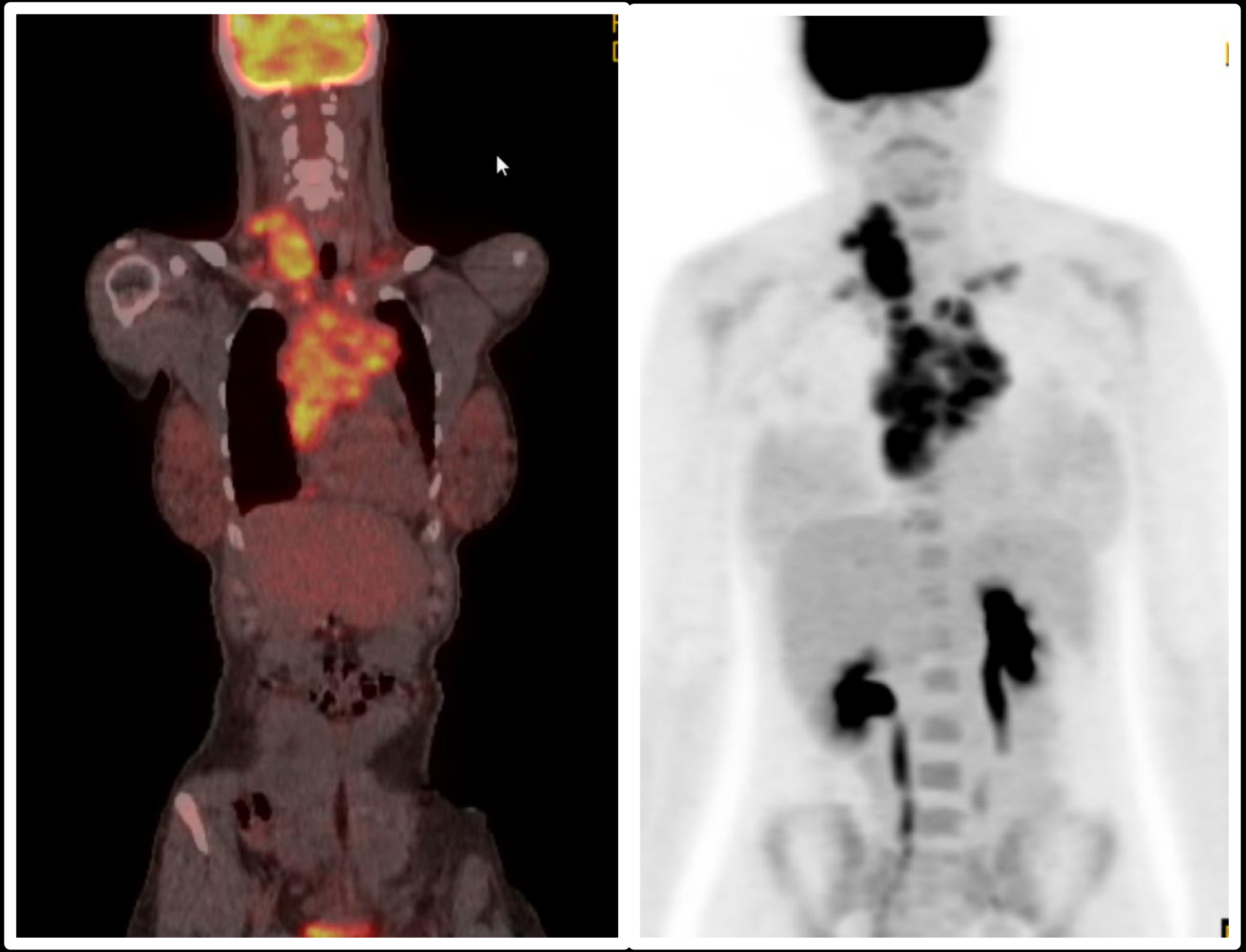
ILROG Lymphoma Mini-Atlas Part II, Hodgkin Lymphoma

Table of Contents

ILROG Mini-Atlas: Mediastinal Location- Planning with Breath Hold

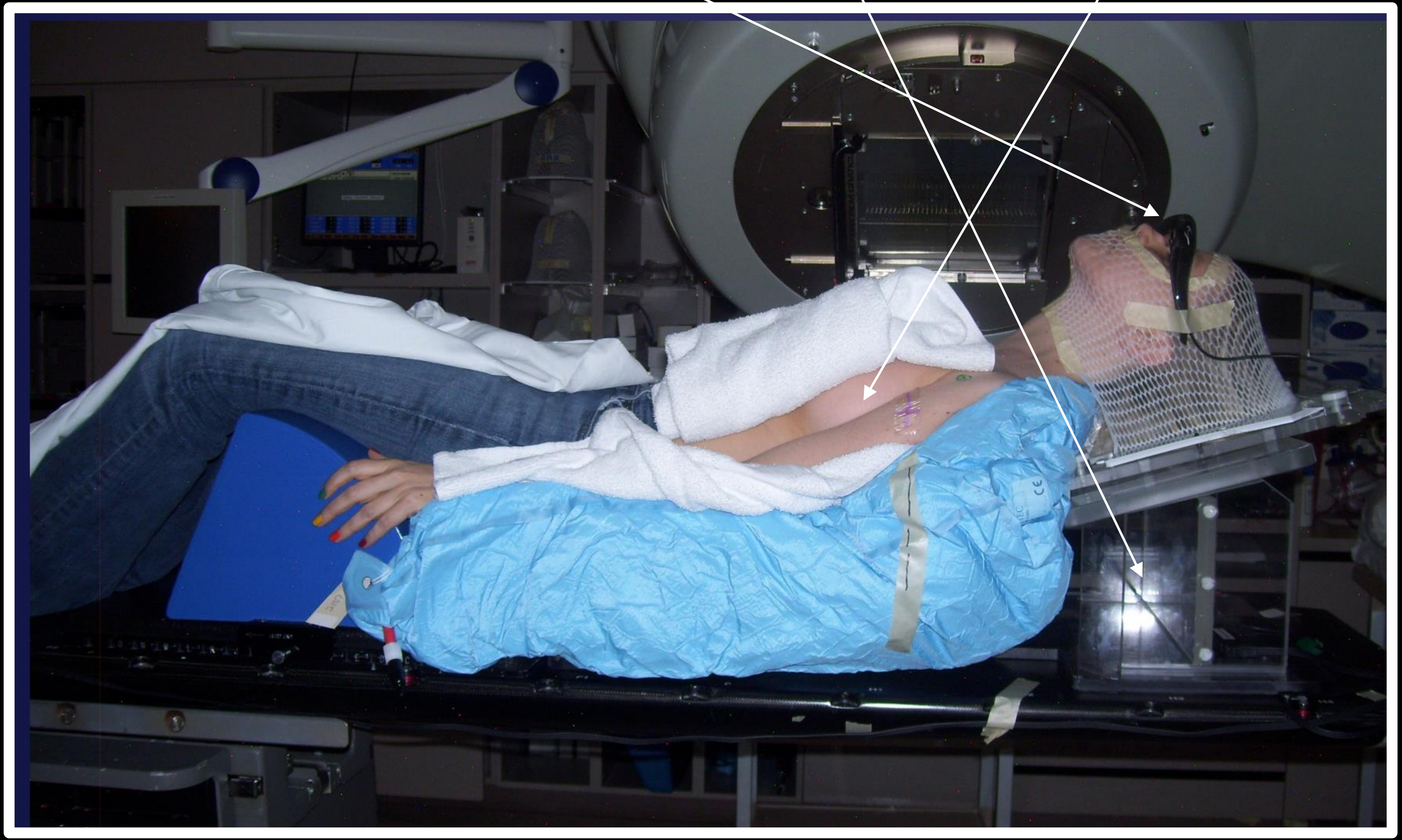
28-year-old female, presenting with a right neck mass and shortness of breath, neck biopsy confirmed the diagnosis of Hodgkin Lymphoma. PET/CT below showing the disease involving the bilateral necks, and mediastinum. The case was best classified as early unfavorable per GHSG 11 [7]. The Patient , as per GHSG received 4 cycles of ABVD, achieving complete remission by PET/CT then presented for consolidation radiation therapy with ISRT[4] to 3060cGy.



Presenting PET/CT showing the disease location

7:Eich et al; JCO vol 28 N 27 sep 20 2010
4:Specht et al. IJROBP. 2014 Jul 15;89(4):854-62

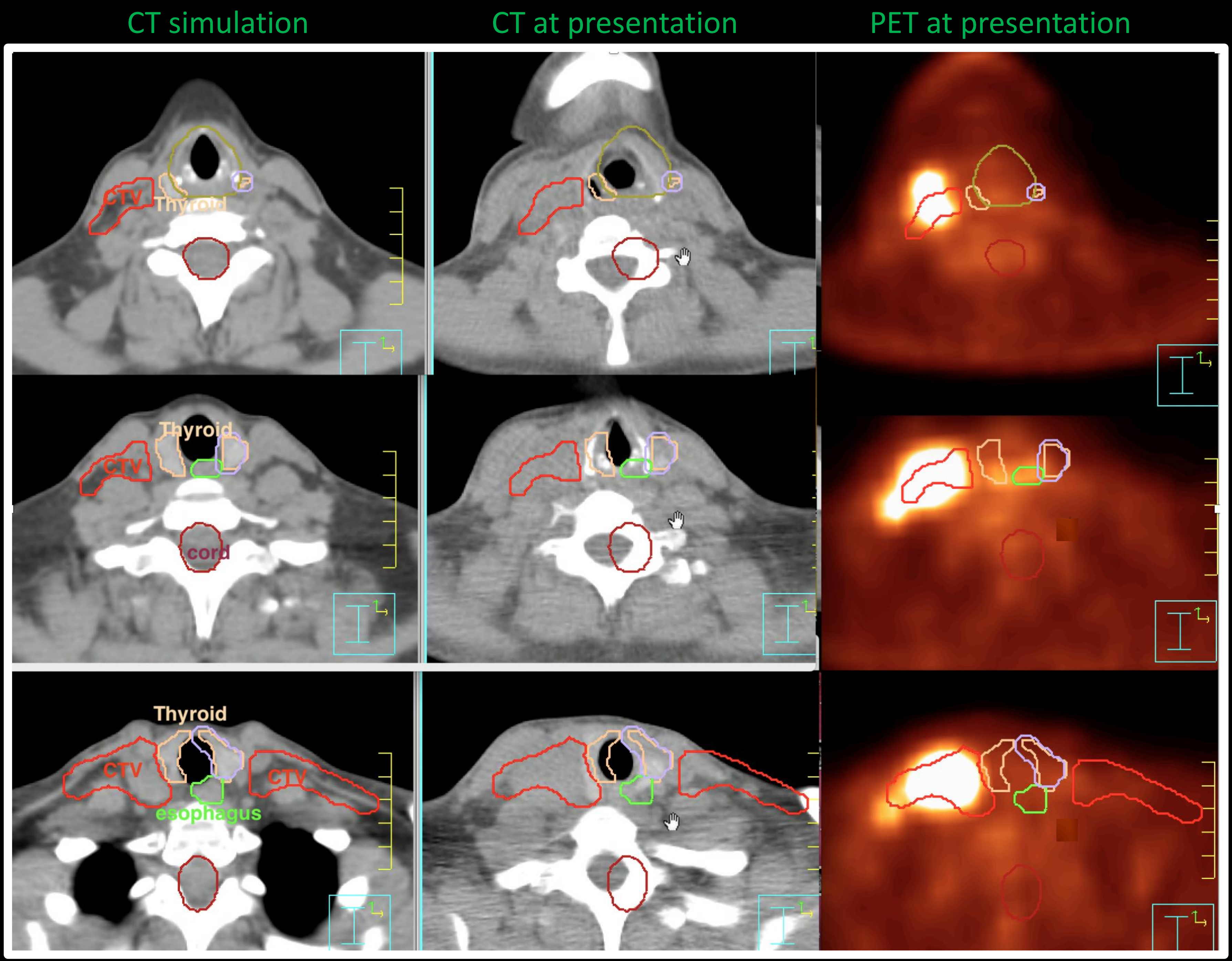
Simulation was done in a supine position, using an inclined board to avoid the breasts[6], with arms down to avoid pulling the breasts up into the radiation field. Deep inspiration breath hold [4] was used to minimize the irradiated lung volume, and displace the heart Inferiorly and away from the mediastinal target, the latter (i.e. mediastinum) becomes slim (decreasing the target volume compared to the lungs). Reproducibility of the daily breath should follow institutional guidelines.



The reproducibility of the breath hold in this case was confirmed with daily CT on board imaging

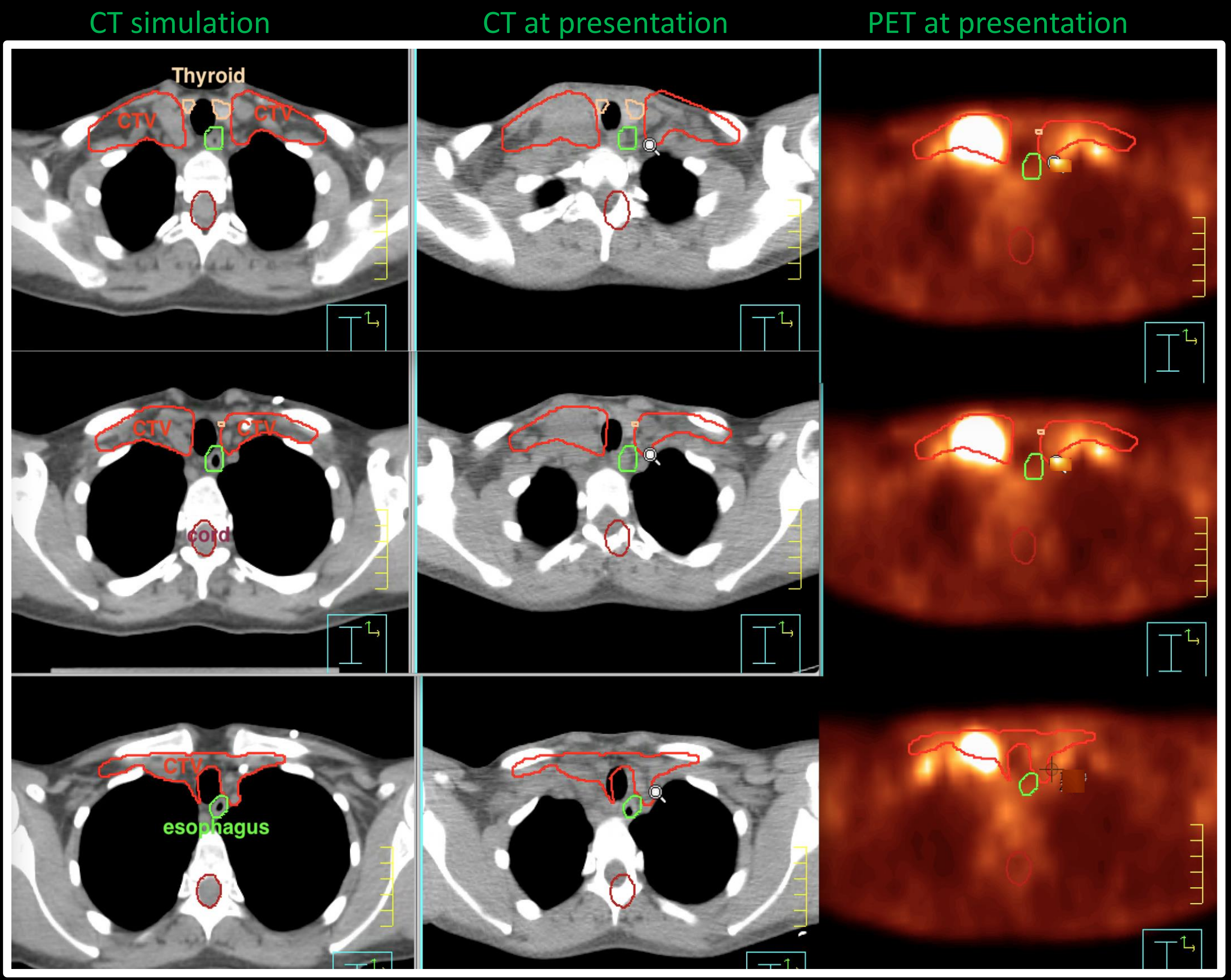
6-Dabaja et al; IROBP. 2011 Feb 1;79(2):503-7
4-Petersen et al: Acta Oncol. 2015 Jan;54(1):60-6

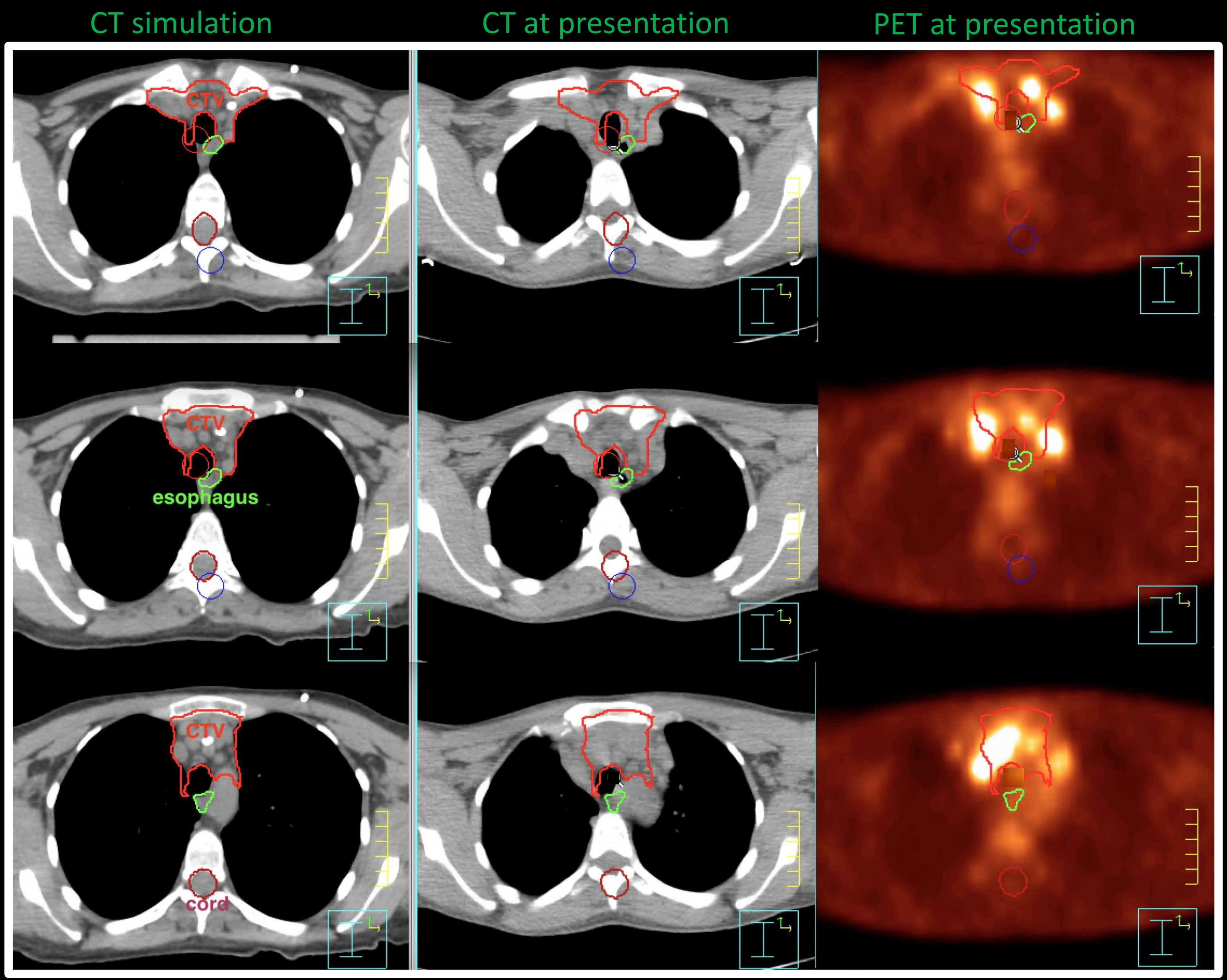
Axial images demonstrating contours of the CTV (red) that encompass the prechemotherapy extent of the disease. Appropriate modifications should be made to exclude normal anatomy after regression of lymphadenopathy post-chemotherapy.
(CT simulation (left), diagnostic CT with contrast (middle), PET/CT (right)



Please note that the use of fusions might not be accurate due to the fact that CT simulations and diagnostic CTs are quite often performed in different positions.

Axial images demonstrating contours of the CTV (red) that encompass the prechemotherapy extent of the disease. Appropriate modifications should be made to exclude normal anatomy after regression of lymphadenopathy post-chemotherapy.
(CT simulation (left), diagnostic CT with contrast (middle), PET/CT (right)





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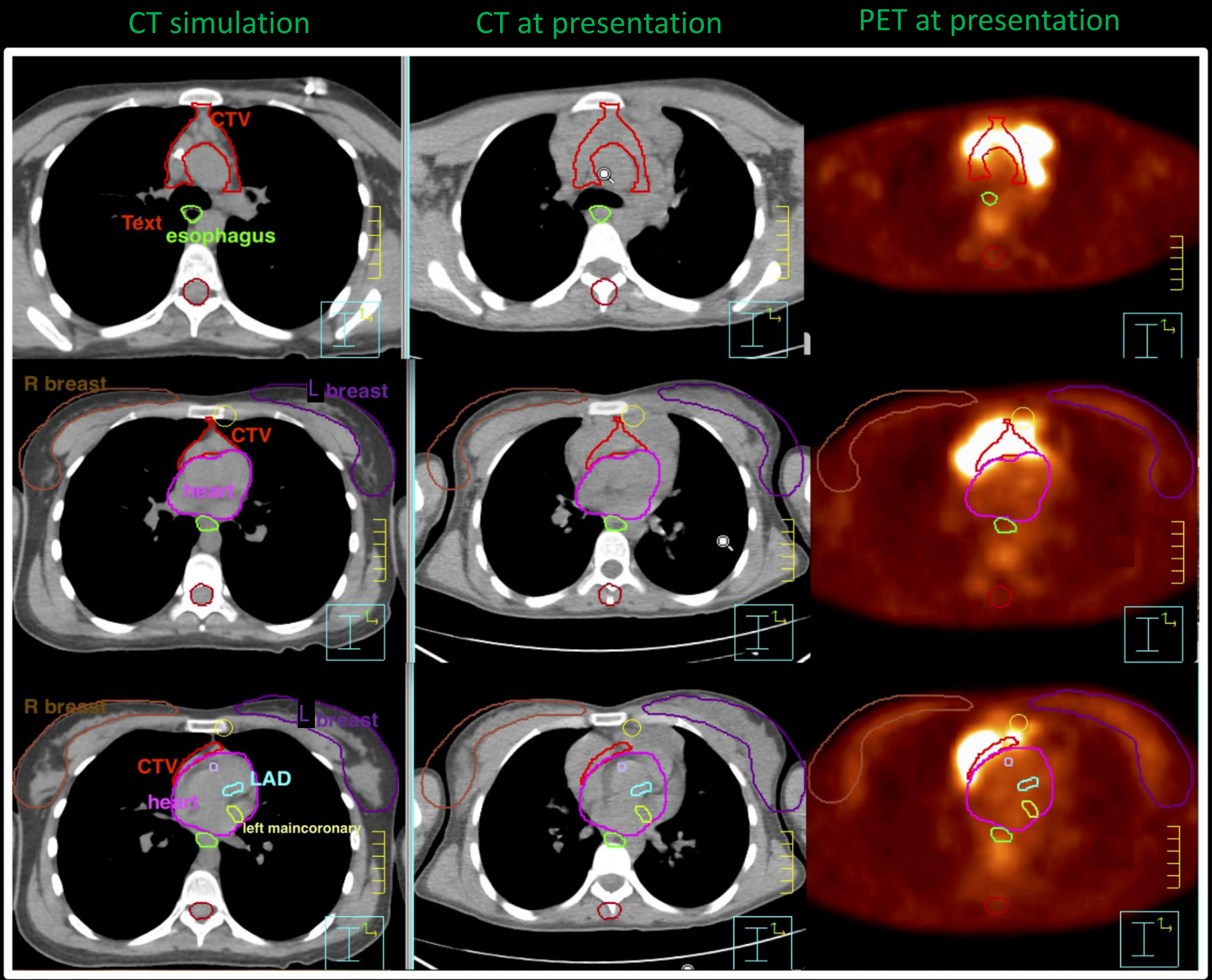
Axial images demonstrating contours of the CTV (red) that encompass the prechemotherapy extent of the disease. Appropriate modifications should be made to exclude normal anatomy after regression of lymphadenopathy post-chemotherapy.
(CT simulation (left), diagnostic CT with contrast (middle), PET/CT (right)

Note here that the heart substructures including, left ventricle, left coronary artery (LAD), and right coronary artery (RCA), are contoured as per the published heart atlas referenced below.

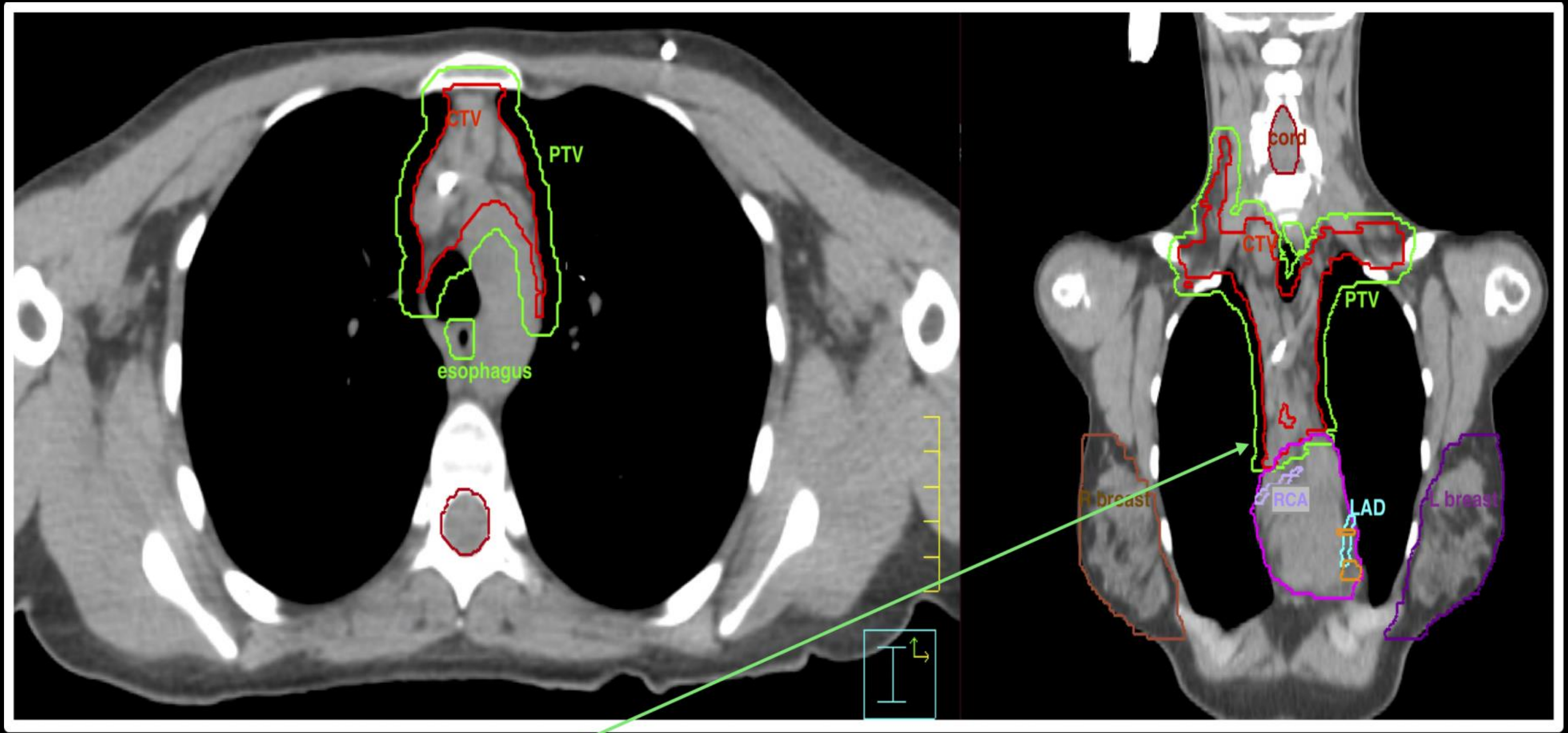
(CT simulation (left), diagnostic CT with contrast (middle), PET/CT (right)



8: Feng et al; IJROBP 2011 Jan 1;79(1):10-8

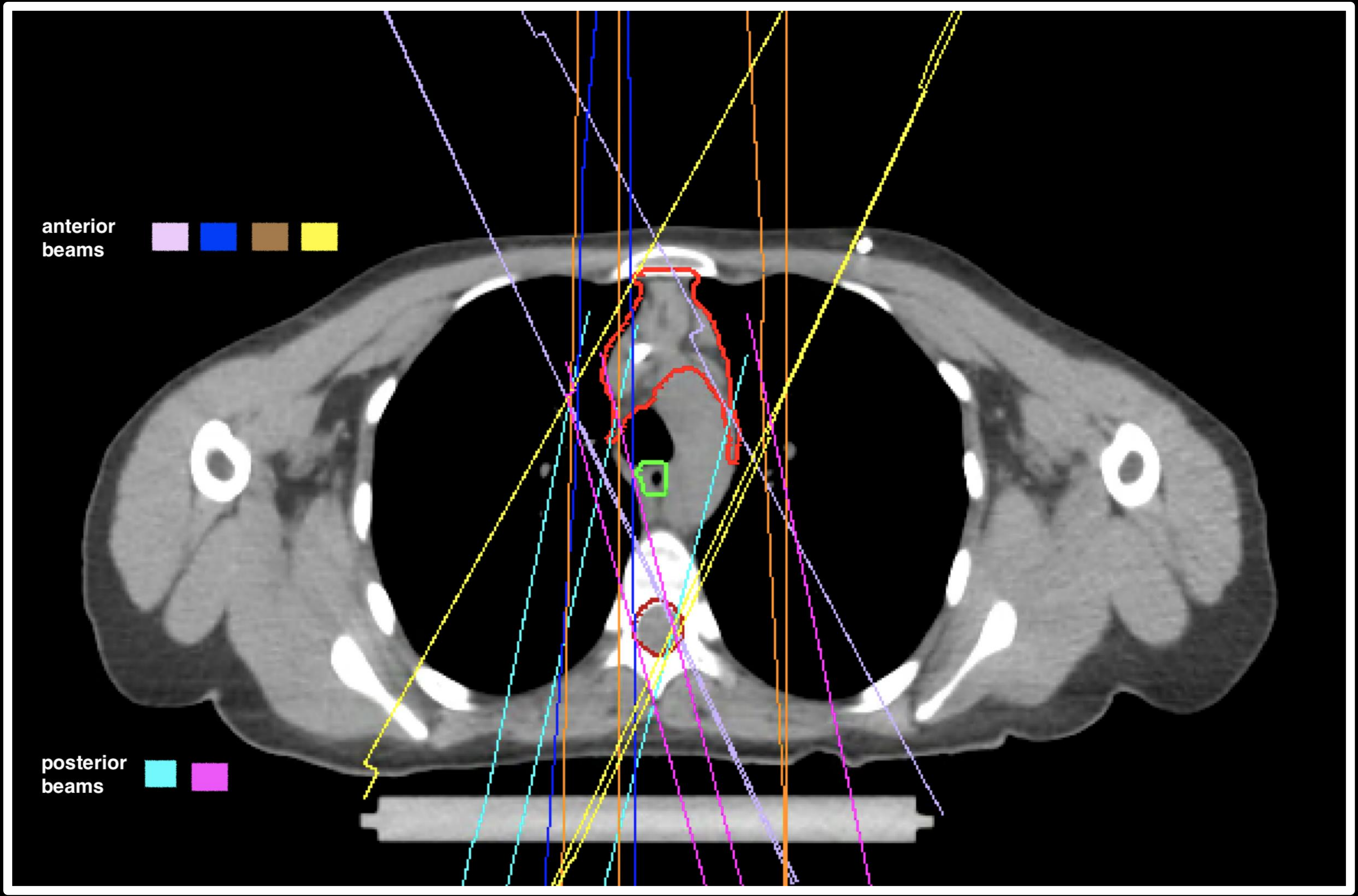
Axial image (left) and coronal (right) showing CTV (red) and PTV (green),
PTV margin was created by adding only 5 mm since DIBH was used.

PET/CT at diagnosis



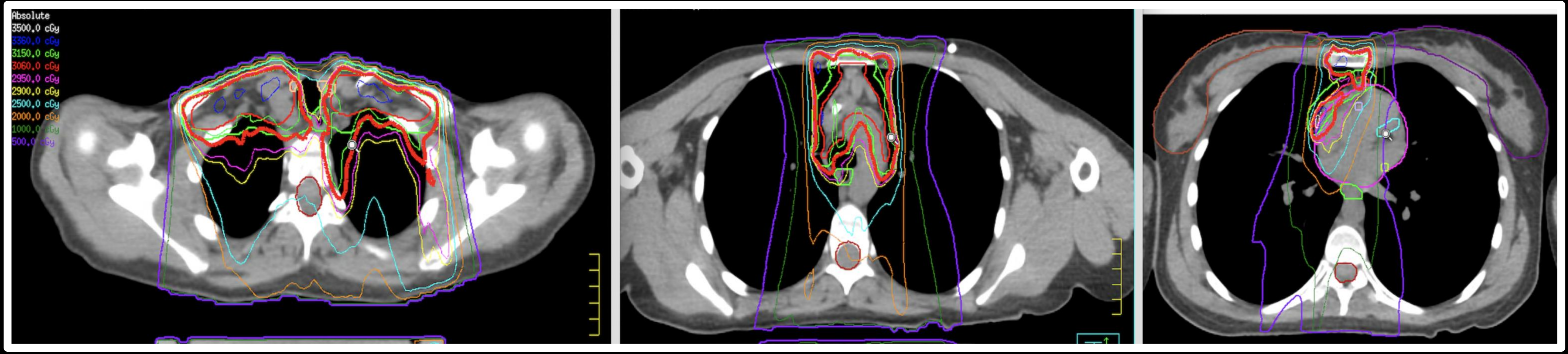
Note that the inferior extent of the CTV compared to the initial baseline PET/CT scan appear to expand shorter , this is owing to the fact that the original mass weighs down and looks lower than what it actually is, additionally the original PET /CT scan is done with free breathing which brings that area closer to the diaphragm.

Only antero-posterior beams' orientation are used to plan using the butterfly[2] IMRT technique. The benefit of this technique will be to avoid the low dose bath to the lungs.



2-Voong et al. Radiation Oncology 2014, 9:94

Isodose lines showing the dose in axial images (top) and coronal images (bottom), the dose is curved off the left and right breast, heart substructures including coronaries, while the 500 cGy line is off most of the lungs.



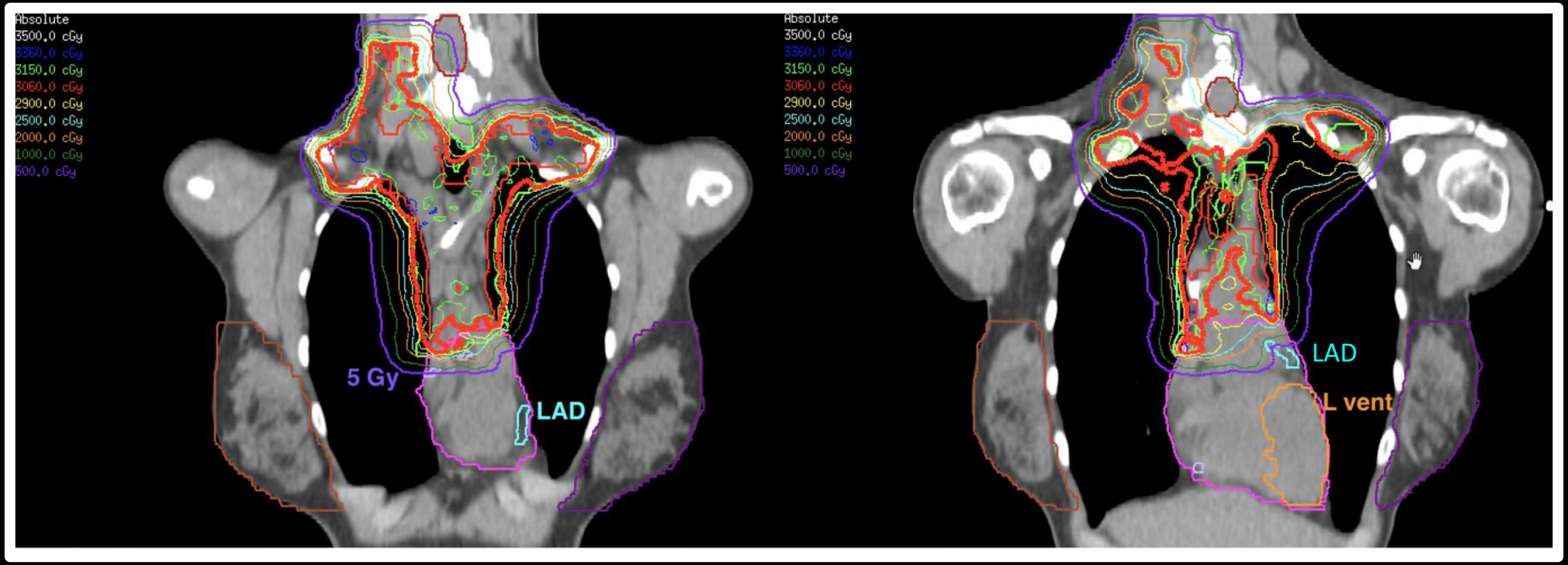


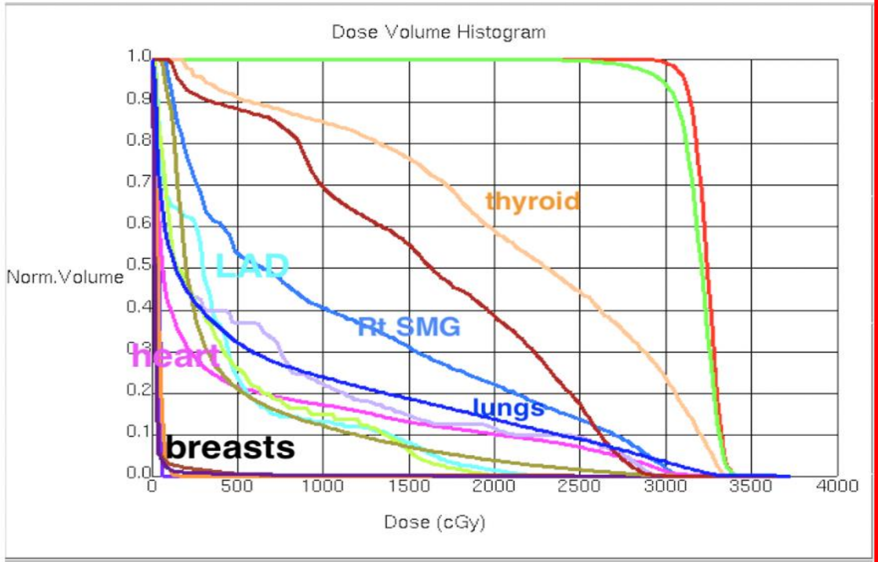
Table guide to acceptable dose, volume, and field considerations[6]

Structures	Ideal	Optimize technique	Optimize field (consider field reduction)	Unacceptable	Avoid maximum dose landing in
Heart: left ventricle, coronary arteries, valves[39-41]	Mean < 5 Gy	Mean, 5-15 Gy	Mean > 15 Gy	Mean > 30 Gy	Coronary vessels
Breast (age dependent)*	Mean < 4 Gy	Mean, 4-15 Gy	Mean > 15 Gy	Mean > 30 Gy	Glandular tissue
Lung[38]	$V_5 < 55\%$	V_5, 55-60%	—	$V_5 > 60\%$	
	$V_{20} < 30\%$	Mean, 10-13.5 Gy		Mean > 13.5 Gy	
	Mean < 10 Gy				
Thyroid[62]	$V_{25} < 62.5\%$	$V_{25} < 62.5\%$			Whole thyroid

6: Dabaja et al; Blood. 2018;132(16)6:1635-46.

Dose Volume Histogram showing how the plan generated respected the dose tolerance to critical organs:
Mean dose < 500 cGy for the heart, left and right breasts, and LAD coronary.
The mean dose to lungs and right coronary < 700 cGy.
The mean dose to both breasts < 400 cGy.

The mean dose to breasts (< 400 cGy), heart < 500 cGy), and lungs (mean < 13.5, V5 < 55%) is based on previously published data. [1,9,10,11]
These values might not be always attainable, but efforts should be made to attain these values as guided by the table in the previous slide.



ROI Statistics

Line Type	ROI	Trial or Record	Min.	Max.	Mean	Std. Dev.
	CTV_3060	BH Mediastinum SAN	2373.8	3603.7	3235.1	76.4
	PTV_3060	BH Mediastinum SAN	1450.0	3606.1	3185.6	133.6
	Glnd_Submand_R	BH Mediastinum SAN	71.0	3113.4	1048.6	963.0
	Glnd_Submand_L	BH Mediastinum SAN	28.0	56.5	39.7	5.3
	Thyroid	BH Mediastinum SAN	156.2	3364.8	2135.2	931.4
	Heart	BH Mediastinum SAN	8.2	3453.0	465.9	828.8
	A_LAD	BH Mediastinum SAN	28.8	2320.4	429.3	497.2
	A_Coronary_R	BH Mediastinum SAN	16.5	2979.0	618.1	851.6
	Ventricle_L	BH Mediastinum SAN	12.2	164.0	38.5	19.5
	Lt Circumflex	BH Mediastinum SAN	21.9	2042.3	400.6	495.5
	Breast_R	BH Mediastinum SAN	--	2457.0	28.4	78.2
	Breast_L	BH Mediastinum SAN	--	1649.5	24.0	62.2
	Larynx	BH Mediastinum SAN	43.1	3051.9	425.0	547.6
	Spinal Cord	BH Mediastinum SAN	83.5	2997.2	1586.7	814.3
	Lungs	BH Mediastinum SAN	7.6	3641.9	647.1	930.5

1-Pinnix et al; IJROBP . 2015 May 1;92(1):175-82
9-Mulrooney; BMJ. 2009 Dec 8;339:b4606
10-Travis JAMA. 2003 Jul 23;290(4):465-75.
11. J Cardiovasc Imaging. 2019 Oct;27(4):268-279.

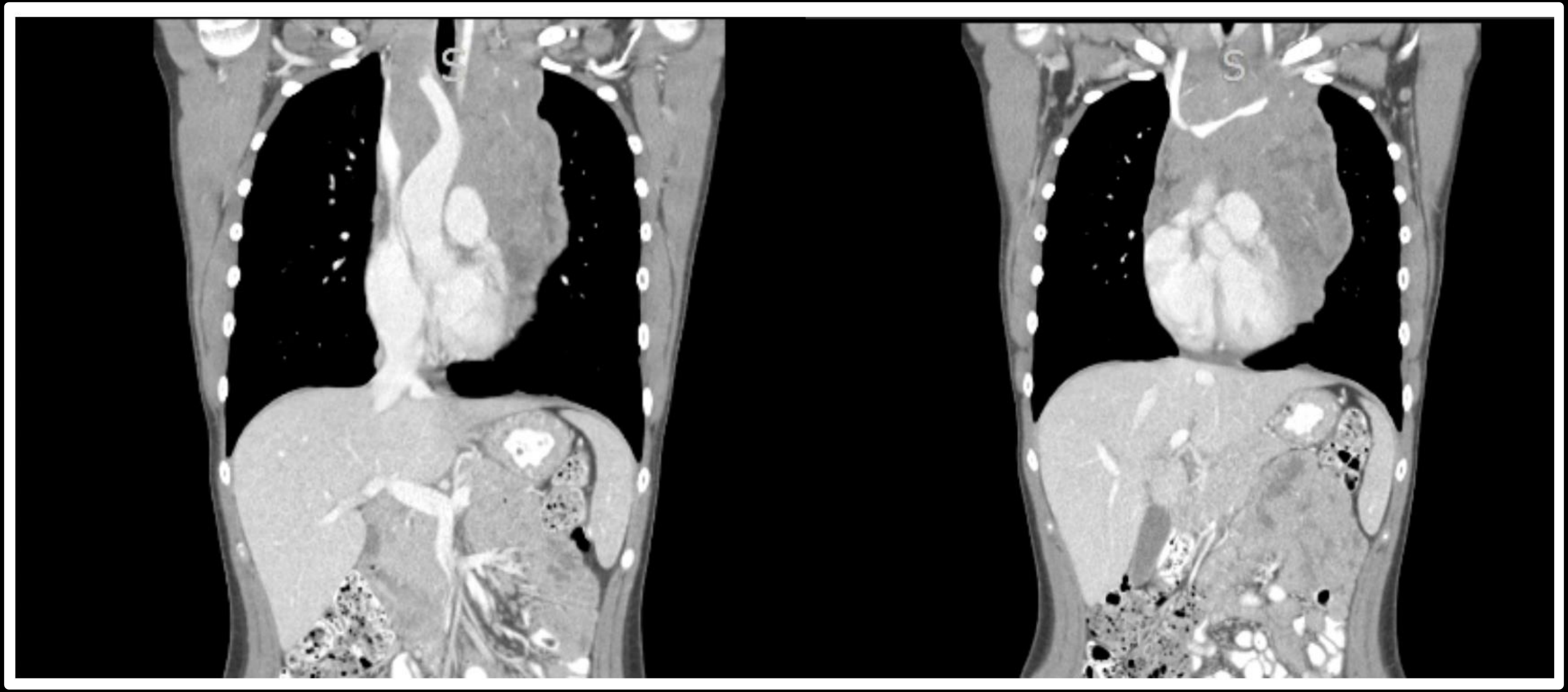
Take home message:
When treating mediastinal locations and to best avoid excess dose to the organs at risks, namely heart and its substructures, breasts in females, and lungs, the following techniques can achieve that goal:

1-Contouring the critical organs including the heart substructures (left ventricle, and coronaries)
2-IMRT using only antero-posterior beams, like the butterfly technique.
3-Breath hold to move the heart downward, to increase the lungs volume, and to slim the mediastinum.
4-Inclined board to move the breasts down, outward, and away from the mediastinum.
5-Consider proton therapy [6]

6: Dabaja et al; Blood. 2018;132(16)6:1635-46.

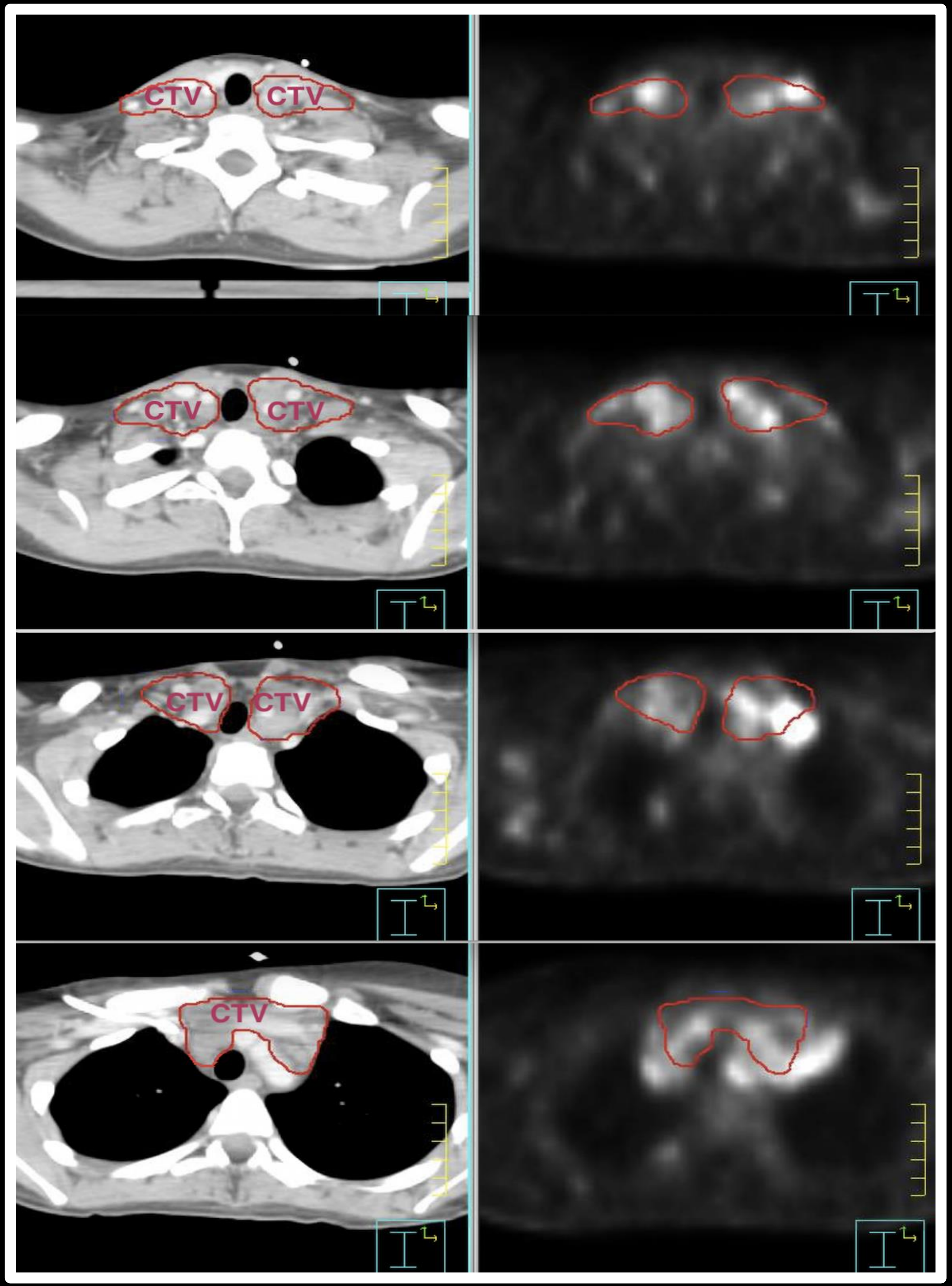
ILROG Mini-Atlas: Mediastinal Location Planning when Breath Hold is not available

This is an 18-year-old female who presented with a stage IIBX (bulky) mediastinal Hodgkin's lymphoma with involvement of the bilateral supraclavicular regions. The patient received 4 cycles of ABVE-PC, complete metabolic response was documented on the end of therapy PET scan. She presented for consolidative ISRT to a dose of 2100cGy as per Children's Oncology Group (COG) protocol).



Coronal images at presentation showing the disease location

Axial images demonstrating contours of the CTV (red) that encompasses the prechemotherapy extent of the disease, appropriate modifications are made to exclude normal anatomy after regression of lymphadenopathy post-chemotherapy. The left panel represents the contours on the CT simulation scan and the right panel depicts the fusion with the pre-chemotherapy PET scan.



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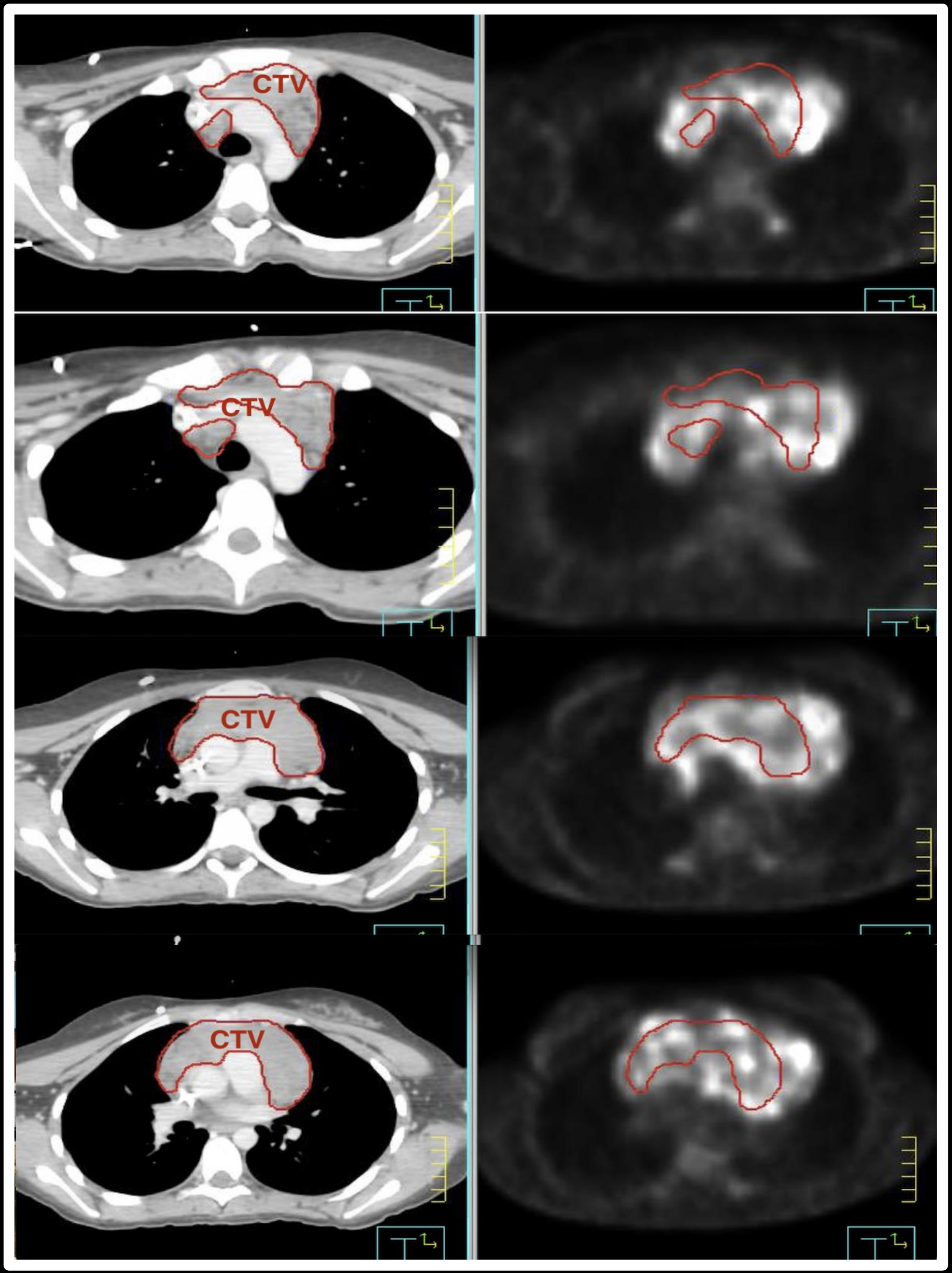

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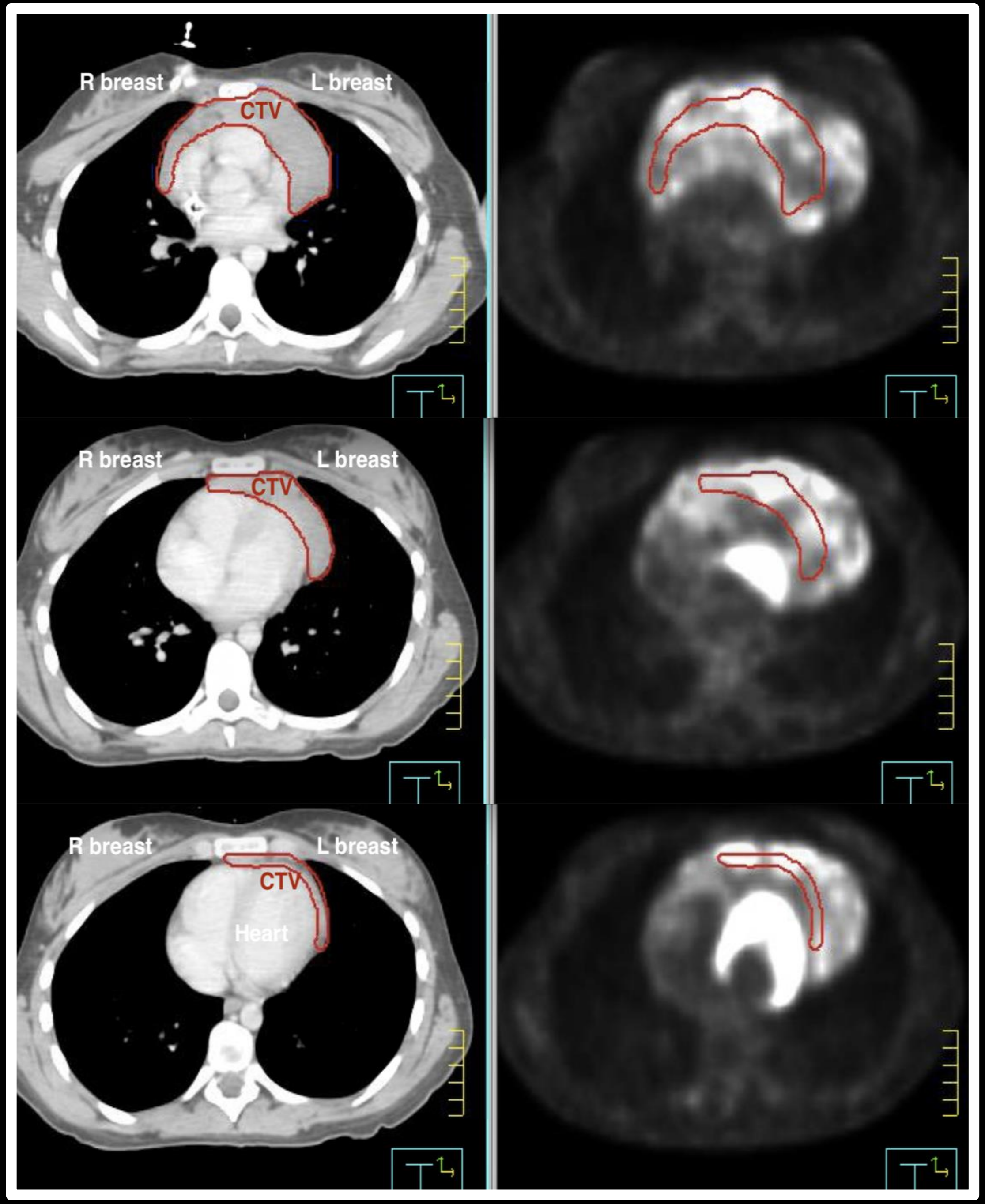
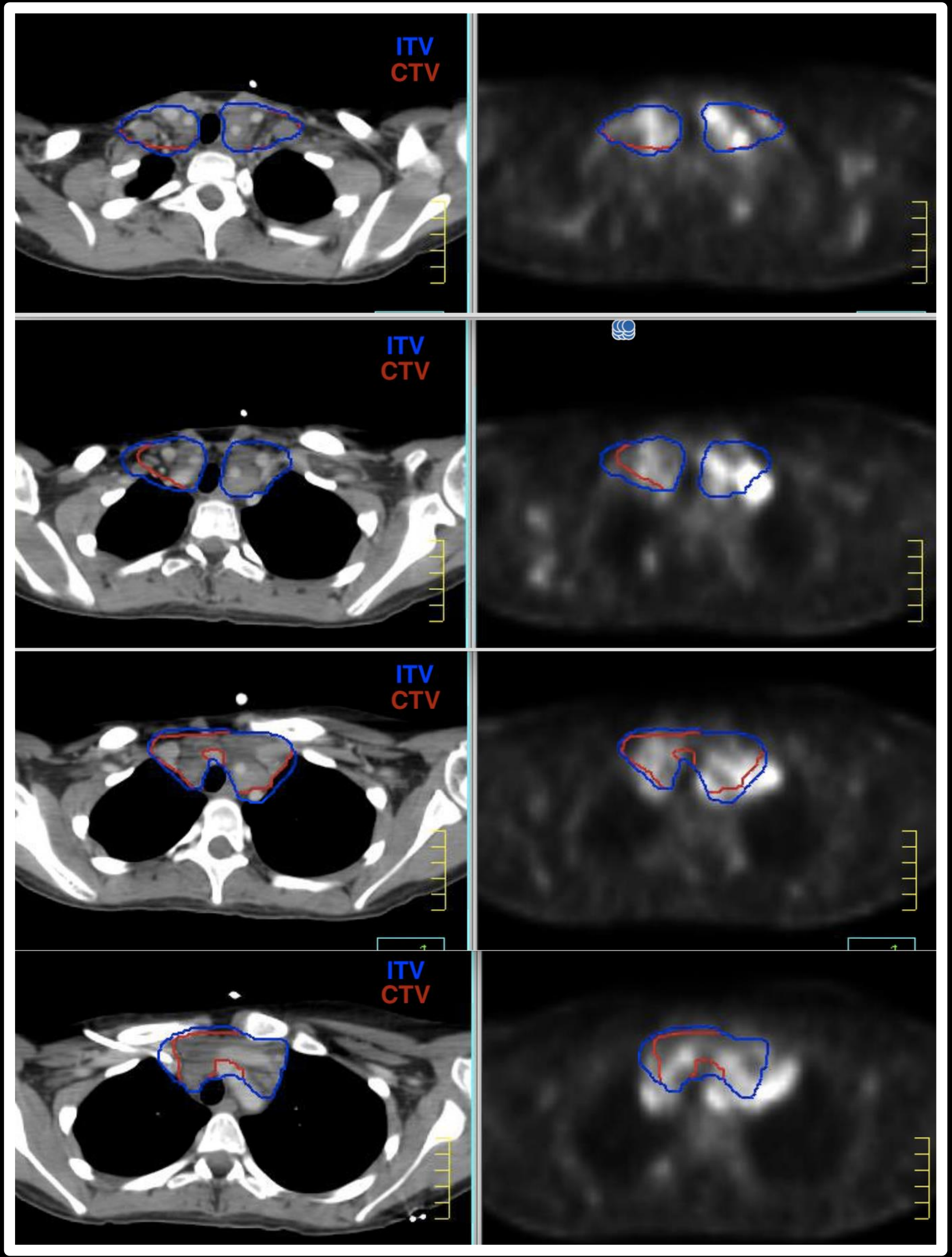


Axial images demonstrating contours of the CTV (red) with the overlying internal target volume (ITV) to account for respiratory and target volume motion as delineated using a 4D CT scan obtained at the time of the simulation.
The target motion can be in all directions and thus, it is important to assess motion using the 4D scan. The right panel again depicts the fusion with the pre-chemotherapy PET scan.



In the absence of motion management Options, and to avoid using empiric expansion, referral of patients to other centers where DIBH is available should be considered. Additionally, referring the patient To a proton facility should be encouraged

Axial images demonstrating contours of the CTV (red) with the overlying internal target volume (ITV) to account for respiratory and target volume motion as delineated using a 4D CT scan obtained at the time of the simulation.

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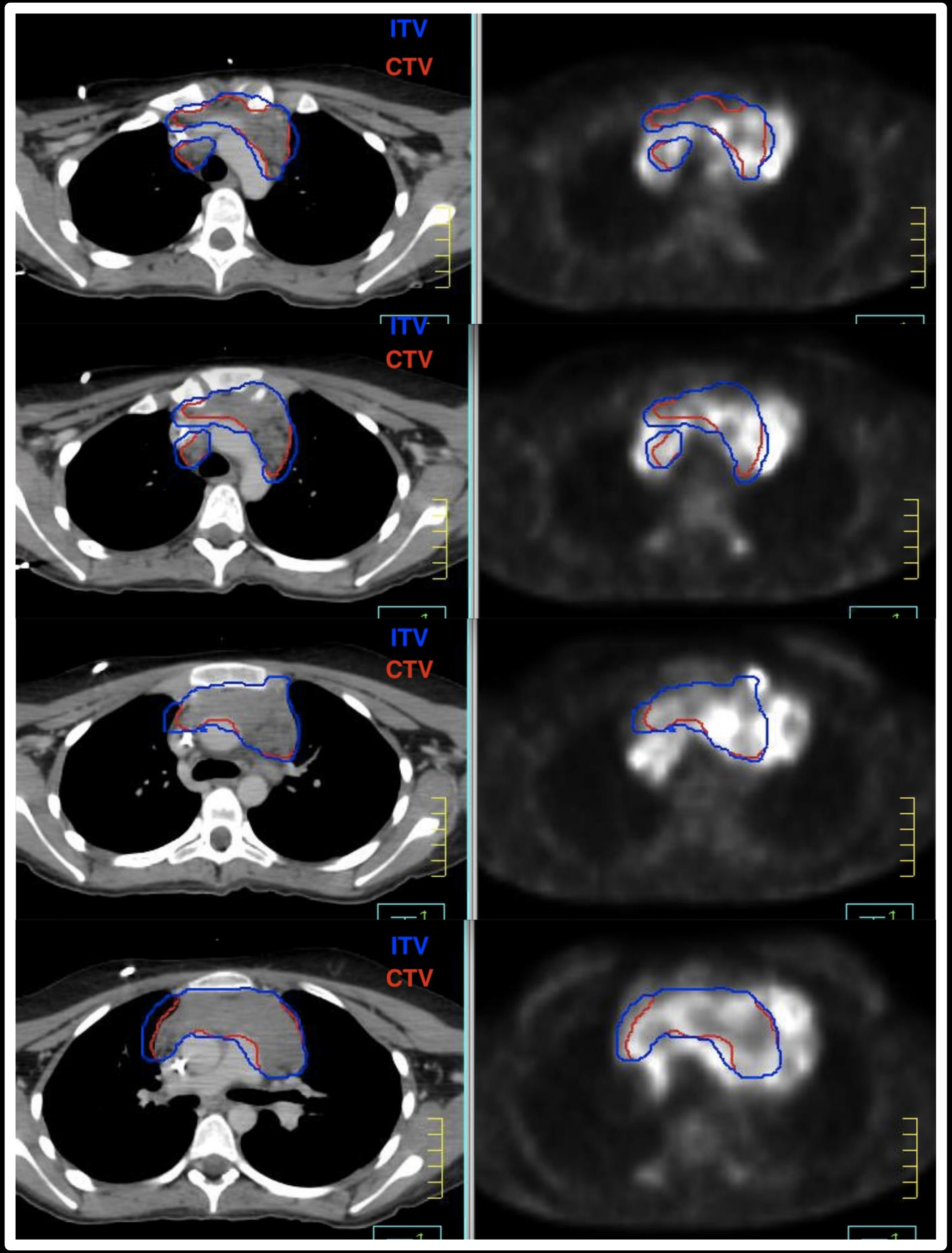
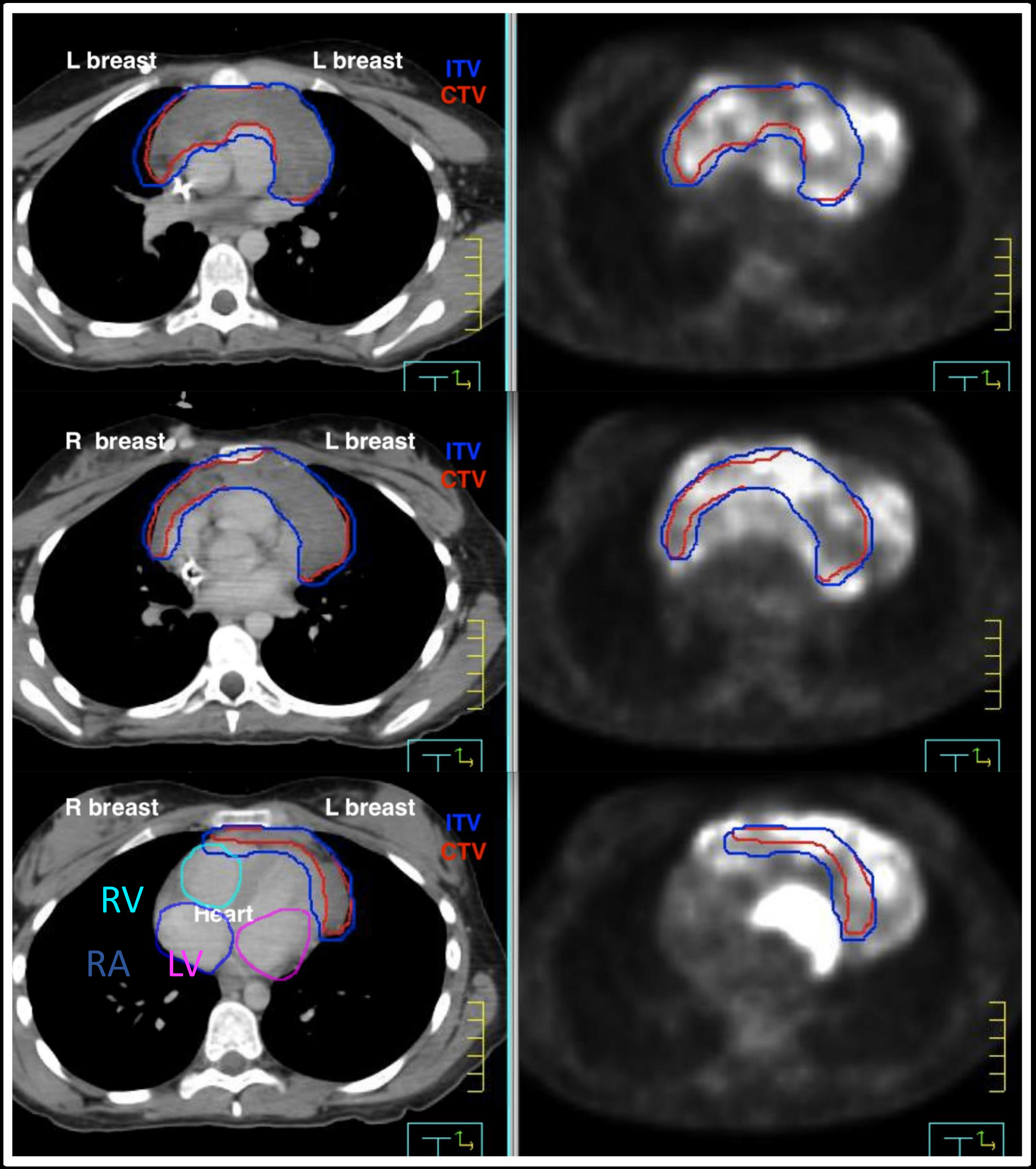
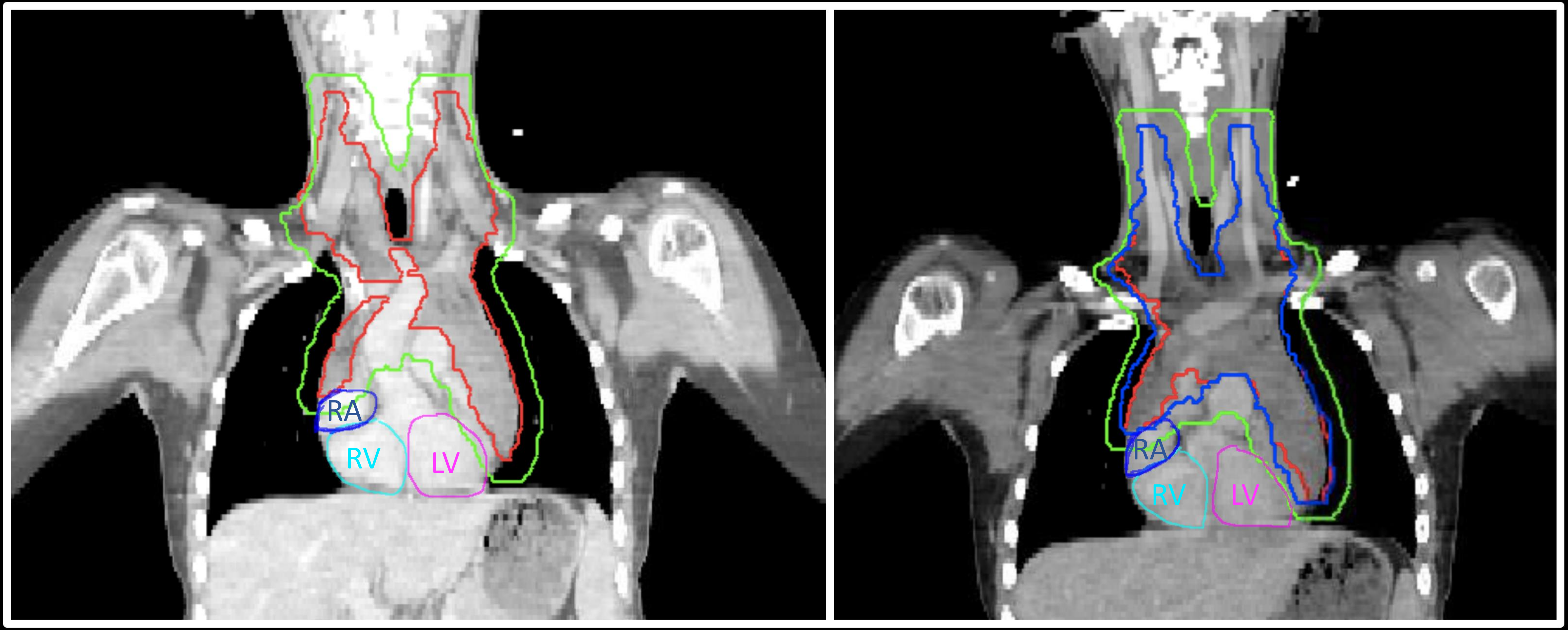


Axial images demonstrating contours of the CTV (red) with the overlying internal target volume (ITV) to account for respiratory and target volume motion which is delineated using a 4D CT scan obtained at the time of the simulation. The target motion can occur in all directions and thus, it is important to assess motion using the 4D CT scan. The right panel again depicts the fusion with the pre-chemotherapy PET scan.



LV: Left ventricle; RV: right ventricle; RA: right atrium

Coronal images demonstrating the CTV contours (red), ITV contours (blue) and PTV contours (green)
The target delineation here will be larger for the lack of using Deep Inspiration Breath Hold and as compared to the previous mediastinal case shown in this atlas.

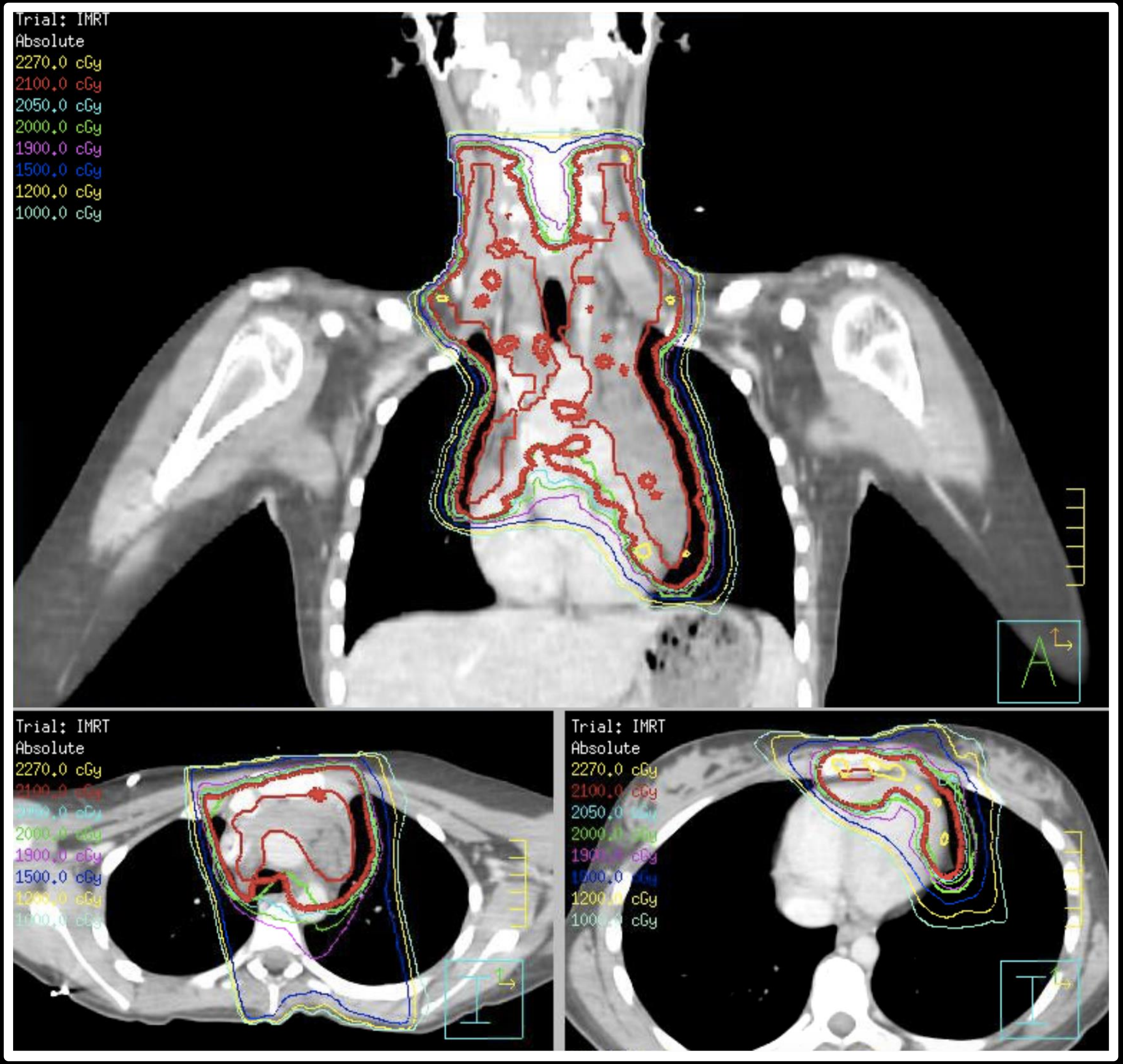


LV: Left ventricle; RV: right ventricle; RA: right atrium

The final plan showing the dose distribution using IMRT and generated based on the ITV. Fortunately in this case the breathing motion was minimal explaining the small difference between the CTV and ITV.

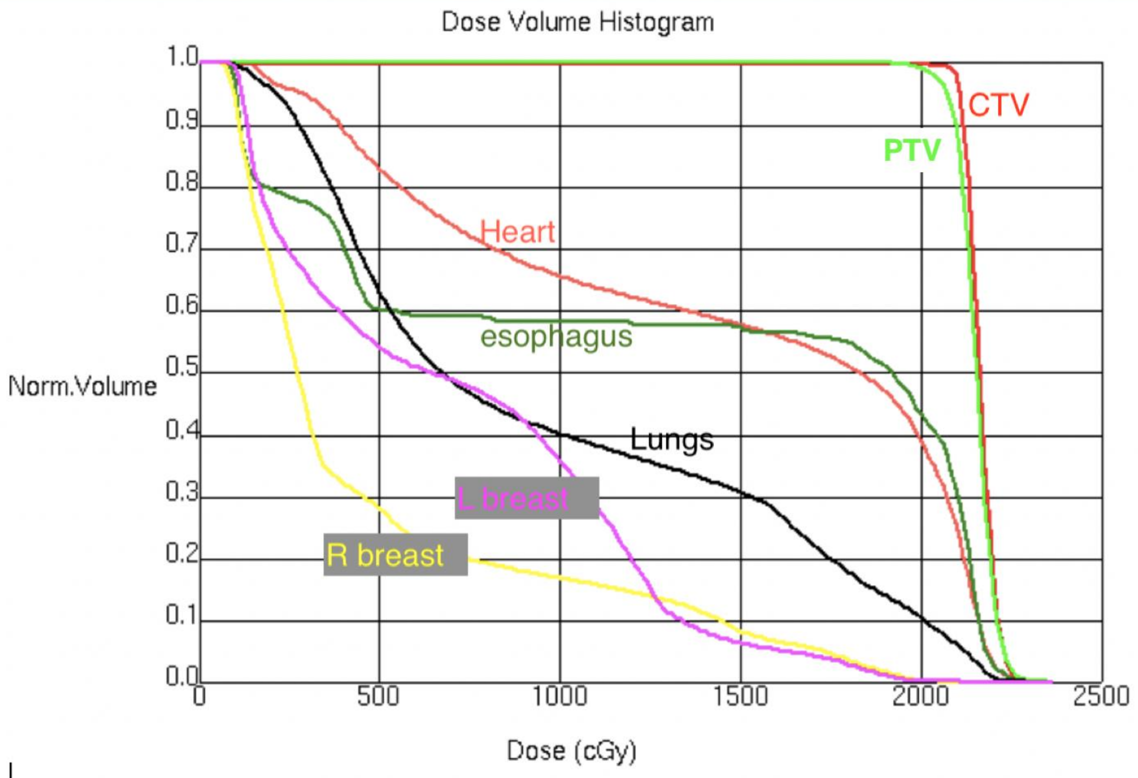
Note that the heterogeneity of the dose is a secondary priority to avoiding critical normal organs.

The IMRT planning used anteroposterior beams to avoid generating a low dose bath especially to the lungs.



Dose Volume Histogram showing a mean dose of 1444 cGy to the heart

The mean dose to the lungs is acceptable (970 cGy) since it is less than 1350 cGy.
the maximum dose to both left and right breasts ended up in the inner portion of the breasts, while 70 % of the right breast and 50% of left breast volumes received less than 500 cGy.
See table from the previous case for acceptable values.



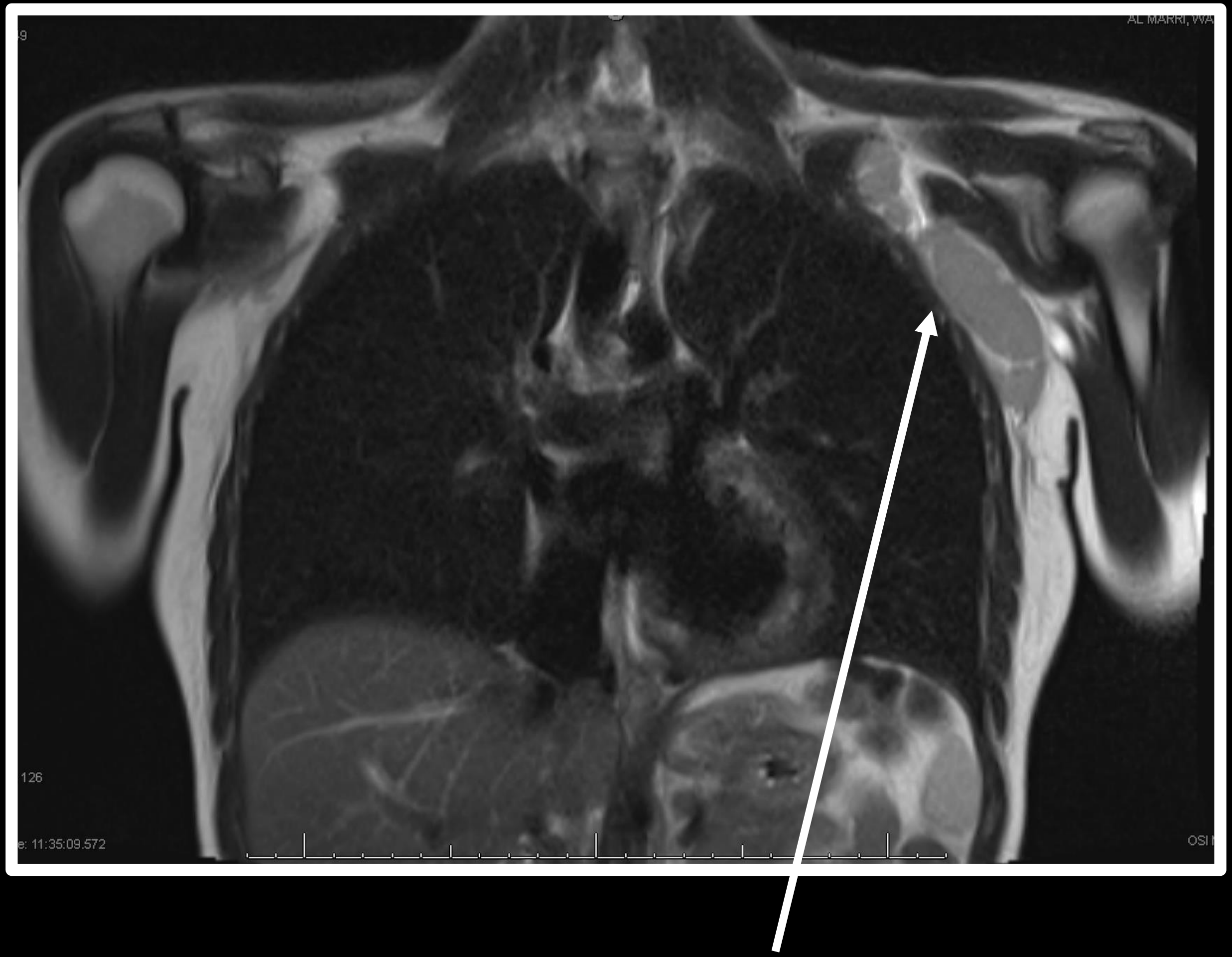
ROI Statistics

Line Type	ROI	Trial or Record	Min.	Max.	Mean	Std. Dev.	% Outside Grid	% > Max
	heart	IMRT	124.7	2337.0	1444.3	724.5	0.00 %	0.00 %
	esophagus	IMRT	83.4	2300.8	1303.8	895.2	0.00 %	0.00 %
	CTV postchemo	IMRT	39.8	2354.2	2153.7	156.6	0.00 %	0.00 %
	PTV	IMRT	1491.4	2354.2	2151.8	51.2	0.00 %	0.00 %
	both lungs	IMRT	65.0	2288.3	970.8	668.8	0.00 %	0.00 %
	right breast	IMRT	48.2	2051.8	488.1	506.5	0.00 %	0.00 %
	left breast	IMRT	48.2	2109.0	709.3	512.3	0.00 %	0.00 %

Take home message:
This case was done without breath hold, understanding that breath hold might not be available in some centers or feasible in some patients.
This case demonstrate how suboptimal the treatment could be without the use of deep inspiration breath hold, we encourage physicians to apply breath hold especially in cases where the mediastinal mass is close to the coronaries.
Additionally, in this young patient with a lung V5 > 60%, and a target close to the heart, Proton therapy should be considered based on the ILROG consensus guidelines for proton therapy treatment for mediastinal locations [6].

ILROG Mini-Atlas: Lymphocyte Predominant Hodgkin's Lymphoma axillary Location

21-year-old female, presenting with lymphocyte predominant Hodgkin lymphoma involving the left level I-III axilla, pregnant at the time of diagnosis she had a diagnostic MRI.
The patient received Rituximab during pregnancy, and after delivery she presented for definitive radiation [12]using ISRT to 3060cGy.

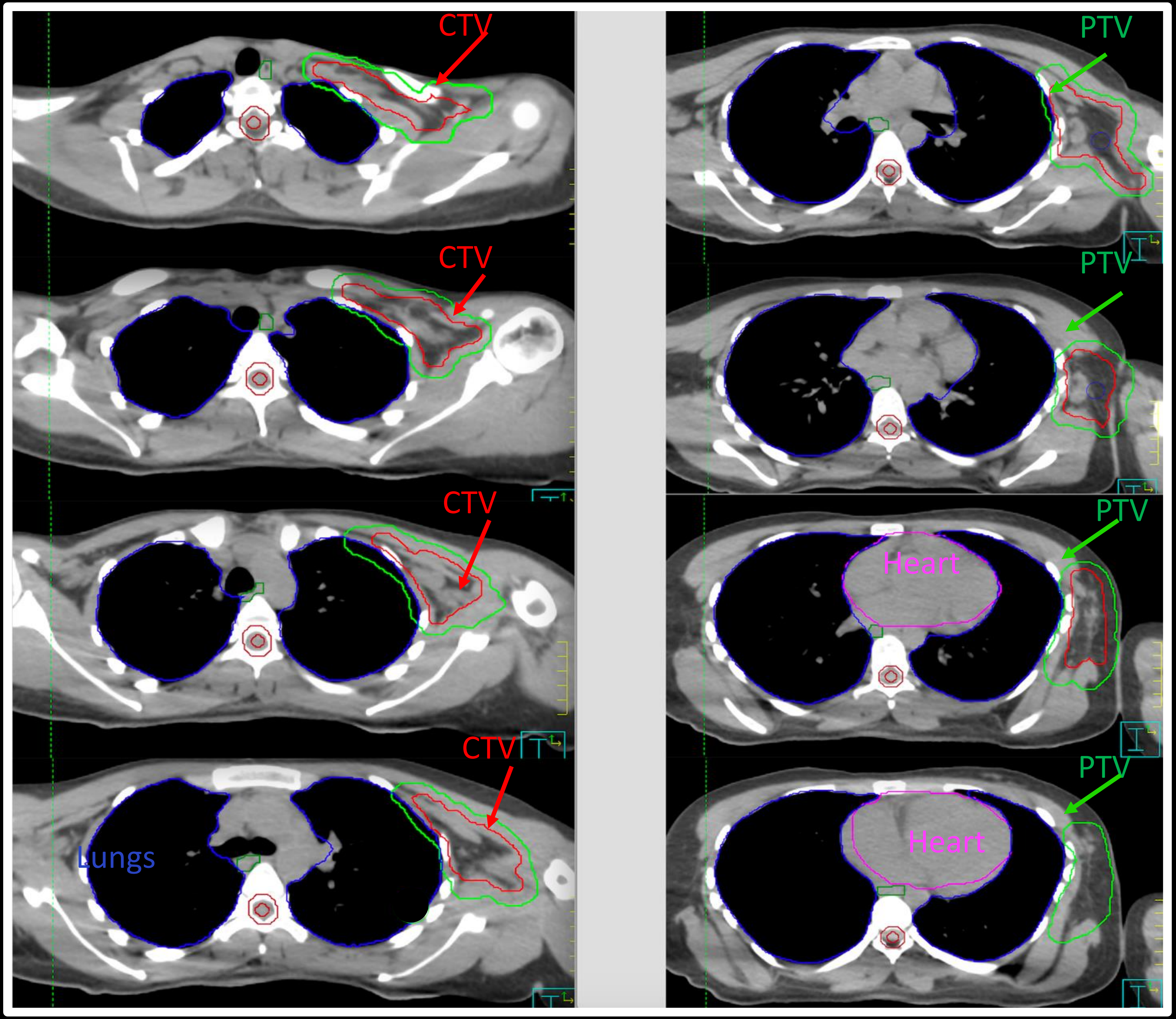


Multilobulated axillary lymph nodes

12: Nogova et al; volume 26 number 3 January 20, 2008

Axial images showing contours of the CTV (red) and a 5-mm added margin to create the PTV (green) using the non-contrasted CT simulation.

Other contours shown includes the organs at risk: esophagus, heart lungs, and cord.



Coronal images showing contours of CTV (red) and a 5-mm added margin to PTV (green) using the non-contrasted CT simulation that shows the disease.

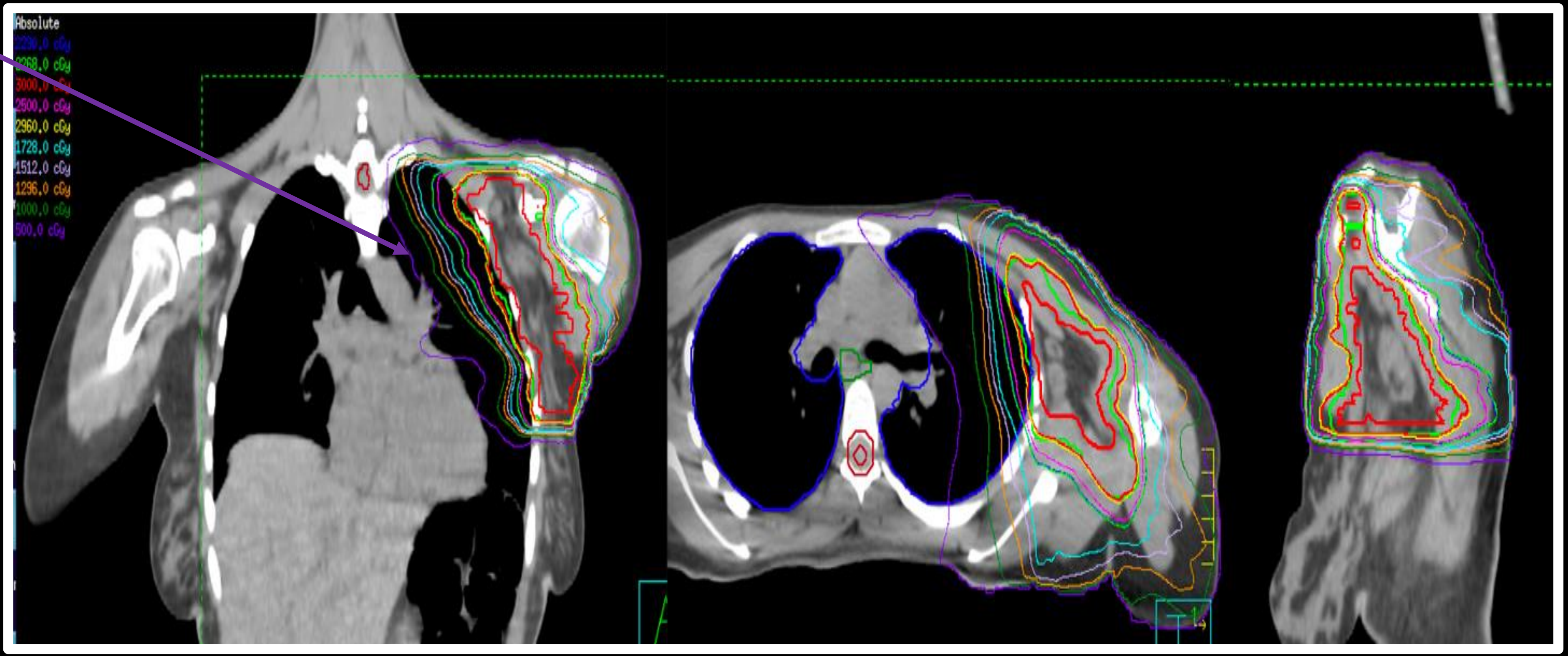
Planning was done using IMRT with efforts to keep the 500cGy isodose line off the breast's glandular tissue (a priority in this young female).

It advisable when using IMRT to avoid lateral beams that can potentially increases the undesirable low dose bath to the lungs.

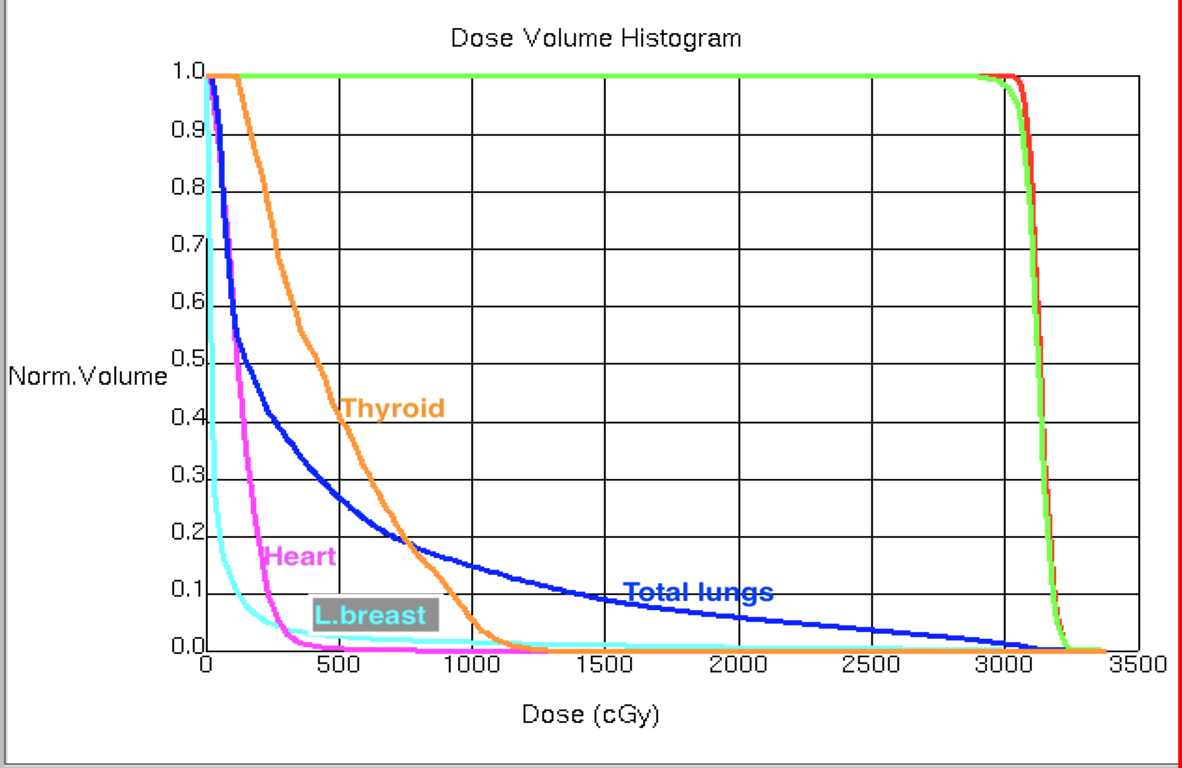
The simulation was done with the left arm down and akimbo to avoid pulling the left breast tissue into the target volume.

Arm up position might be appropriate in a male patient, where the breasts are not an issue.

3 D technique could be also appropriate



Dose volume histogram showing how critical organs are kept way under tolerance.



ROI Statistics

Line Type	ROI	Trial or Record	Min.	Max.	Mean	Std. Dev.
red	pCTV_3000	Lt Axilla BSD Aprvd	2935.6	3338.1	3134.0	38.2
green	pPTV_3000	Lt Axilla BSD Aprvd	2573.1	3357.8	3122.2	49.2
cyan	left breast	Lt Axilla BSD Aprvd	--	2977.8	74.1	244.0
magenta	heart	Lt Axilla BSD Aprvd	22.1	794.2	134.5	80.2
blue	Total lung	Lt Axilla BSD Aprvd	11.1	3227.0	467.1	675.0
orange	thyroid	Lt Axilla BSD Aprvd	120.2	1277.4	480.8	278.5

Take home message:
This is to show that ISRT is an appropriate field even if radiation
Is the only modality used.

There is no need to include uninvolved nodal regions, in another term, discourage the
Use of IFRT.

References to the mini-atlas section

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Lymphocyte-Predominant and Classical Hodgkin's Lymphoma: A Comprehensive Analysis From the German Hodgkin Study Group .
JCO, volume 26, number 3, January 20, 2008