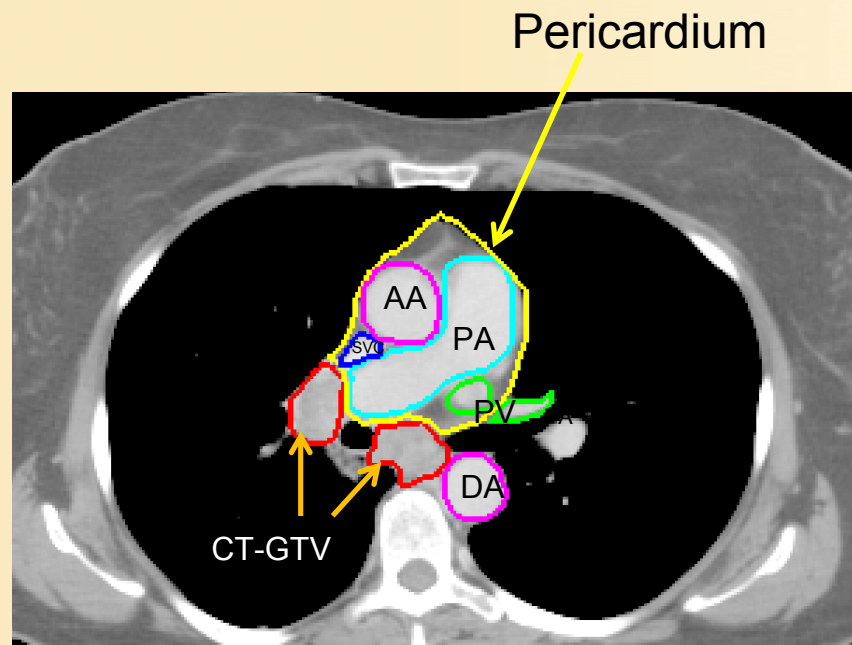
SVC=superior vena cava
PA=Pulmonary artery
AA=Ascending aorta
DA=Descending aorta

Pericardium Continues...



SVC=Superior vena cava
PA=Pulmonary artery
AA=Ascending aorta
DA=Descending aorta

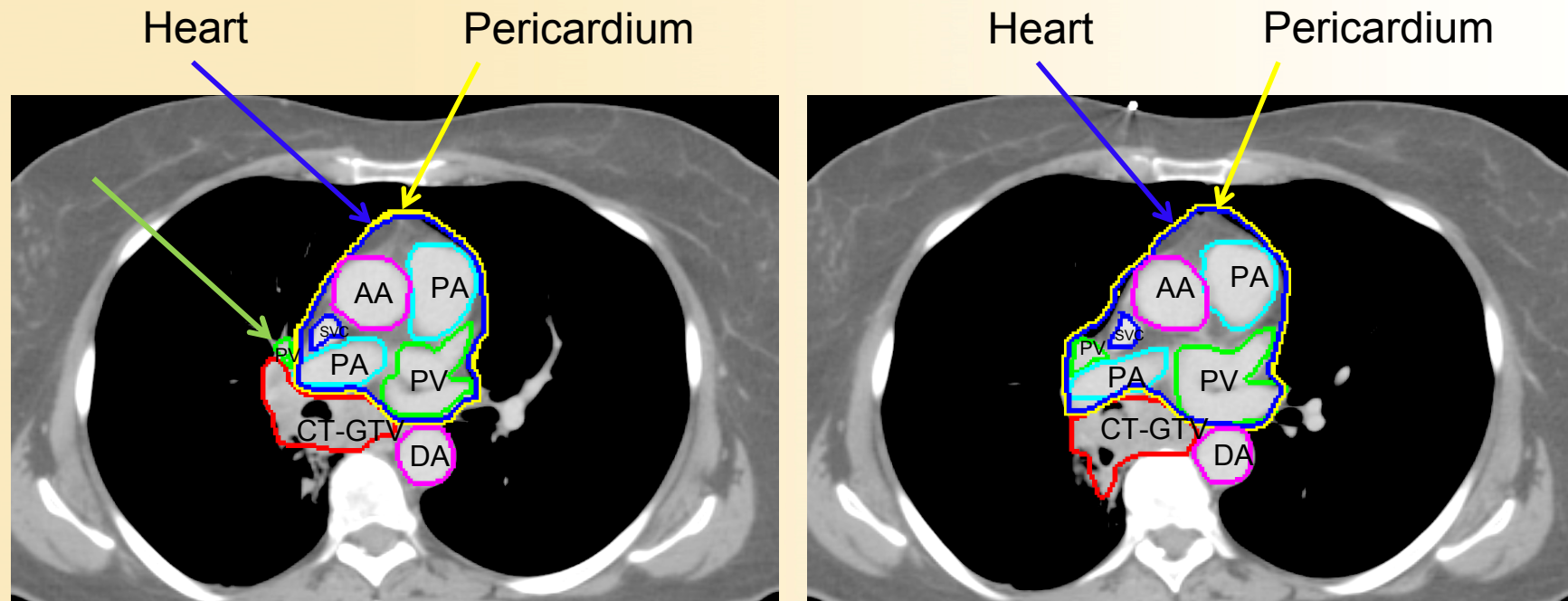
Pericardium Continues...



SVC=Superior vena cava
PA=Pulmonary artery
AA=Ascending aorta
DA=Descending aorta

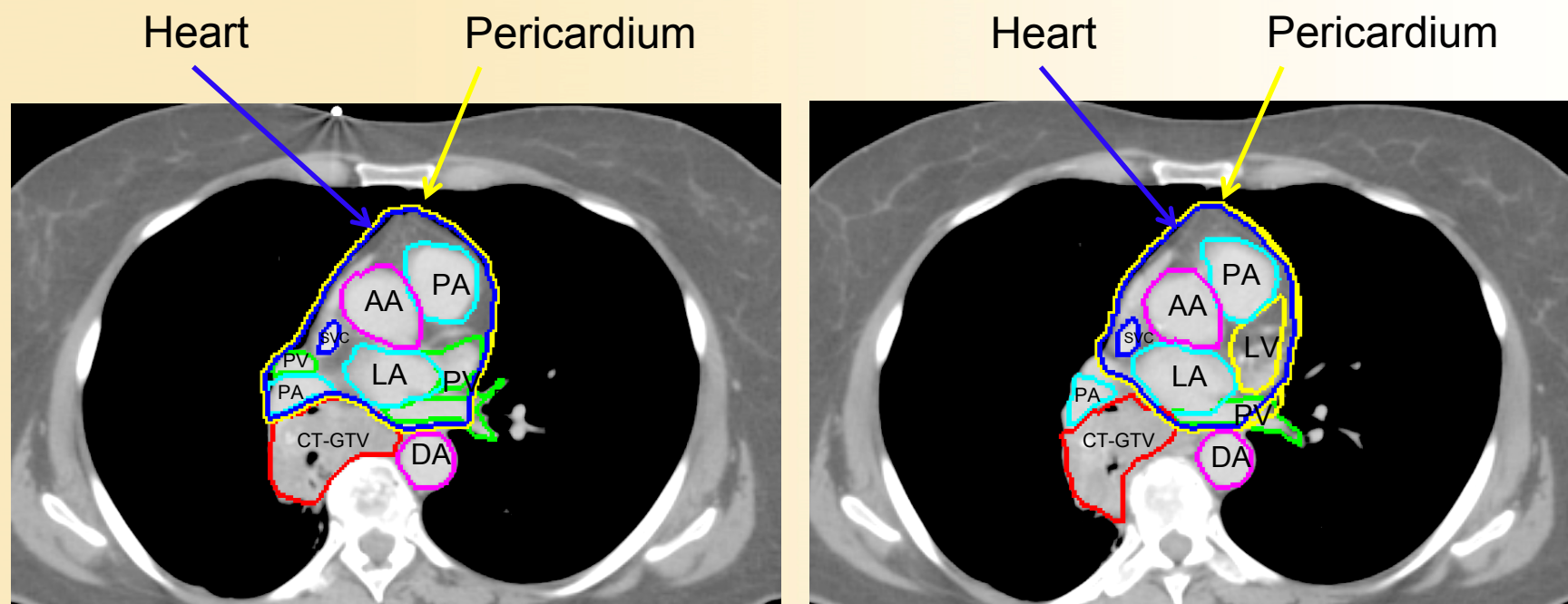
Pericardium continues...

Heart contour starts at this level, 1 slice below pulmonary artery trunk passing the midline



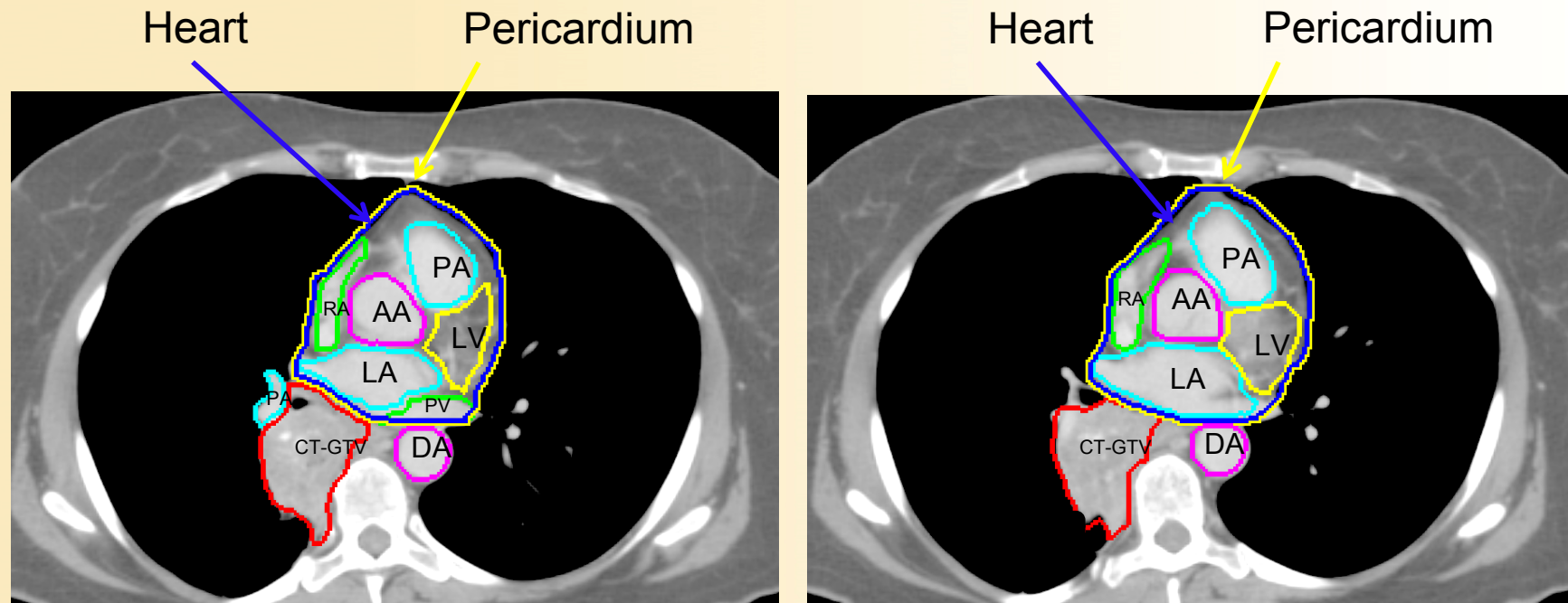
Heart and pericardium are to be overlapped.

Heart and pericardium continue...



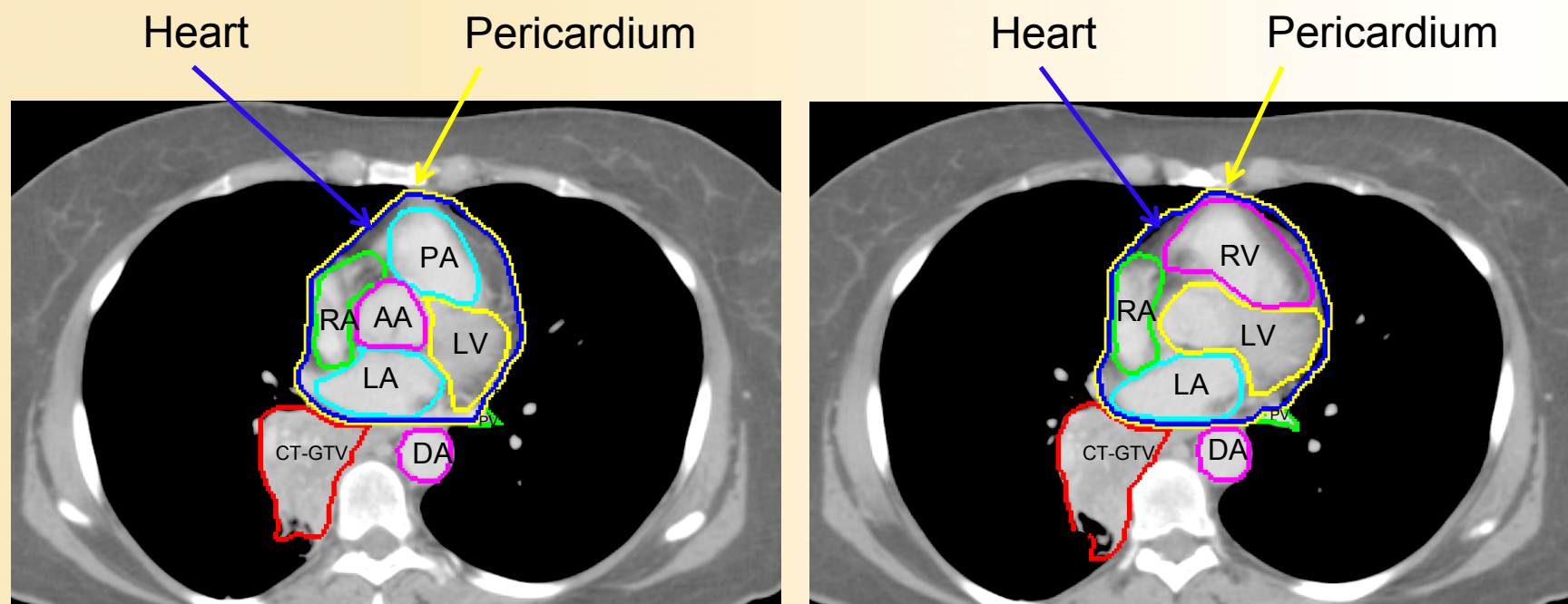
AA=Ascending Aorta, PA=pulmonary artery, RA=right atrium,
RV=right ventricle, LV=left ventricle, LA=Left atrium,
PV=pulmonary vein, DA=descending aorta, SVC=superior vena cava

Pericardium and Heart continue...



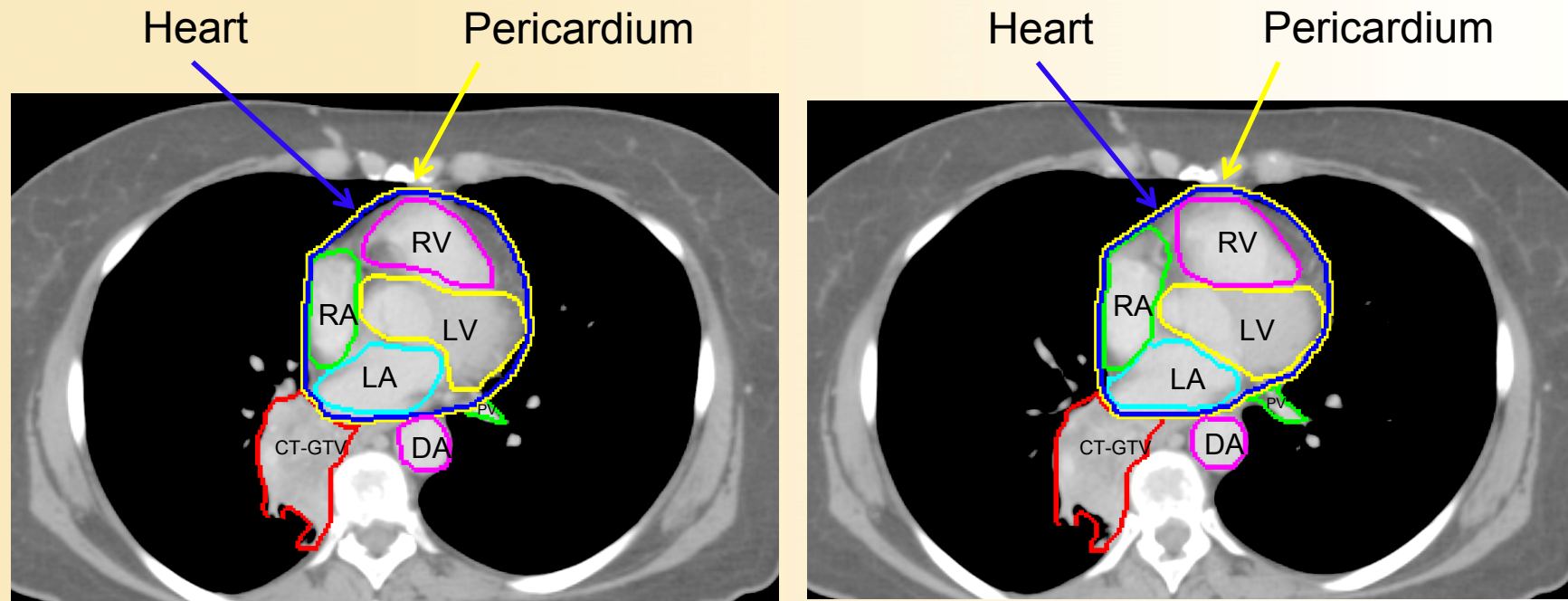
RA=right atrium, RV=right ventricle
LV=left ventricle, LA=Left atrium
DA=descending aorta

Pericardium and Heart continue...



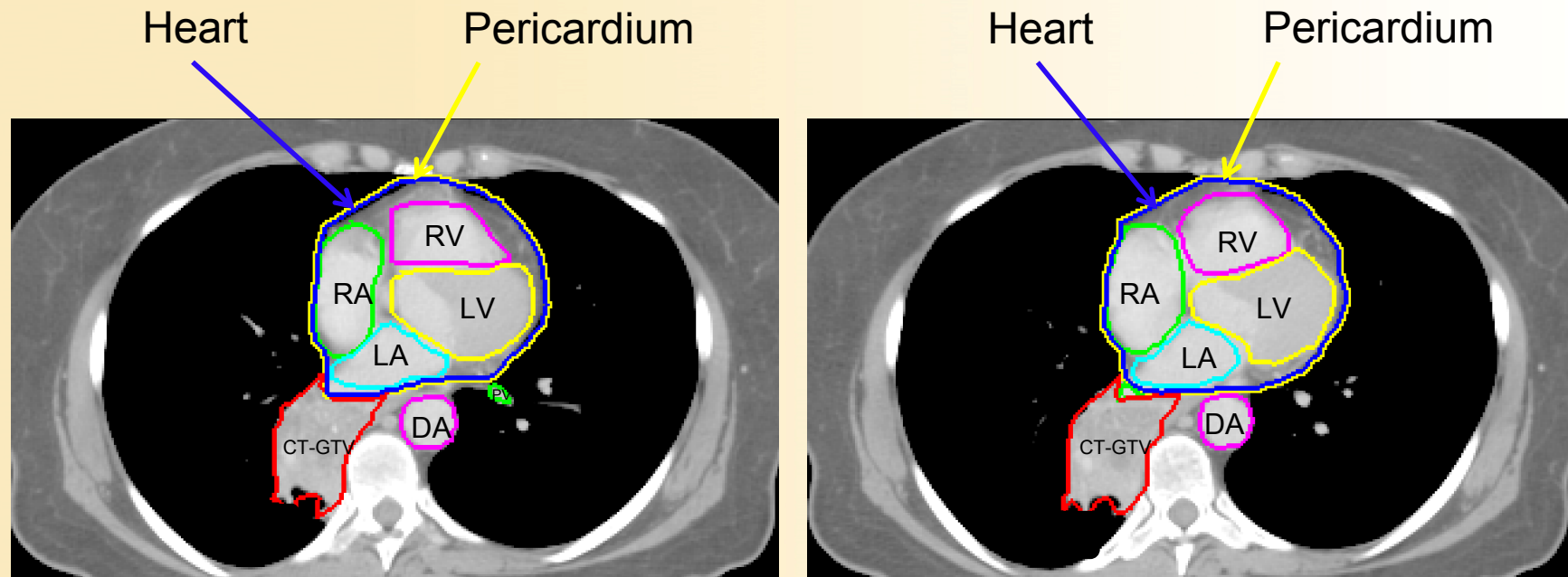
AA=Ascending Aorta, PA=pulmonary artery, RA=right atrium, RV=right ventricle
LV=left ventricle, LA=Left atrium, PV=pulmonary vein, DA=descending aorta

Heart and pericardium continue...



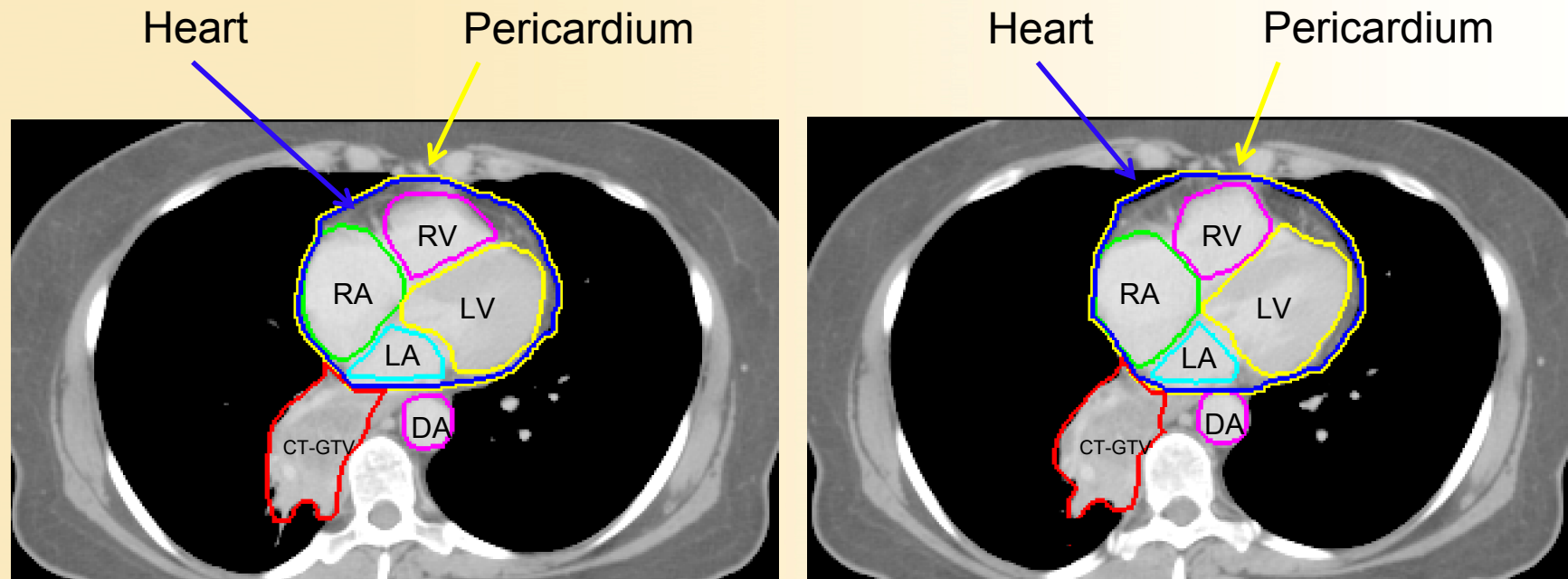
RA=right atrium, RV=right ventricle
LV=left ventricle, LA=Left atrium
DA=descending aorta

Heart and pericardium continue...



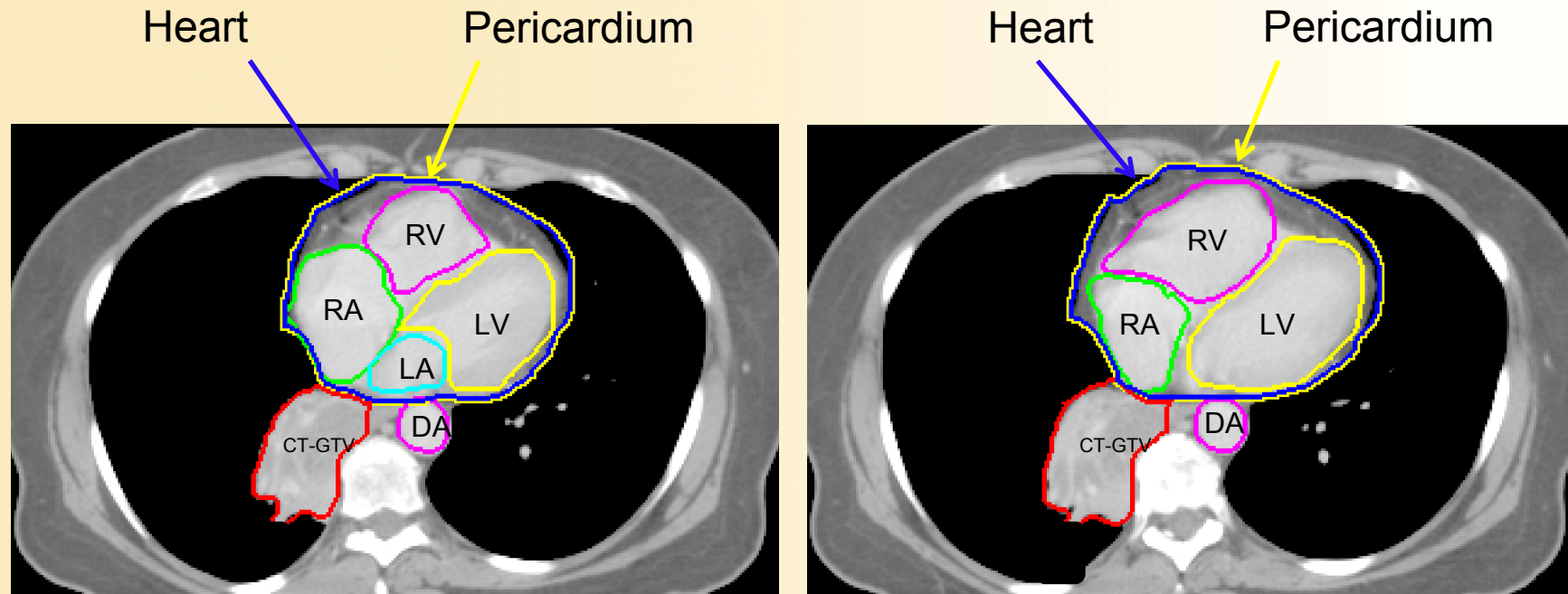
RA=right atrium, RV=right ventricle
LV=left ventricle, LA=Left atrium
DA=descending aorta

Heart and pericardium continue...



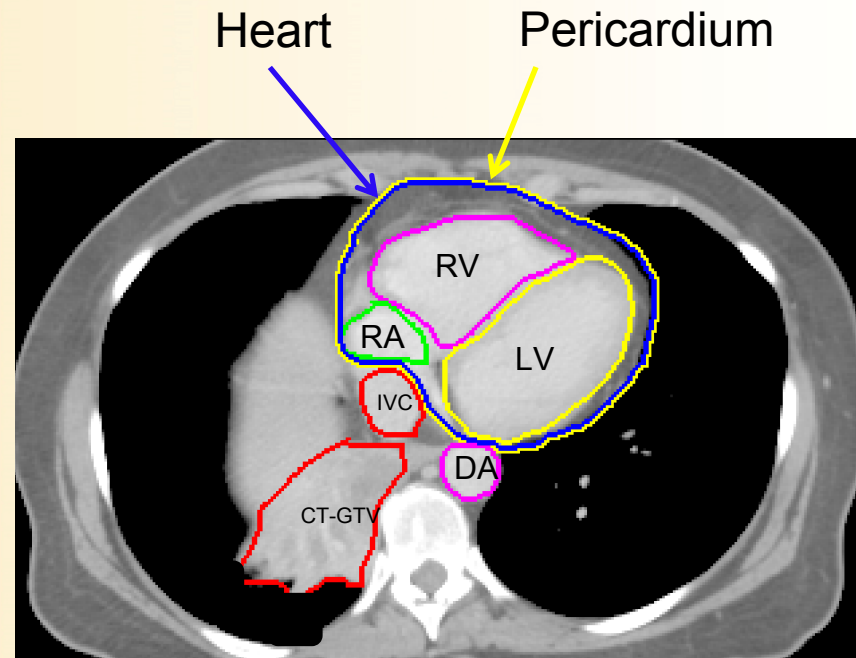
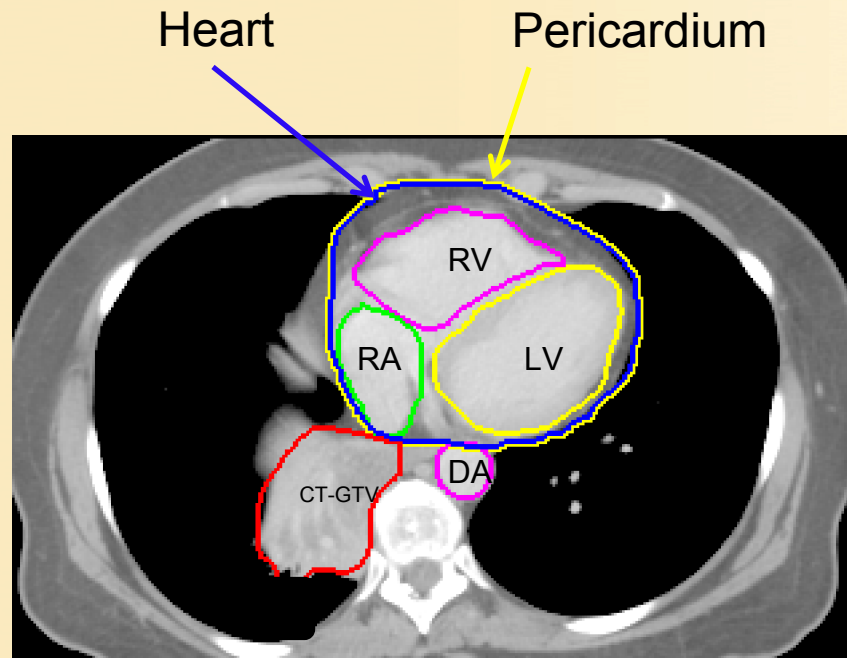
RA=right atrium, RV=right ventricle
LV=left ventricle, LA=Left atrium
DA=descending aorta

Heart and pericardium continue...



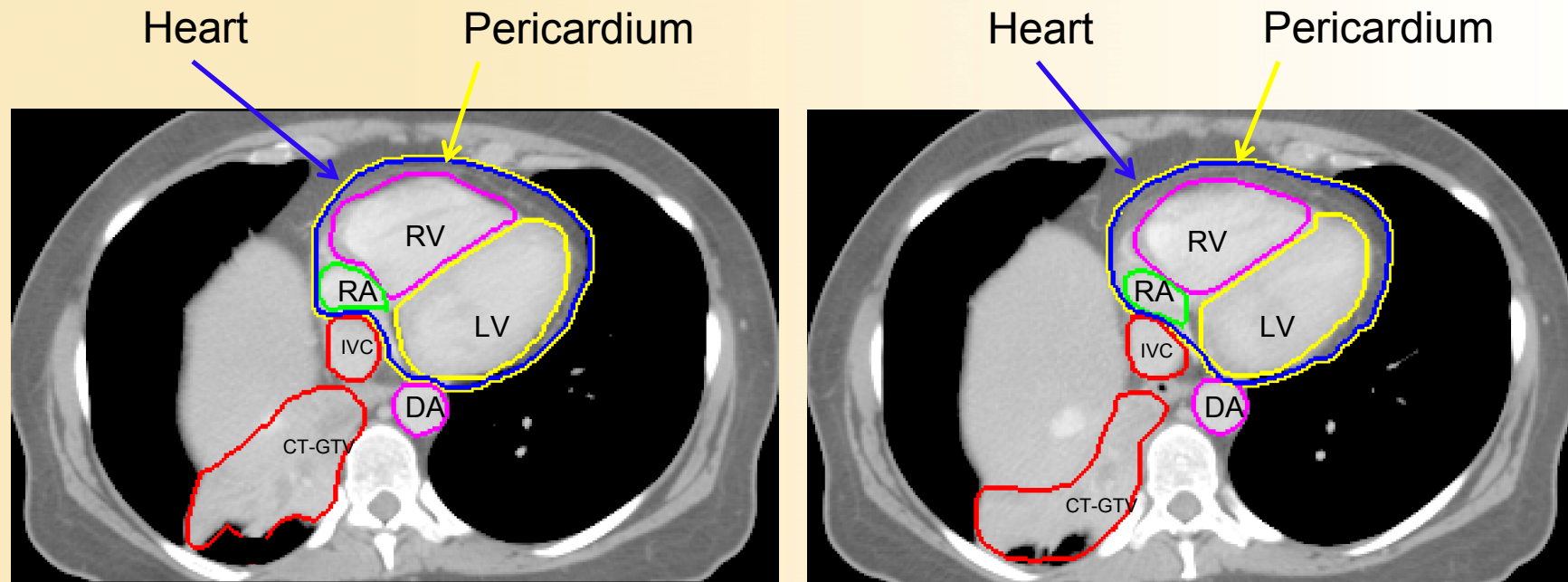
RA=right atrium, RV=right ventricle
LV=left ventricle, LA=left atrium
DA=descending aorta

Heart and pericardium continue...



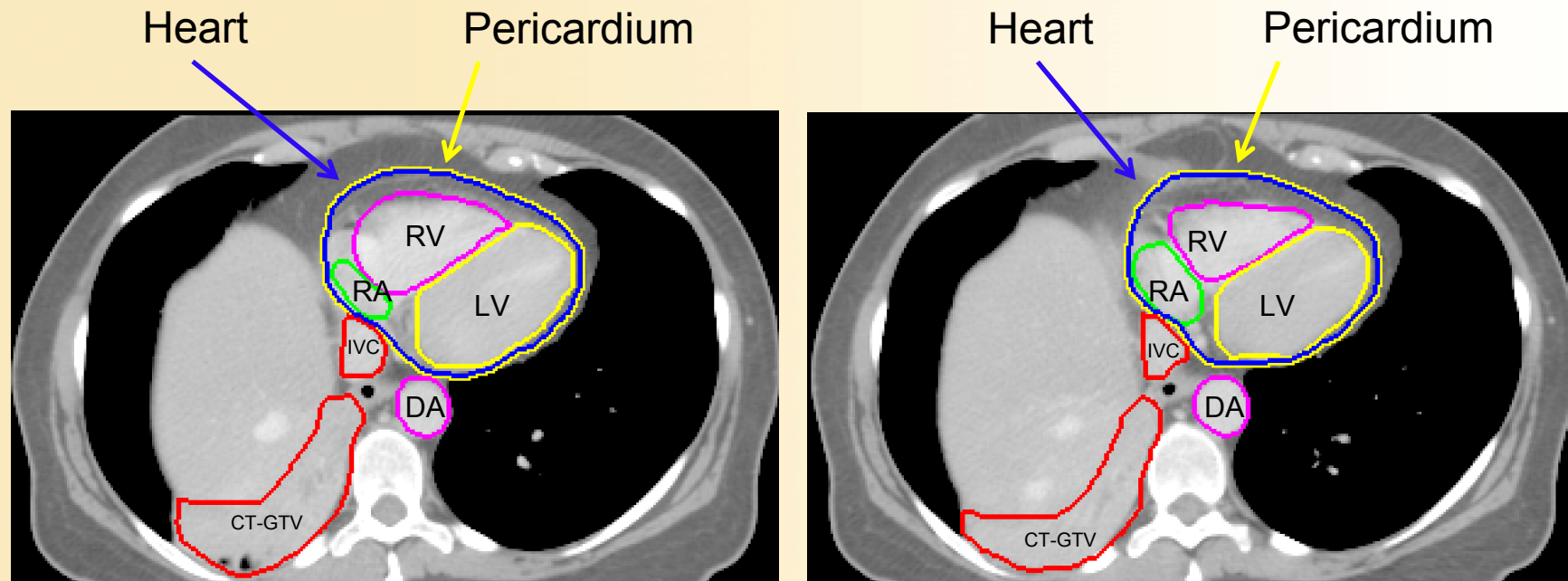
IVC=inferior vena cava
RA=right atrium, RV=right ventricle
LV=left ventricle
DA=descending aorta

Heart and pericardium continue...



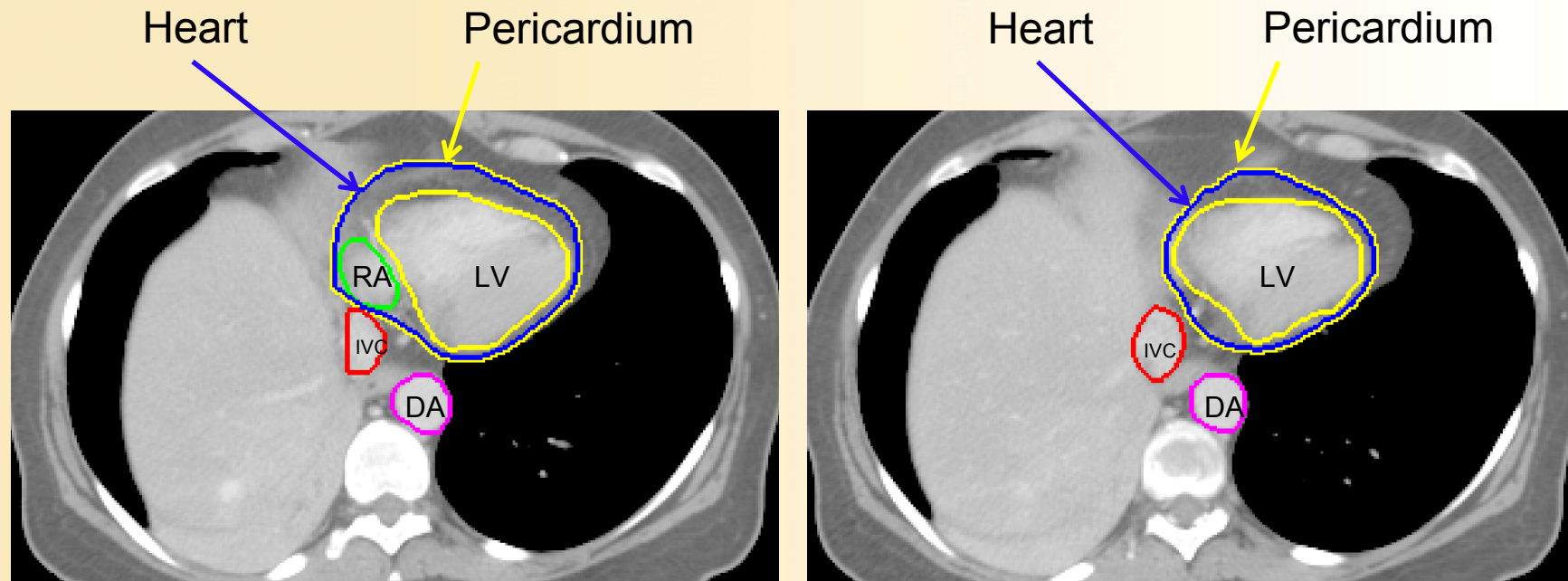
IVC=inferior vena cava
RA=right atrium, RV=right ventricle
LV=left ventricle
DA=descending aorta

Heart and pericardium continue...



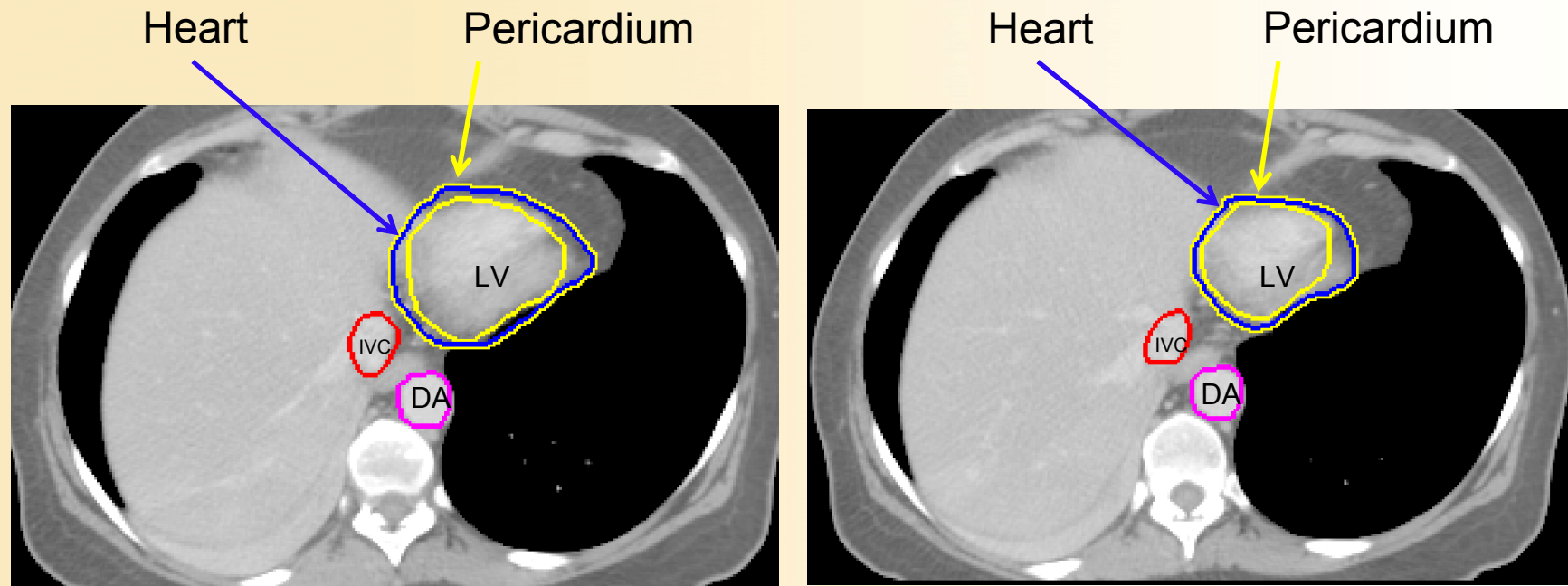
IVC=inferior vena cava
RA=right atrium, RV=right ventricle
LV=left ventricle
DA=descending aorta

Heart and pericardium continue...



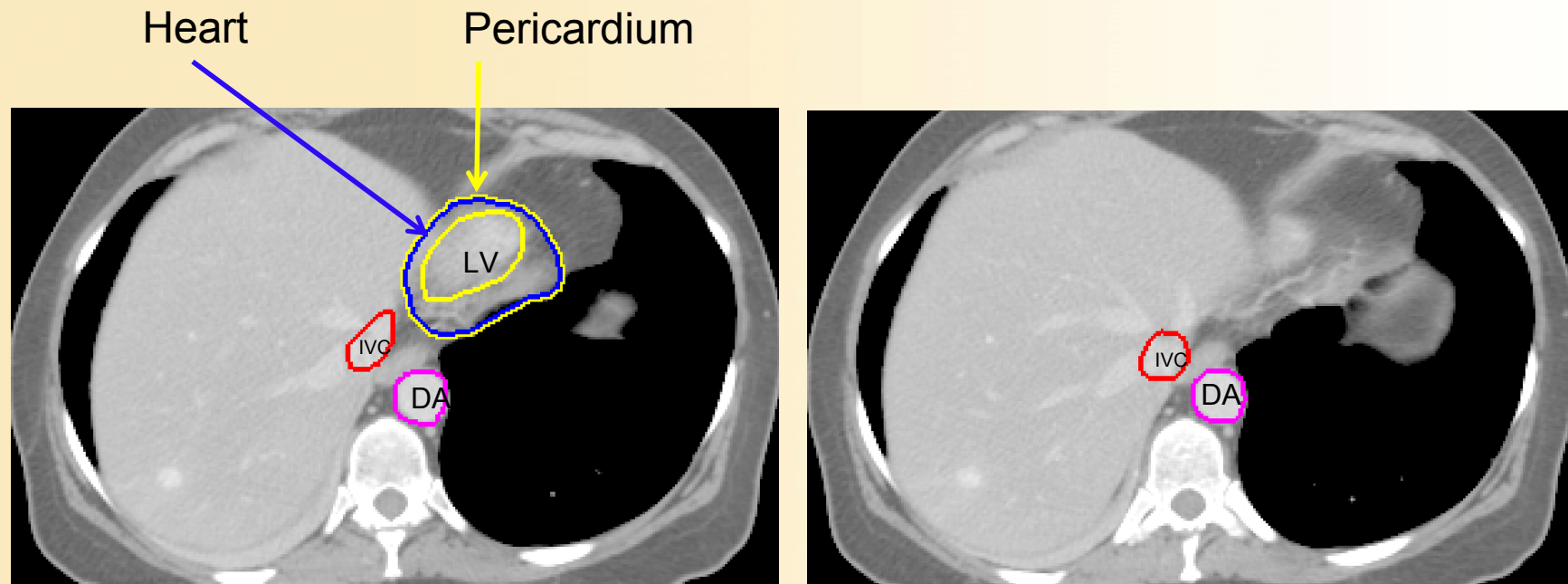
IVC=inferior vena cava
RA=right ventricle
LV=left ventricle
DA=descending aorta

Heart and pericardium continue...



IVC=inferior vena cava
LV=left ventricle
DA=descending aorta

Heart and pericardium end at diaphragm



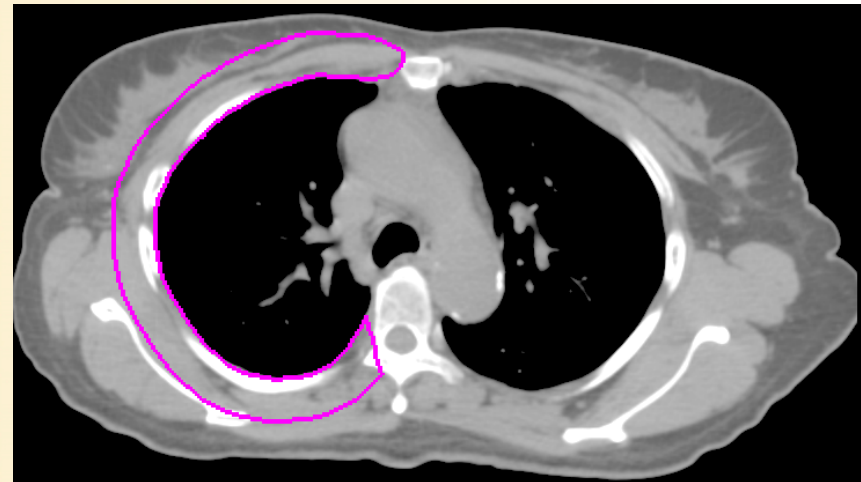
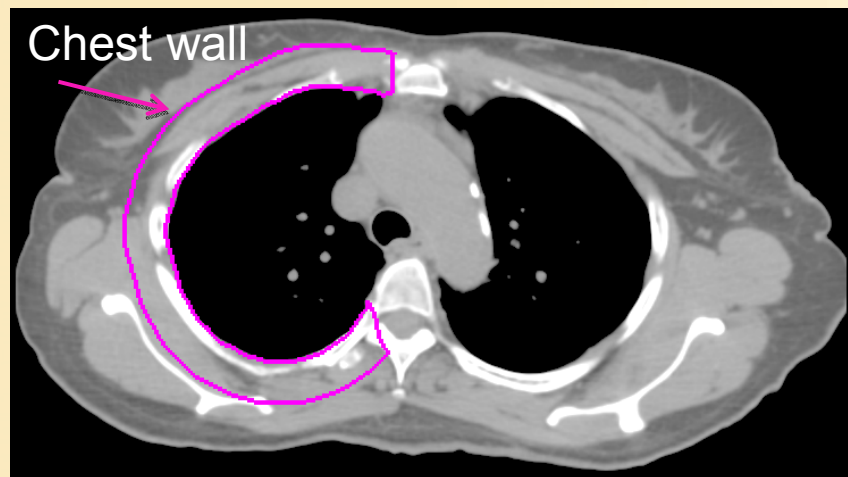
IVC=inferior vena cava
LV=left ventricle
DA=descending aorta

Chest Wall Contours

- Chest wall can be autosegmented from the ipsilateral lung with a 2-cm expansion in the lateral, anterior, and posterior directions. Anteriorly and medially, it ends at the edge of the sternum. Posteriorly and medially, it stops at the edge of the vertebral body with inclusion of the spinal nerve root exit site.
- This recommendation was:
 - based on Kong et al, Int J Radiat Oncol Biol Phys. 2010 Oct 7. [Epub ahead of print]
 - Supported by “CW2cm consistently enabled better prediction of CW toxicity than CW3cm” in Mutter et al, Int J Radiat Oncol Biol Phys. 2011 Aug 23. [Epub ahead of print]

Chest Wall (CW)

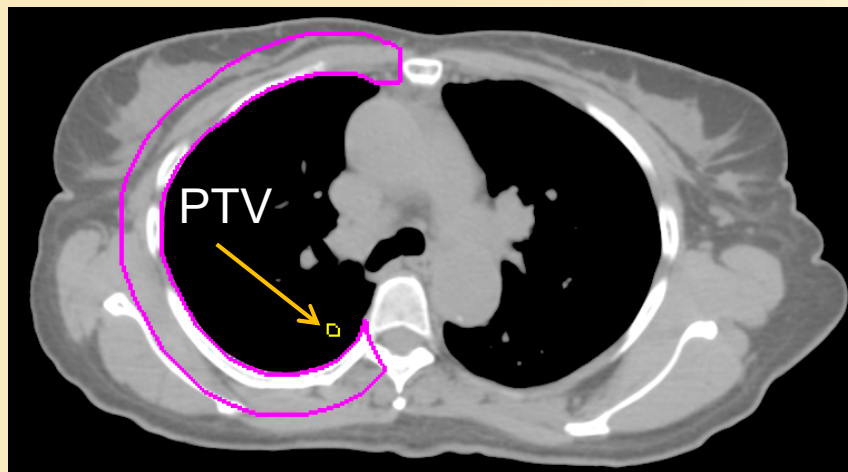
CW refers to CW2cm which include intercostal muscles, nerves exclude vertebrate bodies, sternum and skin. This can be accomplished through auto-expansion of the ipsilateral lung (within 3 cm range of PTV).



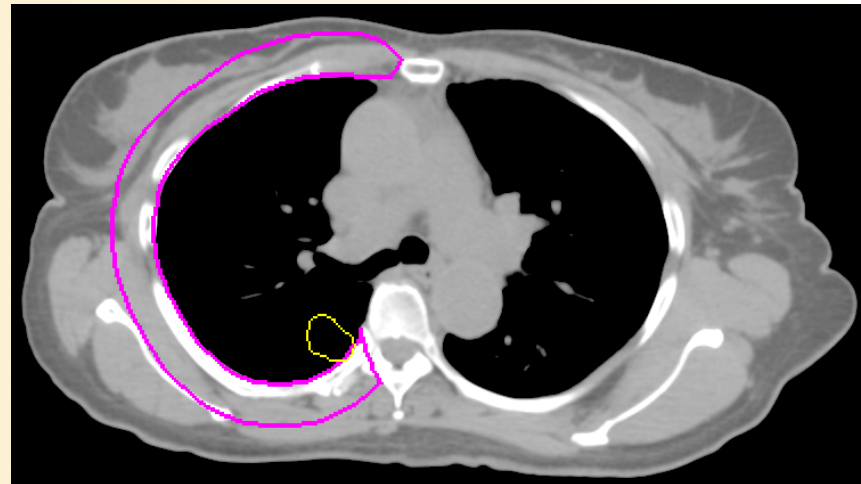
CW contouring starts at 3 cm above the PTV

Chest Wall

CW refers to CW2cm which include intercostal muscles, nerves
exclude vertebral bodies, sternum and skin.

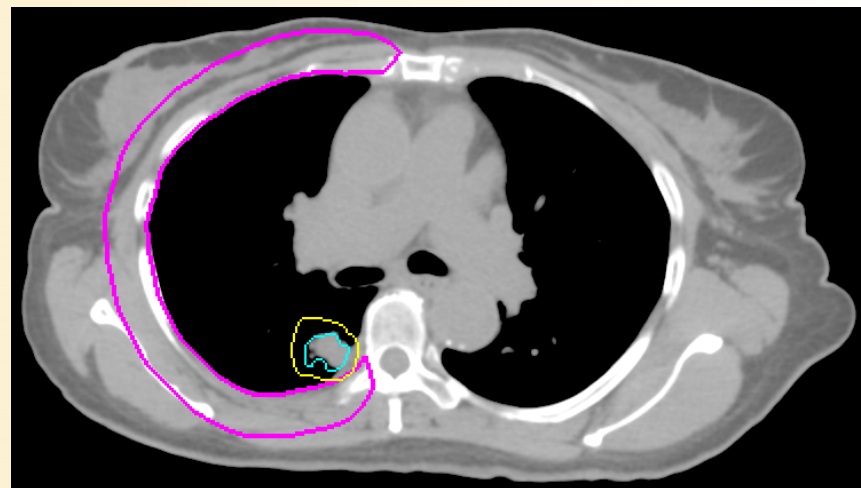
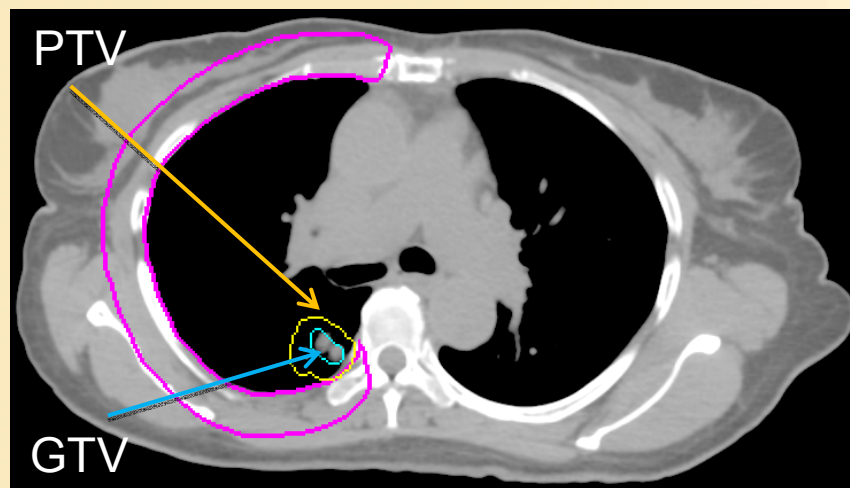


The superior end of PTV



Chest Wall

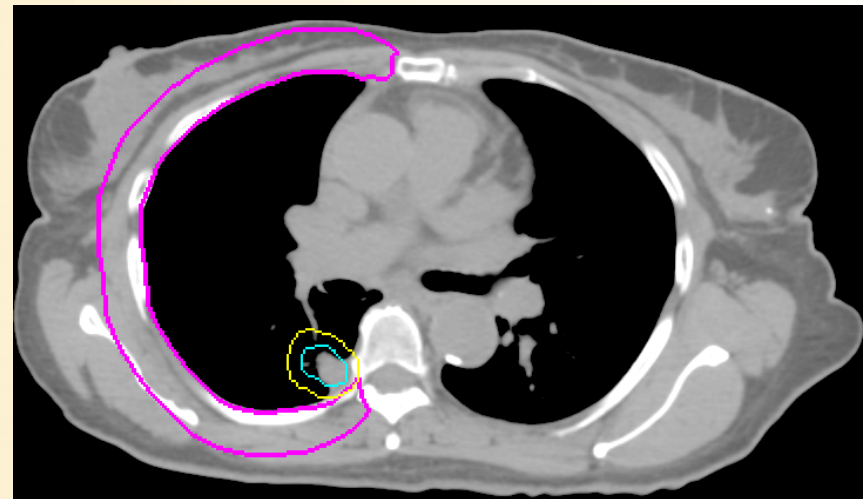
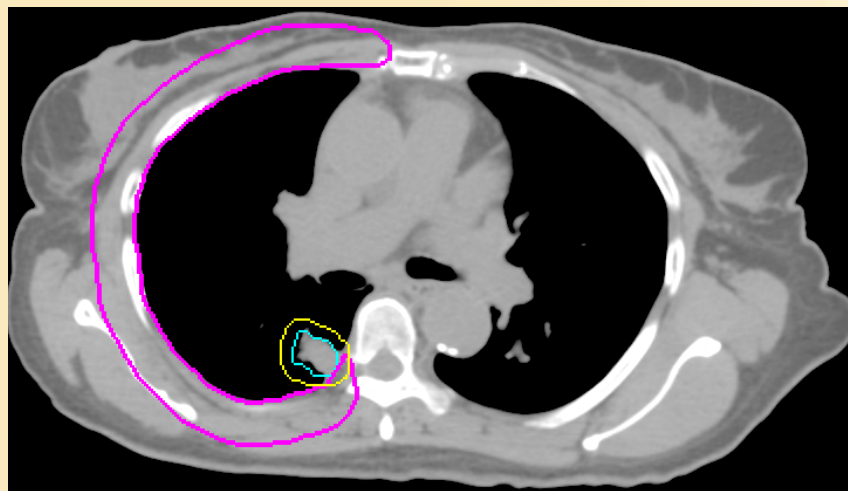
CW refers to CW2cm which include intercostal muscles, nerves
exclude vertebral bodies, sternum and skin.



The superior end of GTV

Chest Wall

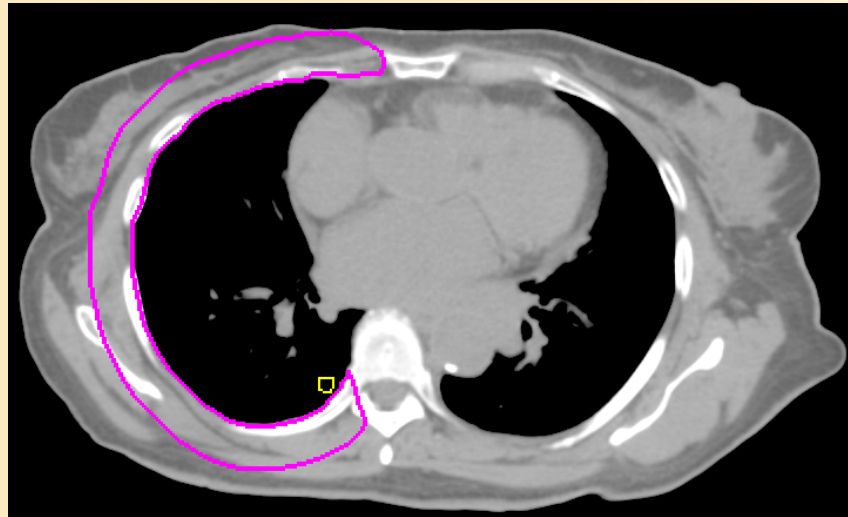
CW refers to CW2cm which include intercostal muscles, nerves
exclude vertebral bodies, sternum and skin.



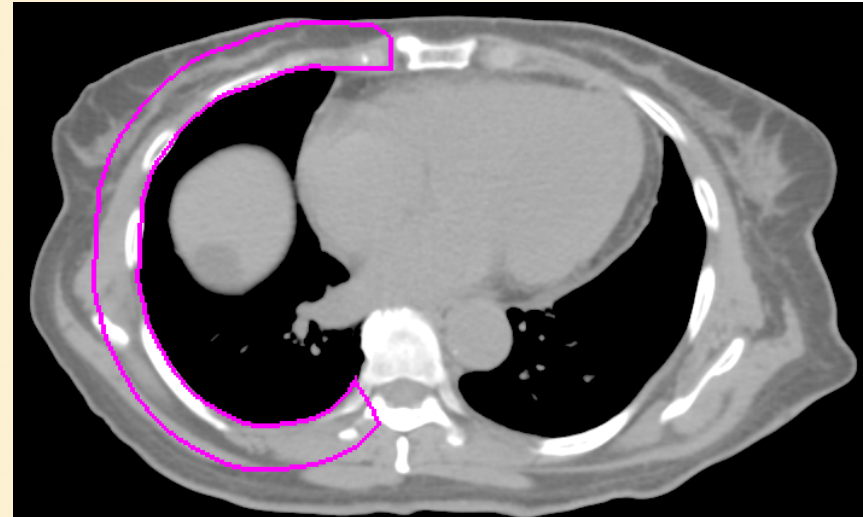
Chest wall contours around GTV.

Chest Wall

CW refers to CW2cm which include intercostal muscles, nerves exclude vertebral bodies, sternum and skin.



The inferior end of PTV



3 cm below PTV

CW ends at 3cm from the inferior edge of PTV.

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