

Atlases for CT Gross Tumor Volume (CTGTV) and PET Metabolic Tumor Volume (PETMTV) for RTOG 1106

**Feng-Ming (Spring) Kong MD PhD,
Ying Xiao PhD, James Galvin D.Sc, Randall
Ten Haken PhD, Mitchell Machtay MD
Jeffrey Bradley MD**

Disclaimers

- The target atlases presented here illustrate the consensus contours reached among radiation oncologists participating in RTOG 1106 dry-run dosimetric studies for individualized adaptive conformal plans. RTOG and authors are not responsible for any use of these guidelines by third parties.

Contributors

- Feng-Ming (Spring) Kong ¹, Ying Xiao ², Mitchell Machtay ³, Maria Werner-Wasik ⁴, Gregory Videtic ⁵, Billy W Loo ⁶, John Varlotto ⁷, Elizabeth Gore ⁸, Henry Wagner ⁷, Sergio Faria ⁹, Thomas Dilling ¹⁰, Alexander Sun ¹¹, Luhua Wang ¹², Todd Swanson ¹³, Ritsuko Komaki¹⁴, James Galvin², Randall Ten Haken ¹, Jeffrey Bradley ¹⁵
- 1 University of Michigan, 2 RTOG RT Quality Assurance Core Lab, 3 Case Western Hospital, 4 Thomas Jefferson University Hospital, 5 Cleveland Clinic, 6 Stanford University, 7 Medical College of Wisconsin, 8 Penn State Hershey University, 9 McGill Hospital, 10 Moffitt Cancer Center, 11 Princess Margaret Hospital, 12 Peking Union Medical College, 13 University of Texas Medical Branch, 14 MD Anderson Cancer Center, 15 Washington University at St Louis

Atlas Generation Process

- Example cases were prepared by investigators from the University of Michigan.
- Participating radiation oncologists contoured the tumor targets independently for the same example cases.
- Imaging and structures were submitted to RTOG, consensus GTVs and MTVs were generated by STAPLE program in RTOG RT QA core lab.
- Atlases were compiled by investigators from University of Michigan, final approval by participating radiation oncologists.

Radiation Oncologists Participated on Atlas Approval

- University of Michigan/AAVA: Feng-Ming (Spring) Kong, MD, PhD
- Case Western University Hospital: Mitchell Machtay MD
- Thomas Jefferson University Hospital: Maria Werner-Wasik MD
- Taussig Cancer Center/Cleveland Clinic: Gregory Videtic MD
- Stanford University Cancer Center: Bill Loo MD
- Medical College of Wisconsin: Elizabeth Gore MD
- Penn State Hershey Cancer Center: John Varlotto MD
- McGill Hospital: Sergio Faria MD
- Moffitt Cancer Center: Thomas Dilling MD
- Princess Margaret Hospital: Alexander Sun MD
- MD Anderson Cancer Center: Ritsuko Komaki MD
- Washington University at St Louis: Jeffrey Bradley MD

RTOG Lung Steering Committee and ATIC Committee

Staff Involved in Imaging and Data Submission and Processing

- University of Michigan case and imaging preparation: Feng-Ming Kong MD PhD, Martha Matuszak PhD, Timothy Ritter PhD, Randall Ten Haken PhD
- RTOG core lab data processing staff: Elizabeth O'Meara MS, Brian J. Bialecki CIIP, Ying Xiao PhD, James Galvin, D.Sc
- RTOG consensus atlas generation: Wenzhou Chen PhD, Yunfeng Cui PhD, Ying Xiao PhD
- University of Michigan data collection team: Paul Stanton BS, Jingbo Wang MD, Chengbo Han MD PhD, Weili Wang MD, Feng-Ming Kong MD PhD
- Key Coordinator: Elizabeth O'Meara MS

Outline

- Example case #1, right lower lobe NSCLC, T4N2M0, stage IIIB: a) pre-treatment CTGTV and PETMTV; b) during-treatment CTGTV and PETMTV.
- Example case #2, right upper lobe NSCLC, T4N2M0, stage IIIB: a) pre-treatment GTV and MTV; b) during-treatment GTV and MTV.
- Example case #3, left lower lobe NSCLC, T3N2M0, stage IIIA: a) pre-treatment GTV and MTV; b) during-treatment GTV and MTV.

Case #3 is the credentialing case of RTOG 1106.

Definitions and Acronyms

- CTGTV is the gross target volume defined on CT, will be a composite volume of the primary tumor mass (GTVT) and nodal diseases (GTVN).
- The primary tumor should be contoured on CT images under a standard lung window/level for its lung borders and under a mediastinal window/level for the borders adjacent to mediastinum.
- The GTVNs should be drawn under the mediastinal window/level.
- In cases with extensive atelectasis and/or pneumonia where tumor margins are obscure, volumes are left to the judgment of the treating radiation oncologist.

Definition of GTVN

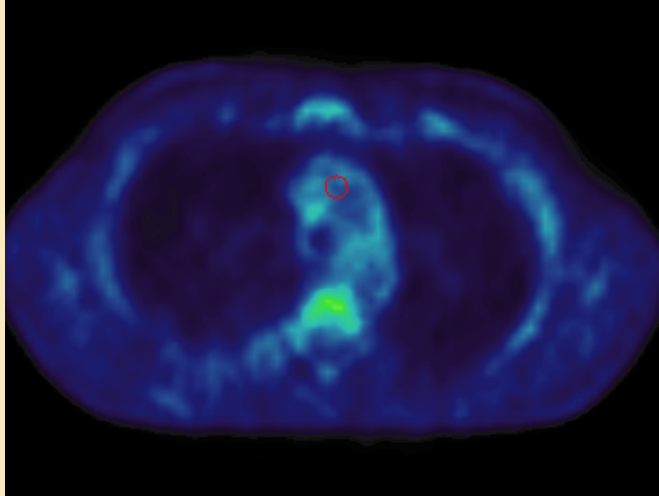
GTVN should include

- 1. any hilar or mediastinal lymph nodes ≥ 1 cm in short axis on any of the phased4D CT, exhale or inhale CT.
- 2. any nodes with abnormal findings detected on bronchoscopy and/or mediastinoscopy.
- 3. any visible nodes that are growing or with abnormal structures;
- 4. two or more nodes clustered in the high risk nodal stations.
- 5. any visible nodes at the 1st echelon or within 1cm proximity to the primary tumor.

Definition of PET MTV

- MTV should be generated using a fixed tumor background ratio
 - 1.5 times of the mean activity of aorta.
- This can be done through various systems, such as MIM PET edge.
- The key issue is consistency between scans and patients.
- What presented is example steps from University of Michigan functional image analysis tools (FIAT).

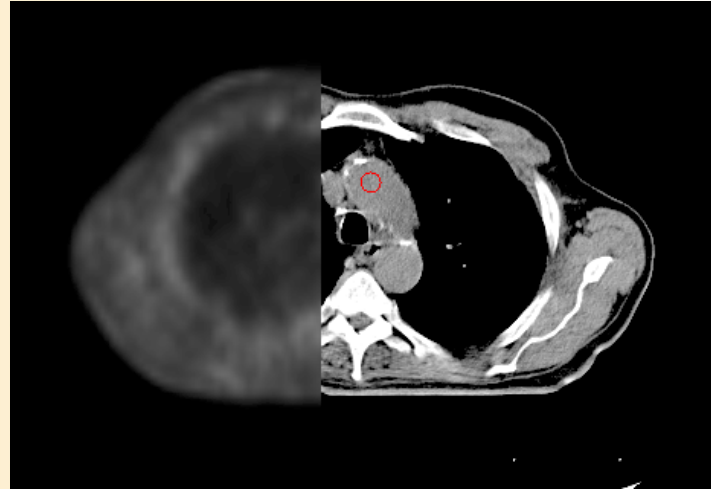
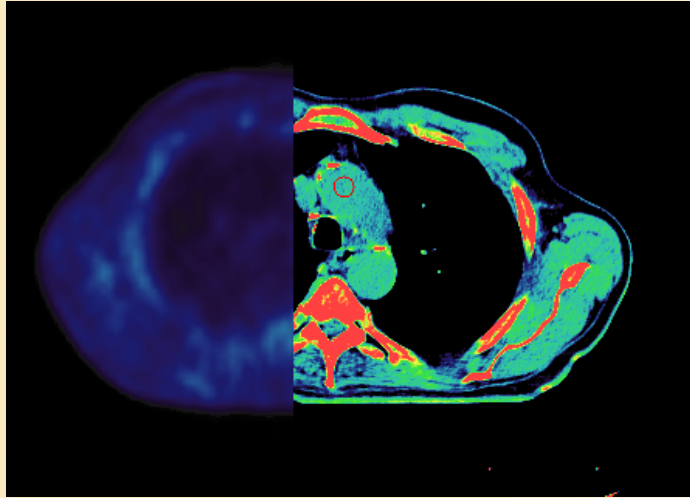
Delineation of PETMTV Step-1



- Contour an aortic structure of 1.2 cm in diameter (1 cc in volume, about 3 slices) in the middle of ascending aorta in CT scan
- Transfer aortic structure to PET scan which is already registered with CT scan.

Method by Pawinee Mahasittiwat and Feng Ming (Spring) Kong

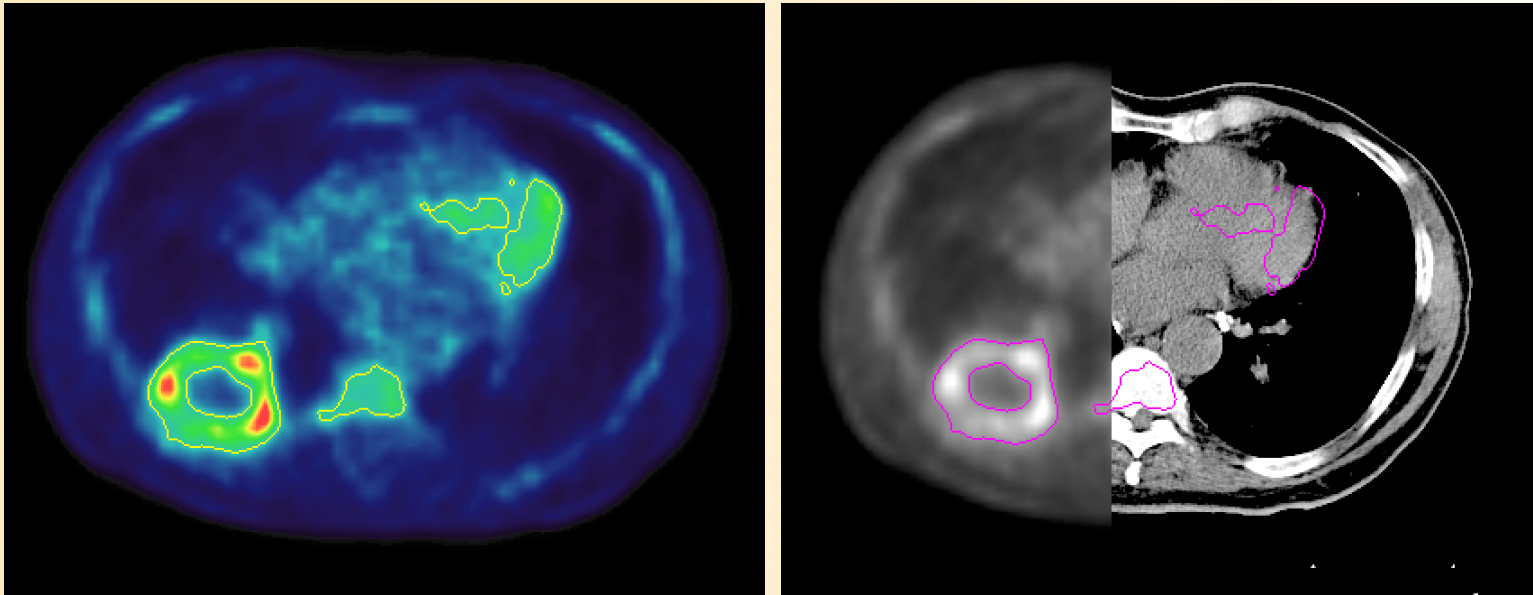
Delineation of PETMTV Step-2



- Check aorta volume on PET and fused PET-CT image
- Calculate the mean intensity of 1cc aortic structure in PET image
- Autotrack the tumor volumes by thresholding at $1.5 \times$ mean intensity of the aortic structure

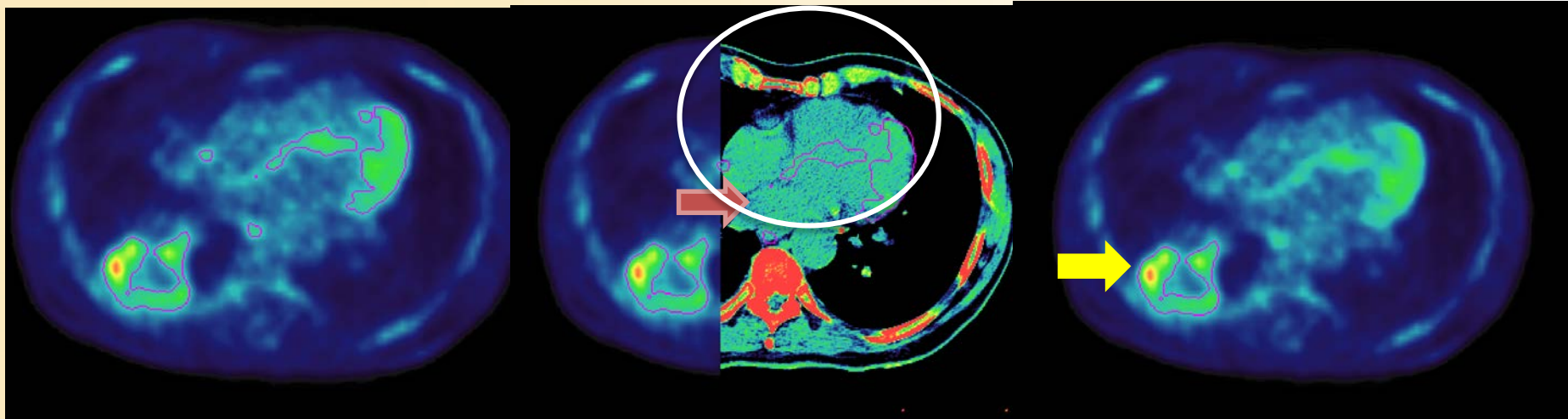
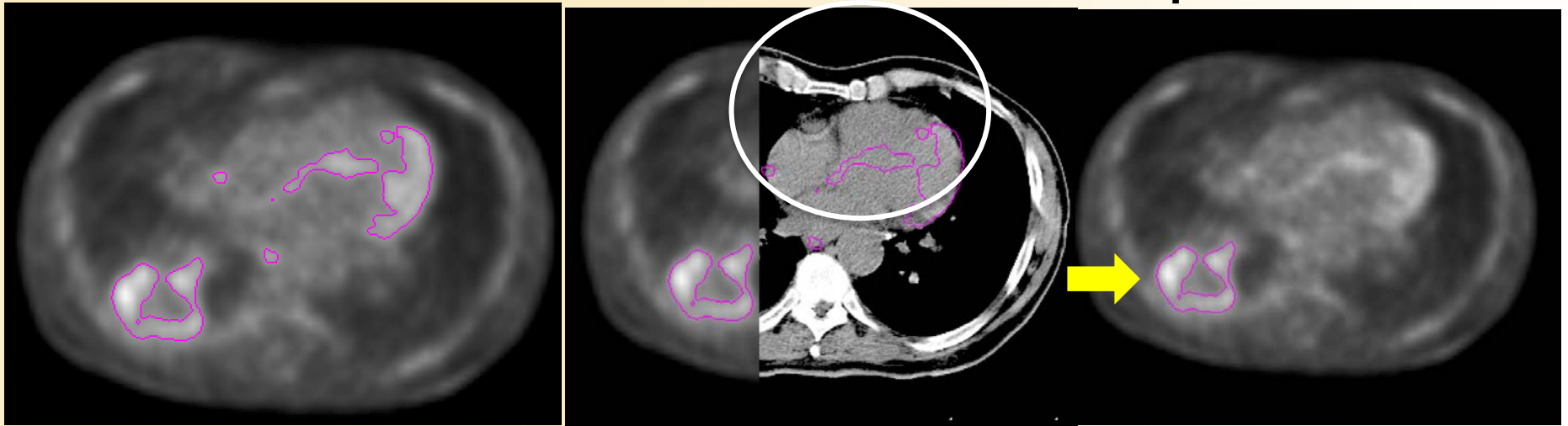
Method by Pawinee Mahasittiwat and Feng Ming (Spring) Kong

Delineation of PETMTV Step-3



- MTV can be done in one click depending on the contouring tool
- Check the MTV slice by slice in fused PET-CT image
- Identify normal structure incidentally included in the MTV

Delineation of PETMTV Step-4



- Manually remove normal structures such as heart and esophagus (dark in the white circle) incidentally included in MTV
- PETMTV (yellow arrows) delineation is now complete.

PET Target Working Group

- University of Michigan:
 - Feng-Ming (Spring) Kong, MD, PhD
- Case Western University Hospital:
 - Mitchell Machtay MD
- Thomas Jefferson University Hospital:
 - Maria Werner-Wasik MD
- Princess Margaret Hospital:
 - Alexander Sun MD
- Taussig Cancer Center/Cleveland Clinic:
 - Gregory Videtic MD
- Washington University at St Louis:
 - Jeffrey Bradley MD

Example case #1, T4N2M0, with a primary tumor of right lower lung

Thick red lines are consensus contours of CTGTV and PETMTV from 14 participating radiation oncologists.

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Participating Radiation Oncologists

Case #1

- University of Michigan/AAVA: Feng-Ming (Spring) Kong, MD, PhD
- Case Western University Hospital: Mitchell Machtay MD
- Thomas Jefferson University Hospital: Maria Werner-Wasik MD
- Taussig Cancer Center/Cleveland Clinic: Gregory Videtic MD
- Stanford University Cancer Center: Bill Loo MD
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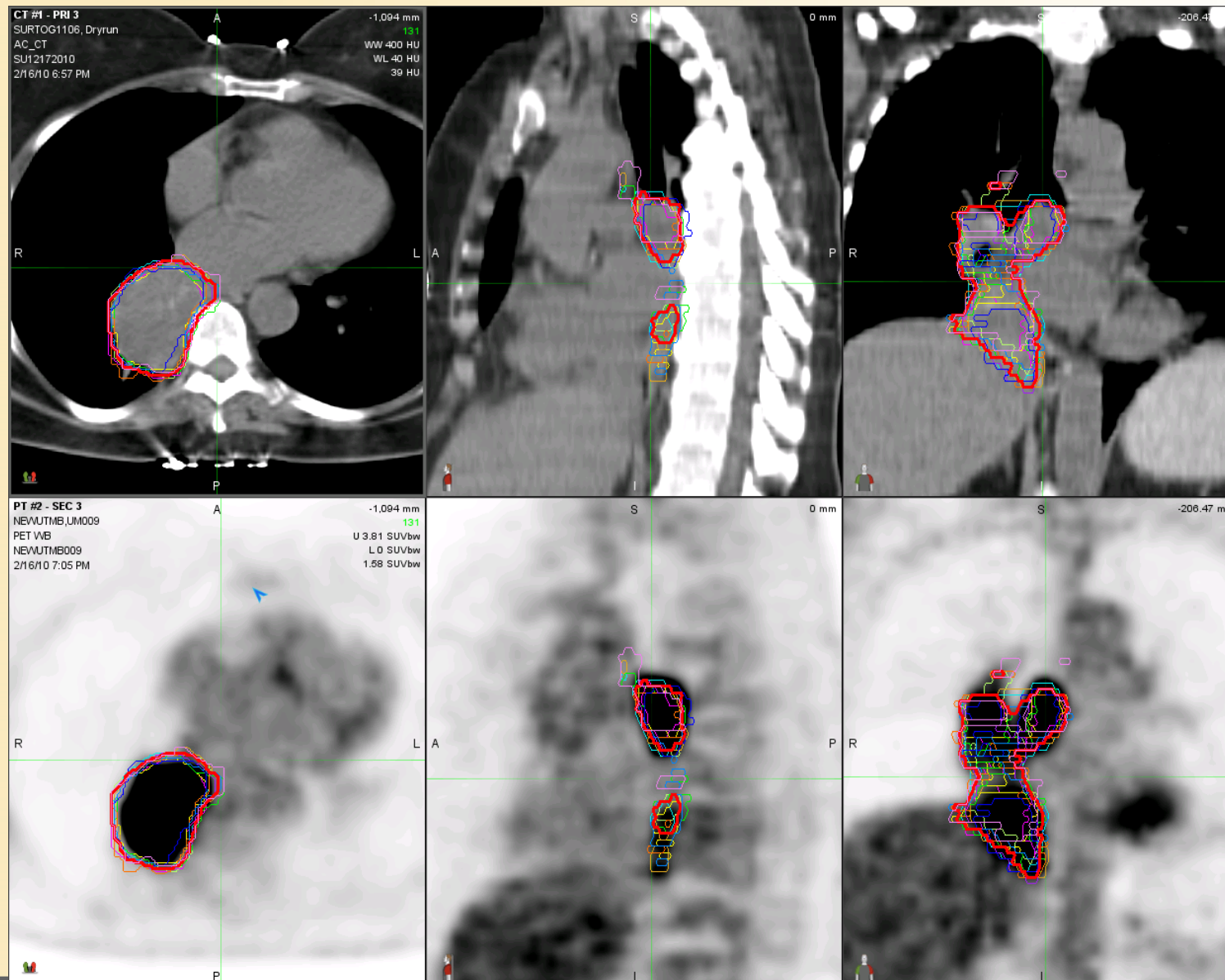
CT1GTV on Pre-treatment PET-CT: Example Case #1

CT1GTV should be generated without consideration of PET1MTV.

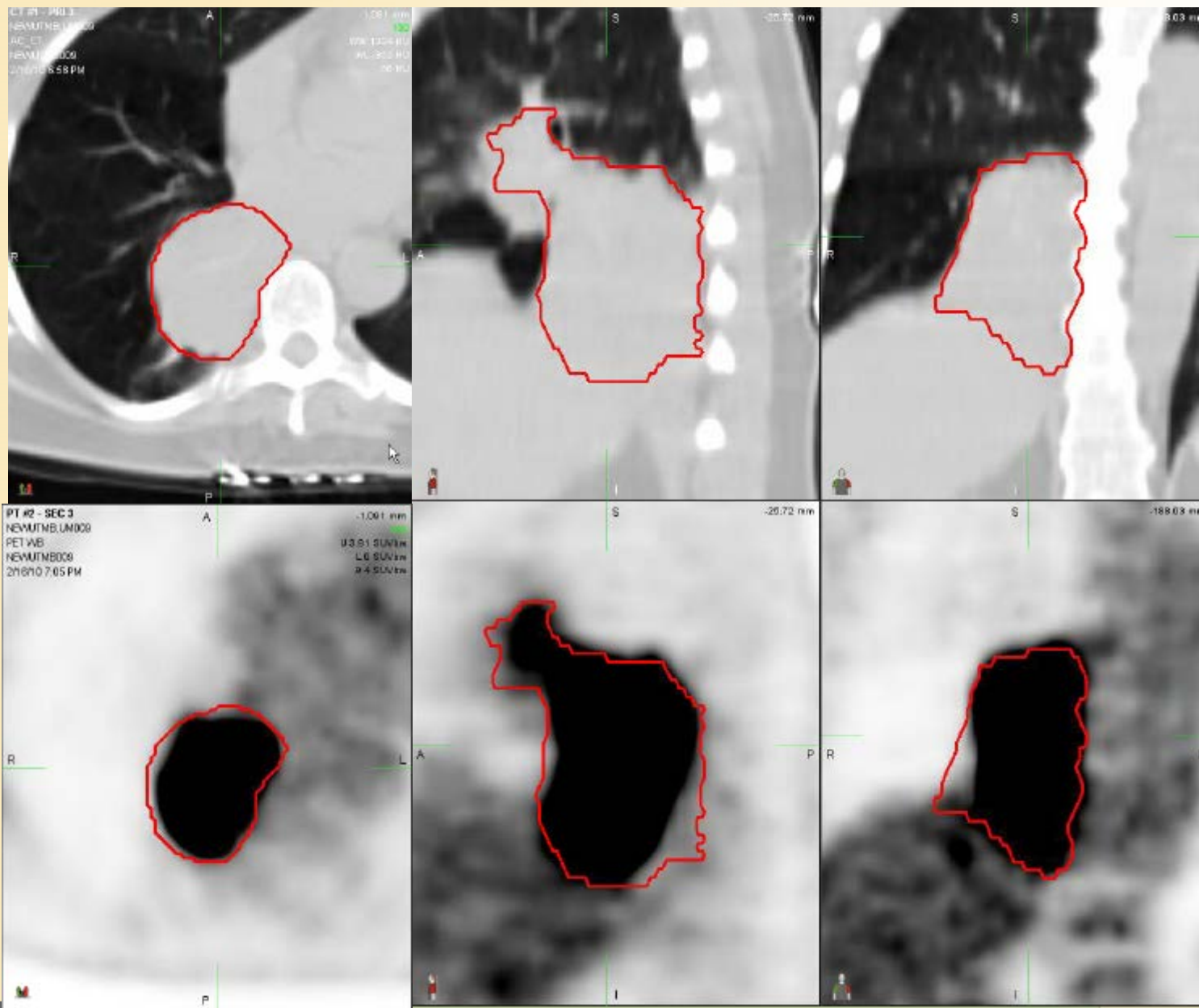
CT1GTV shown in red is the composite of all CT1GTVTs and CT1GTVNs.

CT1GTV on Pre-treatment PET-CT, case 1

Variations (thin lines) and consensus (thick red lines)



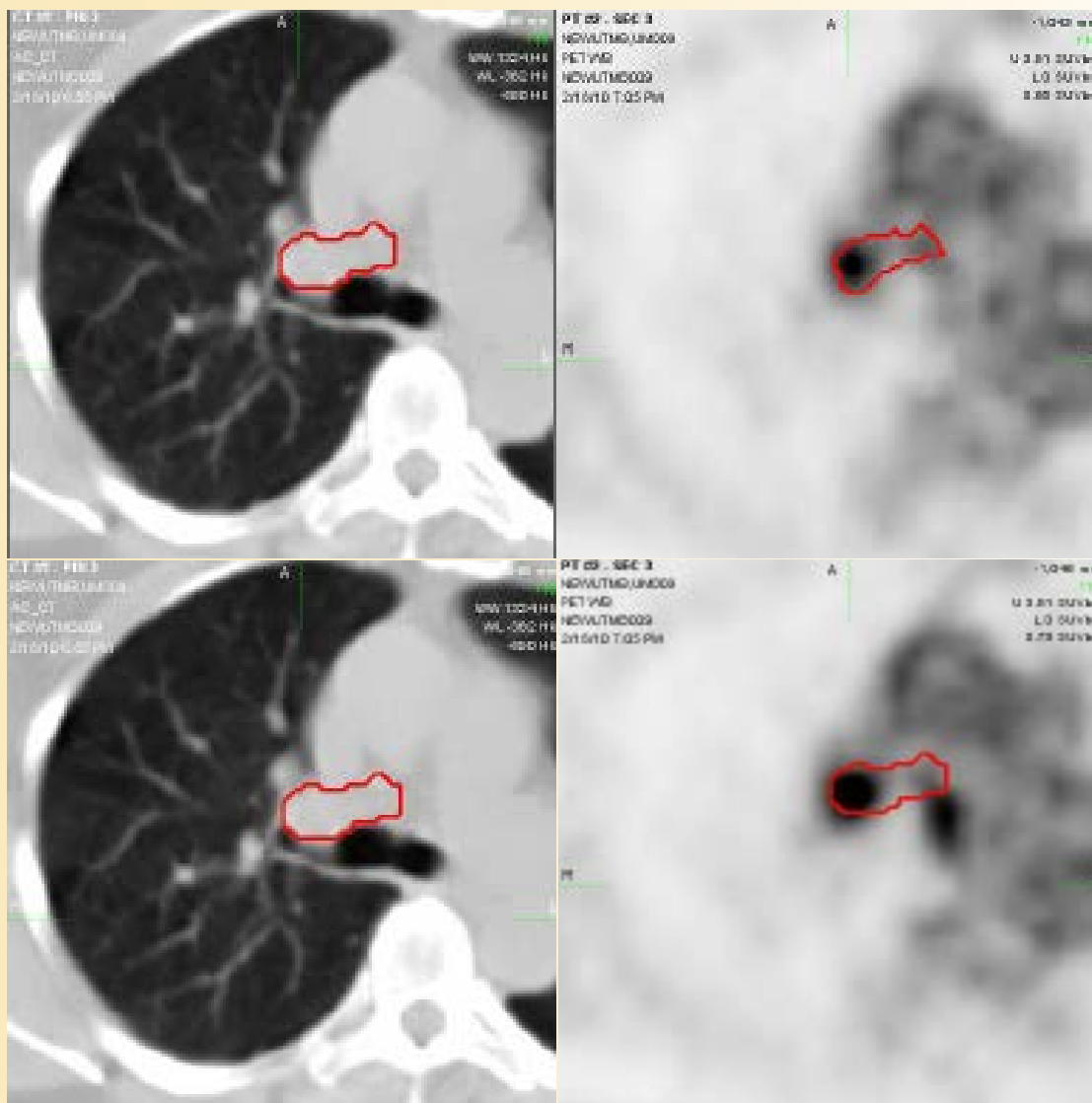
Consensus CT1GTV on pre-treatment PET-CT, case 1



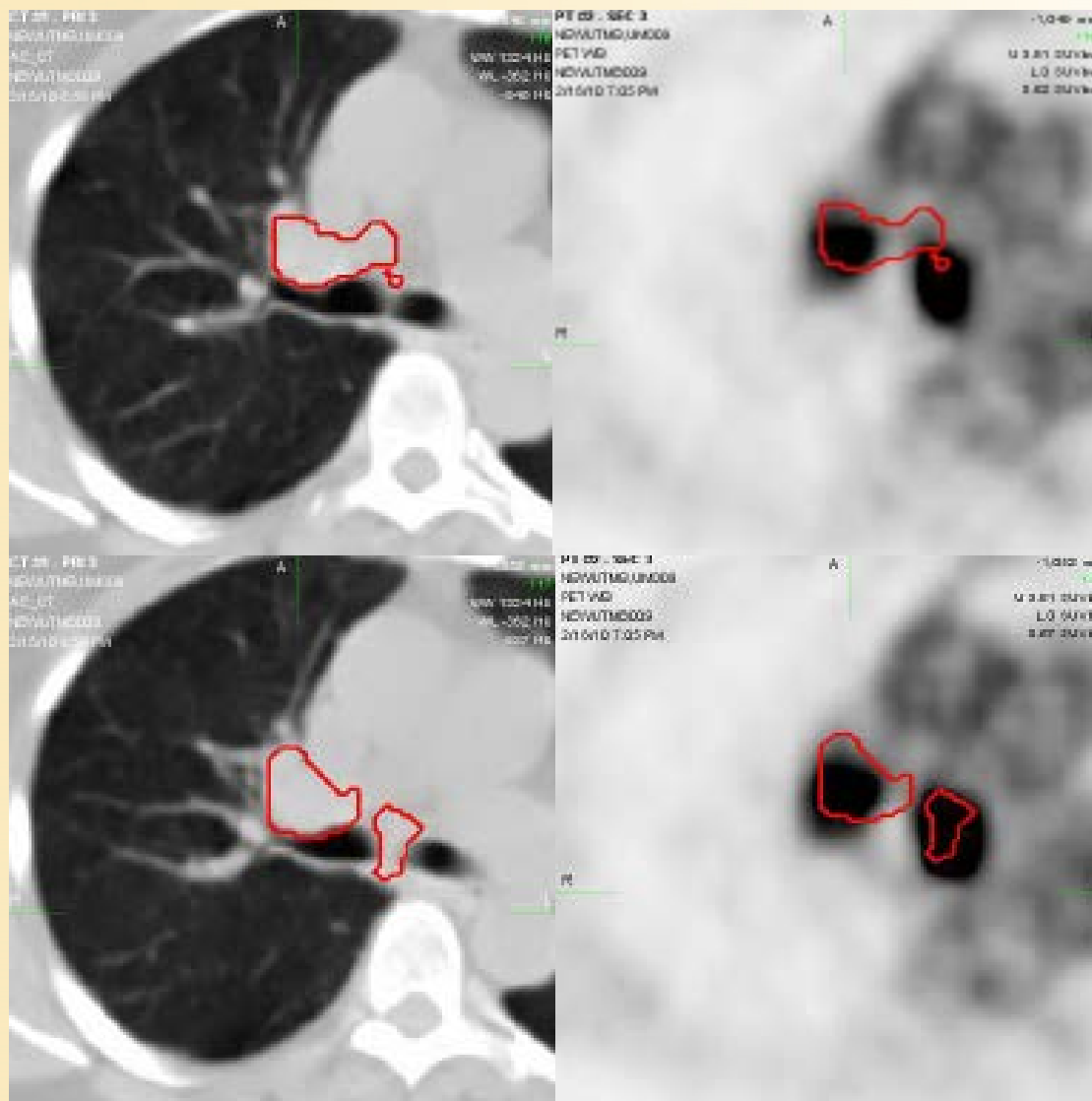
CT1GTV on Pre-treatment PET-CT, case 1



CT1GTV on Pre-treatment PET-CT, case 1



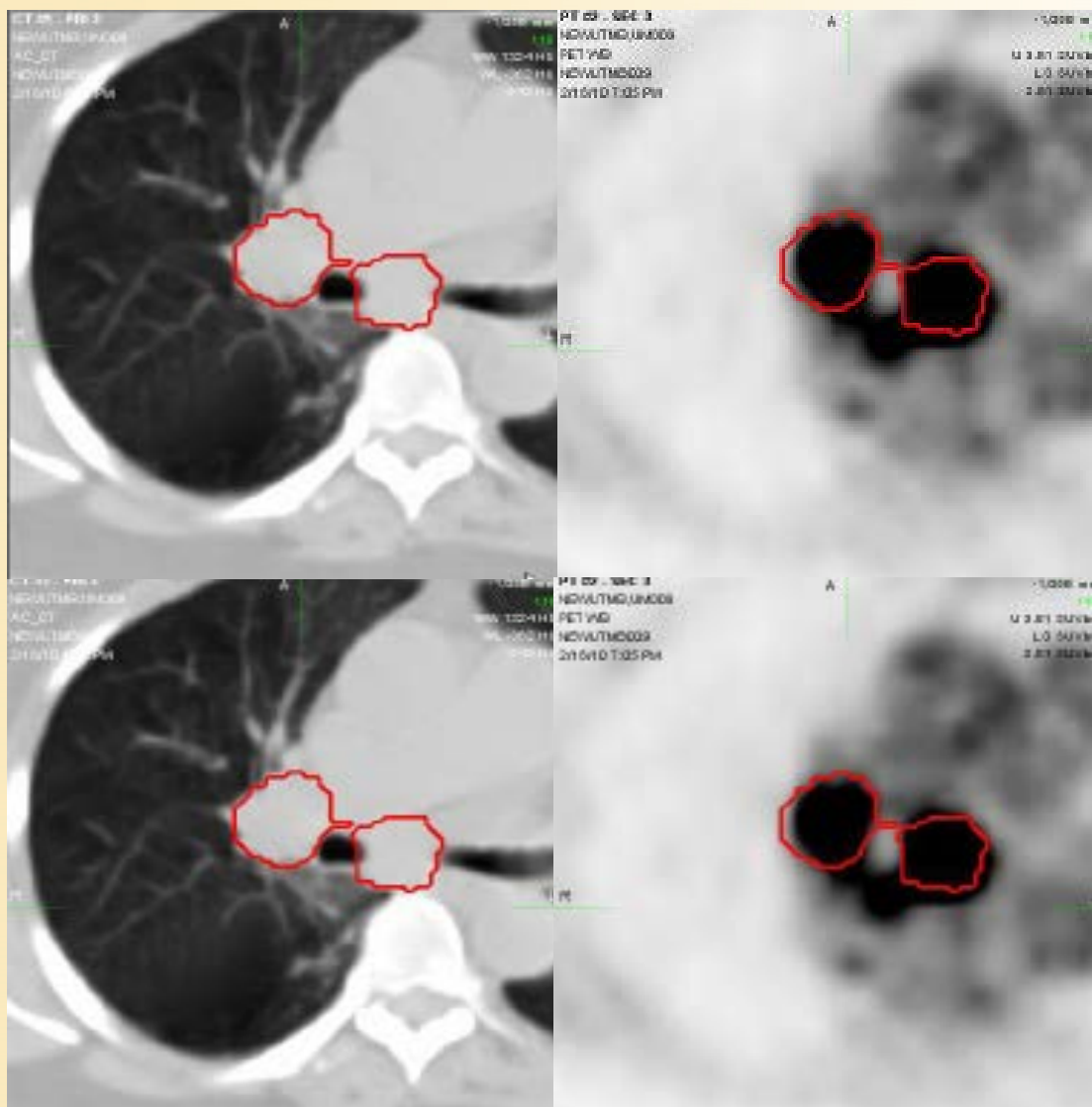
CT1GTV on Pre-treatment PET-CT, case 1



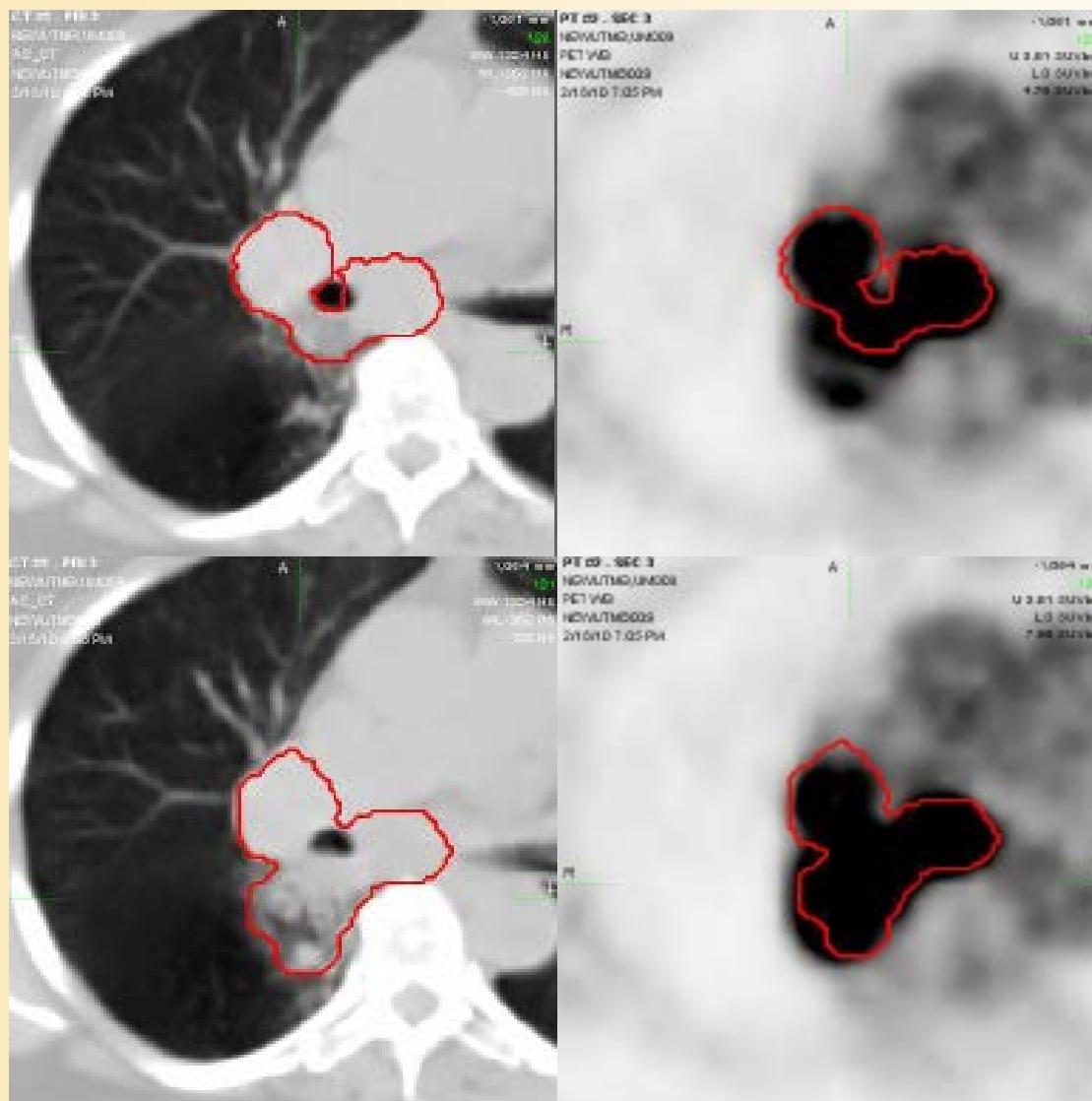
CT1GTV on Pre-treatment PET-CT, case 1



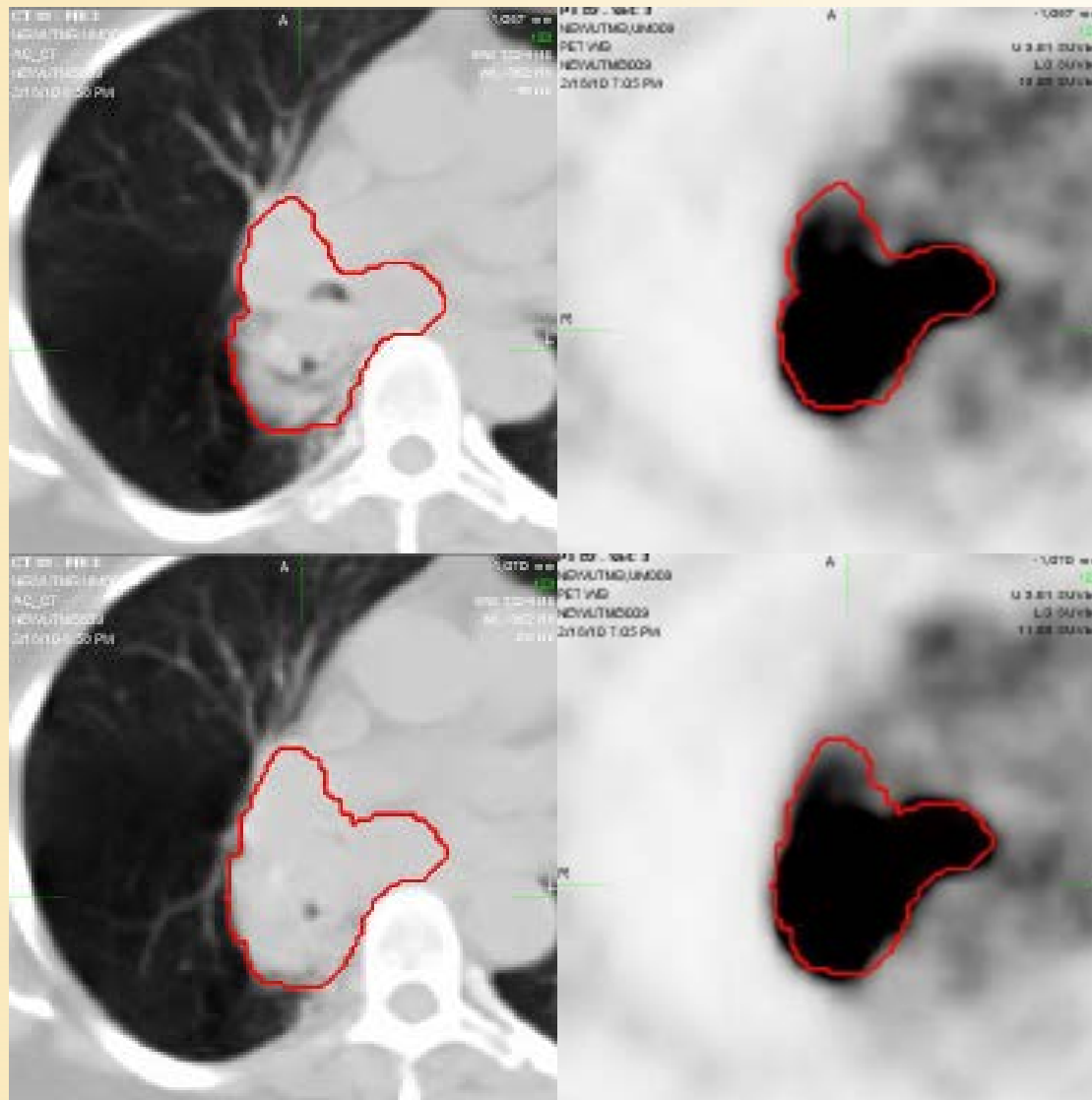
CT1GTV on Pre-treatment PET-CT, case 1



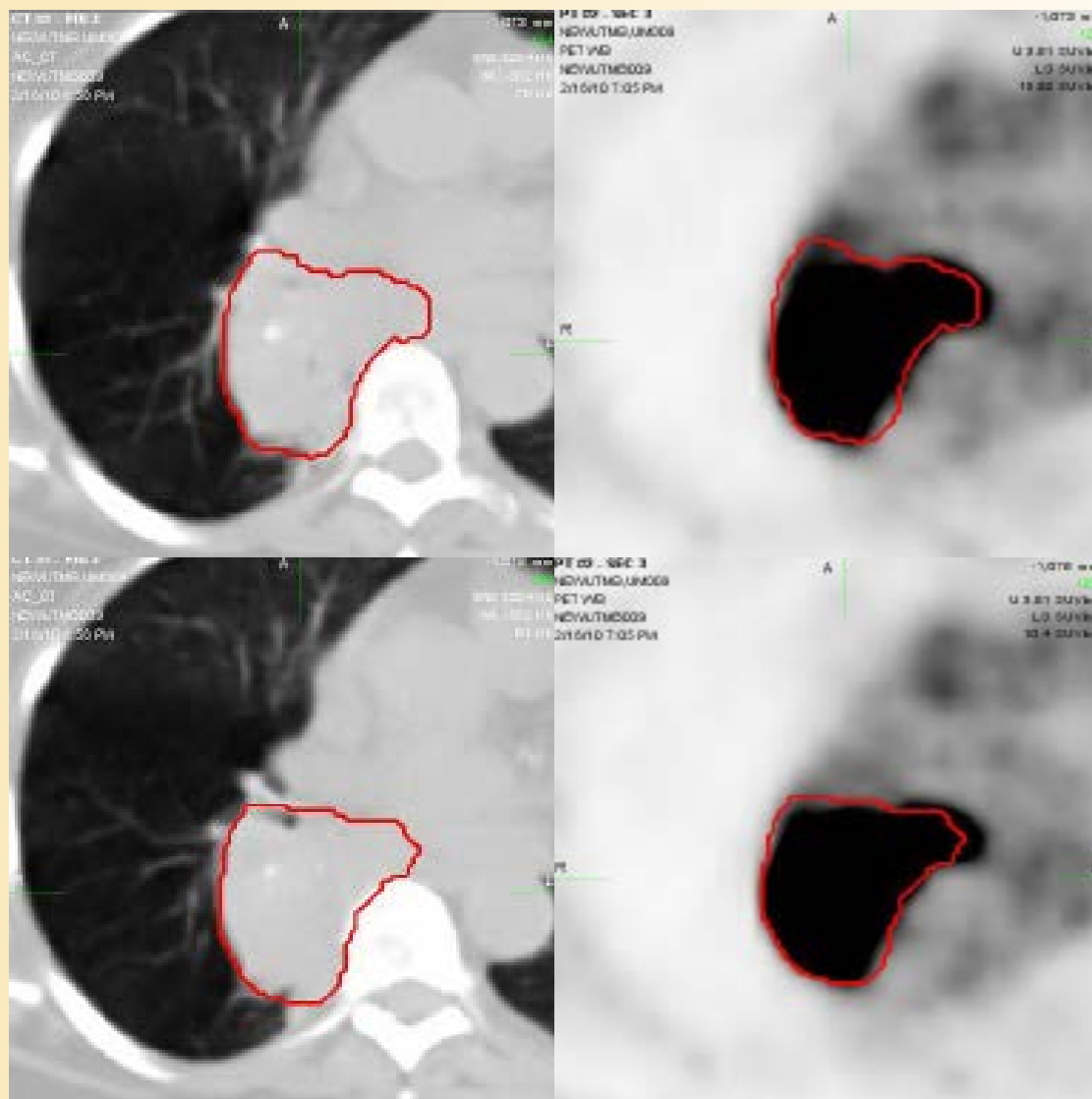
CT1GTV on Pre-treatment PET-CT, case 1



CT1GTV on Pre-treatment PET-CT, case 1



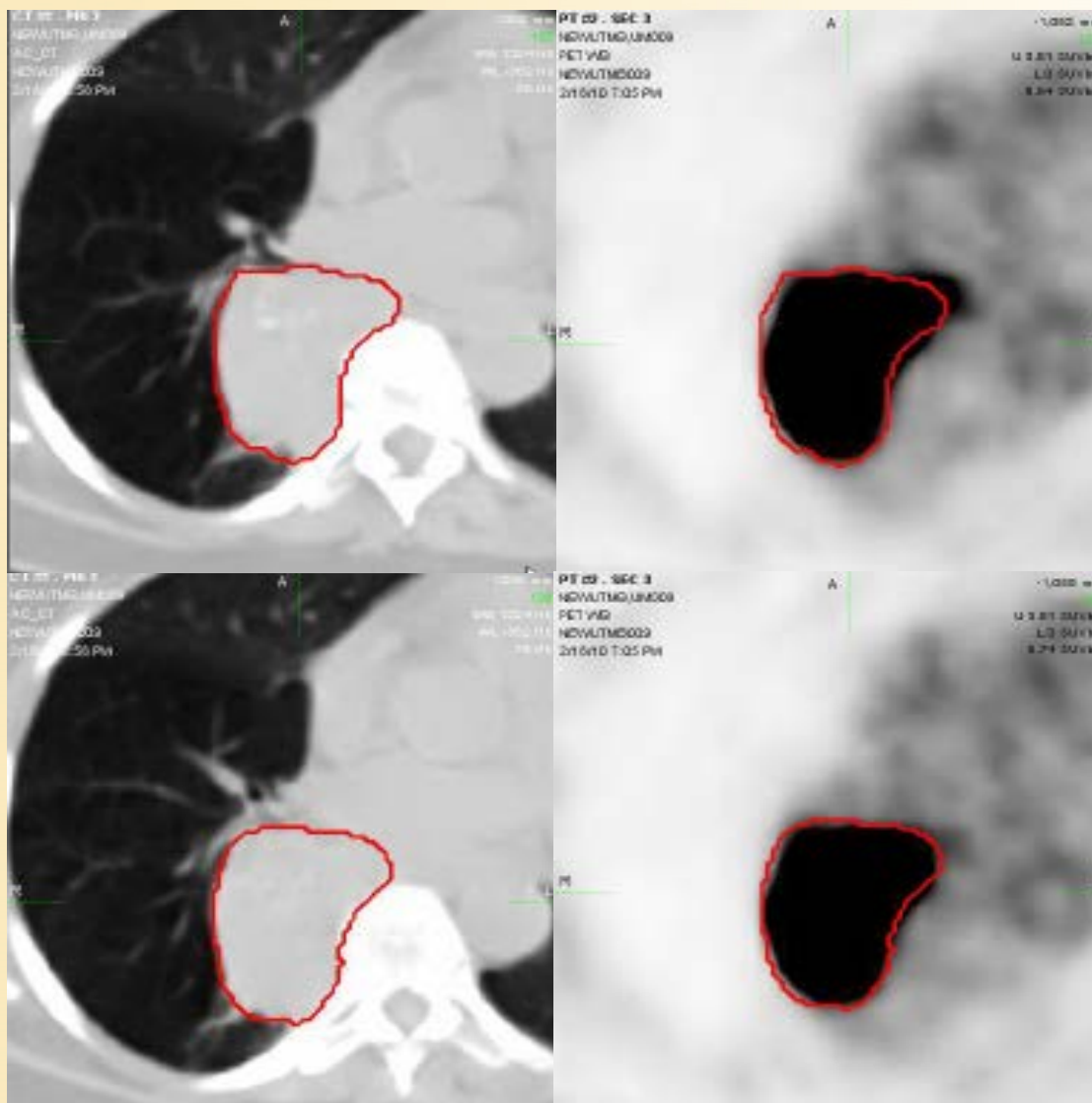
CT1GTV on Pre-treatment PET-CT, case 1



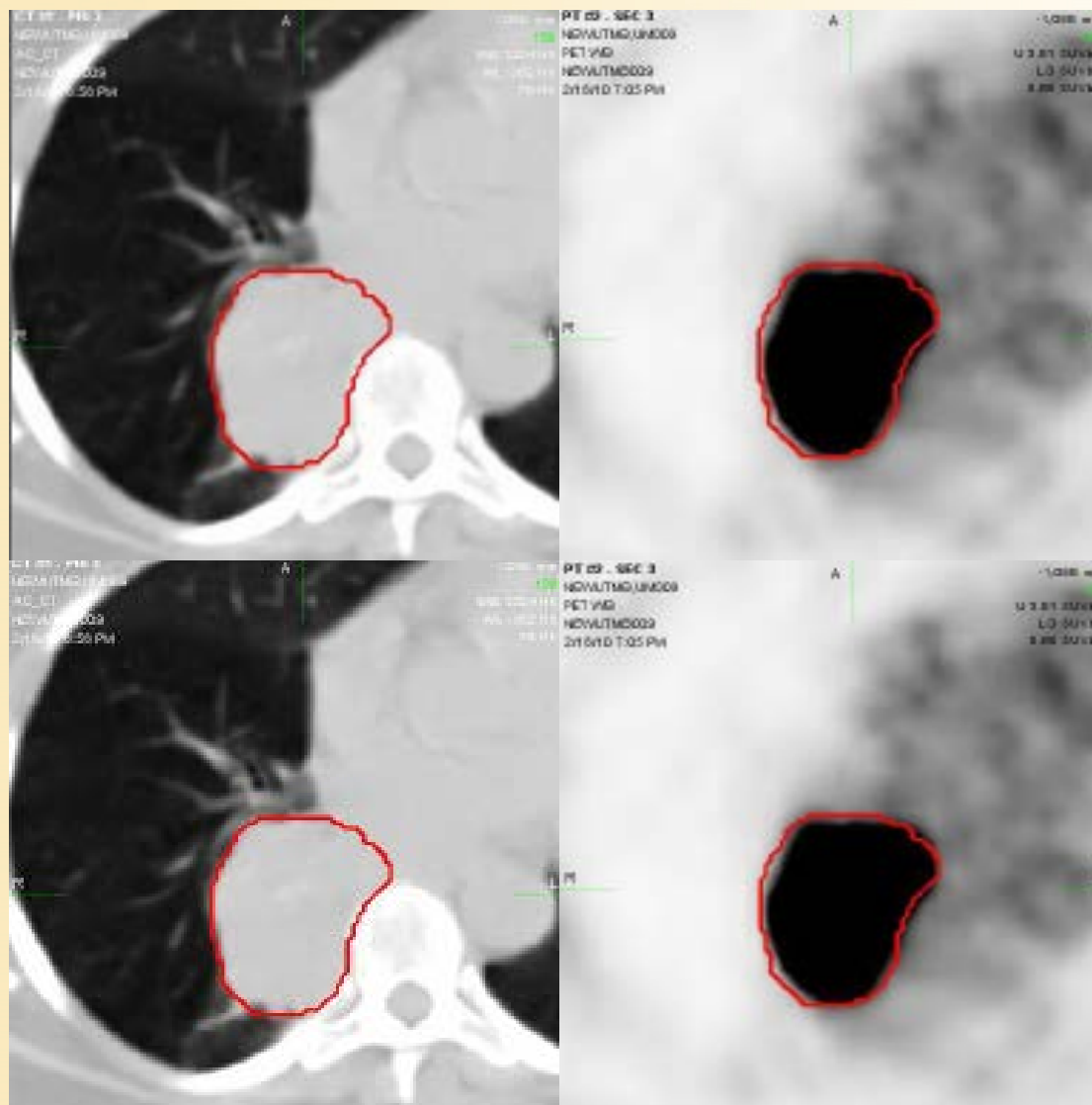
CT1GTV on Pre-treatment PET-CT, case 1



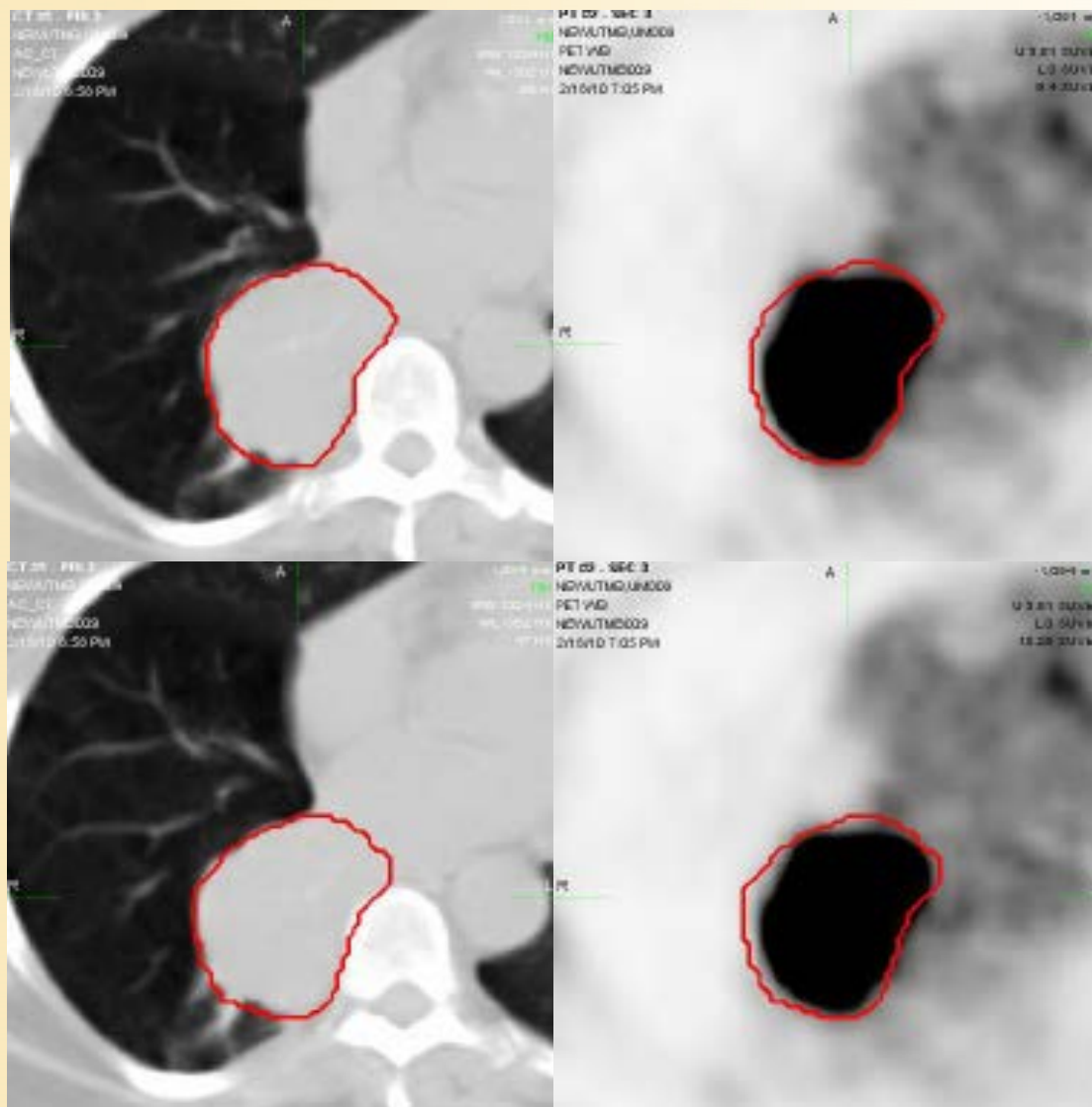
CT1GTV on Pre-treatment PET-CT, case 1



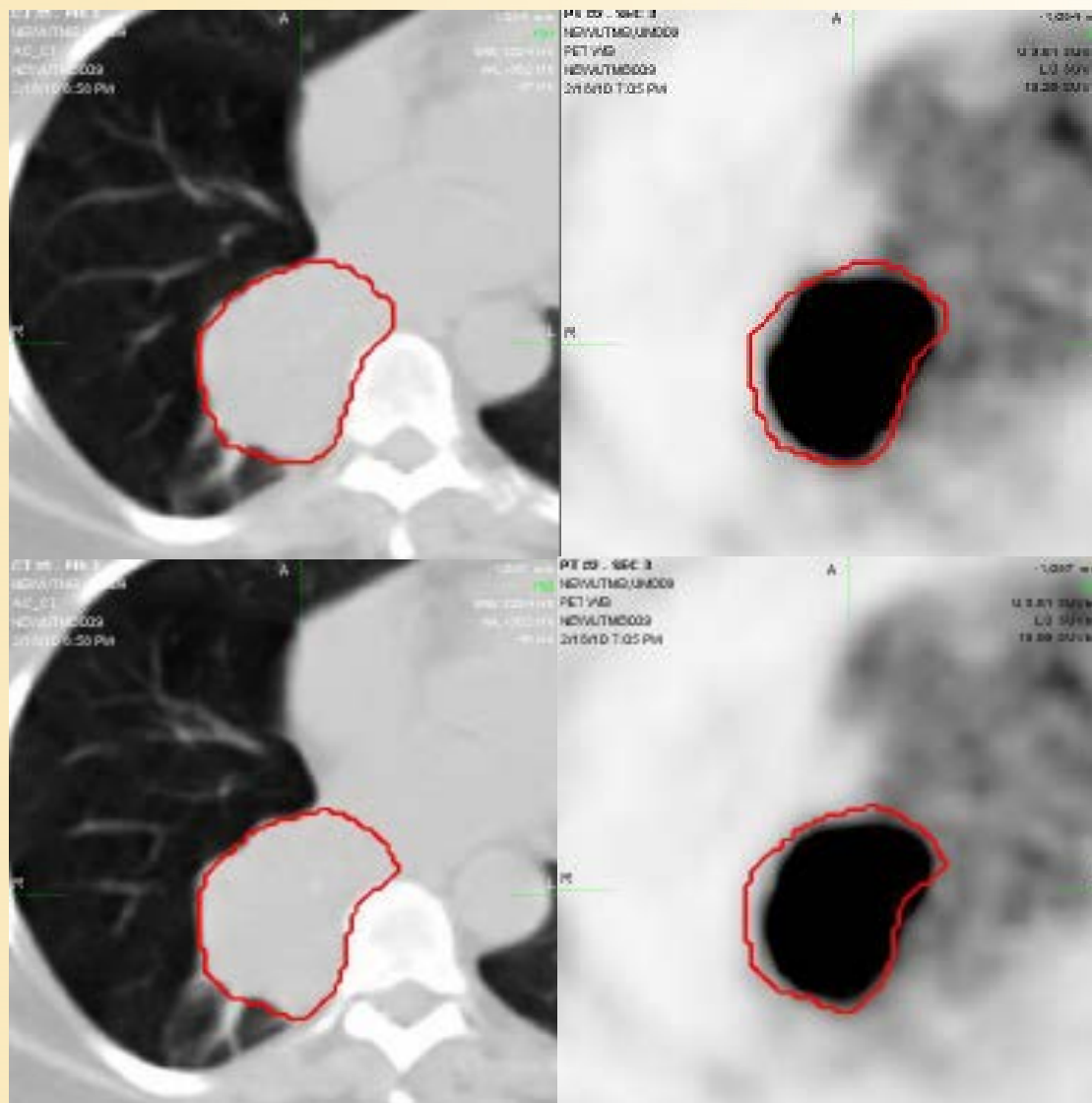
CT1GTV on Pre-treatment PET-CT, case 1



CT1GTV on Pre-treatment PET-CT, case 1



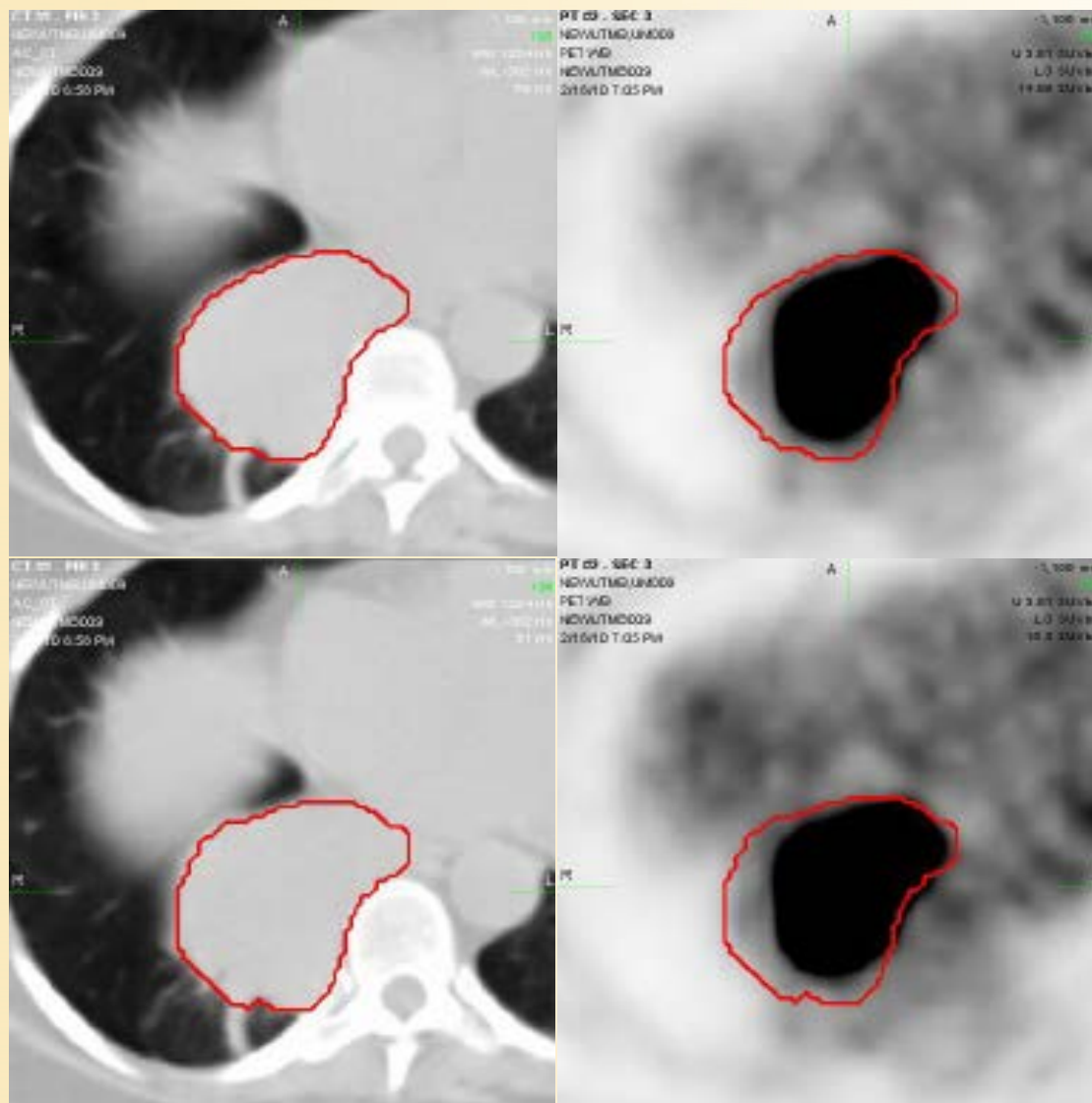
CT1GTV on Pre-treatment PET-CT, case 1



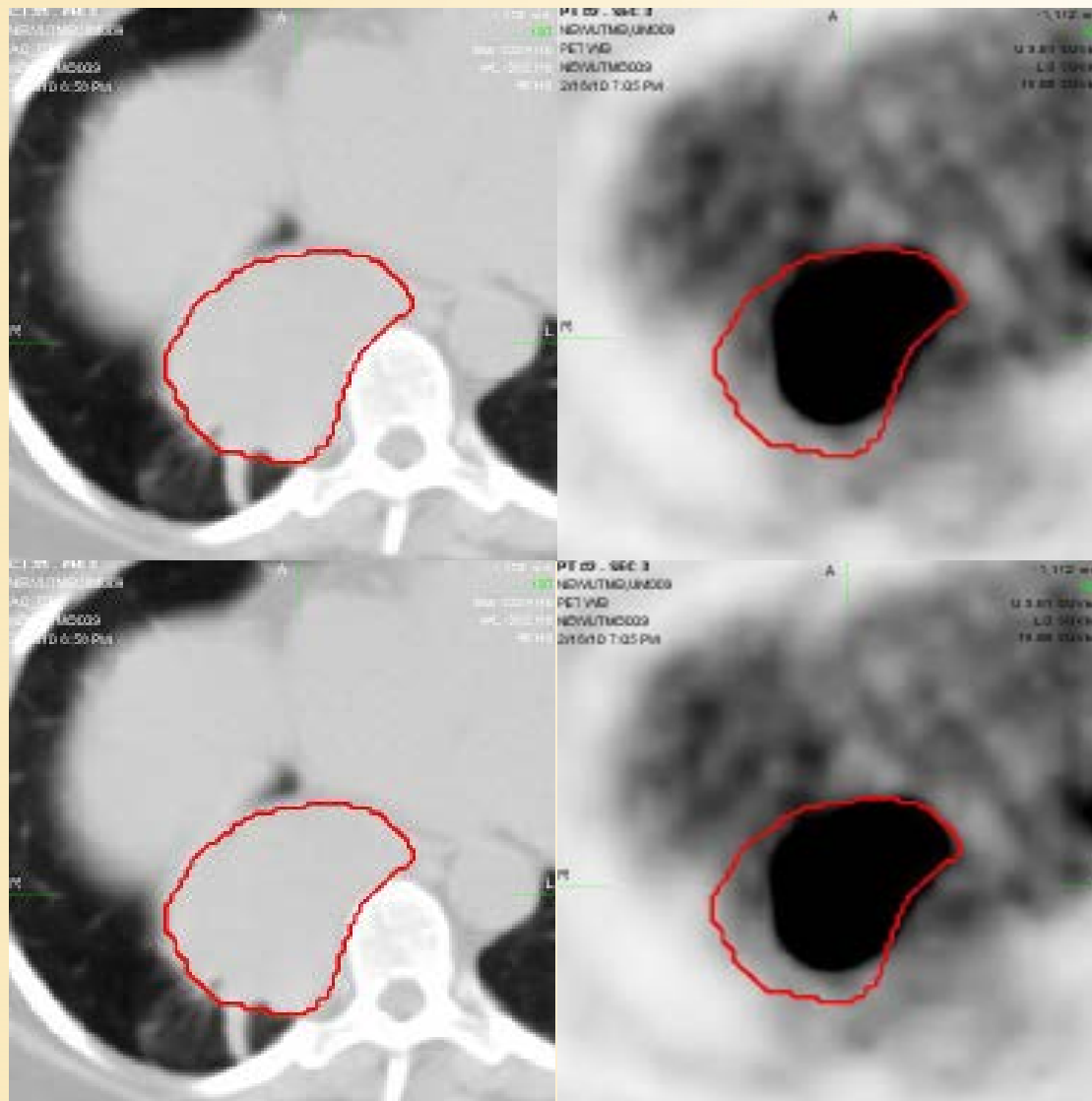
CT1GTV on Pre-treatment PET-CT, case 1



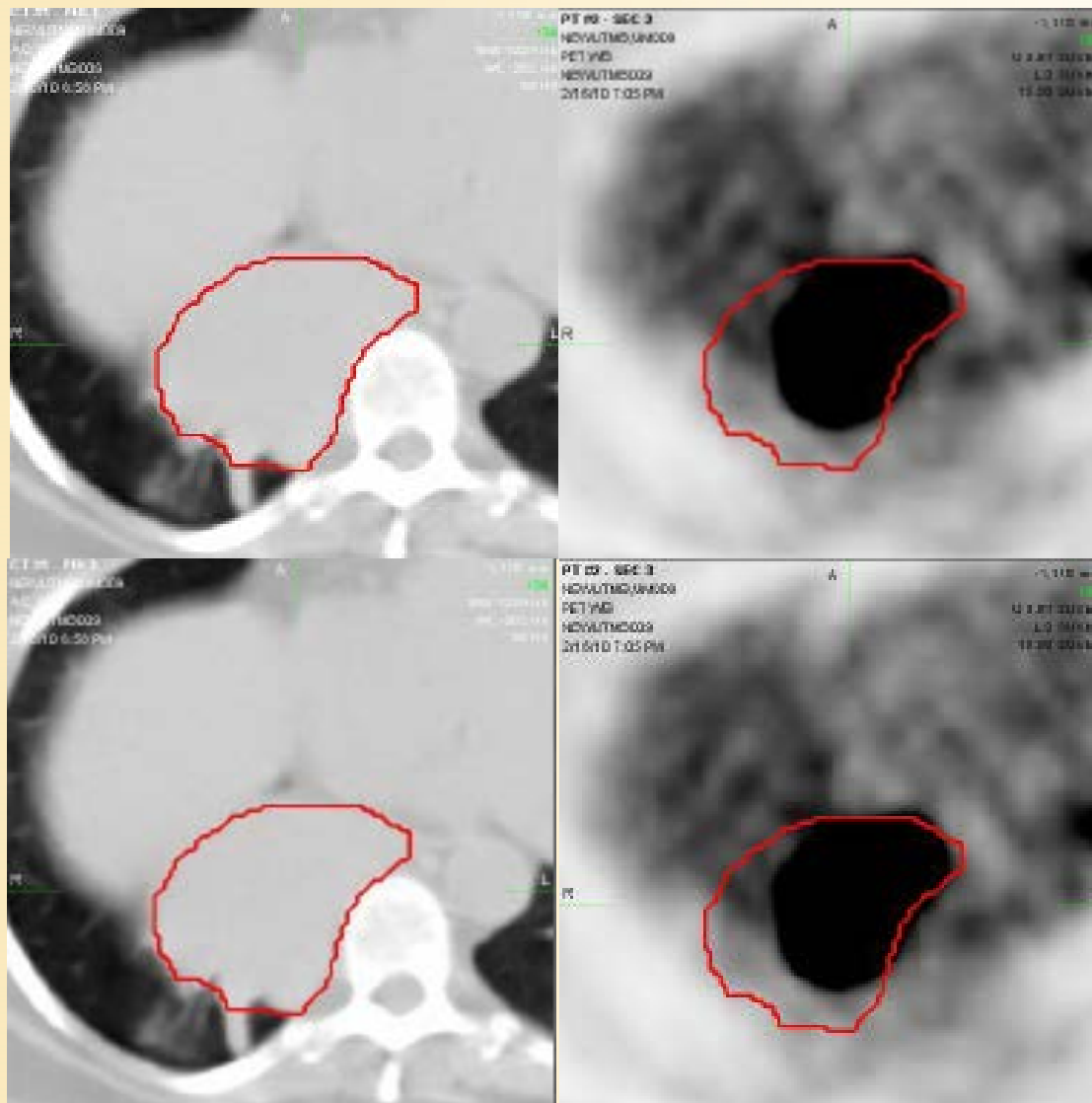
CT1GTV on Pre-treatment PET-CT, case 1



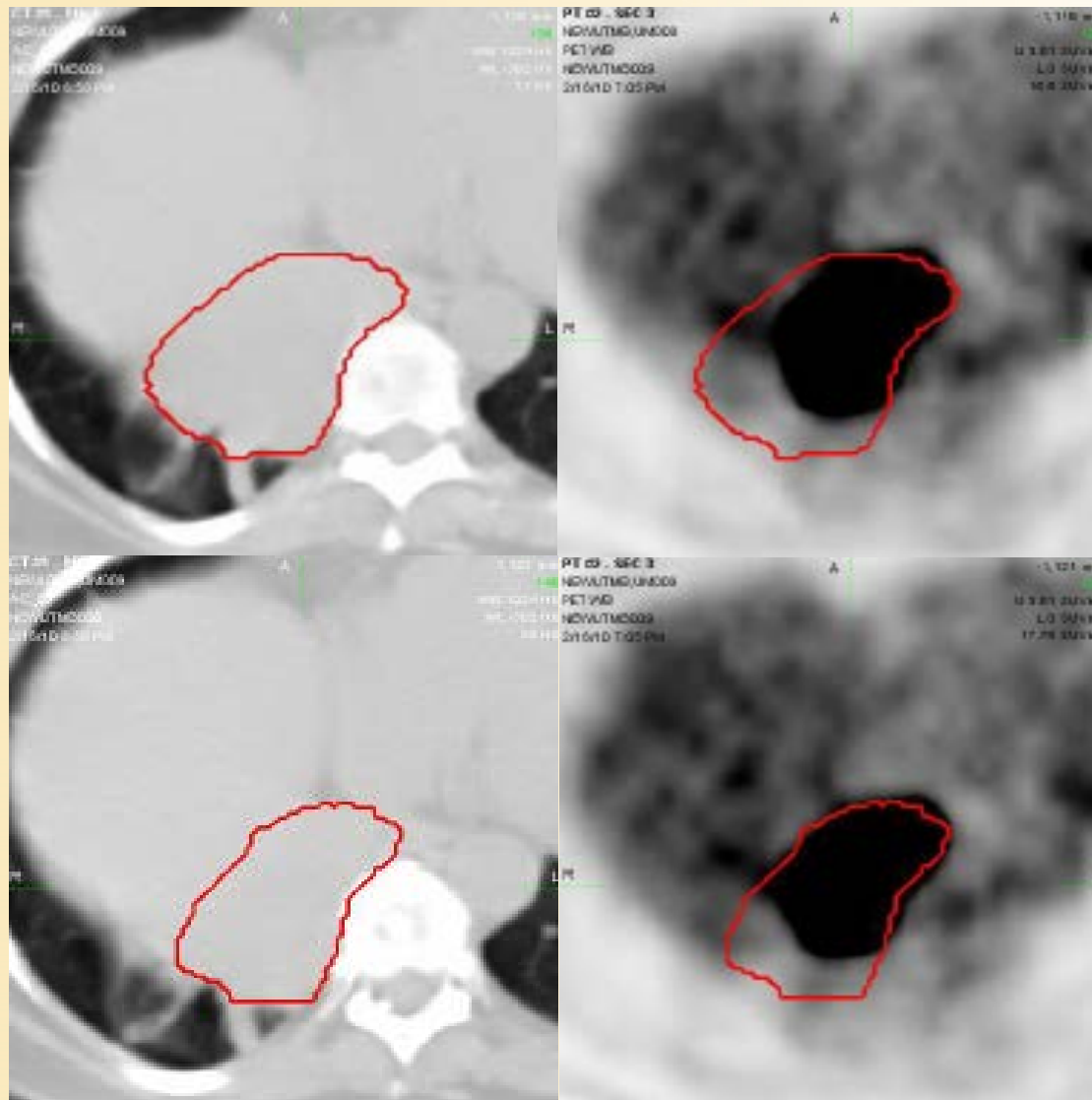
CT1GTV on Pre-treatment PET-CT, case 1



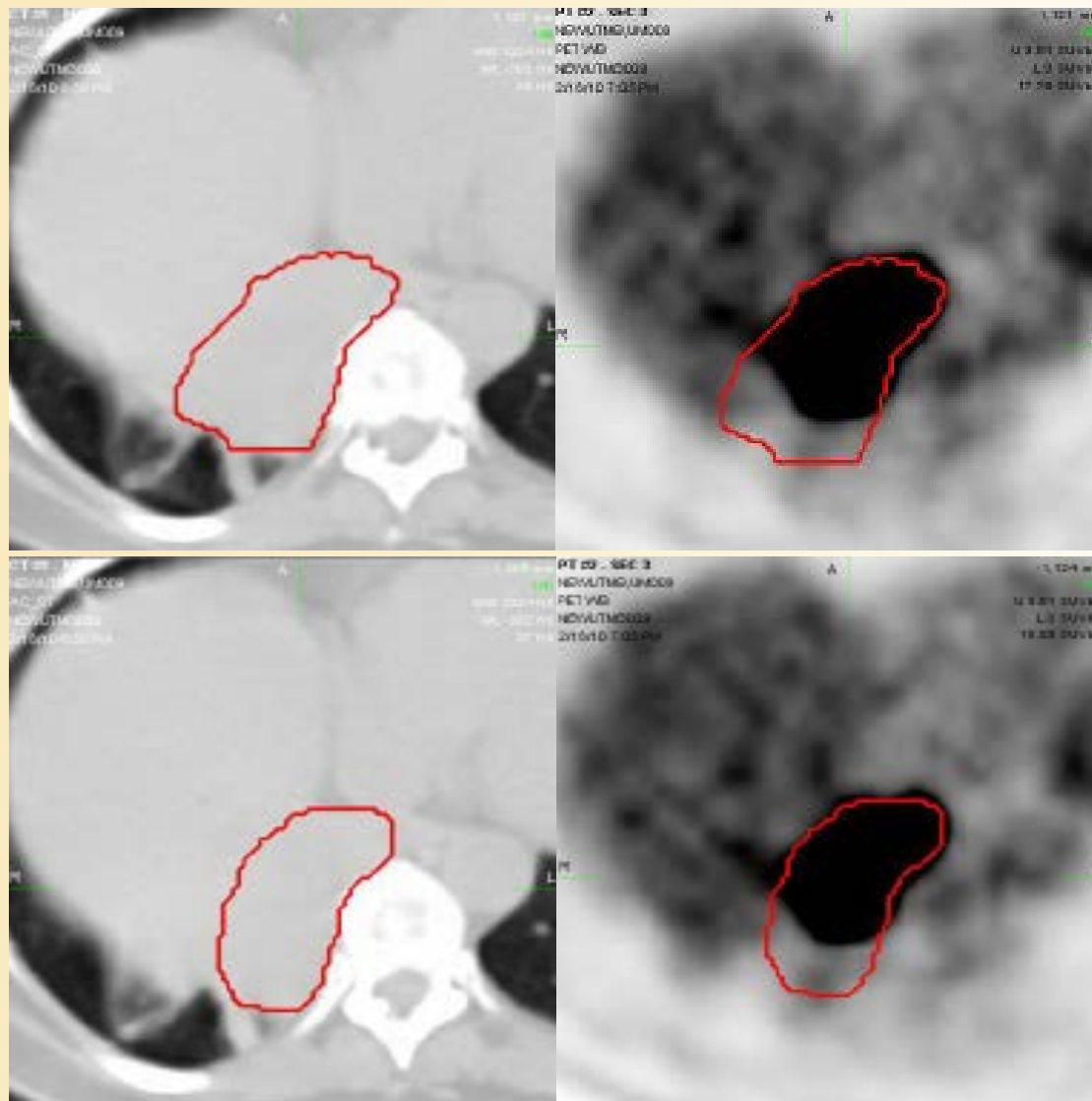
CT1GTV on Pre-treatment PET-CT, case 1



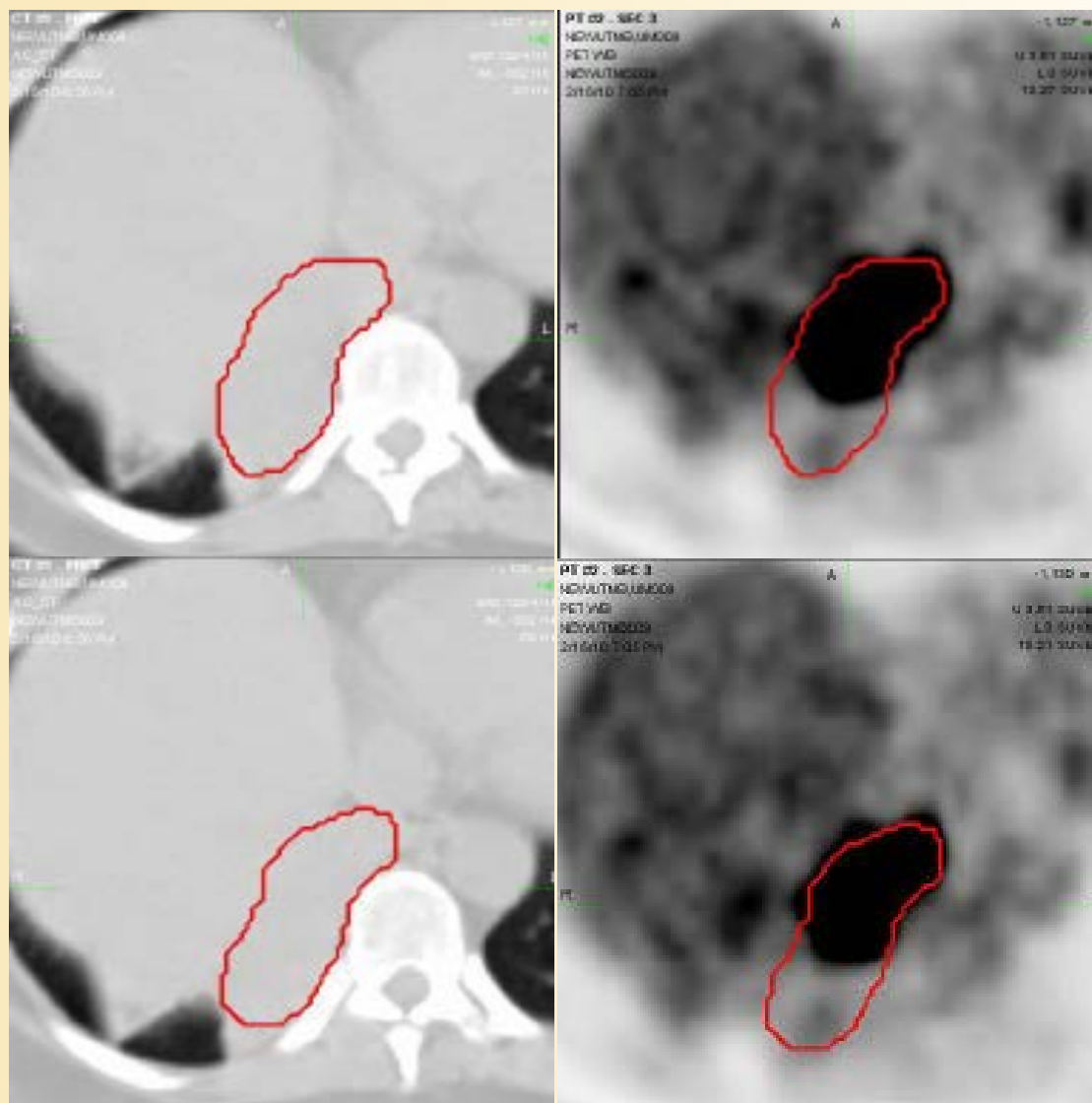
CT1GTV on Pre-treatment PET-CT, case 1



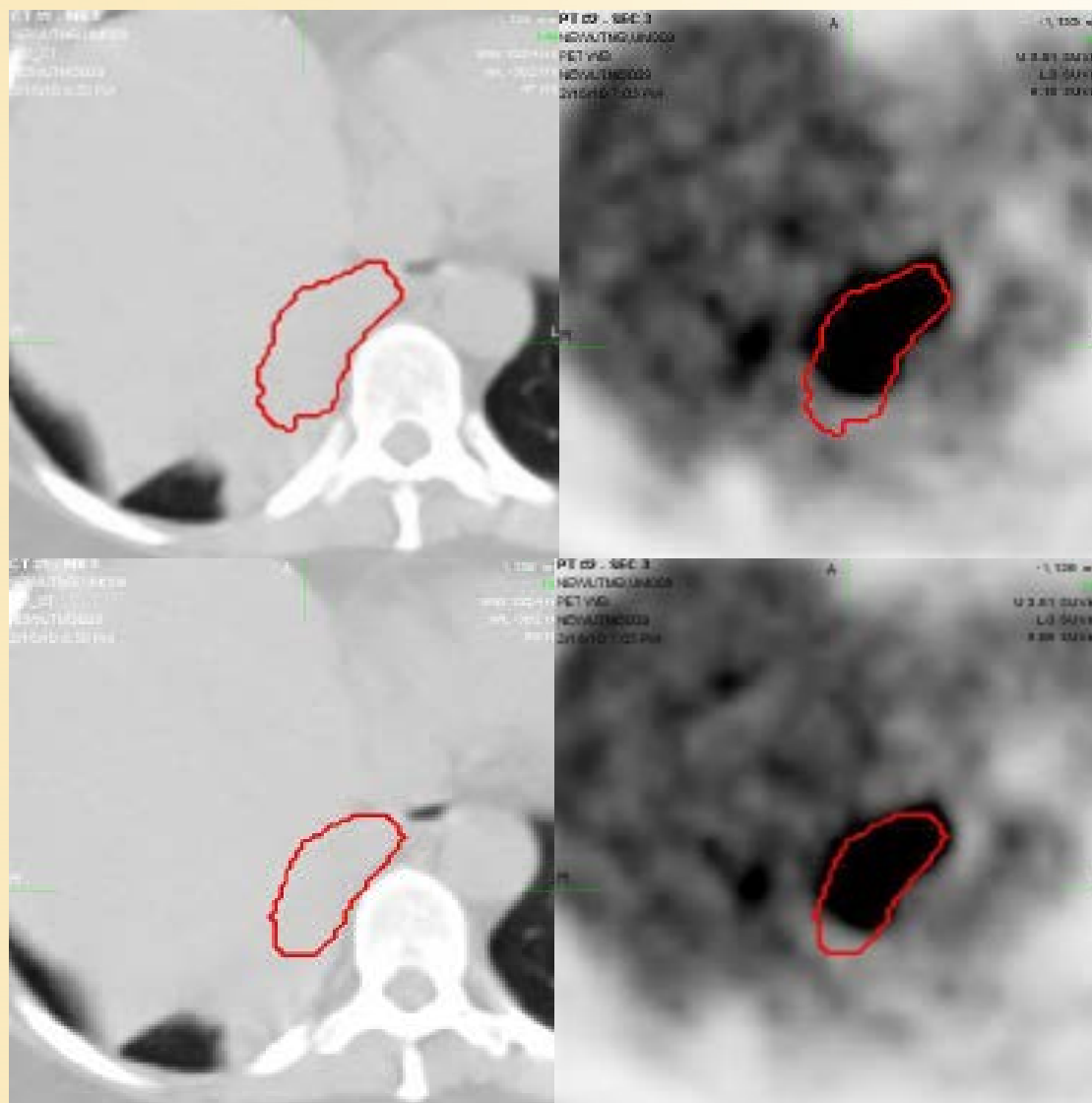
CT1GTV on Pre-treatment PET-CT, case 1



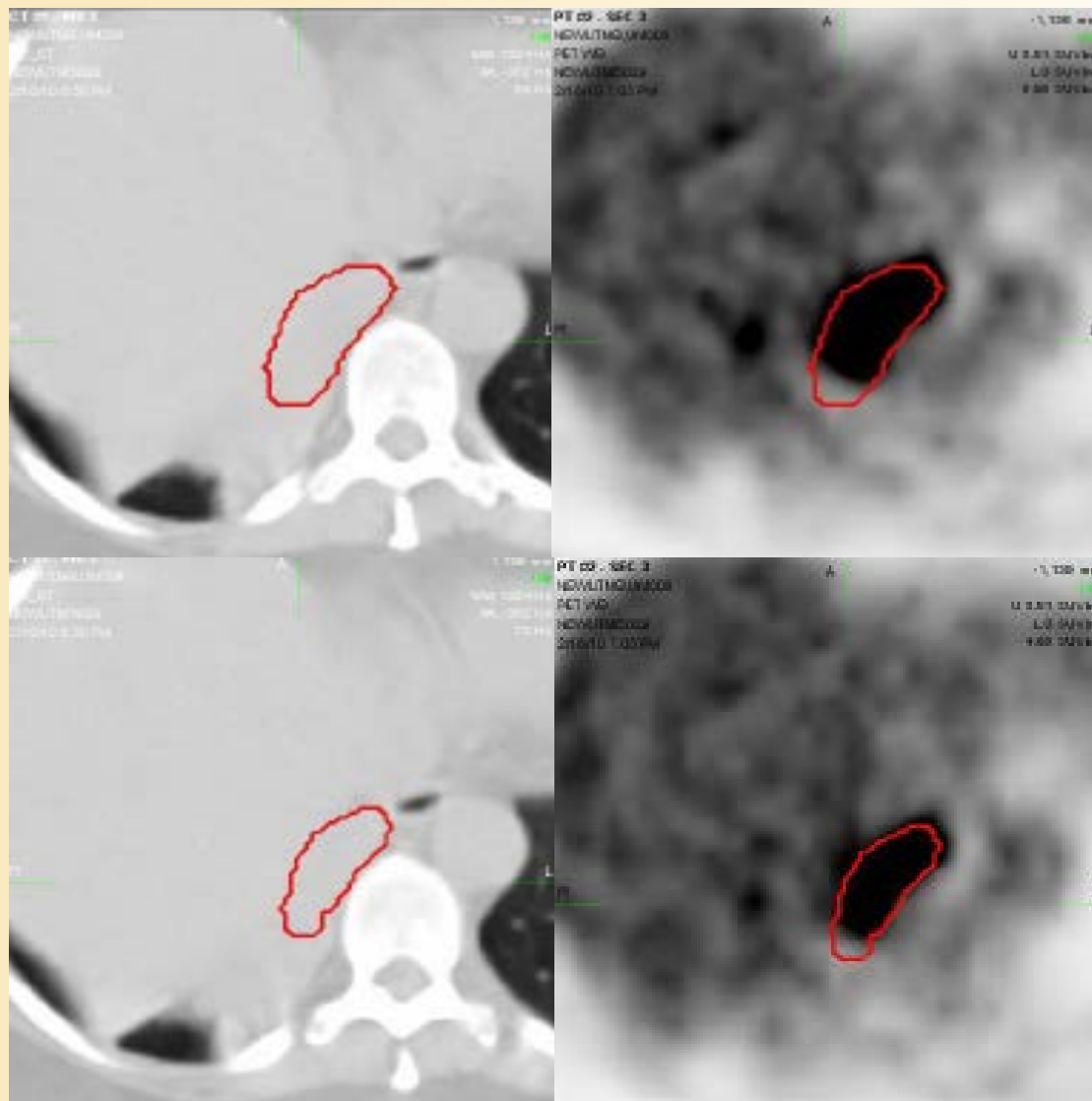
CT1GTV on Pre-treatment PET-CT, case 1



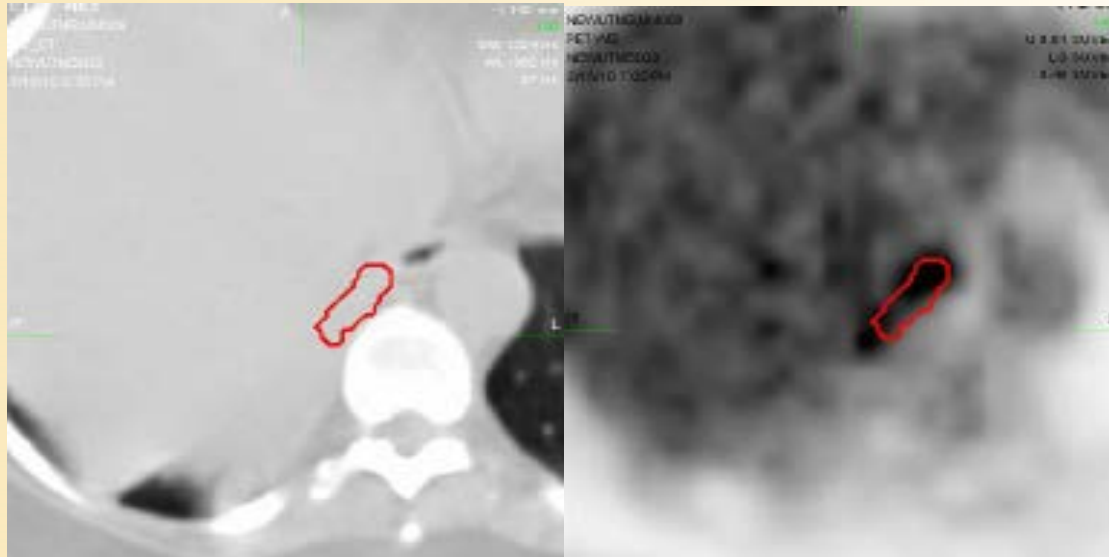
CT1GTV on Pre-treatment PET-CT, case 1



CT1GTV on Pre-treatment PET-CT, case 1



CT1GTV on Pre-treatment PET-CT, case 1

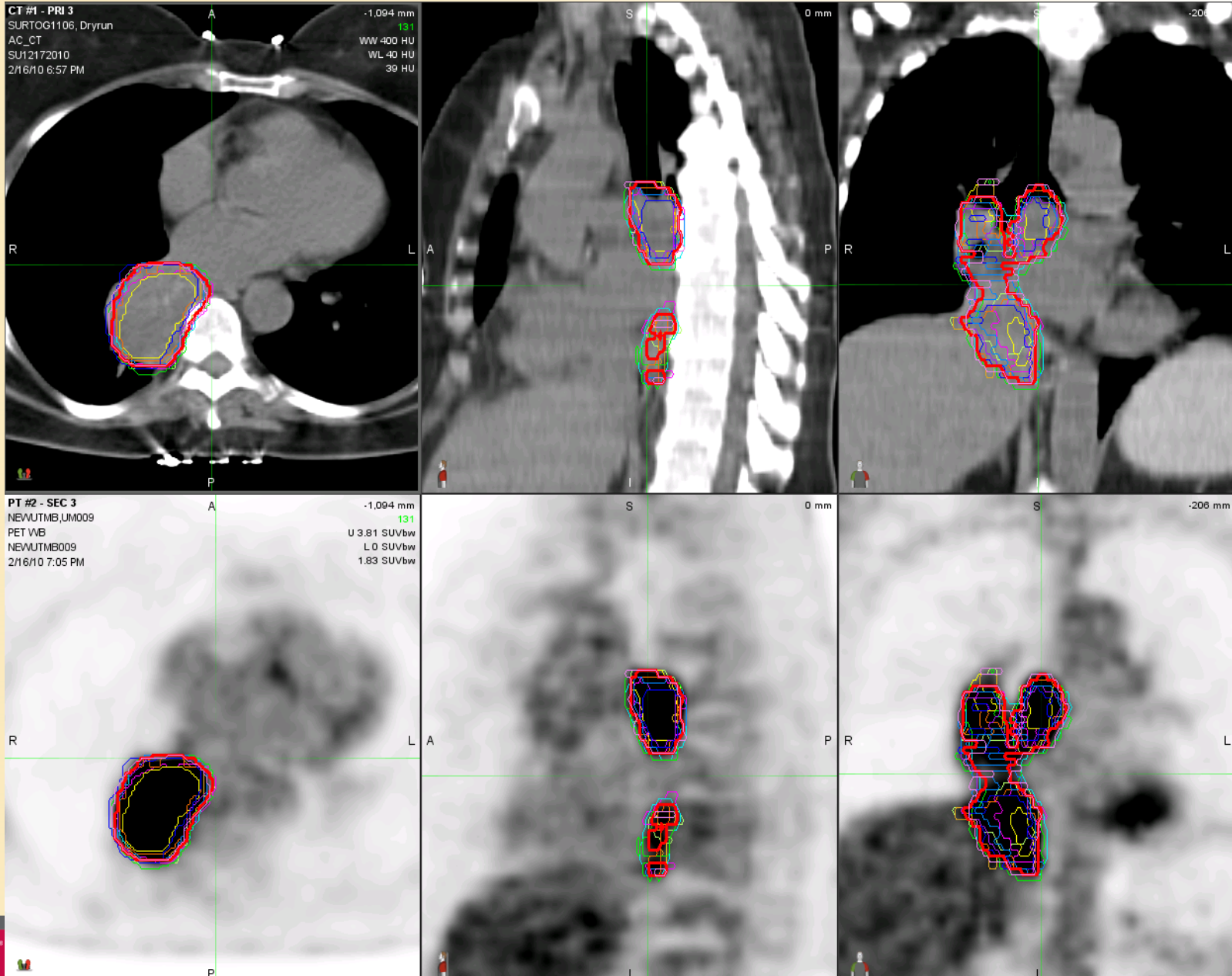


PET1MTV on Pretreatment PET-CT: Example Case #1

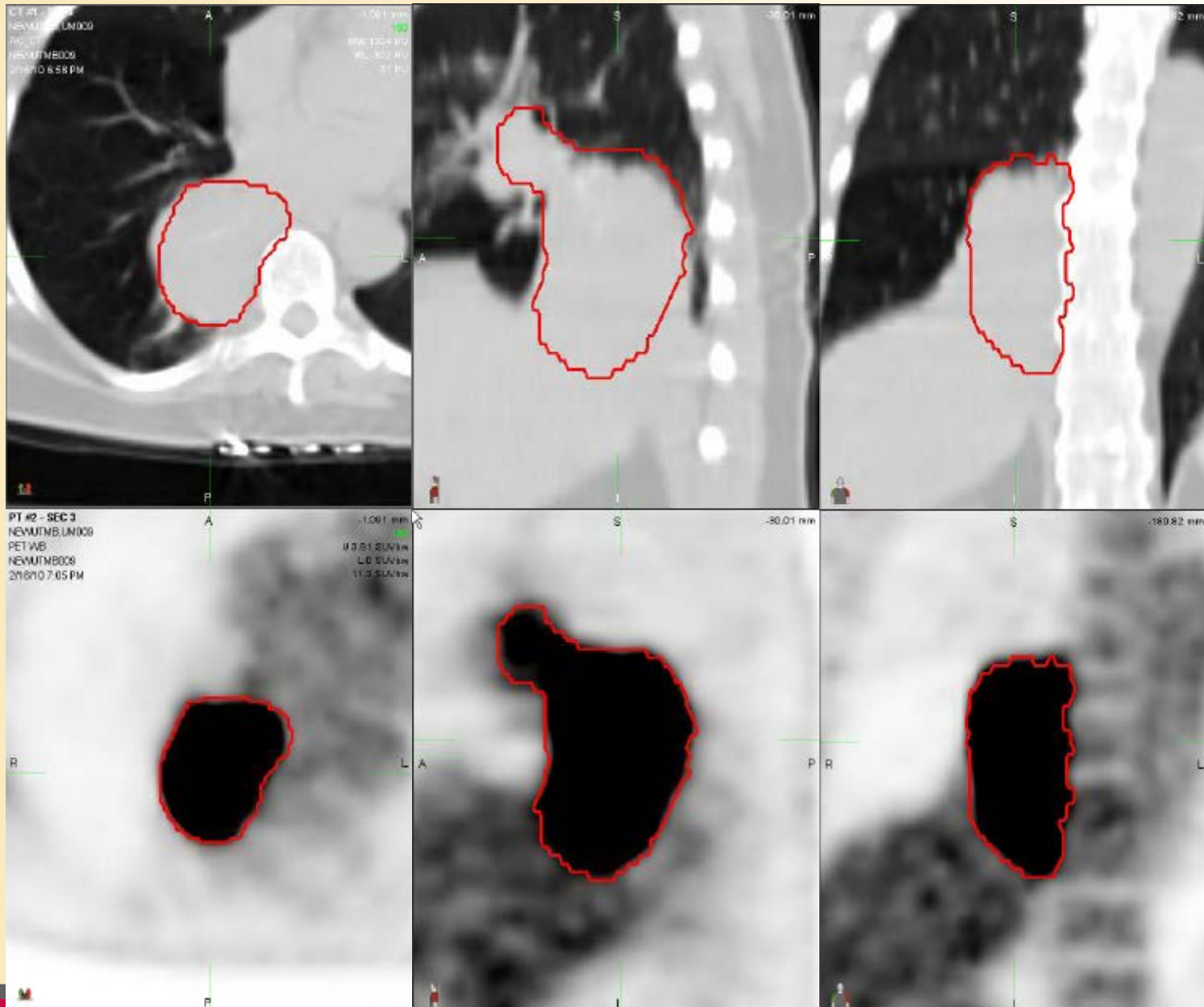
PET1MTV will be generated using
threshold on 1.5^* tumor/aorta
ratio.

PET1MTV on Pre-treatment PET-CT, case 1

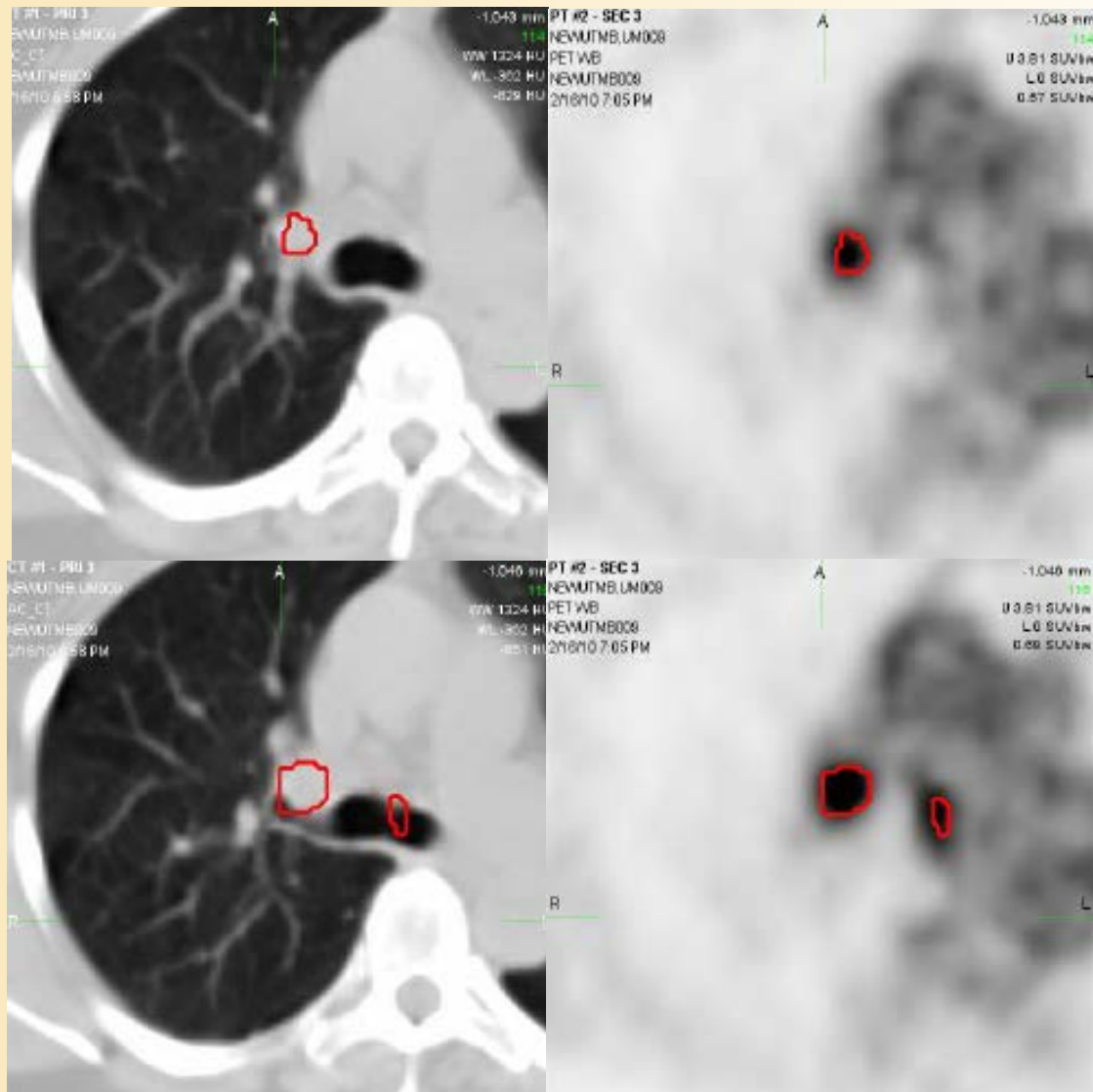
Variations (thin lines) and consensus (red thick lines)



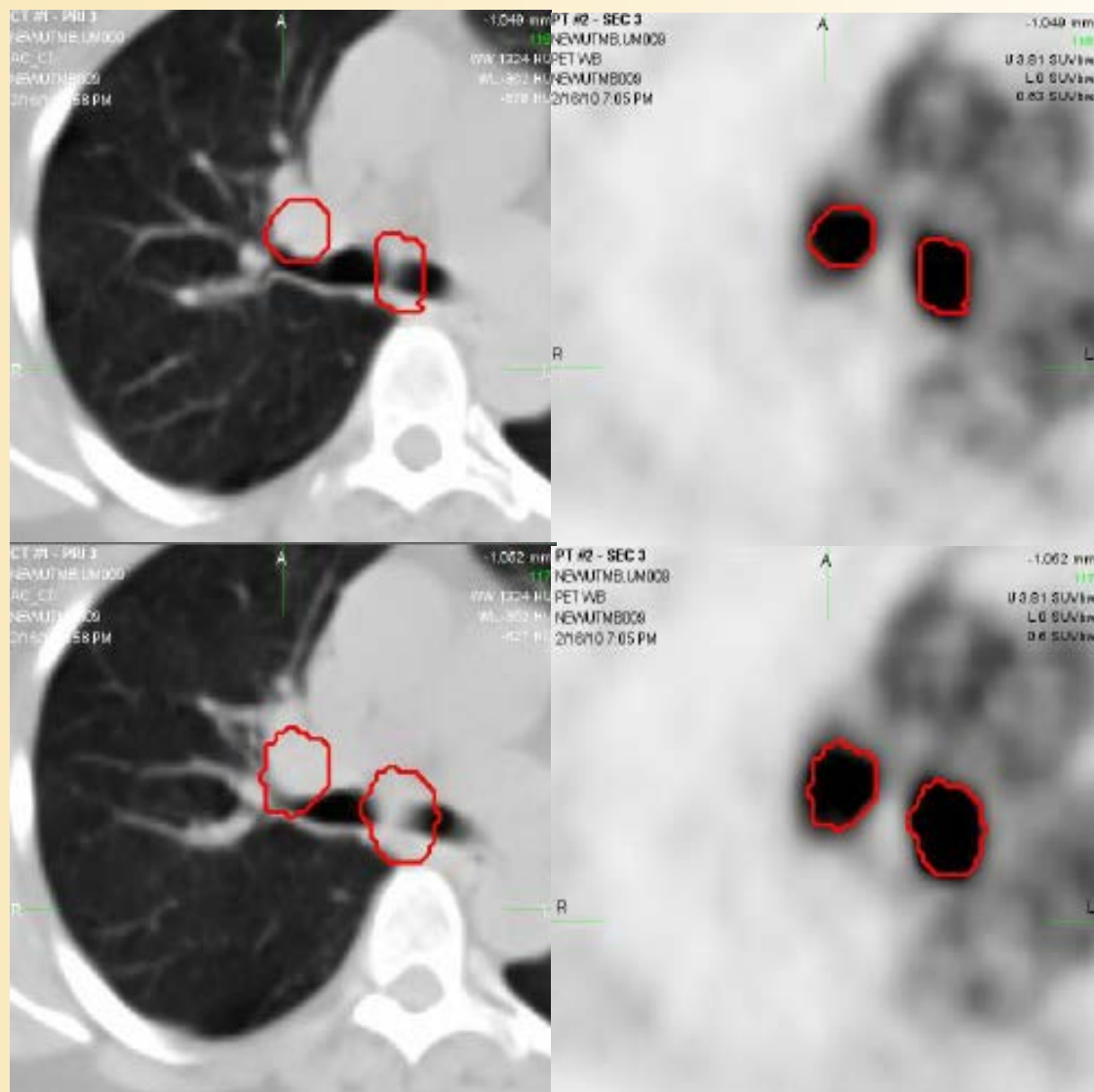
Consensus PET1MTV on Pre-treatment PET-CT, case 1



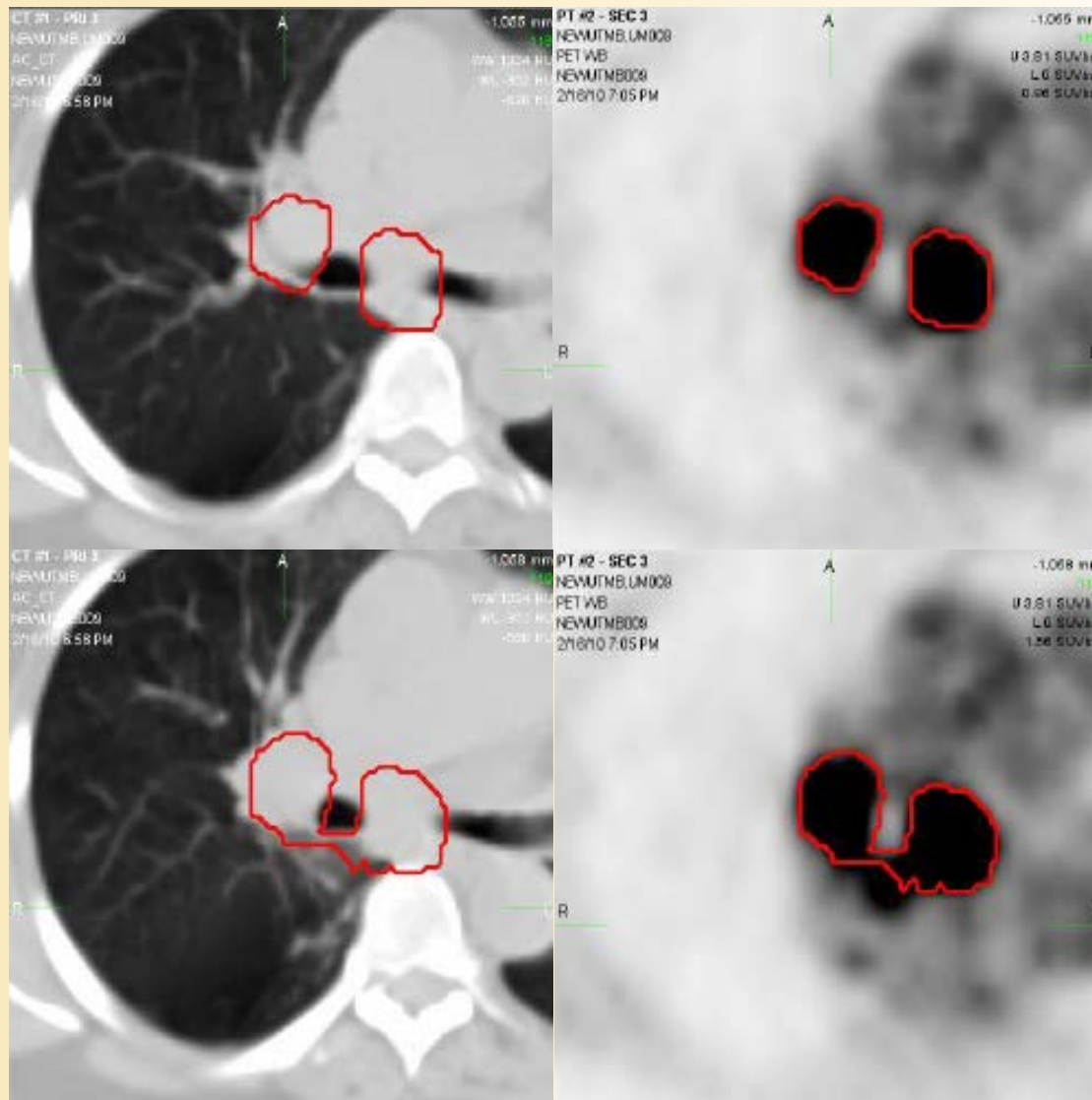
PET1MTV on Pre-treatment PET-CT, case 1



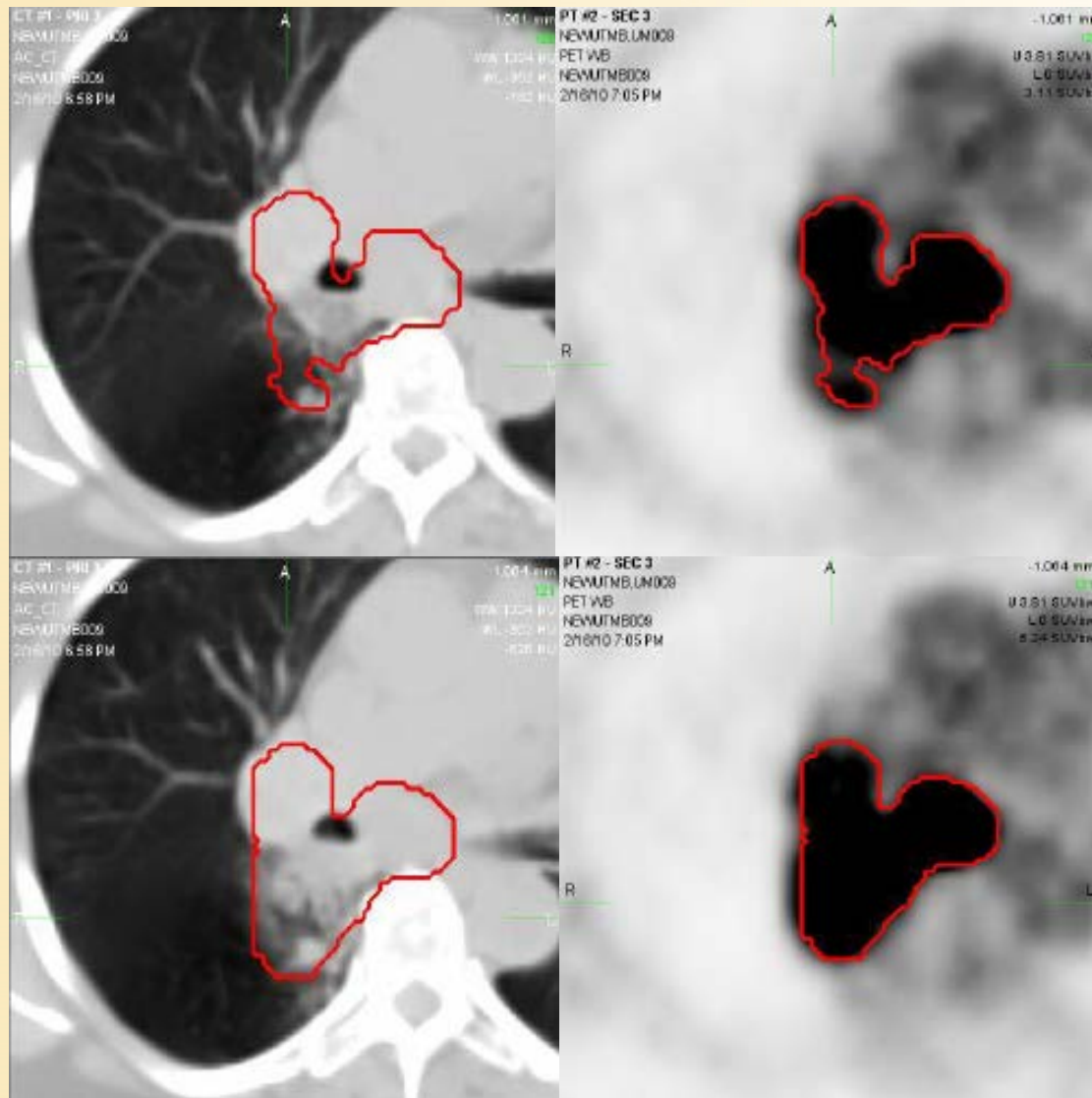
PET1MTV on Pre-treatment PET-CT, case 1



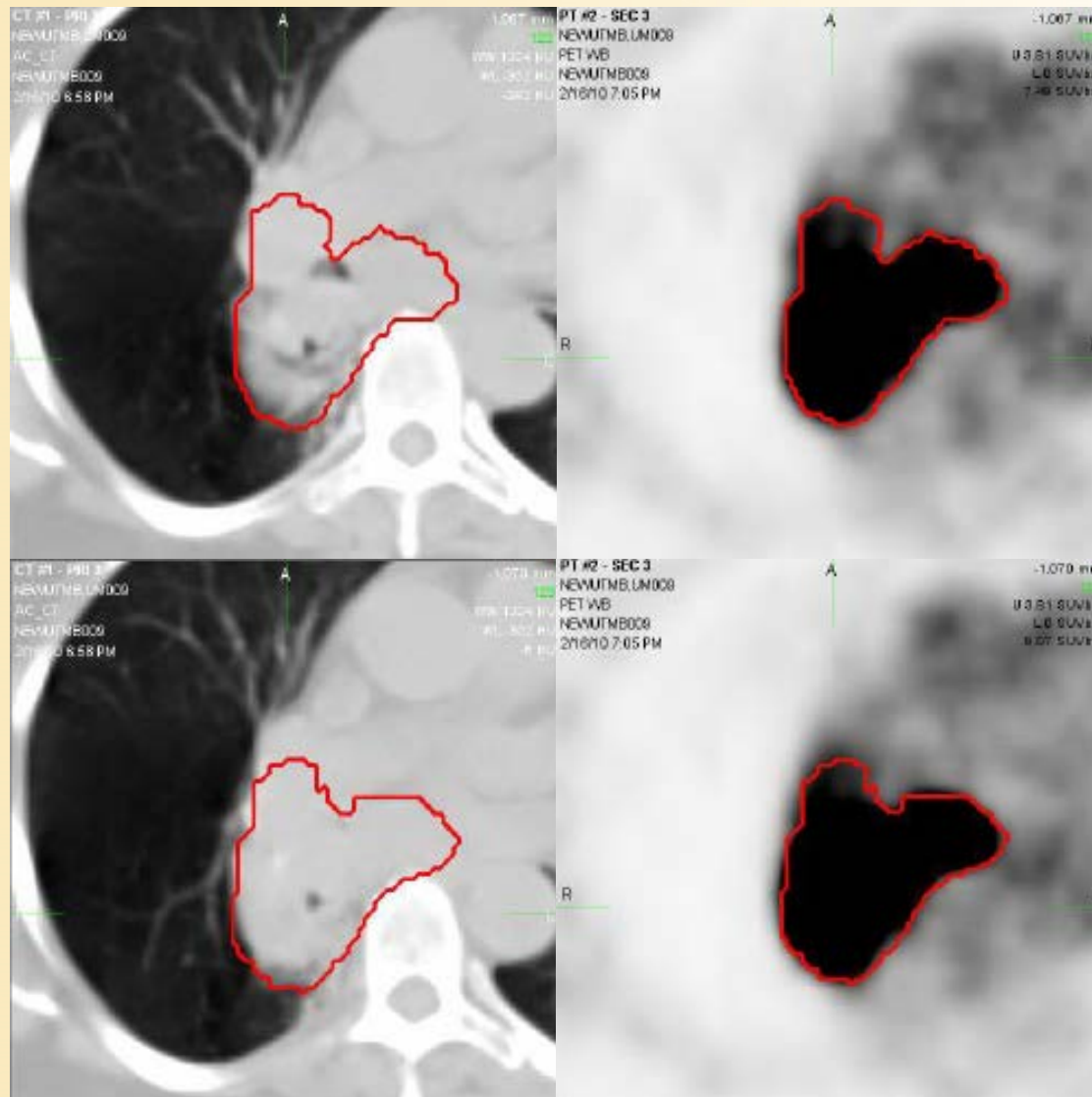
PET1MTV on Pre-treatment PET-CT, case 1



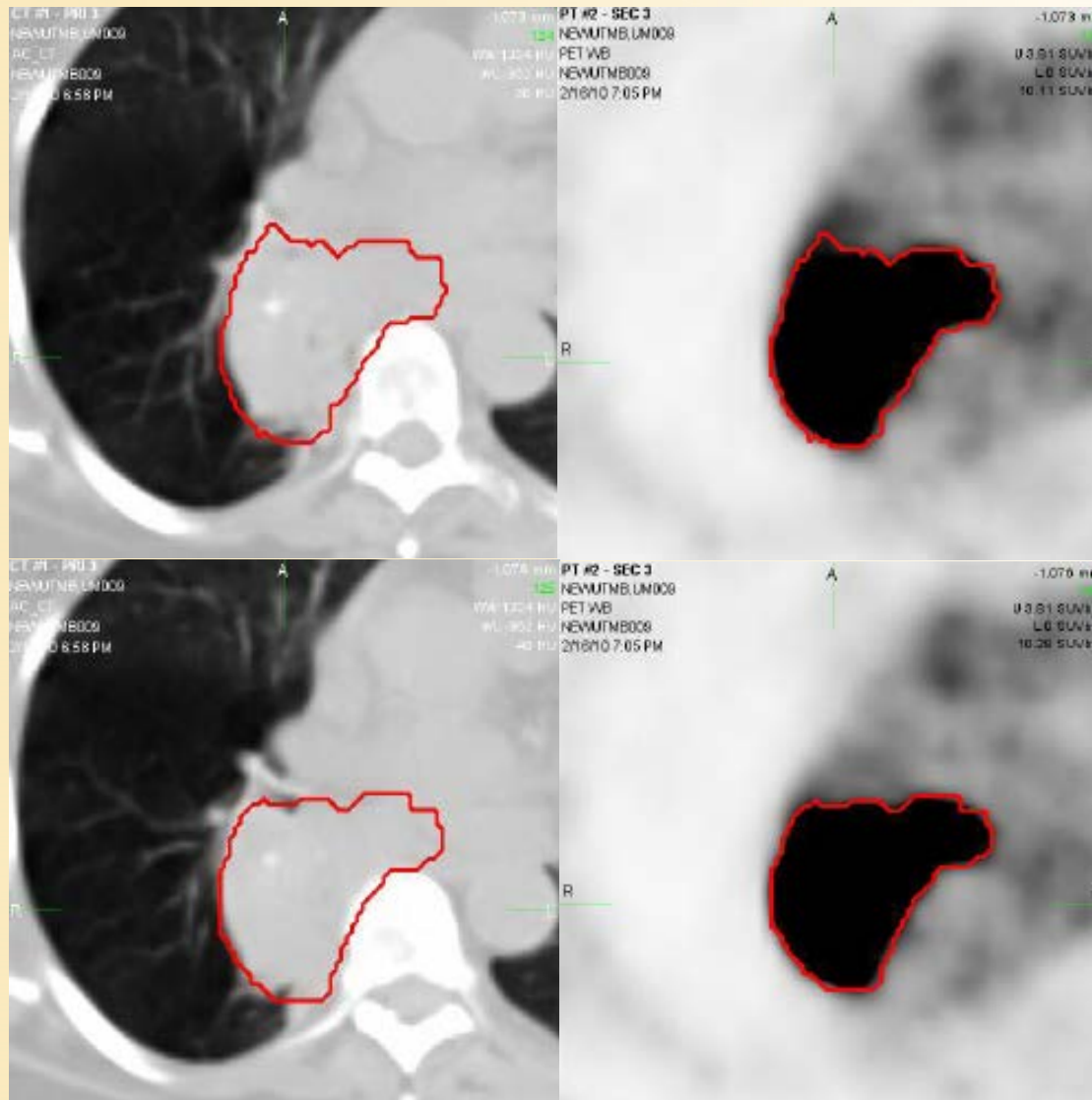
PET1MTV on Pre-treatment PET-CT, case 1



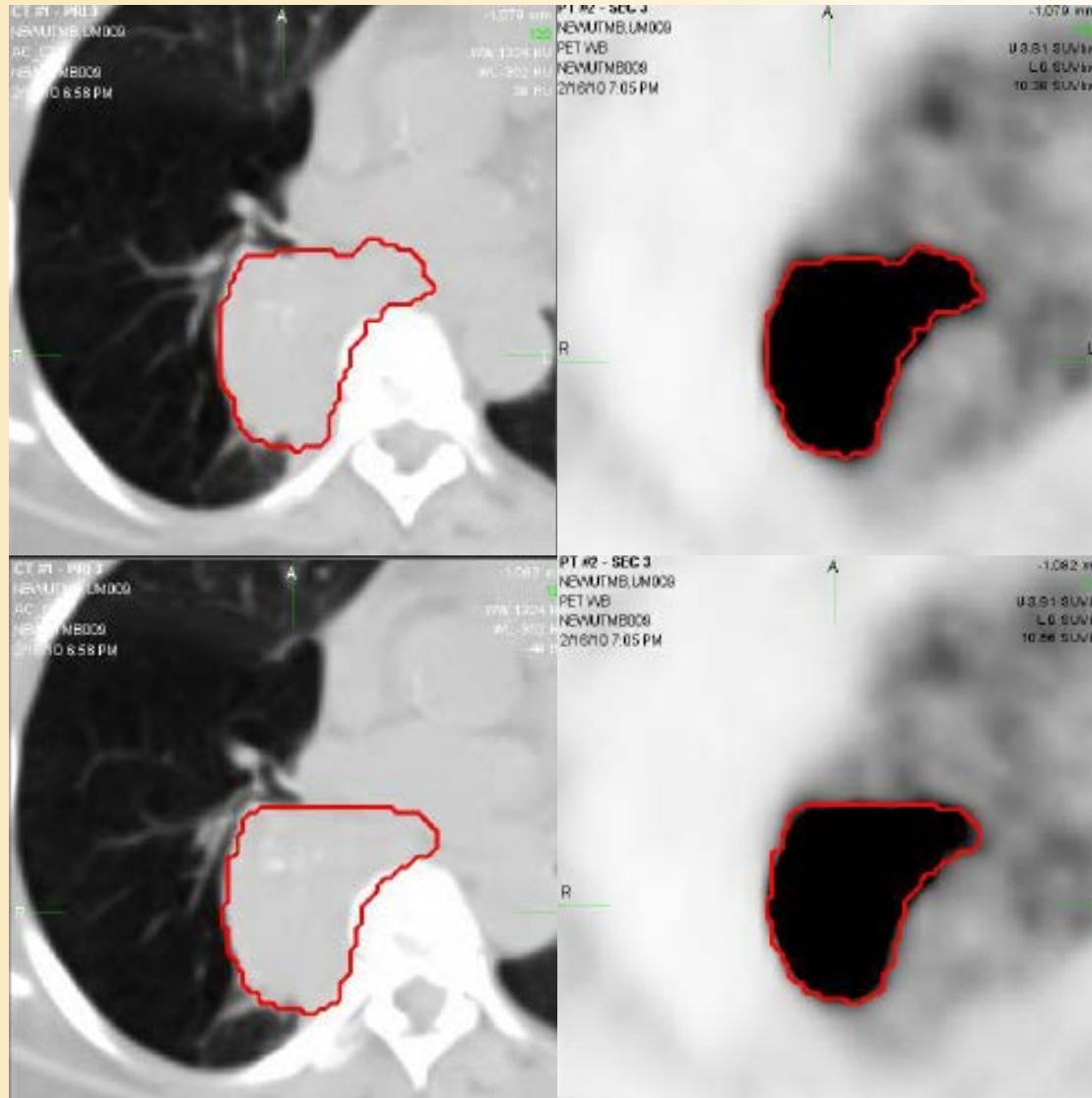
PET1MTV on Pre-treatment PET-CT, case 1



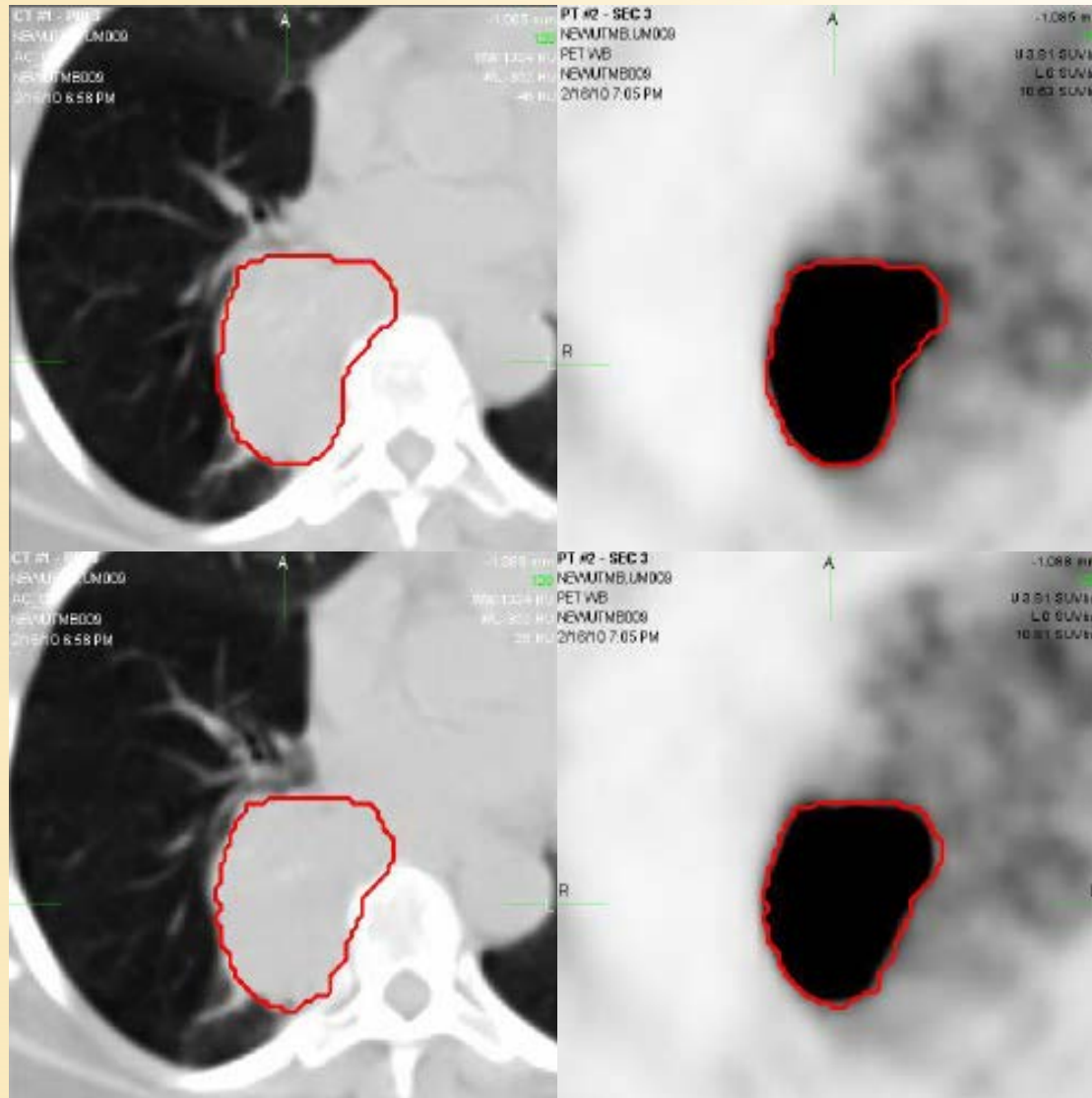
PET1MTV on Pre-treatment PET-CT, case 1



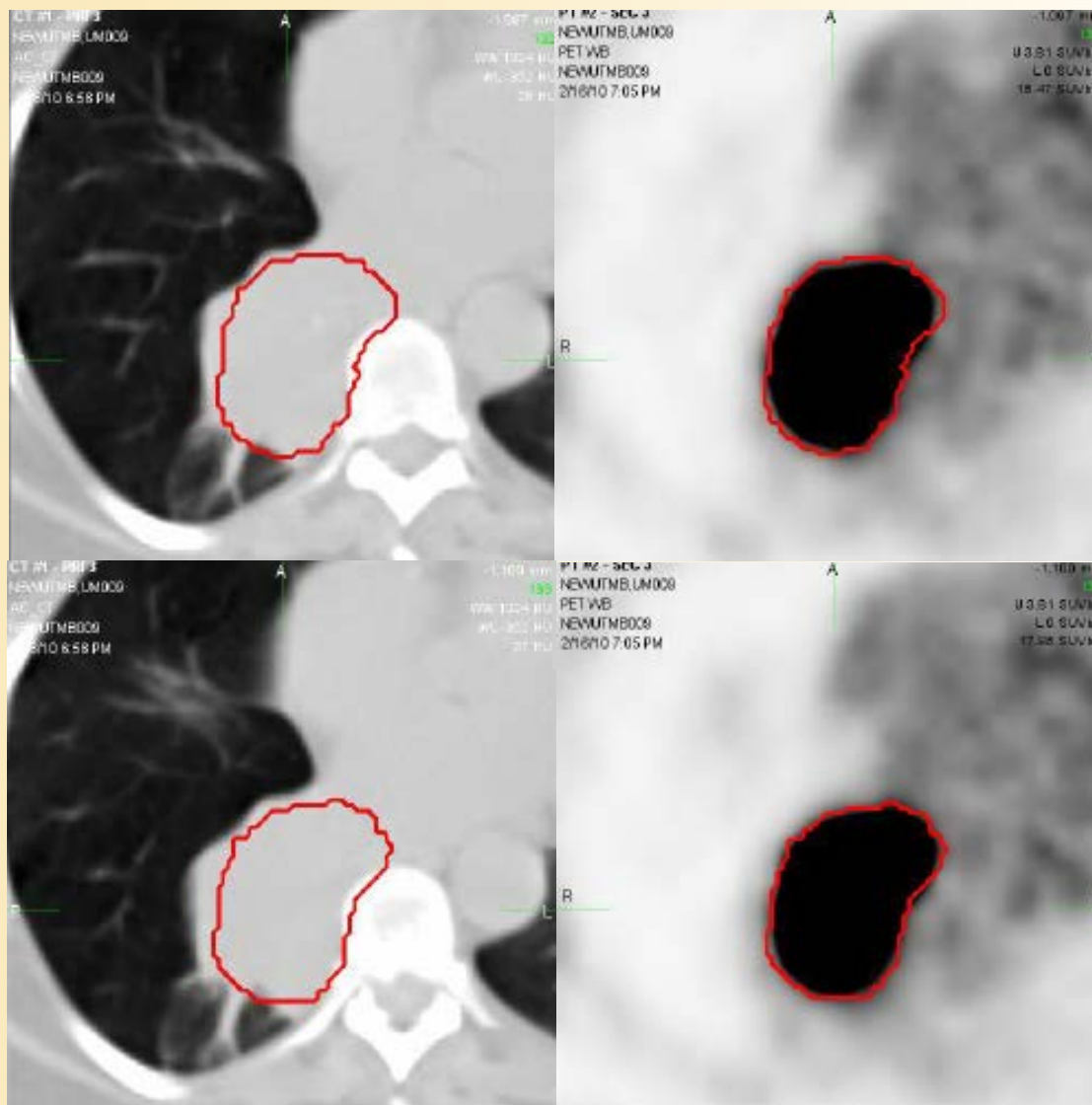
PET1MTV on Pre-treatment PET-CT, case 1



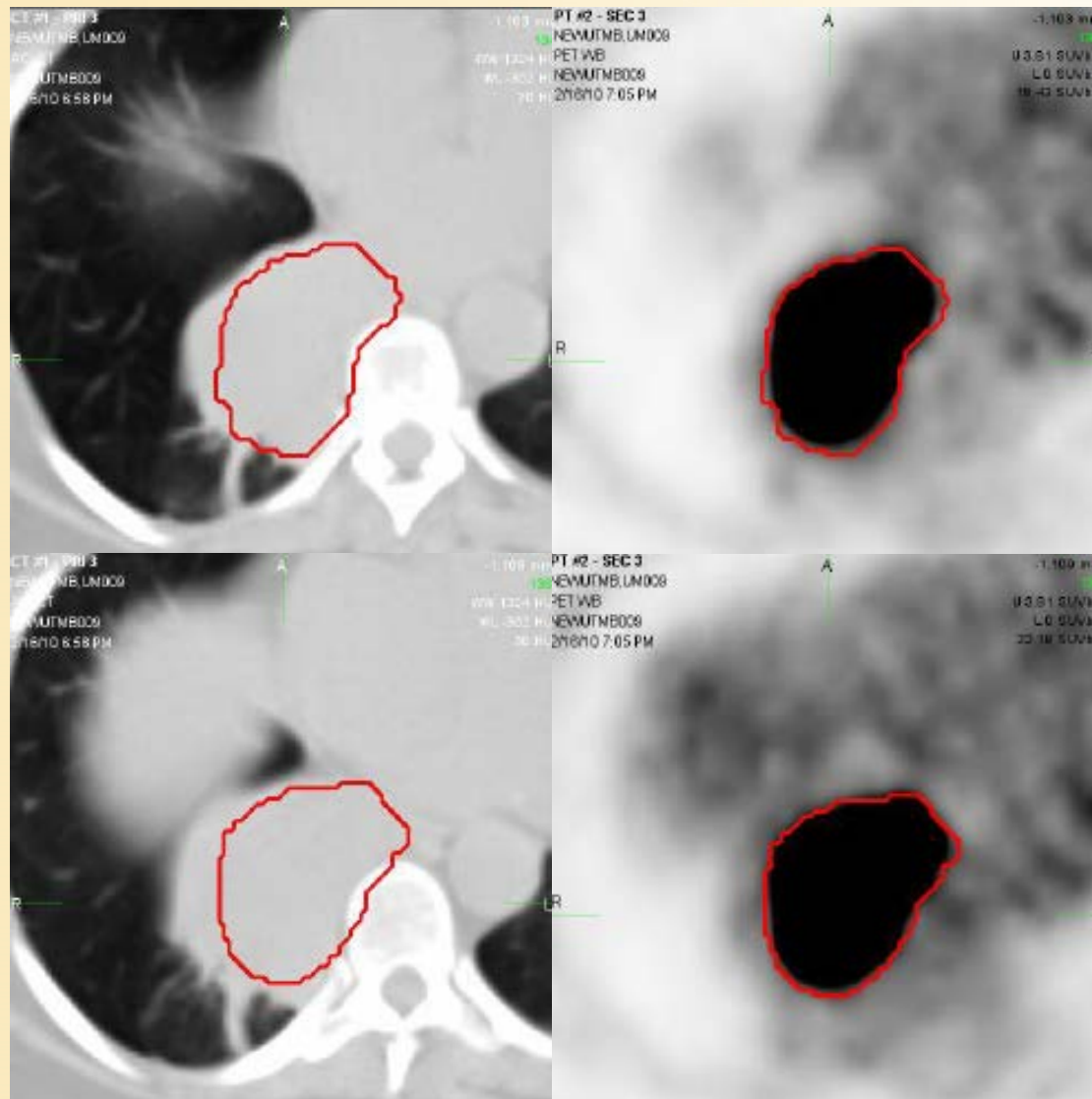
PET1MTV on Pre-treatment PET-CT, case 1



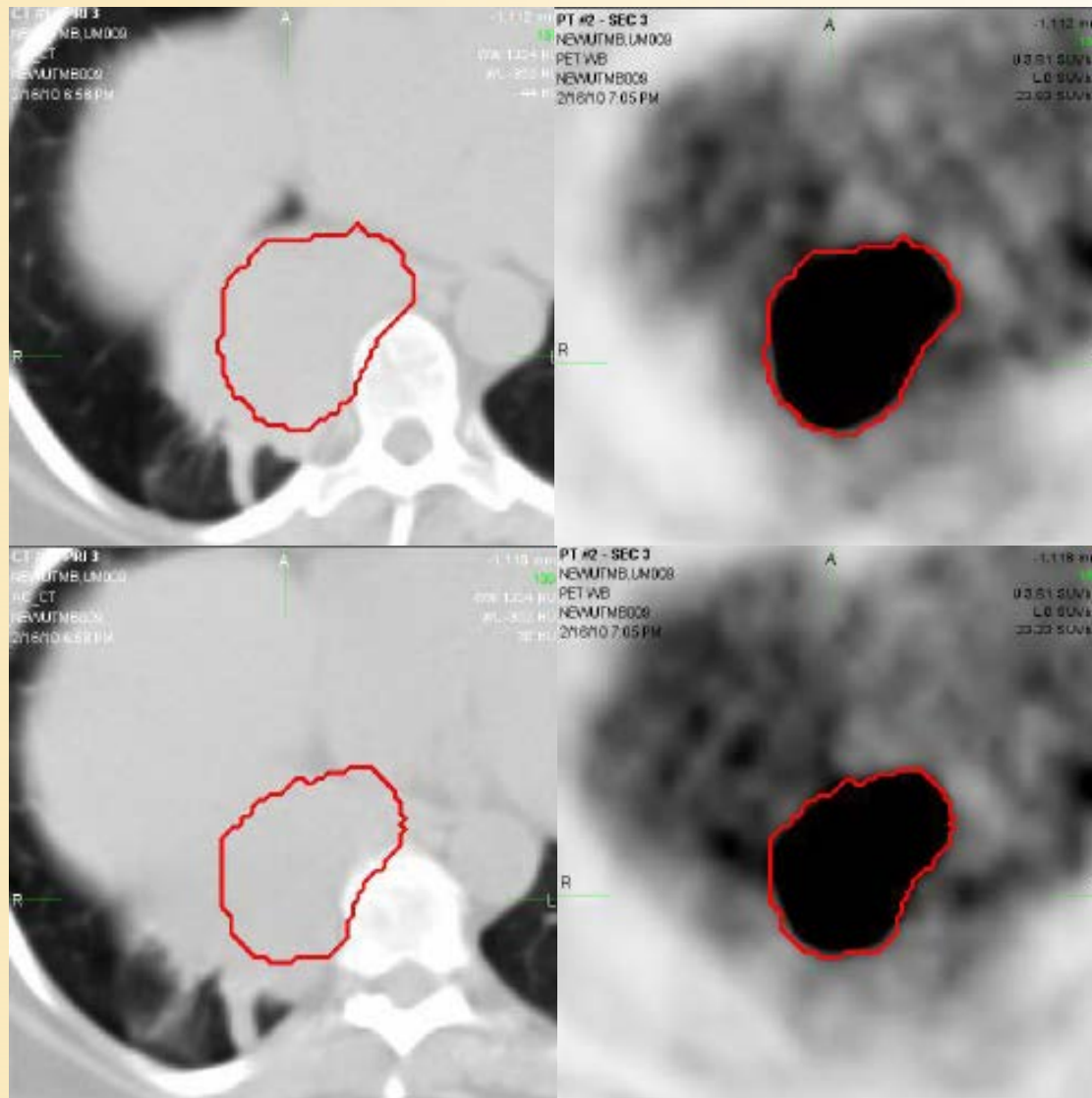
PET1MTV on Pre-treatment PET-CT, case 1



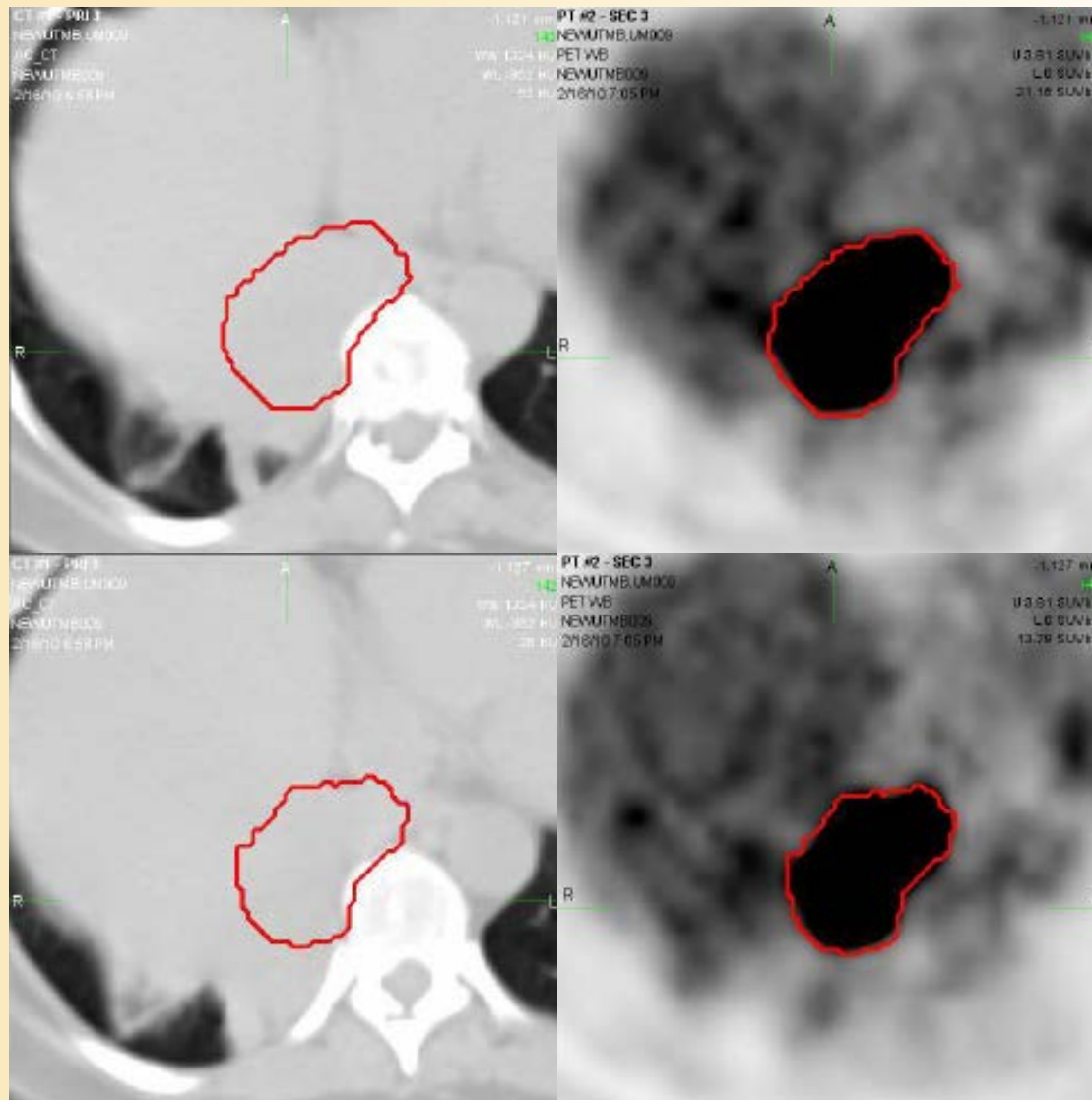
PET1MTV on Pre-treatment PET-CT, case 1



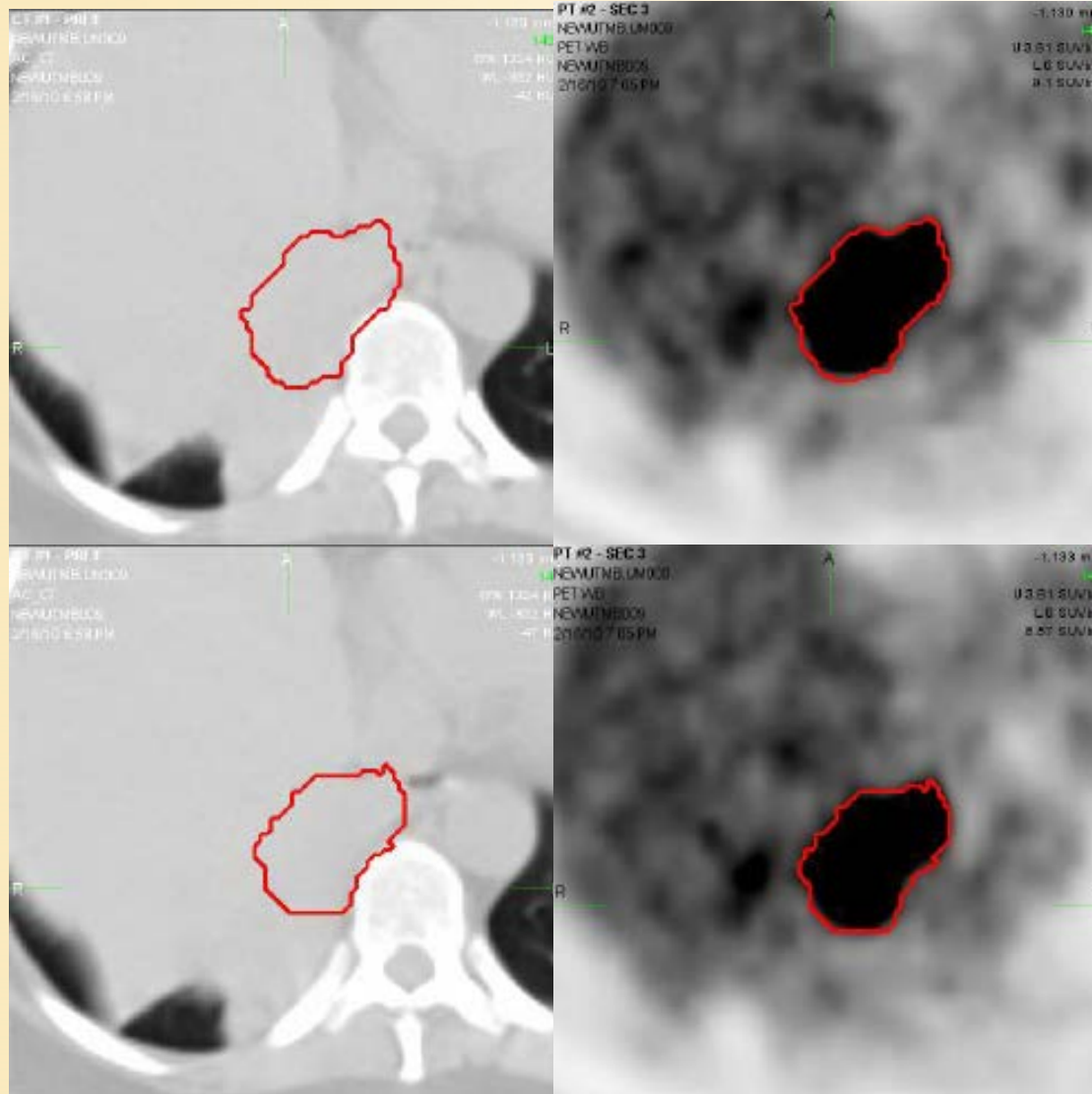
PET1MTV on Pre-treatment PET-CT, case 1



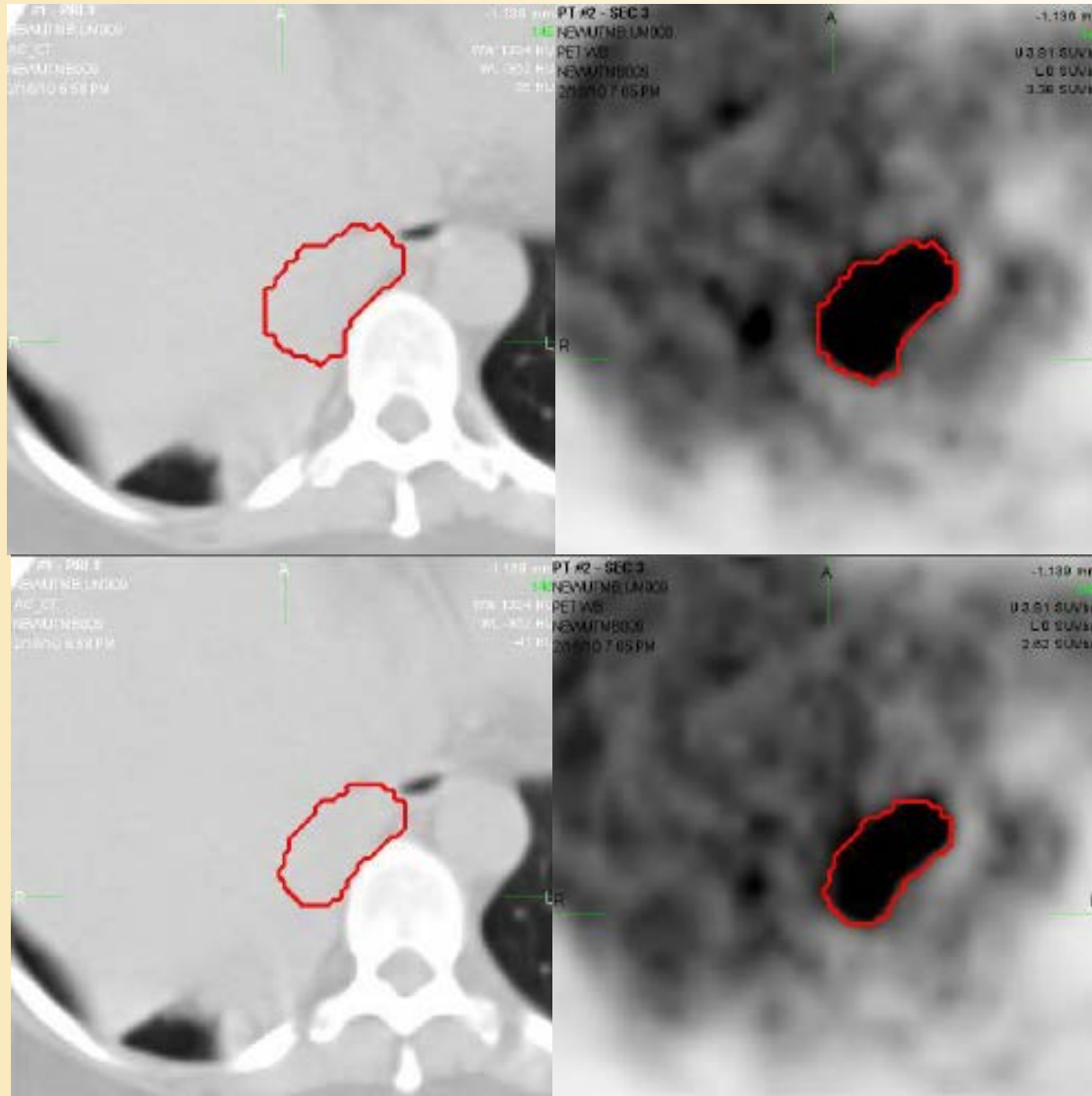
PET1MTV on Pre-treatment PET-CT, case 1



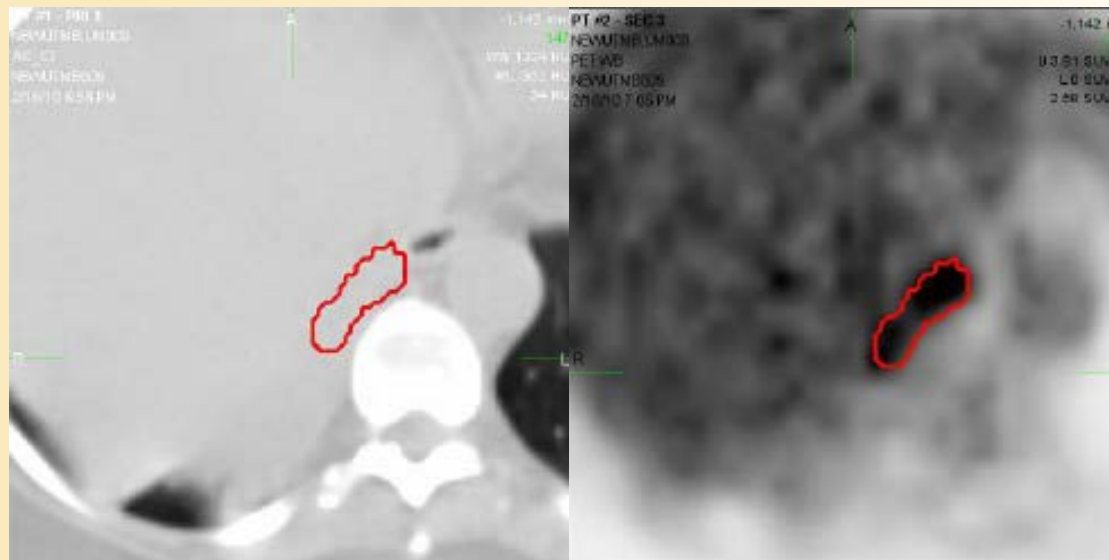
PET1MTV on Pre-treatment PET-CT, case 1



PET1MTV on Pre-treatment PET-CT, case 1



PET1MTV on Pre-treatment PET-CT, case 1

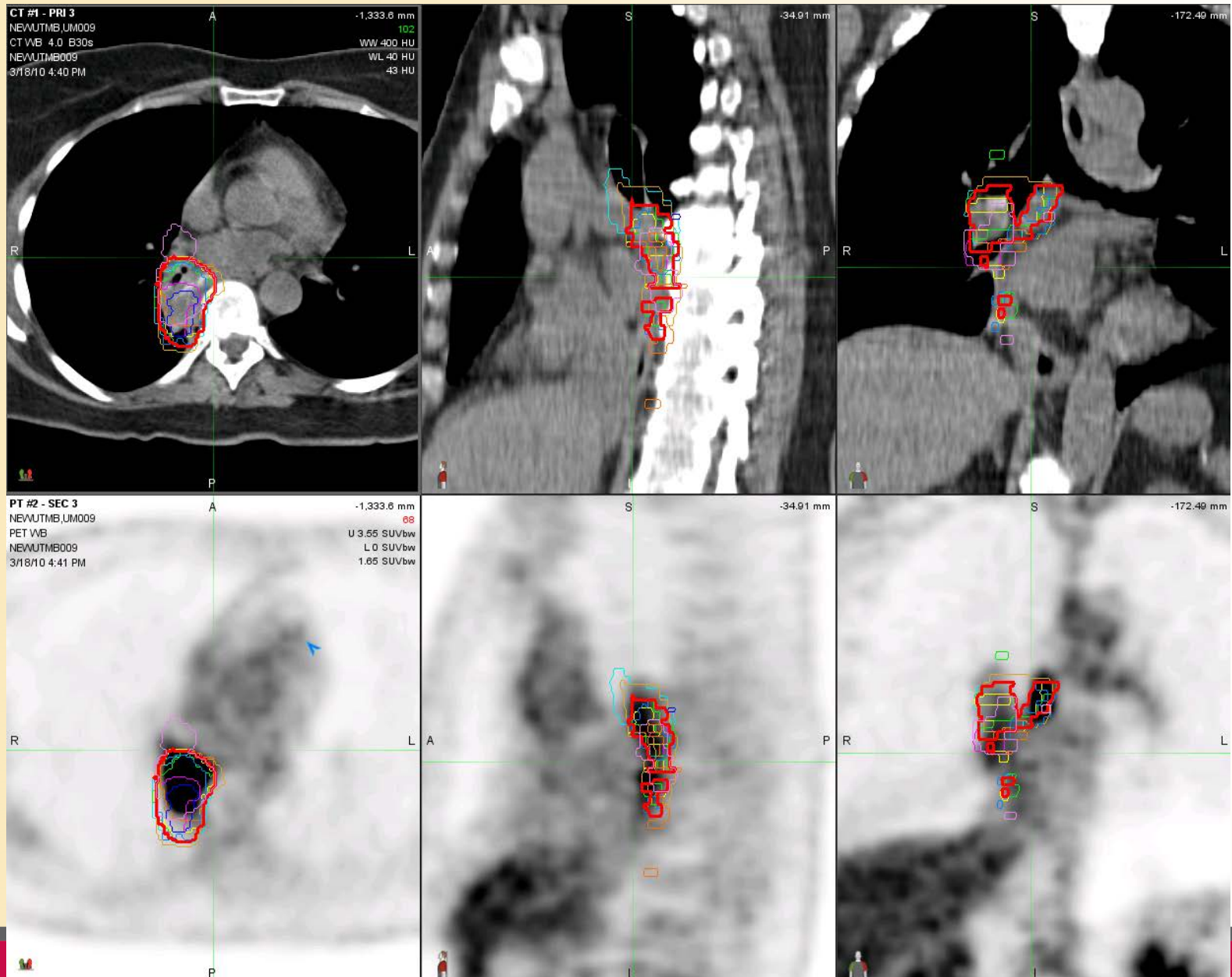


CT2GTV on during-treatment PET-CT: Example Case #1

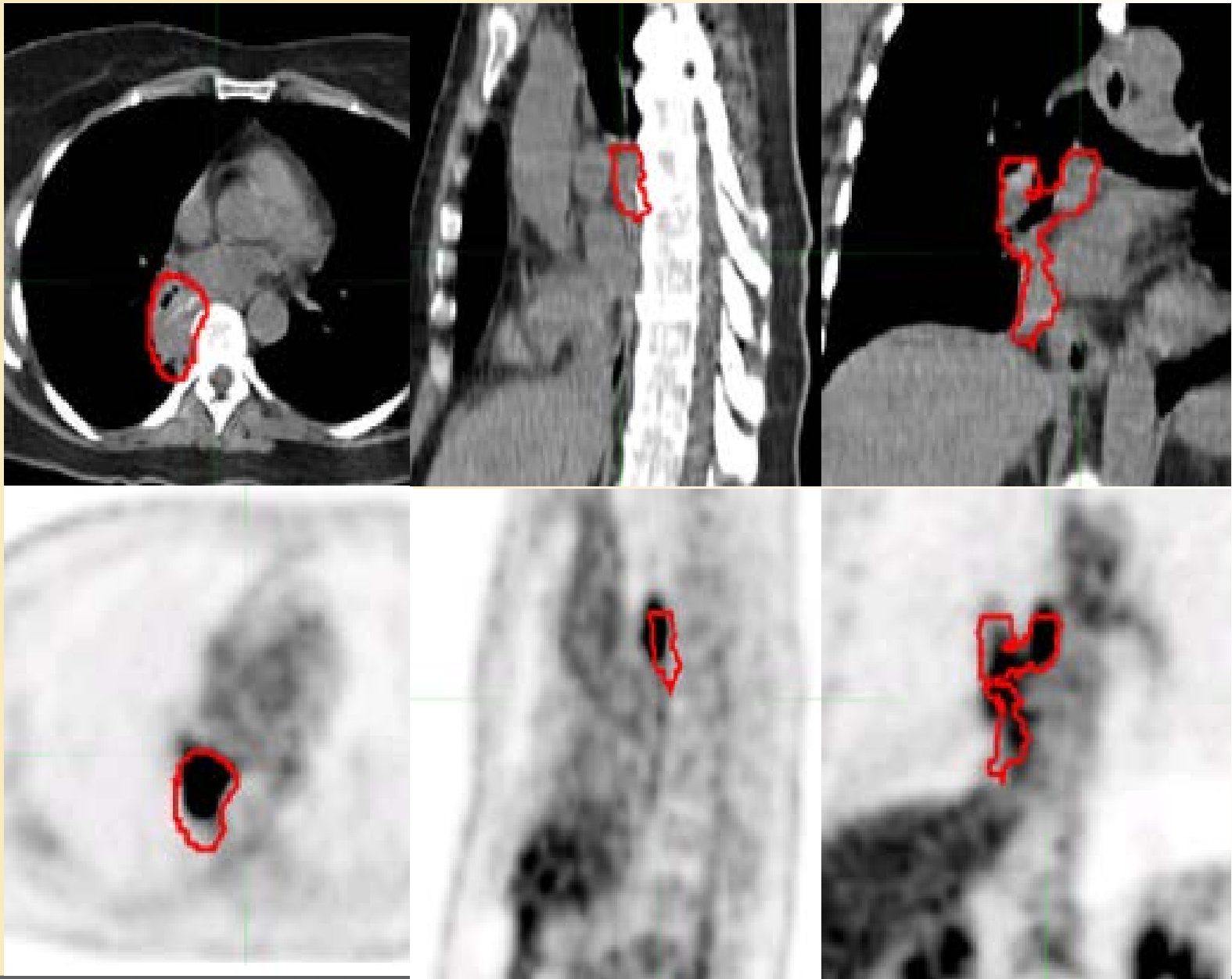
CT2GTV is the composite
structure of CT2GTVTs and
CT2GTVNs

CT2GTV on Pre-treatment PET-CT, case 1

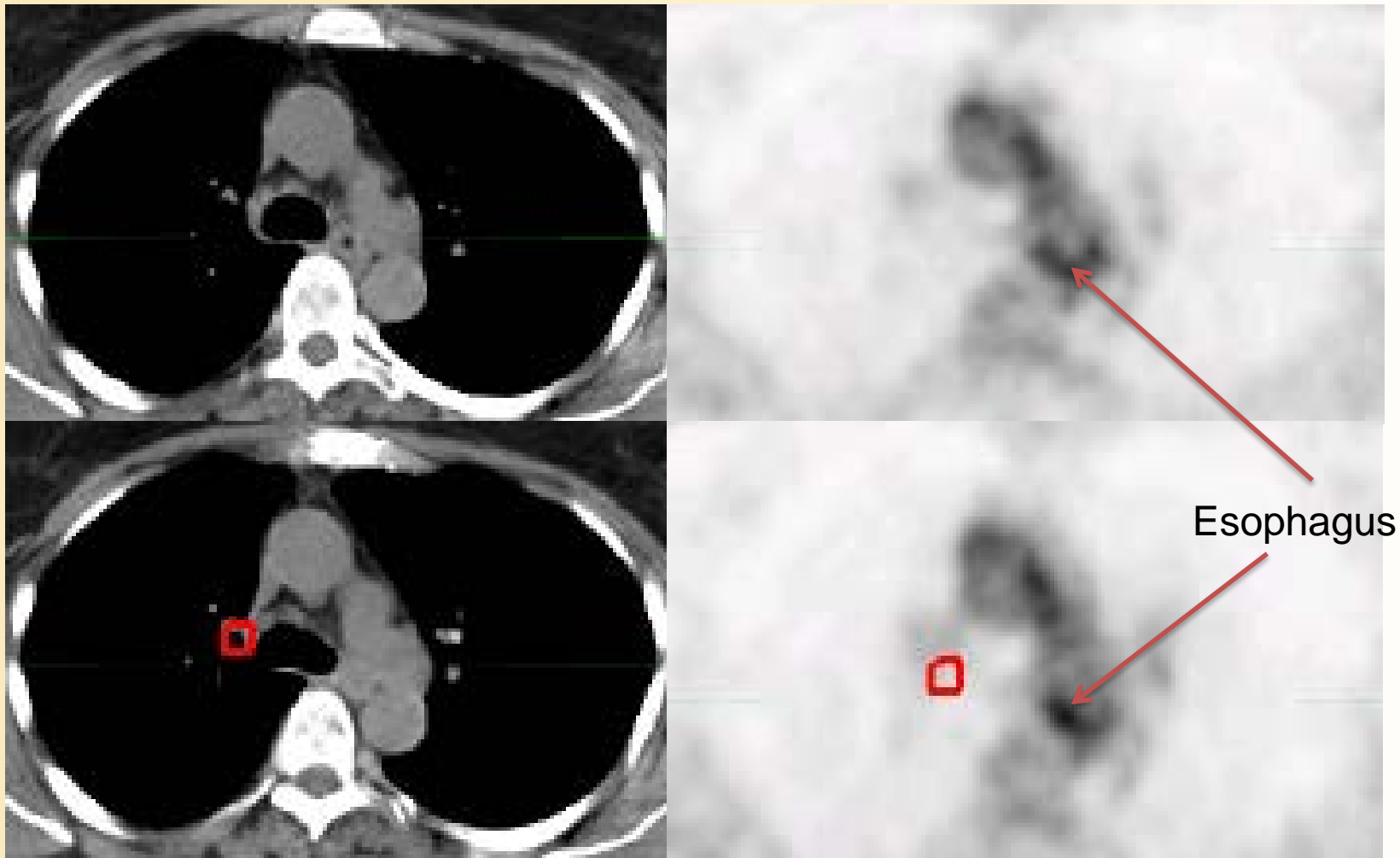
Variations (thin lines) and consensus (red thick lines)



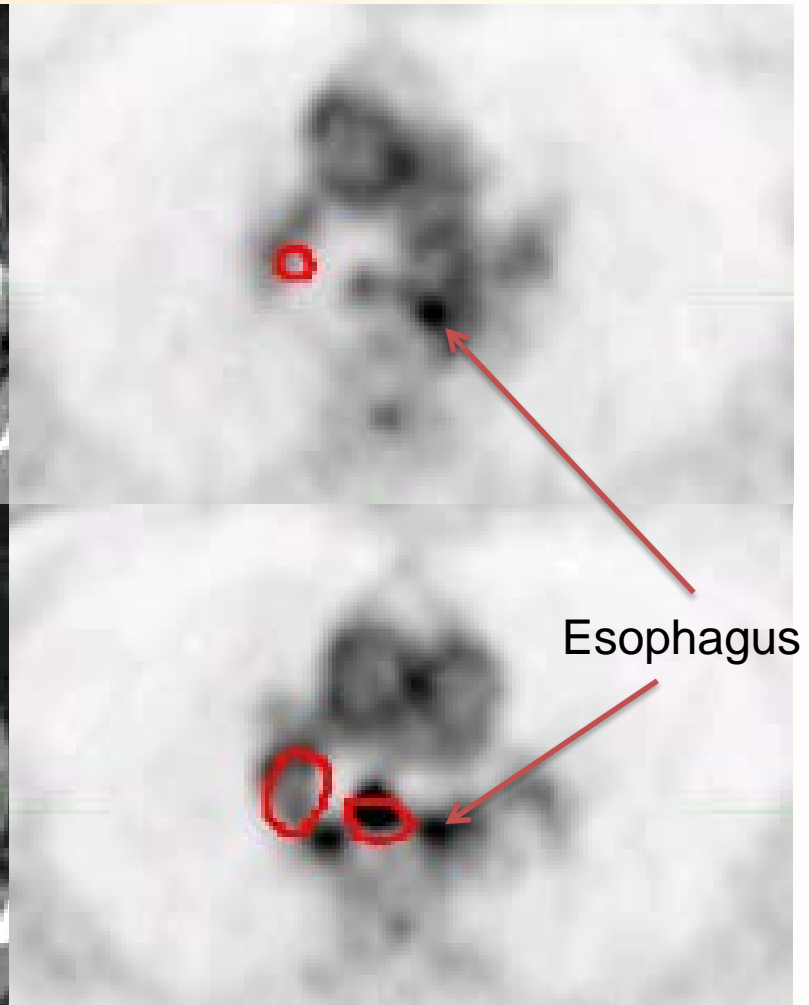
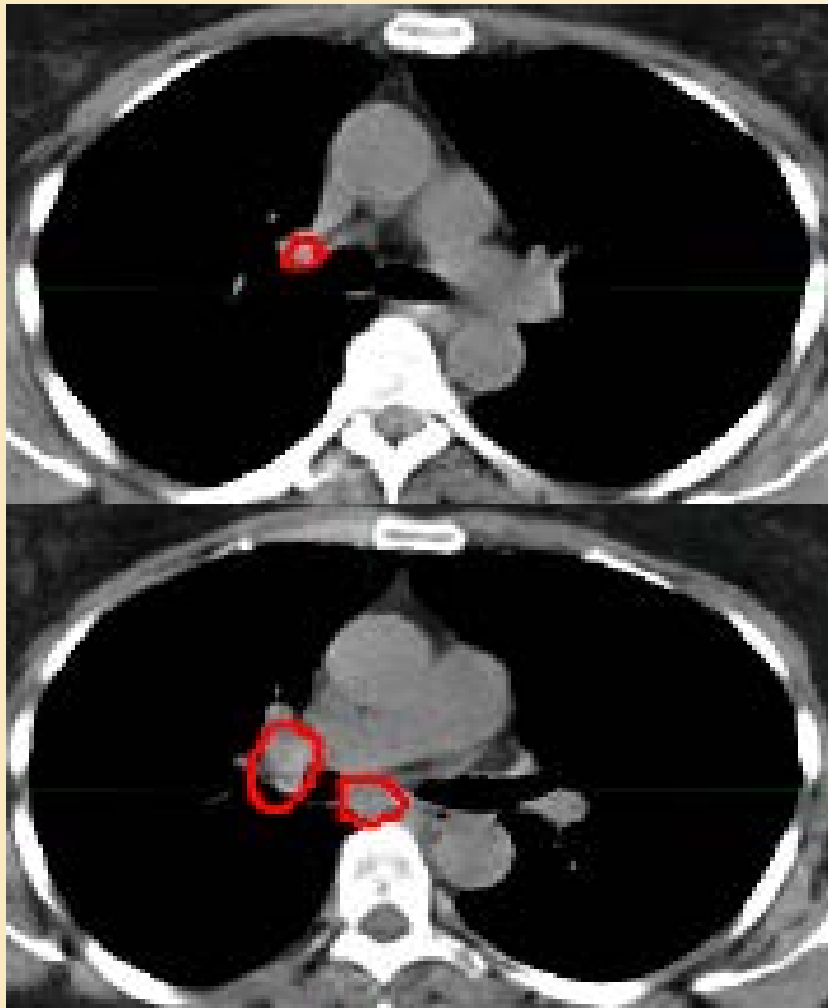
CT2GTV on during-treatment PET-CT, case 1



CT2GTV on during-treatment PET-CT, case 1
Esophagus may be as active as tumor

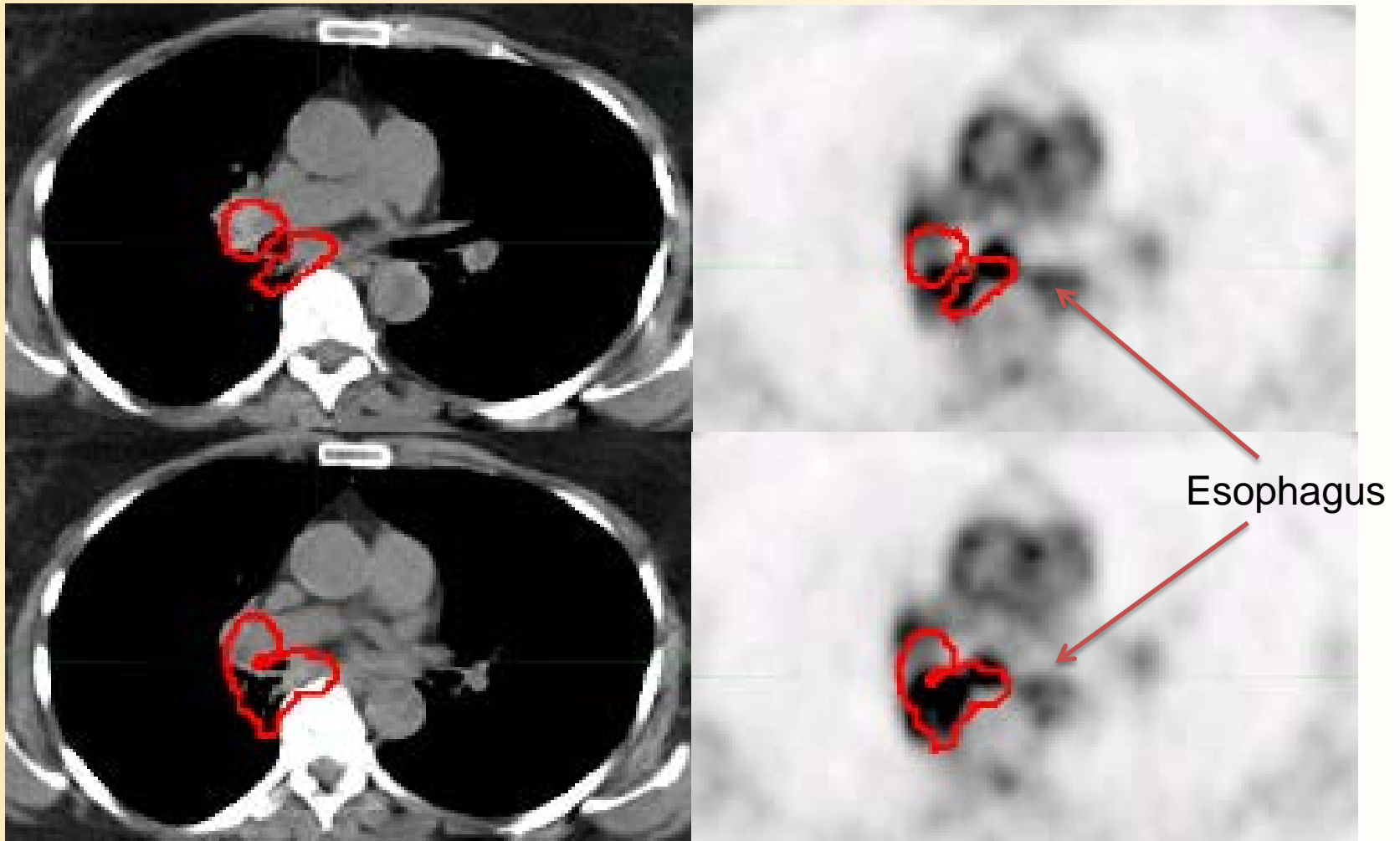


CT2GTV on during-treatment PET-CT, case 1



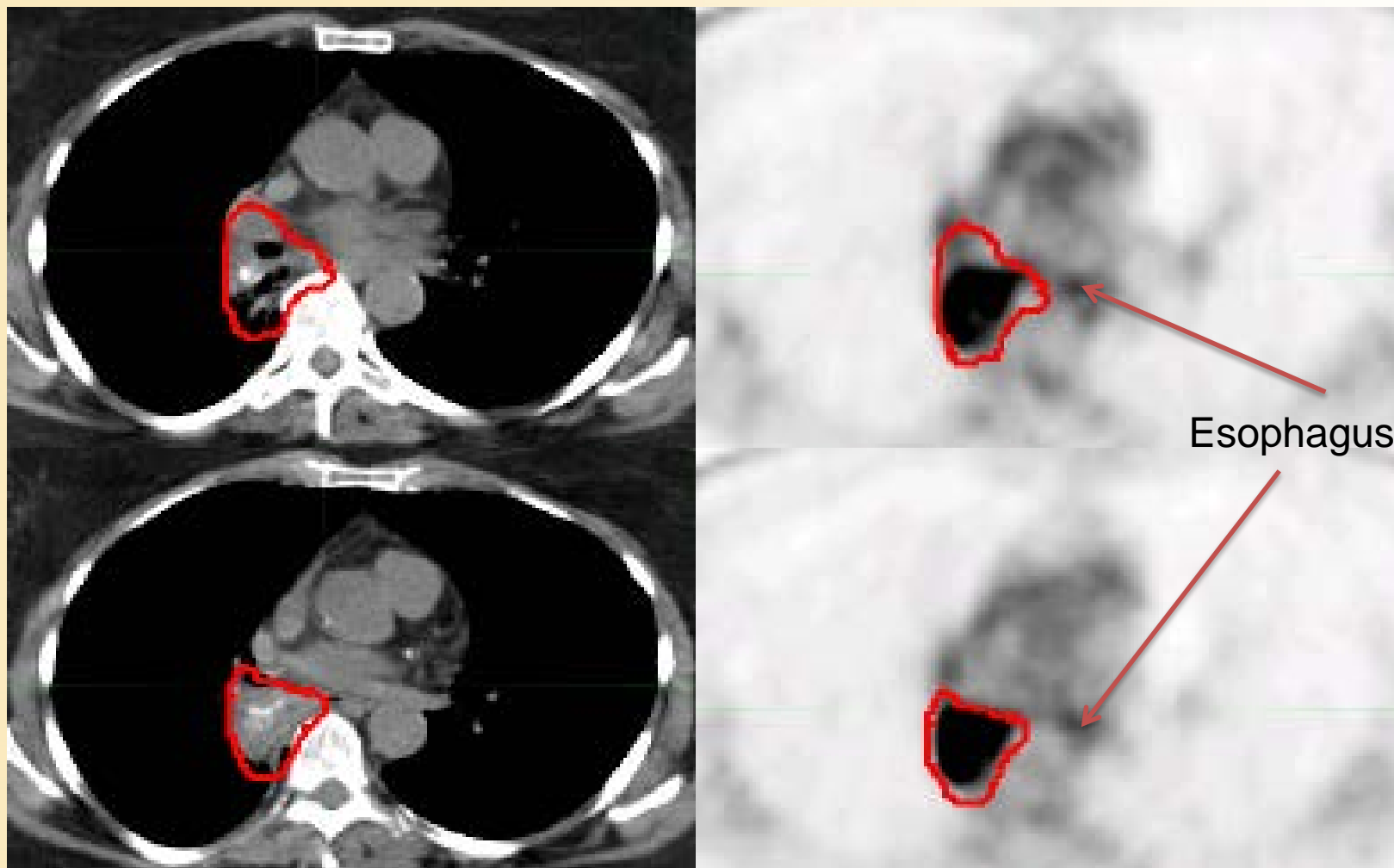
Esophagus

CT2GTV on during-treatment PET-CT, case 1

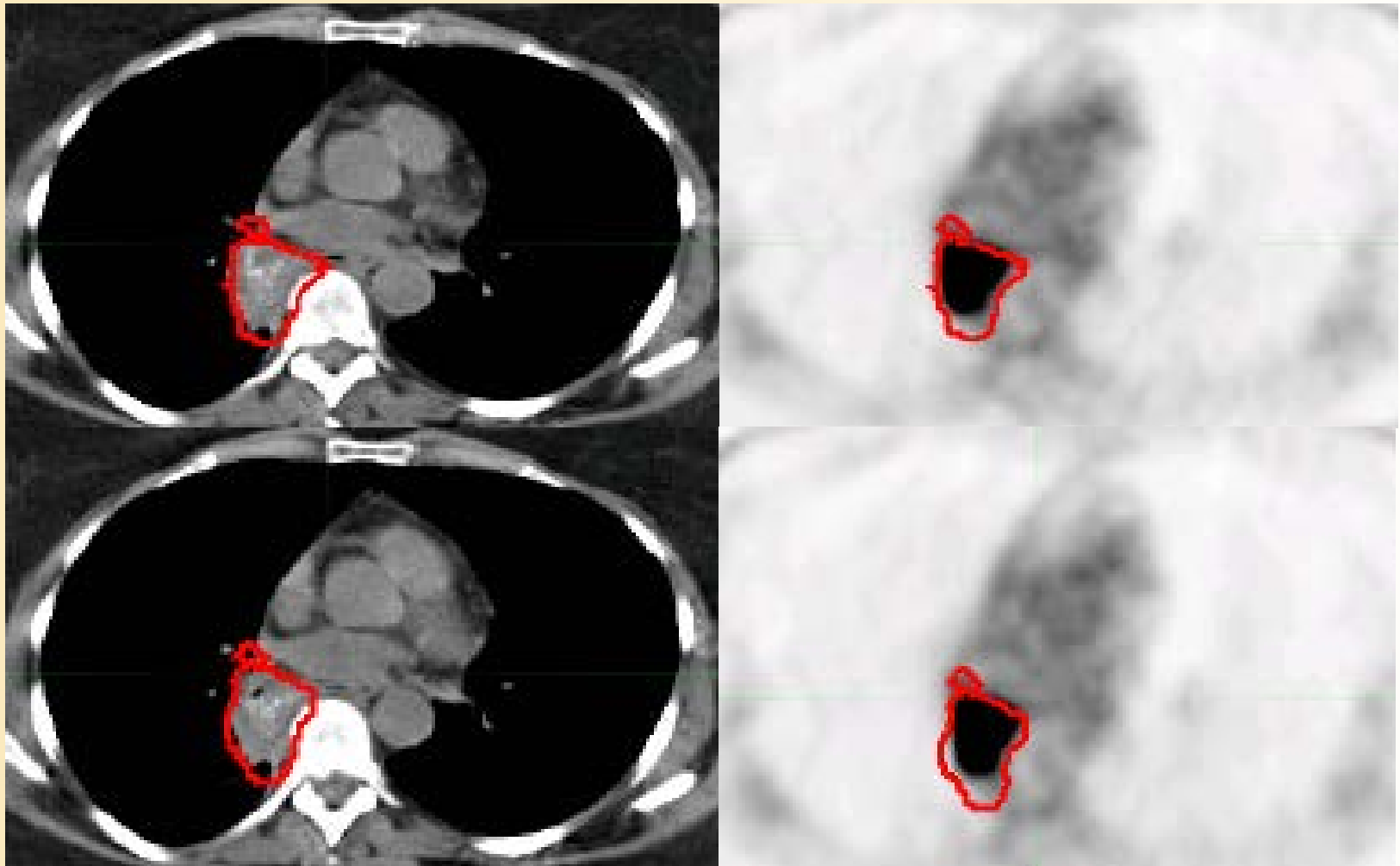


Esophagus

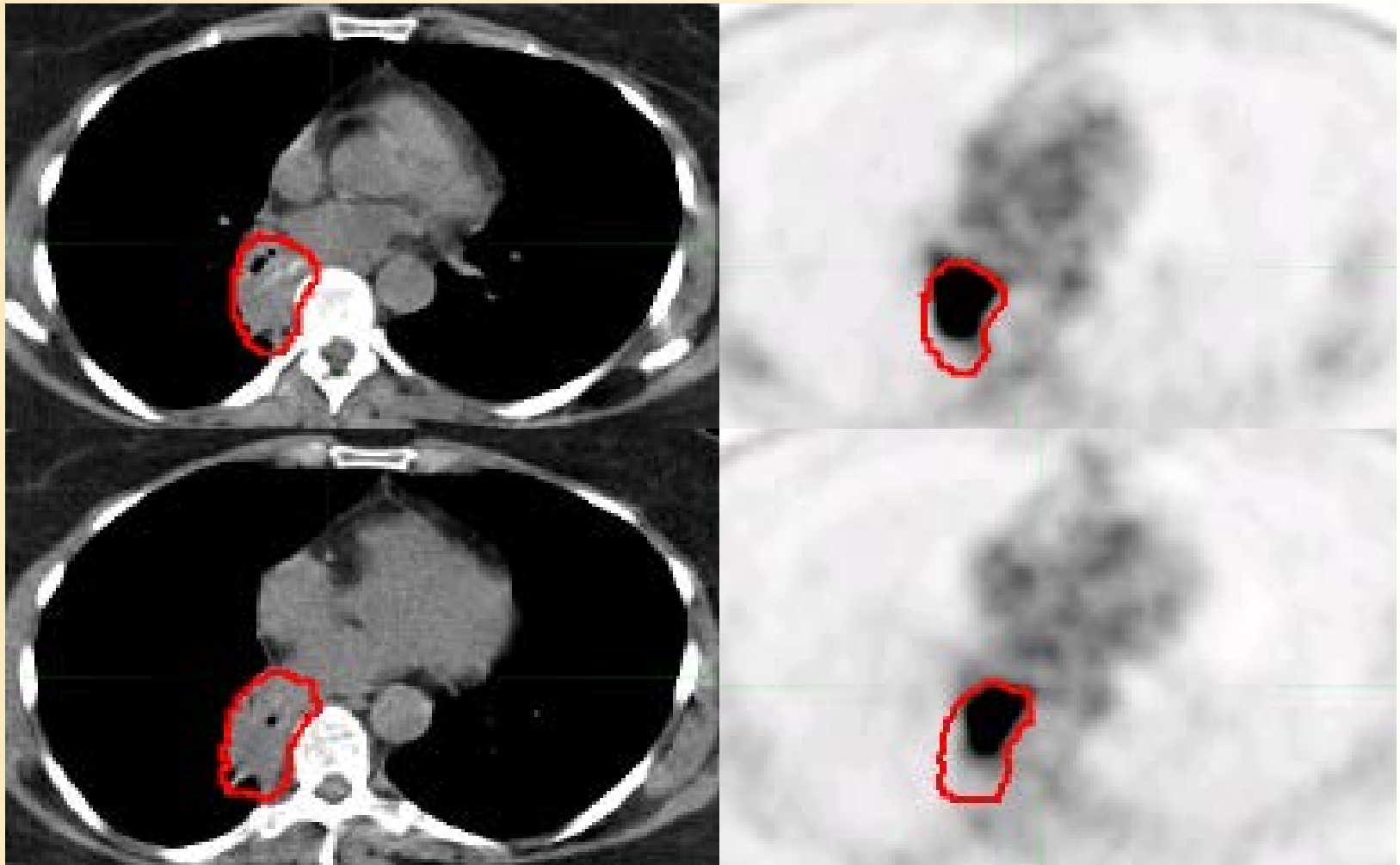
CT2GTV on during-treatment PET-CT, case 1



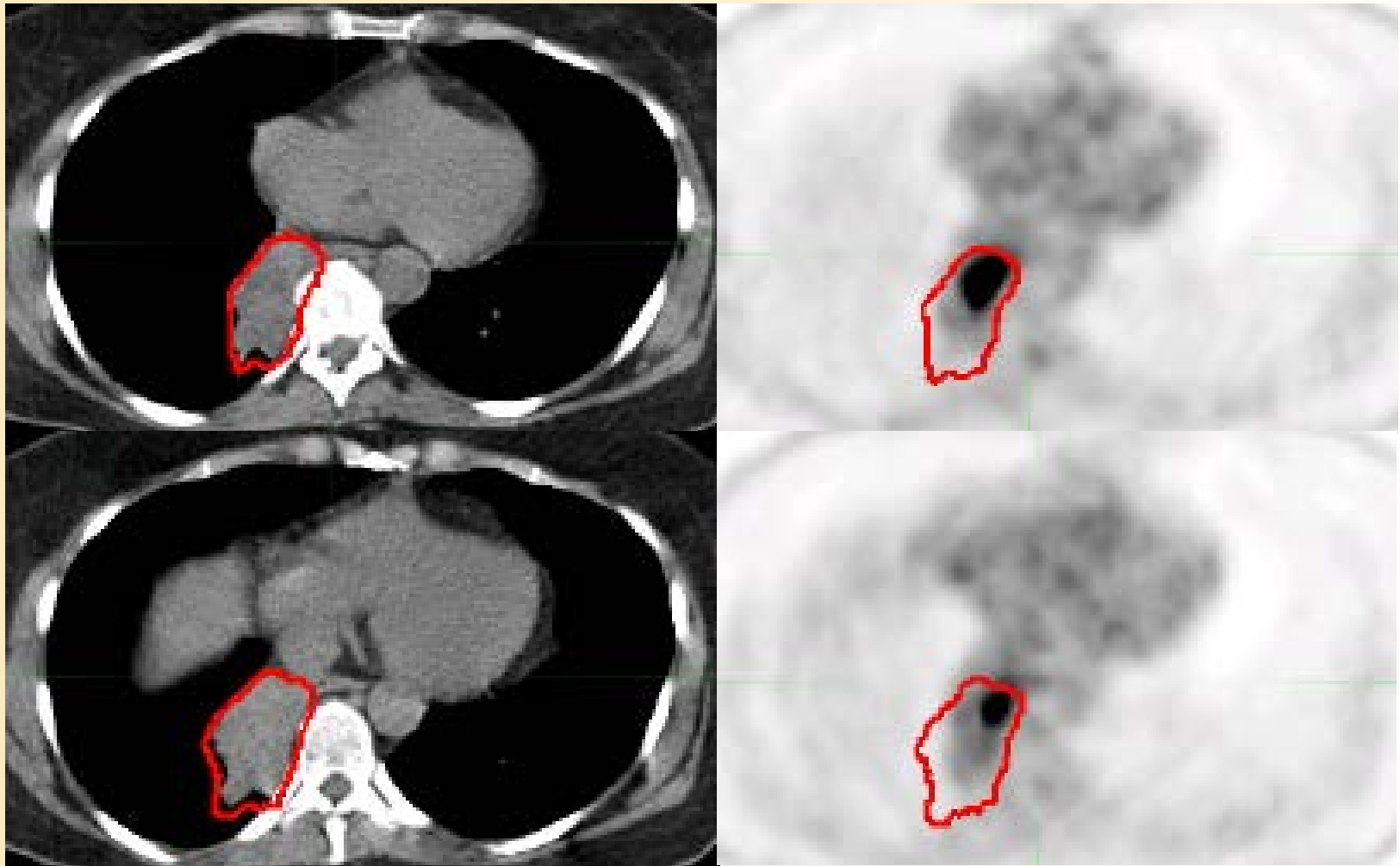
CT2GTV on during-treatment PET-CT, case 1



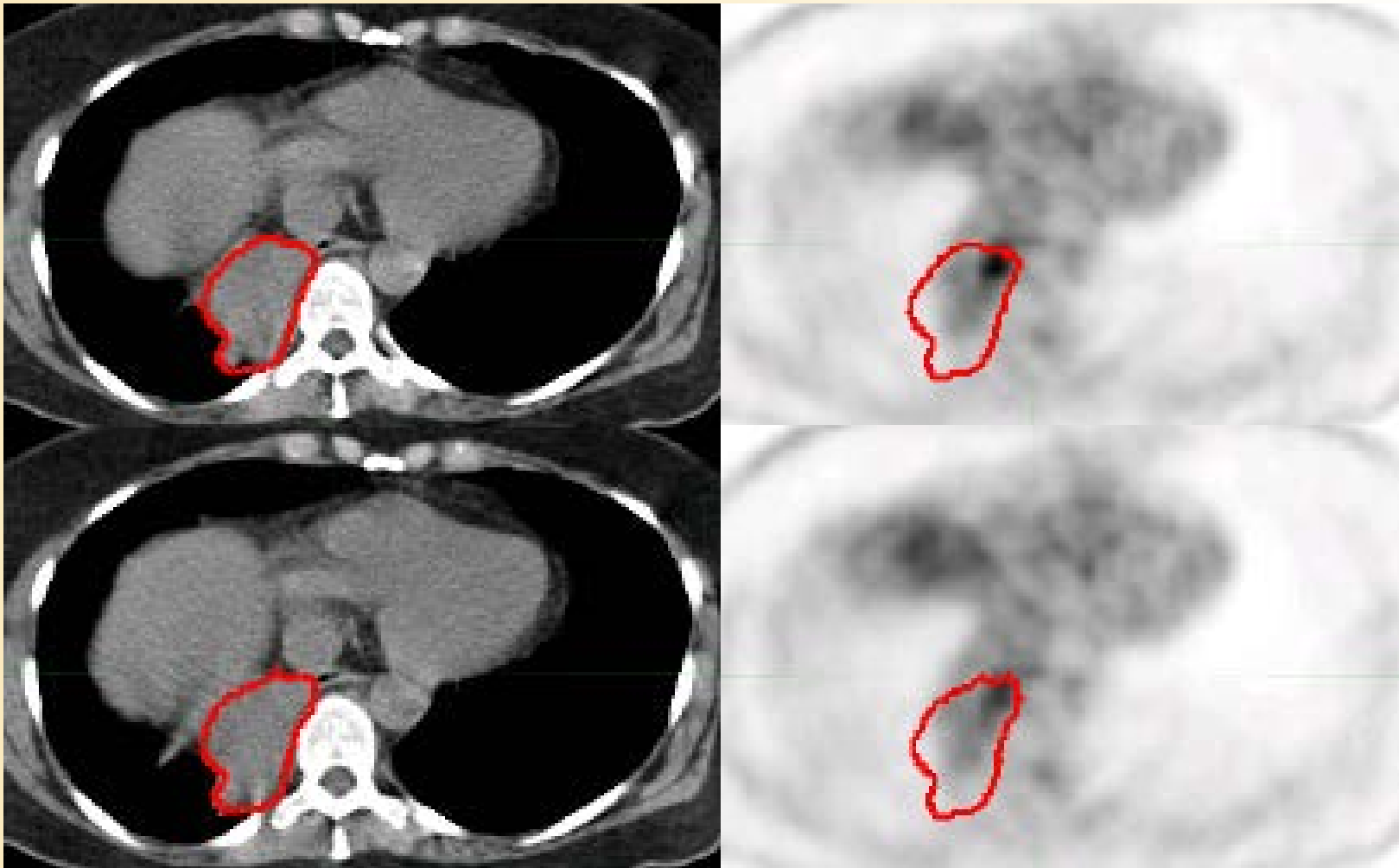
CT2GTV on during-treatment PET-CT, case 1



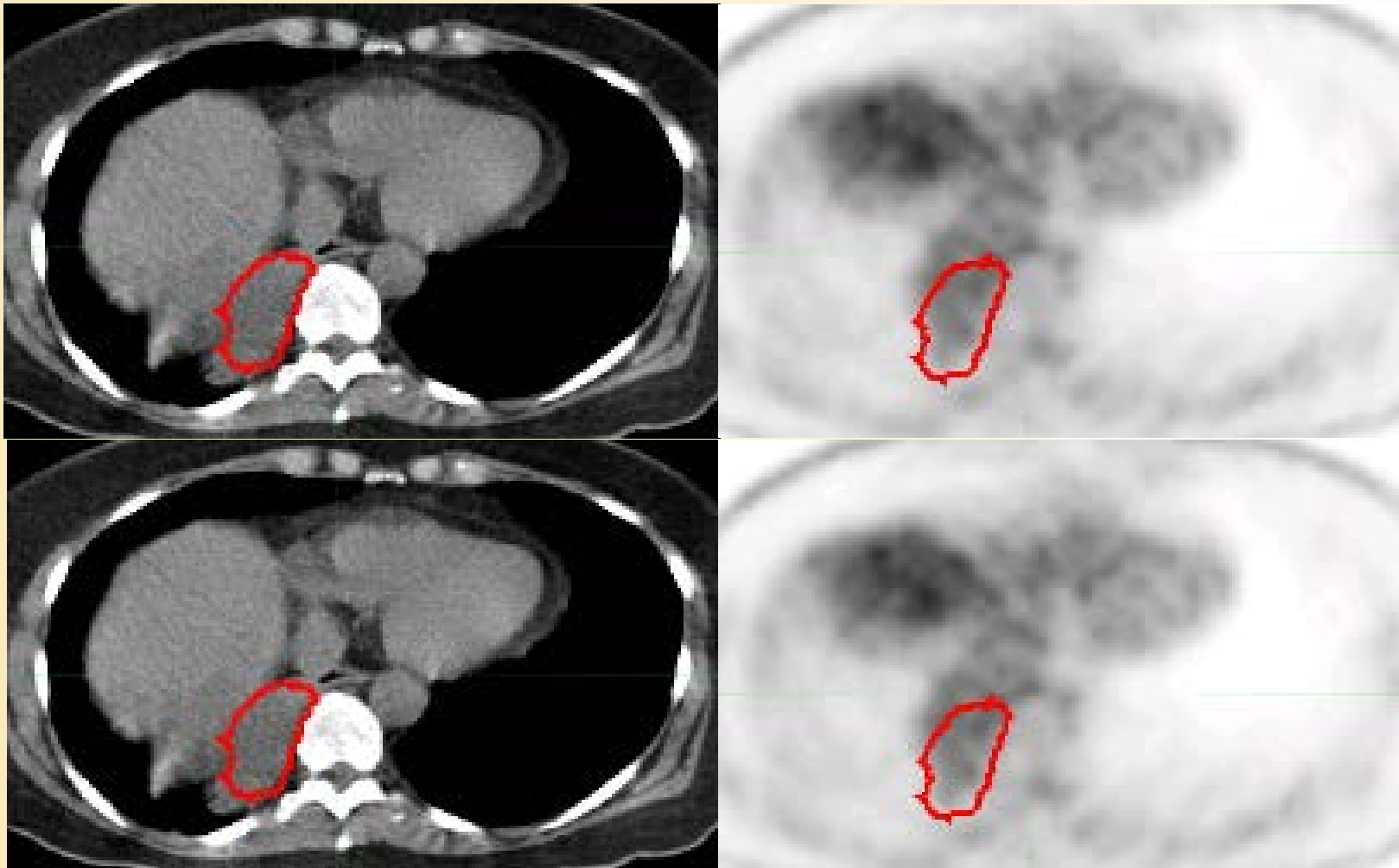
CT2GTV on during-treatment PET-CT, case 1



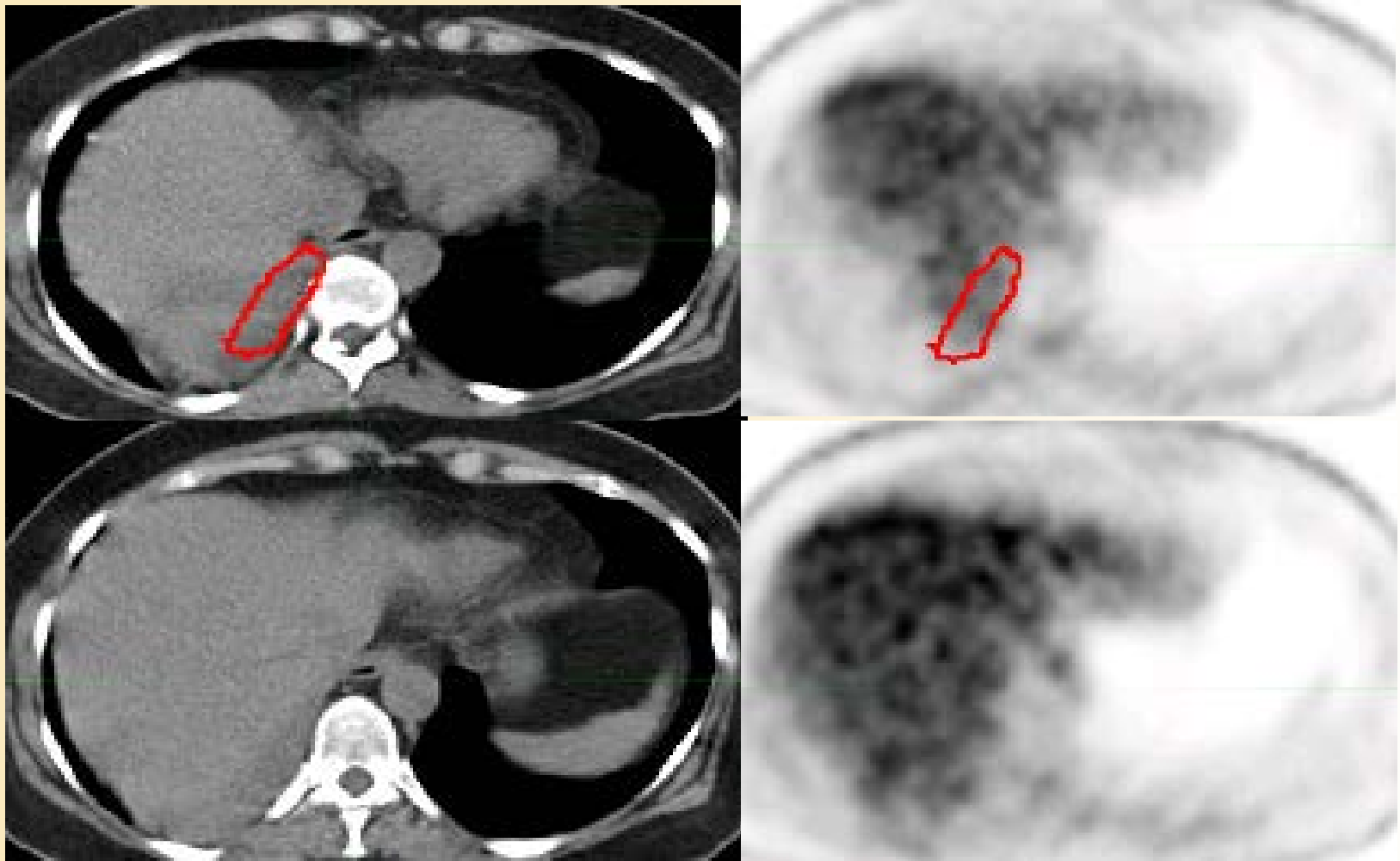
CT2GTV on during-treatment PET-CT, case 1



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CT2GTV on during-treatment PET-CT, case 1

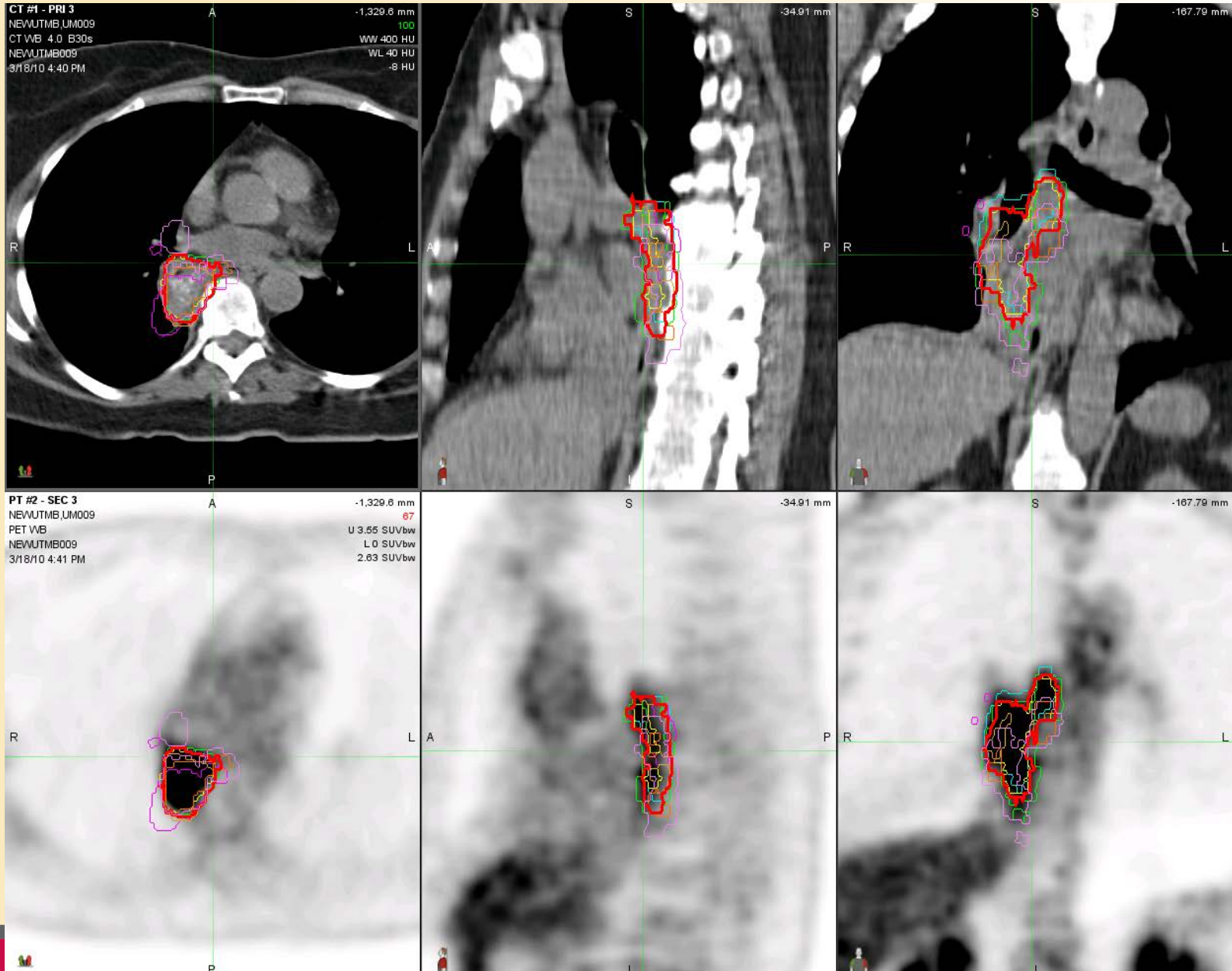


PET2MTV on during-treatment PET-CT: Example Case #1

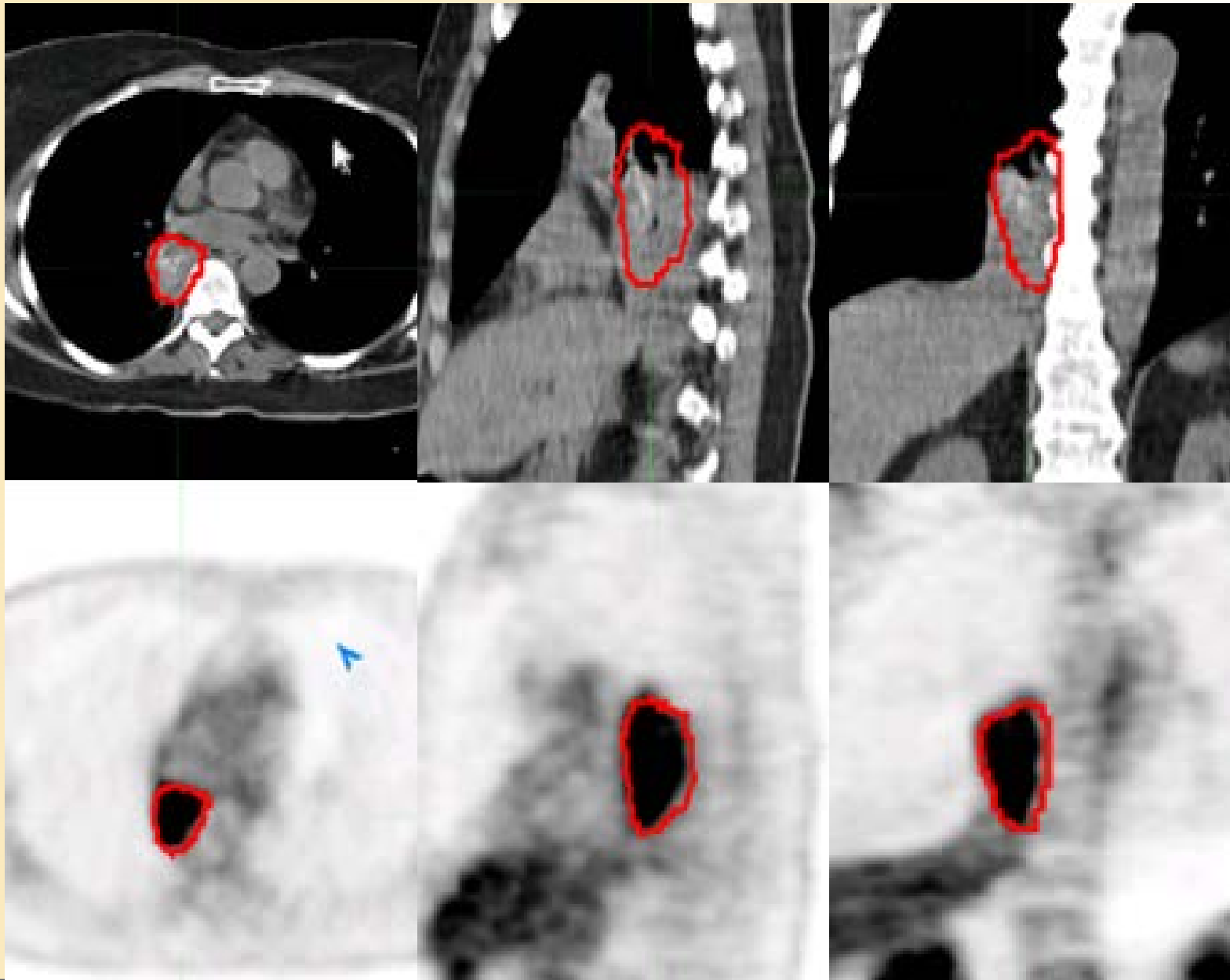
PET2MTV is the composite
structure of MTVTs and MTVNs

PET2MTV on Pre-treatment PET-CT, case 1

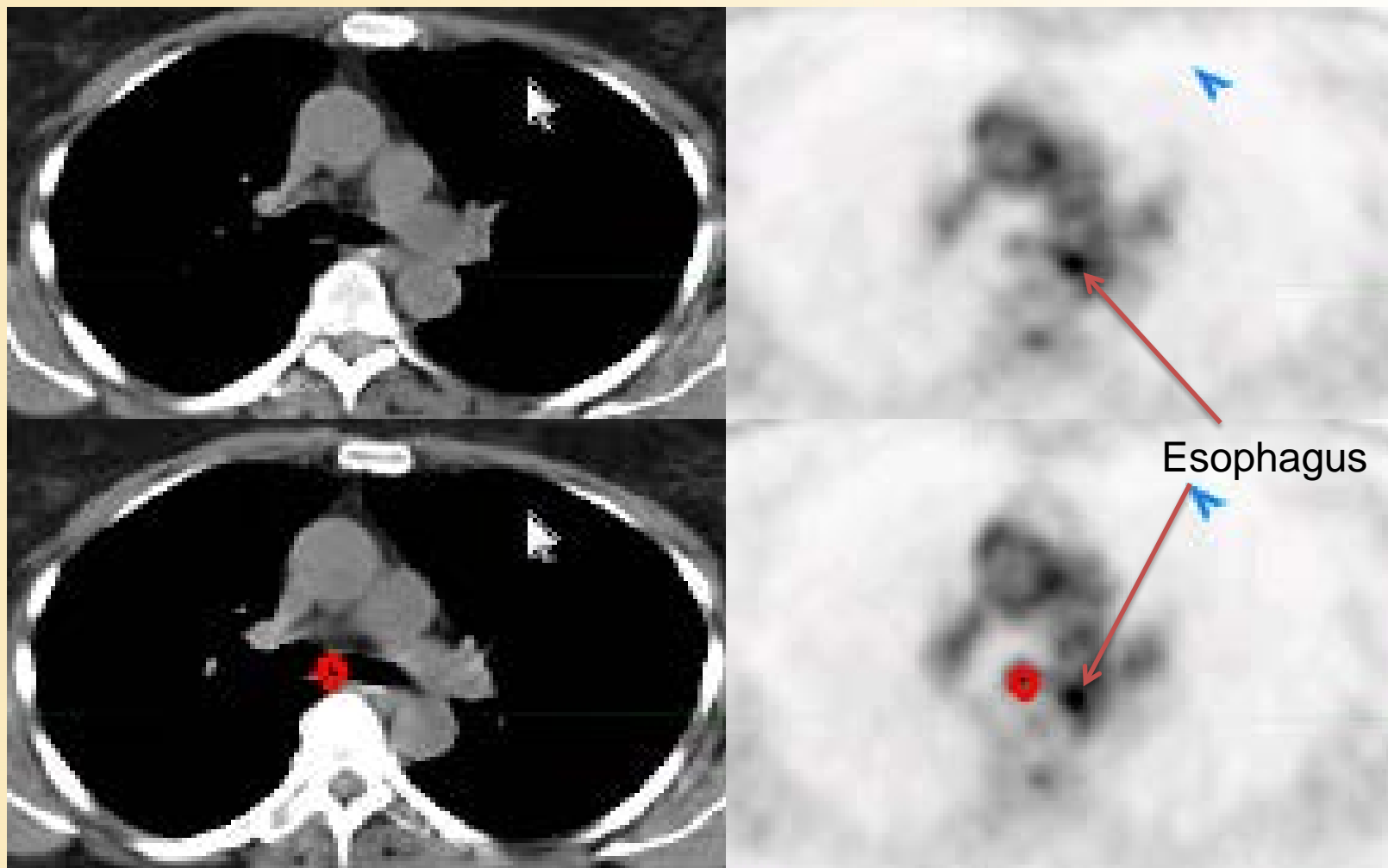
Variations (thin lines) and consensus (red thick lines)



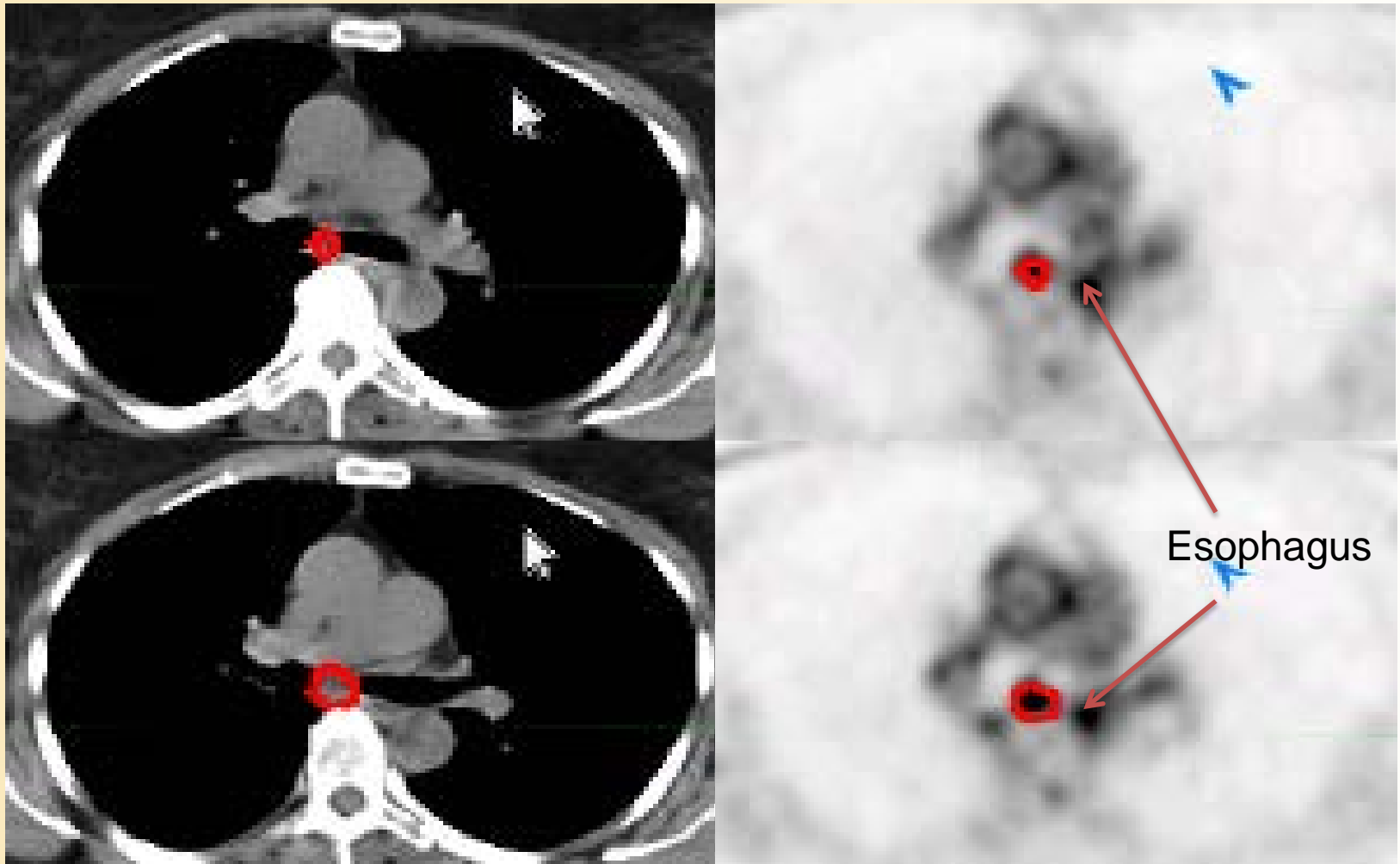
PET2MTV on during-treatment PET-CT, case 1



PET2MTV on during-treatment PET-CT, case 1

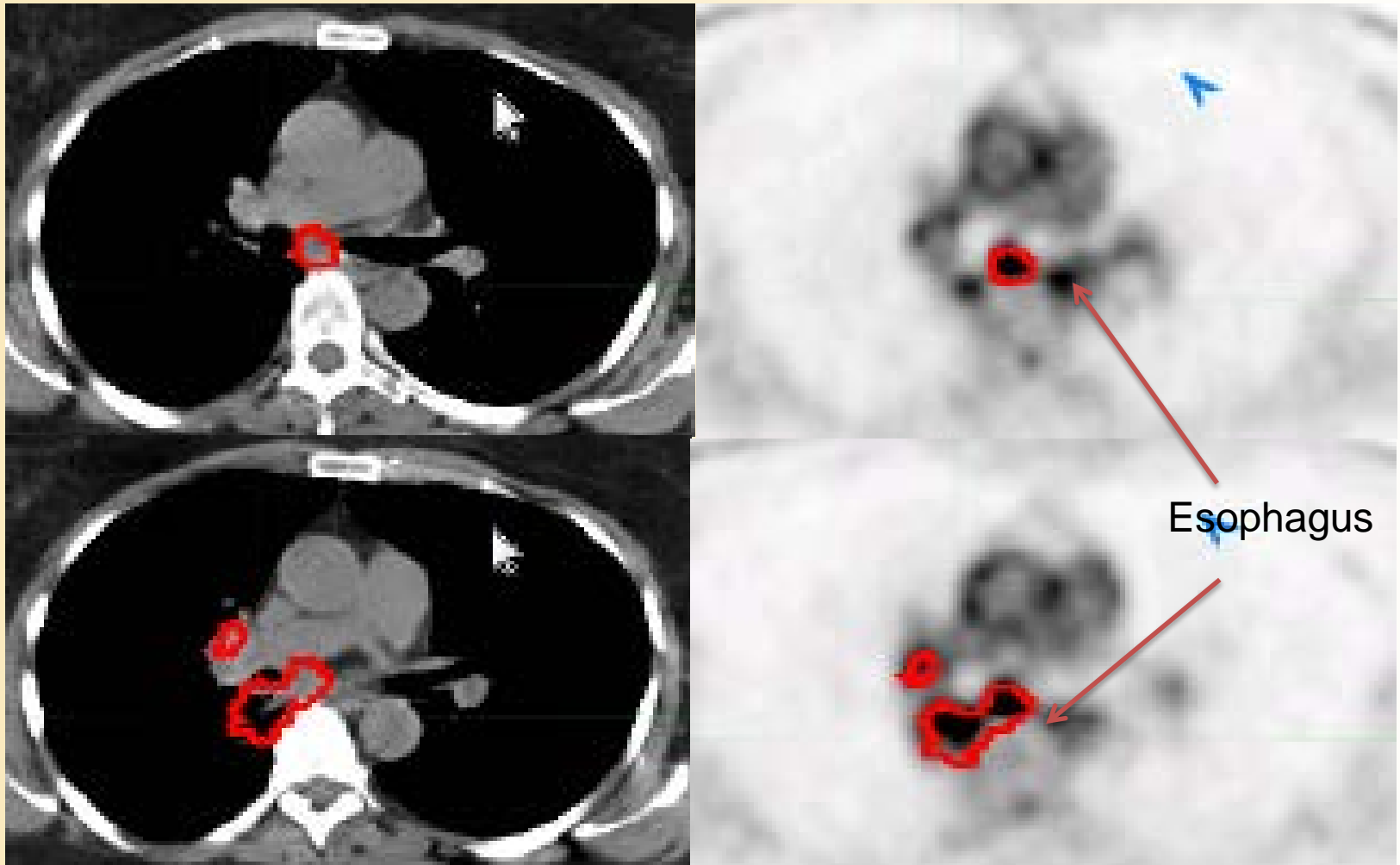


PET2MTV on during-treatment PET-CT, case 1

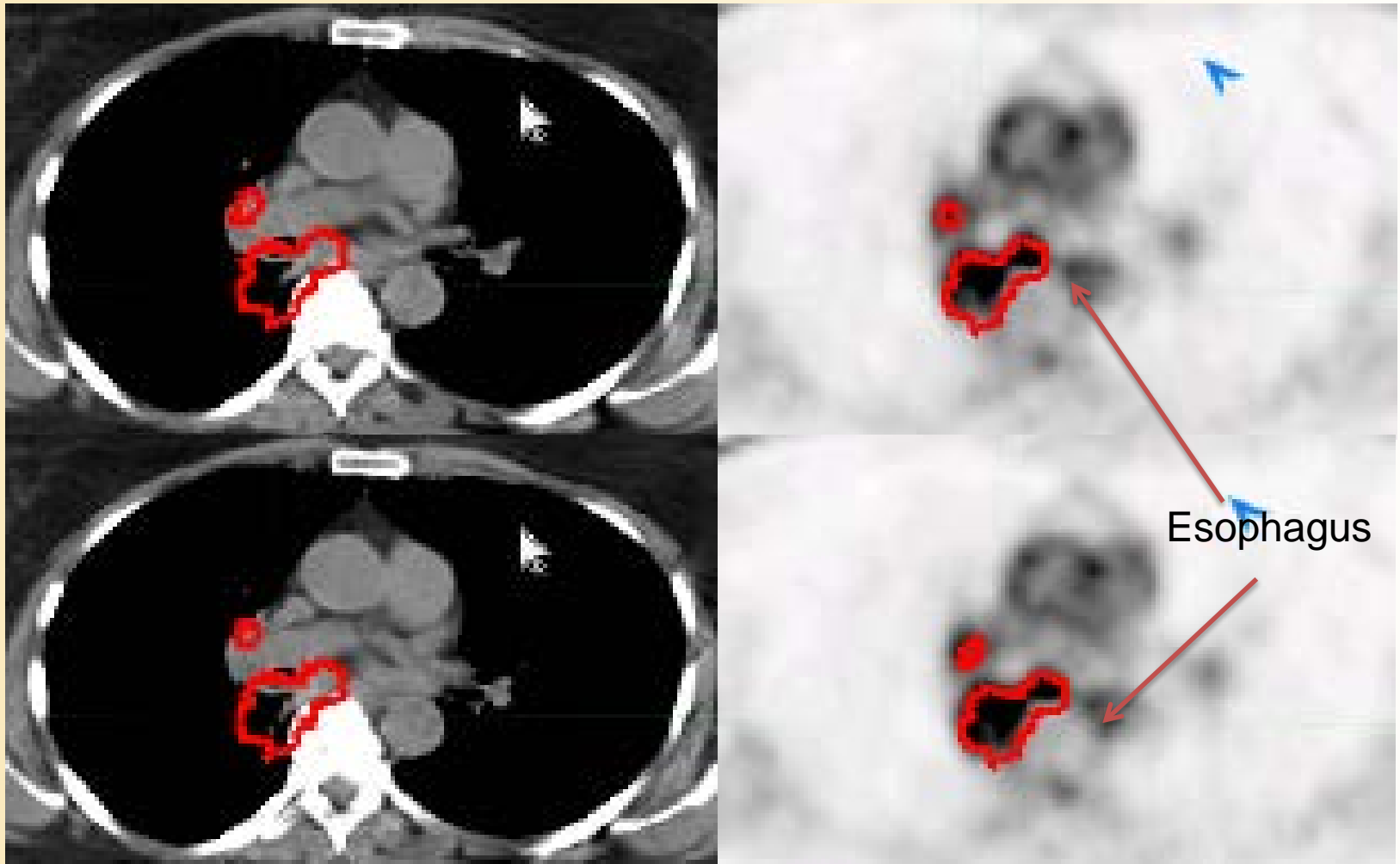


Esophagus

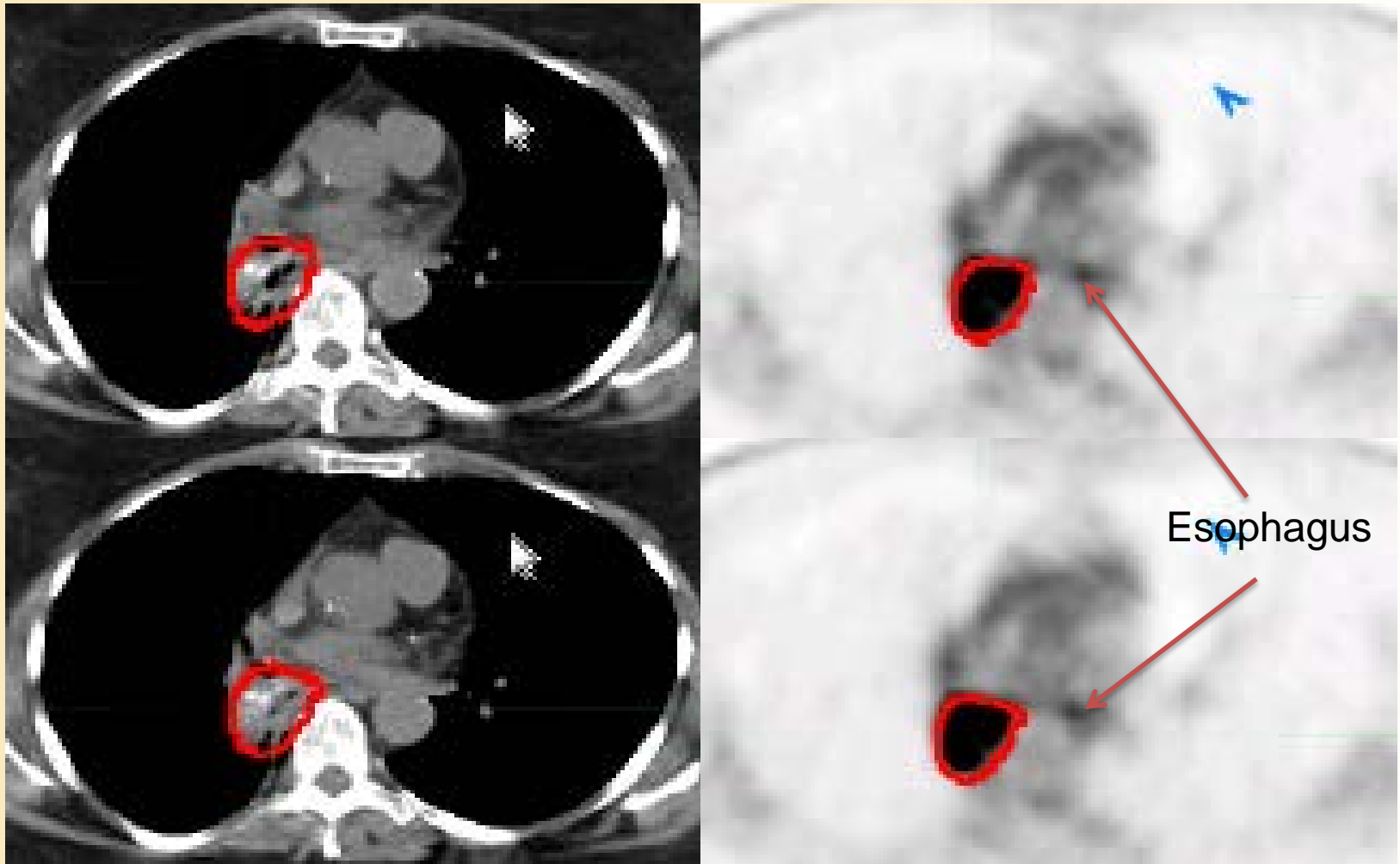
PET2MTV on during-treatment PET-CT, case 1



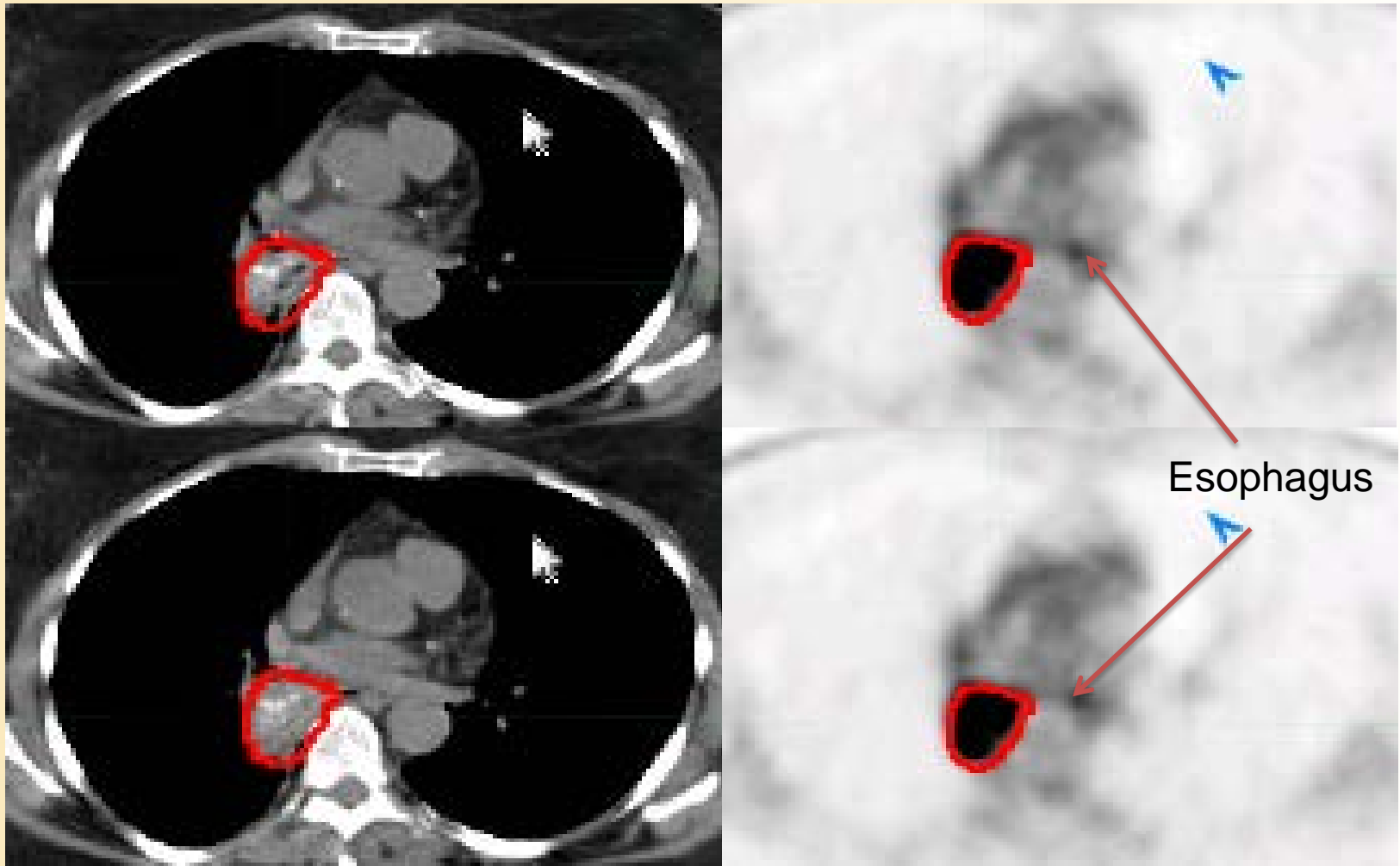
PET2MTV on during-treatment PET-CT, case 1



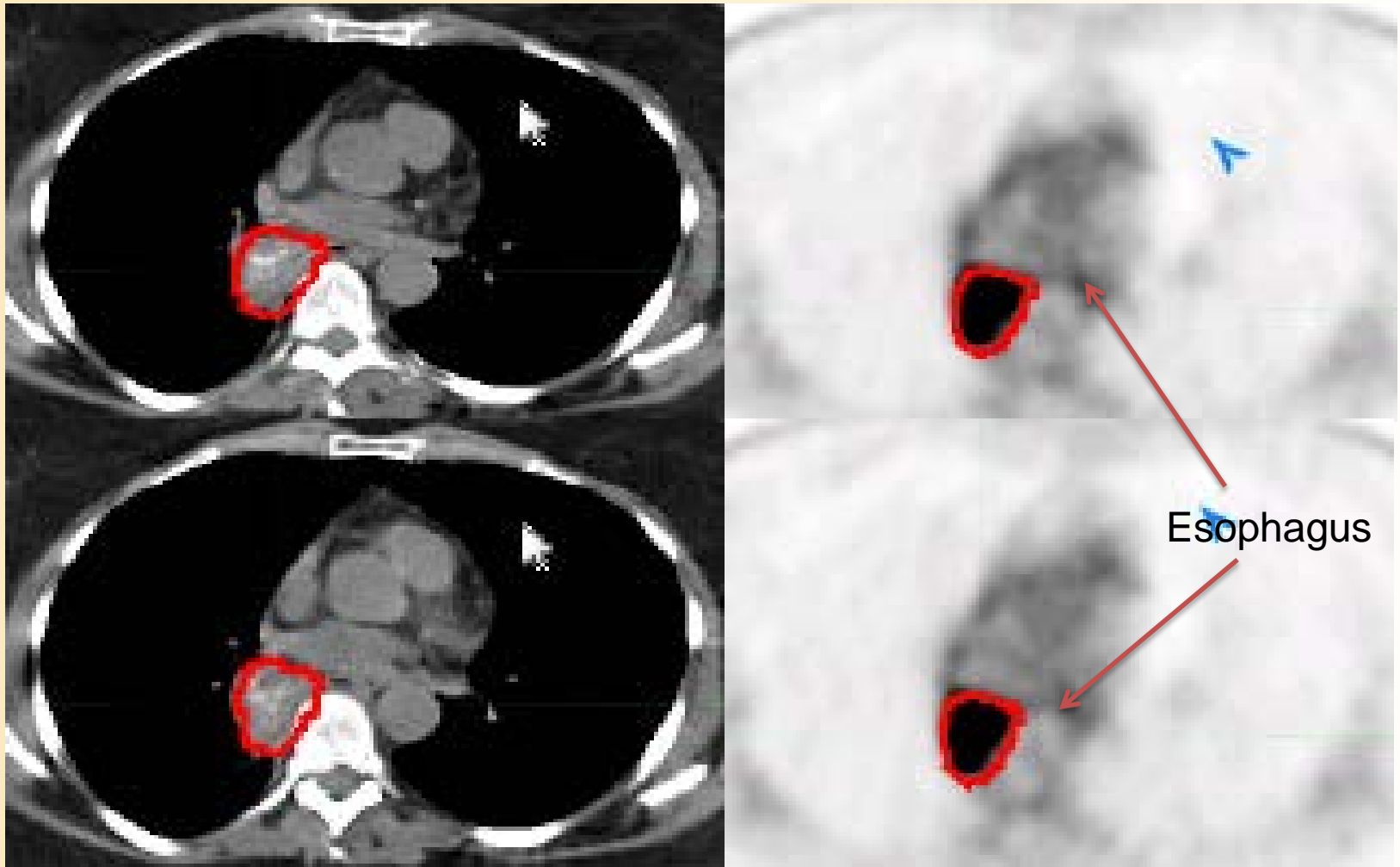
PET2MTV on during-treatment PET-CT, case 1



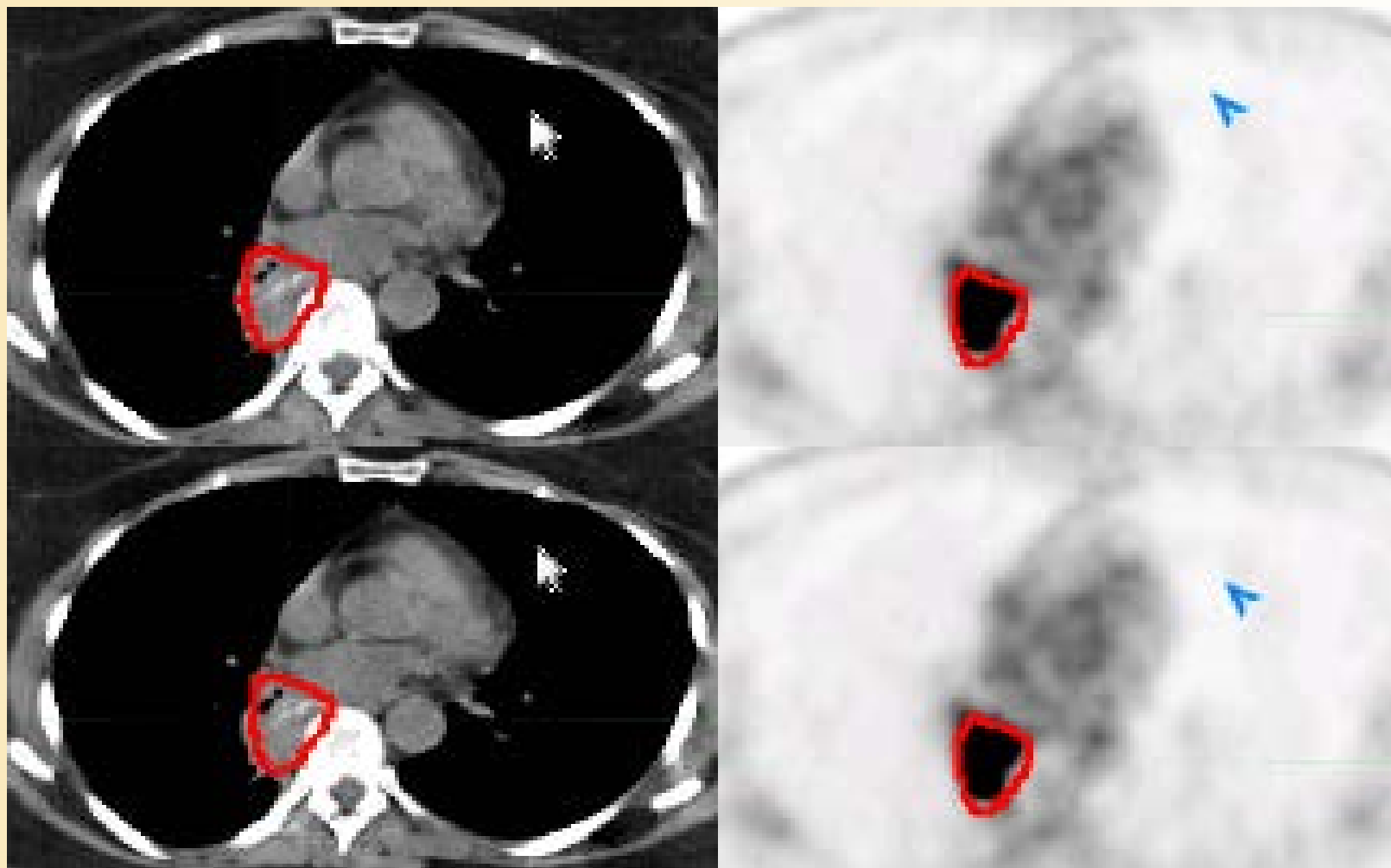
PET2MTV on during-treatment PET-CT, case 1



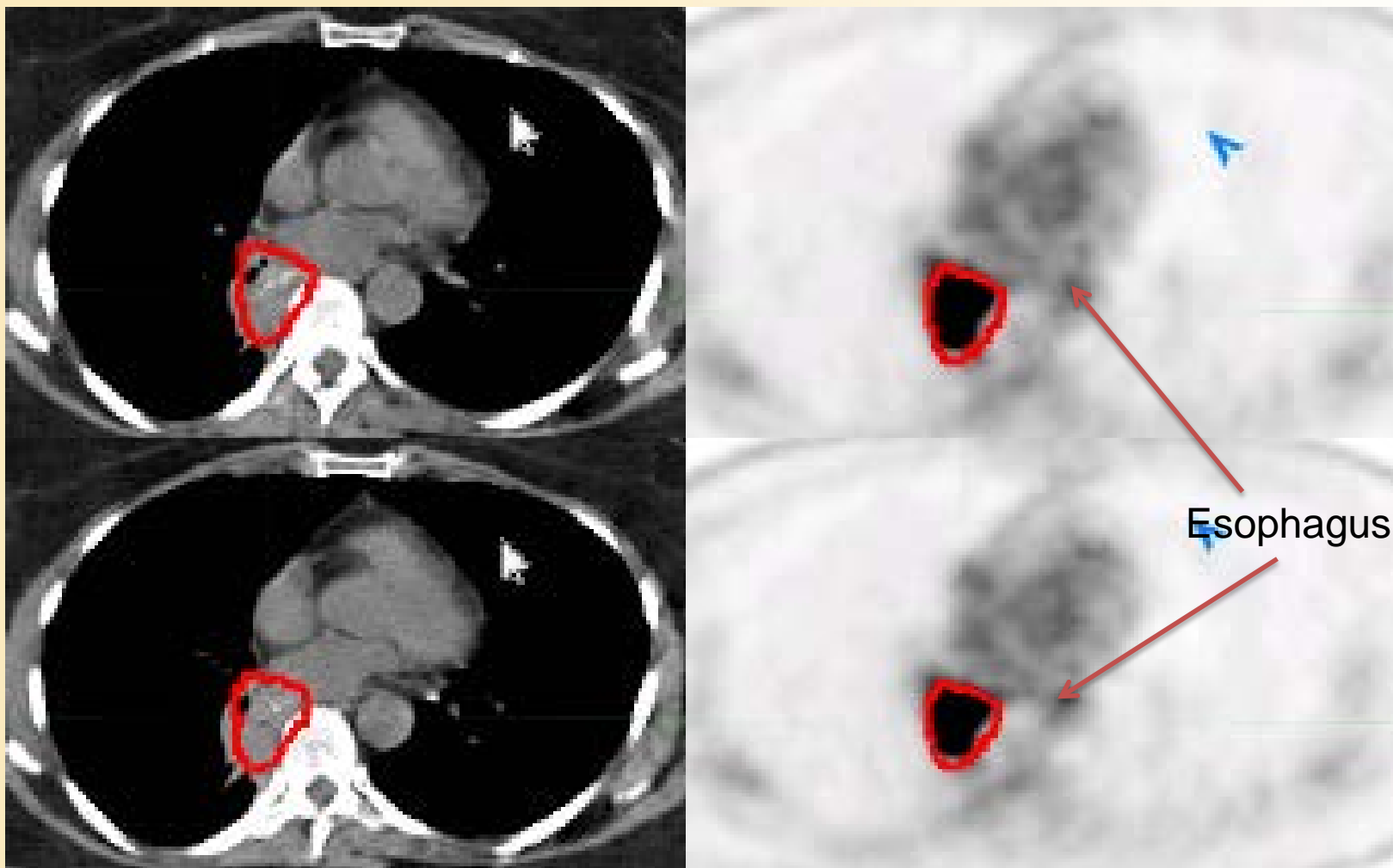
PET2MTV on during-treatment PET-CT, case 1



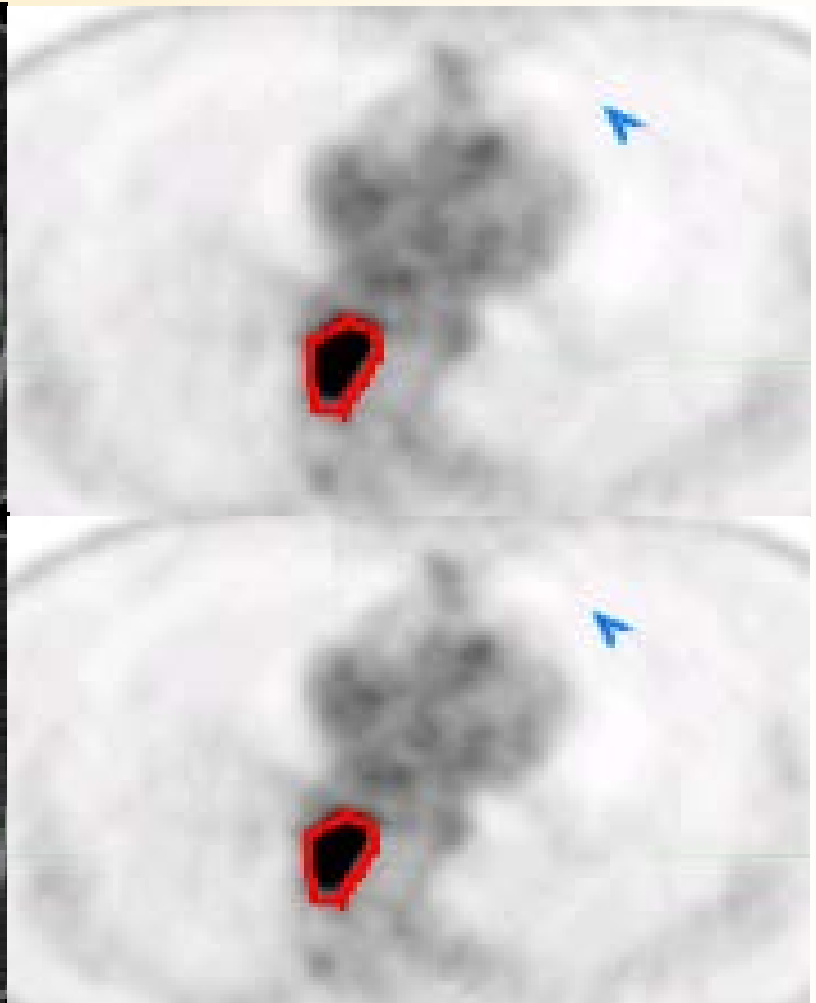
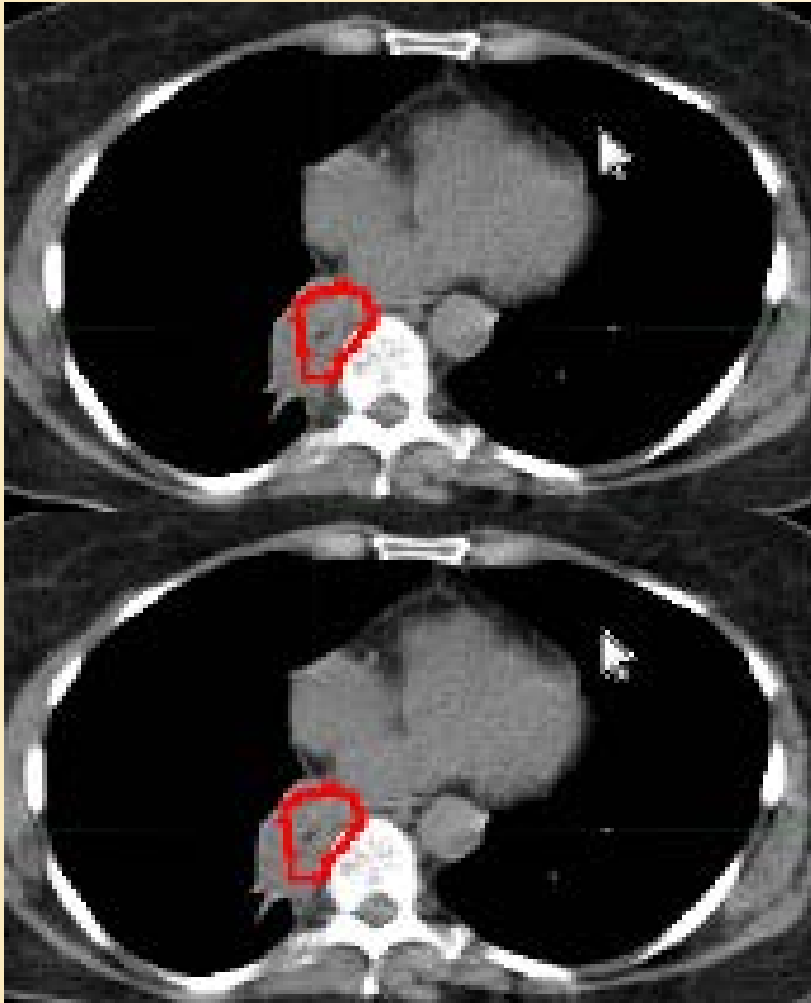
PET2MTV on during-treatment PET-CT, case 1



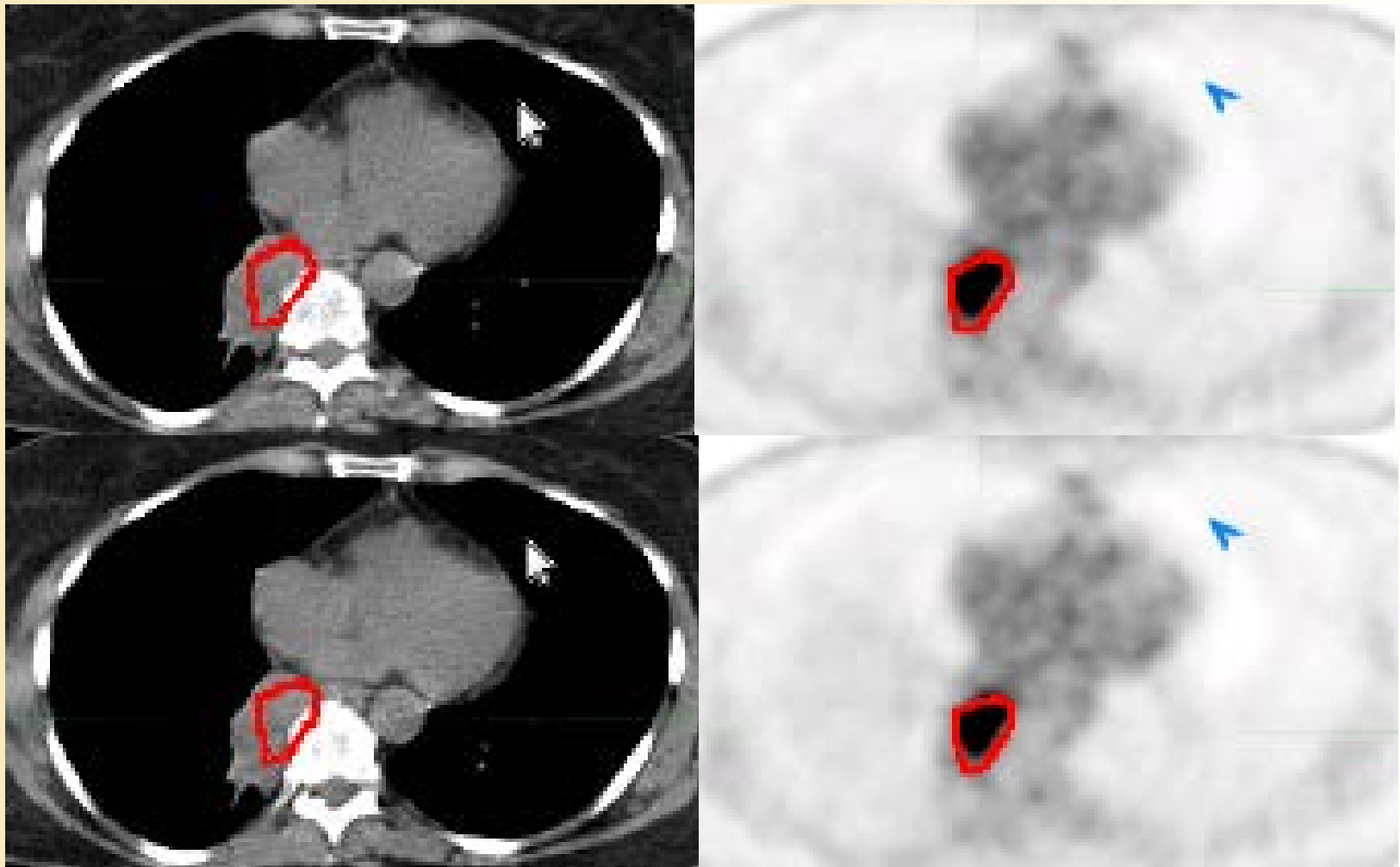
PET2MTV on during-treatment PET-CT, case 1



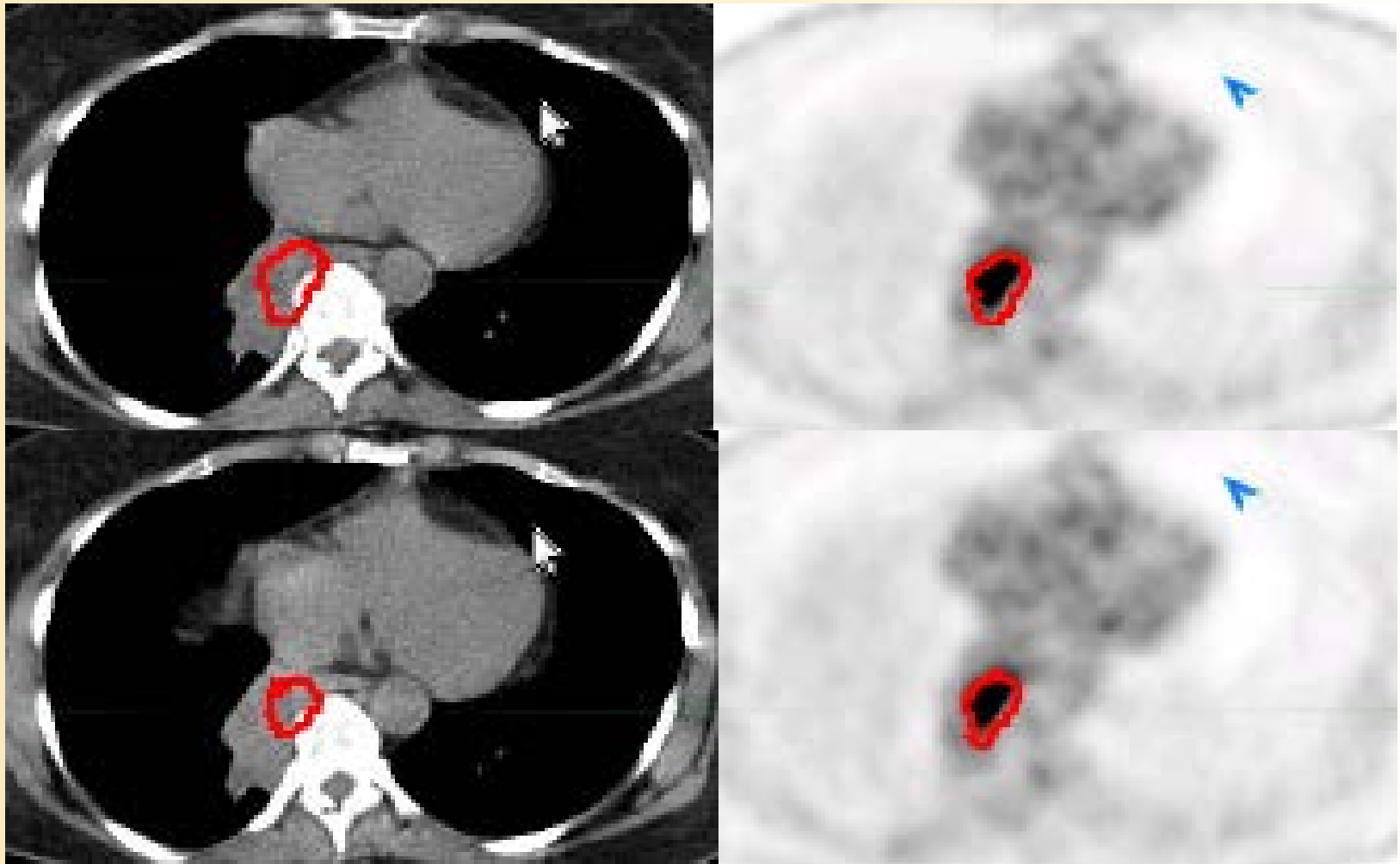
PET2MTV on during-treatment PET-CT, case 1



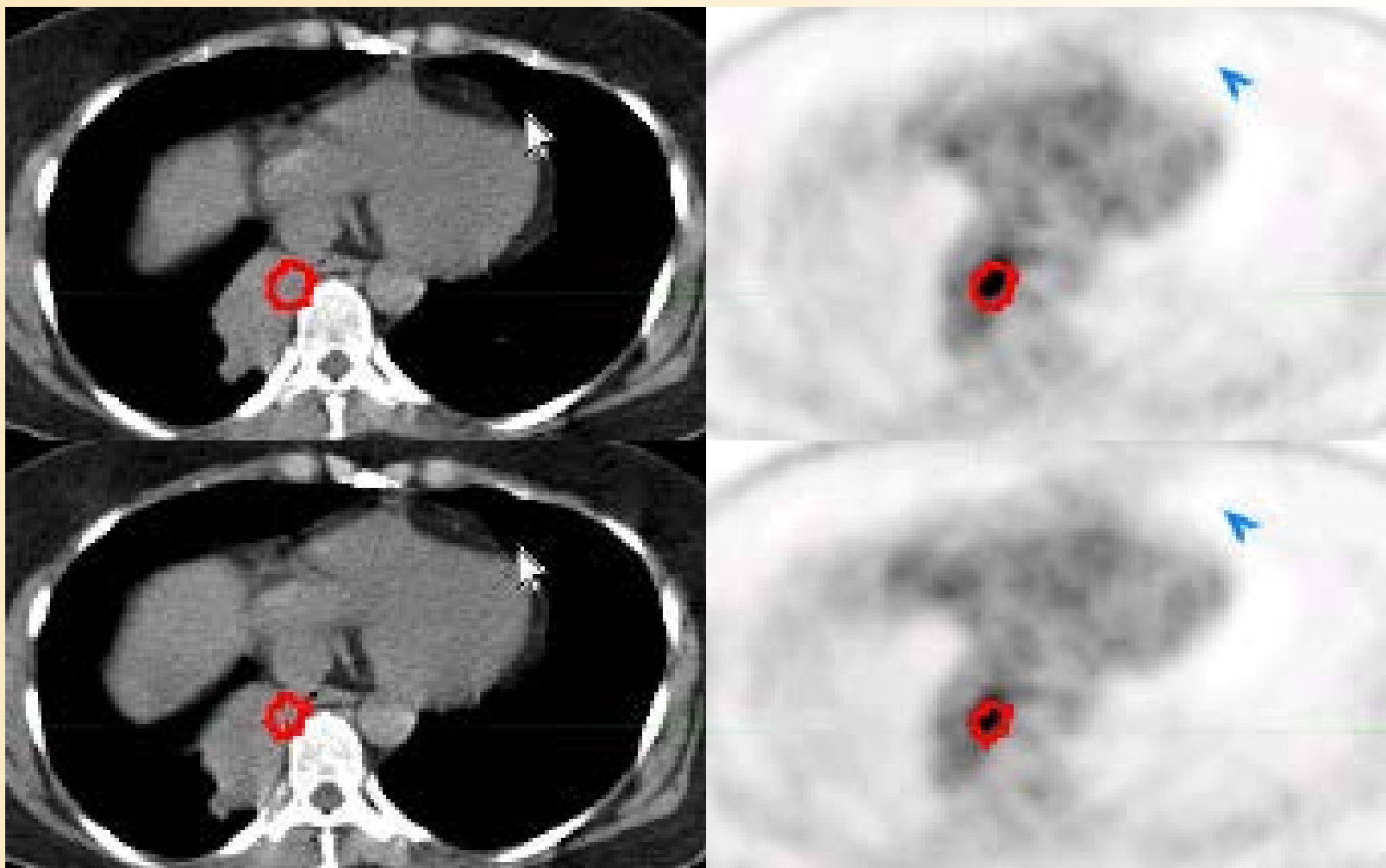
PET2MTV on during-treatment PET-CT, case 1



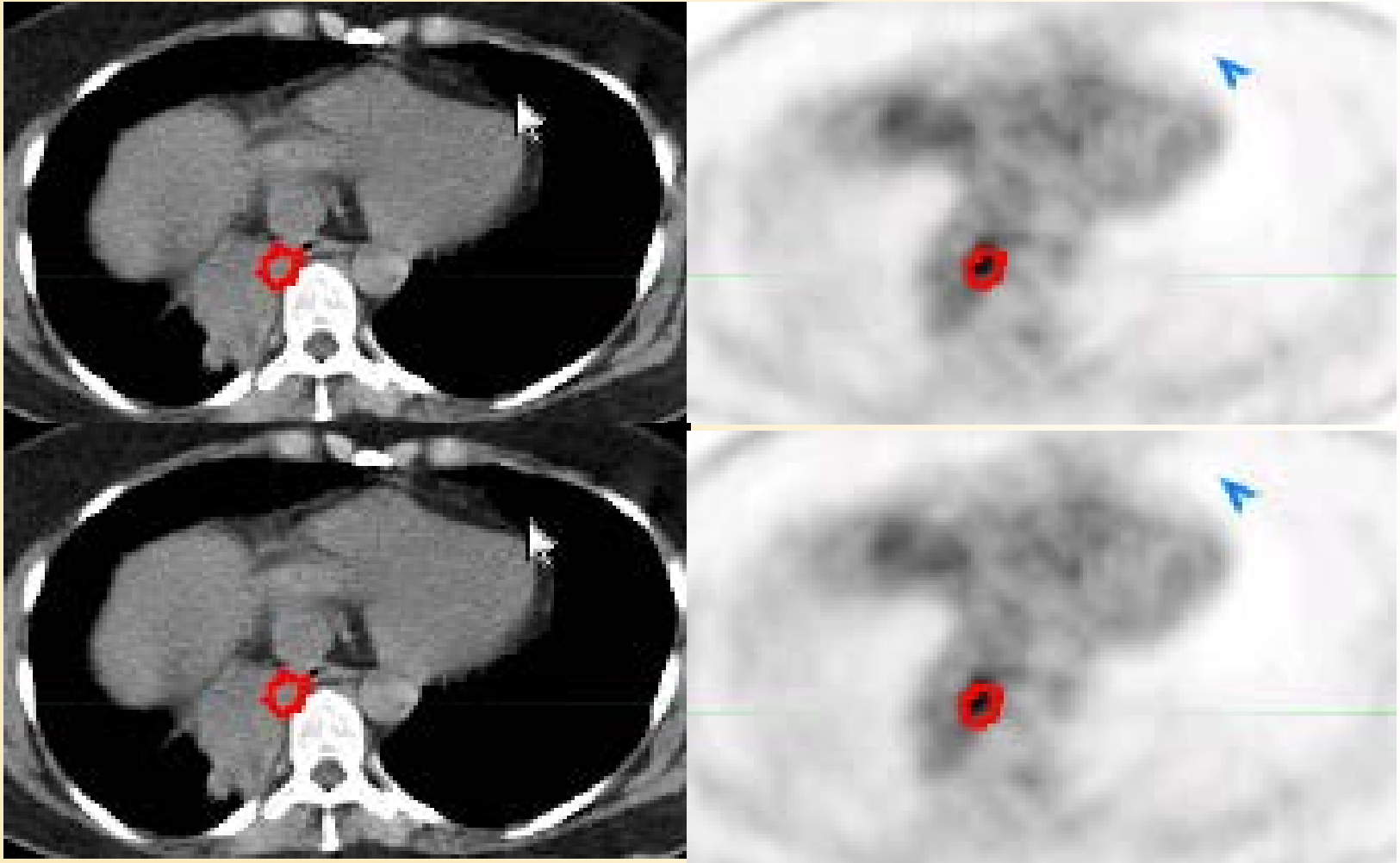
PET2MTV on during-treatment PET-CT, case 1



PET2MTV on during-treatment PET-CT, case 1



PET2MTV on during-treatment PET-CT, case 1



Example case #2, T4N2M0, with a primary tumor of right upper lung. The patient was status post a futile thoracotomy due to tumor invasion to superior vena cava.

Consensus contours of CTGTV and PETMTV of participating radiation oncologists of RTOG lung steering committee.

▪

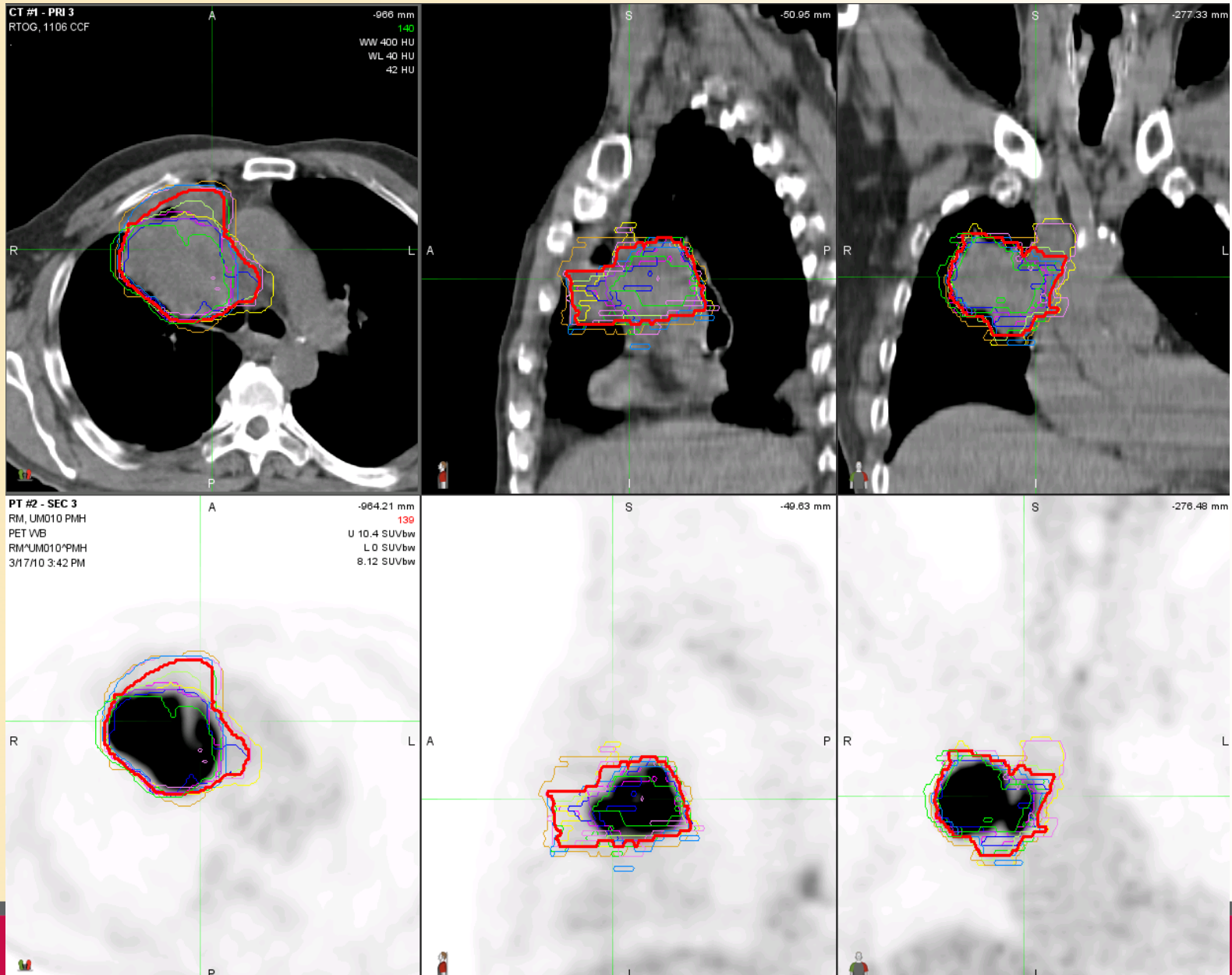
CT1GTV on Pre-treatment PET-CT: Example Case #2

CT1GTV should be generated without consideration of PET1MTV.

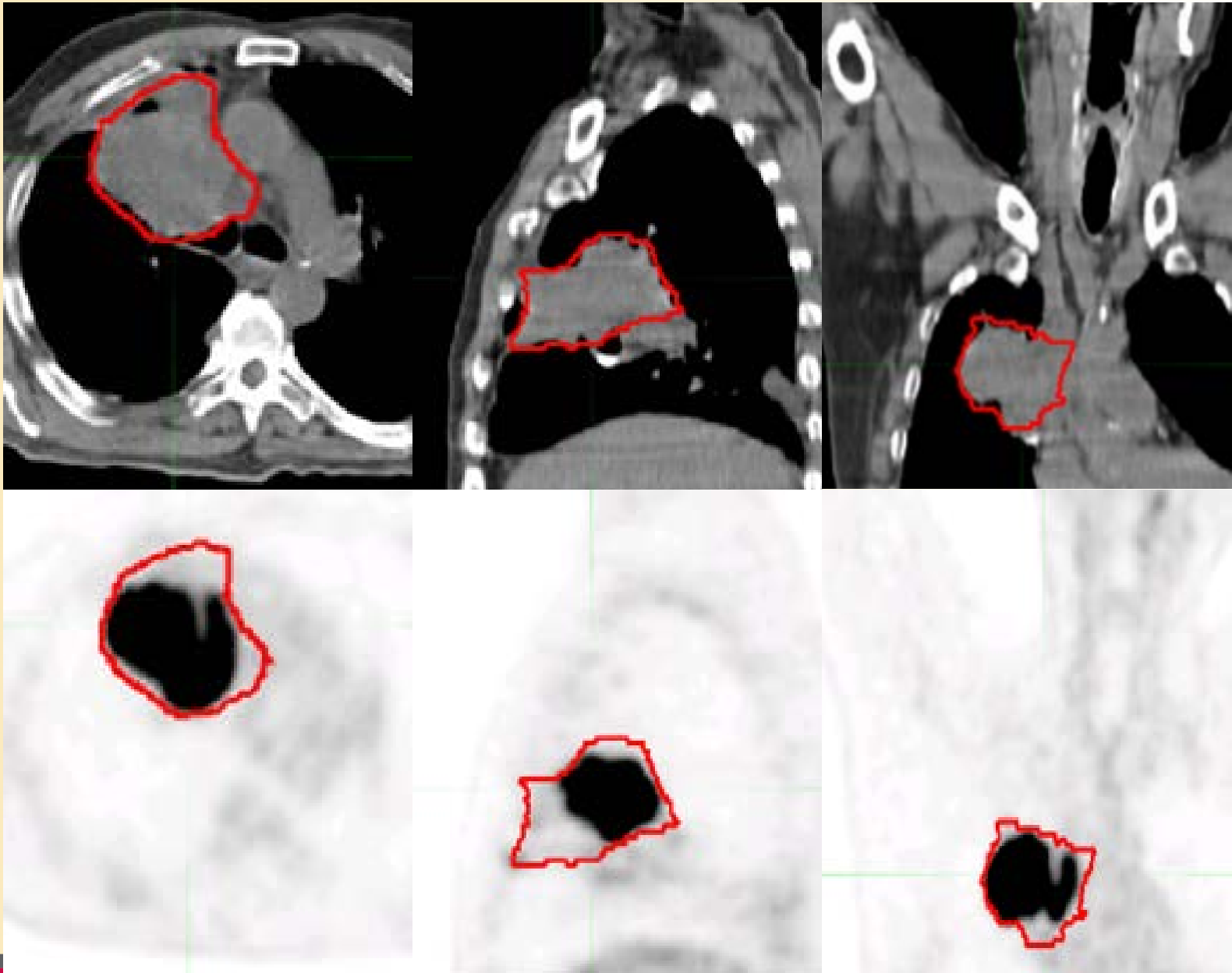
CT1GTV shown in red is the composite of all CT1GTVTs and CT1GTVNs.

CT1GTV on Pre-treatment PET-CT, case 2

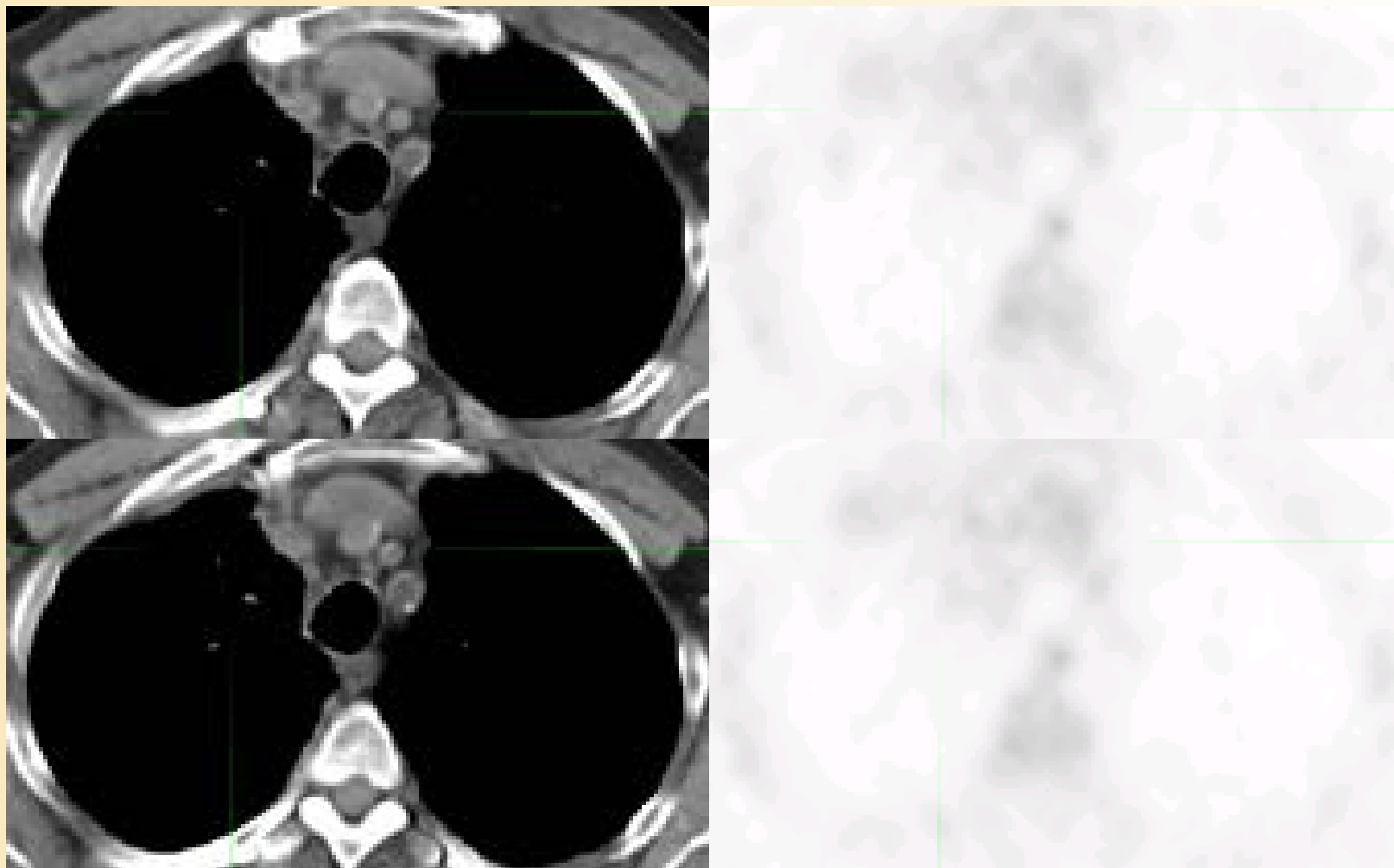
Variations (thin lines) and consensus (red thick lines)



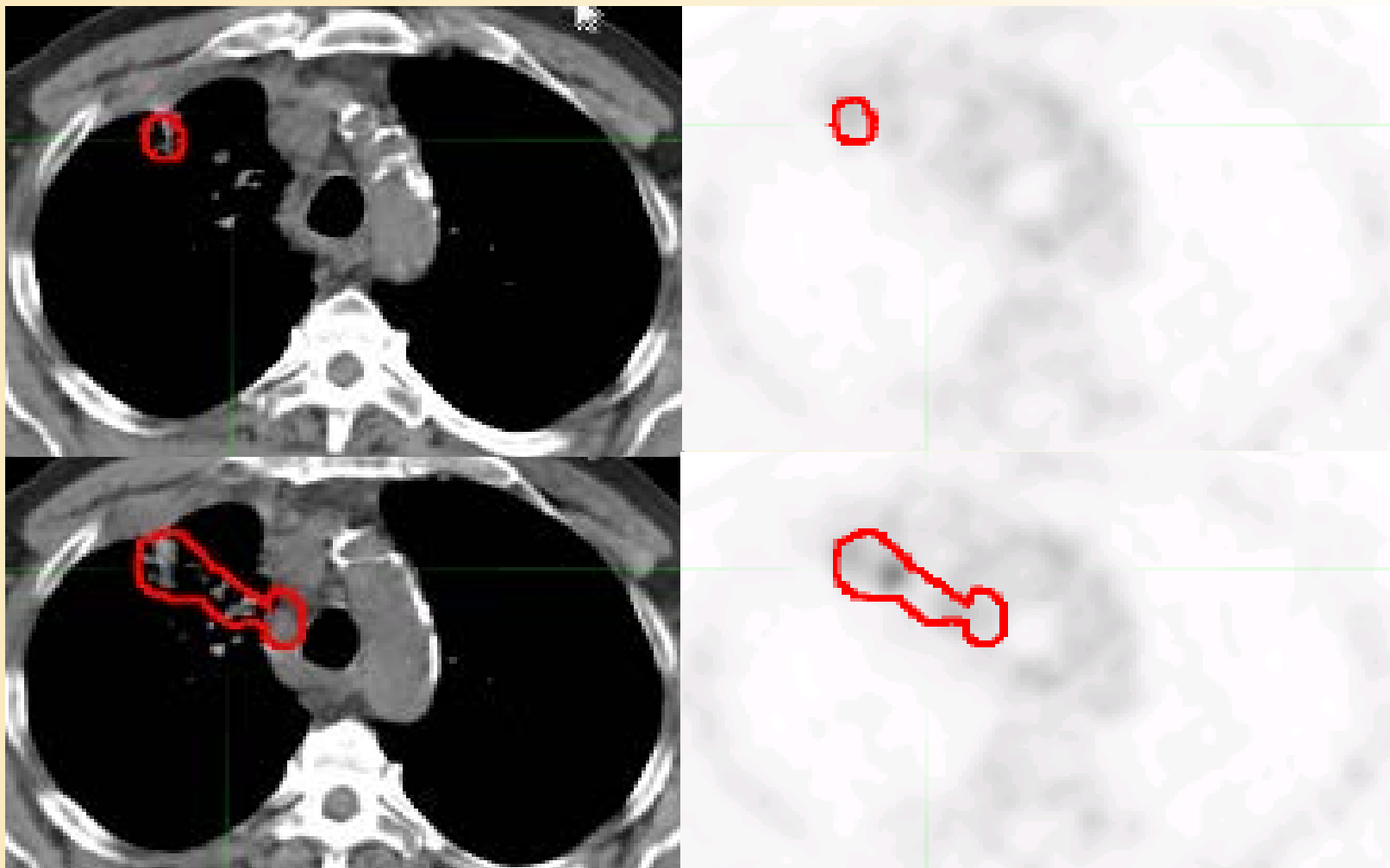
CT1GTV on Pre-treatment PET-CT, case 2



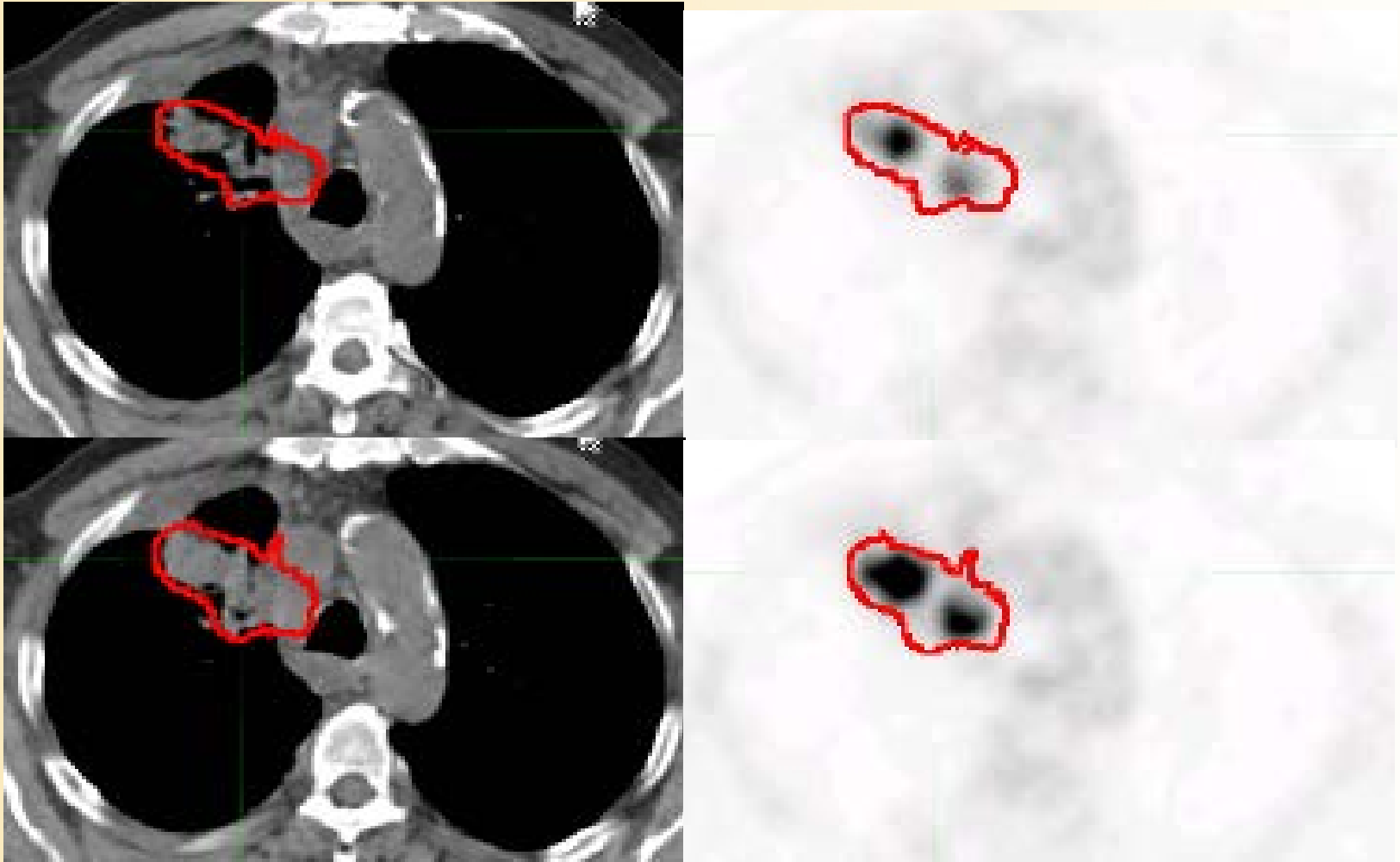
CT1GTV on Pre-treatment PET-CT, case 2
No tumor on this slice



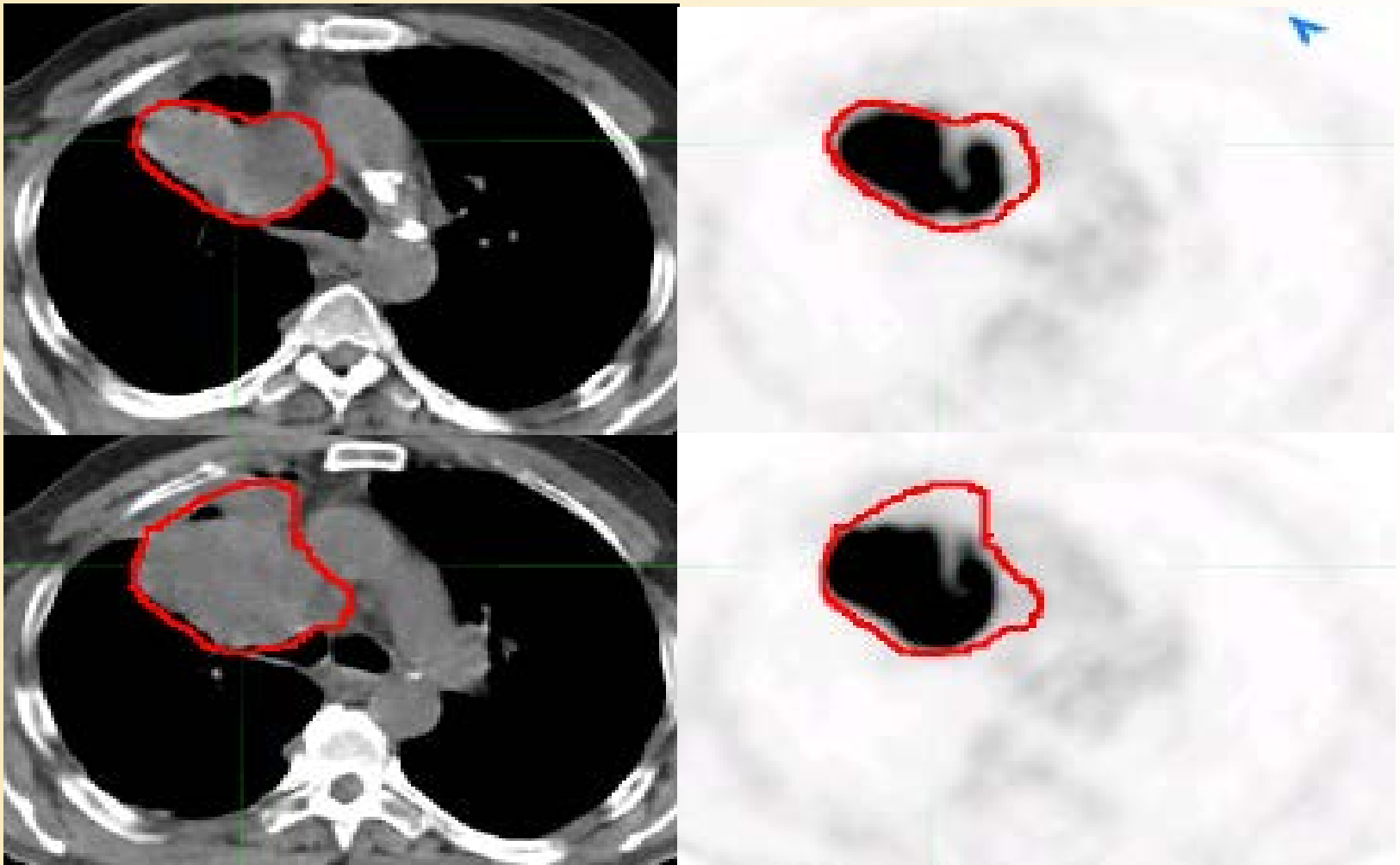
CT1GTV on Pre-treatment PET-CT, case 2



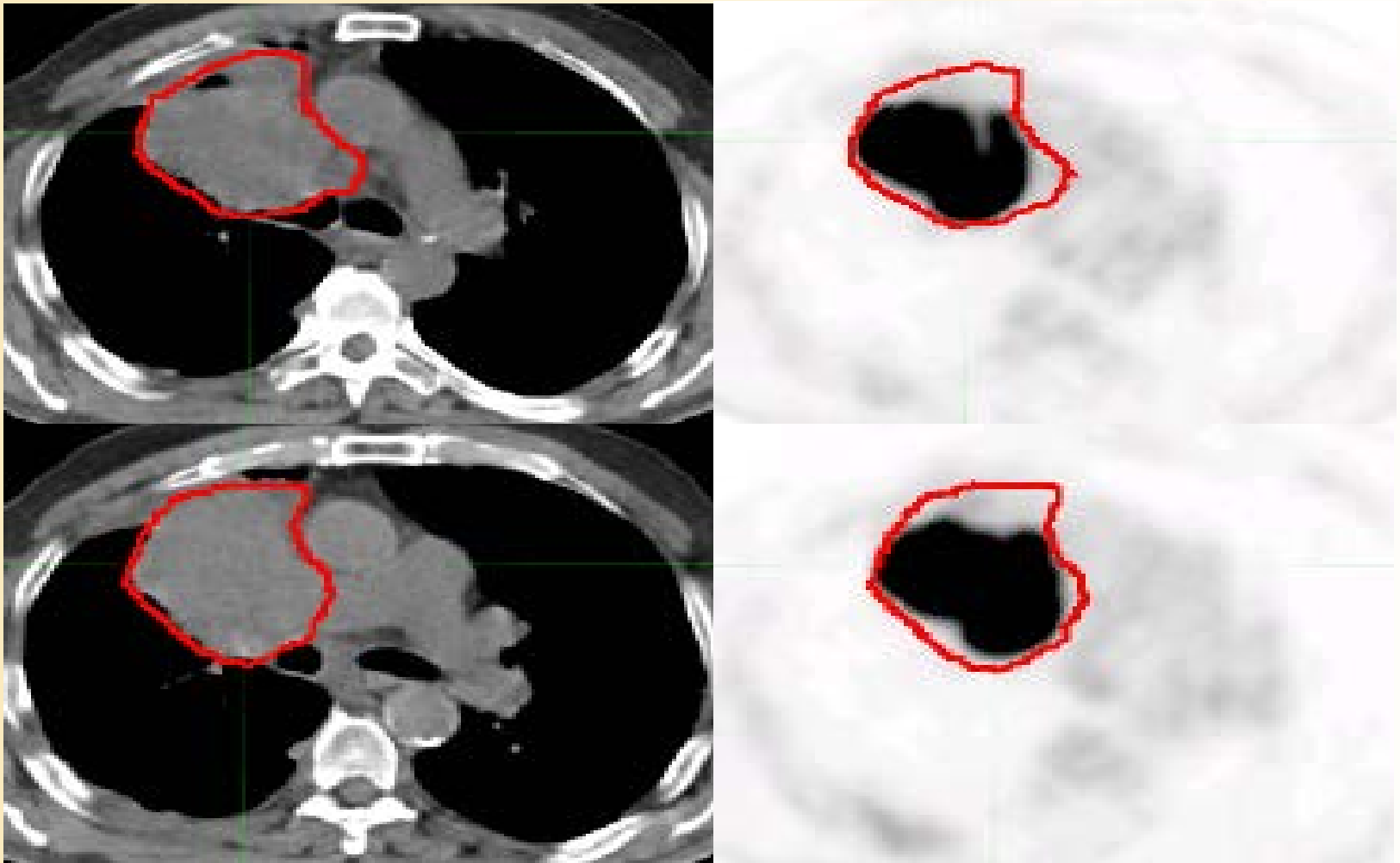
CT1GTV on Pre-treatment PET-CT, case 2



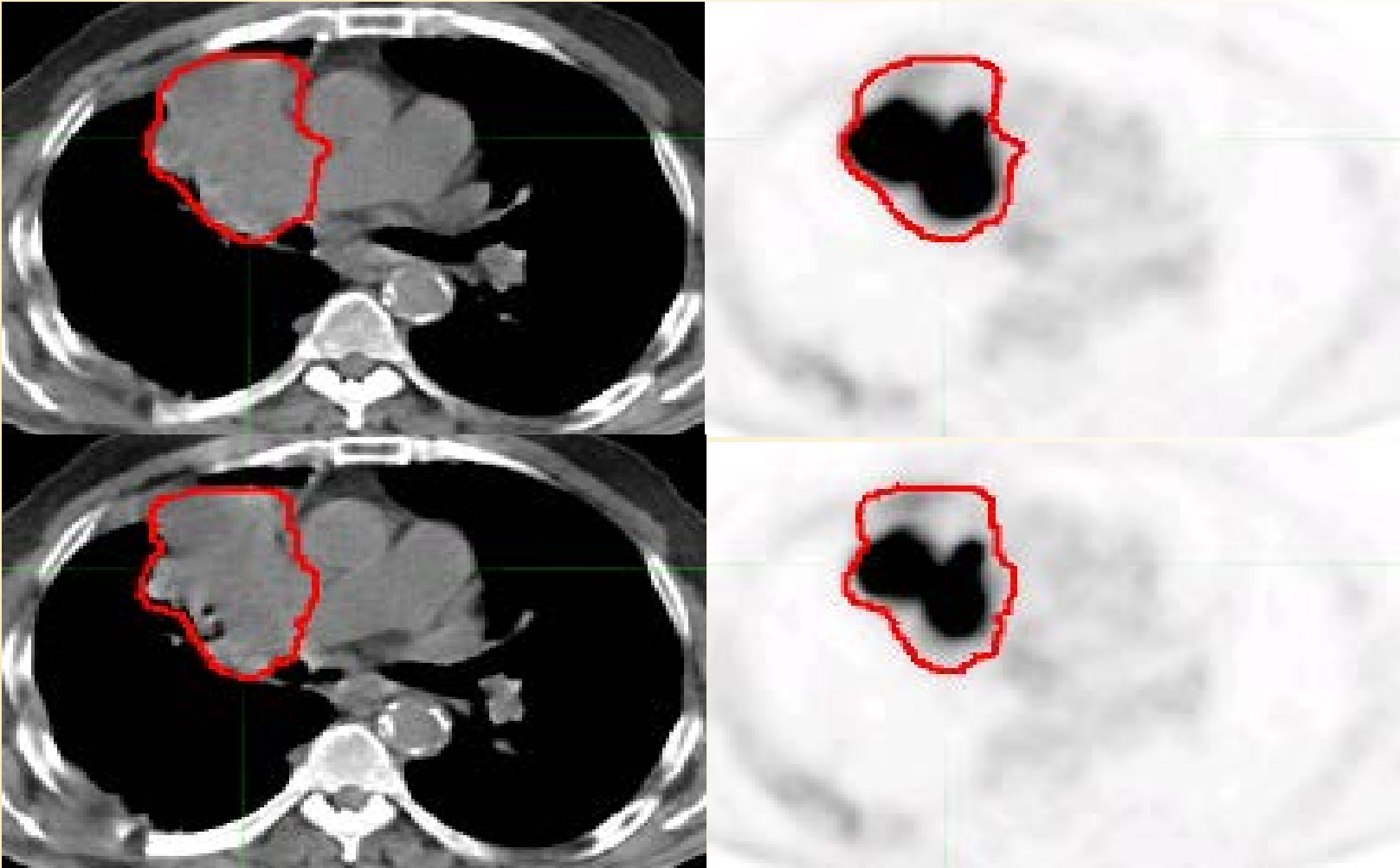
CT1GTV on Pre-treatment PET-CT, case 2



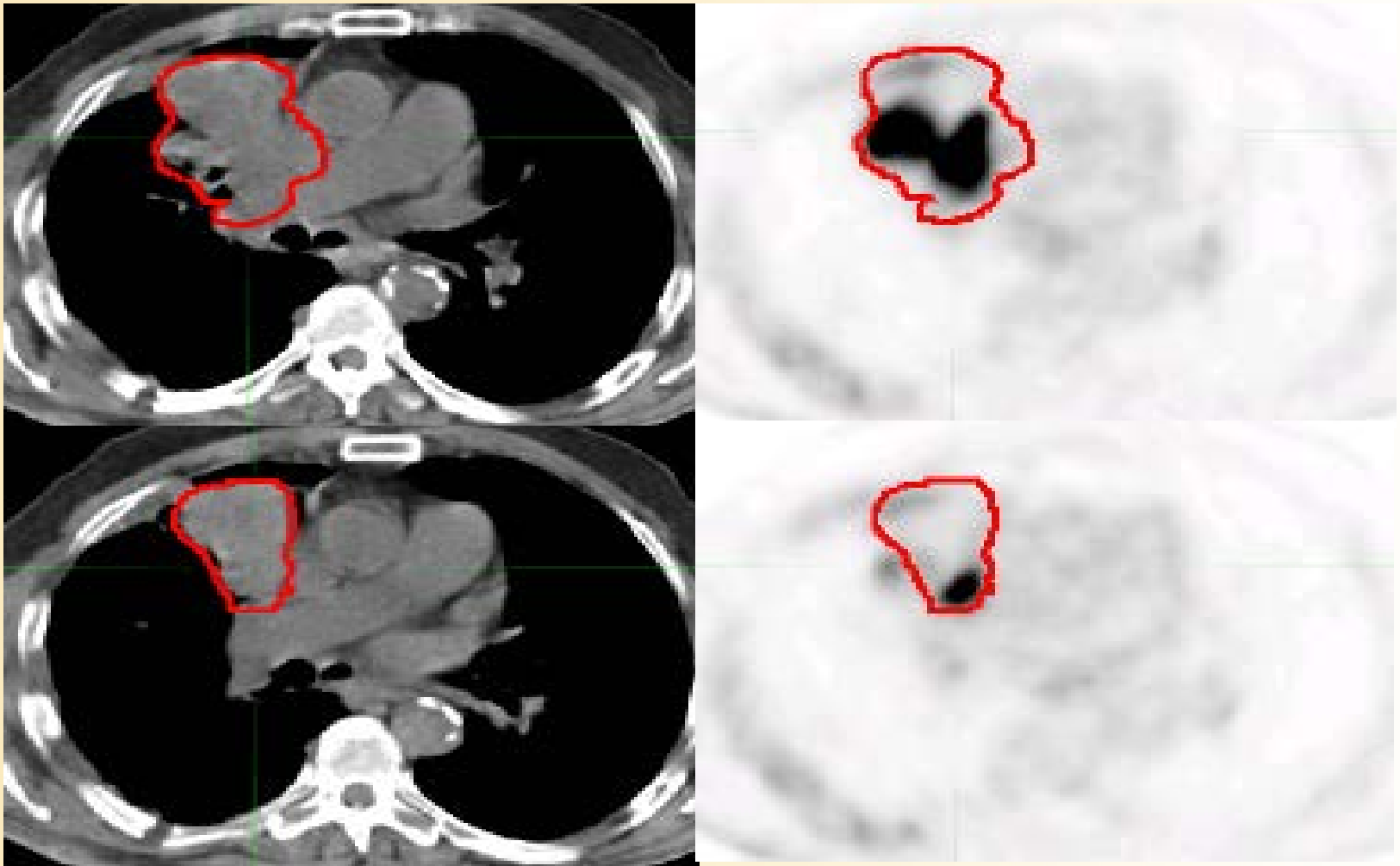
CT1GTV on Pre-treatment PET-CT, case 2



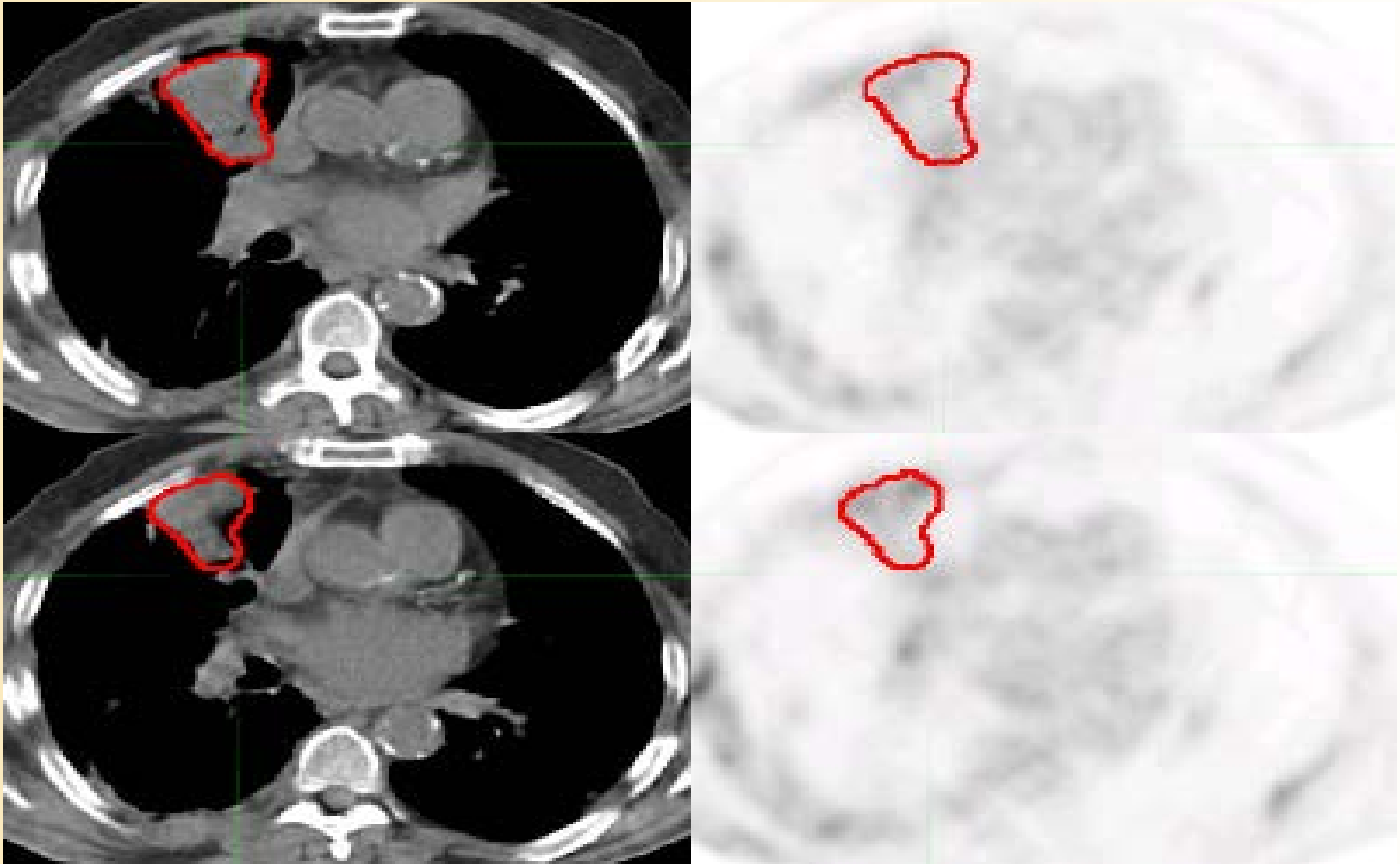
CT1GTV on Pre-treatment PET-CT, case 2



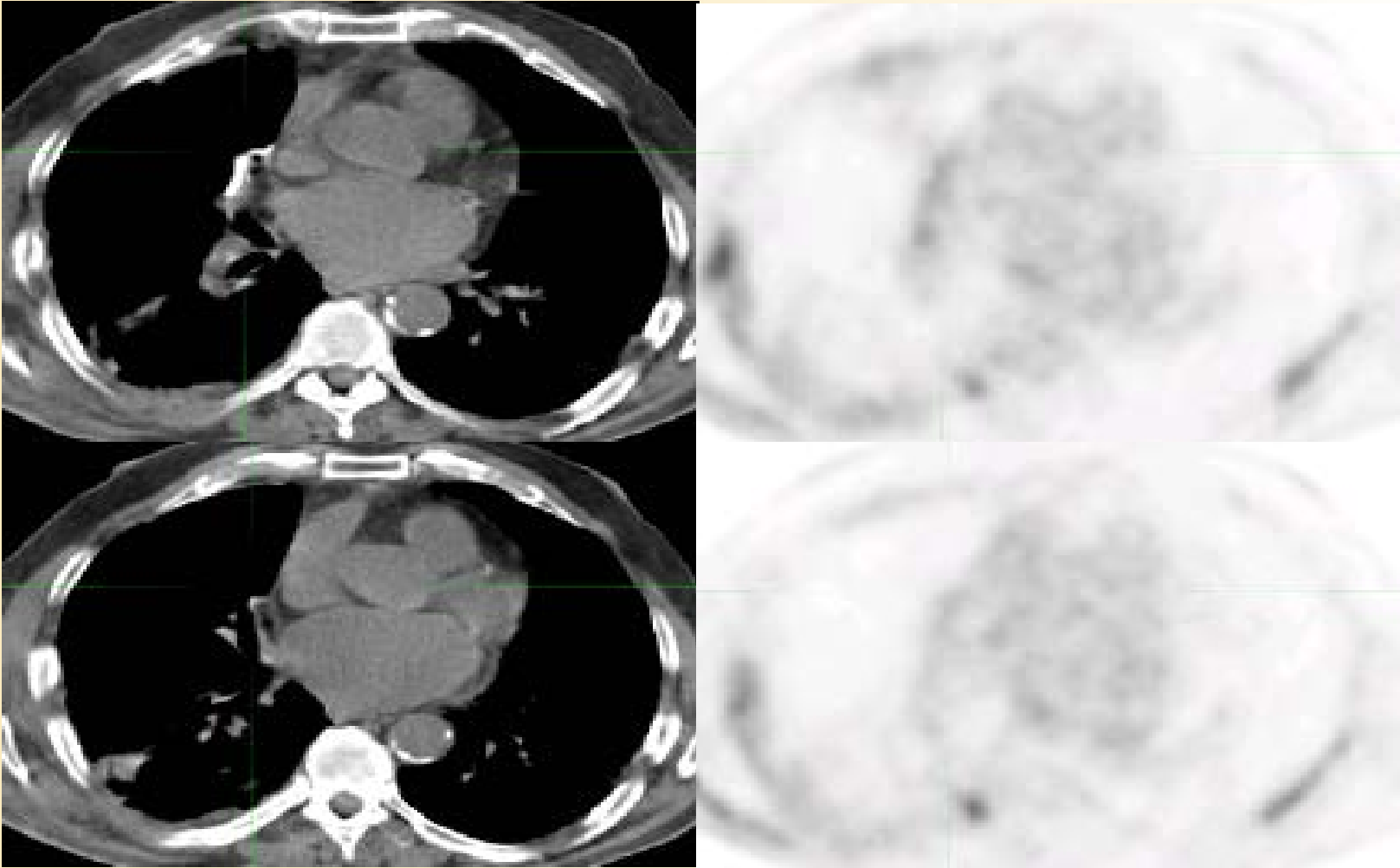
CT1GTV on Pre-treatment PET-CT, case 2



CT1GTV on Pre-treatment PET-CT, case 2



CT1GTV on Pre-treatment PET-CT, case 2



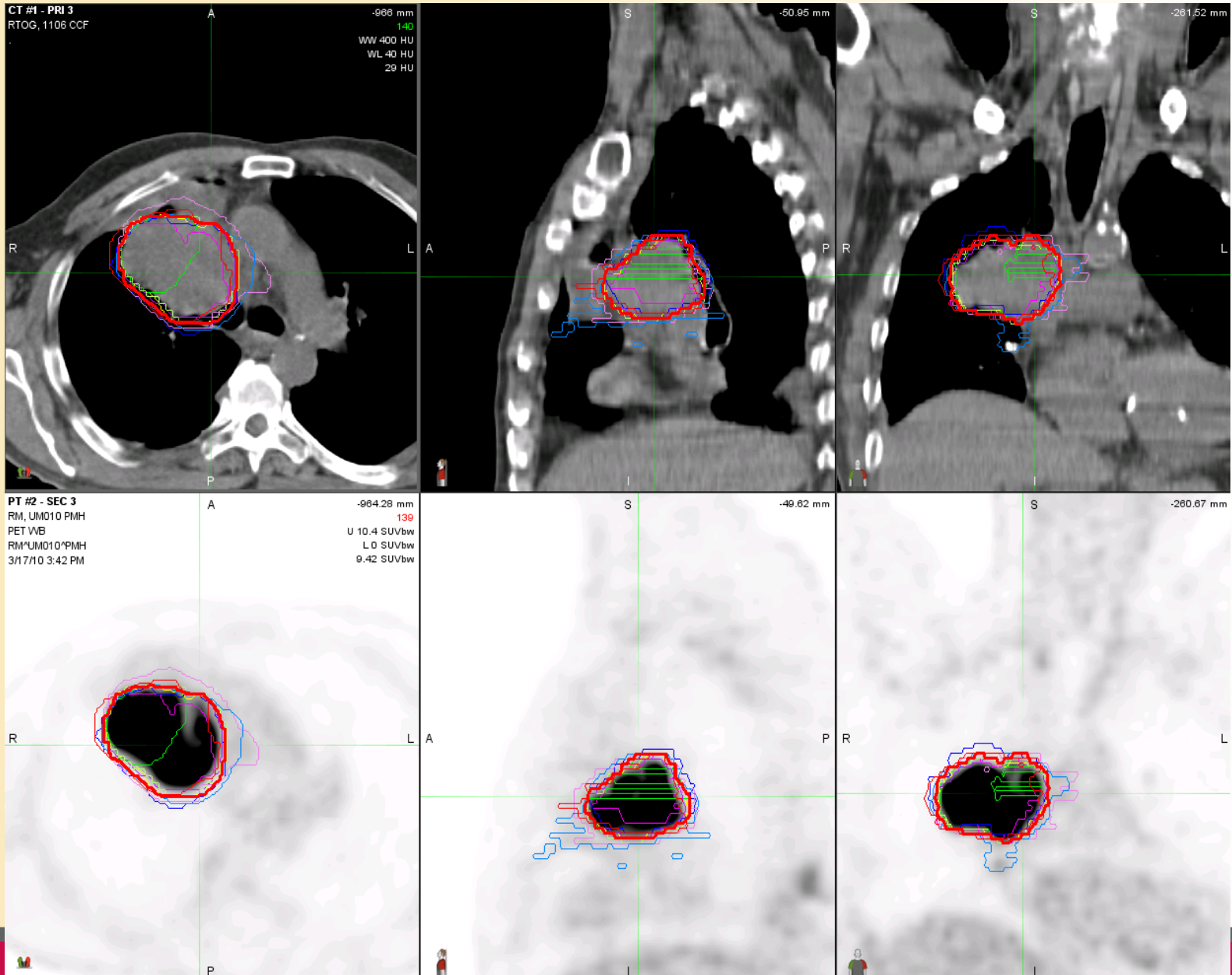
PET1MTV on Pre-treatment PET-CT: Example Case #2

PET1MTV should be generated
without consideration of CT1GTV.

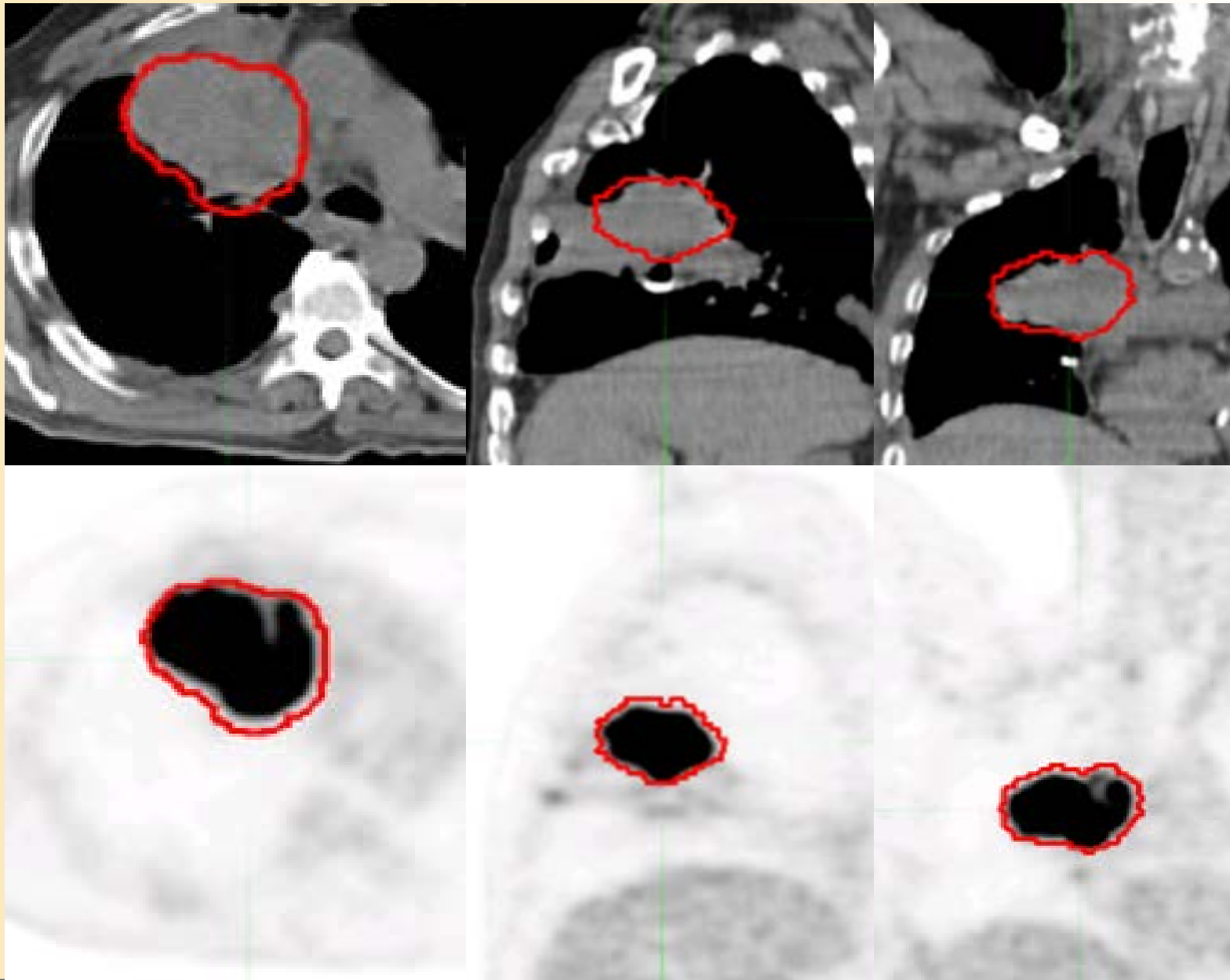
PET1MTV shown in red is the
composite of PET1MTVTs and
PET1MTVNs.

PET1MTV on Pre-treatment PET-CT, case 2

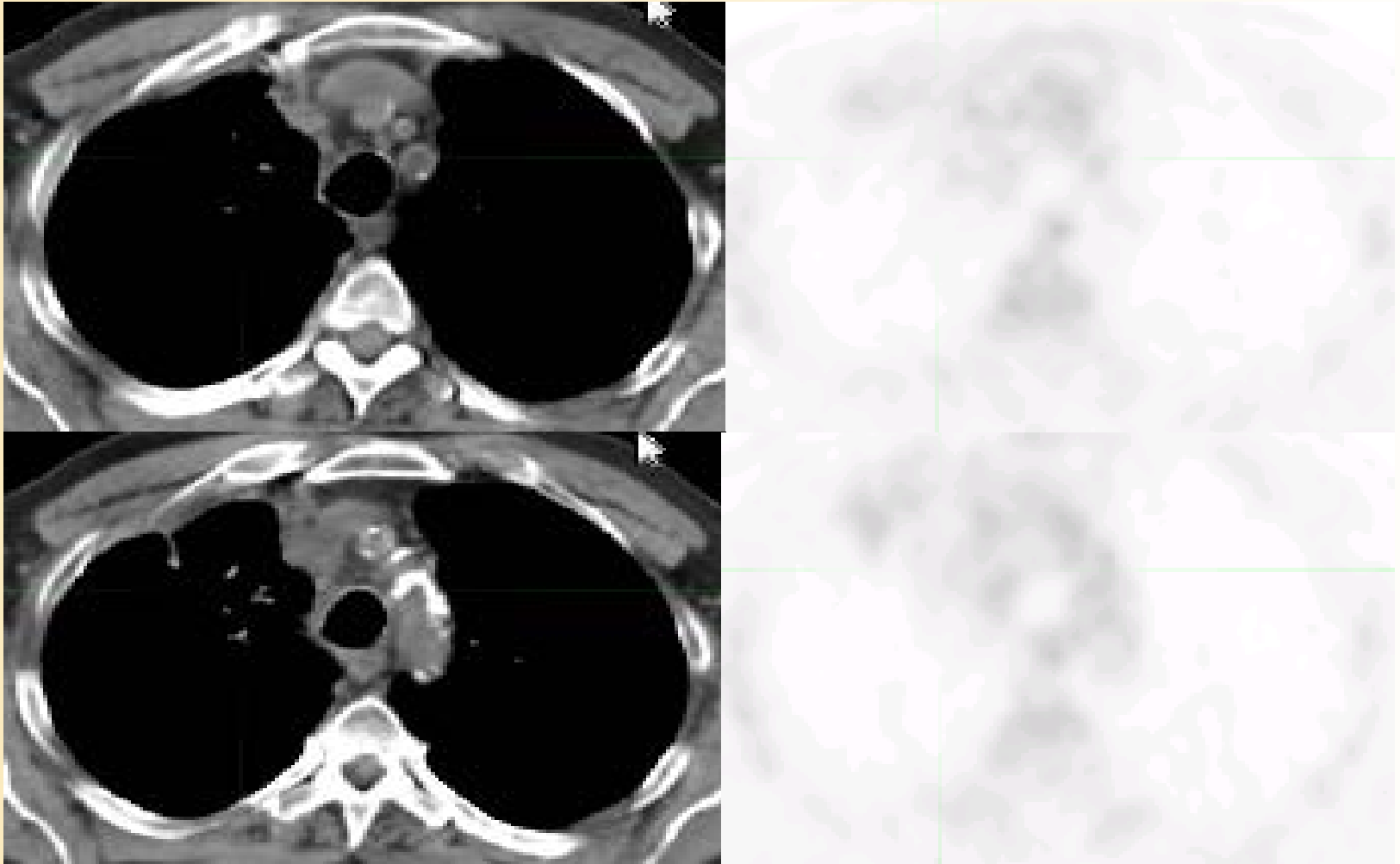
Variations (thin lines) and consensus (red thick lines)



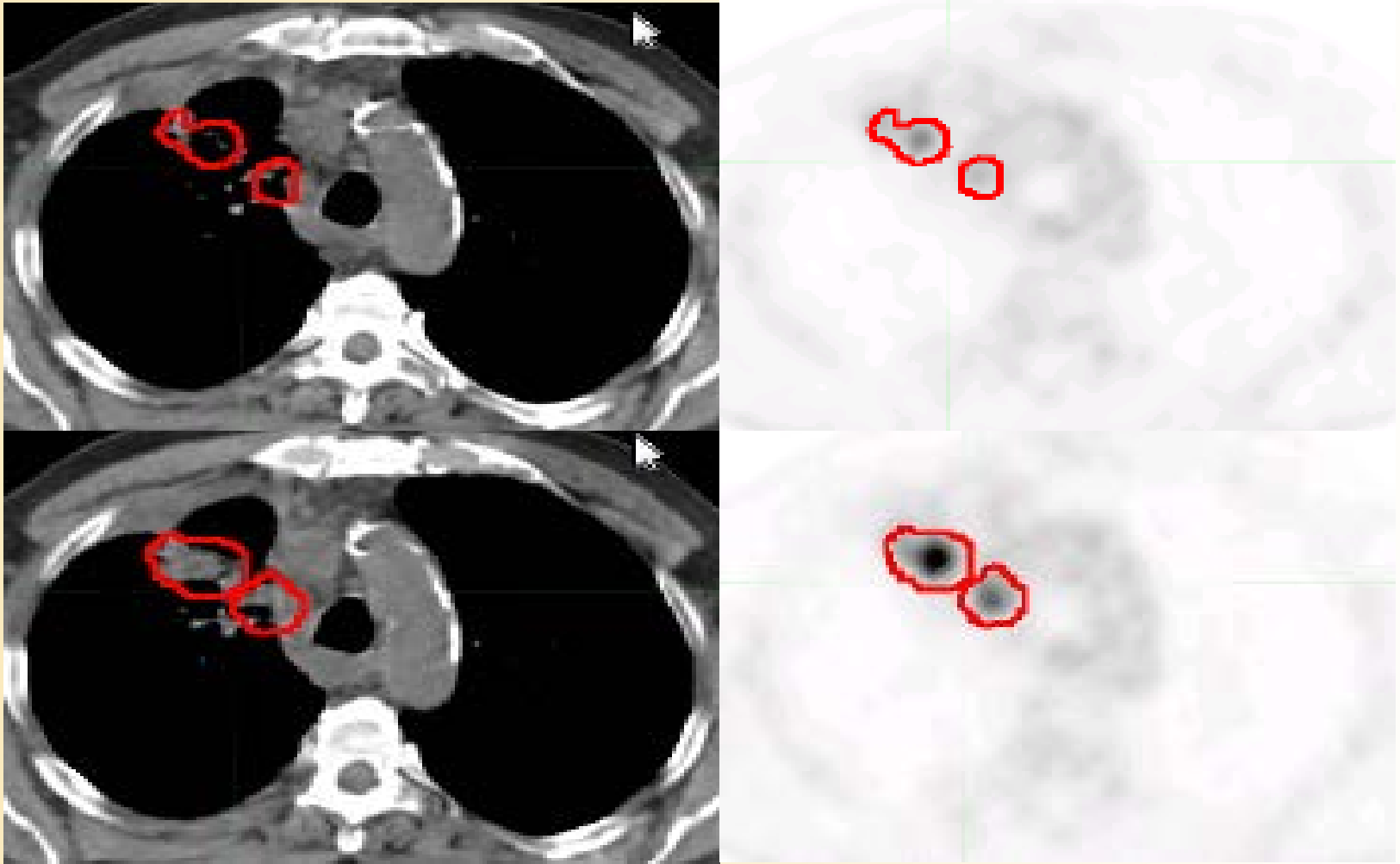
PET1MTV on Pre-treatment PET-CT, case 2



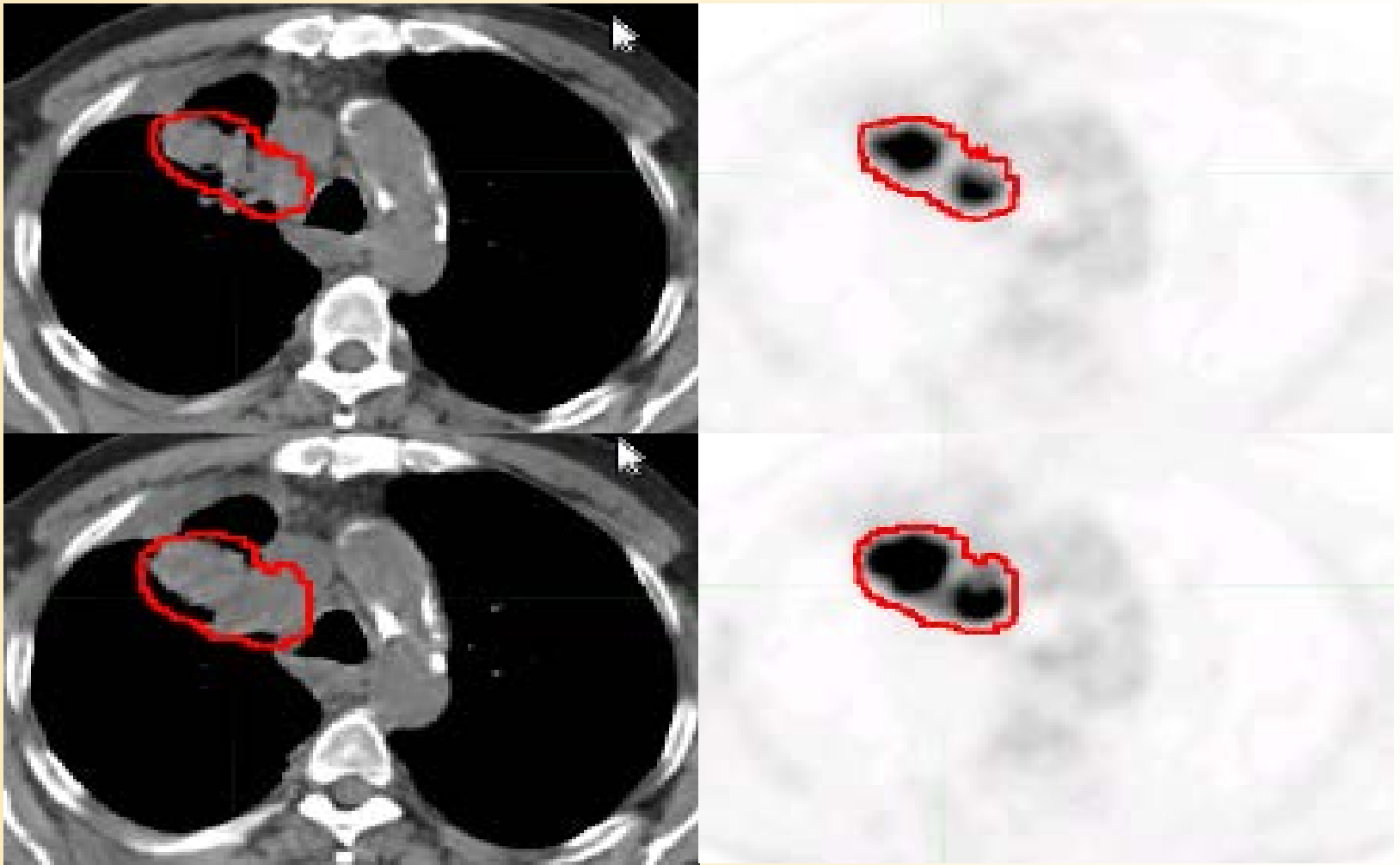
PET1MTV on Pre-treatment PET-CT, case 2



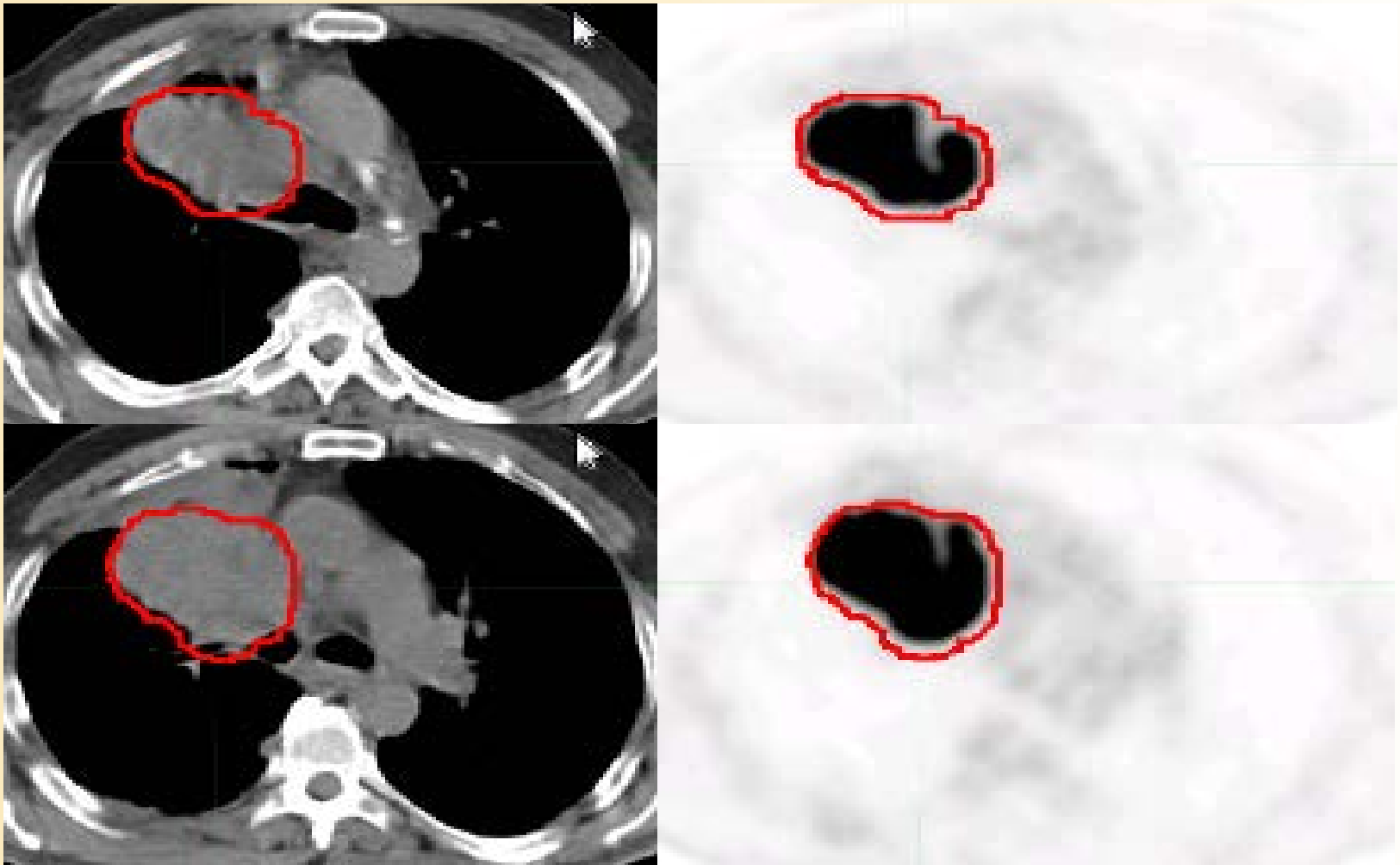
PET1MTV on Pre-treatment PET-CT, case 2



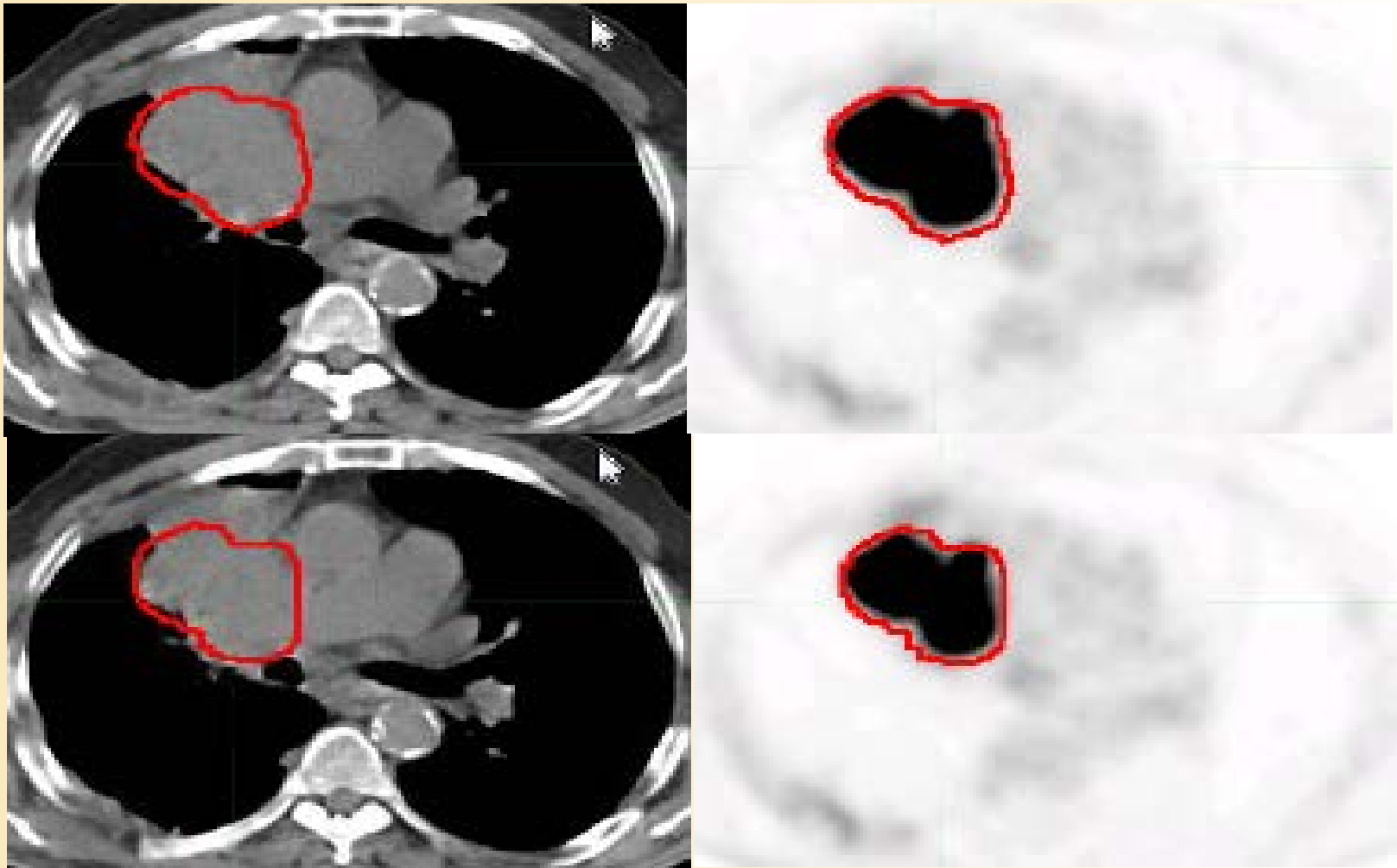
PET1MTV on Pre-treatment PET-CT, case 2



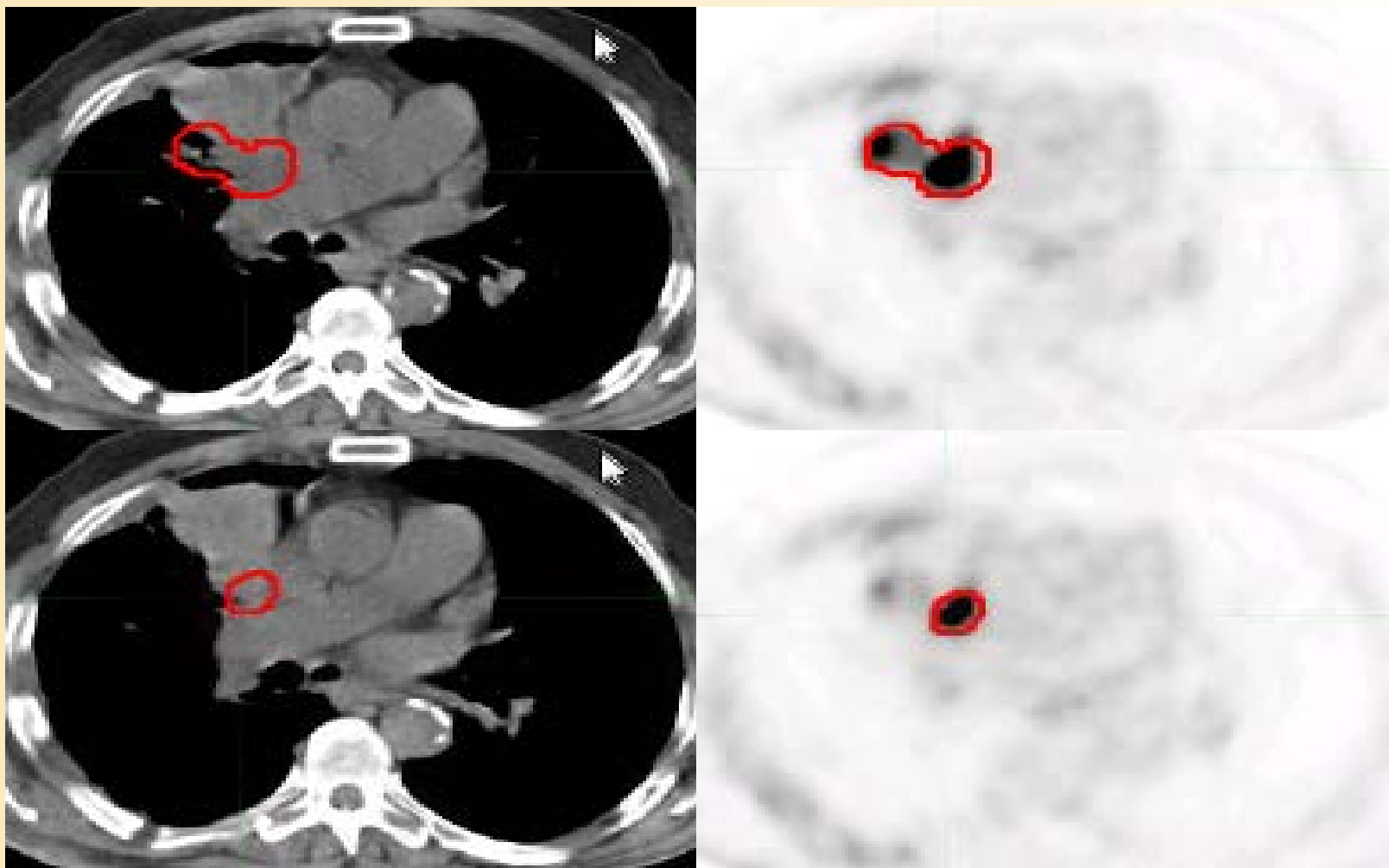
PET1MTV on Pre-treatment PET-CT, case 2



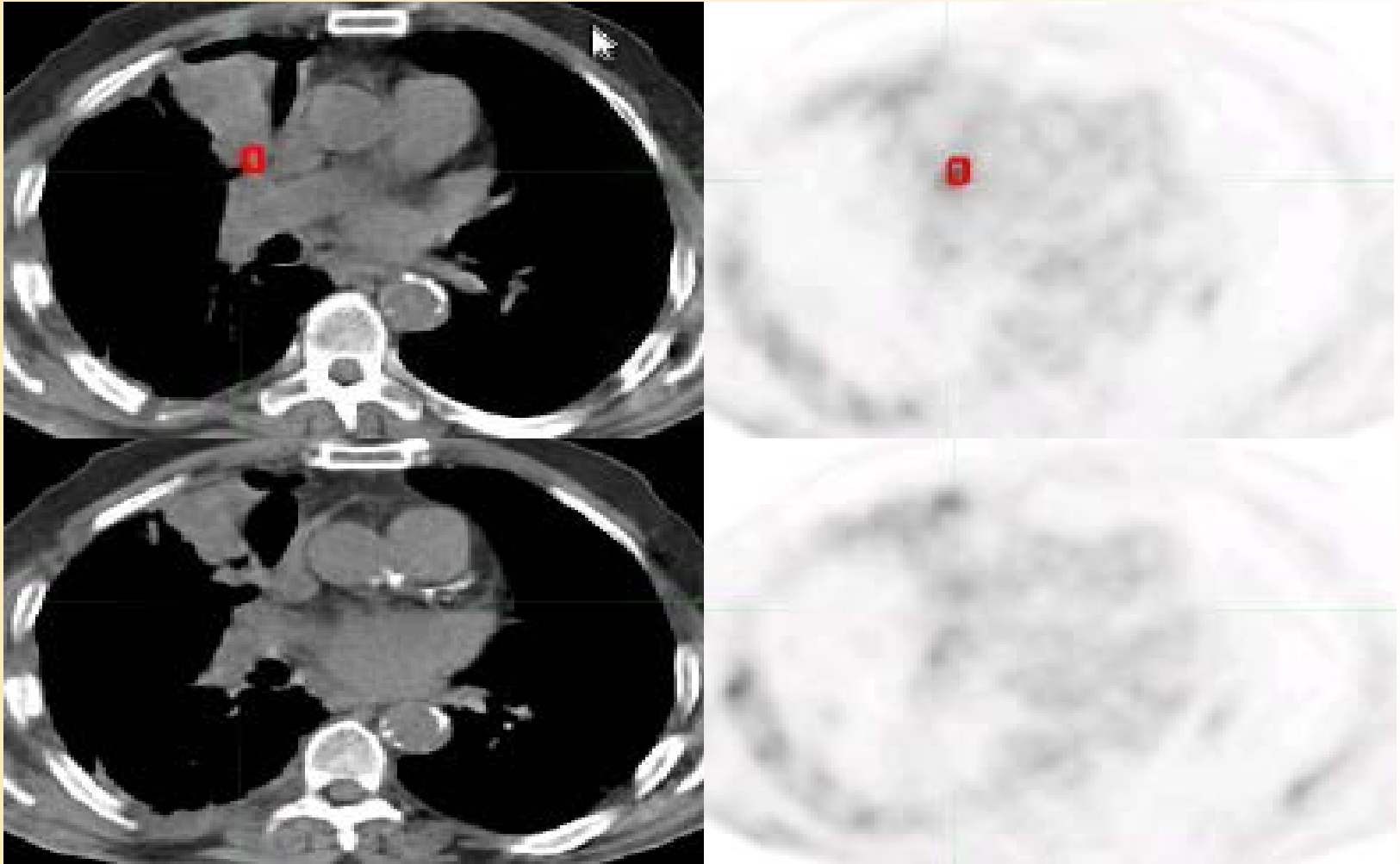
PET1MTV on Pre-treatment PET-CT, case 2



PET1MTV on Pre-treatment PET-CT, case 2



PET1MTV on Pre-treatment PET-CT, case 2



PET1MTV on Pre-treatment PET-CT, case 2

Collapsed lungs without metabolic activity should not be included.

Activity less than 1.5 times intensity of aortic arch are not included in MTV.



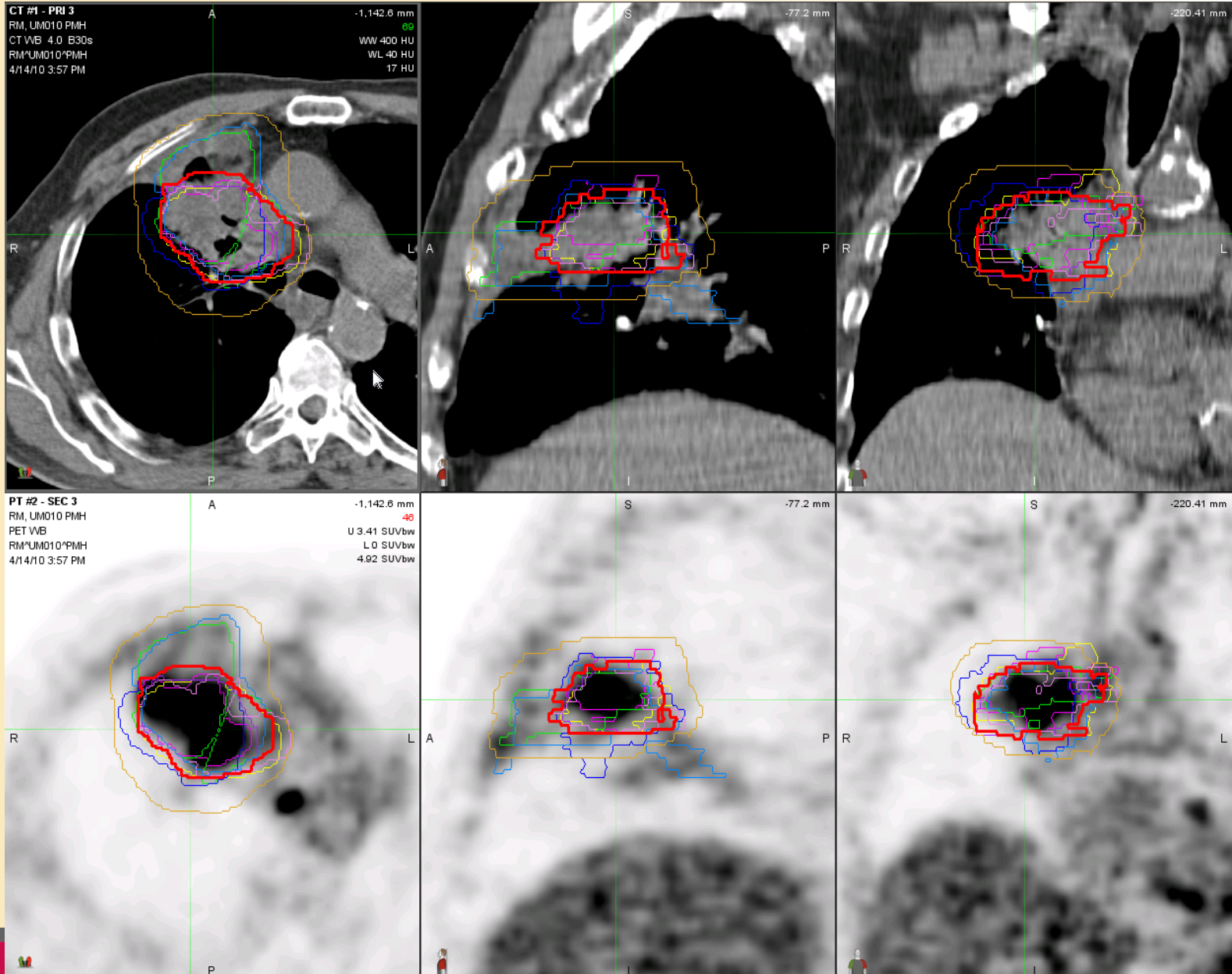
CT2GTV on During-treatment PET-CT: Example Case #2

CT2GTV should be generated
without consideration of PETMTV.

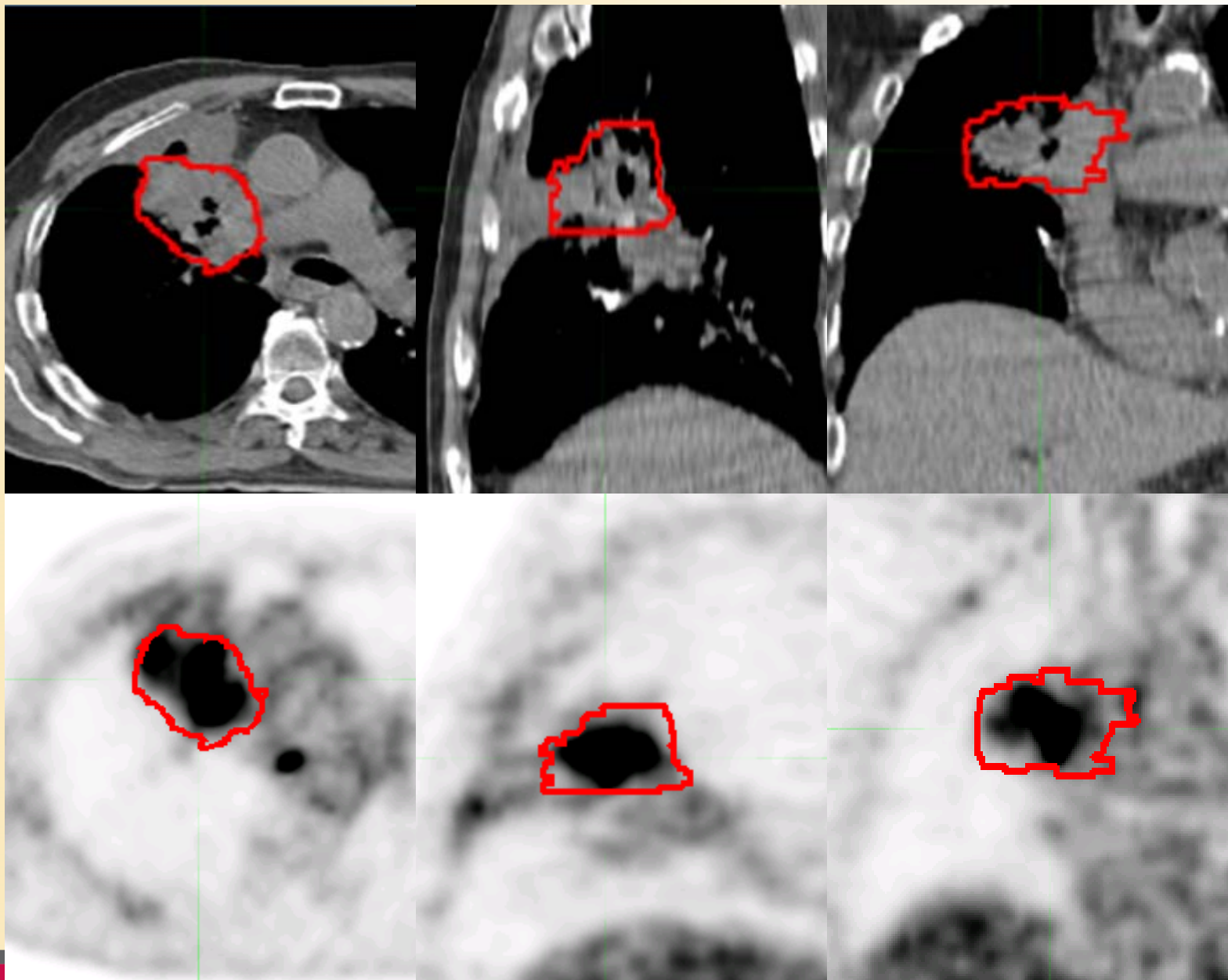
CT2GTV shown in red is the
composite of all CTGTVTs and
CTGTVNs.

CT2GTV on Pre-treatment PET-CT, case 2

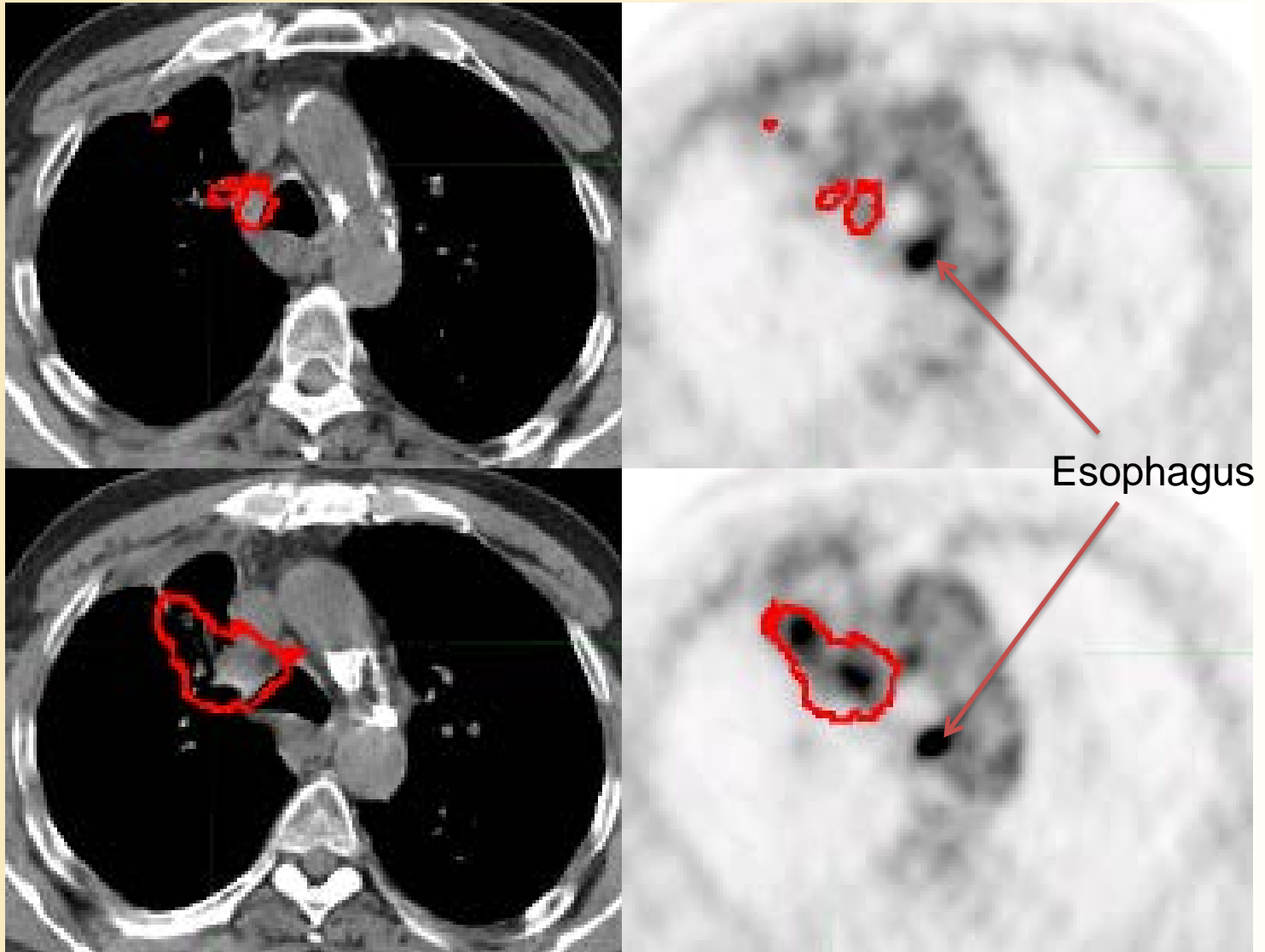
Variations (thin lines) and consensus (red thick lines)



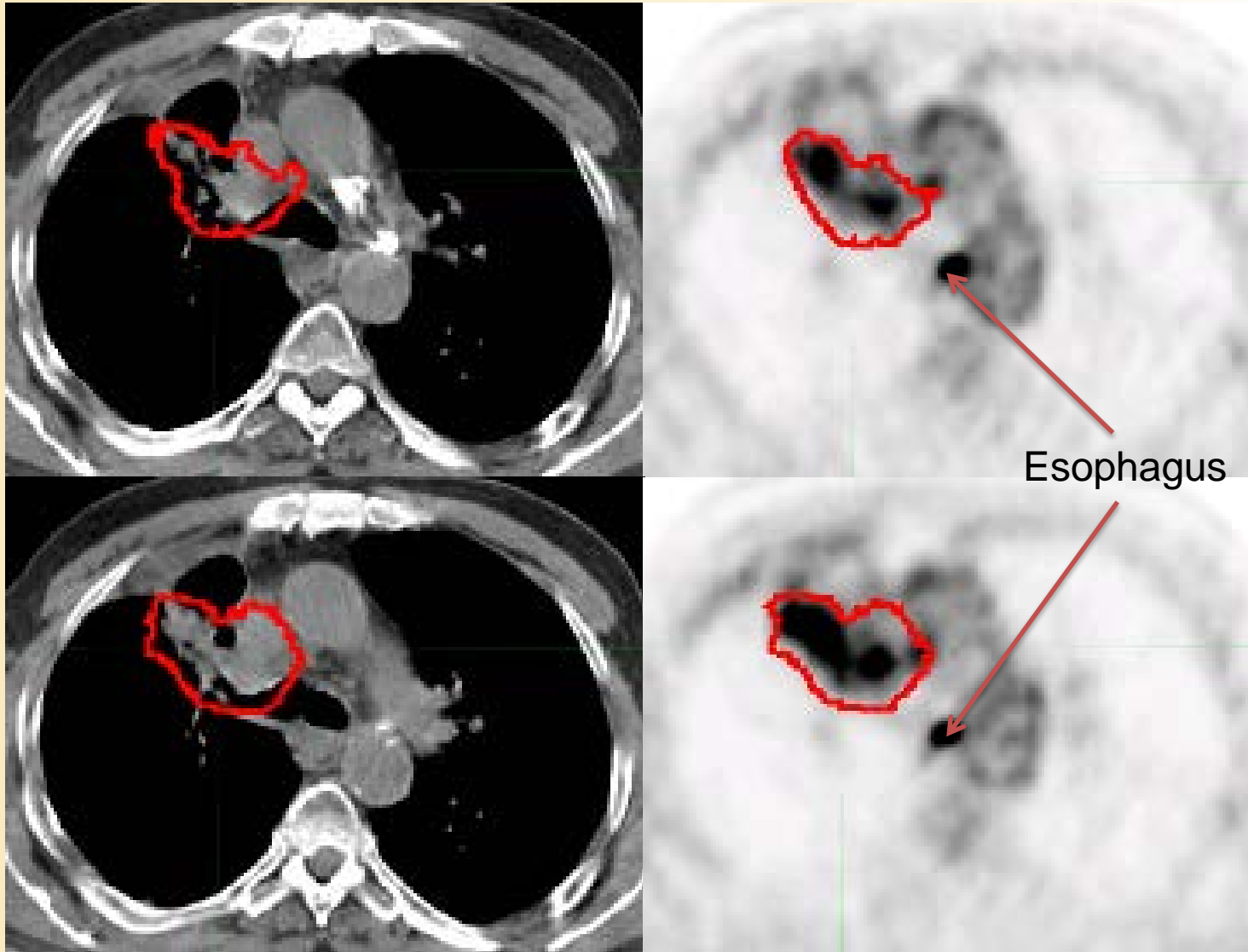
CT2GTV on During-treatment PET-CT, case 2



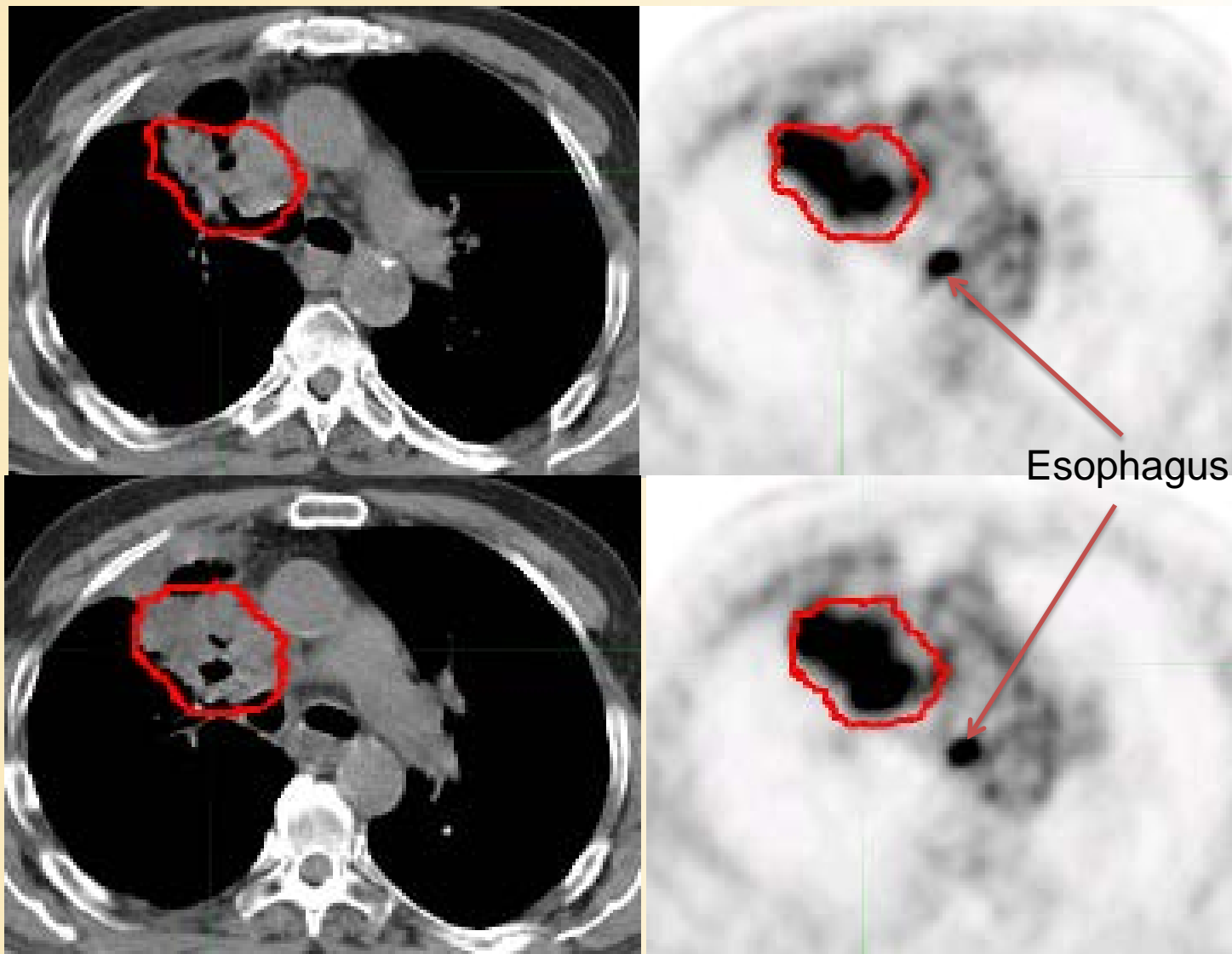
CT2GTV on During-treatment PET-CT, case 2



CT2GTV on During-treatment PET-CT, case 2

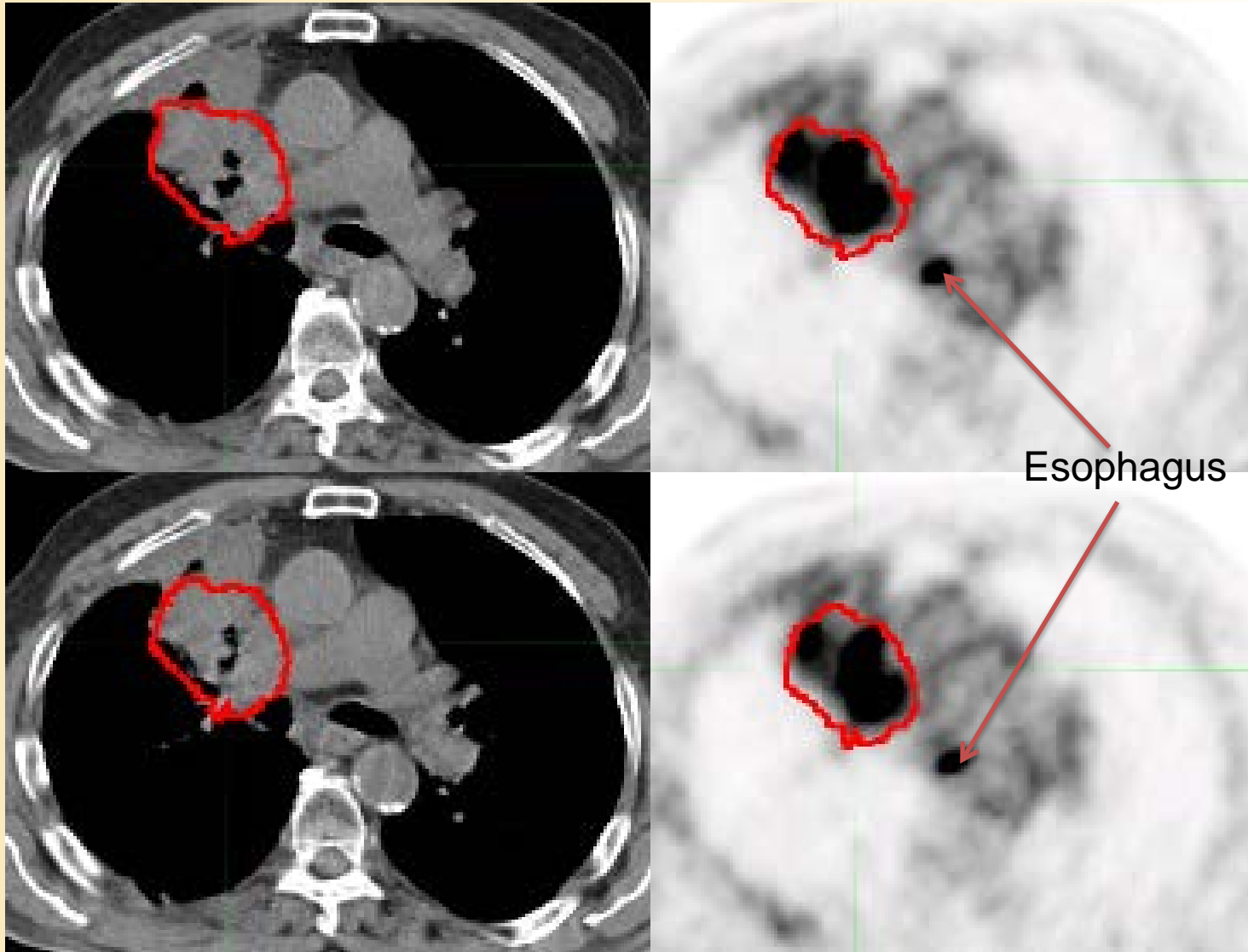


CT2GTV on During-treatment PET-CT, case 2



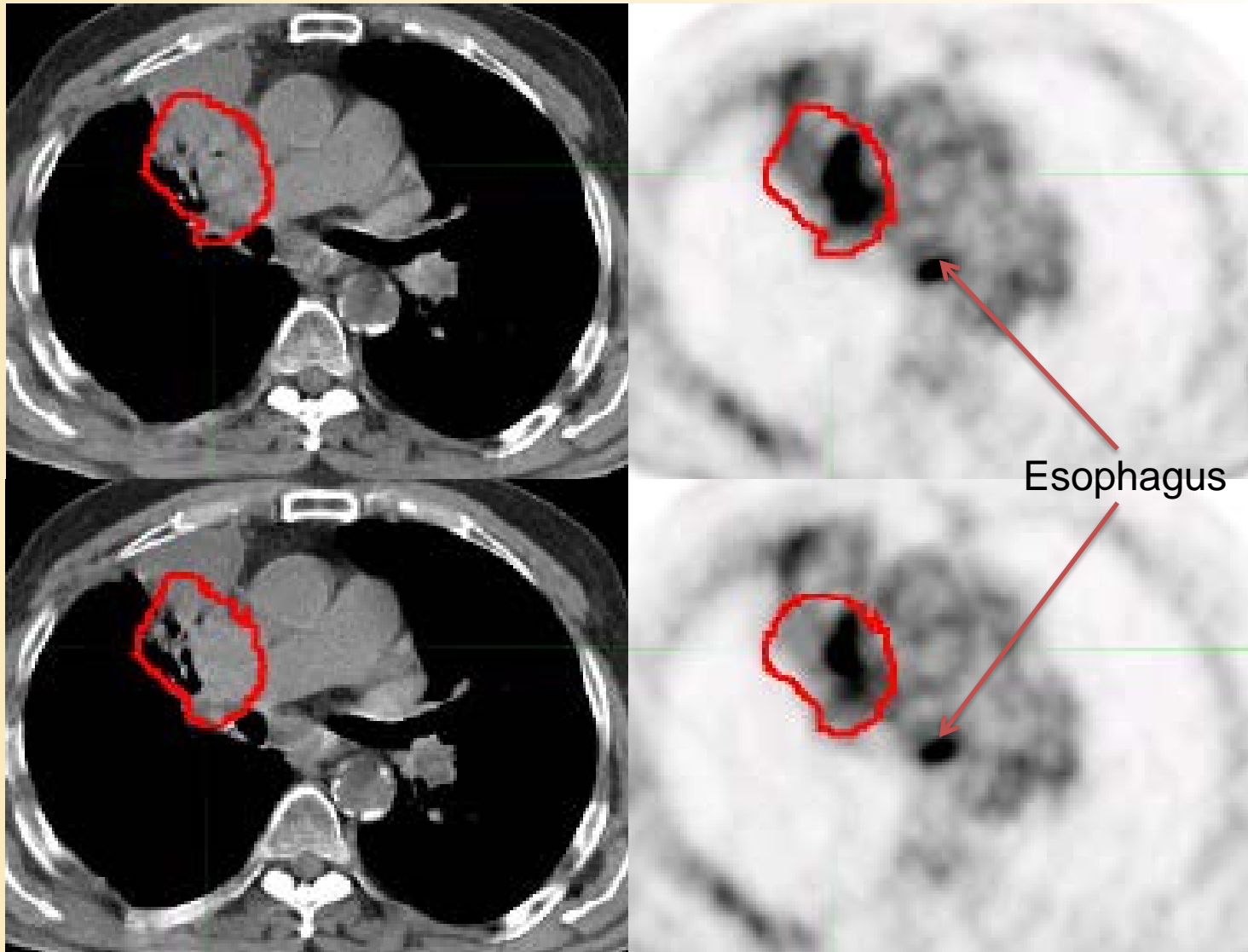
Esophagus

CT2GTV on During-treatment PET-CT, case 2

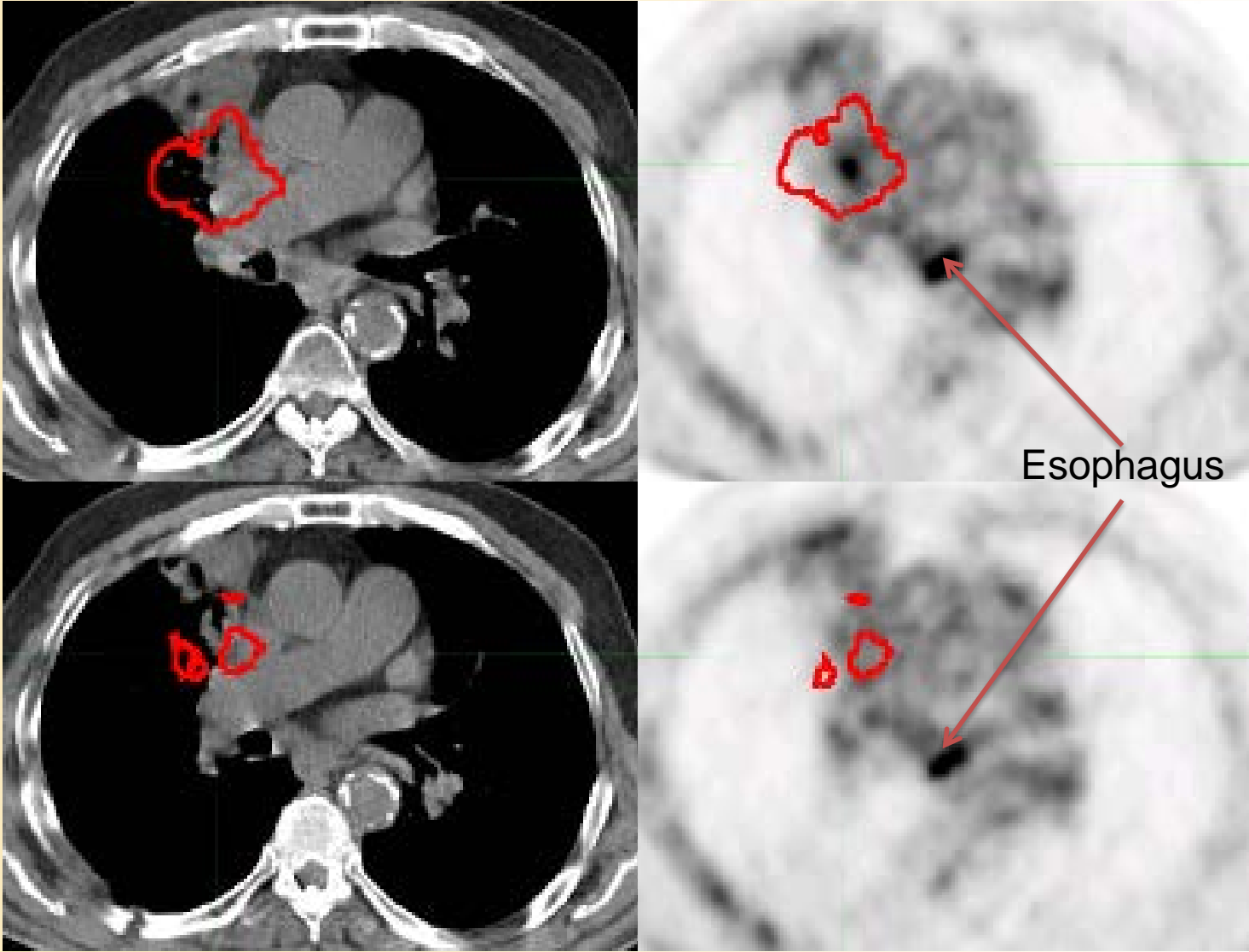


Esophagus

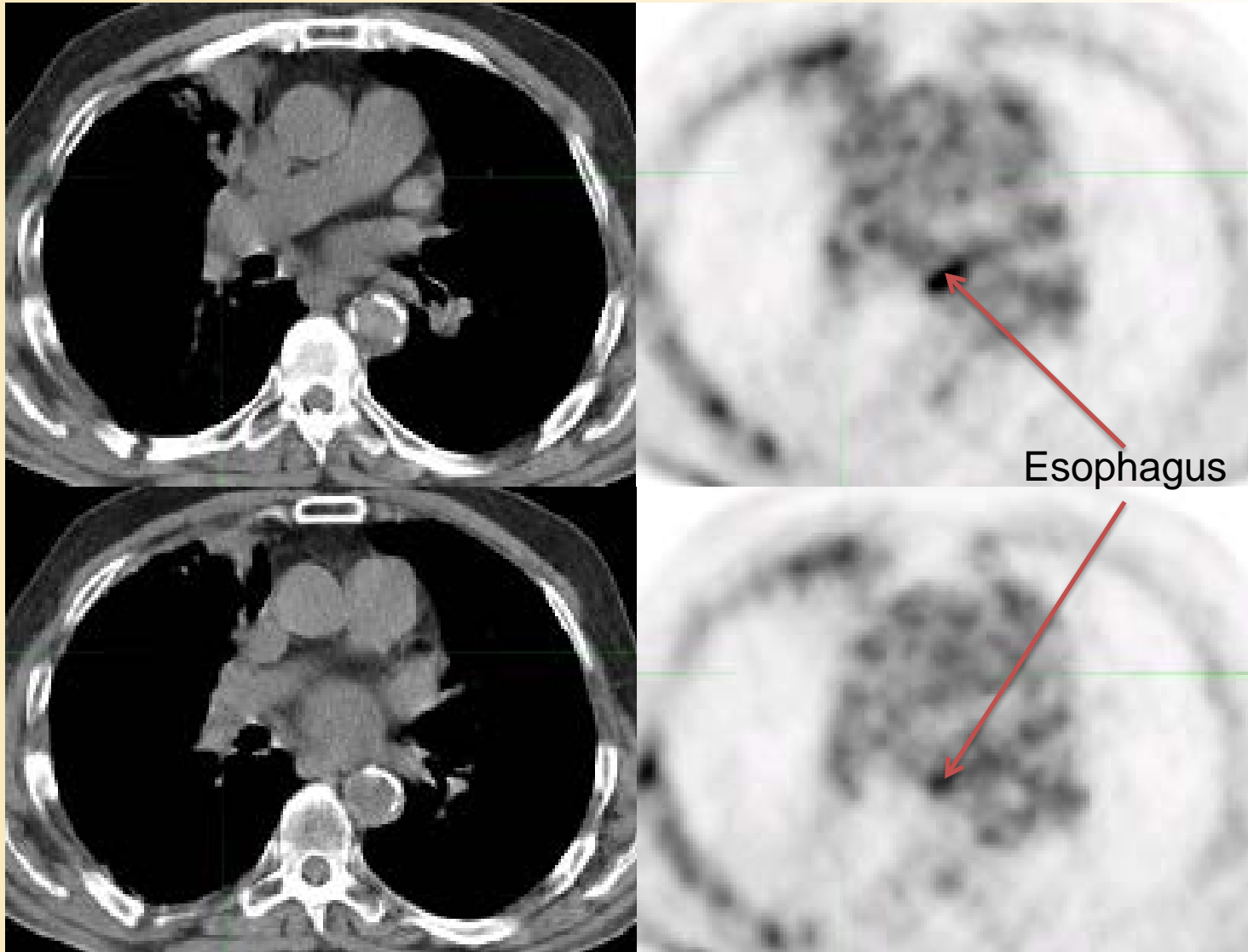
CT2GTV on During-treatment PET-CT, case 2



CT2GTV on During-treatment PET-CT, case 2



CT2GTV on During-treatment PET-CT, case 2



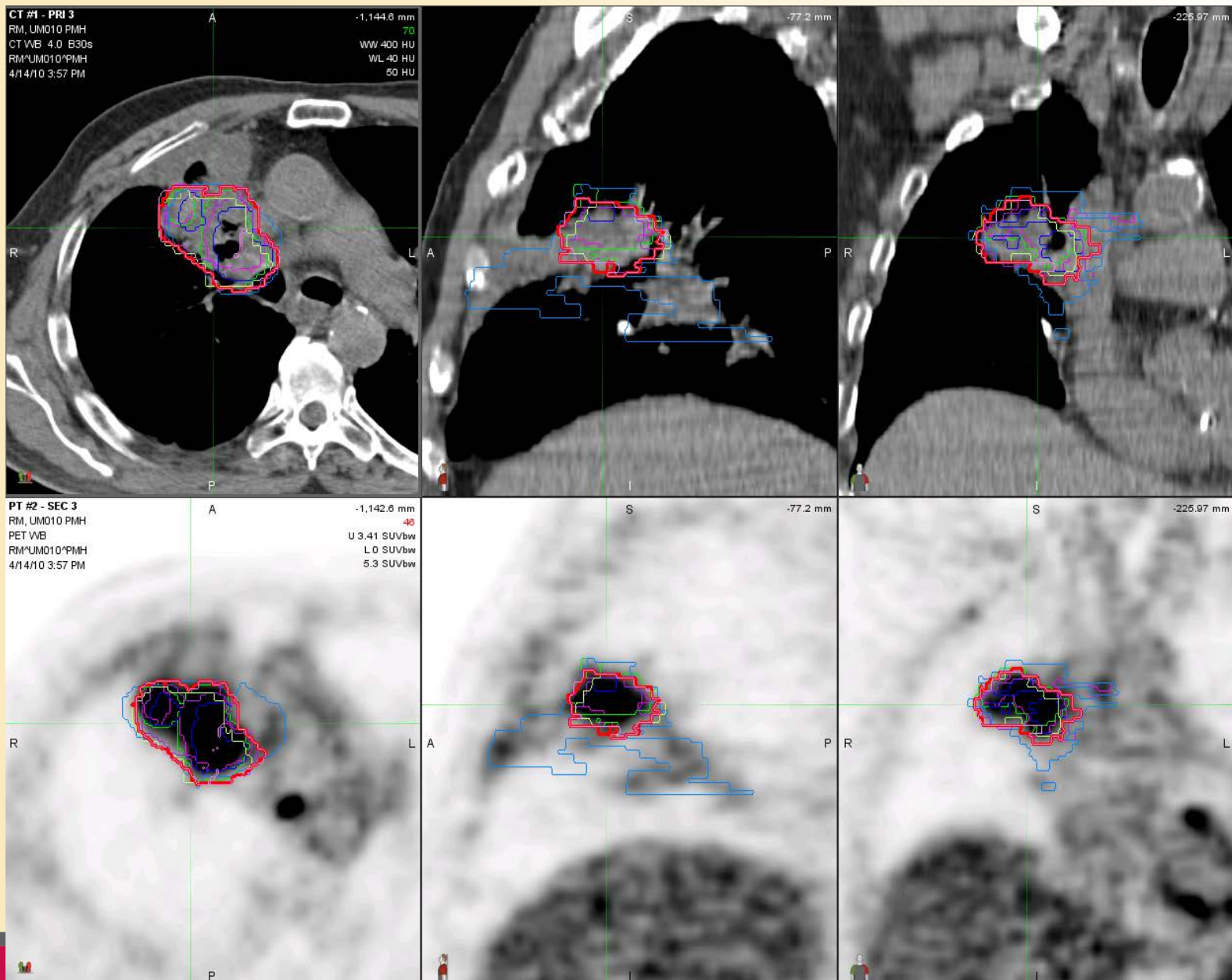
PET2MTV on During-treatment PET-CT: Example Case #2

PET2MTV should be generated
without consideration of CT2GTV.

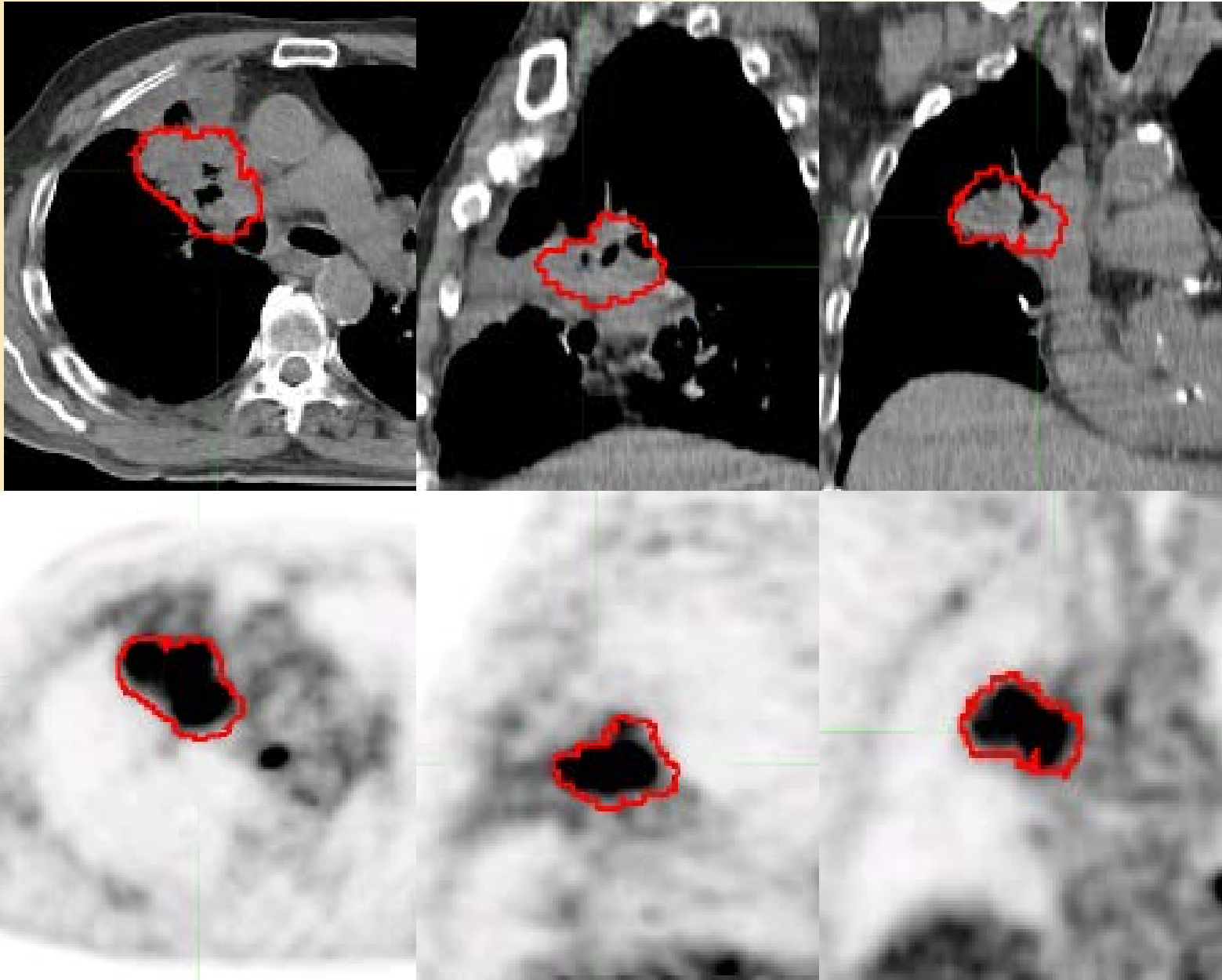
PET2MTV shown in red is the
composite of PET2MTVTs and
PET2MTVNs.

PET1MTV on Pre-treatment PET-CT, case 2

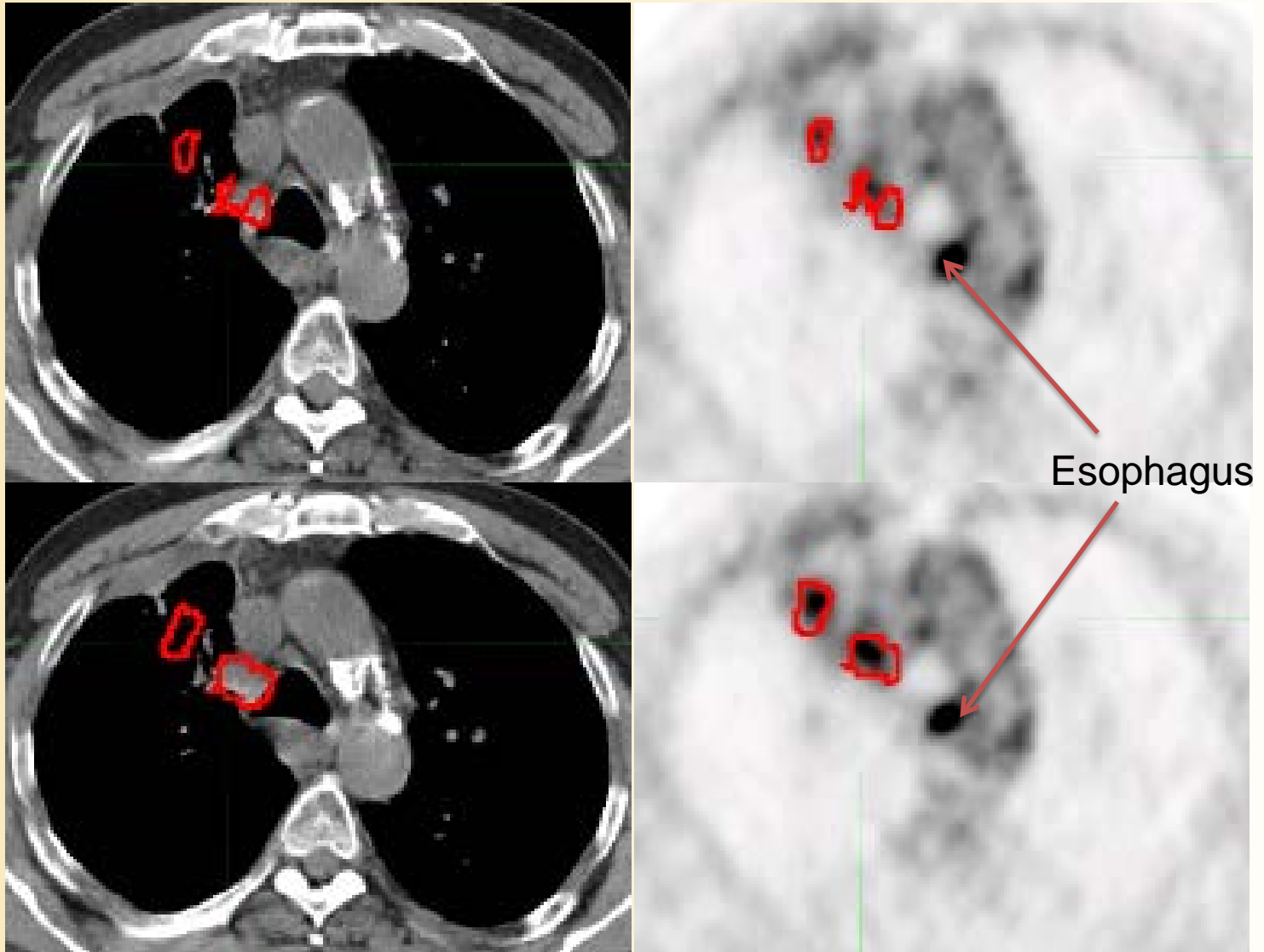
Variations (thin lines) and consensus (red thick lines)



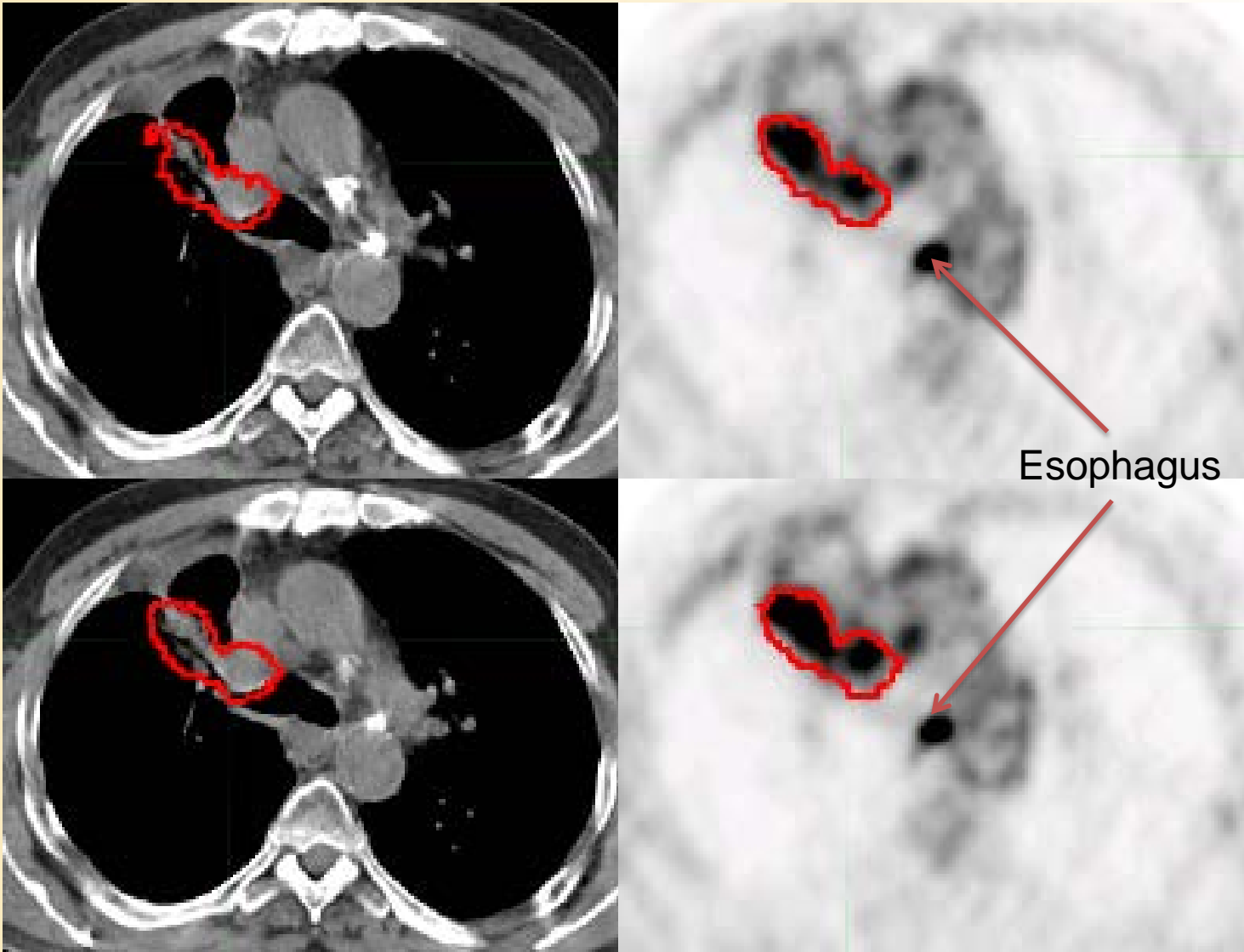
PET2MTV on During-treatment PET-CT, case 2



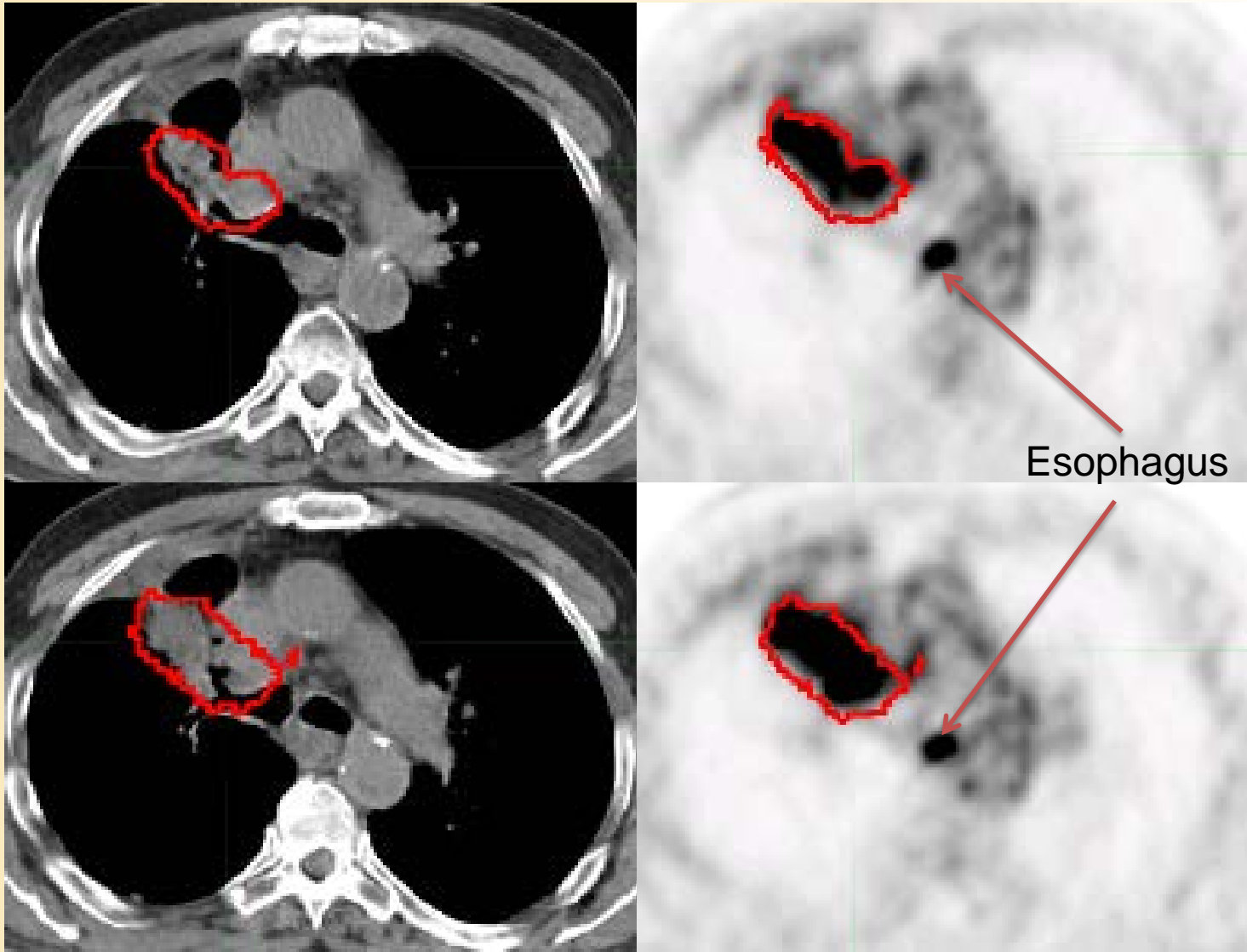
PET2MTV on During-treatment PET-CT, case 2



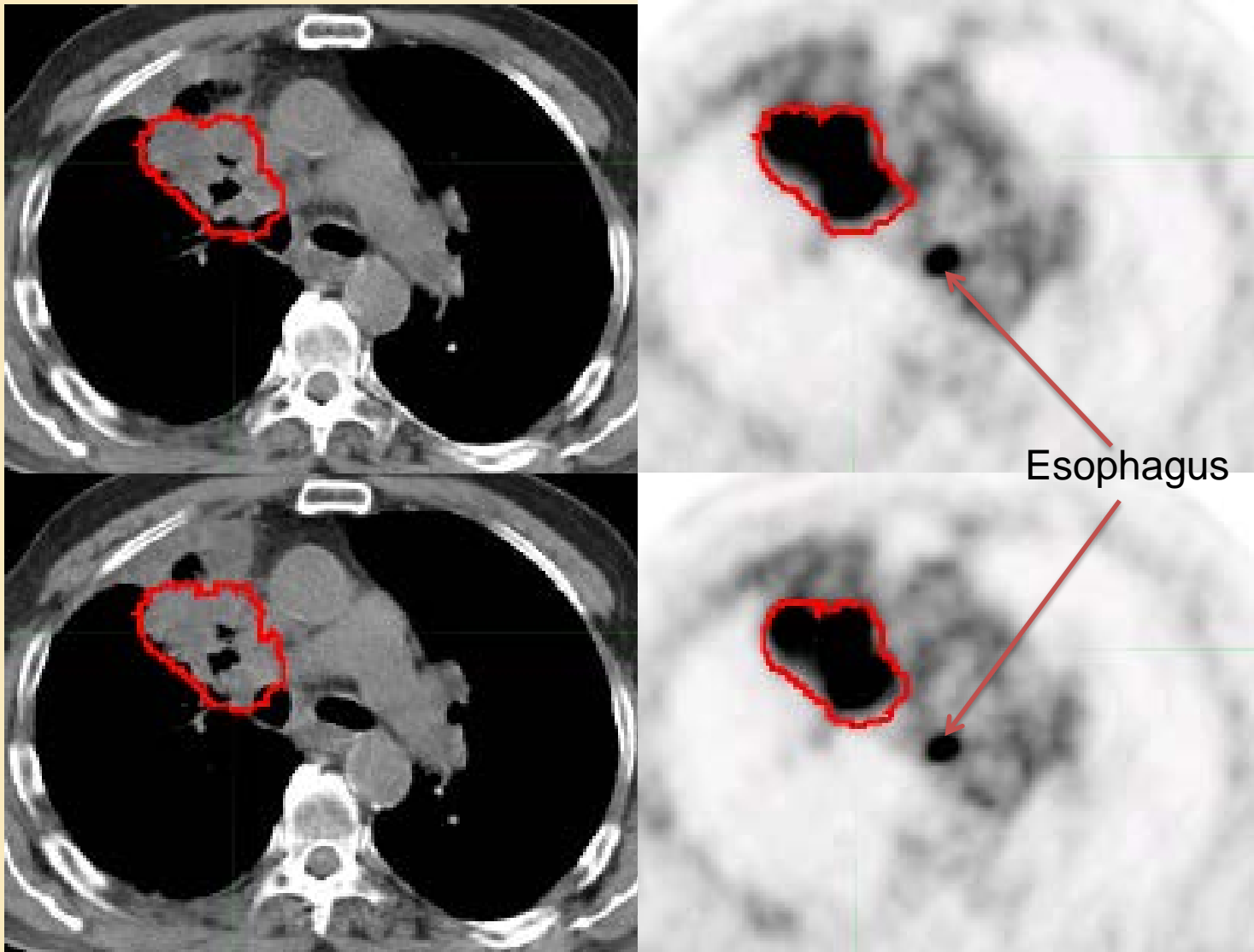
PET2MTV on During-treatment PET-CT, case 2



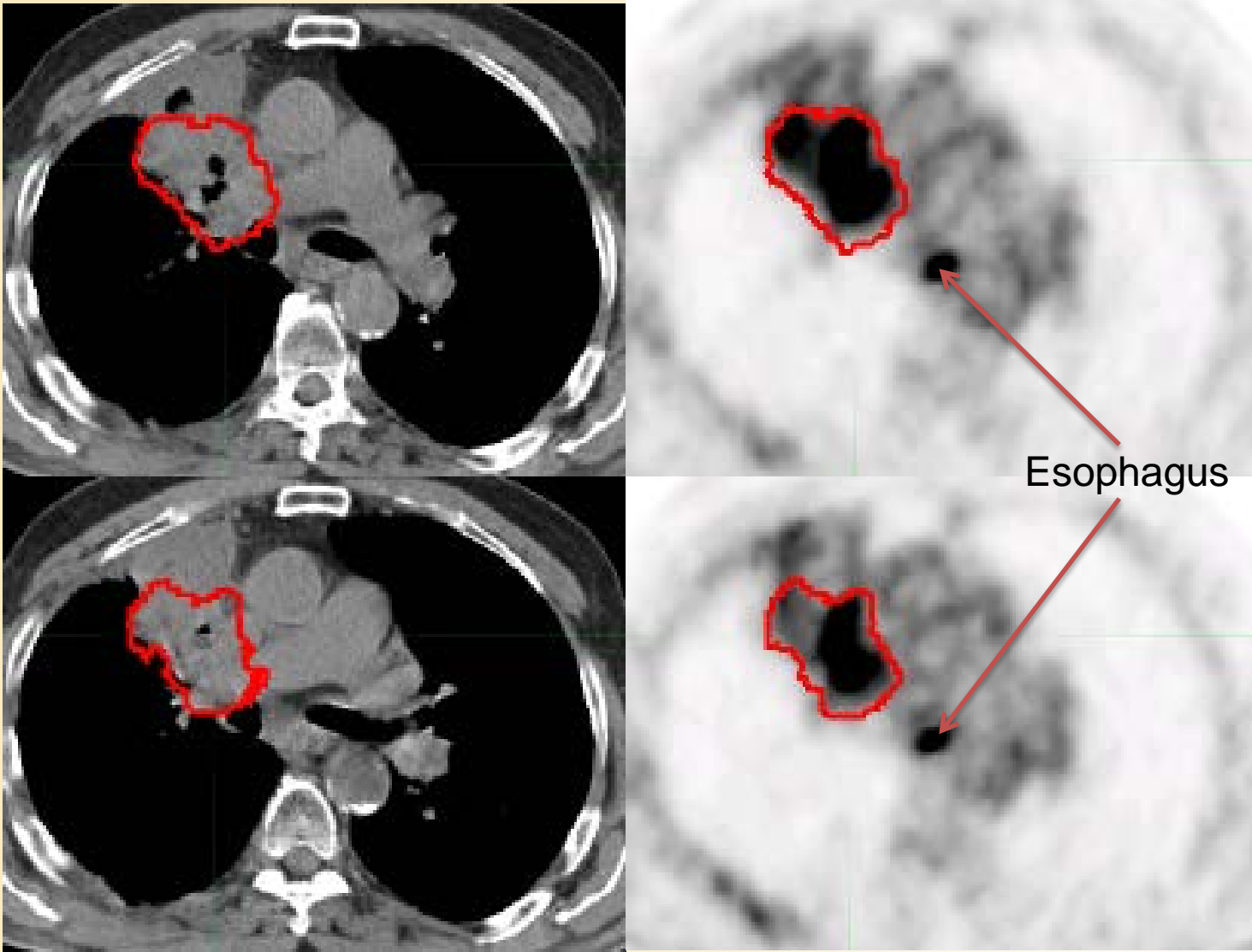
PET2MTV on During-treatment PET-CT, case 2



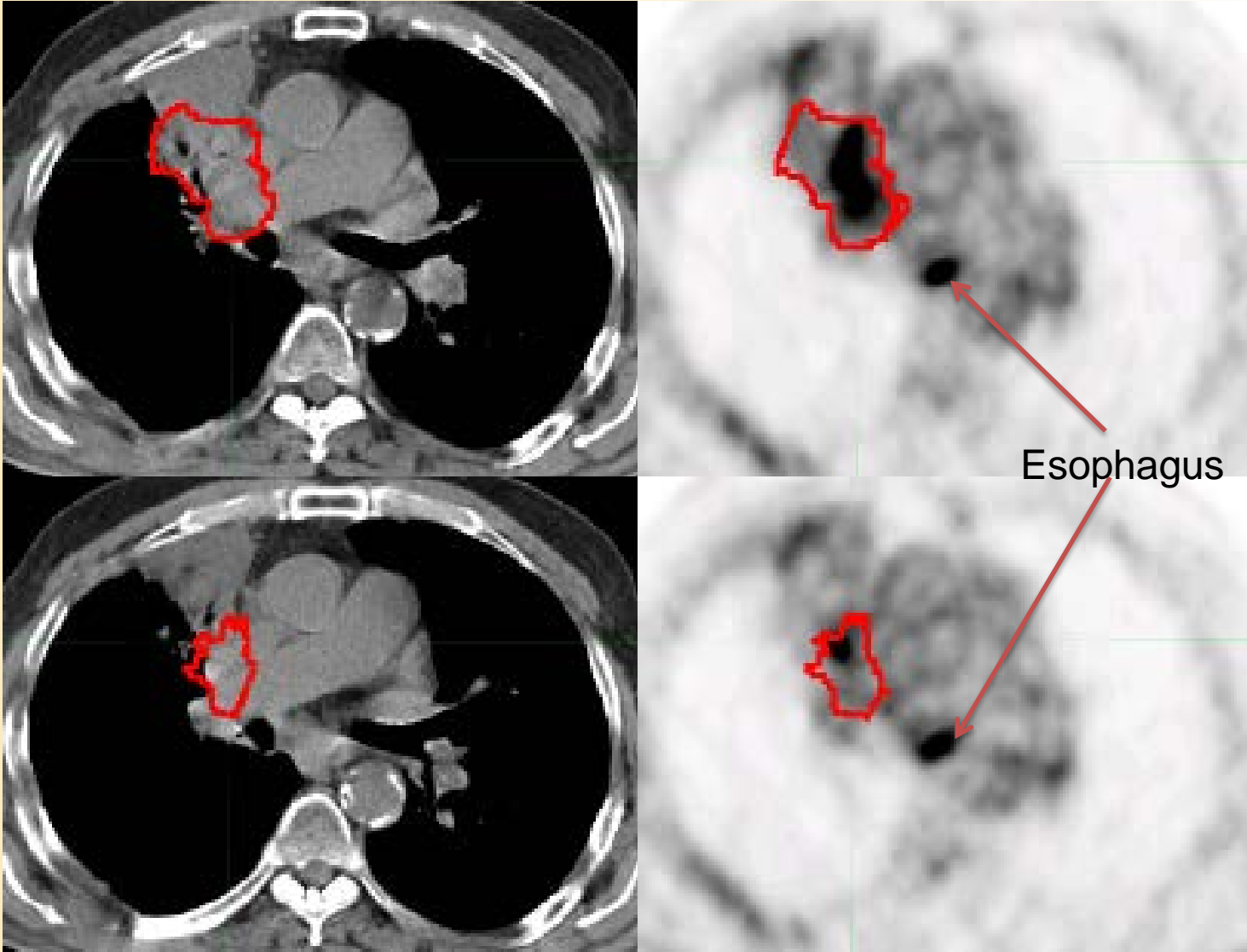
PET2MTV on During-treatment PET-CT, case 2



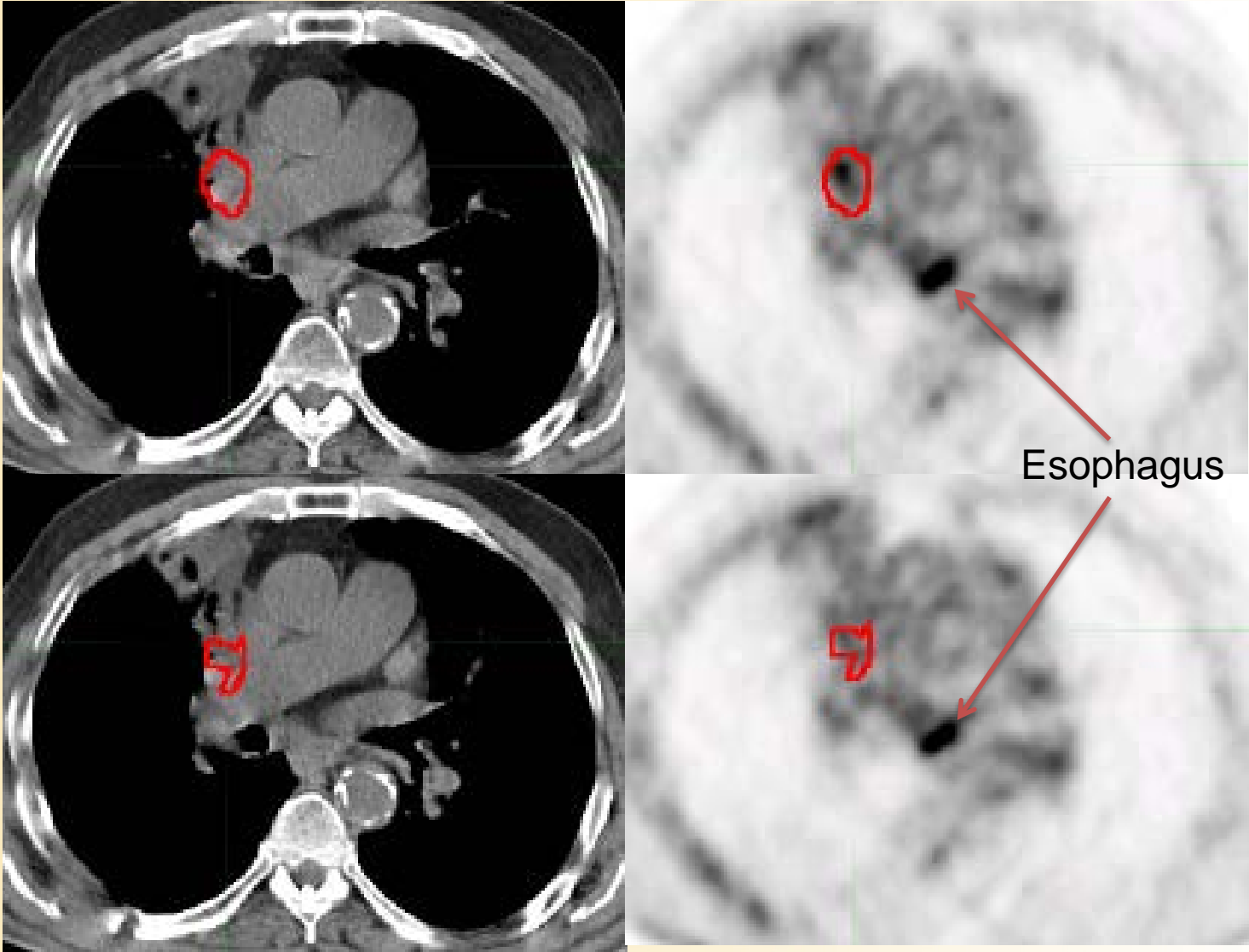
PET2MTV on During-treatment PET-CT, case 2



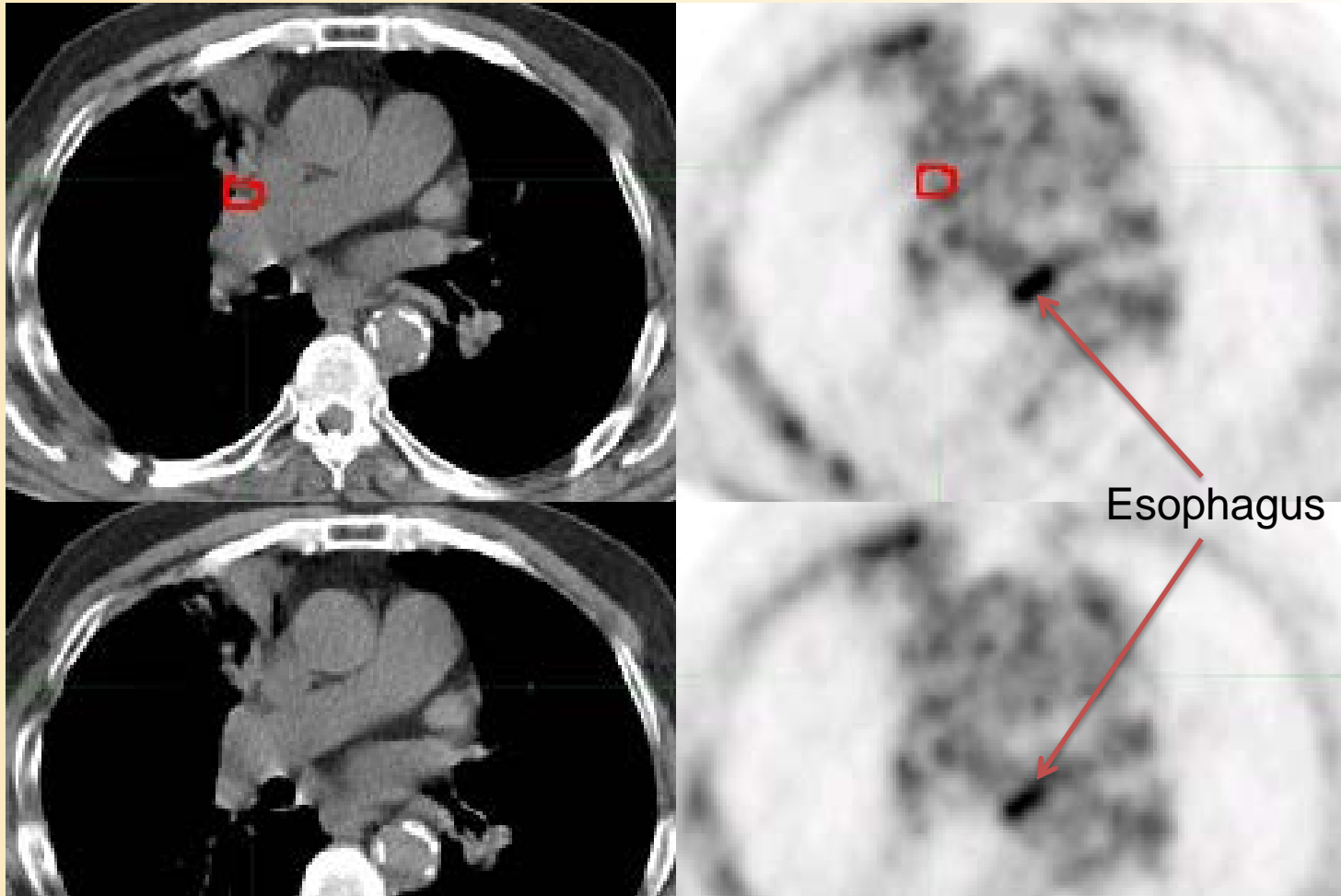
PET2MTV on During-treatment PET-CT, case 2



PET2MTV on During-treatment PET-CT, case 2



PET2MTV on During-treatment PET-CT, case 2



Esophagus is located next to tumor, and often active on during-treatment scan. Special attention should be paid to avoid inclusion of esophagus in MTV.

PET Target Working Group

- University of Michigan:
 - Feng-Ming (Spring) Kong, MD, PhD
- Case Western University Hospital:
 - Mitchell Machtay MD
- Thomas Jefferson University Hospital:
 - Maria Werner-Wasik MD
- Princess Margaret Hospital:
 - Alexander Sun MD
- Taussig Cancer Center/Cleveland Clinic:
 - Gregory Videtic MD
- Washington University at St Louis:
 - Jeffrey Bradley MD

Members Participated 1st Case

- University of Michigan/AAVA: Feng-Ming Kong MD PhD, Cassandra Brooks CMD, Tim Ritter PhD
- Case Western University Hospital: Mitchell Machtay MD, Jason Sohn PhD
- Thomas Jefferson Hospital: Maria Werner-Wasik MD, Ying Xiao PhD, Joyce Keil RTT, Nitin Ohri MD
- Cleveland Clinic: Gregory Videtic MD, Nicole Vassil CMD, Diana Mattson, CMD
- Stanford University: Billy Loo MD, Peter Maxim PhD
- Medical College of Wisconsin: Elizabeth Gore MD, An Tai PhD, Dan Grimm MS
- Penn State Hershey Cancer Center: John Varlotto MD, Jamie Knipple CMD
- McGill Hospital: Sergio Faria, MD, Emily Moon PhD
- Moffitt Cancer Center: Thomas Dilling MD, Mark Russell CMD, MaryLou DeMarco CMD
- Princess Margaret Hospital: Alexander Sun MD, Jane Higgins CMD
- University of Texas Medical Branch: Todd Swanson MD, E.J. Endres CMD
- Peking Union Medical College: Luhua Wang MD, Bo Chen MD
- MD Anderson Cancer Center: Ritsuko Komaki MD, Steph Bilton CMD
- Washington University at St Louis: Jeffrey Bradley MD, Lindsey Appenzoller, MS

Members Participated 2nd Case

- University of Michigan: Feng-Ming Kong MD PhD, Daniel Tatro CMD, Martha Matuszak PhD
- Case Western University Hospital: Mitchell Machtay MD, Jason Sohn PhD
- Thomas Jefferson University Hospital: Maria Werner-Wasik MD, Ying Xiao PhD, Joyce Keil RTT
- Cleveland Clinic: Gregory Videtic MD, Diana Mattson, CMD
- Stanford University: Billy Loo MD, Peter Maxim PhD
- Medical College of Wisconsin: Elizabeth Gore MD, An Tai PhD, Dan Grimm MS
- Penn State Hershey Cancer Center: John Varlotto MD, Jamie Knipple CMD
- McGill Hospital: Sergio Faria, MD, Emily Moon PhD
- Moffitt Cancer Center: Thomas Dilling MD, Mark Russell CMD, MaryLou DeMarco CMD
- Princess Margaret Hospital: Alexander Sun MD, Jane Higgins CMD
- MD Anderson Cancer Center: Ritsuko Komaki MD, Steph Bilton CMD
- Washington University at St Louis: Jeffrey Bradley MD, Lindsey Appenzoller, MS

Third Case Dry-Run Team

- Case, Imaging and Instructions: Feng-Ming (Spring) Kong MD, PhD, Martha Matuszak PhD, Timothy Ritter PhD, Jennifer Presley CMD, Randall Ten Haken PhD, James Galvin D.Sc
- Website Instructions: Walter Bosch D.Sc
- Consensus Generation: Ying Xiao PhD, Wenzhou Chen PhD
- Data Collection: Paul Stanton BS, Elizabeth O'Meara MS, Feng-Ming (Spring) Kong
- Coordination: Elizabeth O'Meara, Jennifer Presley

Members Invited for 3rd Case

- University of Michigan: Feng-Ming Kong MD PhD, Martha Matuszak PhD
- Case Western University Hospital: Mitchell Machtay MD, Jason Sohn PhD
- Thomas Jefferson University Hospital: Maria Werner-Wasik MD, Ying Xiao PhD, Joyce Keil RTT
- Cleveland Clinic: Gregory Videtic MD, Diana Mattson, CMD
- Stanford University: Billy Loo MD, Peter Maxim PhD
- Medical College of Wisconsin: Elizabeth Gore MD, An Tai PhD, Dan Grimm MS
- Penn State Hershey Cancer Center: John Varlotto MD, Jamie Knipple CMD
- McGill Hospital: Sergio Faria, MD, Emily Moon PhD
- Moffitt Cancer Center: Thomas Dilling MD, Mark Russell CMD, MaryLou DeMarco CMD
- Princess Margaret Hospital: Alexander Sun MD, Jane Higgins CMD
- MD Anderson Cancer Center: Ritsuko Komaki MD, Steph Bilton CMD
- Washington University at St Louis: Jeffrey Bradley MD, Lindsey Appenzoller, MS