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NODAL CONTOURING ATLAS

TAILOR RT : A RANDOMIZED TRIAL OF REGIONAL RADIOTHERAPY IN BIOMARKER LOW RISK NODE POSITIVE BREAST CANCER

MIRA GOLDBERG MD FRCPC, VALERIE THEBERGE MD FRCPC,
TANYA BERRANG MD FRCPC & TIMOTHY WHELAN MD FRCPC

Contouring Guidelines

Introduction:

Below is a guide for contouring regional lymph nodes in the supraclavicular, axillary and internal mammary areas for regional nodal irradiation. It is based primarily on the RTOG Atlas with some recommendations from the EORTC guideline and practical experience.

When first contouring regional lymph nodes according to anatomical criteria, there is a tendency to contour large volumes such that when a PTV is added along with a subsequent margin to account for penumbra, the final fields may be larger than the historical field size based on boney landmarks. This tendency should be avoided as historical fields have been shown to be effective and enlarging fields beyond this is unlikely to improve effectiveness but may increase acute toxicity e.g. tracheitis and long-term toxicity e.g. lymphedema. Investigators should be cognizant of this when contouring and trying to follow anatomic guidelines. When contouring please consider the subsequent PTV expansion and the additional penumbra that would have to be accounted for. Continued experience with contouring will help in designing fields that are clinically acceptable.

In general, RTOG contouring guidelines present anatomical landmarks as a suggestion/guide to define the anatomic/nodal space. ESTRO contouring guidelines define the at-risk nodal regions as a 5 mm expansion on the vessels. MA.39 will follow the nodal spaces as presented by the RTOG consensus guideline, but vessels should be used as a guide. Regional nodal irradiation generally includes coverage of the medial supraclavicular (SCV or level IV) region, axillary level I-II-III (following sentinel lymph node biopsy (SLNB) only) or axillary level III (following an axillary dissection), and internal mammary nodes (IMN) in the first three intercostal spaces. The following nodal regions will be contoured as 3 separate regions of interest: SCV, axillary and IMN. Axillary volumes following SLNB alone (Levels I, II, III) may be drawn as separate contiguous levels or as a single region of interest and expanded as a single PTV.

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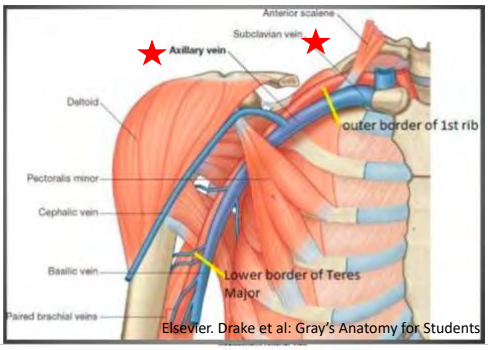
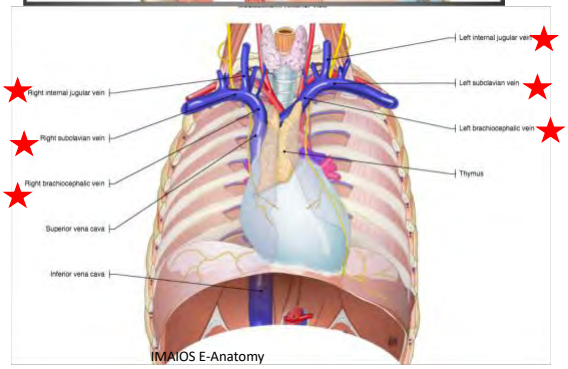
Review of the Anatomy of the Axillary and Mediastinal Veins

- To be used to guide contouring of Level II, III, and SCV nodal spaces
- The brachial vein (located in the proximal arm) becomes the axillary vein at approximately the level of the lower border of the Teres Major muscle
- The axillary vein is easily seen high in the axilla as it passes Level II and through Level III
- The axillary vein passes the lateral border of the first rib and is renamed the subclavian vein
- On coronal CT images the subclavian vein can be seen passing into the Thoracic inlet
  - Just before entering the mediastinum at the confluence of the internal jugular veins with the subclavian vein, the venous structure becomes the Right or Left Brachiocephalic Vein
- In the coronal plane, when scrolling anterior to posterior, the Axillary/Subclavian Vein runs anterior to the Artery



Elsevier. Drake et al: Gray's Anatomy for Students



IMAIOS E-Anatomy

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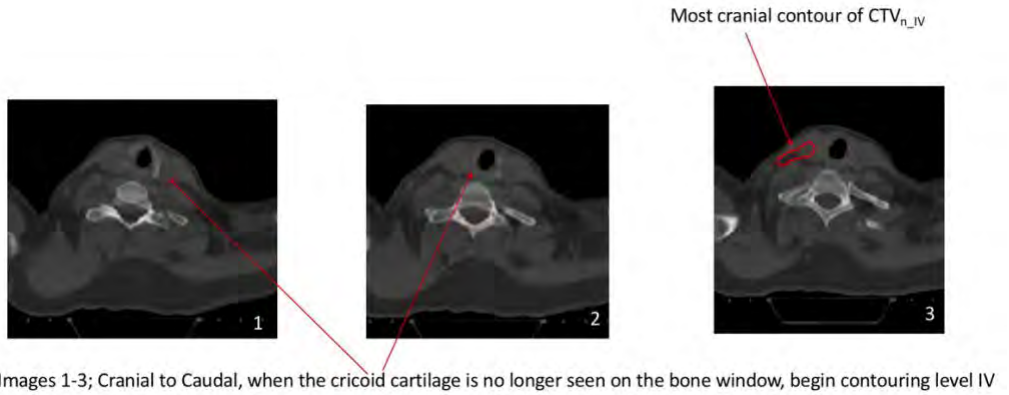
Supraclavicular Nodes (Level IV):

Supraclavicular CTV:
The supraclavicular CTV may be contoured first or following contouring of the axillary CTV. This level is better identified on the *head and neck window*. Contouring cranial to caudal may be the easiest approach. However, the investigator may want to mark the caudal border first by identifying the junction of the brachiocephalic and internal jugular vein. The goal is to essentially identify the internal jugular vein behind the sternocleidomastoid muscle and contour this vessel as well as the surrounding area.

Cranial: Below the inferior border cricoid cartilage
*Extent of the cricoid cartilage is best defined on boney windows

TIP: Identify the Cranial Extent of this level using the Axial CT plane

- Cranially this level begins just below the cricoid cartilage in the neck
  - The end of the cricoid is easily seen in the Bone Window

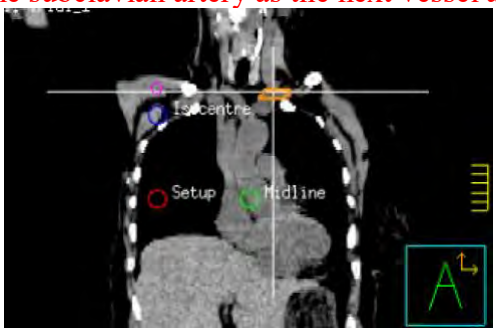


Images 1-3; Cranial to Caudal, when the cricoid cartilage is no longer seen on the bone window, begin contouring level IV

Caudal: Junction of the brachiocephalic and internal jugular veins or the caudal edge of clavicle head *The right and left brachiocephalic veins with the internal jugular and subclavian branches are better identified on coronal views. In the coronal view the brachiocephalic vein can be seen as the first vessel exiting the thorax when scrolling anterior (from the sternum) to posterior. It branches into the subclavian vein arching over the lungs as well as the internal jugular vein travelling vertically into the neck. As you keep scrolling backwards you can then identify the subclavian artery as the next vessel arching over the lungs.

TIP: Identify the Caudal Extent of this level using the Coronal CT plane

- Identify the Subclavian Vein (orange), and Artery
- Caudally this level ends at the confluence of the subclavian vein and the internal jugular vein to form the brachiocephalic vein
  - Locate the brachiocephalic vein entering into the mediastinum
  - In the coronal plane scroll posteriorly from the sternum until a large vessel appearing to exit the thorax and arch over the lungs is seen, this is the **subclavian vein**, the internal jugular vein will be seen branching off and heading vertically up the neck
  - Mark the vein on your axial plane (Hint: Use the Planning software crosshairs)
- Rule of Thumb: Caudal aspect of the head of the clavicle (but frequently this is much lower)



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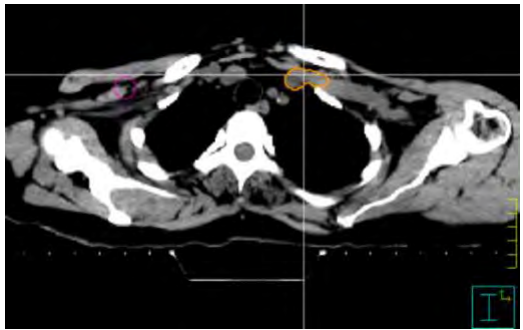
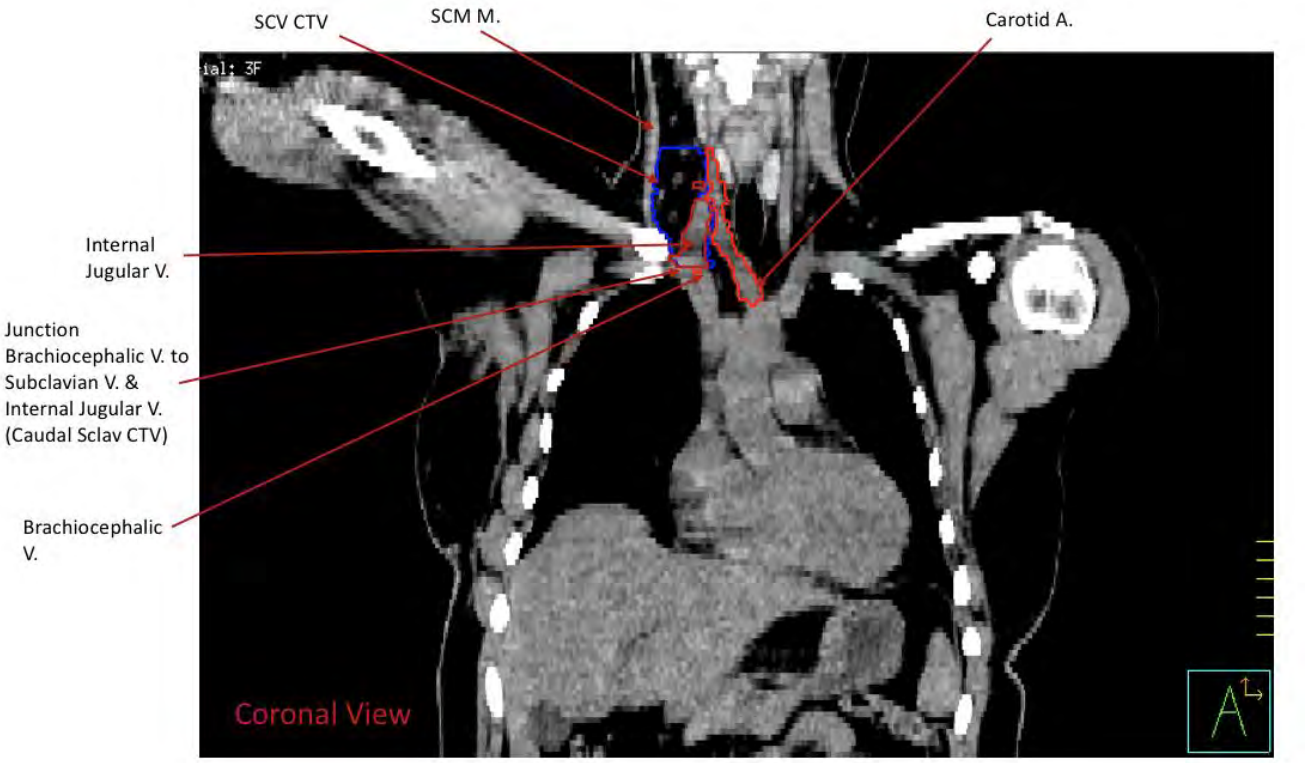
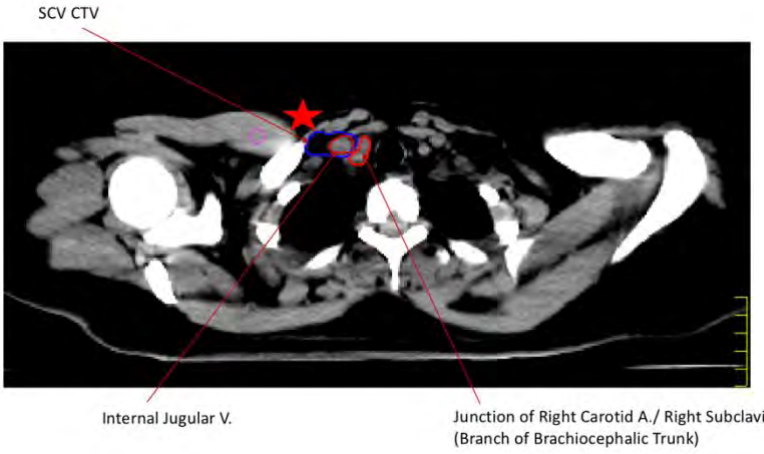




Anterior: Sternocleidomastoid muscle (SCM)
Posterior: Anterior scalene muscle
Lateral: Cranial: lateral extent of the SCM; Caudal: Medial edge of the clavicle/junction 1st rib and clavicle
*Scrolling cranial to caudal on axial CT slices, the SCM can be followed as it travels to insert on the sternum. Once the SCM muscle has moved medial to the SCV nodal contours, the lateral aspect of this nodal level will be the medial aspect of the clavicle.

TIP: The SCM M. travels medially to insert onto the sternum. Once it has done so and is no longer well visualized, the lateral edge of the SCV CTV (blue) is now the medial edge of the clavicle.

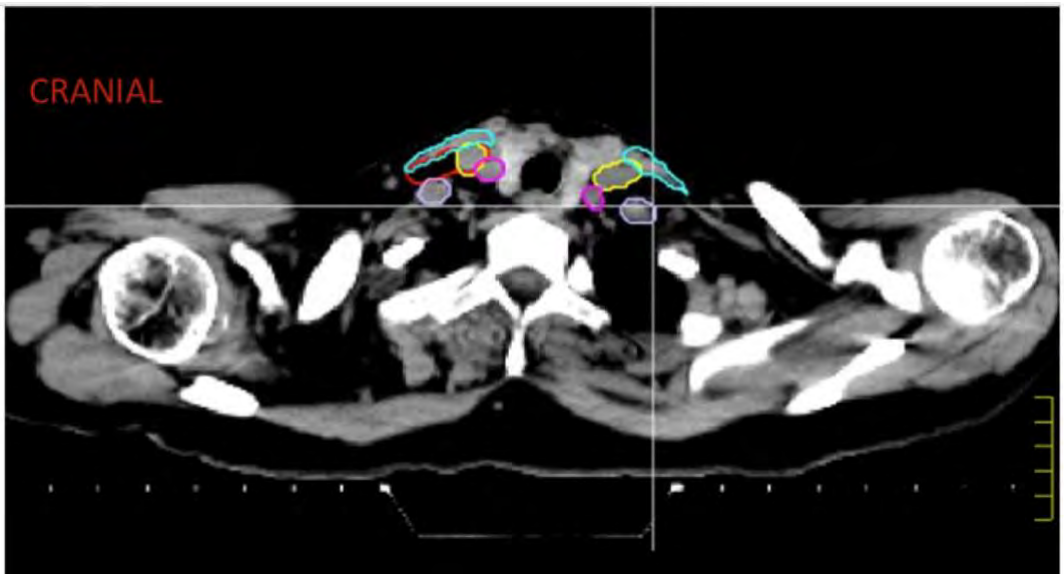


Medial: Include internal jugular vein and if possible the carotid artery, exclude trachea, thyroid and esophagus

*In those patients where the carotid artery lies very medial, it may be excluded from the SCV contour, in order to achieve coverage of the nodal contour while minimizing dose to trachea and thyroid.

TIP: Contour this level using the Head and Neck Window

- Identify Landmarks:
  - Internal Jugular Vein (Yellow)
  - Common Carotid Artery (Pink)
  - Sternocleidomastoid Muscle (Blue)
  - Anterior Scalene Muscle (Purple)
- This nodal space **(red contour)** is defined as the fat plane in the neck that lies lateral to the thyroid, and along the dorsal aspect of the sternocleidomastoid (SCM) muscle
- The posterior boundary of the nodal space is the anterior scalene muscle
- Medially:
  - **Include** the Internal Jugular Vein in the nodal contours
  - **Exclude** the Thyroid, Trachea, Esophagus, ± carotid
- Laterally:
  - The lateral edge of the SCM cranially
  - The clavicle caudally



Supraclavicular PTV:

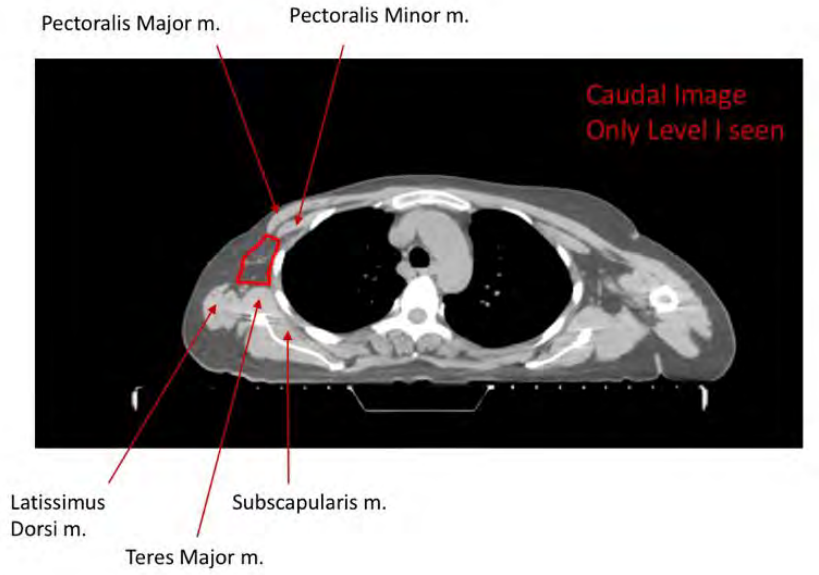
Supraclavicular CTV + 5 mm 3D expansion except medially. Be sure to exclude thyroid, trachea, esophagus, lung, vertebral body and 5 mm inside skin. The medial border of the supraclavicular PTV should be similar to the supraclavicular CTV.

Axillary CTV for SLNB only:

Axillary CTV after **sentinel lymph node biopsy (SLNB)** only; contour axillary Levels I, II, and III
*Axillary levels I-III are best contoured from caudal (level I) to cranial (level III), following the axillary vessels as they travel towards the supraclavicular region and becomes the subclavian vein after crossing the first rib.
*The three axillary levels may be drawn contiguous with one another. More than one nodal level is frequently seen on a single axial slice.
*The axillary vessels (AVs) are a key landmark for levels II and III.

Contouring axillary Level I is challenging as there are a paucity of vessels to follow. Identify where the pectoralis major muscle inserts onto the chest wall (usually around the fourth/fifth rib). Identify the $4^{th}/5^{th}$ rib as it exits off the thoracic vertebral body and follow it to the mid-axillary line in order to mark the caudal extent of level I. Include SLNB scarring and or clips. Contour this space as you scroll cranially including any medial vessels or nodes.

TIP:
Axillary vessels are generally not seen in the low axilla in the treatment position



Axillary Level I:

Caudal: Where the pectoralis major muscle inserts onto the ribs
*Occurs at approximately ribs 4-5 on axial slices, at the mid-axillary line
*Count the ribs from their exit off the thoracic spine then follow the $4^{th}/5^{th}$rib as it moves caudally and anteriorly. Alternatively, in SLNB patients identify surgical clips if present.

Cranial: Level I ends where axillary Level II begins; where the AVs pass the *lateral edge* of the pectoralis minor muscle
*Level I is contoured where the AVs are visualized lateral to the pectoralis muscle.
*When contouring Level I near this location, be mindful not to create contours that would result in field sizes that are wider than historical fields. It may be

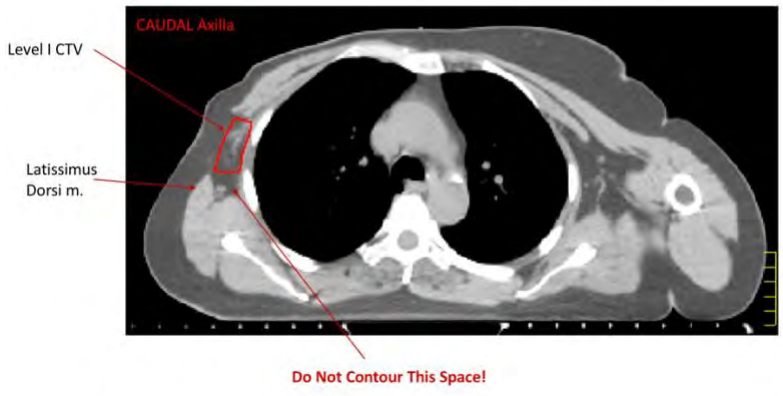
helpful to visualize the contours a 'beams eye view' to ensure that the resultant beam edge will not extend more lateral than the lateral aspect of the humeral head.

*For some patients, it may be helpful to contour the ipsilateral humeral head, with a 1 cm 3D expansion around the humeral head. This may help guide contouring of the axillary CTV as the contours should not come within a 1 cm margin around the humeral head, particularly at the craniolateral extent. This will allow shielding of the humeral head. This can be used as a guide for contouring the axillary CTV and is not used for the DVH.

Anterior: Lateral edge of pectoralis major muscle

Posterior: Imaginary straight line between edge of latissimus dorsi muscle and the intercostal muscles.

*When contouring axillary Level I below the match-line, we recommend limiting the CTV to an imaginary *straight* line posteriorly that runs from the latissimus dorsi to the chestwall, and not including the fat in the plane between the teres major muscle and the chestwall. Including this region within the CTV may result in increasing tangent width, and an increased lung dose.



Lateral: Imaginary line from just inside the lateral edge of the pectoralis major to just inside the antero-medial edge of the latissimus dorsi muscle (caudally)/deltoid muscle (cranially).

Medial: Caudal: ribs and intercostal muscles
Cranial: lateral border of the pectoralis minor muscle.

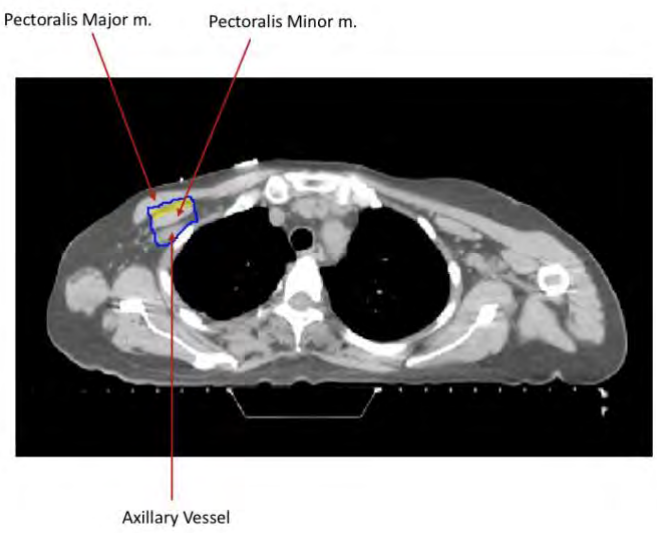
Axillary Level II:

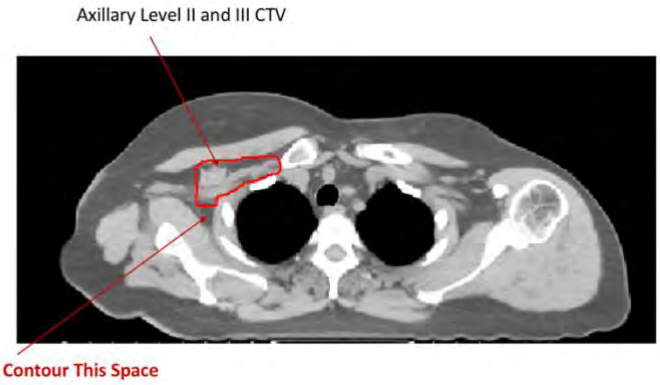
This nodal region essentially follows the axillary vessels where it first crosses the lateral edge of the pectoralis minor muscle to when it finally passes the medial edge of the pectoralis minor muscle. The pectoralis minor muscle should be included within the contour such that the contour extends to the inner surface of the pectoralis major muscle to include Rotter's nodes which are located between pectoralis major and pectoralis minor muscles.

Caudal:	Where AVs pass lateral edge of pectoralis minor muscle
Cranial:	Where AVs pass medial edge of pectoralis minor muscle
Anterior:	Posterior aspect of pectoralis major muscle, to include rotter's nodes
Posterior:	Ribs and intercostal muscles.
Lateral:	Lateral edge of the pectoralis minor muscle
Medial:	Medial edge of the pectoralis minor muscle

TIP:

- This level is easily located after identifying the Pectoralis Minor Muscle and the Axillary Vessels
  - The axillary vessels are located deep to the Pectoralis Minor muscle
- As you scroll cranially from level I, the inferior/caudal extent of Level II begins when the Axillary Vessels pass the *Lateral* Aspect of the Pectoralis Minor muscle, and ends when the same vessels pass the medial Aspect of the Pectoralis Minor muscle
- The Medial and Lateral extent of this space are the medial and lateral extent of the Pectoralis Minor muscle
- The Pectoralis Minor muscle should be contoured within this space (the anterior border is the posterior edge of the Pectoralis Major) in order to include the **Rotter's/Interpectoral Nodes** (Yellow shaded region)
- The posterior aspect of the compartment is the chest wall (ribs and intercostal muscles)





TIP: DO NOT BRING THE CTV CONTOUR TOO FAR POSTERIOR

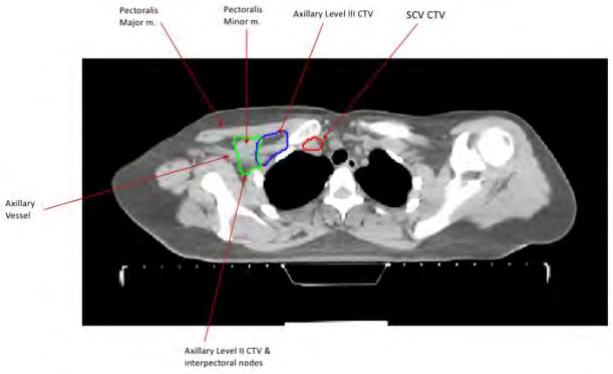
- The posterior border is the chest ribs/intercostal muscles or 5mm border on the axillary vessel.

Axillary Level III:

Axillary level III essentially follows the superior part of the axillary vein as it passes the medial edge of pectoralis minor and then continues on as the subclavian vein past the first rib. The medial limit is clavicle and the junction between the subclavian and internal jugular veins. Subclavian vein is located caudal to the artery. The cranial border includes the artery and connects to the caudal limit of the supraclavicular (sometimes called axillary level IV) CTV.

Caudal:	Where AVs pass medial edge of the pectoralis minor muscle
Cranial:	When pectoralis minor muscle is seen inserting onto the coracoid process
Anterior:	Posterior aspect of pectoralis major muscle
Posterior:	Ribs and intercostal muscles
Lateral:	Medial edge of the pectoralis minor muscle (contiguous with Level II)
Medial:	Clavicle/ribs or lower SCV contours

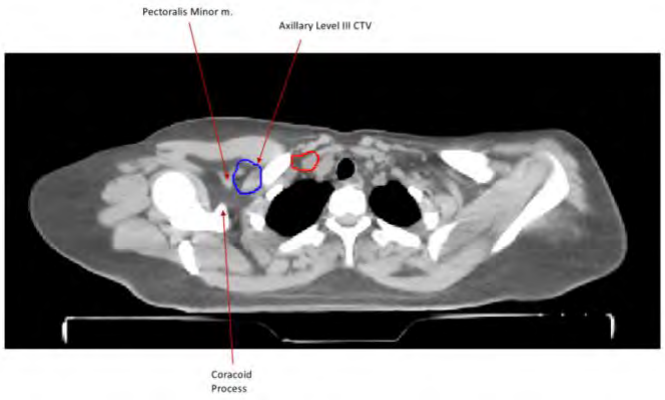
*SCV contours and axillary Level III contours may be seen on some of the same axial slices.



TIP:

As you continue to scroll on the CT images from caudal to cranial, this level begins when the axillary vessels pass the *Medial* aspect of the Pectoralis Minor muscle

- Anteriorly the contour should touch the posterior aspect of the Pectoralis **Major** muscle
- Posteriorly the contours should stop at the chest wall (ribs and intercostal muscles)
- Laterally the nodal space is contiguous to level II
  - The lateral border of the Level III space is the medial aspect of the Pectoralis Minor muscle
- Medially, the nodal space contours end at the thoracic inlet, and may be contiguous with the lower SCV (Level IV) contours
- Superiorly/Cranially contouring of Level III should stop when the Pectoralis Minor muscle is seen inserting onto the coracoid process



*Level I is contoured when AVs are visualized lateral to pectoralis minor, level II is contoured on all slices where AVs are posterior to pectoralis minor, and level III is contoured when AVs are seen medial to pectoralis minor. Frequently more than one nodal level is seen on a single axial slice.

Axillary CTV after axillary dissection:

Consists of the portion of the axilla that remains *un-dissected*. The *un-dissected axilla* typically includes all of **level III axillary nodes** and may include some level II nodes. Using conventional field-based planning, the lateral border of the supraclavicular field is typically at the coracoid process or medial aspect of the humeral head. Note, the axillary dissection often extends beyond the surgically clipped area.

As above except:

Caudal:	Most cranial extent of the dissection taking into account operative report, clips, and operative changes seen on CT *Consider not contouring below the level of the match-line with tangent based planning
Lateral:	Medial border of the pectoralis minor muscle if the intent is to exclude level II. However, this border may be shifted laterally depending on the extent of the surgical dissection.

Axillary PTV:

Axillary CTV plus 5 mm 3D expansion. Axillary PTV should **exclude** lung, therefore, some or all of the medial border of the axillary PTV will be similar to the axillary CTV.

Internal mammary node CTV:

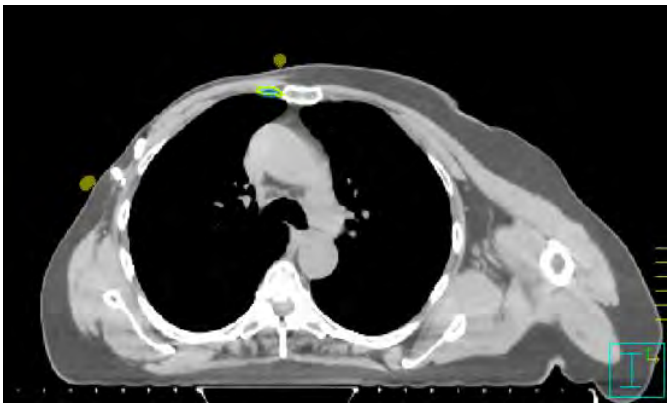
Includes the internal mammary/thoracic vessels, in the first three intercostal spaces.

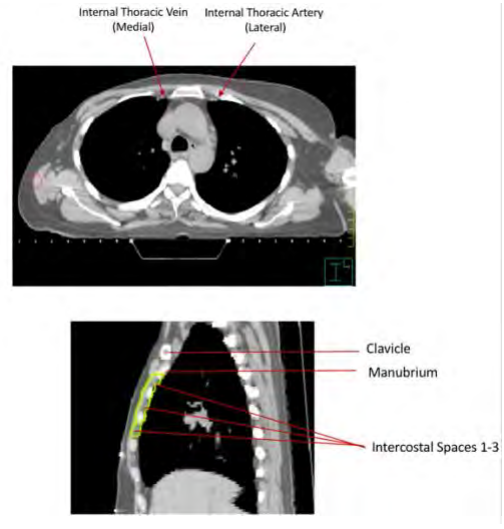
Cranial: Caudal aspect of the first rib
NB: 1st rib inserts onto manubrium *below* the clavicular head

Caudal: Cranial aspect of the 4th rib
*Check your contours in the sagittal plane to ensure the internal thoracic vessels within the intercostal spaces 1, 2, and 3 are fully contoured.

Internal mammary node PTV:

IMN CTV plus 5 mm medially, laterally, superiorly, and inferiorly. PTV expansion excludes the sternum, lung, heart, chestwall or breast. The posterior or deep edge of the IMN PTV will be similar to IMN CTV. No anterior expansion of the CTV is necessary





TIP: Check your contours in the sagittal plane to count the first 3 intercostal spaces

Non-Nodal Contouring Guidelines:

Whole breast and lumpectomy volumes

In the setting of Lumpectomy:

Breast volumes

Breast CTV:

Consists of and takes into account the clinical borders defined at time of CT simulation (with radio-opaque markers), the apparent glandular and fatty breast tissue visualized on CT and should include the Lumpectomy CTV.

Cranial:	Clinical reference or Caudal border of the clavicle head (whichever is higher)
Caudal:	Clinical reference or loss of CT apparent breast (whichever is lower)
Anterior:	5 mm from skin
Posterior:	Excludes pectoralis muscle, serratus anterior muscle, chestwall muscles, ribs, lung
Lateral:	Clinical reference or mid axillary line typically, excludes latissimus dorsi muscle
Medial:	Sternal-rib junction. Does not cross midline.

Breast PTV: Breast CTV plus a 5-7 mm 3D expansion (excluding heart and not to cross midline). This ROI is used for beam aperture generation.

Breast PTV Eval: The Breast PTV Eval is limited to exclude the portion of Breast PTV that extends outside the patient; excludes extension into the bony thorax and lung; excludes the first 5 mm under the skin. This Breast PTV Eval is the structure used for DVH constraints and analysis.

Lumpectomy volumes

Lumpectomy GTV: The term “Lumpectomy” will represent the surgical cavity from breast conserving surgery. It will be contoured using all available clinical and radiographic information, including the excision cavity volume, architectural distortion, seroma and/or surgical clips, when present.

Lumpectomy CTV: Lumpectomy GTV plus a 1 cm 3D expansion with the following limitations: 1) limit the CTV posteriorly from the chestwall/ anterior surface of the pectoralis major; 2) limit anterolaterally 5 mm from skin; and 3) should not cross midline.

Lumpectomy PTV: Lumpectomy CTV plus a 5-7 mm 3D expansion.

Lumpectomy PTV Eval: The Lumpectomy PTV Eval is limited to exclude the portion of the

Lumpectomy PTV that extends outside the ipsilateral breast beyond skin; excludes the first 5 mm of tissue under the skin; excludes the Lumpectomy PTV expansion beyond the posterior extent of breast tissue (chestwall, pectoralis muscles and lung) when pertinent. The PTV Eval should not cross midline, and is the structure used for DVH constraints and analysis.

Chest wall volumes:

In the Setting of Mastectomy:

Chestwall CTV:

Consists of and takes into account the clinical borders placed at time of CT simulation (defined with radio-opaque markers), the postoperative changes visualized on CT, and **should include Mastectomy scar CTV**. (In specific cases, it might be clinically indicated to cross midline to adequately cover the target volumes eg. mastectomy scar. In these cases, it might be difficult to meet compliance criteria and the patient might be unsuitable for enrollment in this protocol).

Cranial:	Clinical reference or caudal border of clavicle head (whichever is higher)
Caudal:	Clinical reference or loss of CT apparent contralateral breast (whichever is lower)
Anterior:	Skin
Posterior:	Rib-Pleural interface (may include pectoralis muscles, chestwall muscles, ribs), excludes lung and heart
Lateral:	Clinical reference + mid axillary line typically, excludes latissimus dorsi muscle
Medial:	Sternal-rib junction. Generally, does not cross midline.

Chestwall PTV: Chestwall CTV plus a 5-7 mm 3D expansion (excluding heart and not to cross midline).

Chestwall PTV Eval: The Chestwall PTV Eval is limited to exclude the portion of the Chestwall PTV that extends outside the patient; excludes the first 3-5 mm under the skin and posteriorly to exclude lung and heart. The PTV Eval should not cross midline and is the structure used for DVH constraints and analysis.

*In the setting of breast reconstruction, expanders, implants or autologous tissue will be included in the chestwall CTV.

Mastectomy Scar volumes;

Mastectomy Scar GTV: Radiopaque wire (placed at CT simulation) and visible postoperative changes on CT, if applicable.

Mastectomy Scar CTV: Mastectomy scar and postoperative changes + 1 cm 3D expansion considering the following:
1) limit the CTV posteriorly at anterior surface of the ribs;
2) limit anterolaterally 3-5 mm from skin; and,
3) should not cross midline

Mastectomy scar PTV: Mastectomy scar CTV + 5-7 mm 3D expansion.

Mastectomy scar PTV Eval: The mastectomy scar PTV Eval is limited to exclude the portion of the mastectomy scar PTV that extends outside the patient; the first 3-5 mm of tissue under the skin, and posteriorly to exclude lung and heart. The PTV Eval should not cross midline and is the structure used for DVH constraints and analysis.

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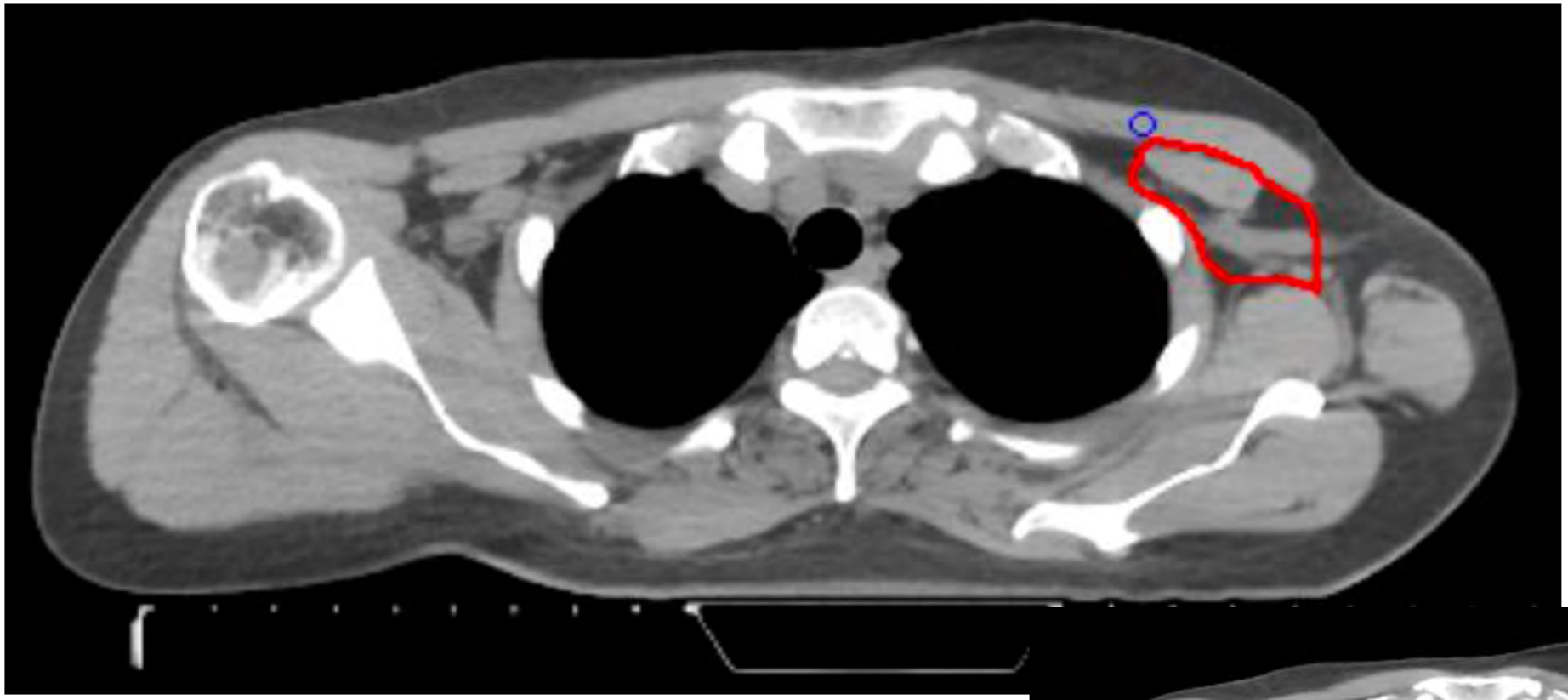
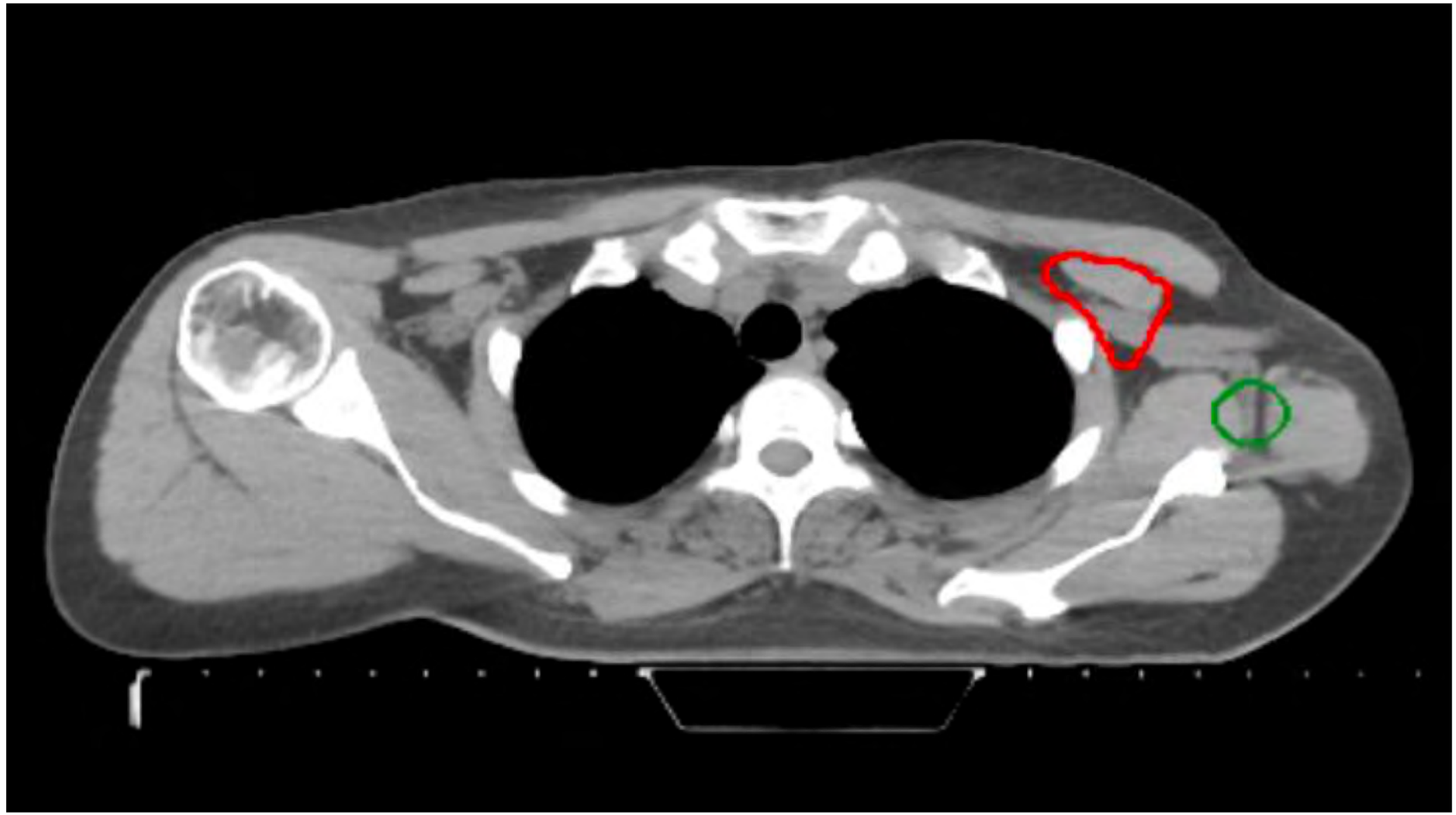
Contouring Cases

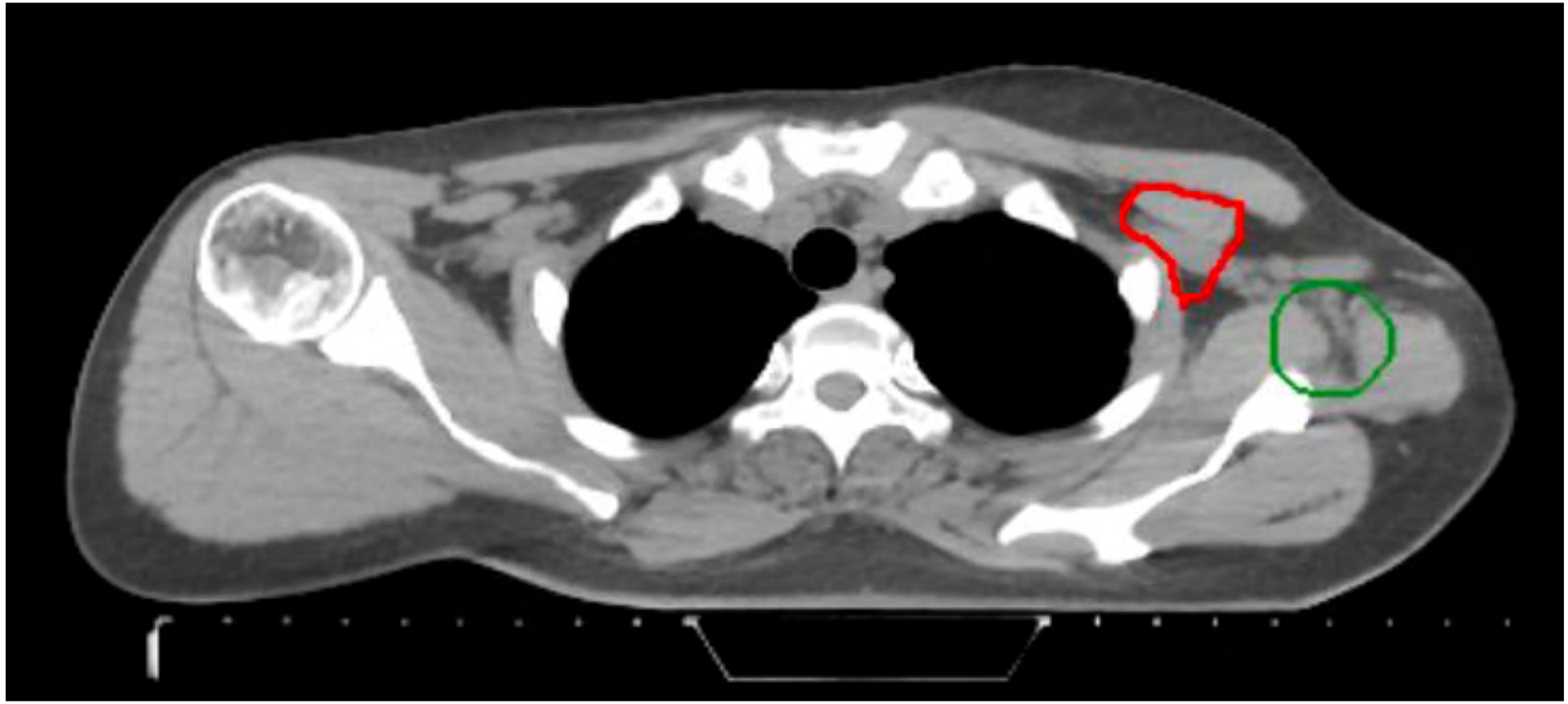
Case #1 Nodal Contouring After SLNbx

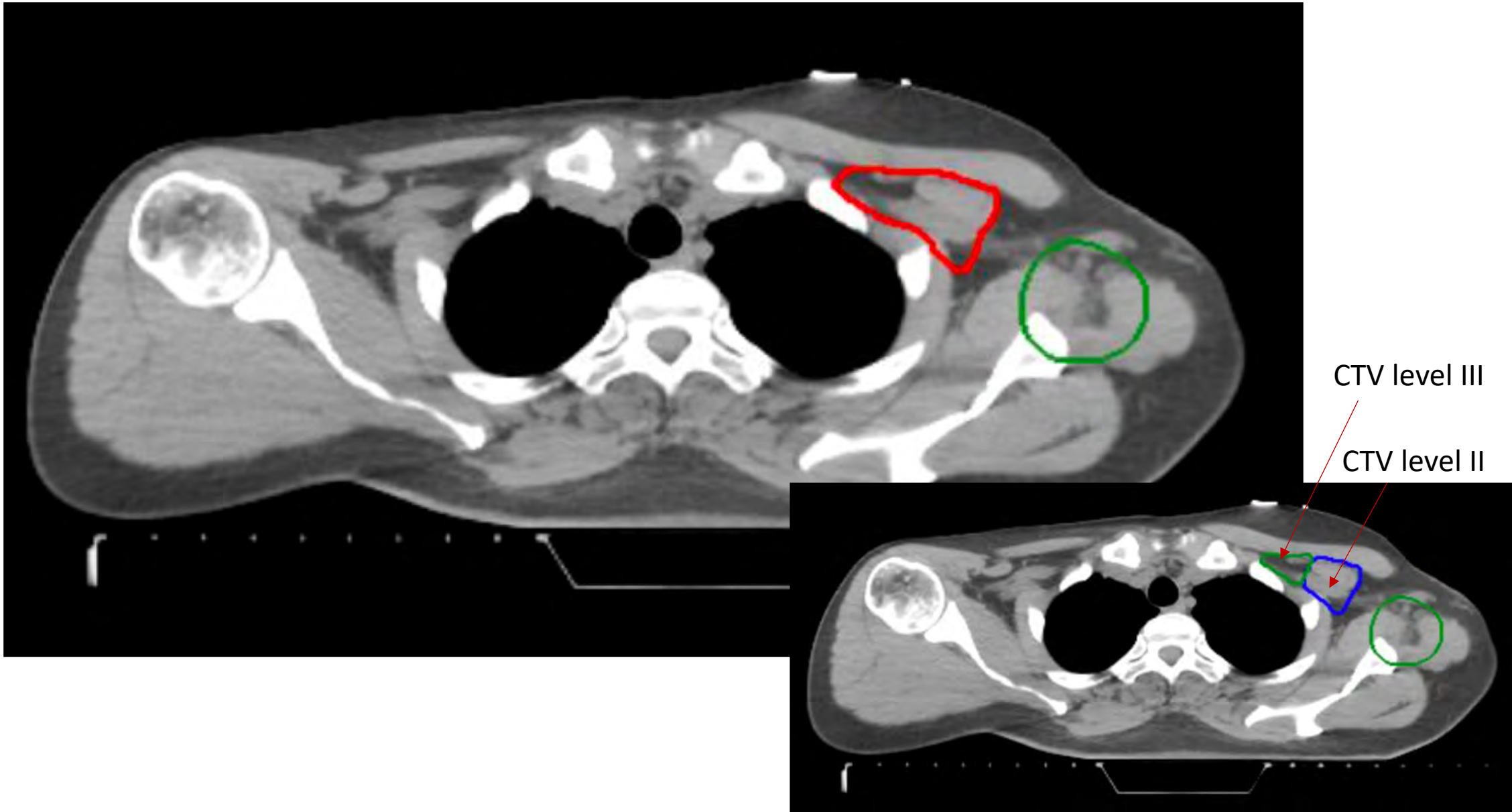
- 57F Post Lumpectomy and Sentinel Node Biopsy
- 1.7cm, Gr I, IDC, no LVI, no DCIS, no LCIS
- 1/3 sentinel nodes involved, no further surgery
- Margins >2mm
- ER99%, PR50%, Her2neu-

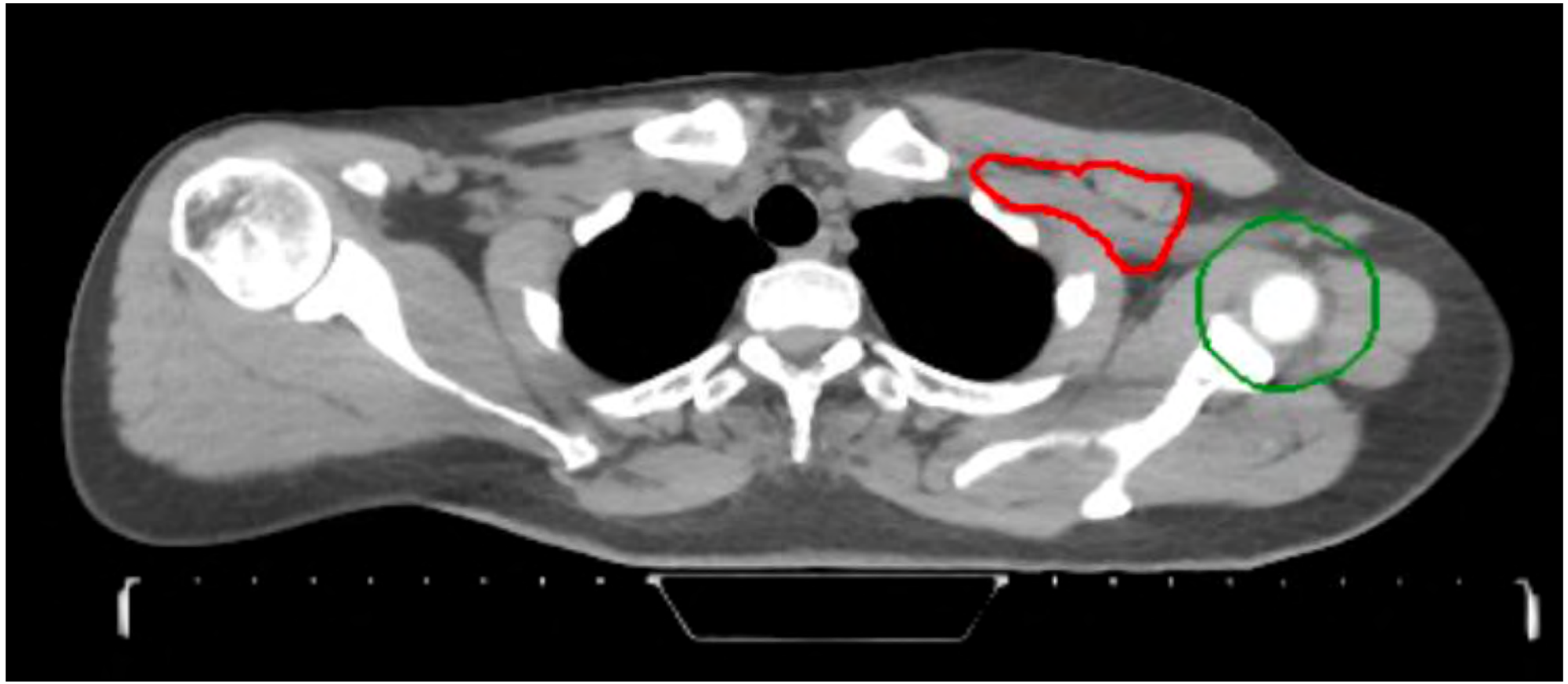

Pectoralis Major and Minor
Latissimus Dorsi m.
Teres Major m.
Subscapularis m.


CTV Level II
CTV
Level I





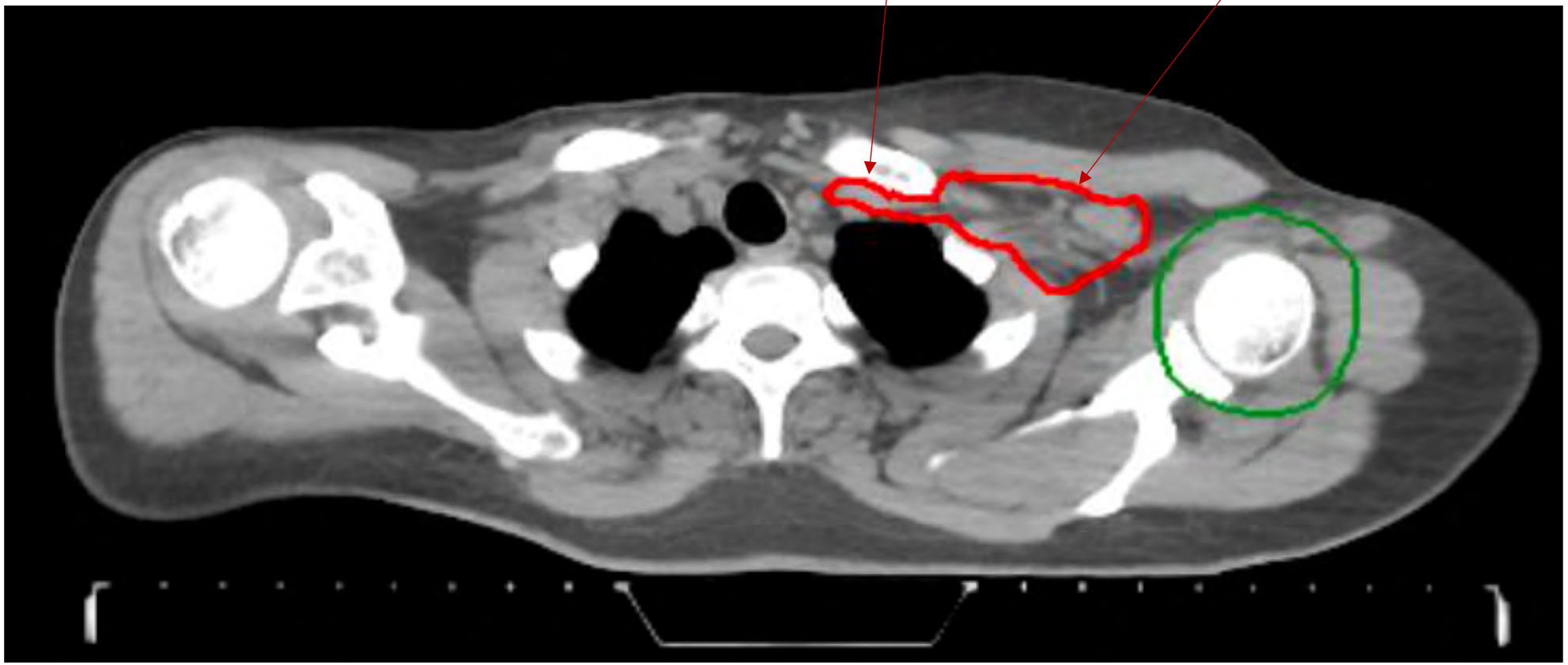

CTV level III
CTV level II

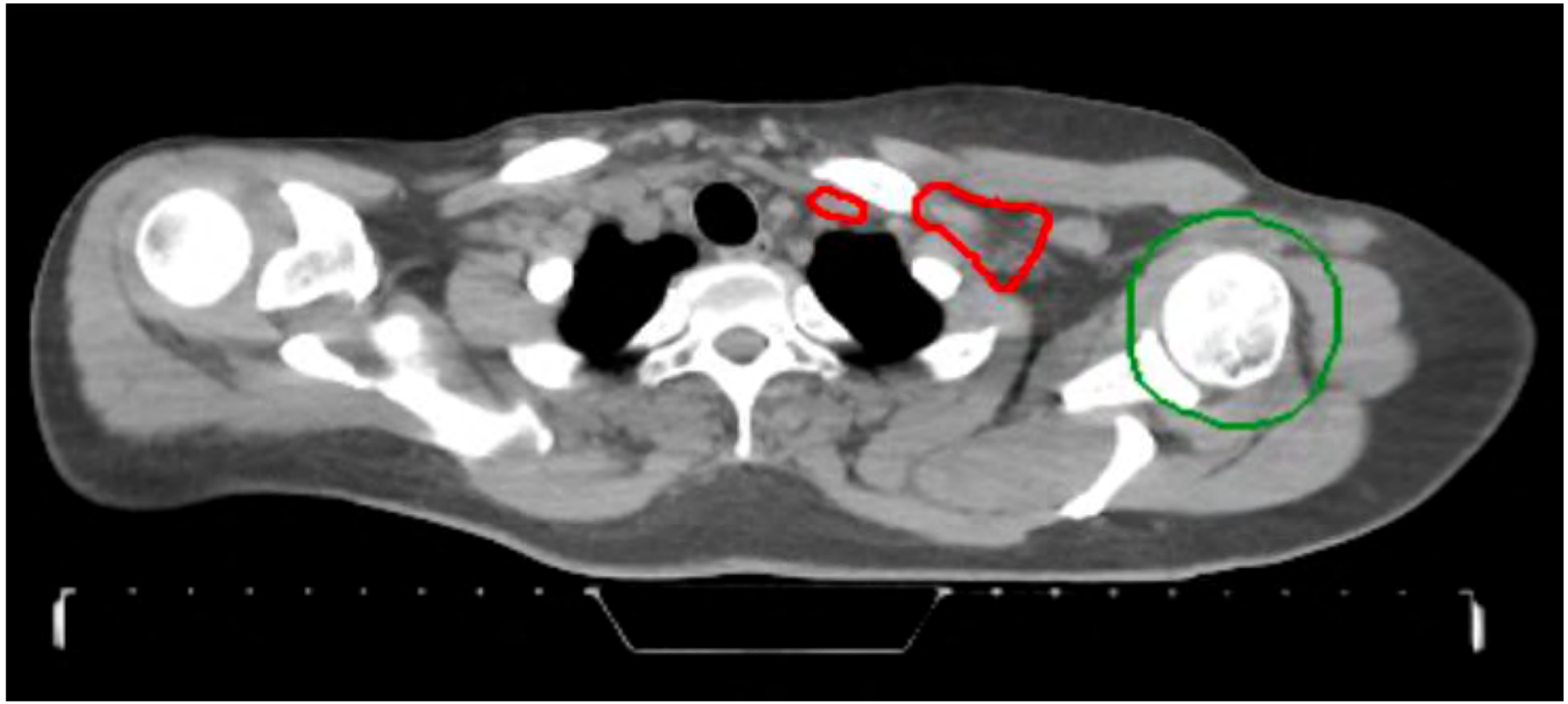


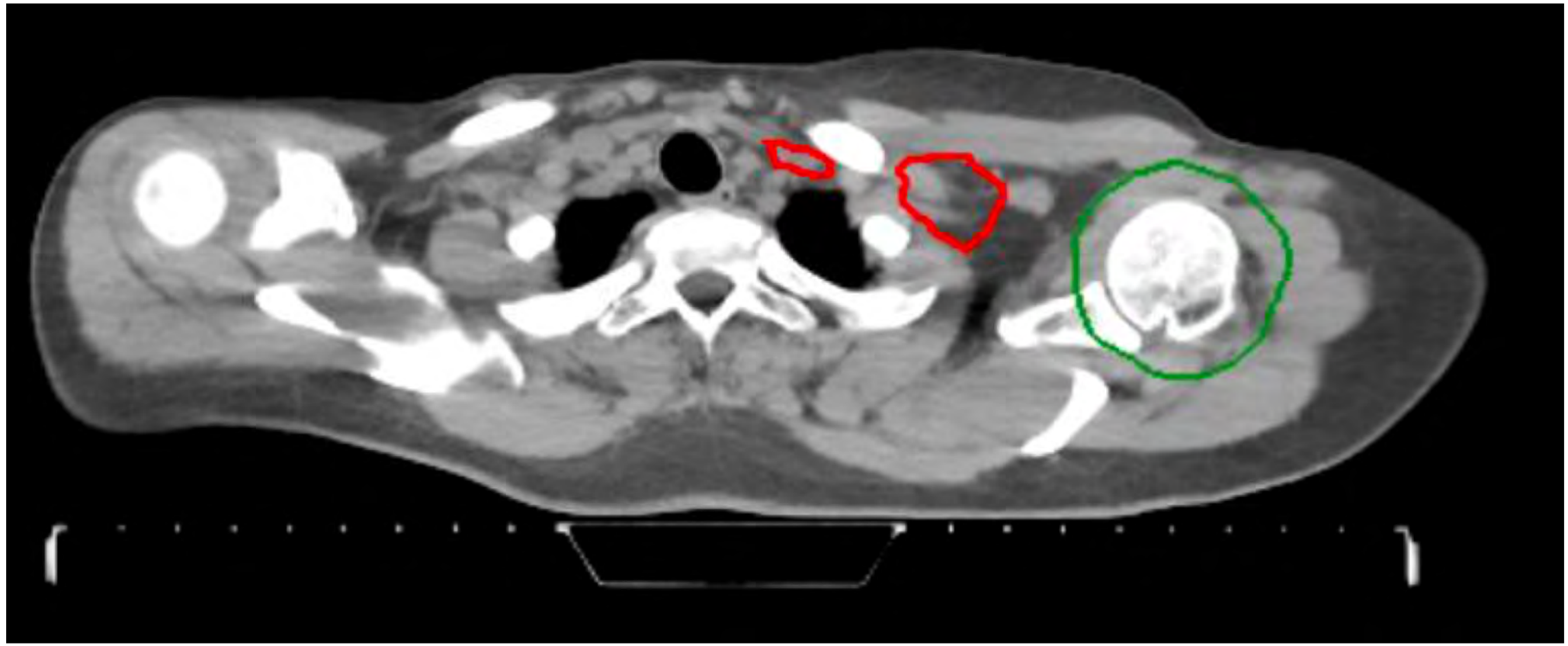

Pectoralis Minor m.
Pectoralis Major m.
1cm Expansion on humeral head
Deltoid m.
Subscapularis m.

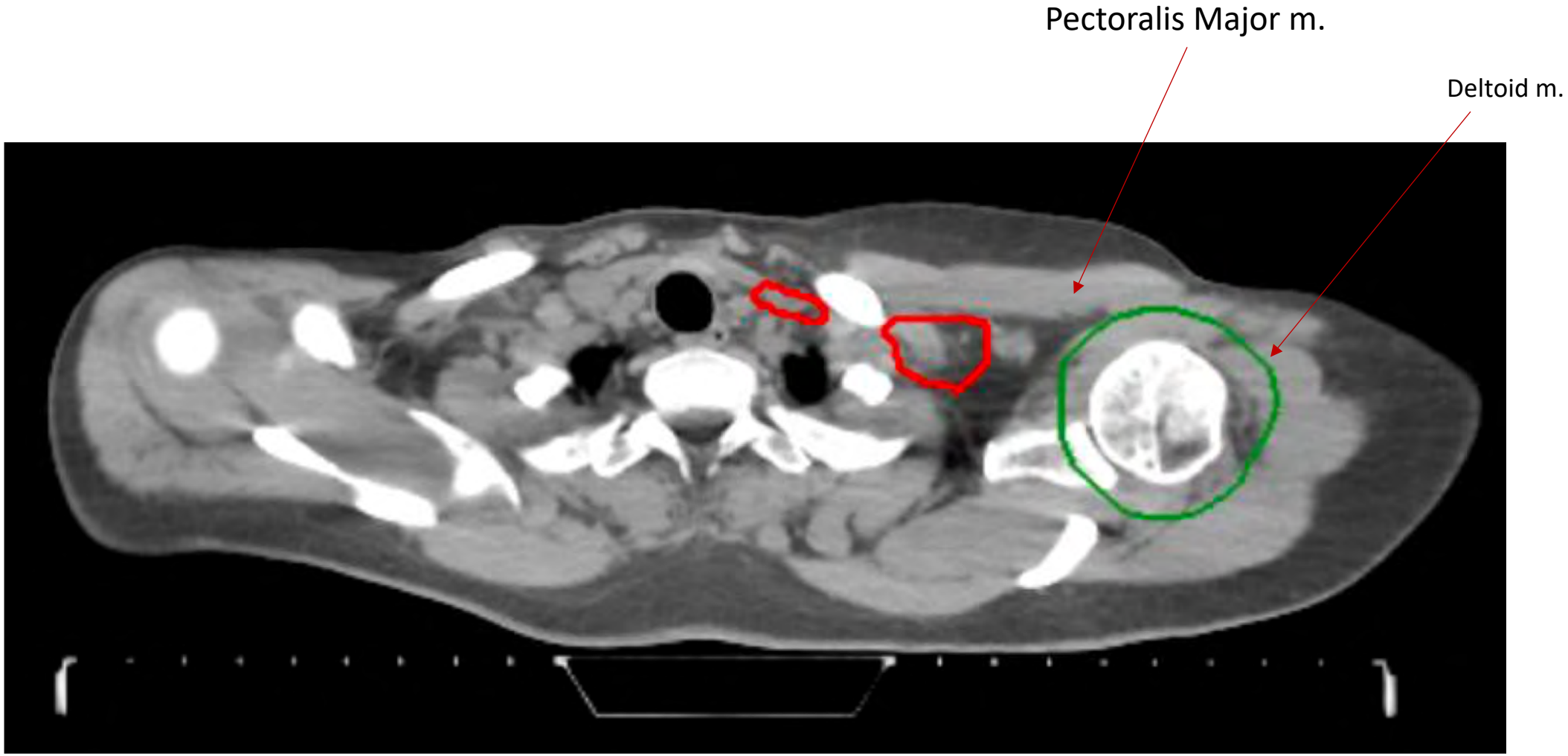
Sclav CTV (Level IV)

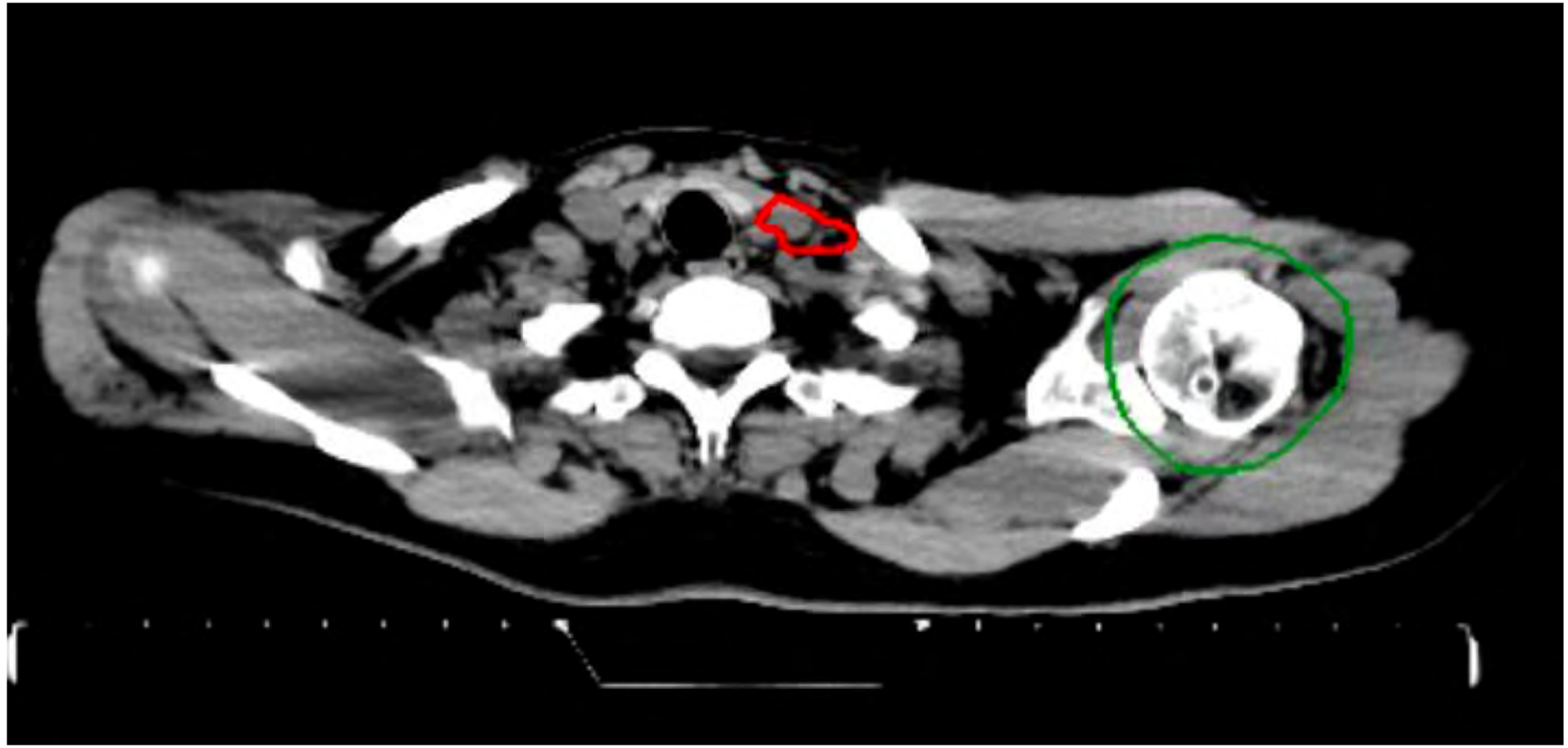
Axillary Level III CTV

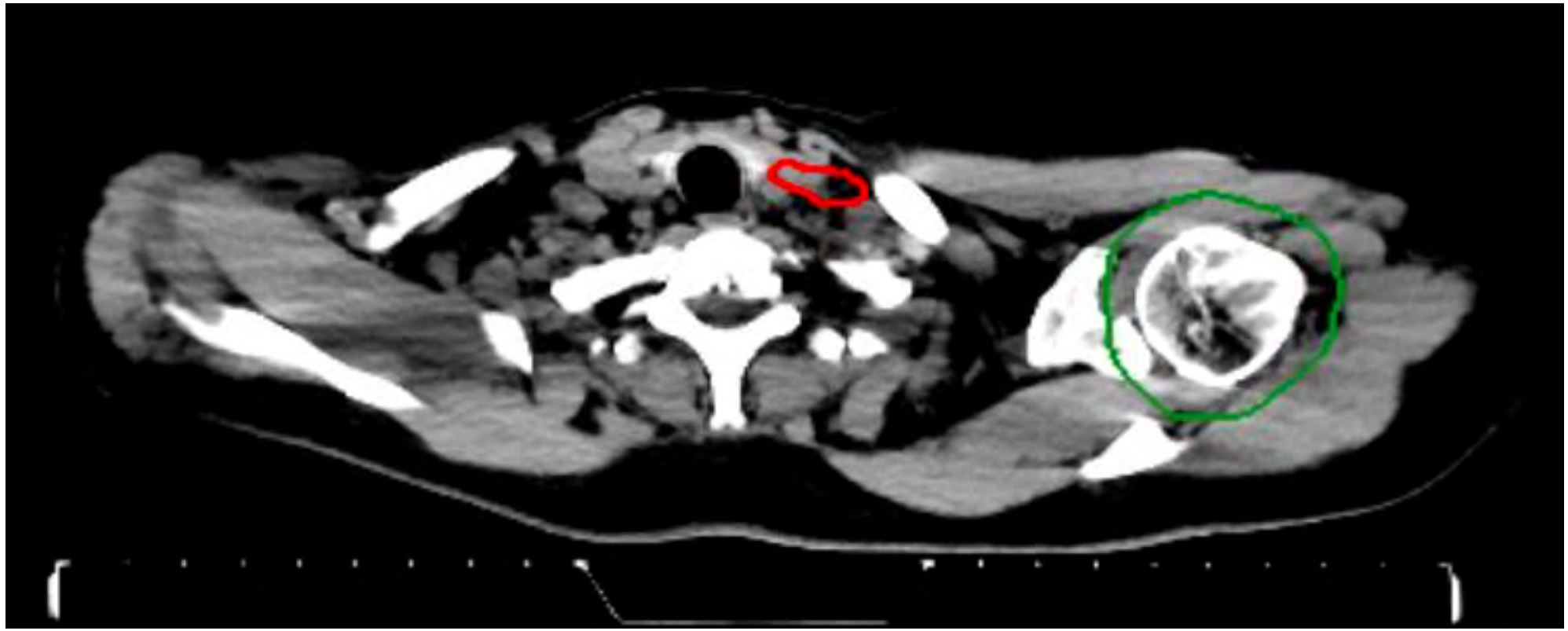


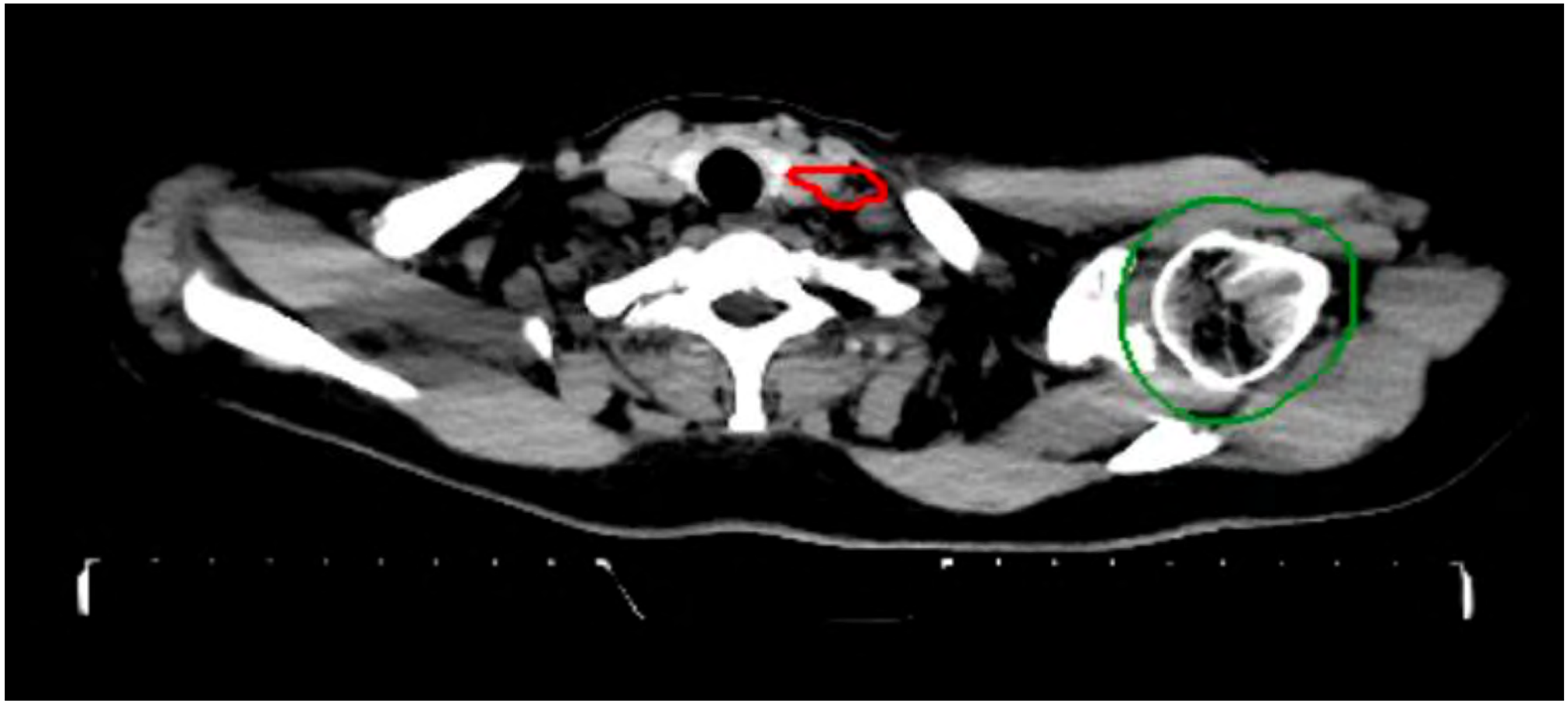


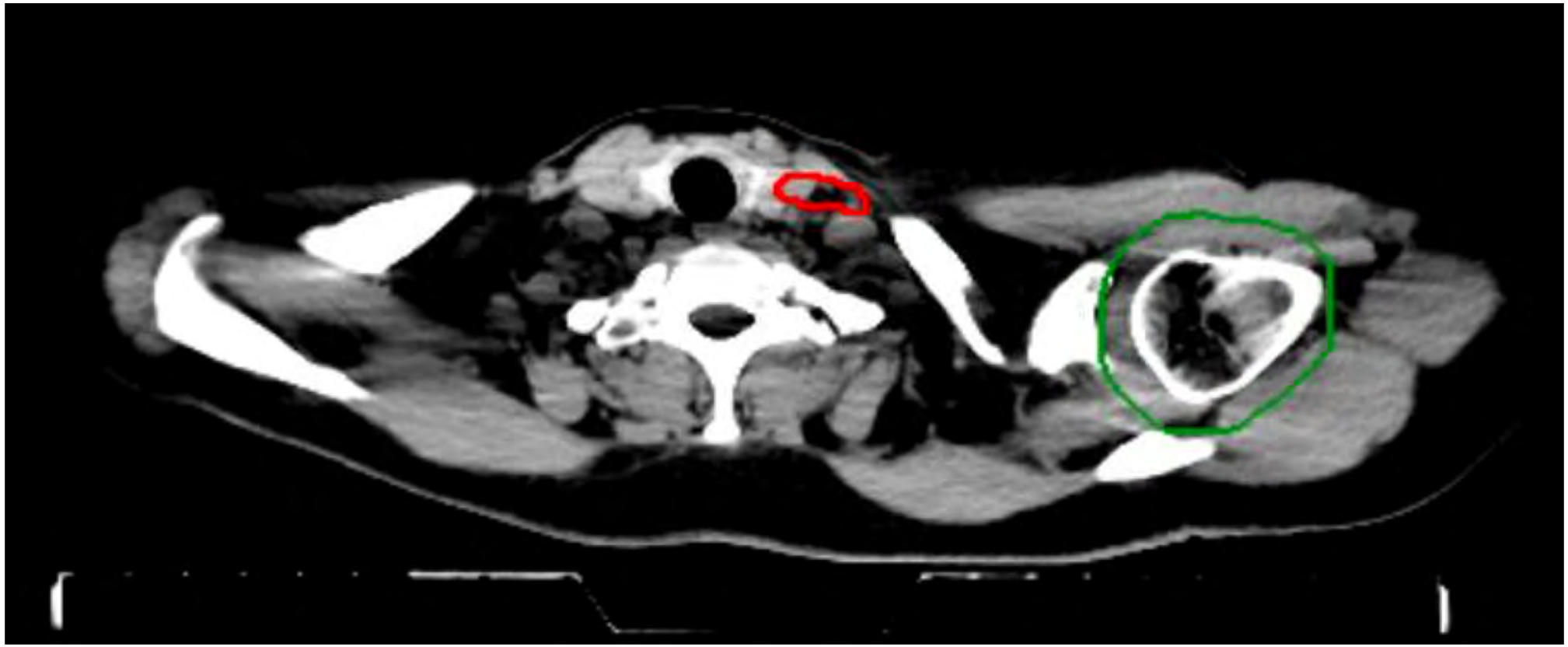


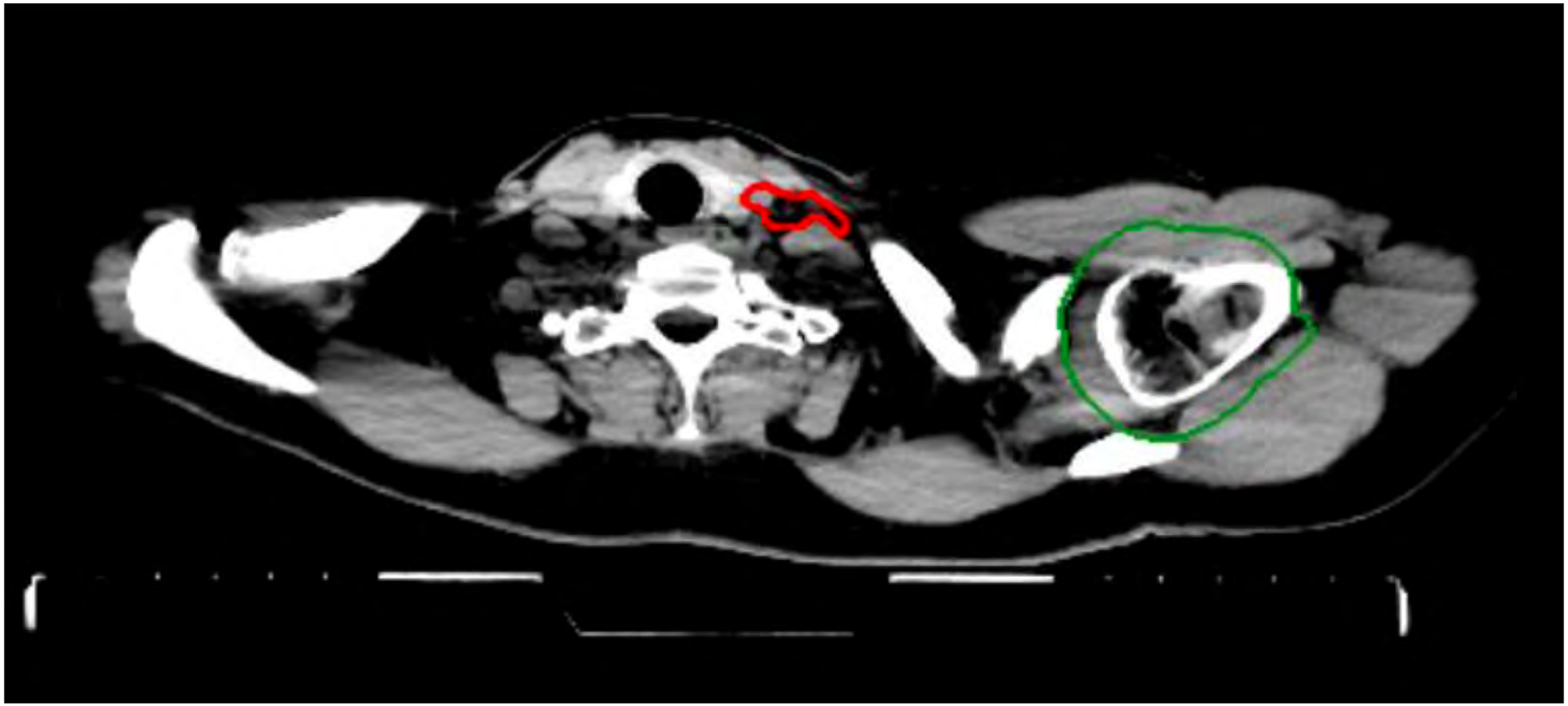

Pectoralis Major m.
Deltoid m.

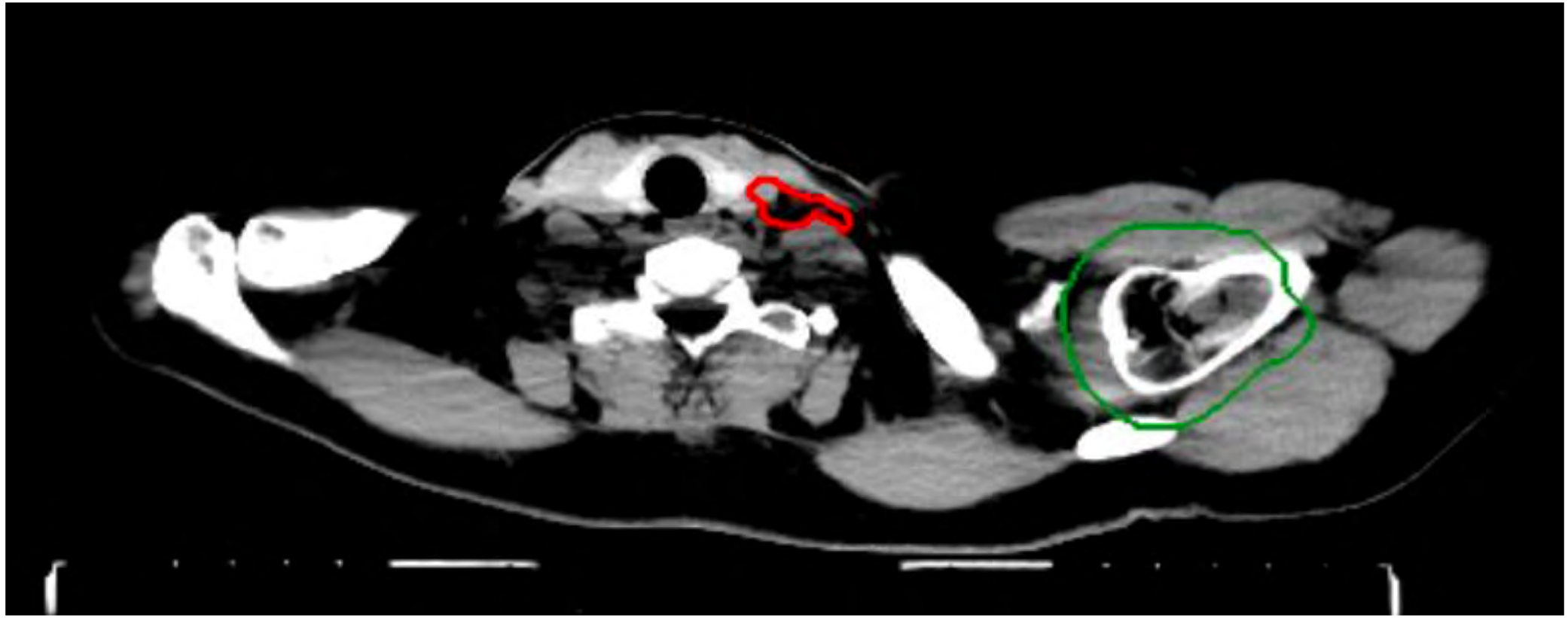


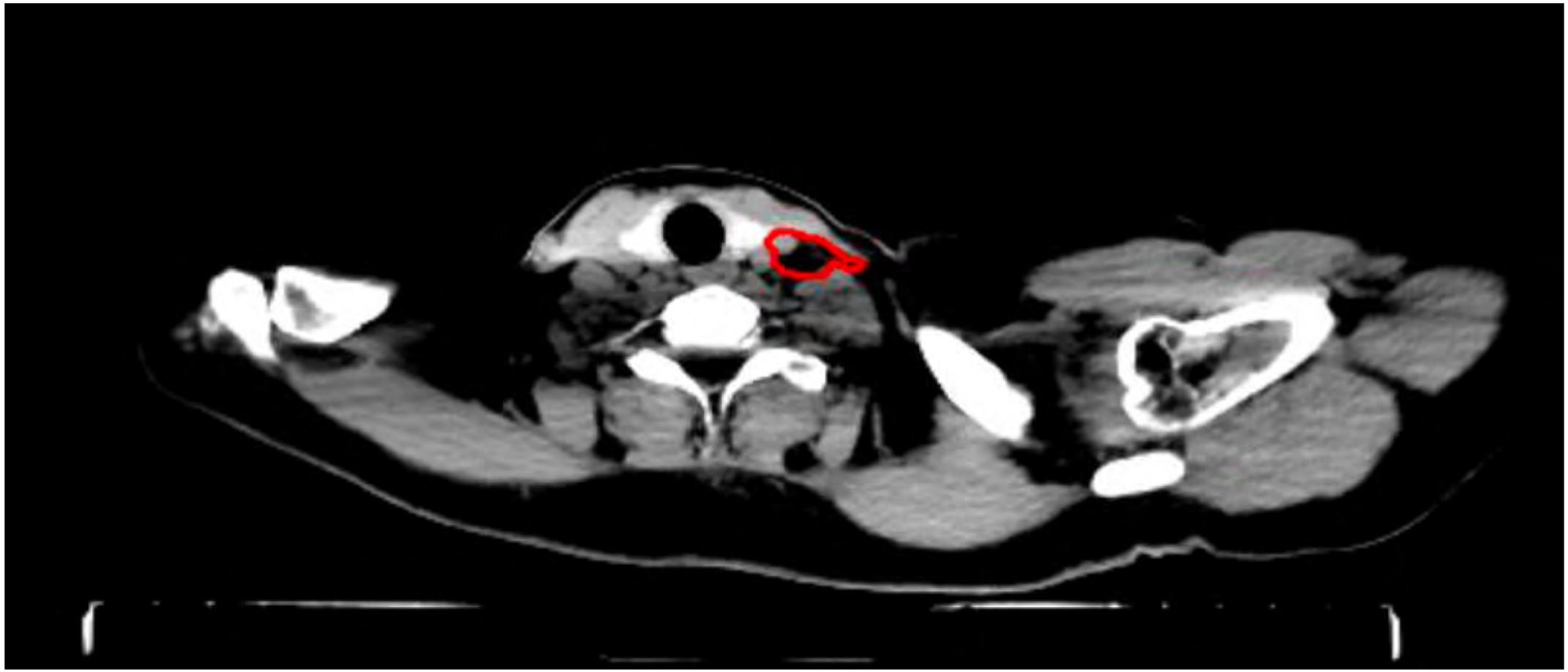


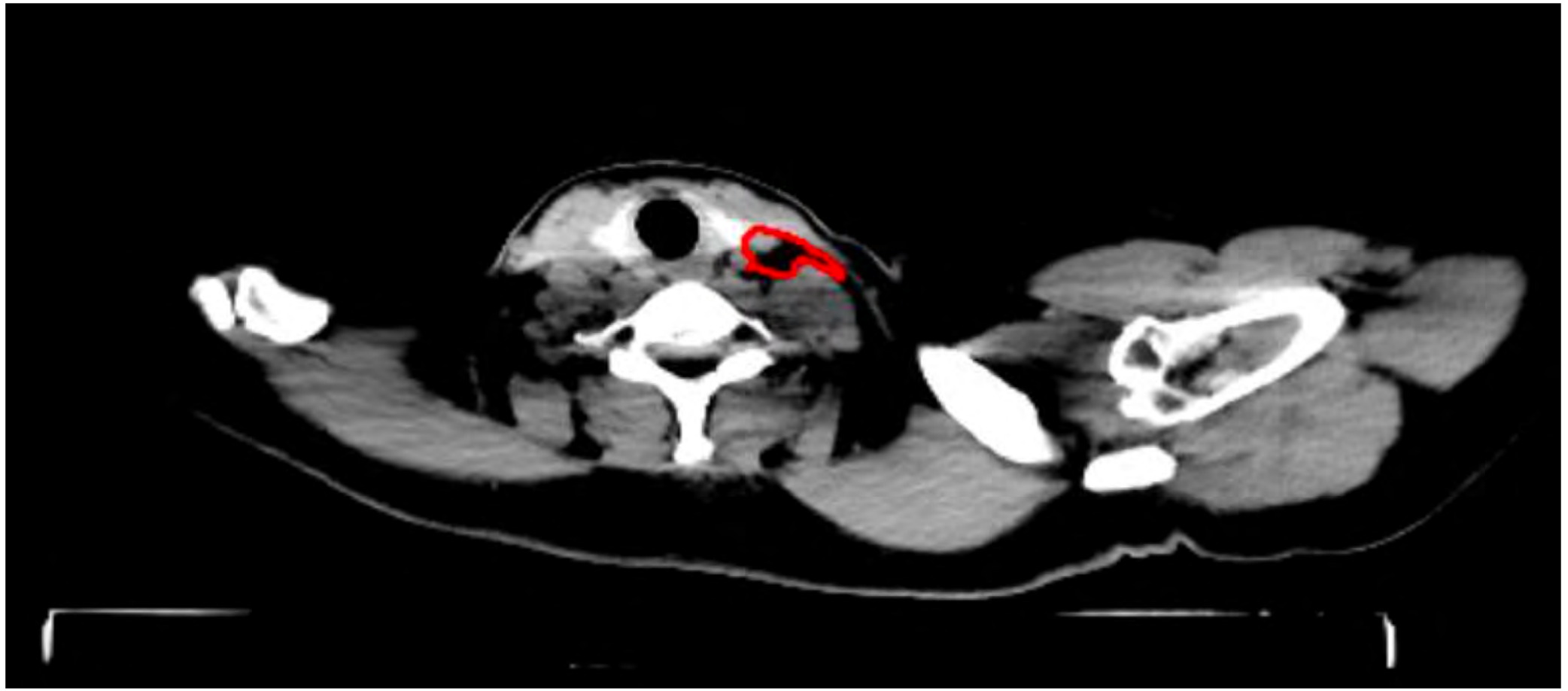


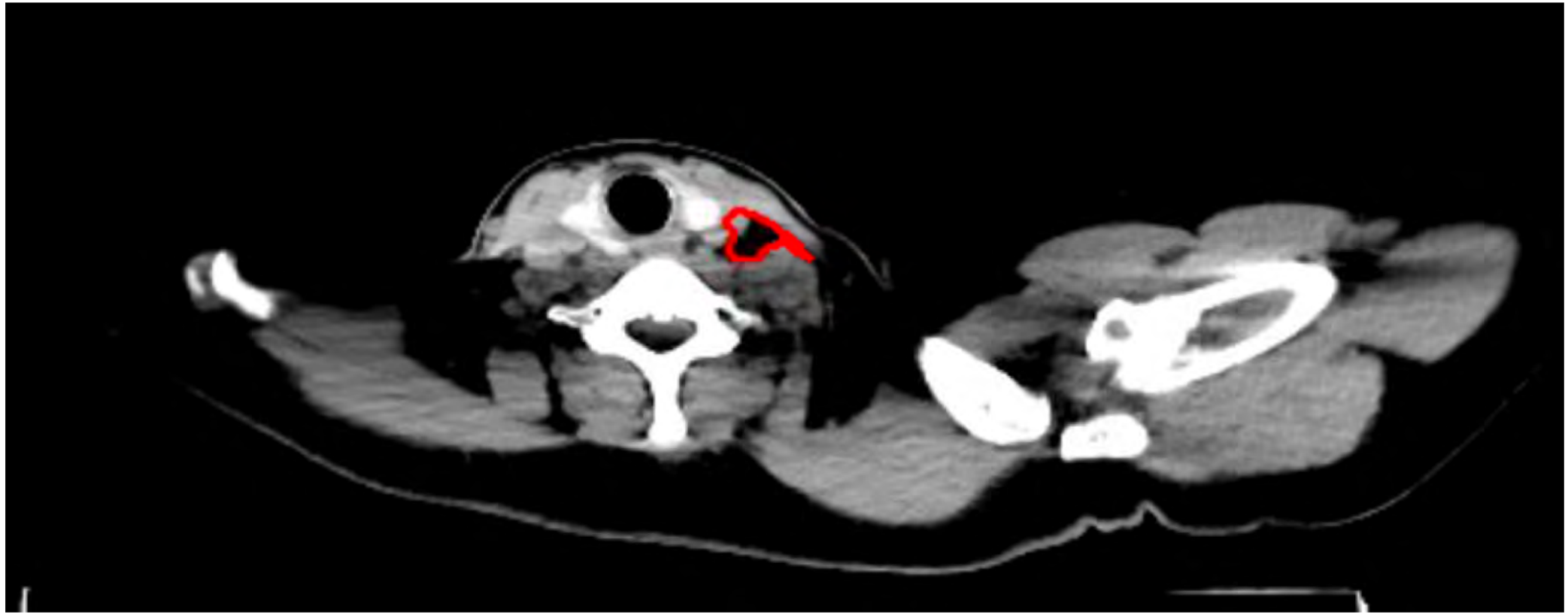


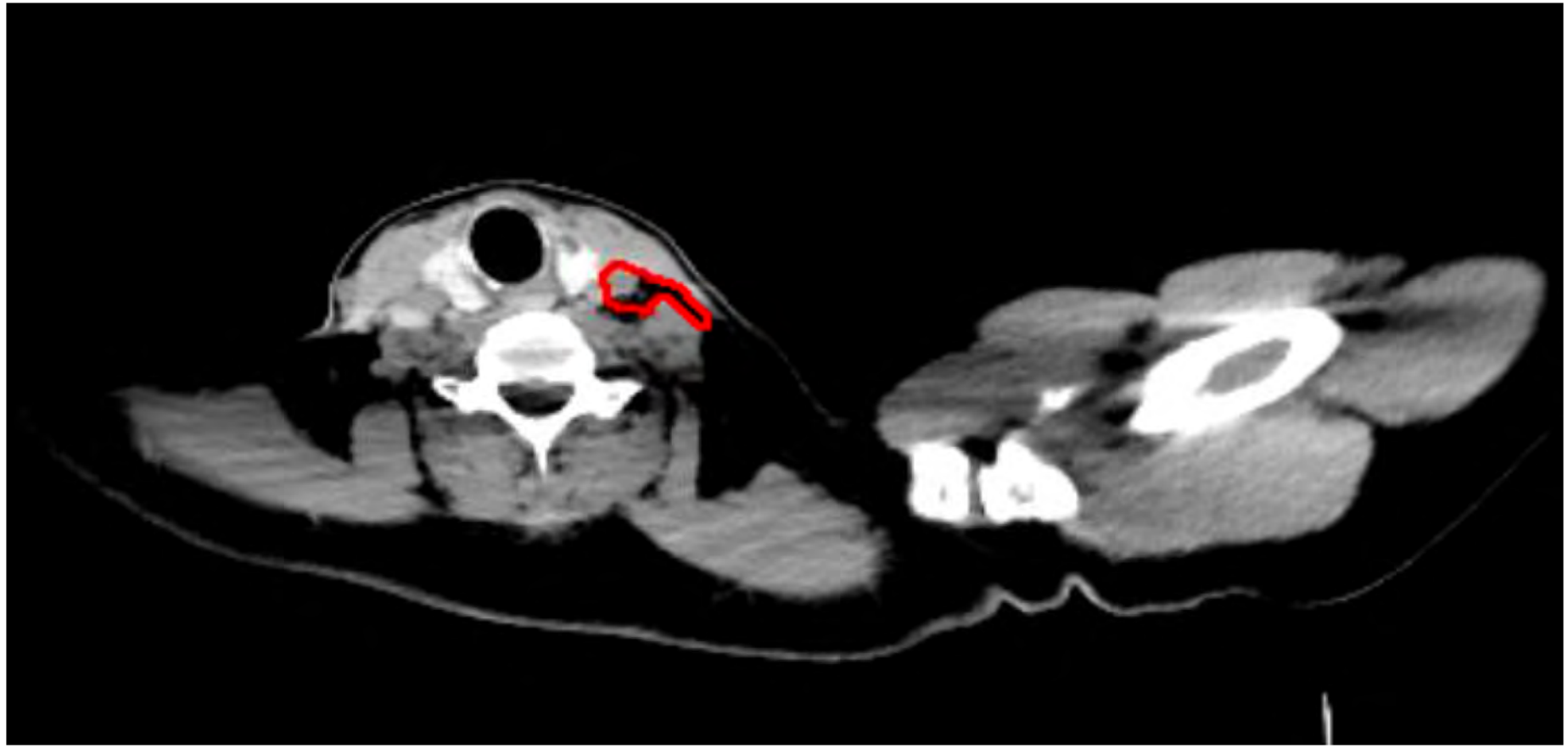


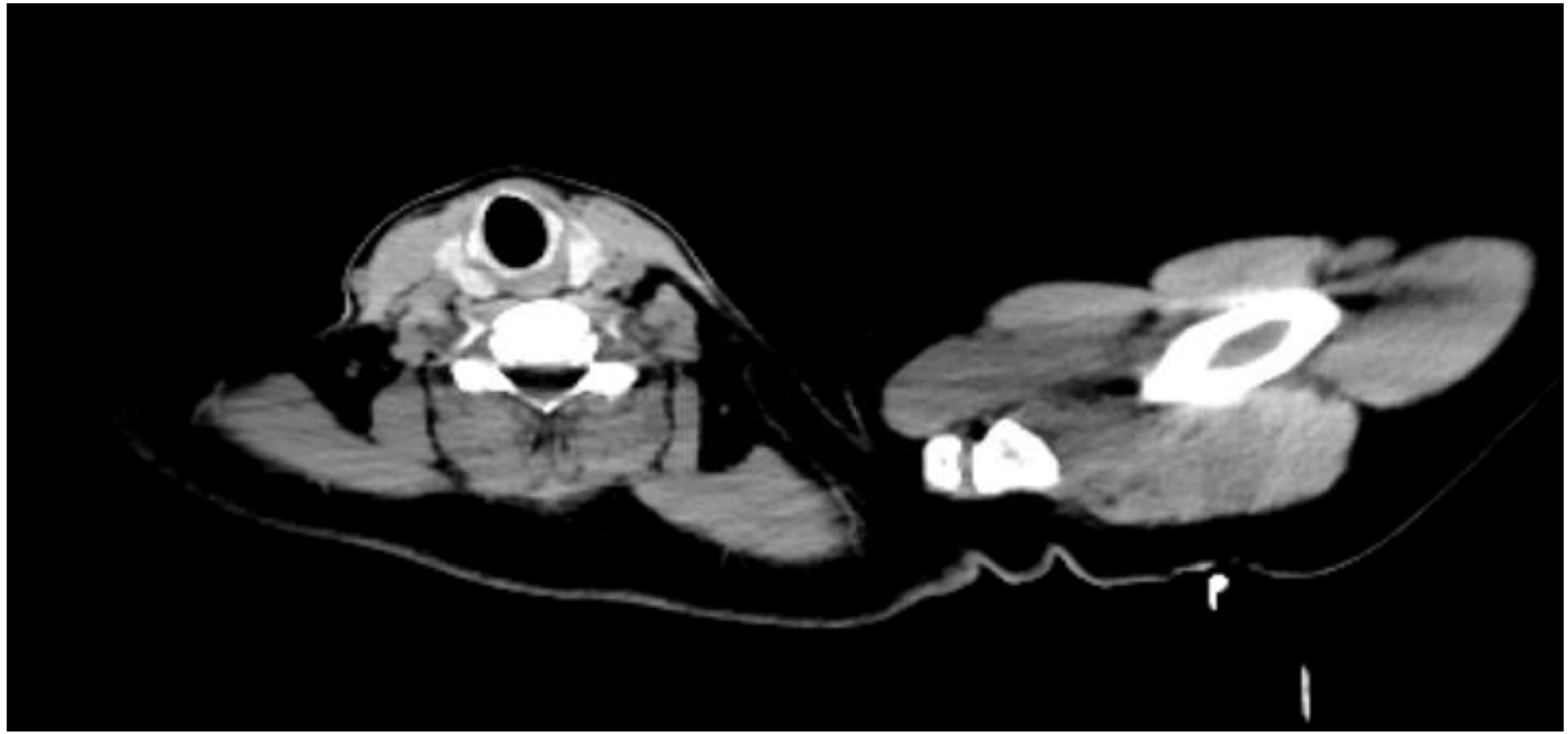






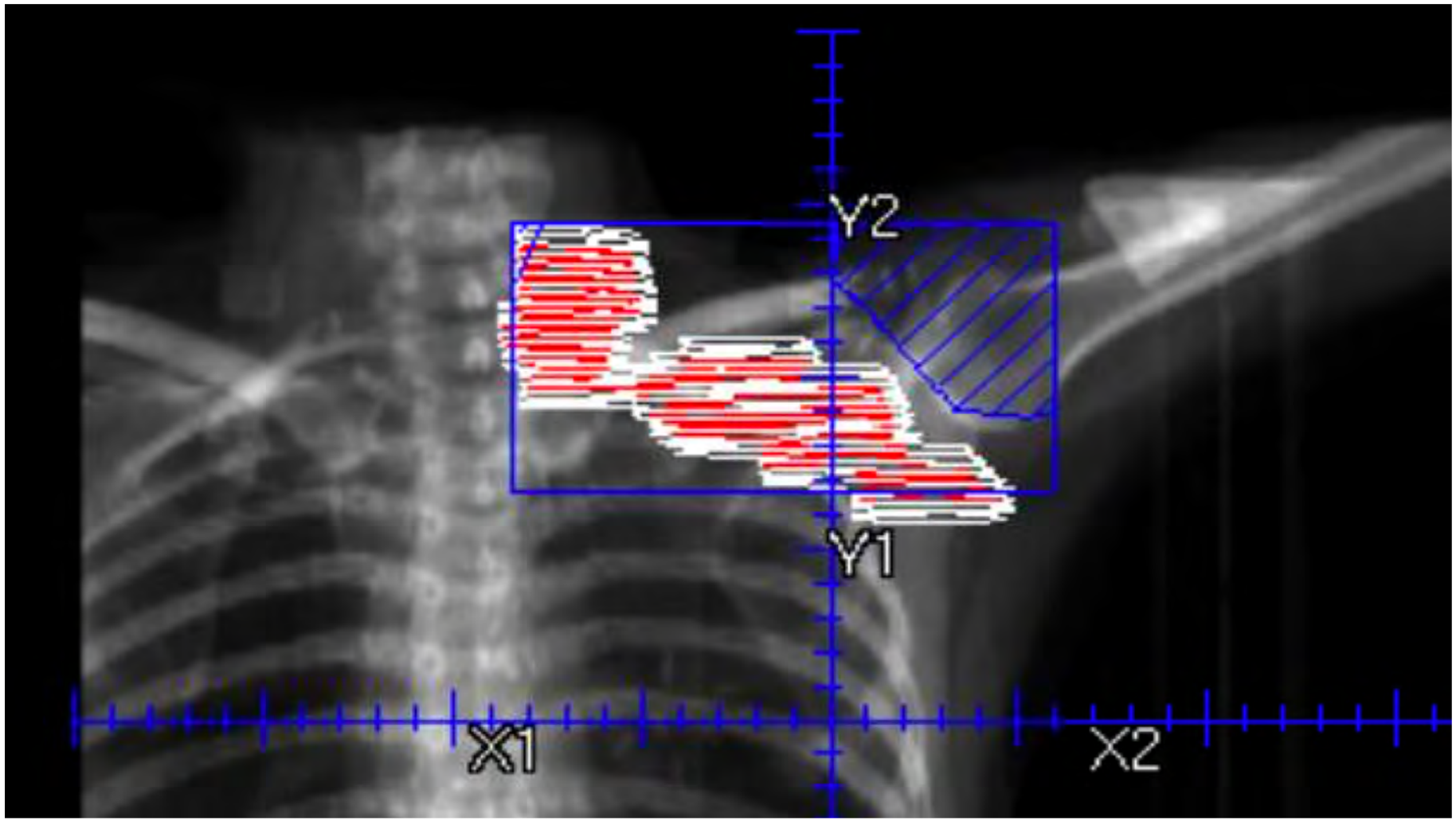






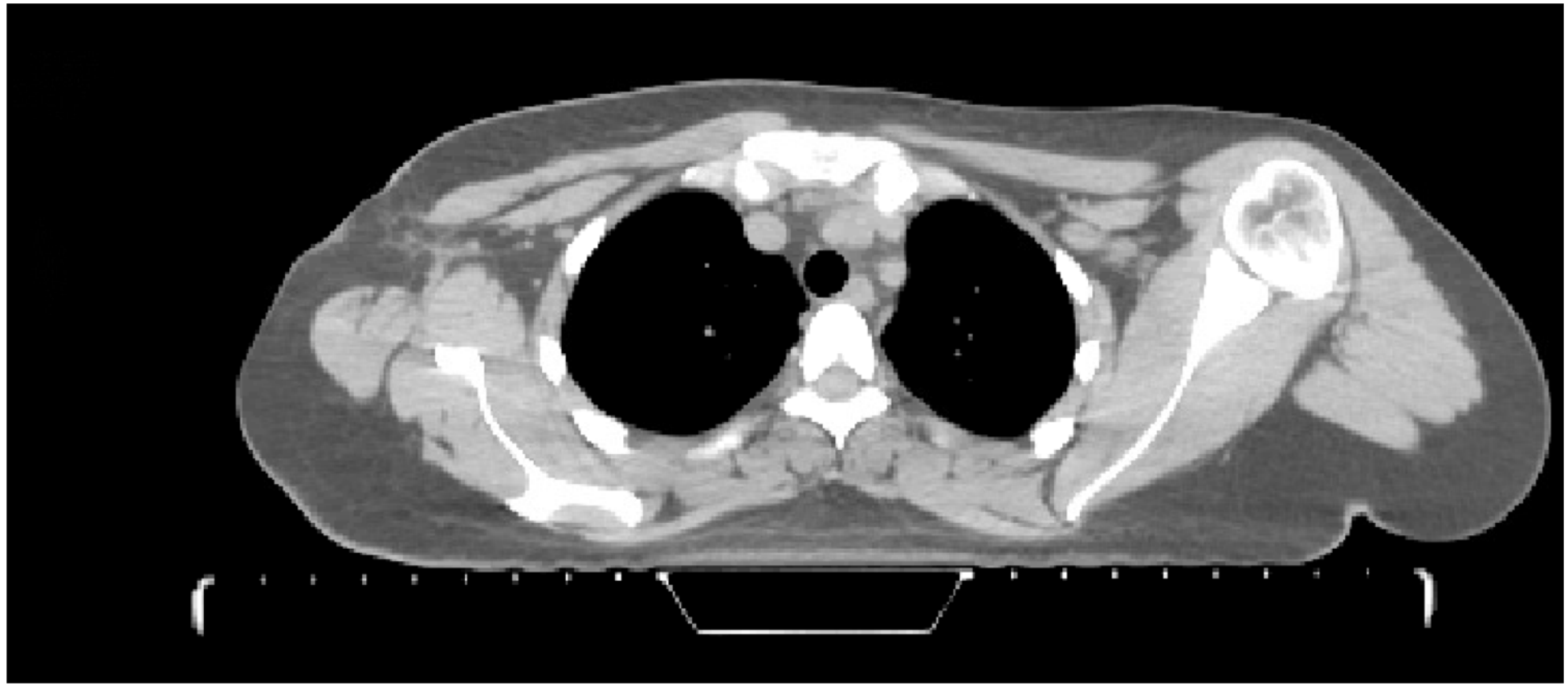
Beam's Eye View of Supraclav Field

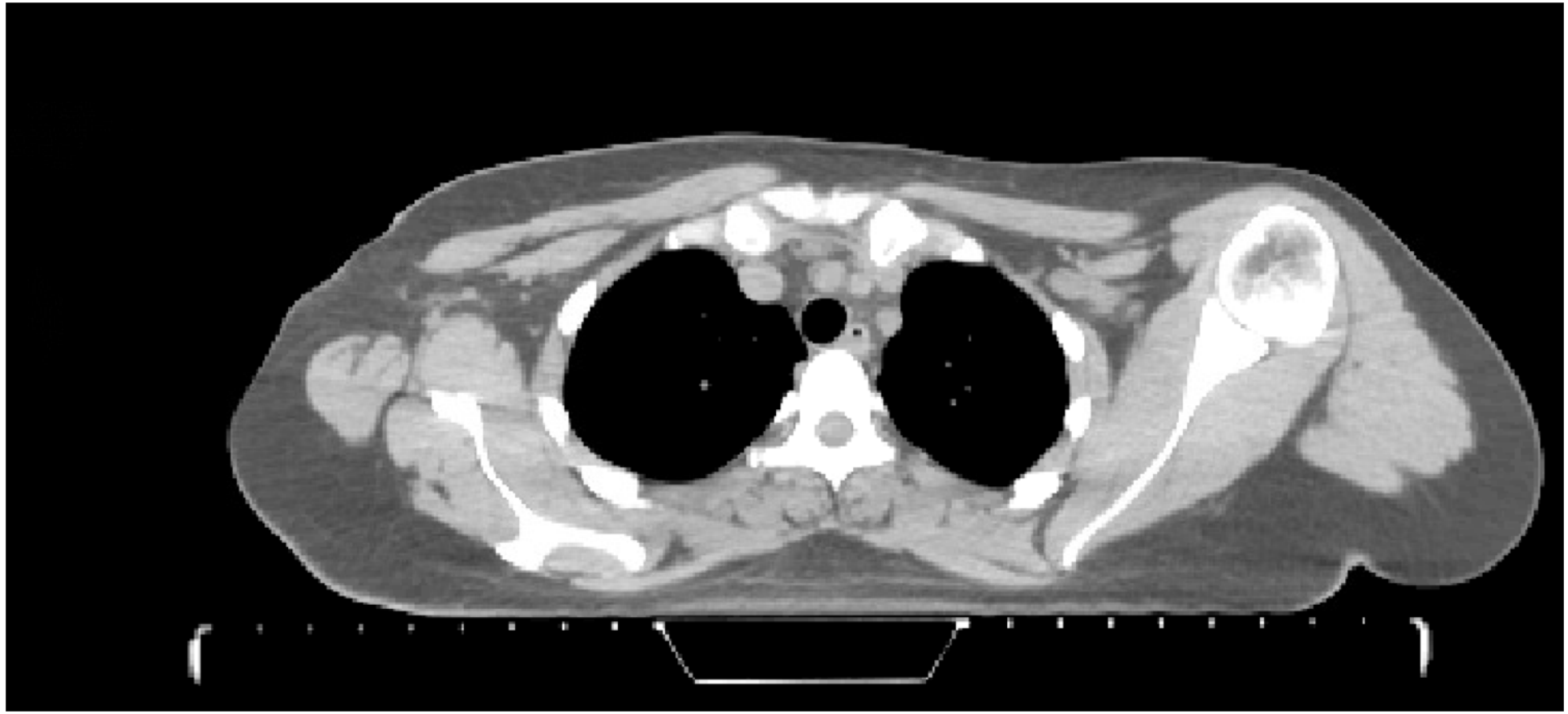
Axillary Level I-III CTV + PTV
Level IV Supraclav CTV + PTV

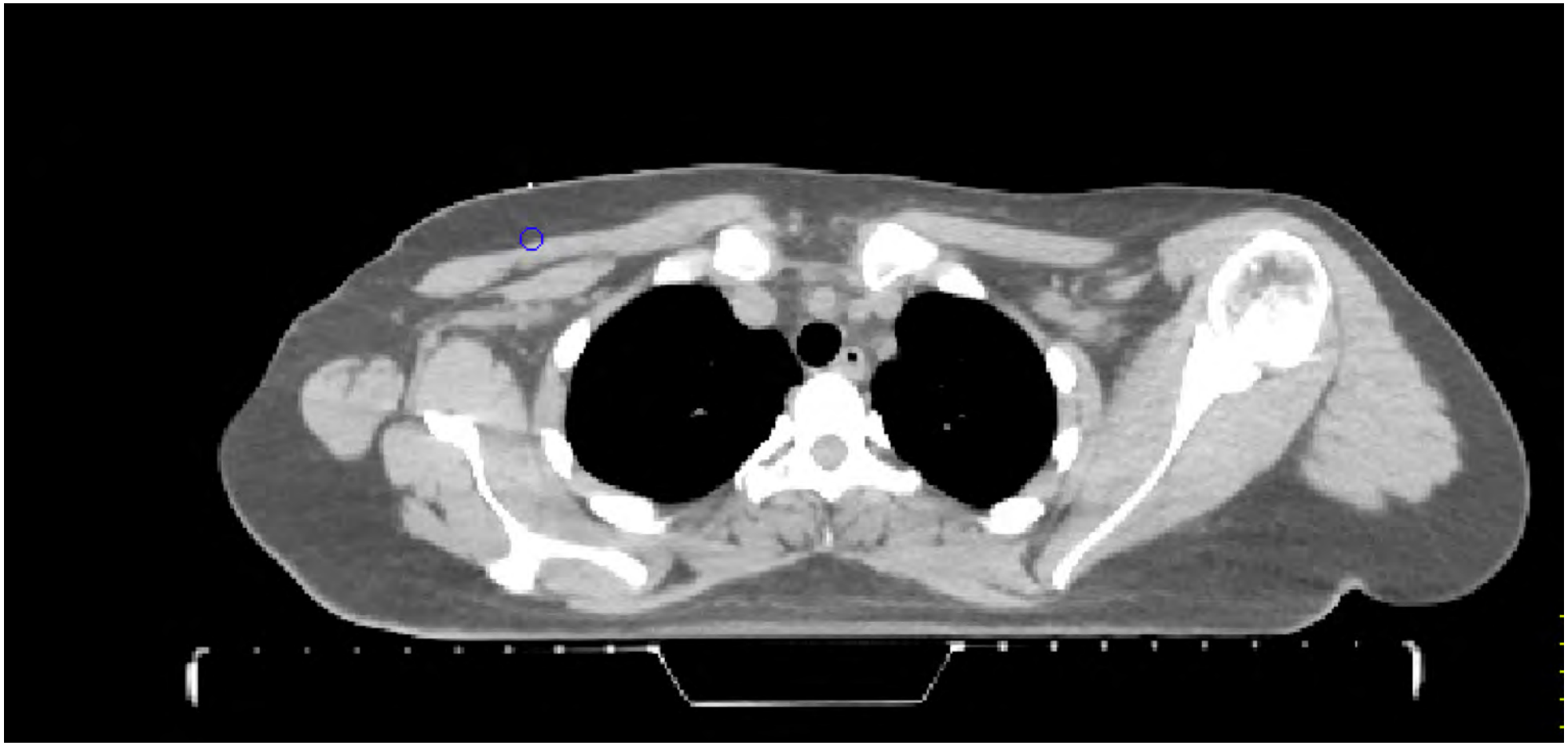


Case 2: Nodal Contouring after Full Axillary Dissection

- 57F Post Lumpectomy + Axillary Lymph Node Dissection
- Pathology: 1.7cm grade II IDC, No LVI,
- 1/16 nodes involved with 4mm macromet, no ENE
- ER90% PR70% Her2(-)
- margins widely clear



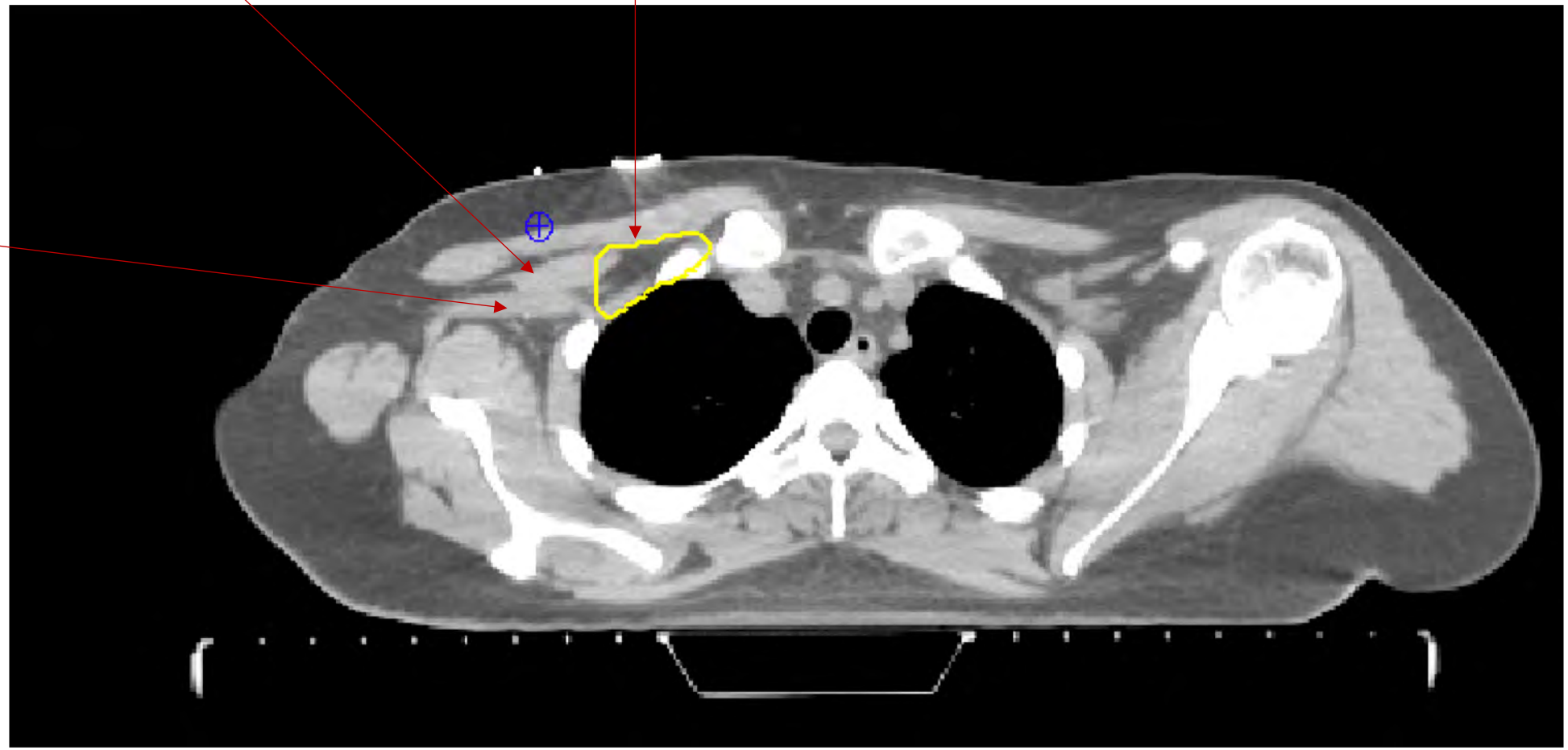


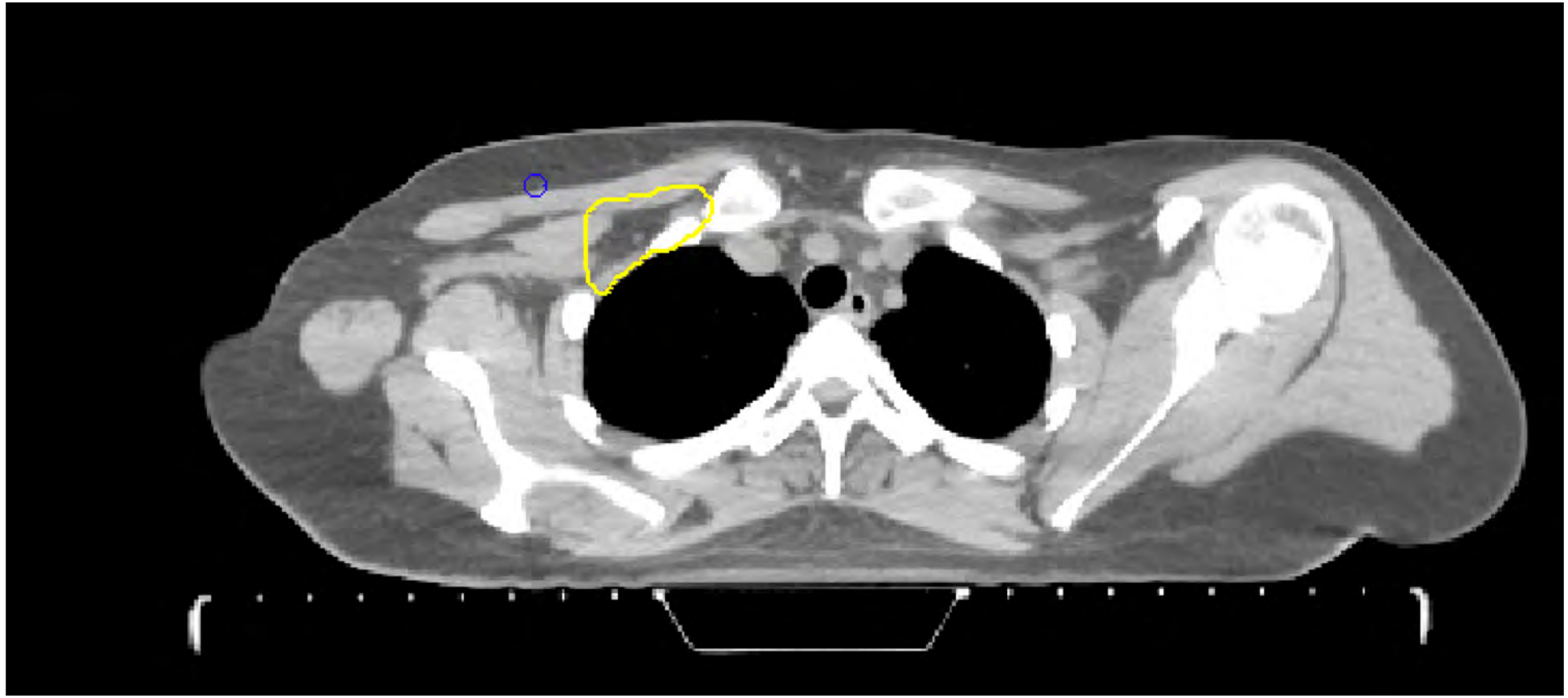


Pectoralis Minor m.

Axillary PTV (5mm)
Level III Axilla

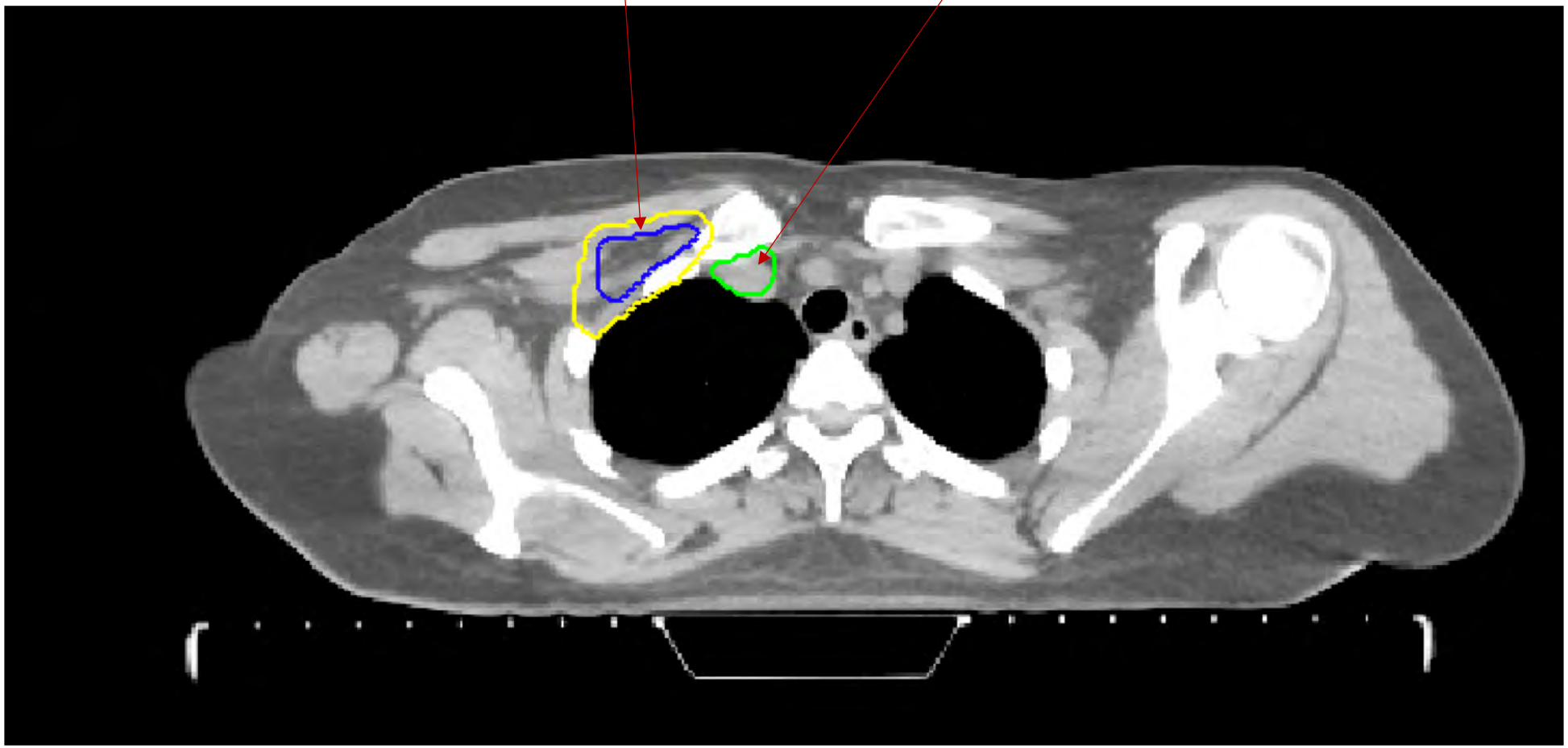
Axillary
Vessels

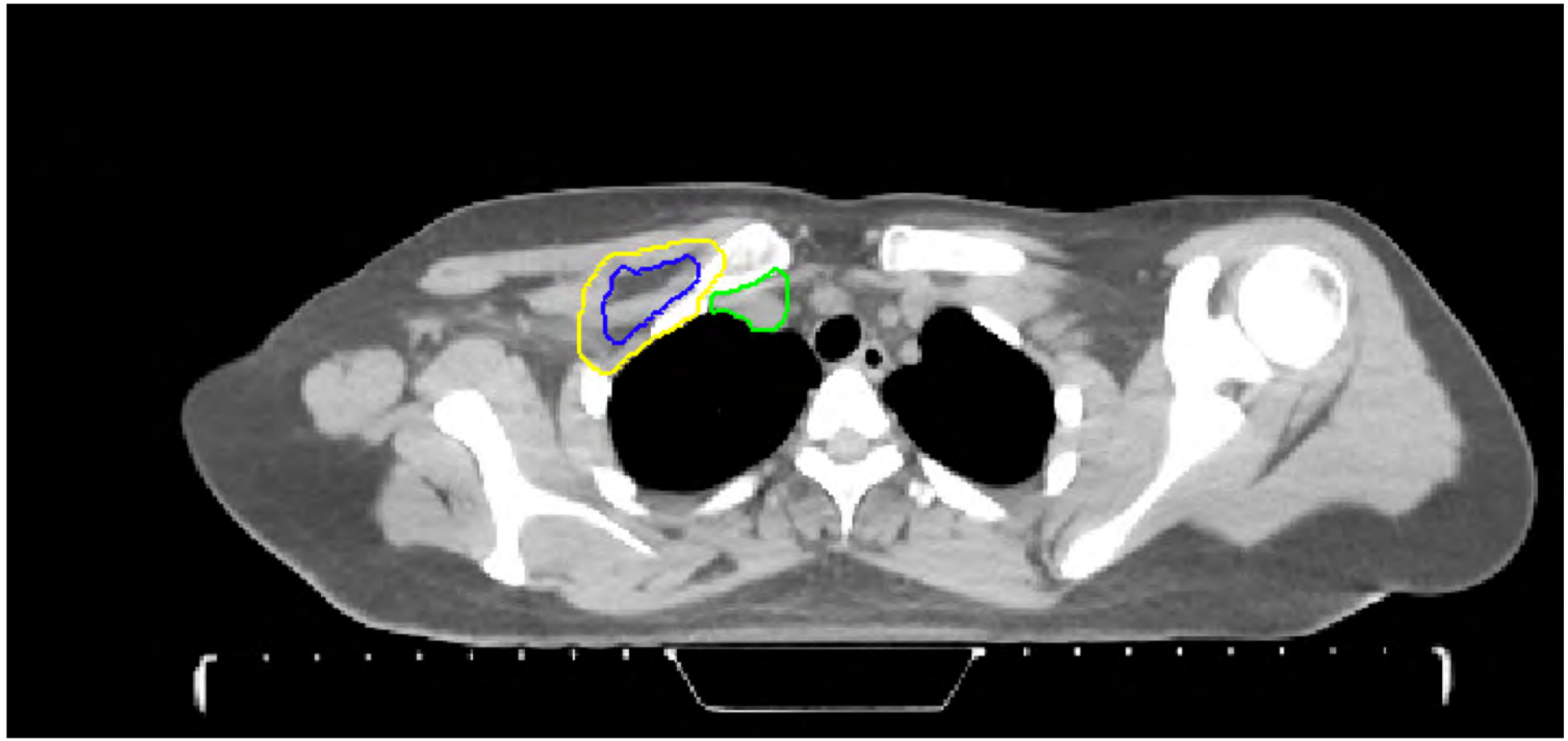




Axillary Level III CTV and PTV

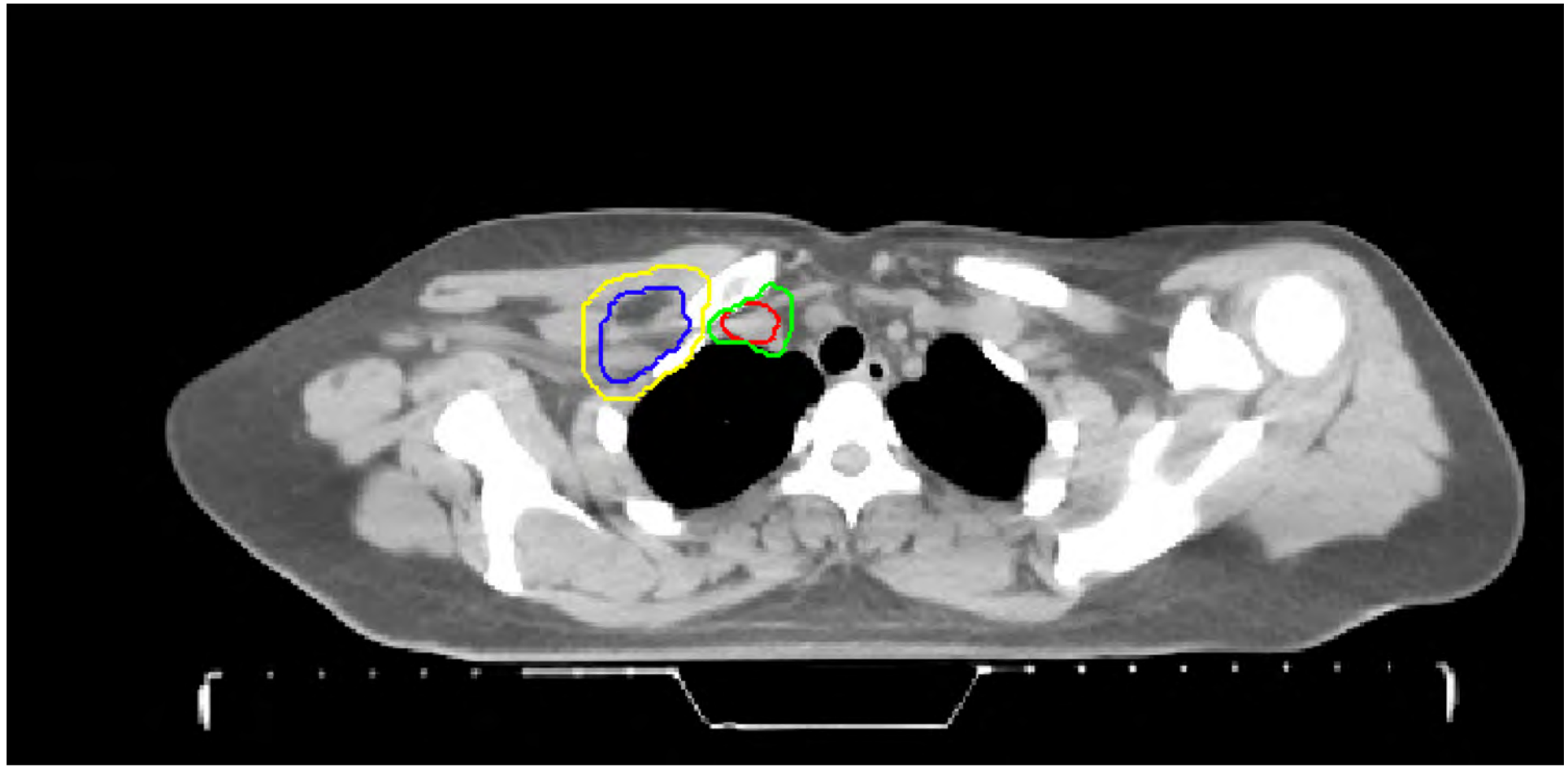
Sclav PTV (5mm)
Level IV Supraclav

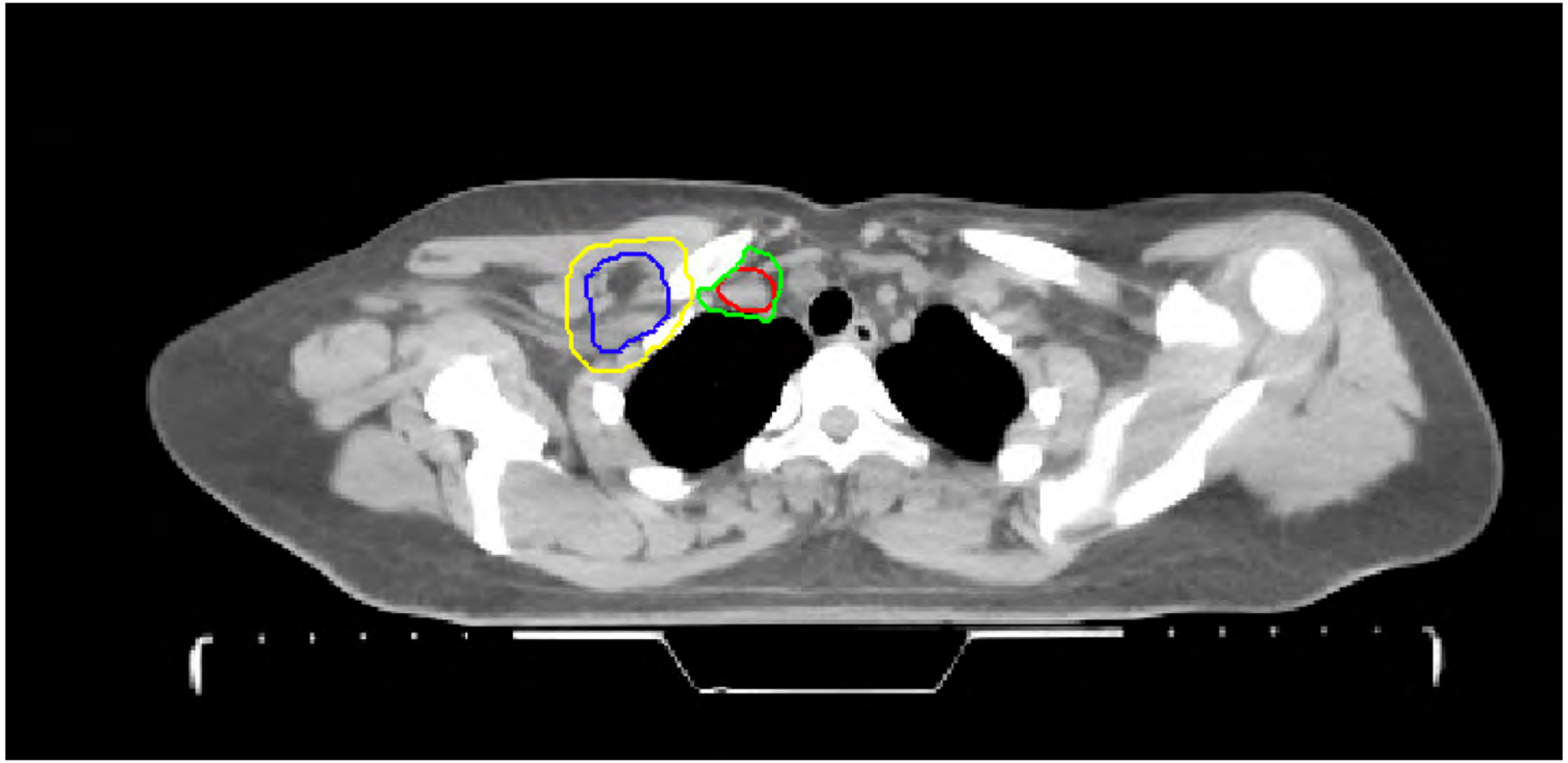


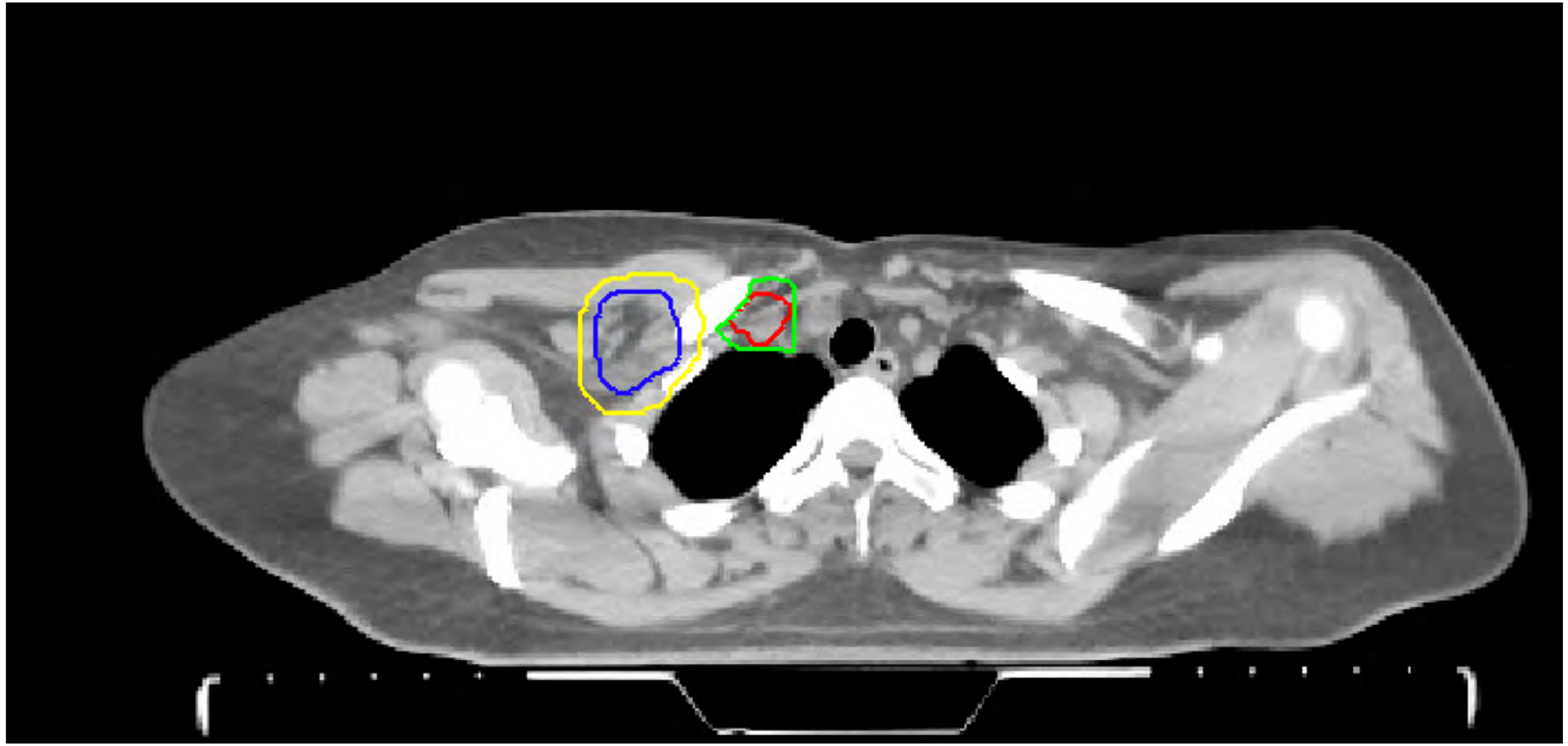


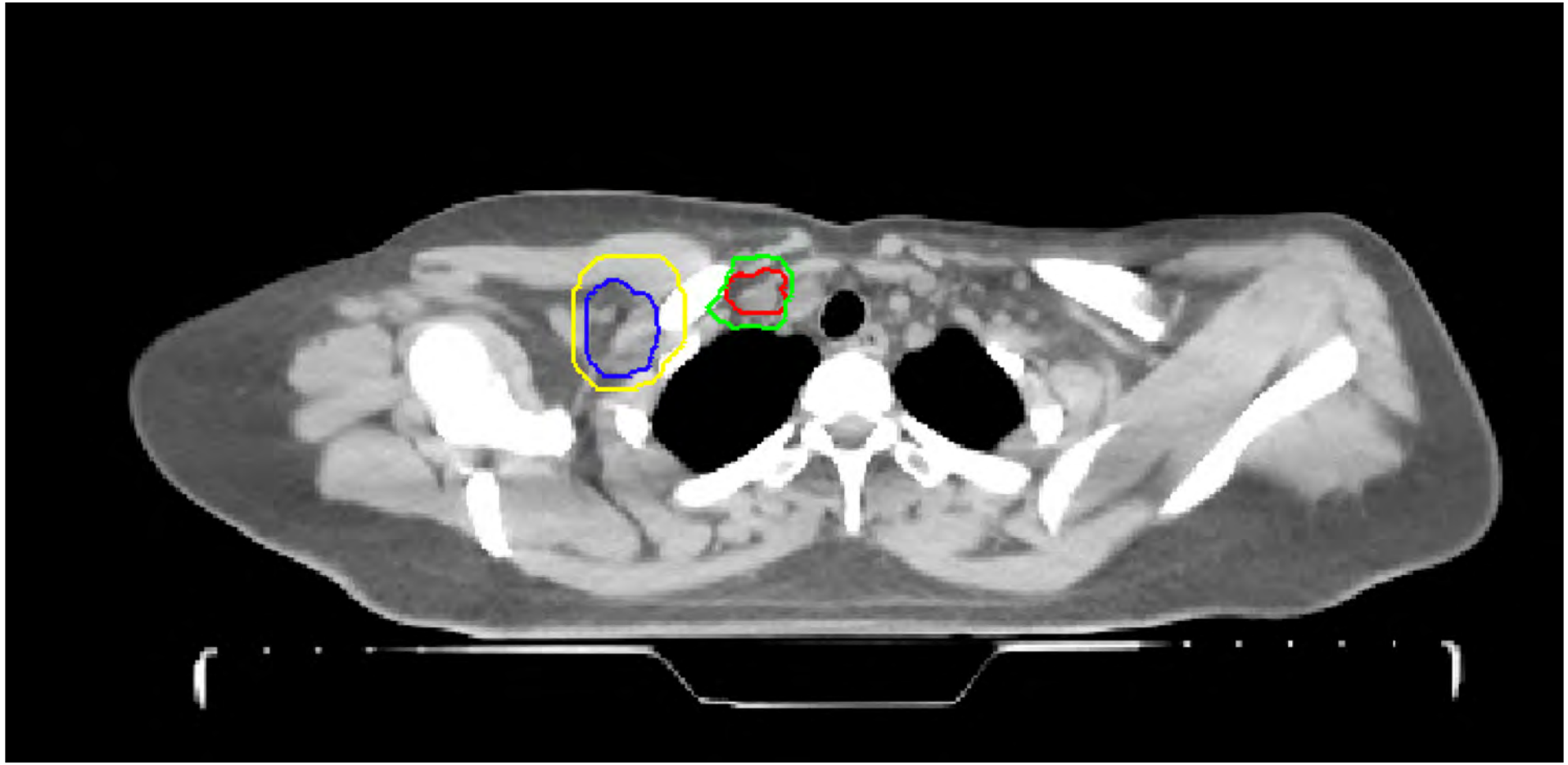
Axillary Level III CTV+ PTV

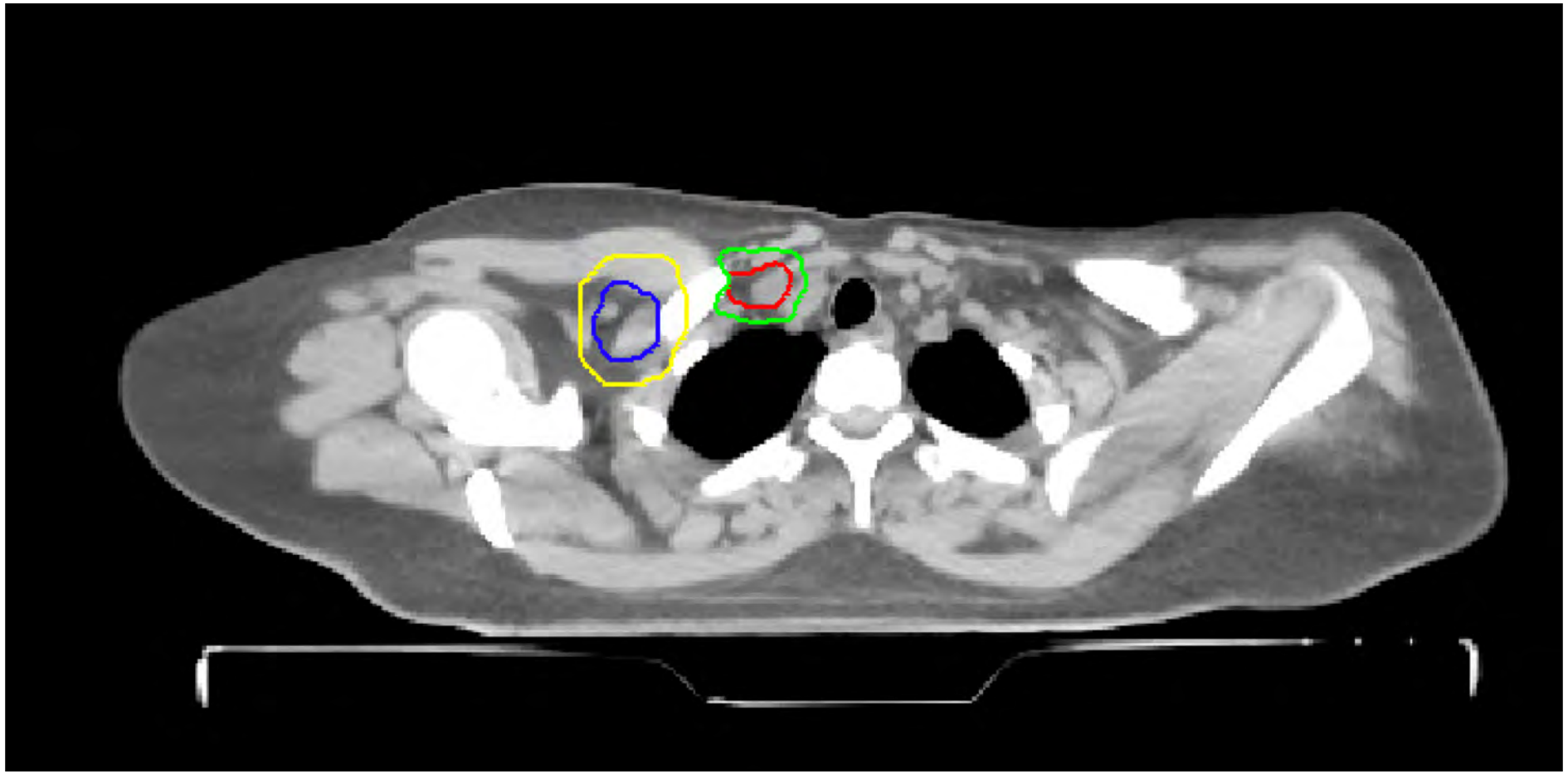
Sclav CTV + PTV

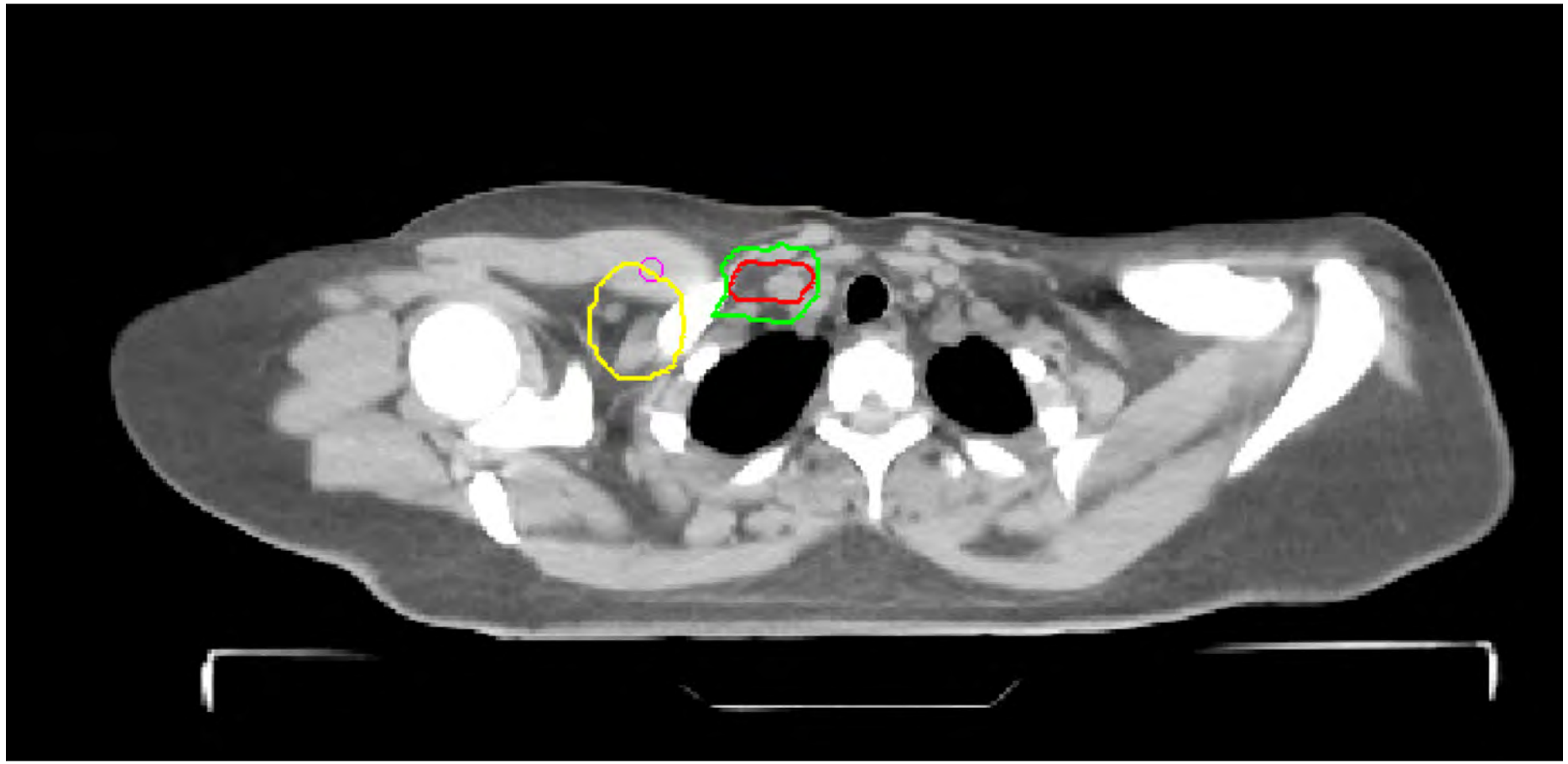


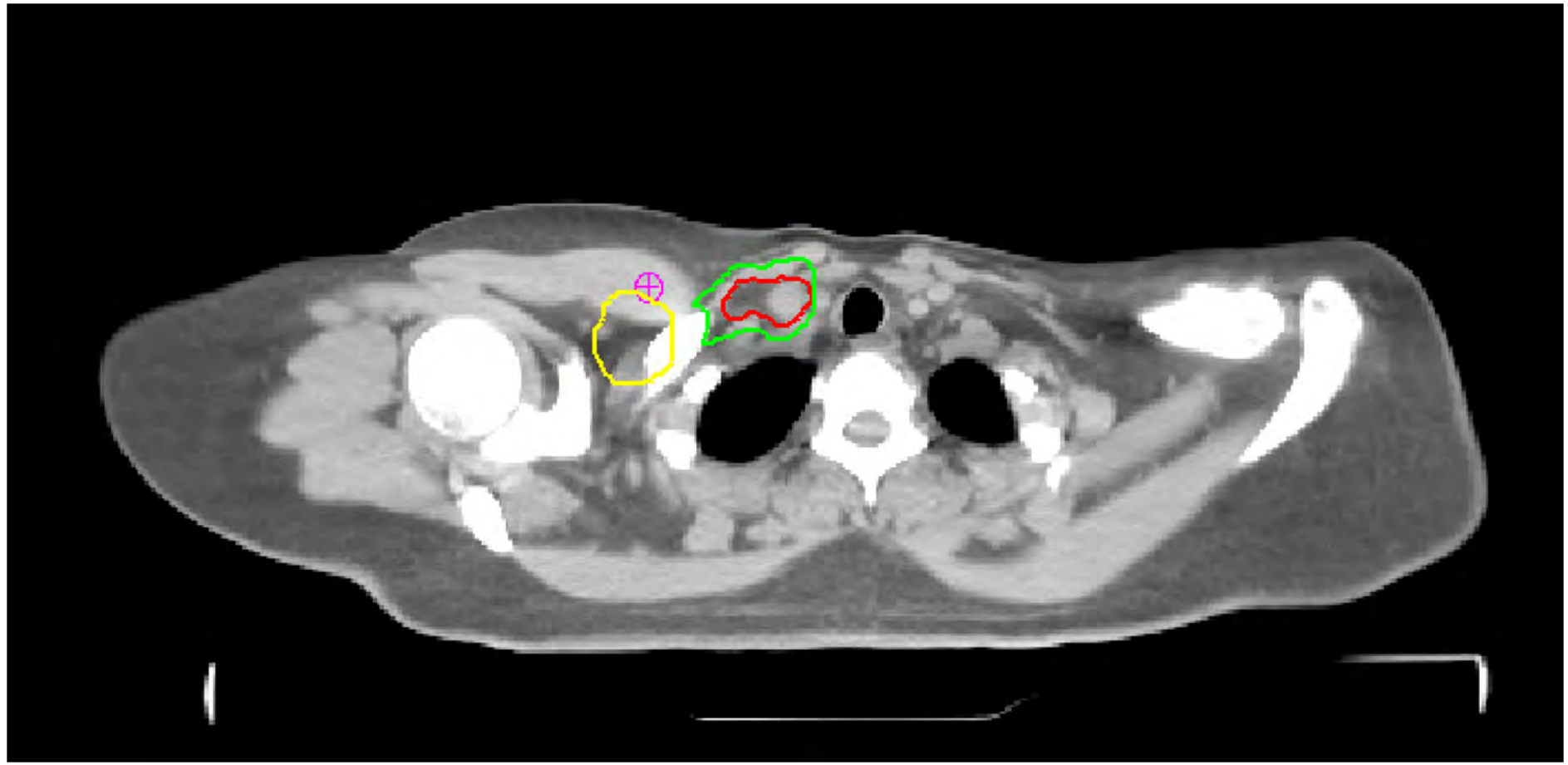


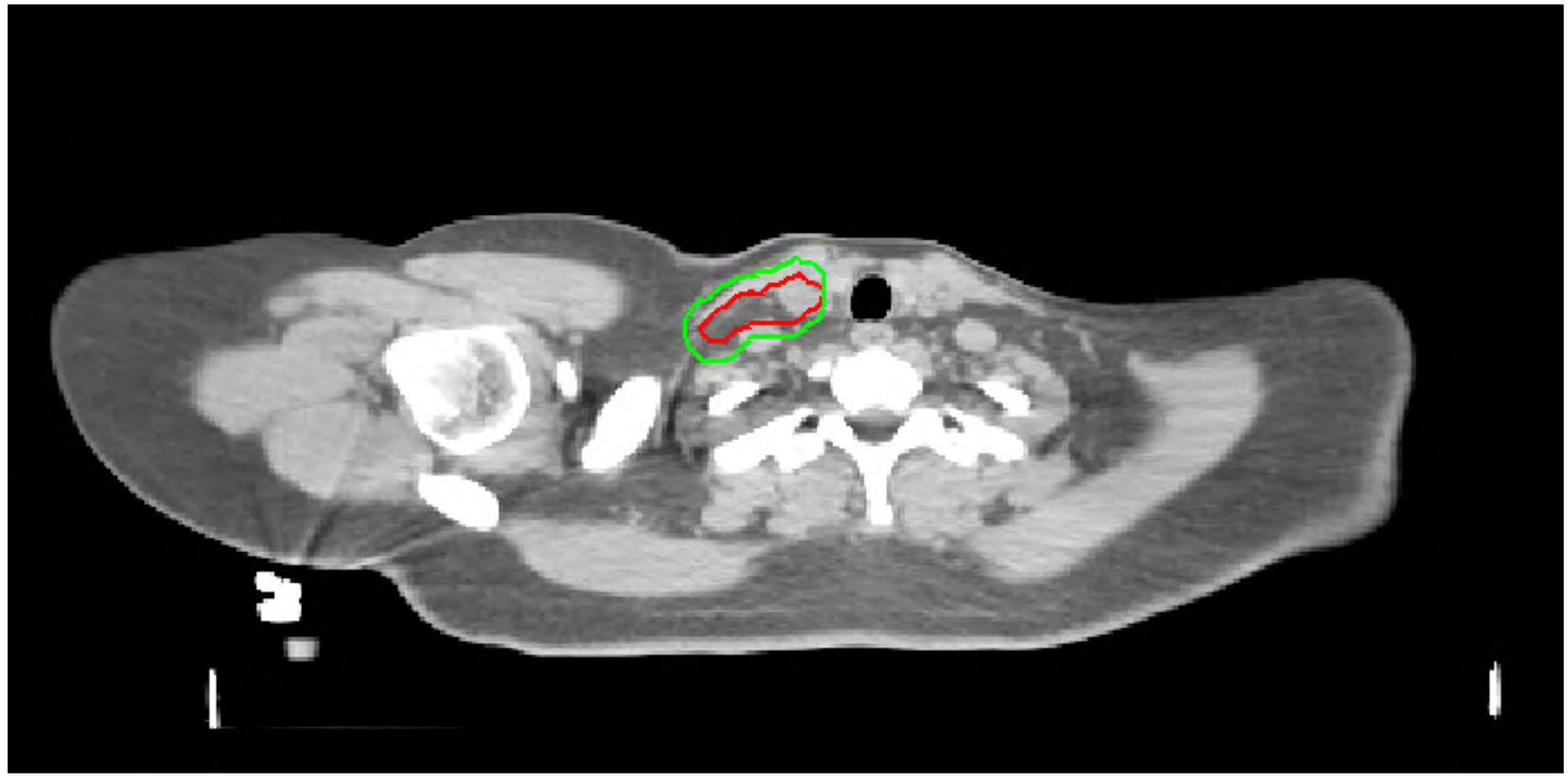


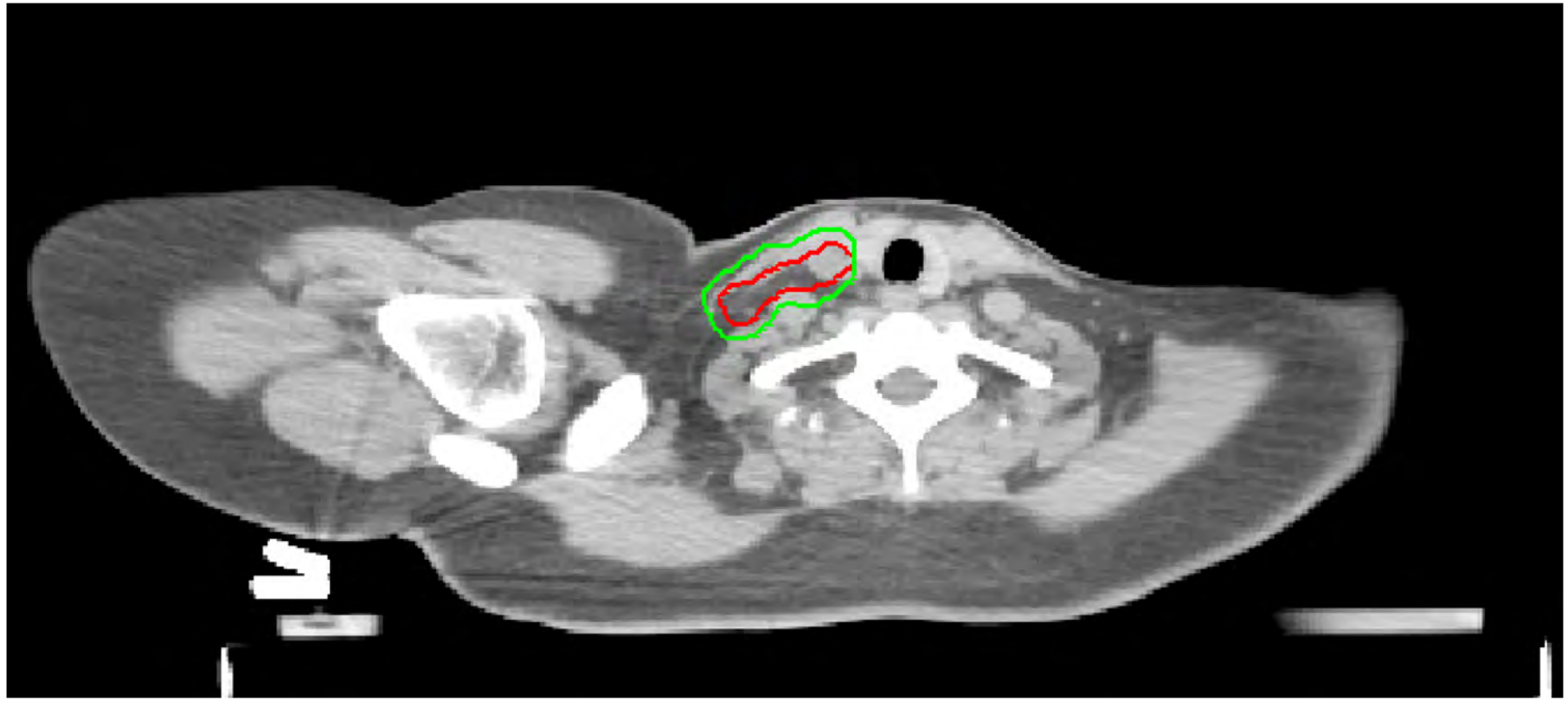


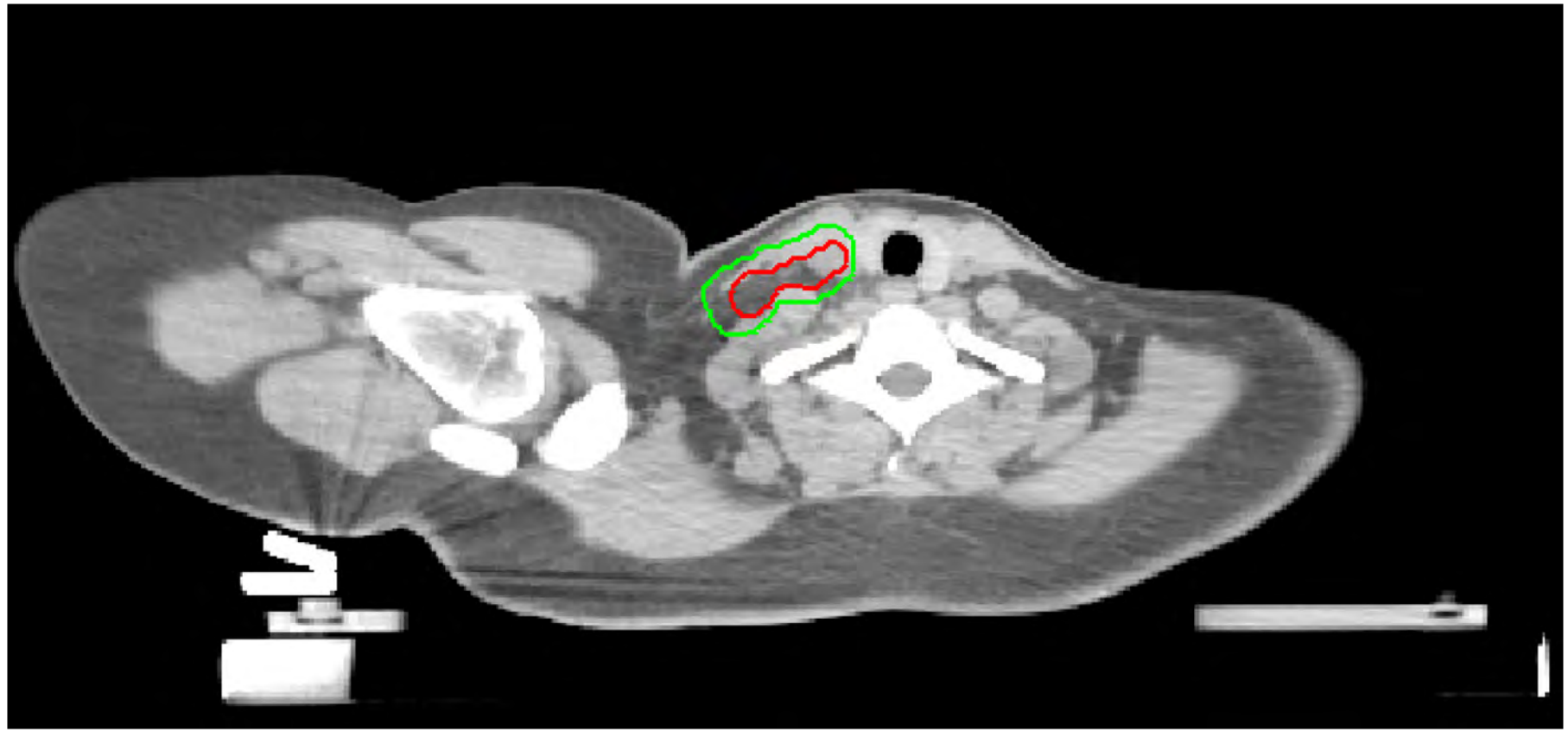


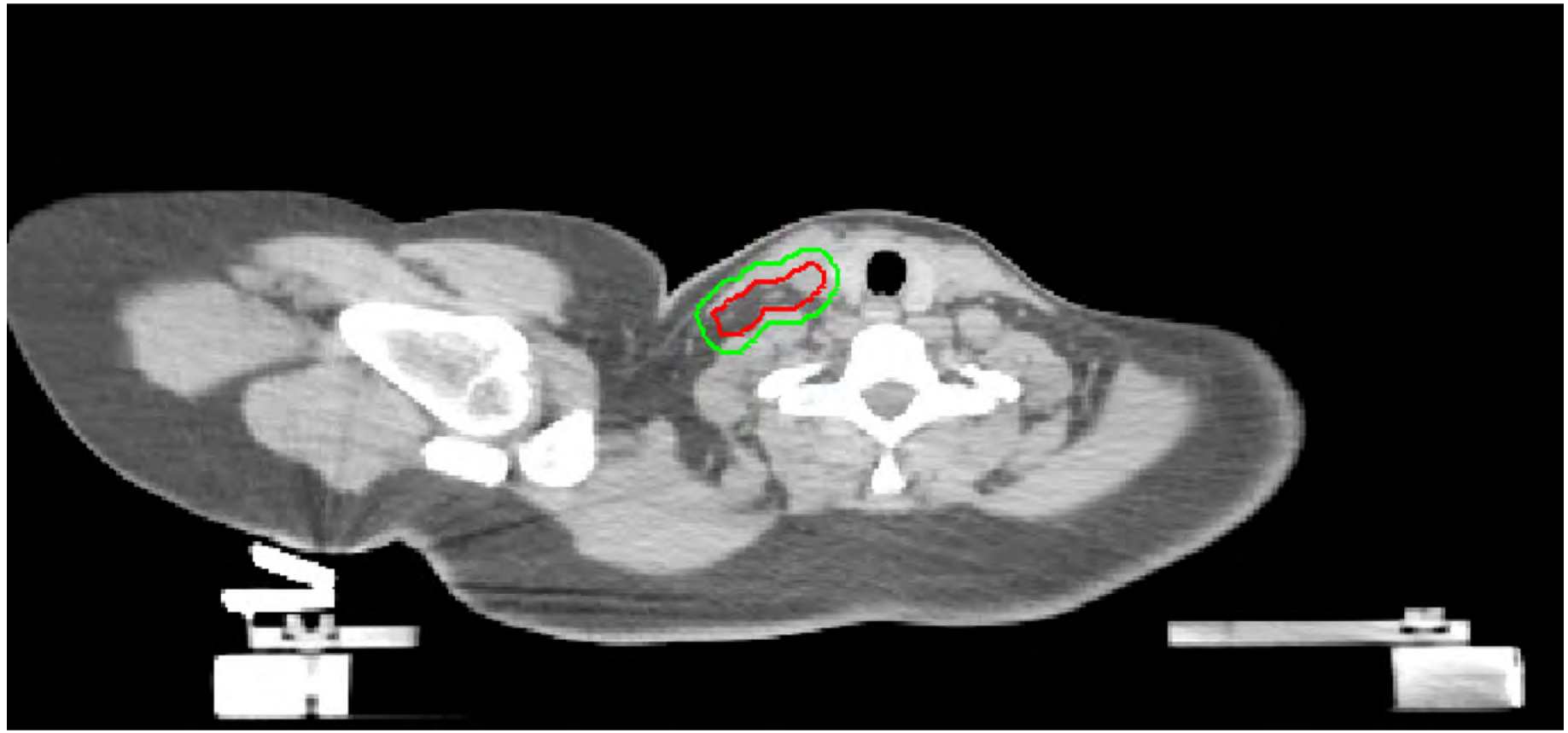


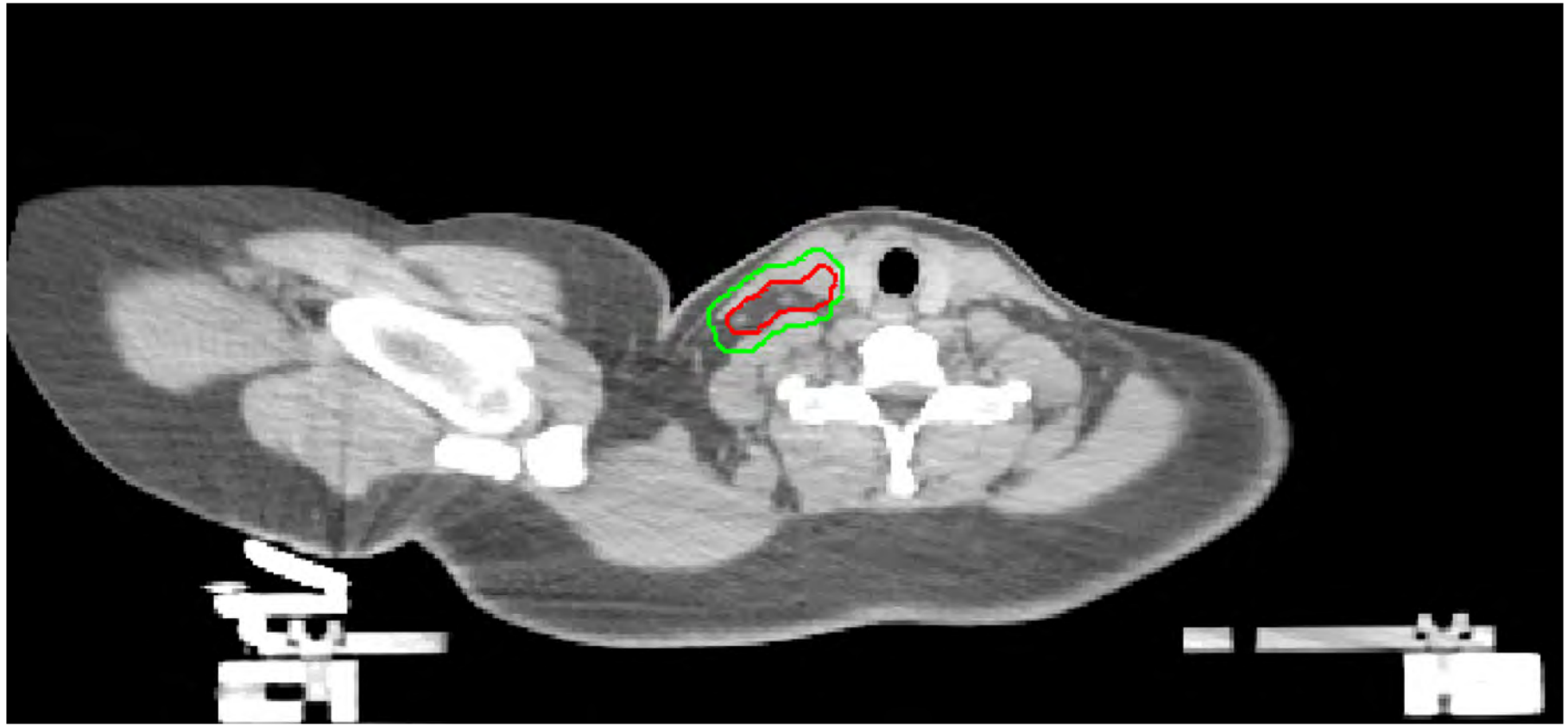


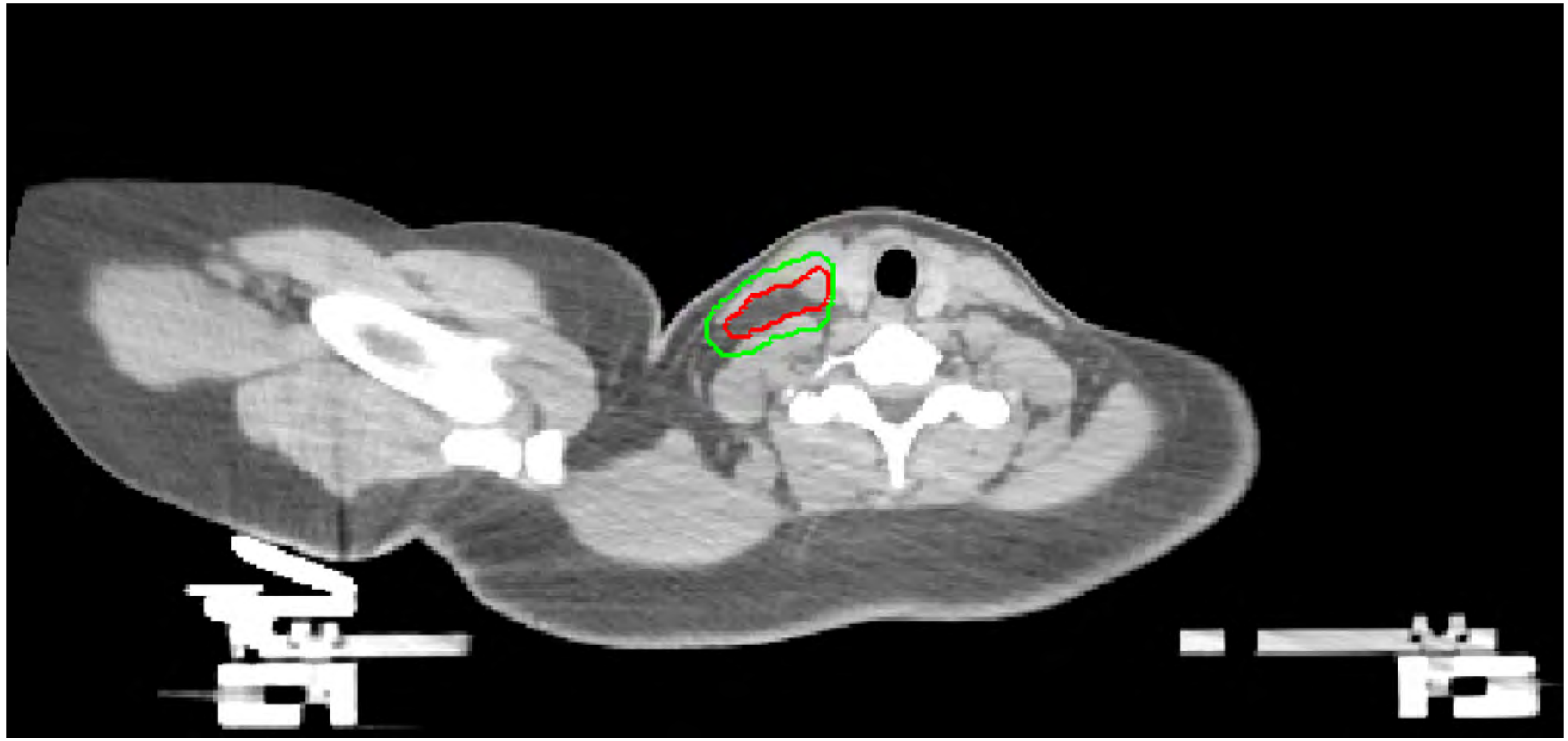


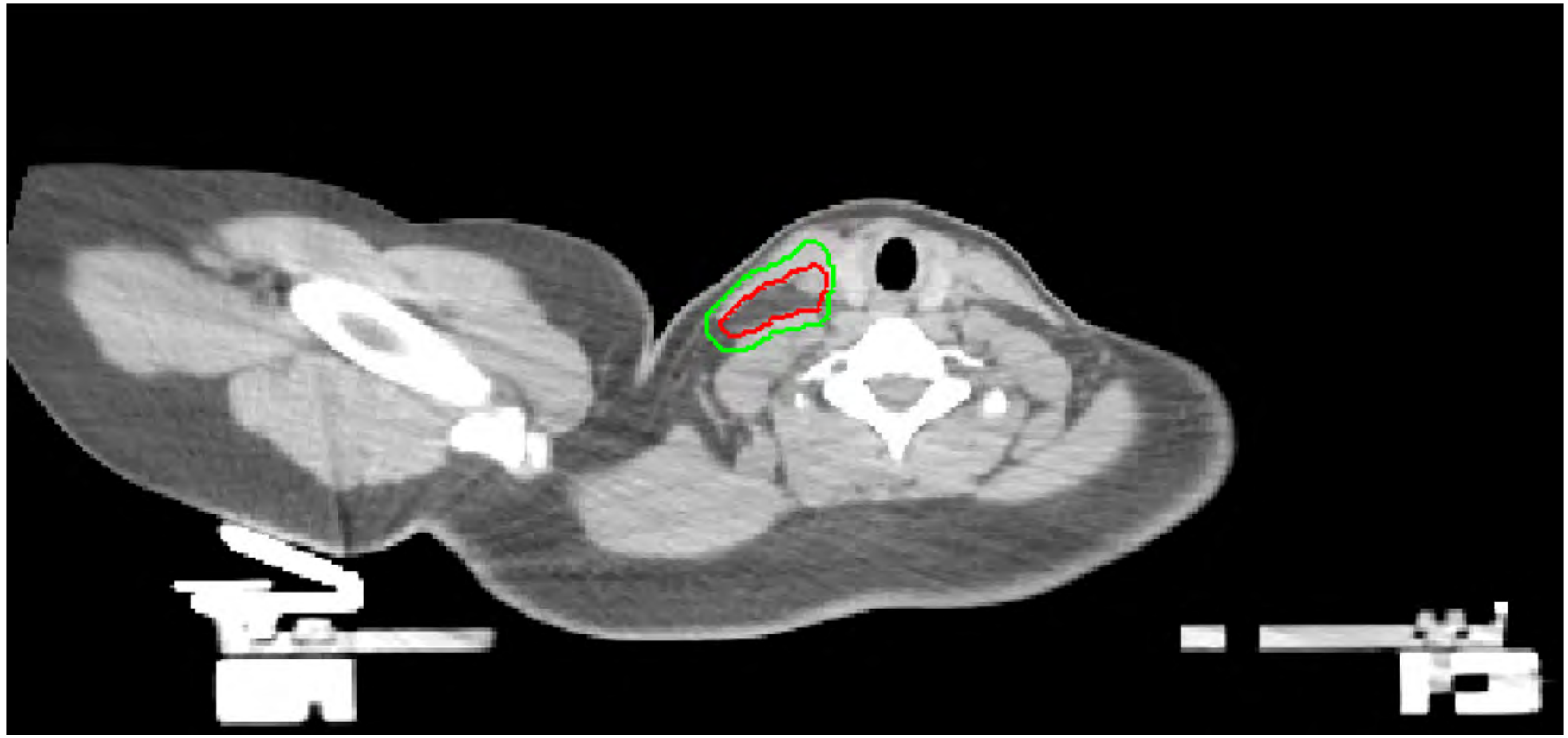


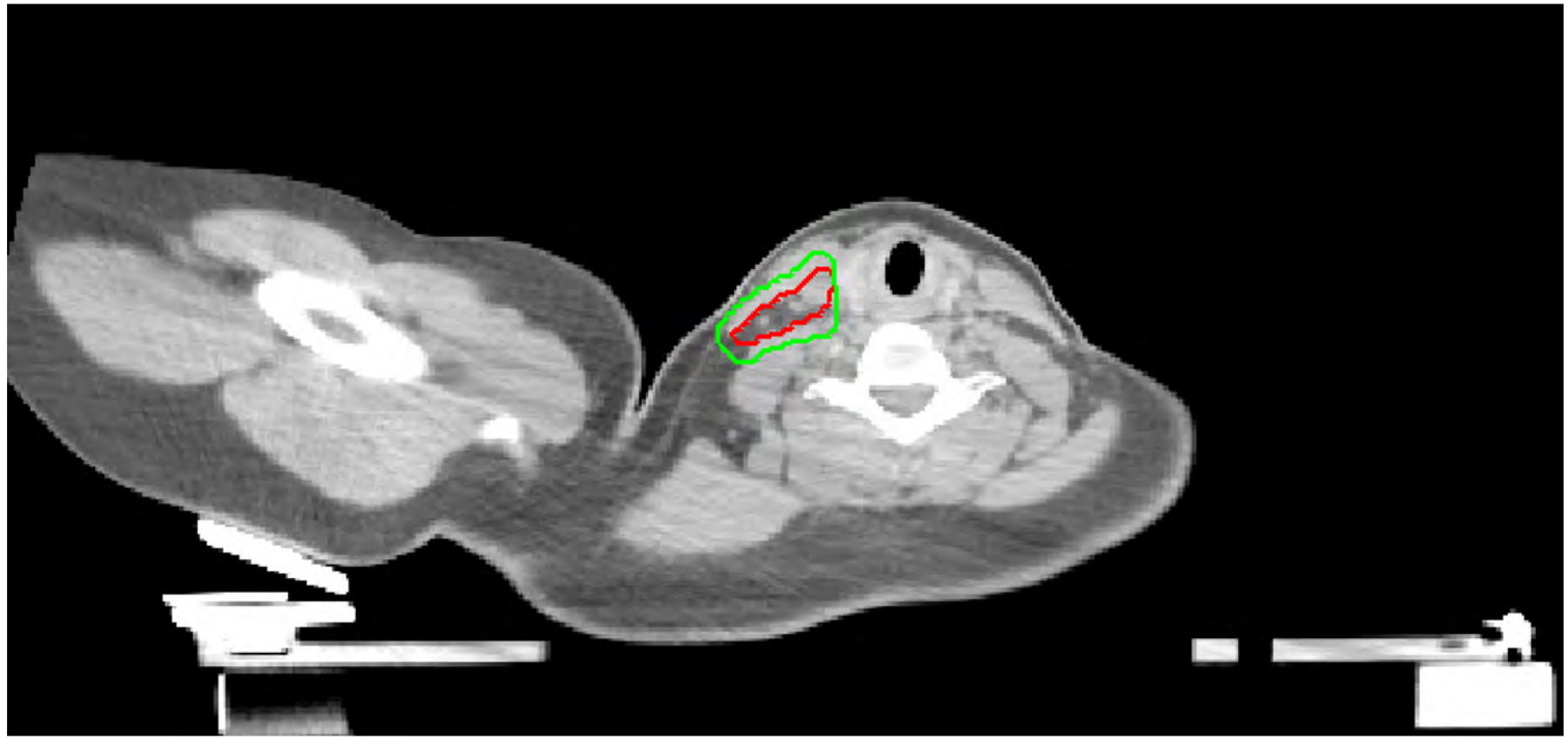


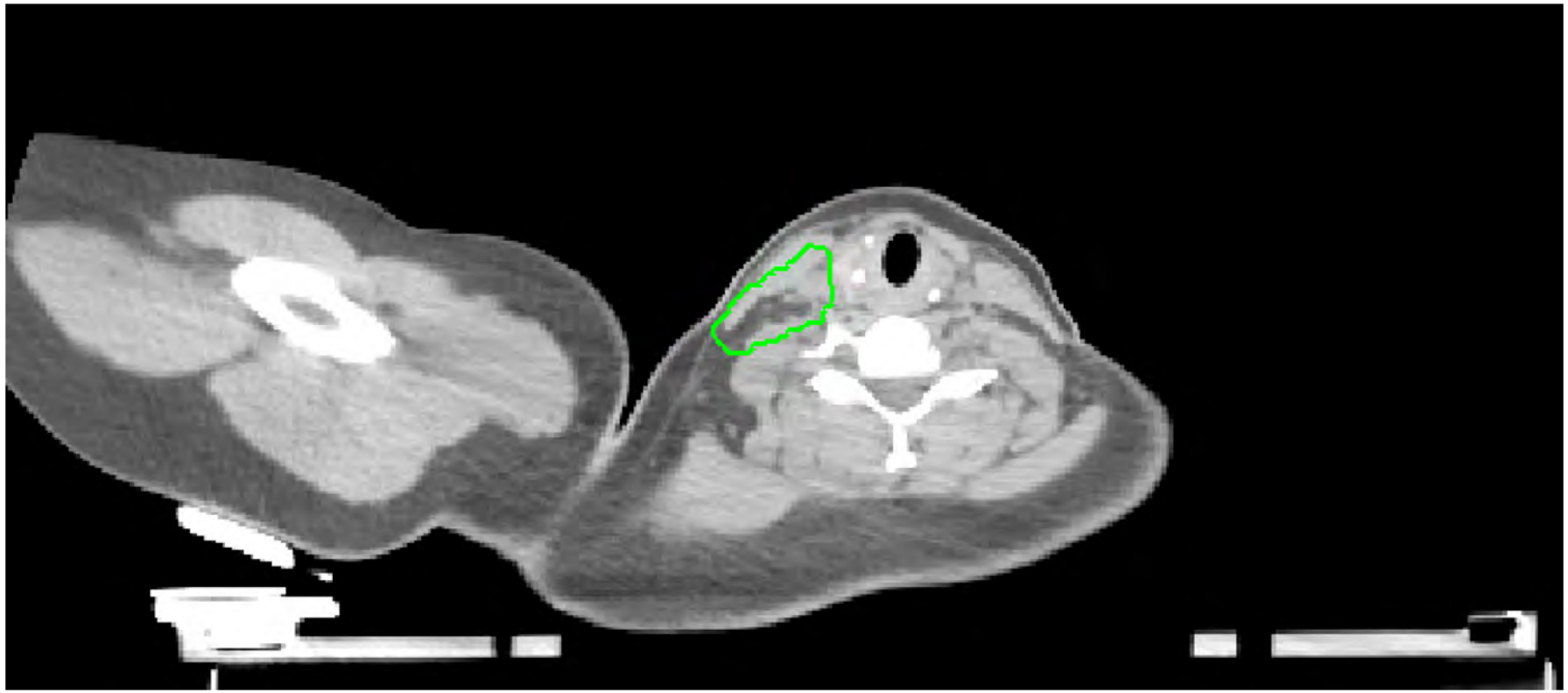


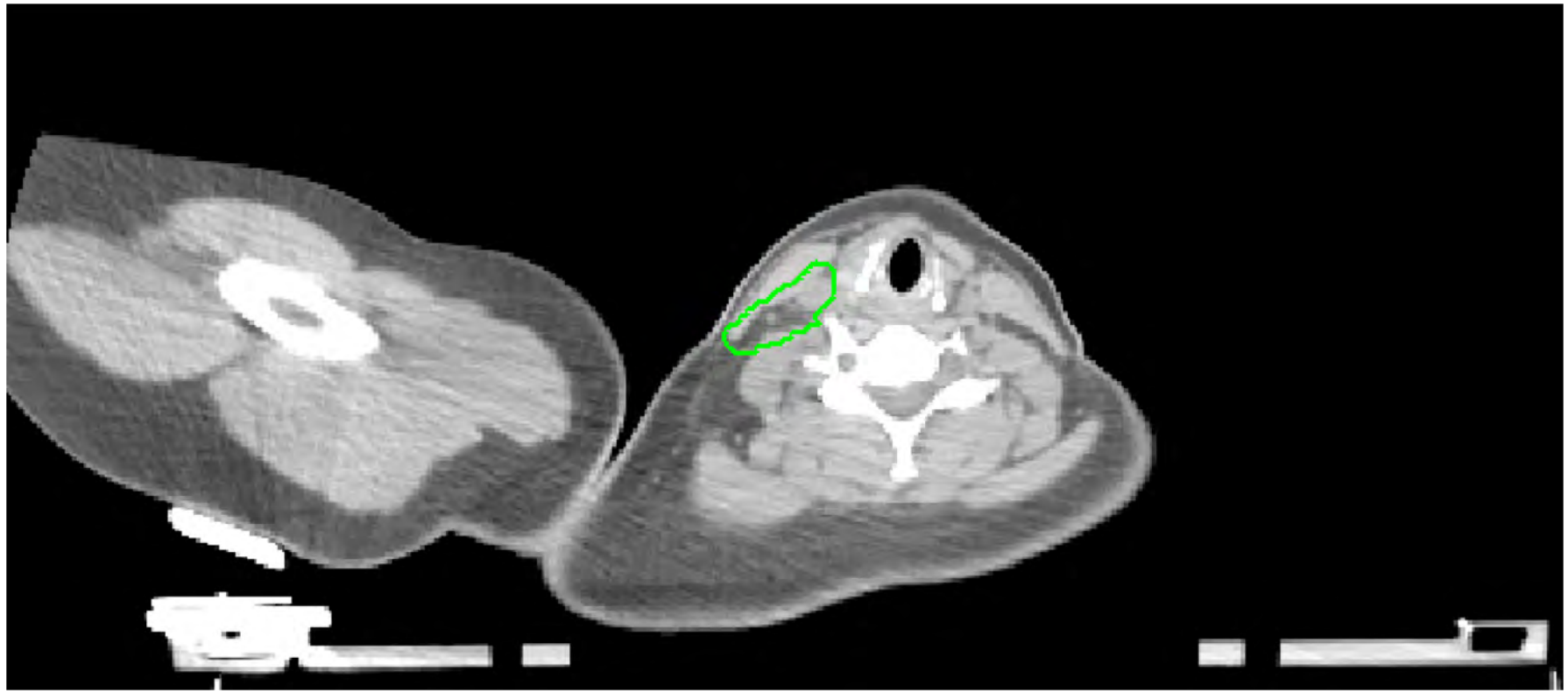


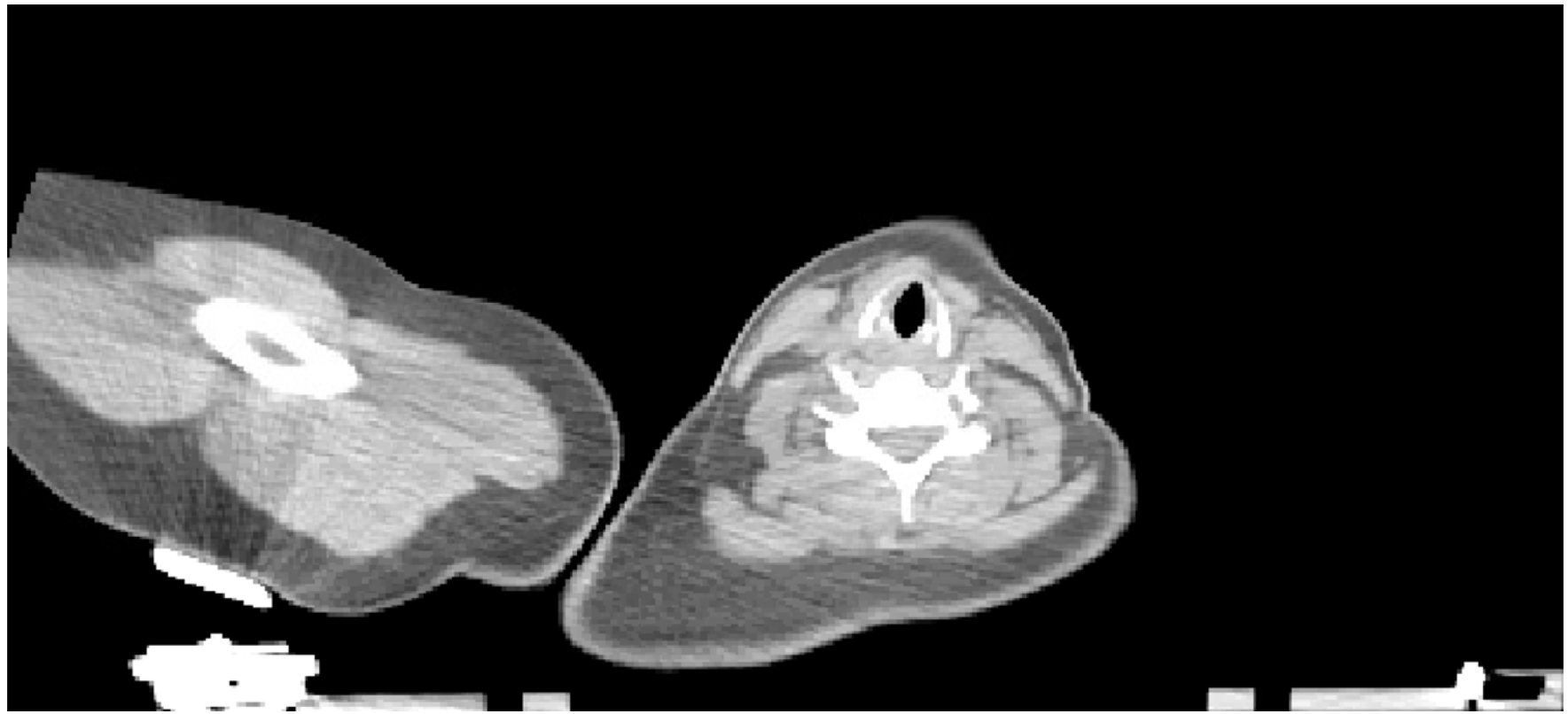












Beam's Eye View of Supraclav Field

Axillary Level III CTV + PTV (Yellow)
Level IV Supraclav CTV + PTV (Green)