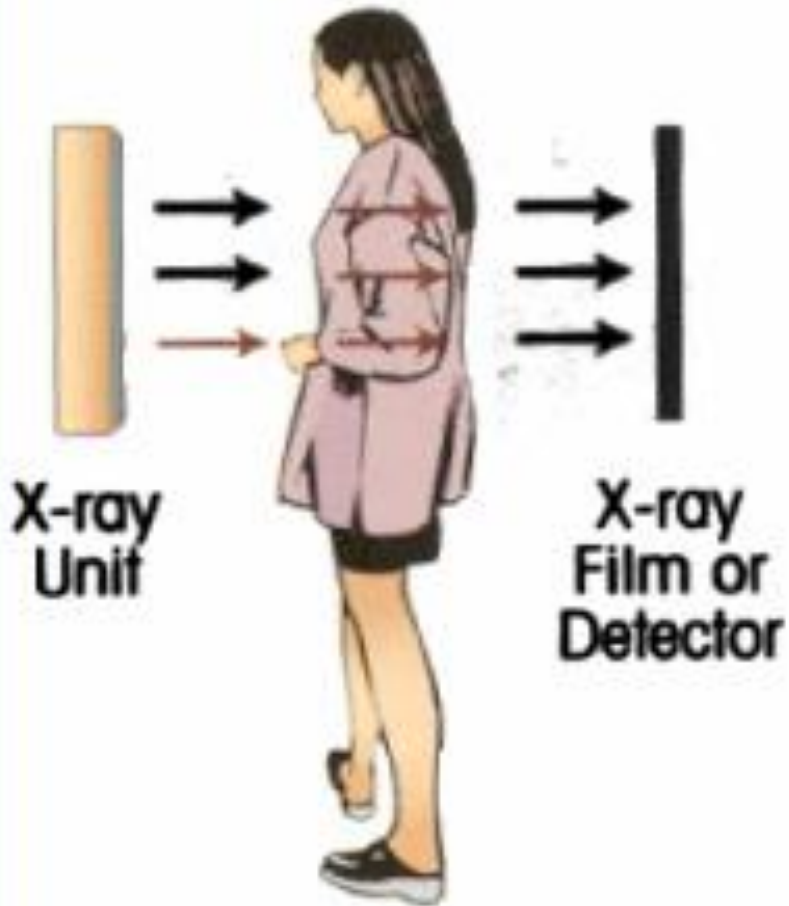


Introduction to Nuclear Medicine

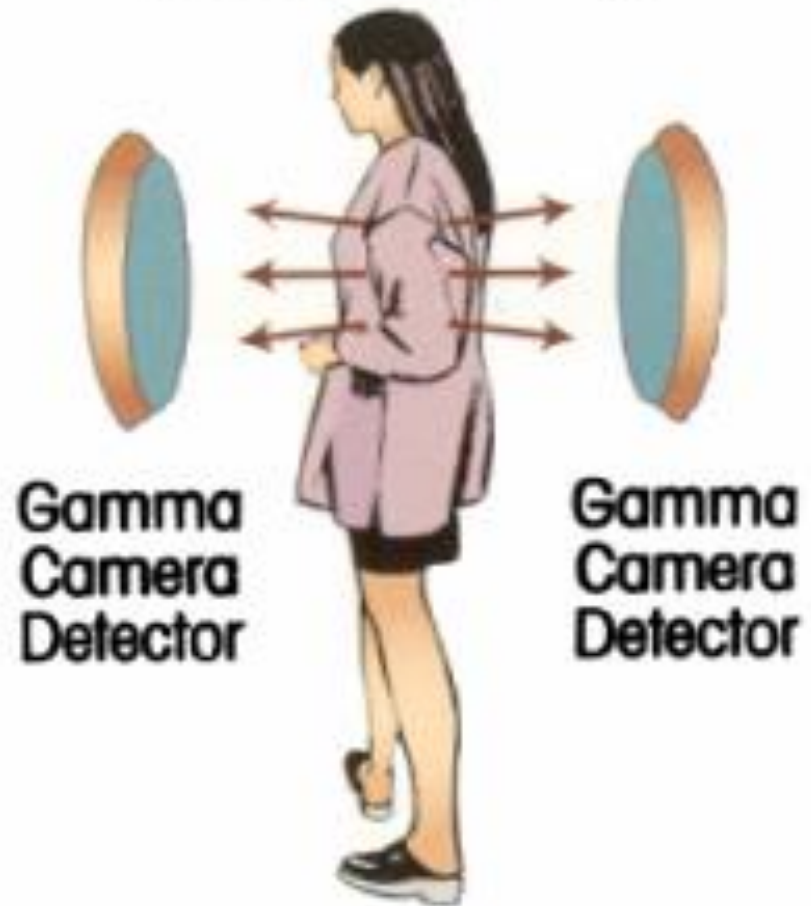
August 2023

X-rays (Radiography)

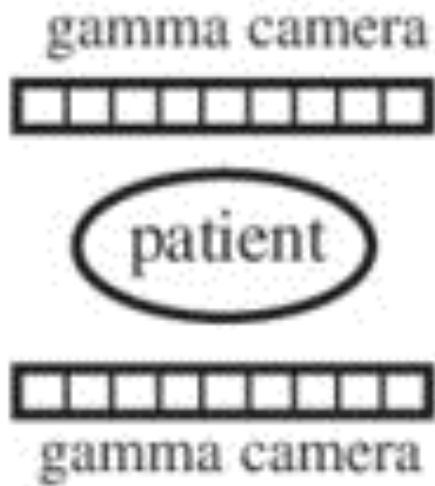


- * Radioactive particles go through the patient
- * Anatomy

Gamma Rays (Nuclear Medicine)



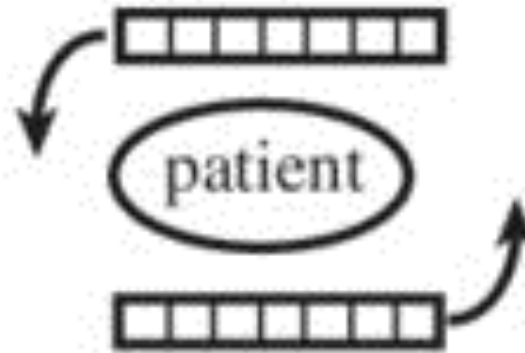
- * Radioactive particles within the patient
- * Structure



Planar

(non-rotating,
in-plane detectors)

2D



SPECT

(rotating detectors)

3D



PET

(ring of detectors)

Tomographic



The key distinction
between nuclear medicine
and almost all other
imaging modalities –
images may indicate
dynamic information –
function, not just structure

What is a radiopharmaceutical?

① A **radionuclide** (radioactive and emits something we can detect, usually gamma rays)

→ gamma → highest penetration
→ β +/-
→ alpha → largest diameter → huge radiation

② A **pharmaceutical** (which gives the physiologic function)

For example, we attach technetium-99m to DTPA, which is filtered by the kidney, to calculate glomerular filtration rate.

Or we can attach it to MDP, which is taken up by the bone, to do a bone scan.

Ideal diagnostic radiopharmaceutical

Pure Gamma Emitter

Alpha and Beta Particles are unimageable and deliver high radiation dose

Energy of Gamma Rays

Ideal: 100 - 250 keV

^{99m}Tc , ^{123}I , ^{111}In

Suboptimal: < 100 keV

^{201}Tl

> 250 keV

^{67}Ga , ^{131}I

Photon abundance to minimize imaging time

High target to non-target ratio

Easily available

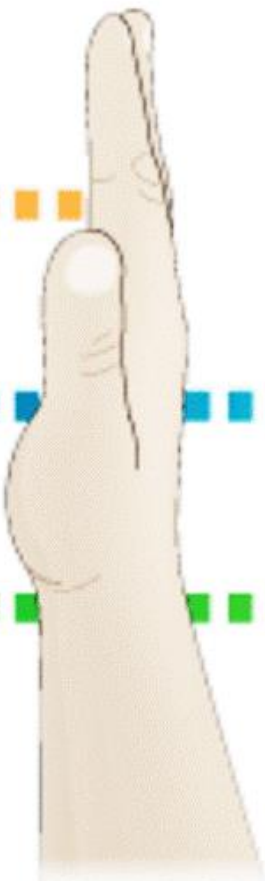
Suitable effective half life

Alpha 


↳ can be stop by paper or hand

Beta 

Gamma 



Aluminium 

Lead 

Radionuclide Production

Characteristics	Production Method			
	Cyclotron	Reactor (Fission)	Reactor (Nuclear Activation)	Generator
Examples	^{201}Tl , ^{123}I , ^{18}F	^{99}Mo , ^{131}I	^{125}I	$^{99\text{m}}\text{Tc}$, ^{68}Ga

^{99m}Tc (99-metastable-Technitium)

Most used radionuclide

Pure gamma radiation

140 keV energy level

Half life of 6 hours

90% photon abundance

Available

Cheap

Produced by a generator from ^{99}Mo

Thyroid Scintigraphy

^{99m}Tc -pertechnetate and ^{131}I

Indications

Low TSH

Diffuse toxic goiter (Graves' disease)

Single toxic nodule

Toxic multi-nodular goiter

Evaluate nodule (hot vs. cold)

↑ uptake

↘ uptake

10-30% → Normal taken

<10% → hypo Hashimoto

30-60% → multi nodular

>60% → Graves

I¹²³

- expensive
- Best for ablation
- emit β radiation
- Half life 8 hours

- cheap ,available
- pure gamma
- Best for image
- Half life 3hrs

¹³¹I Uptake

Radioactive Iodine (RAI) is used for thyroid uptake.

RAI is given orally

Follicular cell traps Iodine and organifys it to be incorporated with thyroid hormone.

Uptake are obtained after 24 hours

Measure photons in the given RAI by a special probe (uptake probe) just before taking RAI.

After 24 hours, measure photons in the neck (thyroid gland).

Calculate % of photons concentrated in thyroid gland.

Norma range = 10 – 30%

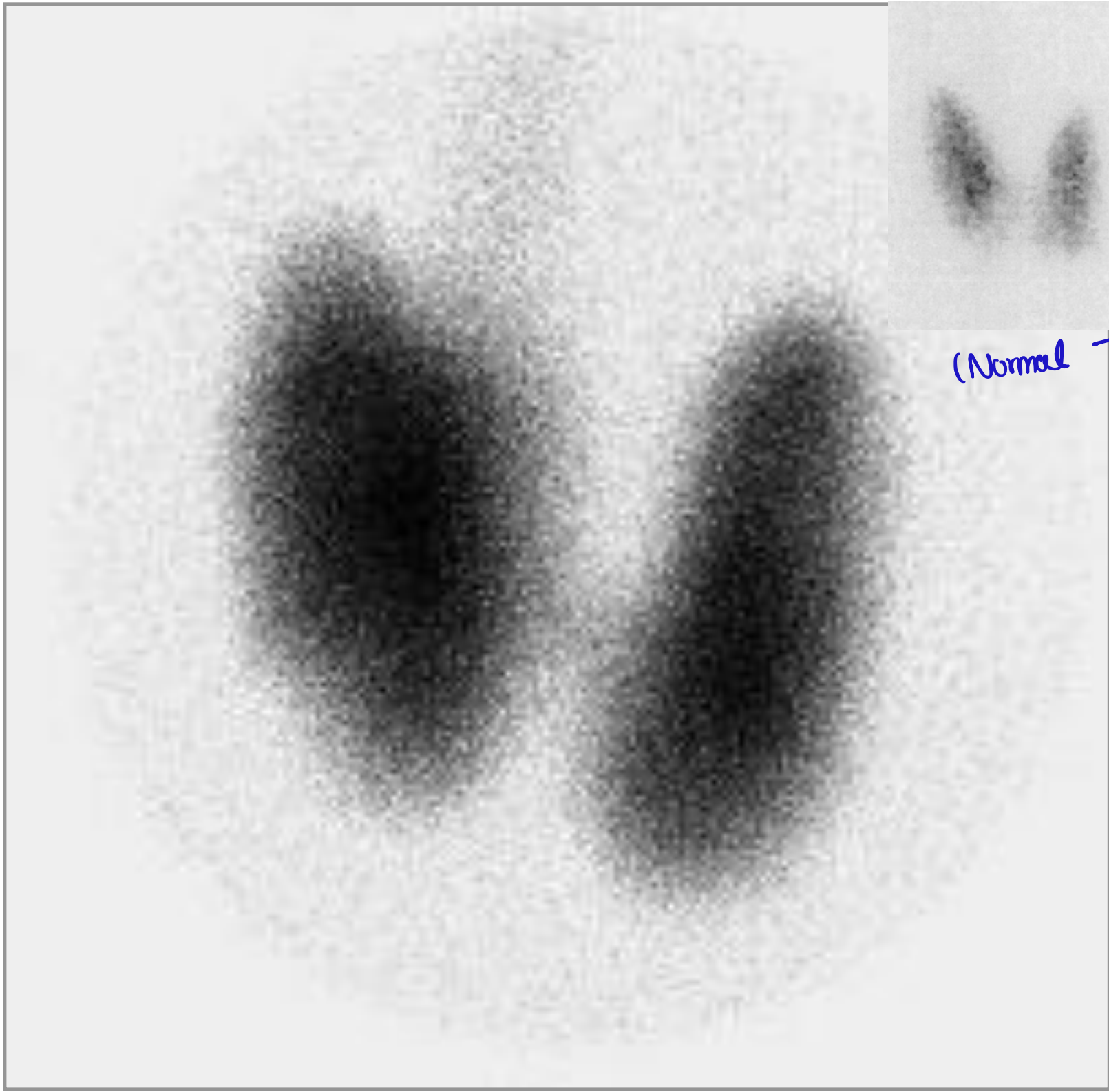


① Comparing with salivary gland
density if presented

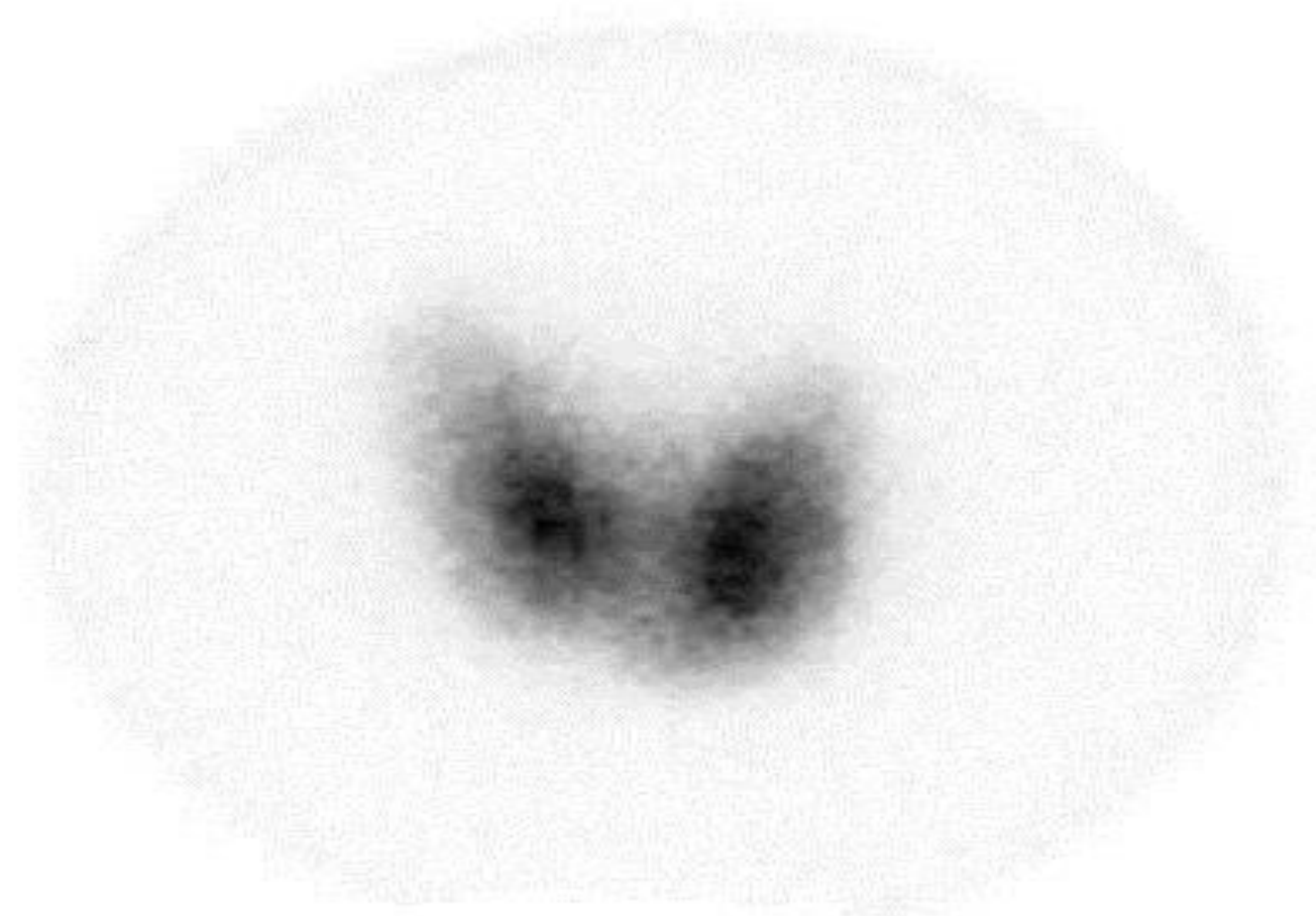
② Description → diffuse intake in both thyroid lobes (high intake)
without nodules

③ DDX → >60% = GRAVES





(Normal Thyroid)



Graves' Disease

Also known as diffuse toxic goiter

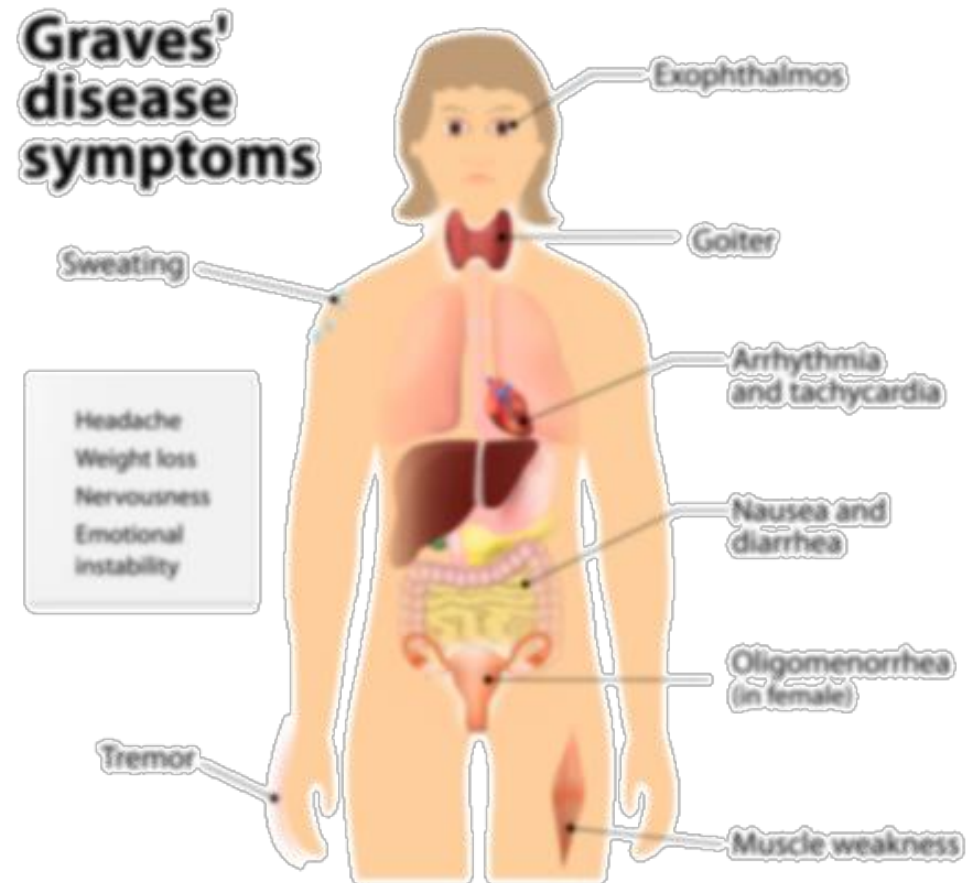
Diffuse enlargement of thyroid gland

Homogeneous or diffuse uptake

No significant focal abnormalities (nodules)

24-hour RAIU is elevated, typically above > 30% (usually above 60%)

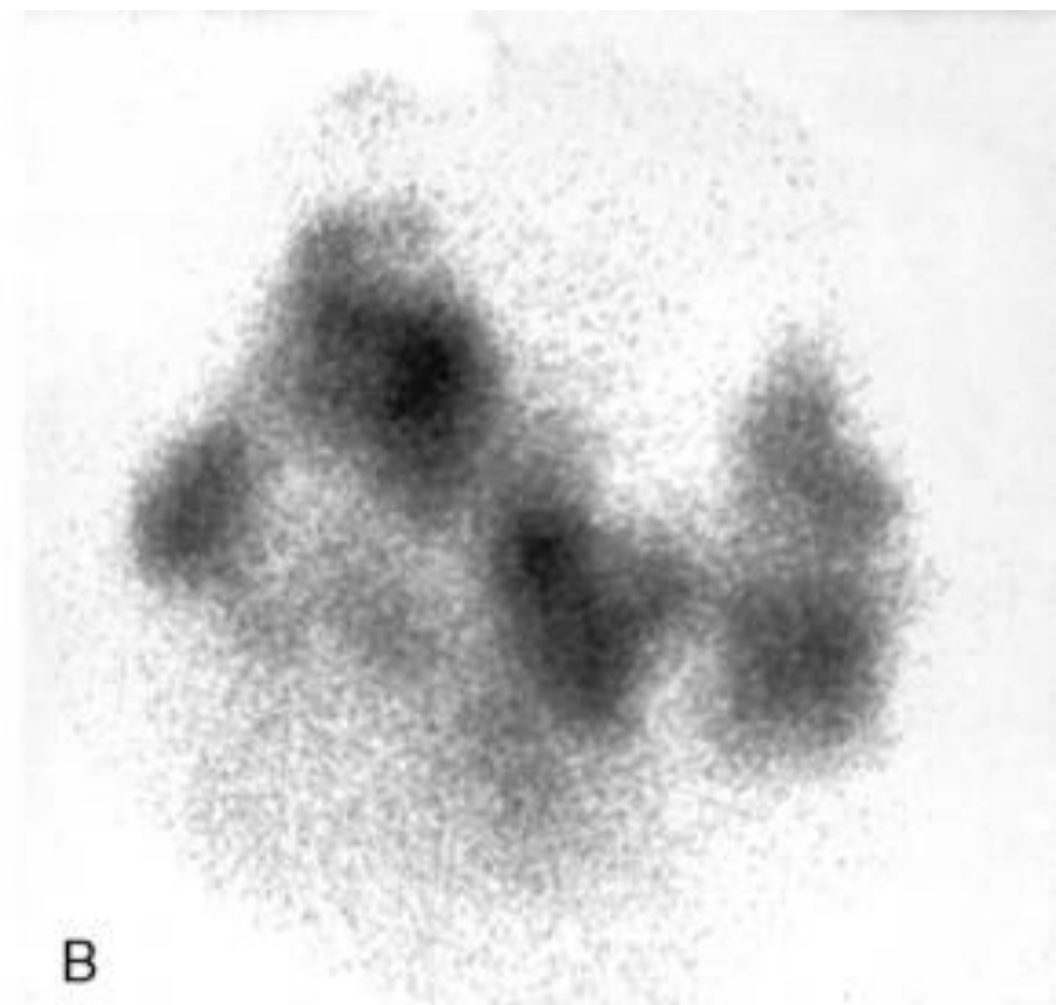
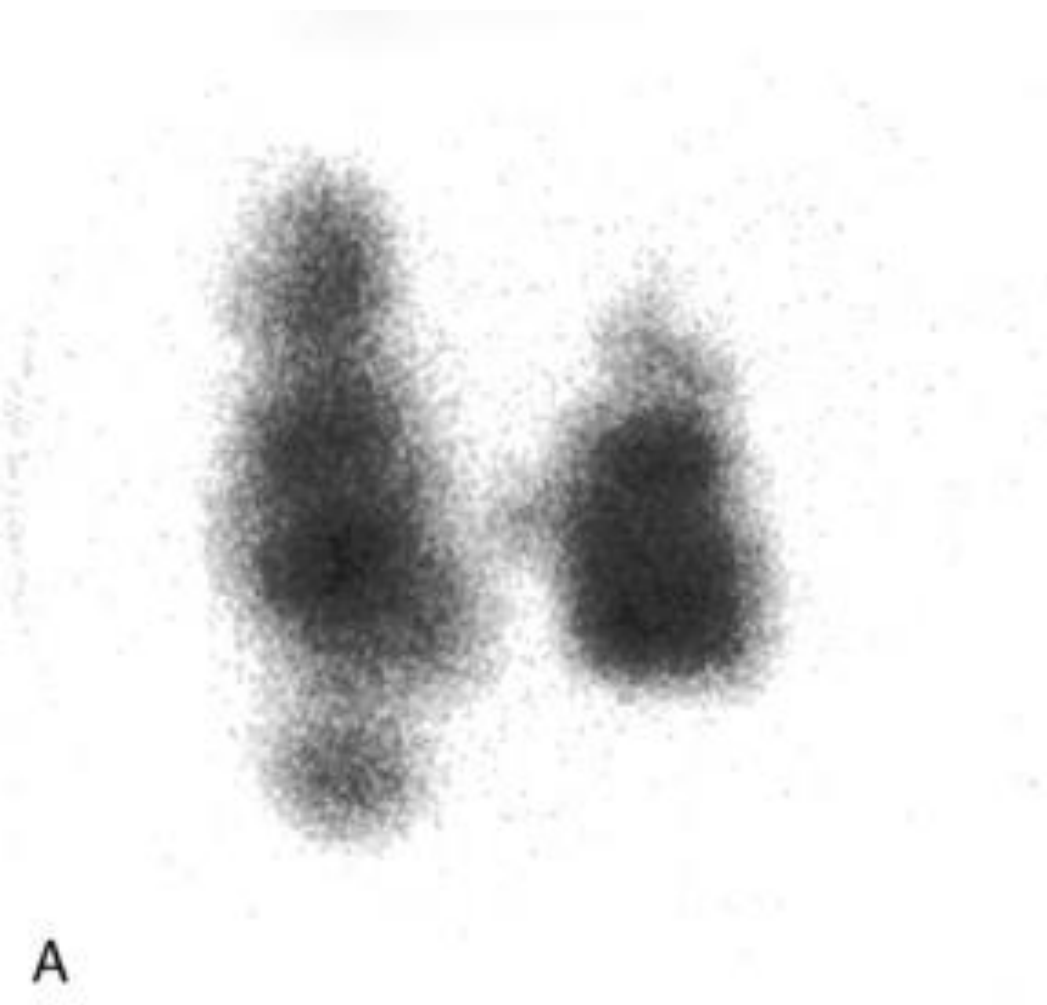
Confirmed by TSH Receptor Antibody (TRAb)



Description → several nodules with increased uptake (Hot)
while the remainder of thyroid is suppressed

DDx → toxic multinodular goiter





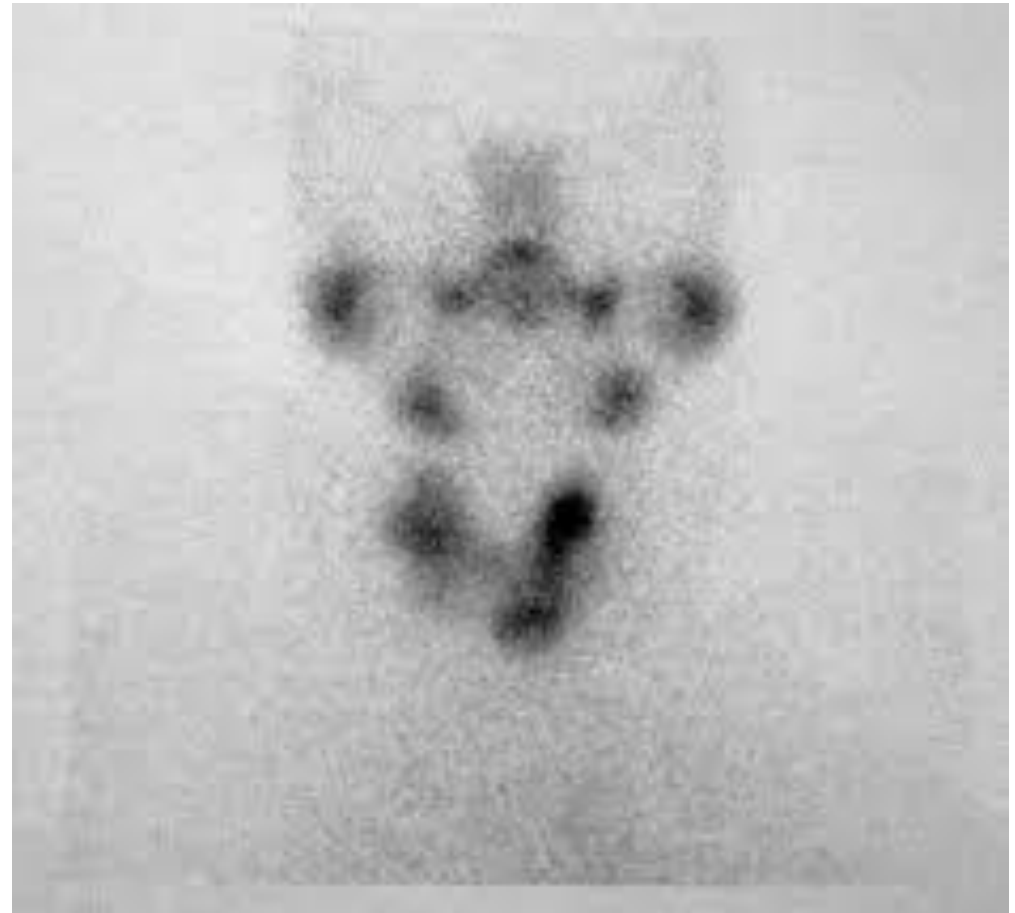
Toxic or Autonomous Multinodular Goiter

Also known as Plummer disease

Inhomogeneous or heterogeneous uptake in thyroid gland.

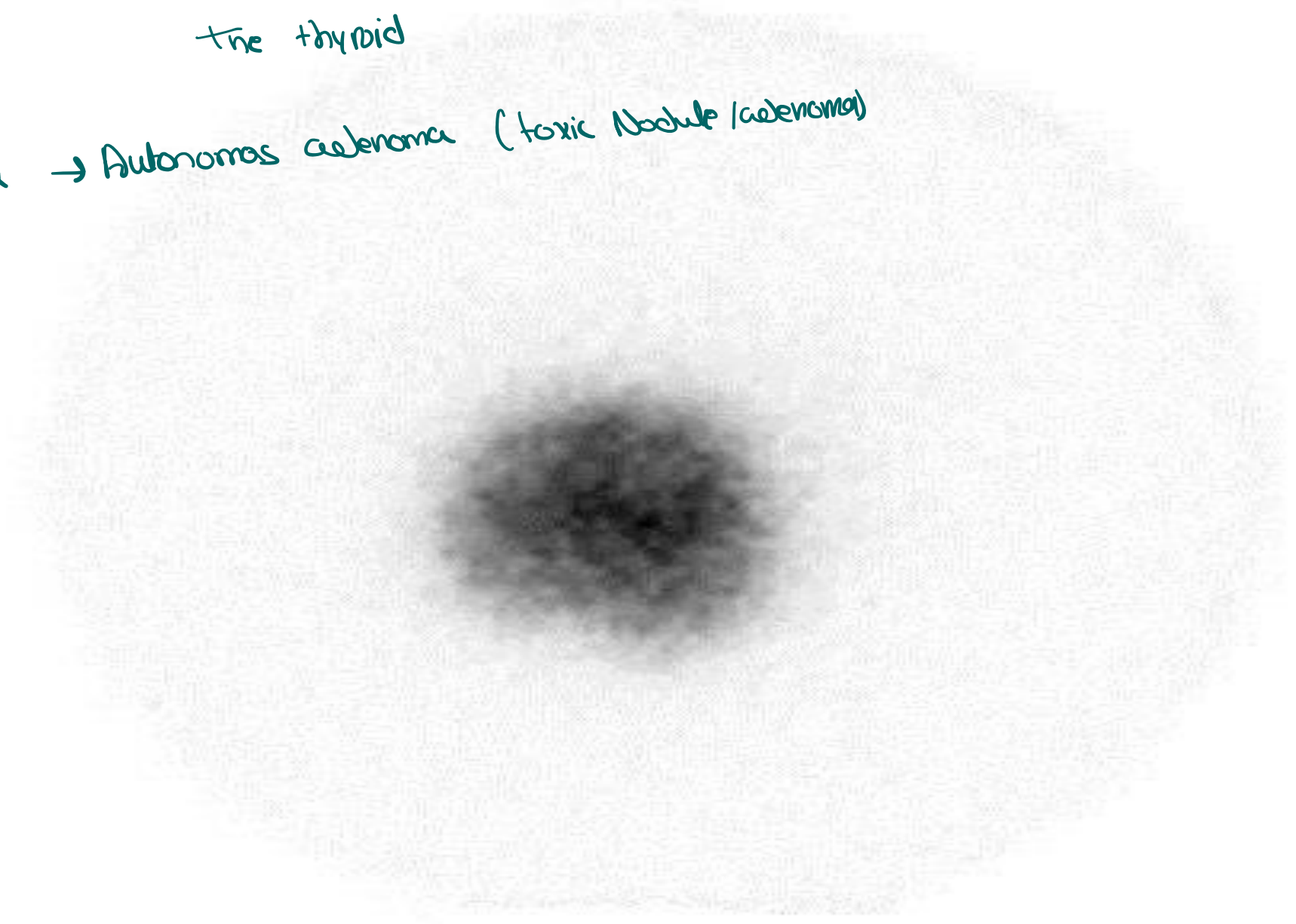
Multiple cold and/or hot nodules in both thyroid lobes.

24-hour RAIU is usually mildly elevated $> 30\%$ (usually between 40% and 50%)



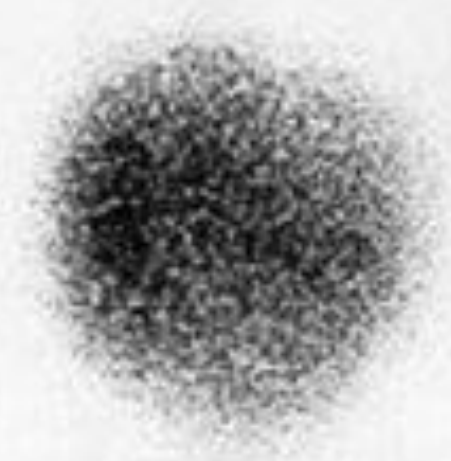
Description → Single hot nodule with suppression of the remainder of the thyroid

DDx → Autonomous adenoma (toxic Nodule/adenoma)

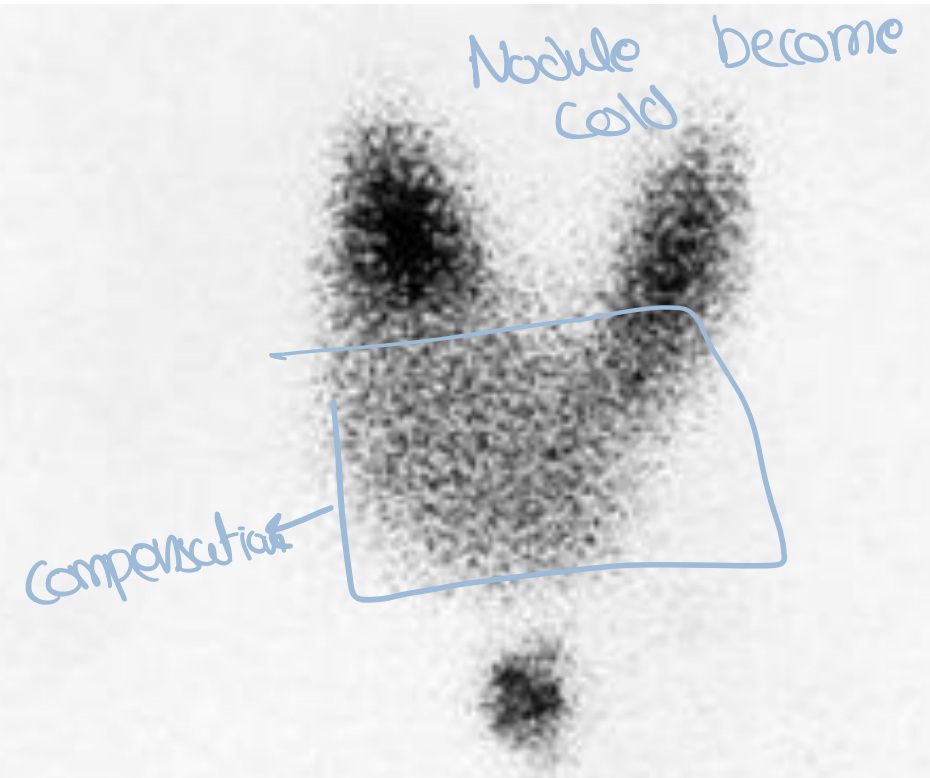


TC MARKER

SSN MARKER



A Before Ablation



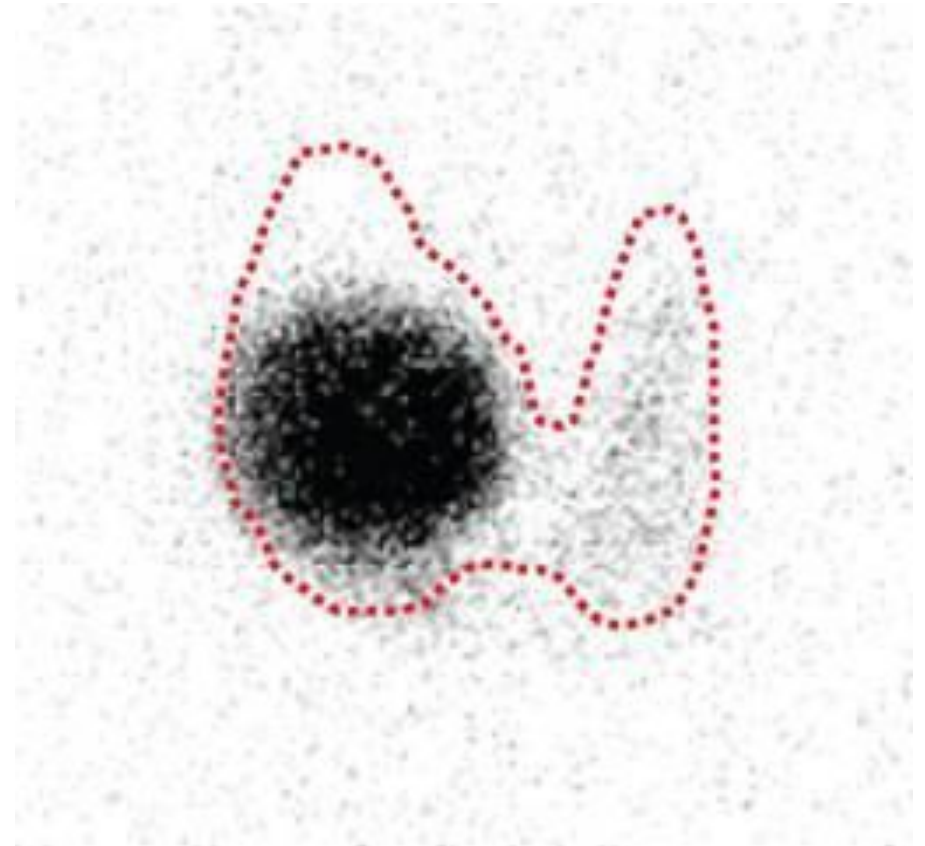
B After iodine ablation

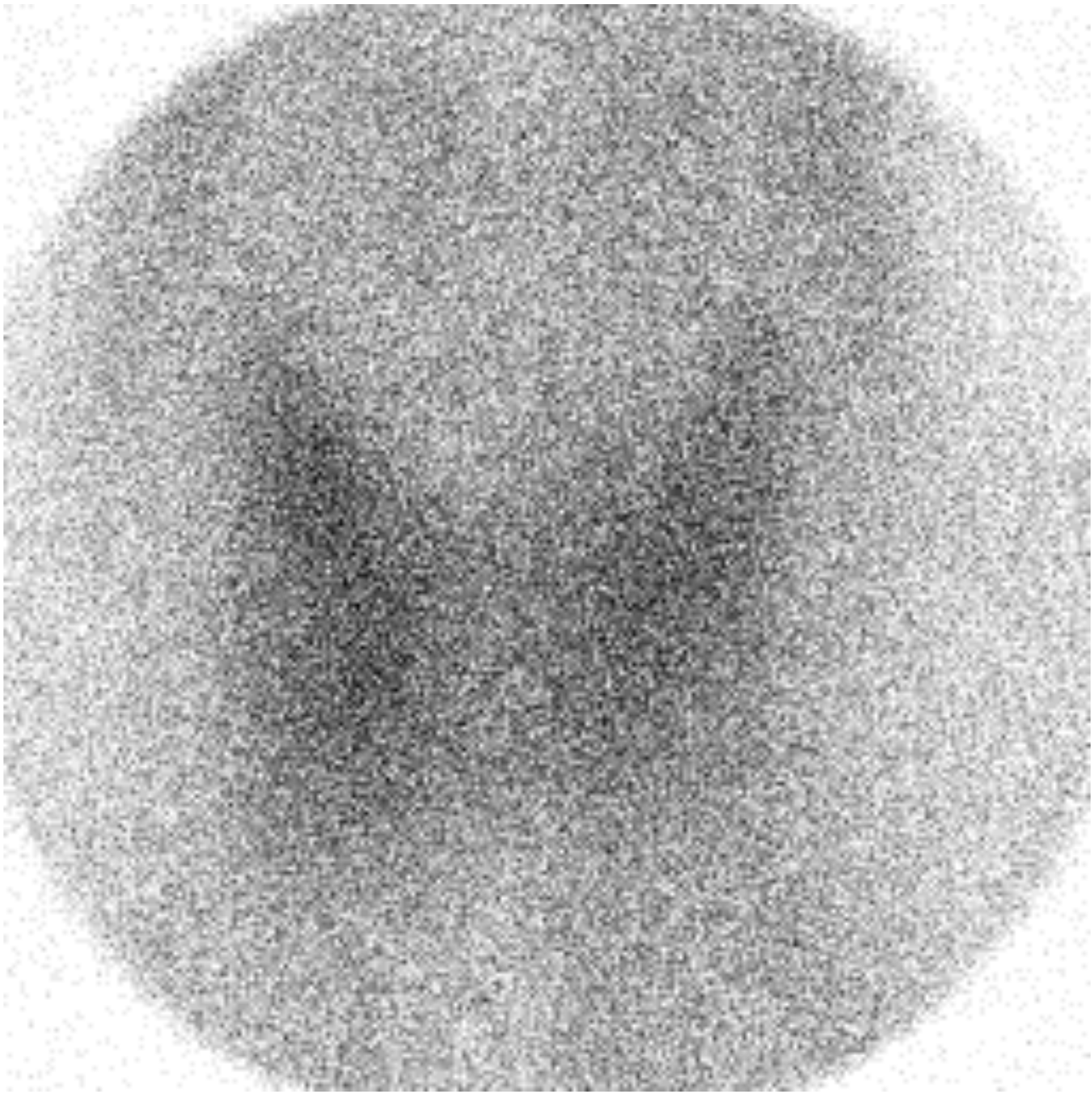
Toxic Adenoma

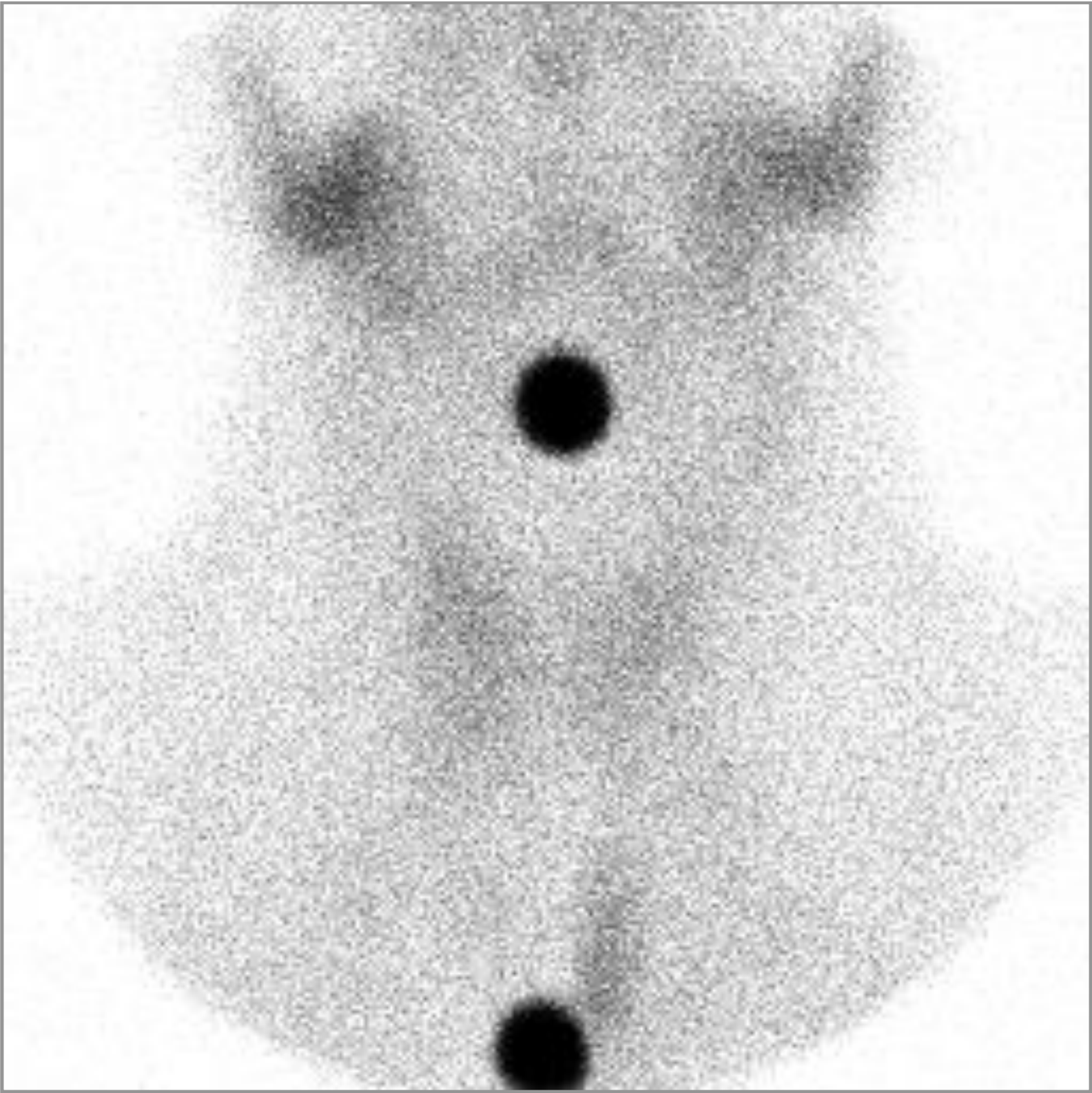
Single hot nodule
(independent of TSH or
autonomous).

Rest of thyroid gland is poorly
visualized due to low TSH level
(TSH dependent).

24-hour RAIU is slightly
elevated, > 30%.





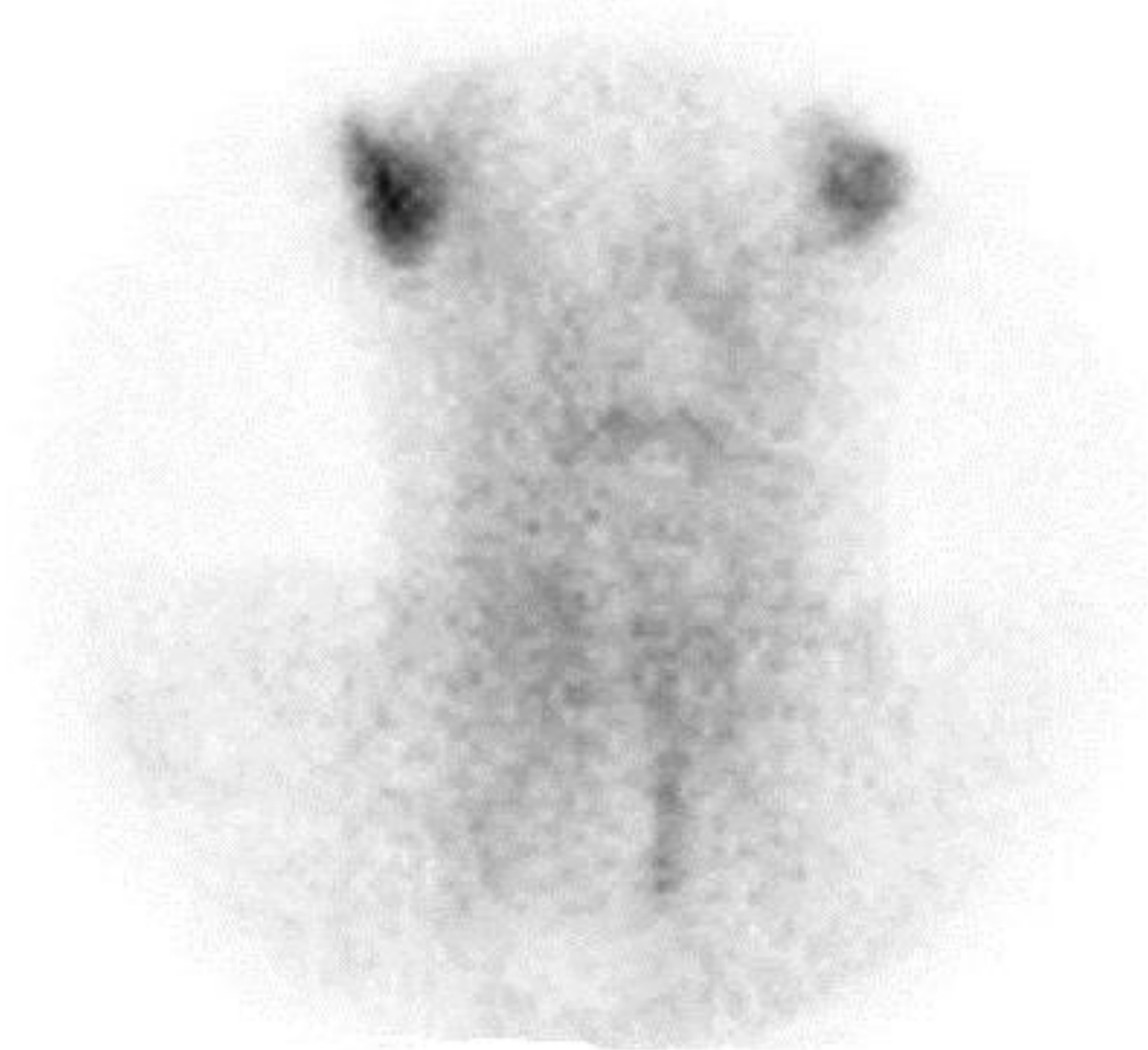


• Hardly Any uptake in the thyroid (less than 5% in 24 hours) - indicating subacute thyroiditis

SARAH MARWAN SHHADEH

• some iodine uptake in the Esophagus that was swallowed because technetium and iodine are taken by salivary gland (parotid, mandibular), so saliva contains Radioactive iodine so you can see it in the Esophagus

09Apr2007



Subacute thyroiditis

Inflammation of thyroid gland that leads to release of stored thyroid hormone due to follicular cell destruction

Heterogeneous uptake, could be mild or severe

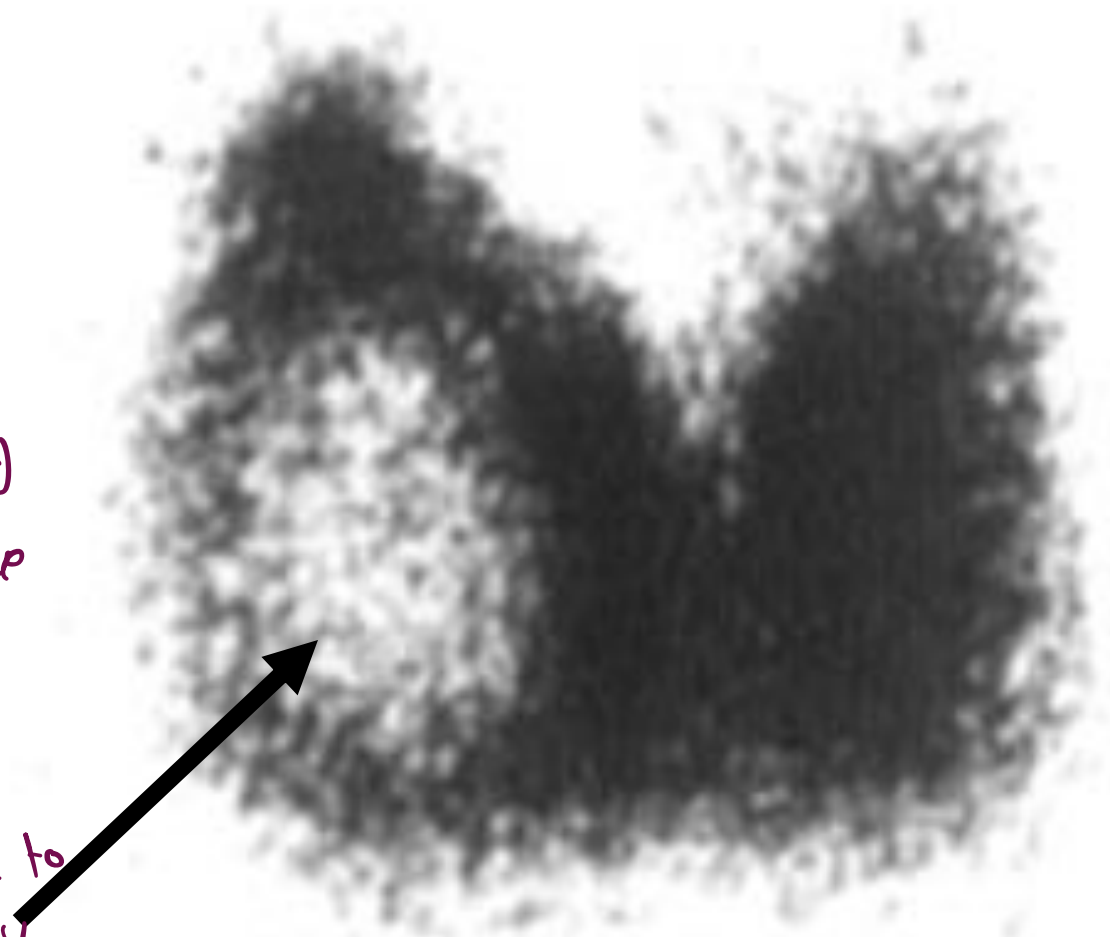
In some cases, thyroid gland is not visualized

No significant focal abnormalities (nodules)

24-hour RAIU is low, usually < 5%.

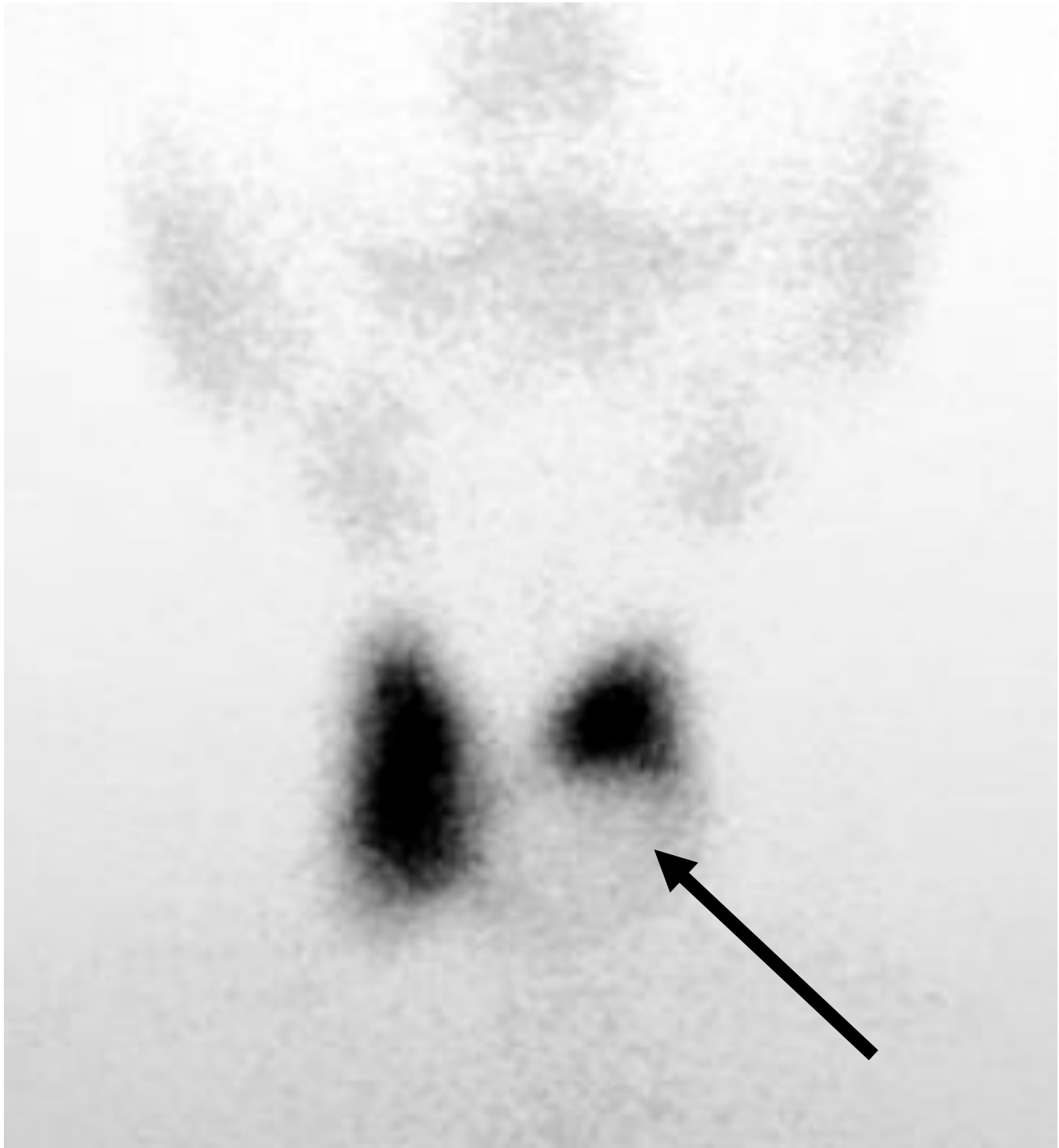
 Salivary

* Less taken in
specific area
of the thyroid
comparing to the
remaining
(Cold Nodule)



* 15-30% chance to
cause malignancy

* FNA required according to US Nod image *



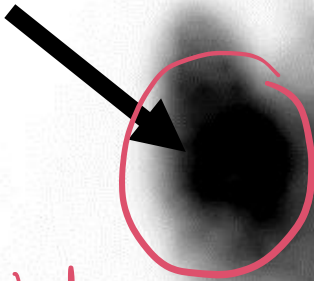
Cold nodules

Focally decreased uptake

15% malignancy risk

Next step is correlate with ultrasound to see if there is need for FNA or biopsy

Hot nodule



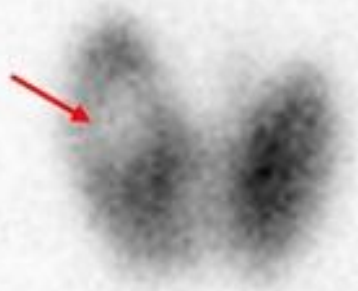
↑ uptake
(comparing
to the
gland)

→ low risk to be
malignant

Hot nodules

Focally increased uptake

Next step is reassurance



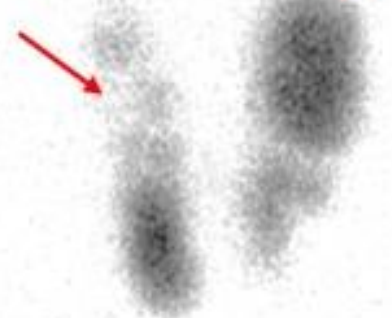
COLD NODULE

pyramidal
lobe

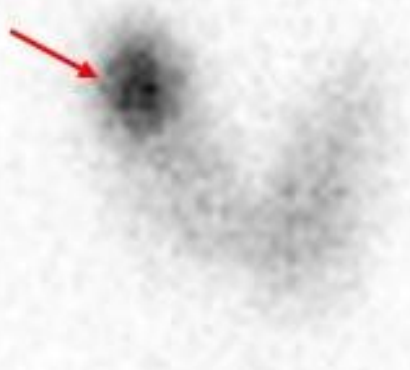


GRAVE DISEASE

hot and cold nodules



TOXIC MULTINODULAR



HOT NODULE

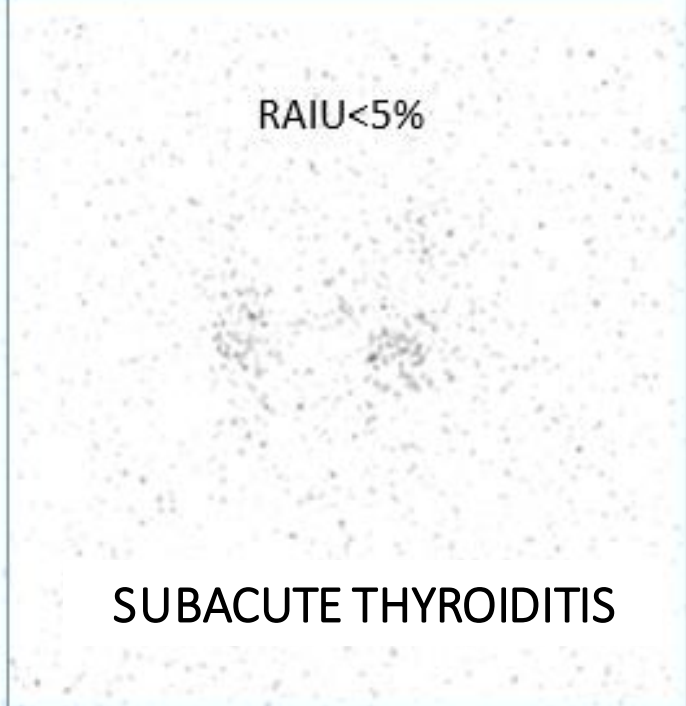
suppression of
remainder of gland



TOXIC ADENOMA

RAIU < 5%

SUBACUTE THYROIDITIS



Therapeutic Options

Radioactive Iodine Treatment

As primary or secondary after medications or surgery

Pharmacologic

Thioureas (Anti-Thyroid Drugs)

Propylthiouracil (PTU)

Methimazole (MZ)

Carbimazole (CBZ)

Symptomatic control with beta blockers

Corticosteroids

Stable Iodide (SSKI, etc.)

Rituximab

Surgery

^{131}I Treatment

Beta-emitting radionuclide

Energy level 606 keV (beta) and 364 keV (gamma)

Produced by reactor (fission)

Half life of 8 days

Indications

Hyperthyroidism

Graves' disease

Toxic multinodular goiter

Toxic adenoma

Differentiated papillary thyroid cancer

Papillary thyroid cancer

Follicular thyroid cancer

Myocardial Perfusion

Radiopharmaceuticals

^{99m}Tc -sestamibi

^{99m}Tc -tetrofosmin

^{201}Tl Thalium

Methods of Inducing Stress

Pharmacologic

Adenosine

Dobutamine

Dipyridamole

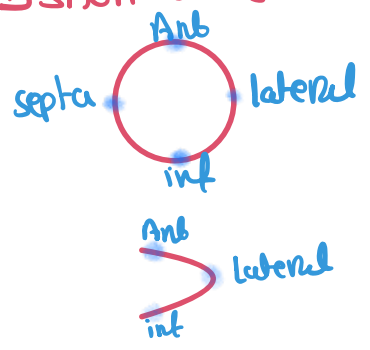
Regadenosone

Exercise

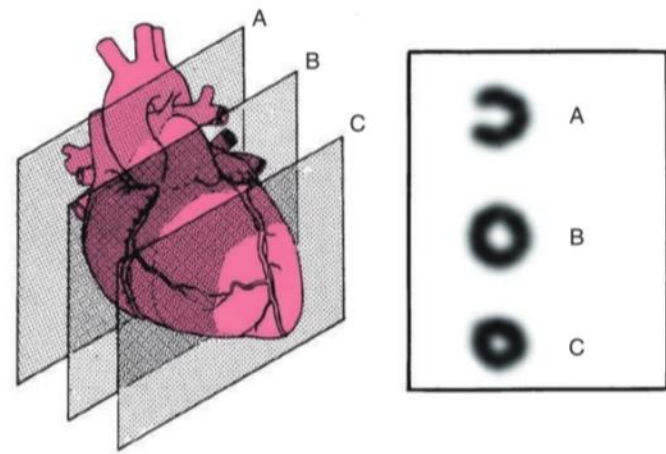
Treadmill

Bicycle

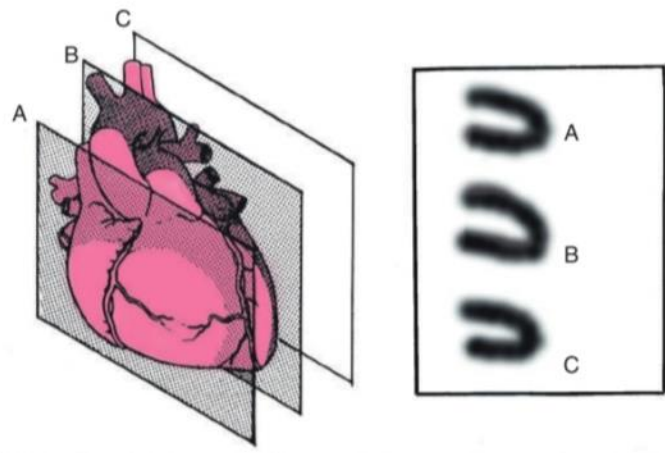
Short axis from apex to base



• Fig. 5.8 Short-Axis Anatomy and Images. Short-axis sections through the left ventricle from the base of the heart to the apex are shown with corresponding single-photon emission computed tomography slices of the myocardium. Note the considerable thinning of the proximal septal wall in plane A (the base of the heart) as a result of the membranous septum.



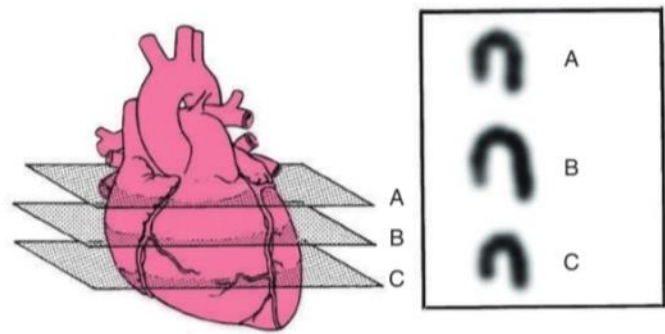
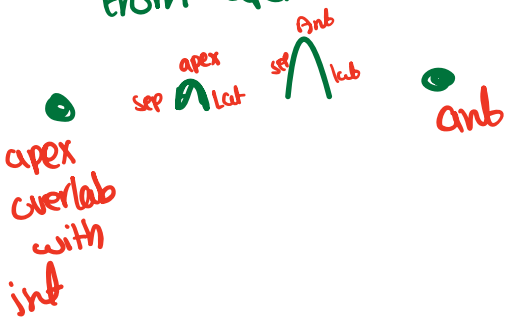
2) Vertical long axis from septal to lateral wall



• Fig. 5.9 Vertical Long-Axis Anatomy and Images. Vertical long-axis sections through the left ventricle from septum to free (lateral) wall are shown with corresponding single-photon emission computed tomography slices of the myocardium.

* fixed defect between rest + stress
 → spurious MI (infarction)
 Treat By medication

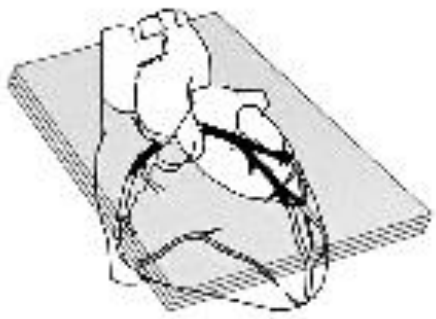
3) Horizontal axis from apex to base (inf to ant)



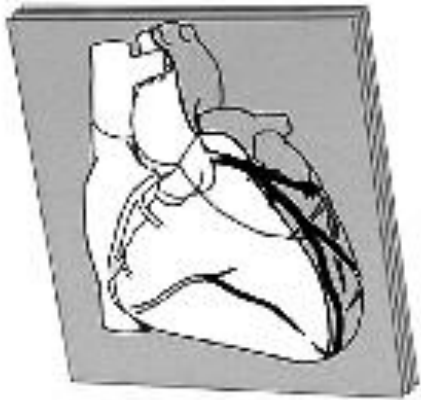
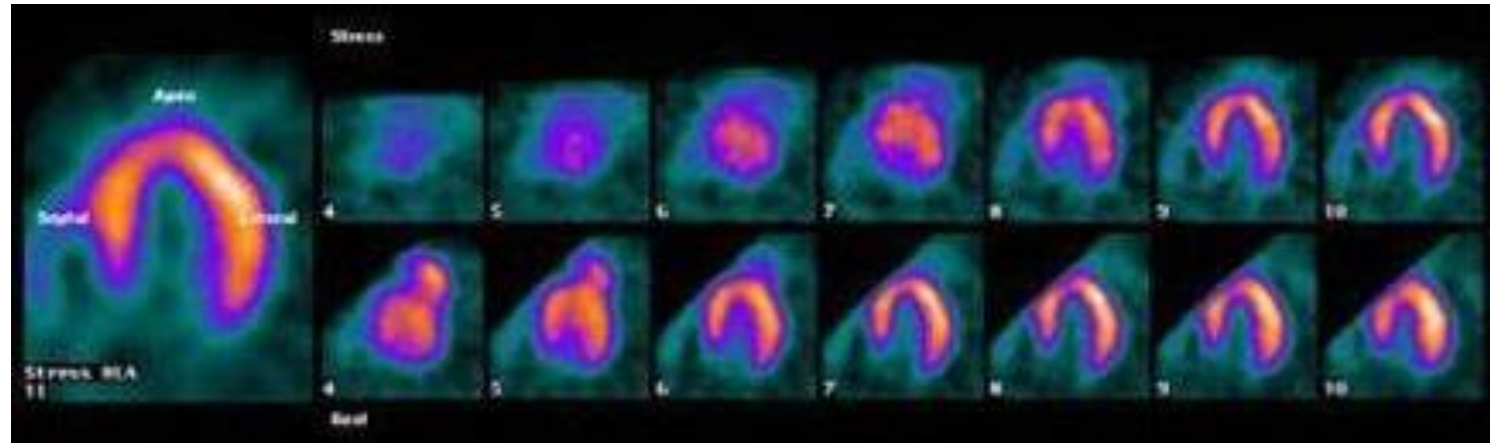
• Fig. 5.10 Horizontal Long-Axis Anatomy and Images. Horizontal long-axis sections through the left ventricle from the anterior to the inferior wall are shown with corresponding single-photon emission computed tomography slices of the myocardium.

* Normal at rest abnormal at stress
 → ischemia → PCI

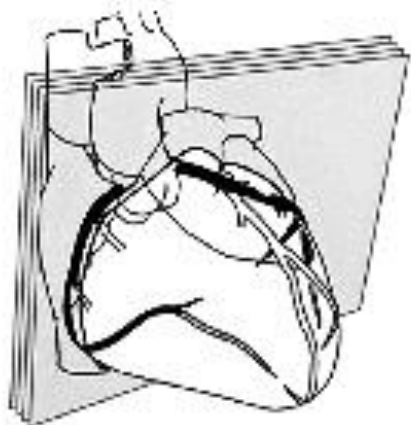
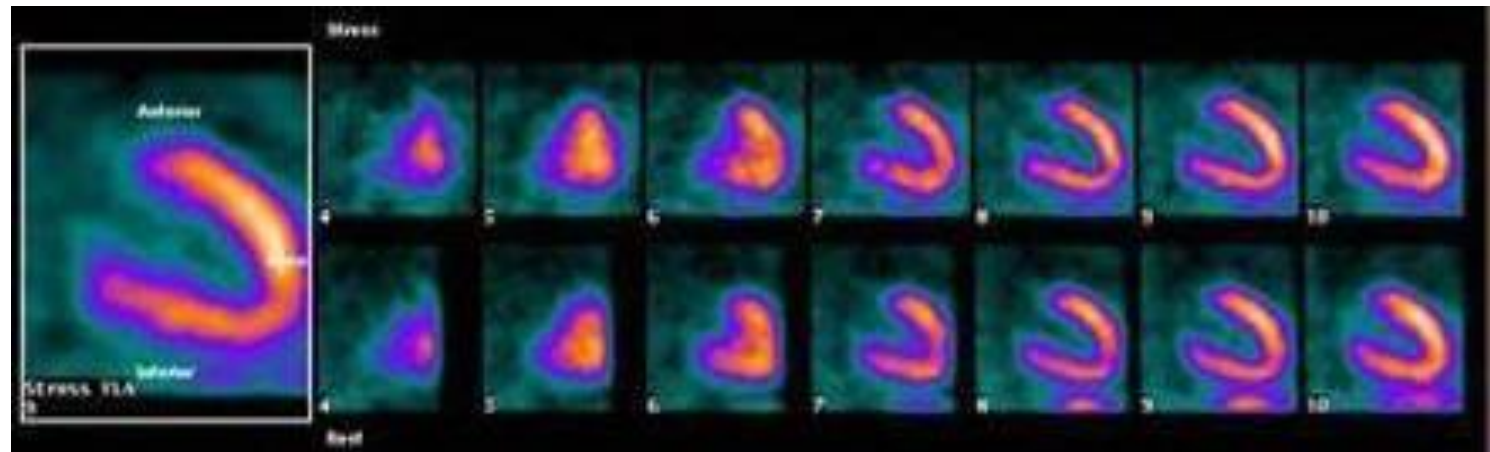
Normal ✖



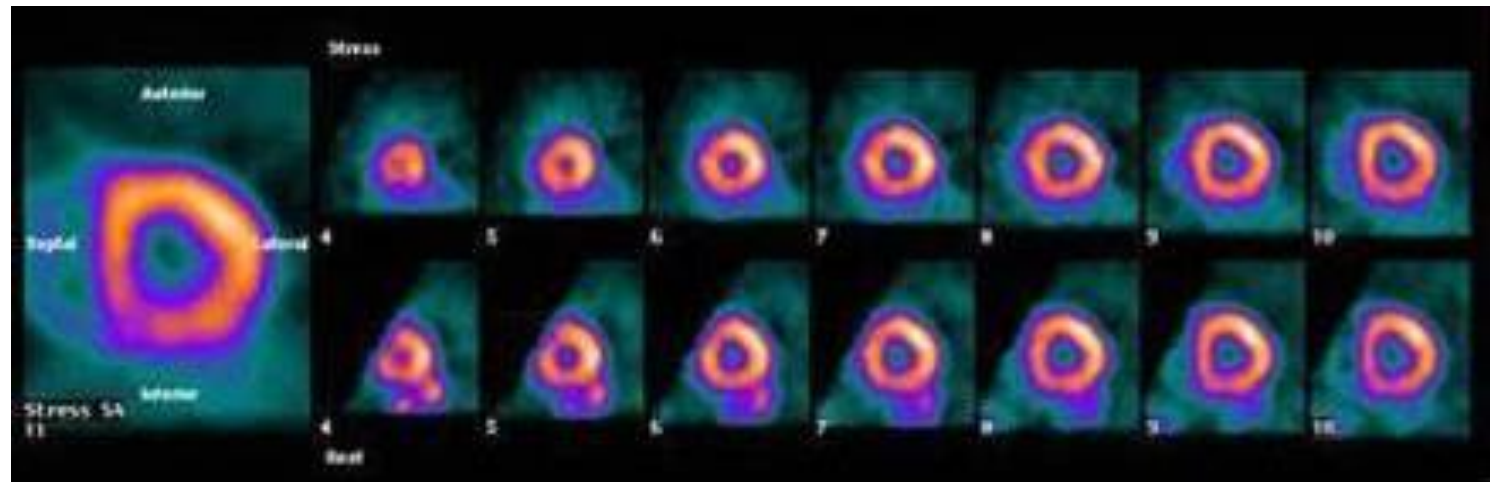
A



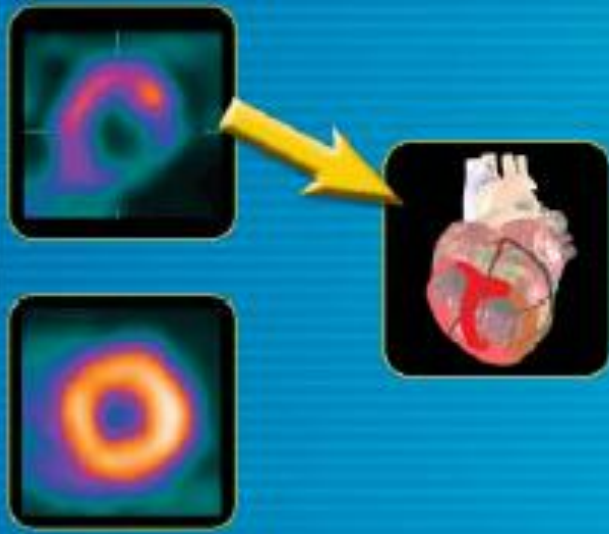
B



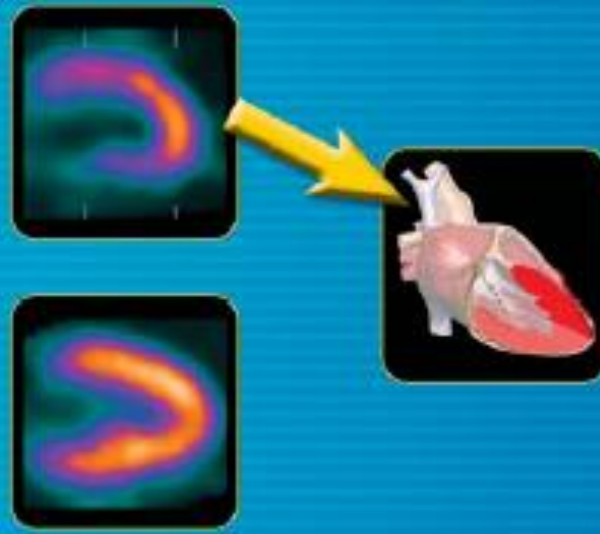
C



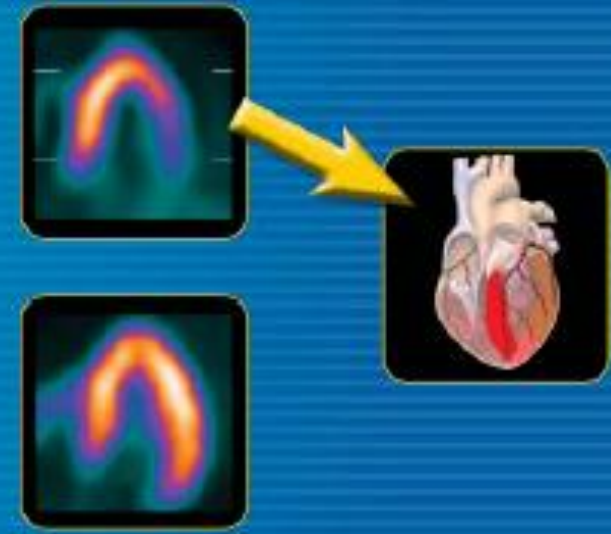
Short



Vertical



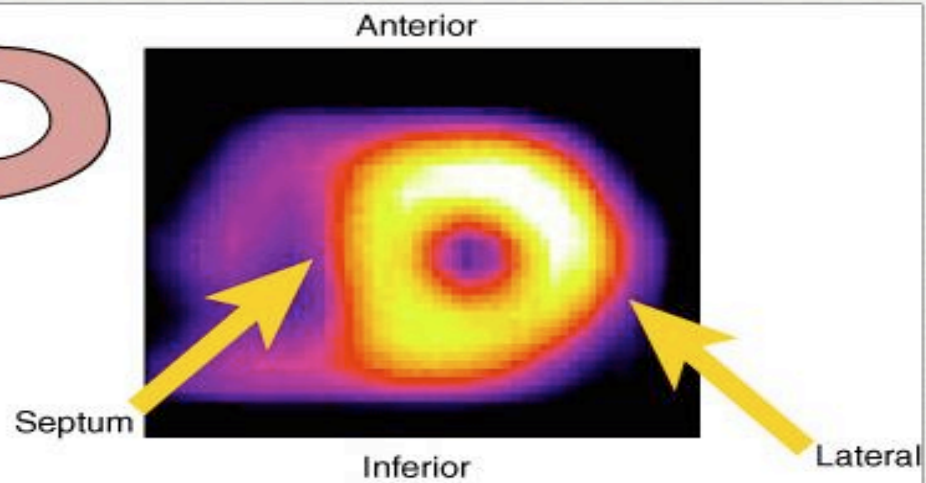
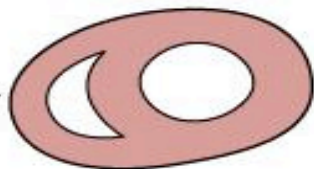
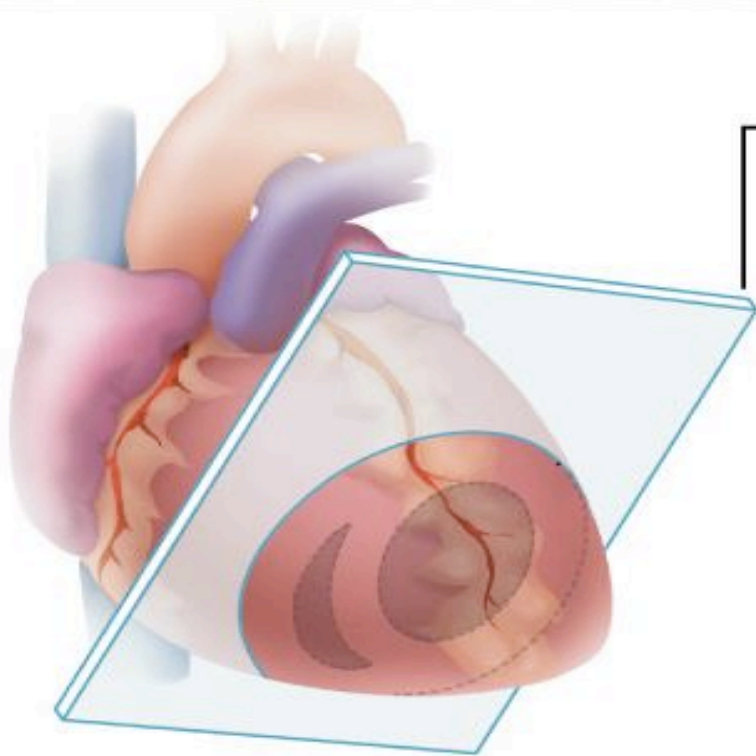
Horizontal



Lateral
wall
ischemia

inferior
wall
ischemia

lateral
wall
ischemia

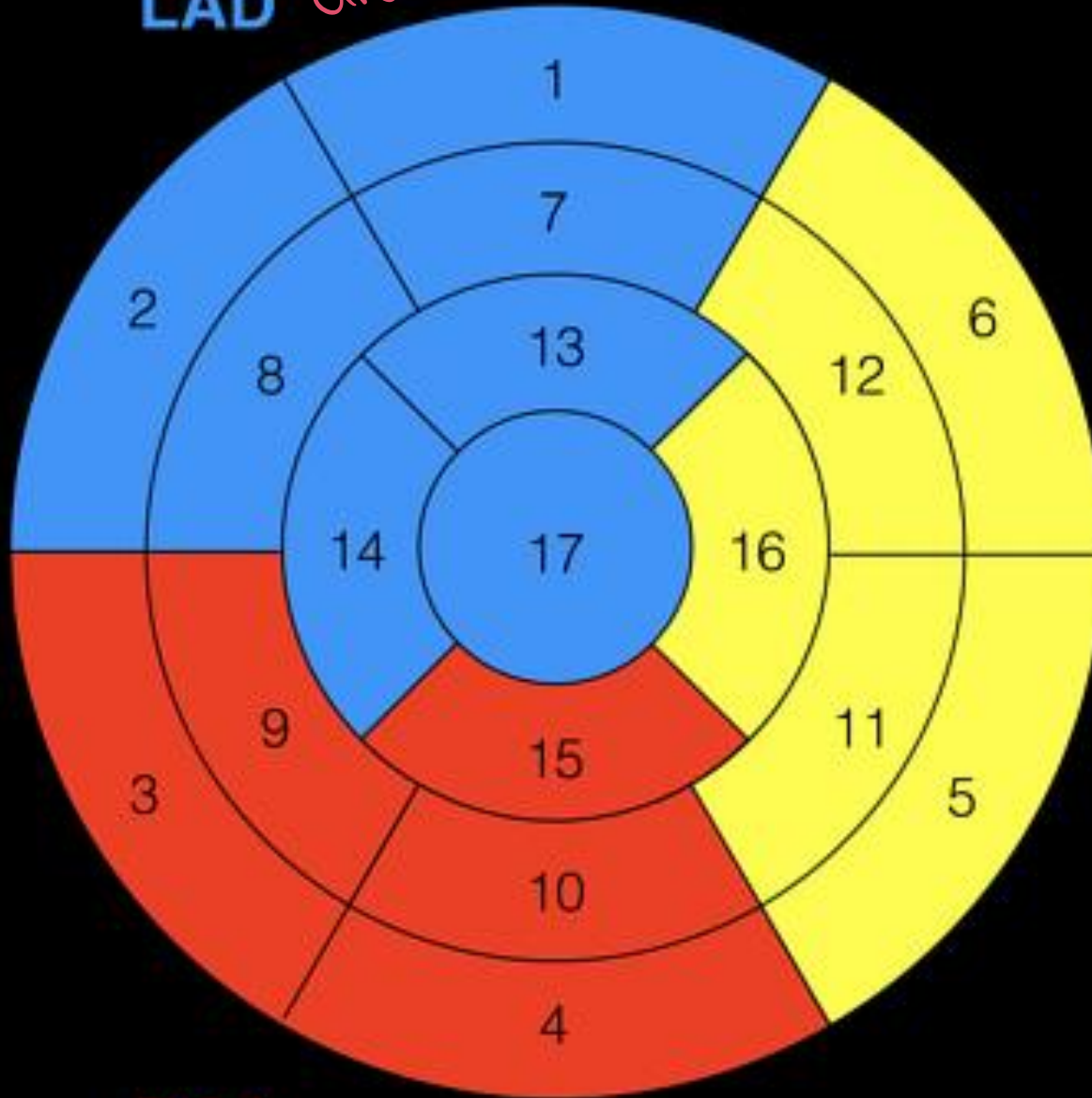


A

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LAD *anteroseptal*



LCx
lateral

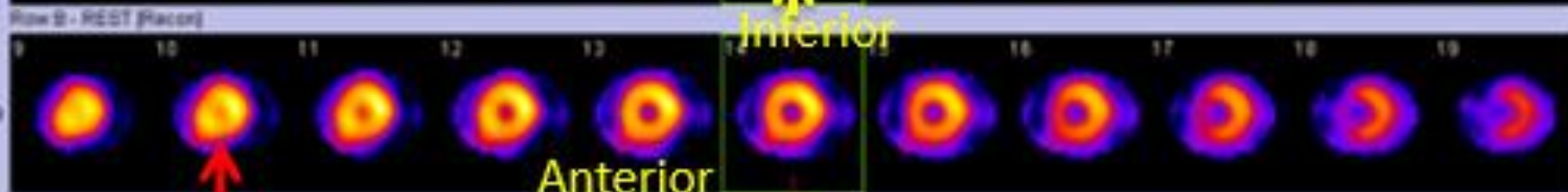
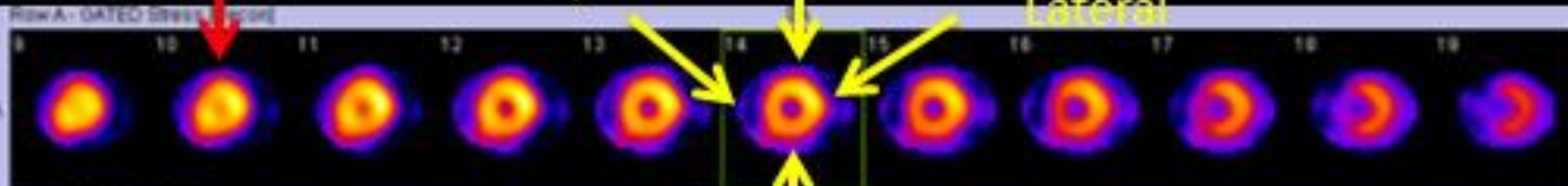
RCA
inf

Stress

Anterior

Septal

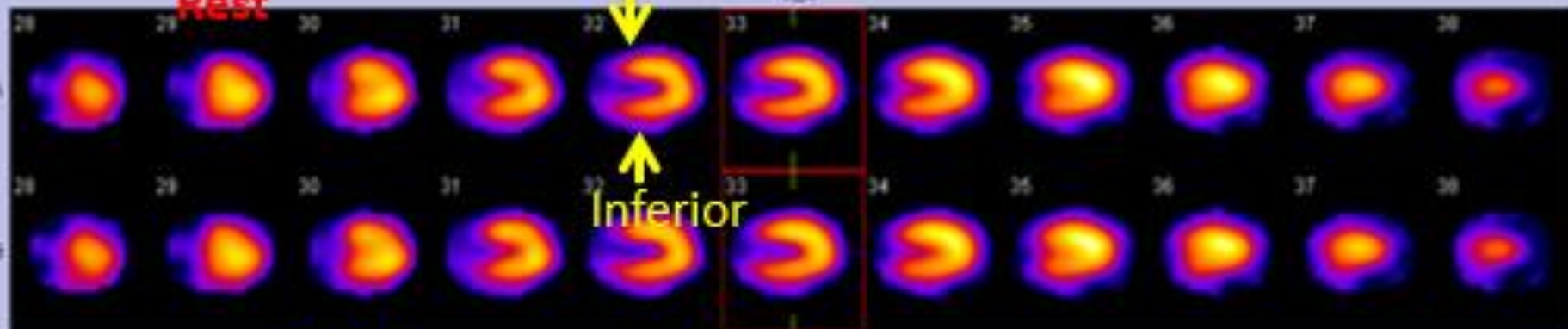
Lateral



Rest

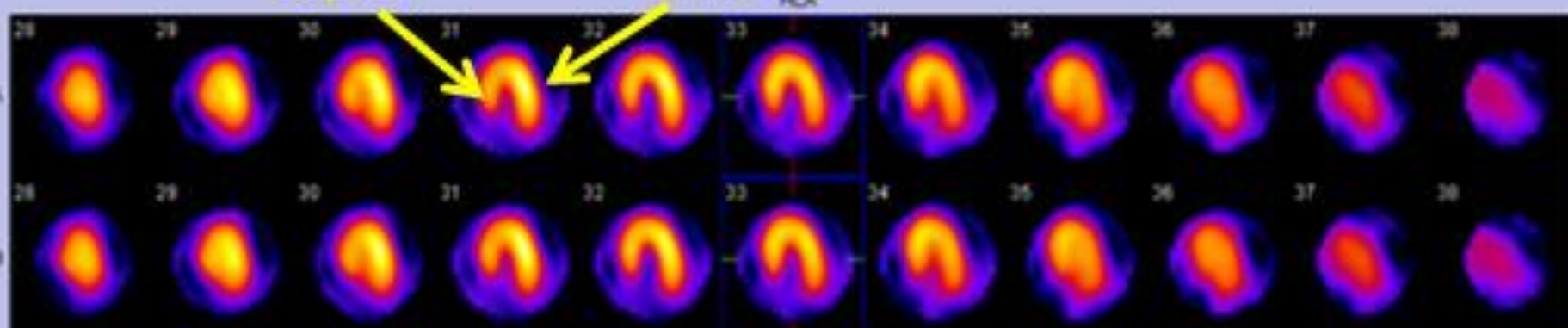
Anterior

Inferior



Septal

Lateral



Color scale: % 0 to 100

Anterior to Inferior

Septal to Lateral

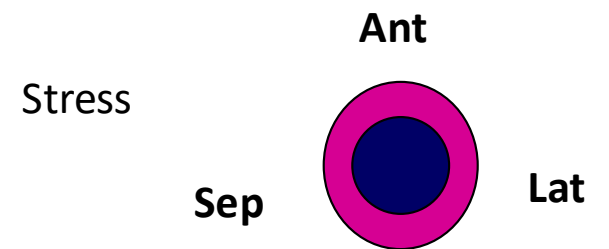
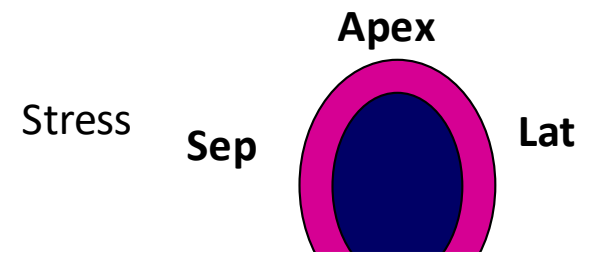
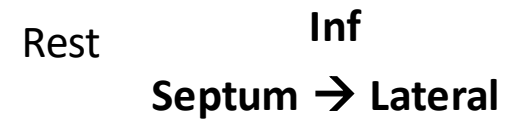
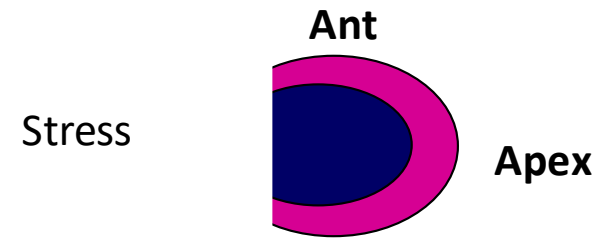
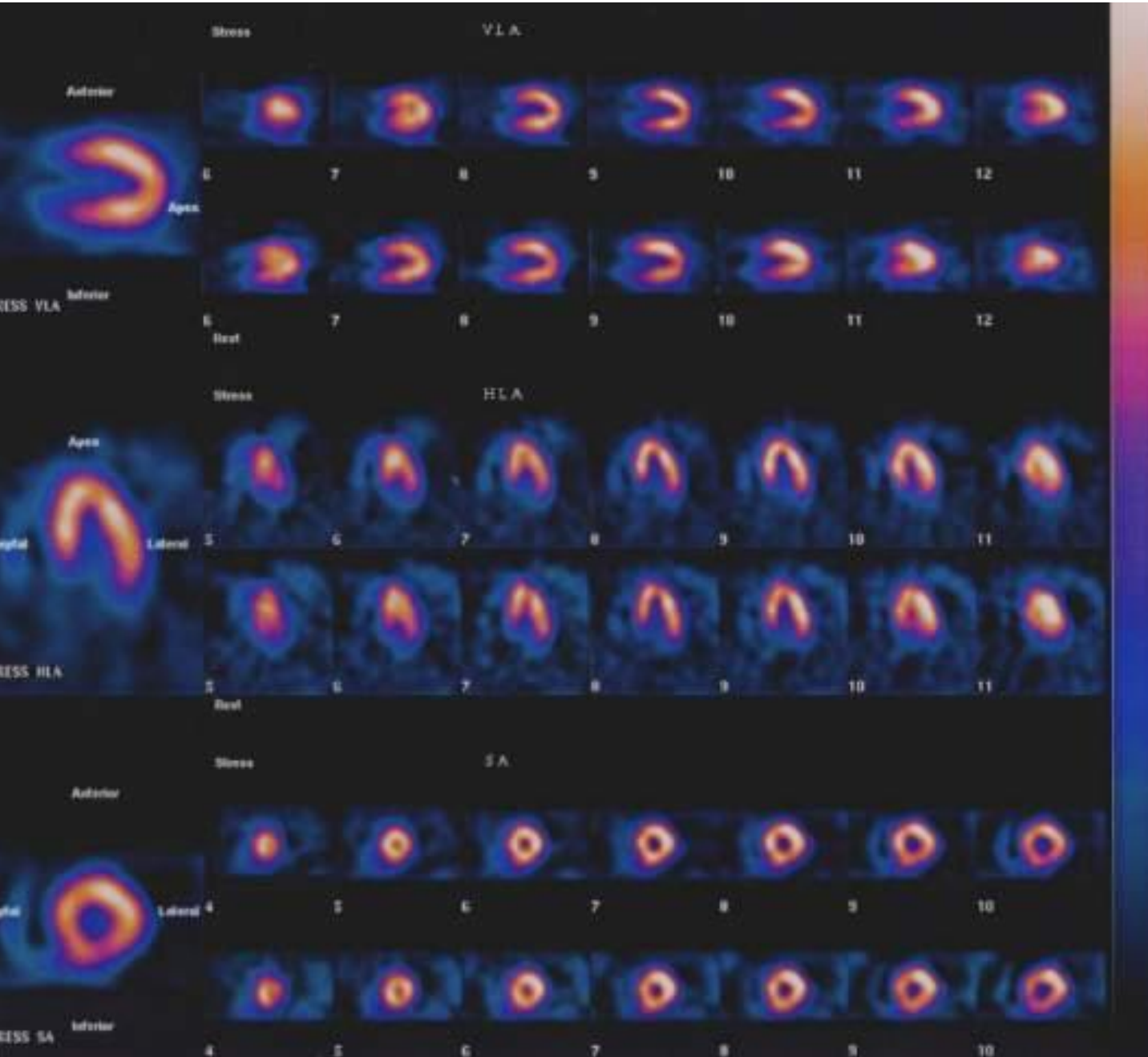
Anterior to Base

Anterior to Inferior

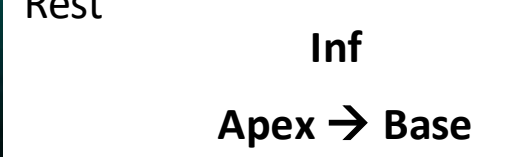
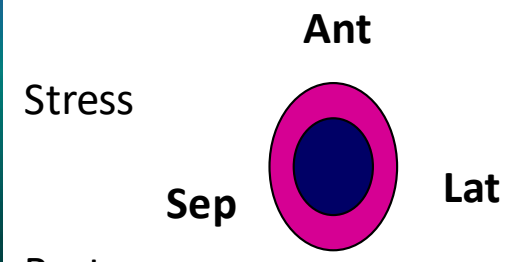
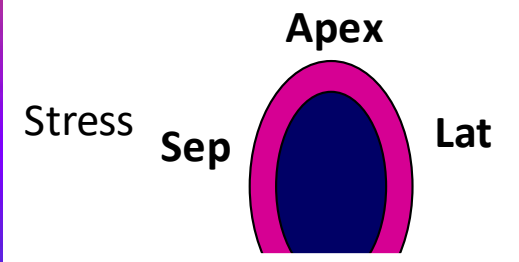
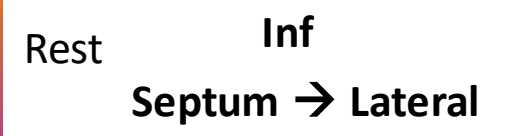
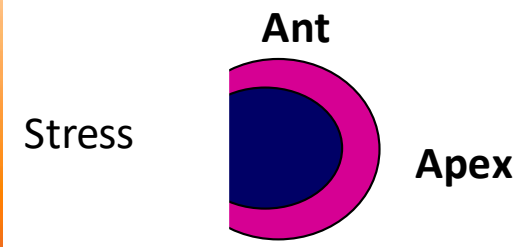
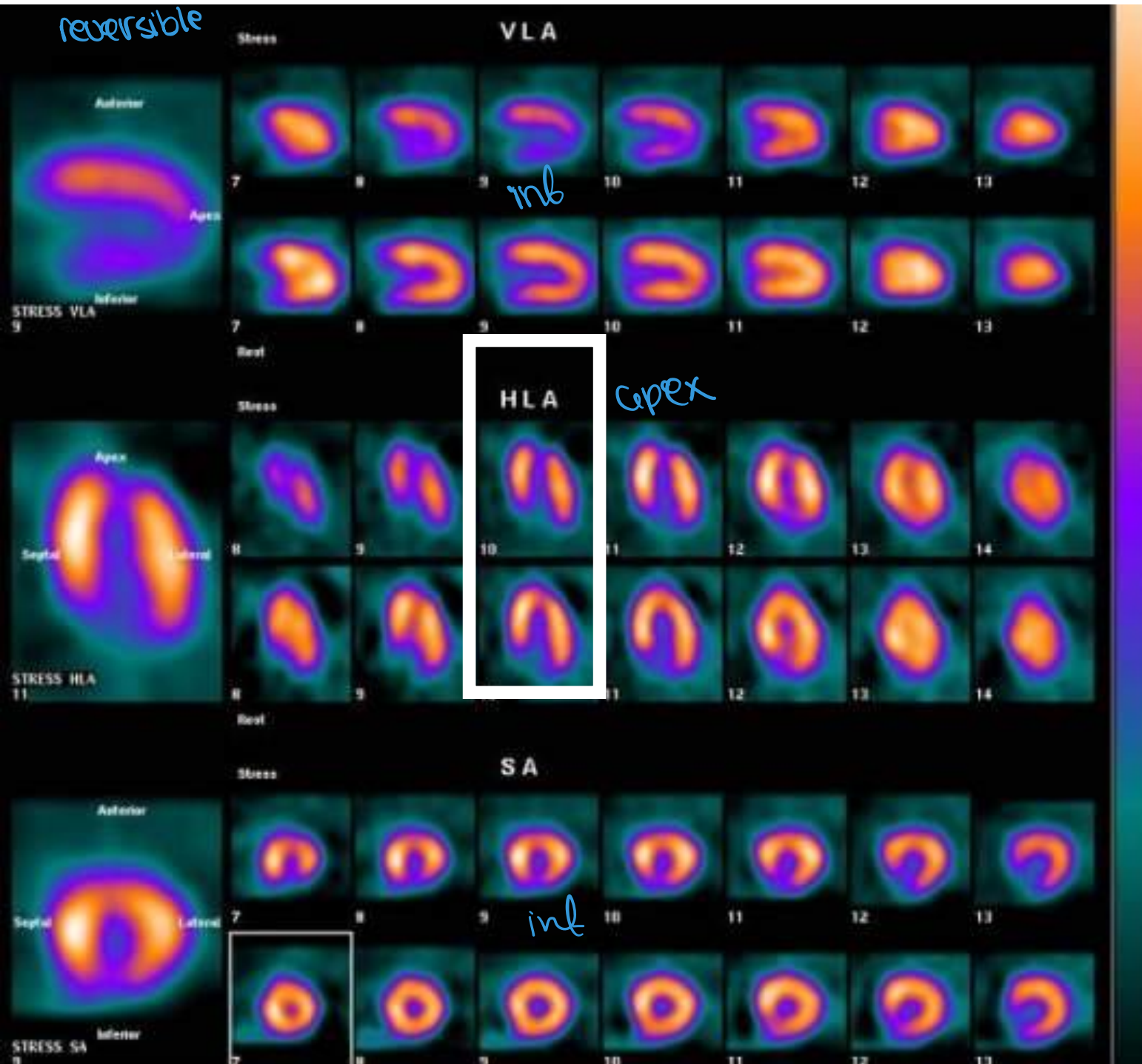
Septal to Lateral

Anterior to Base

Normal

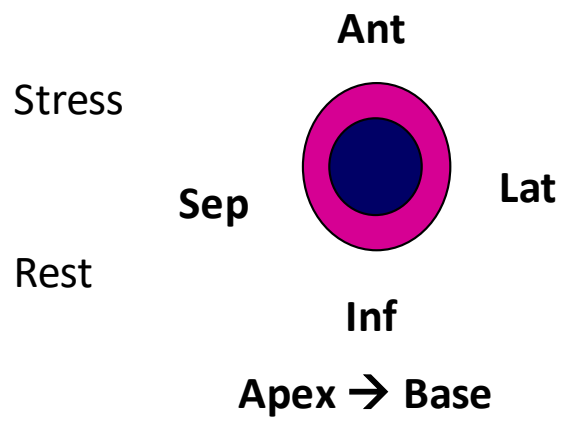
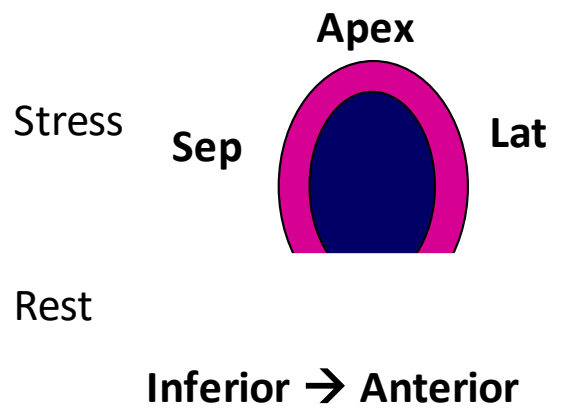
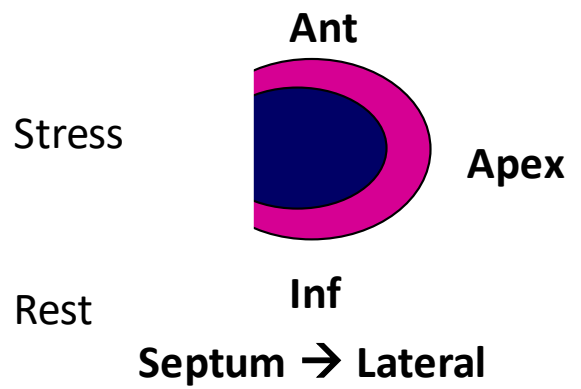
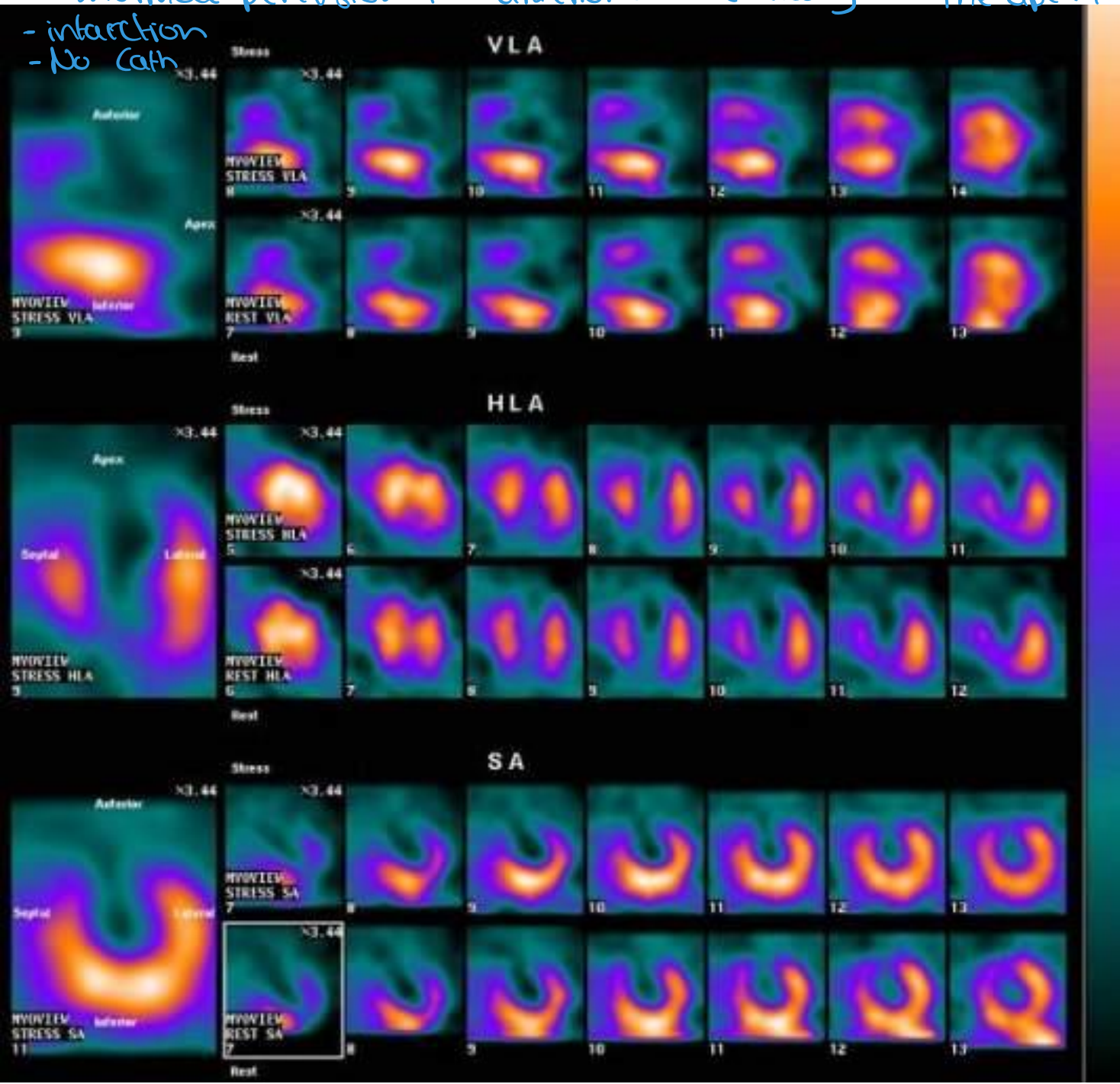


Decrease perfusion in inf wall extending to the apex
reversible

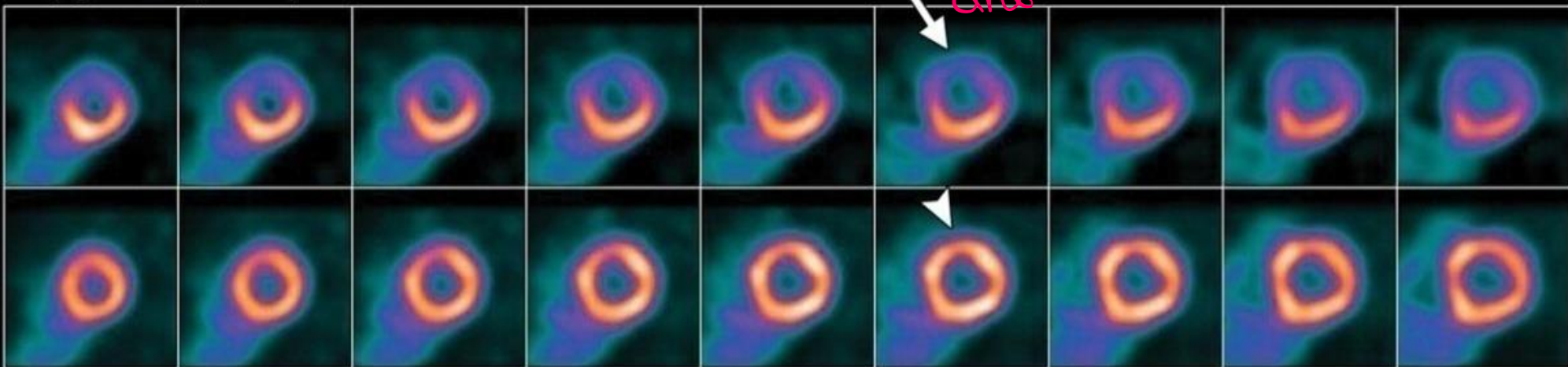


- fixed
 - abnormal perfusion in anterior wall extending to the apex + septum

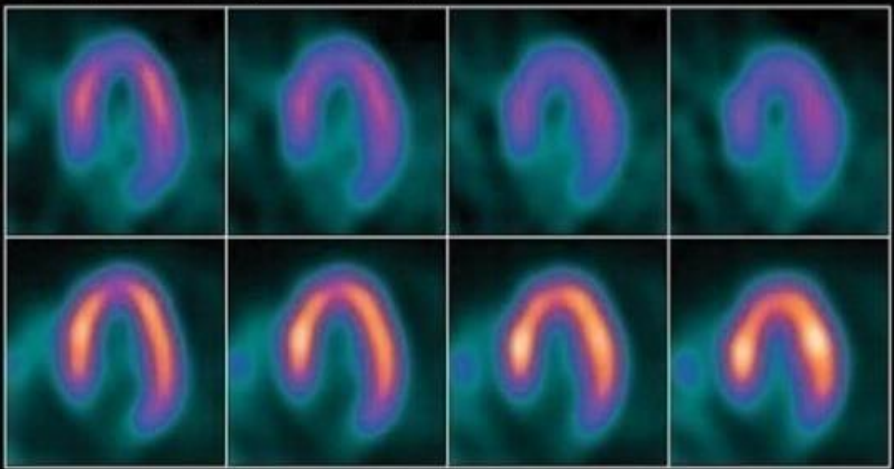
- infarction
 - No Cath



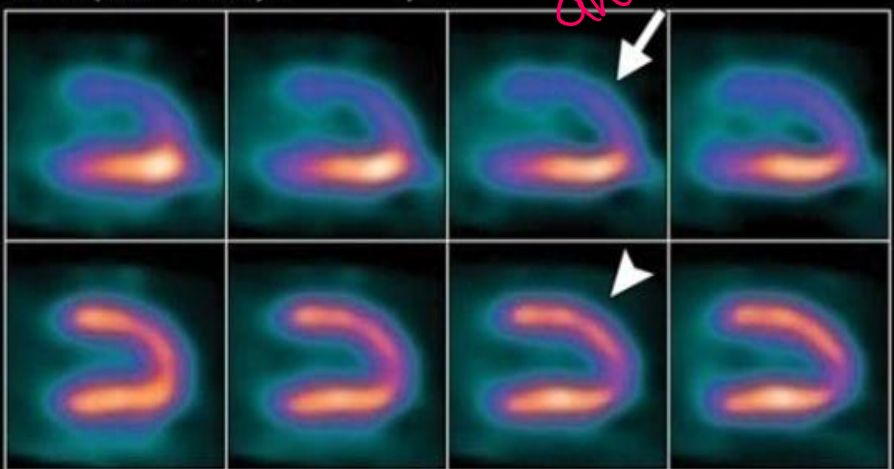
SA (Apex→Base) ←

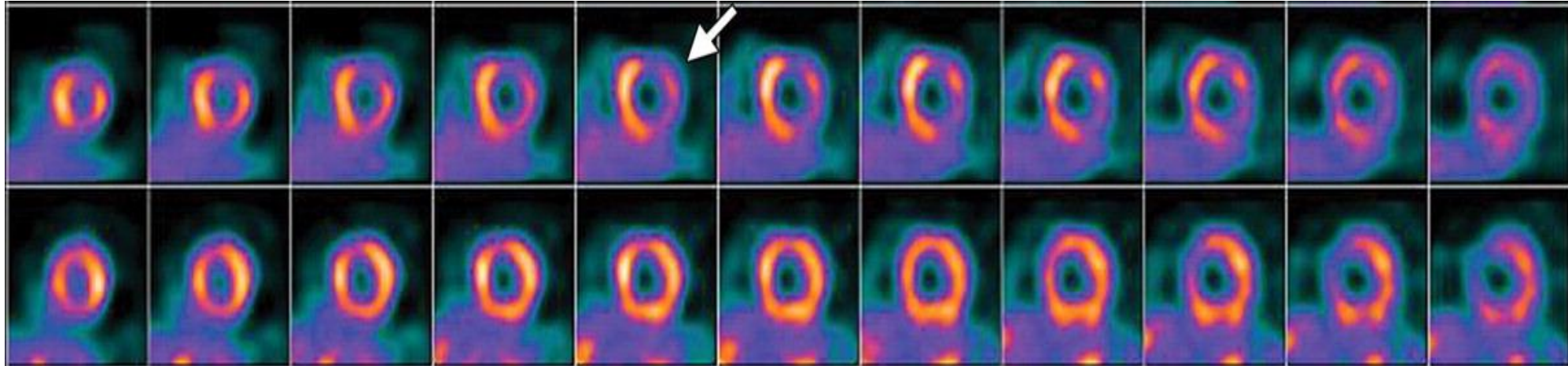


HLA (INF→ANT) ←

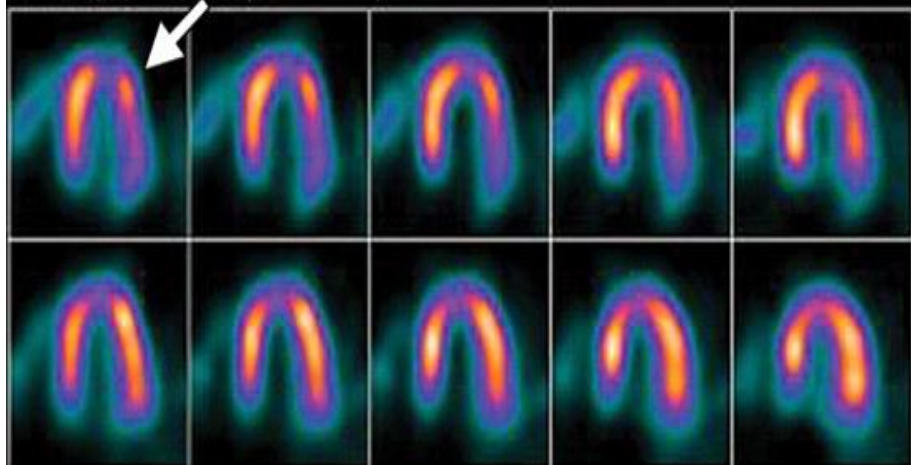


VLA (SEP→LAT) ←

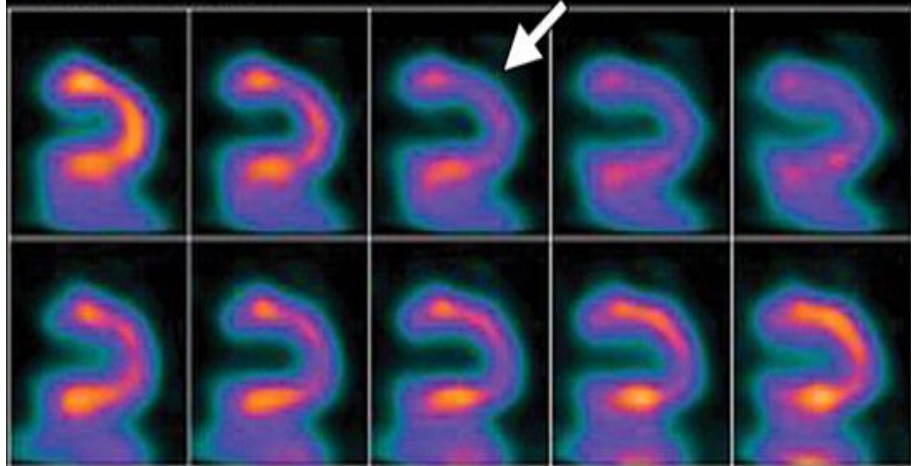


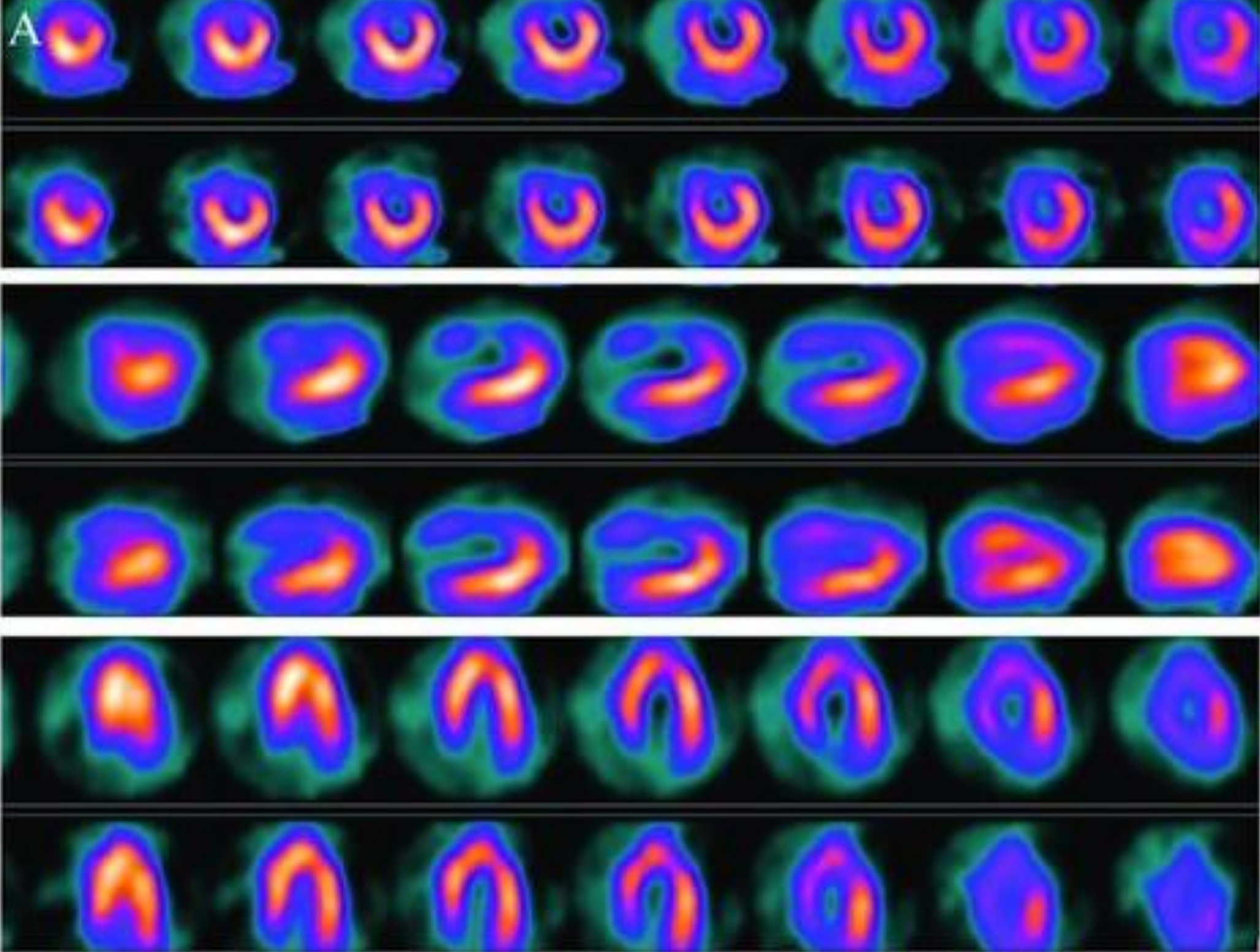


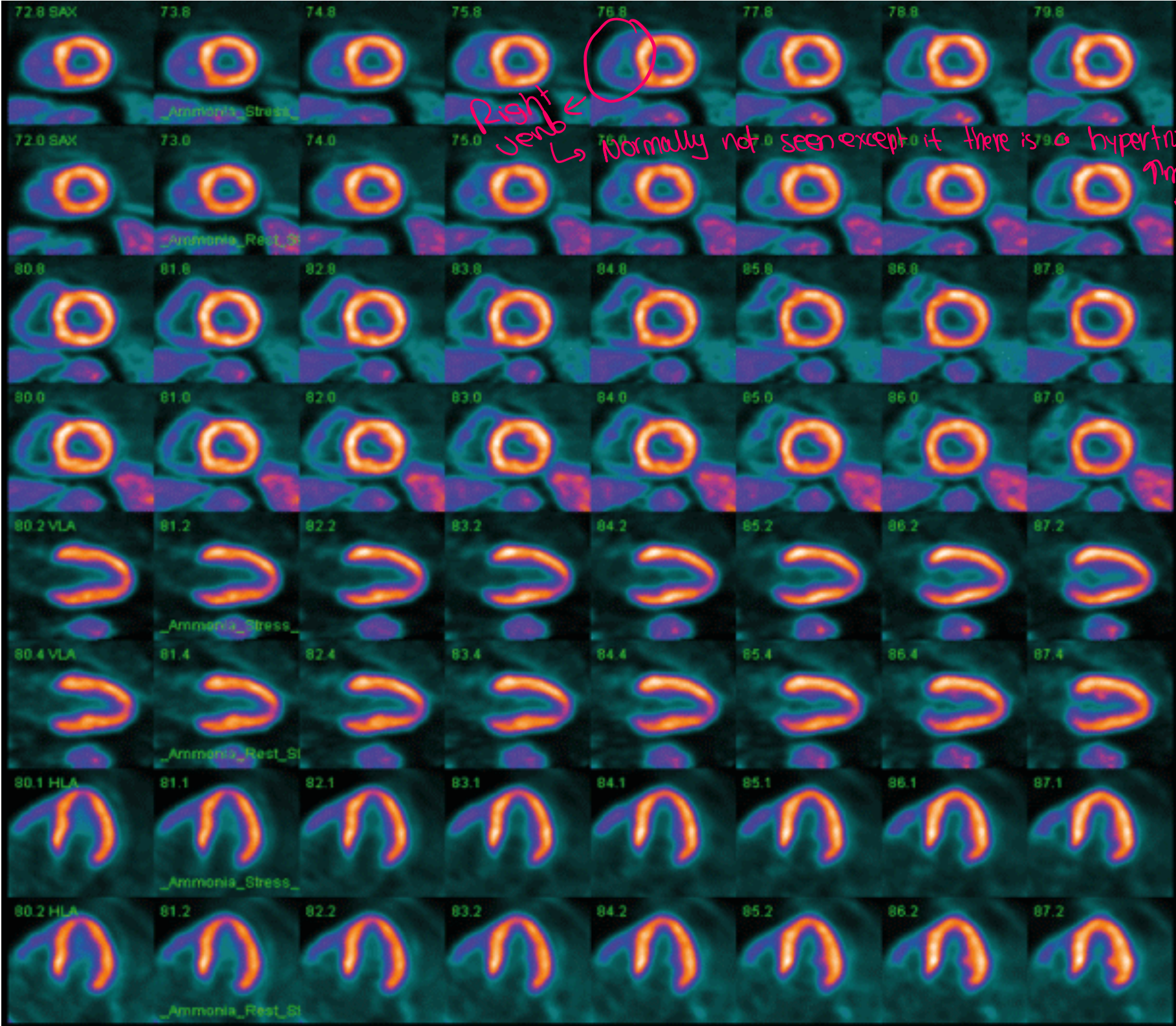
HLA (INF→ANT) ———|—————

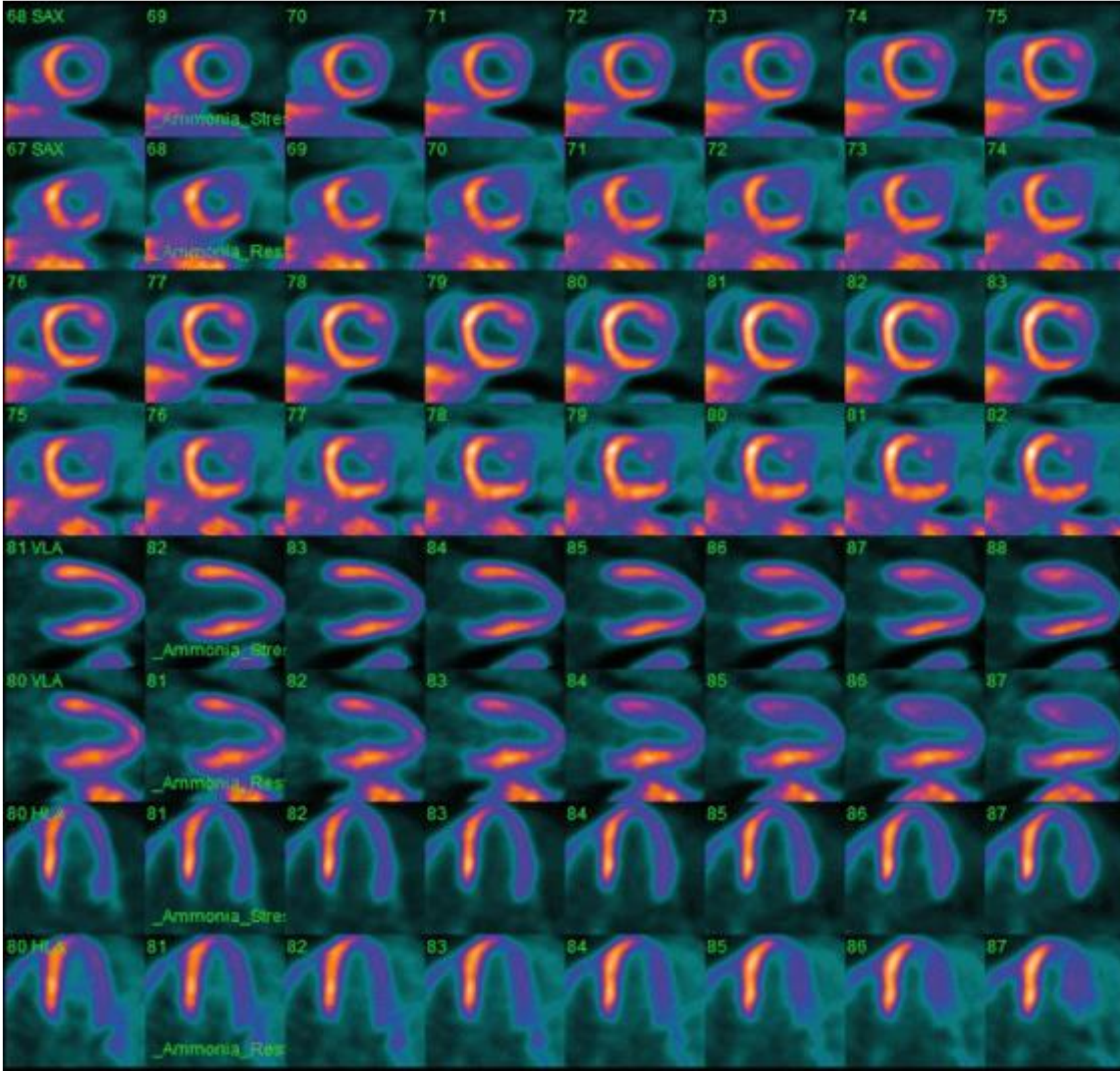


VLA (SEP→LAT) ———|—————





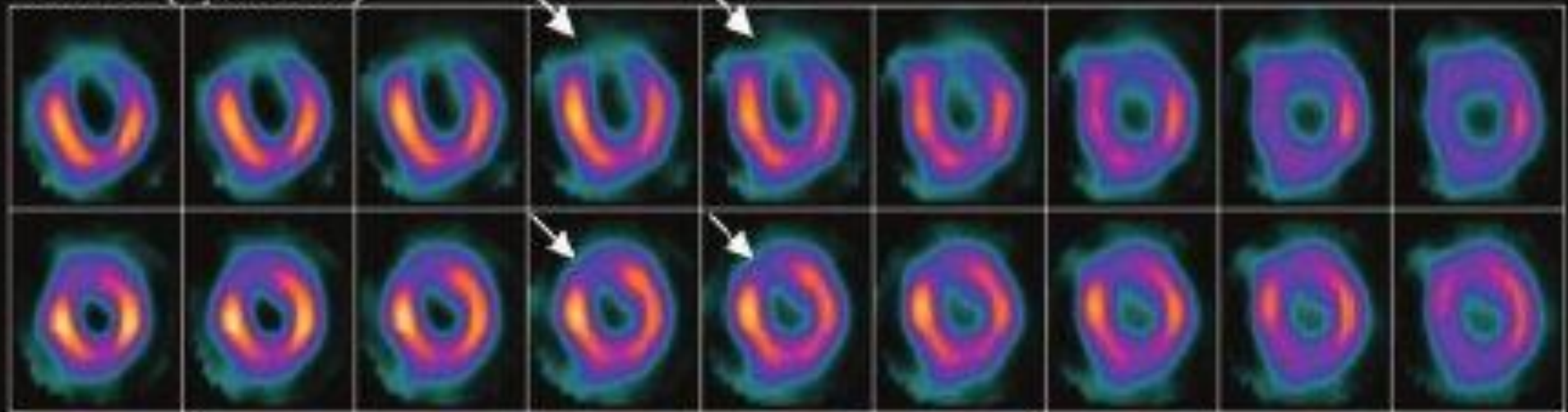




Short Axis (Apex->Base)



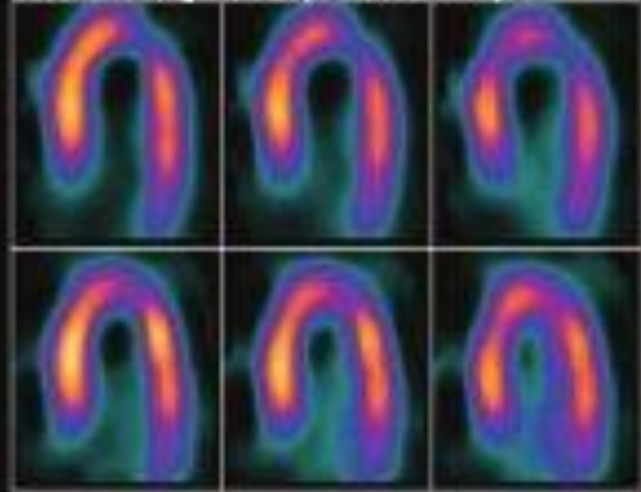
Str



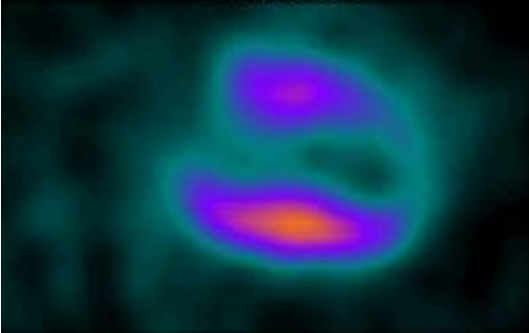
Horiz Long Axis (Post->Ant)



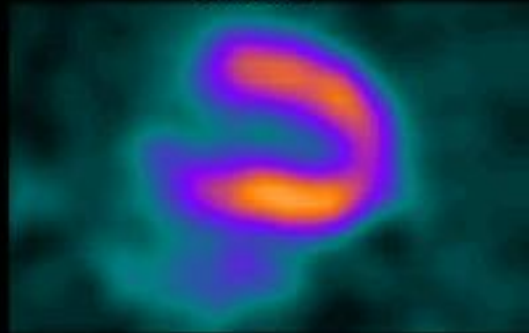
Str



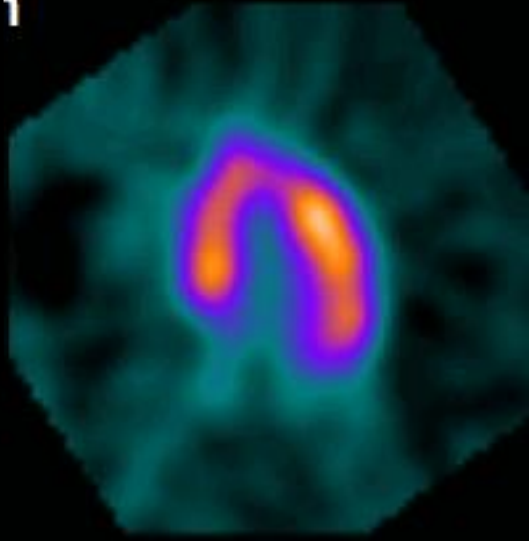
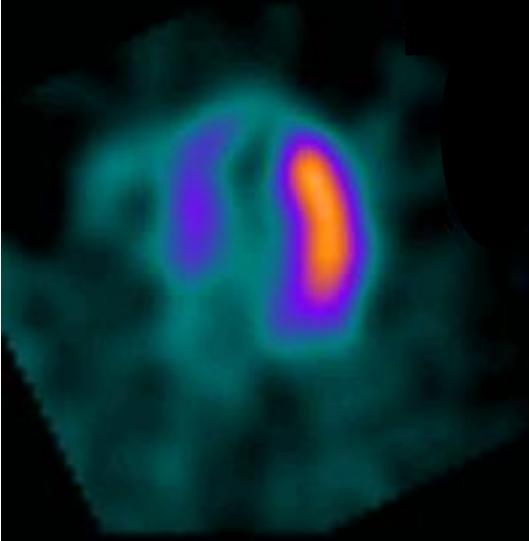
Stress



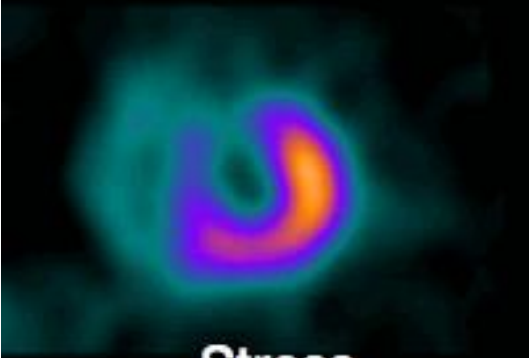
Rest



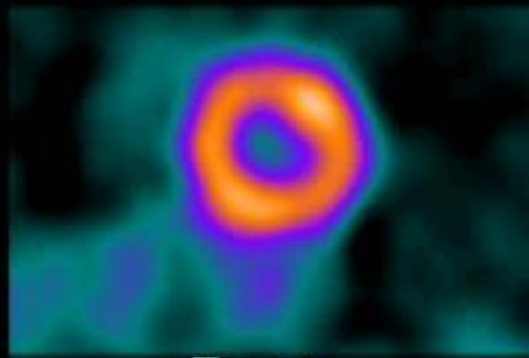
1

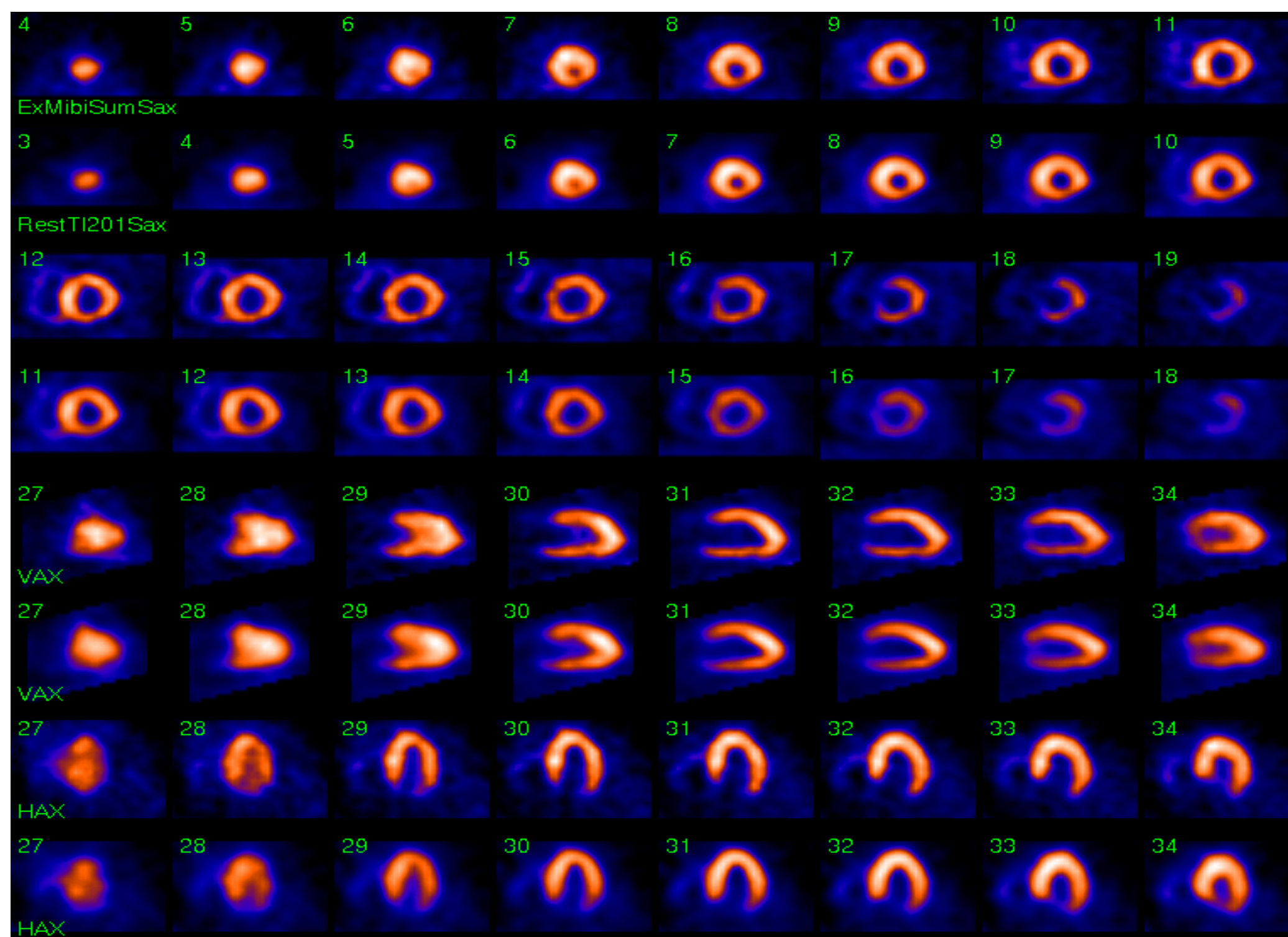


Stress

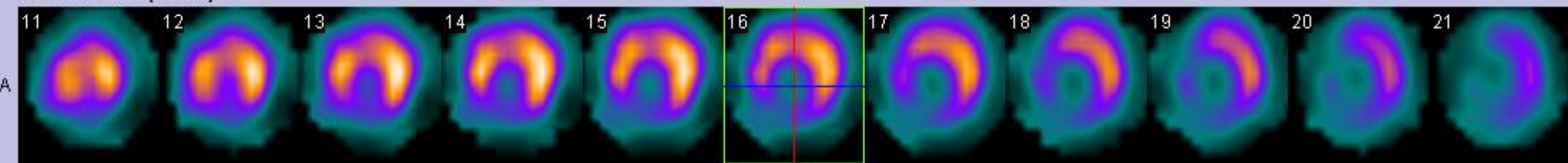


Rest

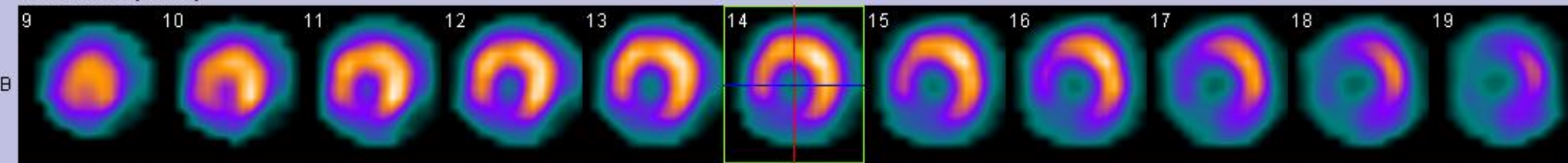




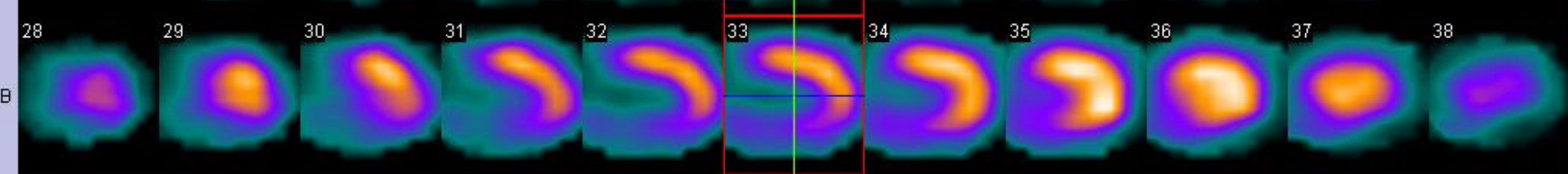
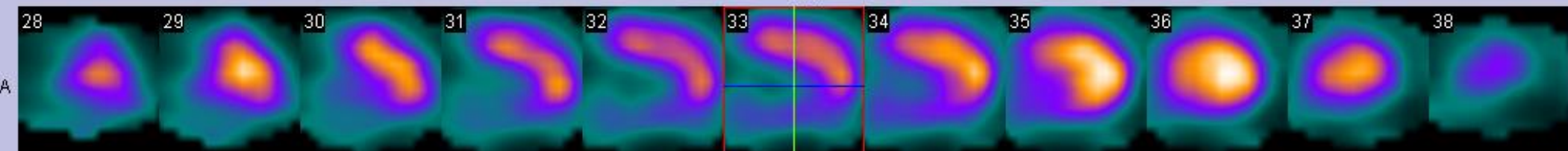
Row A - Stress [Recon]



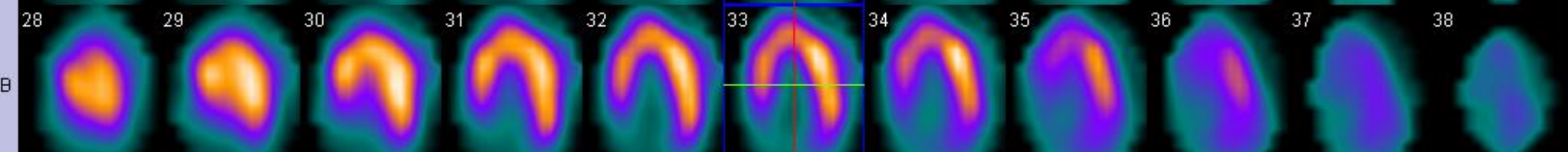
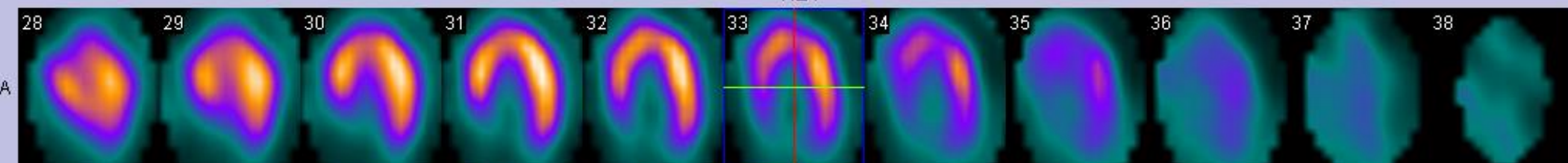
Row B - Rest [Recon]

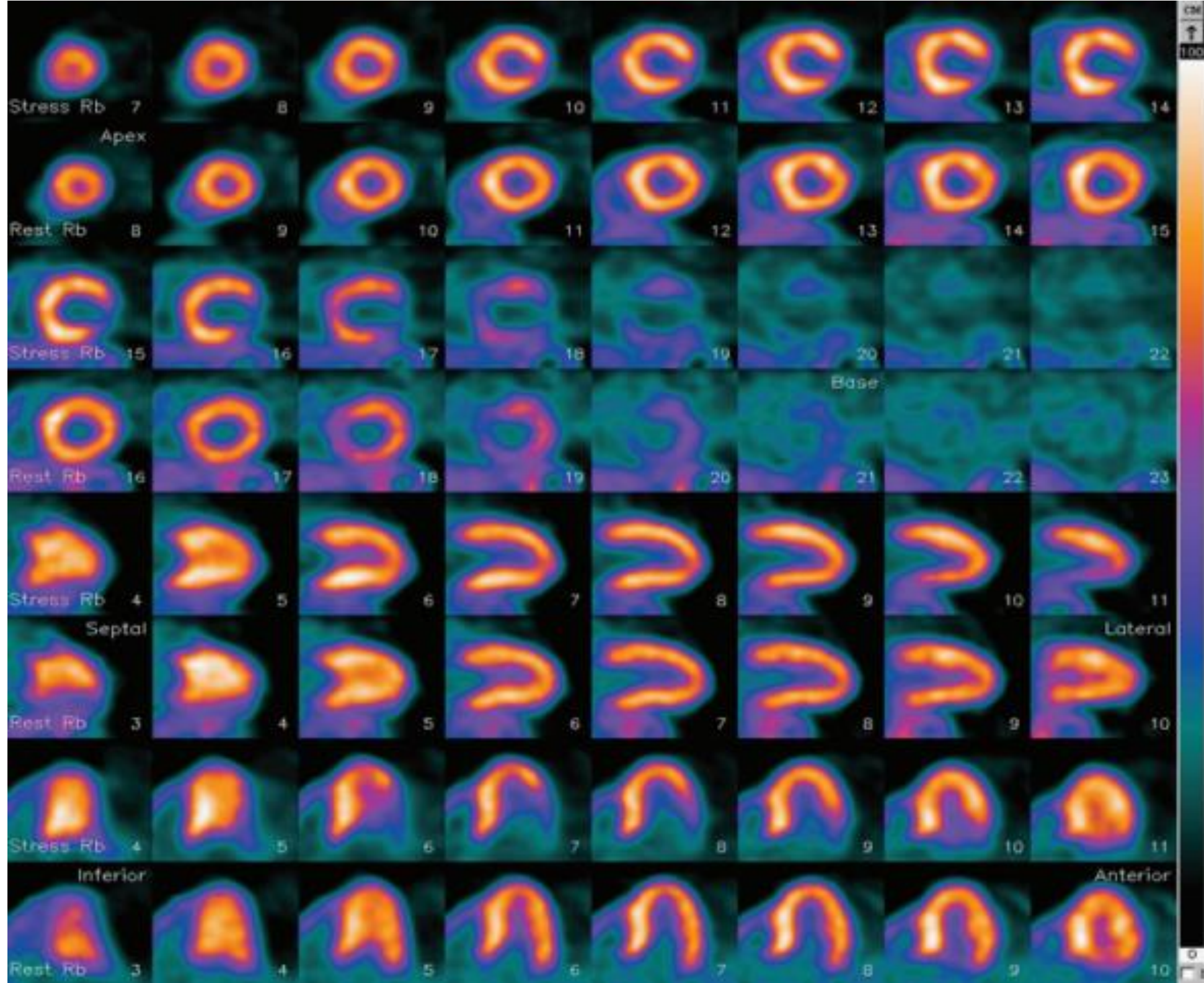


VLA



HLA

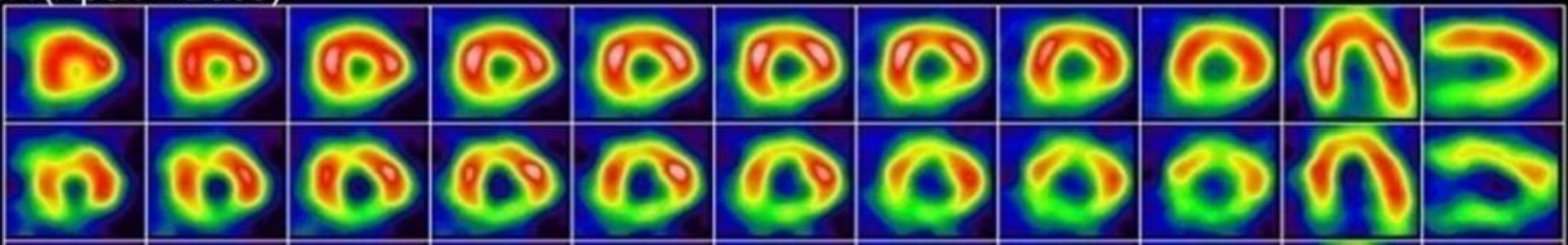


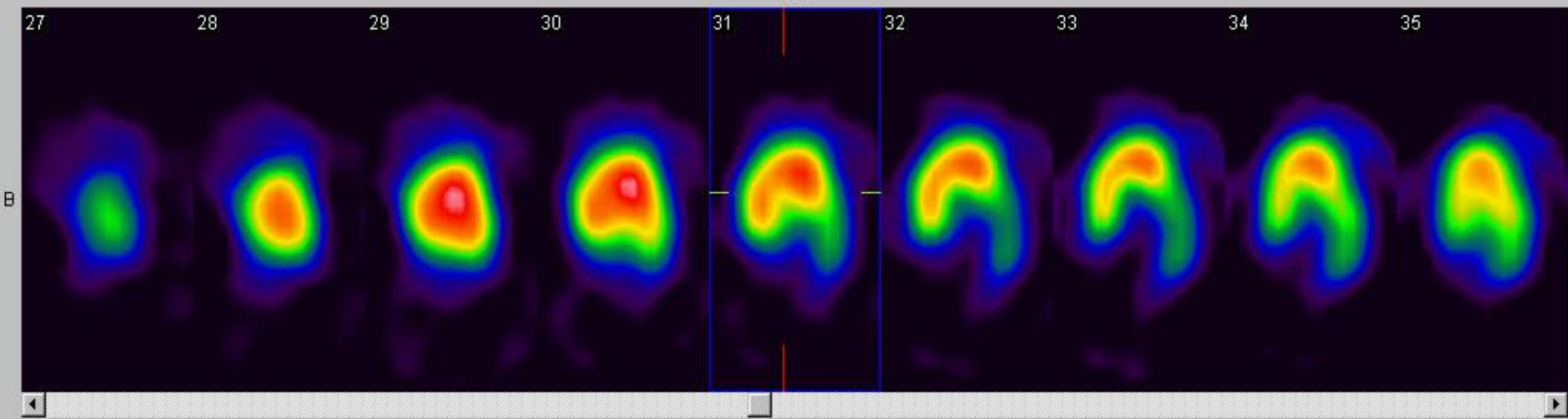
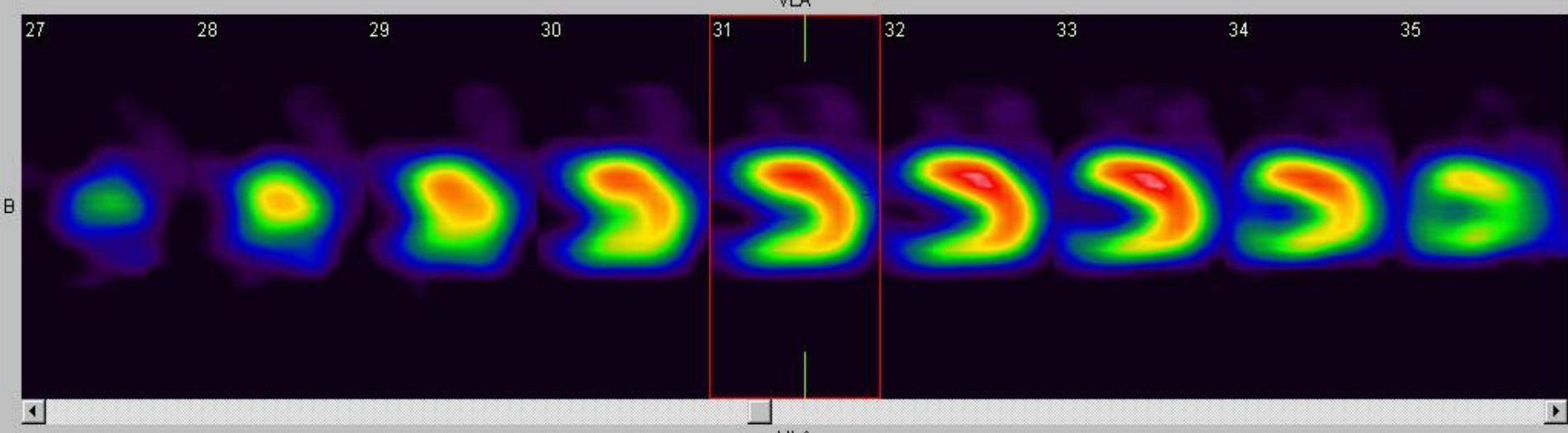
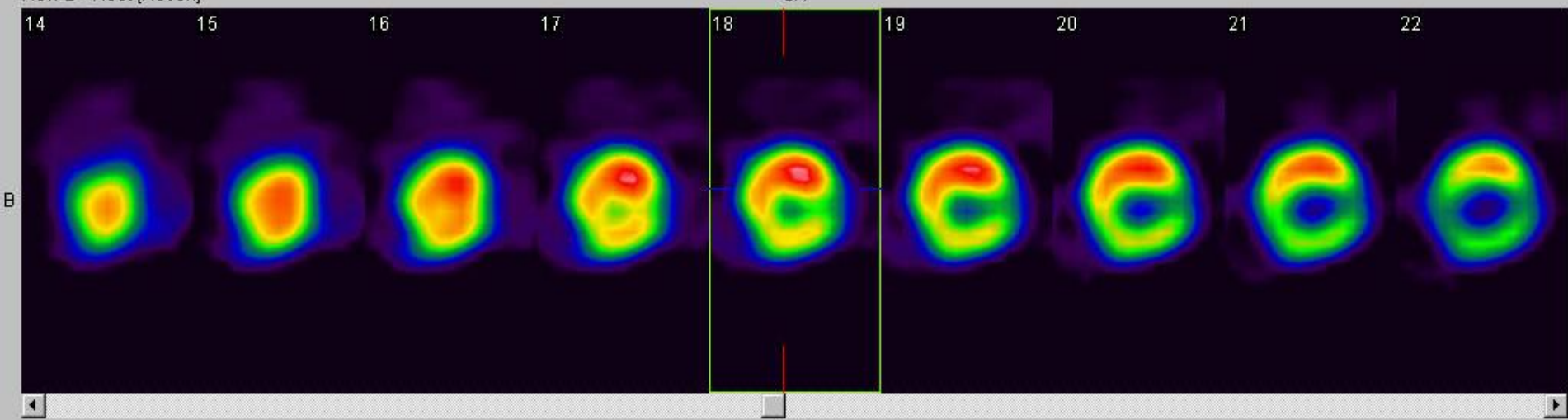


SA (Apex→Base)

Str

Rst





Lung Scintigraphy

Radiopharmaceuticals

Radiopharmaceuticals

Perfusion

^{99m}Tc -MAA (*macroaggregated albumin*)

Ventilation

^{99m}Tc -DTPA

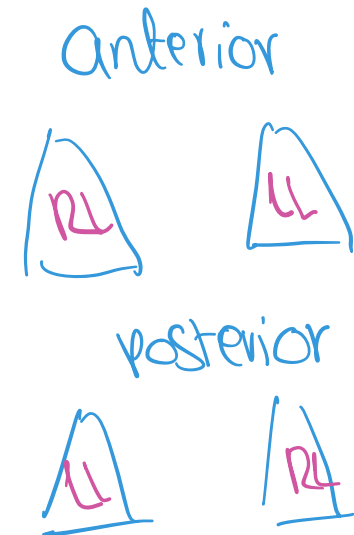
Sulfur colloid aerosols

Indications

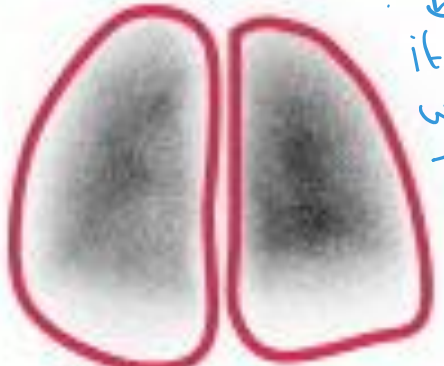
Pulmonary embolism → perfusion defect → Normal ventilation

Chronic thrombo-embolic pulmonary hypertension (CTEPH)

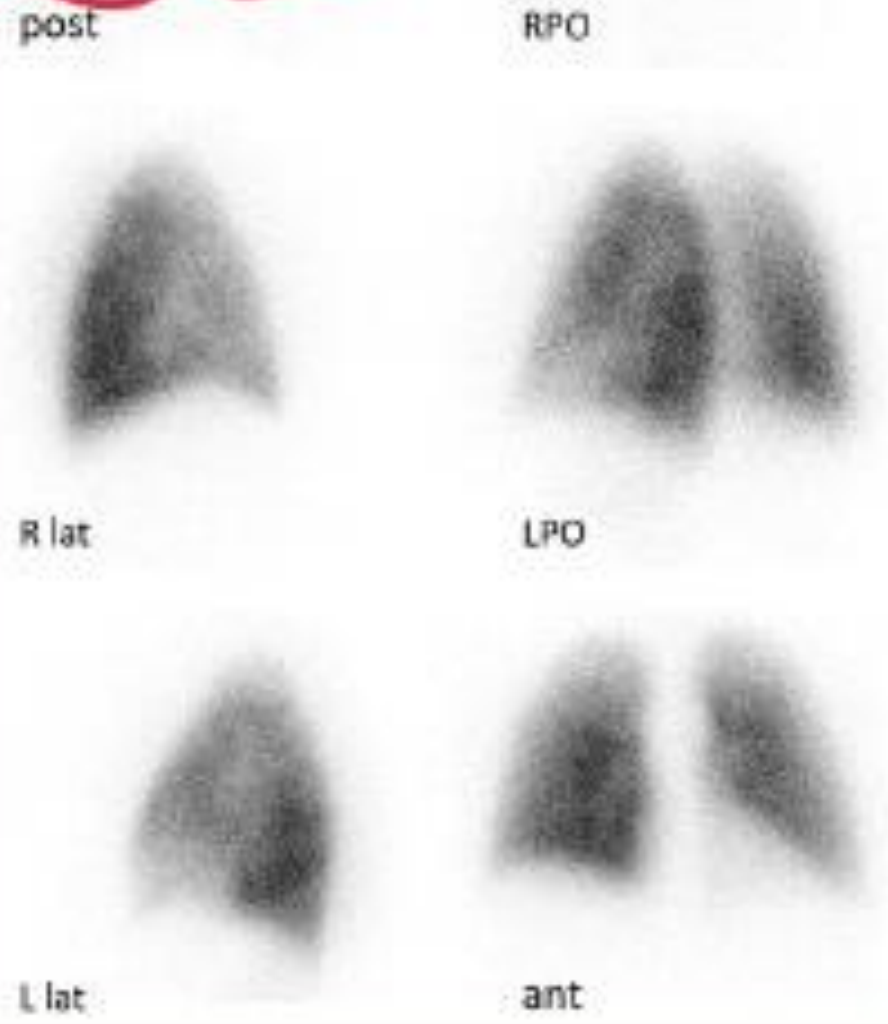
Quantitative function



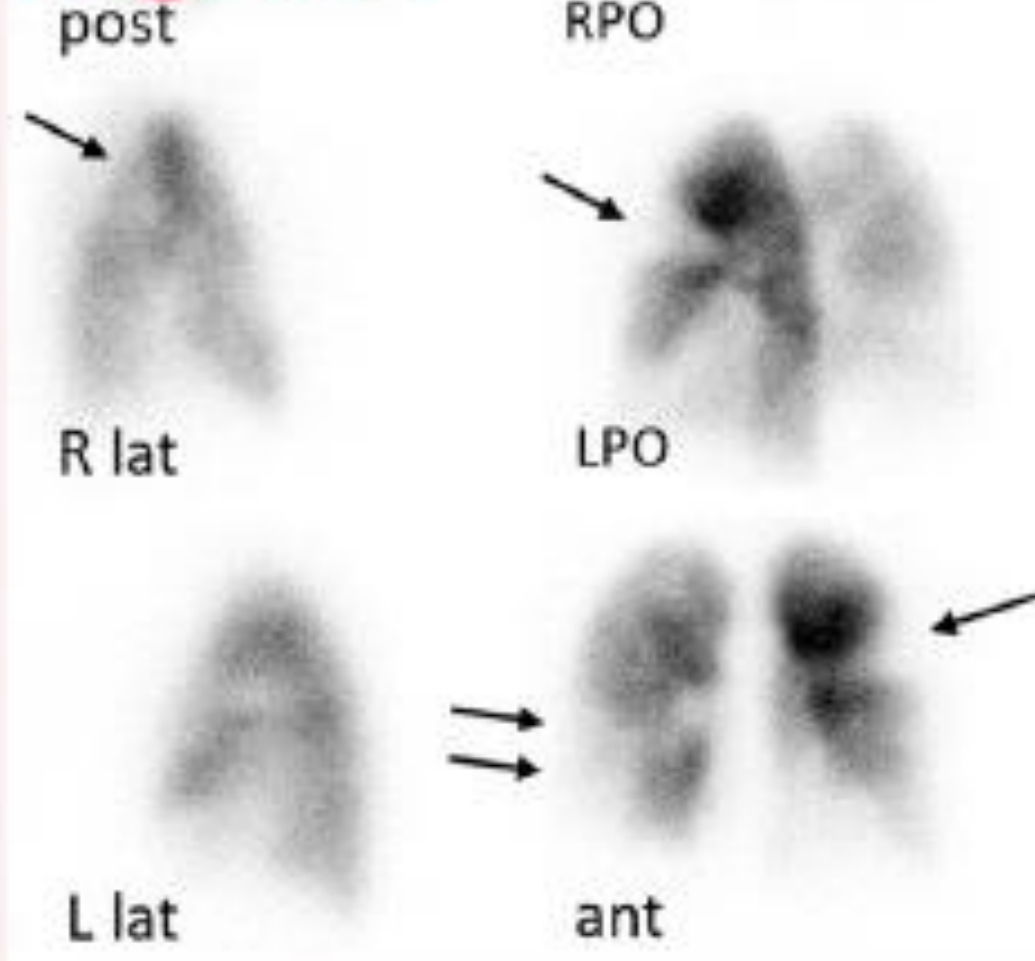
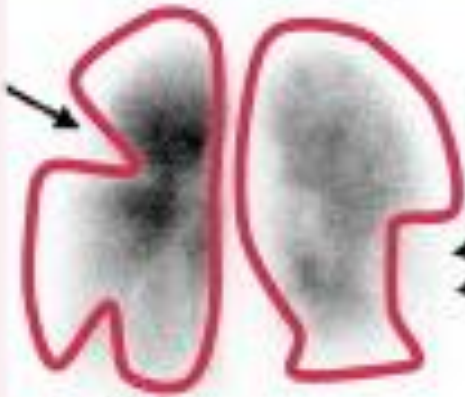
Normal Ventilation [PE]



if abnormal wedge
Think about COPD Asthma

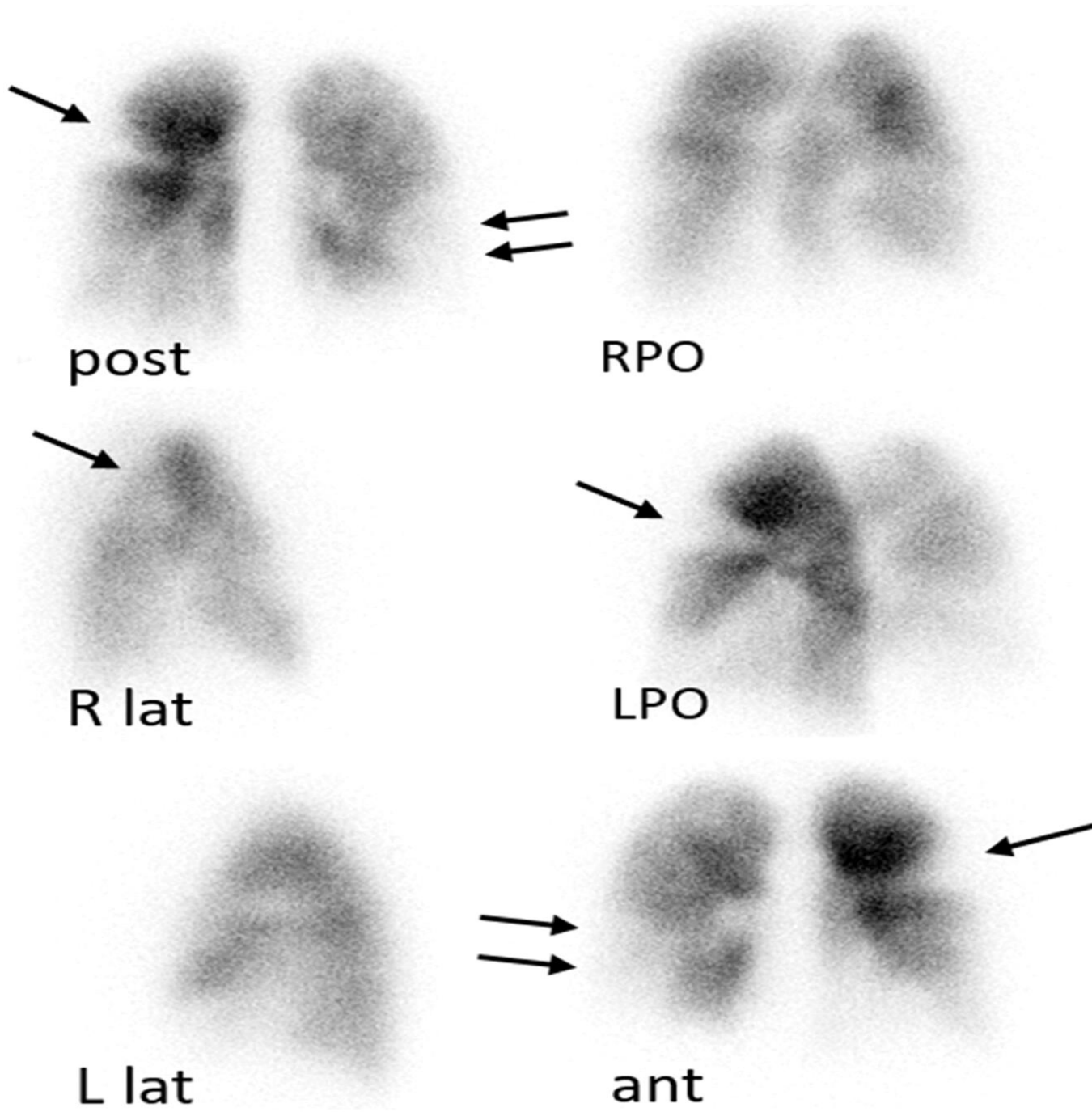


wedge shape peripheral defect in perfusion



Perfusion

PE

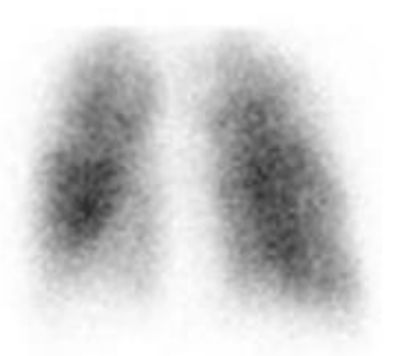


VENTILATION

PERFUSION

VENTILATION

PERFUSION



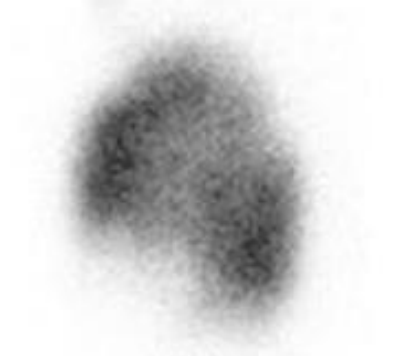
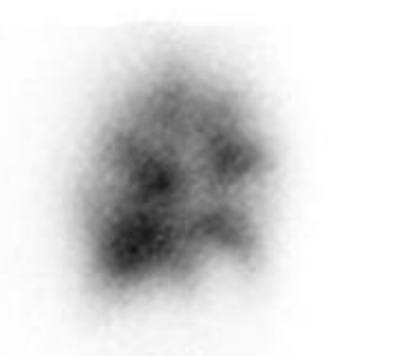
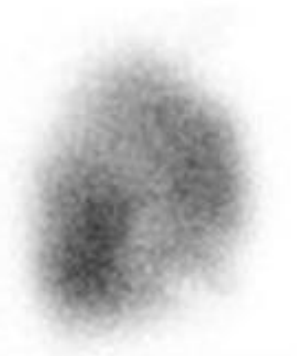
anterior

anterior

PE

posterior

posterior

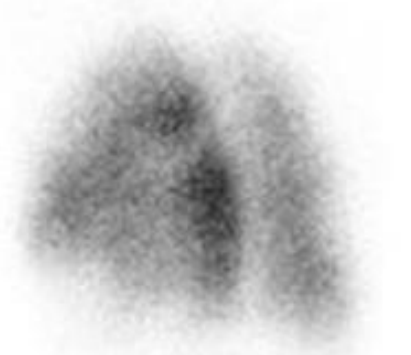
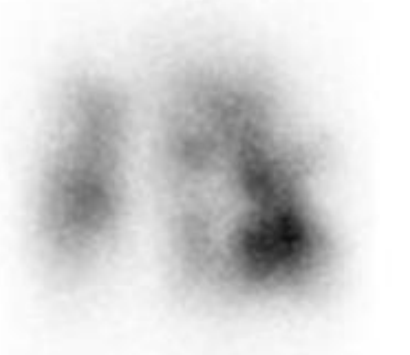
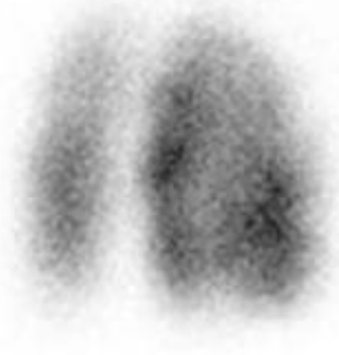


right

right

left

left

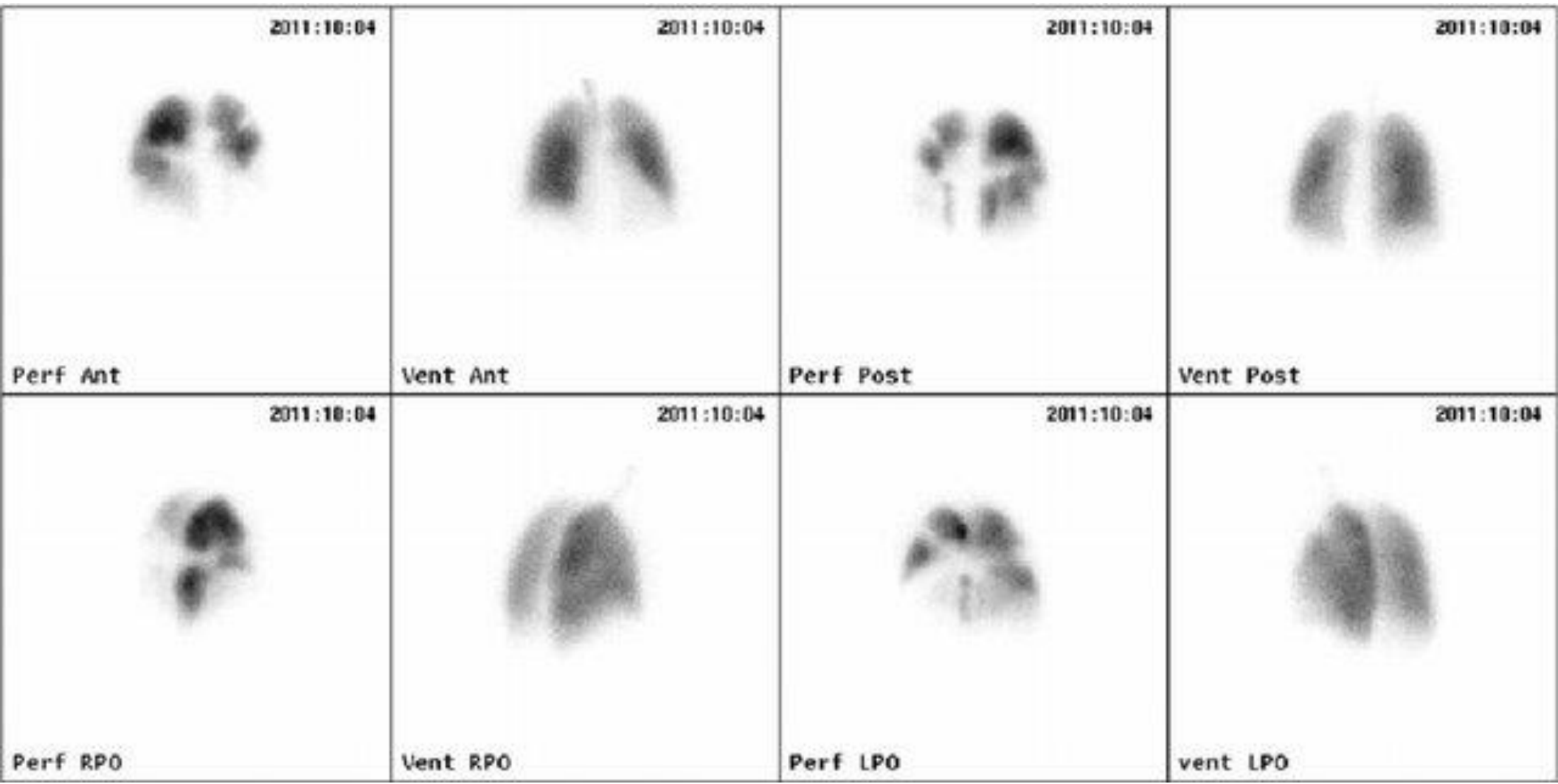


right posterior oblique

right posterior oblique

left posterior oblique

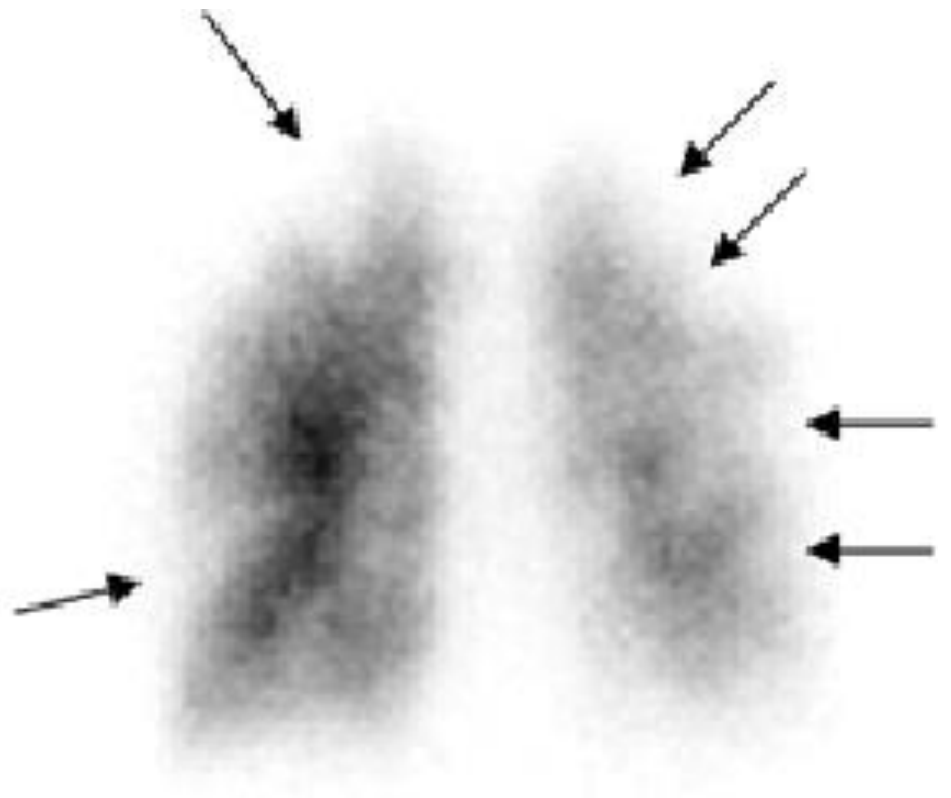
left posterior oblique



PE

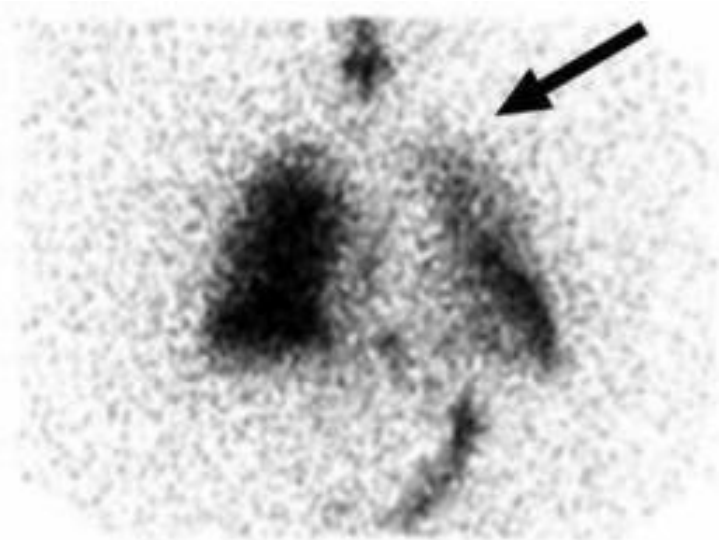


Ventilation

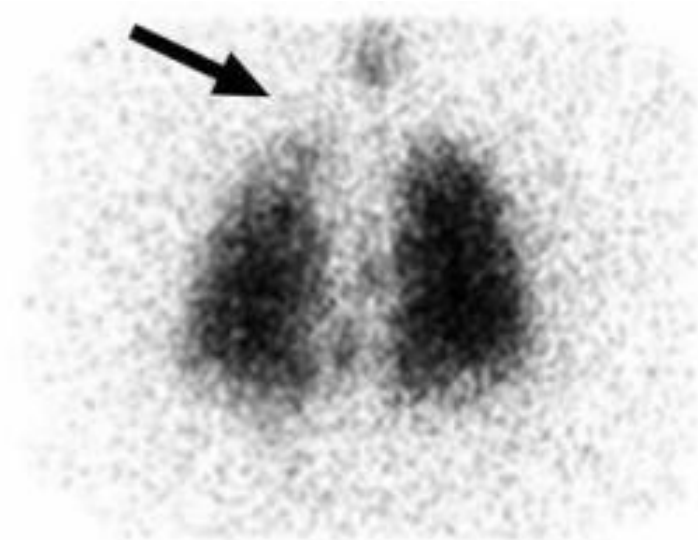


Perfusion

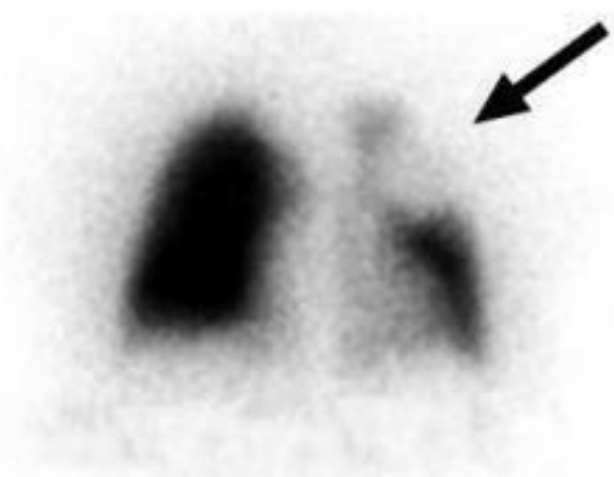
PE



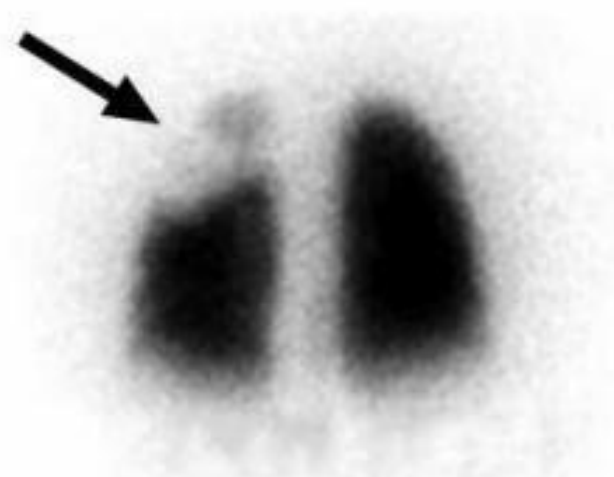
Anterior Ventilation



Posterior Ventilation



Anterior Perfusion



Posterior Perfusion

Bone Scintigraphy

^{99m}Tc -MDP

Basics

* fractures
infection
metastasis
↓
↑ Building of
Bone
↓
↑ uptake

* Type of Metas-
osteoplastic (prostate) ↑ uptake
osteolytic (mm) No effect
osteomixed (Breast) ↑ uptake

Radiopharmaceutical

^{99m}Tc Methylene Diphosphonate (MDP) IV

Which tumors do we get bone scans for?

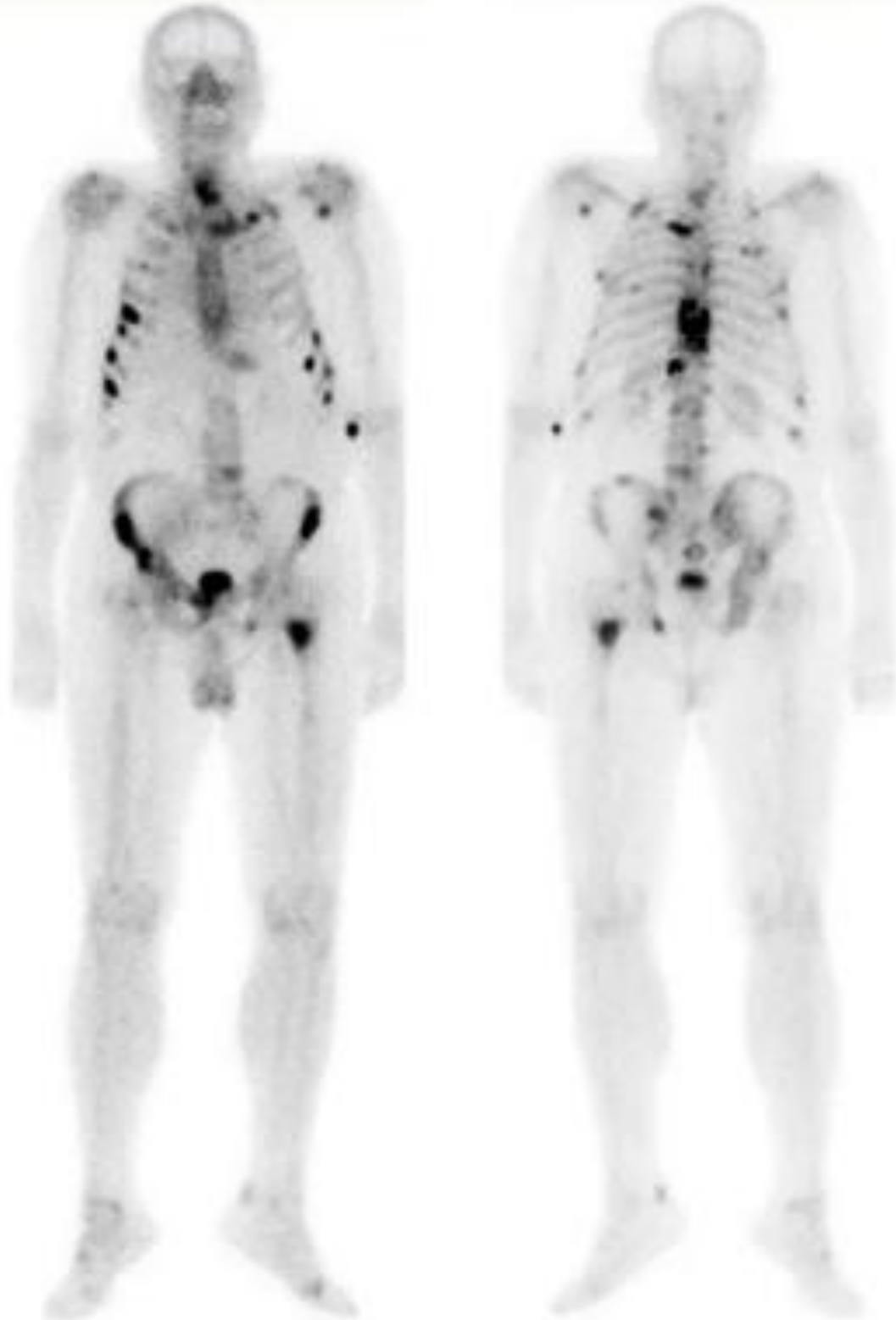
Breast, prostate, most others use PET scan

Breast cancer often sends solitary metastases to the sternum

Prostate cancer metastases often start in the spine



71-year-old male
recently diagnosed
with prostate cancer
was referred to
nuclear medicine to
rule out bony
metastases



68-year-old male
recently
diagnosed with
prostate cancer
was referred to
nuclear medicine
to rule out bony
metastases

+ve mets

%
100

0

%
100

0



ant 153K



post 148K



ant 77K



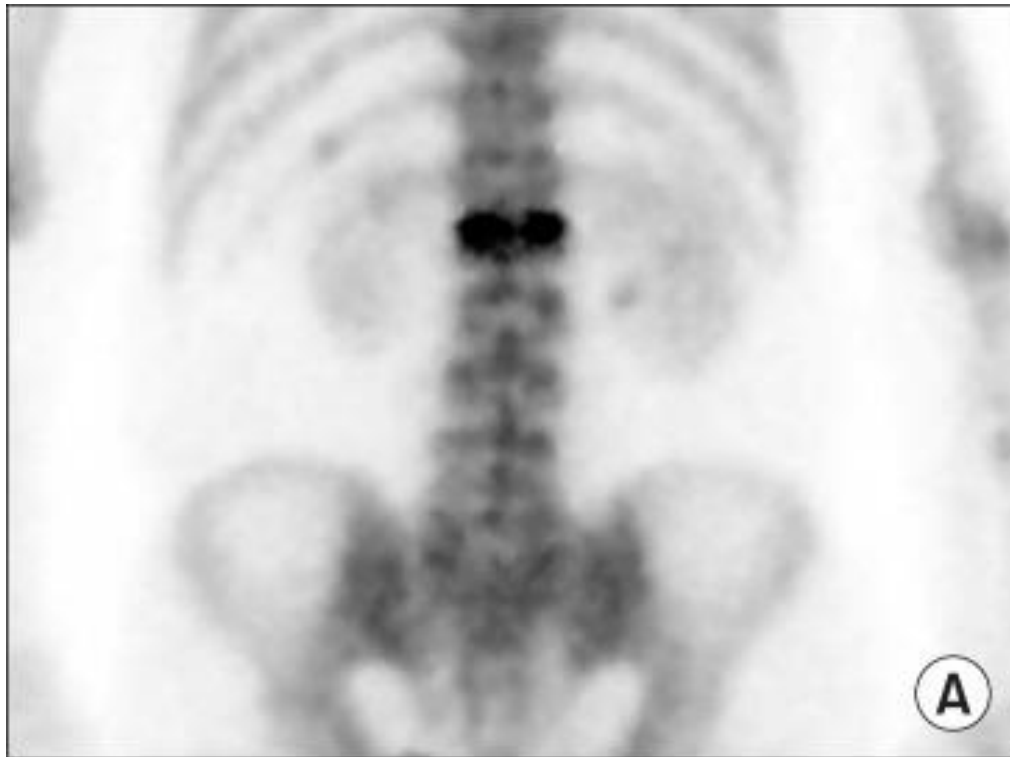
post 76K

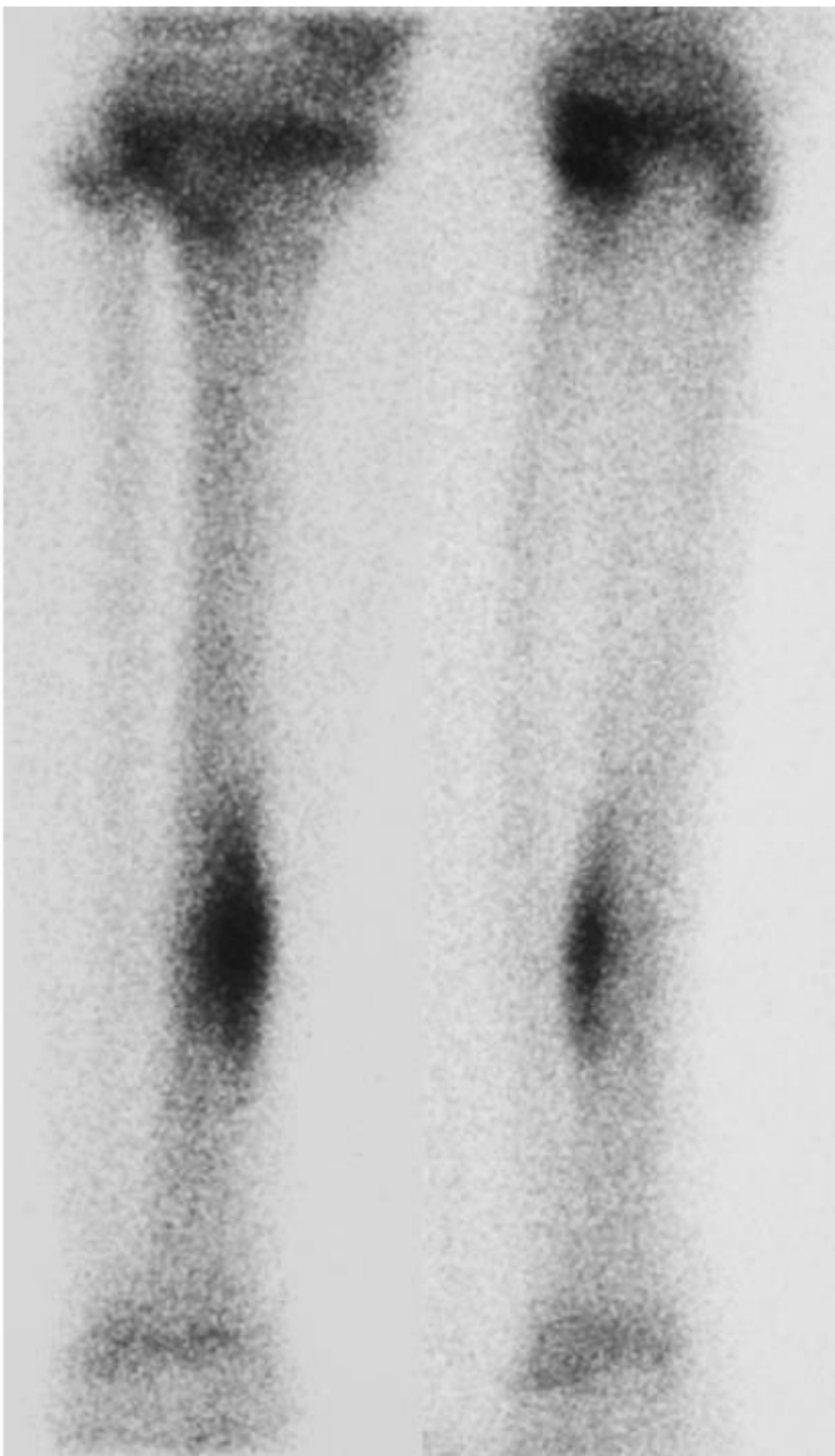
41-year-old female was referred to nuclear medicine to evaluate bilateral joint pain and morning stiffness

RA

79-year-old female with back pain

Compressed fracture





26-year-old female who recently started having to walk 15 km twice a day to get to and from work is now complaining from bilateral shin pain not responding to analgesia.

Shin splint

Renal Scans

for final

Diuretic Renography

Radiopharmaceuticals

^{99m}Tc MAG3

^{99m}Tc DTPA

Pharmacologic protocols: diuretics (e.g. furosemide)

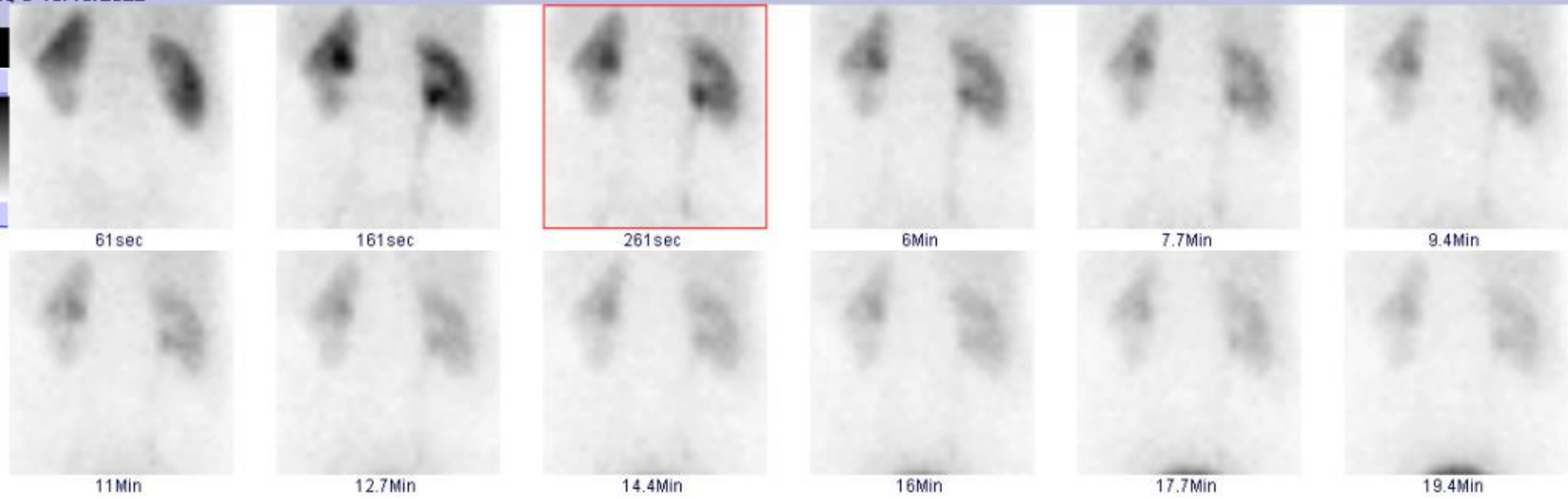
Indications

Obstructive vs nonobstructive hydronephrosis

Stent function

Renal artery stenosis / thrombosis

%
72
0



Phase 2

Kidney

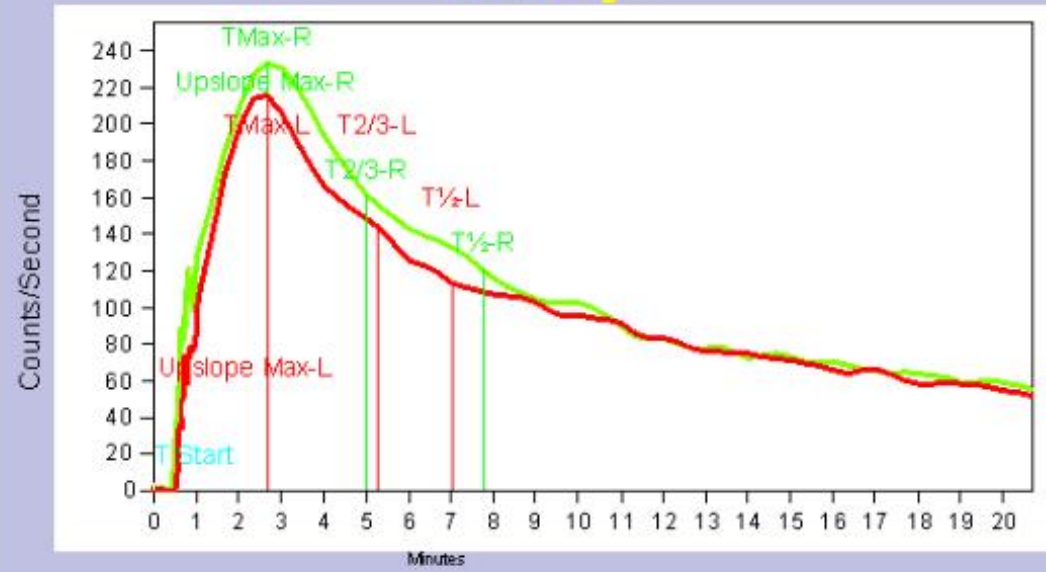
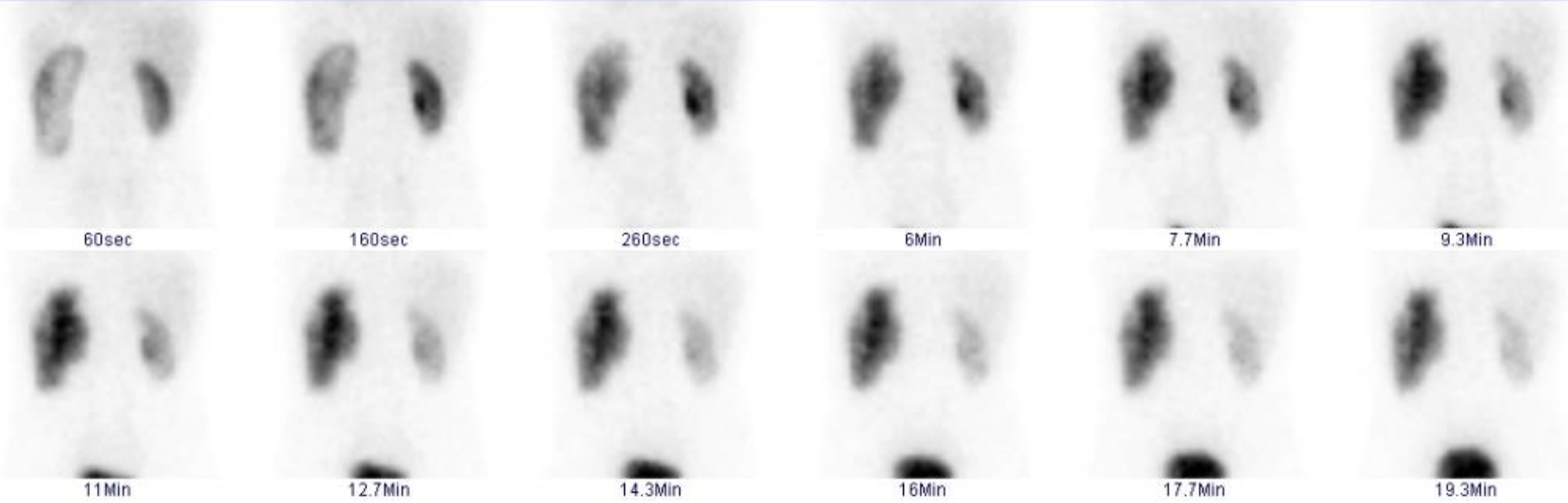


Table of Result Summary

Parameters	Left	Right	Total
Split Function (%)	47.4	52.6	
Kidney Counts (cpm)	8383.3	9315.8	17699
Renal Retention	0.246	0.244	
Time of Max (min)	2.685	2.685	
Time of 1/2 Max (min)	6.986	7.783	
Time from Max to 1/2 Max (min)	4.300	5.098	
Time of 2/3 Max (min)	5.254	5.021	
Time from Max to 2/3 Max (min)	2.569	2.335	
Upslope Time Interval (min)	0.501	2.685	
Max Counts (cps)	219.1	239.7	458.8
Slope from Max to 1/2 Max (cps ²)	0.387	0.377	
Upslope (cps ²)	0.019	0.612	



Phase 2

Kidney

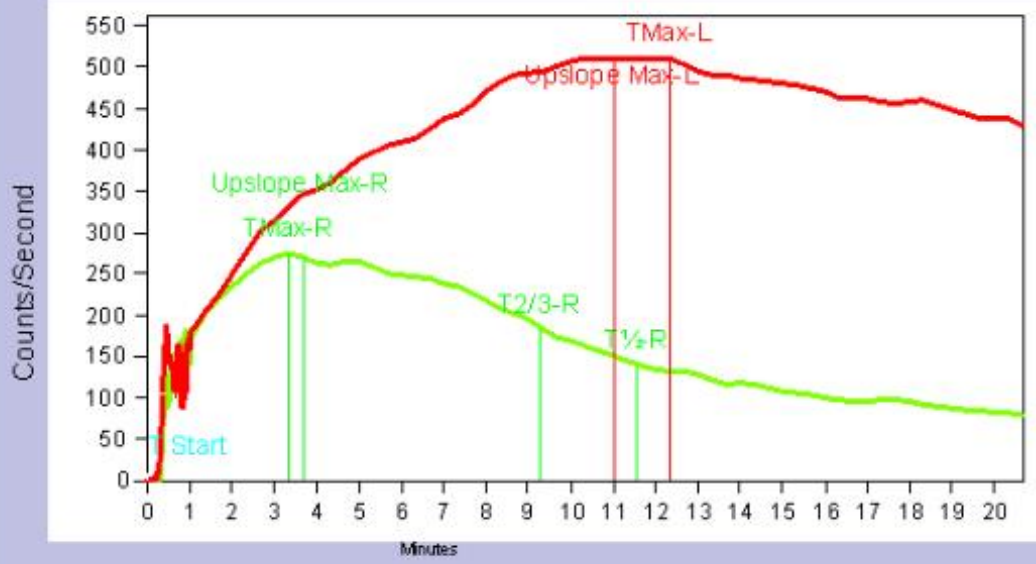


Table of Result Summary

Parameters	Left	Right	Total
Split Function (%)	49.9	50.1	
Kidney Counts (cpm)	12038	12065	24103
Renal Retention	0.846	0.293	
Time of Max (min)	12.3	3.336	
Time of 1/2 Max (min)		11.6	
Time from Max to 1/2 Max (min)		8.218	
Time of 2/3 Max (min)		9.239	
Time from Max to 2/3 Max (min)		5.903	
Upslope Time Interval (min)	11.0	3.669	
Max Counts (cps)	521.4	277.5	798.9
Slope from Max to 1/2 Max (cps ²)		0.290	
Upslope (cps ²)	1.107	1.784	

DMSA

Radiopharmaceutical

^{99m}Tc dimercaptosuccinic acid (DMSA)

Indications

Relative function

Scarring

Pre nephrectomy assessment



Anterior 404K



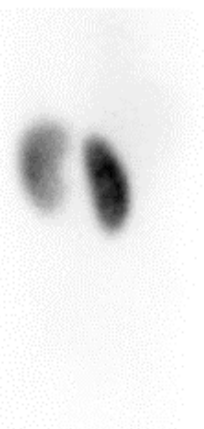
Posterior 407K



RAO 352K



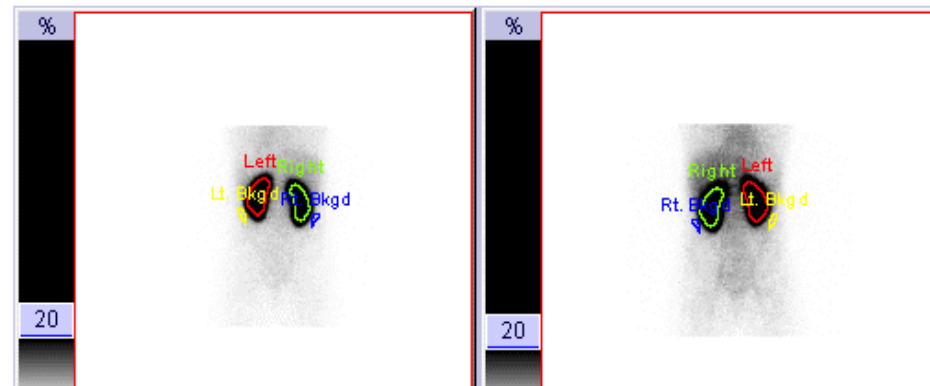
LPO 426K



RPO 391K

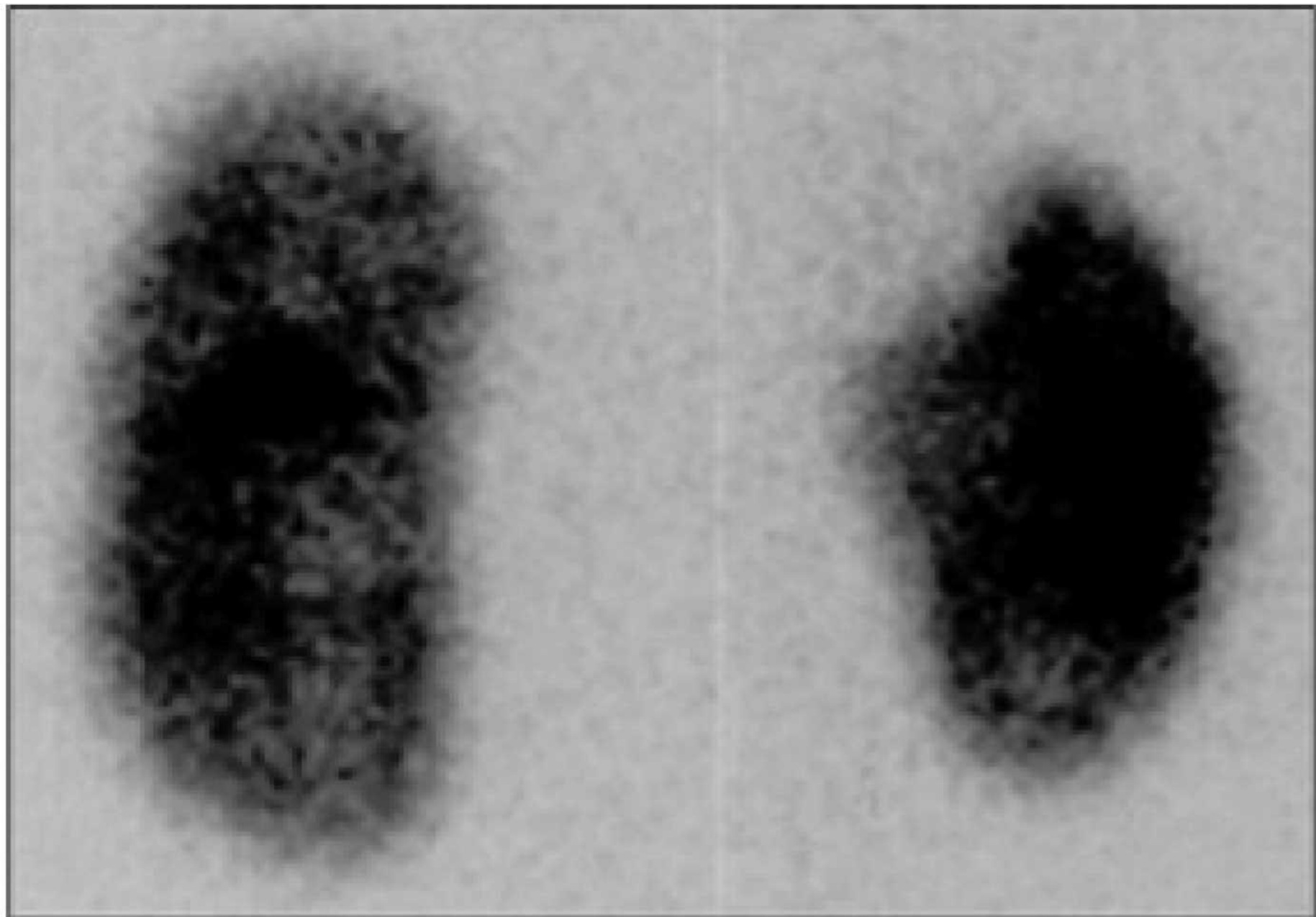


LAO 384K



(% Ratios)	Left	Right
	50.26	49.74
<hr/>		
Total	50.26	49.74





HIDA Scan

Uses ^{99m}Tc -mebrofenin or disofenin

Indications

Acute cholecystitis

Chronic acalculous cholecystitis

Sphincter of Oddi dysfunction

Biliary leak

Biliary atresia

Biliary stent patency

PET Imaging

Positron Emitting Tomography

Radioactive fluorine is the most widely used (^{18}F -FDG)

Also uses ^{11}C , ^{15}O , ^{13}N , ^{68}Ga

Indications

- Staging

- Response assessment

- Interim evaluation of treatment (lymphoma)

- Evaluation of suspected disease recurrence, relapse and/or residual disease

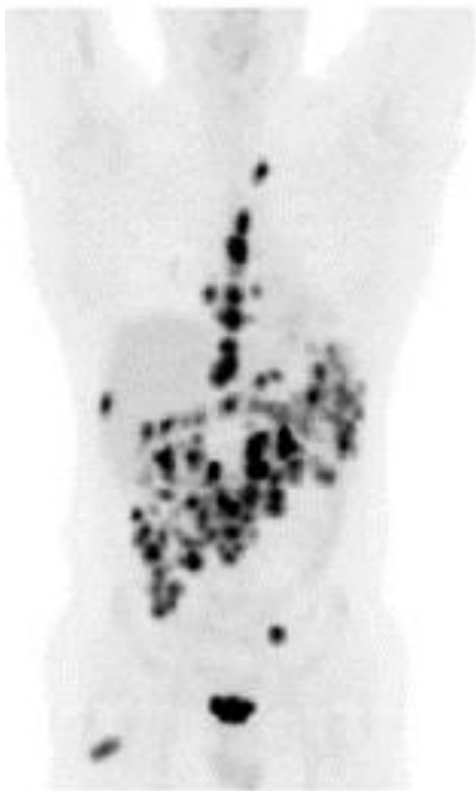
- Evaluation of indeterminate lesion

- Myocardial viability

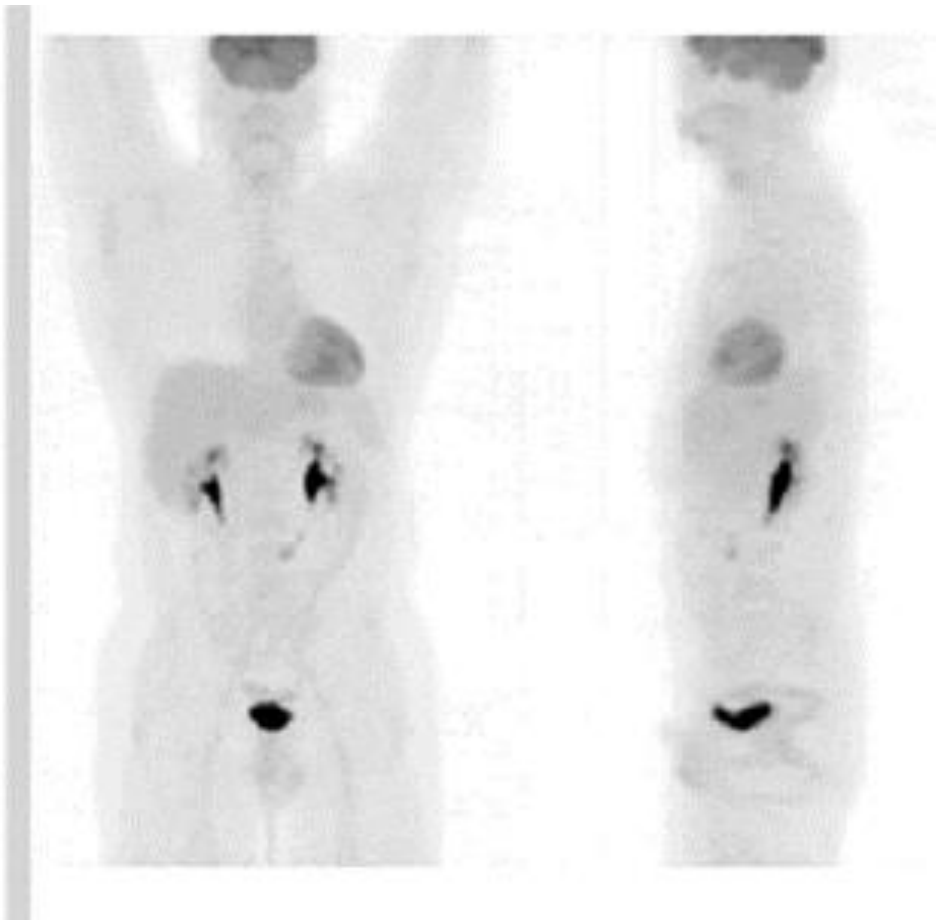
- Localizing seizure foci

Complete Metabolic Response

Lymphoma



Baseline

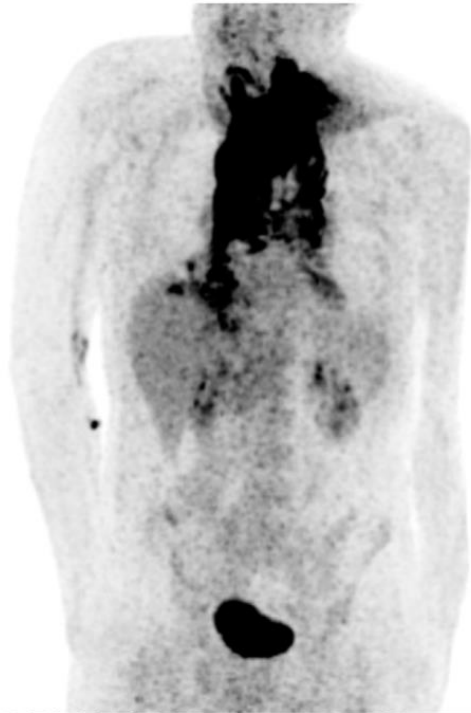


End of Treatment

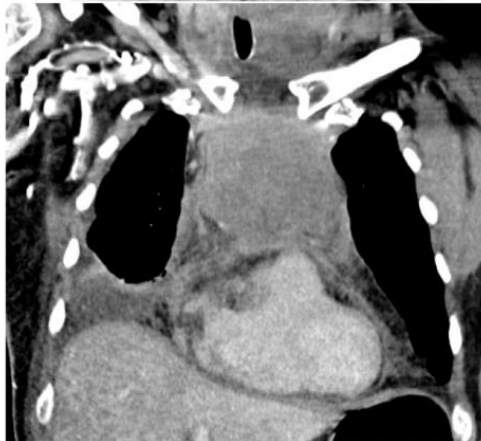
baseline

interim

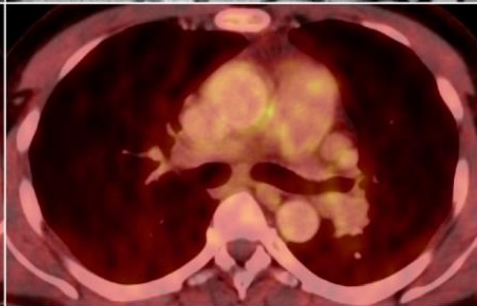
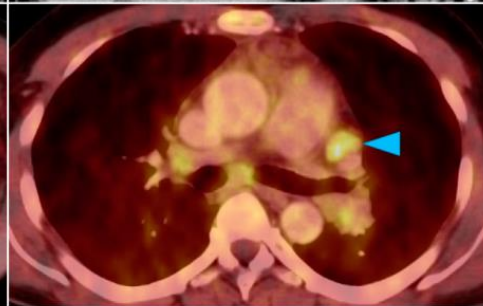
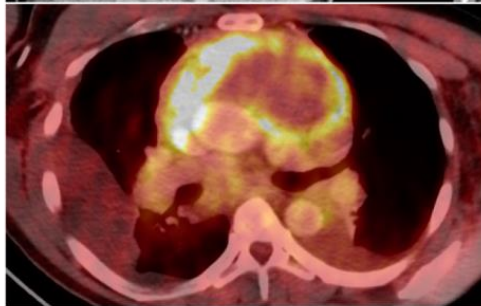
EOT



PET



CT



PET/CT