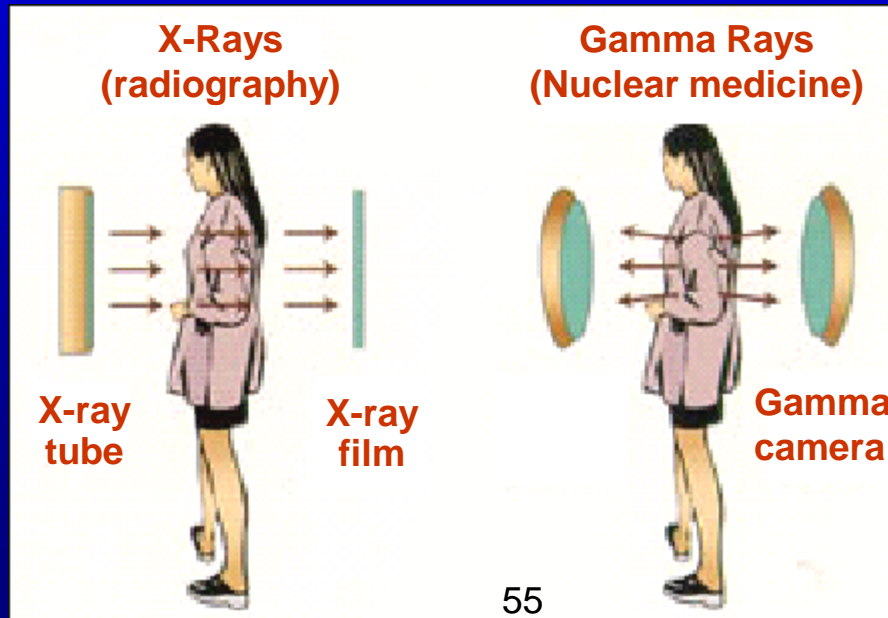


Nuclear Medicine for General Internists

Introduction

Nuclear medicine

Spatial distribution and pharmacokinetics of a radiopharmaceutical in the body



Radiopharmaceuticals

Radiopharmaceutical: radioactive compound used for *in vivo* diagnosis and/or treatment

Radionuclide with suitable chemical and physical characteristics

Pharmaceutical chosen on the basis of its preferential localization in an organ or a physiological process it traces

Radionuclide

Nuclide is an atomic species with a definite number of protons and neutrons in a definite order in the nucleus

Radionuclide is an unstable nuclide that decays by emission of particle or electromagnetic radiations or by nuclear fission

^{99m}Tc (meta stable Technetium 99)

Gamma radiation

Suitable energy level (140 Kev)

Suitable $T_{1/2}$ (6 hours)

Chemistry

Available

Cheap

Imaging Techniques

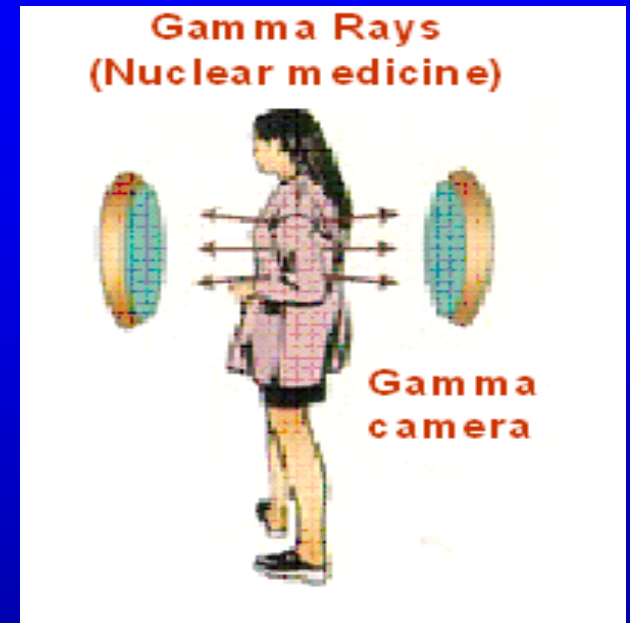
Planar Imaging (Dynamic or Static)

Single Photon Emission Computed Tomography (SPECT)

Positron Emission Tomography (PET)

Imaging Techniques

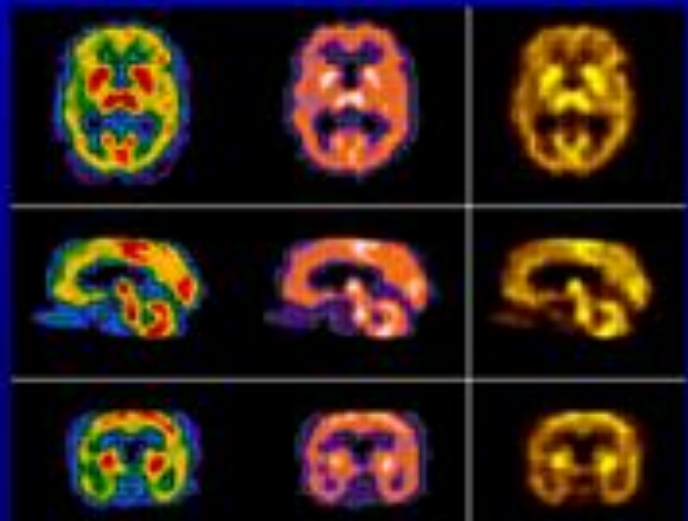
Planar Imaging



Imaging Techniques

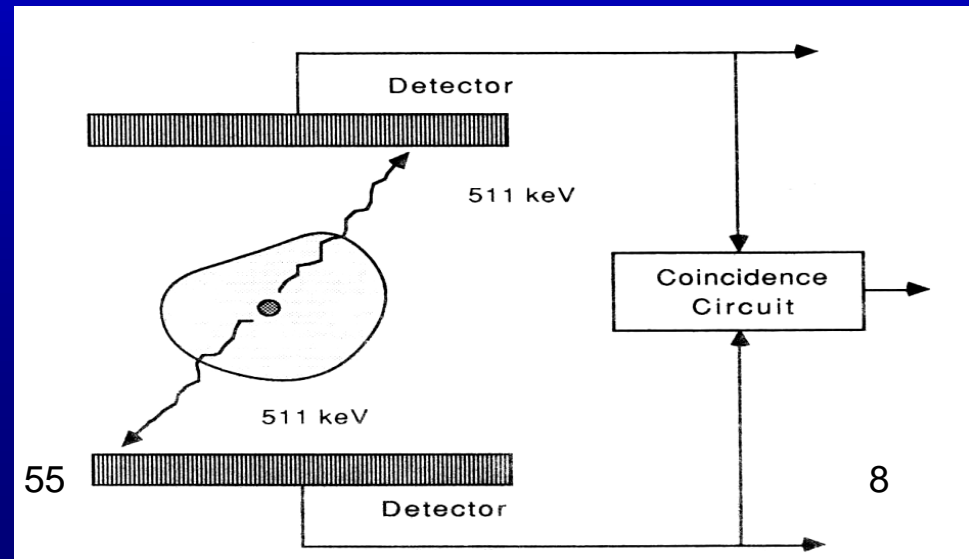
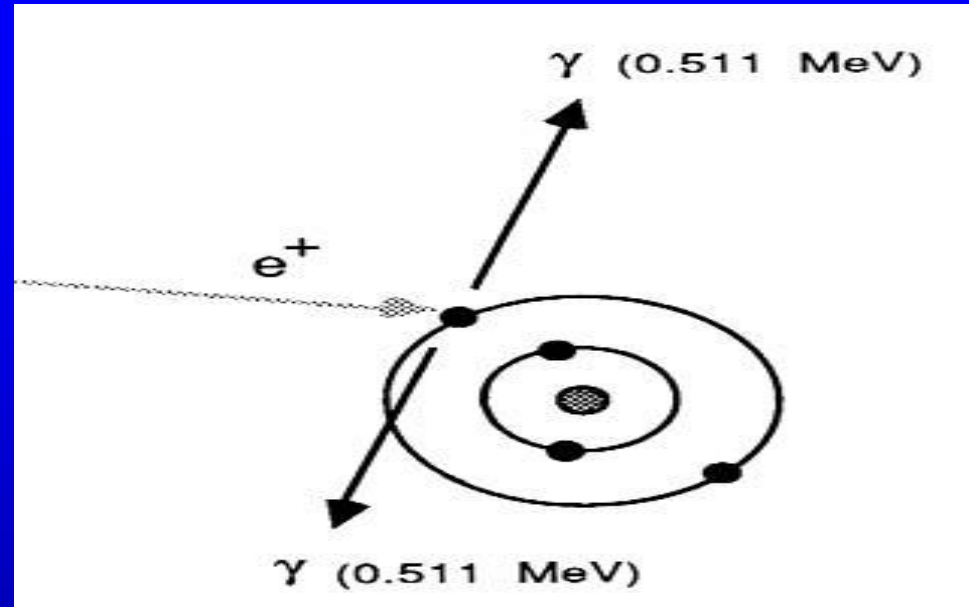


SPECT Imaging



Principle of Positron Emission Tomography

PET



Thyroid Imaging & Therapy

- Thyroid scan typically performed with **Tc-99m-pertechnetate** as iodine surrogate. When available, **I-123** is a good alternative
- **I-131** is obsolete for imaging; used only in very low dose (~5-10 microcuries) for measurement of thyroidal iodine uptake
- Most useful to
 - determine functionality of a thyroid mass palpated or seen by ultrasound
 - differentiate between various causes of hyperthyroidism

Thyroid Imaging & Therapy

➤ **I-131** used for:

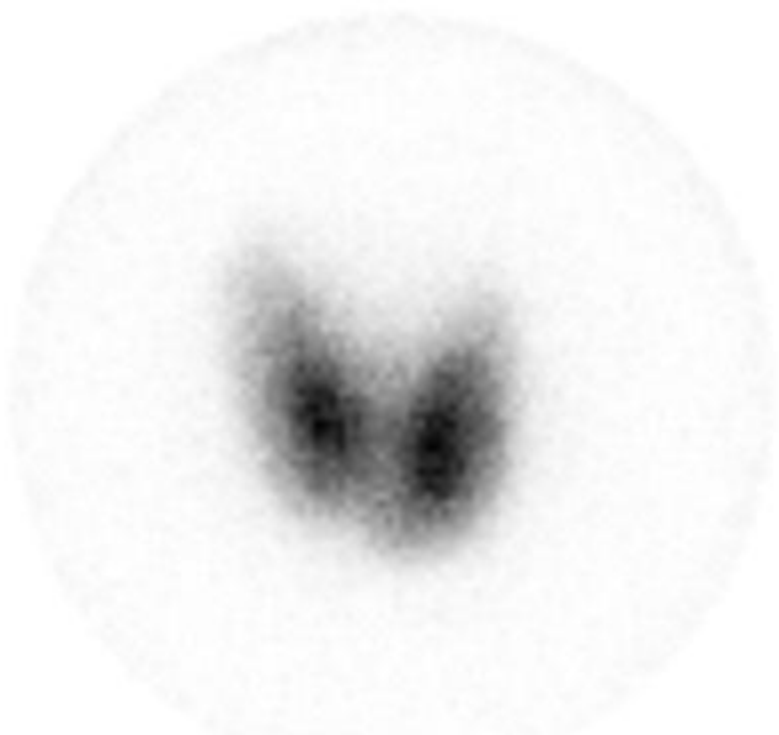
➤ treatment of various causes of hyperthyroidism (Graves' disease, toxic adenoma, toxic multinodular goiter)

➤ ablation of residual thyroid tissue following thyroidectomy for differentiated thyroid cancer

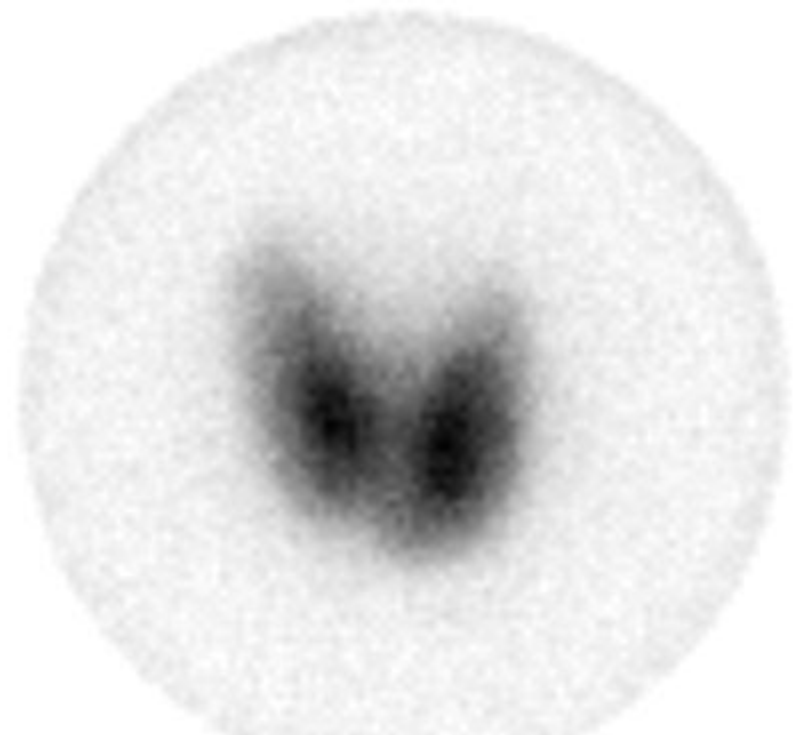
➤ treatment of differentiated thyroid cancer metastases

cold nodule





131-I THYROID



131-I THYROID

131-I Thyroid scan (Graves')

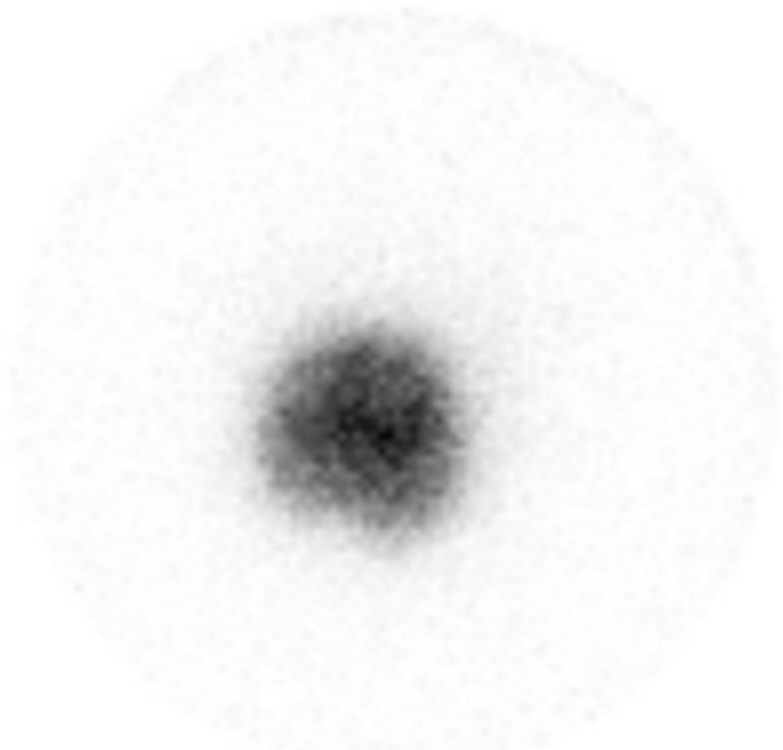


99mTc04- Thyroid

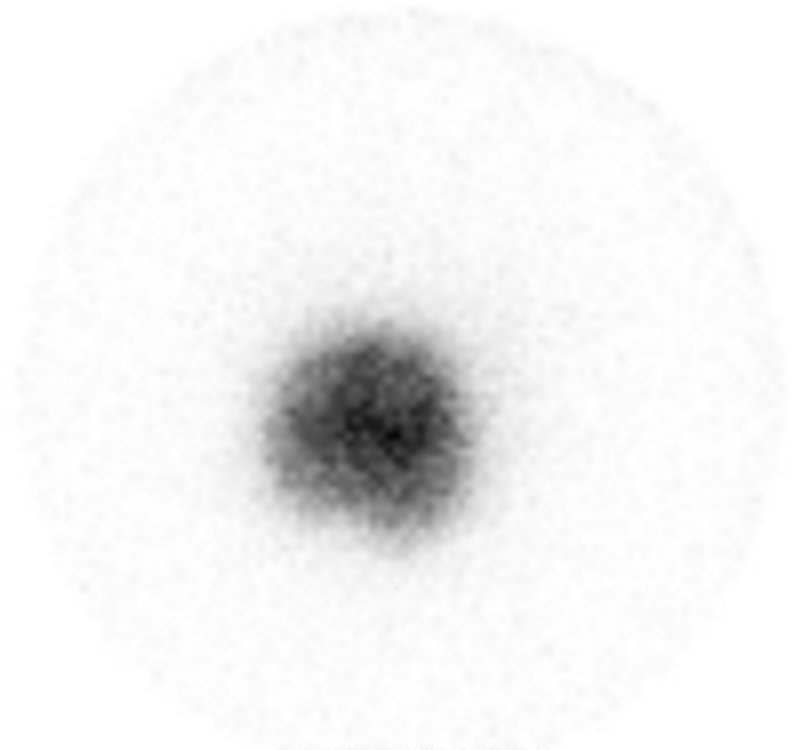


99mTc04- Thyroid

99m-Tc Thyroid scan (Multiple Hot nodule)

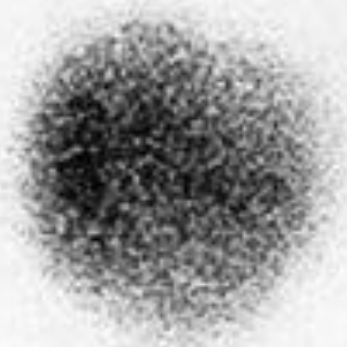


I-131 THYROID



I-131 THYROID

131-I Thyroid scan (Hot nodule)



131-I hot nodule before radioactive iodine ablation

A



After radioactive iodine ablation

B



99mTc04- Thyroid



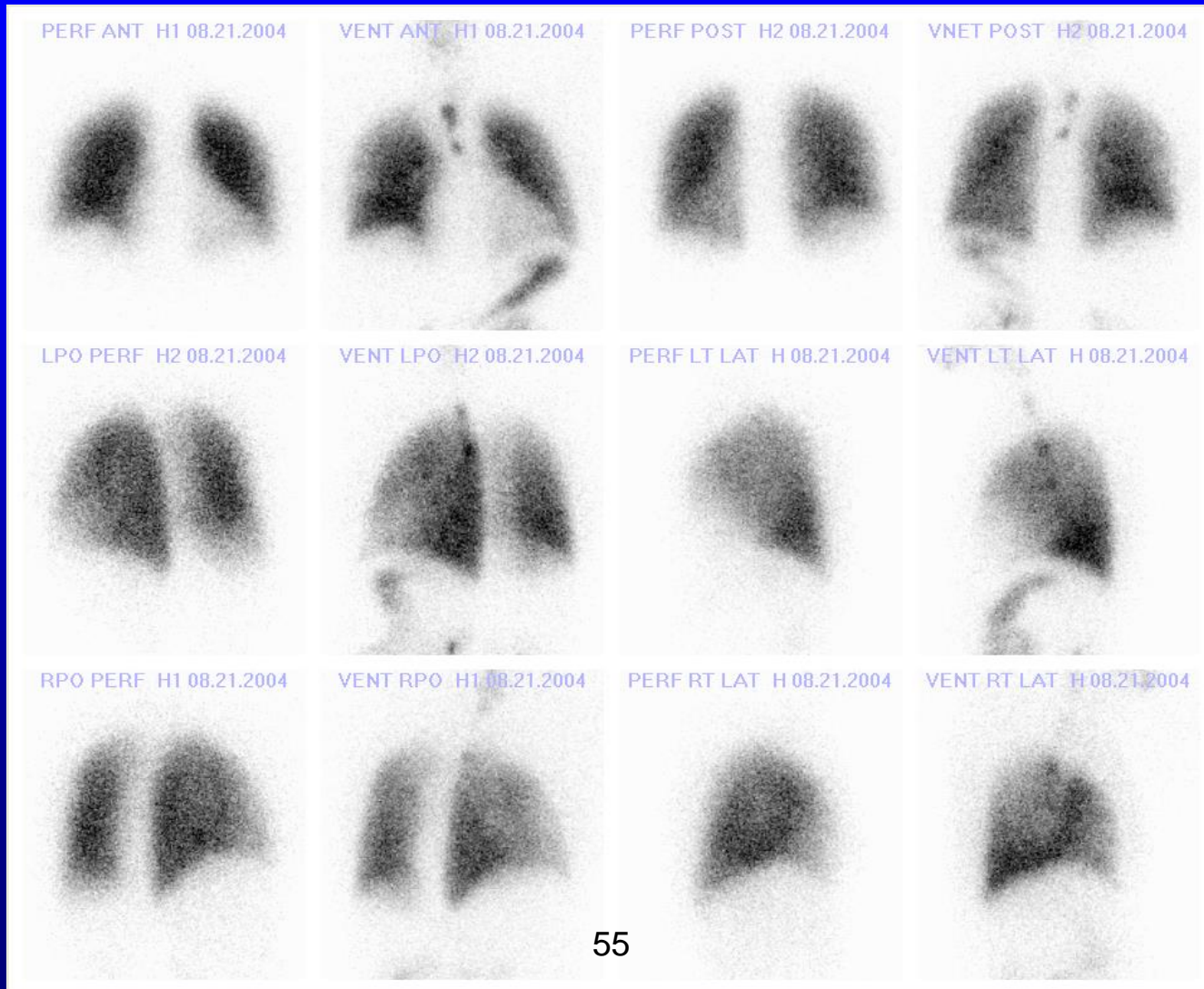
99mTc04- Thyroid

99mTc Thyroid scan (Diffuse thyroiditis)

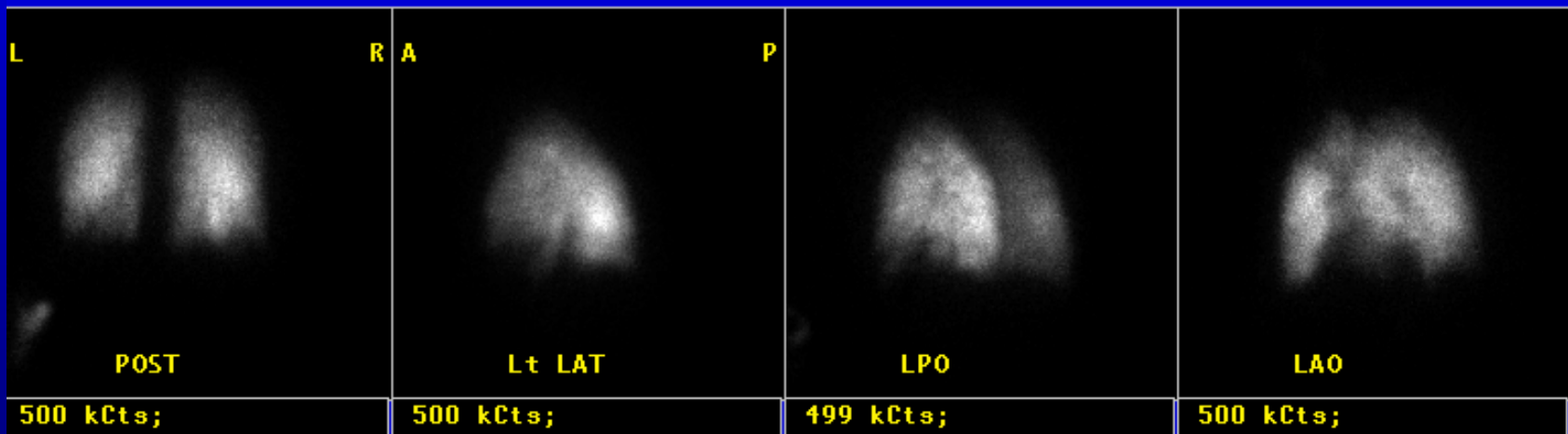
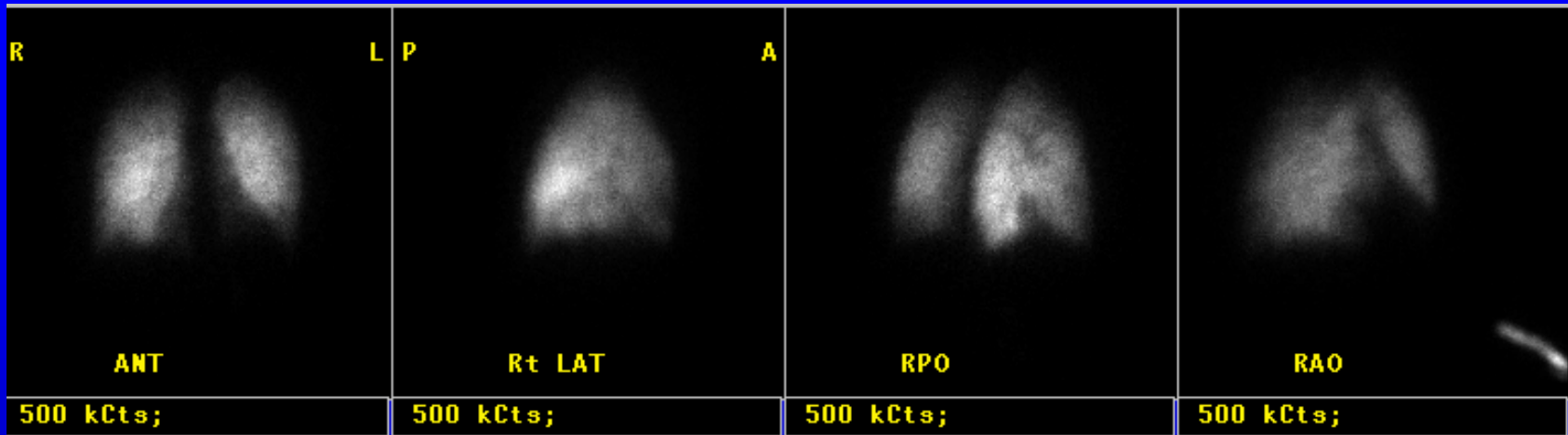
V/Q Scan (Lung Perfusion & Ventilation Scans)

- Lung perfusion (**99mTc-labeled-macro aggregates of albumin or 99mTc-MAA**); lodge in percapillary arterioles obstructing approximately 0.1% of their total number
- Lung Ventilation (**99mTc-labeled-DTPA or sulfur colloid aerosols**); penetrate down to the alveoli
- Primary use is in the diagnosis of pulmonary embolism
- V/Q scan may reveal major ventilatory abnormalities explaining the hypoxemia/dyspnea

Normal V/Q scan



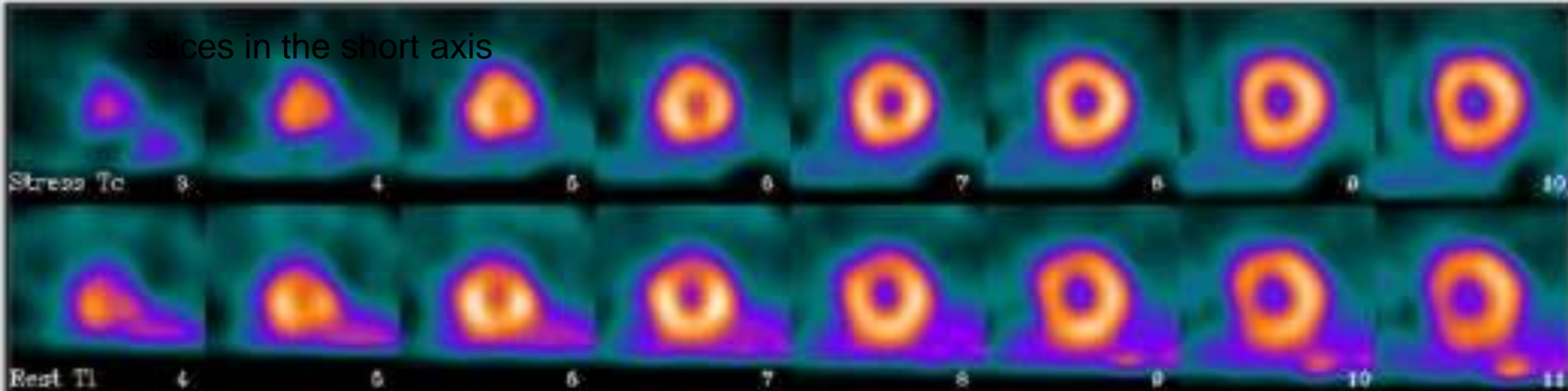
Patient with Pulmonary Embolism



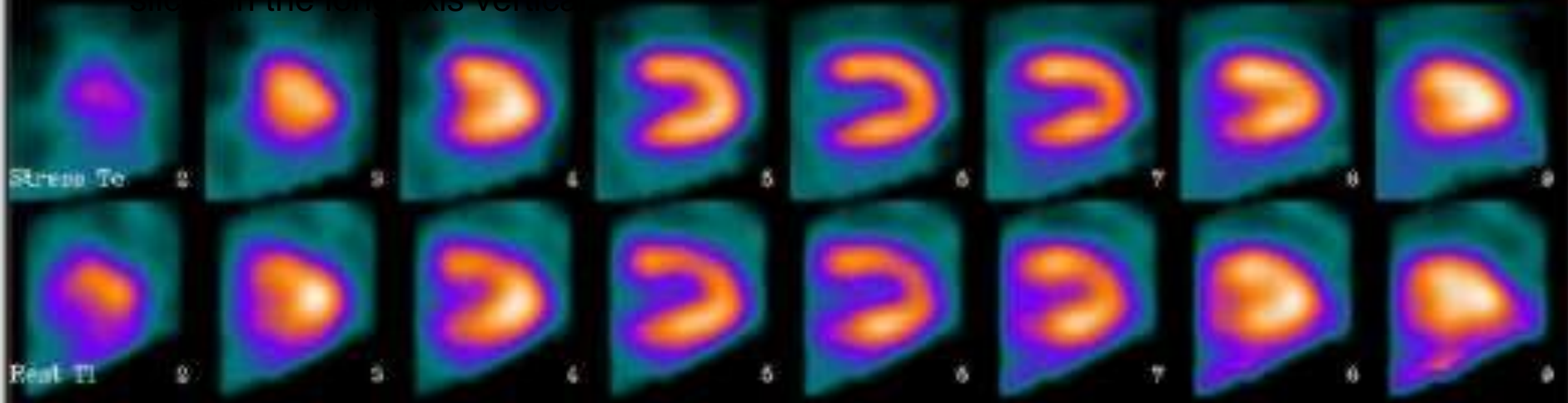
Myocardial Perfusion Imaging

- Typically performed with Tc-99m-labeled myocardial perfusion agents (**Tc-99m-Sestamibi and –tetrofosmin**).
 - TI-201 is currently rarely used except for myocardial viability studies
- Performed in combination with exercise (Treadmill) or pharmacologic stress using vasodilators (**e.g., Adenosine**)
- Used for
 - diagnosis of coronary artery disease
 - determining significance of a borderline lesion by angiography
 - preoperative evaluation in high-risk patient
- More sensitive and specific than exercise ECG

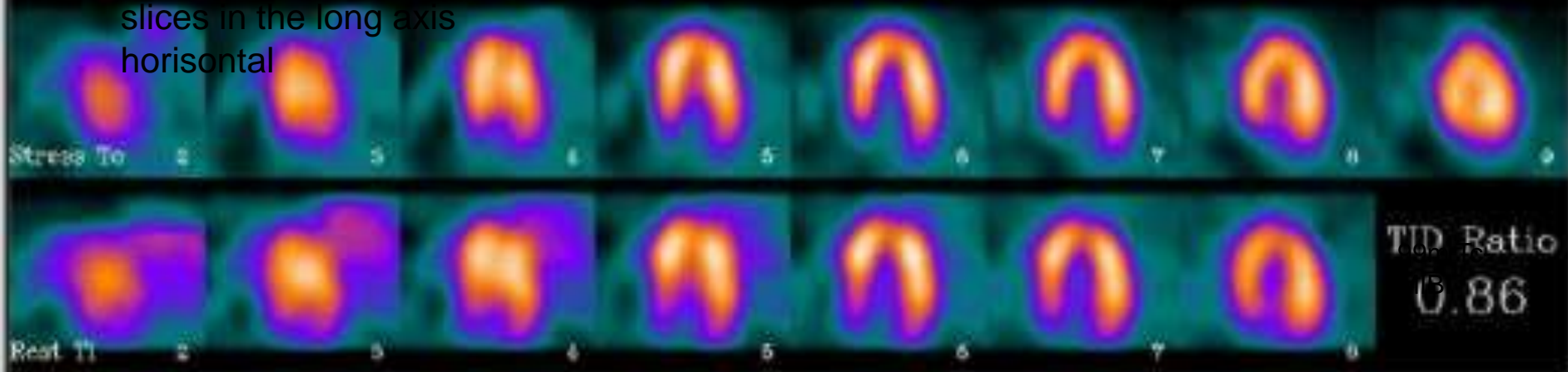
slices in the short axis

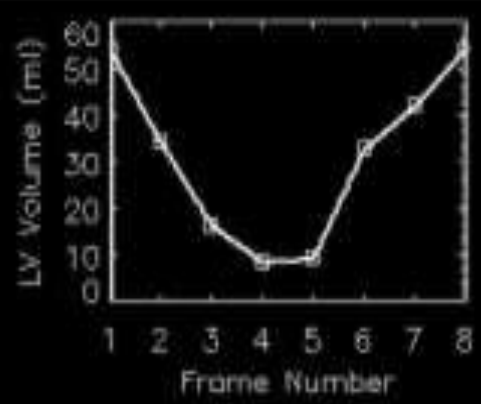


slices in the long axis vertical

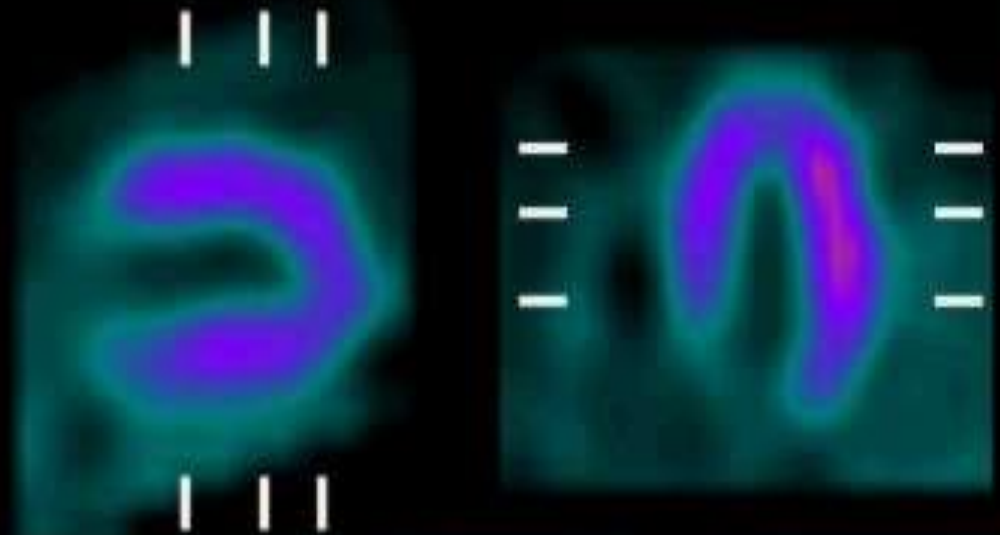


slices in the long axis horizontal

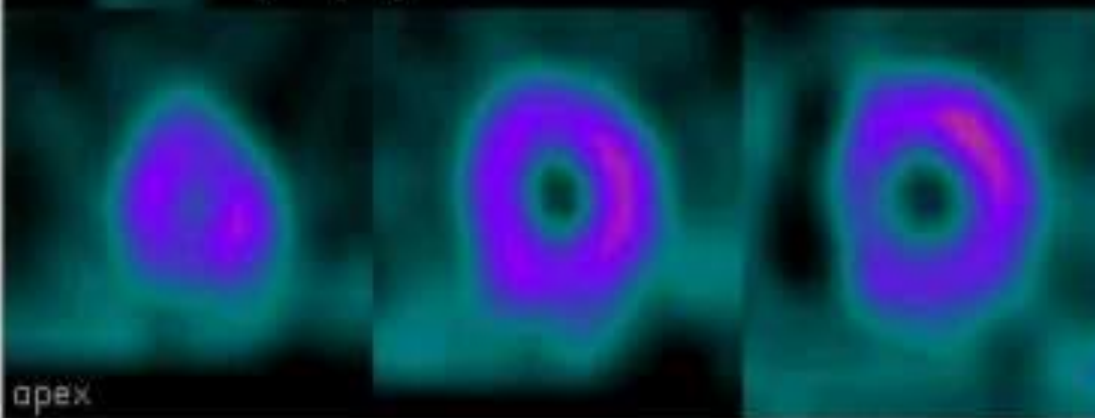


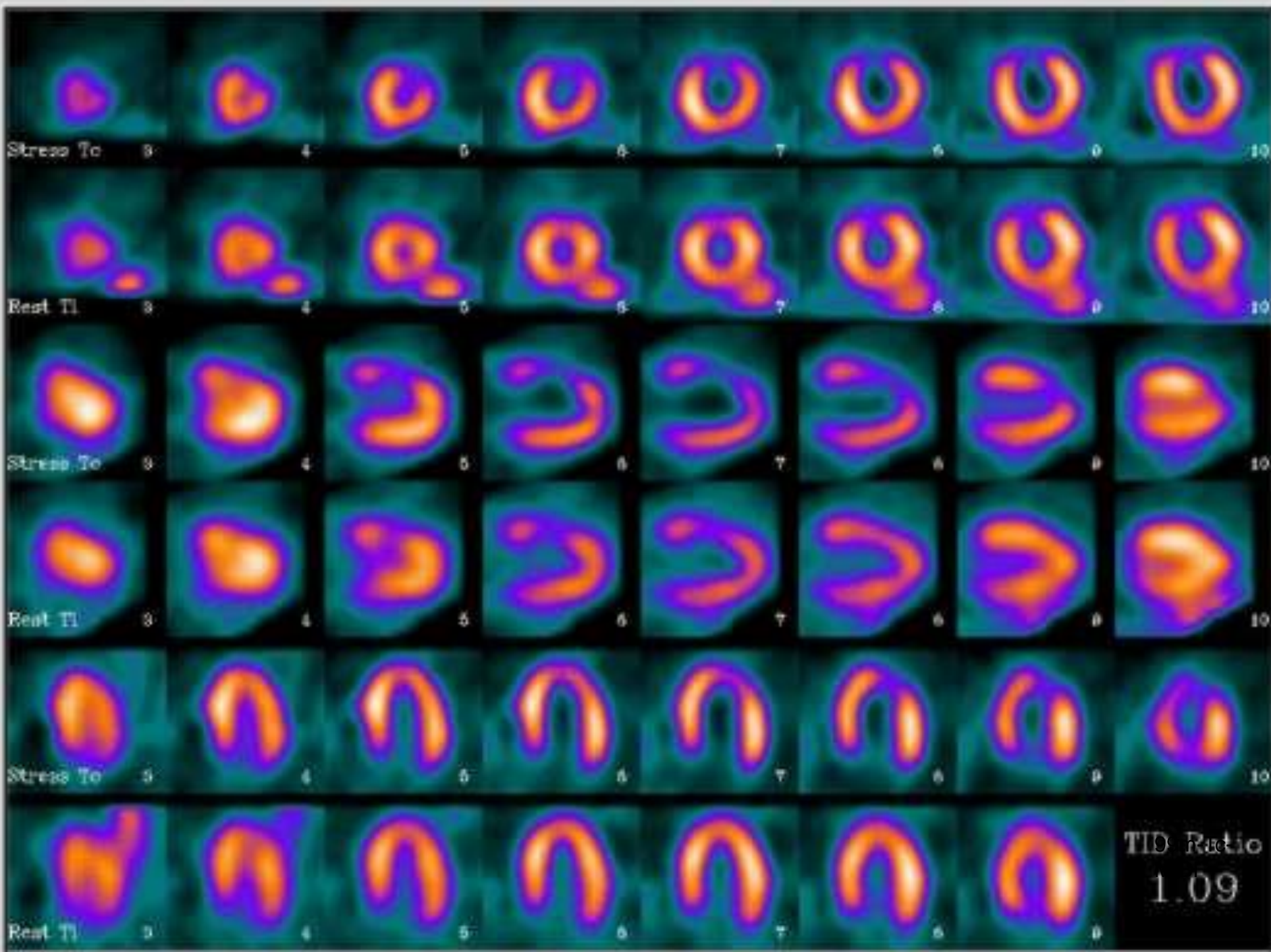


EF = 84%
 EDV = 55 ml
 ESV = 9 ml
 SV = 46 ml
 Mass = 91 gm



Estimated % Thickenin

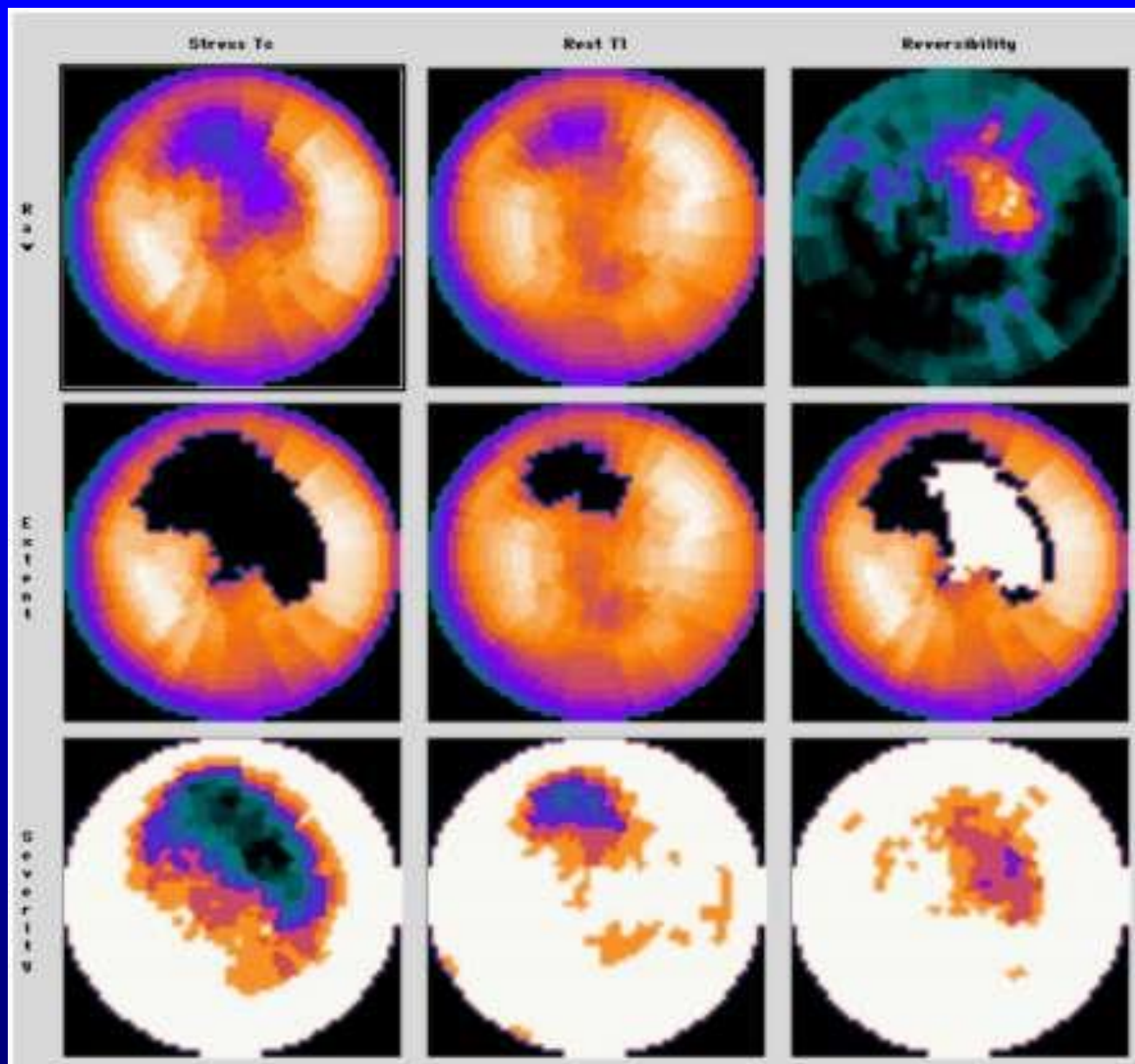


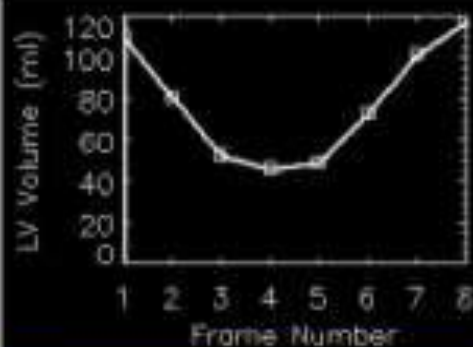


Polar maps

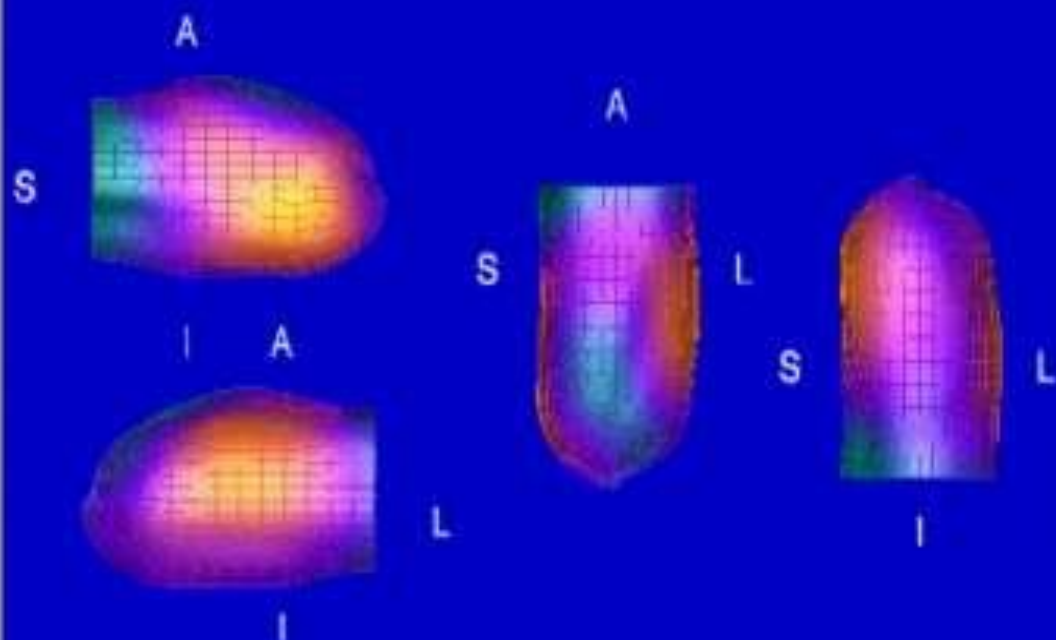
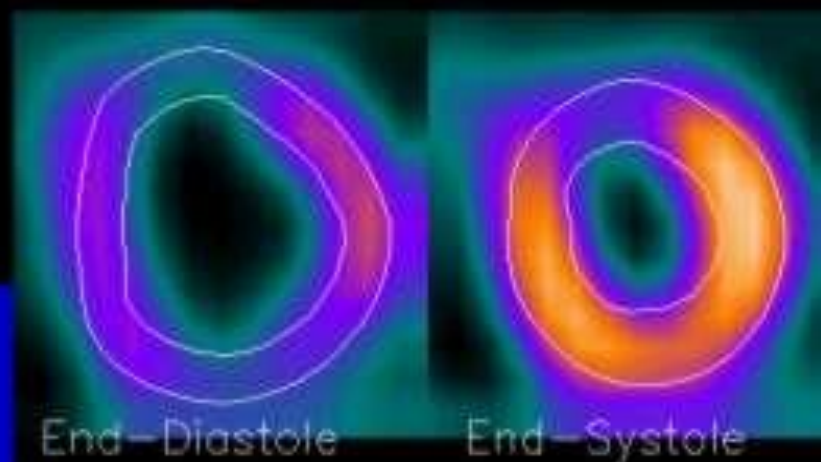
Short axis slices are sequentially displayed from base to apex.

Conical myocardium is transformed into a disk.

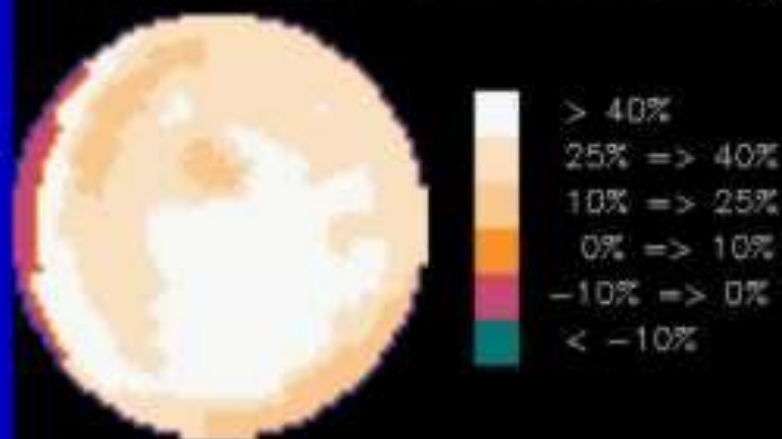


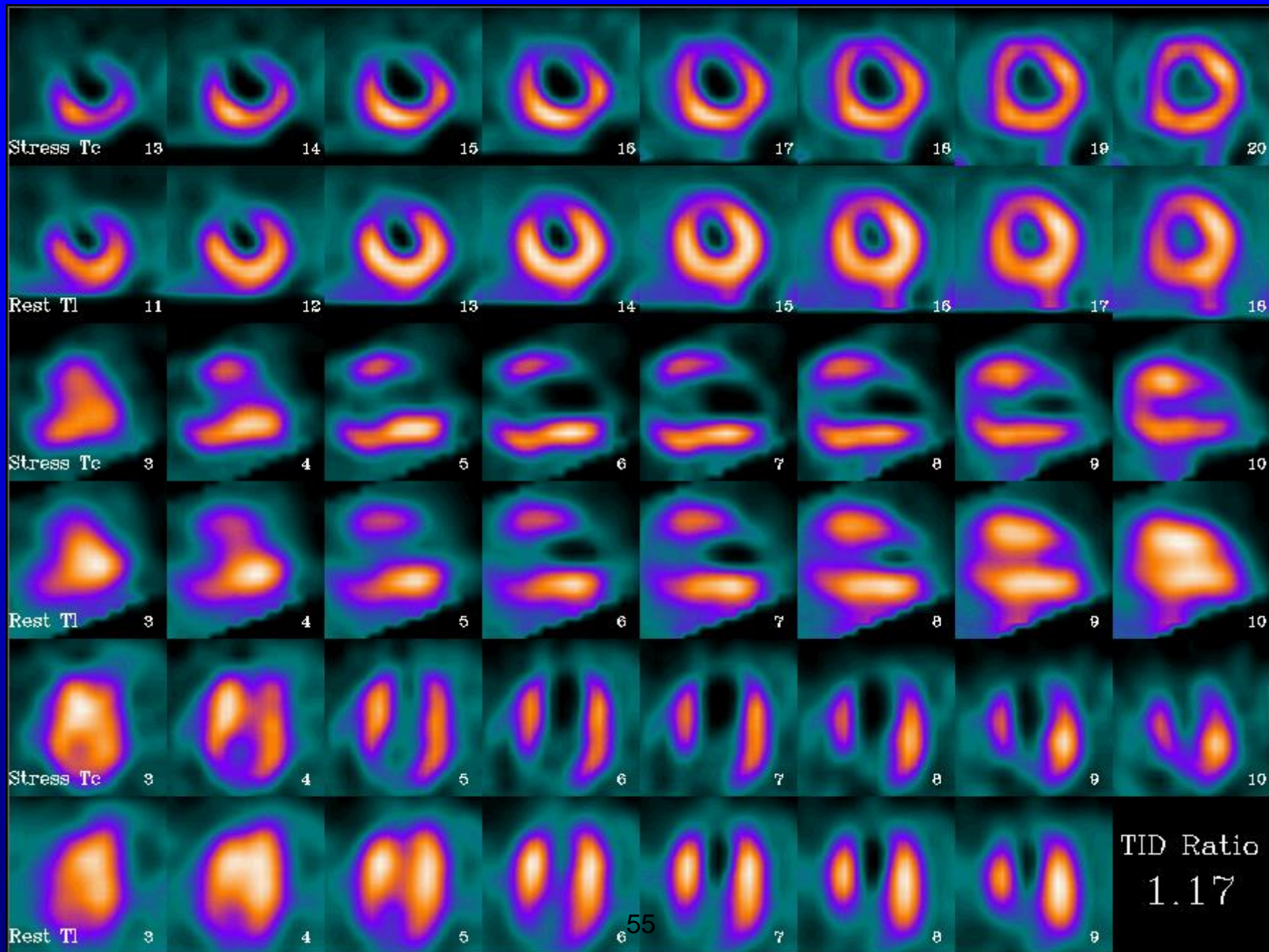


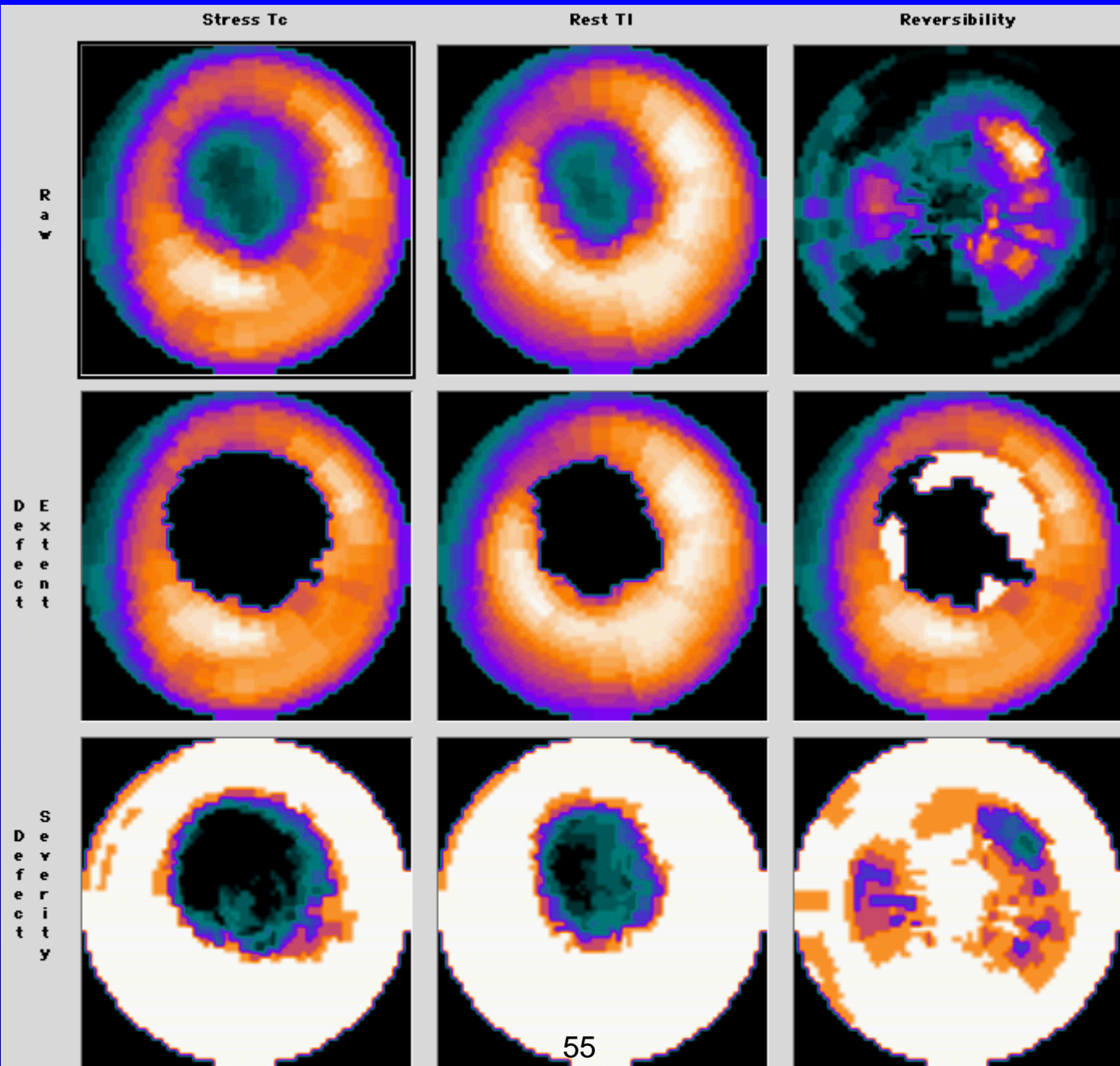
EF = 61%
 EDV = 118 ml
 ESV = 46 ml
 SV = 72 ml
 Mass = 148 gm

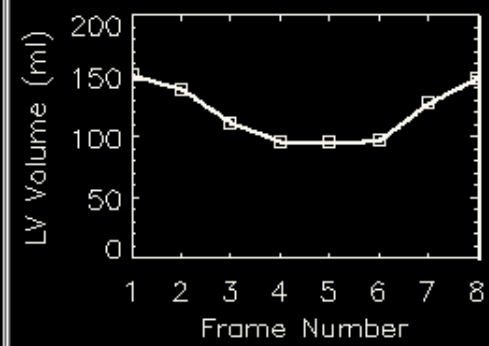


Estimated % Thickening

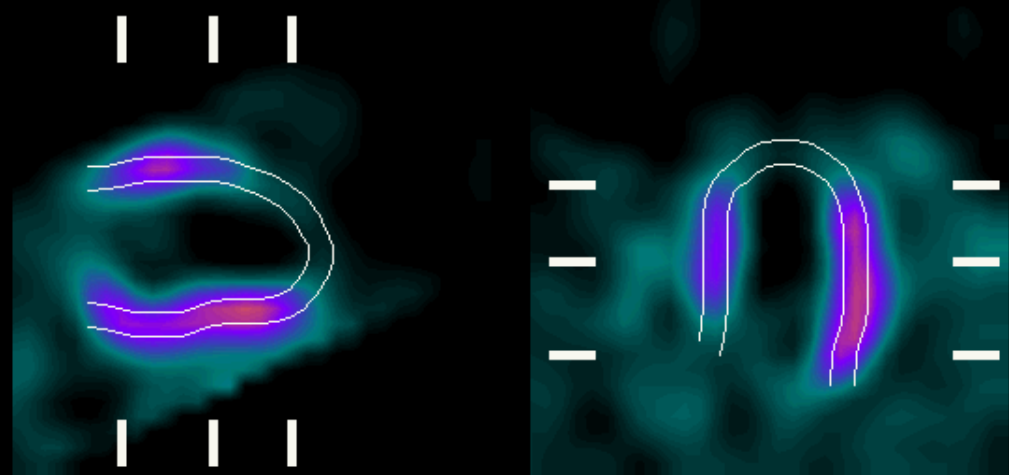
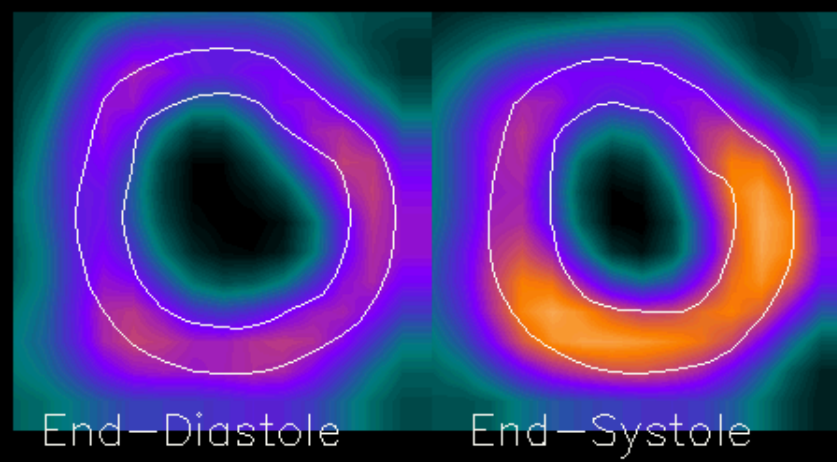




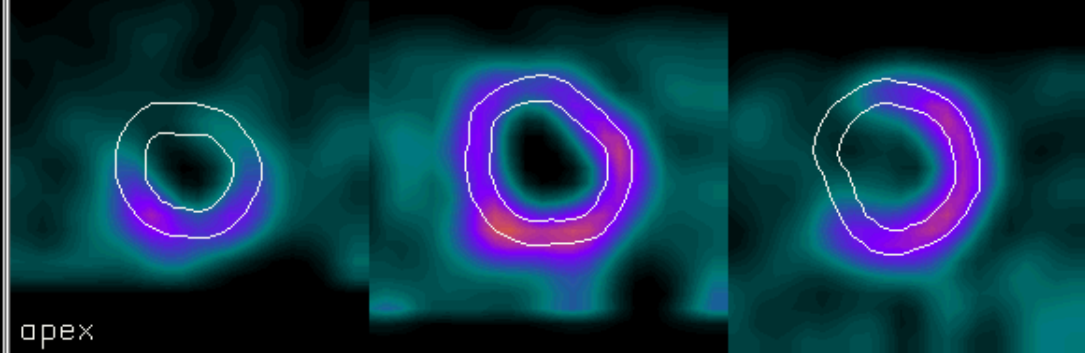
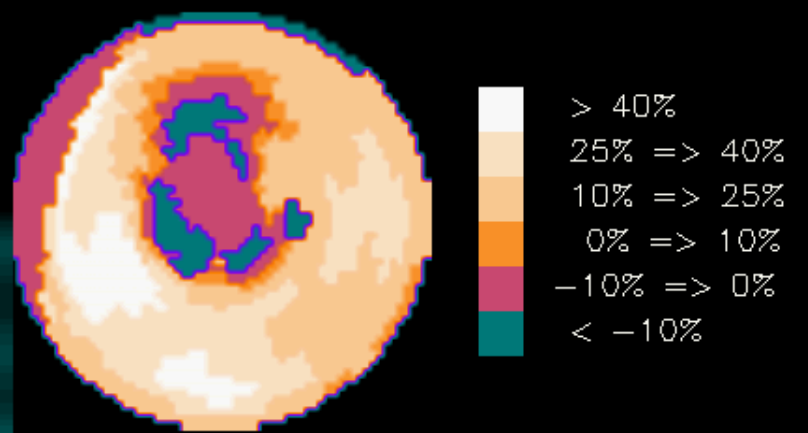




EF = 30% (R1)
EDV = 151 ml
ESV = 106 ml
SV = 45 ml
Mass = 172 gm



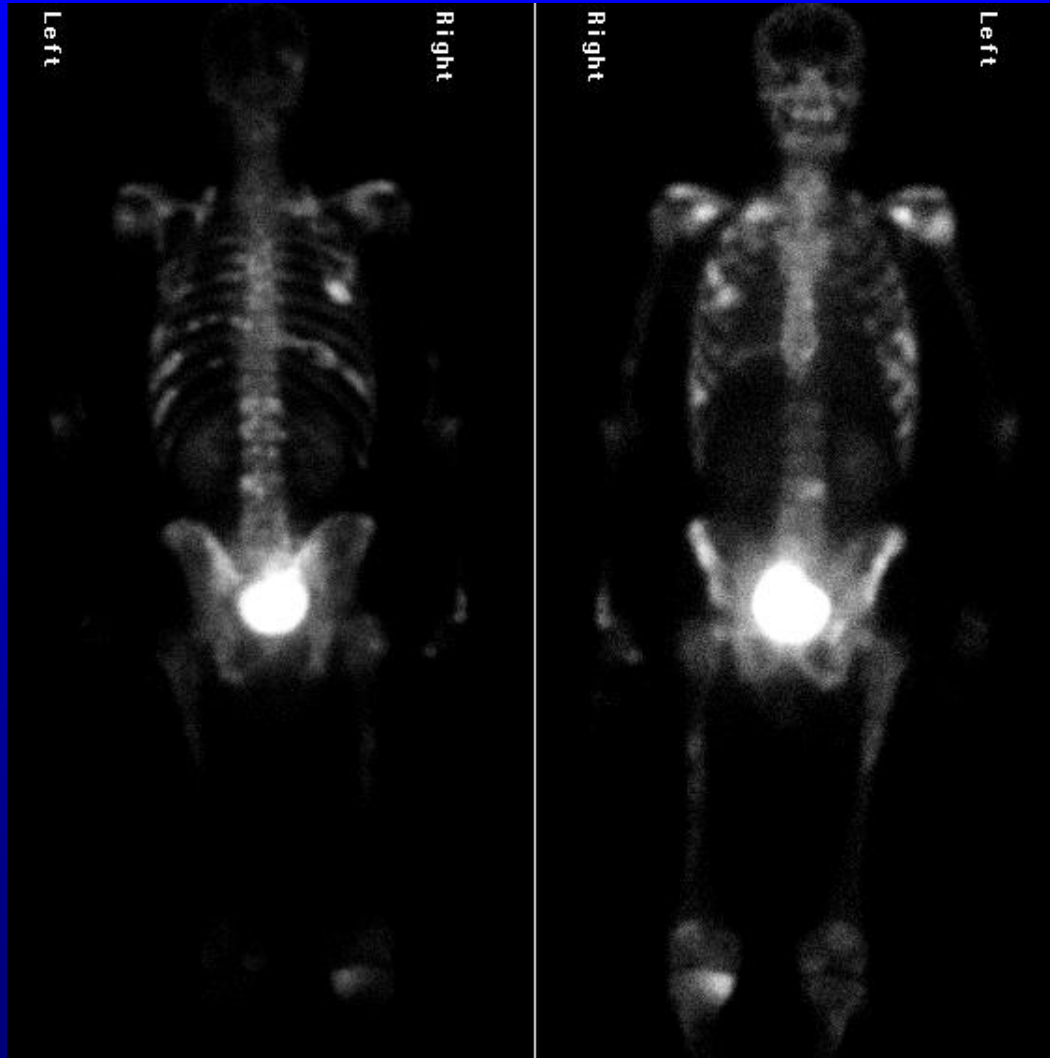
Estimated % Thickening



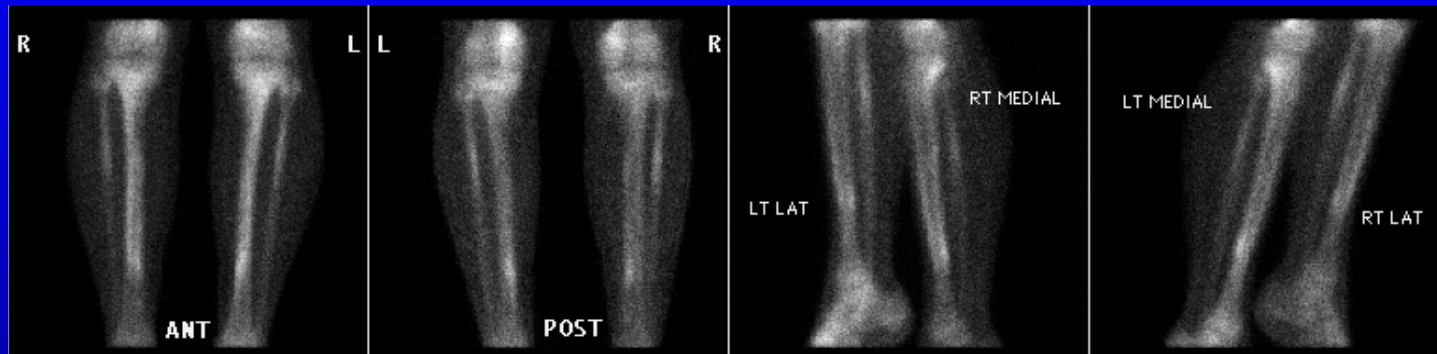
Bone Scan

- Typically performed with **99mTc-methylene diphosphonate (99mTc-MDP)**
- Uptake into hydroxyapatite crystals in bone; increased uptake whenever there is increased bone turnover or remodeling
- Highly sensitive for detecting bony metastasis from most cancer types as long as there is a significant osteoblastic component (**osteoblastic and mixed osteolytic/osteoblastic metastases**)
- Specificity increases with the use of SPECT

Prostate Cancer

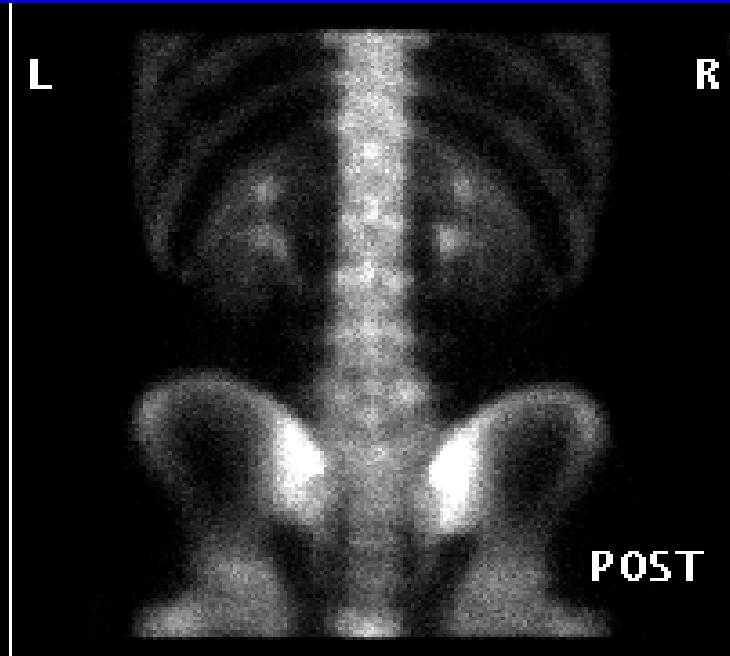
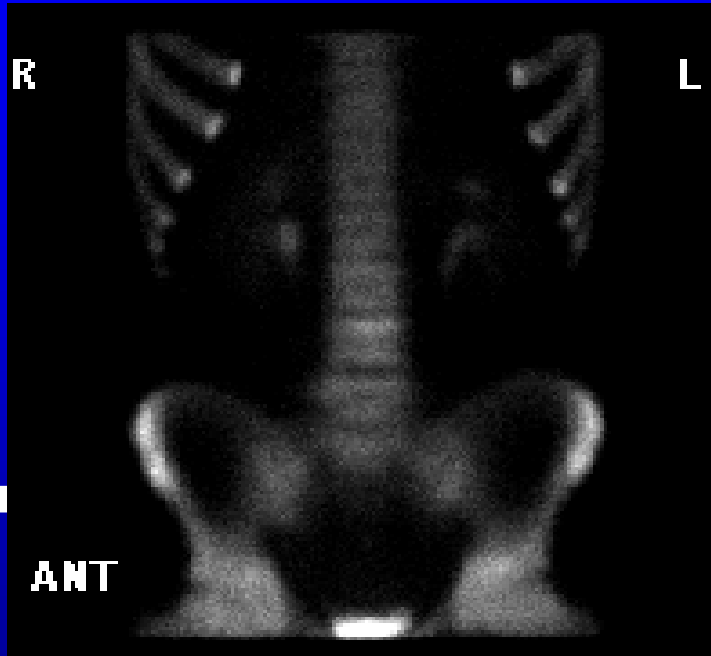


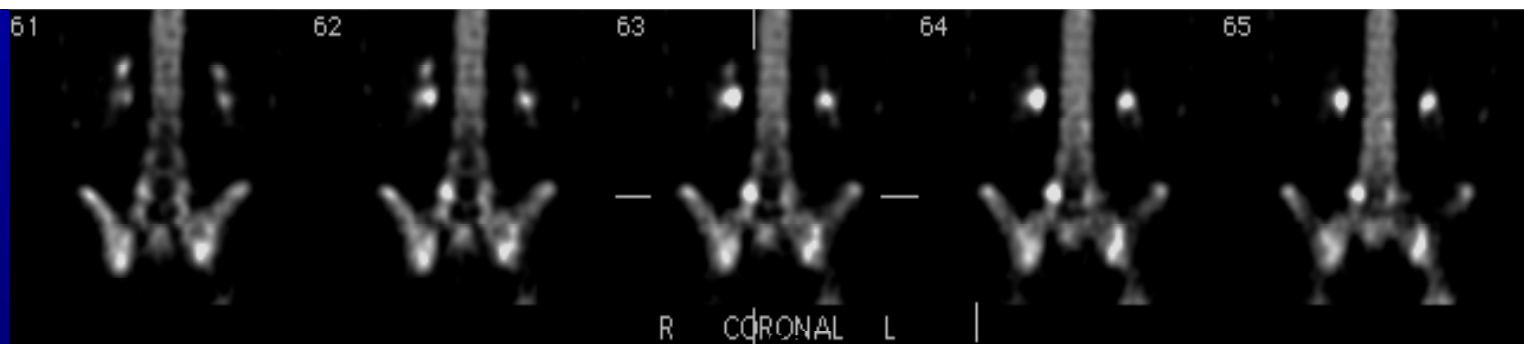
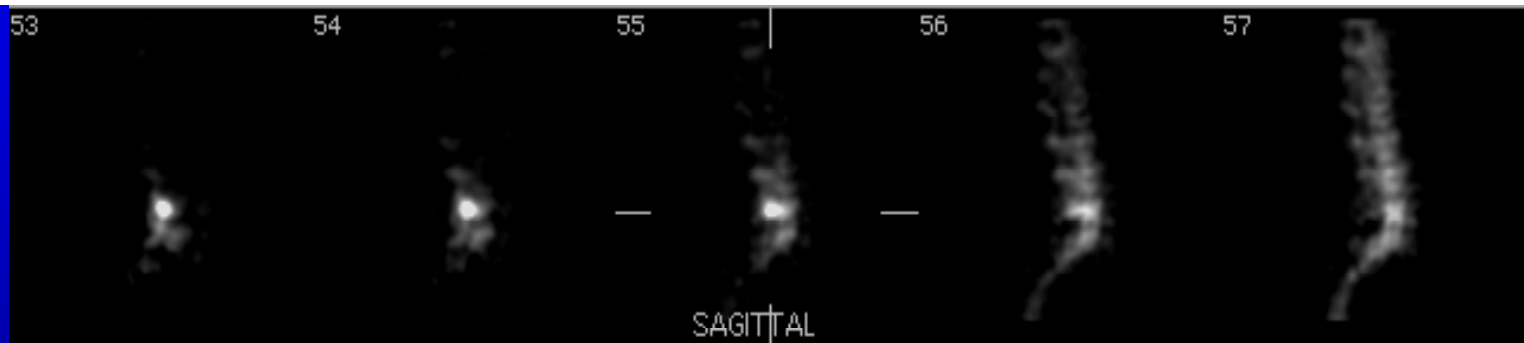
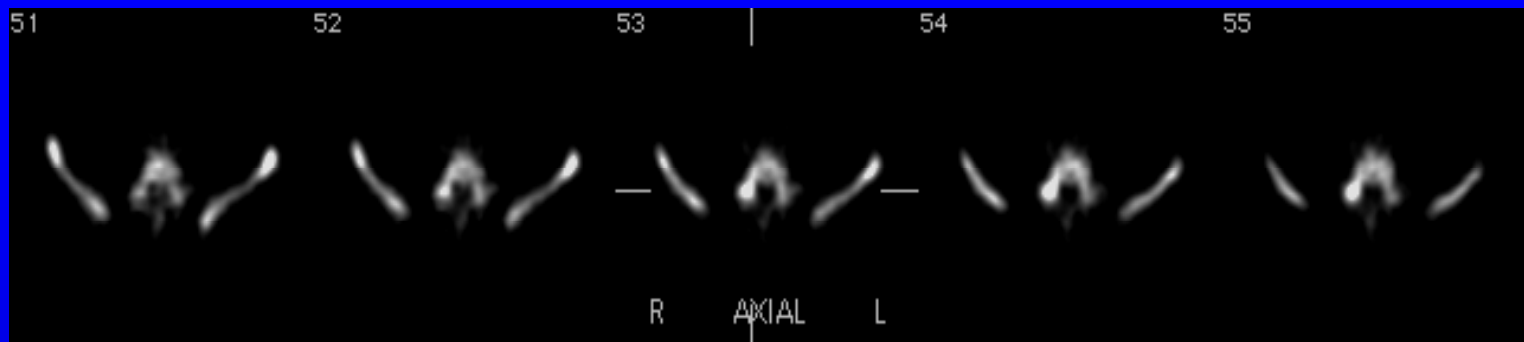
Stress Fracture





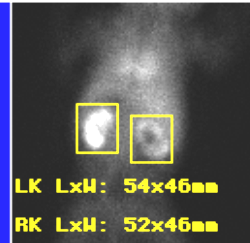
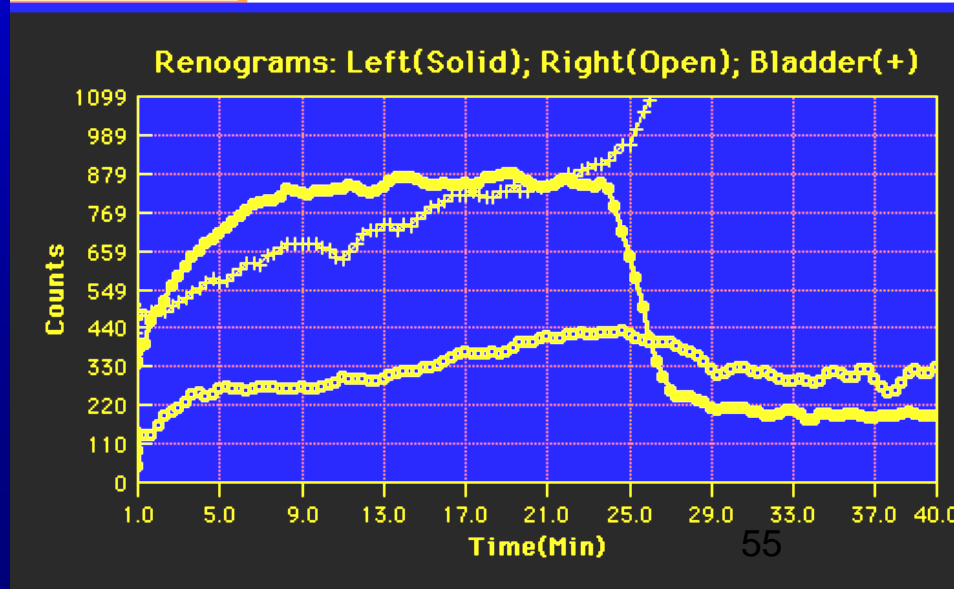
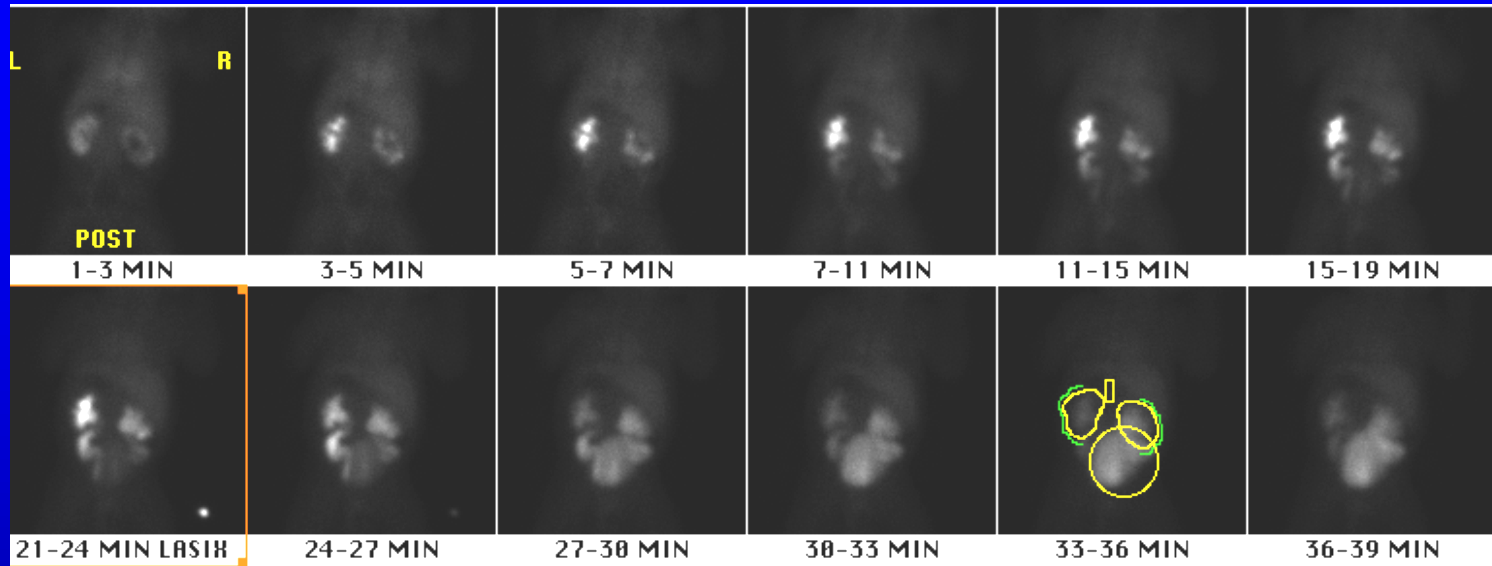
Pagets





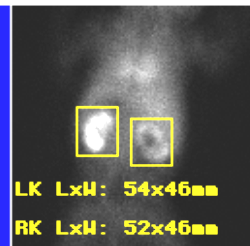
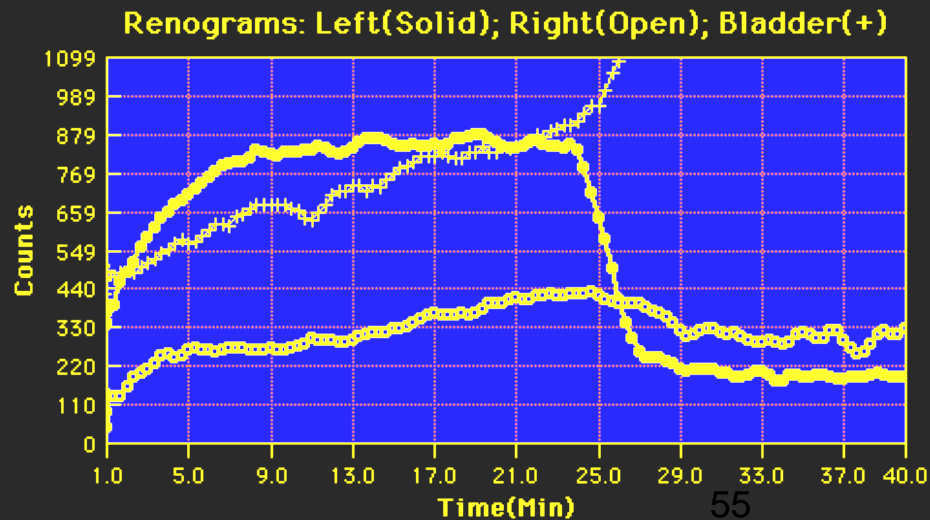
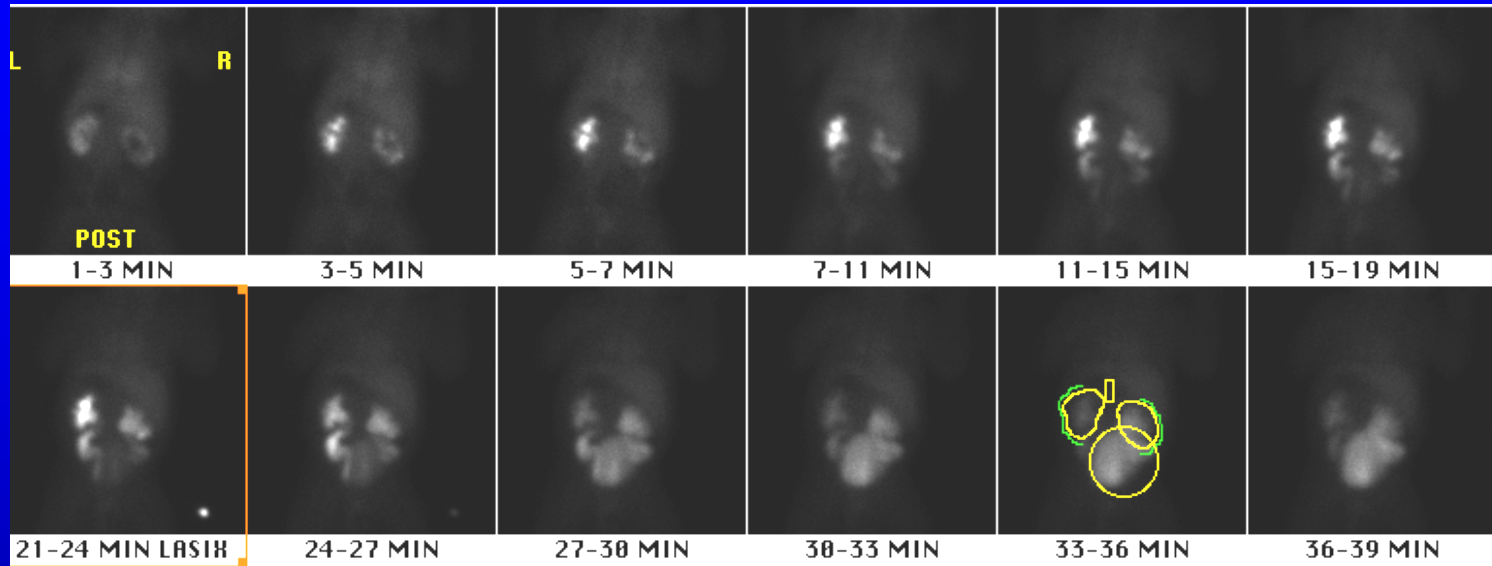
Renal Imaging

- Typically performed with **Tc-99m-MAG3**, a tubular imaging agent, to determine cortical function and collecting system clearance
 - **Tc-99m DTPA**, a glomerular imaging agent, is currently rarely used
- Sometimes performed in combination with **furosemide (diuretic renography)** or **captopril** (to assess for renovascular hypertension)
- Used to:
 - assess differential renal function
 - diagnose urinary tract obstruction (determine urodynamic significance of hydronephrosis seen on ultrasound)
 - assess for renovascular hypertension



***** Renogram Results *****

	Left	Right
Differential Function (1-3 min):	75 %	25 %
Peak Time(Min):	19.0	24.6
20/2-3 Min:	1.62	2.02
20/Peak Min:	1.05	1.01
LASIC T1/2(Min):	1.20	1.06



***** Renogram Results *****

	Left	Right
Differential Function (1-3 min):	75 %	25 %
Peak Time(Min):	19.0	24.6
20/2-3 Min:	1.62	2.02
20/Peak Min:	1.05	1.01
LASIC T1/2(Min):	1.20	1.06

Hepatobiliary Imaging

- Performed using ^{99m}Tc -iminodiacetic acids (**^{99m}Tc -disofenin or mebrofenin**); bilirubin-like agents taken up and excreted into the biliary tree by the hepatocytes
- Most useful to
 - exclude acute cholecystitis (test often performed in combination with **morphine**)
 - rule out chronic acalculus cholecystitis (in combination with **cholecystinin or fatty meal**)
- Other important applications include the diagnosis of common bile duct obstruction, biliary atresia, biliary leak and sphincter of Oddi dysfunction

%
33
0



Ph:1 Fr:1-5 1833K 0sec Duration:300sec
128x128 Pix:3.3mm



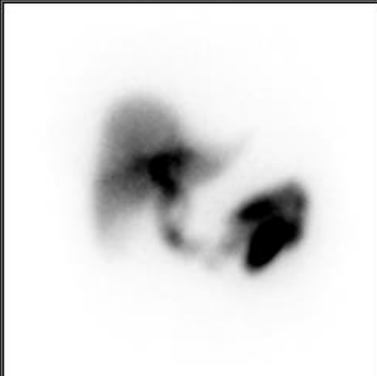
Ph:1 Fr:6-10 2051K 300sec Duration:300sec
128x128 Pix:3.3mm



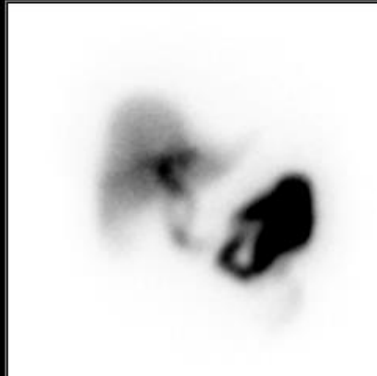
Ph:1 Fr:11-15 2199K 600sec
Duration:300sec 128x128 Pix:3.3mm



Ph:1 Fr:16-20 2219K 900sec
Duration:300sec 128x128 Pix:3.3mm



Ph:1 Fr:21-25 2504K 1200sec
Duration:300sec 128x128 Pix:3.3mm



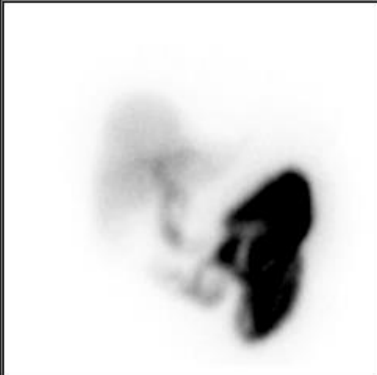
Ph:1 Fr:26-30 2734K 1500sec
Duration:300sec 128x128 Pix:3.3mm



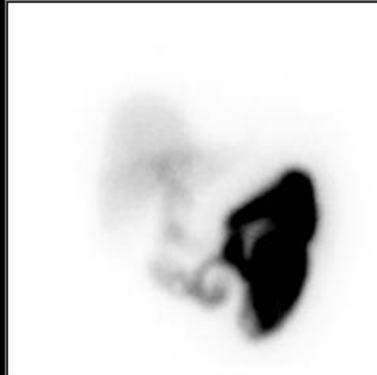
Ph:1 Fr:31-35 2875K 1800sec
Duration:300sec 128x128 Pix:3.3mm



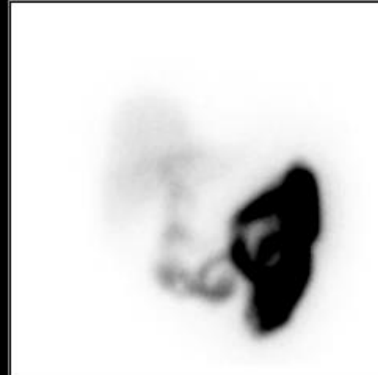
Ph:1 Fr:36-40 3007K 2100sec
Duration:300sec 128x128 Pix:3.3mm



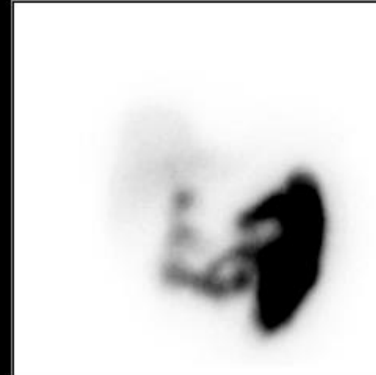
Ph:1 Fr:41-45 3098K 2400sec
Duration:300sec 128x128 Pix:3.3mm



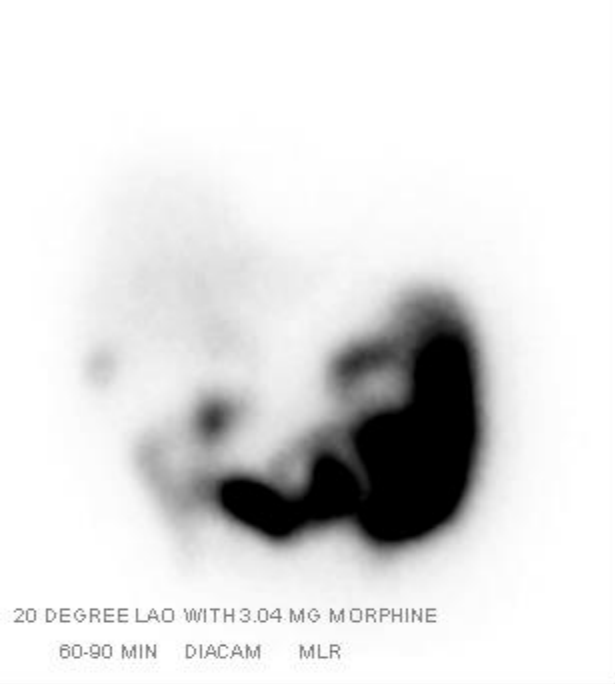
Ph:1 Fr:46-50 3224K 2700sec
Duration:300sec 128x128 Pix:3.3mm



Ph:1 Fr:51-55 3288K 3000sec
Duration:300sec 128x128 Pix:3.3mm



Ph:1 Fr:56-60 3258K 3300sec
Duration:300sec 128x128 Pix:3.3mm

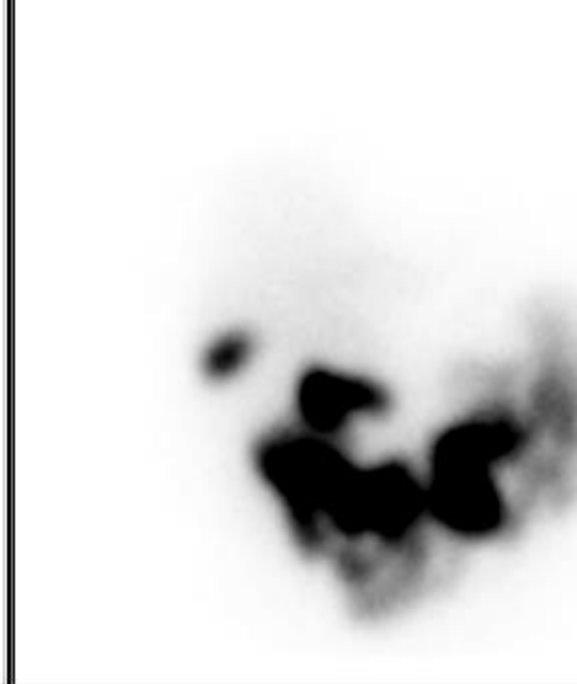


20 DEGREE LAO WITH 3.04 MG MORPHINE
60-90 MIN DIACAM MLR

1-5 3340K 0sec Duration:300sec 128x128 Pix:3.3mm



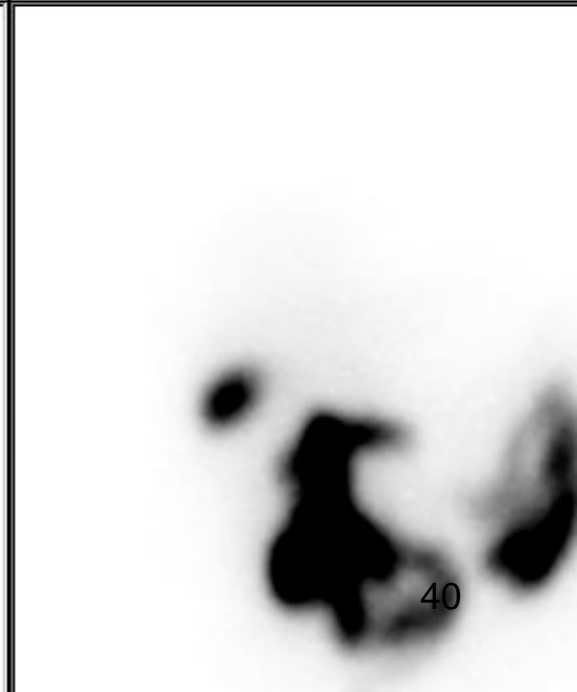
Ph:1 Fr:6-10 3250K 300sec Duration:300sec 128x128 Pix:3.3mm



Ph:1 Fr:11-15 3006K 600sec Duration:300sec 128x128 Pix:3.3mm

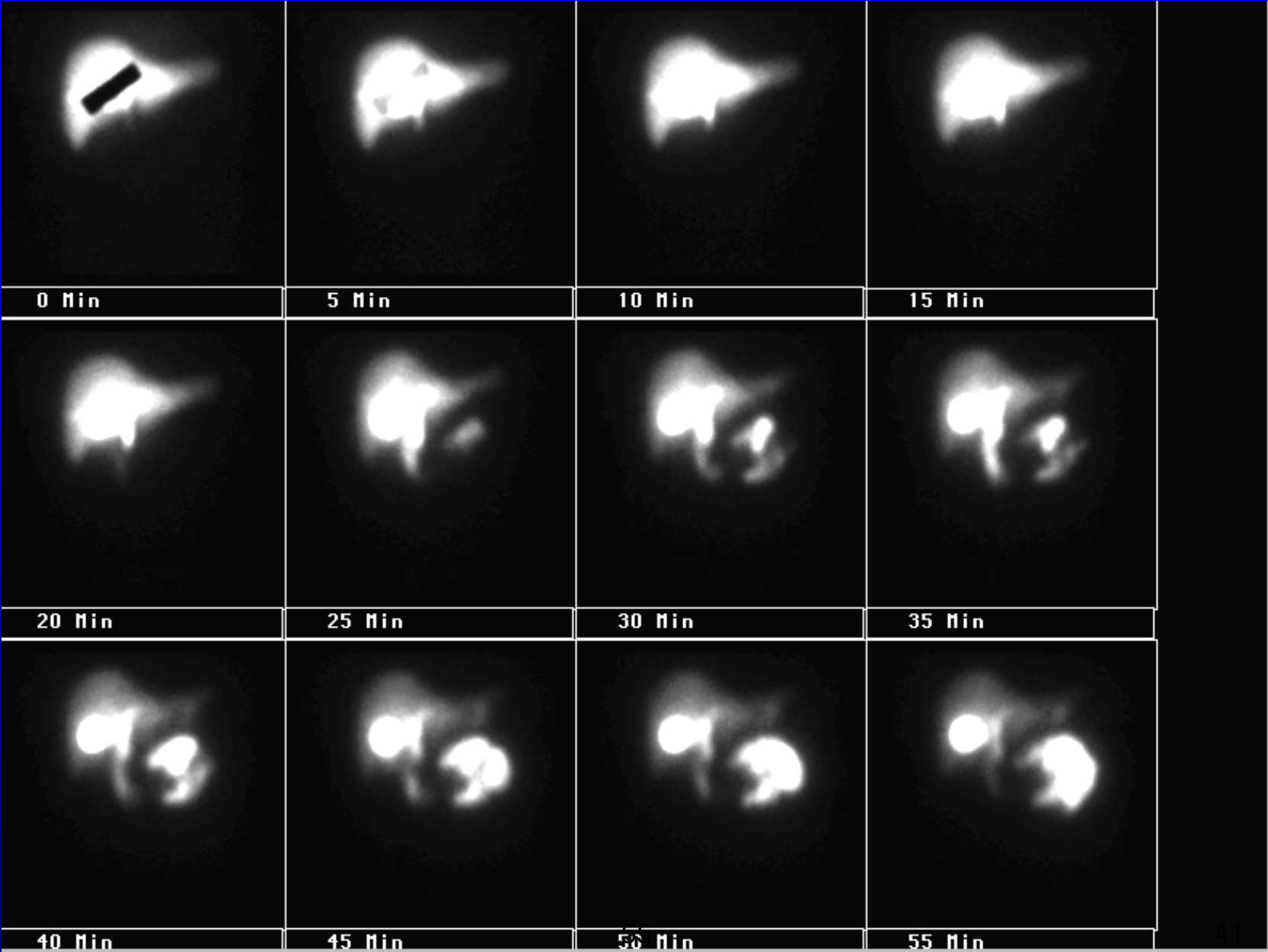


35



40

Postprandial RUQ pain, neg US



Patient Name: MAULDIN, DALE
Patient ID: 68-16197

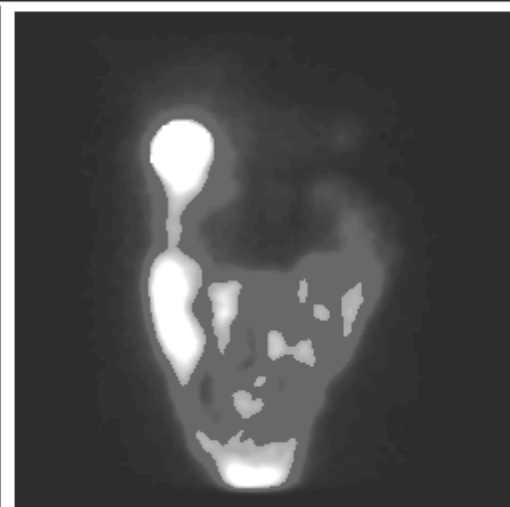
ACQ date: 14-JUN-2000 Tech: jj Camera: DIACAM 11
Protocol: HEPATOBILIARY w/ SINCALIDE Tc99m MEBROFENIN



Pre Eject: Frame # 1



10 min: Frame # 10



30 min frame

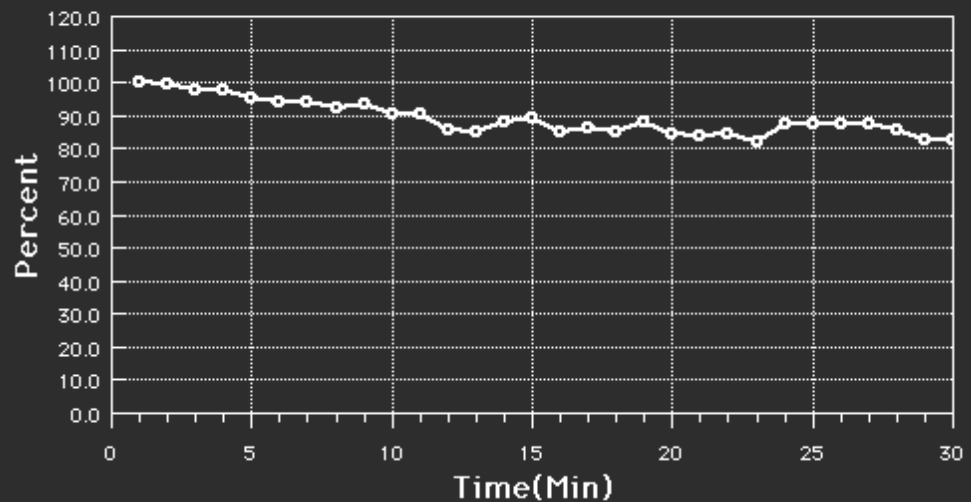
*** 10 Minute EF ***

Pre Eject Counts: 119723.
Post Eject Counts: 118549.
Ejection Fraction: 0.9 %

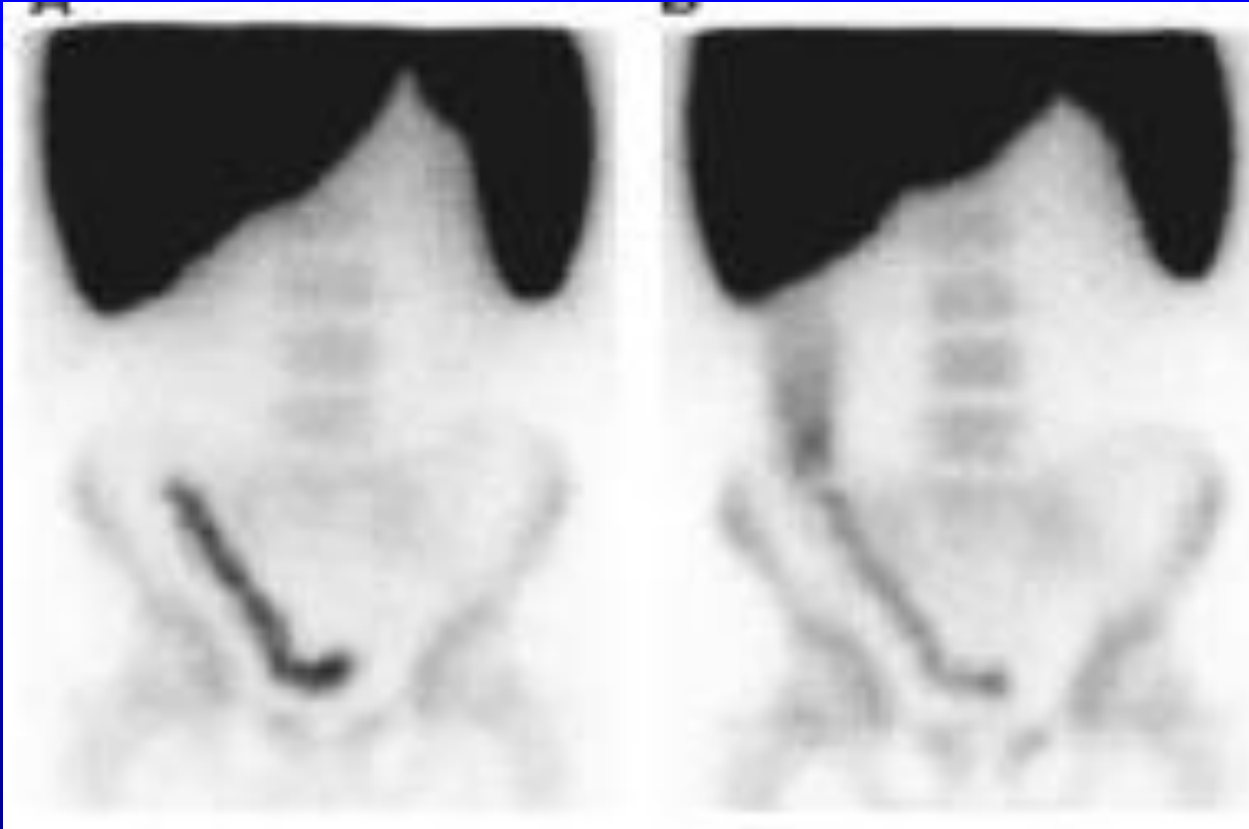
*** 30 Minute EF ***

Pre Eject Counts: 119723.
Post Eject Counts: 110027.
Ejection Fraction: 8.0 %

Gall Bladder TAC



Labeled White Blood Cells



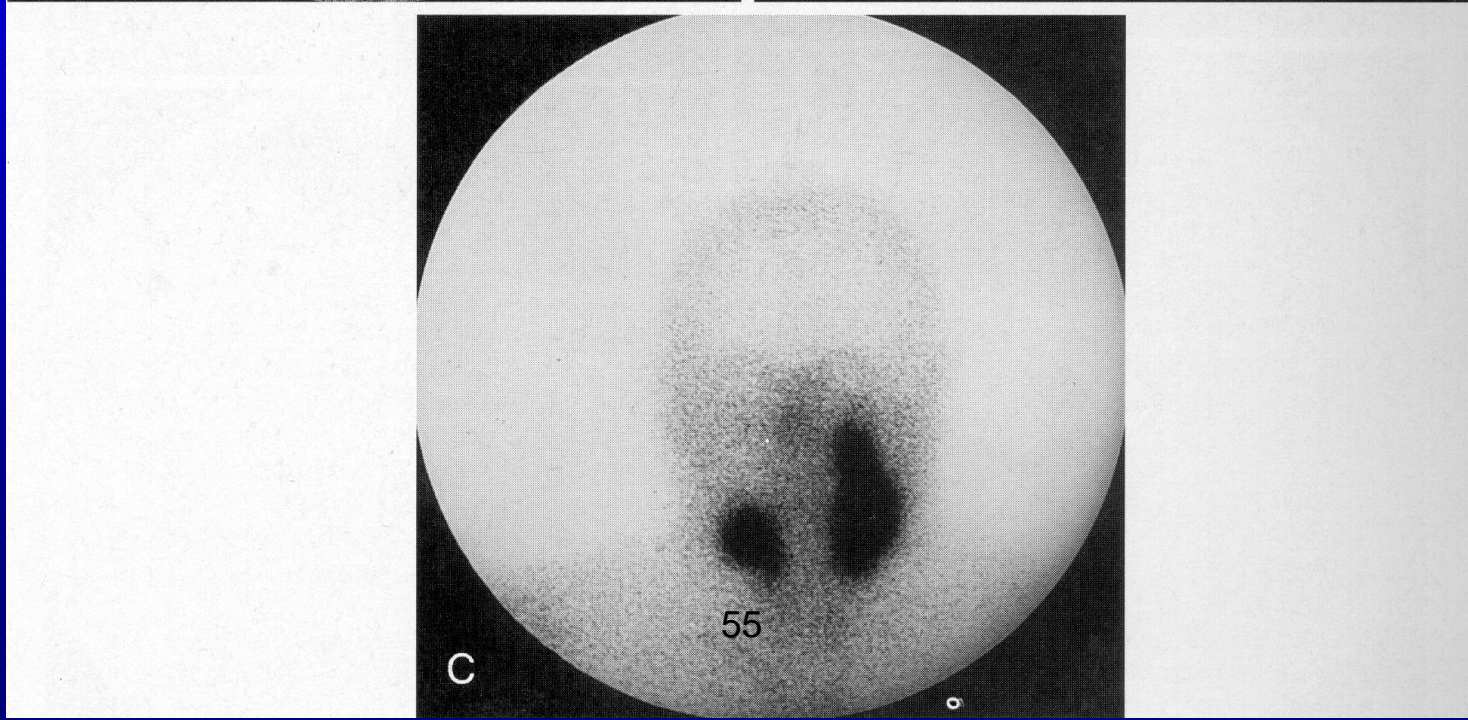
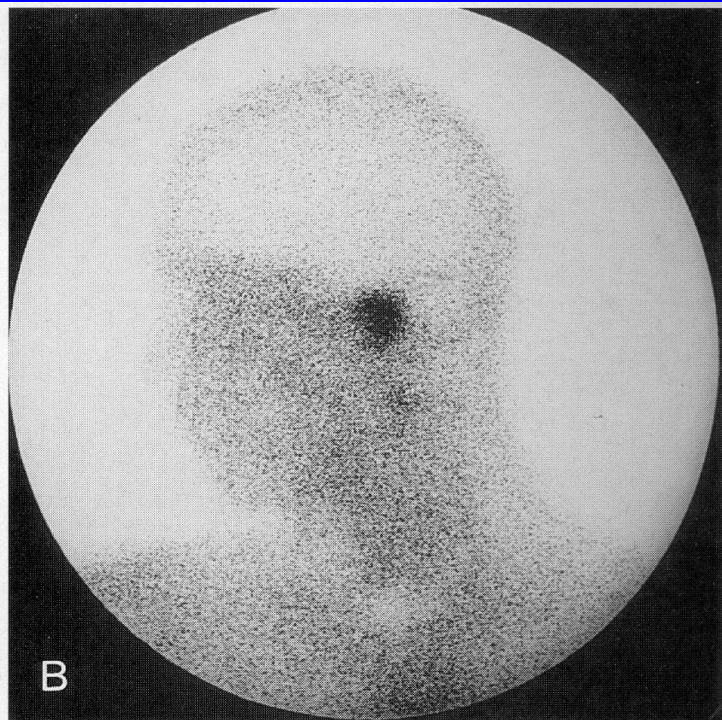
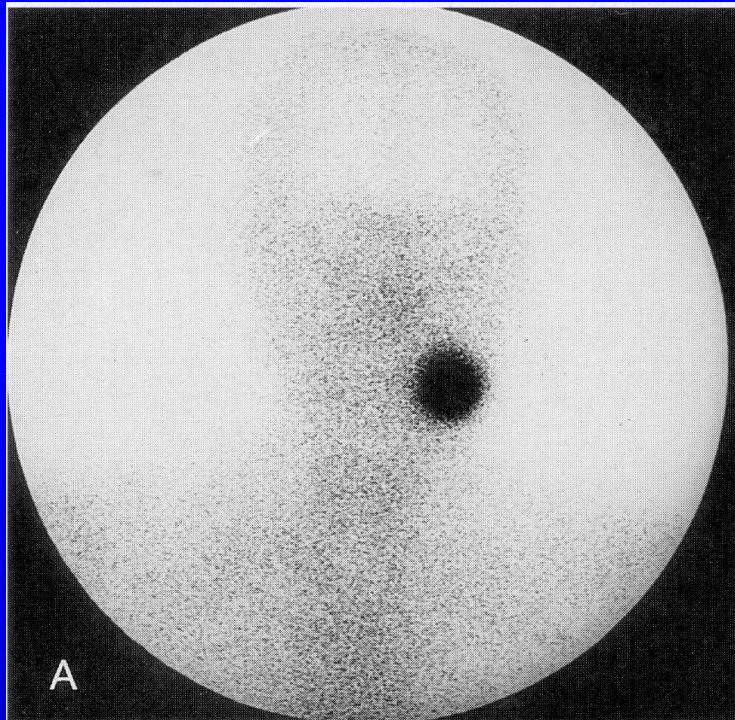
Imaging of Crohn's disease with ^{99m}Tc -stannous fluoride colloid-labeled WBC's

Somatostatin Receptor Imaging



^{111}In Octreotide scintigraphy

Hurthle cell tumor of right thyroid lobe



PET Imaging

➤ Performed using a PET or PET/CT scanner in combination with radiotracers labeled with positron-emitting isotopes:

➤ ^{11}C , ^{18}F , ^{15}O , ^{13}N

➤ **F-18-fluorodeoxyglucose (FDG)**, a glucose analog, is the most widely used and first clinically approved radiotracer for PET imaging, therefore **FDG-PET** imaging

FDG-PET Imaging

used for:

- ✓ Staging, response assessment and restaging of FDG-avid cancers (breast, lung, head& neck, endometrial, cervical, ovarian, esophageal, gastric and colorectal cancers, lymphomas and melanomas)
- ✓ Assessment of myocardial viability
- ✓ Localizing seizure foci
- ✓ Differential diagnosis of dementias



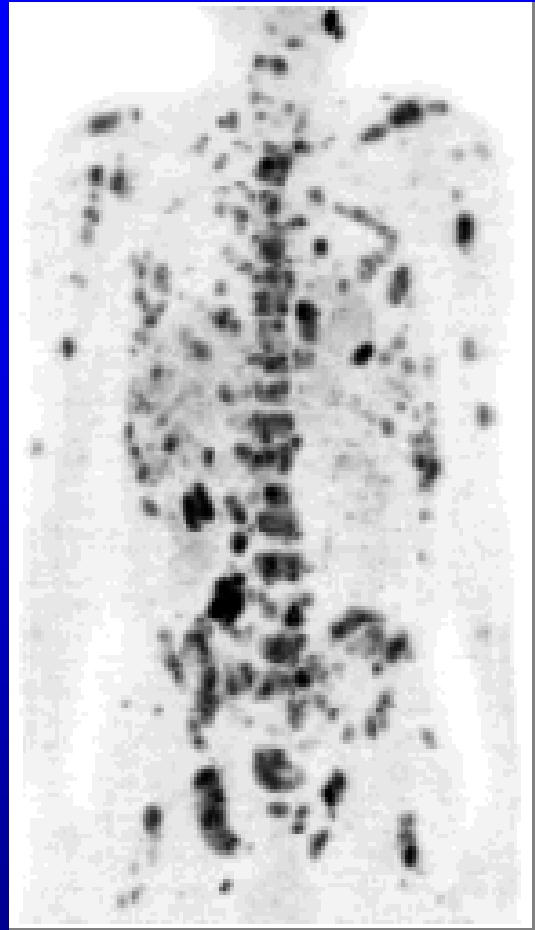


Image courtesy of Rush-Presbyterian-St Luke's Medical Center, Chicago

PRE THERAPY



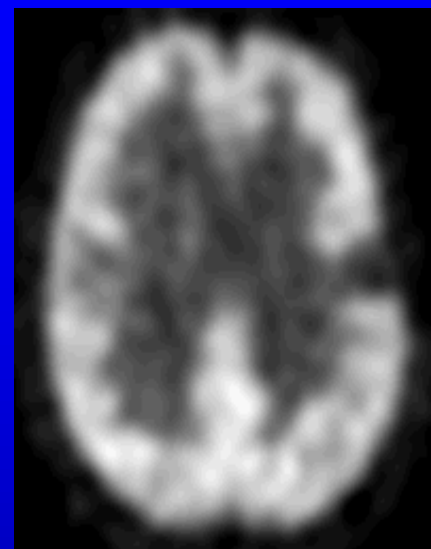
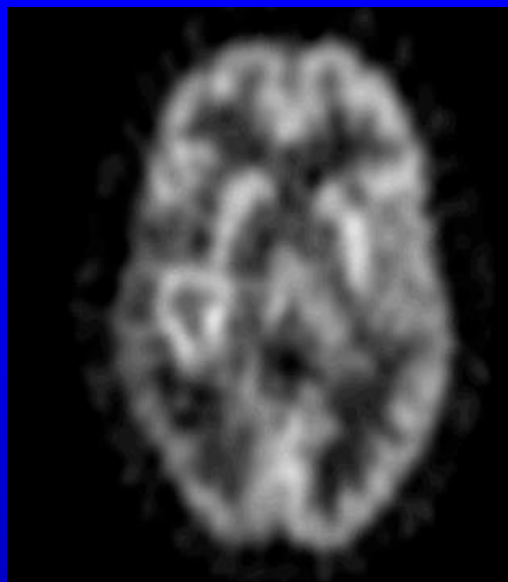
POST THERAPY



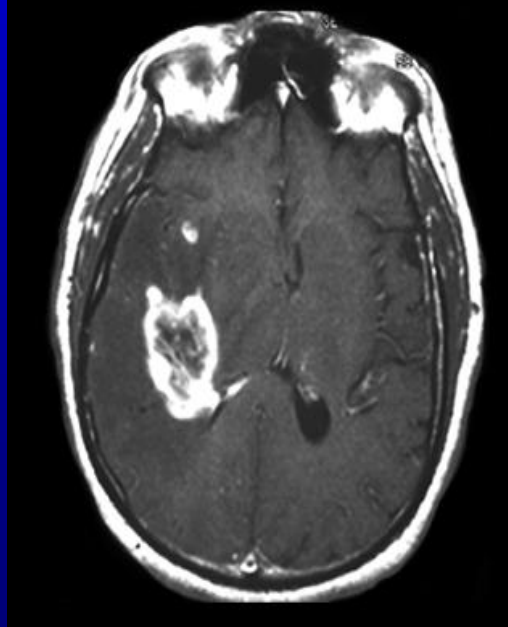
Recurrent Glioma

Radio-necrosis

FDG/PET



MRI

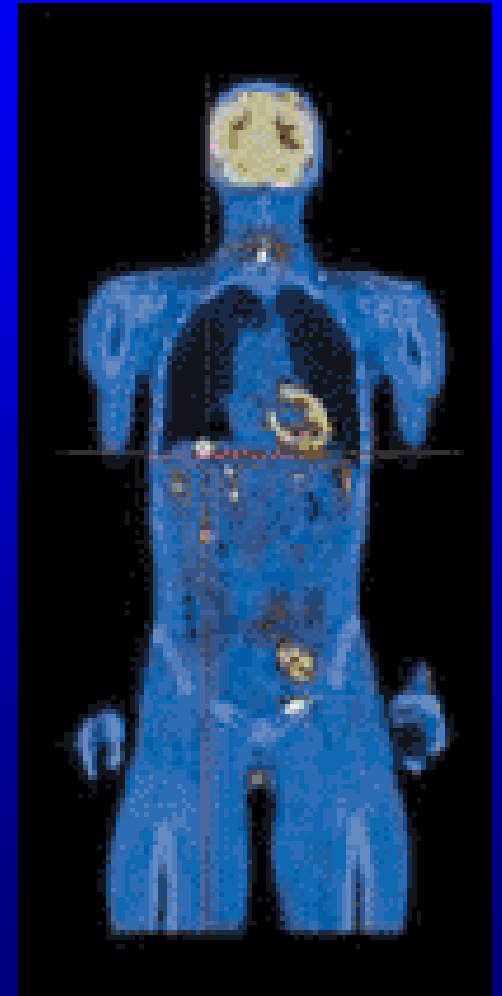


Fused Image Technology

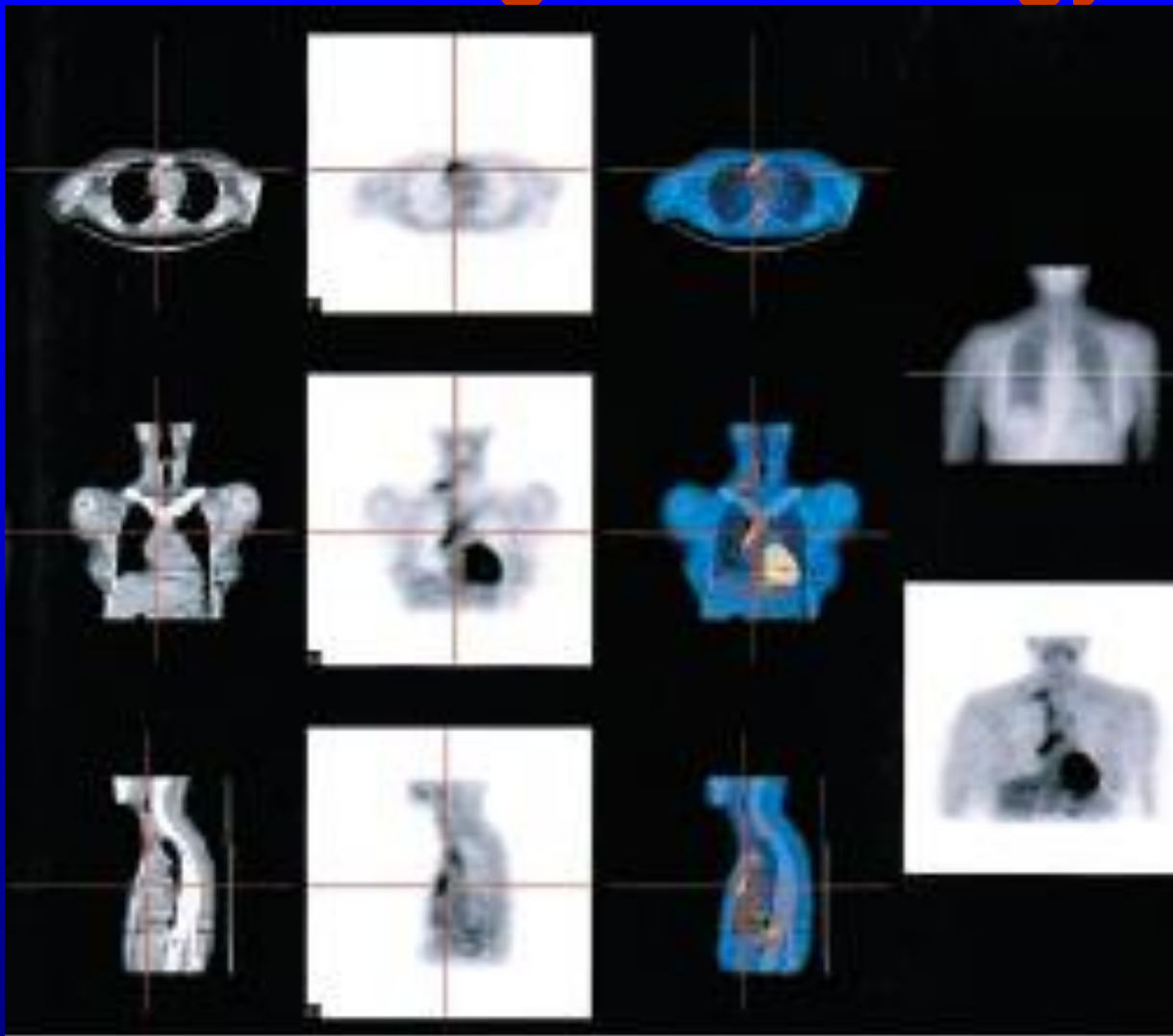
Functional & Anatomical Imaging

PET/CT

PET/MRI



Fused image technology



NHL 18FFDG PET/CT reveal intense 18FFDG uptake in right supraclavicular region and right anterior mediastinum

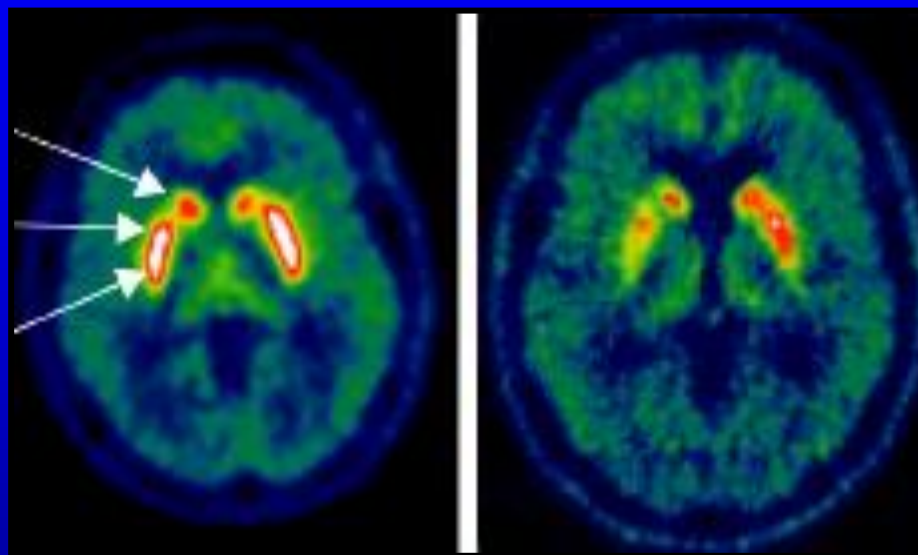
Molecular imaging

Not Just FDG

Caudate nucleus

Rostral putamen

Caudal putamen



^{18}F -DOPA PET images at the striatal level in a healthy volunteer (left) and in a patient with PD (right)

Radiation Protection

- Any radiation, no matter how small, may result in human health effects such as cancer and hereditary damage
- There is substantial and scientific evidence for health risks at high doses
- Risks of health effects are too small to be observed and, therefore, unknown for or for doses below 10 rem (100 mSv)
- Average dose in nuclear medicine procedures 0.46 rem (4.6 mSv)

Radiation Protection

Comparison of various risks in terms of loss of life expectancy (LLE)

Risk	LLE
Cigarette smoking (1 pack/day)	2441
Poor social conditions	1644
Heart disease	1607
Cancer	1247
Motor vehicle accident	205
Astma	11.3
Passive smoking	50
Medical radiation (10 mSv)	2

External exposure hazard of a nuclear medicine patient in the clinic or hospital

The patient is a potential source of radiation exposure to others in the vicinity but not necessarily a radiation hazard at low dose rates encountered in nuclear medicine.

In caring for a bone scan patient nursing staff will receive an average of 2 - 4 μSv if the patient is self-caring

Members of the public have a dose constraint of 1 mSv/year

Nevertheless nurses should be aware of patients to whom radioactive materials have been administered

