Unusual and Less Utilized Procedures in Nuclear Medicine

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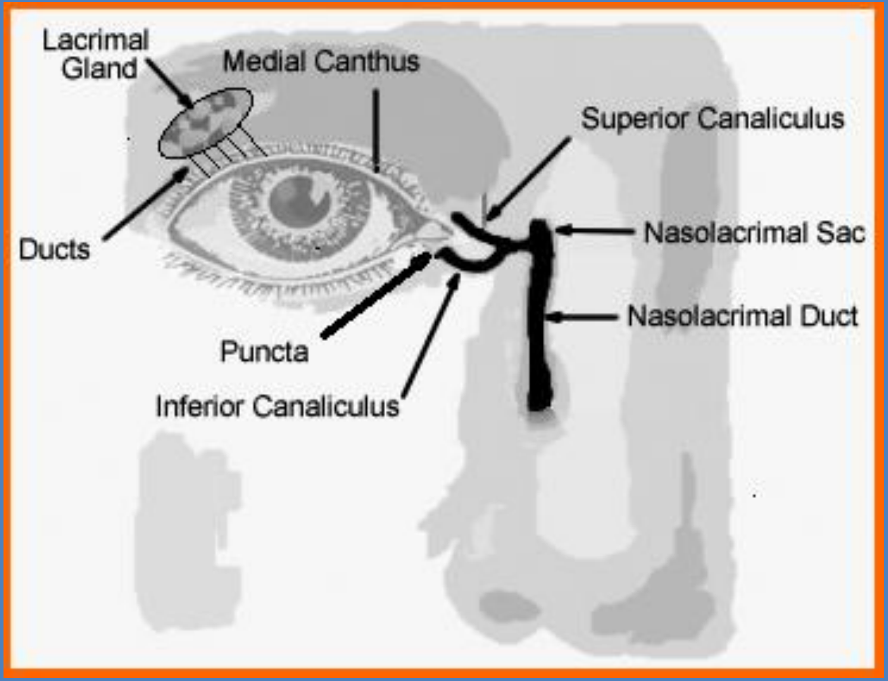
Time to Stand Up – 4:30p Stretch

What do I have to Claim?

- Not working for any Industry related to nuclear medicine
- I don’t own any type of nuclear stock, unless my 401k has invested in something I don’t know about
- I’m just a technologist that loves to educate and misses patient care

Anatomy of Tear Production

- Tears bathe the eye
- Fluid contains water, mucin, lipids, lysozyme, lactoferrin, lipocalin, lacritin, immunoglobulins, glucose, urea, sodium, and potassium
- Exit out the puncta and travel down the nasolacrimal duct



Nasolacrimal Duct Obstruction (NLDO)

- NLDO appears as epiphora and periocular discharge
- Causes
  - Congenital
  - Blockage
    - Stone
    - Tumor
  - Infection

Dacryoscintigraphy – Nuke it!

Dose preparation

- Requires ~ 200 µCi per eye of pertechnetate
- Goal – make a 200 µCi drop
- So how do we get there?
- Do a couple of calculations

To get 1 drop to equal 200 µCi

1 - About 20 drops = 1 mL
200 µCi x 20 = 4.0 mCi

2 - Prepare 10 mL soluition

3 - 4.0 mCi x 10 mL = 40 mCi

4 - If you have a vial of activity that measures 100 mCi/mL you need 0.4 mL

5 - 40 ~~mCi~~ x 1mL/100 ~~mCi~~ = 0.4 mL

6 - To make 10 mL solution add 9.6 mL of saline (10 mL - 0.4 mL = 9.6 mL)

The 20 drop challenge

- In an attempt to prove that 20 drops = a mL
- Prepared vial of activity that had 40 mCi in 10 mL.
- Placed one drop at a time and measured the dose
- Drops 1 – 5 were measured and recorded
- Average drop = 118.8 µCi

1 drop = 119.4 µCi
2 drops = 234 µCi
3 drops = 347 µCi
4 drops = 465 µCi
5 drops = 585 µCi

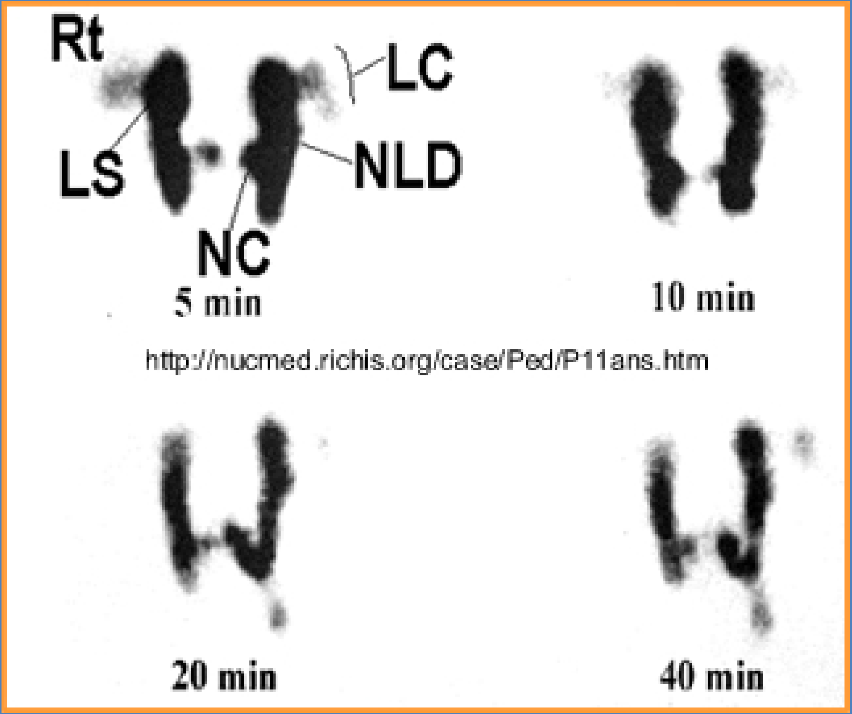
Sum of acitivity = 1750 µCi
Average drop = 118.8 µCi

Dacryoscintigraphy

- Place 1 drop in each eye
- Using a pinhole collimator image 64 or 128 matrix
- Acquire 30 sec/frame for 5 minutes
- FOV to include both eyes
- If drainage is sluggish use digital massage over nasolacrimal duct
- If needed add saline to flush the radiopharmaceutical
- Evaluate your results

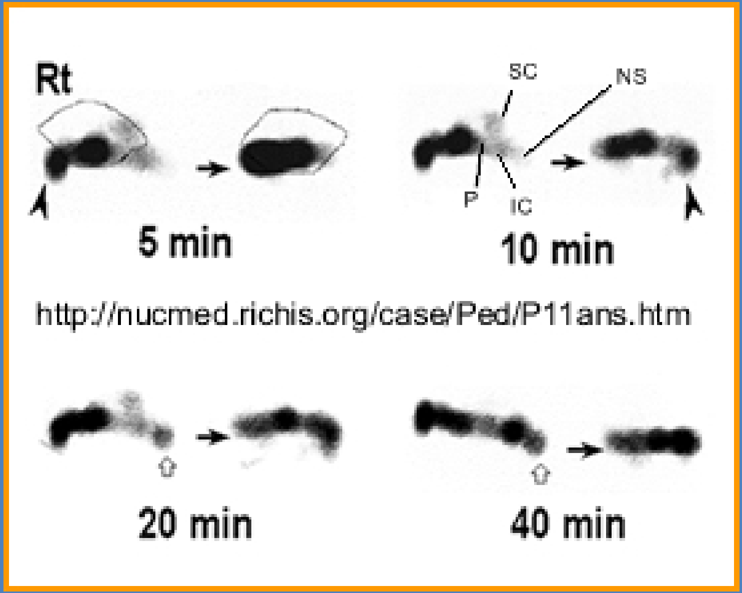
Results

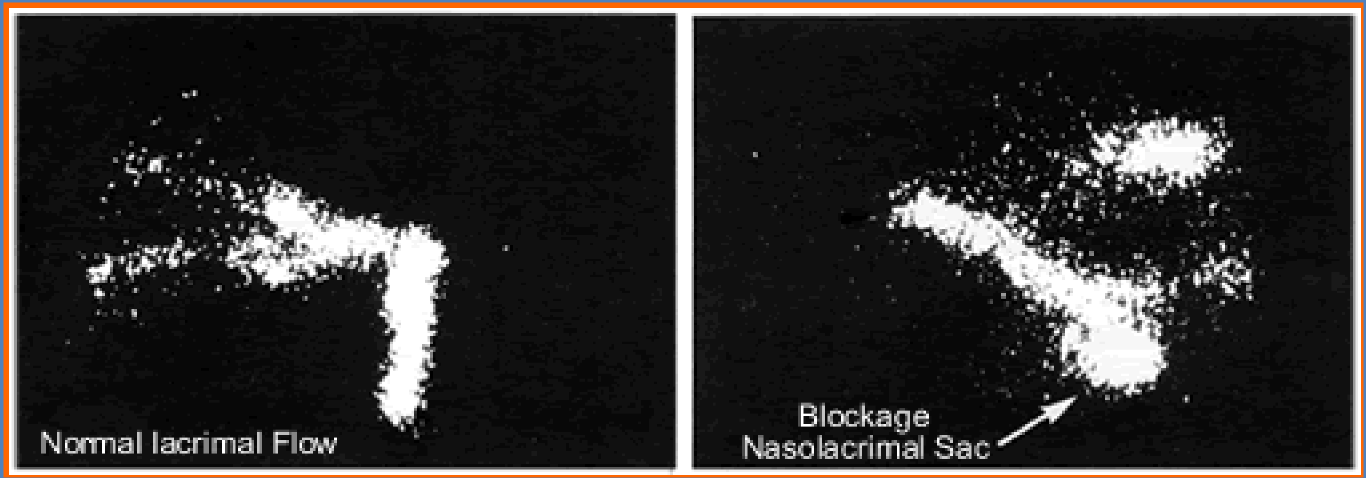
- Here is an example of normal tear flow
- Activity is seen flowing from the puncta to the Nasolacrimal duct
- Both sides are approximately equal in draining the radio-tracer



Results

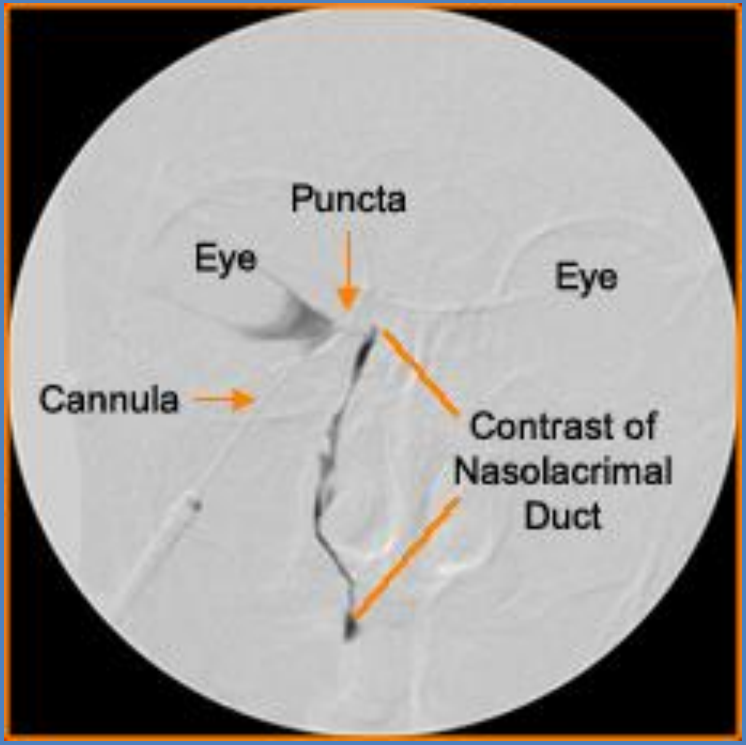
- Here are two examples of a positive study
- Both show the lack of activity flowing down to the nasolacrimal duct(s)





What About Radiography?

- Dacryocystography
- Requires cannulation and the injection of contrast
- Gives anatomical detail
- Greater radiation dose
- Possible trauma due to contrast
- Shams PH (2016) uses the nuclear approach
  - His literature suggests nuclear as pre and post surgical procedure



Brain Death

- Trauma to the brain causes, “irreversible cessation of circulatory and respiratory function.”
- Tests for brain death
  – Apnea test
  – EEG
  – Transcranial Doppler
  – Angiography
  – Nuclear Medicine

Application of ^{99m}Tc-DTPA

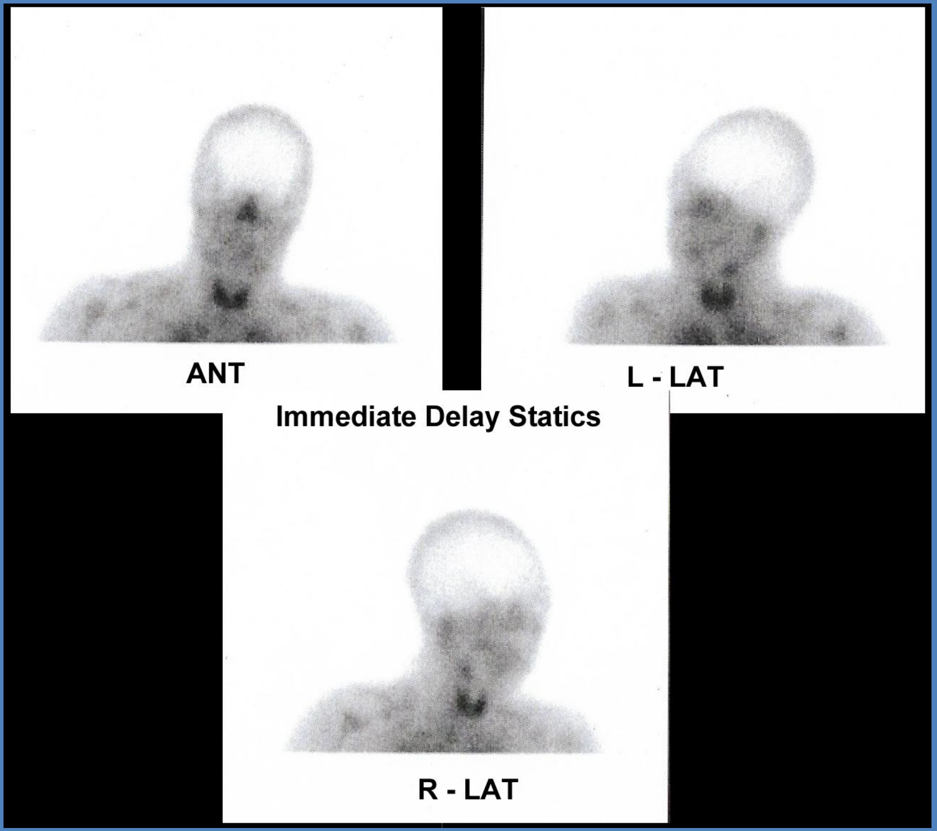
3 – Second Flow Study

Immediate Static
5 – Minute Acquire
Repeat static if necessary

Where is the Sagittal Sinus?

Application ^{99m}Tc-HMPAO

- 5 – Second flow study
- Immediate statics
  - 5-minutes per frame Anterior, R/L – LAT
- Statics may be repeated
  - Up to 1 – hour post
- Attending physician must interpret the results



Discussion

- Harvesting the body parts
- Which radiopharmaceutical should be used?
  - DTPA
  - HMPAO
  - ECD
    - Spieth ME (1994): HMPAO and DTPA gave the same results, however, HMPAO is more "sensitive"
    - Güzel Y (2014): DTPA cost less and answers the question. Evaluation done on rats
  - MCV
    - HMPAO costs less than ECD
    - Crosses the BBB
    - Even though HMPAO is an rCBF agent a blood flow is also completed

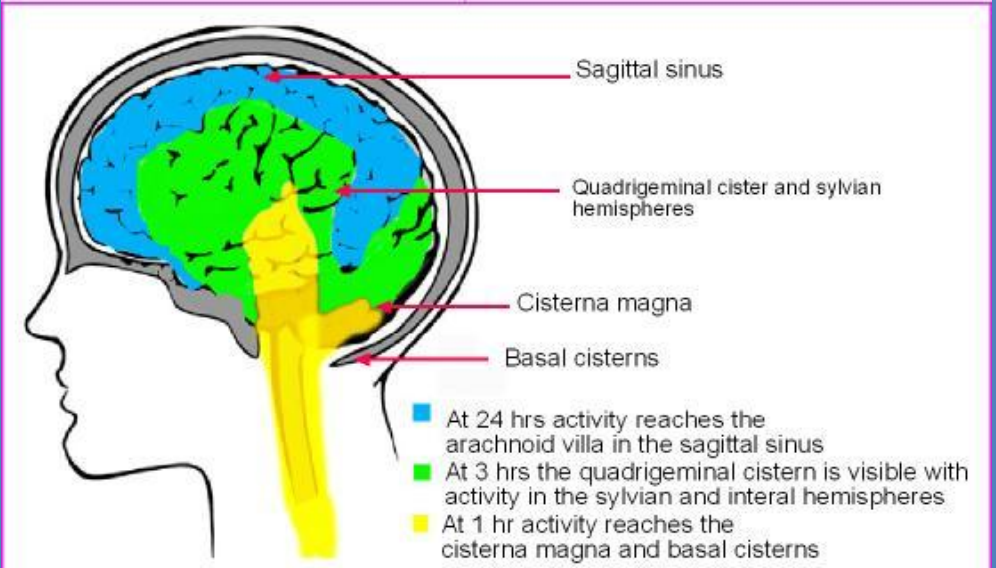
Cisternogram - Hydrocephalus

- Cause
  - Genetic or developmental disorder
  - Meningitis, tumors, trauma, subarachnoid hemorrhage

- Symptoms
  - Infants: increased cranium circumference
  - Adult: vomiting, balance or gait issue, incontinence, mental impairment
- Diagnose by CT, MR, intracranial pressure, and NM

Flow of the CSF

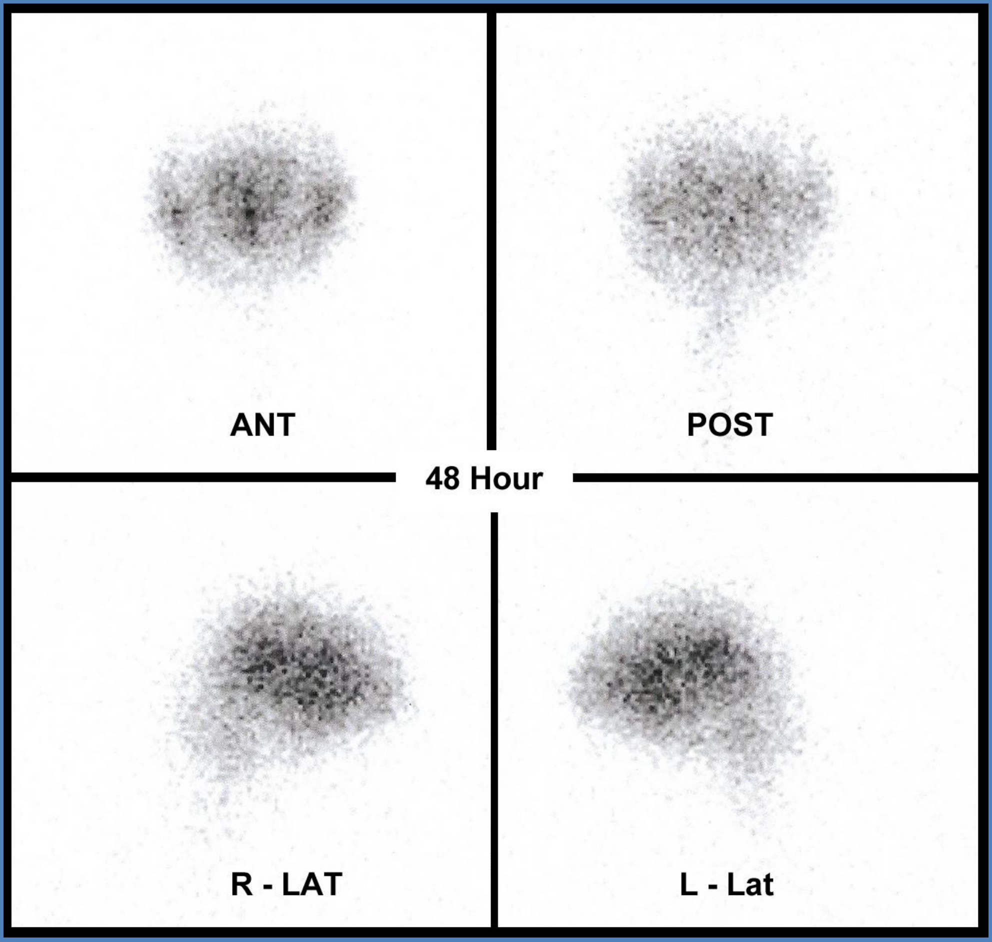
- Flowing ~500 µCi ^{111}InDTPA intrathecal injection
  - May require flouroscopy
- Tracer flows a path
  - 1 Hour cisterna magna and basal cisterns
  - 3 Hours reaches sylvian fissure and internal hemispheres
  - 24 Hours SSS exits out arachnoid villa



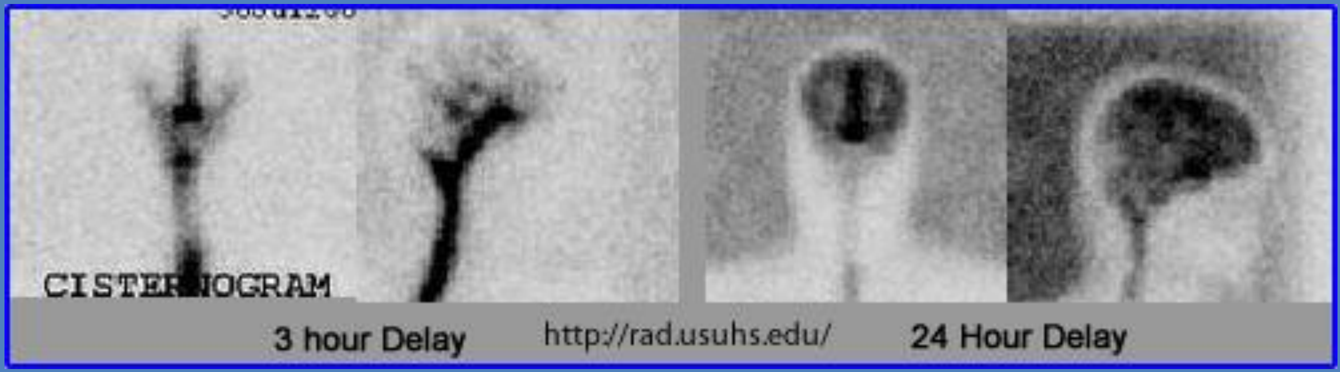
Normal CSF Flow Following Radiotracer Administration

Normal Pressure Hydrocephalus

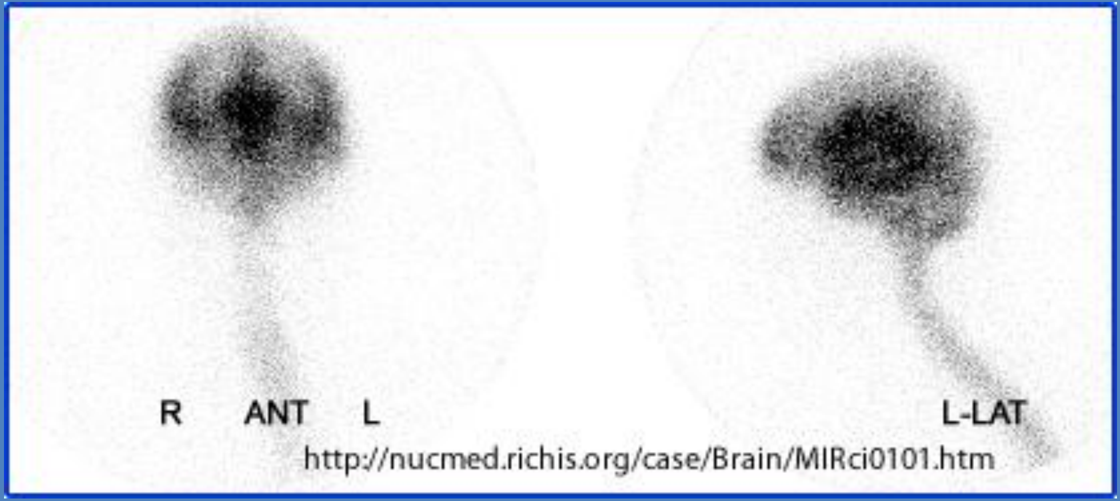
- A 73-yr old male received 550µCi ^{111}InDTPA
- 4 Hrs image appears somewhat normal
- Activity reaching sylvian fissure and internal hemispheres
- However, at 24 and 48 hrs tracer uptake fails to exit the SSS



Other cases



Normal – Distribution of the 111In-DTPA

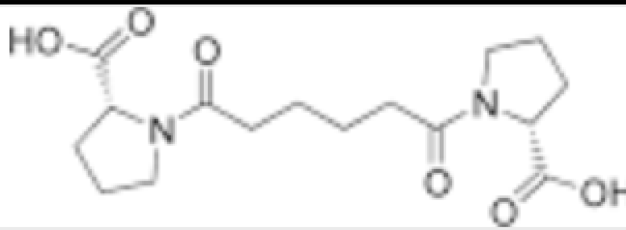


48 Hrs shows activity in the ventricles and possible activity reaching the SSS

Amyloidosis and Transthyretin (ATTR)

- TTR is produced in the liver

CPHPC



CPHPC is a proline-derived small molecule able to strip amyloid P from deposits by reducing levels of circulating serum amyloid P. The SAP-amyloid association has also been identified as a possible drug ...
Wikipedia

Formula: $C_{16}H_{24}N_2O_6$

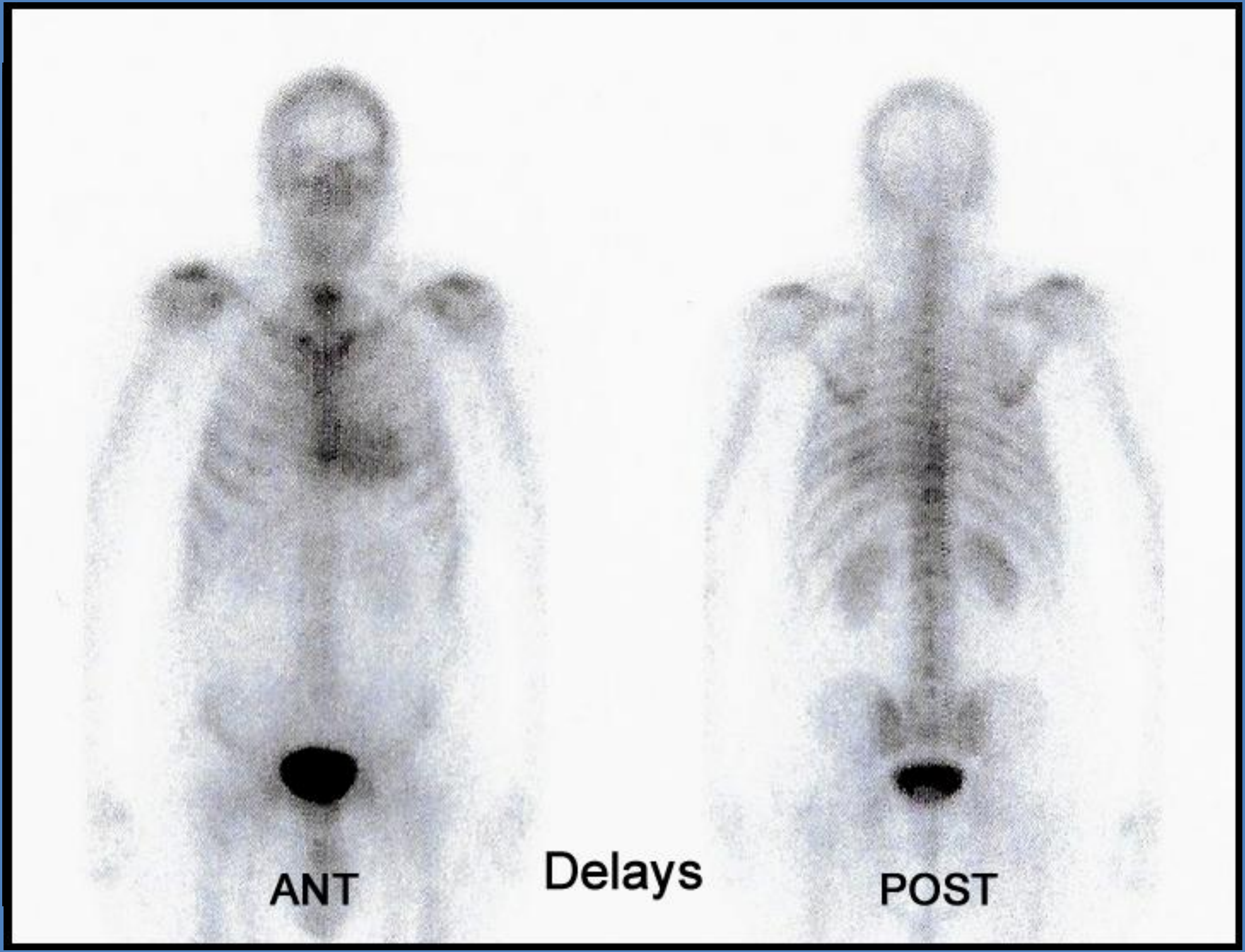
Molar mass: 340.37 g/mol

PubChem CID: 125516

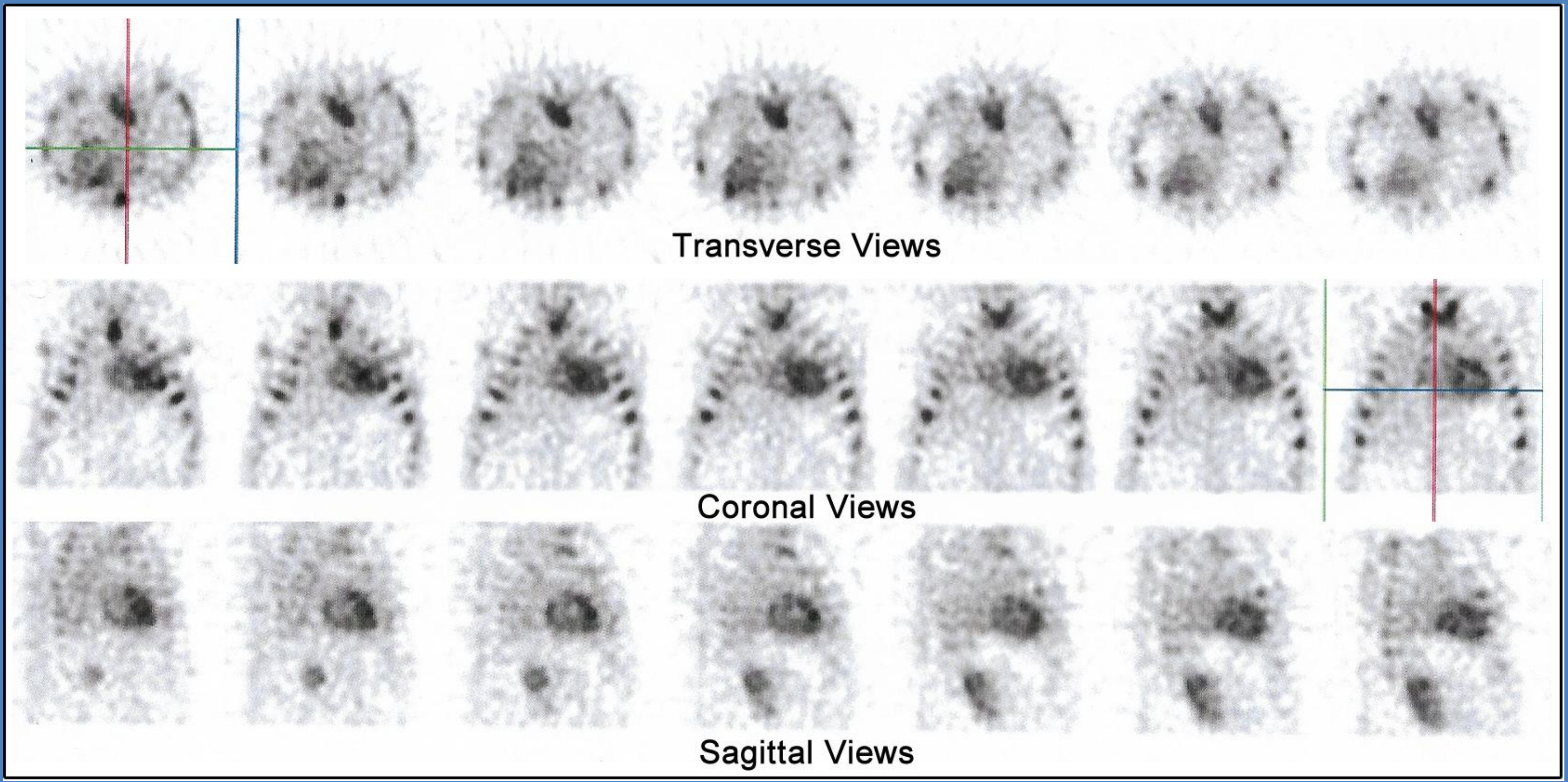
Diagnosis via Nuclear Medicine

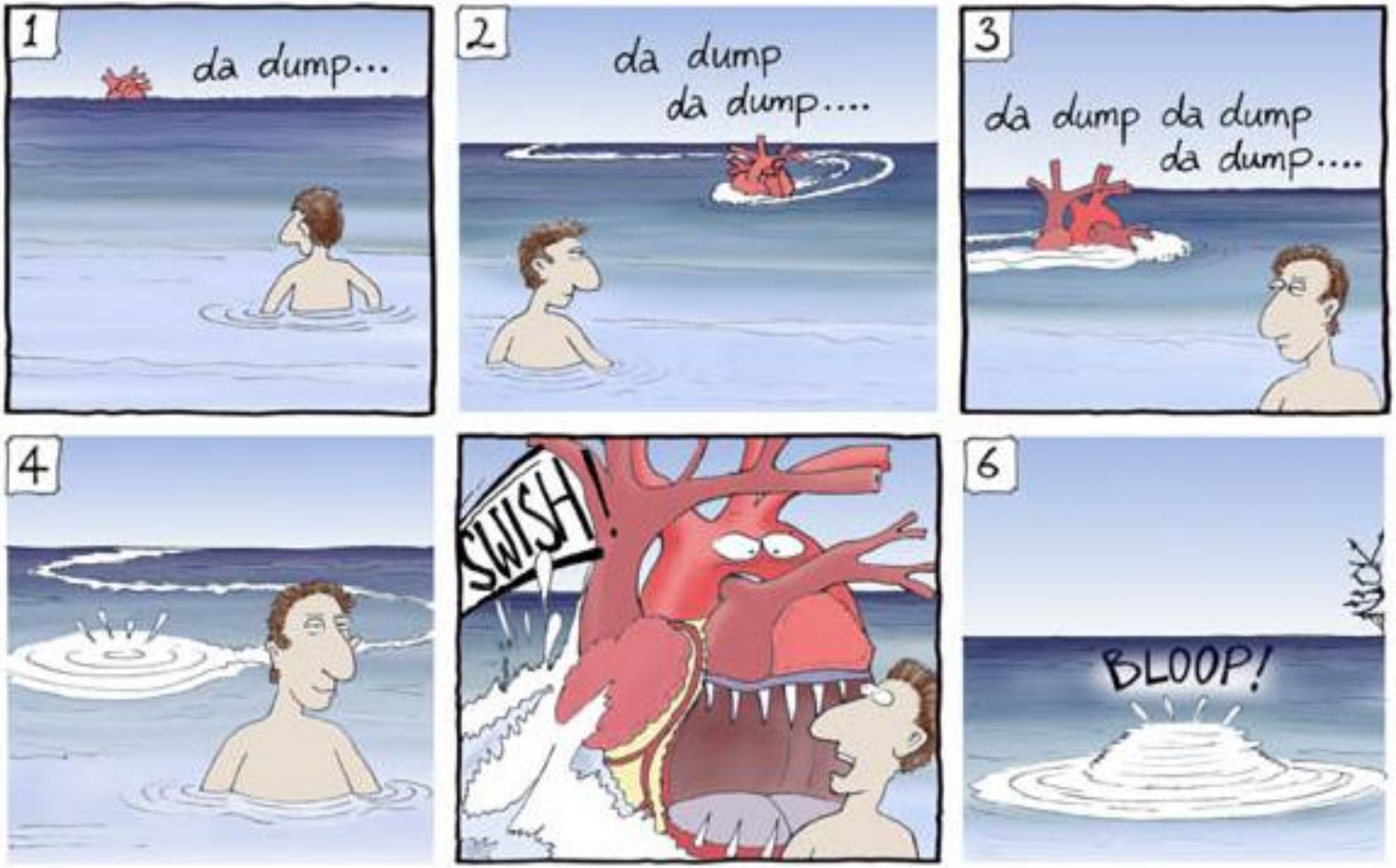
- ^{99m}TcPYP accumulates in the myocardium containing amyloid deposits that can define the source of cardiomyopathy
- ~20 mCi is injected IV
- Planar images are taken 5 minutes and 1 hour post dose
- SPECT is usually ordered if the heart lacks PYP uptake

Blood Pooling and Delays



SPECT



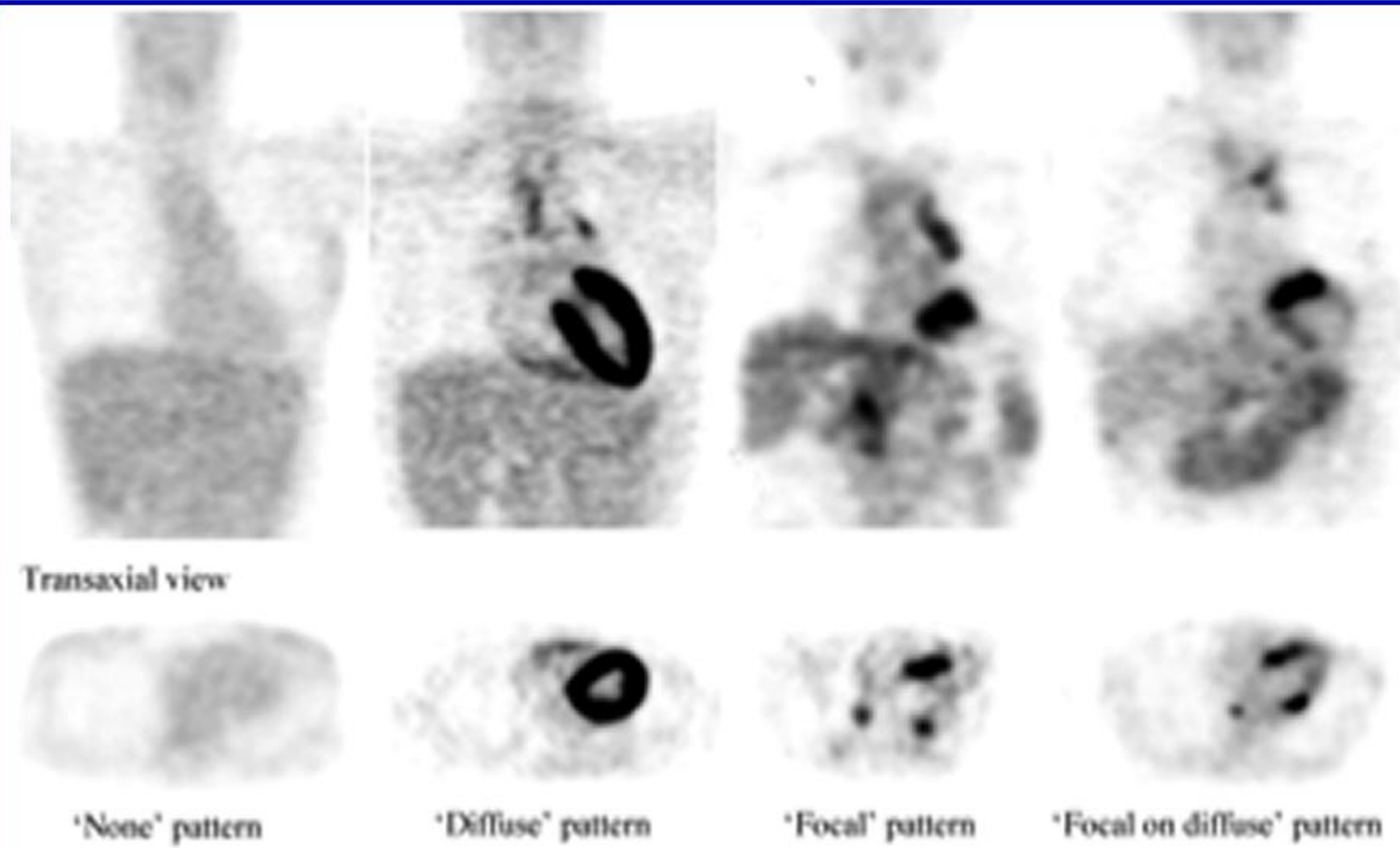


TOO BAD DESMOND HAD NEVER LEARNED TO RECOGNIZE
THE EARLY WARNING SIGNS OF A HEART ATTACK.

Cardiac Sarcoidosis (CS)

- CS if left untreated causes death
- Okumura W (1999) assess ^{67}Ga, $^{99m}TcMIBI$, and FDG
- Schatka I (2014) confirms the use of MIBI and FDG as one approach
  - FDG uptake is based on glucose requirement by inflammatory cells
  - Consider the energy states of the heart - Oxidation and Glycolysis
  - Need to consider low carb, high fat, and fasting
    - Suggests the addition of heparin to increase plasma free fatty acid levels 50 U/kg (not done at VCU Health)

Cardiac Sarcoidosis Imaging

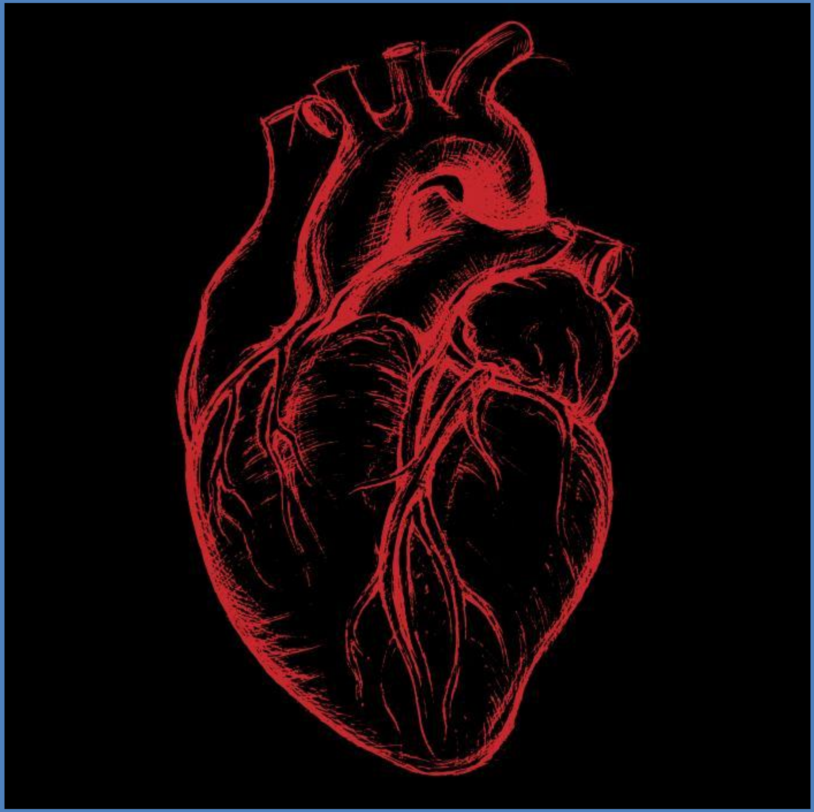


From: **Focal uptake on ^{18}F-fluoro-2-deoxyglucose positron emission tomography images indicates cardiac involvement of sarcoidosis[1]**

Eur Heart J. 2005;26(15):1538-1543. doi:10.1093/eurheartj/ehi180

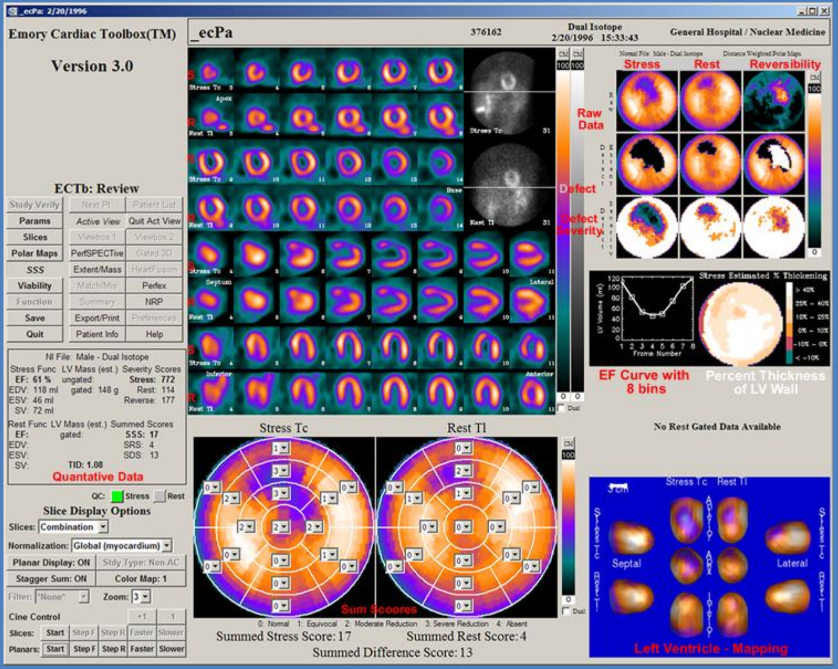
Getting Around Metabolic Energy

- Glycolytic (Metabolic) state
  - Just eaten a meal
  - Glucose level increases
  - Runs on sugar
  - Heart ❤ FDG
- Oxidative State
  - Occurs ~4 hours post meal
  - Burns fat
  - The energy state is preferred
  - **Nuclear Goal** – get the heart into this state to image



Imaging Protocol

- Day 1 – Resting ^{99m}Tc-tetrafosmin (or sestamibi)
  - Administer 20 mCi
  - Image 30 to 45 minutes post dose
  - Process with Emery Tool box
    - Emery Tool Box is used to process ^{99m}Tc and FDG images



Patient Prep for PET

- Day 2 – (24 hrs) patient follows dietary protocol to include no vigorous exercise

Cardiac PET Scan Diet Menu

- Unsweetened iced tea without milk or coffee without milk or sugar
- Hamburger, no bun or condiments
- Hotdog. no bun or condiments
- Hard cooked egg
- 4 slices bacon
- Condiment kit : salt, pepper, and aspartame packet (no Splenda)
- Kraft Mayonnaise (only)
- Mustard

Process

1. Beginning with dinner the day prior to PET imaging the patient will consume an Atkins type shake or the above referenced diet. Dinner should consist of a high fat no carbohydrate meal.
2. After dinner, water and medications may be taken without restriction, but no other FOOD, NO CARBS, NO SUGAR AT ALL.
3. At "______ time" you must consume an Atkins like shake. Please take no more than 5-10 minutes to consume this shake. You may still have plain water and take oral medications after your shake and prior to PET appointment, but nothing else.

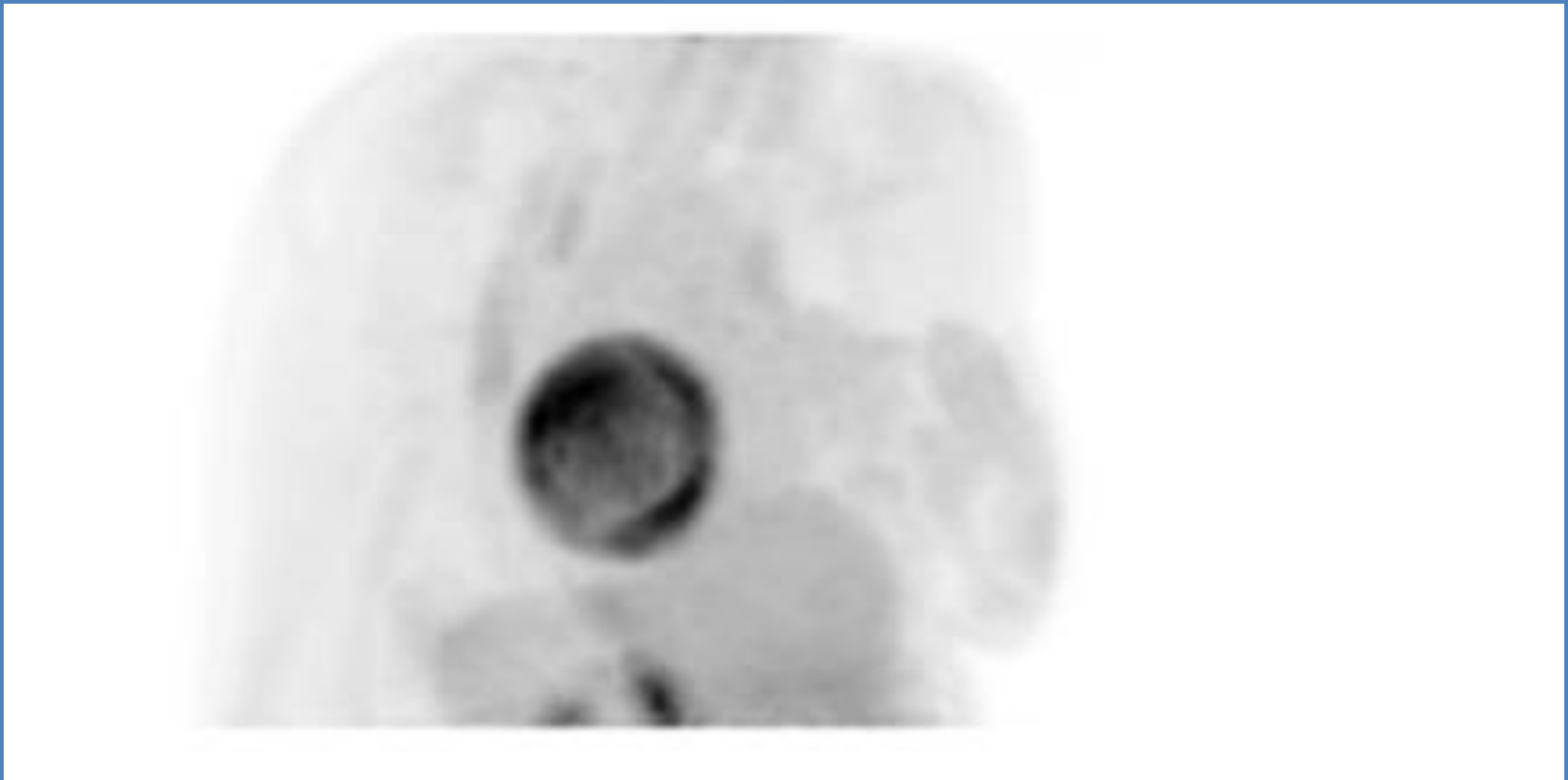
PET Scan

- Prior to Scan
  - Glucose level < 200mg/dL
  
  - Keep warm
  - Sedation for claustrophobia may be given – Xanax 1mg
  - Inject IV
    - 12 – 16 mCi of FDG <220 lbs.
    - 16 – 24 mCi of FDG >220 lbs.
  
  - Patient rests in dark quiet room to limit patient movement
  - Patient weight, pre/post dose syringe measurements, record injection time for SUV assessment
  - Image 45 minutes post FDG administration

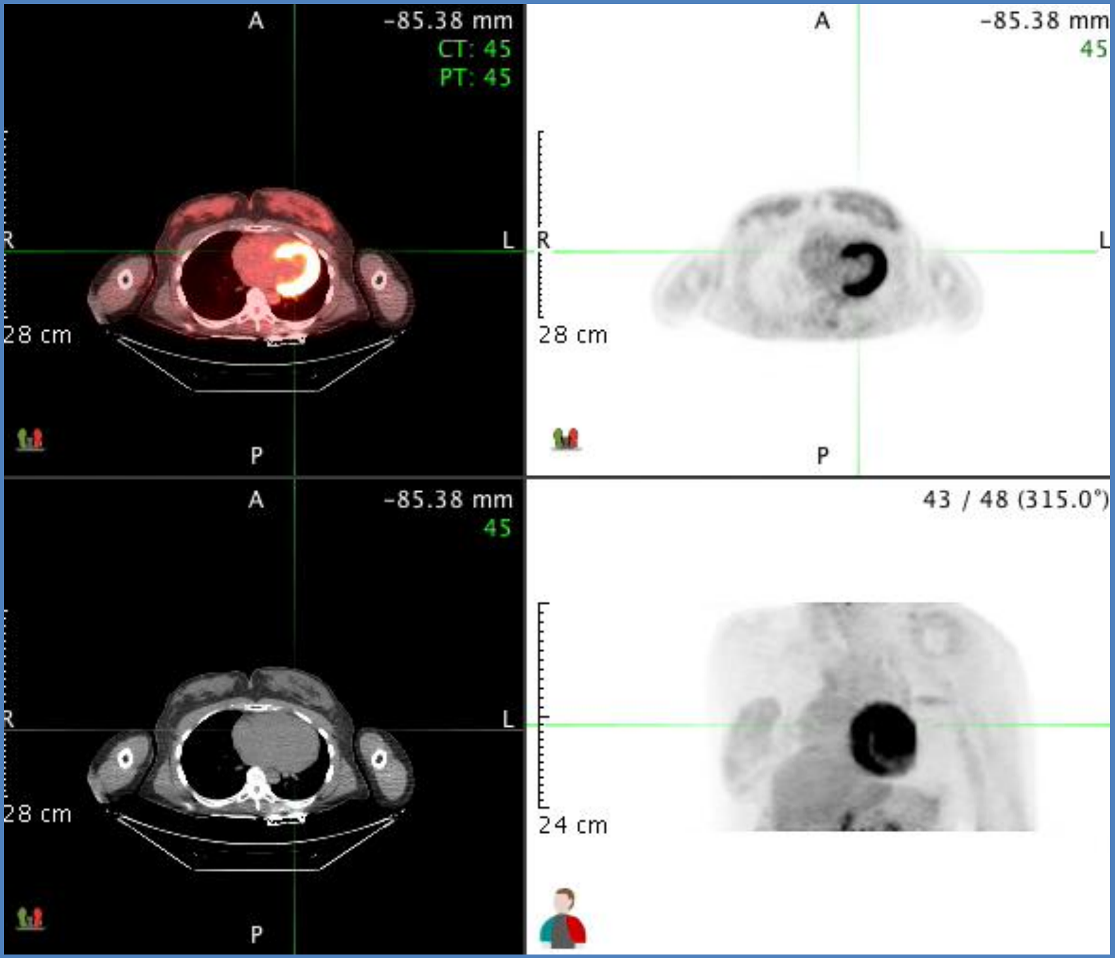
Imaging

- CT scout and scan to determine the 2 bed positions of the thoracic cavity
- PET scan acquired for 10 minutes (5 min/bed)
- Raw data is processed with AC and PET images reconstructed with IR
- Data is then sent to another processing station where ^{99m}Tc and PET data are reconstructed and quantified with Emery Tool Box
- Tomographic images and polar maps are generated
- Physician then evaluates results

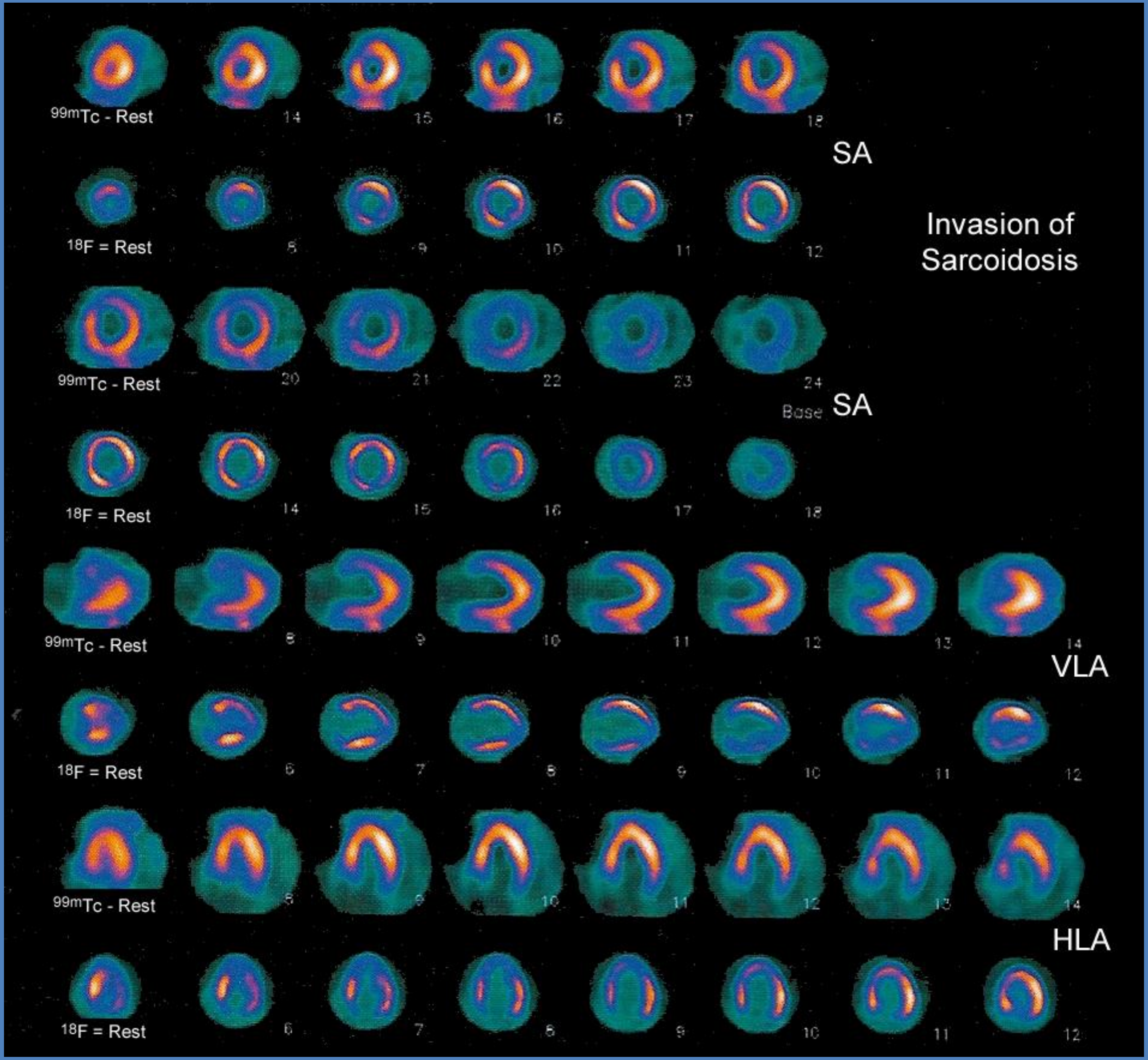
PET Scan - MIP



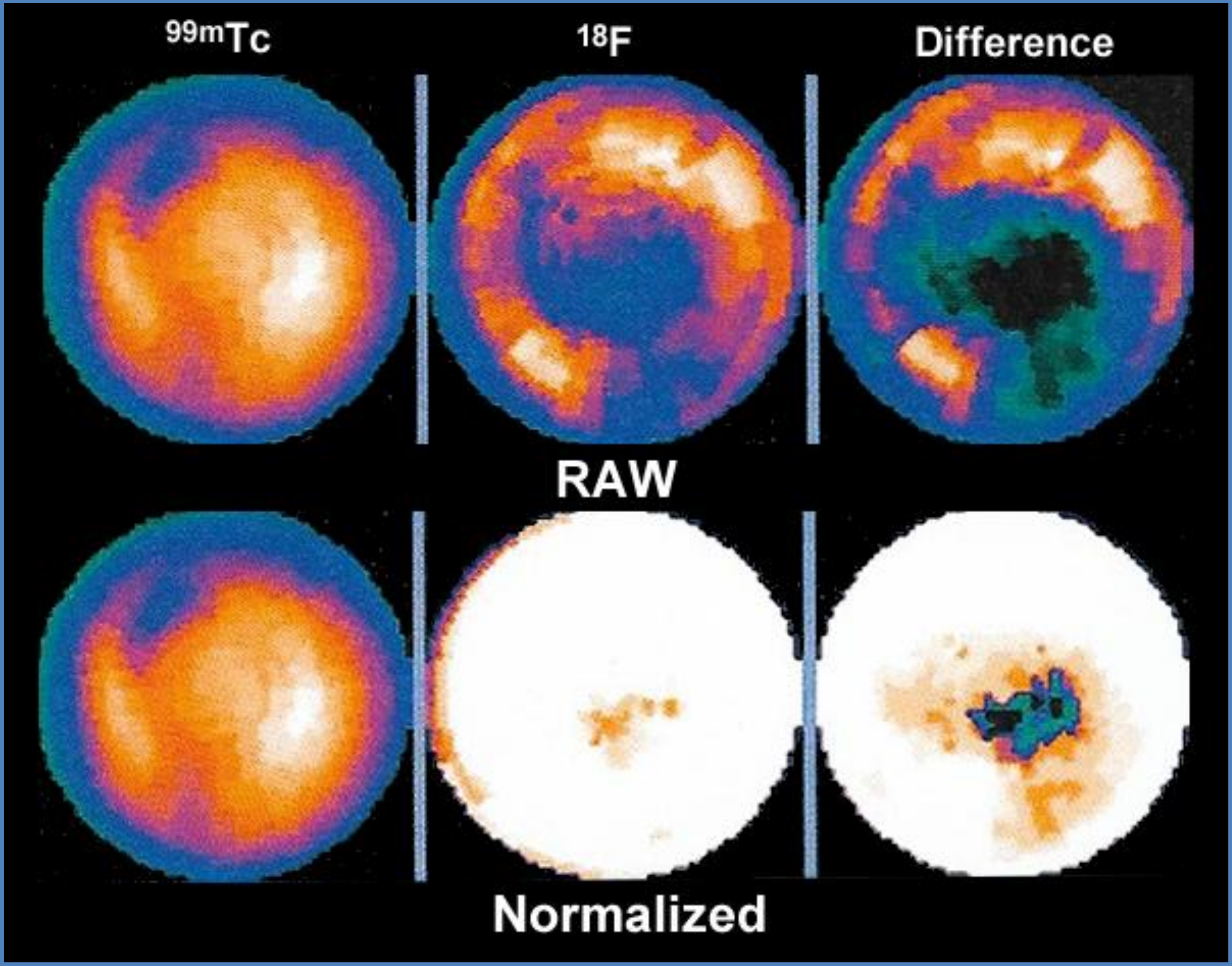
PET/CT 4 View with MIP



Rest ^{99m}Tc and Rest ^{18}FDG



Polar Maps - ^{99m}Tc and Rest ^{18}F



Consider the Issues

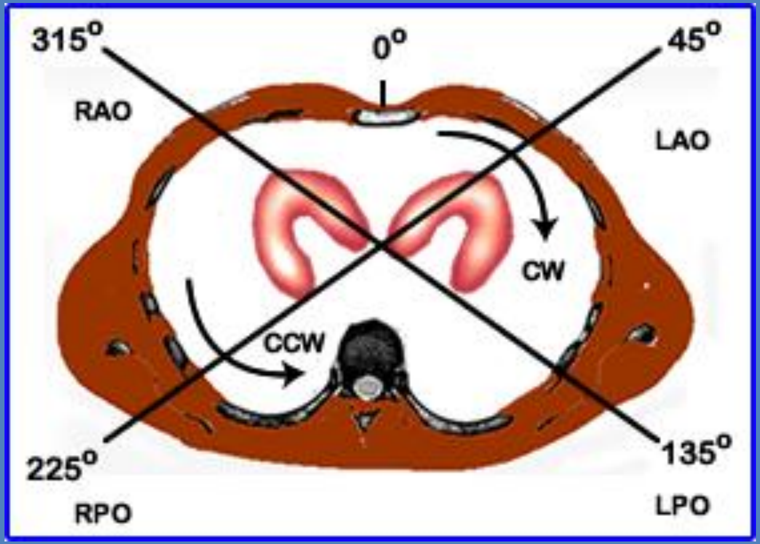
- Variation in matrix size: 128 PET and 64 ^{99m}Tc
- Different imaging systems
  - Placing the LV in the same 3D space
  - 511 keV vs. 140 keV
  - AC PET vs. un-AC ^{99m}Tc
- Polar maps have a totally different meaning

Approach to Dextrocardia

- Dextrocardia or situs inversus
- Congenital defect causing the heart to be mirrored on the right side of the thoracic cavity.
- 1 in 12,000 patients have it
- 1 in 25 with dextrocardia patients have situs inverse
- Primary ciliary dyskinesia
  - Effects the cilia and results in inability to keep the lungs and sinuses clear of fluids, causing congestion, infection, and various other complications. Effects cilia in the brain and reproductive organs. Patient may have chronic headaches, hydrocephalus and infertility.
  - It can also effect the ability to walk or effect the way they walk

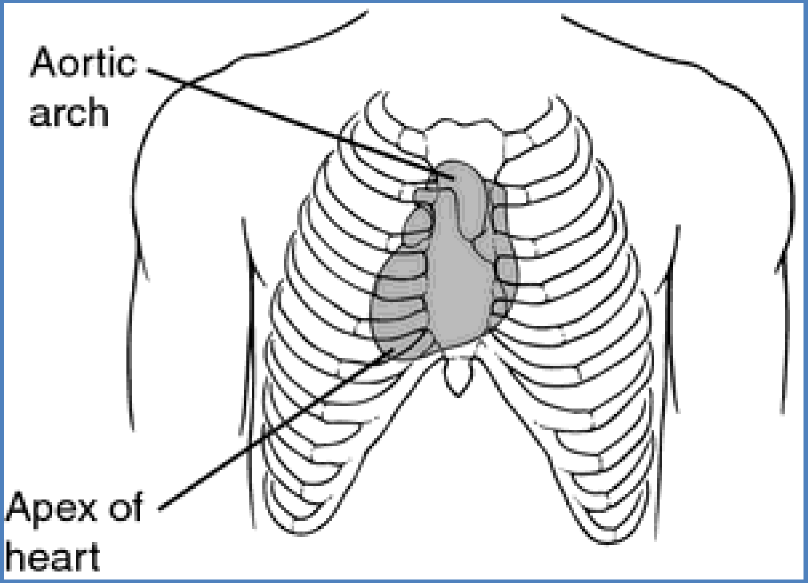
Change in Imaging Protocol

- Since the heart is on the opposite side you have to reverse your imaging protocol
- From 315 degrees to 125 degrees clockwise to 45 degrees to 225 degrees counter clockwise
  Treadmill stress test conducted separately



Patient History

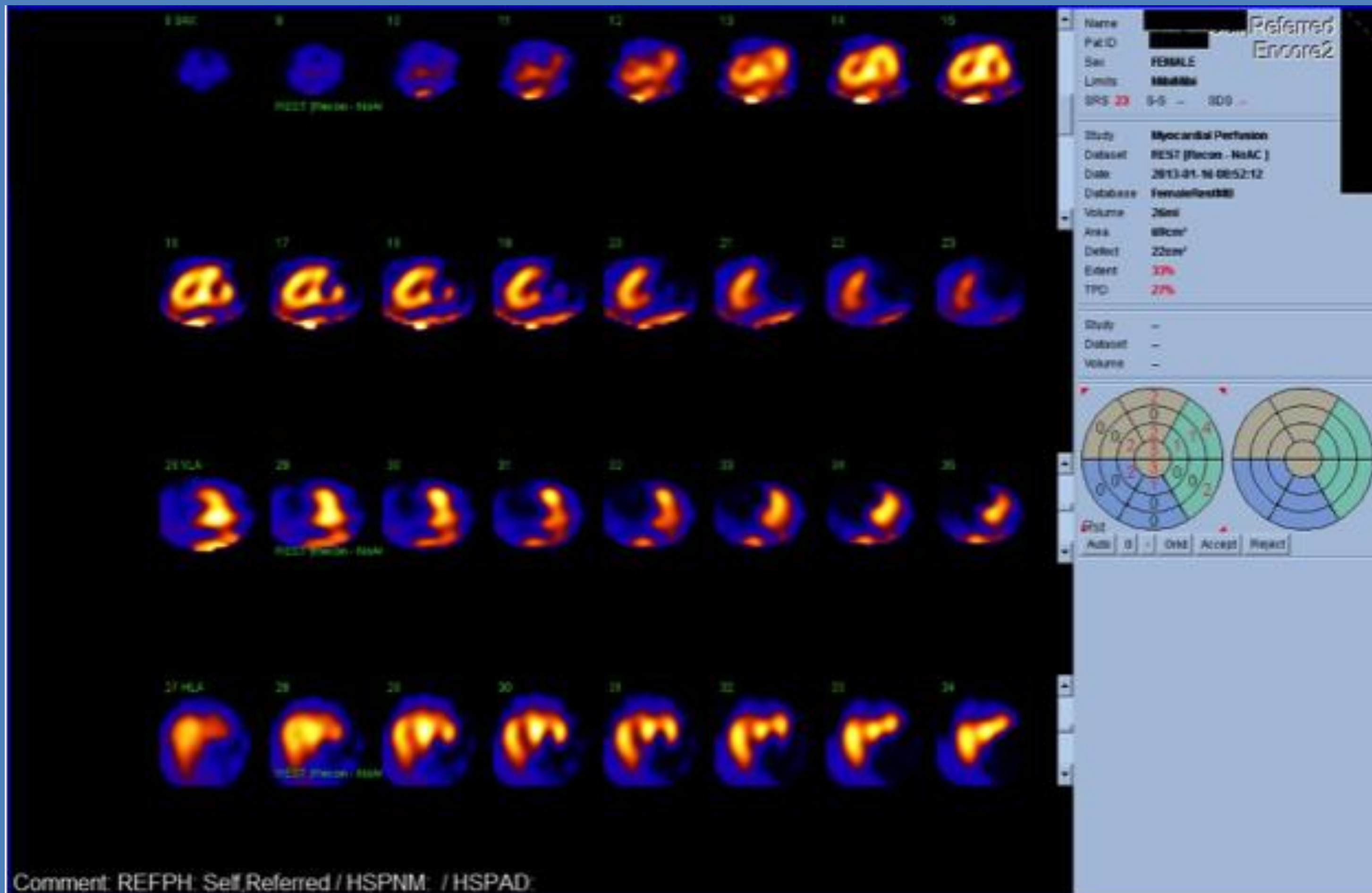
- 20 year old female with congenital heart disease
- Patient presented to the ED with chest pain after unknown surgery
- Chest film shows dextrocardia, median sternotomy and cardiac pacemaker



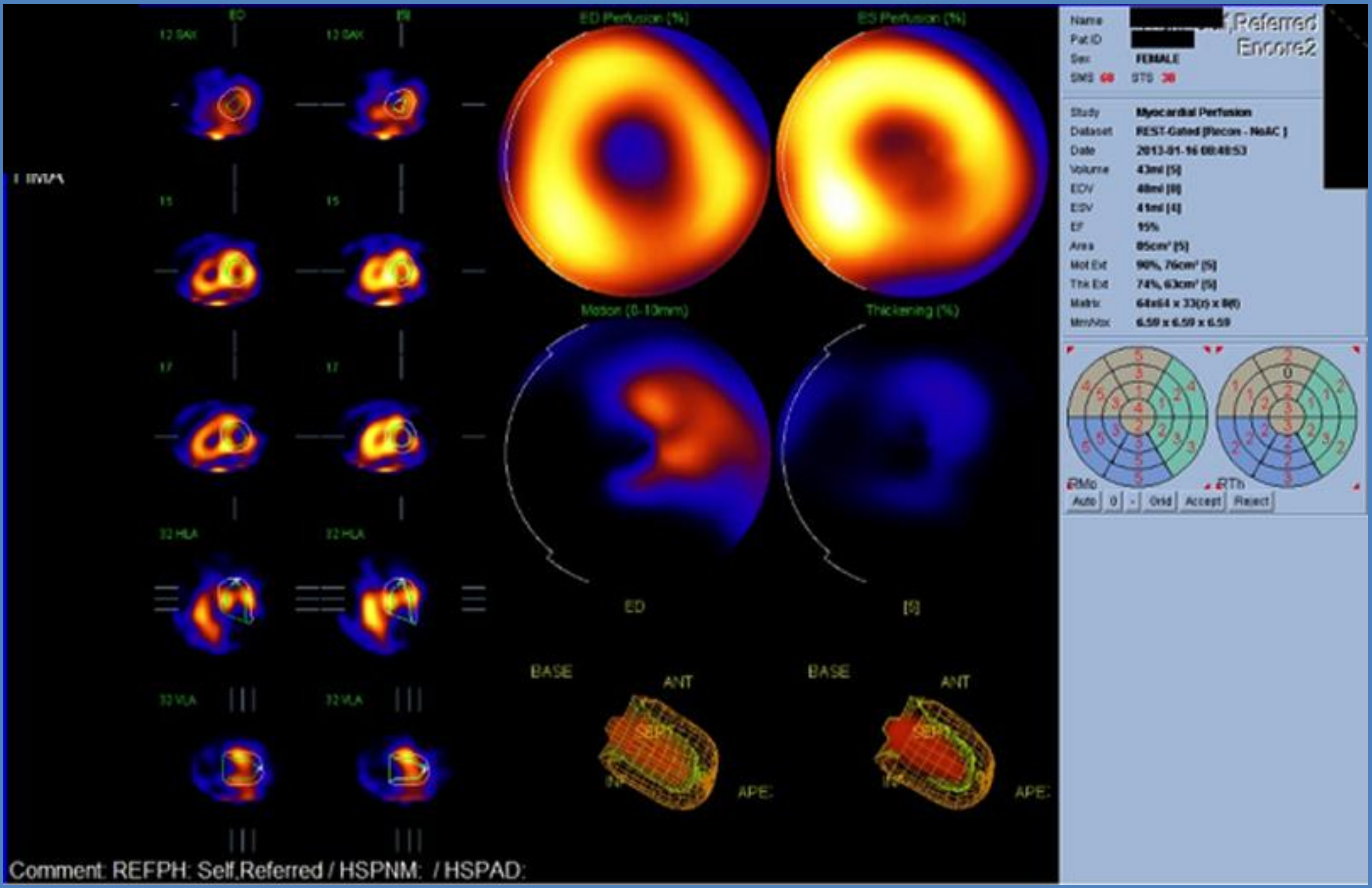
Procedure & Imaging Protocol

- 9 mCi of ^{99m}Tc-tetrafosmin was injected
- Images were taken 45 minutes post dose
- LEHR collimator
- 140 keV, 20% window
- 64 x 64 matrix
- 180° rotation
- 64 stops at 20sec/stop
- Images were also gated

Reconstructed Images



Patient Results



Patient Results

- Abnormal study showing dextrocardia with normal systolic function
- Increased tracer uptake in right ventricle, indicative of right ventricular hypertrophy
- Small, moderate grade left ventricular apical defect consistent with a region of myocardial scarring

Did you know?
Lexiscan vs. Adenosine

- Most of the world uses lexiscan, but is that a good idea? (Check the audience)
- Brink HL, et al (2016) compared the agents
  - 489 patients – 235 with adenosine and 254 with lexiscan
  - 80% had reaction to lexiscan and 31.5% had a reaction to adenosine
  - Reactions –arrhythmias, dyspnea, headache
  - Aminophylline – 19.2% lexiscan and 0.8% adenosine
- Results
  - Adenosine better tolerated
  - Adenosine cost $25k less
- Why was adenosine better tolerated? Assume it had to do with the biological $T_{1/2}$ ~ 10 seconds

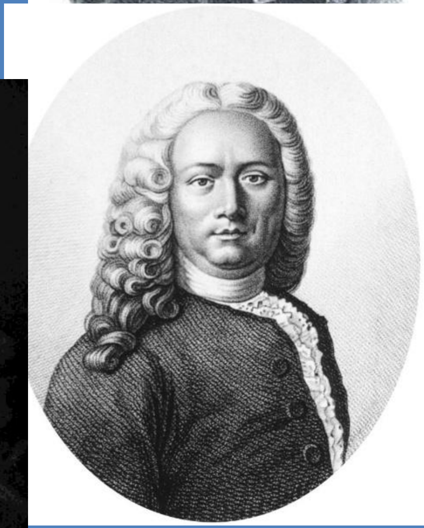
Let's Talk About Lymphatic Mapping

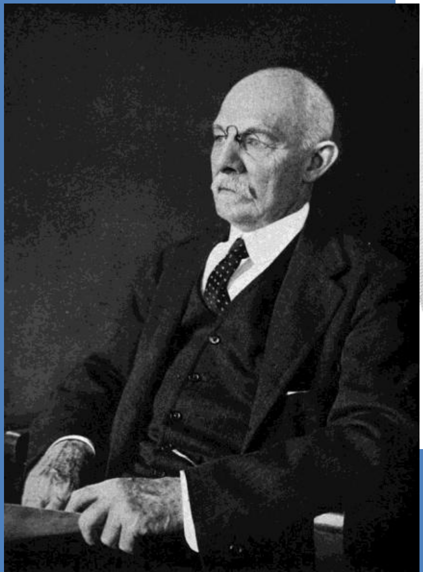
- Ideal tracer should have fast clearance from the injection site, rapid uptake with the SNL with high retention, and lack of uptake in distal nodes that lack disease([7])
- Lymphatic system is designed like a road map, hence mapping it we can follow the progression of an invading cancer
- Most common agents used for mapping
  - Vital blue dye
  - ^{99m}TcSC
  - ^{99m}Tc ATC
  - ^{99m}Tc tilmanocept (TM)

Trivia - Early Lymphatic Researchers

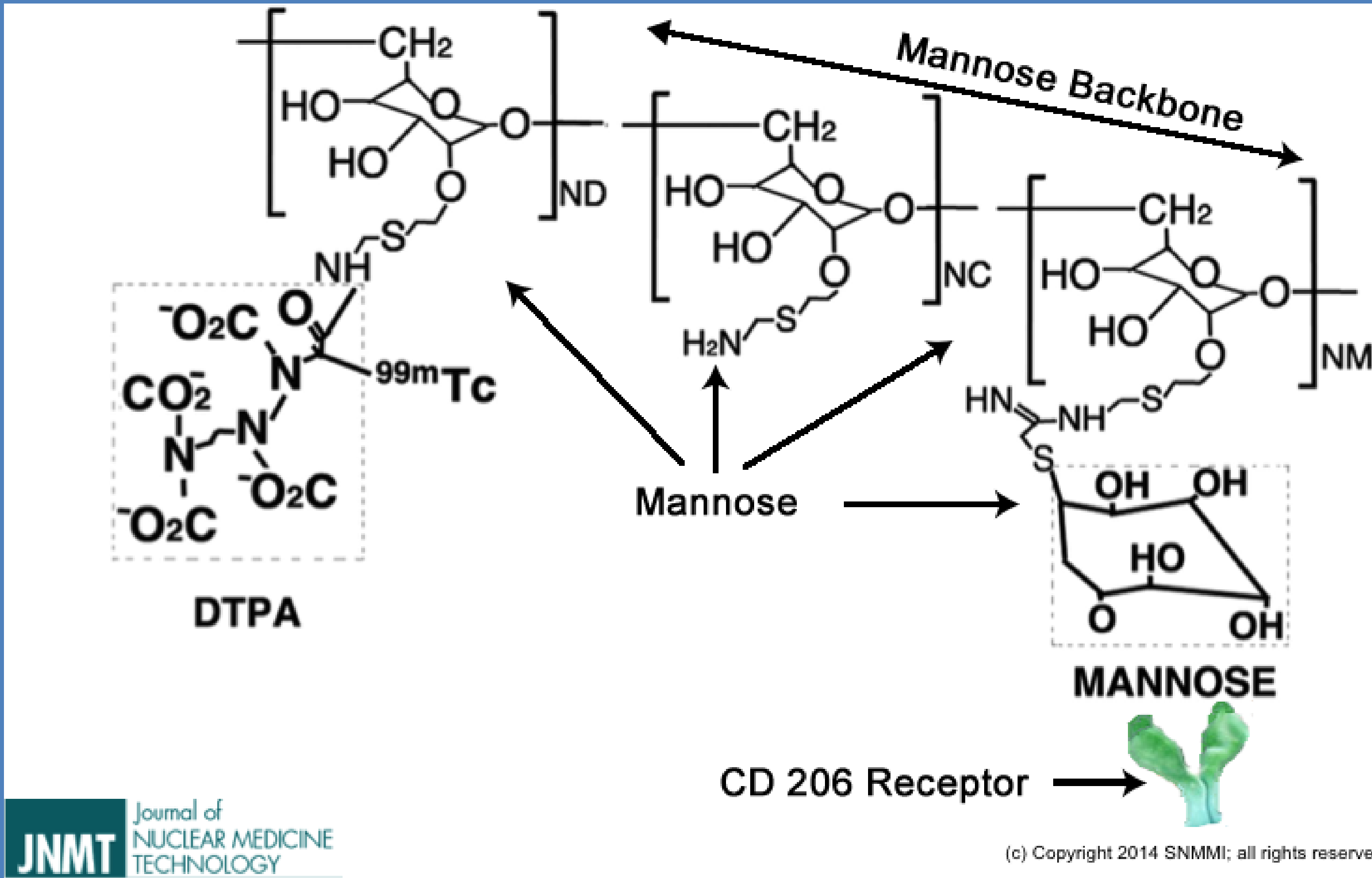
The following individuals were involved with initial lymphatic research

- 1653 T. Bartholin
- 1685-1770 H.F. LeDran
- 1890 W. Halstead





^{99m}Tc-Tilmanocept Bond



Molecular structure of 99mTc-tilmanocept. Devaki Shilpa Surasi et al. J. Nucl. Med. Technol. 2015;43:87-91

^{99m}Tc-Tilmanocept: A Novel Molecular Agent for Lymphatic Mapping and Sentinel Lymph Node Localization
Surasi D (2015) – recommended reading

Comparison

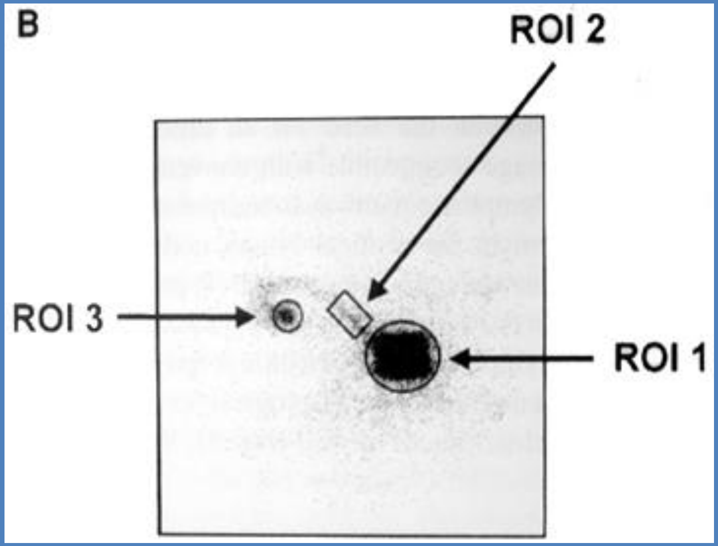
^{99m}TcTM

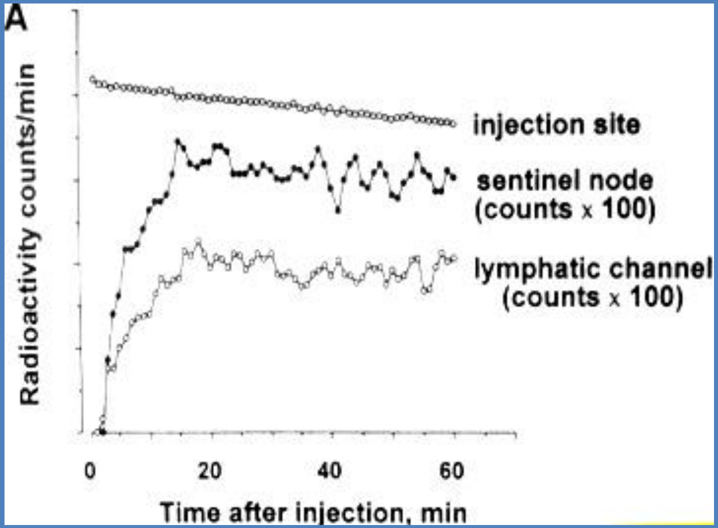
- Travels well though lymphatics
  - Faster clearnce
- Size 7 nm
- Binds to the CD 206 receptor
- Imaged up to 15 hrs
- Fewer nodes removed with higher positive yield (1.7 to SC)
- Cost ~$400

^{99m}TcSC (filtered)

- Travels “poorly” through lymphatics
  - Slower clearance
- Size 100 and 220 nm
- Binds to active macrophages
- Image up to?
- Cost ~ $150

Sulfur Colloid Change

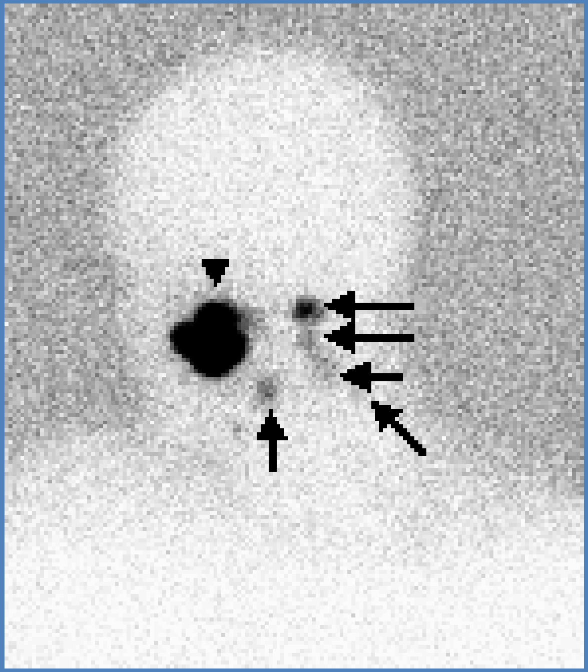


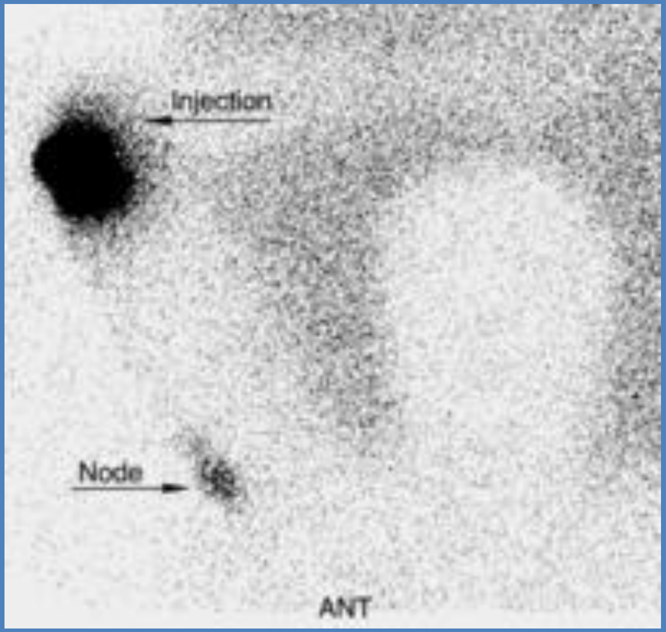


Graph displays the radio-colloid traveling through the lymphatic system over time

- ROI 1 – Injection site
- ROI 2 – Flow of the colloid through the lymphatic
- channel
- ROI 3 – Uptake at the SNL

Sulfur Colloid | Tilmanocept





Melanoma shows tracer uptake in the submandibular and posterior cervical lymph nodes

Melanoma in right arm sentinel node was identified in right axilla.

Should You Map or Head to Surgery?

- Vucetić B (2006)
  - Research question - Image first **or** skip and head to surgery using a gamma probe?
  - Map it before your cut! This define the drainage and determine the number and position of the sentinel node
  - Imaging may change the surgical approach because the drainage can be unpredictable
  - Evidence supports to look first and then remove
- What does your Medical Facility do?

Splenic Imaging

Spleen

- Reservoir of blood elements
- Stores and produces antibodies and platelets
- Increases blood volume when needed
- Sequestration
  - Culling (reprocesses)
  - Pitting (repairs)

http://www.livescience.com/44725-spleen.html

What are We Looking for?

- Splenomegalia
  - Acute and chronic infectious diseases as well as non- infectious inflammatory diseases
  - Associated diseases usually include tuberculosis, infectious mononucleosis, subacute bacterial endocarditis, and septicemia. Leukemia may cause obstruction or excess cell formation. Benign and malignant infiltrate diseases
- Spleen trauma
  - Blunt trauma to the abdomen or to the lower rib cage may cause contusion or laceration to the spleen which may result in excessive bleeding
  - Outcome - Splenectomy
  - Splenetic remnants have been found post trauma.
  - Splenosis may occur
- Hyposplenism
  - Surgical removal or splenetic infarctions may result that can lead to future serious illness
  - Causes increase in blood elements
  - Platelet counts may elevate since the spleen is a platelet reservoir

Patient History

- Fifty-five year old Female
- Caucasian
- Patient had abdominal pain
- Abnormal ultrasound suggesting multiple abdominal and pelvic masses
- Patient history reveals prior trauma with splenectomy.
- Role out - splenosis.

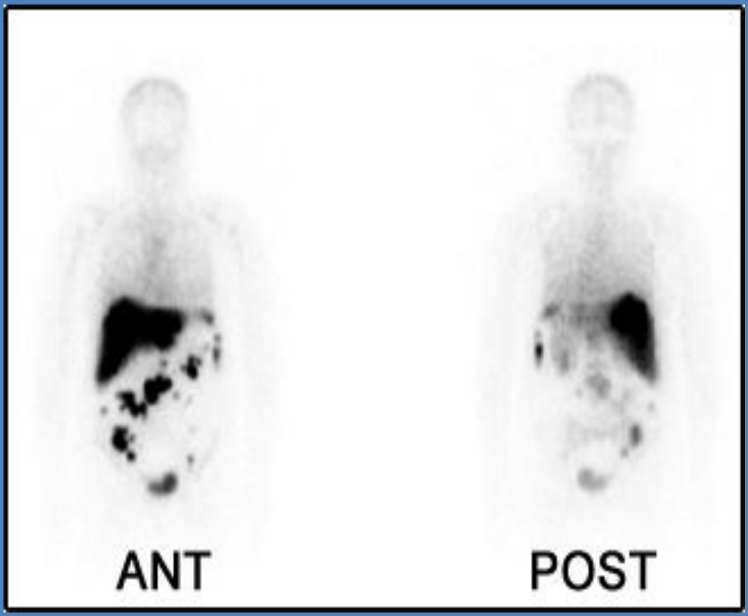
Radiopharmaceutical Preparation

- Remove ~3 mL of patient blood and tag it with 10 to 15 mCi of $^{99m}TcO_4^-$ using an Ultra-tag kit
- Denatured RBCs by placing in a water bath for at 49-51° C for 20 minutes

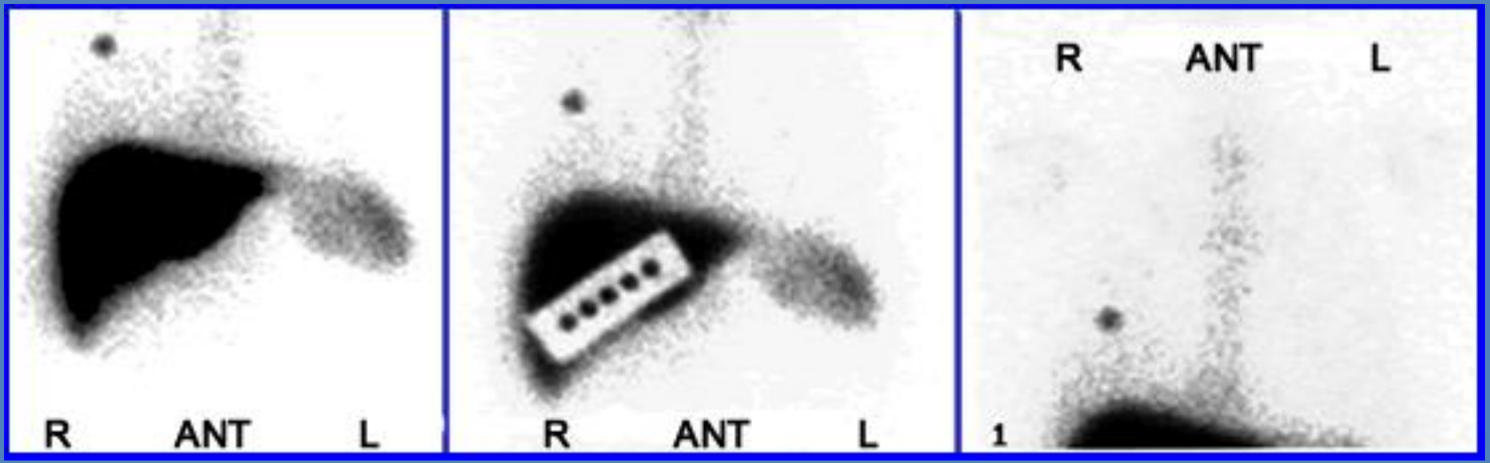
- Denaturing changes the shape of the biconcave disks to spherical type object. Cell membrane also develops knobby projection
- Let the dose reach room temperature before injecting

Planar Images - WB

- Planar Images
- Defines extensive uptake in the abdominal cavity that was apparently caused by trauma
- This correlated with an abdominal ultrasound which indicated intra-abdominal and intrapelvic soft tissue masses

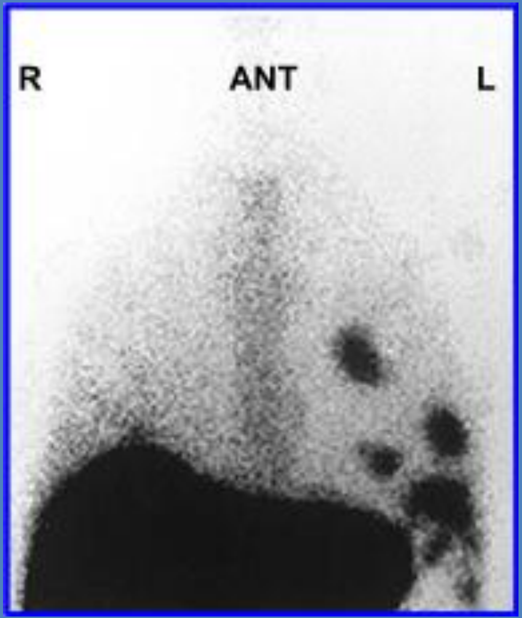


Colloid vs. denatured RBCs



99mTc-SC

^{99m}Tc-D.RBCs



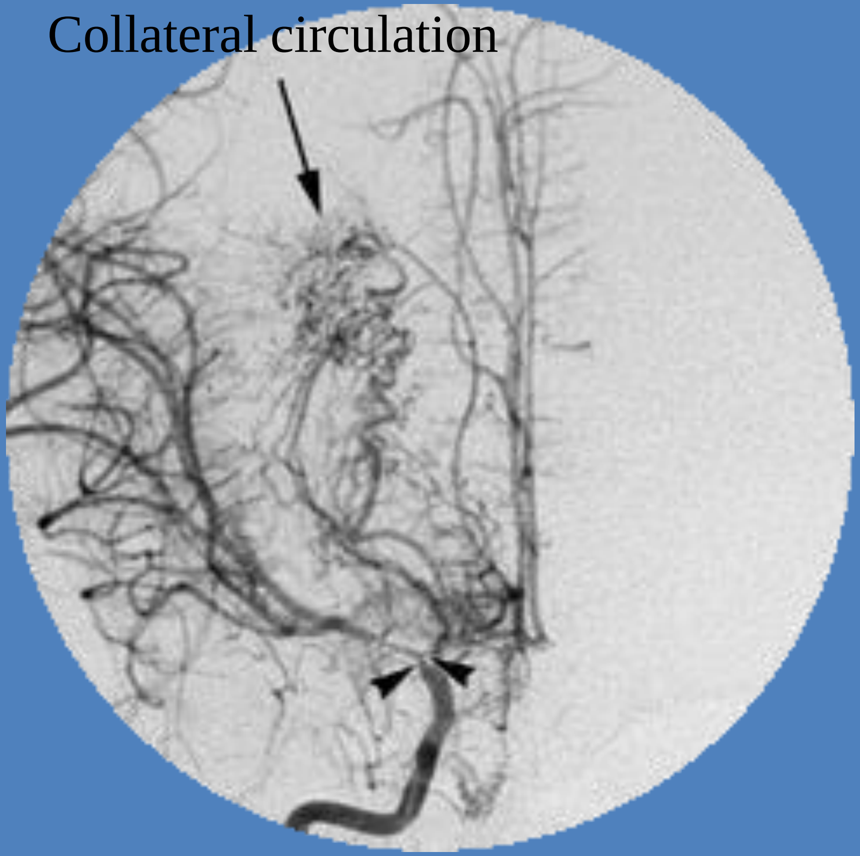
http://www.medscape.com/viewarticle/428338_2

Diamox Challenge

- Hypoperfusion of the brain can be caused by occlusion or stenosis in arteries that feed the brain, resulting in decreased rCBF
- Diamox is a carbonic anhydrase inhibitor with its main role is to treating glaucoma and mountain sickness, among others disorders
- In the brain it causes vasodilation via carbonic acidosis
- Blood flows to the unaffected or less affected area

Imaging the Effects of Moyamoya

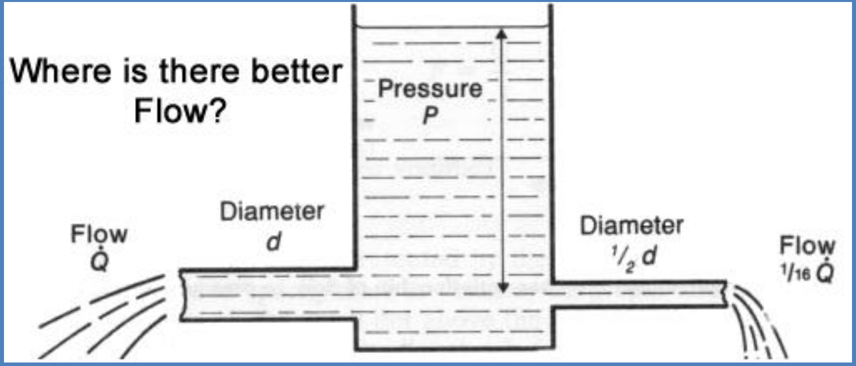
- Diamox assess TIA, CVA (vascular issues), dementia
- Today's application will be used to assess Moyamoya disease
- "Like a puff of smoke"
- It is a genetic disorder (most commonly), causing collateral circulation to compensate for the blockage
- Results - bleeding, aneurysm, and/or thrombosis
- Etiology unknown but not likely atherosclerosis



http://pubs.rsna.org/doi/abs/10.1148/radiol.2473050588?journalCode=radiology

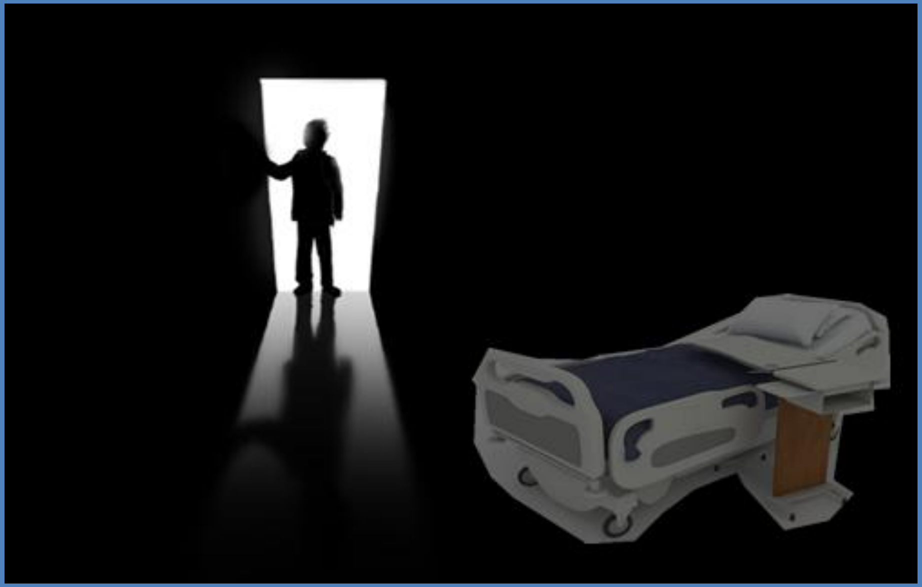
Physics of Flow

- Series of two brain scans
- 1 – Baseline scan
- 2 – Diamox Challenge
  - Compared to a stress/rest MPI
  - Coronary vs. Cranial steal



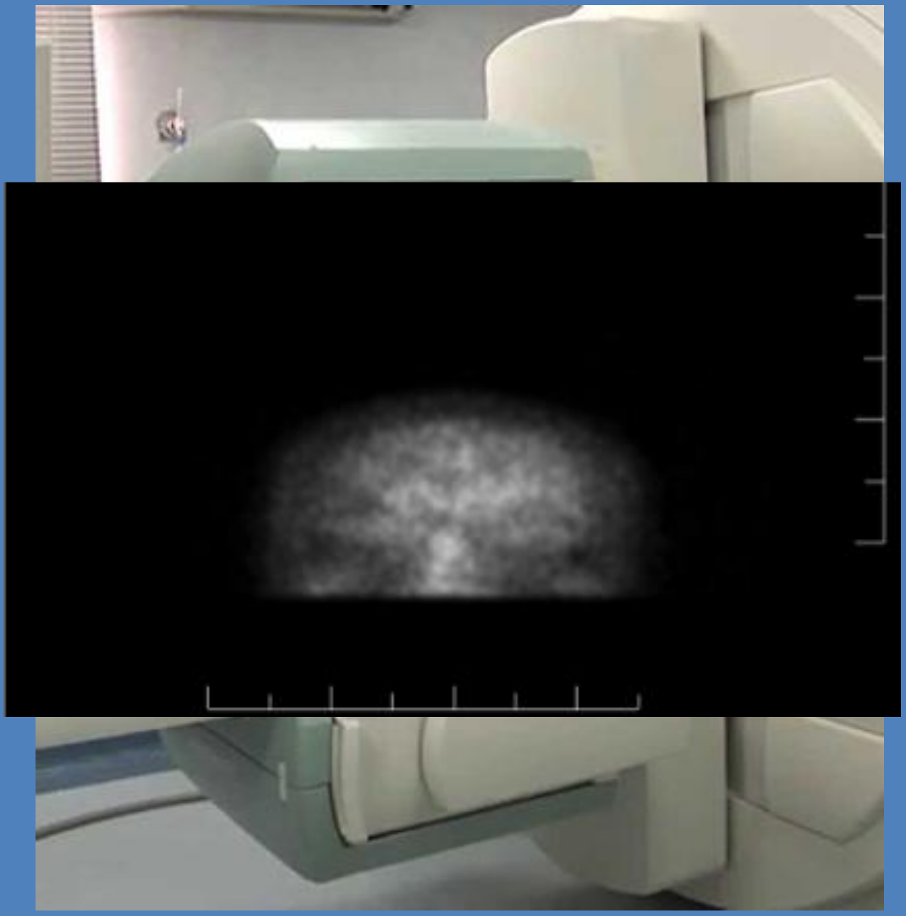
Protocol

- Acquisition parameters
  - Fan beam collimator
  - 128 matrix
  - Dual headed camera
  - SPECT at 30 sec/stop, 128 stops
  - Circular orbit
- Place patient in dark quiet room
- Place IV 15 minutes prior to injecting
- Inject ~25 mCi ^{99m}TcECD IV
- Image 45 minutes post IV



Patient Positioning

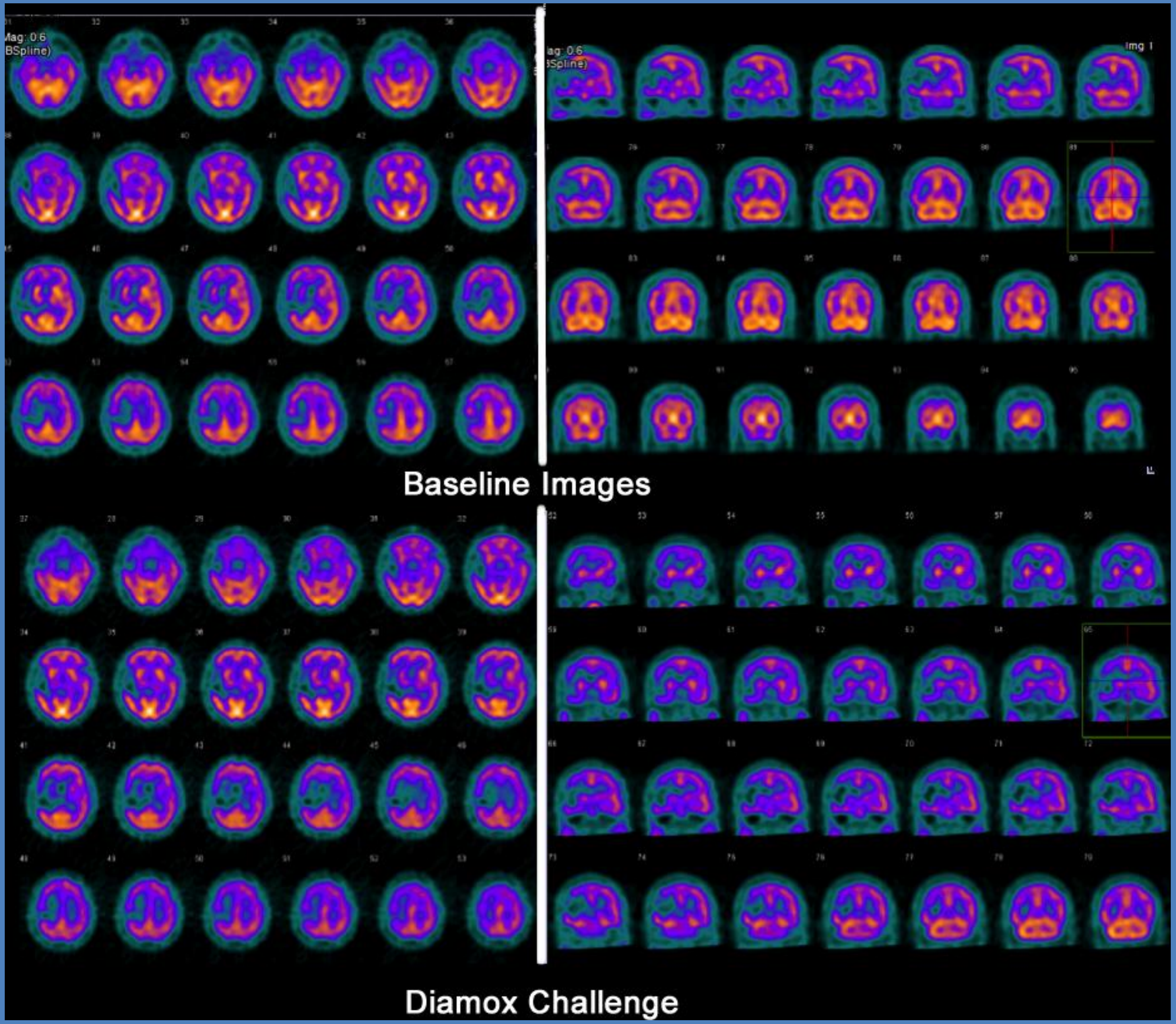
- Supine, head first, using head extension
- Bring camera heads close (<15 cm) and maintain equal distance
- Confirm the detectors clear the patient in a circular orbit
- FOV the entire brain ONLY



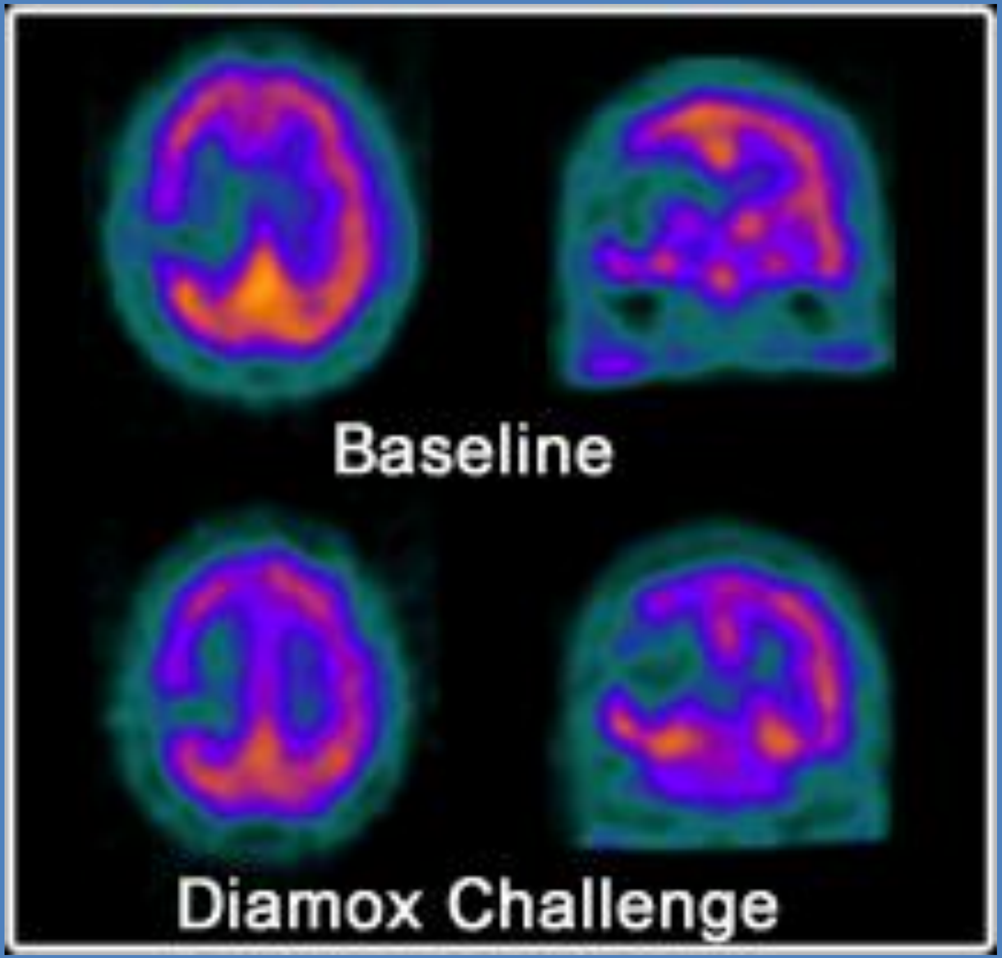
Acquisition: Diamox Challenge

- 48 hours post baseline study repeat the procedure
- However, this time administer Diamox over 15 minutes through IV pump
  - Adult 1000 mg
  - Pediatric dose 12 mg/kg
- Wait 20 minutes
- Inject 20-30 mCi ^{99m}Tc-ECD
- Wait 45 minutes
- Repeat the acquisition protocol

Transverse and Coronal Data



Closer Look



This Presentation Made Possible BY

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Thank You!

Fiona Jones, CNMT
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The End

The Acetazolamide Challenge: Techniques and Applications in the Evaluation of Chronic Cerebral Ischemia, Vagal AS (2009)

SNMMI suggested protocol for Diamox Challenge - http://interactive.snm.org/docs/pg_ch21_0403.pdf