Stereotactic Body Radiotherapy for Lung Tumours

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SBRT

Definition

SBRT is a method of External Beam Radiation that accurately delivers a high irradiation dose to an extracranial target in one of few treatmen t sessions

AAPM Task Group 101; (ASTRO and ACR); (CARO-SBRT) and the National Radiotherapy Implementation Group of the UK all agree on the following items:

SBRT is

(1) a method of external beam radiotherapy (EBRT) that
(2) accurately delivers a
(3) high dose of irradiation in
(4) one or few treatment fractions to an
(5) extracranial target.

Indication

- Patients with T1, T2 (≤ 5 cm), T3 (≤ 5 cm), N0, M0 non-small cell lung cancer(squamous cell carcinoma, adenocarcinoma, large cell carcinoma, large cell neuroendocrine, and non-small cell carcinoma not otherwise specified) patients with T3 tumors must have chest wall primary tumors only.
- Oligometastasis of lung from primary elsewhere.

the 2-year OS was 60.3% for patients with 1–3 metastases compared with 21.9% for patients with4–5 metastases

- *Zone of the proximal bronchial tree.*

- *Patients with T3 tumors based on mediastinal invasion or < 2 cm toward carina invasion*

…… should be dealt with caution

Concepts and recommendations on patient selection

ASTRO PRO 2017

When is SBRT appropriate for patients with T1-2, N0 NSCLC who are medically operable?

Any patient with operable stage I NSCLC being considered for SBRT should be evaluated by a thoracic surgeon, preferably in a ultidisciplinary setting, to reduce specialty bias

For patients with “standard operative risk” (ie, with anticipated operative mortality of less than .5%) and stage I NSCLC, SBRT is not recommended as an alternative to surgery outside of a clinical trial.

For this population, lobectomy with systematic mediastinal lymph node evaluation remains the recommended treatment, though a sublobar resection may be considered in select clinical scenarios

For patients with high operative riskd discussions Regarding SBRT are encouraged

When is SBRT appropriate for medically inoperable patients with T1-2, N0 NSCLC:

<u>For centrally located tumours</u>

- **3 fractions should be avoided**
- **Significant risks should be considered**

<u>For more than 5 cm tumours</u>

- **Only if acceptable therapeutic ratio**
- **Volumetric , maximum dose constraints can be adhered to**

For patients who underwent pneumonectomy and now have a new primary tumor in their remaining lung?

SBRT may be considered a curative treatment option for patients with metachronous in a postpneumonectomy setting. While SBRT for metachronous MPLC appears to have equivalent rates of local control and acceptable toxicity compared to single tumors, SBRT in the postpneumonectomy setting might have a higher rate of toxicity than in patients with higher baseline lung capacity.

Recommendation strength: Conditional
Quality of evidence: Low

Contouring

Contouring: Challenges

- Respiration induced motion compromises the intention to deliver prescribed dose to tumours.
- Motion artefacts
- Erroneous Hounsfield unit (HU) causing insufficient dose coverage
- to tumours which may adversely affect hypofractionated stereotactic treatment especially for their small volume.

Planning: Image acquisition

- Computed tomography will be the primary image platform for targeting and treatment planning.

- Contrast to be used which will allow better distinction between tumor and adjacent vessels or atelectasis.

- spacing ≤ 3.0 mm between scans in the region of the tumor should be used.

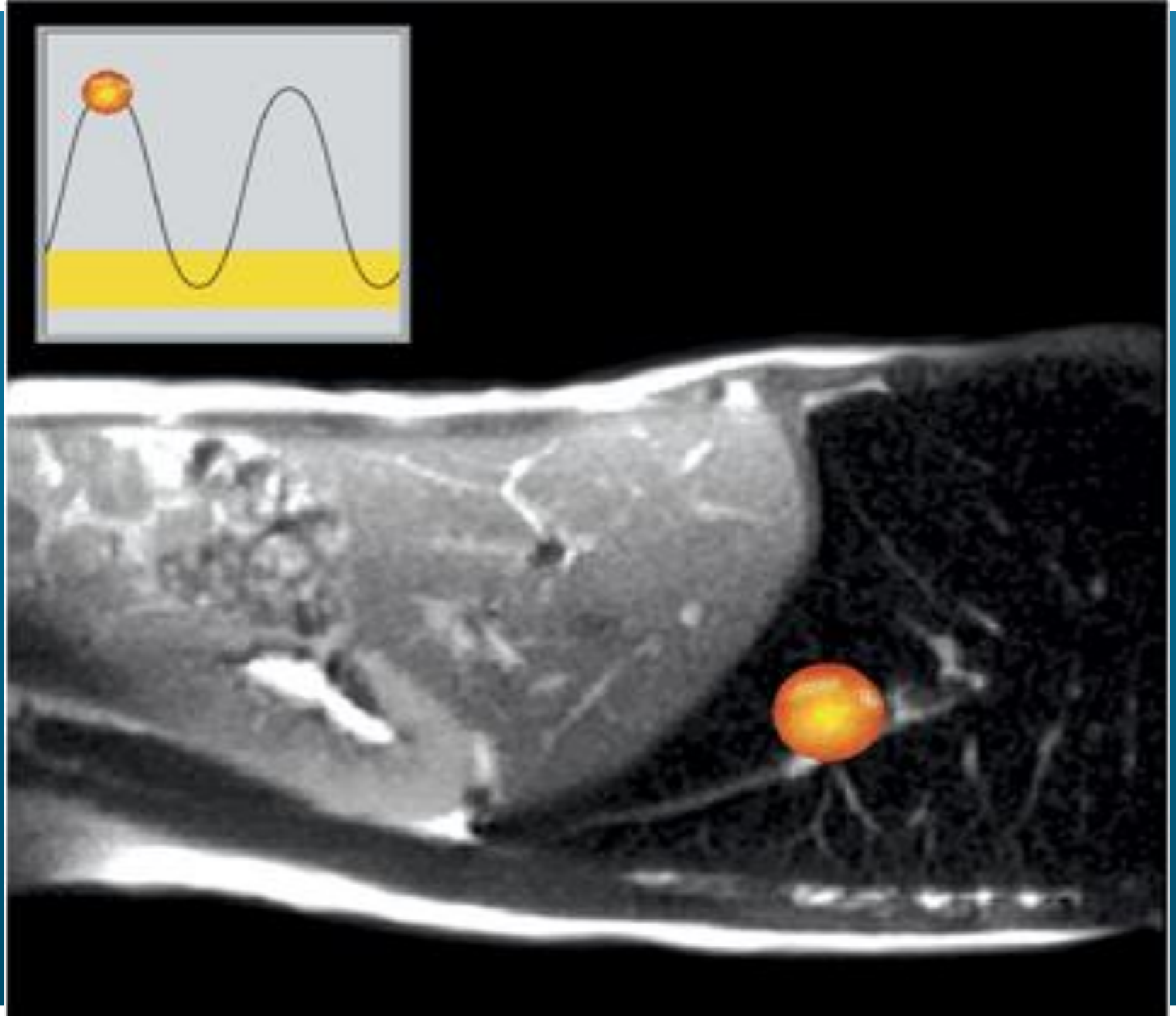
- If equipped with 4 DCT system , this should be used.

Planning: Image acquisition

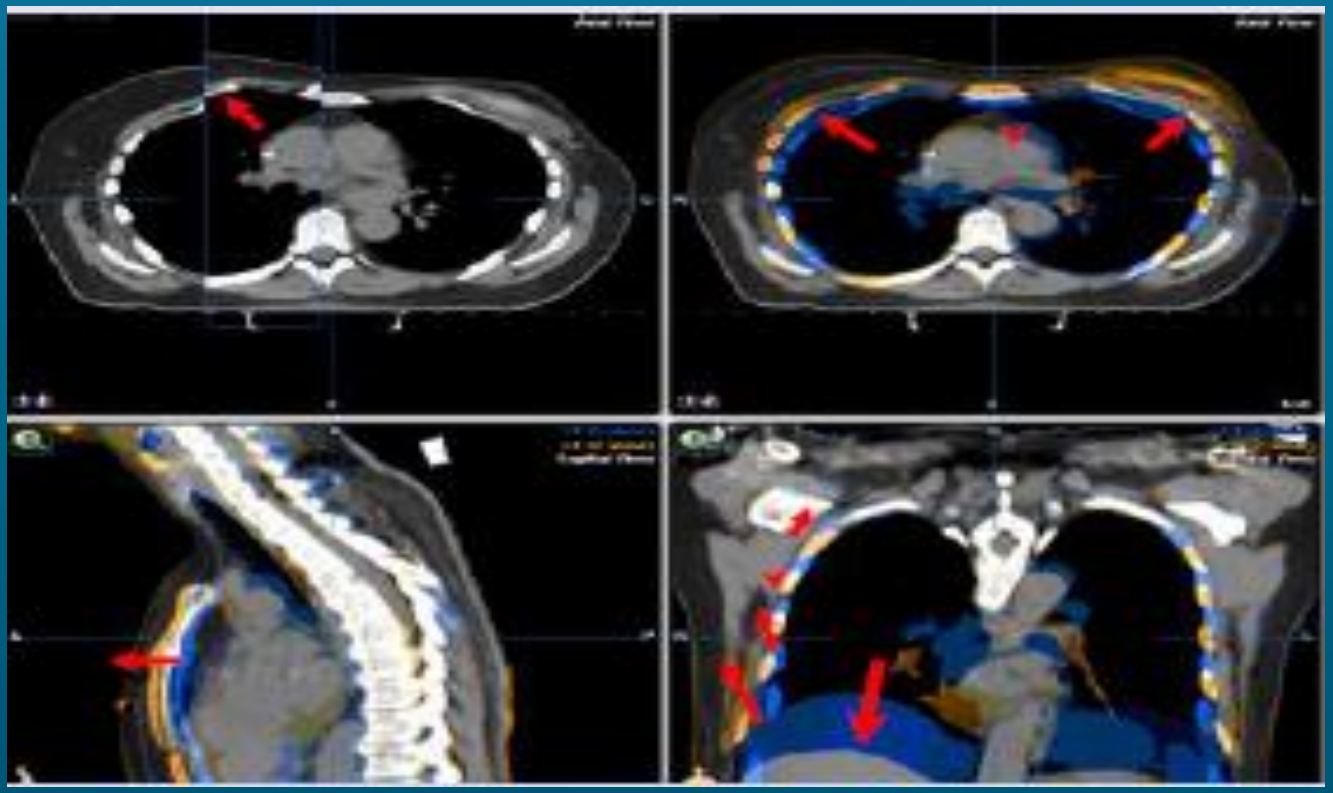
- In case of multiple measurements of ranges of motion (at simulations and/or at treatments, possibly pre- and post-treatments) provide information about the day and time when the data have been collected.

- When data for some patients/treatment fractions is not collected the record of the missing measurement has to be kept and reported. If there is a clinical reason for not collecting data, it needs to be reported as well.

- The reported range of motion has to be separated from setup errors

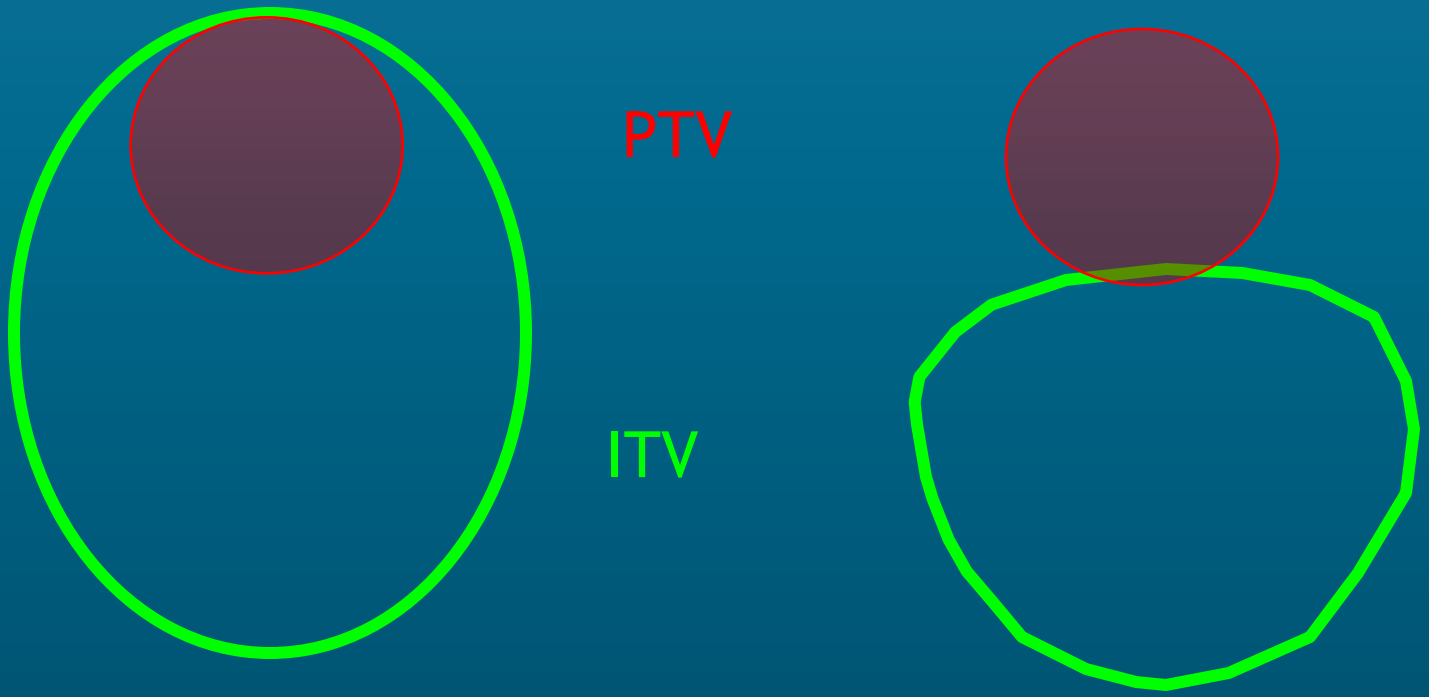


Moving direction of anatomy from exhale to inhale status



4D Treatment Planning

Internal target `Volume (ITV) Concept



Contouring:

- Patient specific tumor ITV to be determined in order to ensure adequate tumor coverage.
- 4 dimensional CT (4DCT) is the widely used method to obtain volumetric information due to tumor motion.
- Precise delineation of the target with a relatively tight Planning Target Volume (PTV), conformal RT planning with the management of target motion with respiration is pre-requisite to deliver high dose per fraction.

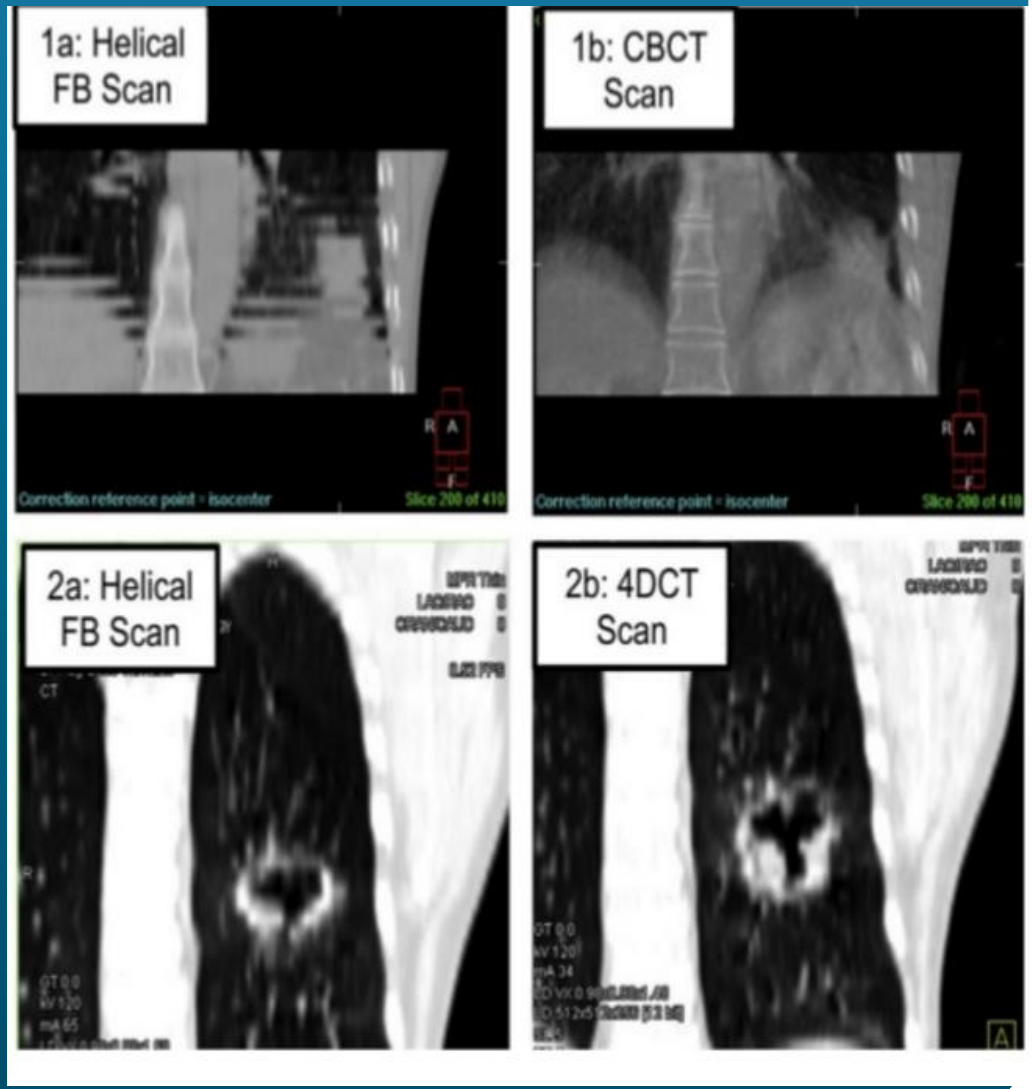
Contouring

•Due to respiratory motion there s image distortion

• GTV on single respiratory phase can under or overestimate the tumor volume

•Also mean tumour position can be misrepresented.

• Respiratory motion management should be considered if available.



Contouring:

Simulation: Supine

Contrast : IV contrast

Non 4DCT system : PTV should be expanded 5 mm axially and 1 cm craniocaudally

4 DCT system: To generate ITV based on 4DCT data set and to give 5 mm symmetrical margin over the ITV to generate PTV

Contouring:

Methods of ITV generation:

-GTV to be contoured in all respiratory phases , then to draw the boolean structure to generate ITV

-ITV can be drawn based on maximum intensity projection

-In case of inhale , exhale and free breathing scan taking , GTV can be contoured in all these 3 phases an then to boolean hem o generate ITV.

Contouring: Tumor

- The target will generally be drawn using CT pulmonary windows;

- Soft tissue windows with contrast may be used to avoid inclusion of adjacent vessels, atelectasis, or mediastinal or chest wall structures within the GTV.

- This target will not be enlarged whatsoever for prophylactic treatment (including no "margin" for presumed microscopic extension)

- Rather, include only abnormal CT signal consistent with gross tumor (i.e., the GTV and the clinical target volume [CTV] are identical).

Motion management and CT simulation:

- Forced shallow breathing techniques
  (Compression paddle , Pressure belt)

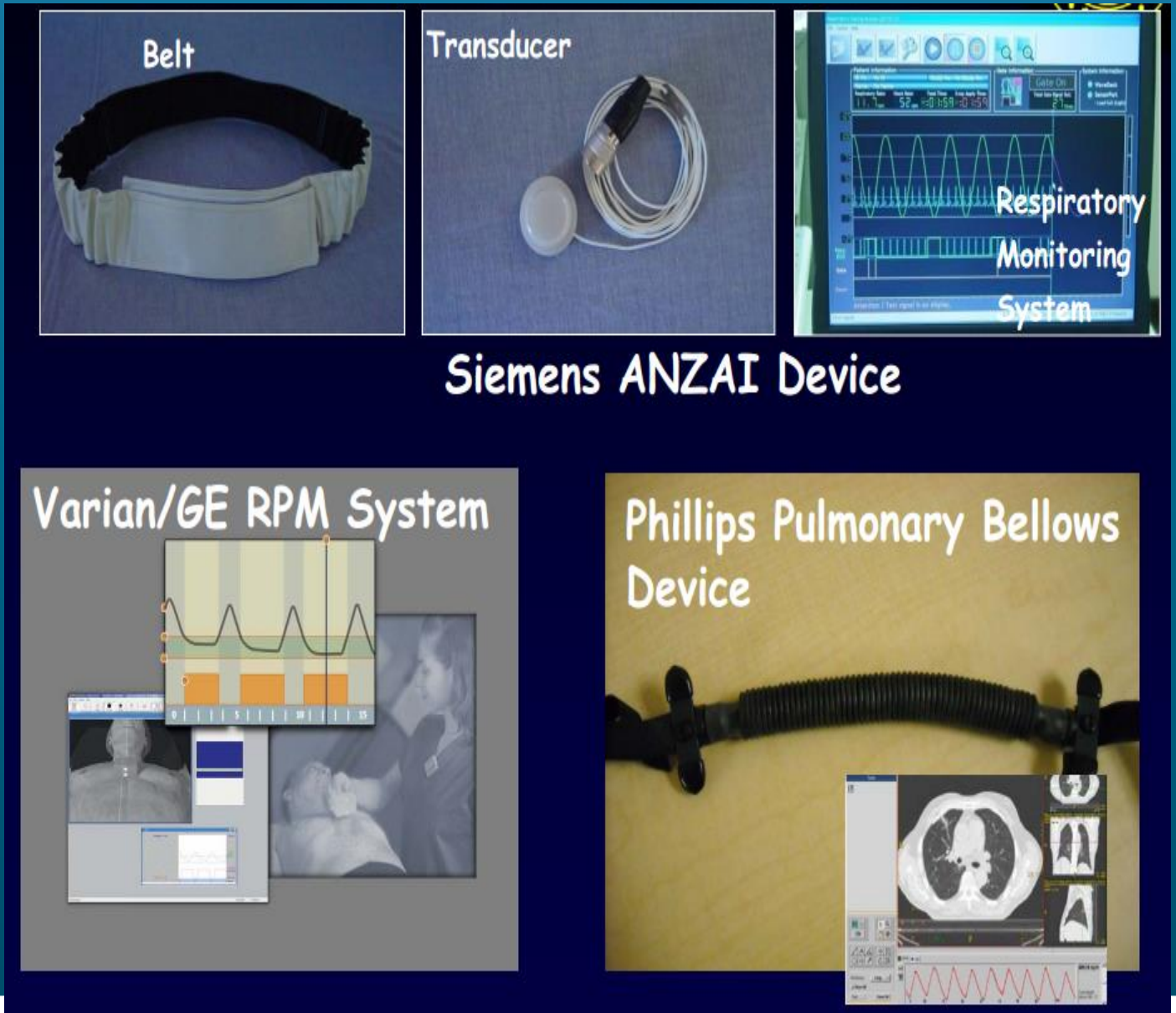
- Respiratory gated CT and 4DCT

- Free Breathing and slow CT Scanners

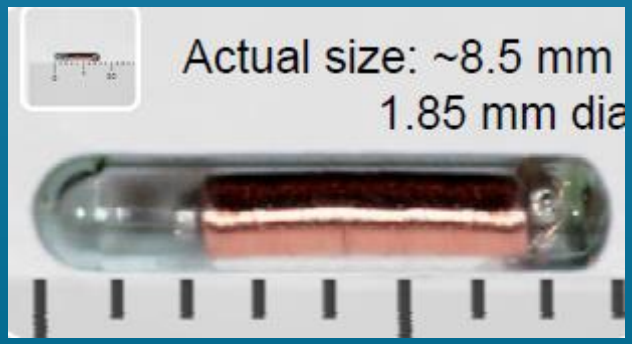
- Free Breathing and Fast CT Scanners

- Breath Hold CT Scans

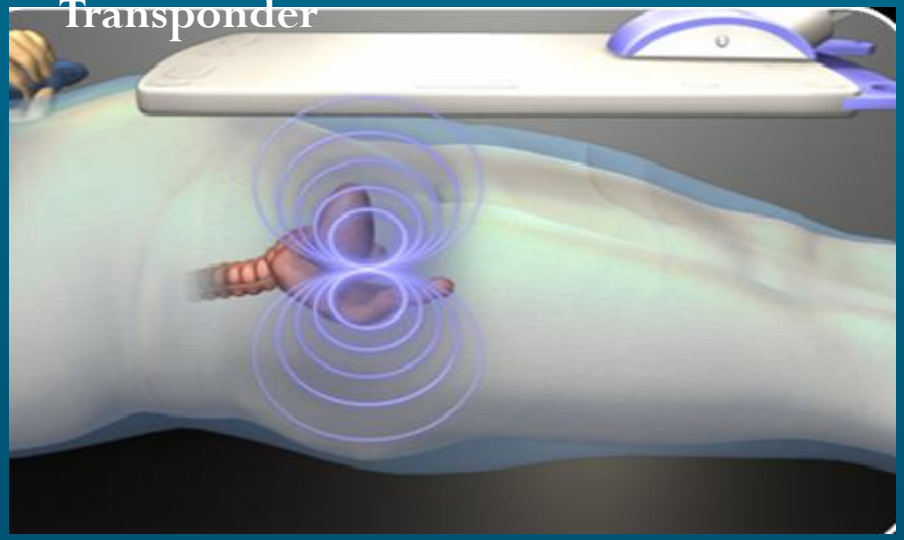
Respiratory Motion management Device:



Radio frequency (RF) signals

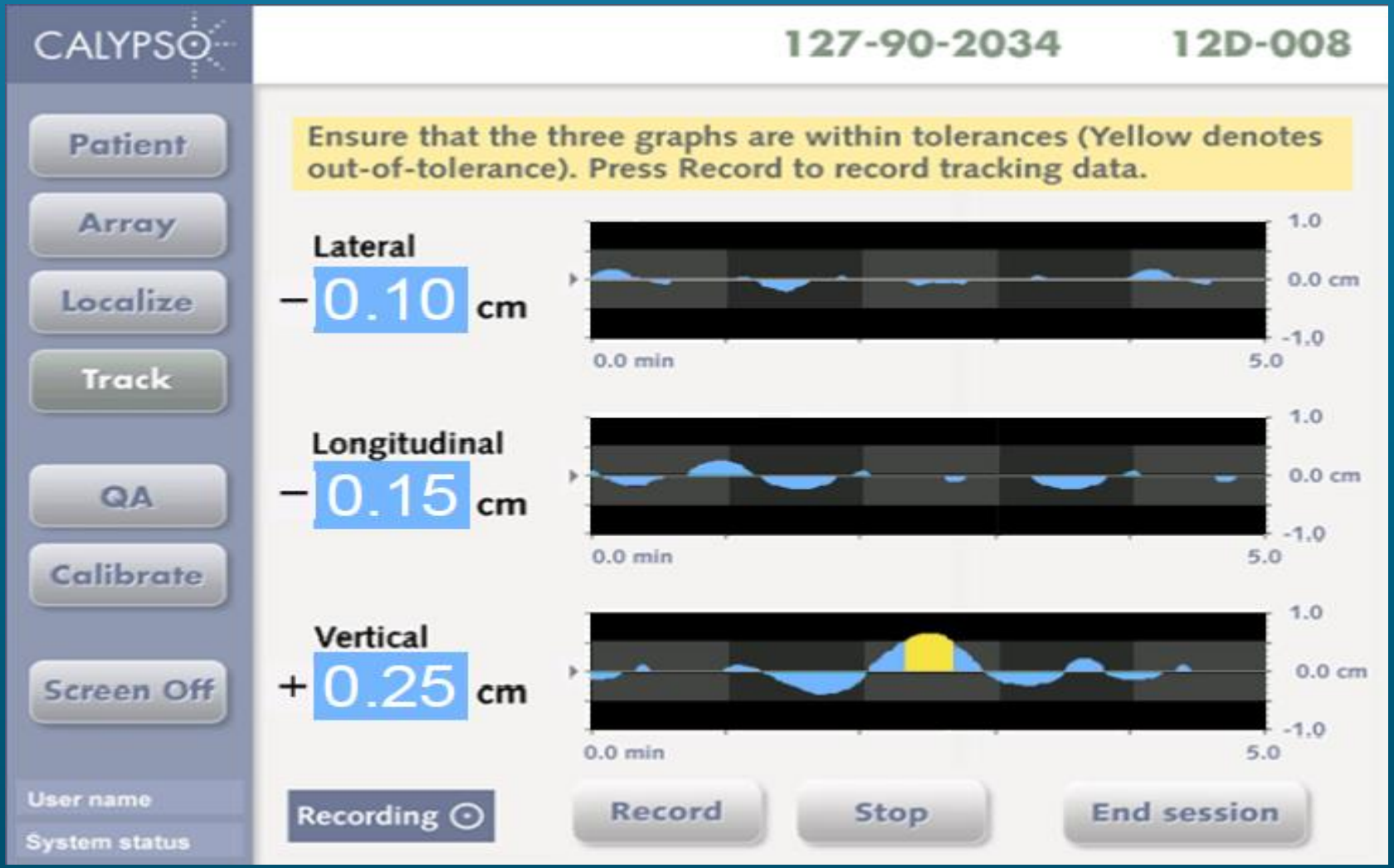


Beacon®Electromagnetic Transponder

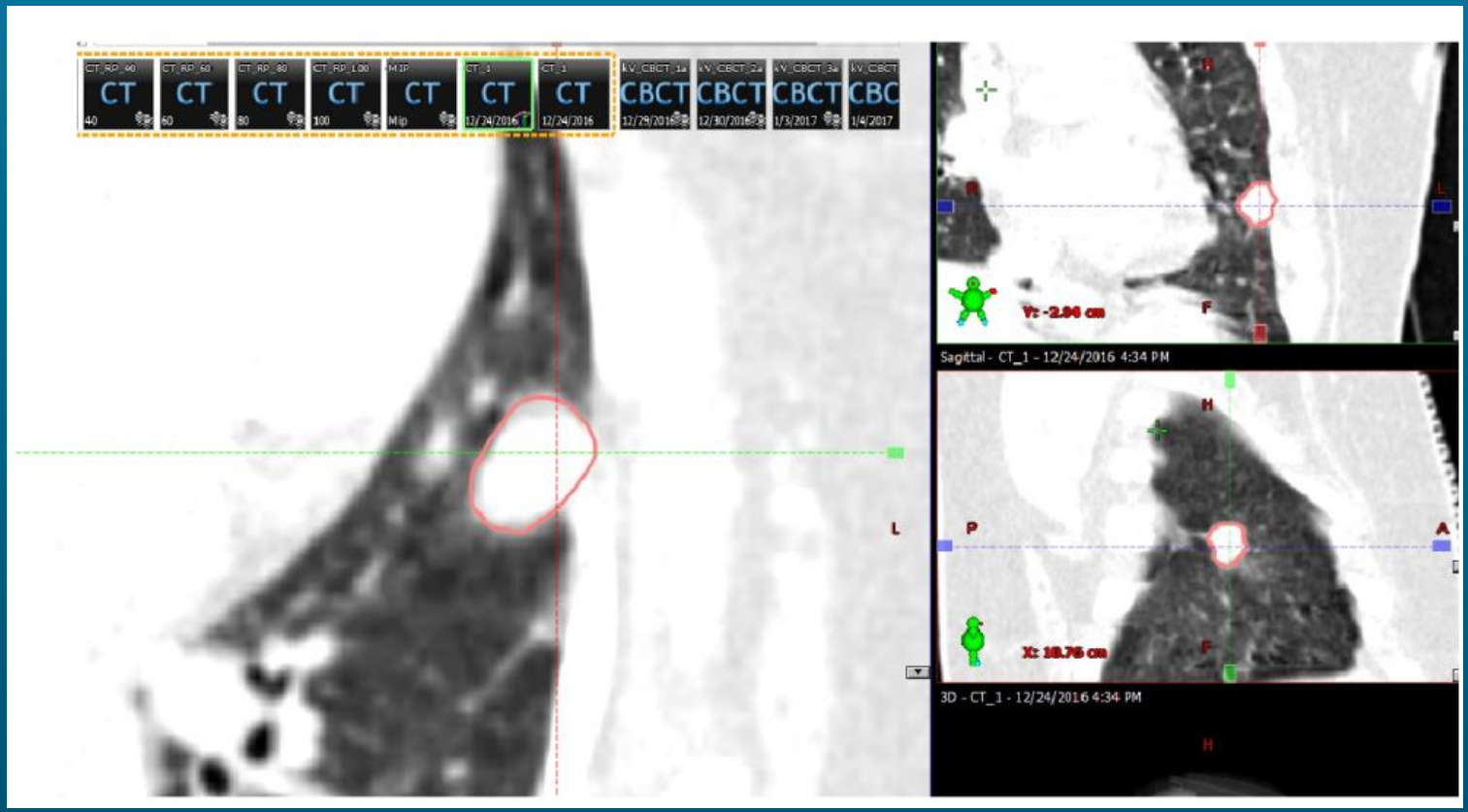


Electromagnetic Signals:Locate and Track Continuously

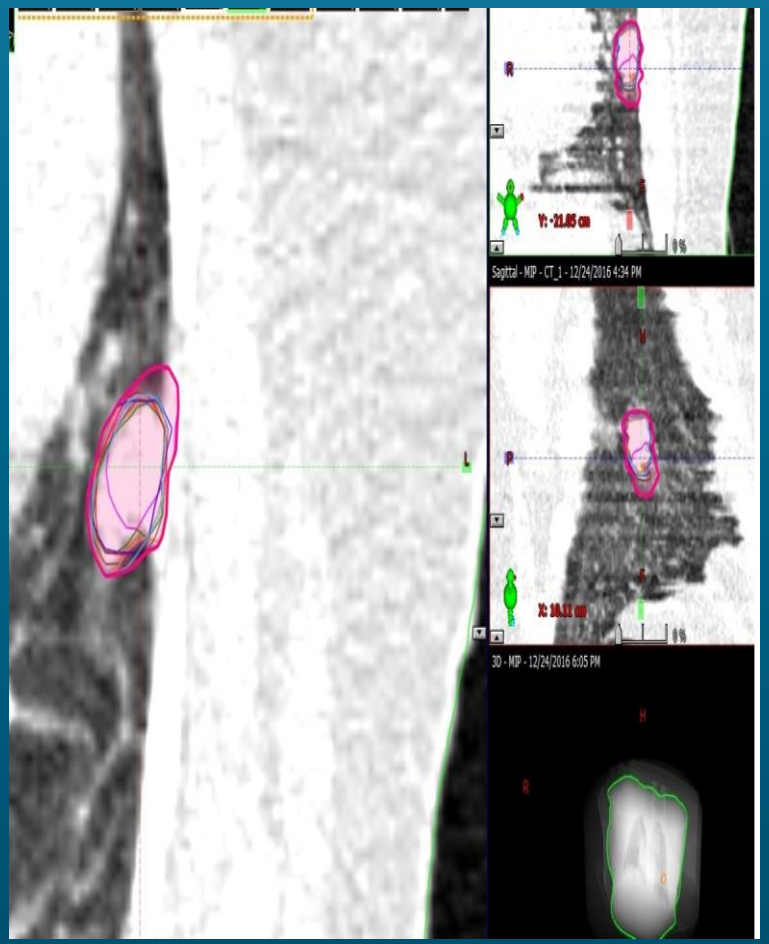
Real-time tracking of target motion

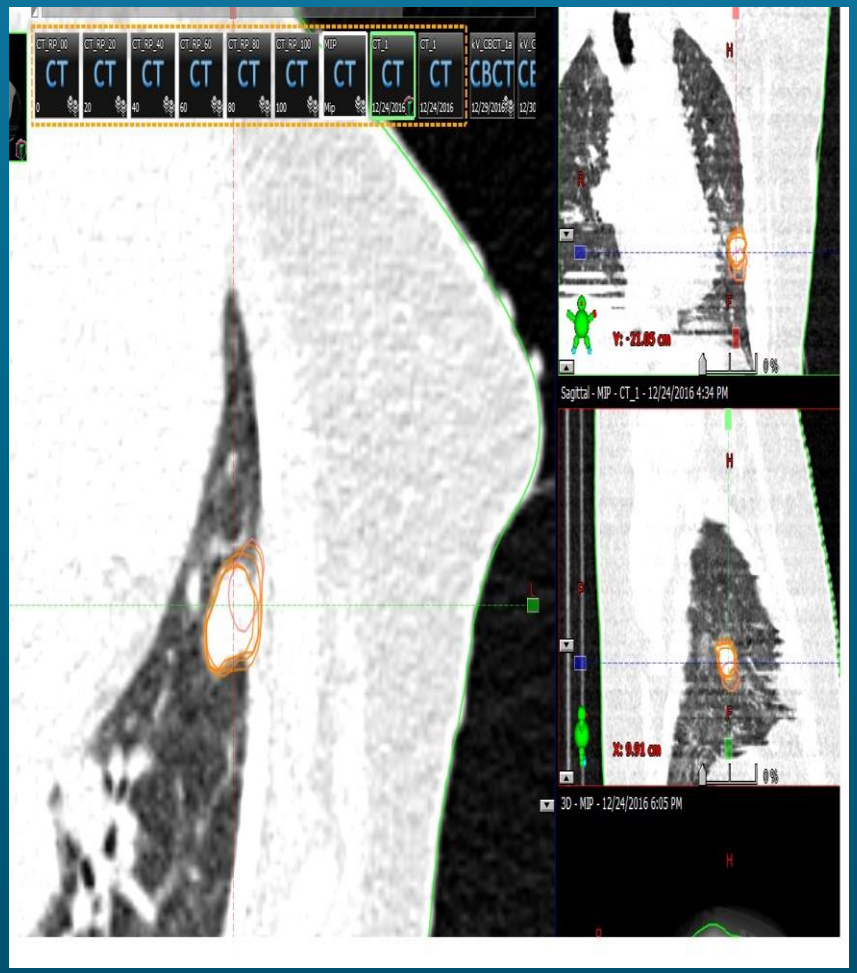


Contouring: Tumor

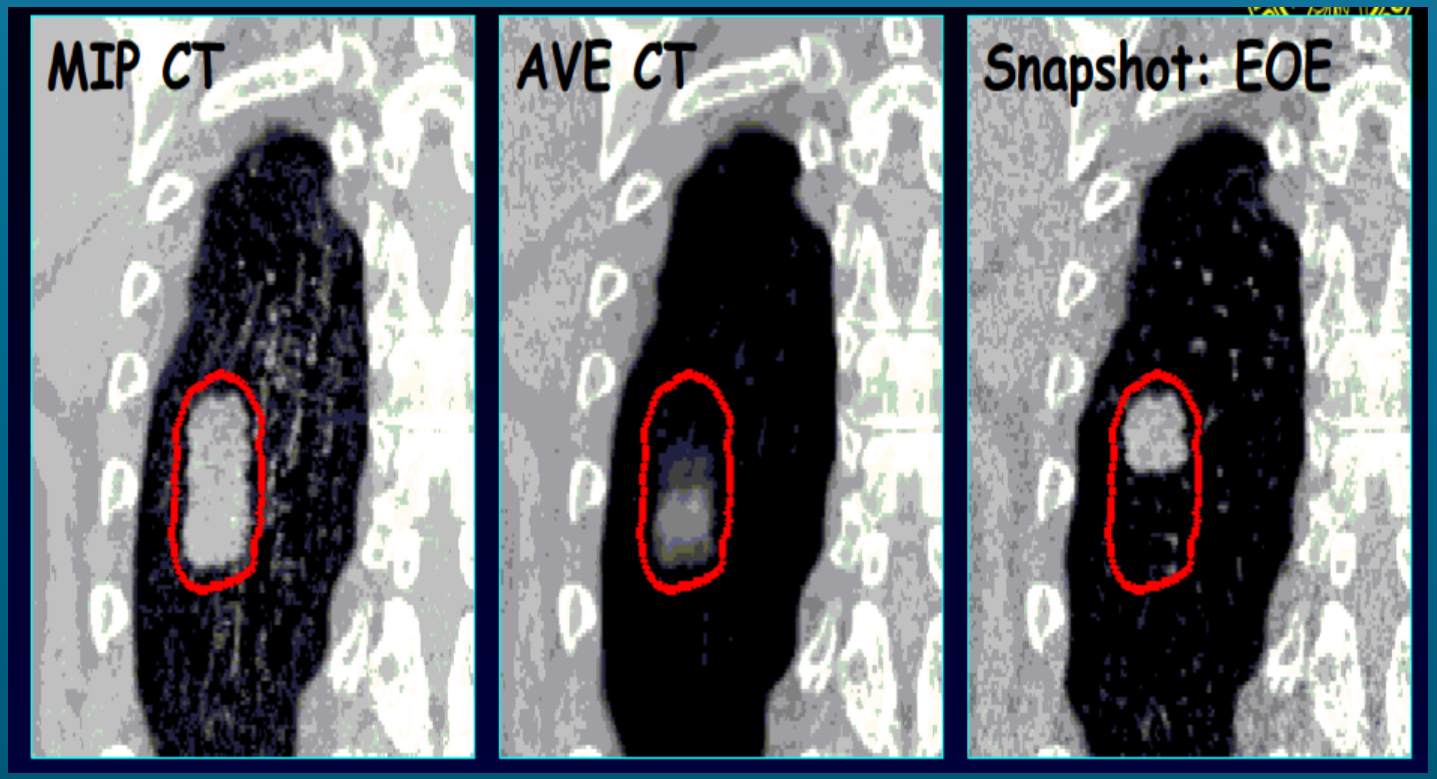


Contouring: Tumor





LUNG CONTOURING ON MIP :



- This target will not be enlarged whatsoever for prophylactic treatment (including no “margin” for presumed microscopic extension)

- Only nly include abnormal CT signal consistent with gross tumor (i.e., the GTV and the Clinical Target Volume, CTV, are identical)

An additional 0.5 cm in the axial plane and 1.0 cm in the longitudinal plane (cranio-caudal) will be added to the GTV to constitute the planning treatment volume (PTV)

Contorting: Normal structures

- **Spinal Cord**

- Contoured based on the bony limits of the spinal canal. The spinal cord should be contoured starting at least 10 cm above the superior extent of the PTV and continuing on every CT slice to at least 10 below the inferior extent of the PTV.

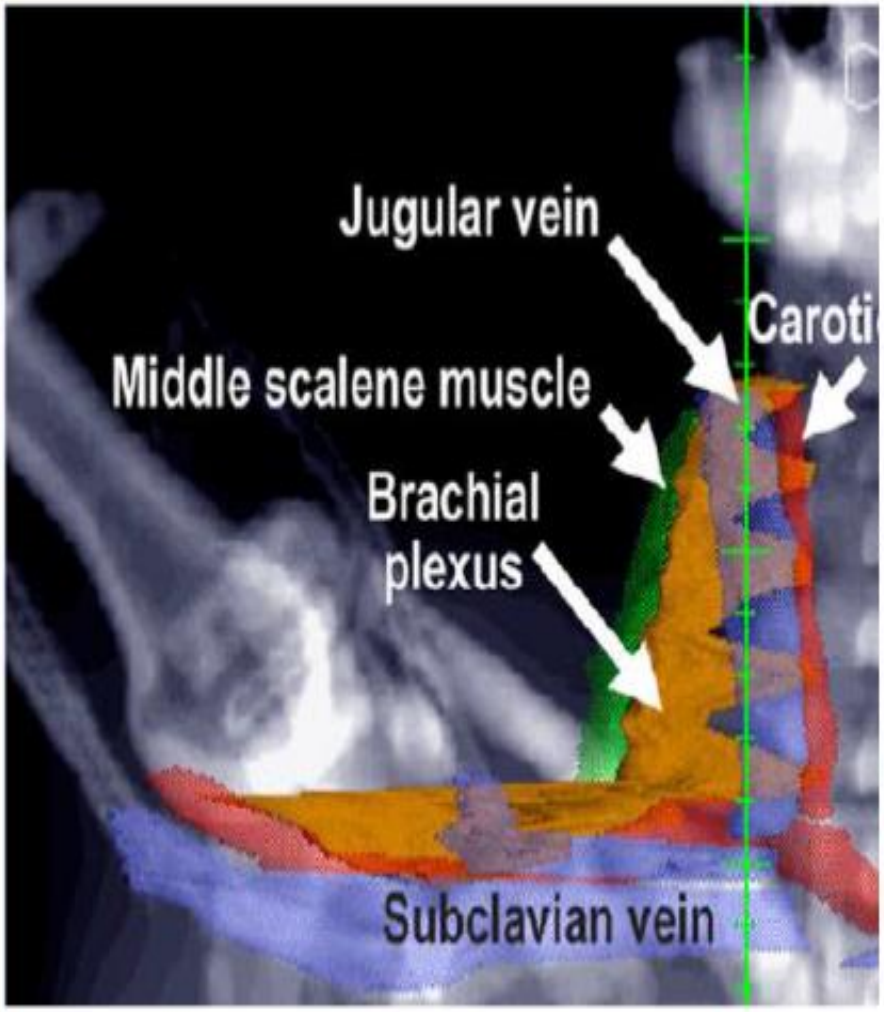
- **Esophagus**

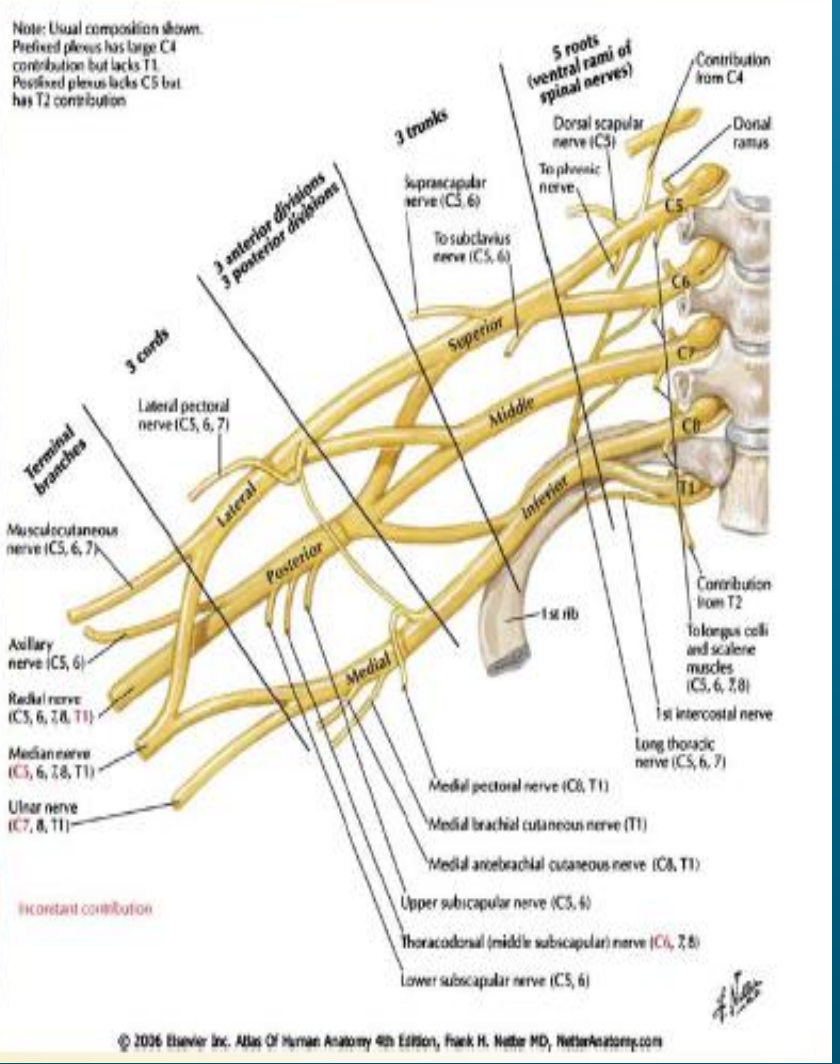
- Contoured using mediastinal windowing on CT to correspond to the mucosal, submucosa, and all muscular layers out to the fatty adventitia. Extent as cord.

Contorting: Normal structures

•Brachial Plexus :The defined ipsilateral brachial plexus originates from the **spinal nerves exiting the neuroforamine on the involved side from around C5 to T2.**

•This neurovascular complex to be contoured starting proximally at the bifurcation of the brachiocephalic trunk into the jugular/subclavian veins (or carotid/subclavian arteries) and following along the route of the subclavian vein to the axillary vein ending after the neurovascular structures cross the second rib.


Jugular vein
Caroti
Middle scalene muscle
Brachial plexus
Subclavian vein


Note: Usual composition shown. Prefixed plexus has large C4 contribution but lacks T1. Postfixed plexus lacks C5 but has T2 contribution
5 roots (ventral rami of spinal nerves)
Contribution from C4
Dorsal scapular nerve (C5)
Dorsal ramus
To phrenic nerve
3 trunks
Suprascapular nerve (C5, 6)
To subclavius nerve (C5, 6)
3 anterior divisions
3 posterior divisions
3 cords
Terminal branches
Lateral pectoral nerve (C5, 6, 7)
Superior
Middle
Inferior
C5
C6
C7
C8
T1
Musculocutaneous nerve (C5, 6, 7)
Lateral
Posterior
Medial
Contribution from T2
1st rib
Axillary nerve (C5, 6)
Radial nerve (C5, 6, 7, 8, T1)
Median nerve (C5, 6, 7, 8, T1)
Ulnar nerve (C7, 8, T1)
To longus colli and scalene muscles (C5, 6, 7, 8)
1st intercostal nerve
Long thoracic nerve (C5, 6, 7)
Medial pectoral nerve (C8, T1)
Medial brachial cutaneous nerve (T1)
Medial antebrachial cutaneous nerve (C8, T1)
Inconstant contribution
Upper subscapular nerve (C5, 6)
Thoracodorsal (middle subscapular) nerve (C6, 7, 8)
Lower subscapular nerve (C5, 6)
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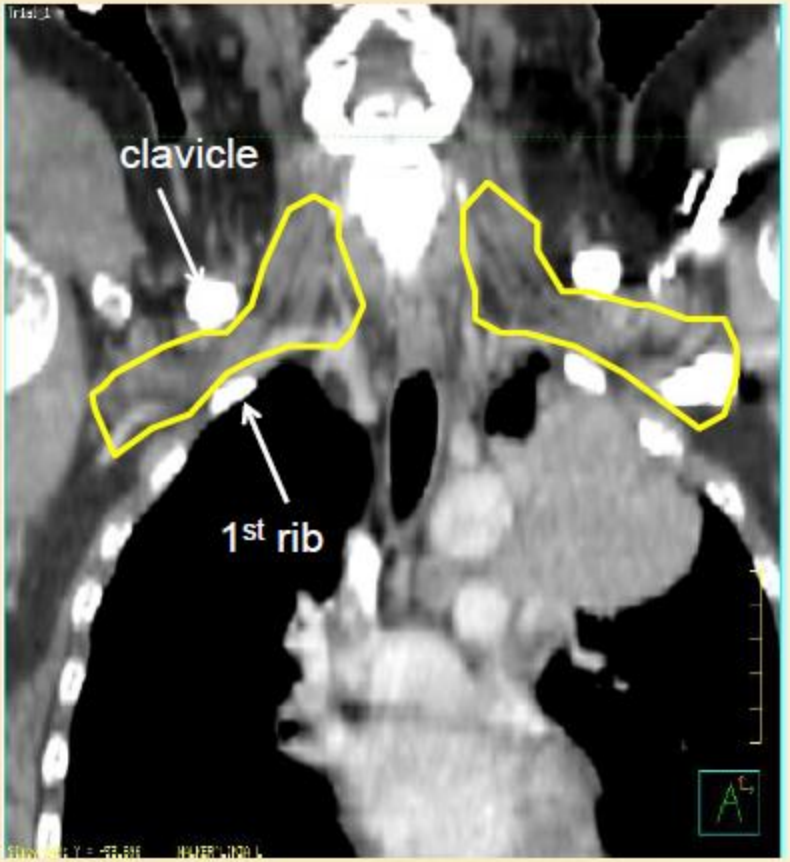
Locating the Brachial Plexus

Timmerman's Trick-1



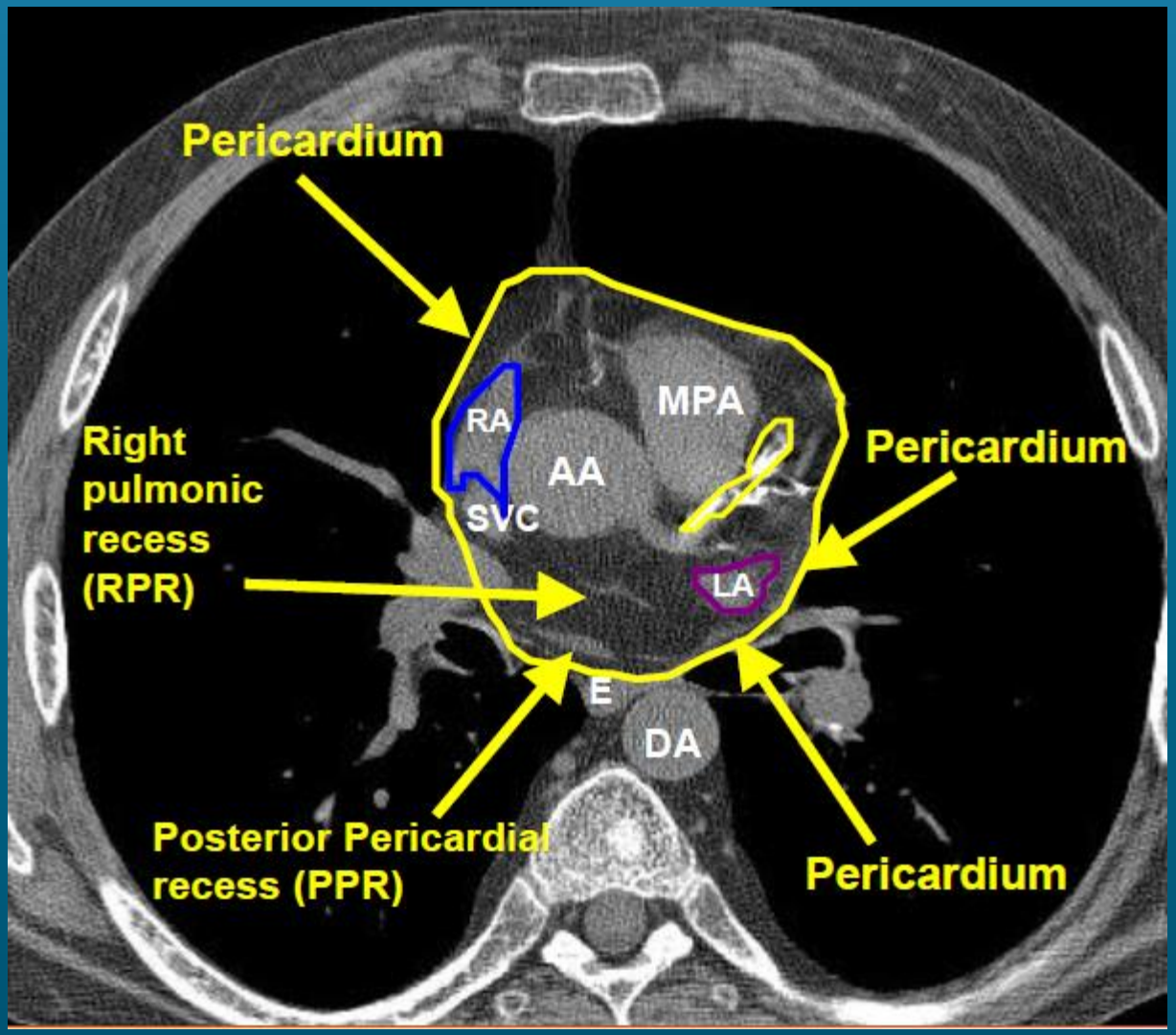
- Vein, artery, and nerve (VAN, anterior to posterior) will go over the 1st rib and under the clavicle
- Using coronal images, find the plane where vascular/nerve structures (tubes and wires) pass between the 1st rib and clavicle
- Roughly contour these neuro-vascular tissues in this coronal plane (as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

Contorting: Normal structures

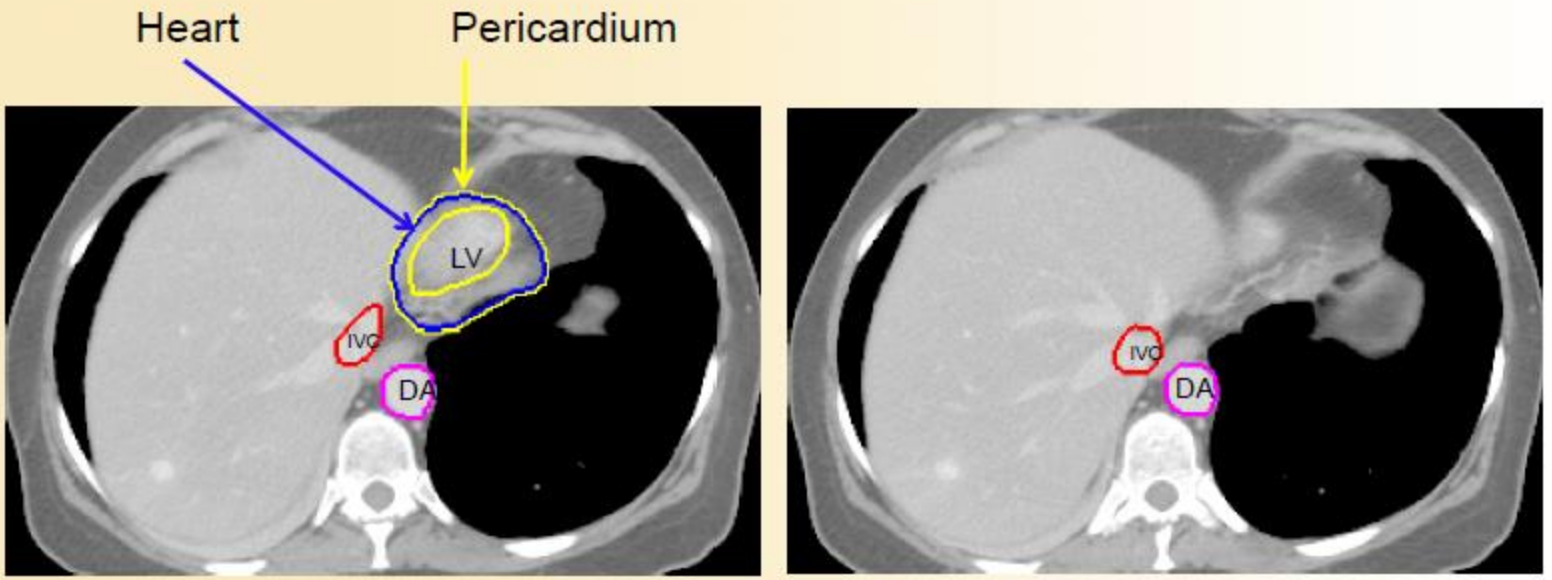
- **Heart** to be contoured along with the **pericardial sac.**

- The superior aspect (or base) for purposes of contouring will begin at the level of the **inferior aspect of the aortic arch** (aortopulmonary window)

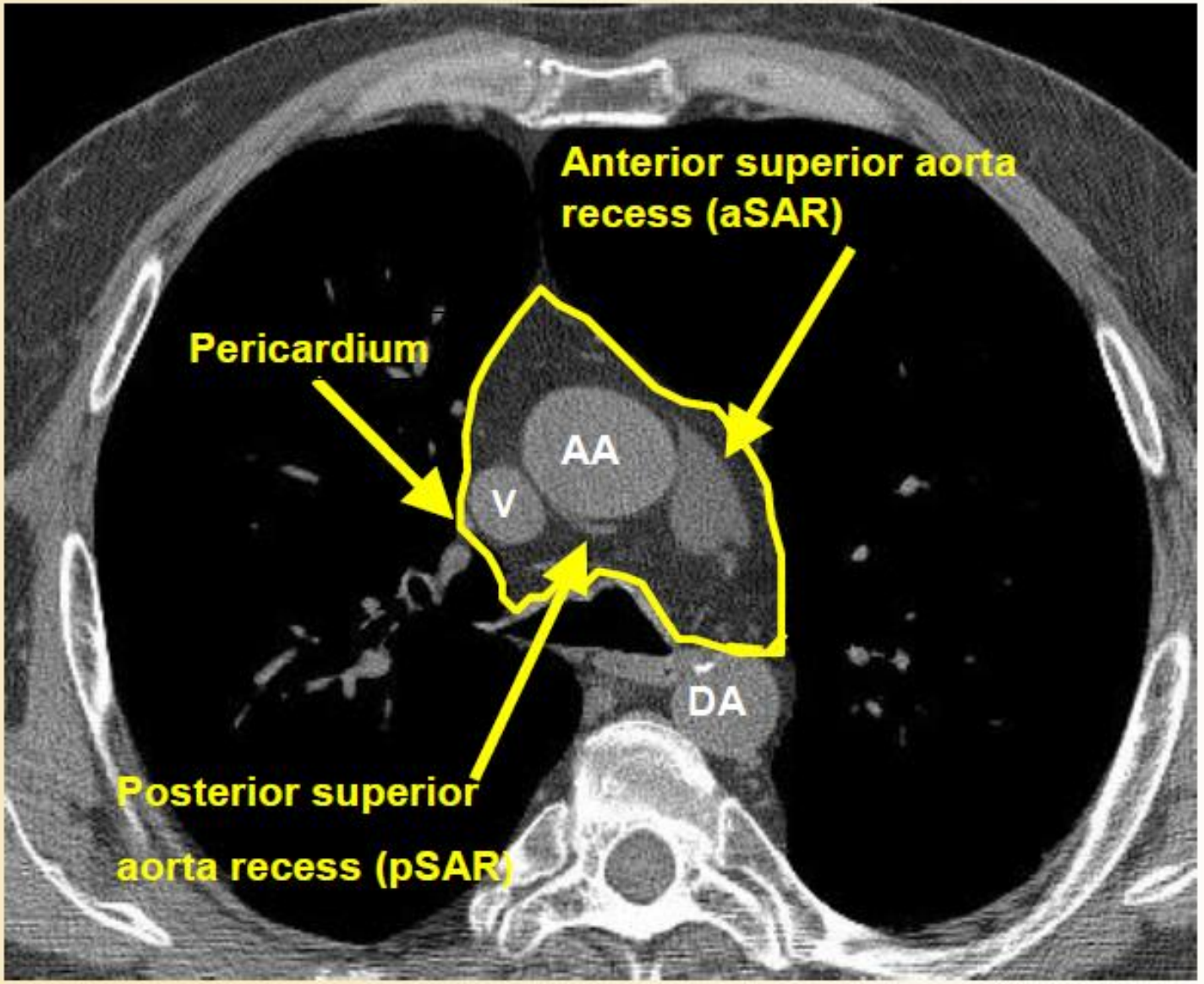
- Extend inferiorly to the **apex of the heart / diaphragm** .


Pericardium
Right pulmonic recess (RPR)
RA
SVC
AA
MPA
Pericardium
LA
E
DA
Posterior Pericardial recess (PPR)
Pericardium

Heart and pericardium end at diaphragm



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


Anterior superior aorta recess (aSAR)
Pericardium
AA
V
DA
Posterior superior aorta recess (pSAR)

Contorting: Normal structures

- **Trachea and Proximal Bronchial Tree to be contoured as two separate structures** using
- Mediastinal windows on CT to correspond to the mucosal, submucosa and cartilage rings and airway channels associated with these structures.

- For this purpose, the trachea will be divided into two sections:

Proximal trachea

Distal 2 cm of trachea.

- The proximal trachea will be contoured as one structure, and the distal 2 cm of trachea will be included in the structure identified as proximal bronchial tree.

Contorting: Normal structures

- **Contouring of the proximal trachea**

should begin at least 10 cm superior to the extent of the PTV or 5 cm superior to the carina (whichever is more superior) and continue inferiorly to the superior aspect of the proximal bronchial tree.

- The proximal bronchial tree will include the most inferior 2 cm of distal trachea and the proximal airways on both sides

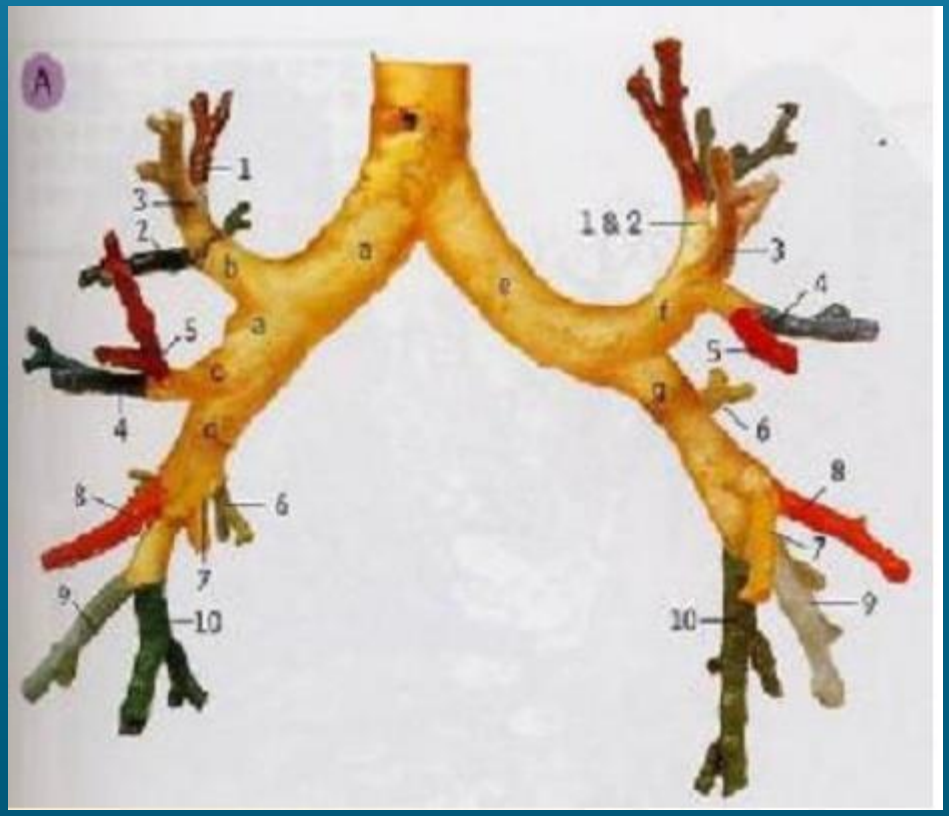
Contorting: Normal structures

•The following airways will be included according to standard anatomic relationships:

- **distal 2 cm of 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.**

•Contouring of the lobar bronchi will end immediately at the site of a segmental bifurcation.

•If there are parts of the proximal bronchial tree that are within GTV, they should be contoured separately, as **"proximal bronchial tree GTV"**


A
1
3
2
b
a
5
c
4
d
8
6
7
9
10
1&2
3
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g
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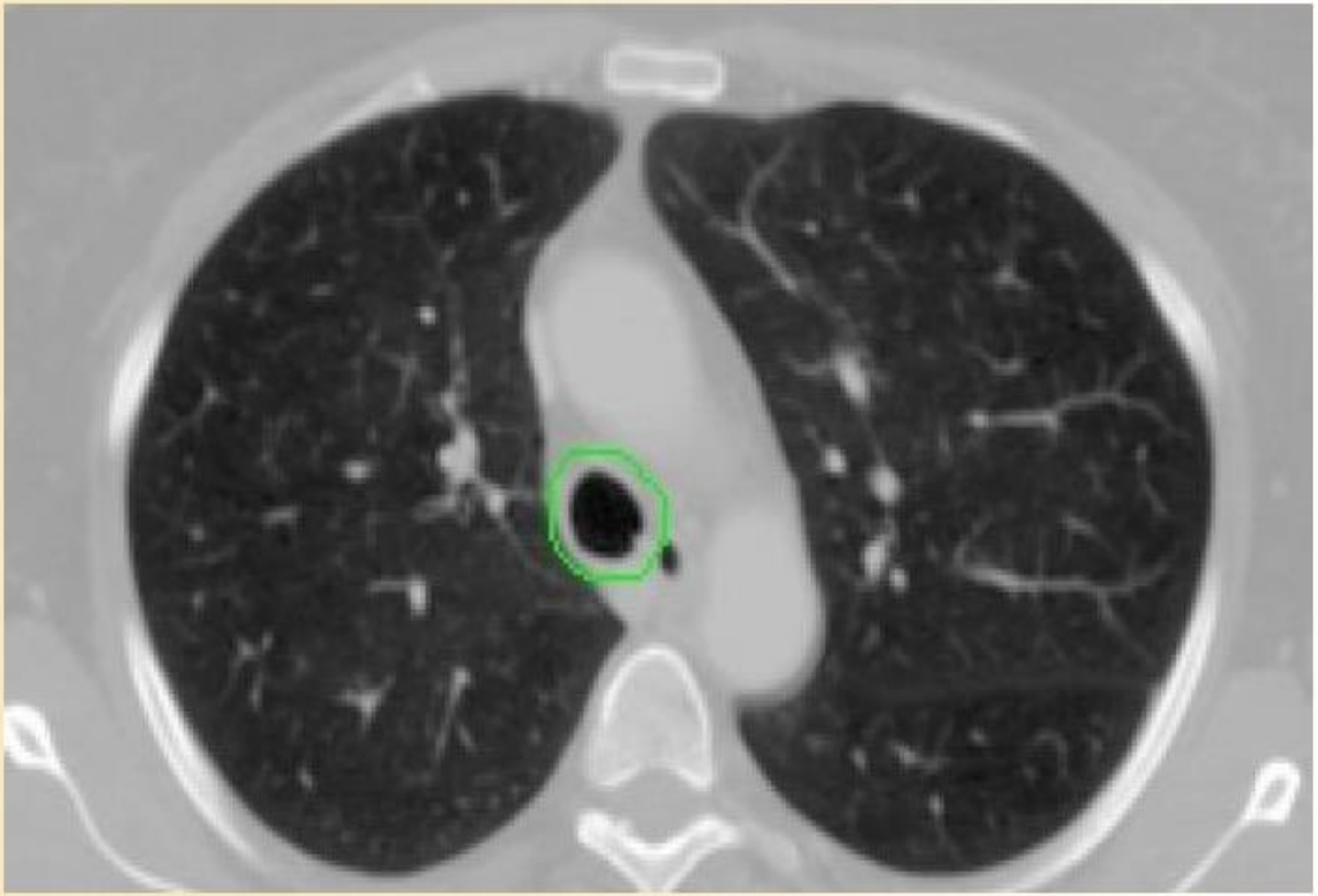
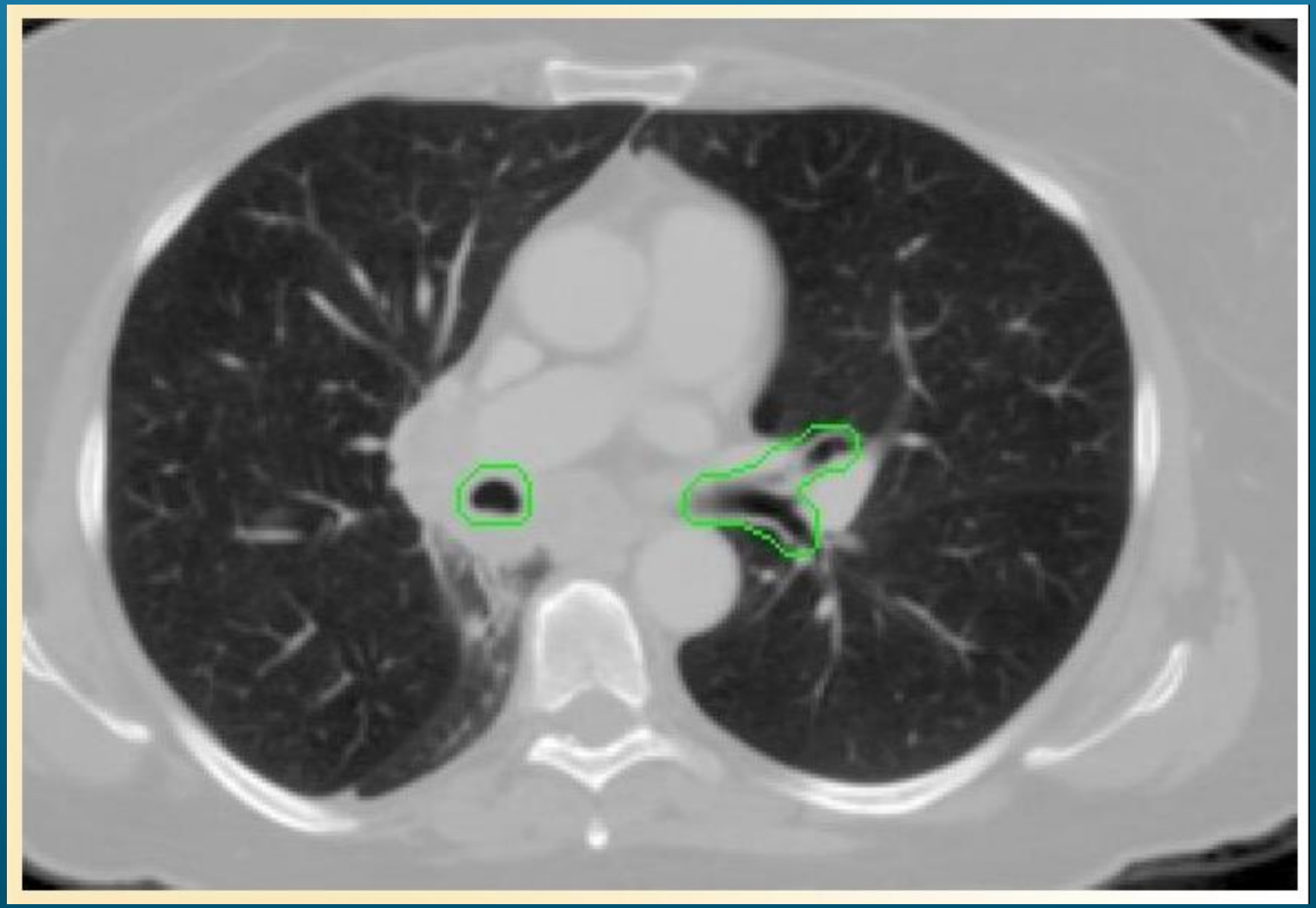
7
9
10

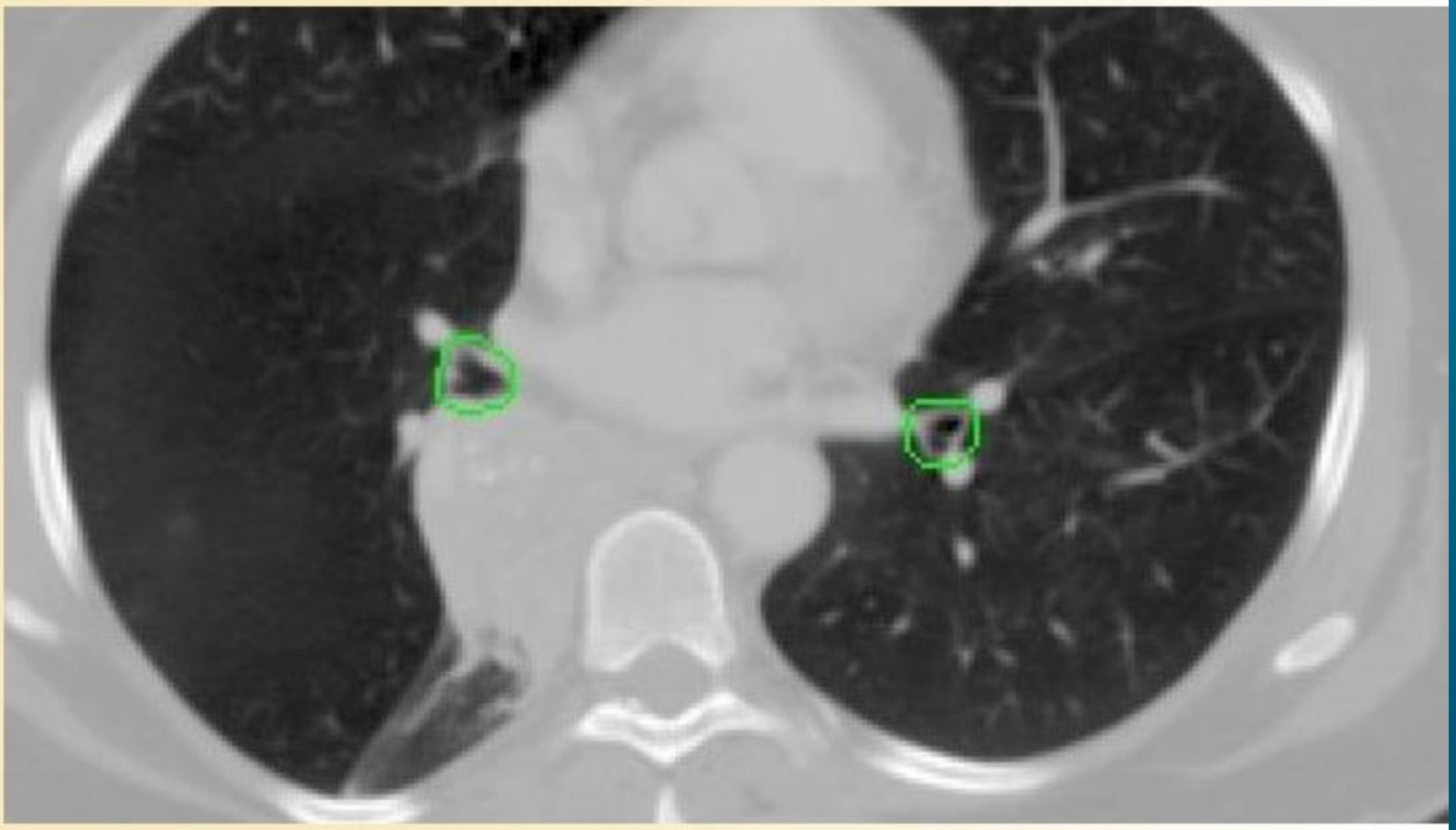
PBT starts at 2 cm above carina





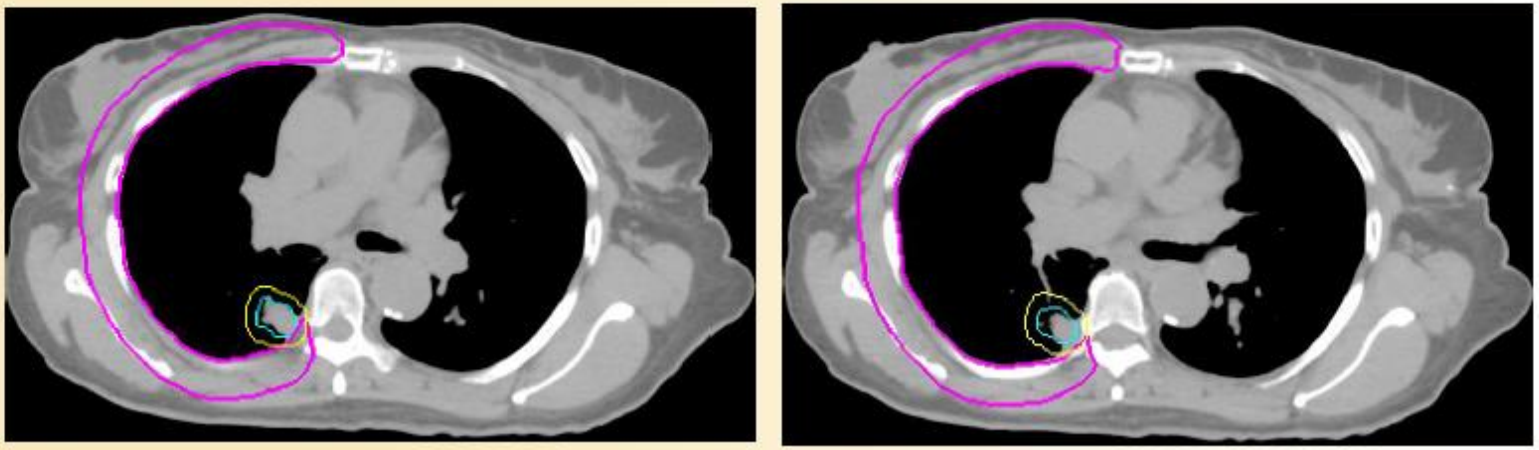
Proximal Bronchus Tree Ends

at the level of lobar bronchus bifurcating
into segmental bronchus



Chest wall

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



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.

Contorting: Normal structures

Whole Lung

- **Both the right and left lungs should be contoured as one structure.**
- **Contouring should be carried out using pulmonary windows.**
- **All inflated and collapsed lung should be contoured**
- **Gross tumor (GTV) and trachea/ipsilateral bronchus as defined above should not be included in this structure.**

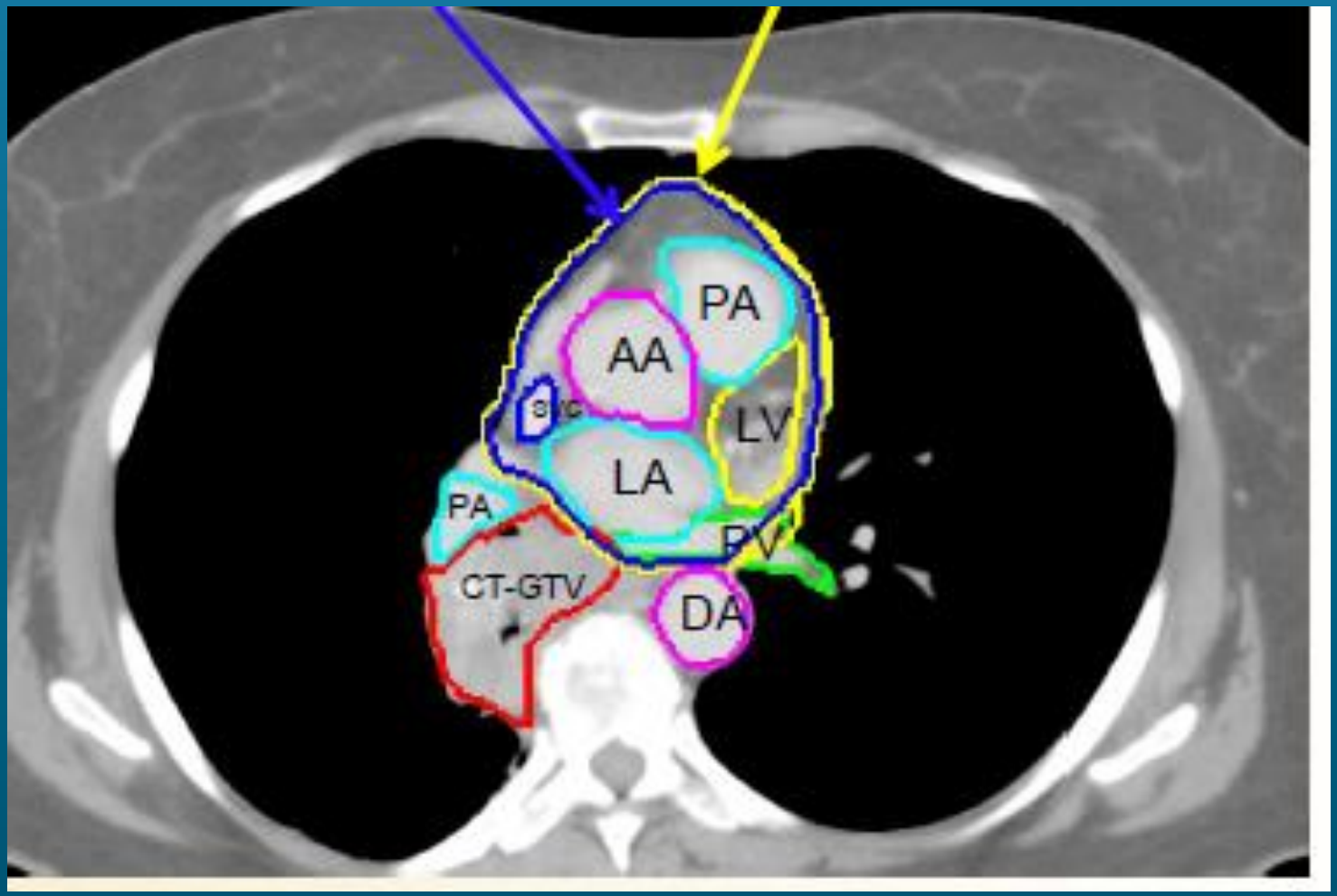
Contorting: Normal structures

•The skin is the outer 0.5 cm of the body surface. As such it is a rind of uniform thickness (0.5 cm) which envelopes the entire body in the axial planes.

•The great vessels (aorta and vena cava, not the pulmonary artery or vein) contoured using mediastinal window on CT to correspond to the vascular wall and all muscular layers out to the fatty adventitia.

•The great vessel should be contoured starting at least 10 cm above the superior extent of the PTV and continuing on every CT slice to at least 10 cm below the inferior extent of the PTV.

•For right sided tumors, the vena cava will be contoured, and for left sided tumors, the aorta will be contoured.


PA
AA
SVC
LV
LA
PA
PV
CT-GTV
DA

Contorting: Normal structures

• Non-adjacent Wall of a Structure For the esophagus, trachea and proximal bronchial tree, and great vessels, corresponds to the half circumference of the tubular structure not immediately touching the GTV or PTV

•These contours would start and stop superiorly and inferiorly just as with the named structure. The half lumen of the structure should be included in this contour

Plan evaluation:

- Lung SBRT planning and evaluation has some basic principles.

- Based on RTOG 0813 it has been described.

Planning: Dosimetry; 3D conformal planning

- 3 D coplanar or non-coplanar beam arrangements will be custom designed to deliver highly conformal prescription dose distributions.
- Non-opposing, noncoplanar beams are preferable.
- Typically, 7-10 beams of radiation will be used with roughly equal weighting. Generally, more beams are used for larger lesion sizes.
- When static beams are used, a minimum of seven non-opposing beams should be used.
- For arc rotation techniques, a minimum of 340 degrees (cumulative for all beams) should be utilized. For this protocol, the isocenter is defined as the common point of gantry and couch rotation for the treatment unit.

Planning: Dosimetry; 3D conformal planning

- Field aperture size and shape should correspond nearly identically to the projection of the PTV along a beam's eye view (i.e., no additional "margin" beyond the PTV).
- The only exception will be when observing the minimum field dimension of 3.5 cm when treating small lesions.
- Prescription lines covering the PTV will be the 60-90% line (rather than 95- 100%); however, higher isodoses (hotspots) must be manipulated to occur within the target and not in adjacent normal tissue.
- The isocenter in stereotactic coordinates will be determined from system fiducials (or directly from the tumor in the case of volumetric imaging) and translated to the treatment record.

Planning: Dosimetry; 3D conformal planning

- The plan should be normalized to a defined point corresponding closely to the center of mass of the PTV (COMPTV). Typically, this point will be the isocenter of the beam rotation

- The point identified as COMPTV must have defined stereotactic coordinates and receive 100% of the normalized dose. Because the beam apertures coincide nearly directly with the edge of the PTV (little or no added margin).

Planning: Dosimetry; 3D conformal planning

- The external border of the PTV will be covered by a lower isodose surface than usually used in conventional radiotherapy planning, typically around 80% but ranging from 60-90%.

- The prescription dose will be delivered to the margin of the PTV and fulfill the requirements below. As such, a "hotspot" will exist within the PTV centrally at the COMPTV with a magnitude of prescribed dose times the reciprocal of the chosen prescription isodose line (i.e., 60-90%).

Planning: Dosimetry; IMRT

- IMRT should be considered only when target coverage, OAR dose limits, or dose spillage are not achievable with 3D conformal planning.

- The number of segments (control points) and the area of each segment should be optimized to ensure deliverability and avoid complex beam fluences.

- Ideally, the number of segments should be minimized (2- 3 segments per beam should be adequate), and the area of each segment should be maximized (the aperture of one segment from each beam should correspond to the projection of the PTV along a beam's eye view).

Planning: Evaluation

Successful treatment planning will require accomplishment of all of the following criteria:

•Normalization: The treatment plan should be normalized such that 100% corresponds to the center of mass of the PTV (COMPTV). This point will typically also correspond (but is not required to correspond) to the isocenter of the treatment beams.

• Prescription Isodose Surface Coverage: The prescription isodose surface will be chosen such that 95% of the target volume (PTV) is conformally covered by the prescription isodose surface and 99% of the target volume (PTV) receives a minimum of 90% of the prescription dose.

Planning: Evaluation

- Target Dose Heterogeneity: The prescription isodose surface selected must be

  - ≥ 60% of the dose at the center of mass of the PTV (COMPTV) and
  - ≤ 90% of the dose at the center of mass of the PTV (COMPTV).

- The COMPTV corresponds to the normalization point (100%) of the plan.


Selection
Contouring
Image Registration
External Beam Planning
Brachytherapy Planning
Brachytherapy 2D Entry
Plan Evaluation
KH1000475278
C1
6SCF_F-R
6SCF_F
6SCF_F - Retired - Transversal - CT_1
Transport in medium
Dose to medium
6SCF_F - Retired - Model View - CT_1
3D Dose MAX: 6178.8 cGy
3D MAX for PTV_60: 6178.8 cGy
3D MIN for PTV_60: 4078.3 cGy
3D MEAN for PTV_60: 5617.5 cGy
Standard
Head First-Supine
6SCF_F - Retired - Frontal - CT_1
6SCF_F - Retired - Sagittal - CT_1

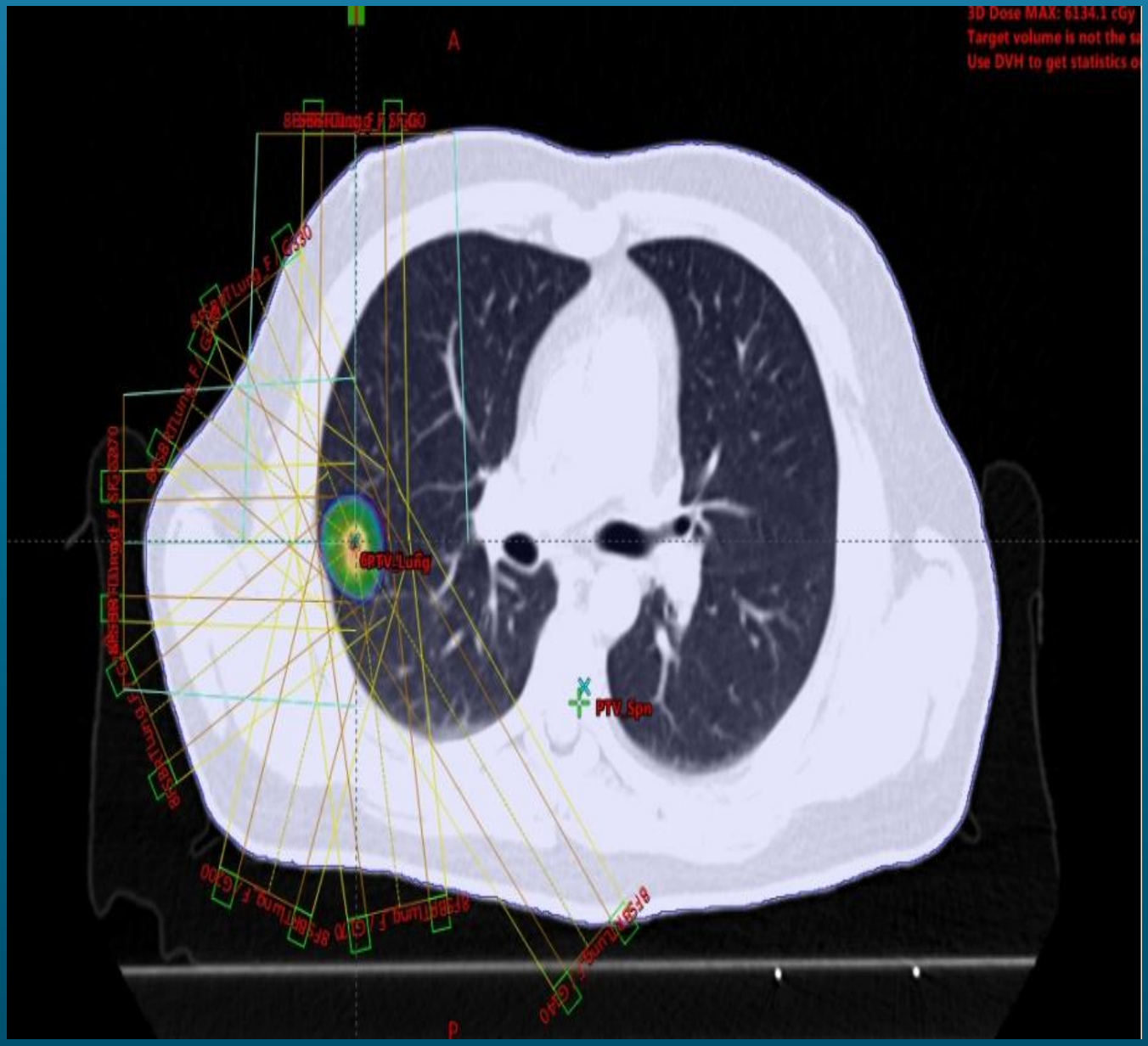
Planning: Evaluation

High Dose Spillage:

a. **Location:** Any dose > 105% of the prescription dose should occur primarily within the PTV itself and not within the normal tissues outside the PTV. Therefore, the cumulative volume of all tissue outside the PTV receiving a dose > 105% of prescription dose should be no more than 15% of the PTV volume.

b. **Volume:** Conformality of PTV coverage will be judged such that **the ratio of the volume of the prescription isodose to the volume of the PTV is ideally < 1.2 .**

•These criteria will **not be required to be met in treating very** small tumors (< 2.5 cm axial GTV dimension or < 1.5 cm craniocaudal GTV dimension) in which the required minimum field size of 3.5 cm.


A
P
PTV_Lung
PTV_Spn

Planning: Evaluation

• **Low Dose Spillage:** The falloff gradient beyond the PTV extending into normal tissue structures must be rapid in all directions and meet the following criteria:

a. **Location:** The maximum total dose over all fractions in Gray (Gy) to any point 2 cm or greater away from the PTV in any direction must be no greater than D2cm where D2cm is given by the table below.

b. **Volume:** The ratio of the volume of 50% of the prescription dose isodose to the volume of the PTV must be no greater than R50% where R50% is given.

Planning: Evaluation

Table 1: Conformality of Prescribed Dose for Calculations Based on Deposition of Photon Beam Energy in Heterogeneous Tissue

PTV Volume (cc)	Ratio of Prescription Isodose Volume to the PTV Volume		Ratio of 50% Prescription Isodose Volume to the PTV Volume, $R_{50\%}$		Maximum Dose (in % of dose prescribed) @ 2 cm from PTV in Any Direction, D_{2cm} (Gy)		Percent of Lung Receiving 20 Gy Total or More, V_{20} (%)	
	Deviation		Deviation		Deviation		Deviation	
	None	Minor	None	Minor	None	Minor	None	Minor
1.8	<1.2	<1.5	<5.9	<7.5	<50.0	<57.0	<10	<15
3.8	<1.2	.<1.5	<5.5	<6.5	<50.0	<57.0	<10	<15
7.4	<1.2	<1.5	<5.1	<6.0	<50.0	<58.0	<10	<15
13.2	<1.2	<1.5	<4.7	<5.8	<50.0	<58.0	<10	<15
22.0	<1.2	<1.5	<4.5	<5.5	<54.0	<63.0	<10	<15
34.0	<1.2	<1.5	<4.3	<5.3	<58.0	<68.0	<10	<15
50.0	<1.2	<1.5	<4.0	<5.0	<62.0	<77.0	<10	<15
70.0	<1.2	<1.5	<3.5	<4.8	<66.0	<86.0	<10	<15
95.0	<1.2	<1.5	<3.3	<4.4	<70.0	<89.0	<10	<15
126.0	<1.2	<1.5	<3.1	<4.0	<73.0	>91.0	<10	<15
163.0	<1.2	<1.5	<2.9	<3.7	<77.0	>94.0	<10	<15

Note 1: For values of PTV dimension or volume not specified, linear interpolation between table entries is required.

Note 2: Protocol deviations greater than listed here as “minor” will be classified as “major” for protocol compliance (see Section 6.7).

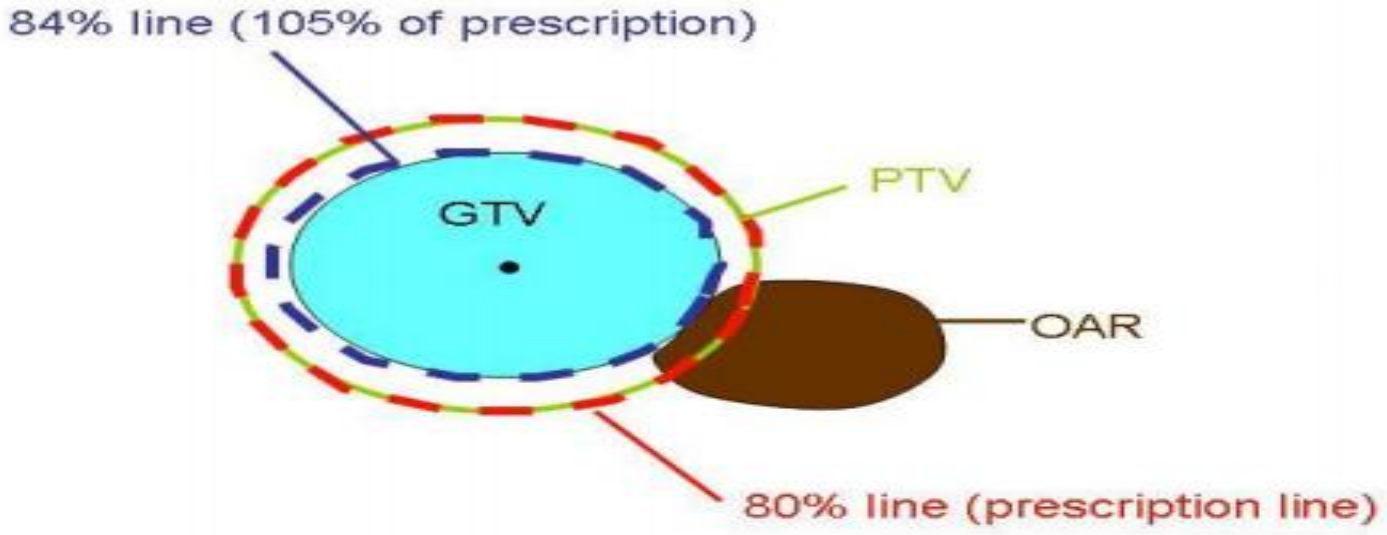
Planning: Evaluation

- The esophagus, trachea, bronchi and heart may be situated adjacent to the treated GTV/PTV.

- There is no specified limit as tumors that are immediately adjacent to that organ will not be able to be treated to any of the prescription doses without irradiating a small volume of that organ to the prescribed dose.

- In such a case, the **planning needs to be done so that there is no hot spot within that organ, even if that organ is part of the PTV**, i.e., that no part of any OAR receives more than 105% of the prescribed dose

Planning: Evaluation



1. Prescription dose 50 Gy
2. Prescription isodose 80%
3. 105% of prescription dose 52.5 Gy (corresponds to 84% isodose line)
4. Maximum dose (normalization) at isocenter is 62.5 Gy

Planning: Evaluation

Serial Tissue	Volume	Volume Max (Gy)	Max Point Dose (Gy)	Avoidance Endpoint
Spinal Cord	<0.25 cc <0.5 cc	22.5 Gy (4.5 Gy/fx) 13.5 Gy (2.7 Gy/fx)	30 Gy (6 Gy/fx)	myelitis
Ipsilateral Brachial Plexus	<3 cc	30 Gy (6 Gy/fx)	32 Gy (6.4 Gy/fx)	neuropathy
Skin	<10 cc	30 Gy (6 Gy/fx)	32 Gy (6.4 Gy/fx)	ulceration
Parallel Tissue	**Critical Volume**	**Critical Volume Dose Max (Gy)**		**Avoidance Endpoint**
Lung (Right & Left)	1500 cc	12.5 Gy (2.5 Gy/fx)		Basic Lung Function
Lung (Right & Left)	1000 cc	13.5 Gy (2.7 Gy/fx)		Pneumonitis

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Planning: Evaluation

Serial Tissue*	Volume	Volume Max (Gy)	Max Point Dose (Gy)	Avoidance Endpoint
Esophagus, non-adjacent wall	<5 cc	27.5 Gy (5.5 Gy/fx)	105% of PTV prescription	stenosis/fistula
Heart/Pericardium	<15 cc	32 Gy (6.4 Gy/fx)	105% of PTV prescription	pericarditis
Great vessels, non-adjacent wall	<10 cc	47 Gy (9.4 Gy/fx)	105% of PTV prescription	aneurysm
Trachea and ipsilateral bronchus, non-adjacent wall	<4 cc	18 Gy (3.6 Gy/fx)	105% of PTV prescription	stenosis/fistula

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Tab. 1 Normal tissue constraints according to published major clinical studies. Radiation Therapy Oncology Group (RTOG) protocols can be found on the RTOG website at http://www.rtog.org/ClinicalTrials/ProtocolTable.aspx

Organ at risk	Single fraction (RTOG 0915)	Three fractions (RTOG 0618/1021)	Four fractions (RTOG 0915)	Five fractions (RTOG 0813)	Eight fractions (Haasbeck et al. 2011 [76])
Trachea and large bronchus	D_{max} 20.2 Gy	D_{max} 30 Gy	D_{max} 34.8 Gy 15.6 Gy <4 cc	D_{max} 105%[a] 18 Gy <5 cc[b]	D_{max} 44 Gy
Heart	D_{max} 22 Gy 16 Gy <15 cc	D_{max} 30 Gy	D_{max} 34 Gy 28 Gy <15 cc	D_{max} 105%[a] 32 Gy <15 cc	–
Esophagus	D_{max} 15.4 Gy 11.9 Gy <5 cc	D_{max} 25.2 Gy 17.7 G <5 cc	D_{max} 30 Gy 18.8 Gy <5 cc	D_{max} 105%[a] 27.5 Gy <5 cc[b]	D_{max} 40 Gy
Brachial plexus	D_{max} 17.5 Gy 14 Gy <3 cc	D_{max} 24 Gy 20.4 Gy <3 cc	D_{max} 27,2 Gy 23.6 Gy <3 cc	D_{max} 32 Gy 30 Gy <3 cc	D_{max} 36 Gy
Chest wall	D_{max} 30 Gy 22 Gy <1 cc	30 Gy <30 cc 60 Gy <3 cc [77, 78]	D_{max} 27,2 Gy 32 Gy <1 cc	30 Gy <30 cc 60 Gy <3 cc [77, 78]	–
Spinal cord	D_{max} 14 Gy 10 Gy <0.35 cc	D_{max} 18 Gy (RTOG 0236)	D_{max} 26 Gy 28.8 Gy <0.35 cc	D_{max} 30 Gy 22.5 Gy <0.25 cc	D_{max} 28 Gy

[a]PTV prescription [b]Volume constraint for non-adjacent wall D_{max} maximum dose.

Toxicity documentation and reporting

- Cardiac and Pericardial injury

- Gastrointestinal/Esophageal Injury (Esophagitis , ulceration ,stenosis fistula) The radiation effects on the esophagus can be acute: esophagitis

- Central Airway/Bronchial Injury This bronchial injury with subsequent focal collapse of lung may impair overall pulmonary status. The consequences of bronchial toxicity, e.g., cough, dyspnea, hypoxia, impairment of pulmonary function test parameters, pleural effusion or pleuritic pain

- **Lung Injury :Radiation pneumonitis is a subacute (weeks to months from treatment) inflammation of the end bronchioles and alveoli. Radiation fibrosis is a late manifestation of radiation injury to the irradiated lung.**

- **Rib Fracture**

Thank You