# Radiotherapy Planning

## (Contouring Lung Cancer for Radiotherapy dose prescription)

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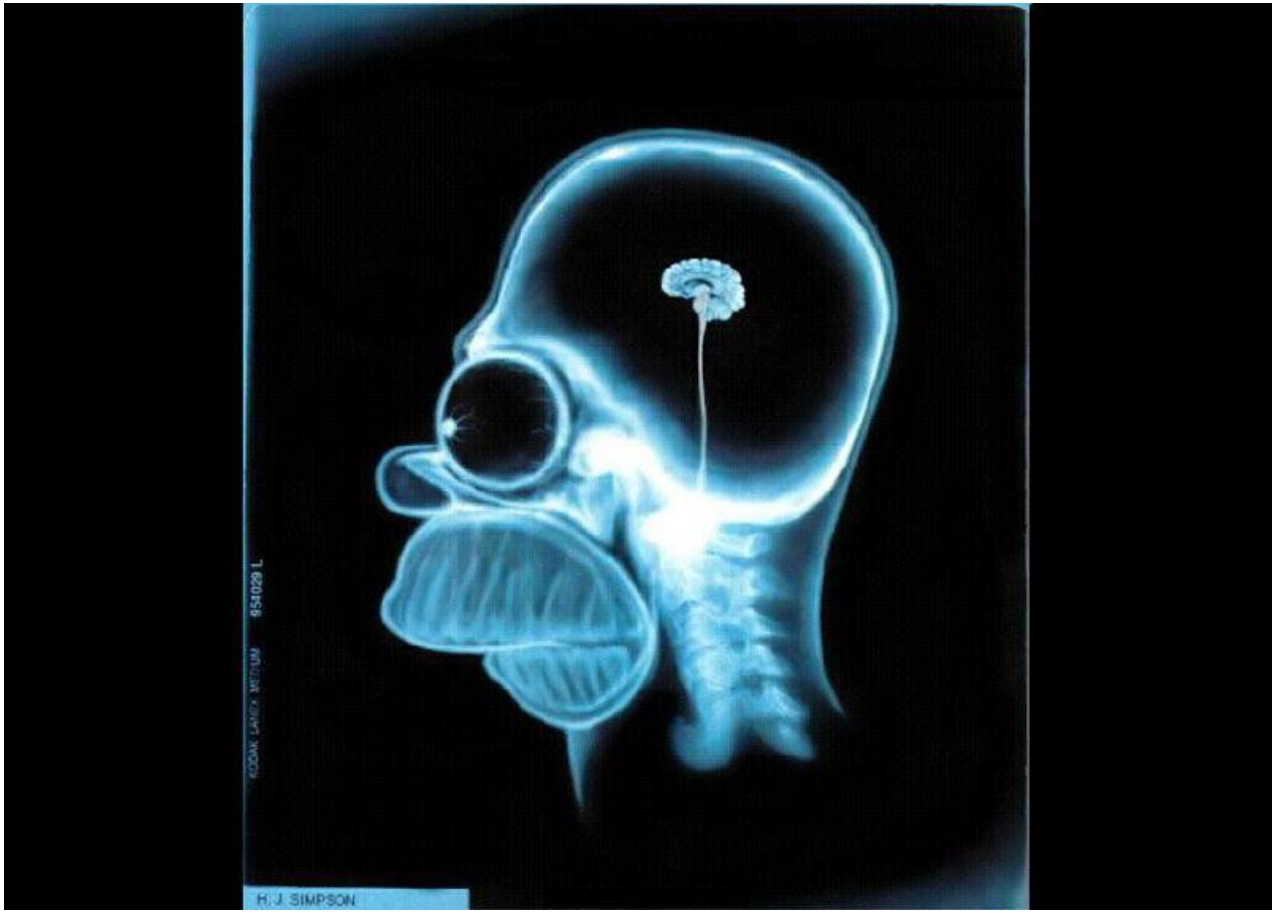
# Let us keep this simple and stick to some basic rules



# Patient positioning

- Must be reproducible
- Must be stable and comfortable
- Options are:
    - arms above the head, T-bar, Vac-loc, wing board, etc

# Planning image

- IV contrast should be used, if possible
- Thin slices enable high-resolution DRRs

- The best concordance between measured and actual diameters and volumes has been obtained with the following settings:
  - W = 1600 and L = -600 for parenchyma
  - W = 400 and L = 20 for mediastinum [16].
- improves consistency in contouring

» **Giraud P. Radiother Oncol 2000; S39.**

# Planning image

- Fluoroscopy for motion – not the best
- Slow CT is better

- 4D CT with phase binning and composite image reconstruction – gold standard

- To be correlated with PET-CT images

» **Senan S et al. Radiother Oncol 2004; 71: 139-146**

# Decision on lymph nodes

- Lymph nodes with a short axis diameter of ≥1 cm are generally considered pathological

- Included in the GTV unless
  - metastases have been excluded by other means such as mediastinoscopy or PET scanning

    - **Glazer GM, et al. Am J Roentgenol 1985; 144:261-5.**
    - **Kiyono K, et al. Am J Radiol 1988; 150: 771-6**

- Table

# Elective nodal irradiation

- No evidence to suggest that elective nodal irradiation is indicated in any patient group receiving curative / radical doses of radiotherapy for NSCLC

- Publications where disease recurrence patterns were established following involved field radiotherapy in stage III NSCLC:
  - no induction chemotherapy was administered in one study
  - a majority of patients in a second study received no chemotherapy
- In all these studies, the incidence of isolated failures in initially uninvolved nodes was <7%.

- Induction chemotherapy has not been shown to improve local control over that achieved using radiotherapy alone,
- the entire pre-chemotherapy GTV is to be treated to the full dose
  - use co-registered pre-treatment and planning CT scans
  - a more accurate reconstruction of pre-chemotherapy target volumes
    - **Senan S, et al. IJROBP 2002; 54: 999-1006.**
    - **Lagerwaard FJ, et al. Lung Cancer 2002; 38: 297-301.**

- Three-dimensional software tools
  - for generating 3D margins around contoured GTVs or CTVs
  - they decrease inaccuracies and reduce inter-clinician variations in contouring

» **Senan S, et al. Radiother Oncol 1999; 53: 245-53.**

» **Stroom JC, et al. IJROBP 1999; 43: 905-19.**

# Functional imaging – PET

- More accurate staging
- More accurate tumour outlining
    - Distinguishing tumour from collapse
    - Selective irradiation of involved mediastinal LNs
- Targeted dose escalation
    - RTOG phase-II trials ongoing

# FDG-PET

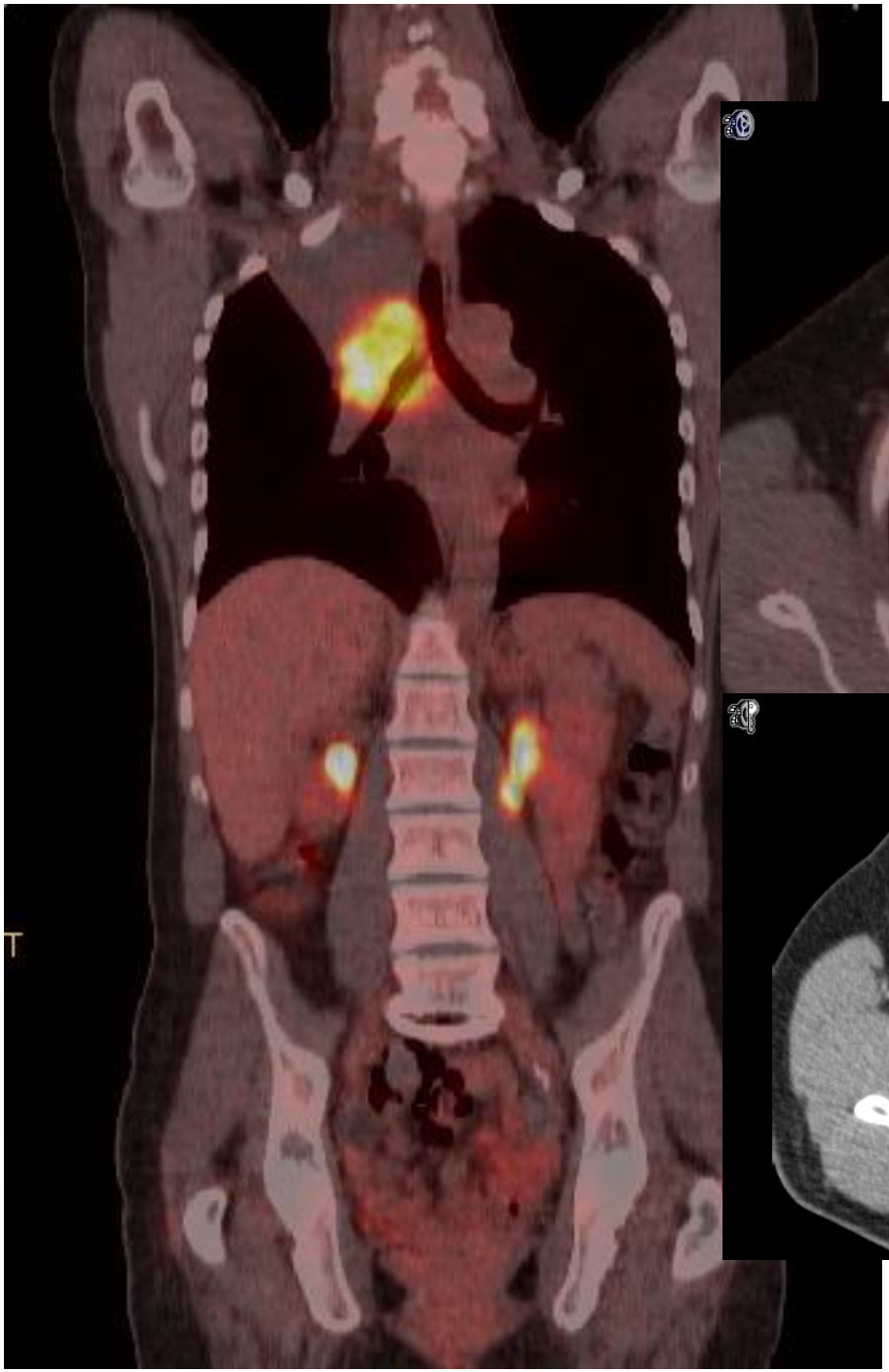
- FDG-PET scans are superior to CT scans alone for correctly staging mediastinal nodes
  - » **Dwamena BA, et al. Radiology 1999; 213: 530-6.**
- Incorporating FDG-PET findings into CT-based planning scan
  - Results in changes to radiotherapy plans in a significant proportion of patients [18,37,72]
    - » **Giraud P, et al. IJROBP 2001; 50: 1249-57.**
    - » **Mah K, et al. IJROBP 2002; 52: 339-50.**
    - » **Vanuytsel L, et al. Radiother Oncol 2000; 55: 317-24.**
  - May increase or decrease target volumes
  - Can reduce inter-observer variability in delineating target volumes [37].
    - » **Mah K, et al. IJROBP 2002; 52: 339-50.**
  - Inflammation or infection also influences FDG-PET uptake

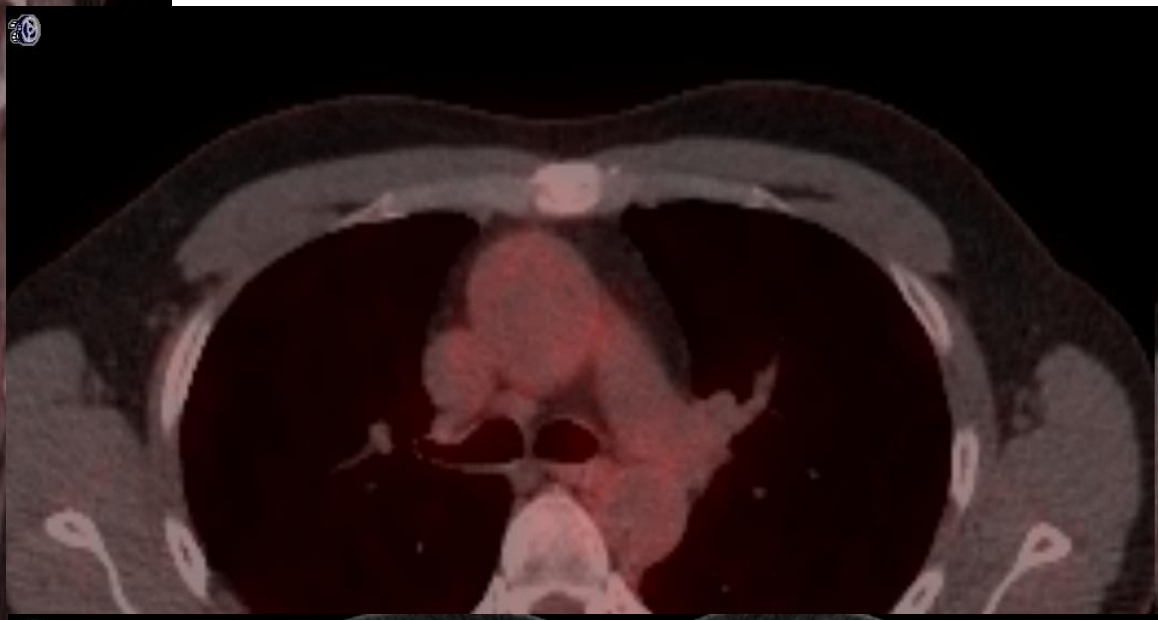
# Functional imaging – PET

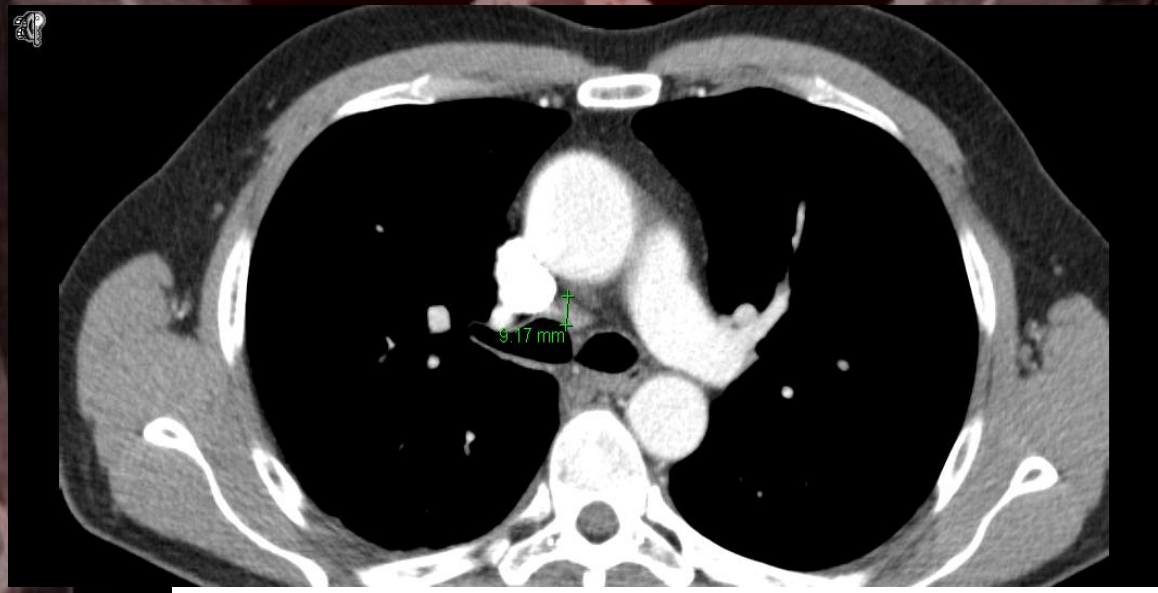
- Reduces tumour delineation variability among radiation oncologists
  - **Nestle et al. Radiother Oncol 2006; 81: 209-25.**
  - **Van Der Wel et al. IJROBP 2005; 61:649-55.**

- Makes radiation fields generally smaller, may lead to less side-effects
  - **De Ruysscher et al. IJROBP 2005; 62: 988-94.**
  - **Belderbos et al. IJROBP 2006; 66: 126-34.**

- Selective mediastinal node irradiation did not lead to higher isolated nodal recurrances
  - **Steenbakkers et al. Radiother Oncol 2005; 77: 182-90.**






9.17 mm

# Margins – CTV

- Standard recommendation:
  - Margin for microscopic extension is 5–6 mm for RT planning in NSCLC

» **Giraud P, et al. IJROBP 2000; 48: 1015-24.**

# Margins – PTV

- To establish the random and systematic errors in treatment planning and delivery at your institution
- To establish tumour motion and organ motion
- 3D margins for the PTV can be calculated based upon the requirement for a certain coverage probability
  - e.g. a large part of the CTV (99%) should receive 95% of the prescribed dose
    - » **Stroom JC, et al. IJROBP 1999; 43: 905-19.**
    - » **Van Herke M, et al. IJROBP 2000; 47: 1121-35.**

# Organs at risk (OAR) – Spinal cord

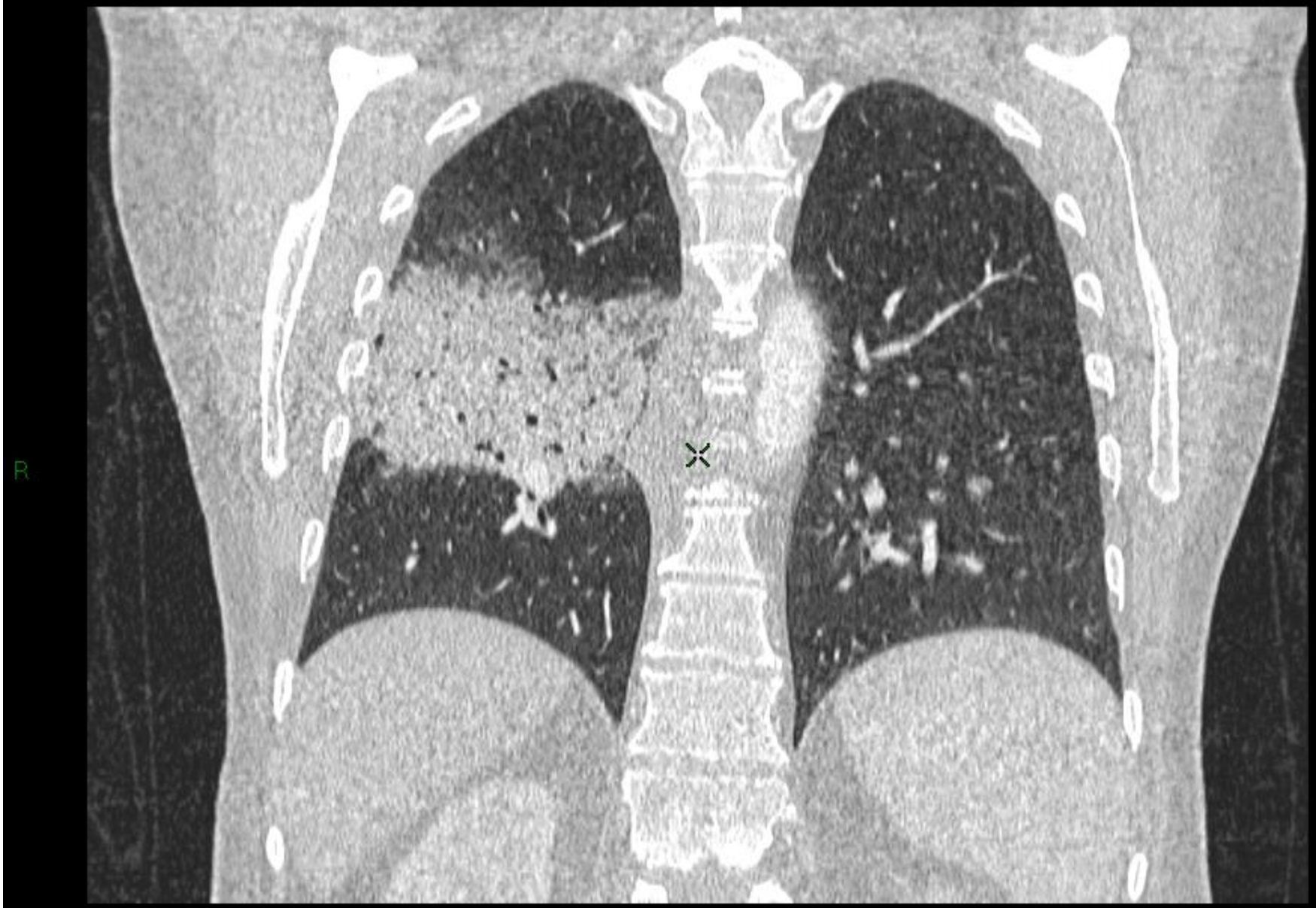
- Traditional: 44 Gy in 2Gy/ fraction
- Some trial protocols: 48Gy in 30 fractions

- **QUANTEC paper**
  - $D_{max}$ of 50Gy – 0.2% risk of myelopathy
    (for partial or full cross-section)
  - $D_{max}$ of 13Gy (single fraction) – 1% risk of myelopathy (for partial or full cross-section)
  - $D_{max}$ of 20Gy (hypofractionation) – 1% risk of myelopathy (for partial or full cross-section)

# Organs at risk (OAR) – Lungs

- Establised facts: the following predict the risk of high-grade radiation pneumonitis:
  - V20; i.e. the volume of both lungs minus the PTV receiving 20 Gy
  - mean lung dose
    - » **Graham MV, et al. IJROBP 1999; 45: 323-9.**
    - » **Kwa SL, et al. IJROBP 1998; 42: 1-9.**
- Whole lung V20 ≤ 30%
  - <20% risk of symptomatic pneumonitis
- Mean lung dose = 20Gy
  - 20% risk of symptomatic pneumonitis
    - » **QUANTEC paper**

- **Pneumonitis/fibrosis**
  - < 10% of patients
  - Can be fatal
  - Can have a long term impact on quality of life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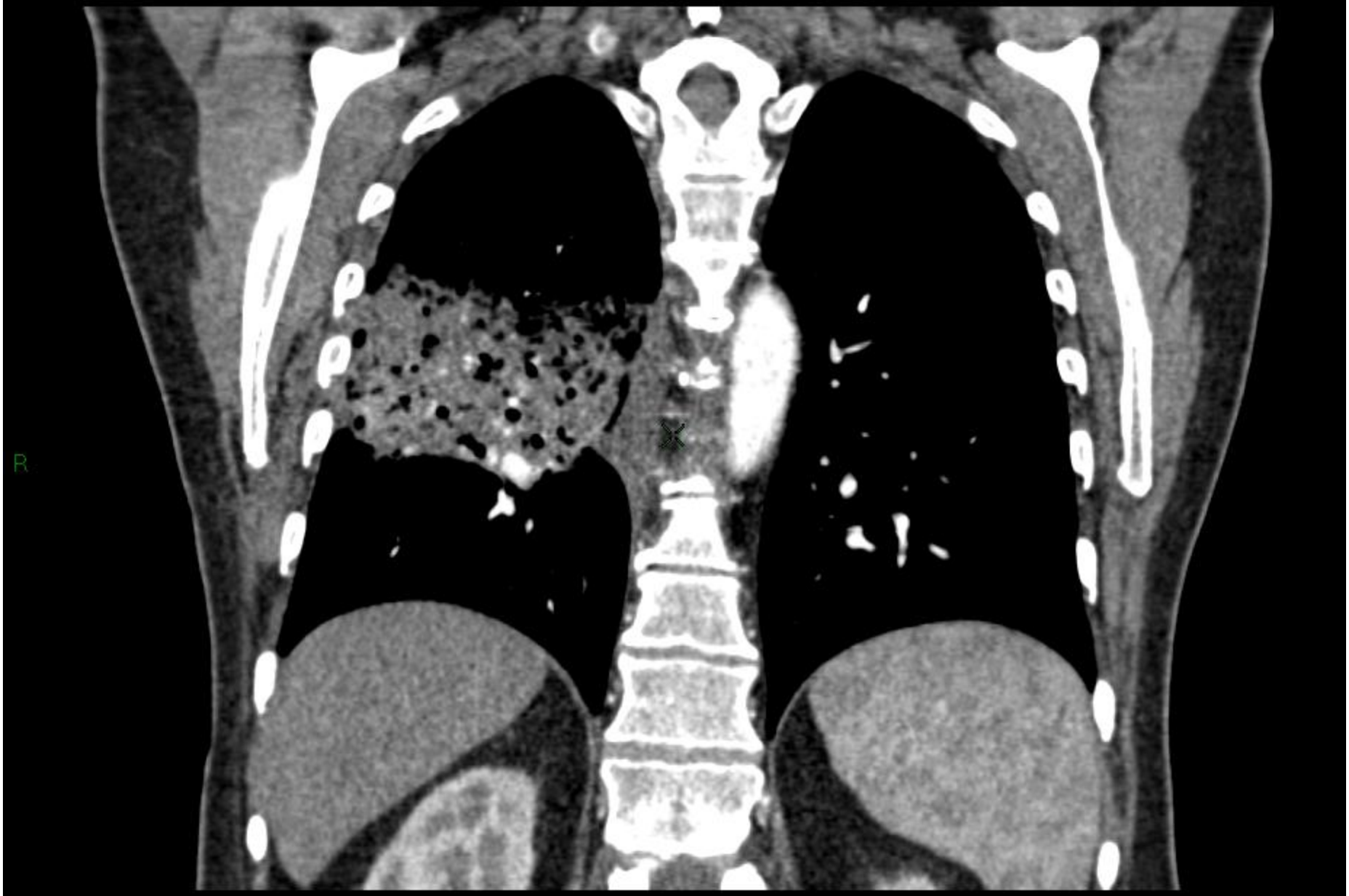
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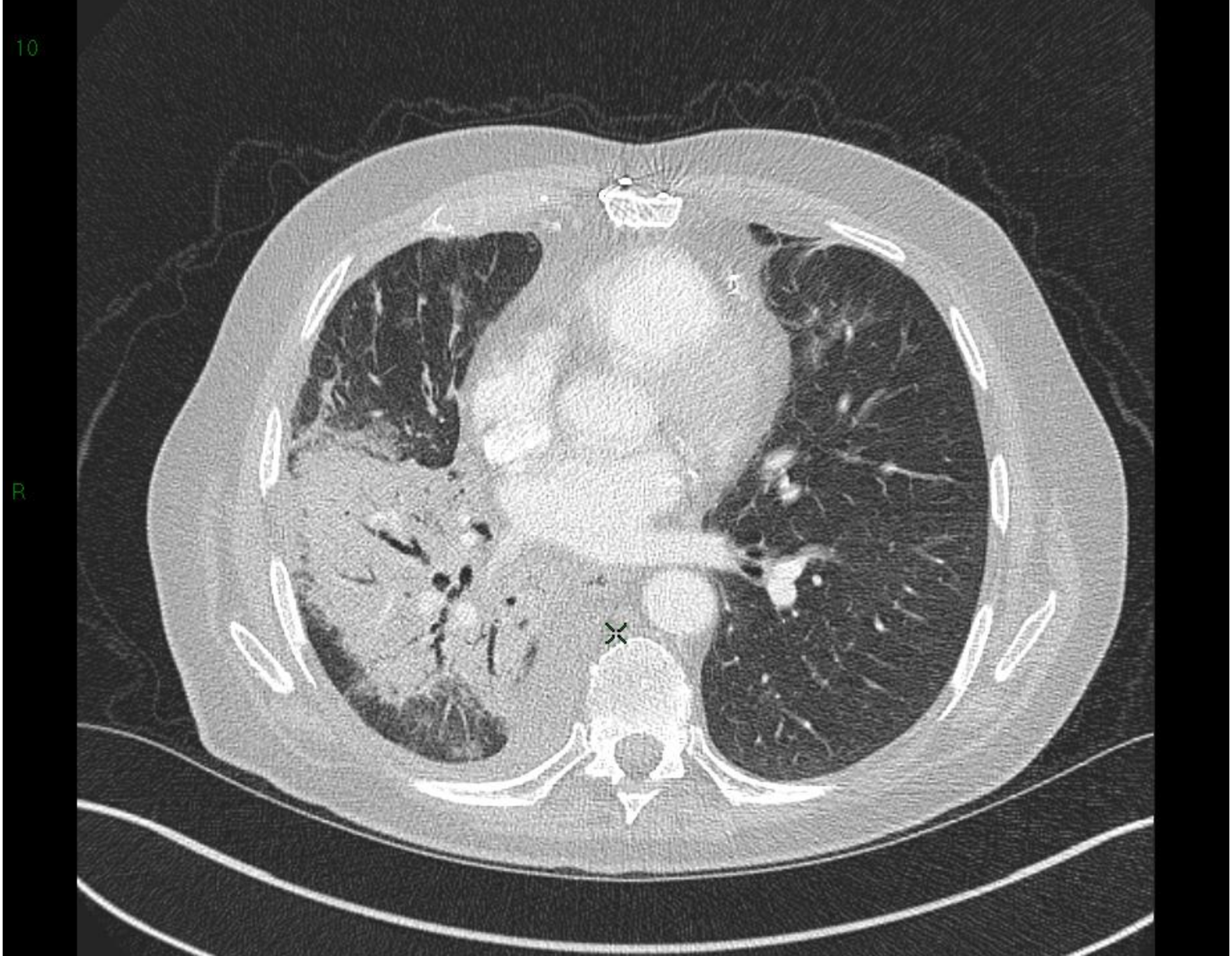
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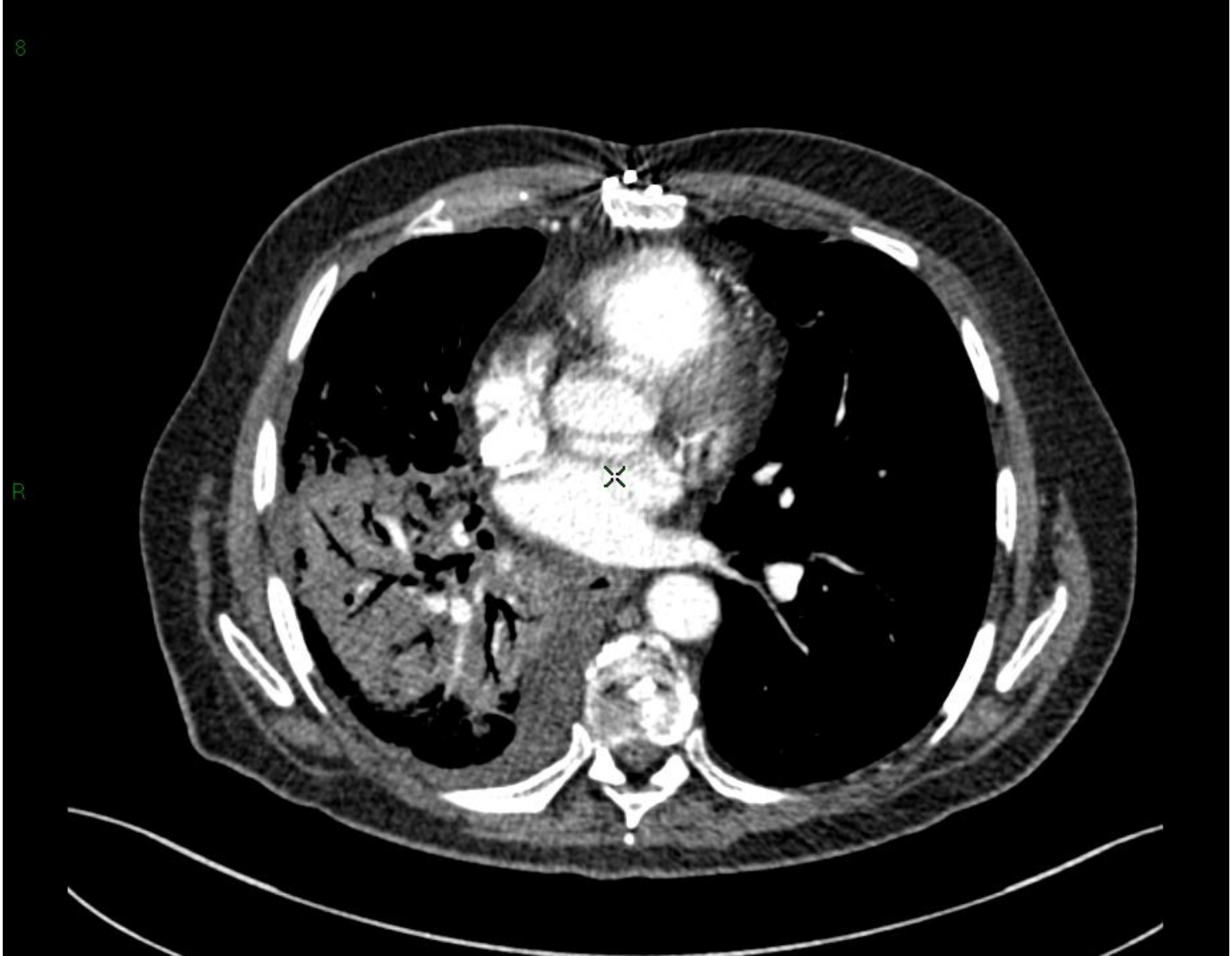
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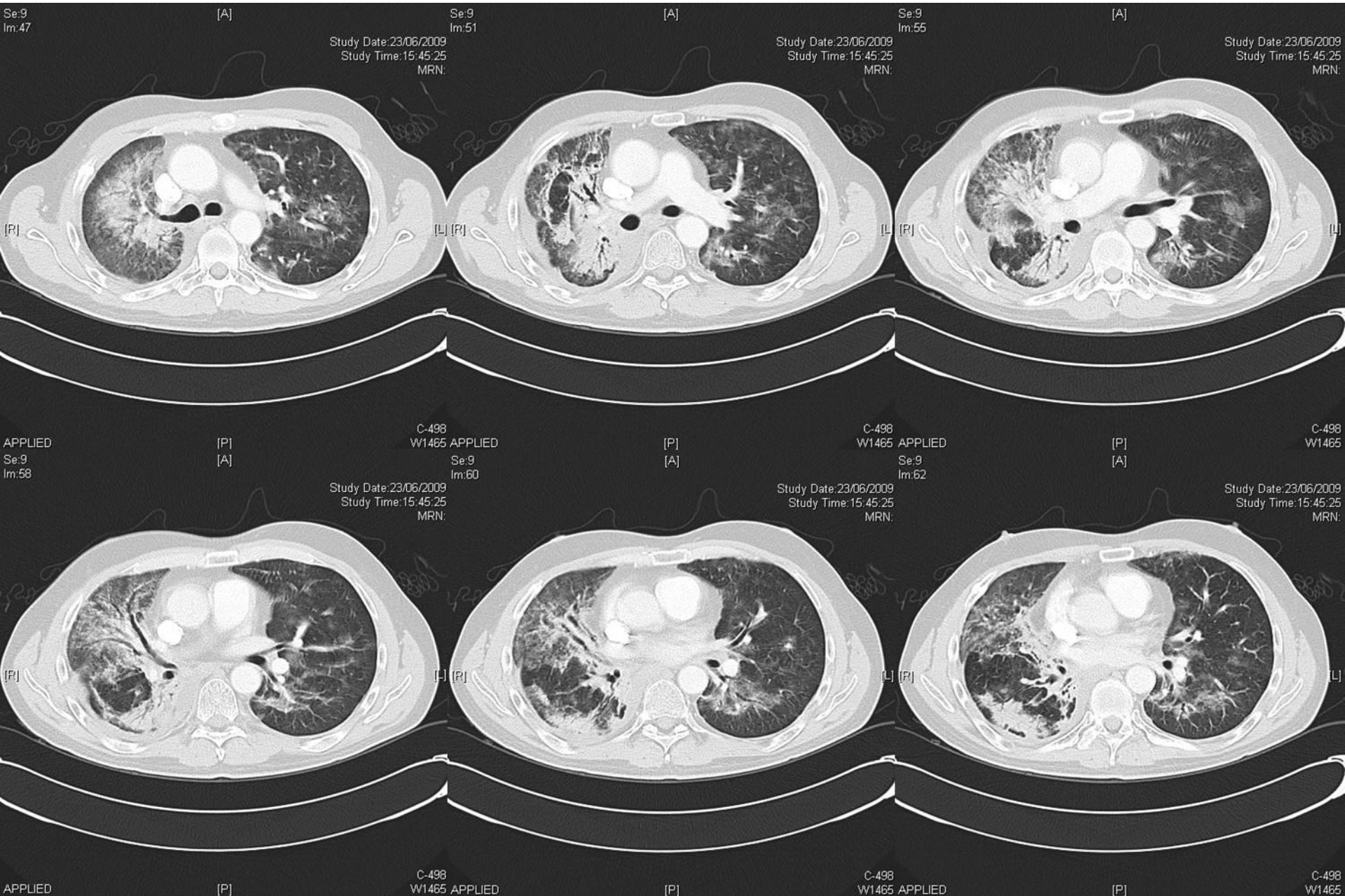
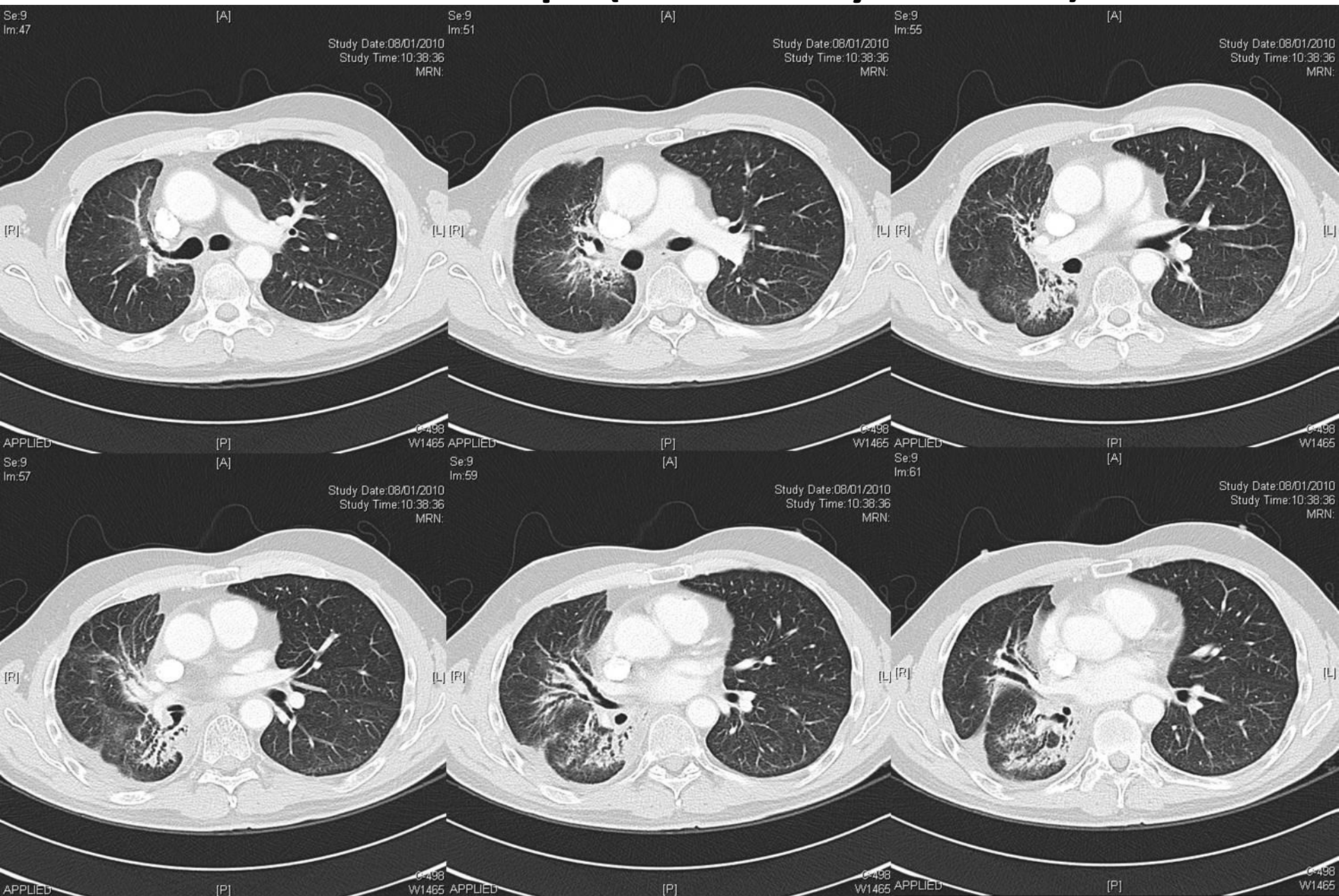
# Acute RP (June 2009)



# Follow-up (January 2010)



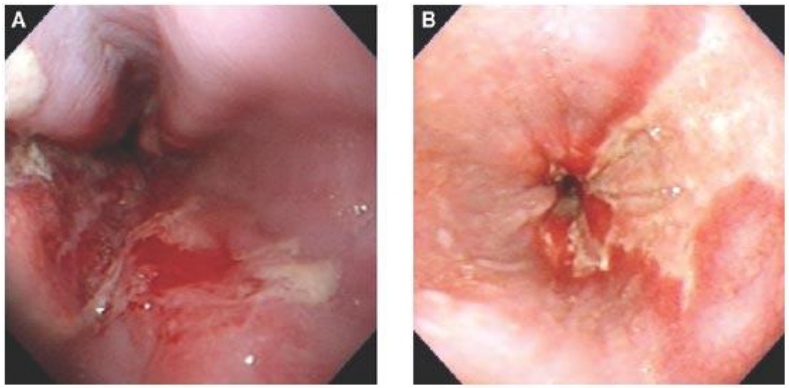
# Organs at risk (OAR) – Oesophagus

- High-grade esophagitis
  - an important dose limiting toxicity for chemo-radiotherapy
  - it correlates with treatment scheme used and volume of irradiated organ
- The incidence of grades 3–4 acute esophagitis is low (5%) with conventional fractionation, even when elective nodal irradiation is performed

» **Choy H, et al. Semin Radiat Oncol 1999; 9: 90-6.**

# Toxicity of concurrent CTRT

- Oesophagitis
  - Up to 30% of patients
  - Can lead to dehydration and hospitalisation
  - Transient
  - Manageable
  - Very rarely leads to long terms complications




- Pneumonitis/fibrosis
  - < 10% of patients
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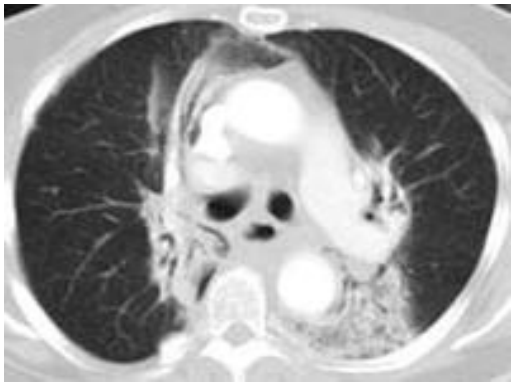


# Organs at risk (OAR) – Others

- There is presently limited data correlating 3D planning parameters with late cardiac and pericardial toxicity

- As the 5-year disease-free survival in stage III NSCLC remains under 20%, these risks may not be an issue for most patients

  » **Senan S et al. Radiother Oncol 2004; 71: 139-146**

# the impact analysis


"THIS COULD GET TRICKY -- BEFORE I CAN OPERATE, I'LL HAVE TO FILE AN ENVIRONMENTAL IMPACT STATEMENT."

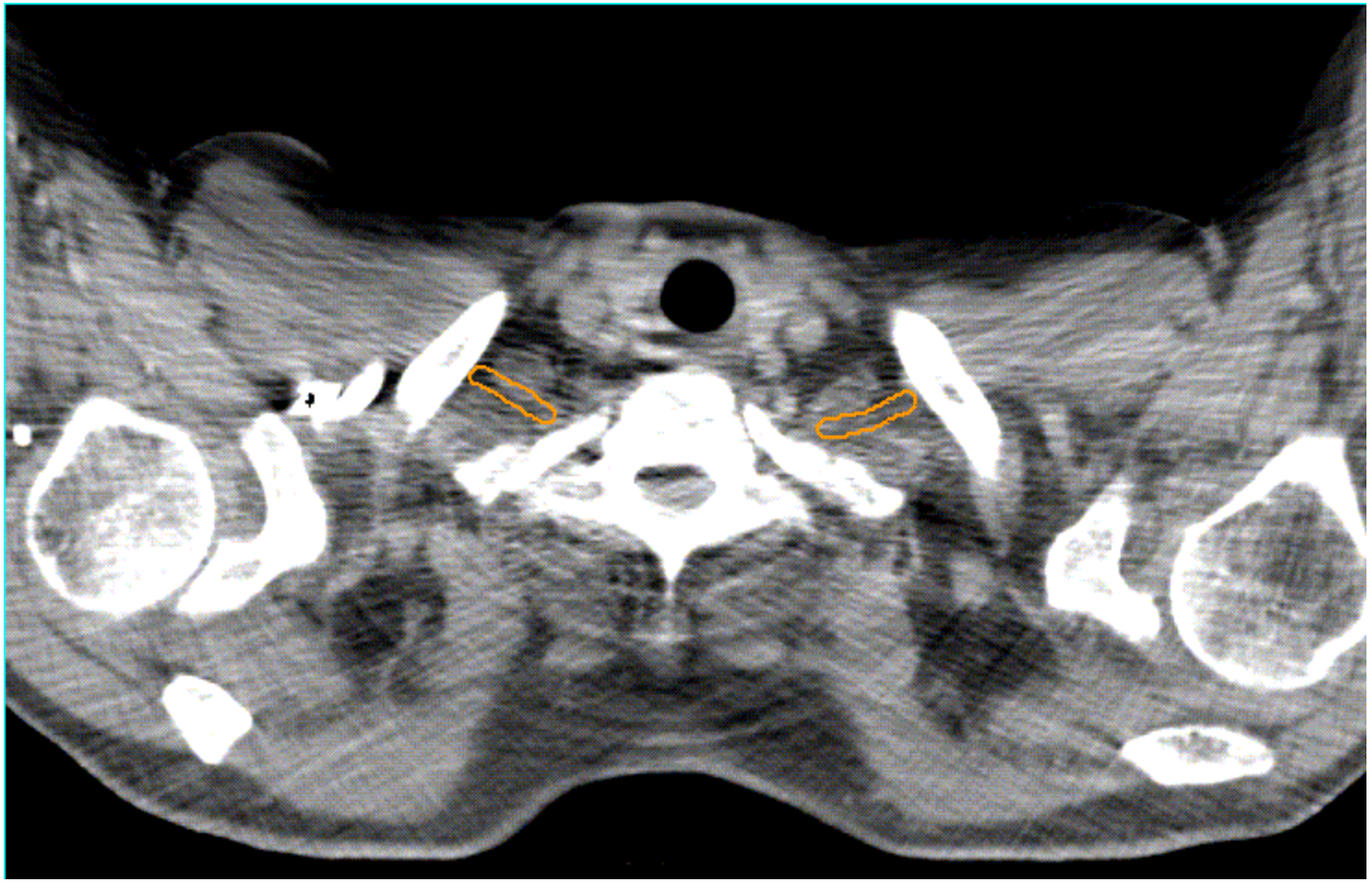
# OARs

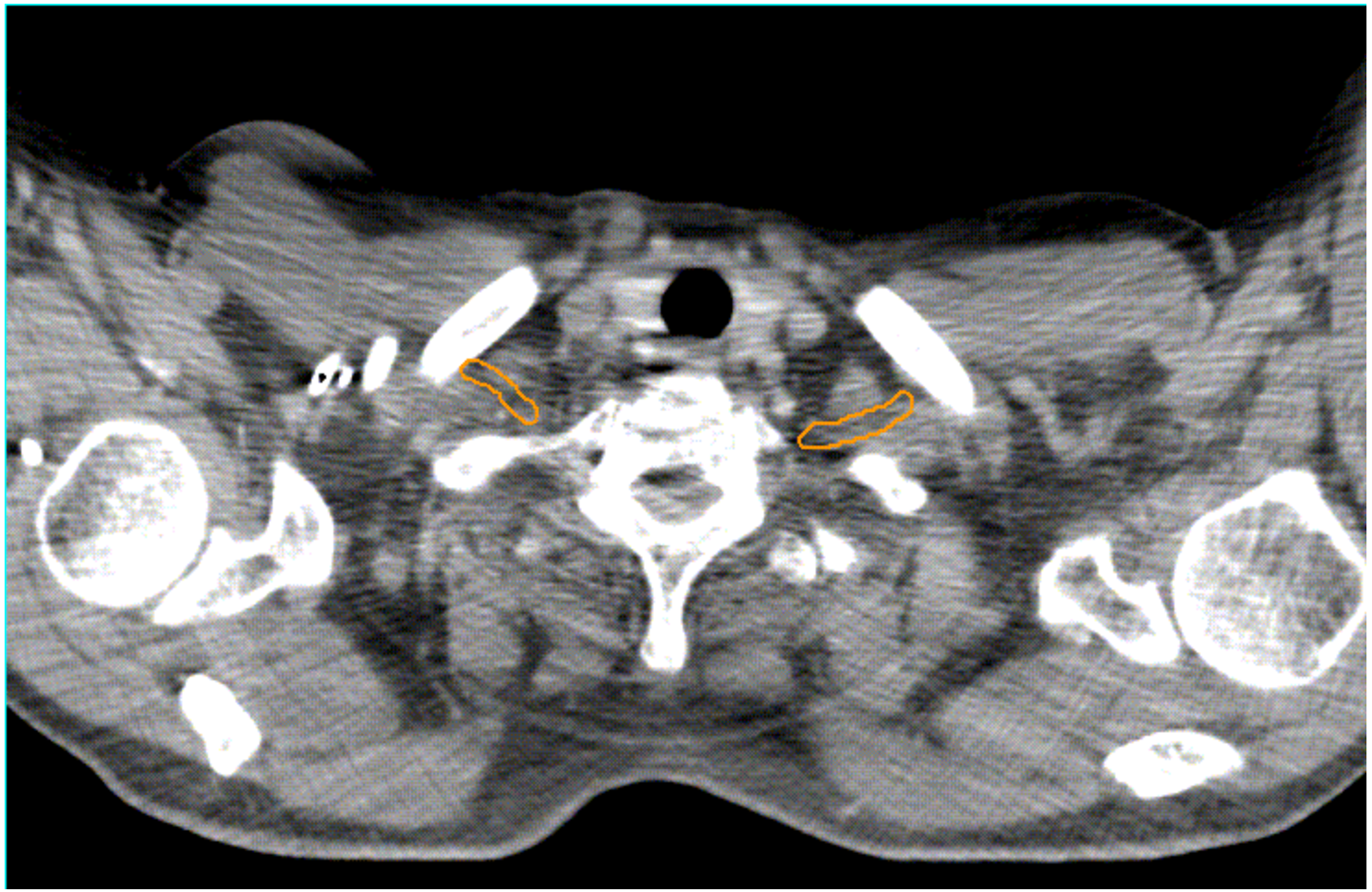
- Lungs: auto-contouring tools, then visual check
- Spinal canal
- Brachial Plexus: Pancoast tumours, SABR/SBRT
- Heart / Pericardium: some trial protocols, SABR/SBRT
- Central airways (prox bronchial tree): for SABR/SBRT

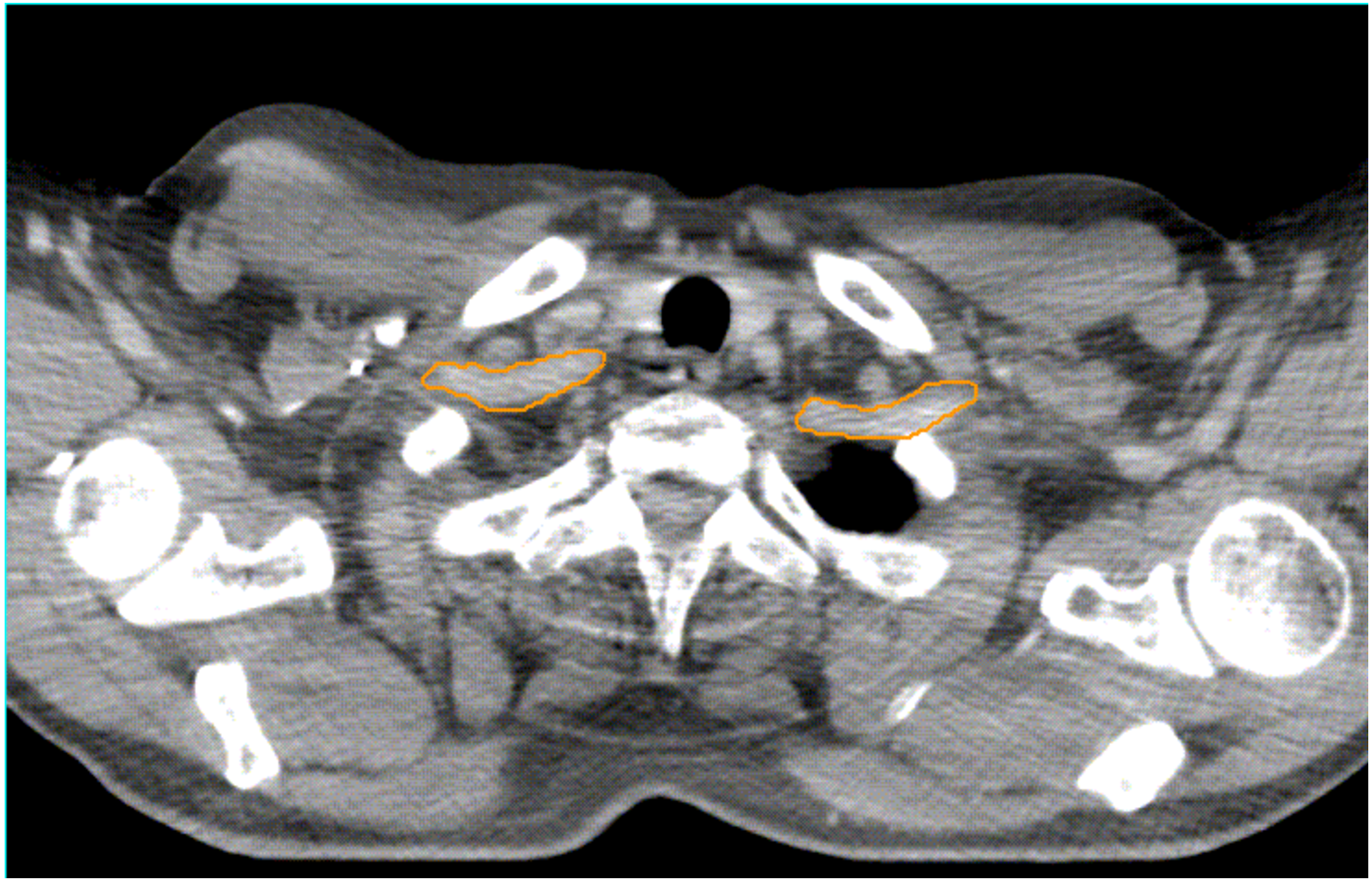
# Contouring OARs

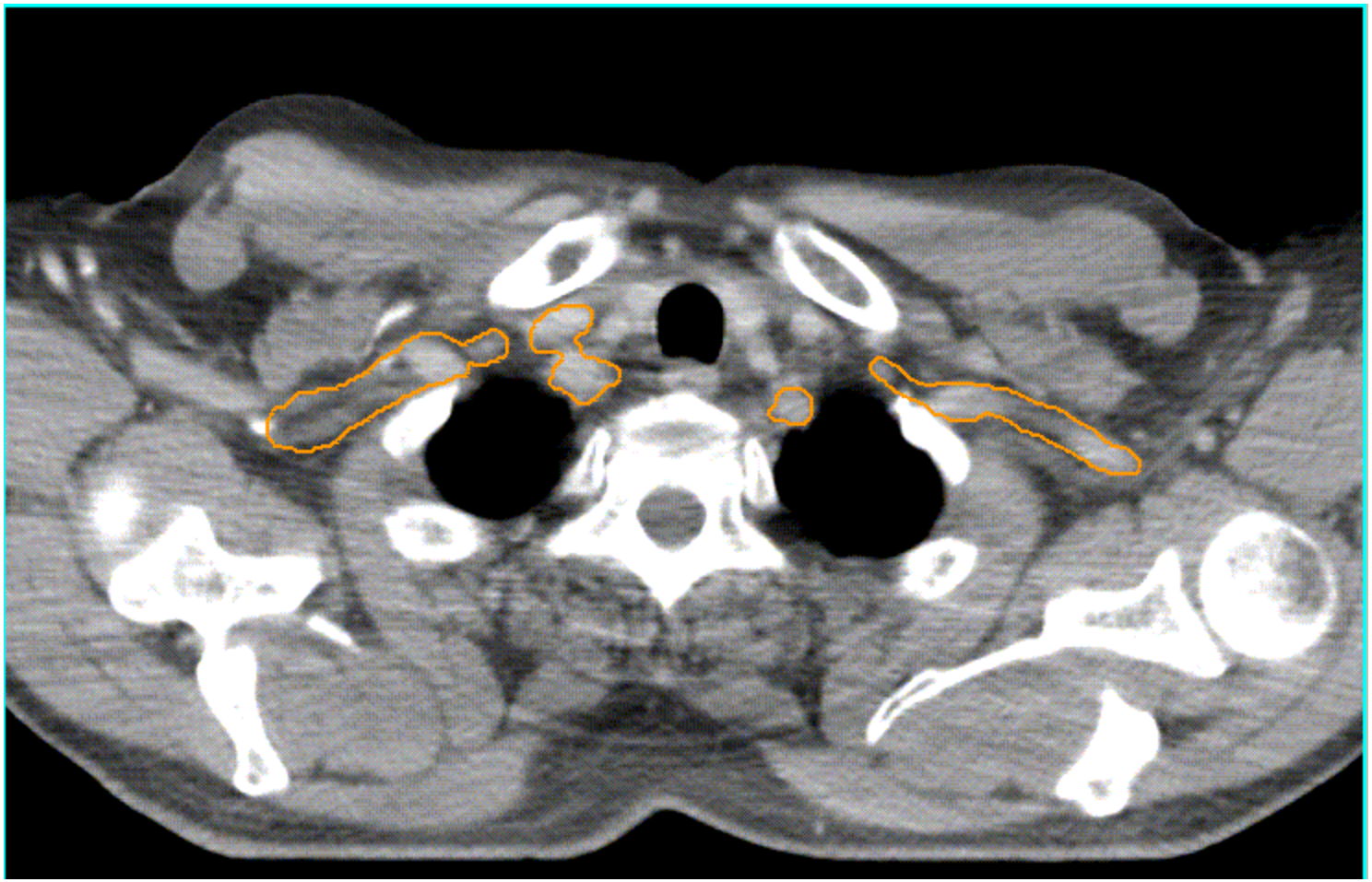
# Brachial Plexus

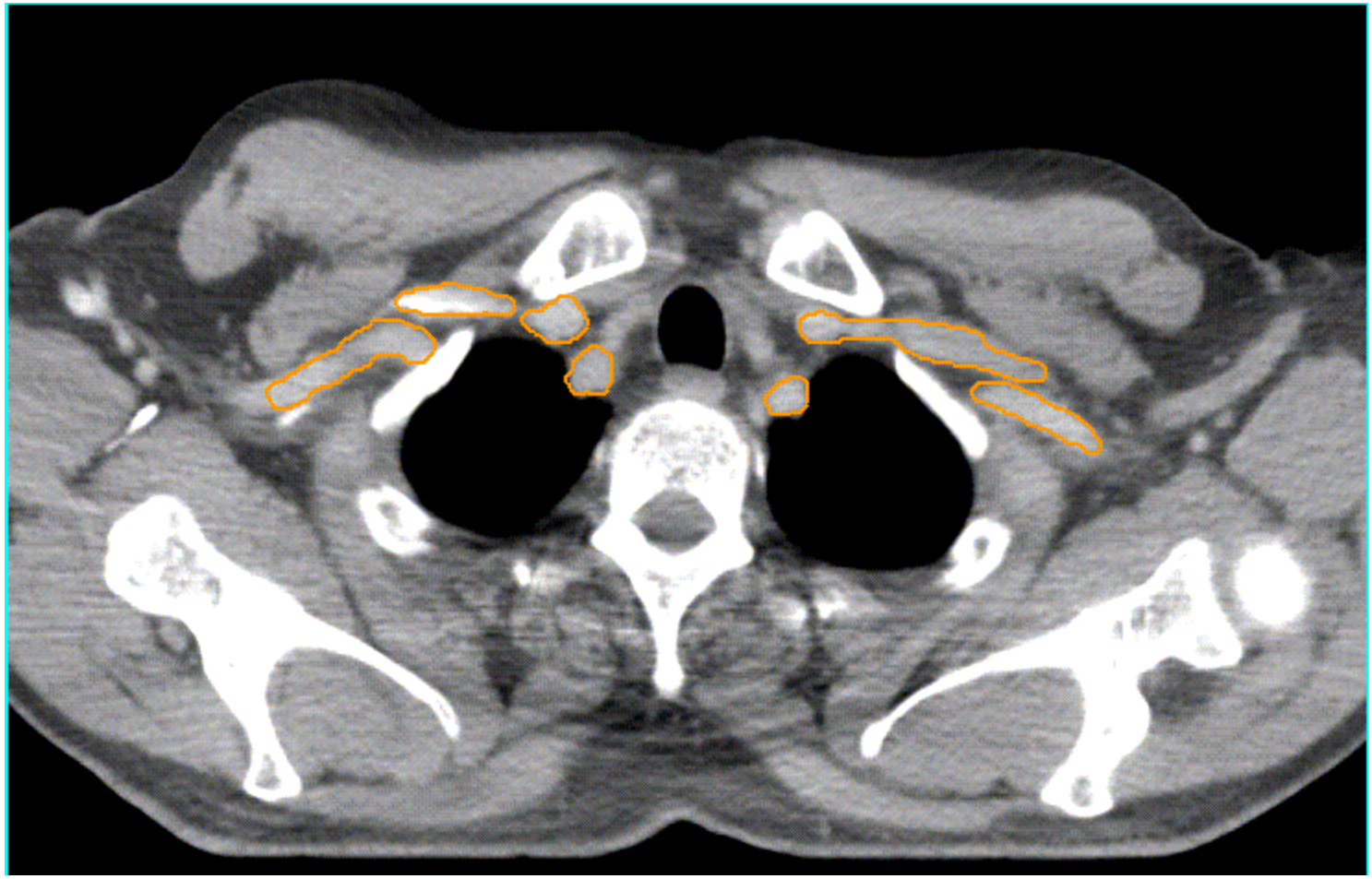
- Only major trunks to be contoured
- Using Subclavian and axillary vessels as surrogate
- Start inferiorly at the bifurcation of the Brachiocephalic vein/artery
- Follow the vessels upwards
- Stop when the vessels cross the Second rib

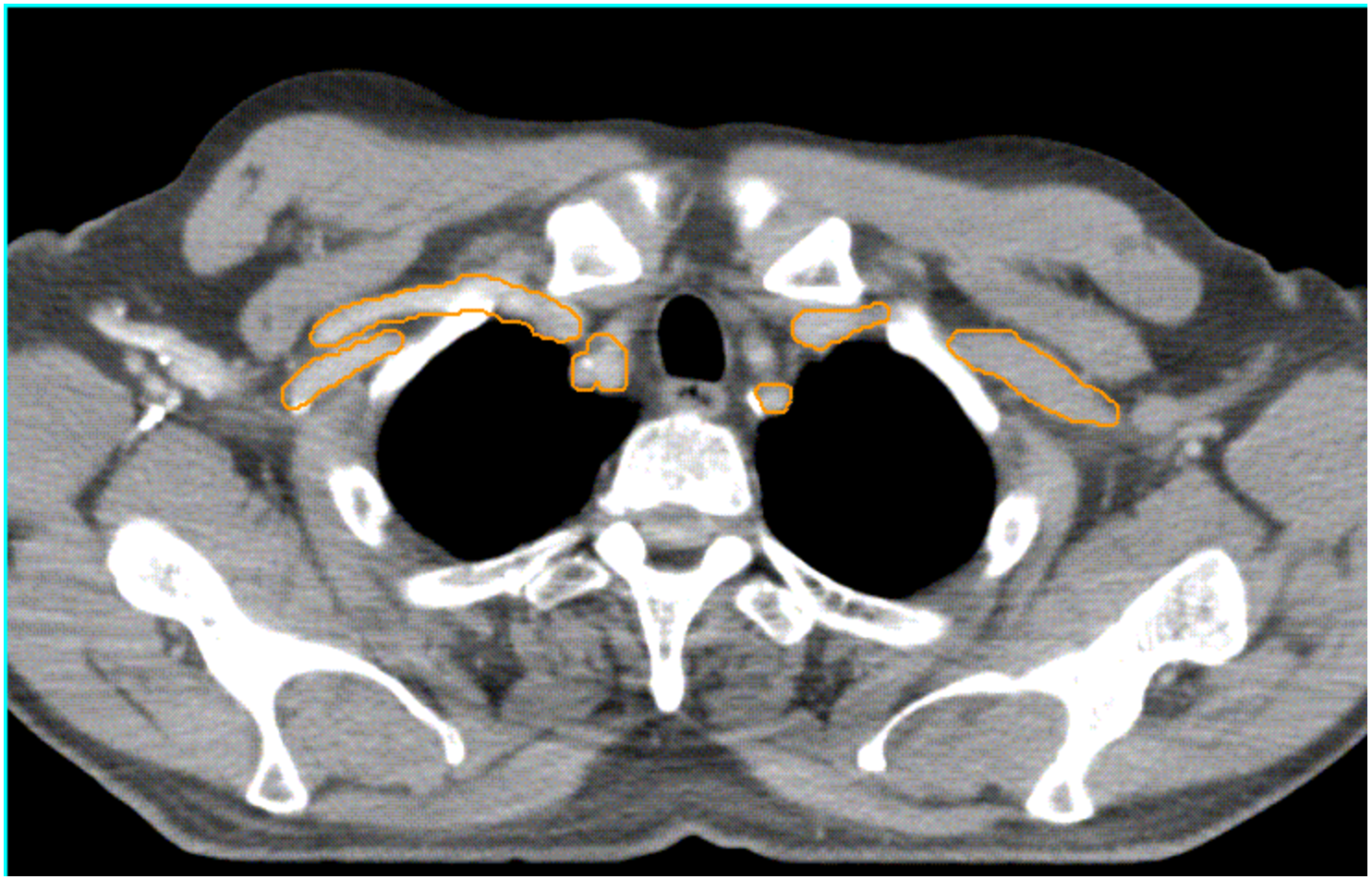


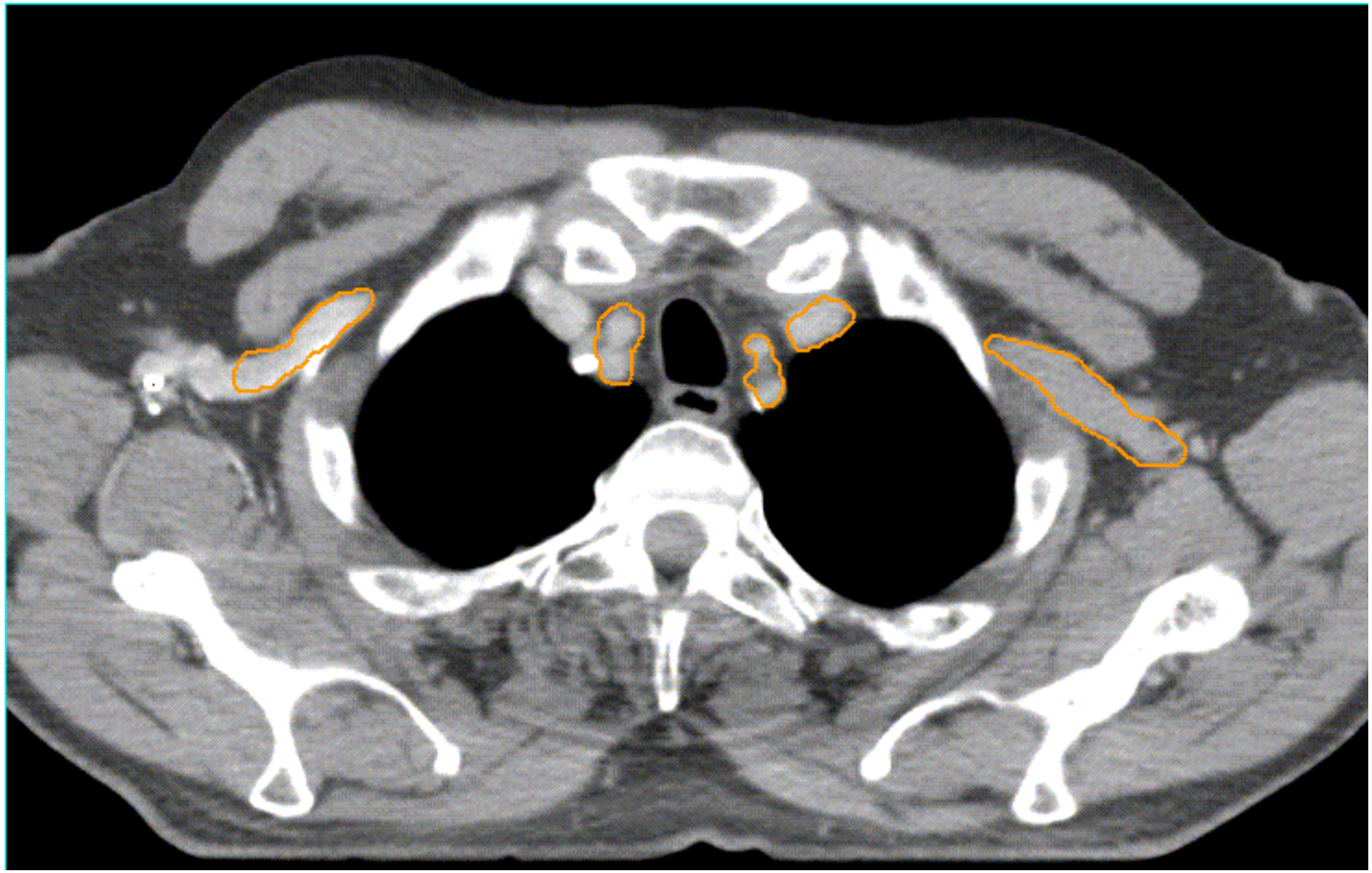


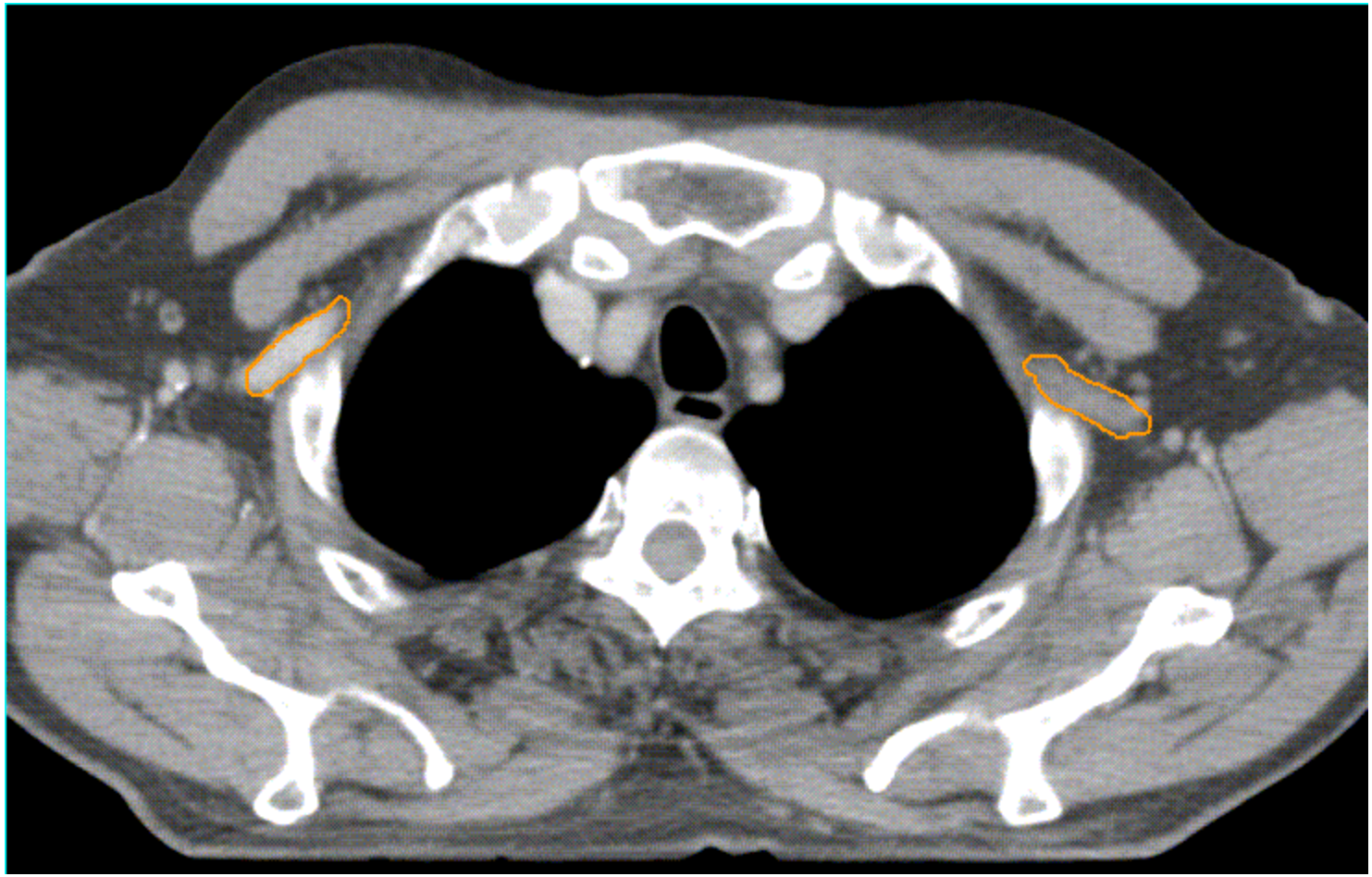


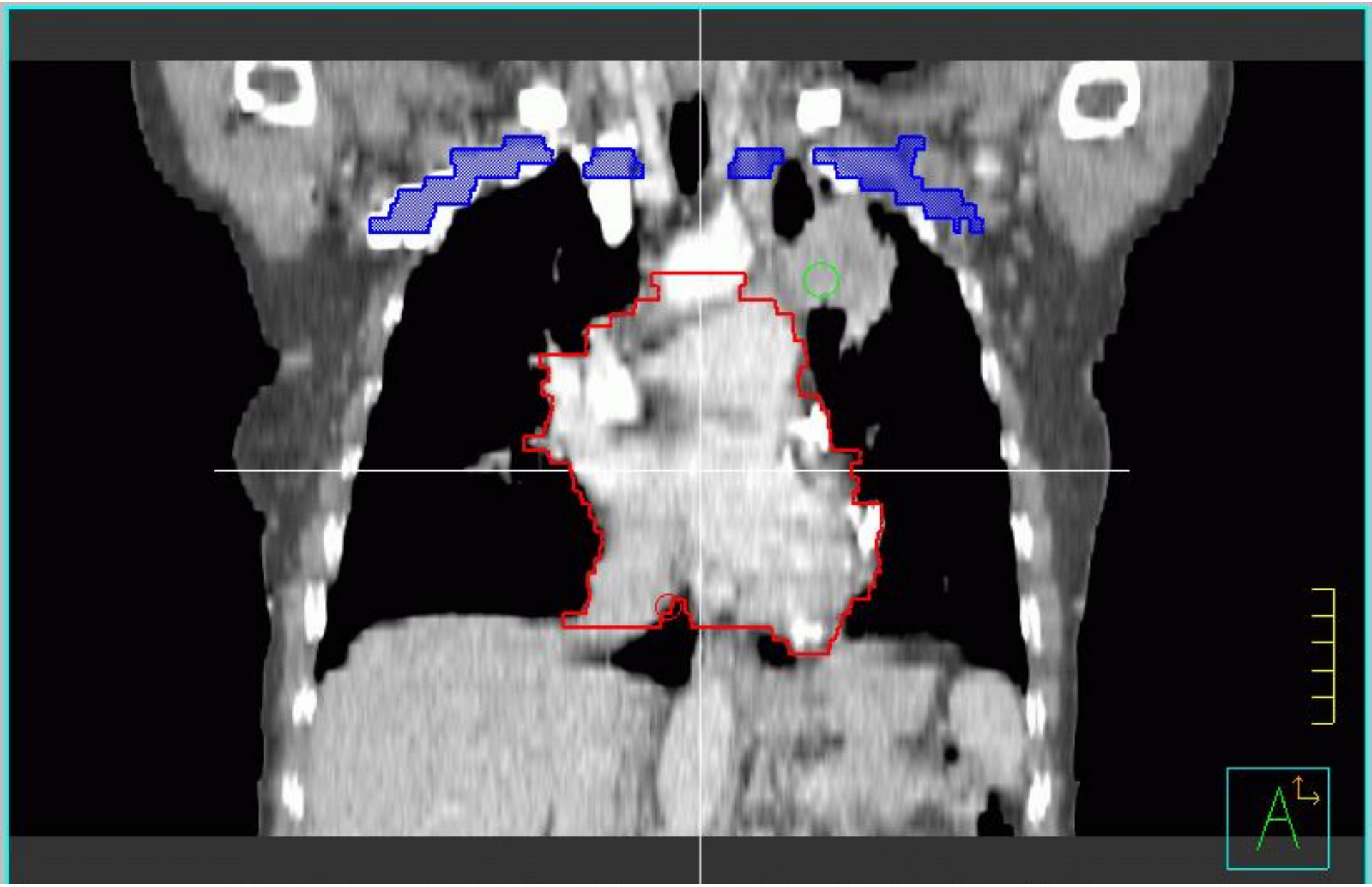


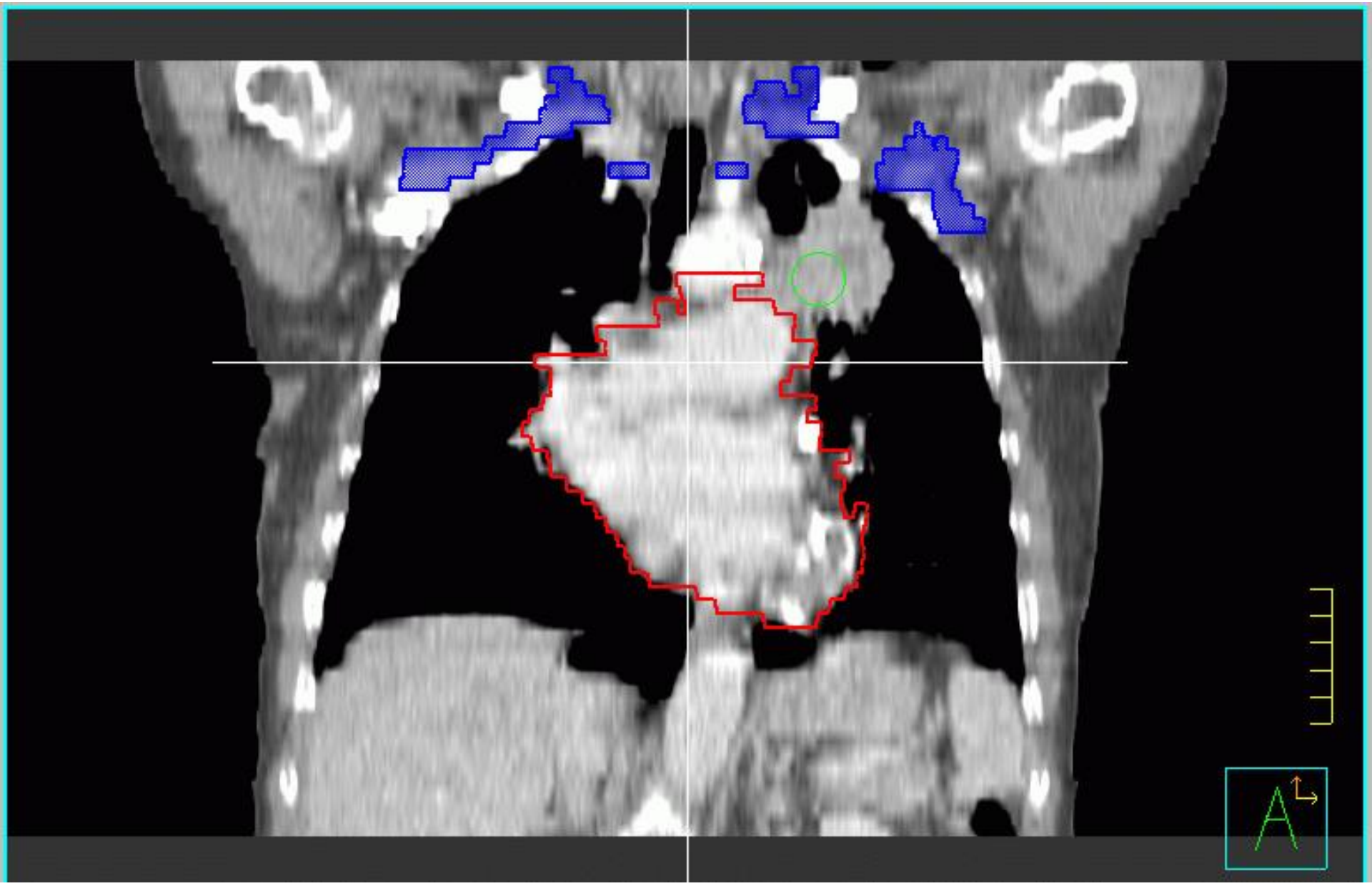


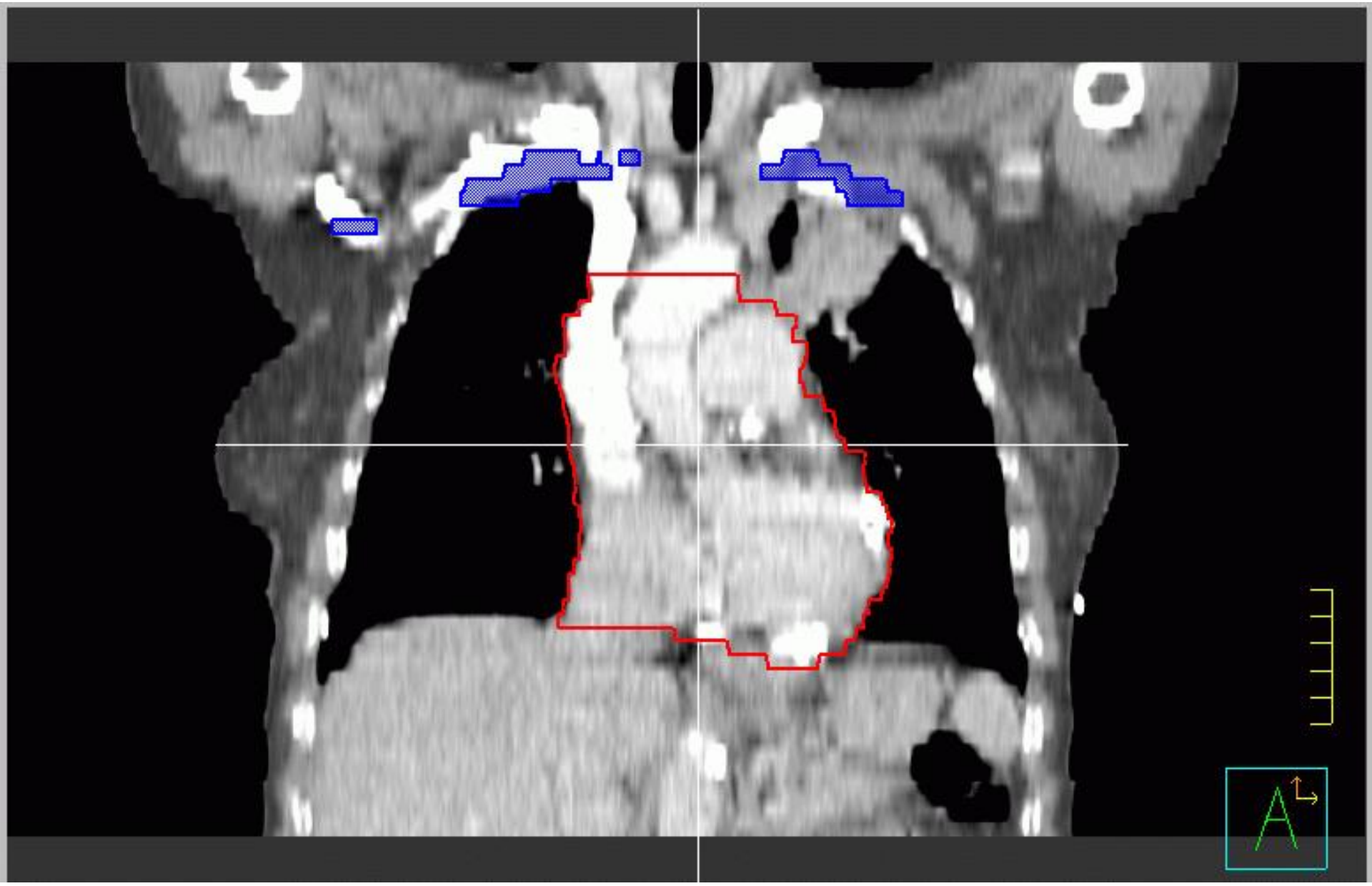


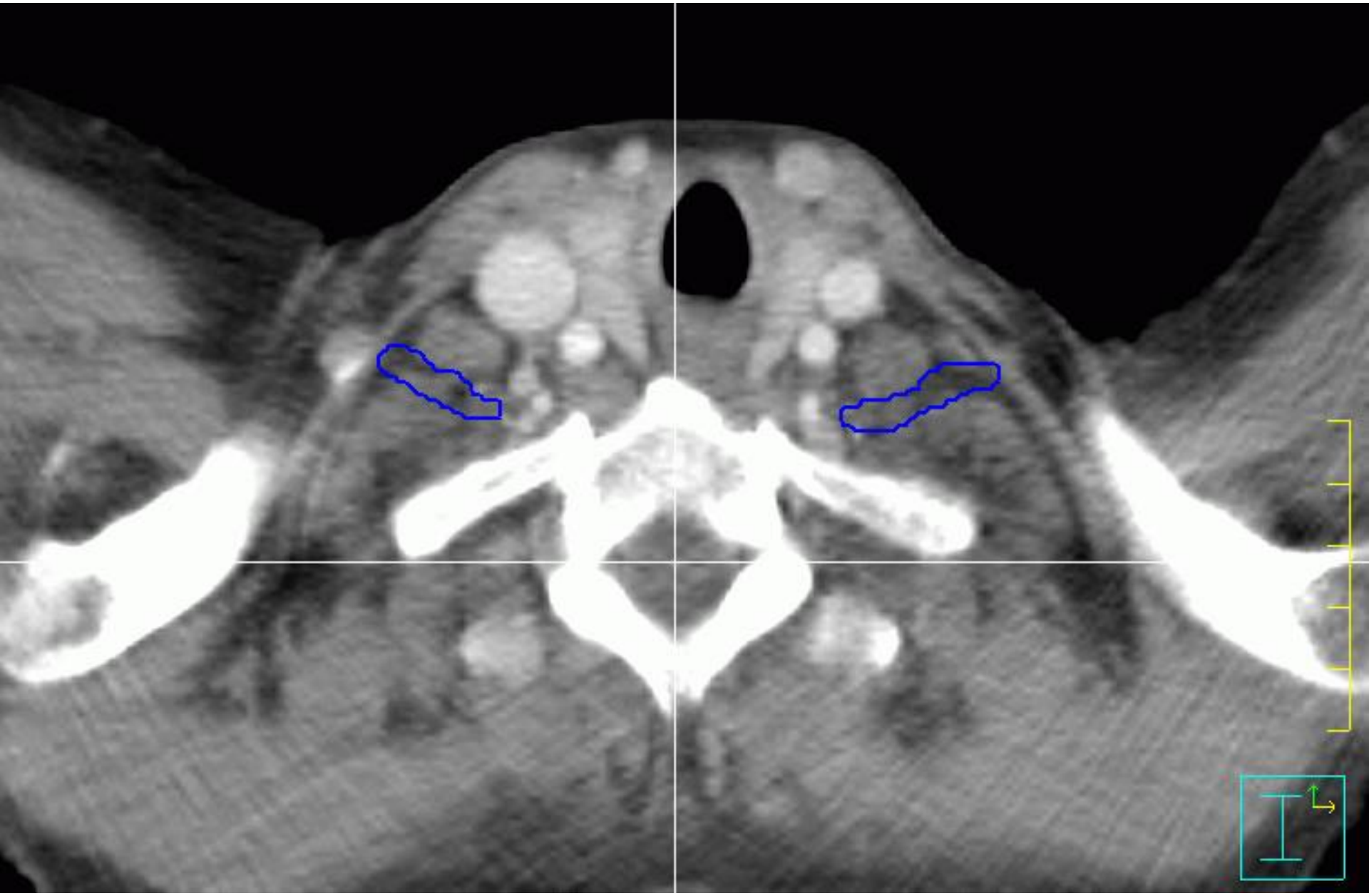


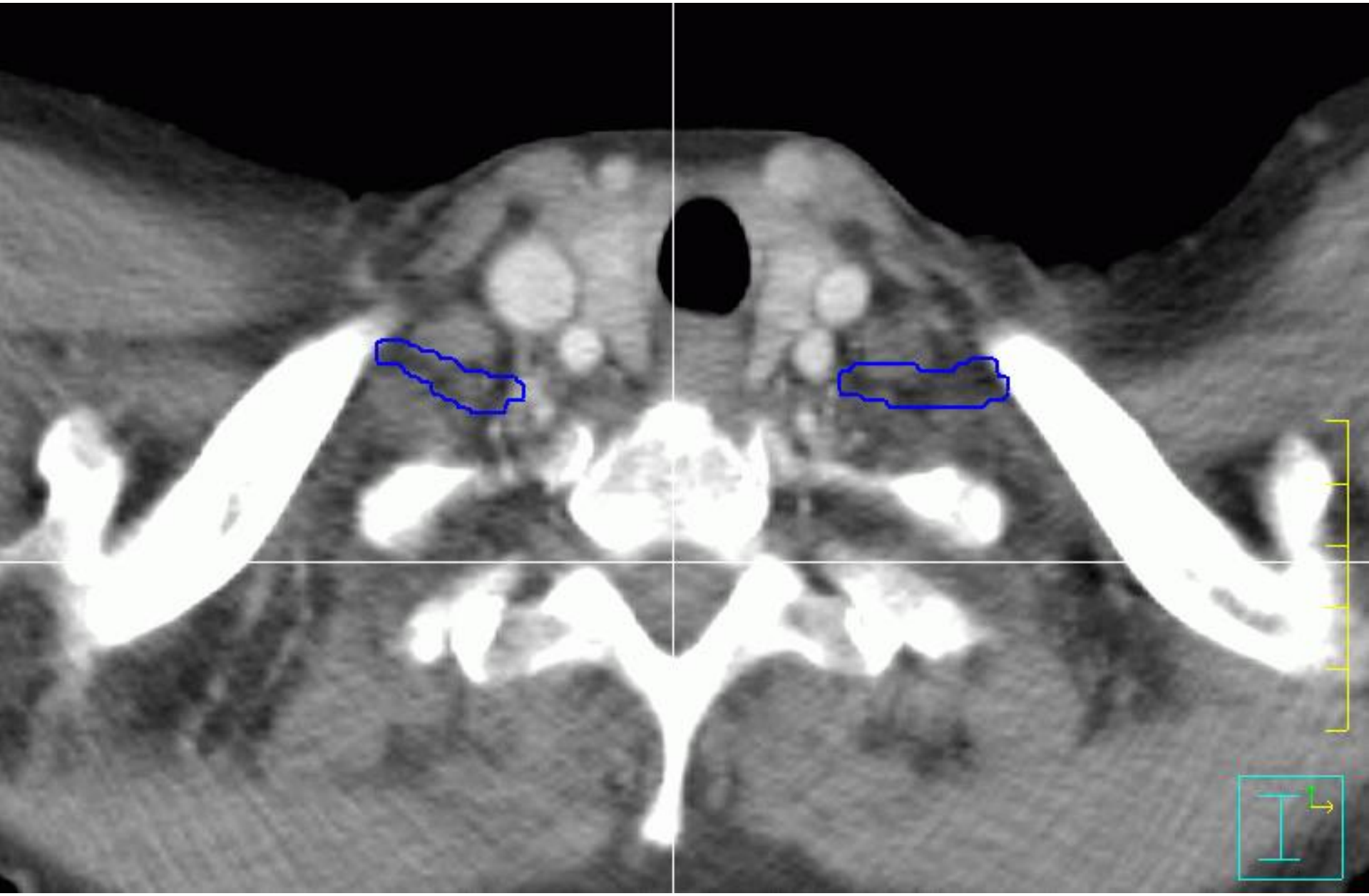


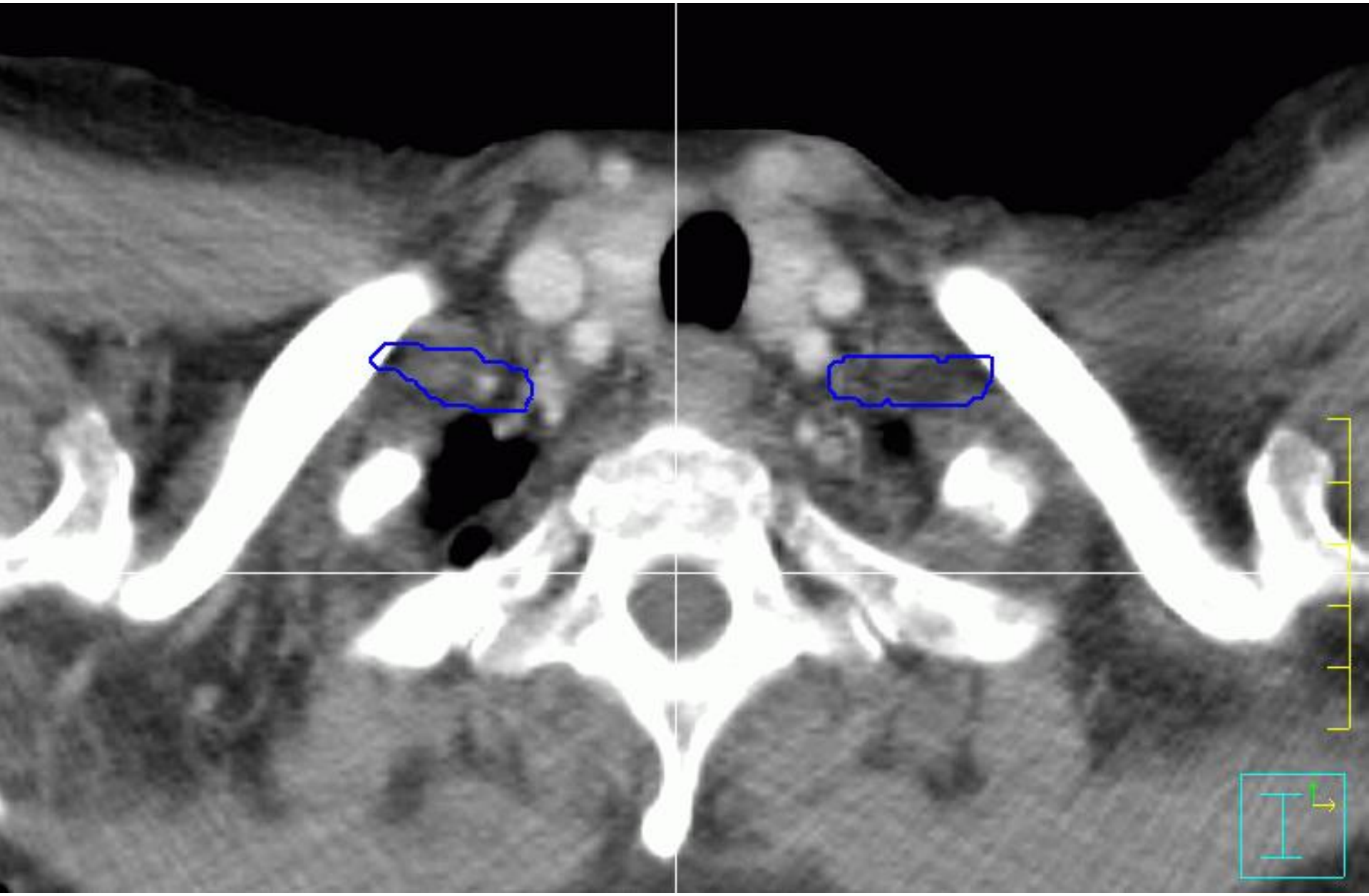


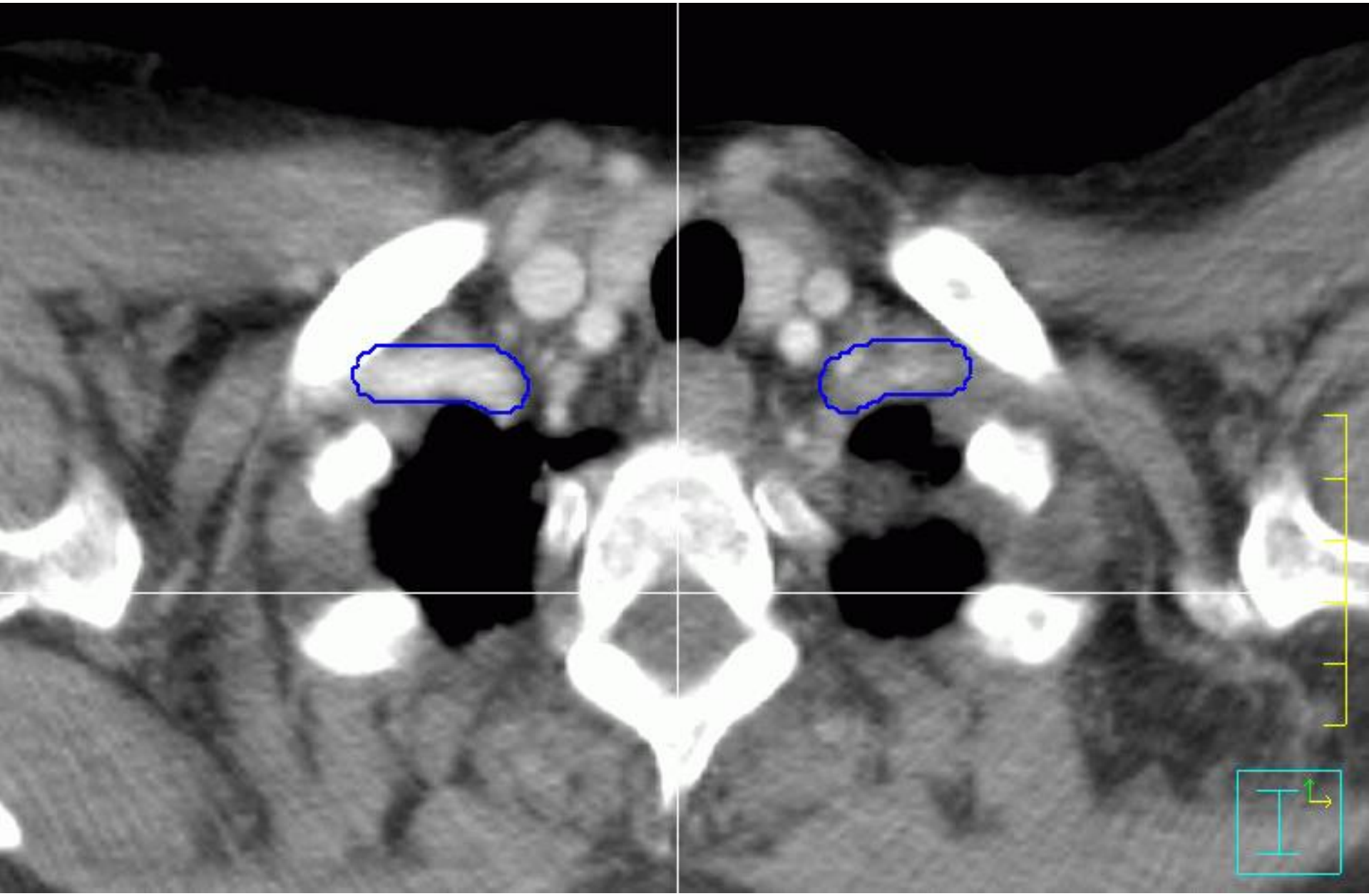


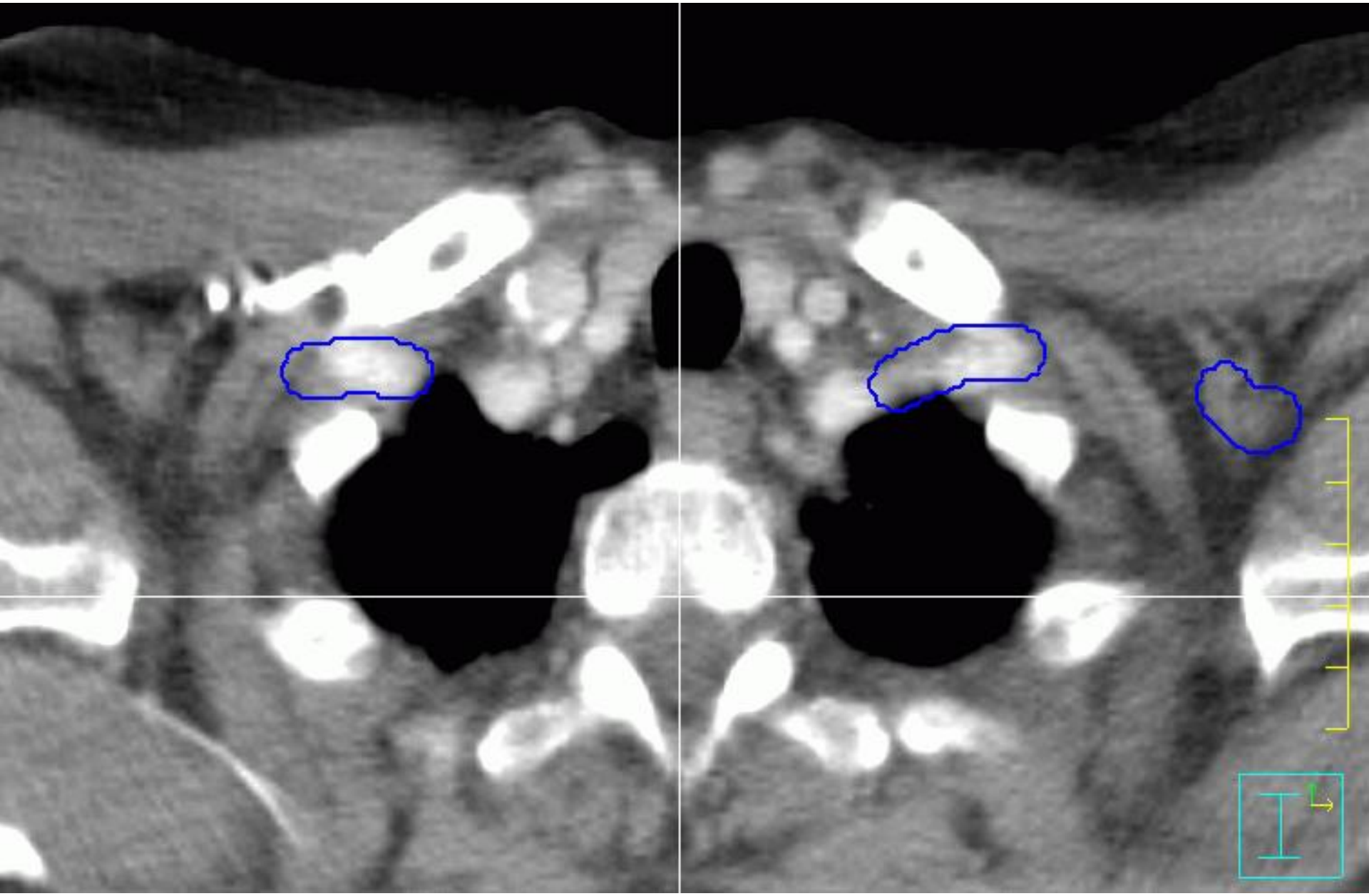


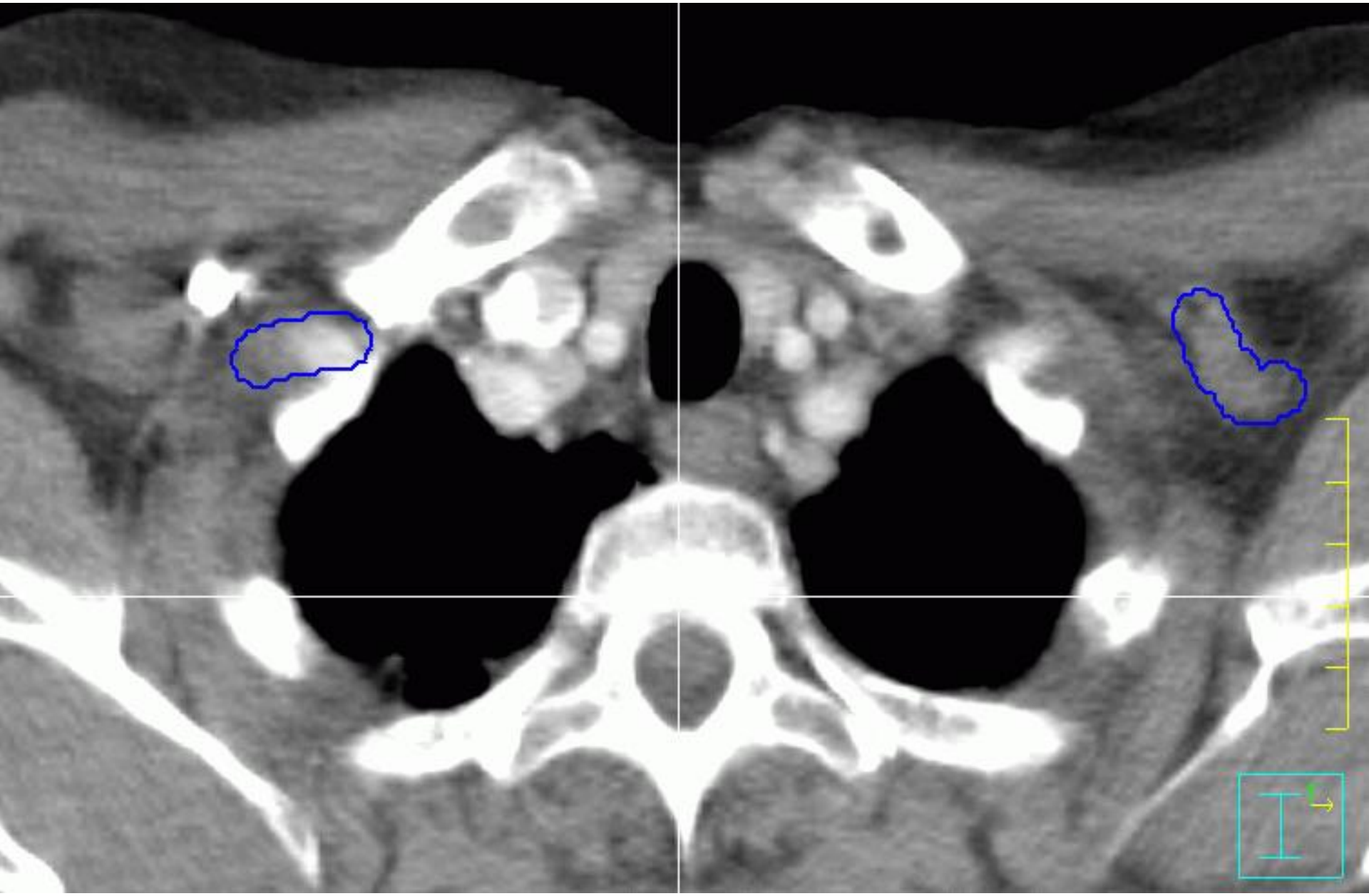


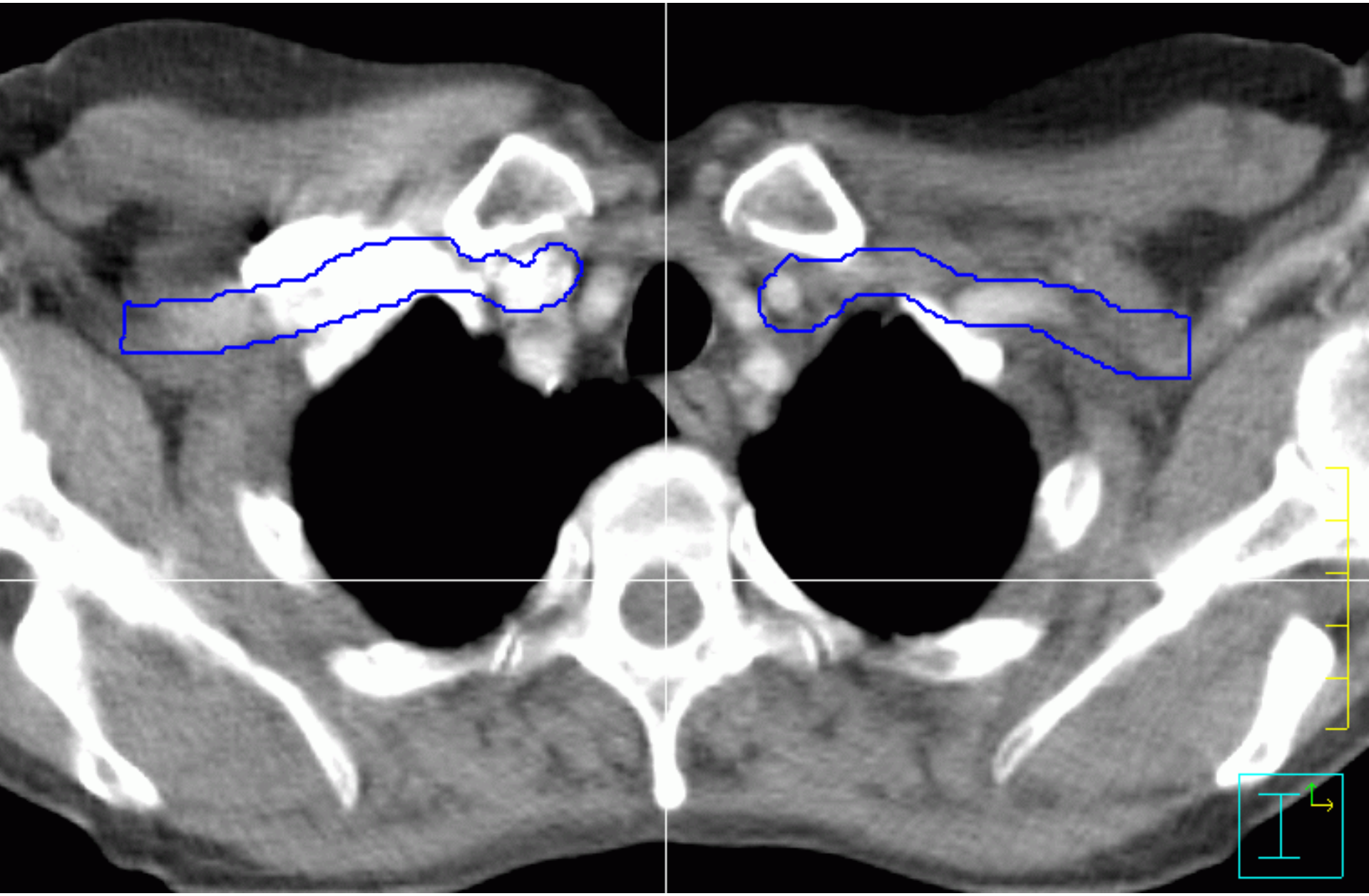


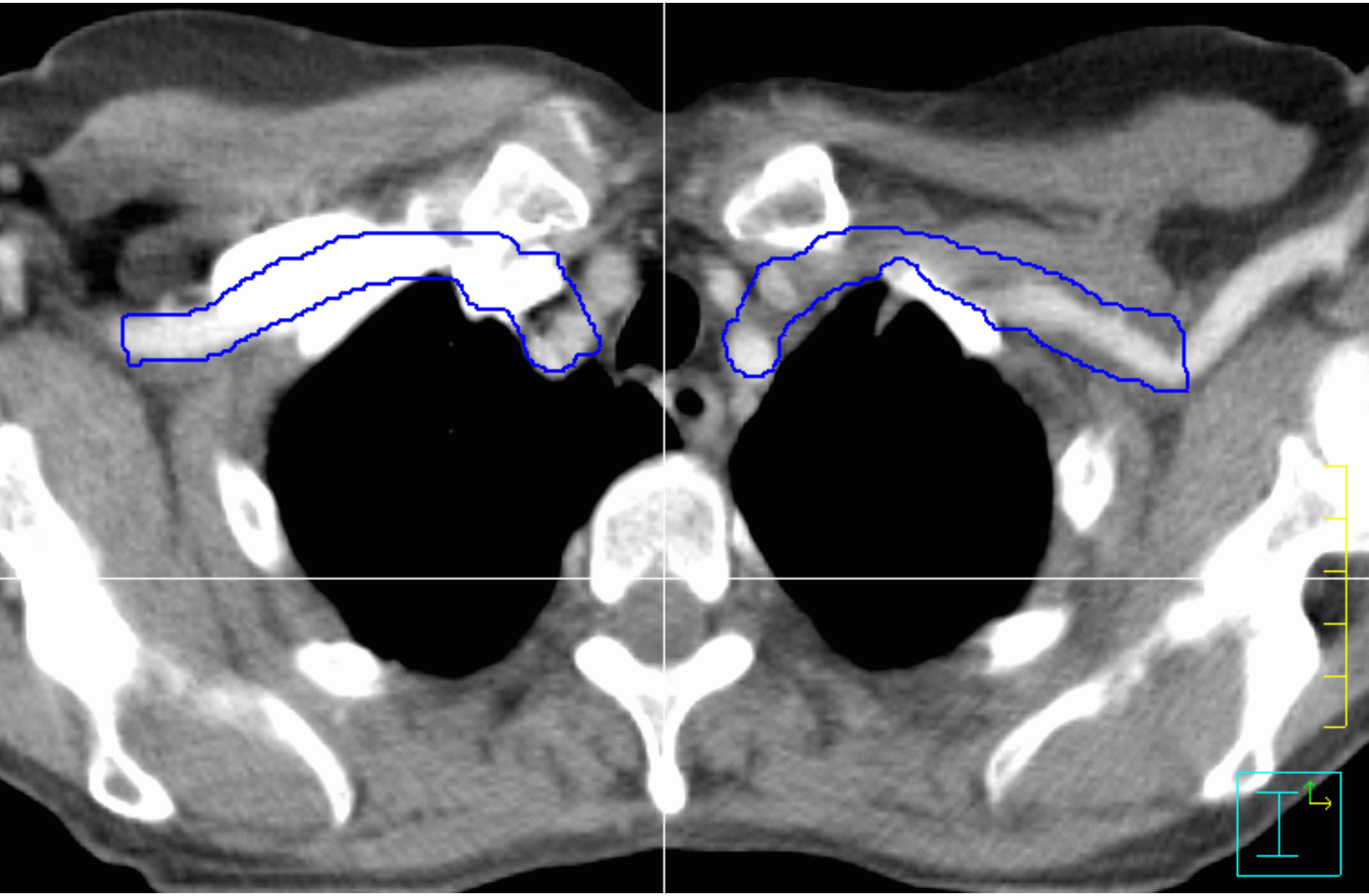


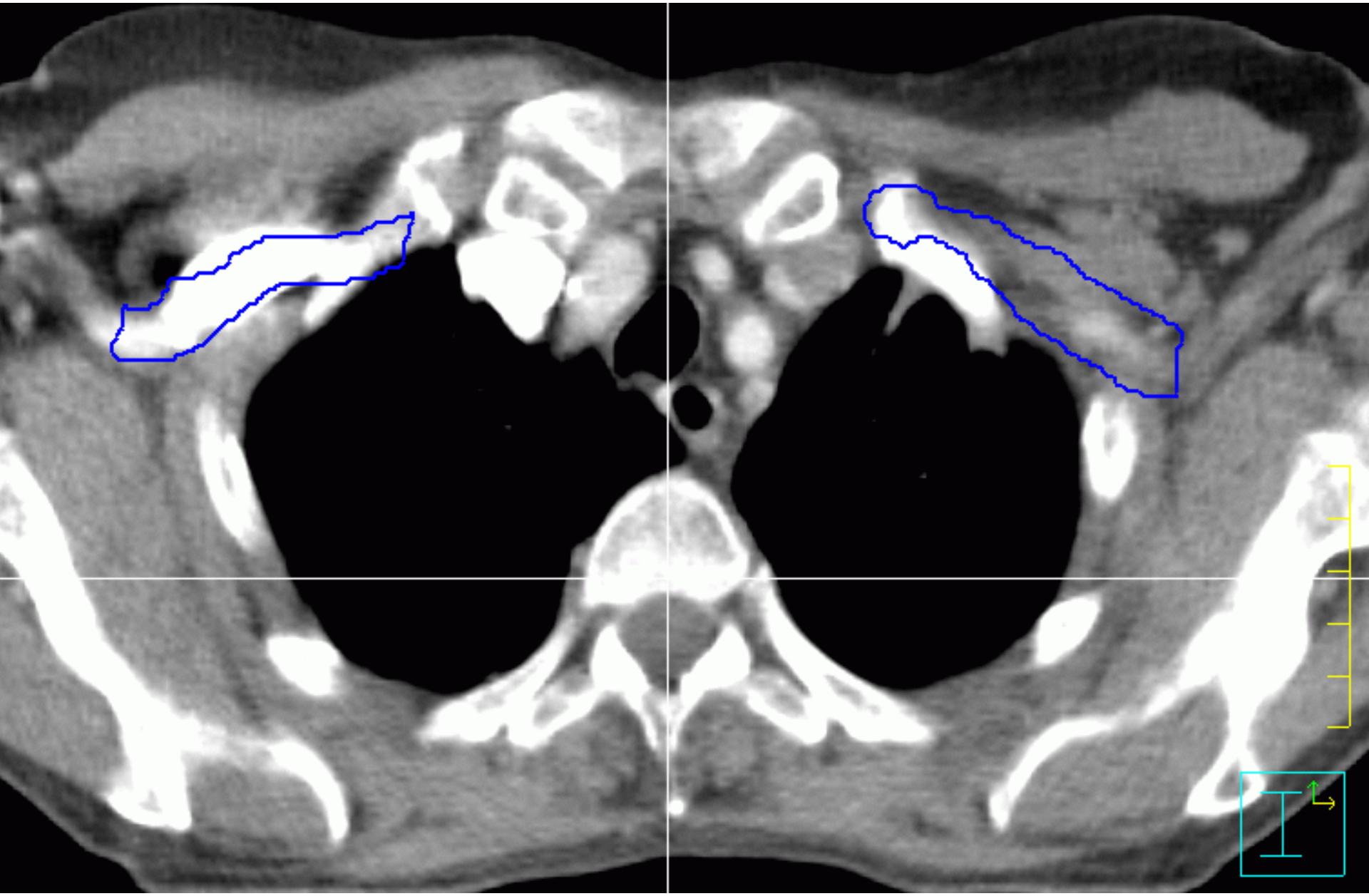


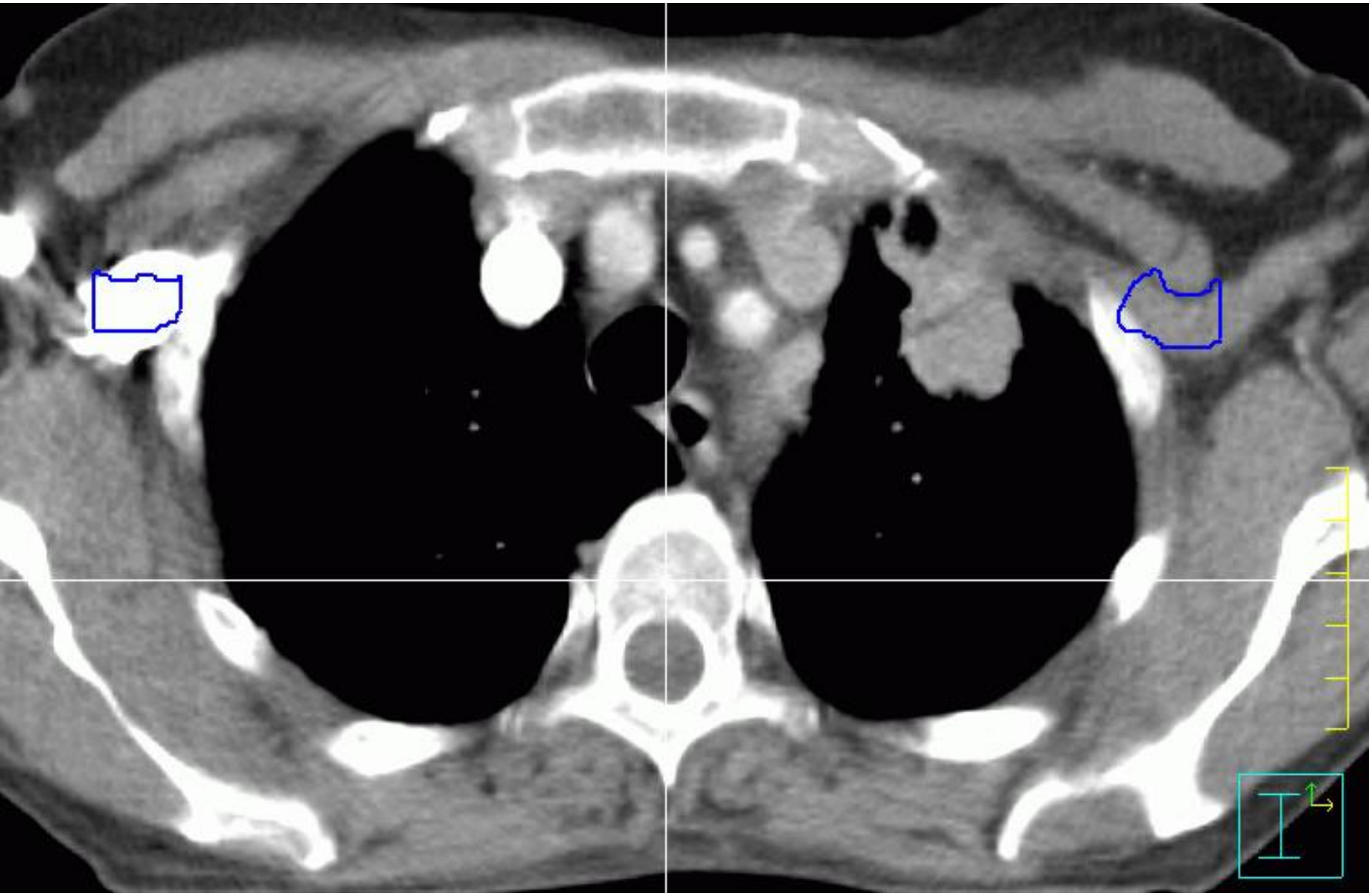






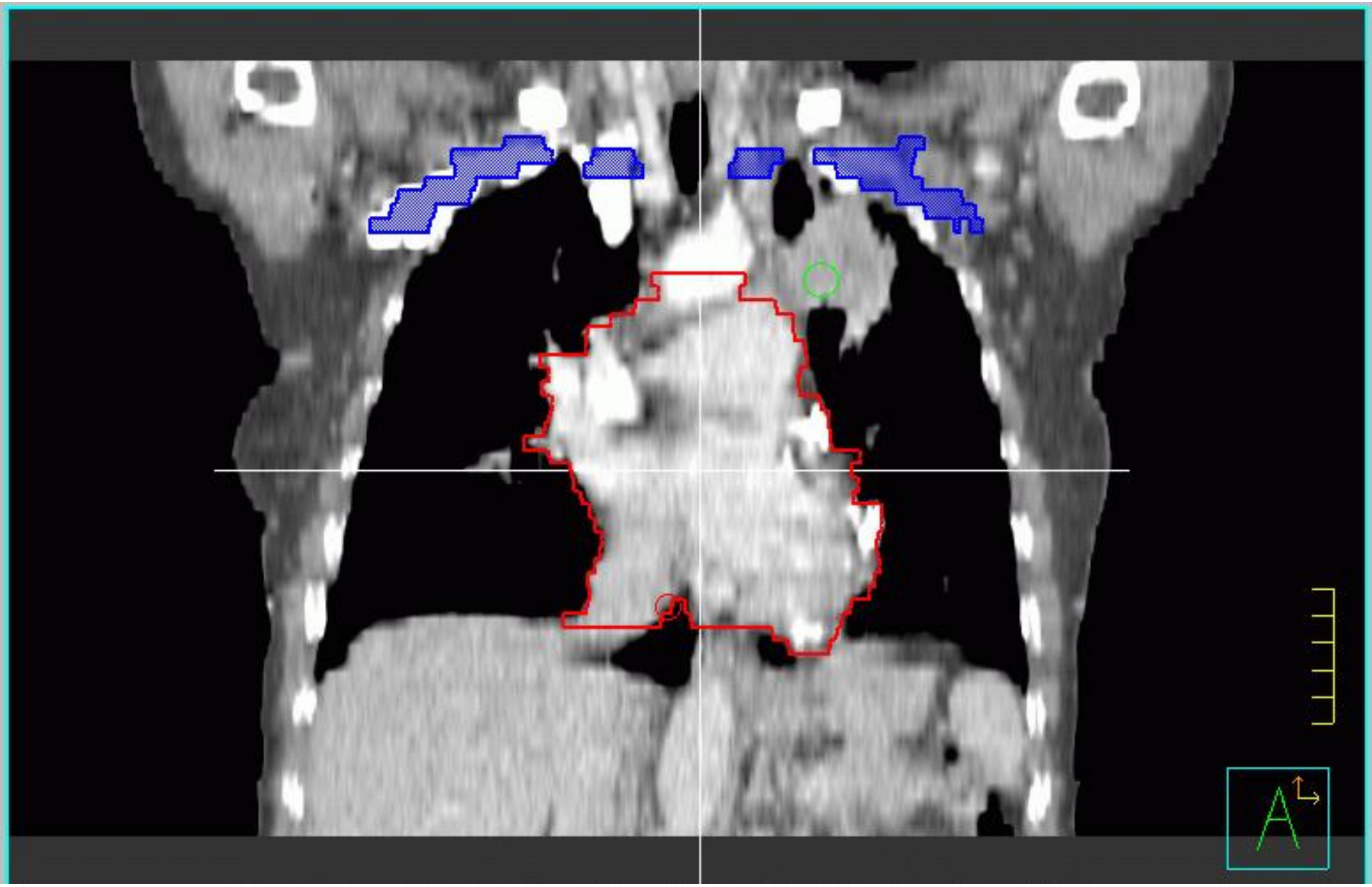


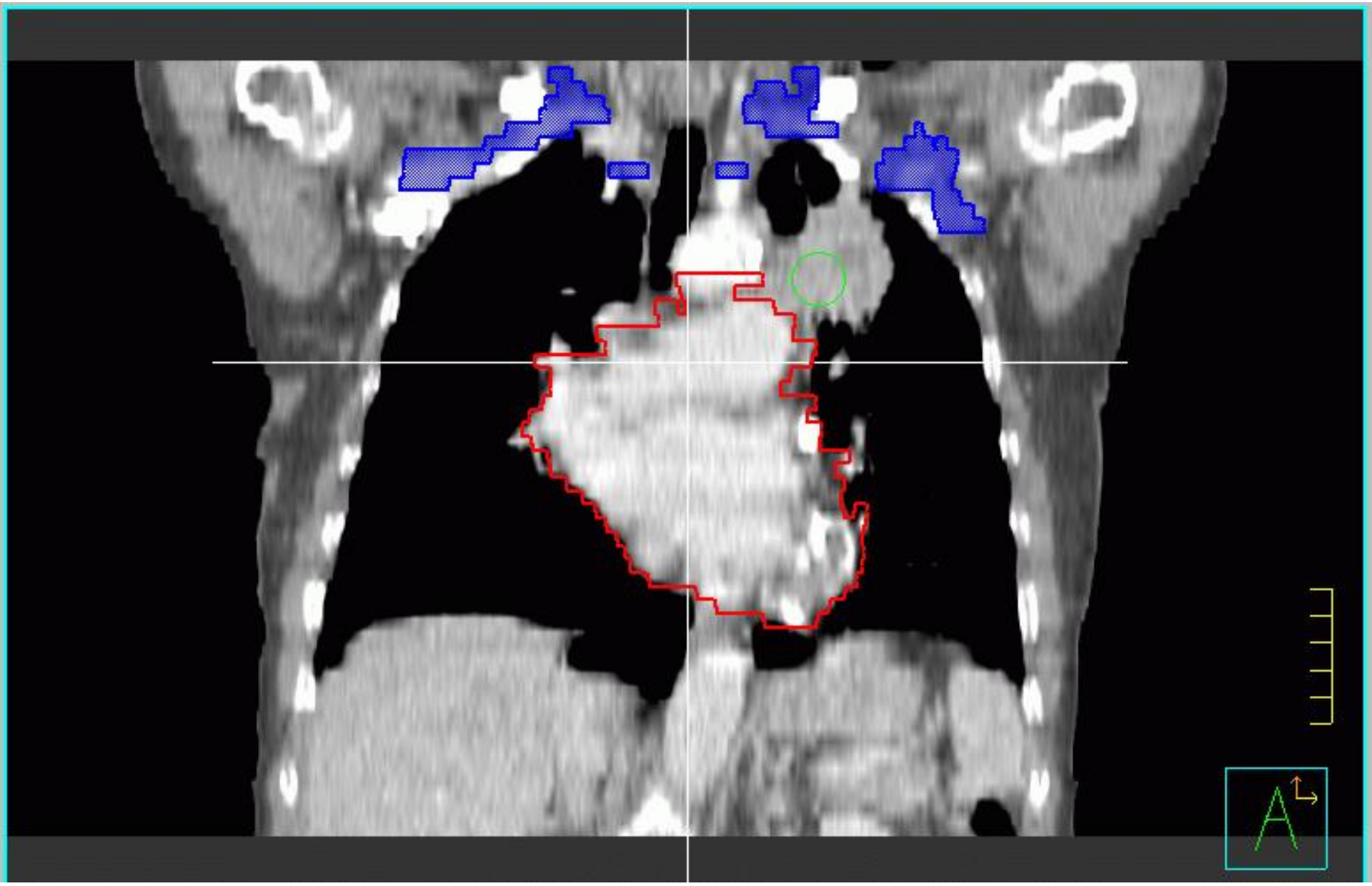


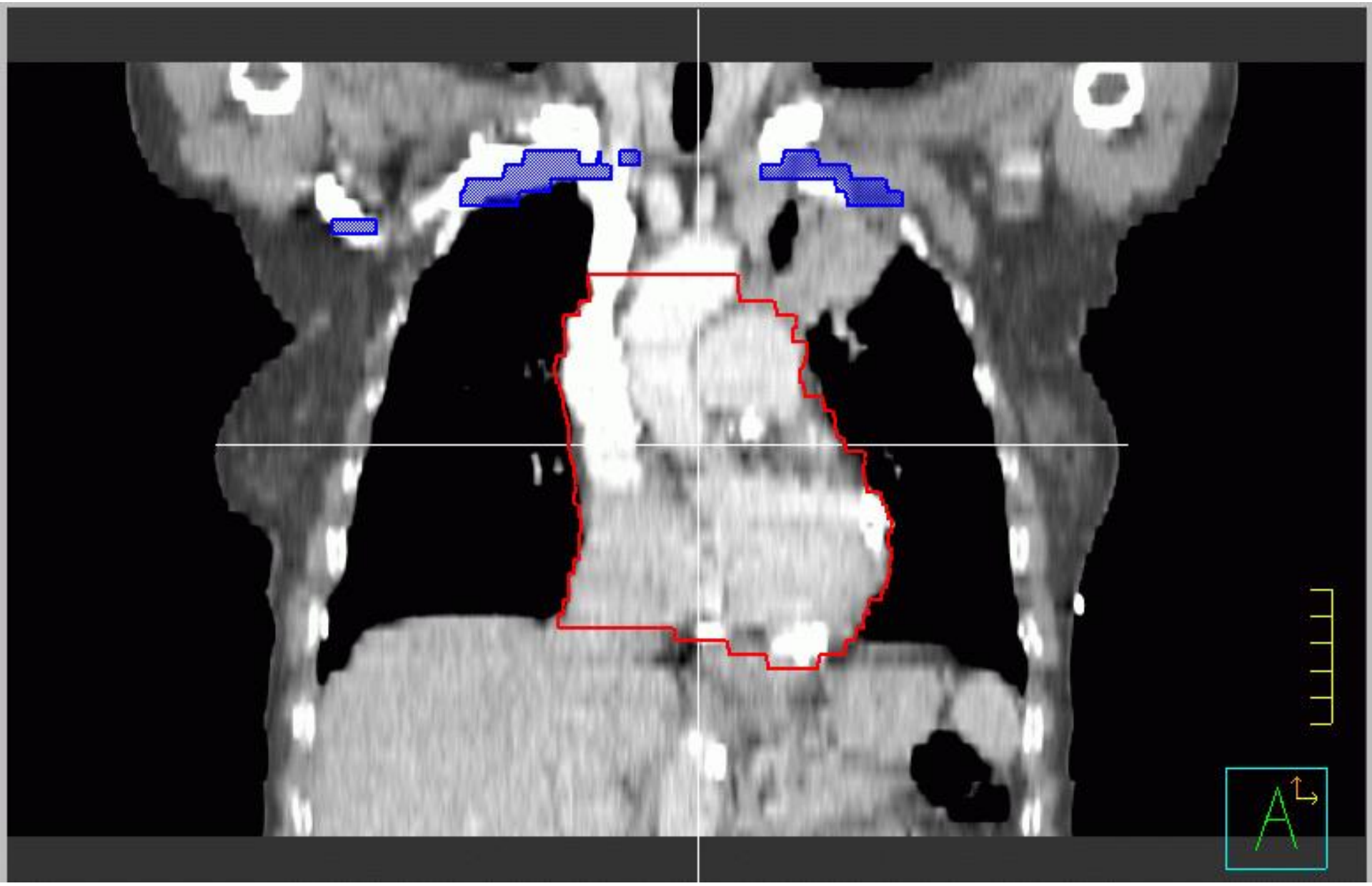


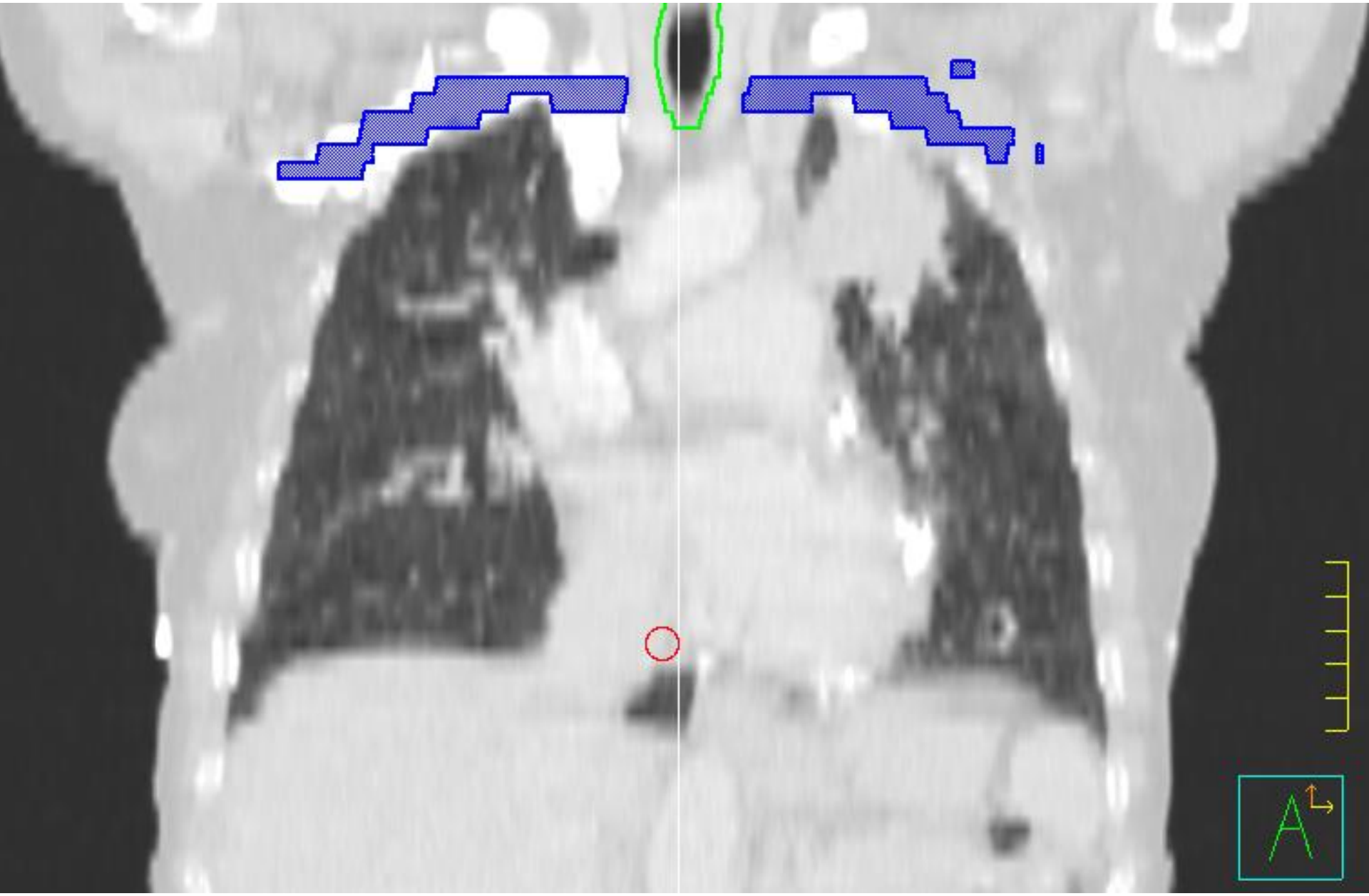
# Brachial Plexus

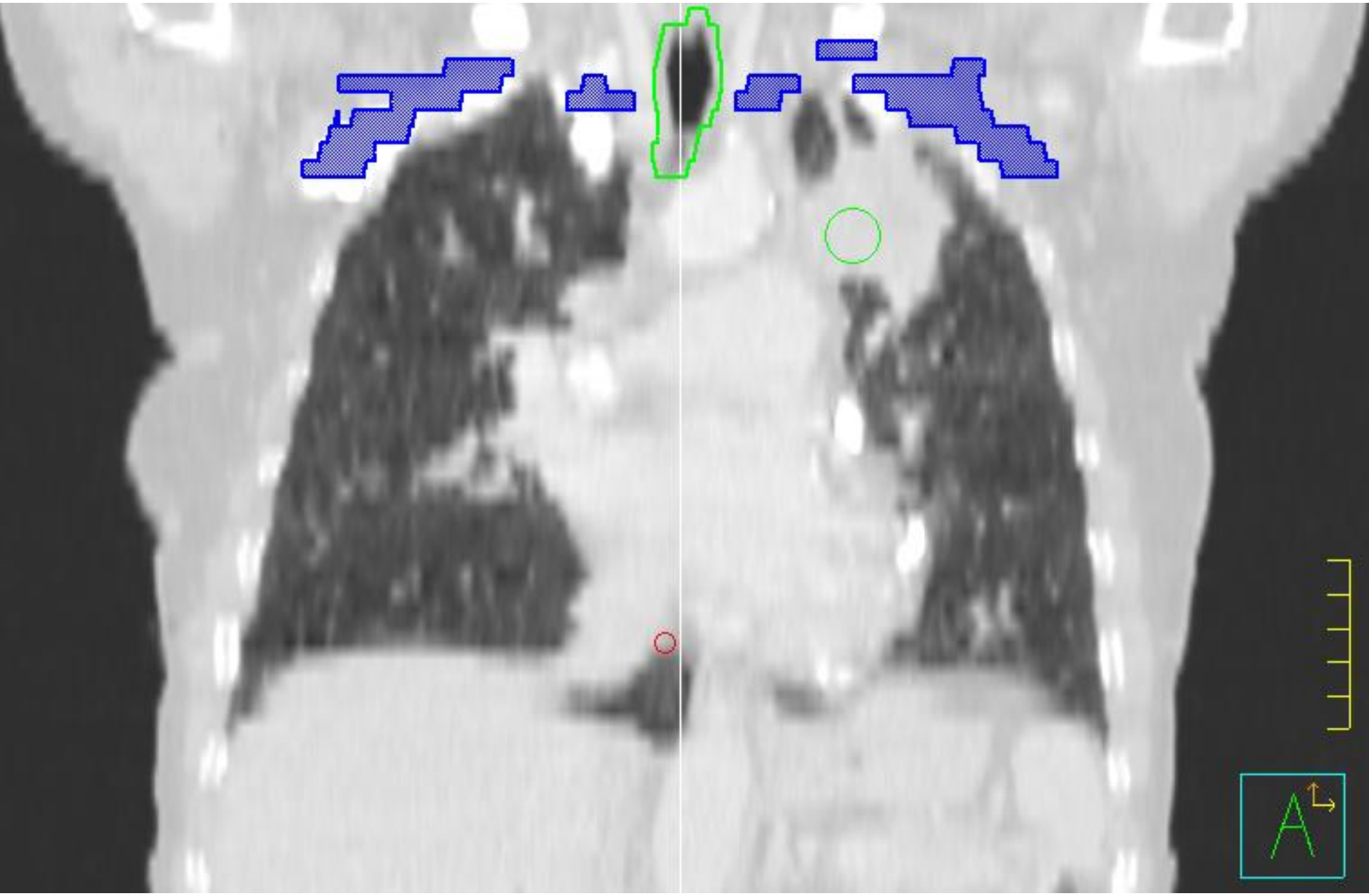
Some coronal images





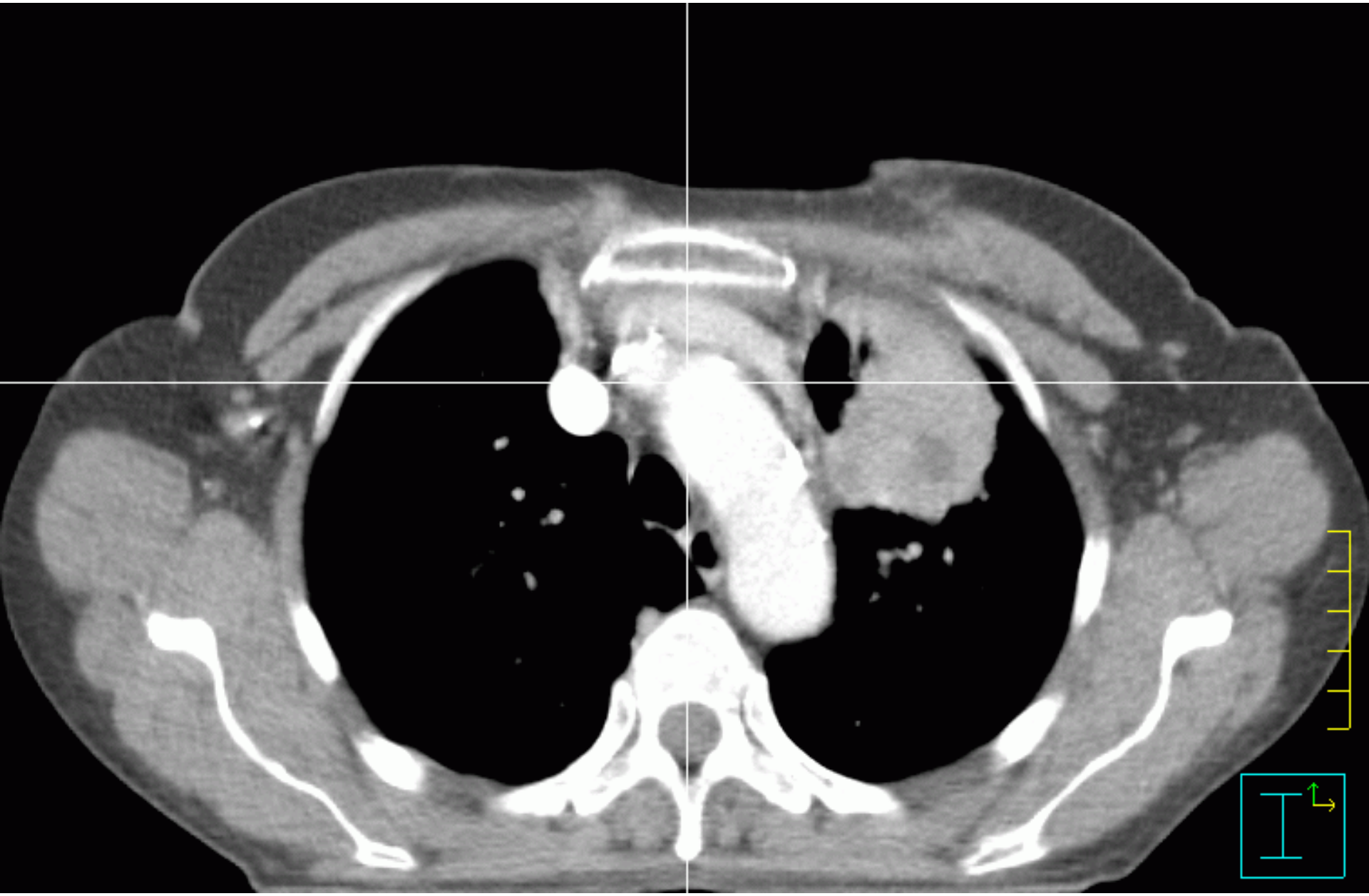


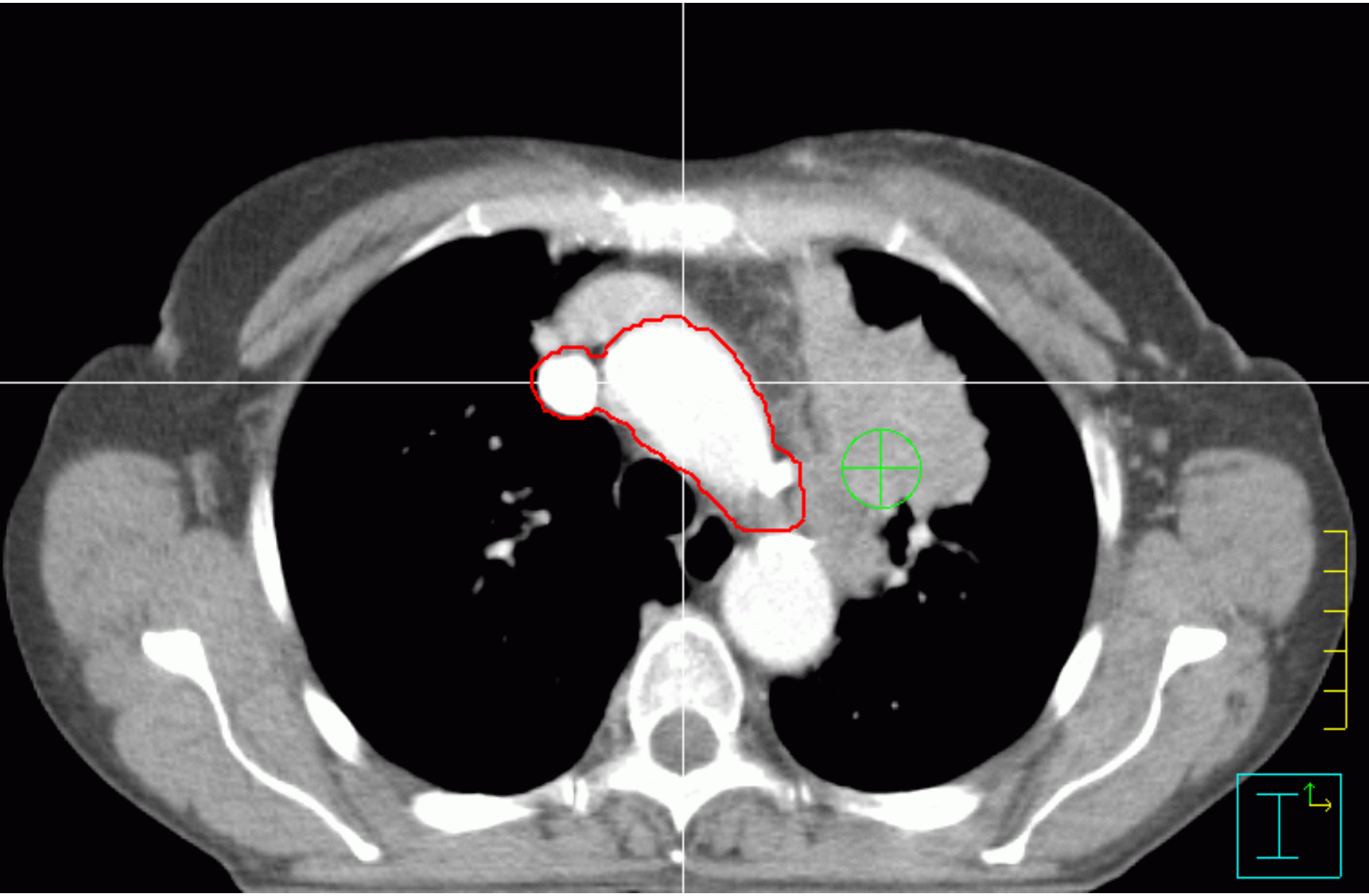


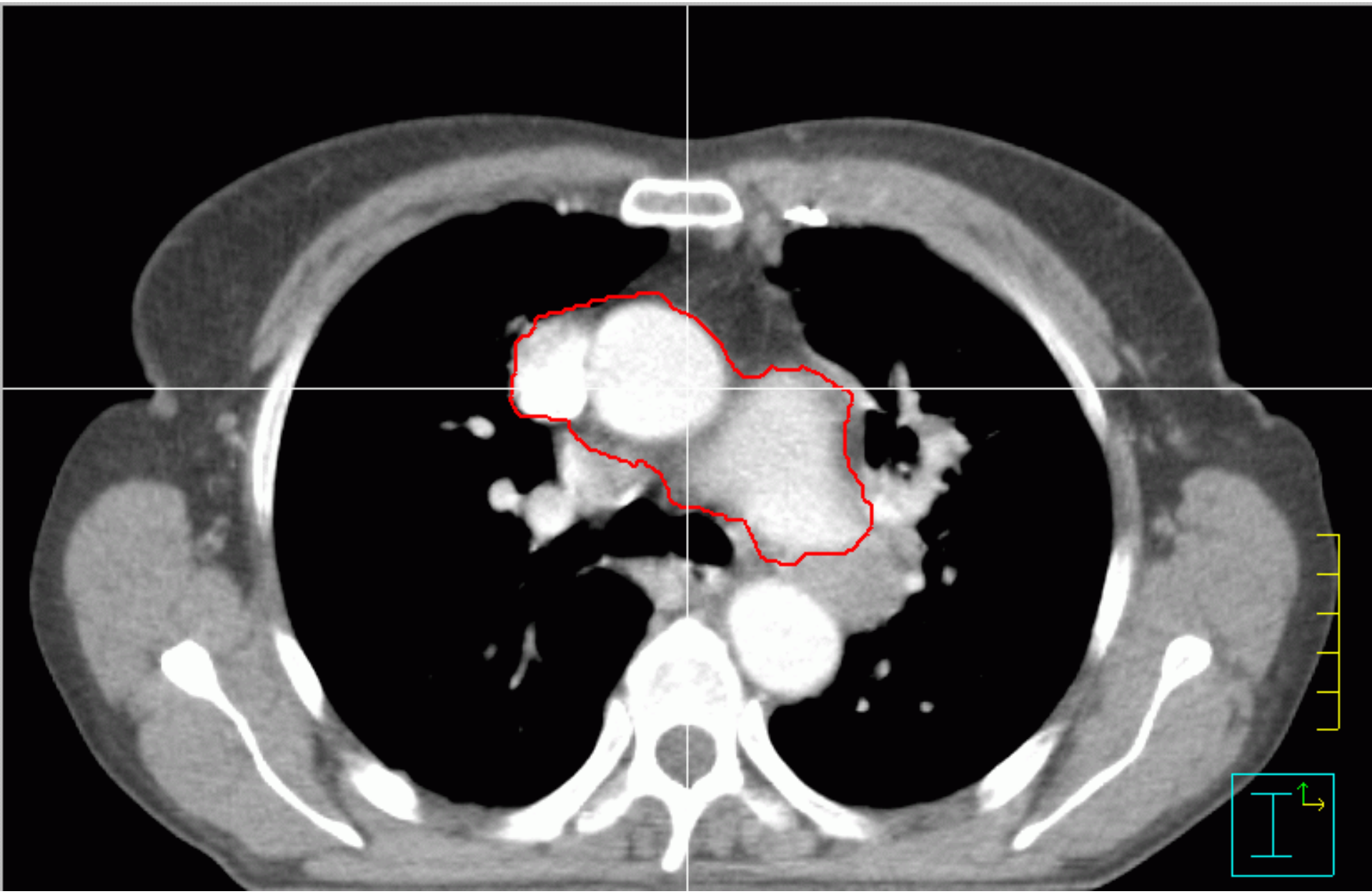


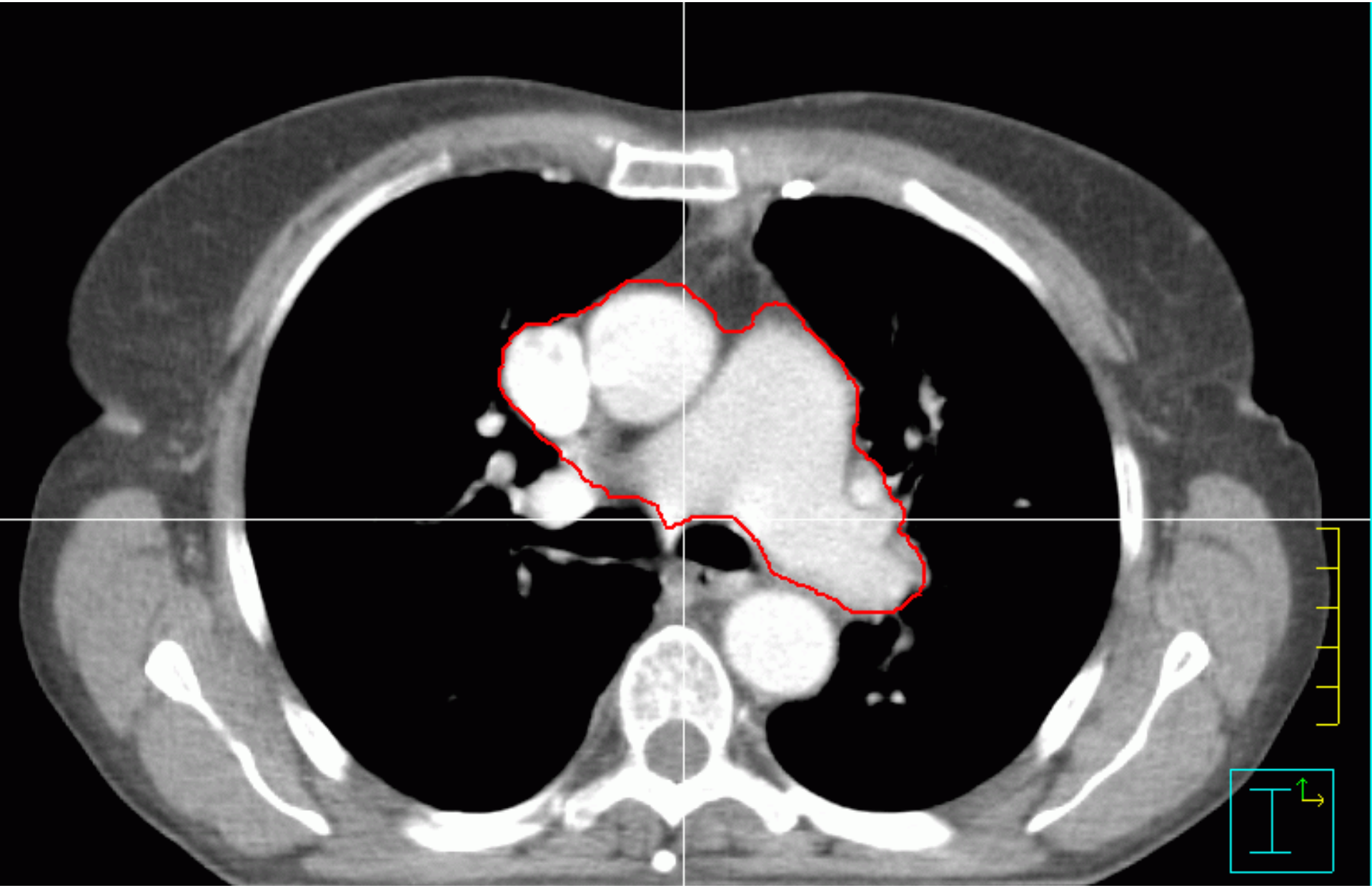
# Heart & Pericardium

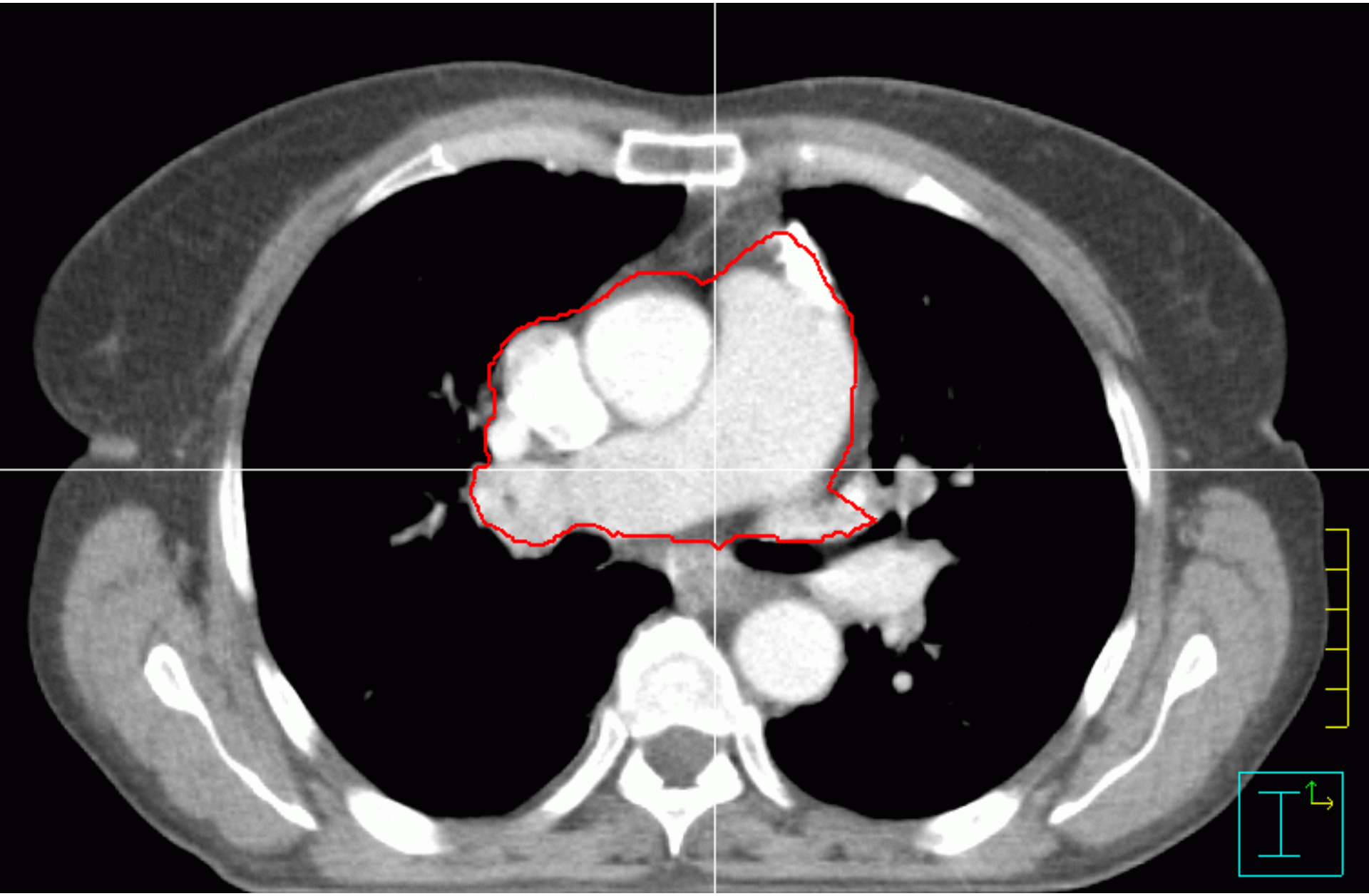
- Heart is to be contoured with the pericardial sac
- Superior limit of the contouring is the inferior extent of the aortic arch
- Inferior extent is the lowest part of the left ventricle's inferior wall, that is distinguishable from the liver
- Includes the heart, main pulmonary vessels, ascending aorta, SVC.

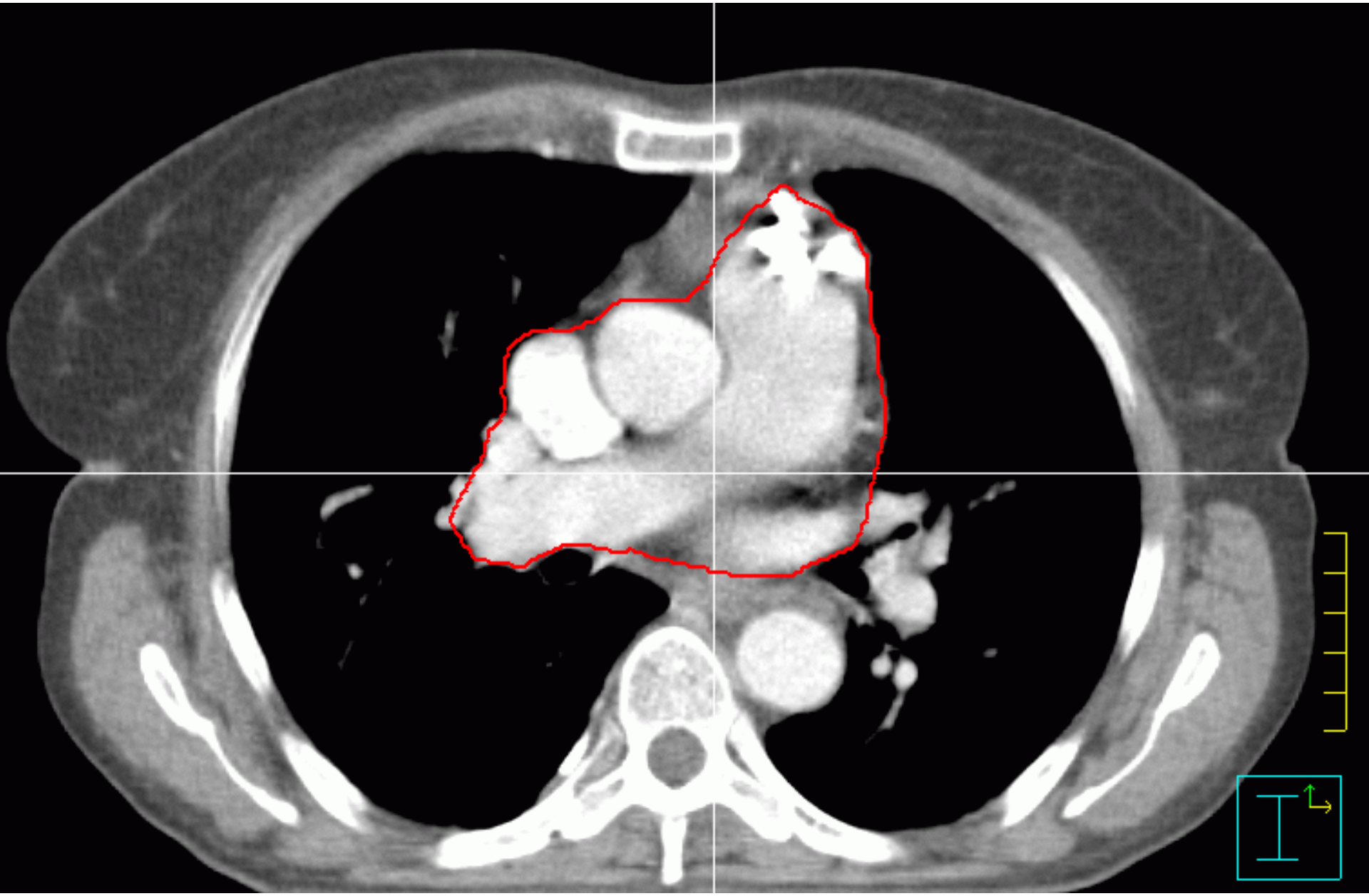


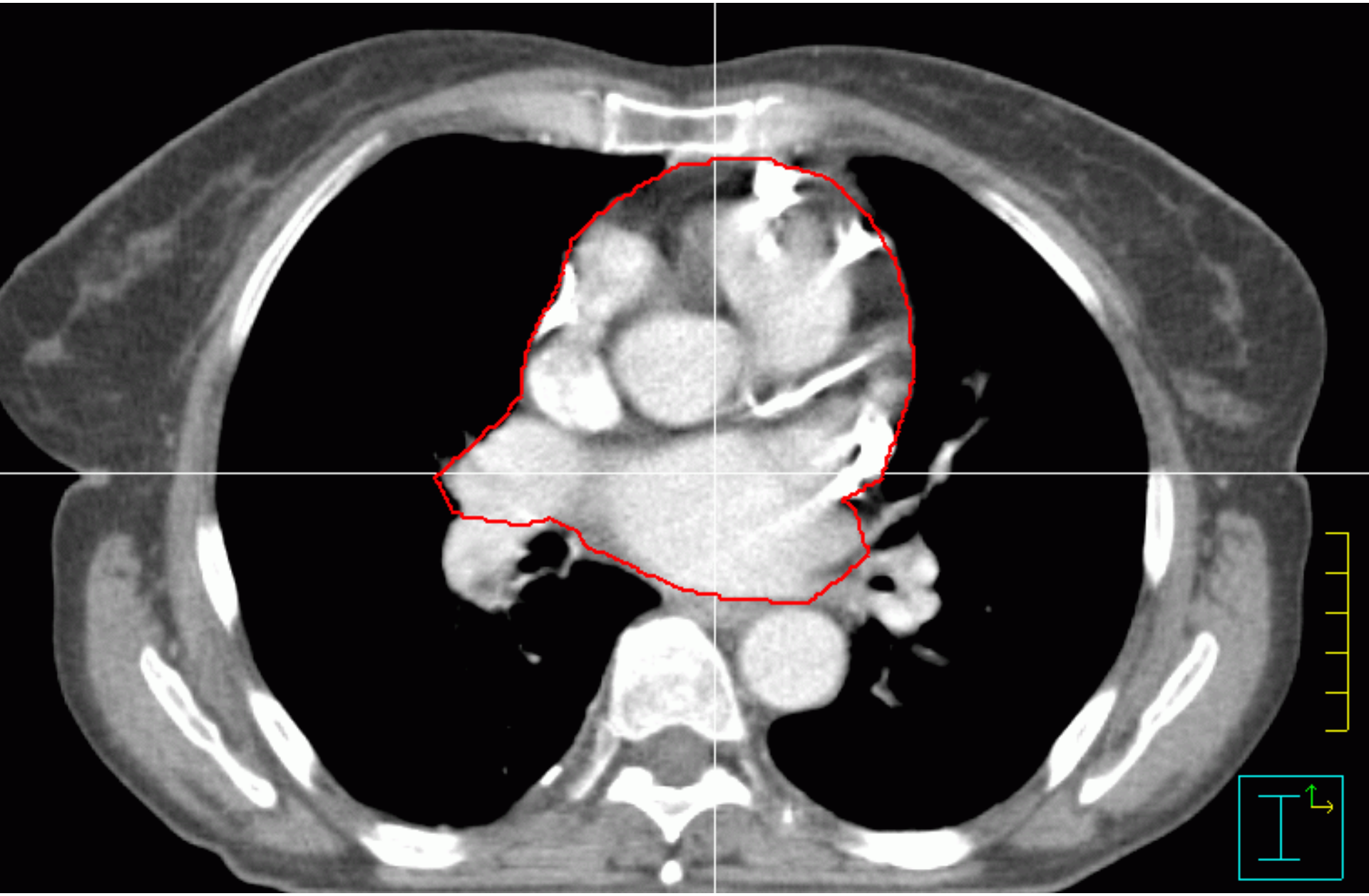


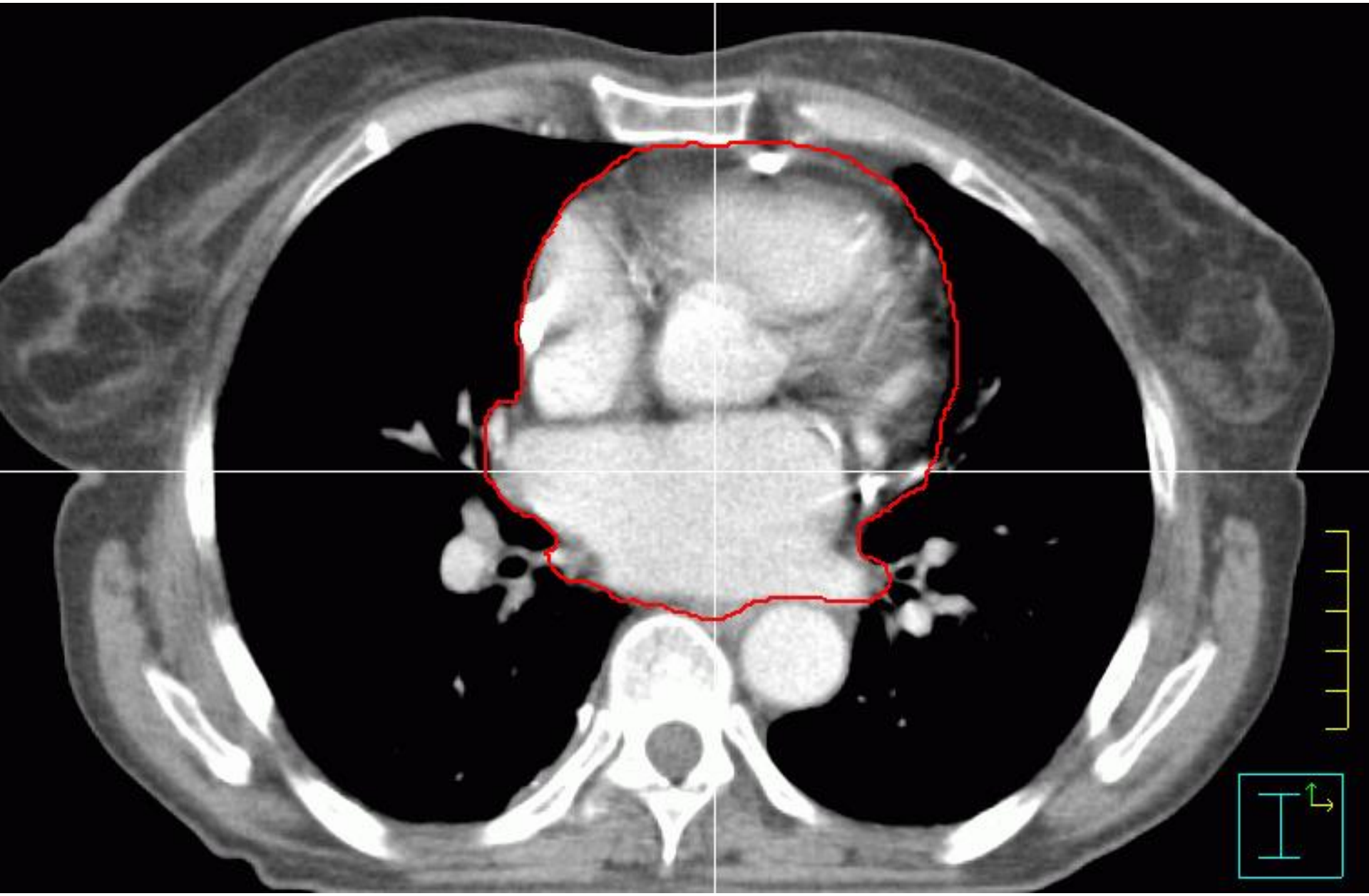


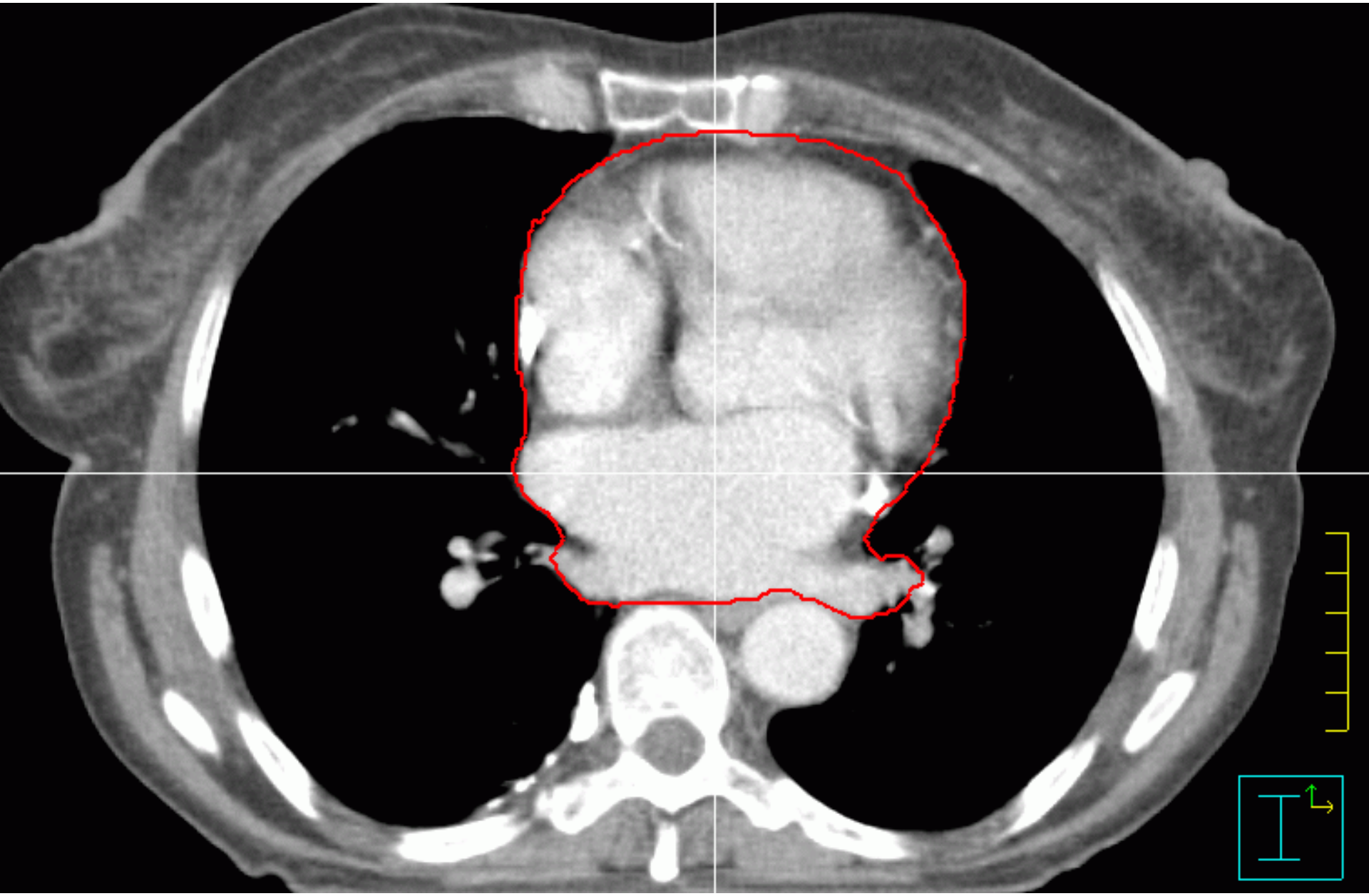


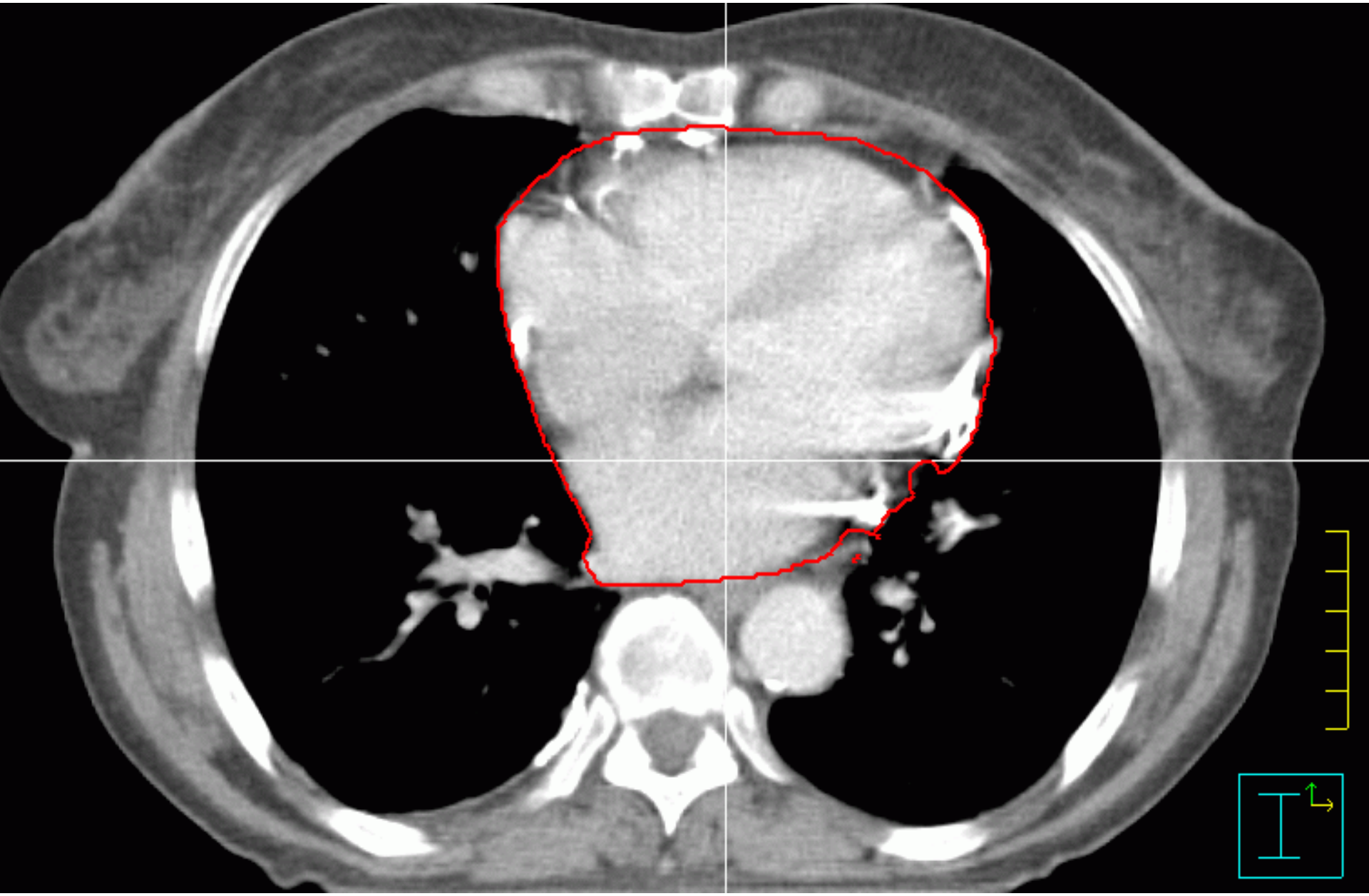


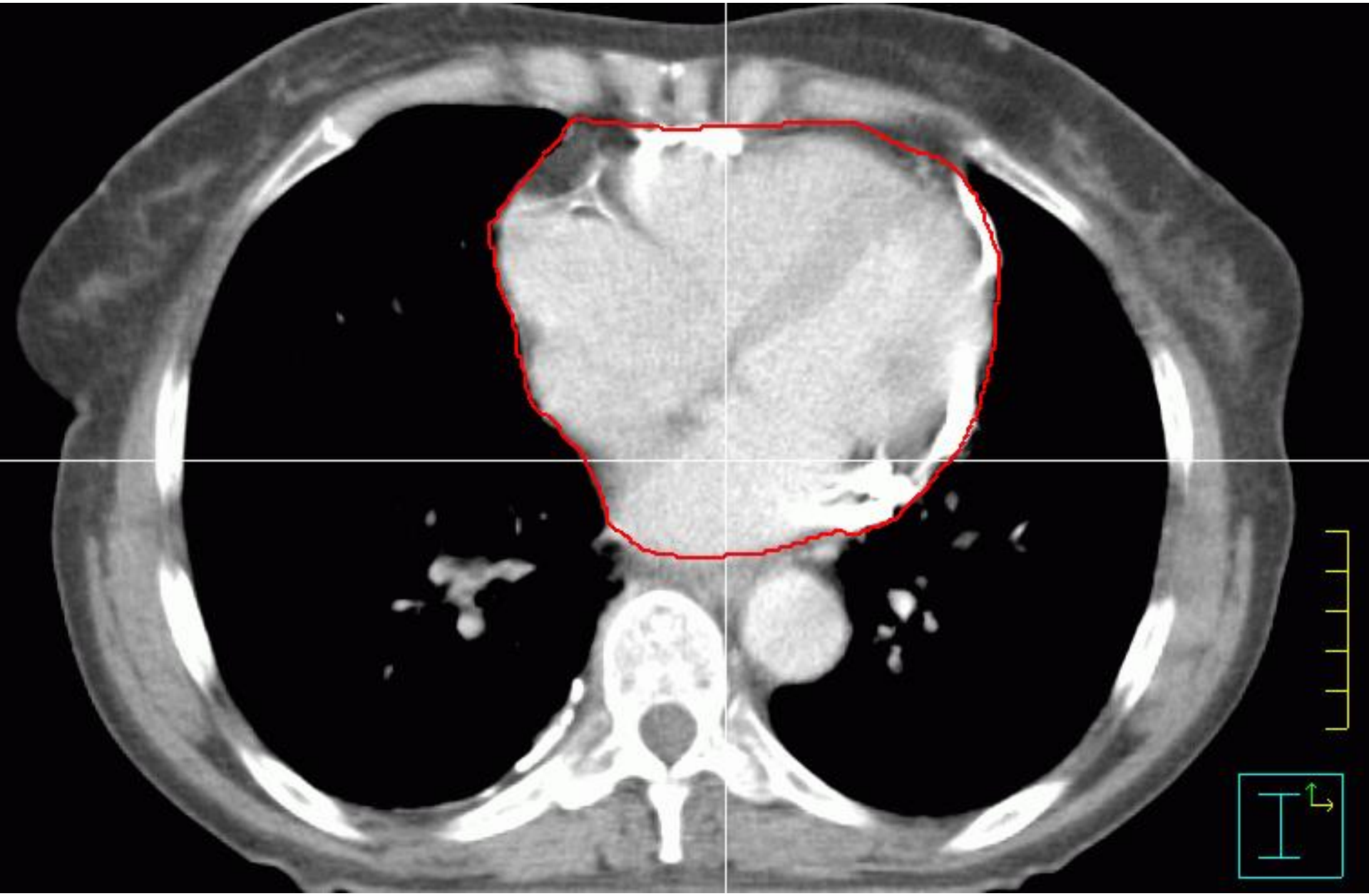


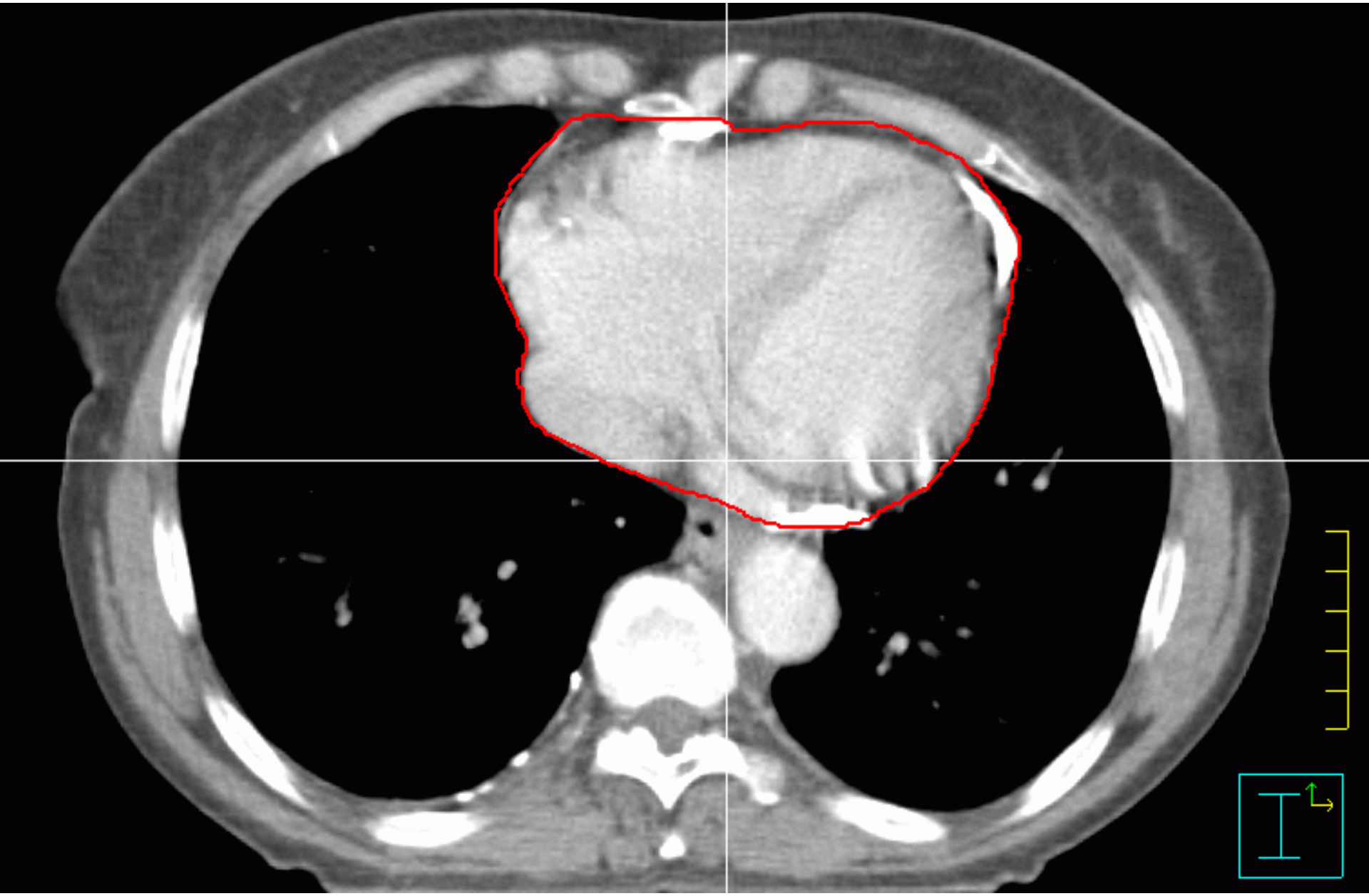


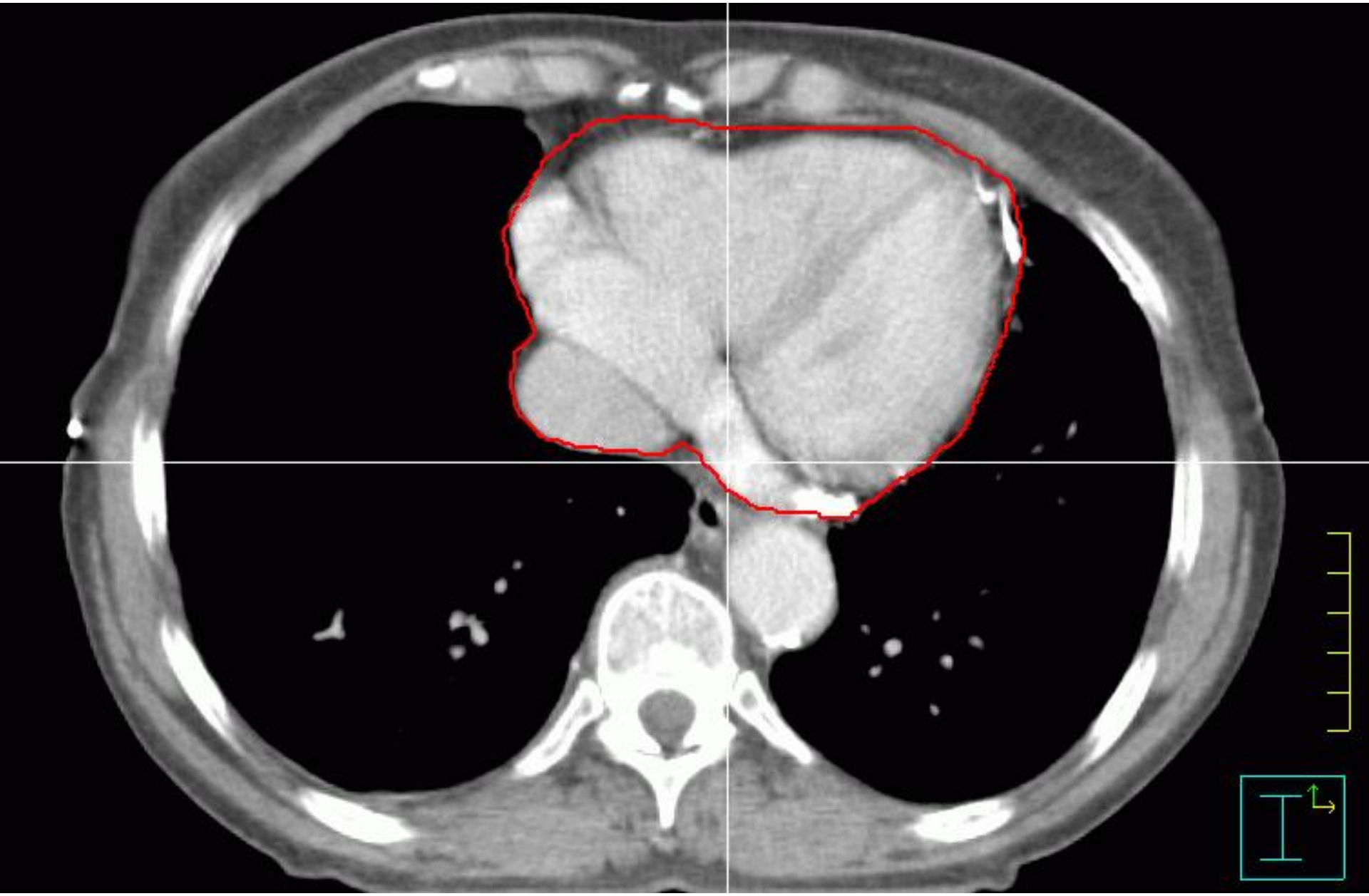


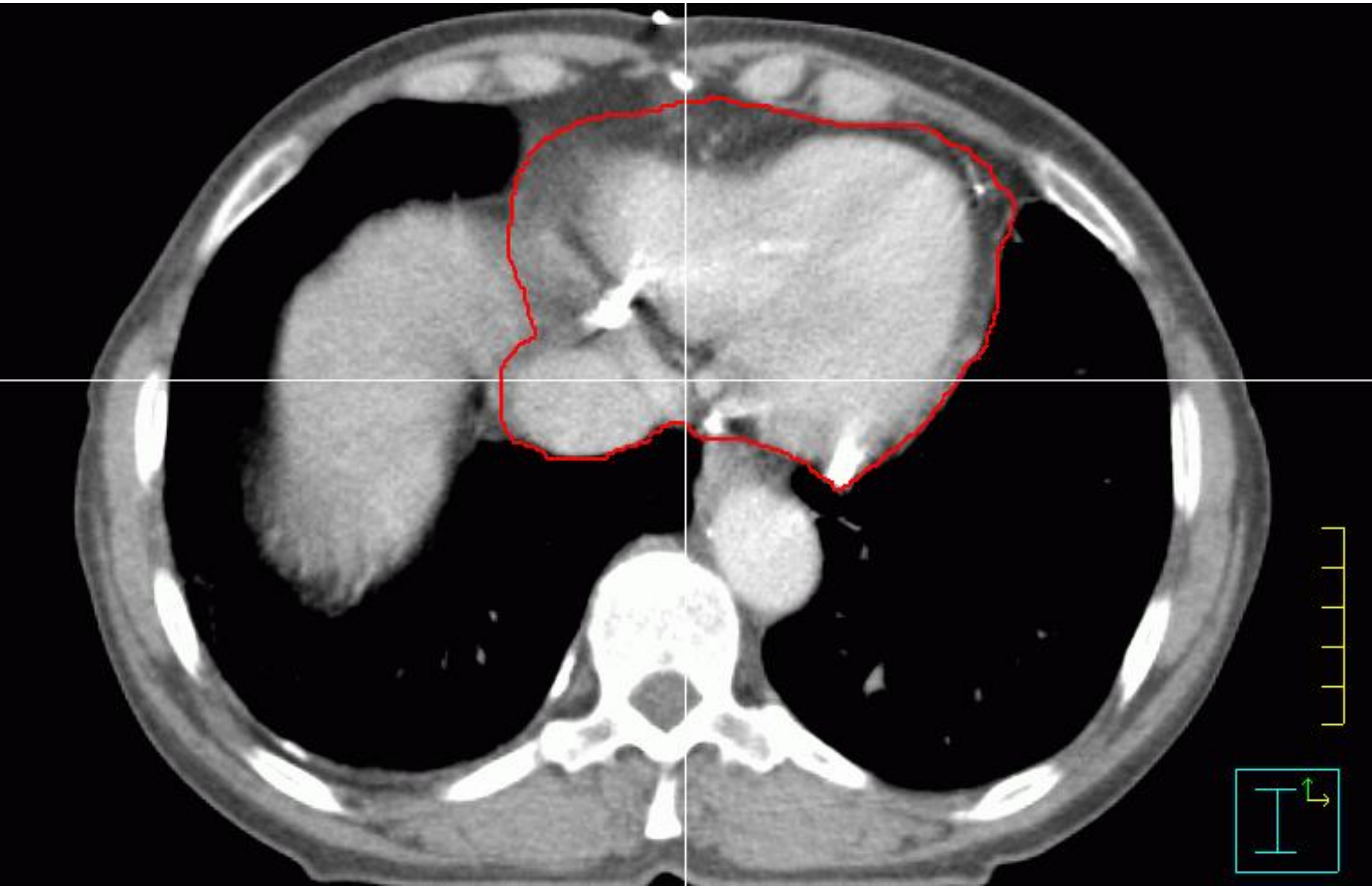


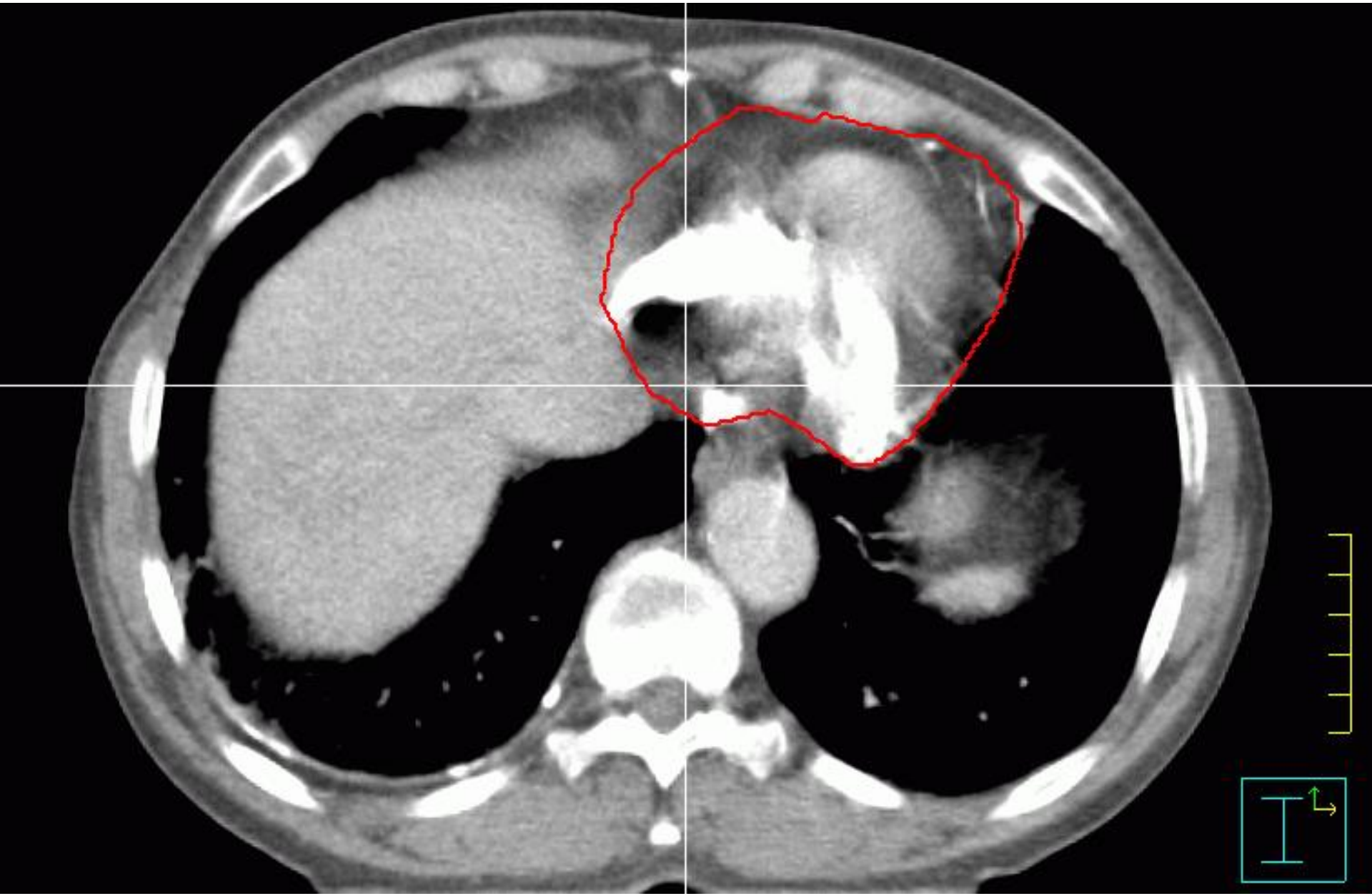


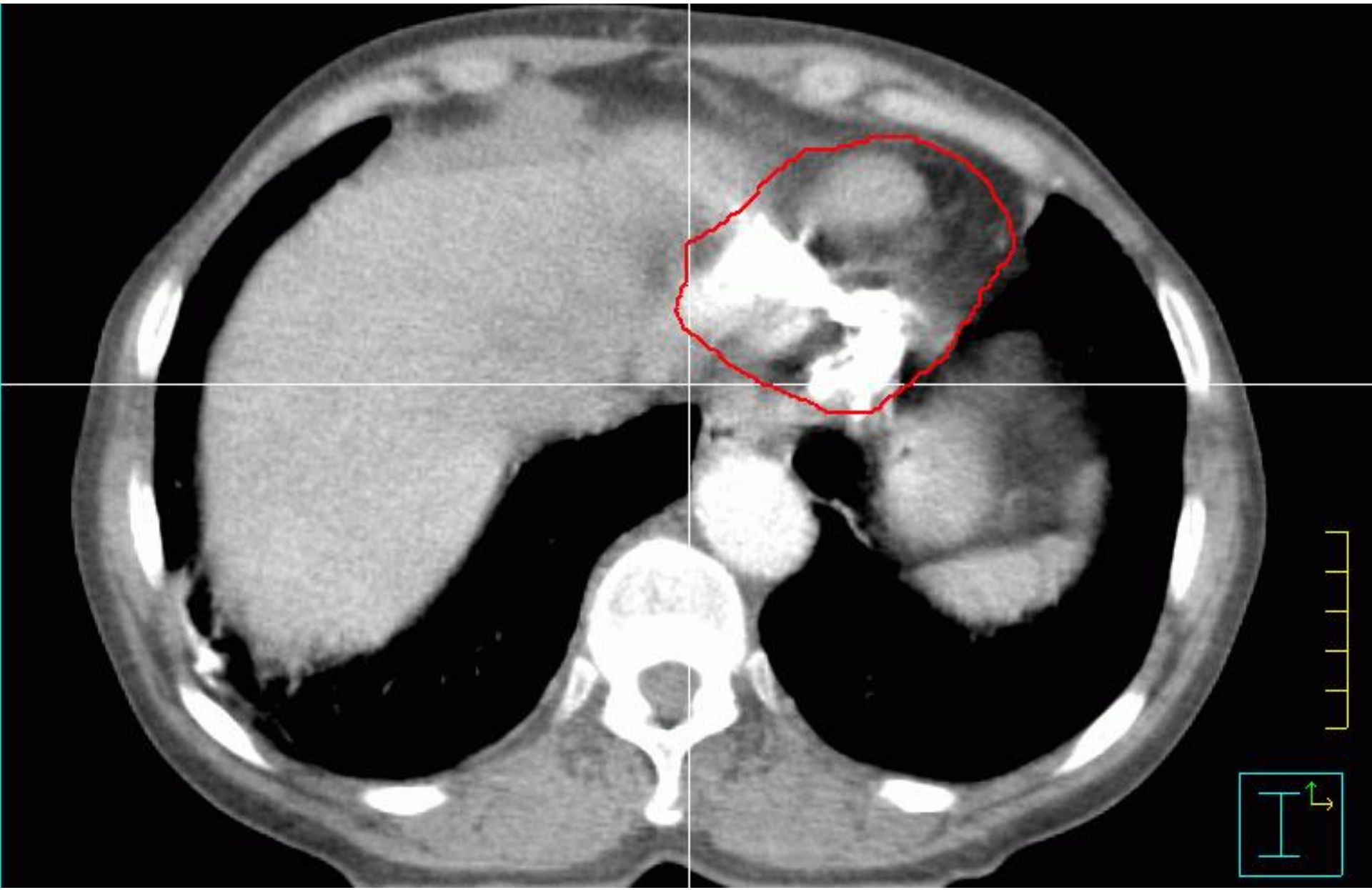


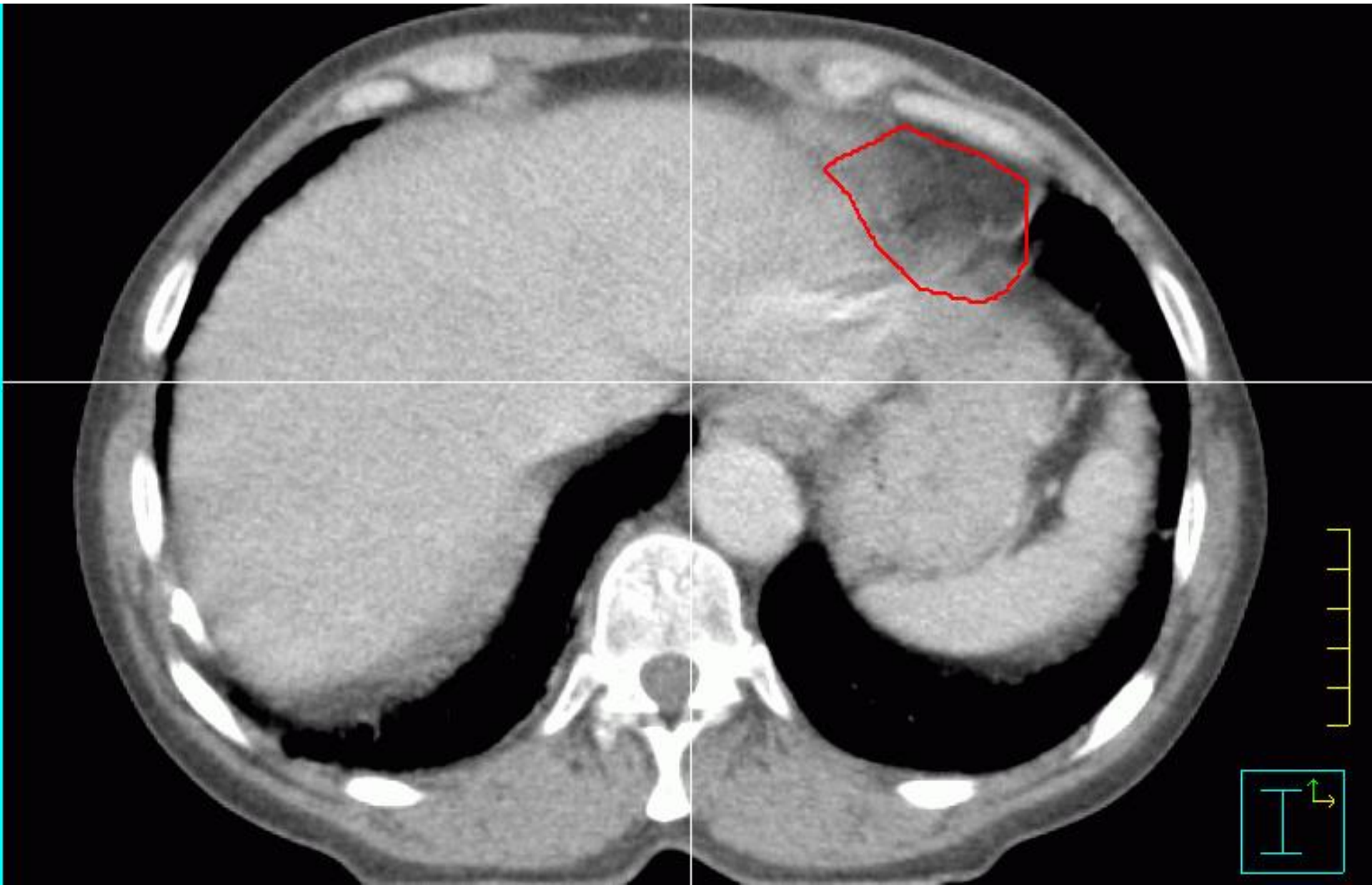






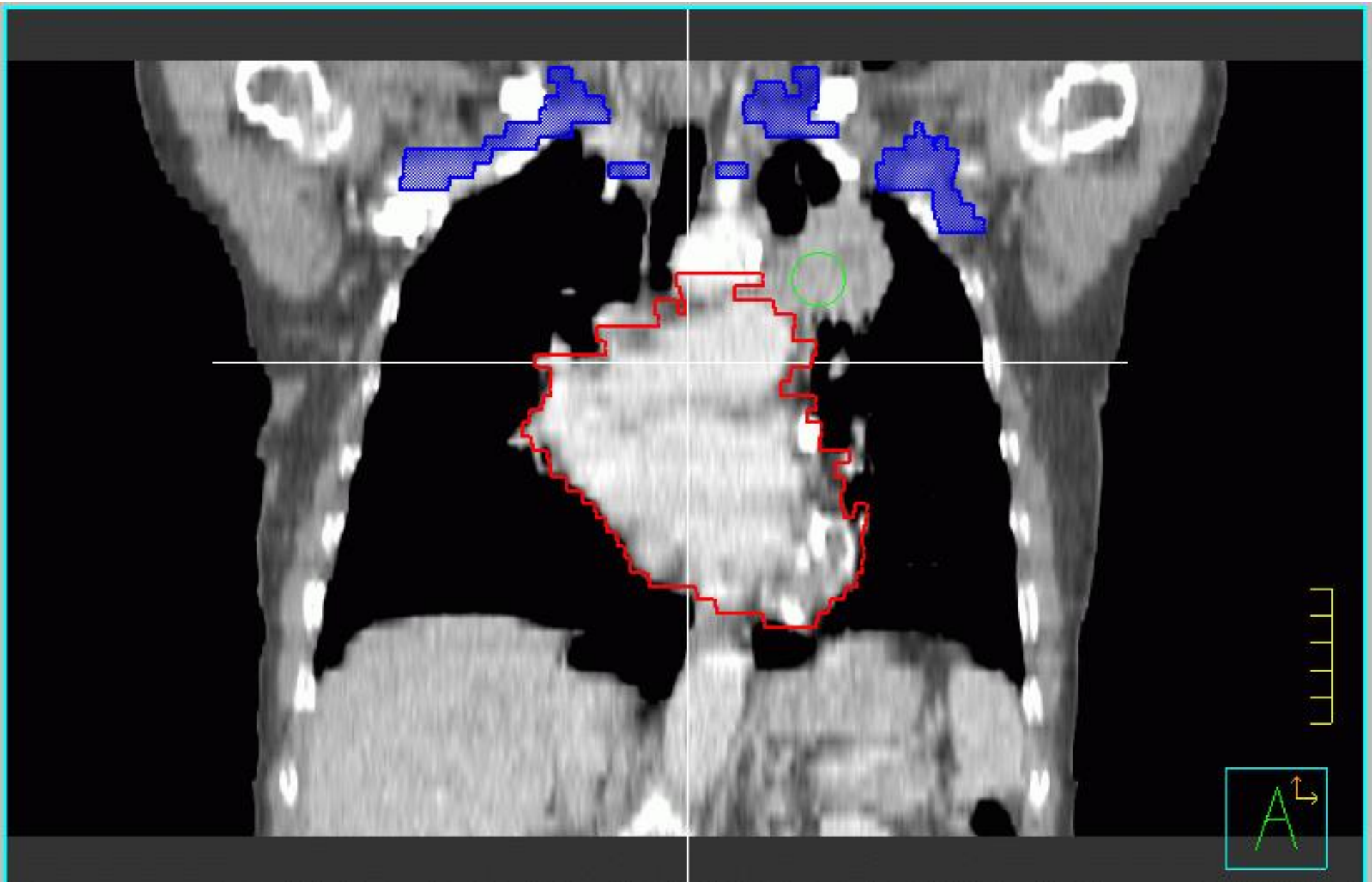


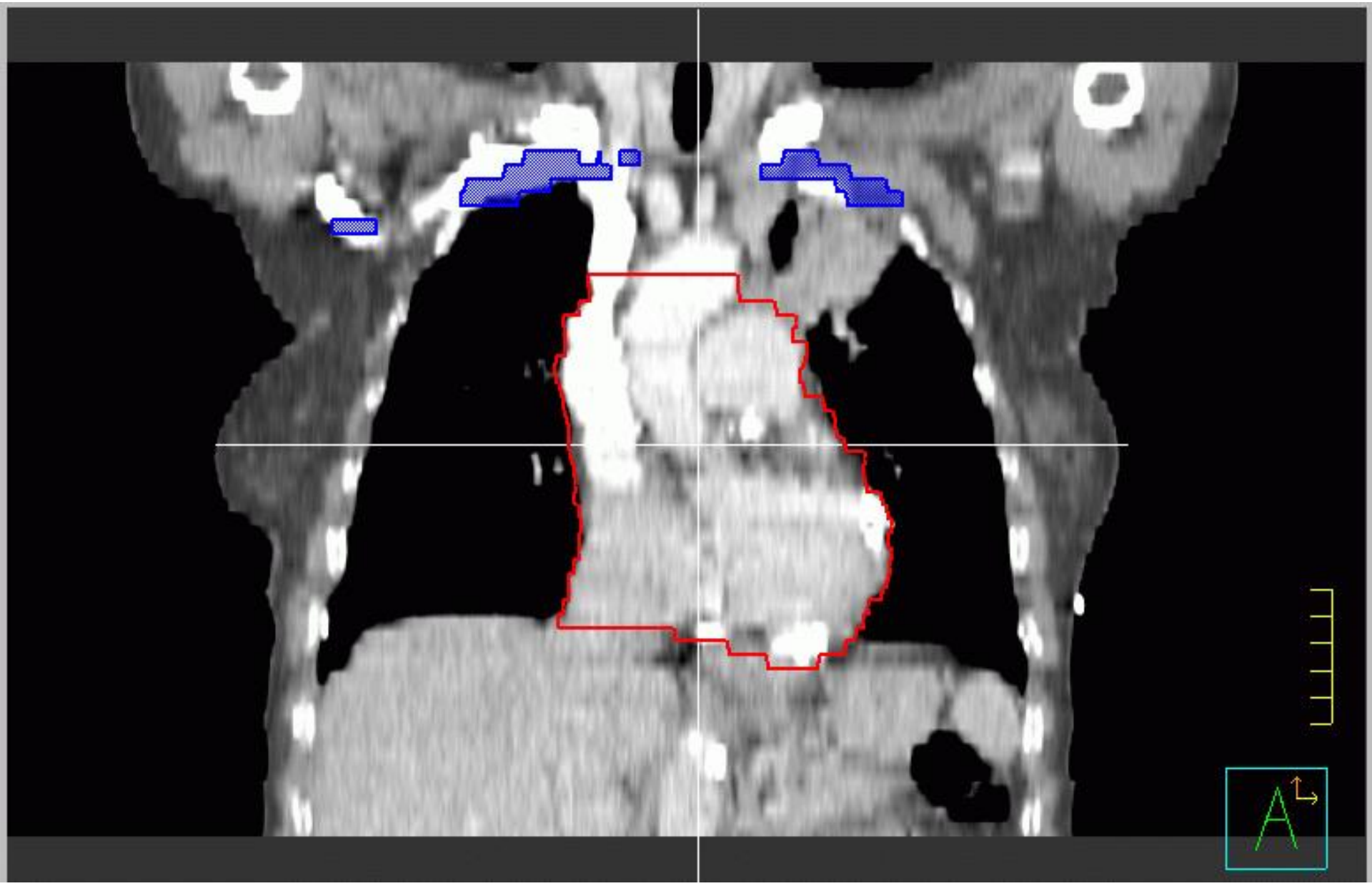


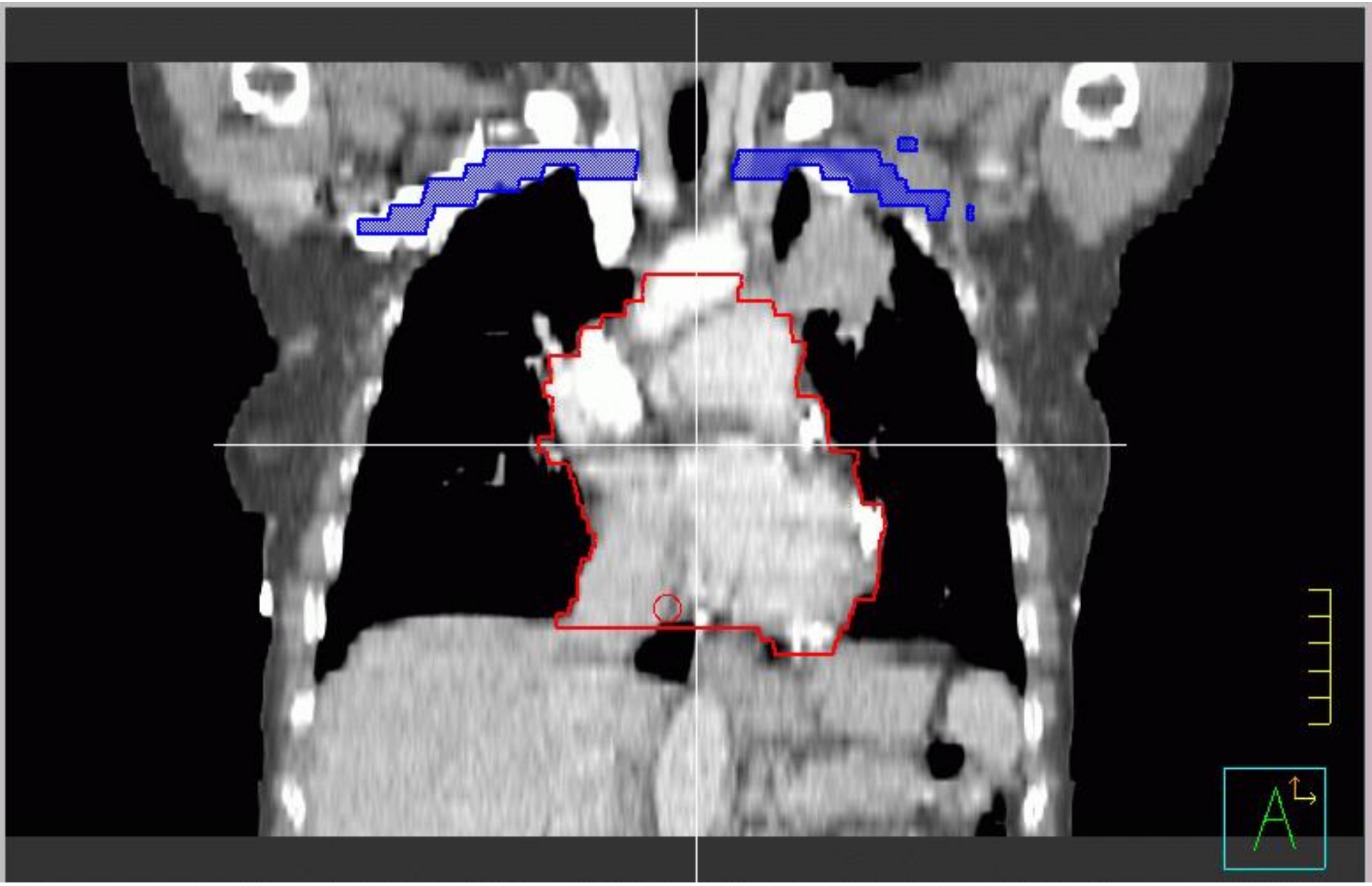


# Heart & Pericardium

Some coronal images





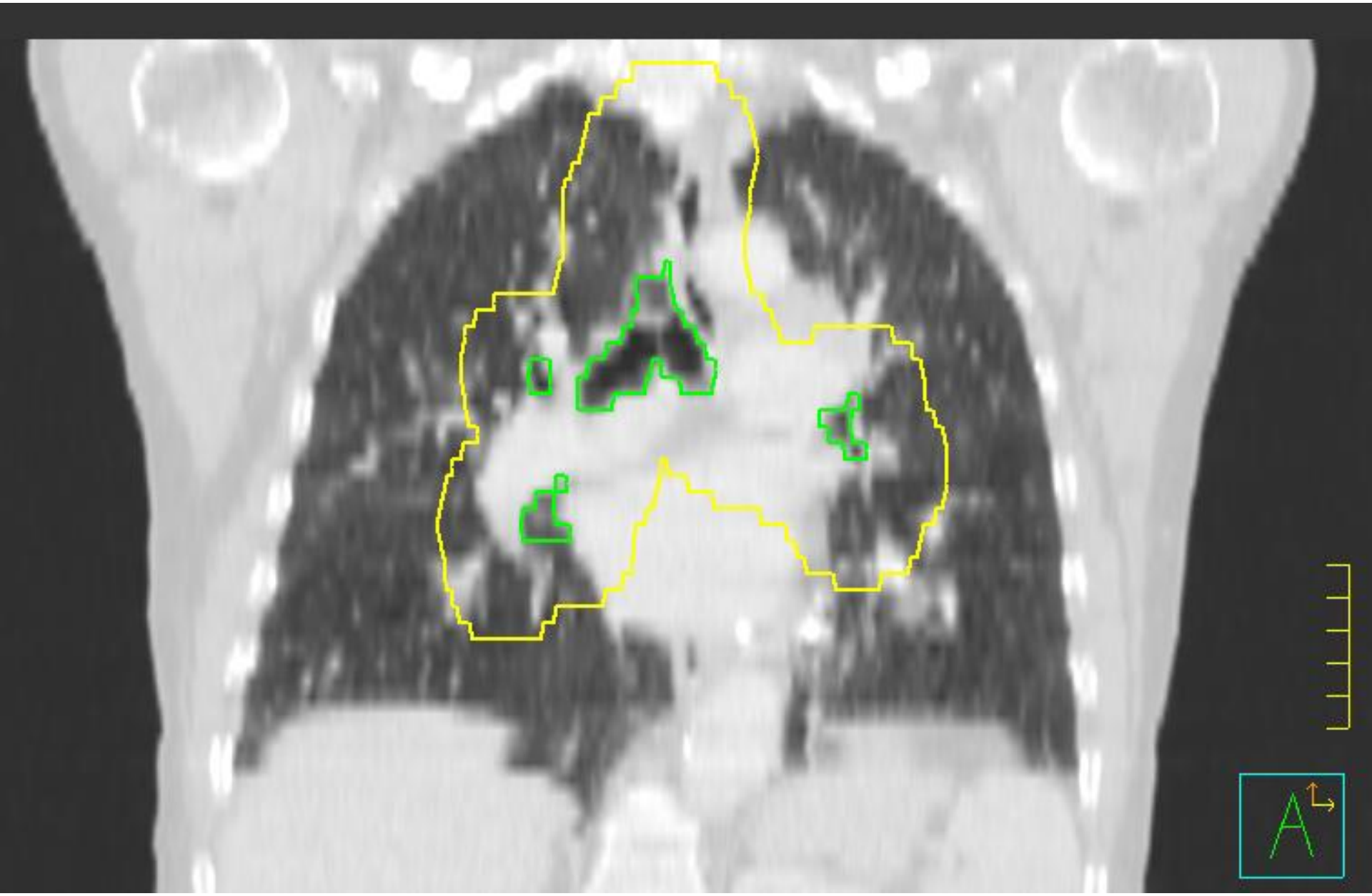


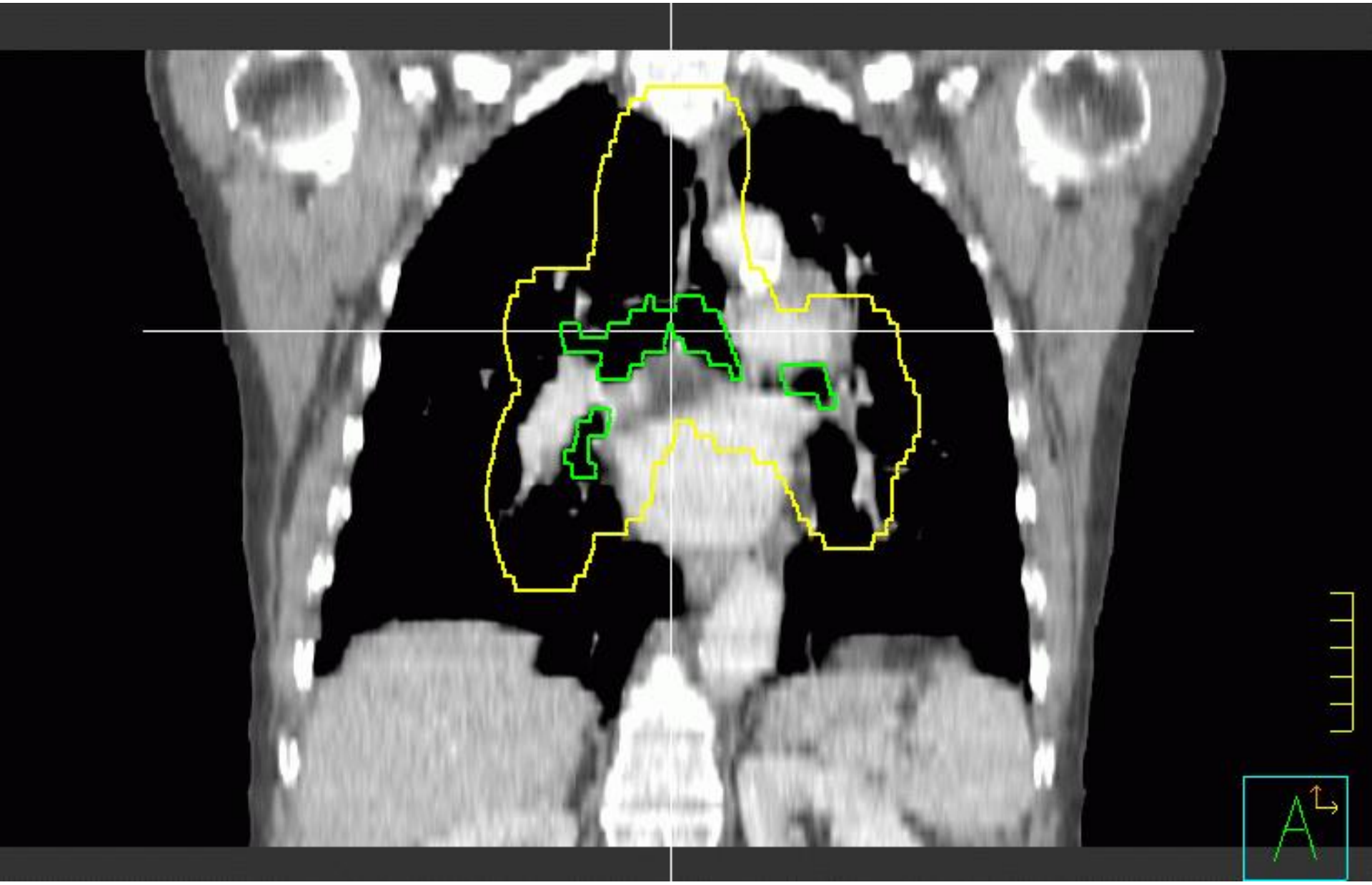
# Proximal Bronchial Tree

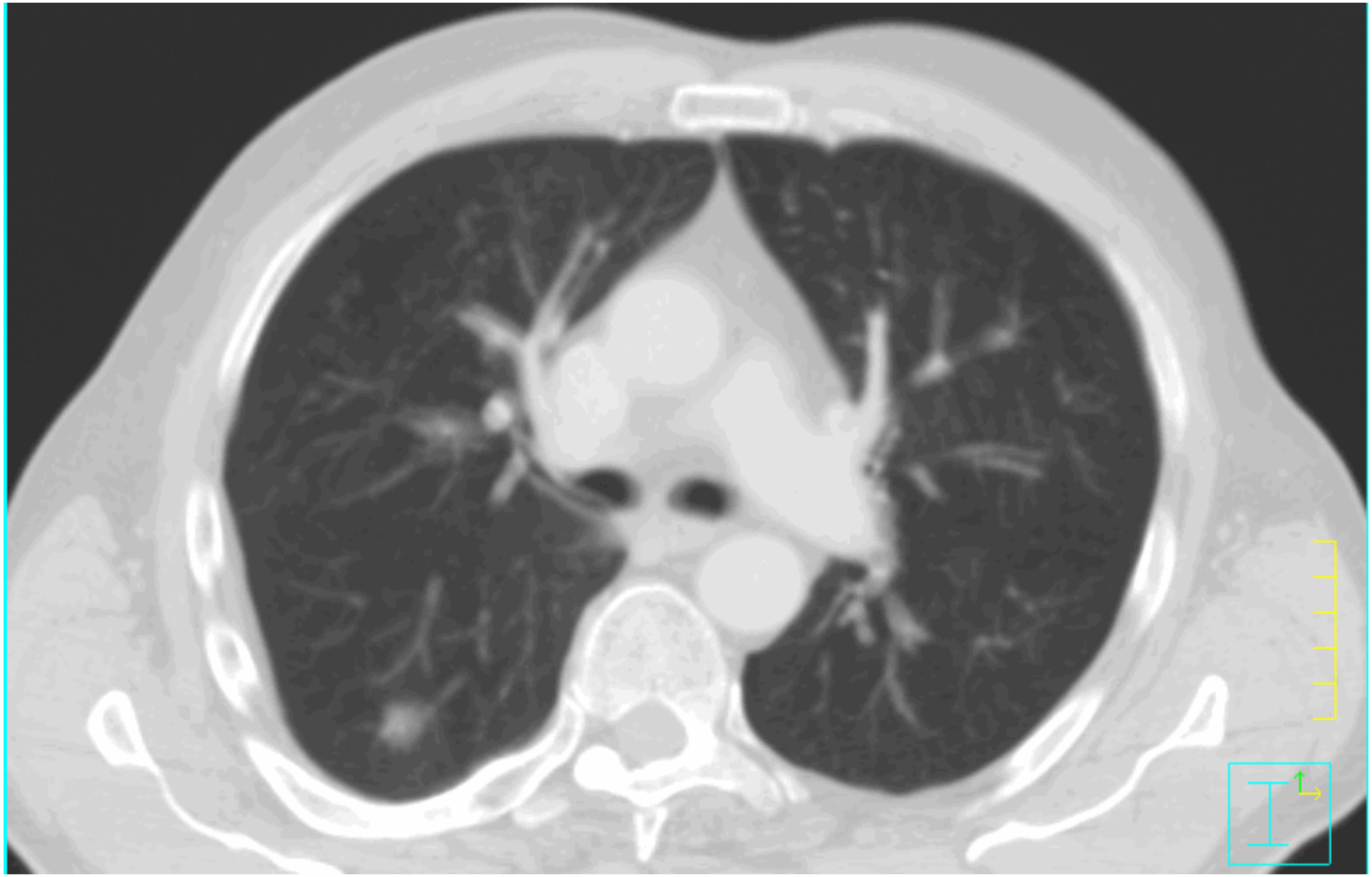
- Start at least 10 cm superior to the extent of the PTV or 5 cm superior to carina
- PBT + 2 cm all around is the “no-fly zone”
- PTV (but not the ITV) can encroach on the “no-fly zone”

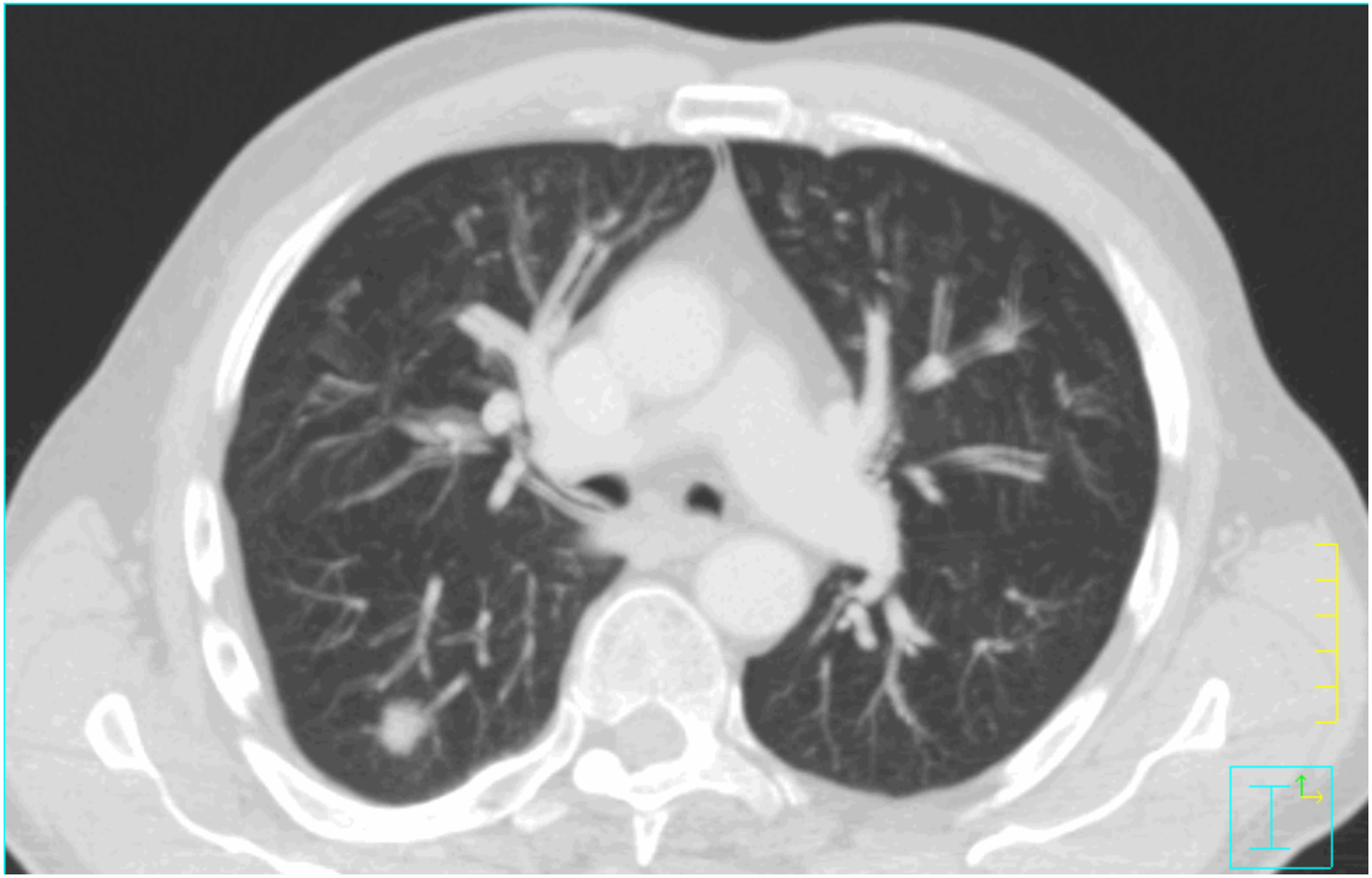
# Proximal Bronchial Tree

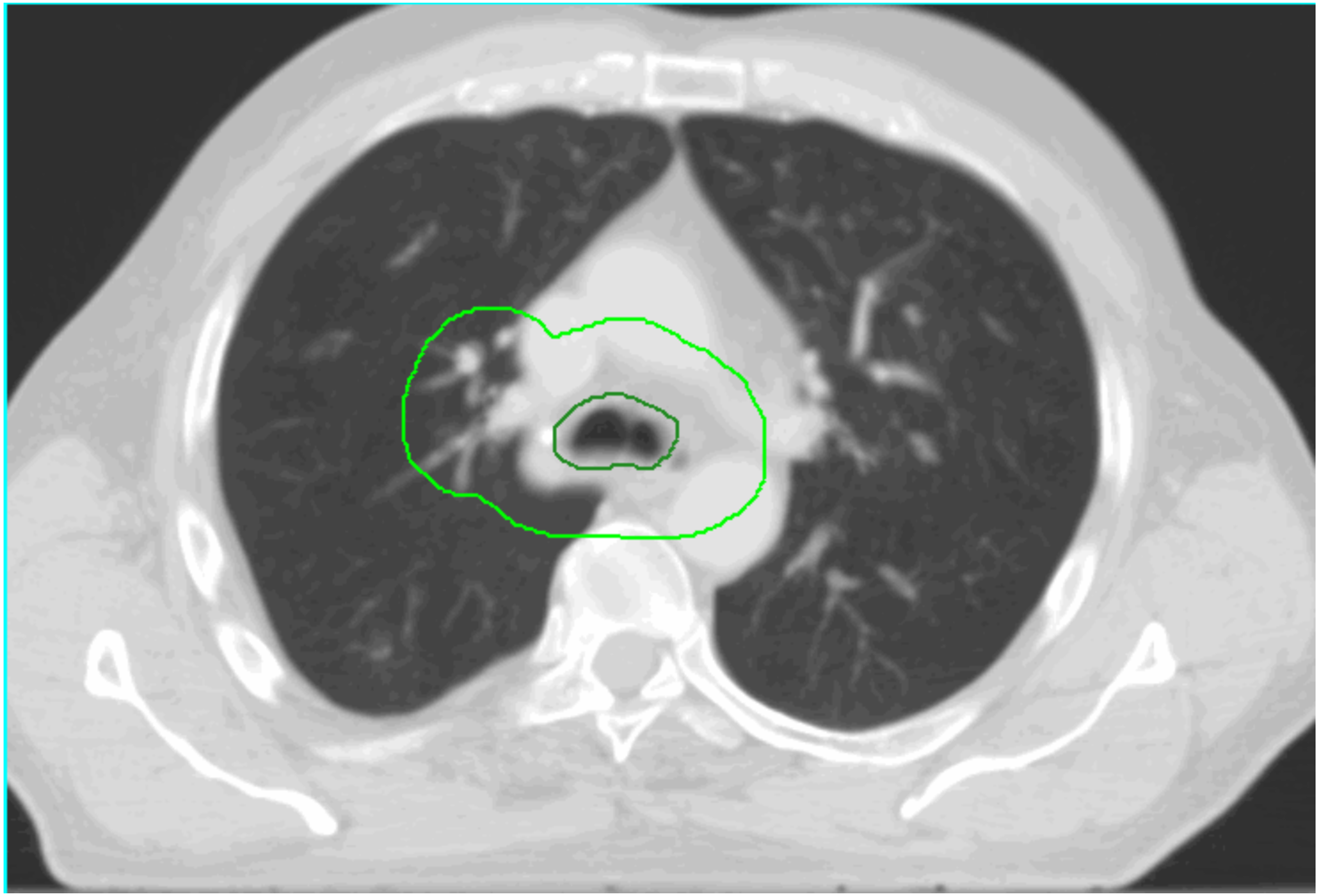
Some coronal images of
the PBT (green) and
the “no-fly zone” (yellow)

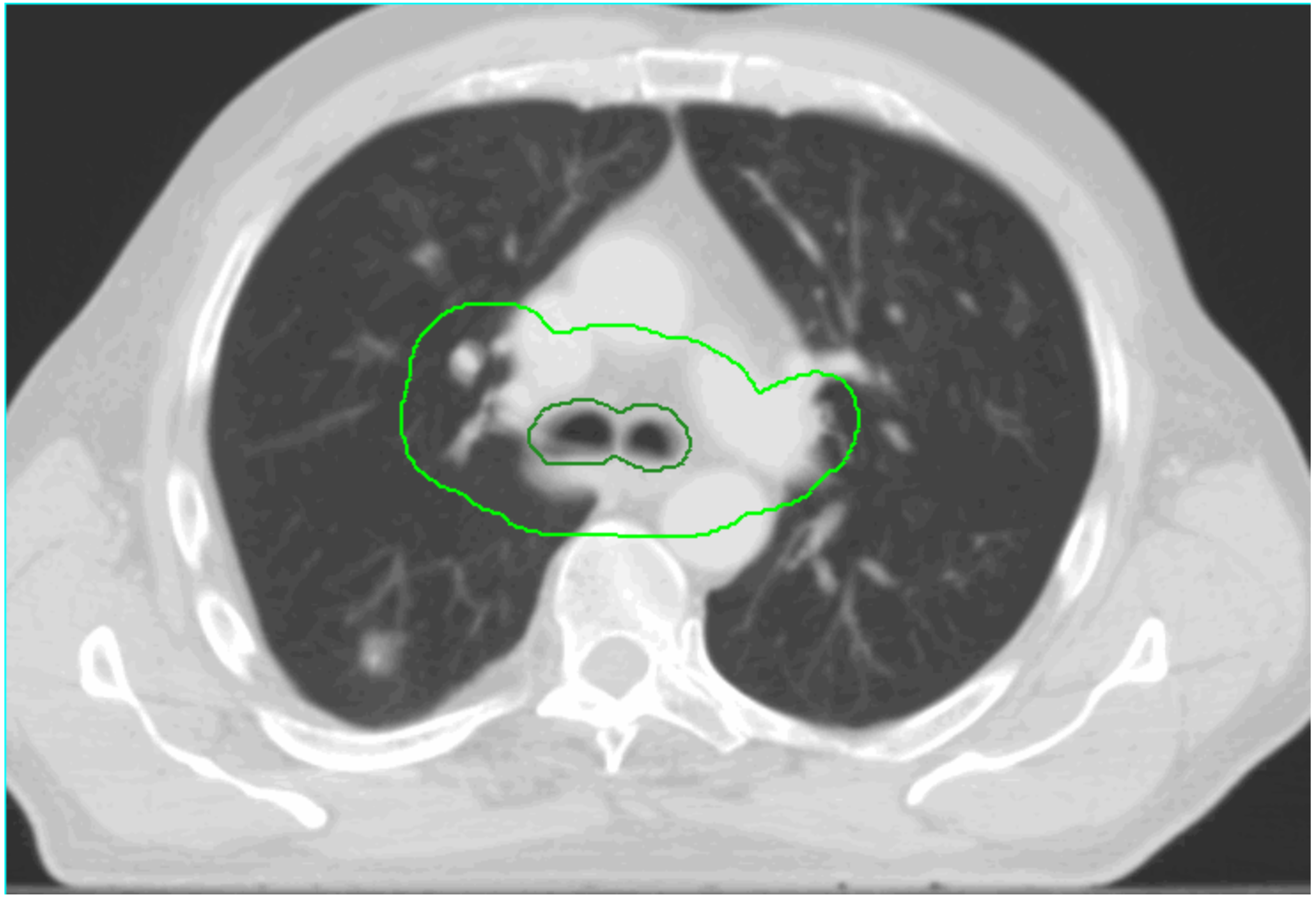


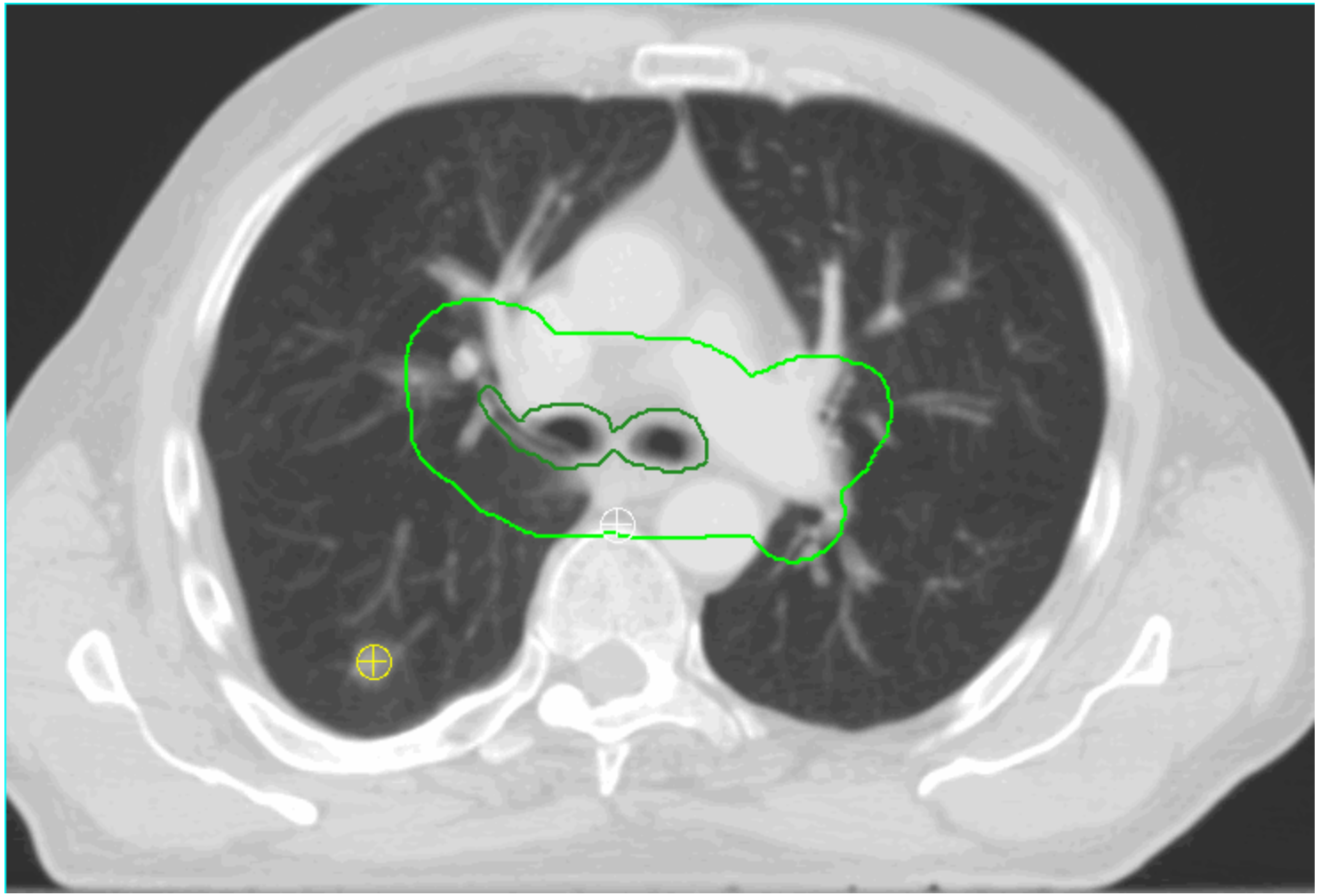


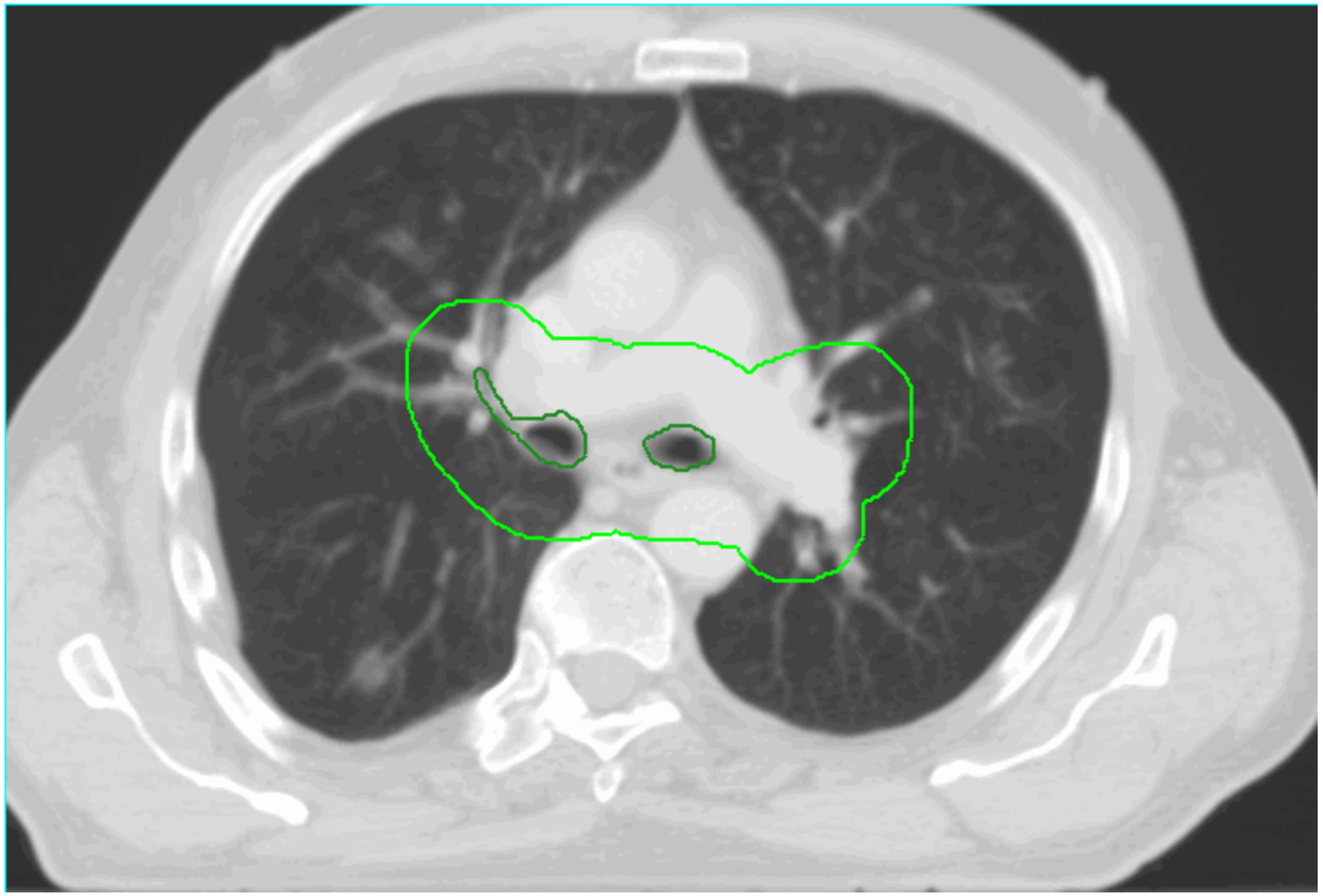


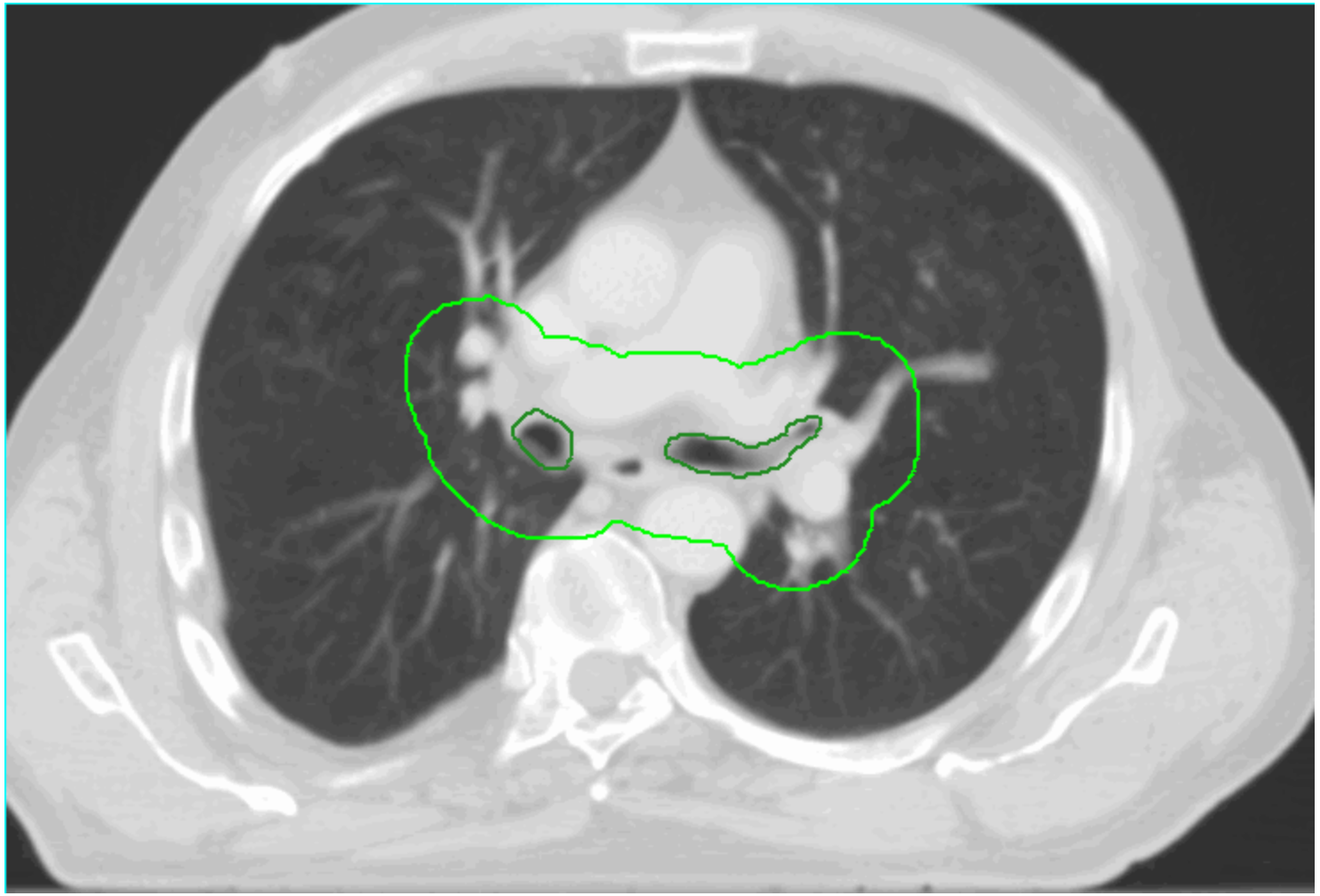


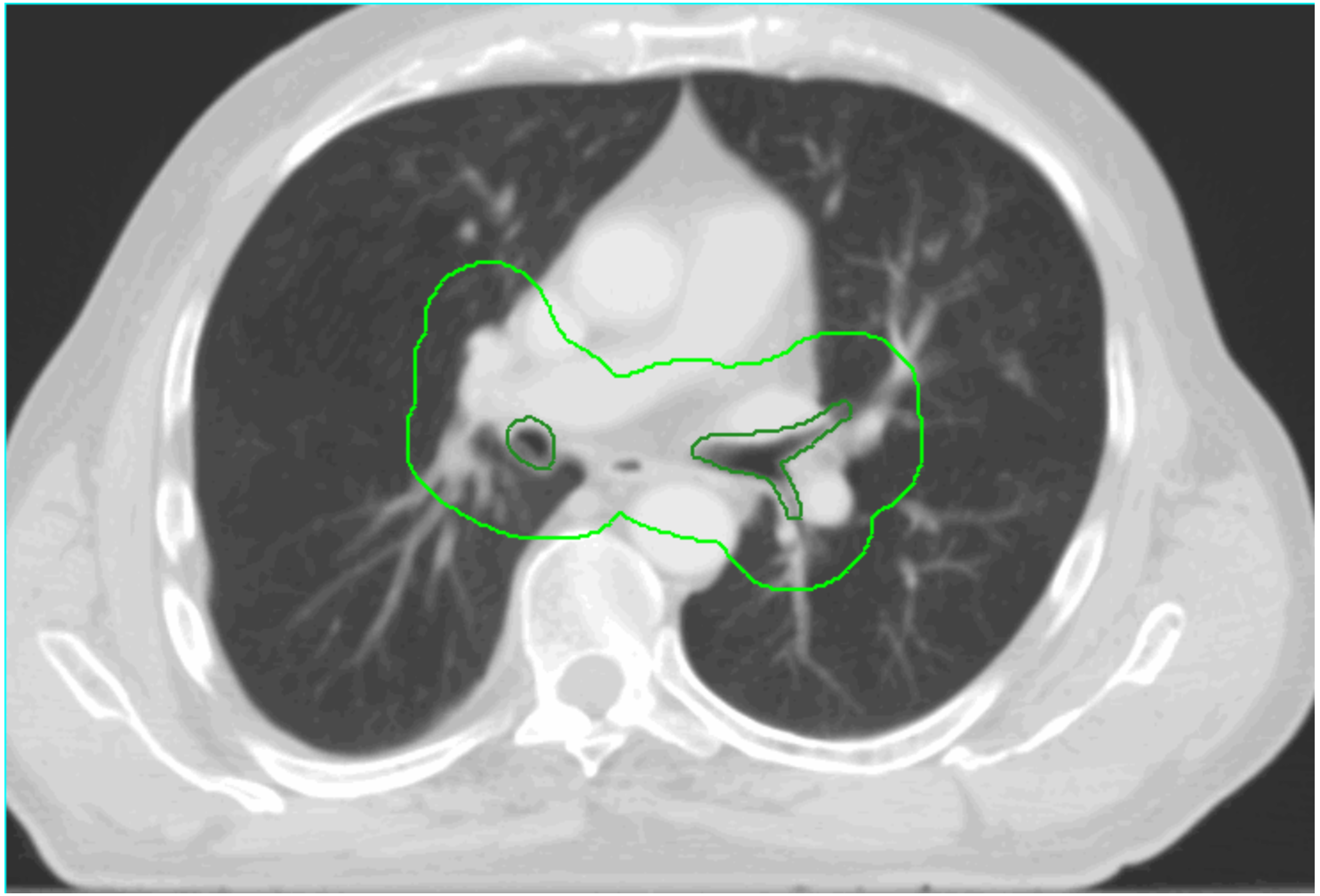


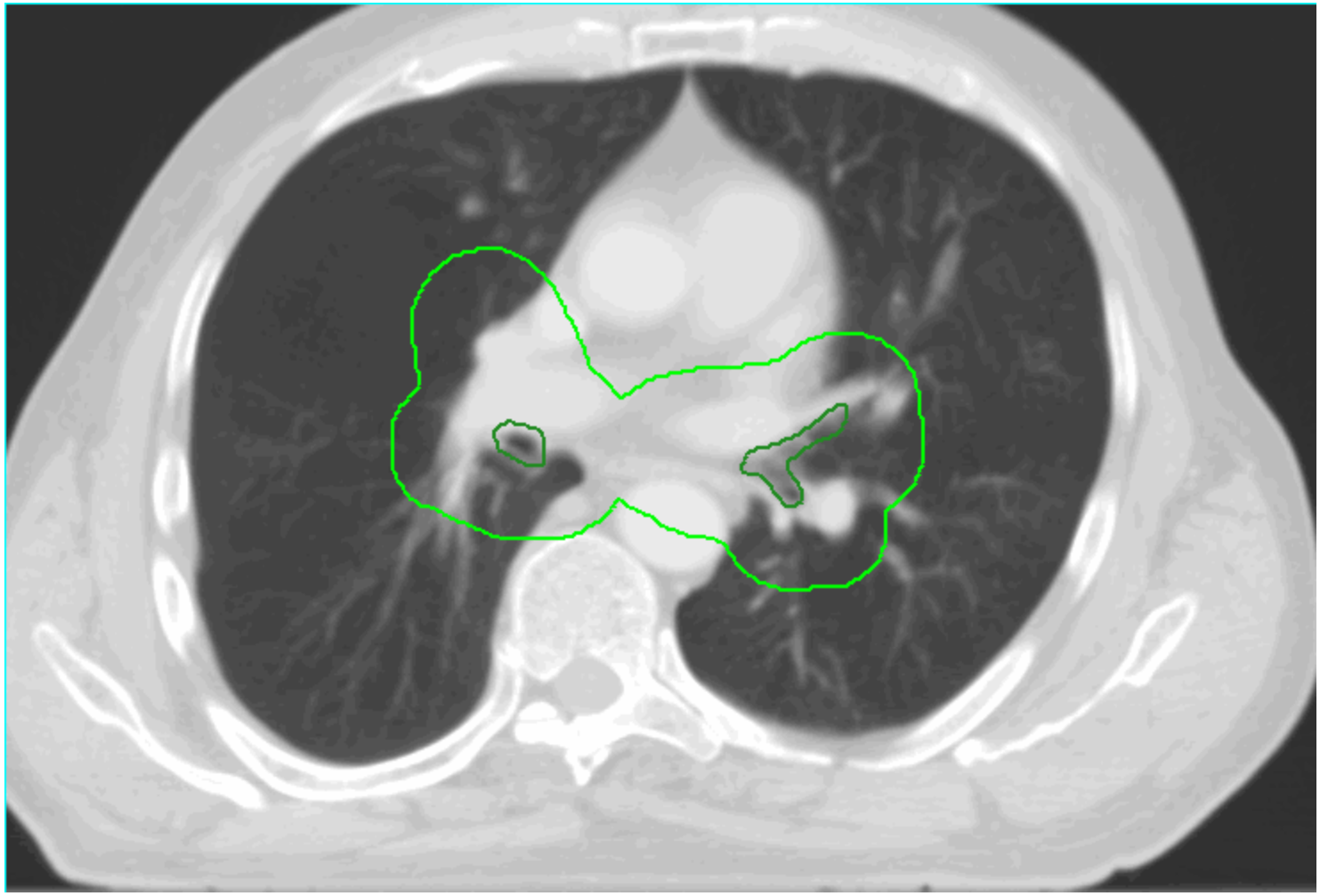


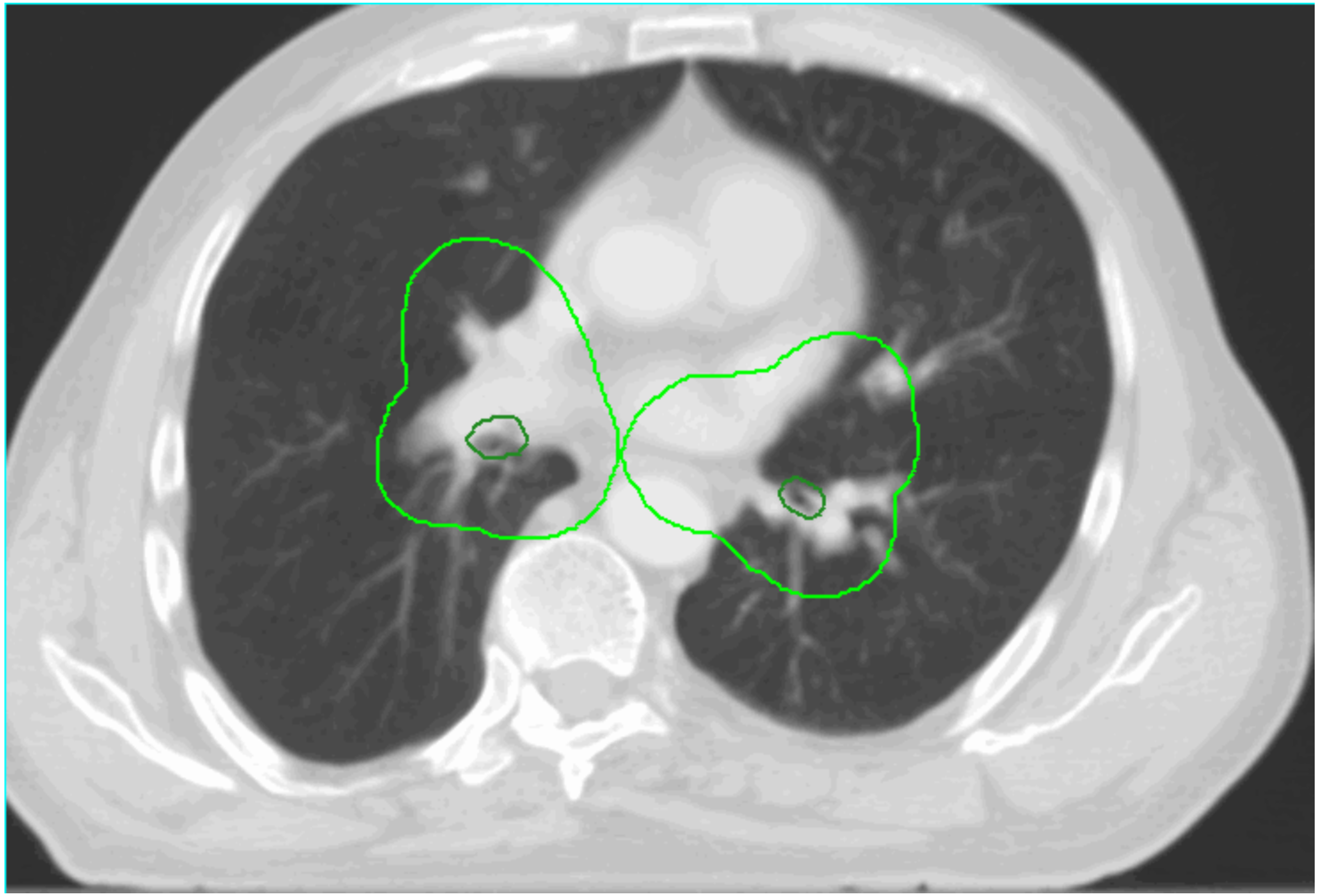


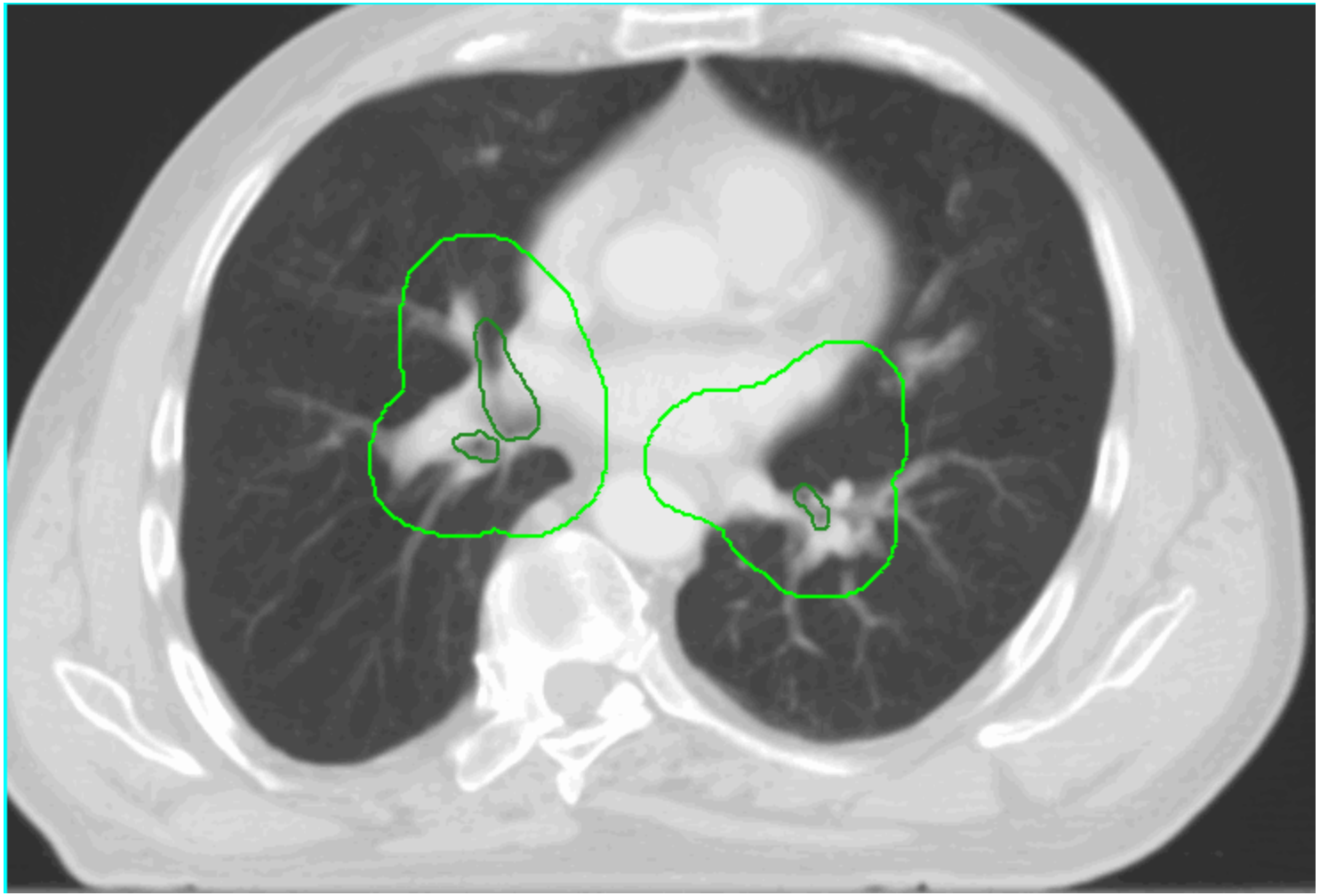


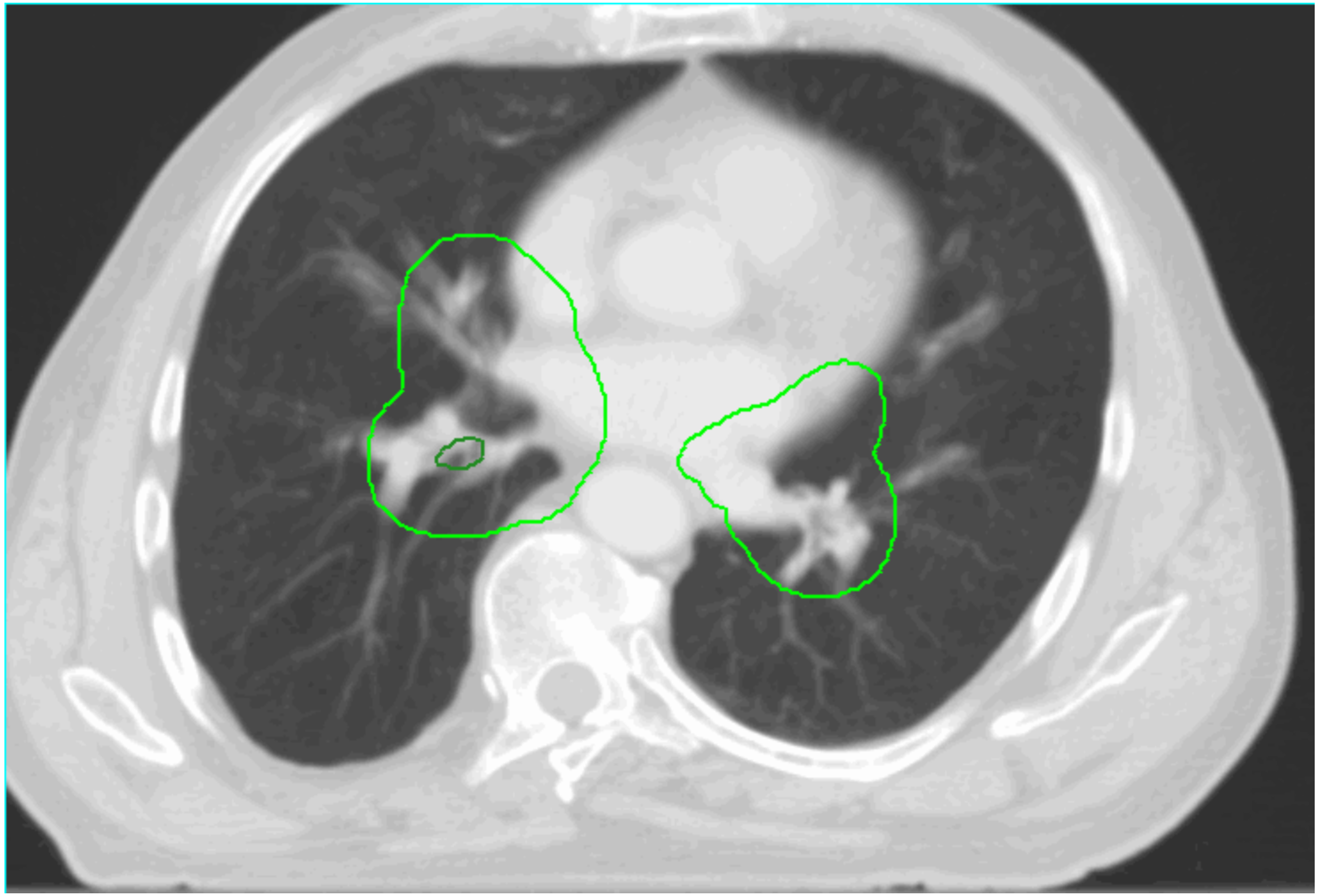


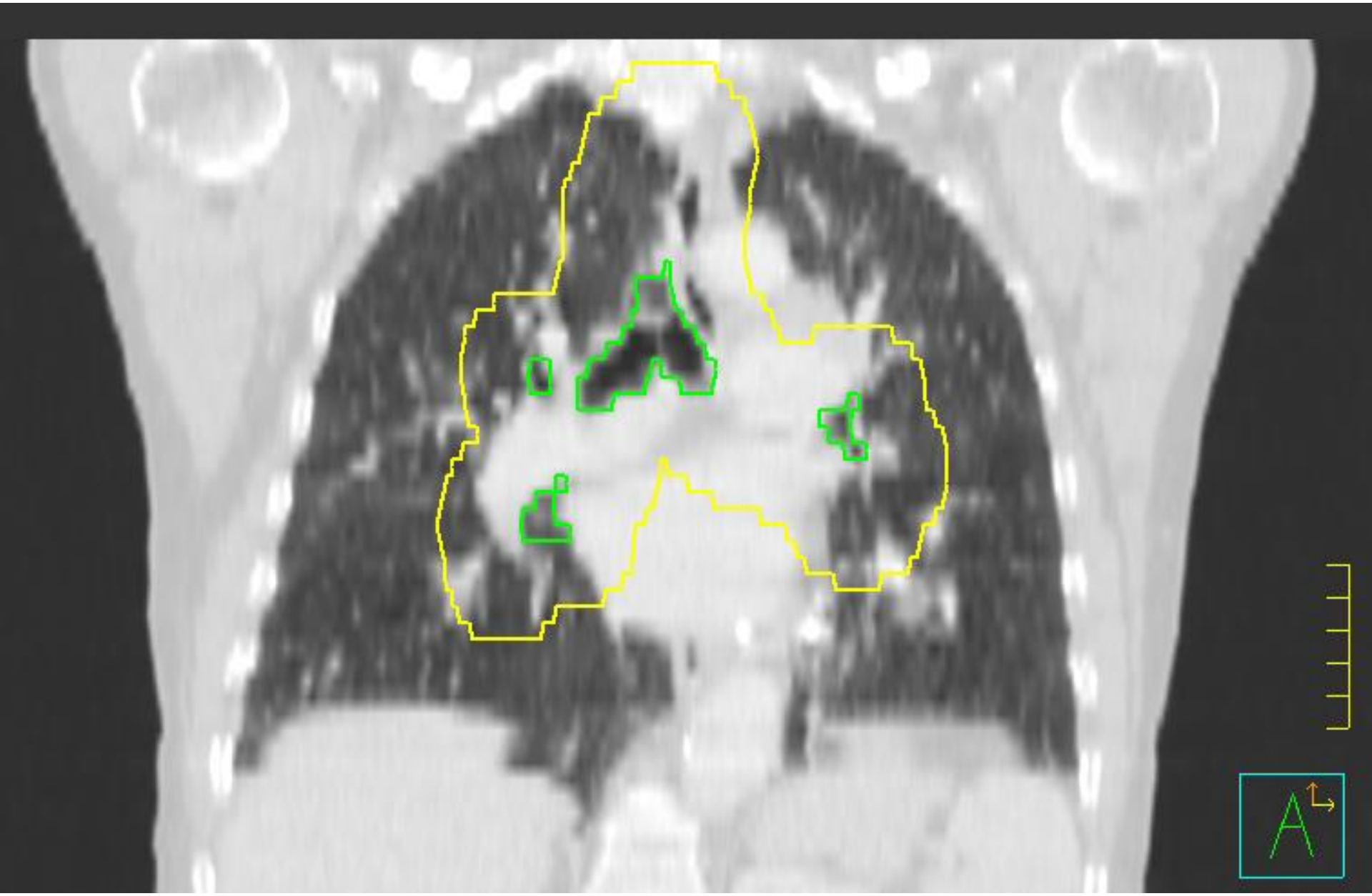


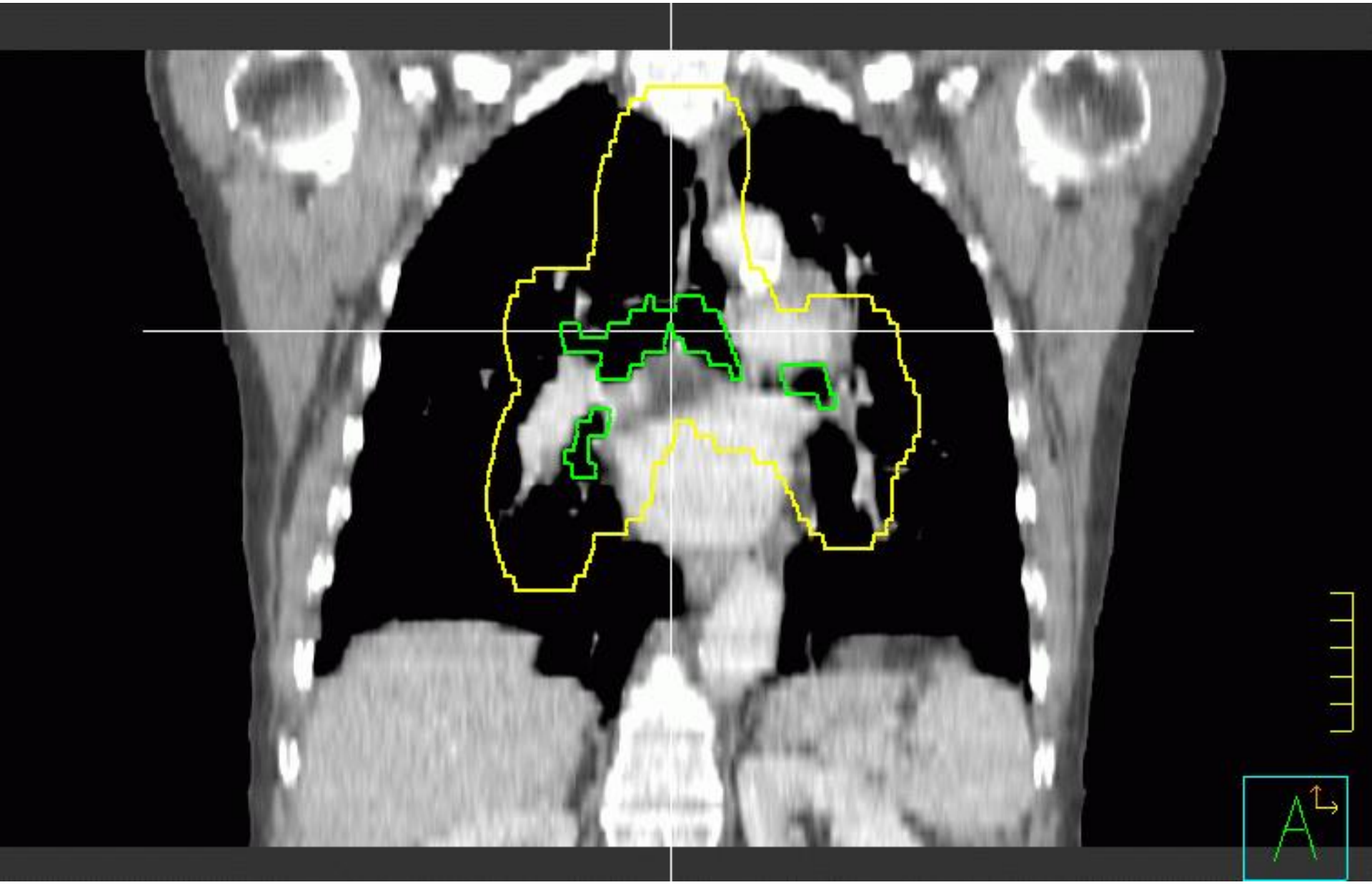












# Prescriptions can be …

- Dose based
  - The PTV should receive 60Gy
  - The spinal cord should not receive >44-48Gy
- DVH based
  - 95% of the PTV should receive 60Gy
  - No more than 35% of the lung(-PTV) should receive 20Gy or more
- Biological
  - The tumour control probability should be >95%
  - The risk if grade 2+ lung toxicity should be <8%
  - *Less known about exactly how to do this/ what numbers to use*

# Plan Evaluation

- Check plan against dose constraints
  - Have objectives / constraints been met
- Isodoses
  - Scroll through specific isodose levels
    - 95% of PTV(s)
    - Identify hot spots
  - ? dose dumped into an unexpected place
- Look at Dose Volume Histogram
- Check for the unexpected!
  - Things that you had not thought of!

# Dose volume histograms

- 3D plan information can be summarised into a 2D graph:
  - but remember some spatial information is lost
  - a DVH only tells you information about the structures you have accurately contoured
- Volume and dose statistics can be read off from a DVH
  - $D_V$ (absorbed dose in fraction V of the volume)
  - $V_D$ (volume receiving at least an absorbed dose D)

# Pitfalls

- Things to look out for:
  - Structures undefined / unclear nomenclature
  - Over complication
  - Hot spot outside PTV
  - Baggy PTV coverage
  - Build up region
  - Bolus

Now, some contouring…….

**Thank you**