

UNIVERSITY OF WASHINGTON SCHOOL OF MEDICINE



Department of Radiology
Division of Nuclear Medicine
Didactic



Problem Solving with Shuntograms

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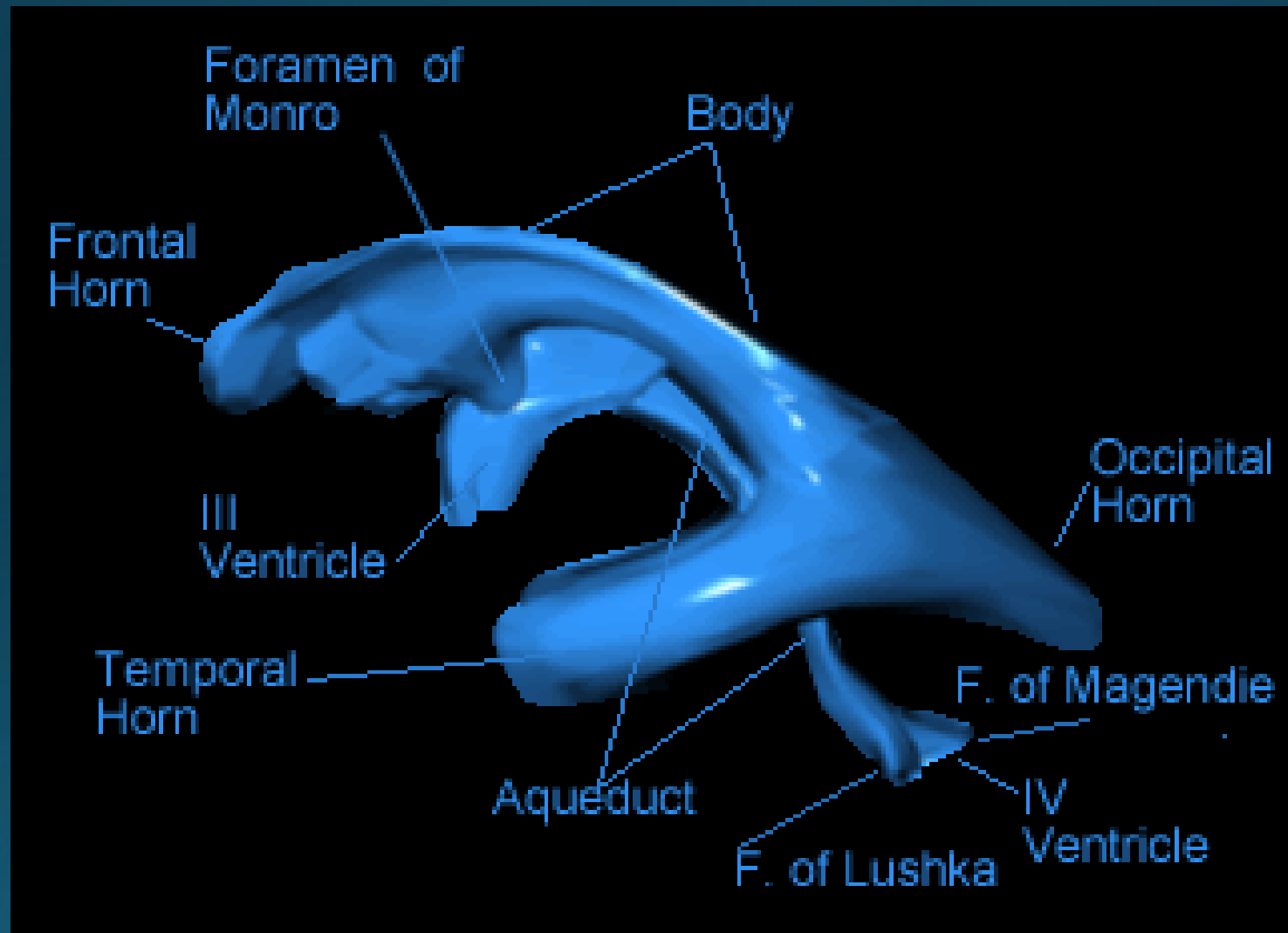
Outline

- Review Anatomy & Hydrocephalus
- Drains Shunts & Reservoirs
- CSF Shunt Scintigraphy

Physiology of CSF

- CSF produced by the choroid plexus in the lateral, third and fourth ventricles
- Choroid plexus consists of projections containing capillaries and pia mater in a loose connective tissue matrix
- Specialized layer of ependymal cells called the choroidal epithelium overlies these villi
- CSF is formed in the choroid plexus by both filtration and active transport.
- Normal rate of production is 20 ml/hour, normal volume is 125-150 ml

Ventricular Anatomy



Normal CSF

- 400-500mL/day produced
- 120-150mL present at any given time, 40mL intraventricular
- 4th V -> SA space -> arachnoid granulation
- Small % absorbed across meninges and ependymal lining

Hydrocephalus

- Communicating

NPH

Impaired resorption

- Obstructive

Tumor/Cyst

Infection

Hemorrhage

Malformation

Hydrocephalus

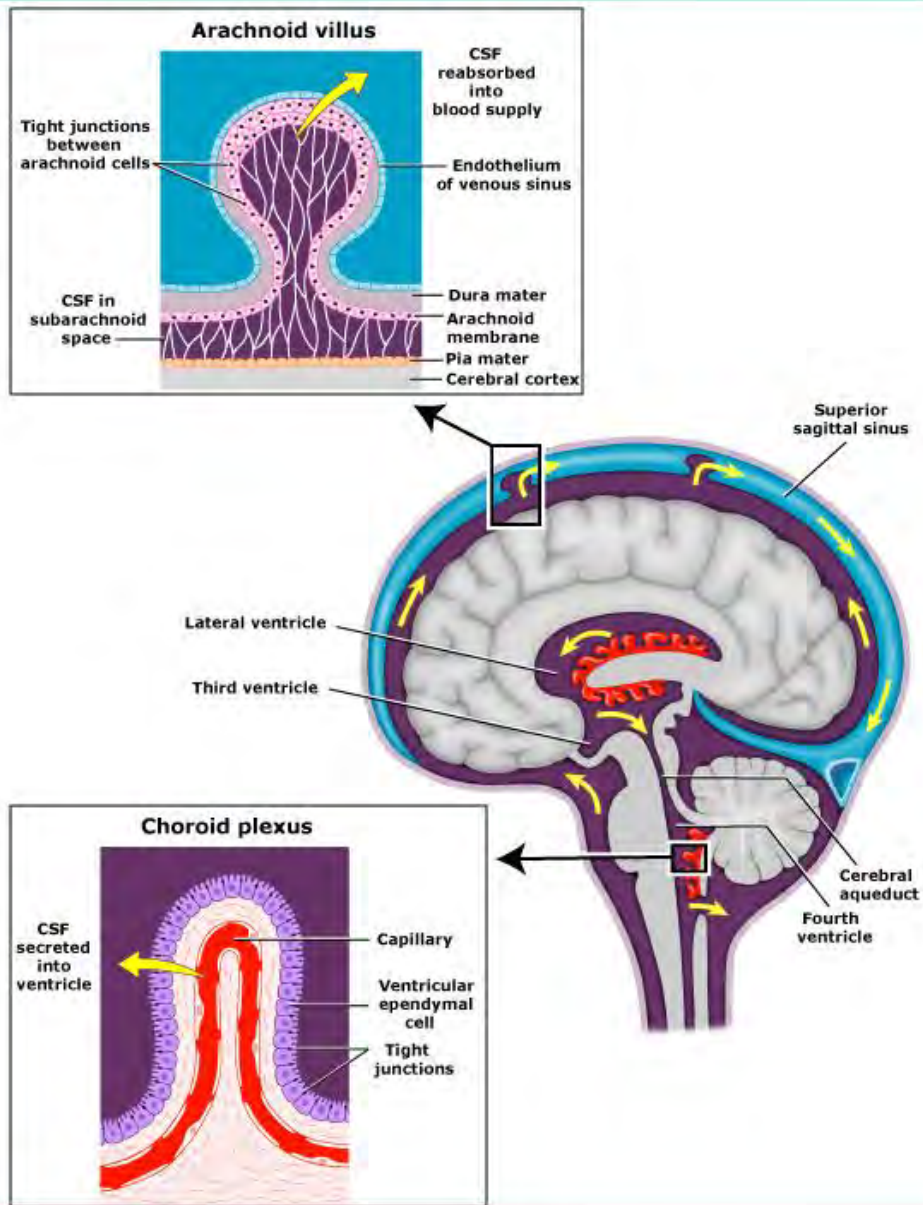
- Congenital

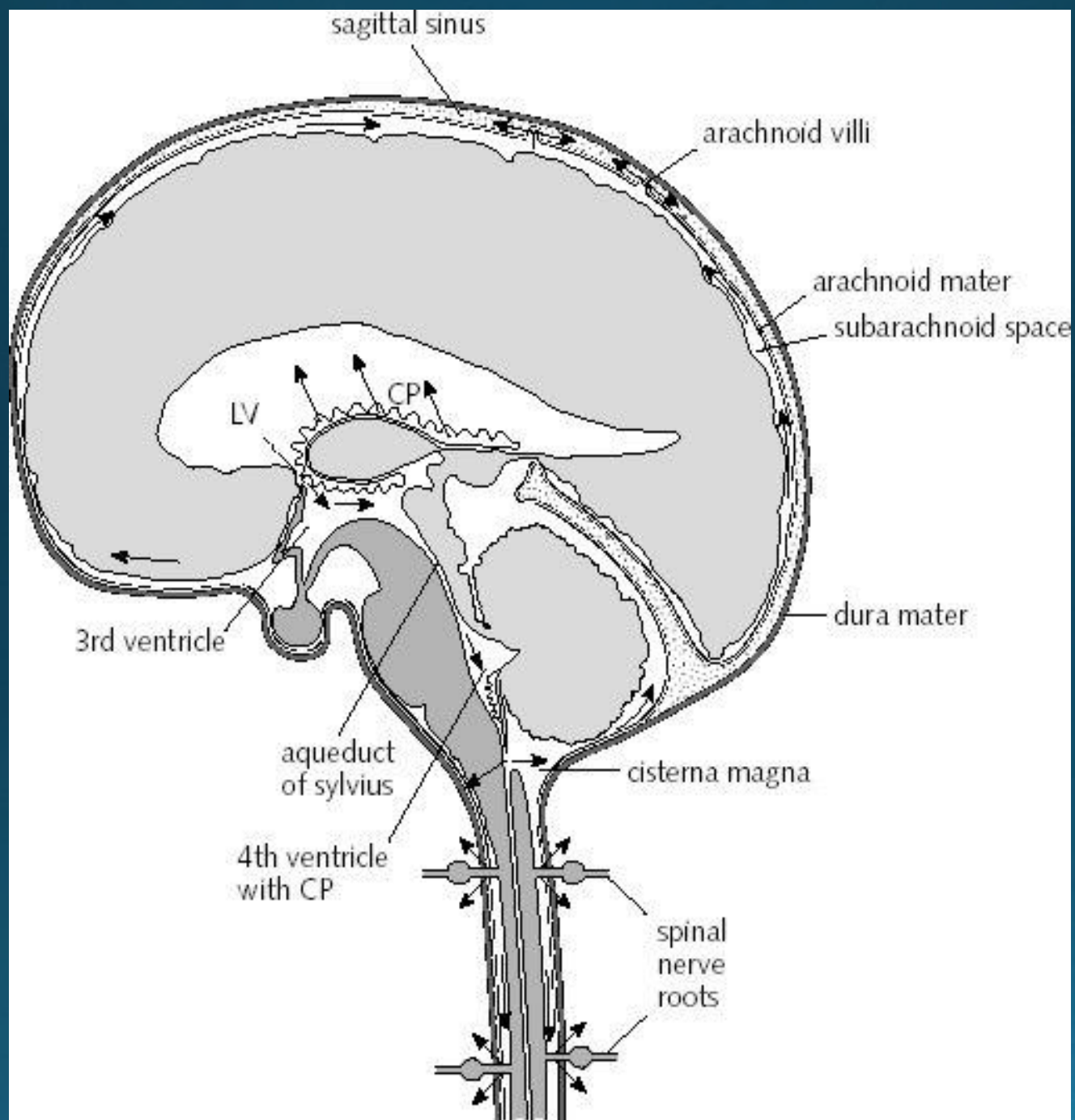
- Aqueductal stenosis
- Chiari malformations
- Dandy-Walker
- Neural tube defects
- Encephalocele
- In utero infections
- Trisomy 21

- Acquired

- Subarachnoid hemorrhage
- Meningitis
- Mass
- NPH

Cerebrospinal fluid formation and reabsorption



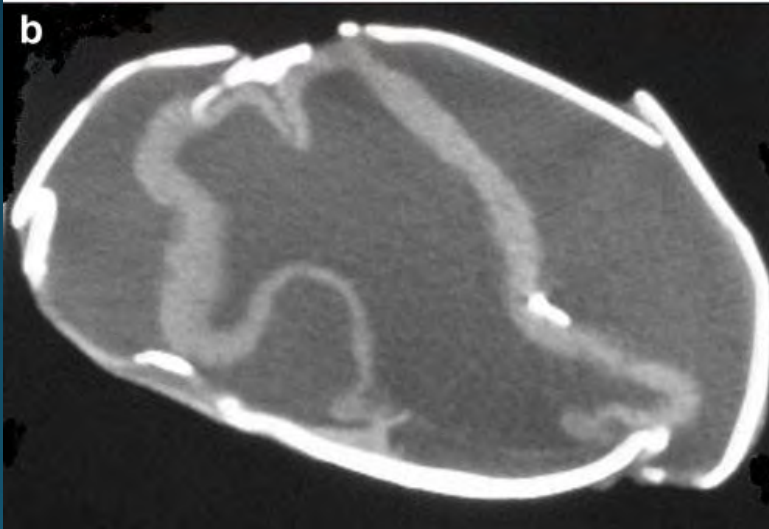
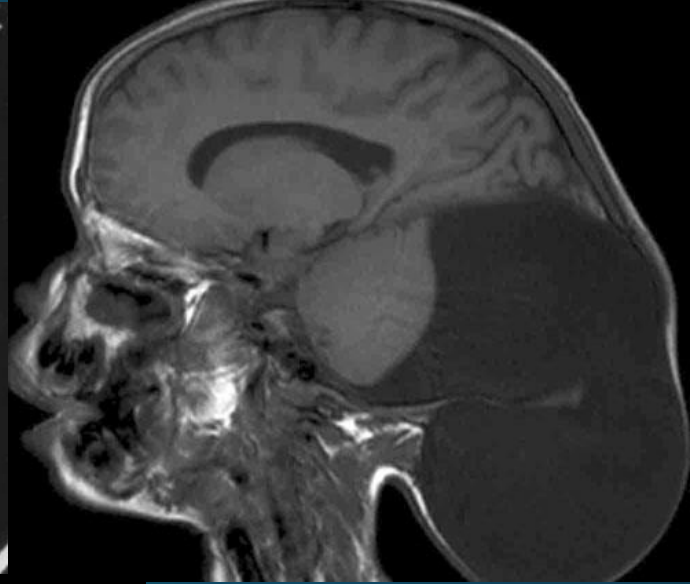
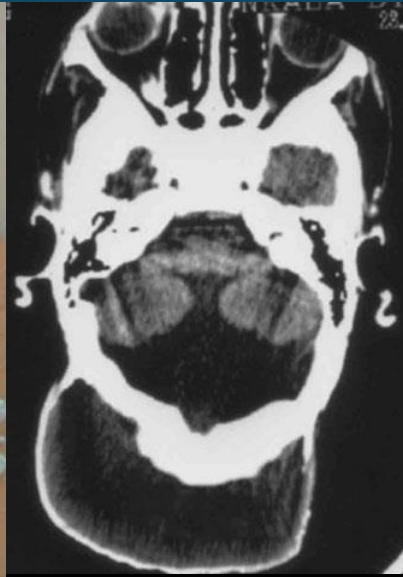


Hydrocephalus



- Non-communicating
 - Abnormalities in CSF flow between the choroid plexus and the arachnoid villi
 - Examples include obstruction by masses, cerebral aqueduct stenosis, Chiari malformation or Dandy-Walker syndrome, interventricular hemorrhage, infection, arachnoid cysts, or cysticercosis.
- Communicating
 - Defective absorption of CSF at the level of the arachnoid villi
 - Examples include repetitive subarachnoid microhemorrhage, meningitis, or arachnoid villi malfunction
 - Benign external hydrocephalus
 - NPH and Pseudotumor cerebri

Hydrocephalus



Hydrocephalus

- 40,000 new cases per year in the US
- Most commonly congenital including Arnold-Chiari malformation, Dandy-Walker malformation, trisomies 13, 18 and 9, aqueduct atresia and stenosis, myelomeningocele, agenesis or dysgenesis of the corpus callosum, small brain stem or absence of the pyramidal tracts
- Acquired cases from brain tumors, craniosynostosis, infections such as meningitis, arachnoid cysts, trauma, hemorrhage from IVH at birth, AVM or aneurysm, advanced age (NPH)

Complications of Hydrocephalus

- Depends on etiology
- Survival poor without shunt
 - 50% congenital hydrocephalus die within 3 years if untreated
 - 77-80% die before reaching adulthood, if untreated
 - 89-95 % survival with shunt, not associated with tumor

Treatment of Hydrocephalus

- Third Ventriculostomy (ETV)
 - Perforation in the third ventricle to the subarachnoid space
 - Obstructive hydrocephalus
- Shunt
 - Ventriculo-peritoneal (VP)
 - Ventriculo-atrial (VA)
 - Ventriculo-pleural(VPL)
- Medical management
 - Repeat LP
 - Diuretics – furosemide, acetazolamide

Ventriculostomy (Drain)

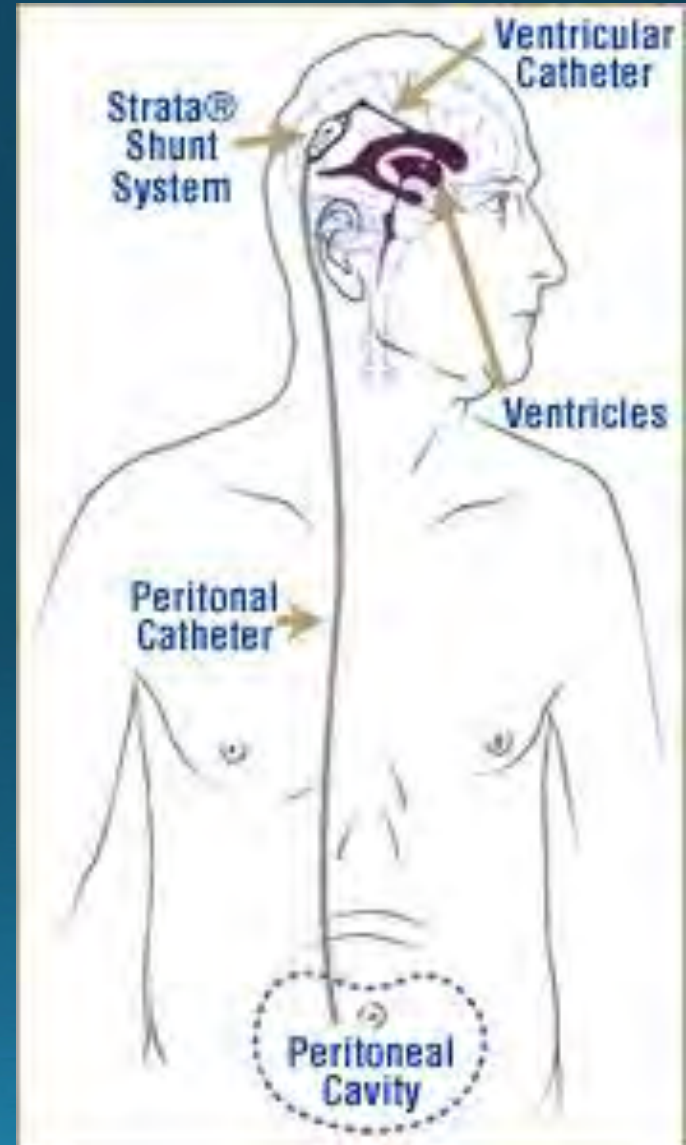
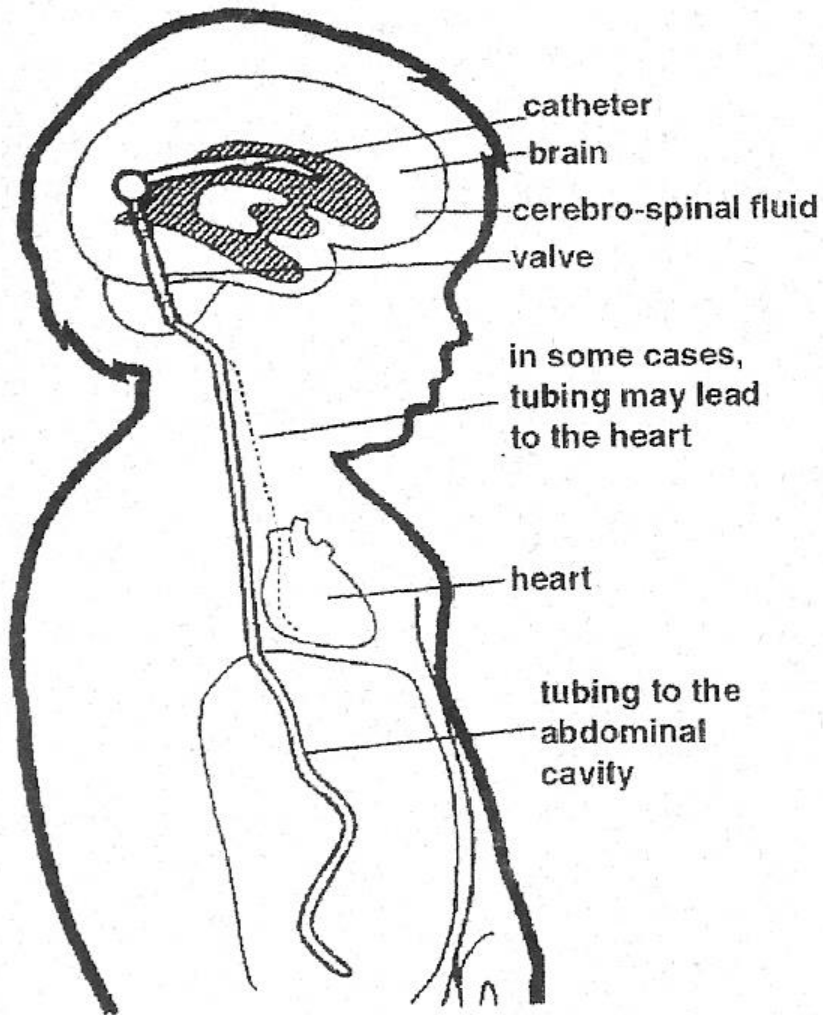
- Drain to exterior
- Pressure monitoring
- Temporizing measure
 - Evacuate IVH
 - Elevated ICP



The Shunt

- Mechanical device designed to transport excess CSF to a reabsorption site
- Components of the shunt
 - Proximal shunt catheter (lateral ventricle)
 - Valve and reservoir (low, med, high or programmable)
 - One way flow
 - Threshold
 - Distal shunt catheter (peritoneum, atria, pleural and GB)
- Average life expectancy of a Shunt is 10 years

The Shunt System

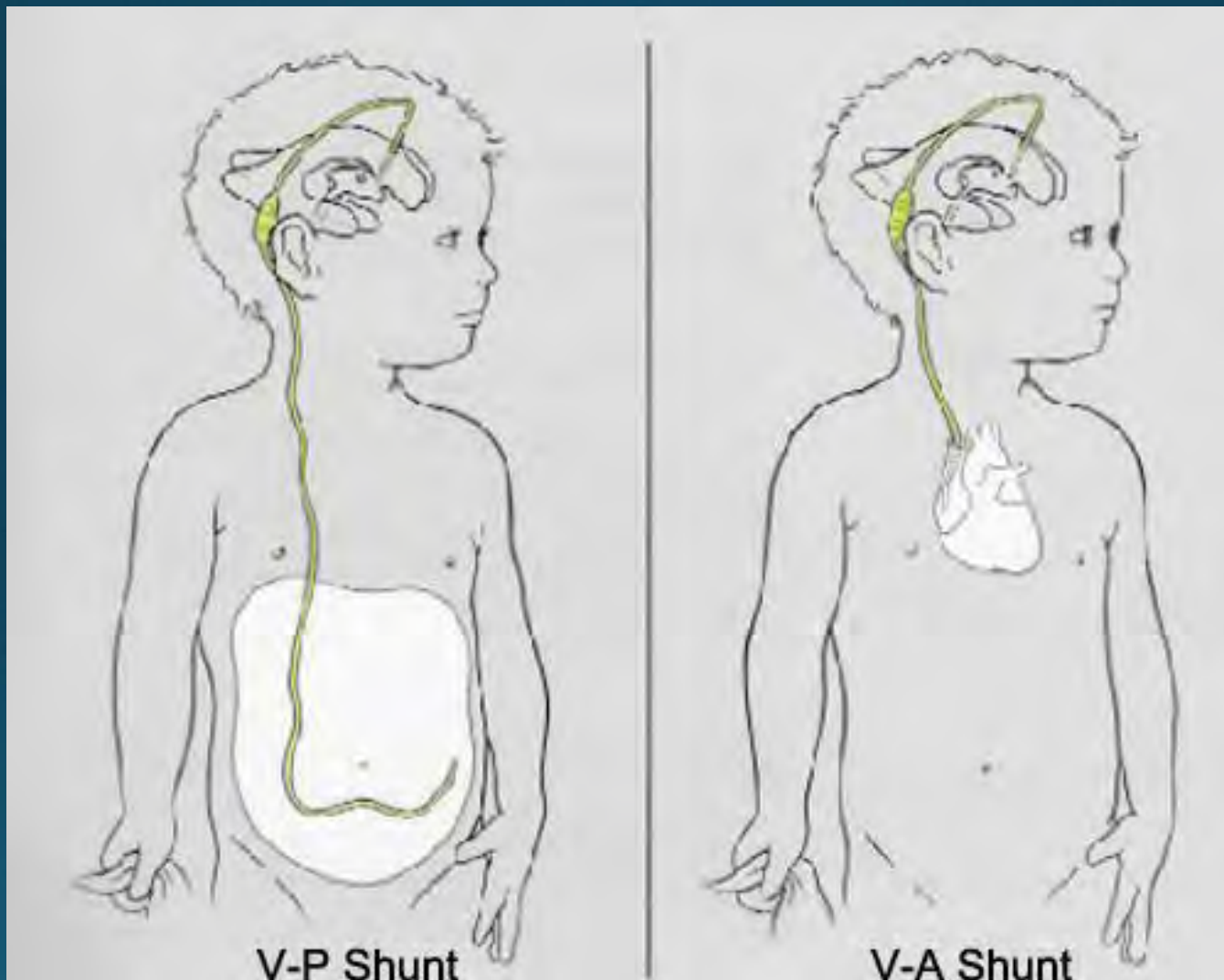


Ventricular Shunt

- More permanent
- CSF diversion for the relief of chronic hydrocephalus



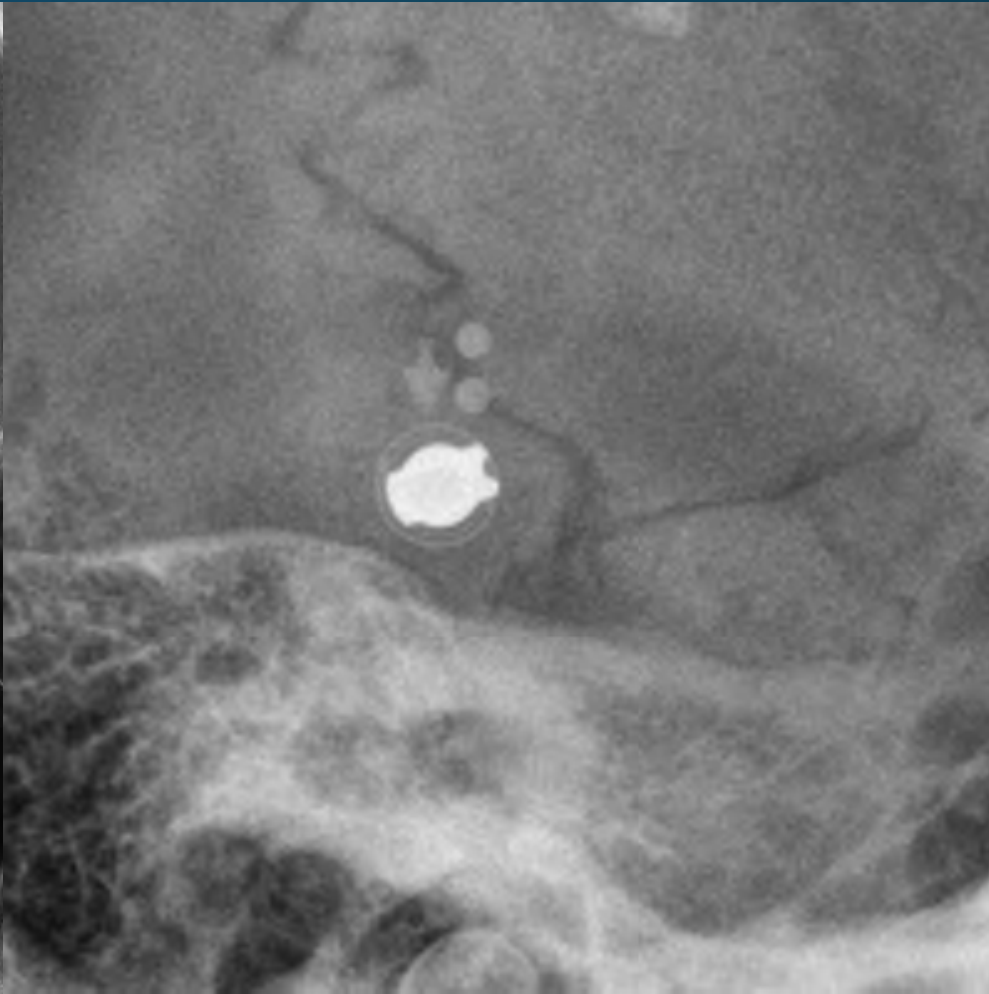
Ventricular Shunt



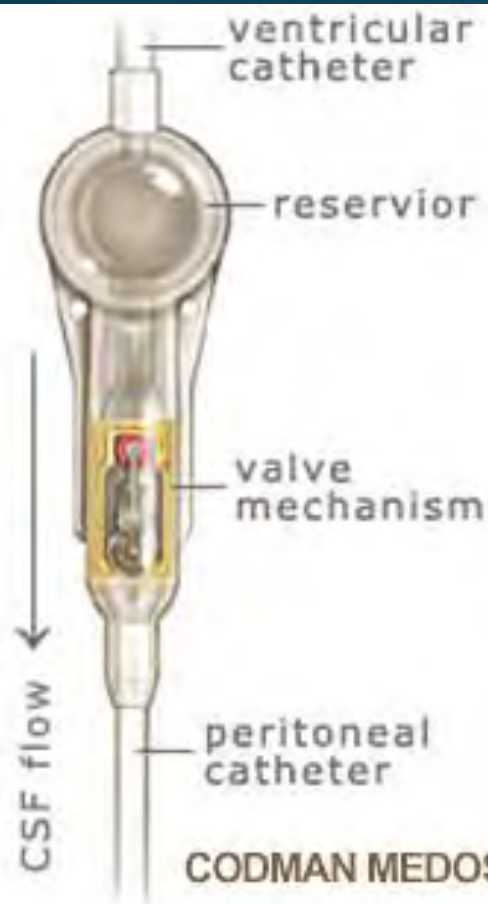
Ventricular Shunt

- Many different types/brands
- Three basic components
 1. Ventricular Catheter
 2. Shunt Valve
 3. Distal Catheter

Ventricular Shunt



Ventricular Shunt

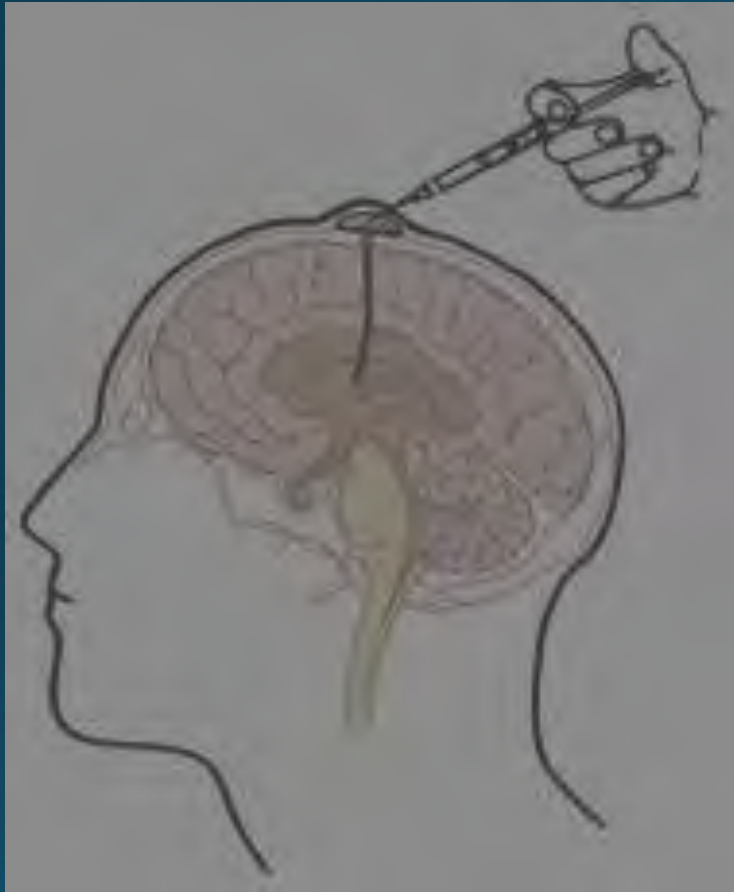


MEDTRONIC STRATA VALVE

Ommaya Reservoir

- Main use is not drainage
- Instead, primary uses are:
 1. Repeated delivery of CTX to CSF
 2. CSF sampling
- Two basic components
 1. Ventricular Catheter
 2. Shunt Valve

Ommaya Reservoir



Etiology of shunt malfunction

- ventricular catheter obstruction
- valve malfunction
- distal catheter obstruction
- pressure mismatch
- kinking
- dislodgement or component disconnection
- average life expectancy of a shunt is 10 years

Imaging Evaluation of Suspected Shunt Malfunction

1. Plain Radiographs (shunt series)
2. CT Scan or an MRI
3. Radionuclide shuntogram

Shunt series

- -Radiographs
 - AP and lateral skull
 - chest
 - abdomen
- Not a very useful tool
 - can be useful in situations where CT scan was either normal/unchanged

(Radiographic evaluation for suspected cerebrospinal fluid shunt obstruction. Pediatric Emergency Care. 18(5):337-340, October 2002).

CT scanning:

-can be of some utility if it shows change in the ventricular size from normal to dilated to increased size of ventricular dilation in the pediatric population.

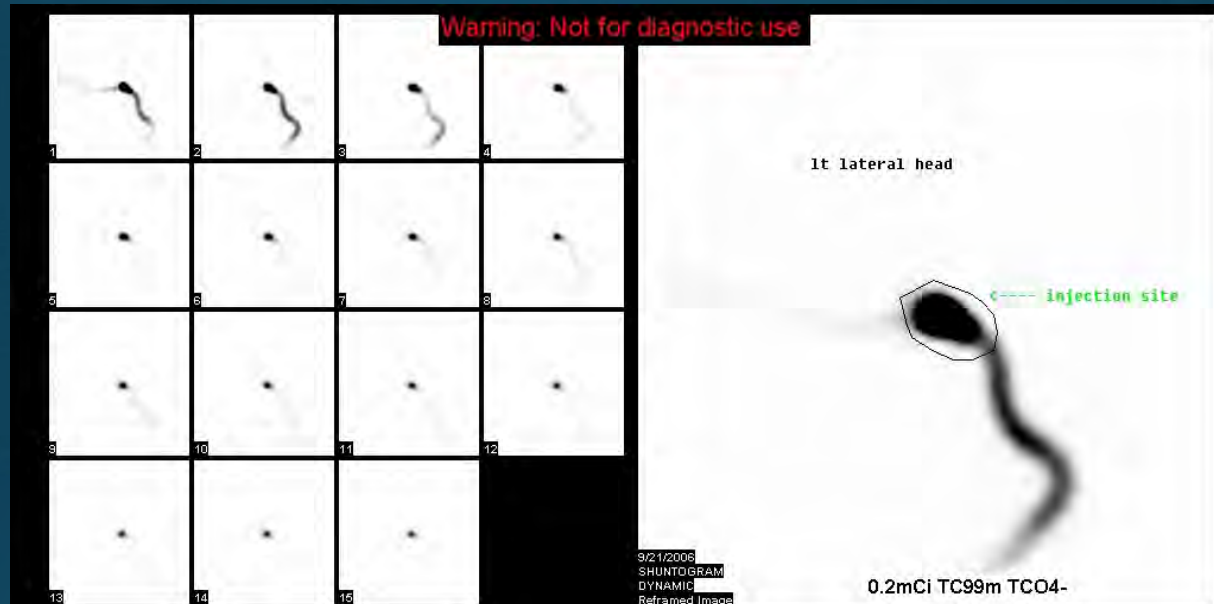
“Even under the best circumstances in a children’s hospital with a busy and competent radiology department, radiology reports may be misleading”. (*Pediatrics* 1998;101;1031-1036)

Methodology

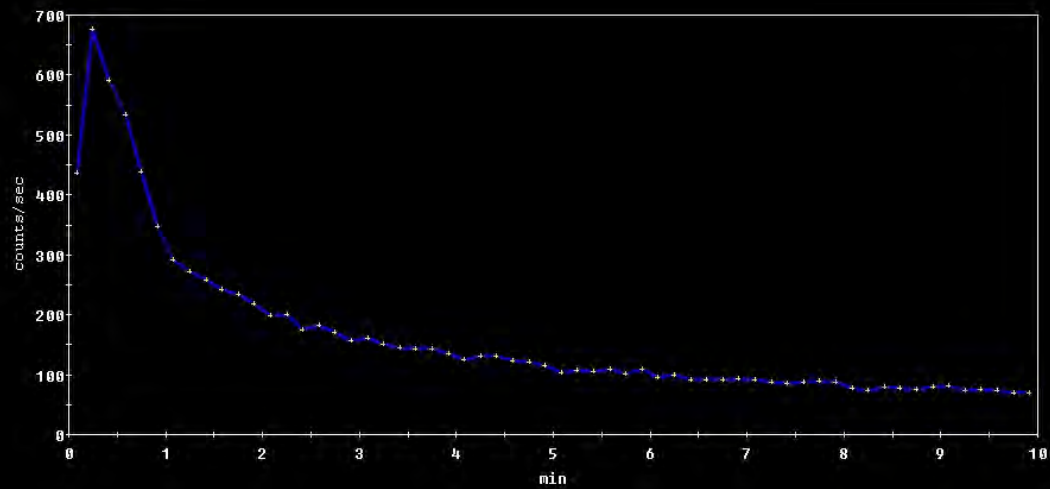
1. Obtain consent
2. Review prior CT scan images and shunt series if available
3. Explain the procedure to the patient in detail including the risks
4. Clean and shave the area overlying the reservoir
5. Palpate, but do not press reservoir

6. Introduce 25 gauge needle into reservoir and wait for CSF to flow back into the attached tubing
7. Measure the opening pressure
8. Collect CSF for the lab mainly for the cell count and gram stain
9. Inject 25 microcurie of Tc99m DTPA or pertechnetate after placing the patient under the camera
10. Start the camera right away
11. Obtain the images for first 15 minutes
If no drainage, do other maneuvers

Normal

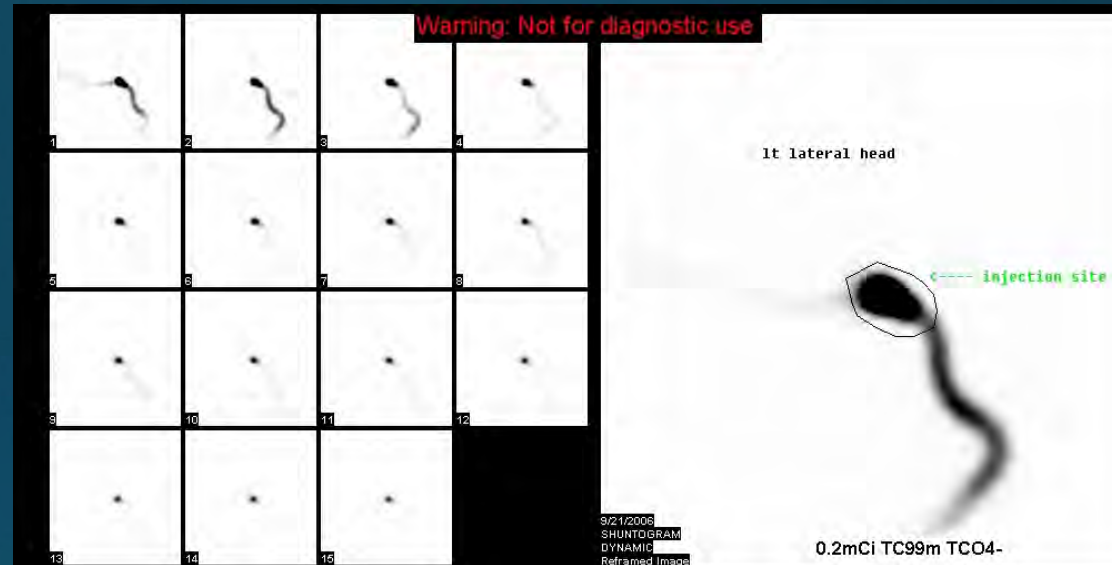


Shunt Curve

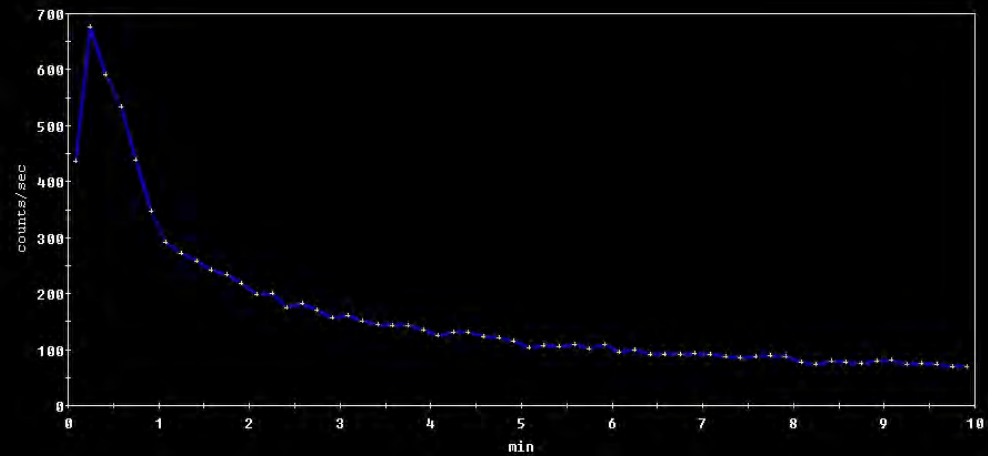


Normal

- Transit time 10-20min
- Dispersal of activity in abdomen or circulation
- Opening pressure ~5 mmHg



Shunt Curve



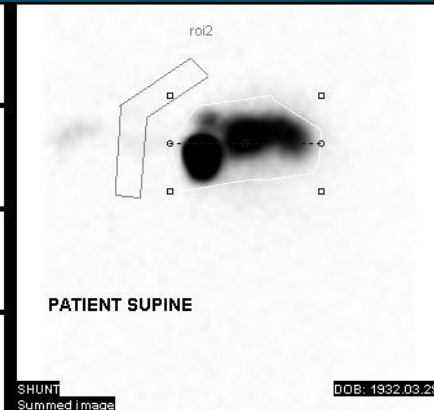
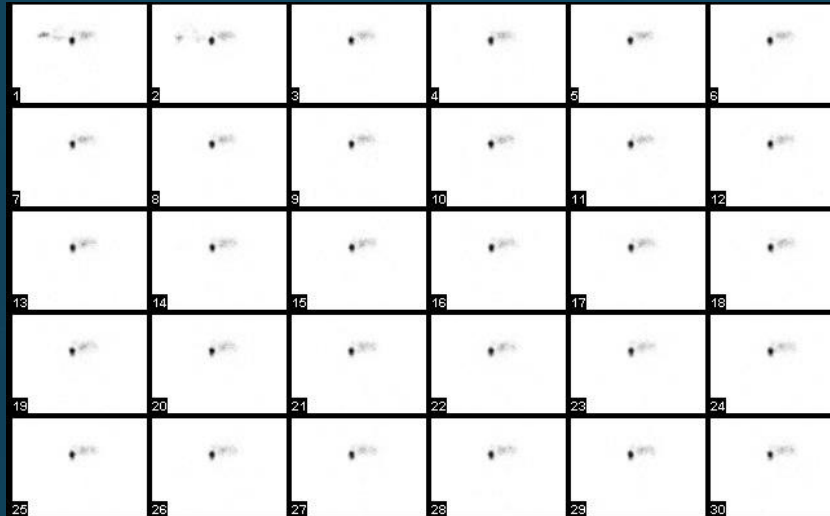
Occlusion

- Absence of contrast in peritoneum/RA
- Distal > Proximal
- Elevated OP suggests distal obstruction
- Low OP suggests proximal obstruction
- +/- position dependent
- +/- reflux into ventricles
- ⁹⁹Tc-DTPA in kidneys suggests some degree of patency

Etiology of shunt malfunction

- ventricular catheter obstruction
- valve malfunction
- distal catheter obstruction
- pressure mismatch
- kinking
- dislodgement or component disconnection

Occlusion



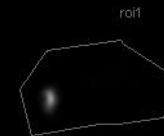
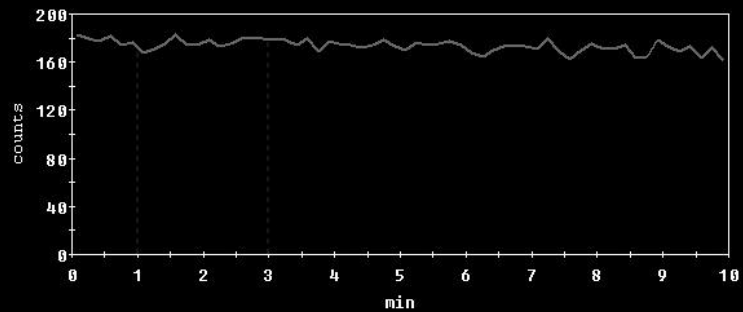
Statistics

Integral 1.->3.m
Integral percent
Integral Ratio
Time to 1/2 max
Time to peak
T 1/2

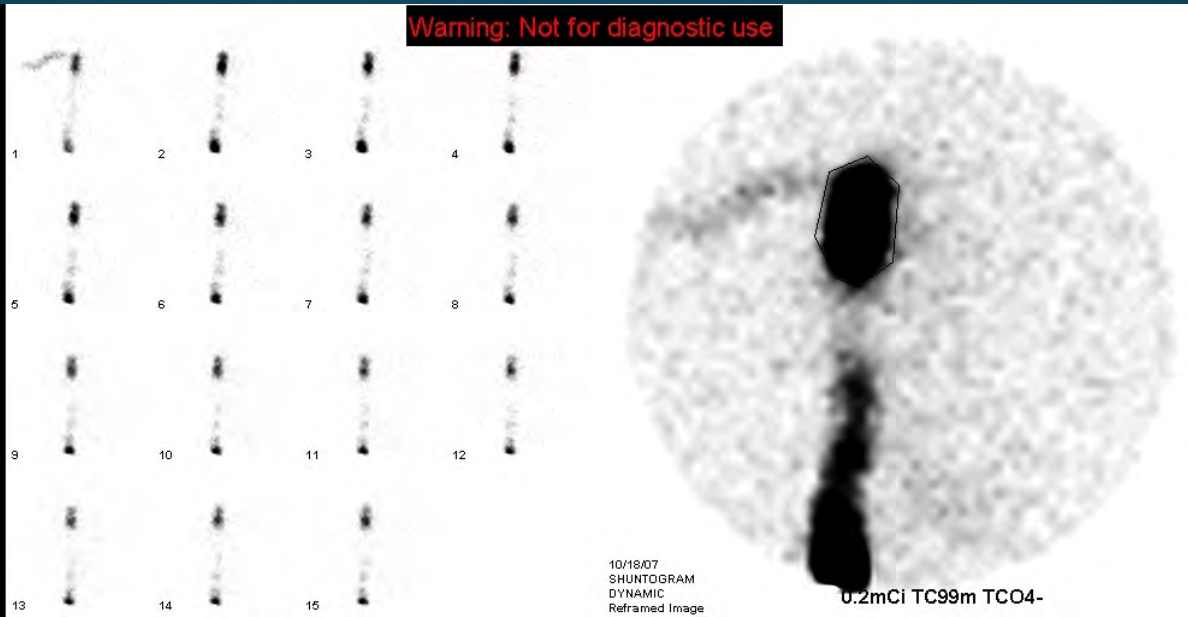
Curve A

21.1 Kc*sec
100.00%
Not reached.
.1 min
Not reached.

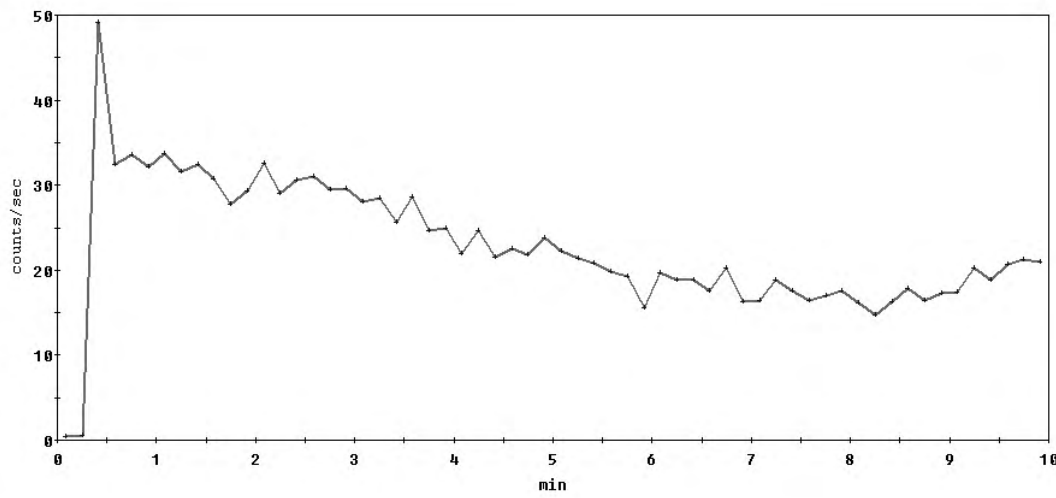
— roi1



Occlusion

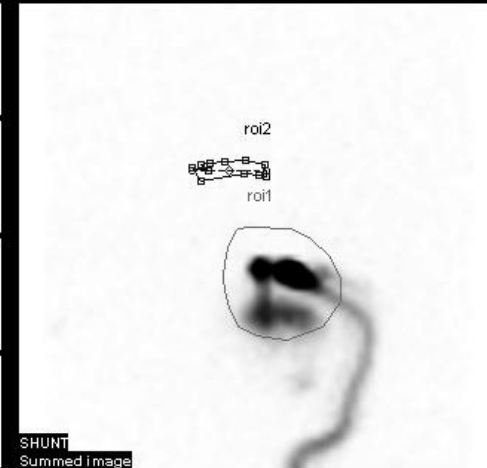
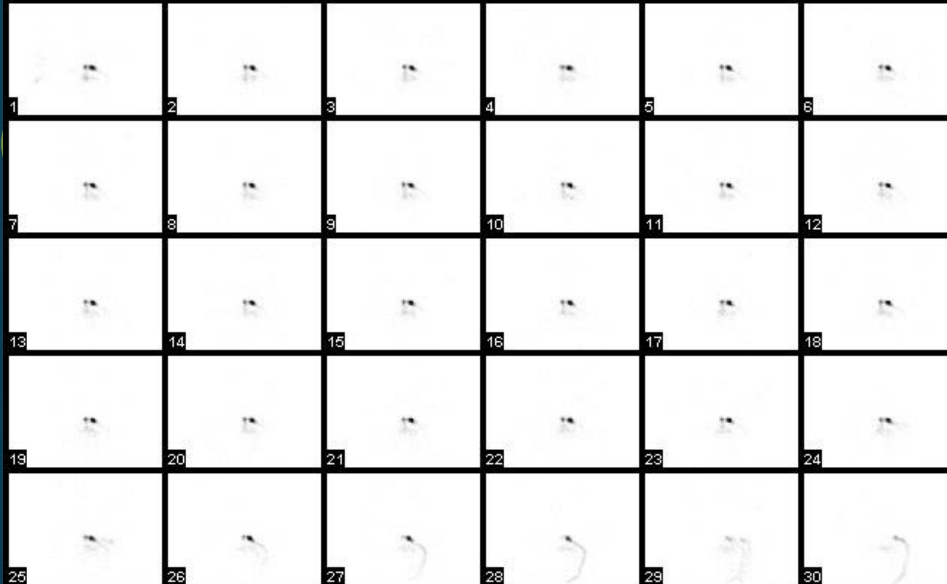


— Shunt Curve



Overdrainage

- Low opening pressure
- Rapid transit, often positional



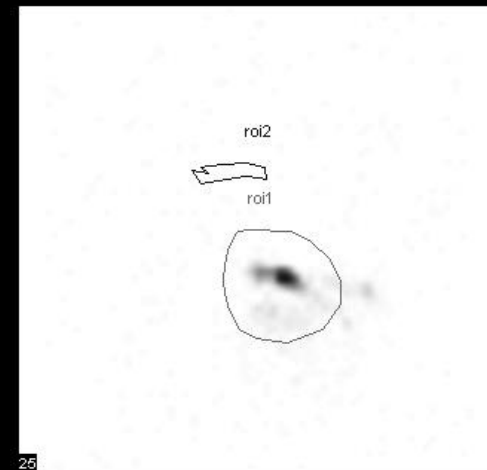
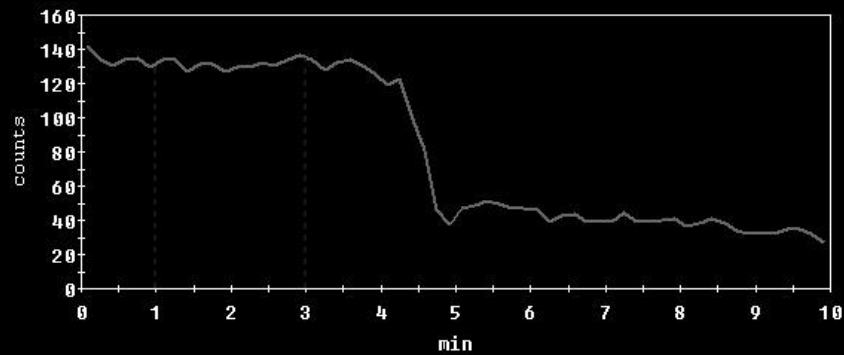
Statistics

 Integral 1.->3.m
 Integral percent
 Integral Ratio
 Time to 1/2 max
 Time to peak
 T 1/2

Curve A

 15.7 Kc*sec
 100.00%
 Not reached.
 .1 min
 4.6 min

— roi1 -roi2

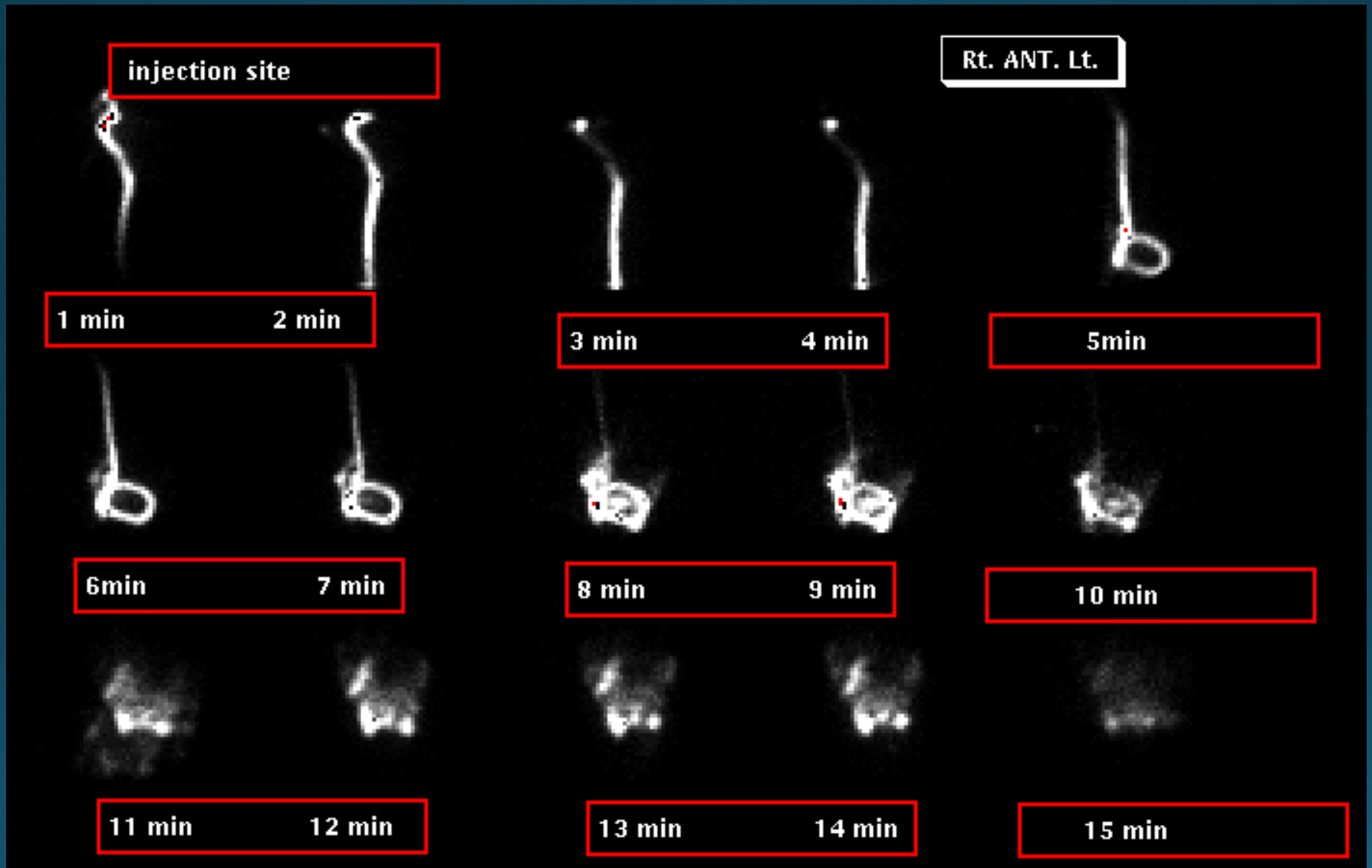


Case 1

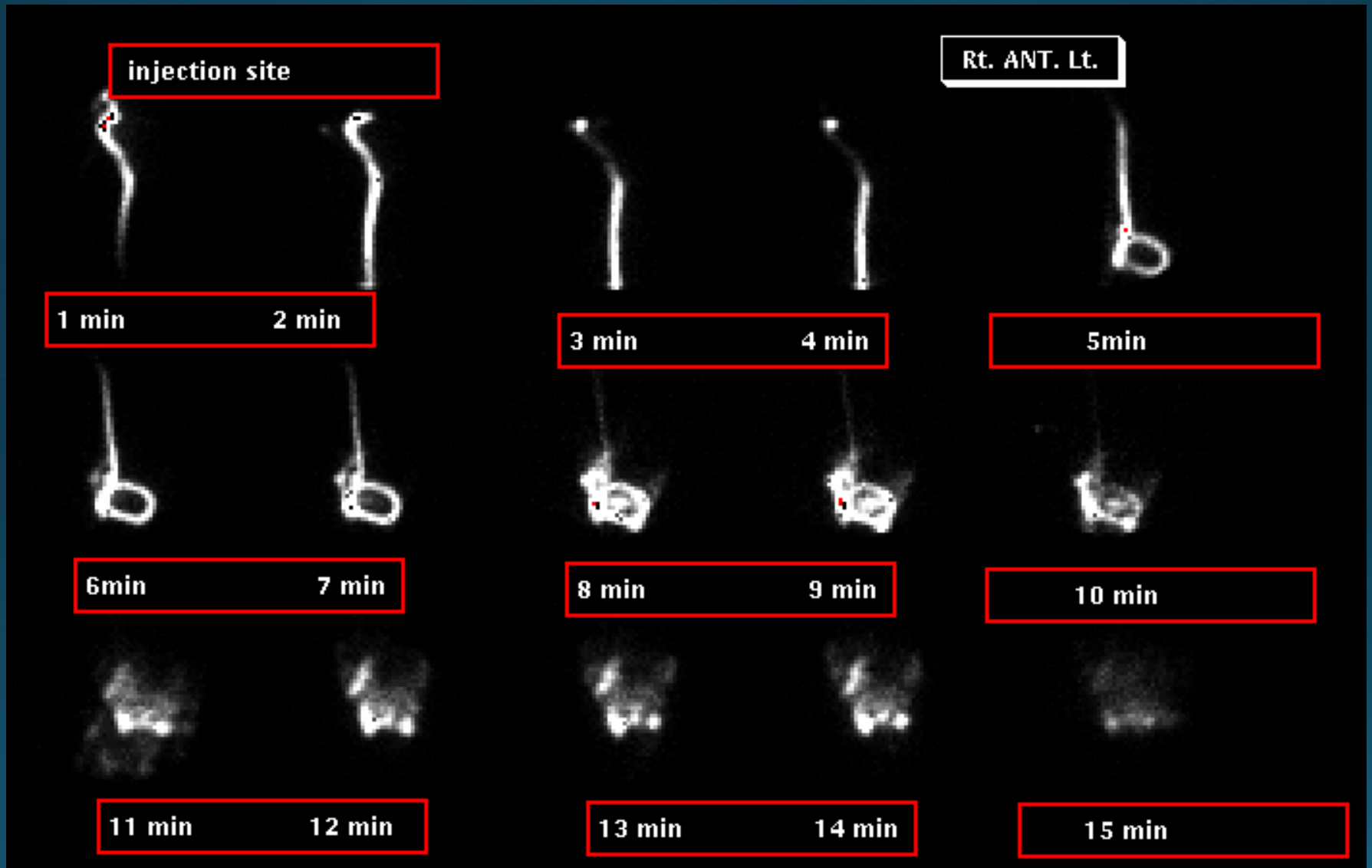
- 4 y/o with VP shunt after resection of posterior fossa tumor, now with n/v, headache, lethargy

<http://gamma.wustl.edu/home.html>

Case 1



Normal Study

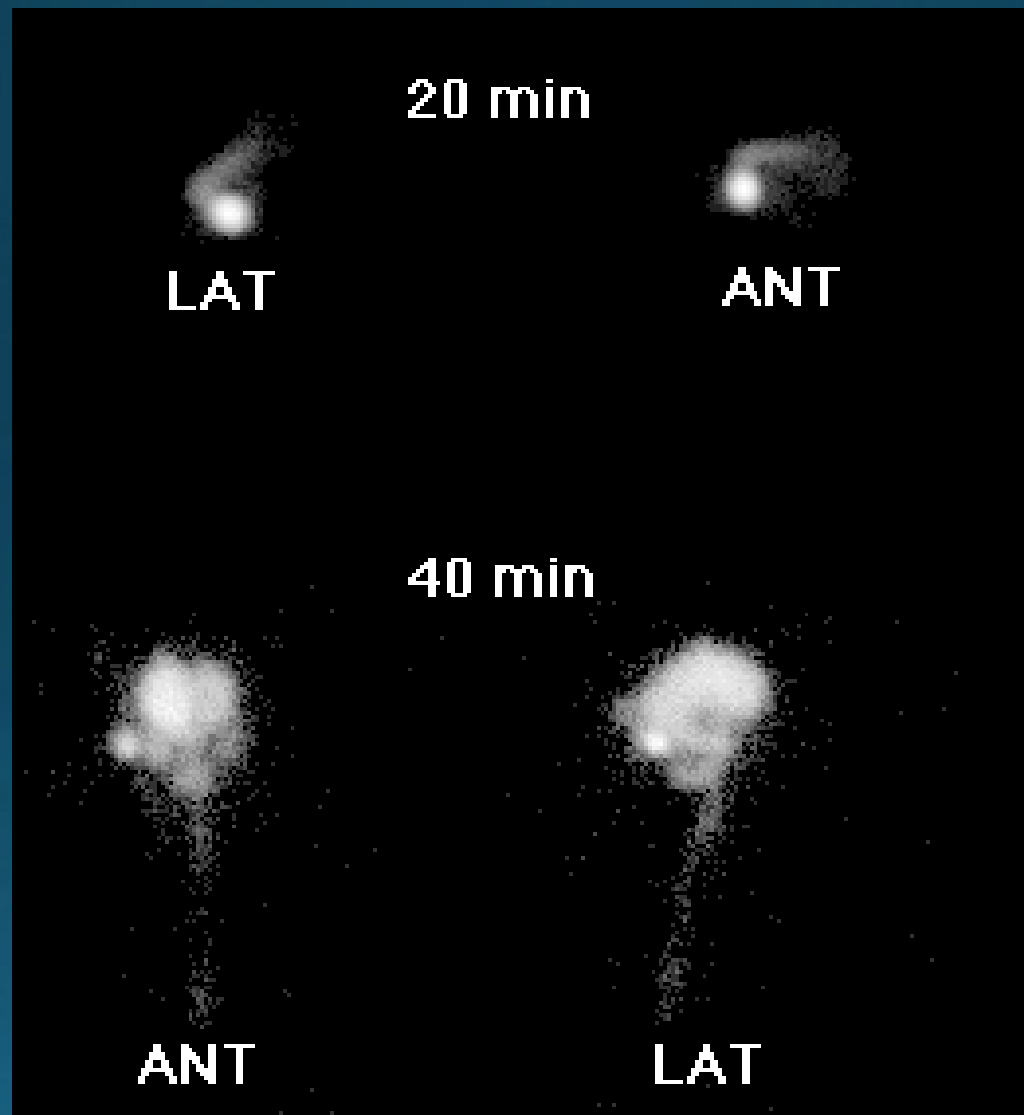


Case 2

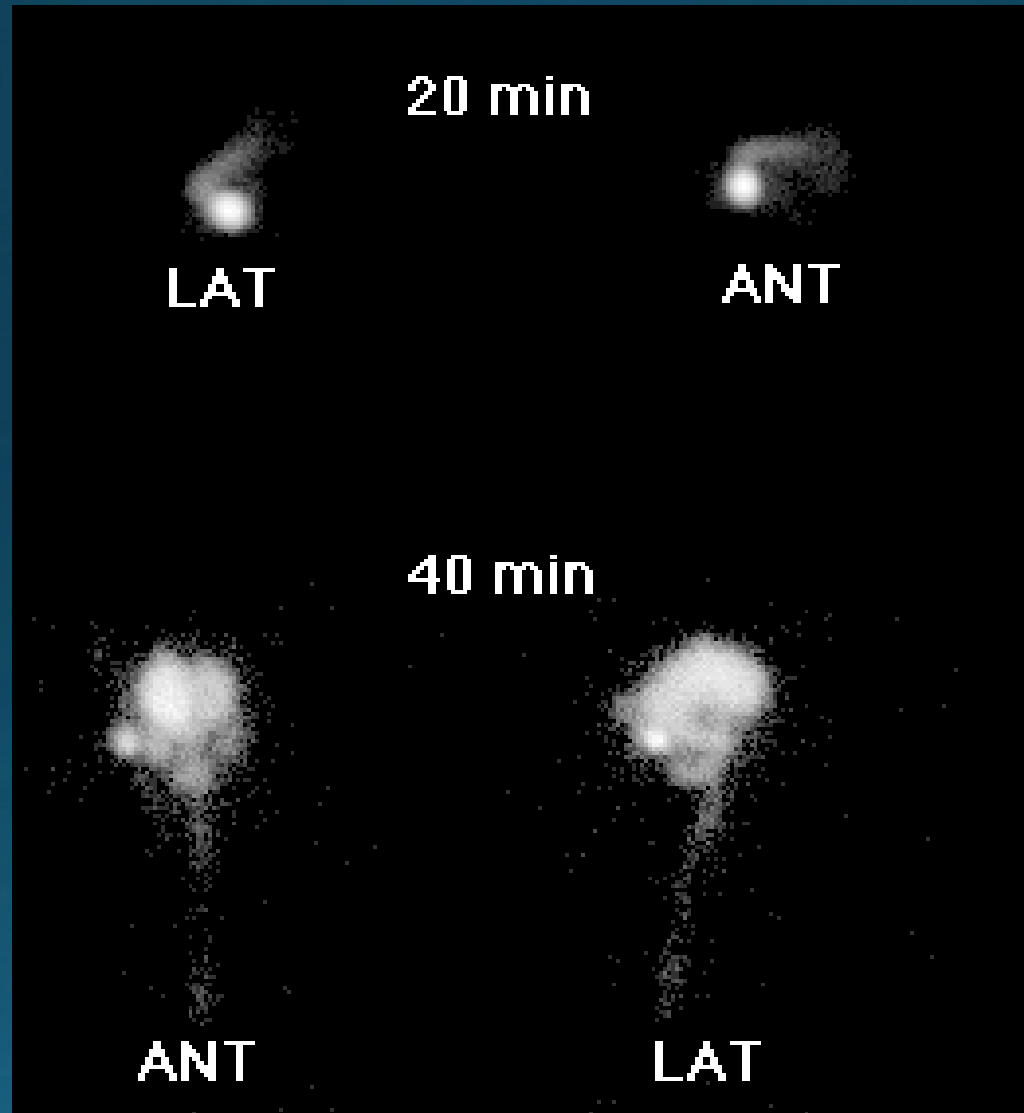
- 3 month old with VP shunt, increasing lethargy, loculated fluid collection on abdominal ultrasound

<http://gamma.wustl.edu/home.html>

Case 2



Obstructed Shunt

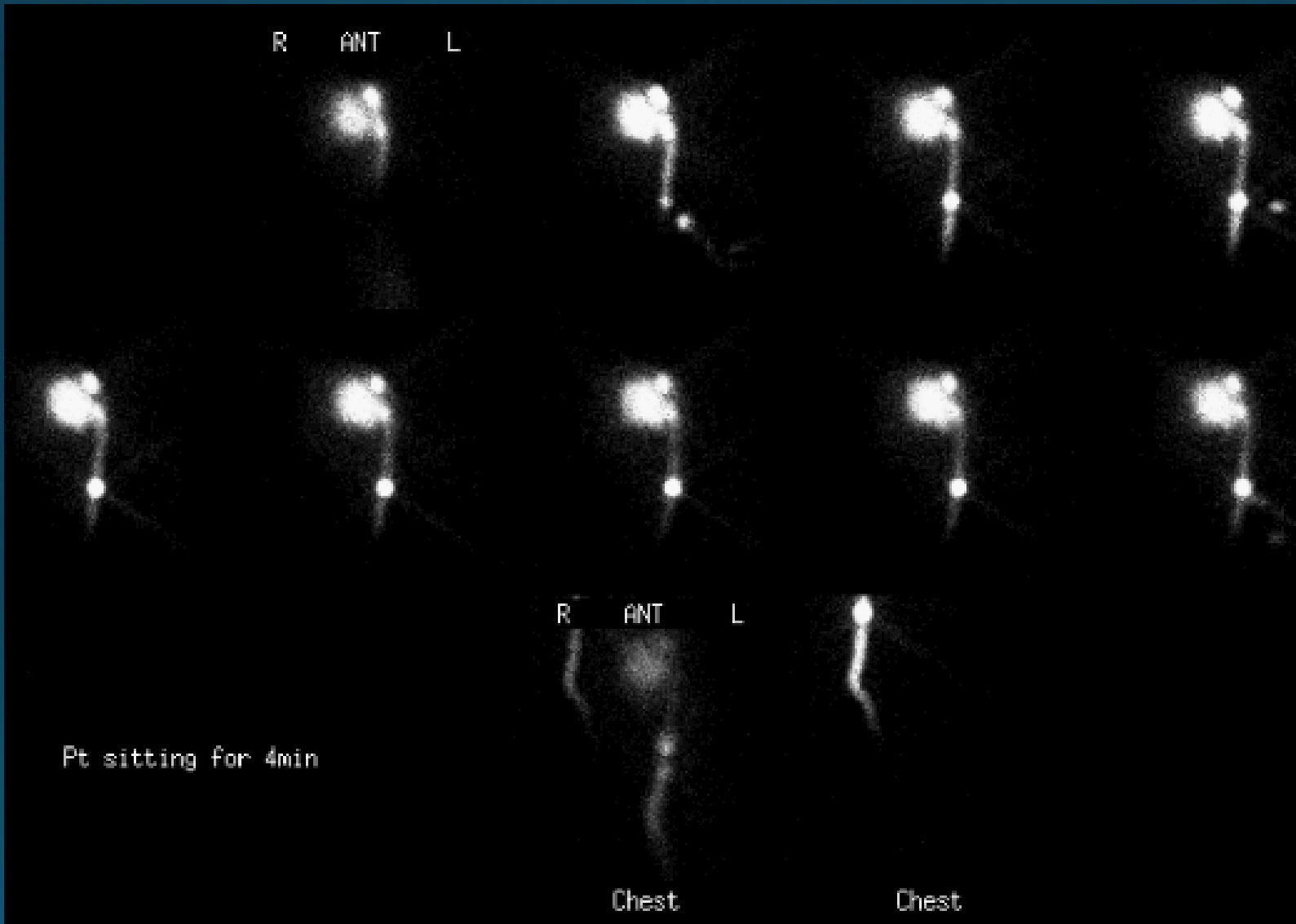


Case 3

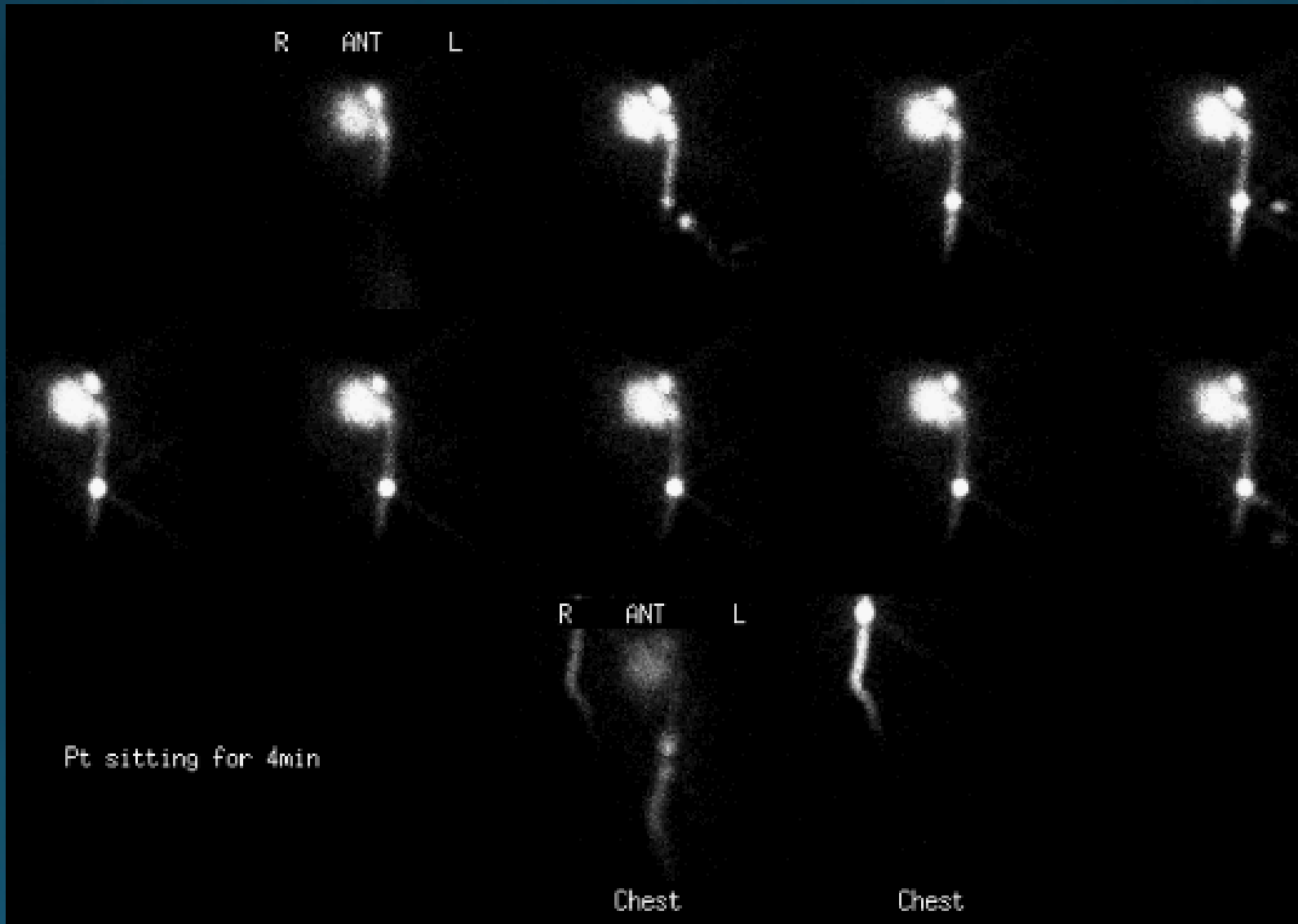
- 37 y/o with history of Chiari malformation and arachnoid cyst treated with VP shunt, now with neck swelling and worsening headaches

<http://gamma.wustl.edu/home.html>

Case 3



CSF Leak



CSF Leak

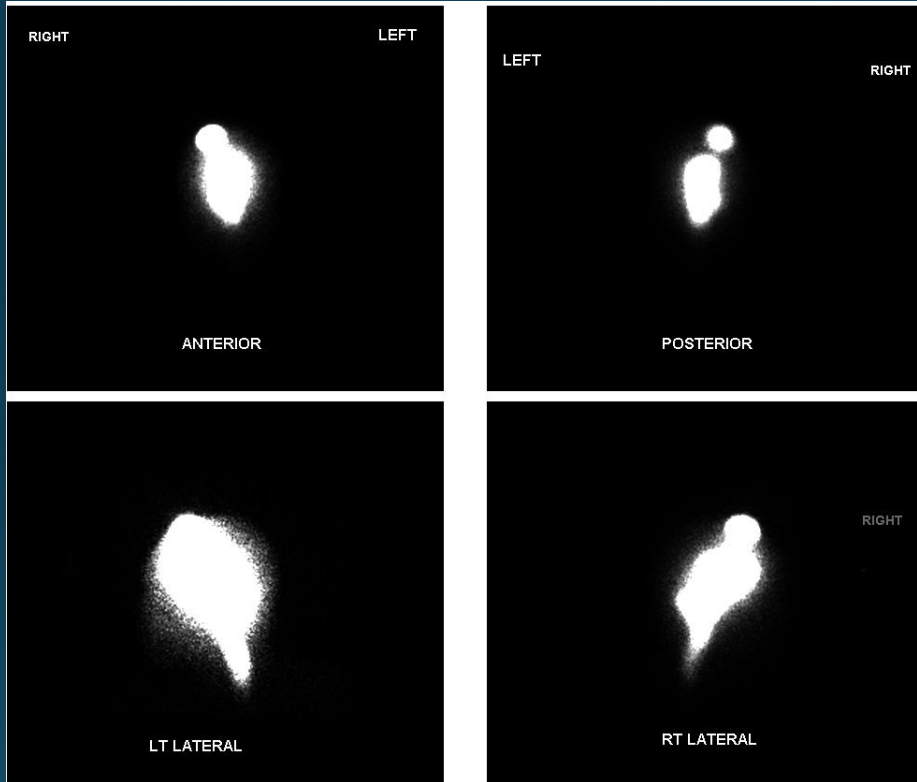


Case 4

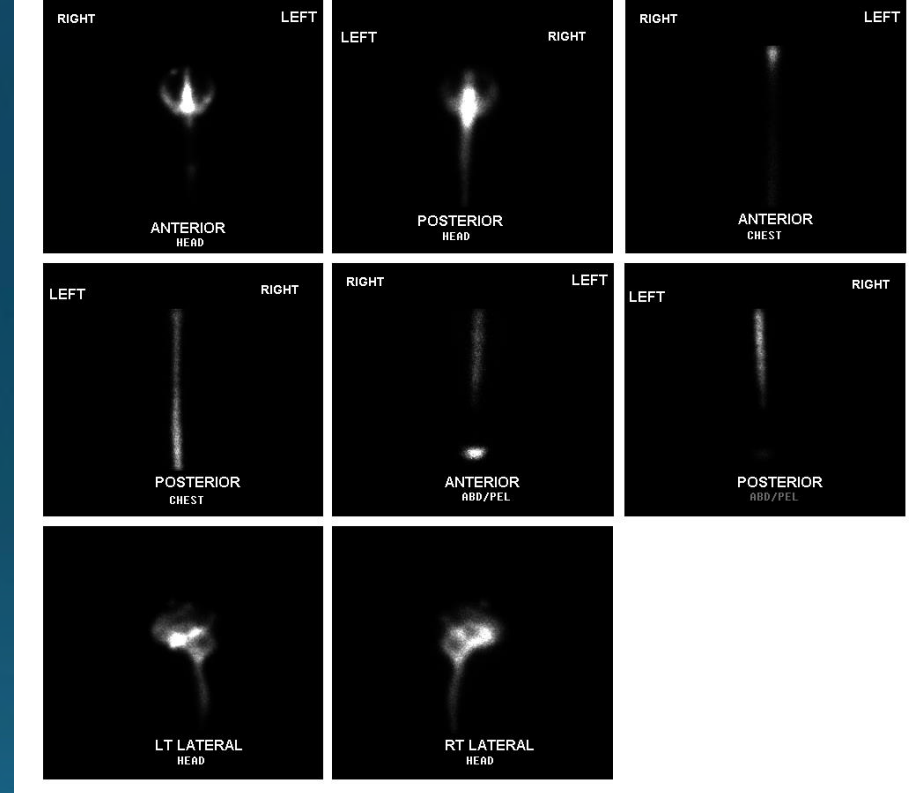
- History withheld

Case 4

Immediate



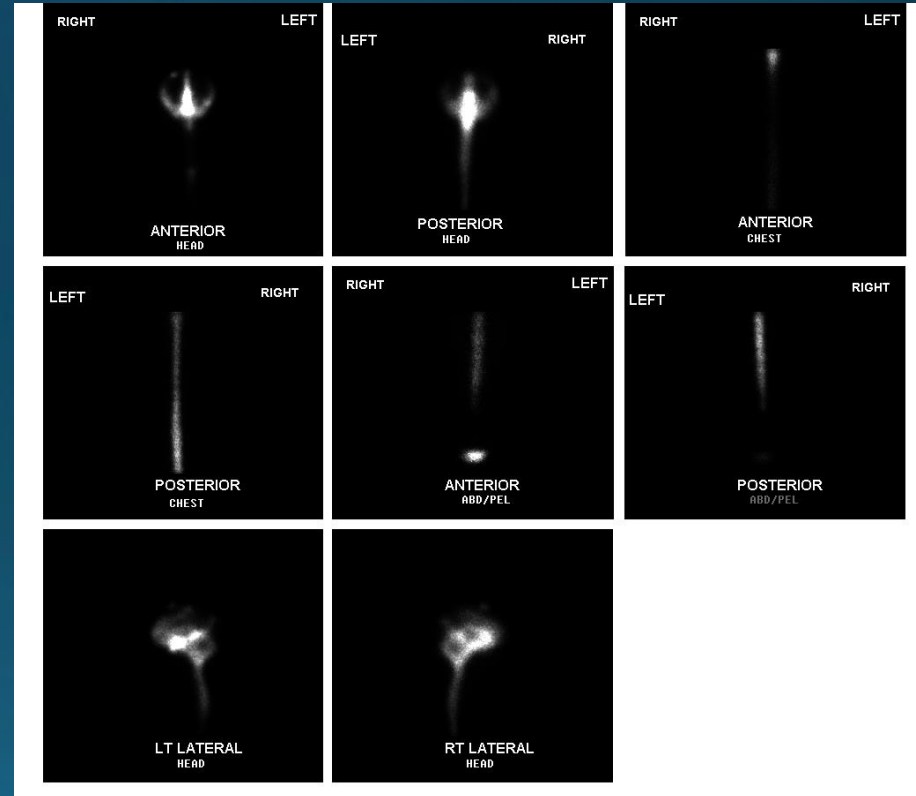
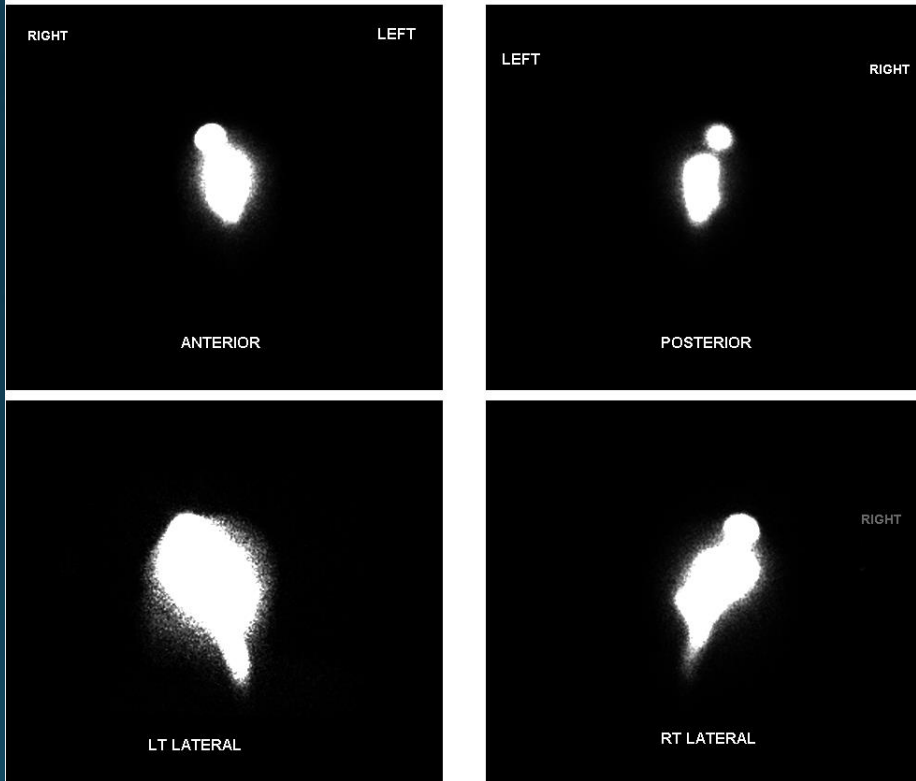
4 hours



Normal Ommaya Shunt

Immediate

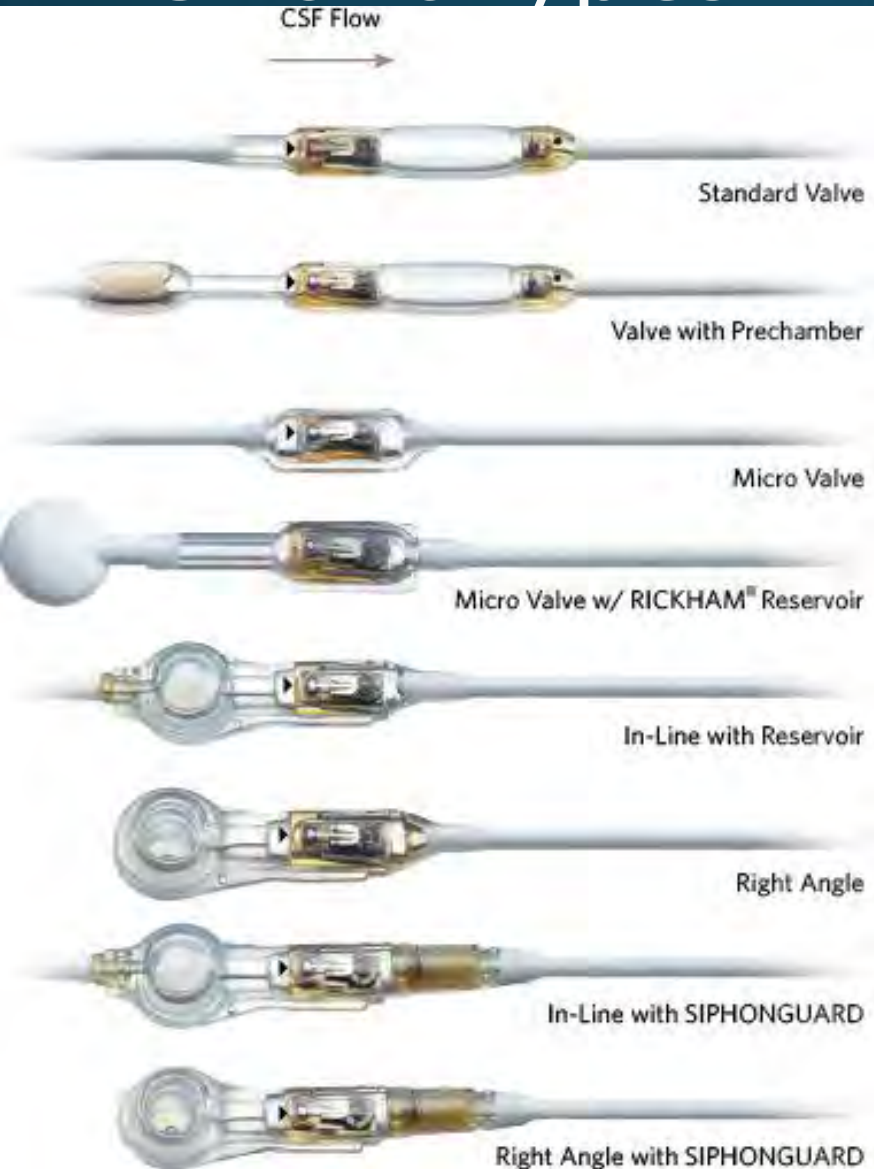
4 hours



Ventricular Valves

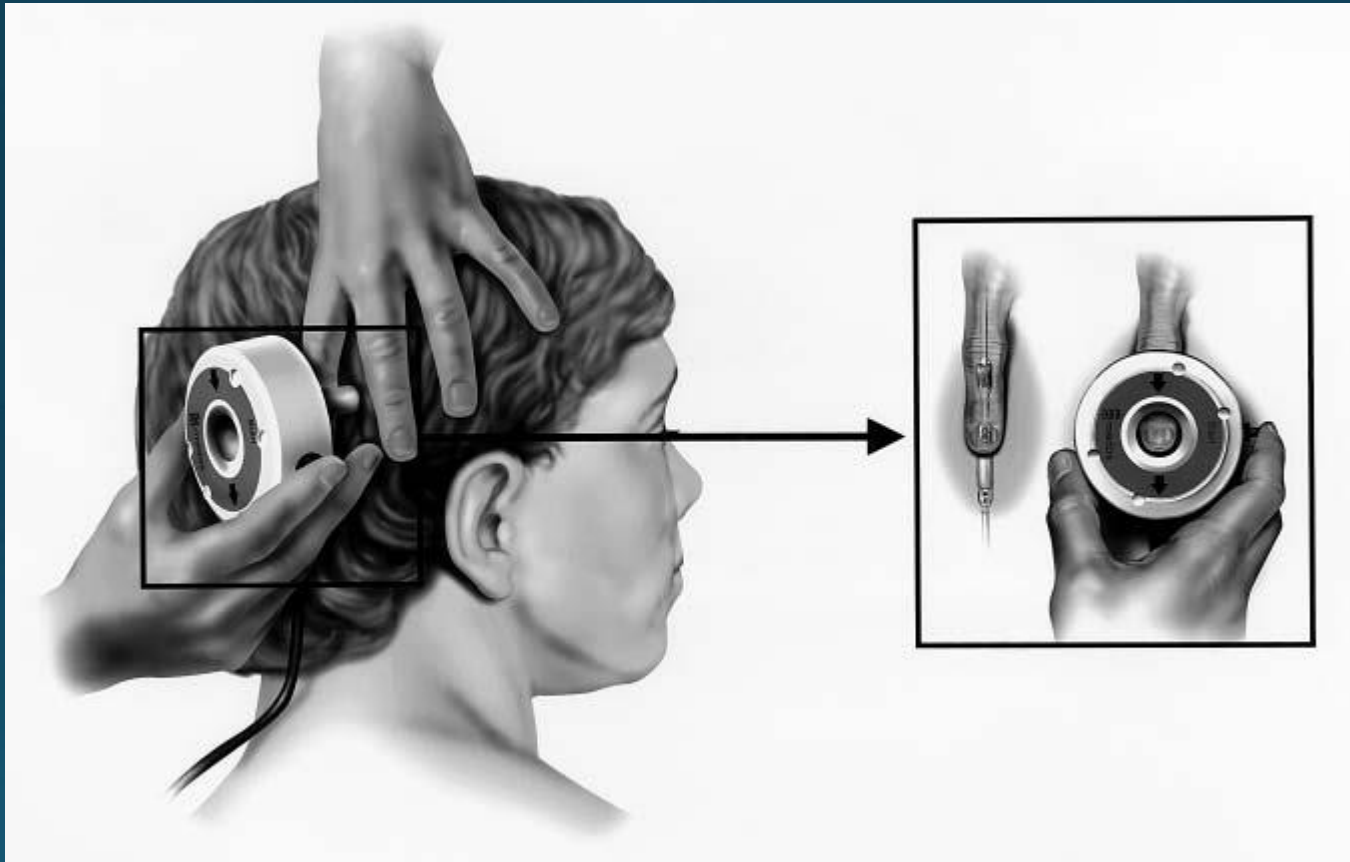
- Nulsen – Spitz: 2-ball-valves, not adjustable (1956)
- Pudenz-Schulte
- Strata (Medtronic with a delta valve)
- Codman (Hakim)
- Medium pressure: prone to uneven drainage
- OSV II Smart valve: flow-control (Integra)
- Novus valve (Integra)
- Miethke proGAV shunt (Aesculap) – MRI safe
- Anti-Siphon: prevents overdrainage by closing the valve when pressure is negative
 - Delta valve (Medtronic)
 - Designed to prevent overdrainage
 - Remains closed until ICP reaches a predetermined level
 - Intentionally leaves shunted ventricle larger than non-shunted

Shunt Types

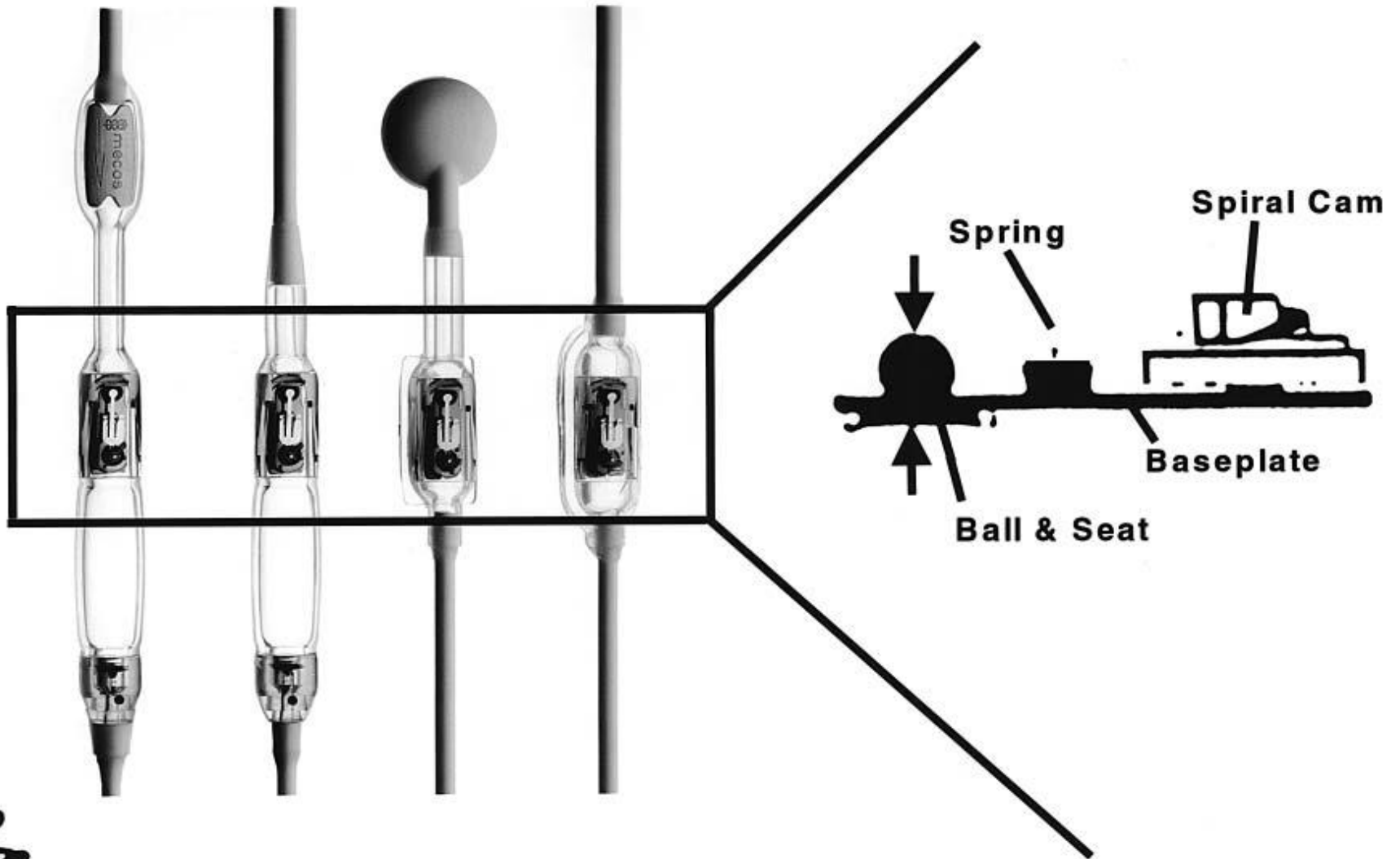


The programmable Strata valve

Magnetic Valve Adjustment



Adjustable valve VP shunts





Source: Neurosurg Focus © 2007 American Association of Neurological Surgeons

Complications in Shunted Patients

- Infection – 5-10 %
 - Most occur in the first 6 months
 - Promote development of loculated compartments
- Mechanical failure – 40%
 - Majority from catheter obstruction
- Epilepsy - 32%
- Motor defects - 60%
- Auditory defects - 25%
- Overdrainage
 - Risk for extra-axial fluid collection
 - Slit-like ventricle syndrome
- Acquired Chiari Malformation
- IVH – 31% of shunt revisions

Radionuclide Shuntogram

- Penetrate the reservoir with 25 ga butterfly needle
- Measure OP (5-10 cm/H₂O) and collect 0.5-1.0 ml CSF
- Move under gamma camera and inject 0.5-1.0 ml Tc-99m DTPA (VP), MAA (VA) or pertechnetate
- Dynamic acquisition over 10-minutes with ROI around reservoir
- If T_{1/2} not reached, by 10 minutes, initiate maneuvers
 - Sit upright and image for 10 minutes. If no drainage,
 - Ambulate for 5 minutes and re-image. If no drainage,
 - Pump the reservoir 4-6 times and obtain static image
- Image peritoneum if VP shunt, whole body if VA shunt and Chest if VPL shunt to confirm free flow at destination

Shuntogram Technique

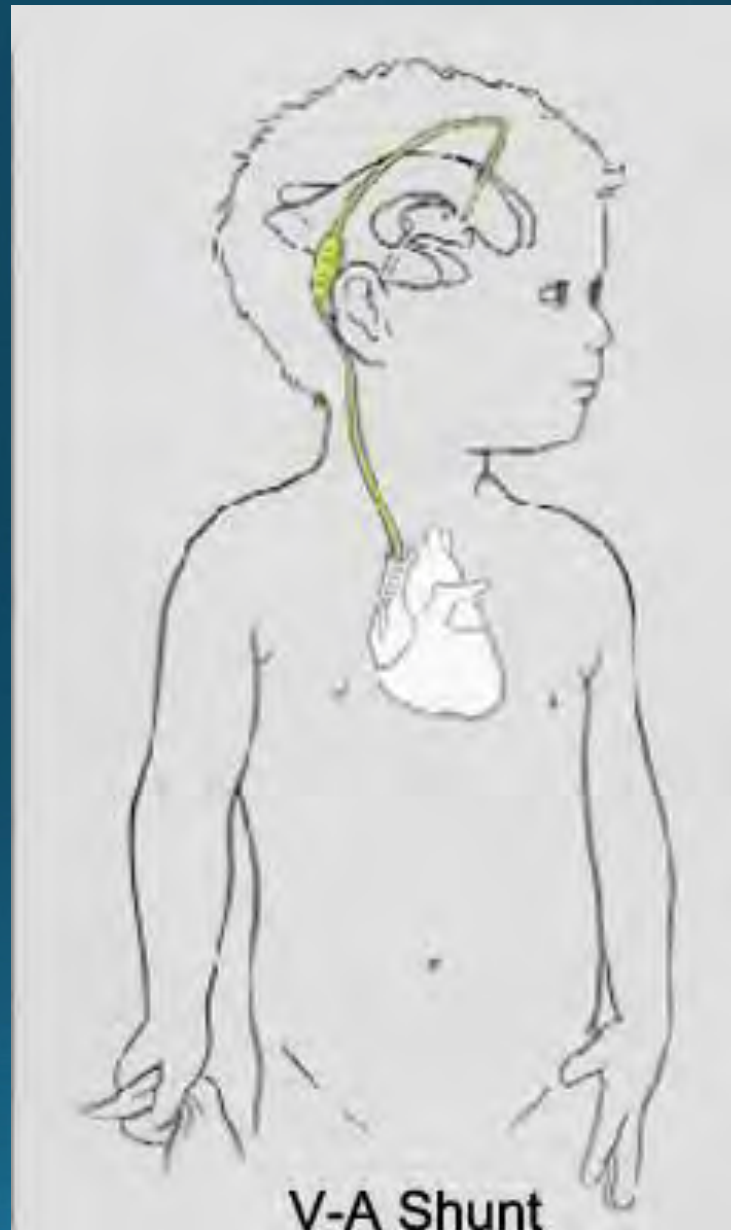
- Using sterile technique, penetrate the reservoir with 25 ga butterfly needle
- Measure opening pressure and collect 0.5-1.0 ml CSF
- Move under gamma camera and inject 0.5-1.0 ml Tc-99m DTPA (VP), MAA (VA) or pertechnetate
- Dynamic acquisition over 10-minutes with ROI around reservoir
- If $T_{1/2}$ not reached, by 10 minutes, initiate maneuvers
 - Sit upright and image for 10 minutes. If no drainage,
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 - Pump the reservoir 4-6 times and obtain static image
- Image peritoneum if VP shunt, whole body if VA shunt and Chest if VPL shunt to confirm free flow at destination

Normal Shuntogram Findings

- Normal opening pressure: ~ 2-15 cm H₂O
- Tracer flow
 - VP shunt:
 - Rapid flow of tracer into distal tubing (to level of mid-abdomen)
 - Clearance T-1/2 = ~ 1-10 minutes
 - Free dispersal into peritoneum on anterior abdominal images
 - VA shunt:
 - Rapid flow of tracer into distal tubing (within atrium)
 - Thyroid, stomach, and urinary bladder uptake indicating dispersal into blood pool

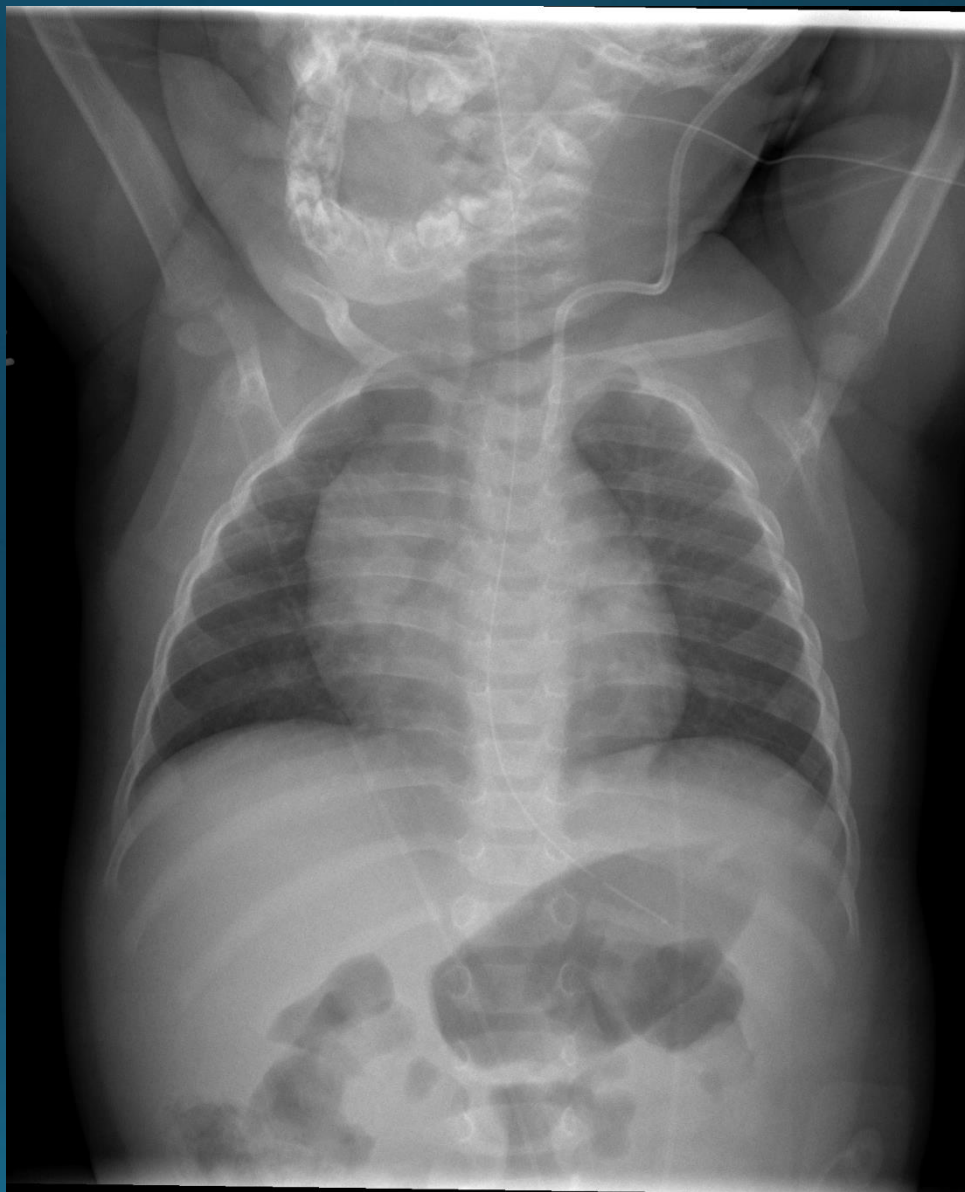
	Opening Pressure	Distal flow	Retrograde flow
Proximal limb obstruction	Low (0-2cm H ₂ O) or Negative (<0 cm H ₂ O)	None or minimal in supine position, may have distal flow after pumping or ambulation	None if complete, +/- with partial (maneuvers may help)
Distal limb obstruction	High (> 15cm H ₂ O)	None if complete, +/- with partial (maneuvers may help)	+/-
Gravity or Position-dependent flow	Normal or High	None when supine, but prompt drainage in upright position	+/-
Overdrainage	Low	Rapid drainage (T-1/2 < 1min), may be position dependent	Usually not

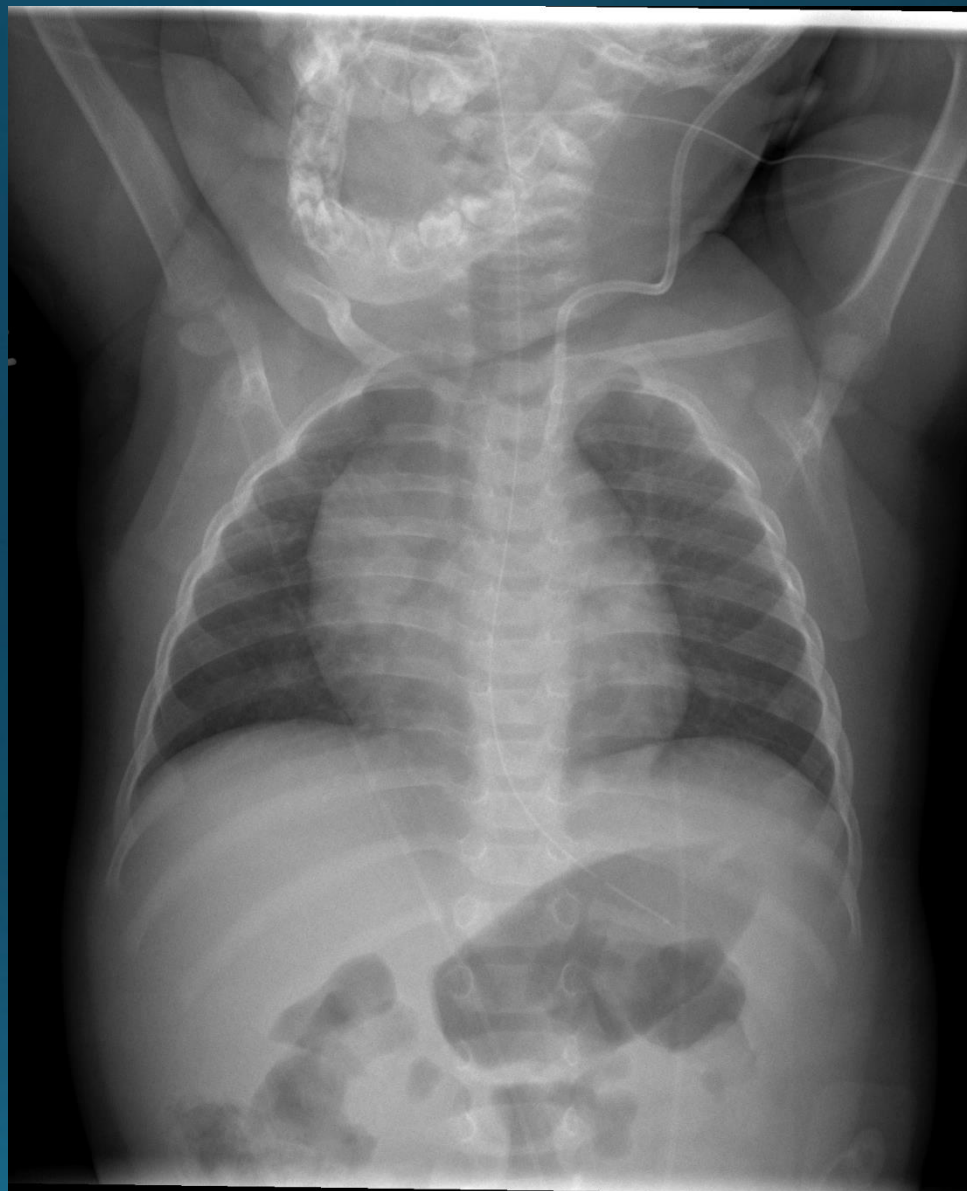
VA Shunts



Case 5

- 11-month-old with subgaleal shunt placed at birth for neonatal IVH (intraventricular hemorrhage) with subsequent progressive hydrocephalus. Given a history of necrotizing enterocolitis, a VA shunt was placed.
- Patient presented with increasing fussiness and vomiting.
- Order requests evaluation of VP shunt function.





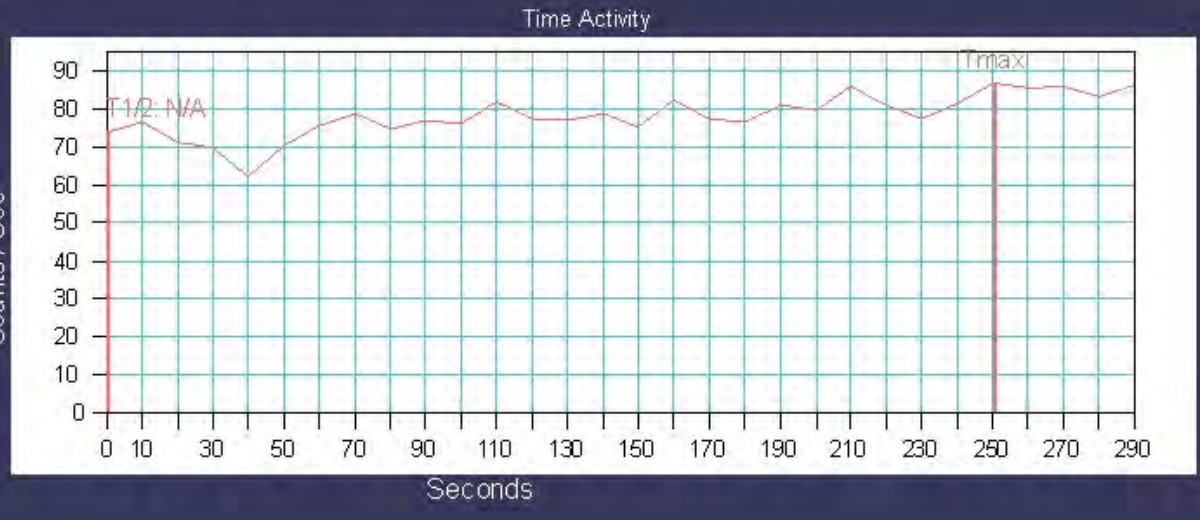
Confirm type of shunt and site of reservoir
– left frontoparietal VA shunt in this case

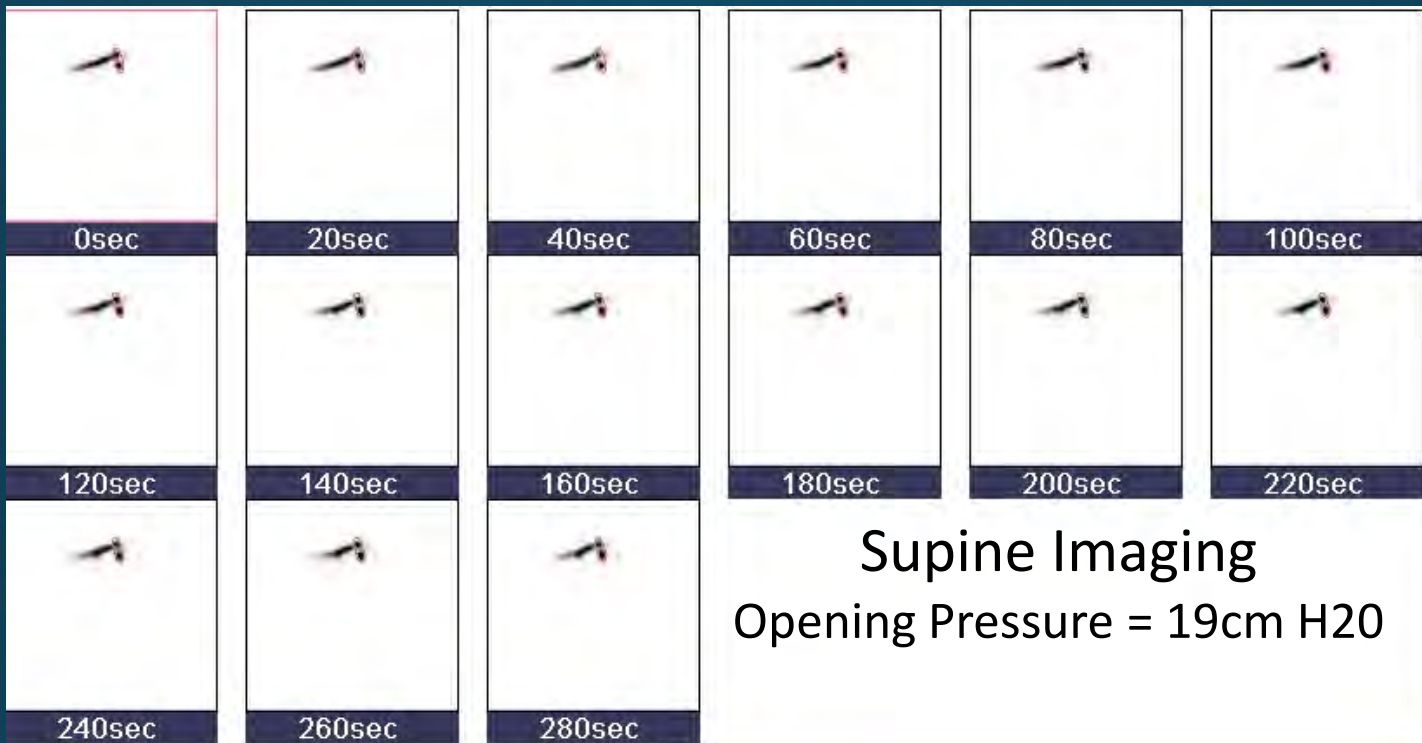


Supine Imaging

,T:33%)

Curve 1-D1E1

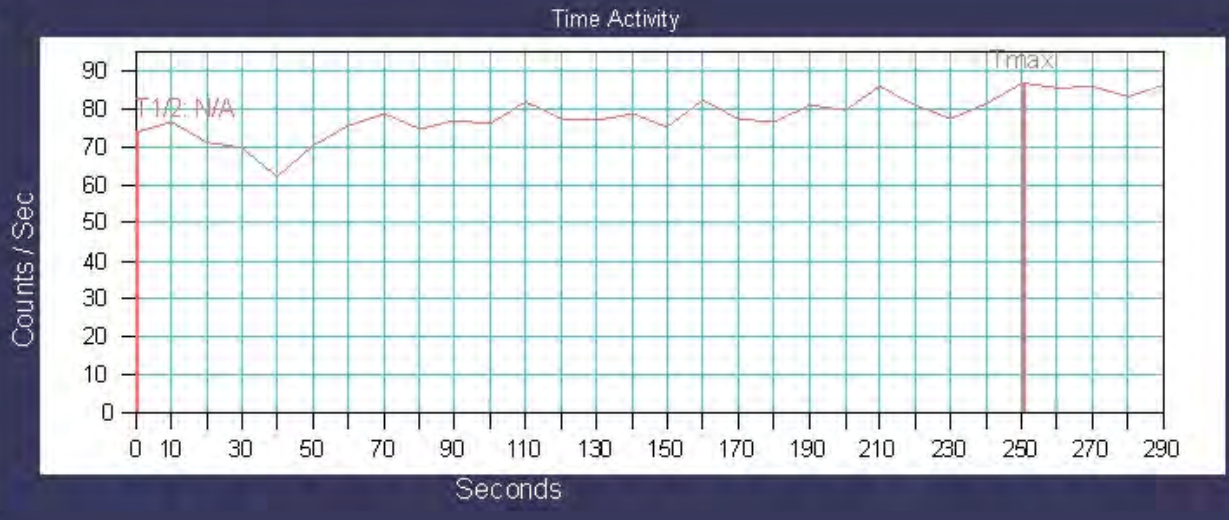




Supine Imaging
 Opening Pressure = 19cm H2O

,T:33%)

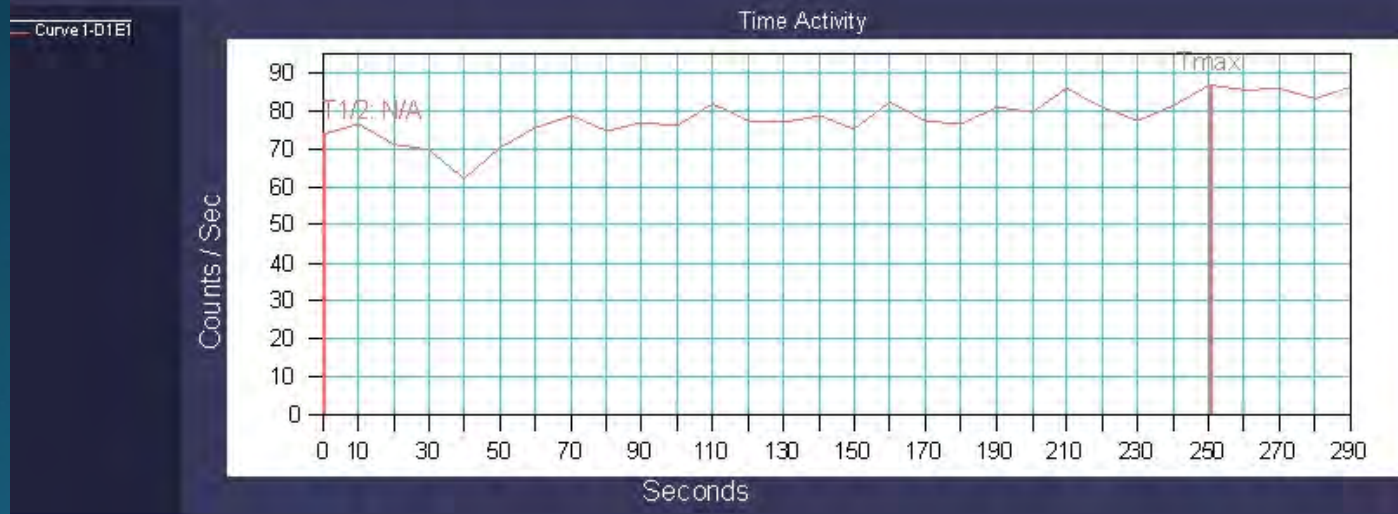
Curve 1-D1E1





Upright Imaging

(,T:33%)



10 minutes
Post-pumping

15 minutes
Post-pumping

Post-pumping, still supine



ANTERIOR 10 MIN HEAD POST PUMP

%

26

0



ANTERIOR 15 MIN

10 minutes
Post-pumping

15 minutes
Post-pumping

Post-pumping, still supine

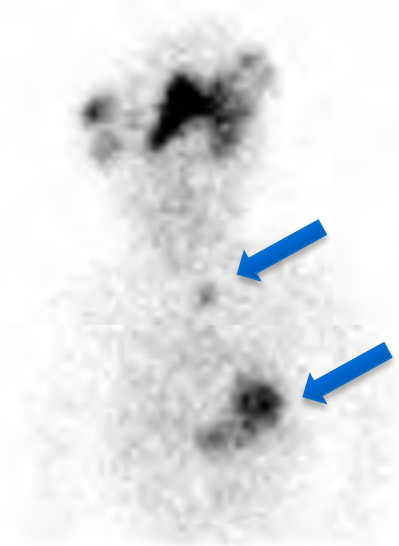


%

26

0

ANTERIOR 10 MIN HEAD POST PUMP



ANTERIOR 15 MIN

Findings

- Elevated opening pressure of 19 cm of water.
- Initial images immediately following injection with patient in supine position demonstrate focus of radiotracer activity within the reservoir with possible reflux into the ventricle, excluding the possibility of proximal obstruction. No egress of radiotracer is seen within the distal limb of the catheter. Time/activity curve confirms no clearance of radiotracer through the catheter.
- Following pumping maneuver of the reservoir and sitting the patient upright, more diffuse radiotracer is seen within the ventricles, again excluding the possibility of proximal limb obstruction. Radiotracer is also seen within the distal limb of the catheter, terminating within the superior mediastinum. These findings suggest that gravity may play a role in the shunt function, however radiotracer clearance is more sluggish than is usually seen.
- Delayed images, after sitting the patient upright for another five minutes, demonstrate clearance of radiotracer through the distal limb of the catheter, with dispersion of radiotracer into the blood pool, with expected radiotracer activity in stomach and thyroid gland.

Impression

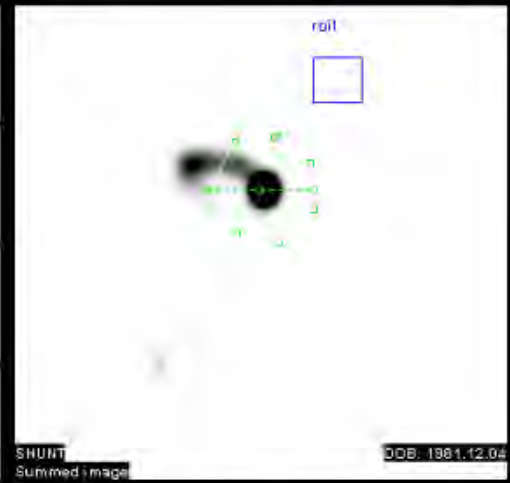
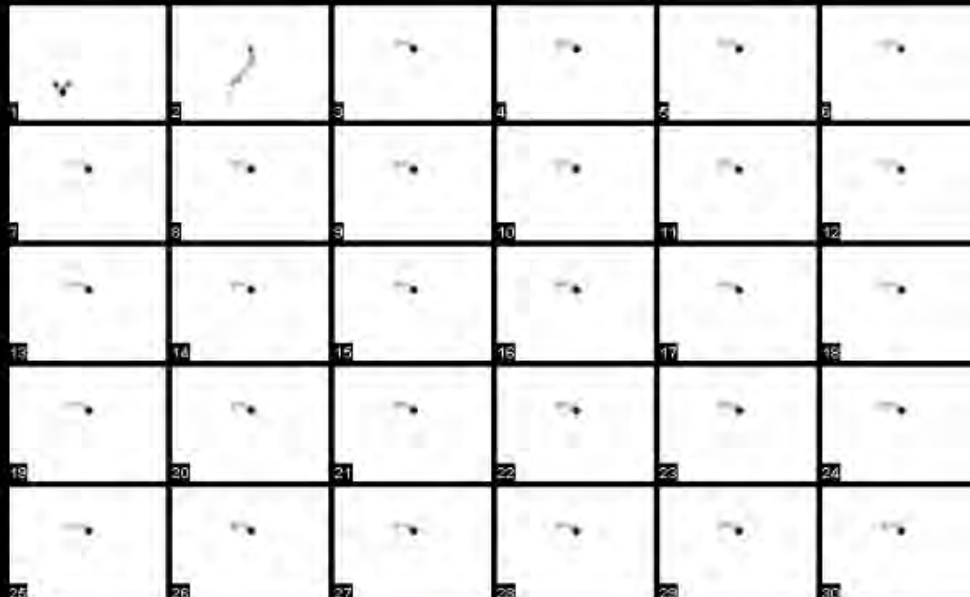
- Patent but dysfunctional shunt. No distal flow in the supine position and sluggish flow following provocative maneuvers are suggestive of a partial distal limb obstruction/dysfunction or severely gravity dependent shunt dysfunction. However, the elevated opening pressure of 19 cm H₂O and persistently sluggish flow despite provocative maneuvers, makes partial distal limb obstruction/dysfunction more likely.

Confirmation of Findings

- Patient was taken to OR and found to have dysfunctional valve and atrial catheter resulting in sluggish CSF flow and elevated ICP of 24 cm H₂O.
- Valve and catheter replaced with good result.

Case 6

- 28 yo female with headache



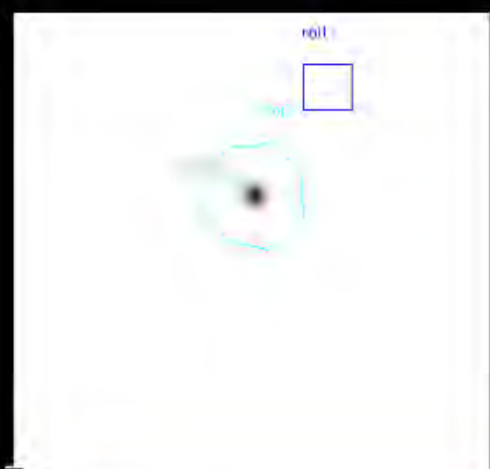
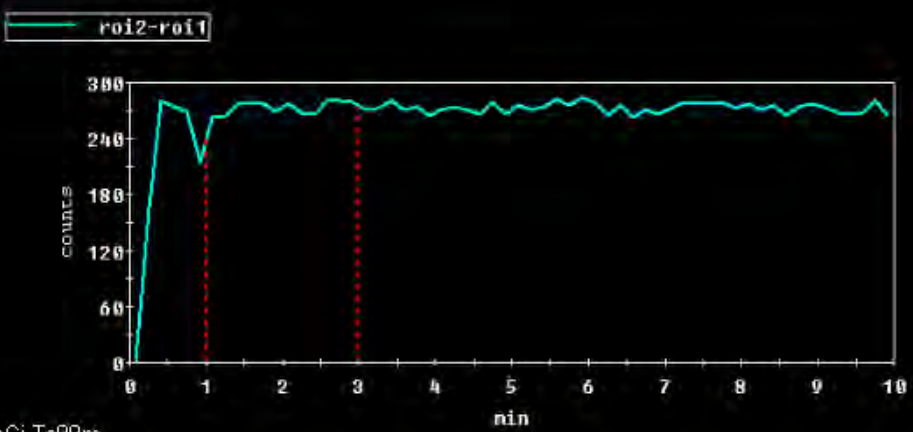
Statistics

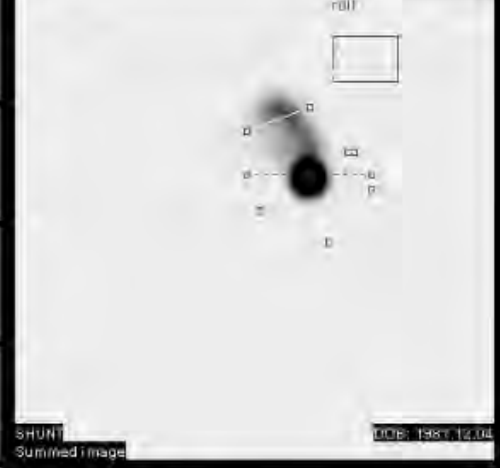
Integral 1.->3.m
 Integral percent
 Integral Ratio
 Time to 1/2 max
 Time to peak
 T 1/2

Curve A

32.8 Kc/sec
 100.00%
 .2 min
 5.9 min
 Not reached.

Supine Imaging





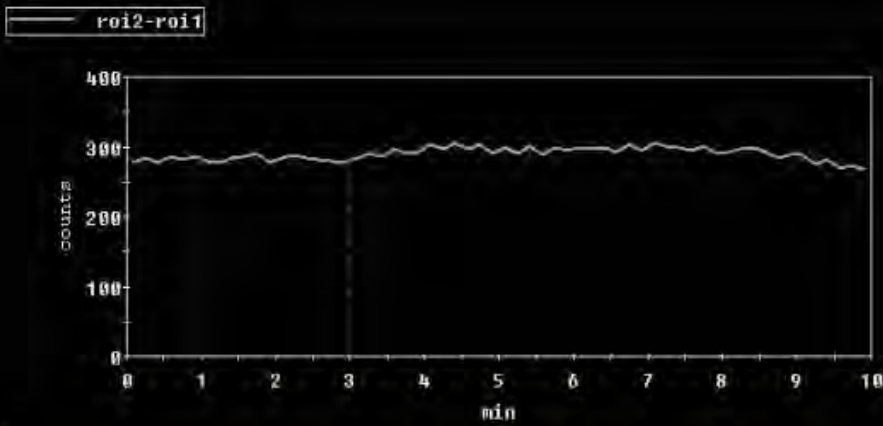
Statistics

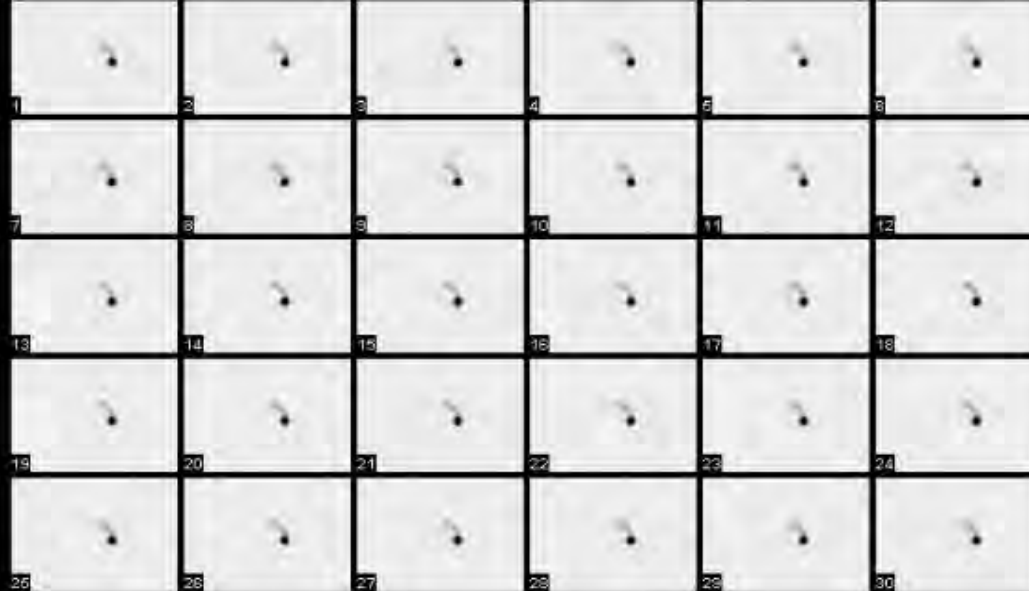
Integral 1.→3.m
Integral percent
Integral Ratio
Time to 1/2 max
Time to peak
T 1/2

Curve A

33.9 Kc*sec
100.00%
Not reached
4.4 min
Not reached

Upright Imaging





Statistics

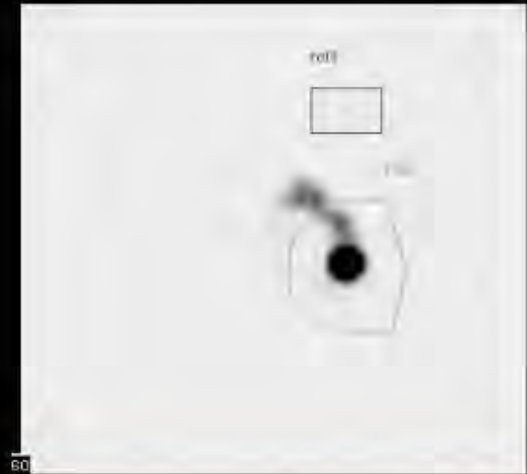
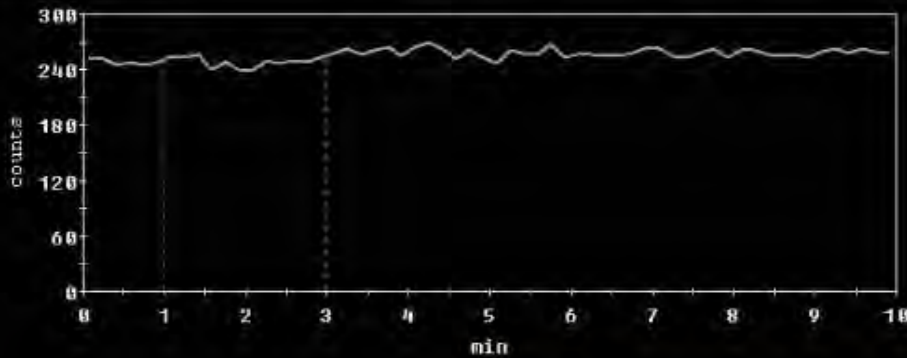
 Integral 1.->3.m
 Integral percent
 Integral Ratio
 Time to 1/2 max
 Time to peak
 T 1/2

Curve A

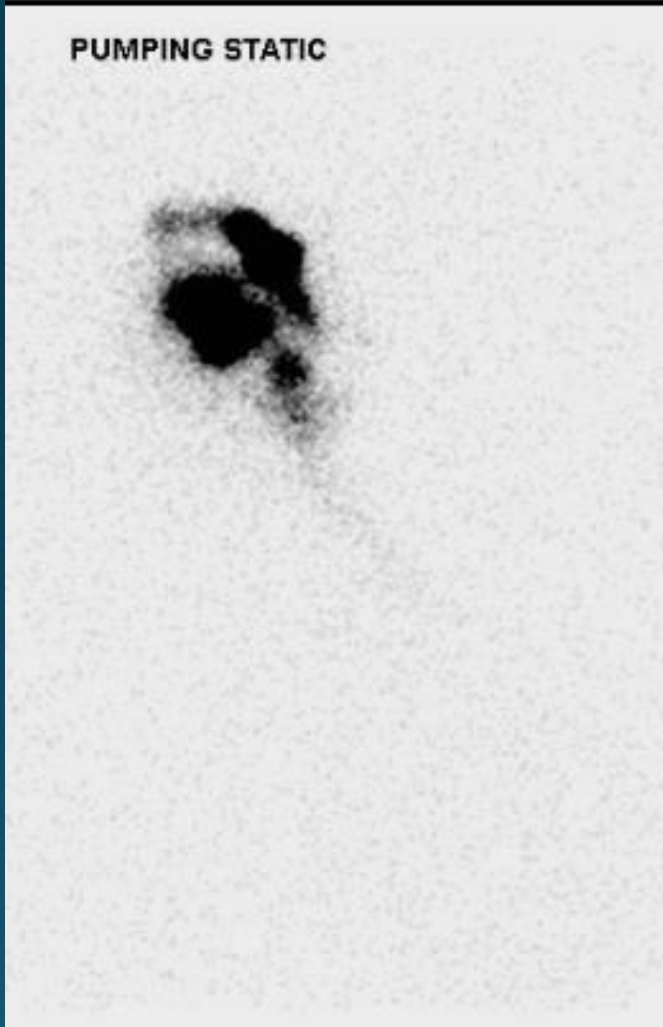
 29.8 Kc*sec
 100.00%
 Not reached.
 4.2 min
 Not reached.

Post-Ambulation Imaging

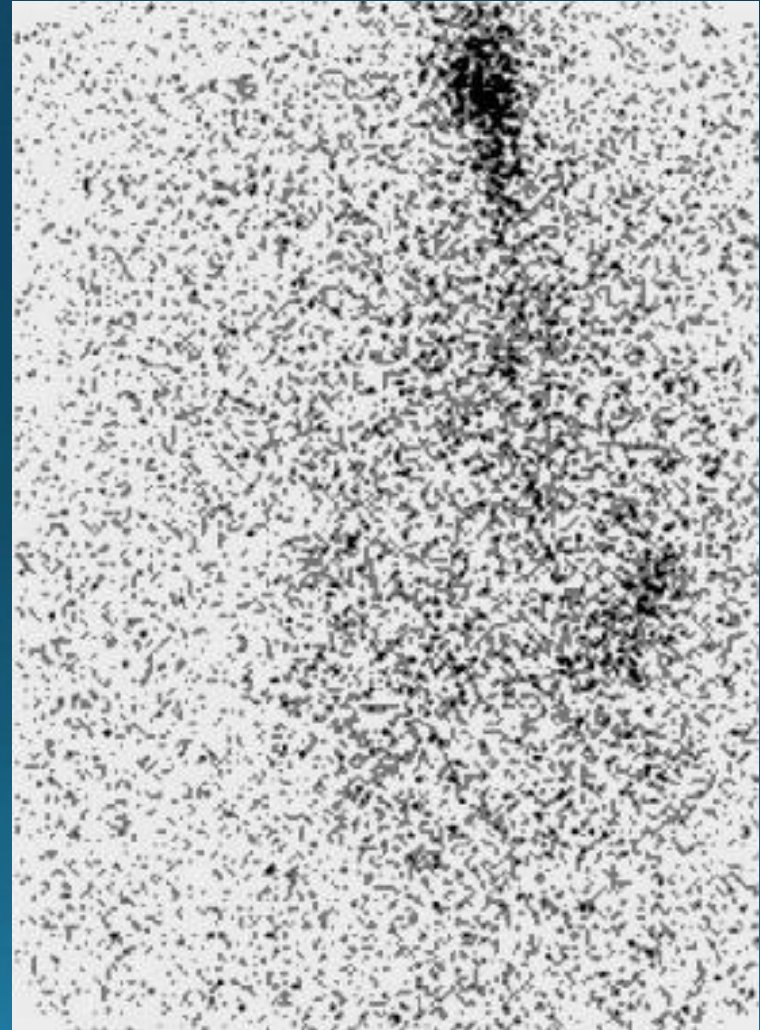
roi2-roi1



Post-Pumping Head Imaging



Post-Pumping Chest/Abdominal Imaging



Findings

- Normal opening pressure of 4 cm H₂O.
- The initial supine images show radiotracer in the shunt reservoir with reflux of the injected radiotracer into the proximal limb of the catheter. The tracer does not move from the reservoir into the distal limb of the shunt. Static images show no radiotracer in the thyroid or stomach.
- In the sitting position, radiotracer is visualized again, only in the shunt reservoir and proximal limb of the shunt. The static image reveals no activity in the thyroid or stomach.
- After walking, the radiotracer is again only visualized in the shunt reservoir and proximal limb. There is no flow of radiotracer into the distal limb or activity in the thyroid or stomach.
- After pumping the shunt, there is only minimal radiotracer activity demonstrated in the proximal aspect of the distal limb without significant drainage from the shunt reservoir. Focal radiotracer adjacent to the reservoir may be due to patient movement or possibly local leak for the needle puncture site of the reservoir. Static images do demonstrate mild activity in the thyroid and stomach that is physiologic, associated to the minimal free Tc following pumping.

Impression

VA shunt obstruction of the distal limb, likely high-grade (complete) given distal flow could not be provoked by change in position or pumping.

Case 7

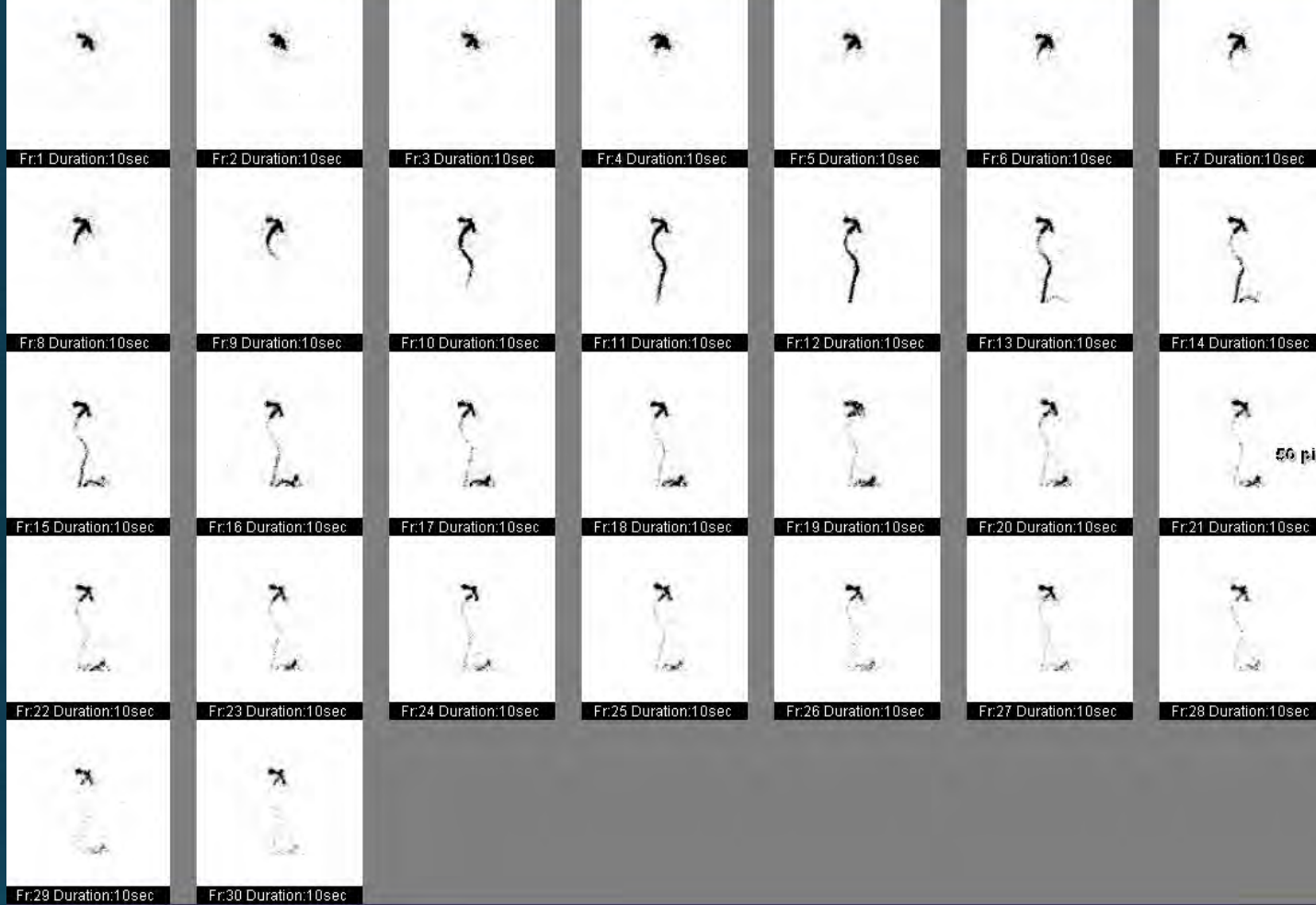
- 3-year-old female with right frontal programmable VP shunt.
- Evaluate shunt patency and function.

Opening Pressure

- Elevated at 24 cm H₂O

Opening Pressure

- Elevated at 24 cm H₂O
- What do you anticipate your supine time activity curve will look like?

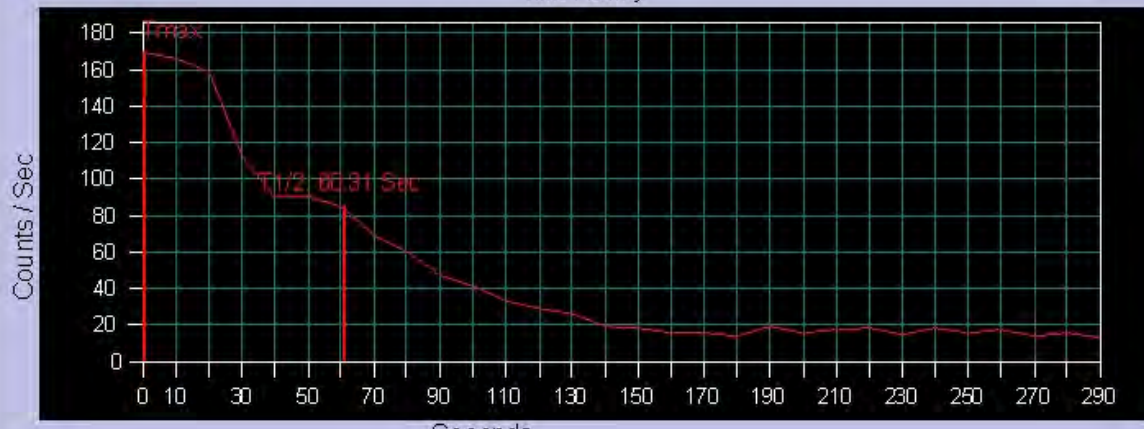


Series: CSF SHUNT FLOW

56 pix

Curve 1-D1E1

Time Activity



Series: CSF SHUNT FLOW



Findings

- Elevated opening pressure of 24 cm of H₂O, but quite variable (ranging from 10-24 cm of H₂O) and probably overestimated due to the patient's crying during the procedure.
- Initial image demonstrates proximal reflux into the ventricle, excluding the possibility of proximal limb obstruction. Tracer is seen progressively migrating along the distal limb of the catheter by 40 seconds. Tracer is likely seen within the abdomen by 120 seconds. T-1/2 is approximately 1 minute.
- Delayed images of the abdomen demonstrate dispersion of radiotracer throughout the peritoneal cavity.

Variability of opening pressures

- The meniscus will fluctuate between 2 and 5 mm with the patient's pulse and between 4 and 10 mm with respirations.
- Straining can increase the opening pressure
- Hyperventilating will lower the opening pressure.

Case 8

- 10-year-old female with congenital hydrocephalus status post ventriculoperitoneal shunt since birth, now with increasing headaches over last six months.
- Evaluate for shunt malfunction.

Initial Image: Anterior Head

- What is wrong with this picture?
- What is your next step?

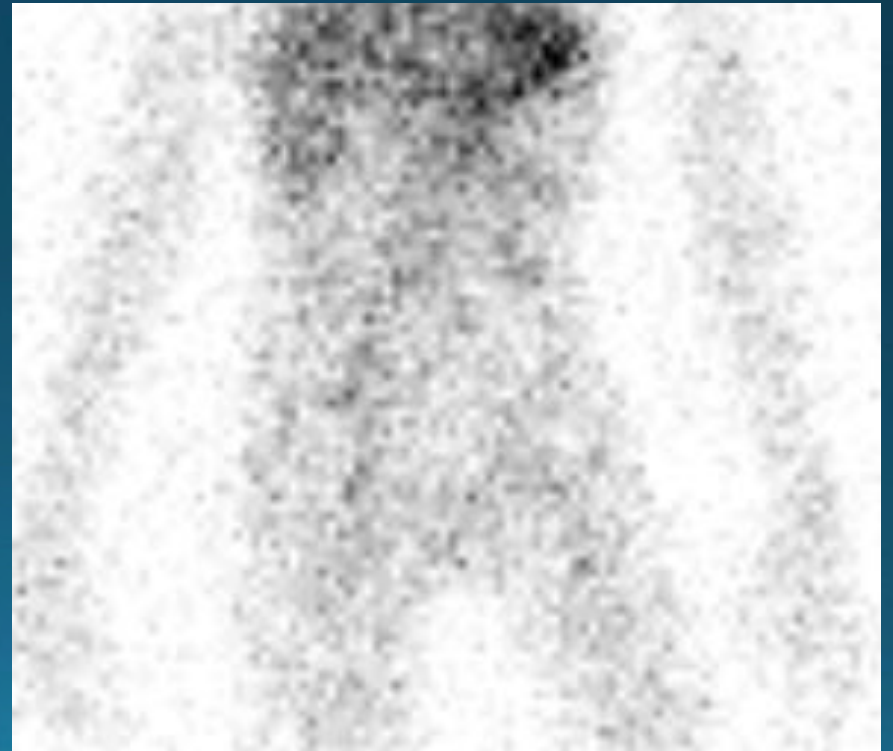
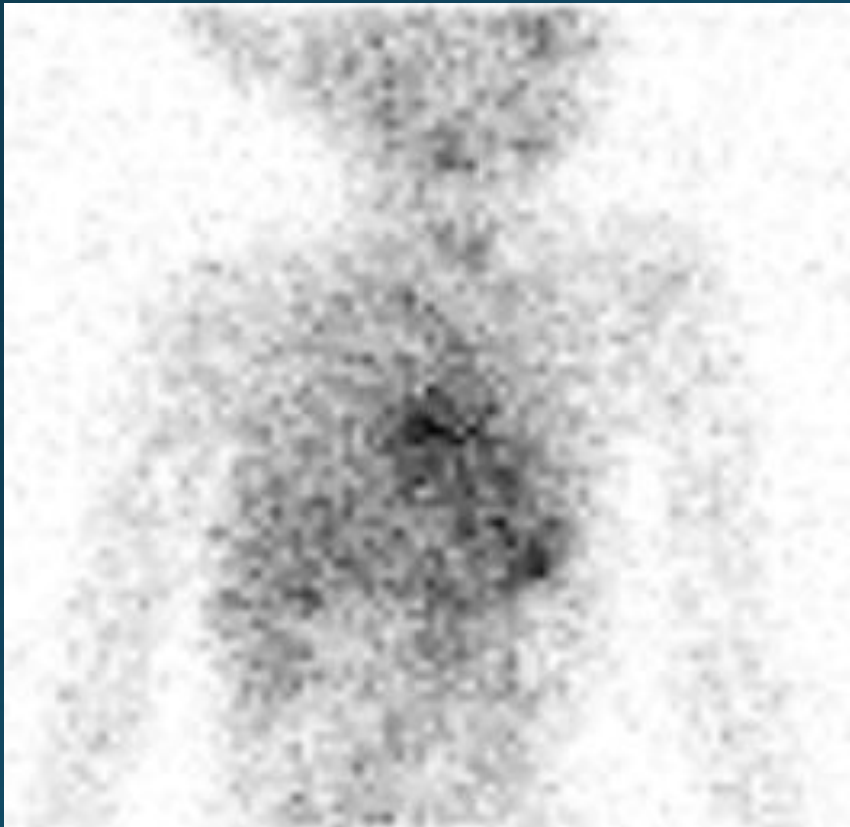


Initial Image: Anterior Head

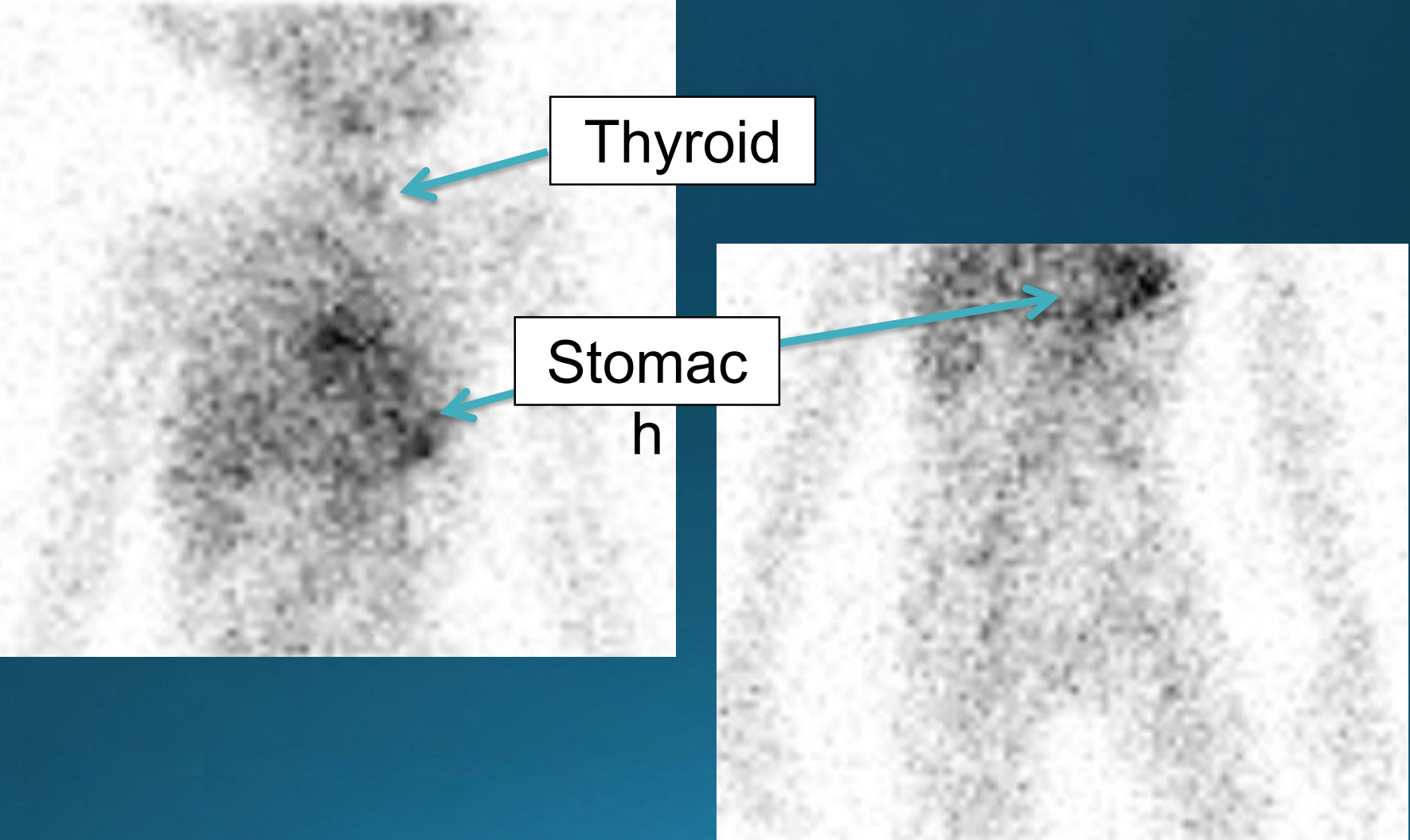
- Concerning for tracer extravasation
- Take images over neck and upper abdomen



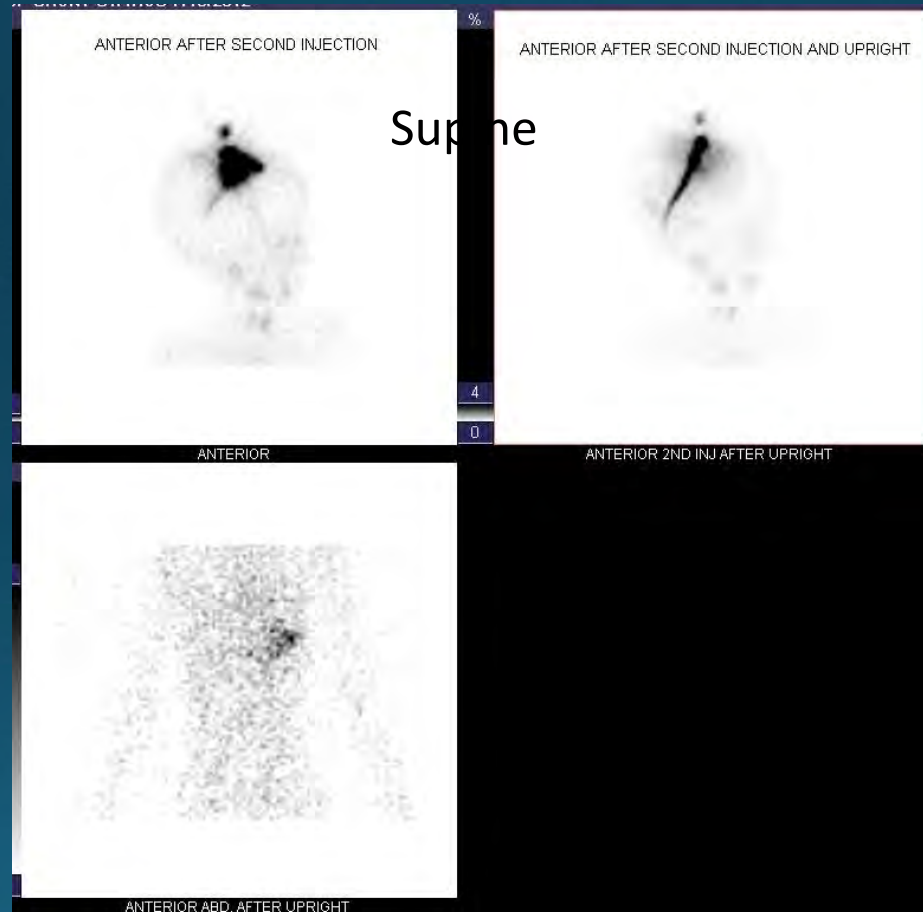
Images over neck and upper abdomen



Confirmation of extravasation of tracer



Elected to re-inject after consultation with referring provider



Upright Imaging

ANTERIOR AFTER SECOND INJECTION AND UPRIGHT



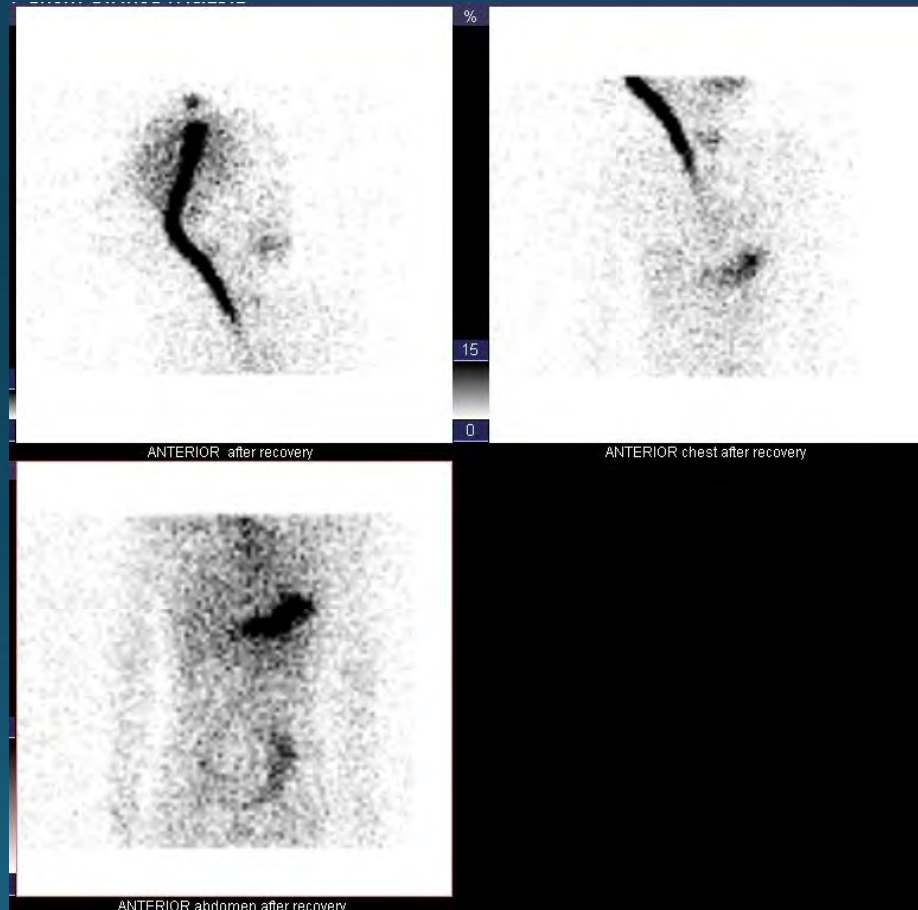
ANTERIOR 2ND INJ AFTER UPRIGHT

ANTERIOR



ANTERIOR ABD. AFTER UPRIGHT

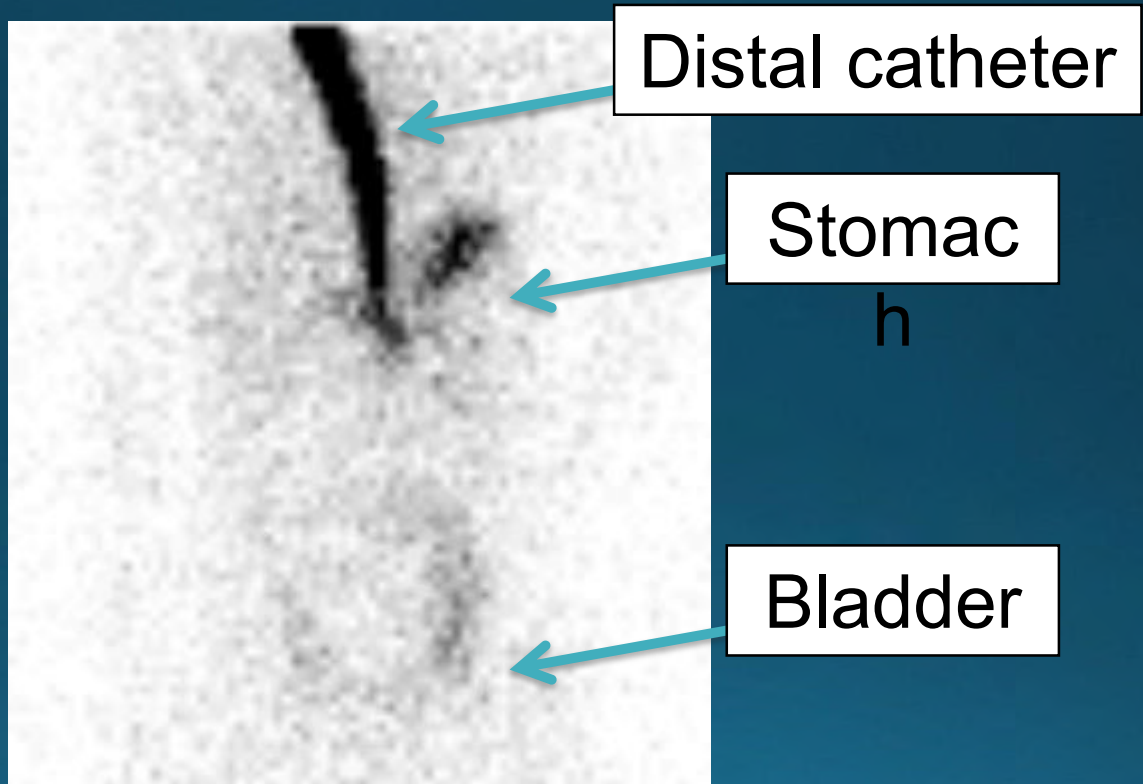
After 40 minutes in recovery with head of bed elevated



Abdominal image
after patient sat upright for
10 minutes



Abdominal image
after patient sat upright for
10 minutes



Findings

- Opening pressure was ~2 cm of water.
- Initial images demonstrate a focus of radiotracer activity within the reservoir with possible reflux into the ventricle, excluding the possibility of proximal obstruction. Subtle radiotracer accumulation was seen within the soft tissues of the head and neck, therefore anterior images of the neck and chest were obtained, which show presence of radiotracer within the thyroid, heart, stomach and blood pool, confirming extravasation of radiotracer into the soft tissue.
- Following the second injection of radiotracer, a focus of intense radiotracer is seen at the site of injection into the reservoir, with small amount of reflux into the ventricle, again excluding the possibility of proximal obstruction. No distal flow is visualized on initial imaging.
- Following pumping maneuver of the reservoir, no tracer is seen flowing distally.

Findings

- After positioning the patient with her head elevated, a small amount of radiotracer is seen flowing distally within the catheter, to the approximate level of the ear. Intra-abdominal images show no distribution of radiotracer within the peritoneum.
- After at least 40 minutes with the patient in a head elevated position, radiotracer is seen within the distal tubing to the level of the superior chest, just below the thyroid. Intra-abdominal images show no obvious dispersion of radiotracer within the peritoneum. Physiologic uptake of radiotracer following prior extravasation is seen within the stomach and bladder. The elongated focus of radiotracer accumulation within the pelvis, to the left of midline, may represent displaced bladder, raising the question of displacement by a large fluid collection, such as a CSF pseudocyst.
- After approximately 10 minutes in an upright position, the radiotracer is seen to travel slightly more distal within the shunt catheter tubing, now near the level of the pylorus. There is still no obvious dispersion of radiotracer within the peritoneal cavity. Again, the bladder appears to be displaced to the left of midline.

Impression

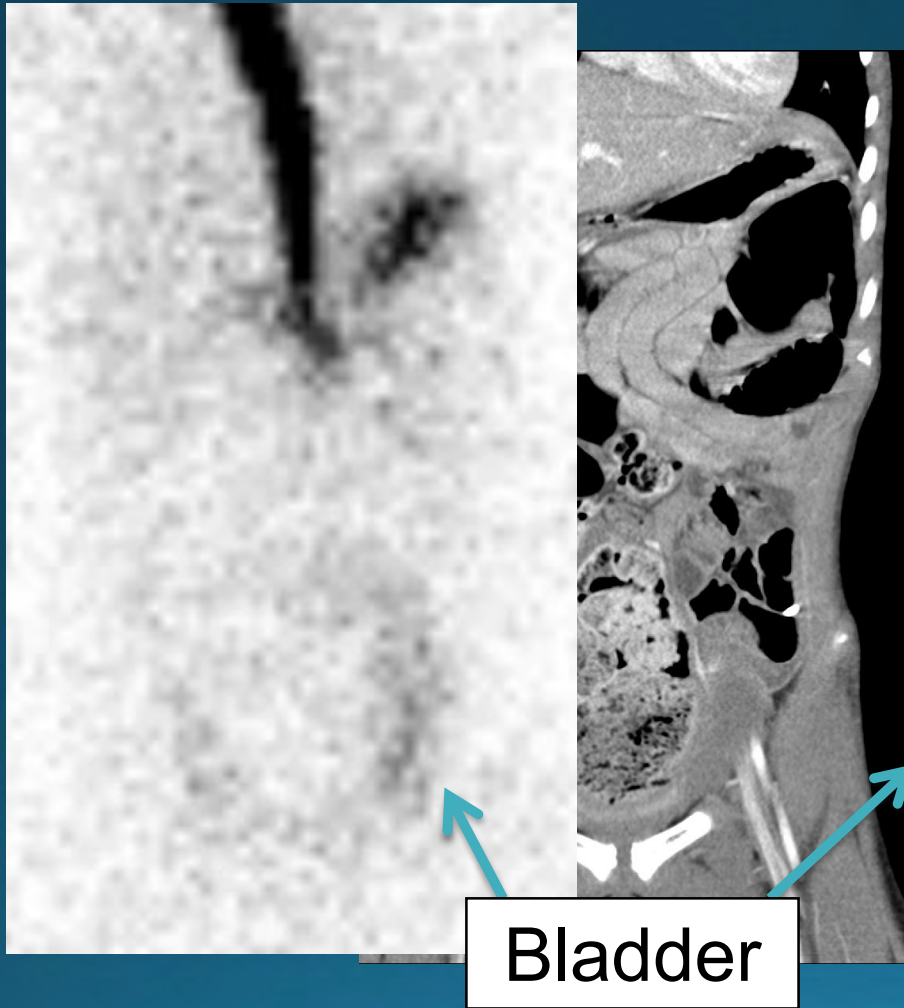
- Extremely sluggish flow through the catheter, with no dispersion of radiotracer within the peritoneal cavity after over two hours of imaging and multiple provocative maneuvers, suggestive of a severe partial distal limb obstruction.
- Possible lateral displacement of the bladder, raising the question of a large fluid collection, such as a CSF pseudocyst. Abdominal ultrasound is recommended for further evaluation.

DDx Shunt Obstruction

- Fibrous adhesions at the distal tip
- Distal tubing kinking
- Perforation of a viscera
- Shunt tip migration
- Peritonitis preventing reabsorption of CSF
- Increased intraabdominal pressure
- Interrupted catheter
- Failed shunt

Slide initially created by Jon Umlauf, MD

Habibian MR, et al. Nuclear Medicine Imaging: A Teaching File, 2009



CT findings

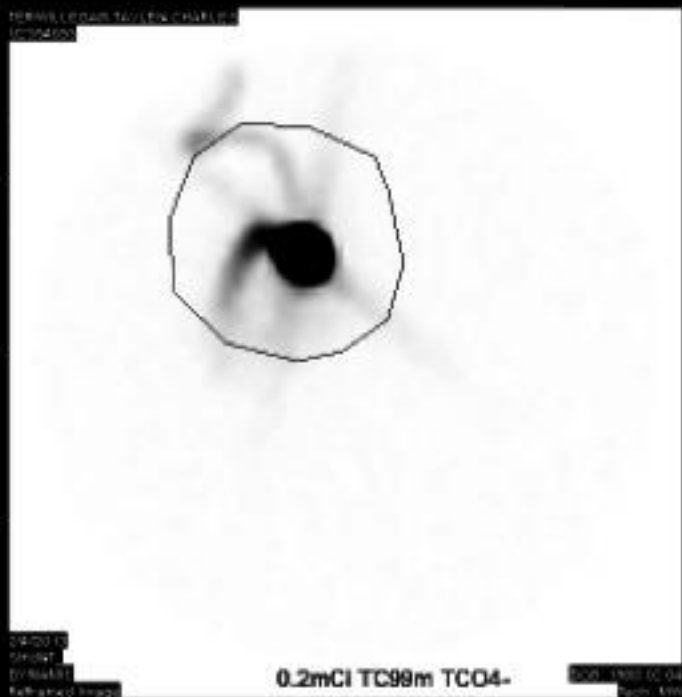
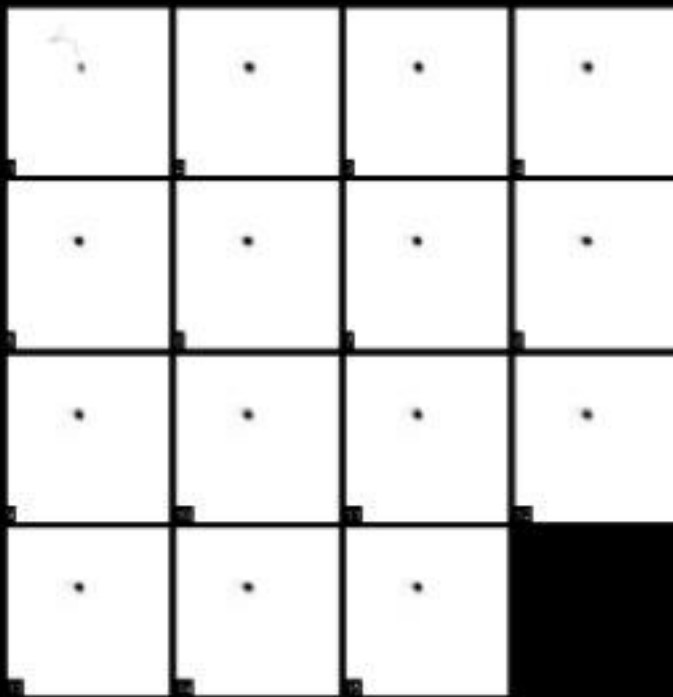
- No evidence of pseudocyst.
- Visualized portions of VP shunt show no kink or discontinuity.
- Photopenic area seen on today's nuclear medicine shunt study is likely from the markedly distended rectum filled with stool, possibly increasing intra-abdominal pressure to result in sluggish flow.

Confirmation of findings

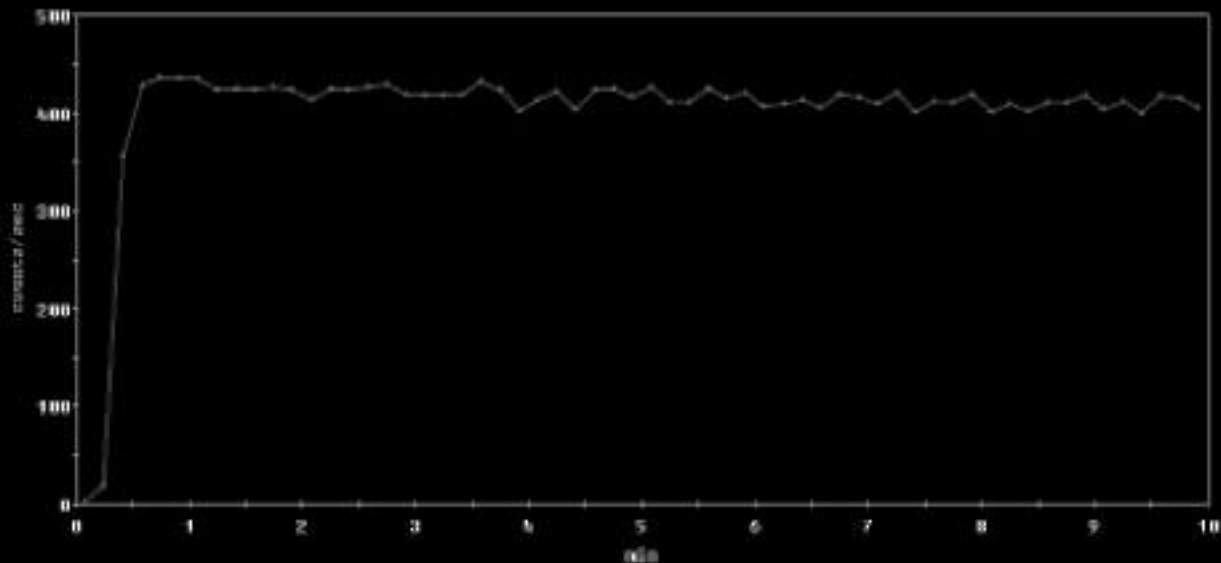
- Lumbar puncture was undertaken in the operating room to confirm normal opening pressure
 - found to be normal at 8.5 cm H₂O
- Aggressive bowel regimen resulted in improvement of headaches.

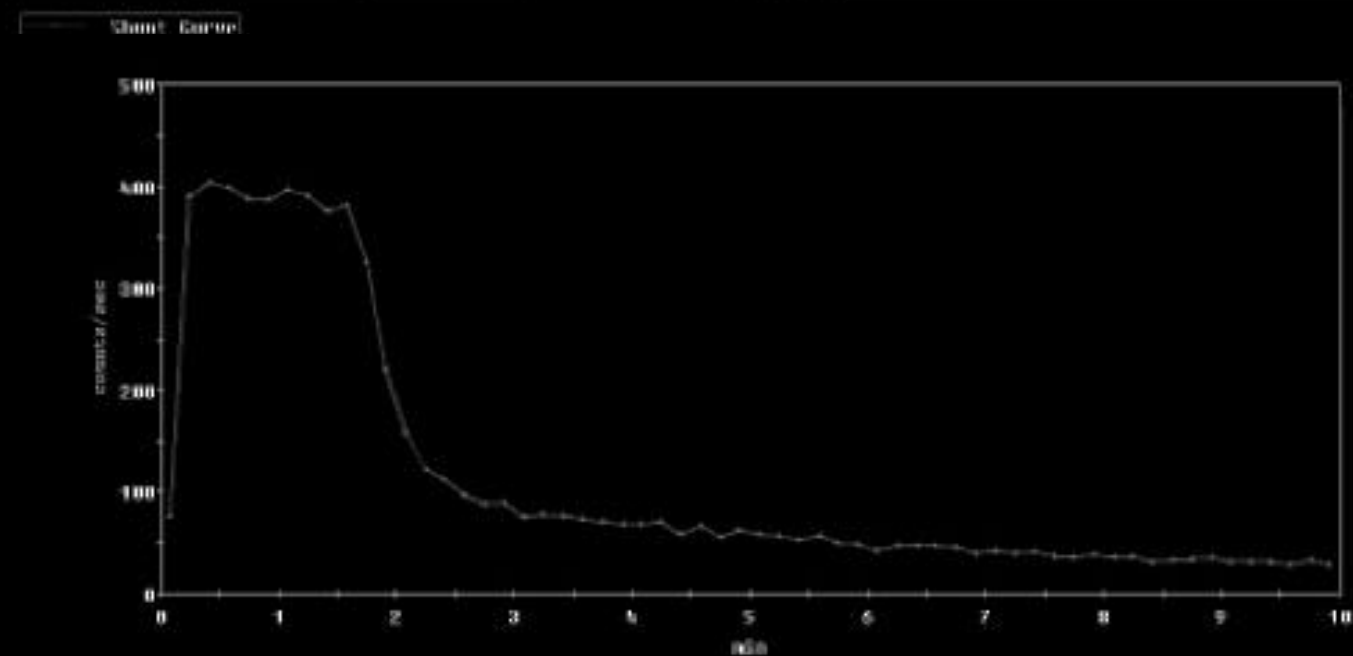
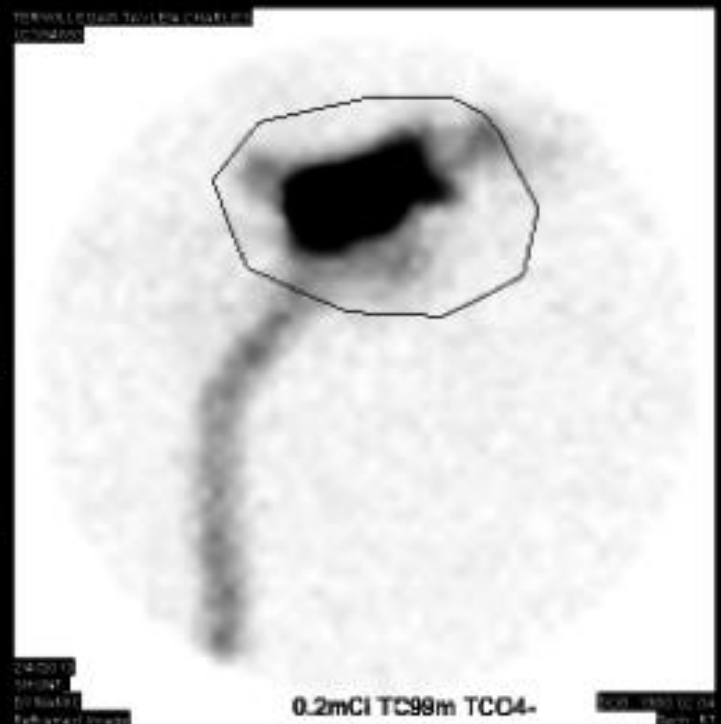
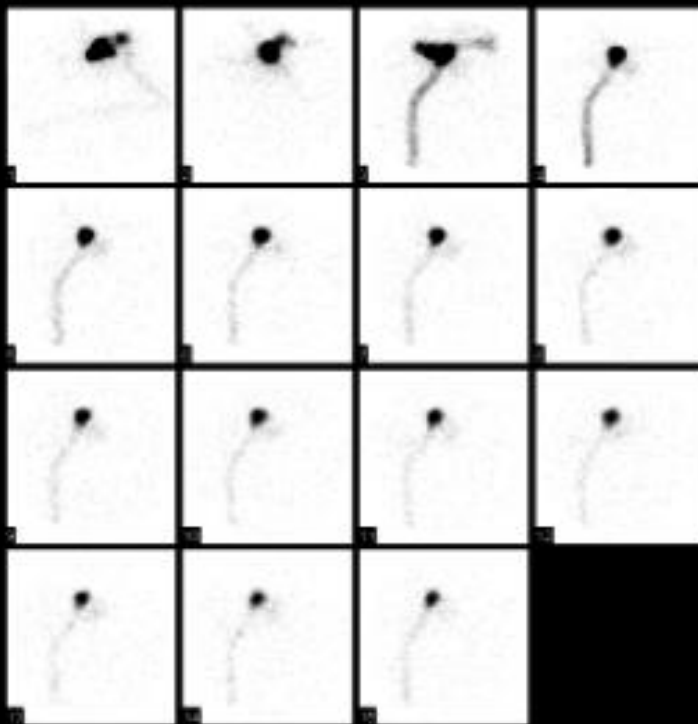
Case 9

- 33-year-old male with left frontal VP shunt, presenting with headaches.
- Evaluate for shunt malfunction.

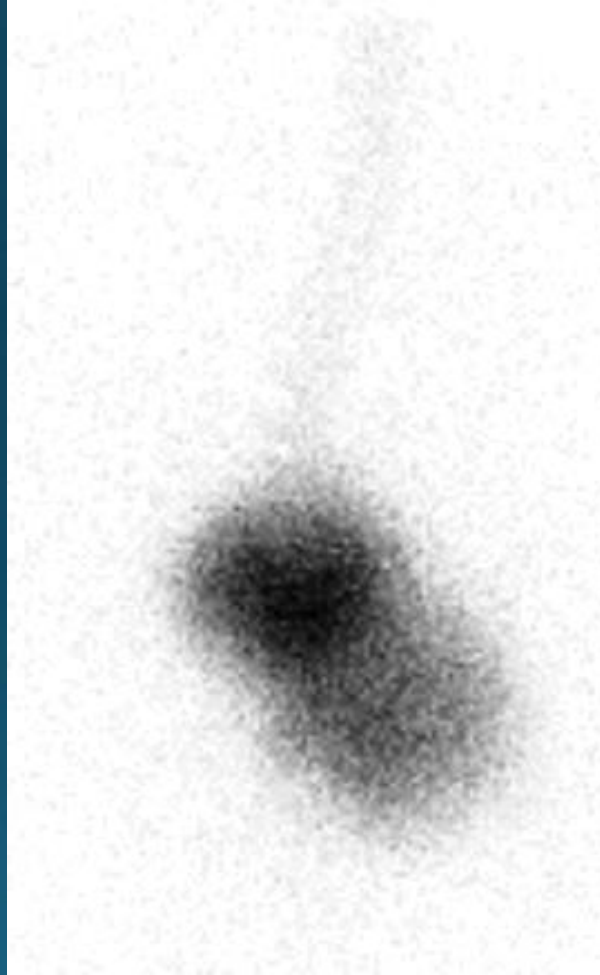


Summed Curve

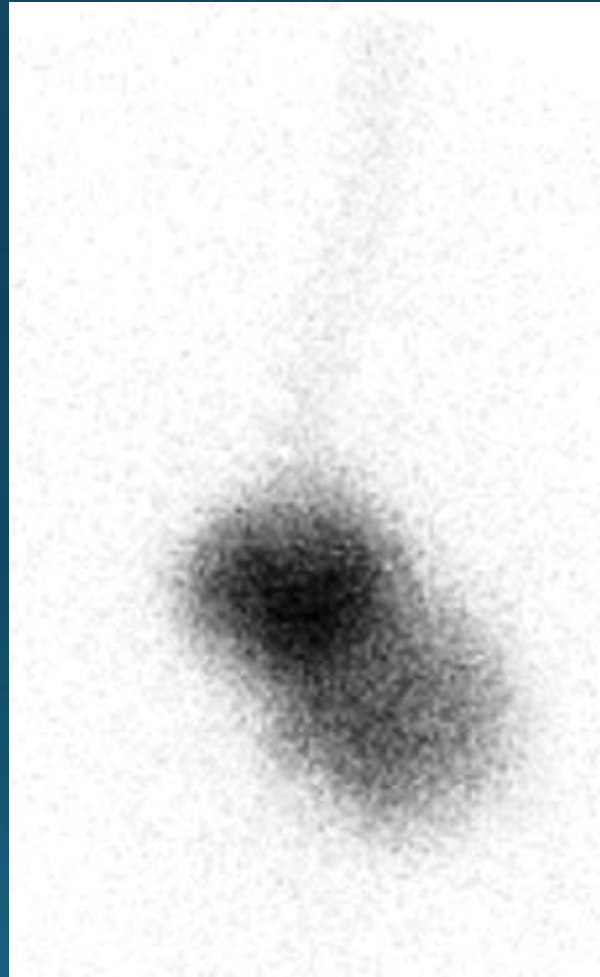




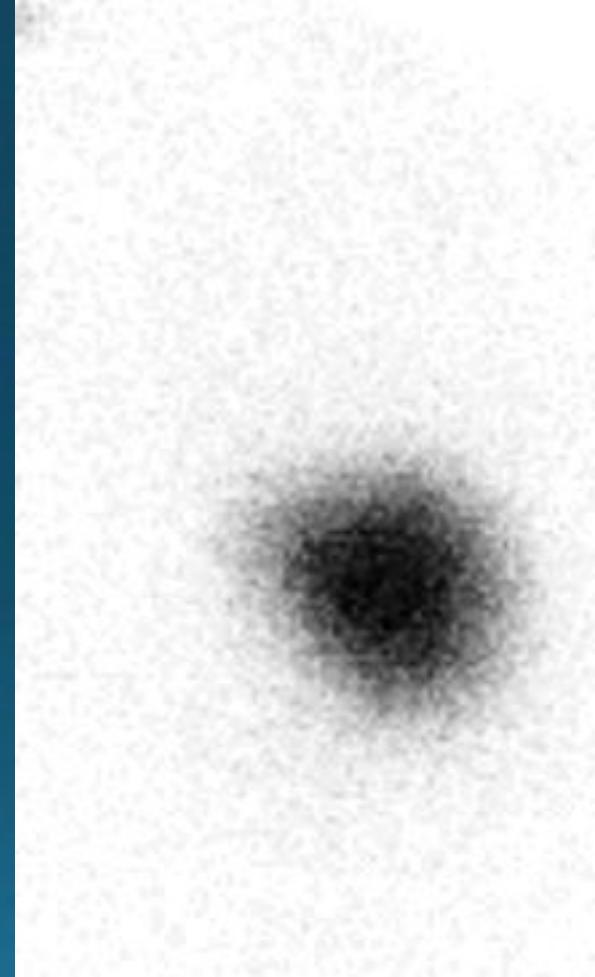
Static Abdominal Image



Static Abdominal Image

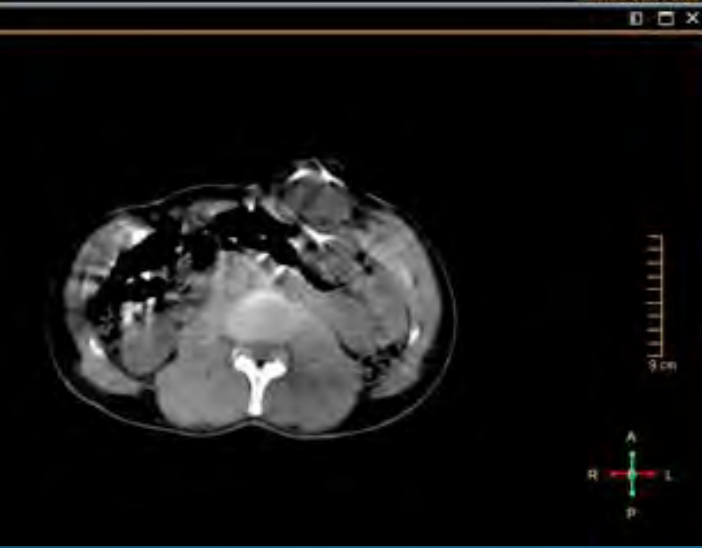


Current study



1 month prior





Findings

- The opening pressure was markedly elevated (greater than 27 cm H₂O).
- In the supine position, radiotracer is seen within the reservoir without flow into the distal or proximal limbs.
- By 2 minutes into imaging in the upright position, radiotracer is seen moving freely in an antegrade direction in the distal limb of the shunt and upper abdomen (left upper quadrant).
- Imaging of the abdomen in the upright position demonstrates a collection of tracer in the left upper quadrant, similar to that seen on the VP shuntogram dated January 18, 2013. However on today's image, this focus appears increased in size and appears bilobed, with a more medial intense focus, similar in size and shape to that seen on January 18th, and a 2nd more inferolateral collection which has less intense uptake, which is new compared to prior exam. In addition, planar imaging demonstrates that all or a portion of the left upper quadrant activity is in a subcutaneous collection/skin hernia. In order to elucidate the etiology of this collection, SPECT/CT was performed.

Findings

- SPECT/CT images demonstrate VP shunt tubing coursing through the subcutaneous tissues of the abdomen and entering the peritoneal cavity within the left upper quadrant. A fluid collection showing radiotracer uptake is seen measuring up to 5.5cm in maximal diameter anterior to the rectus sheath within the subcutaneous tissues, which surrounds the catheter as it enters the peritoneum. This corresponds to the new collection of radiotracer seen on planar images (described above).
- Within the peritoneal cavity, the catheter is coiled within a larger fluid collection, better measured on correlative ultrasound performed the same day to be approximately 7.6 x 5.3 x 7.2 cm, which demonstrates intense radiotracer uptake.

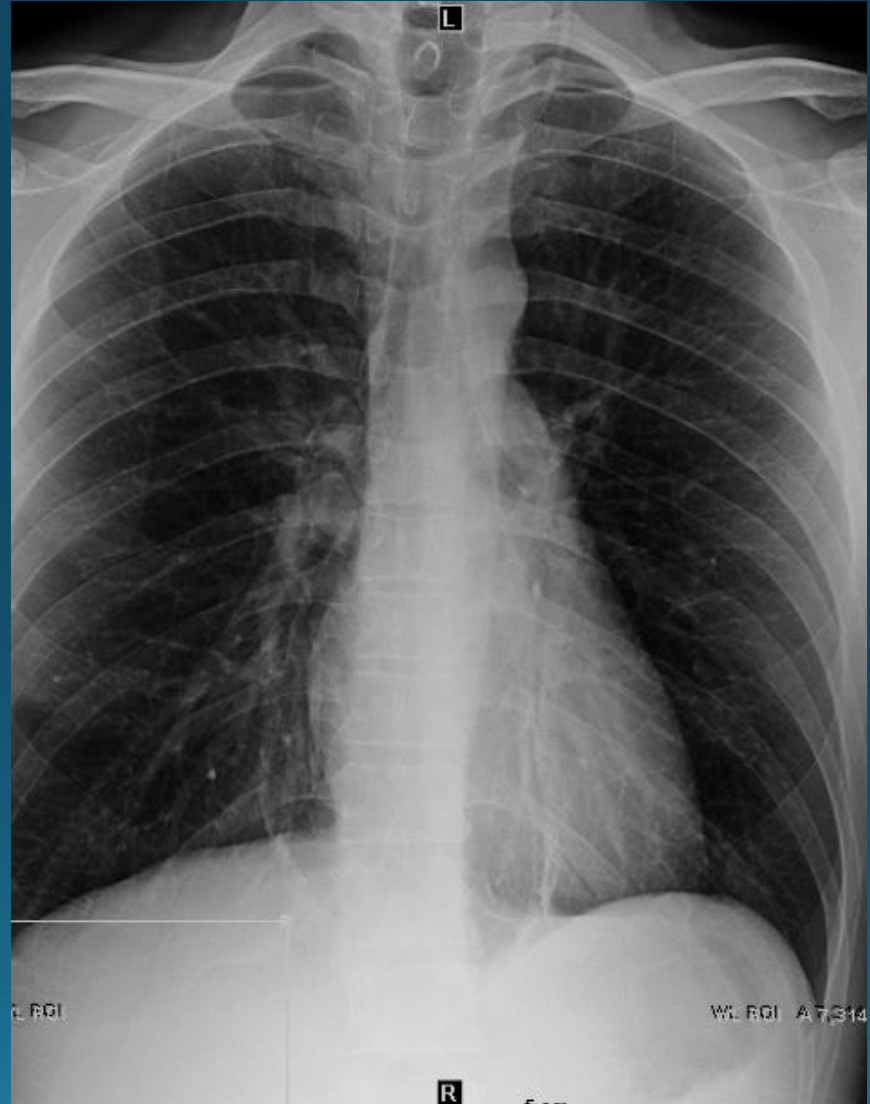
Impression

- 1. Increasing size of CSF pseudocyst which extends from the peritoneal cavity into the anterior abdominal wall subcutaneous tissue surrounding the VP shunt catheter as it enters the peritoneum.
- 2. Position-dependent VP shunt dysfunction, with obstruction of flow through the distal limb in the supine position, but improved flow in the upright position. However, loculation of CSF at the tip of the distal limb within the CSF pseudocyst prevents dispersion of radiotracer into the abdomen.

Confirmation of findings

- CSF pseudocyst identified in OR.
- Conversion of left frontal-to-left upper quadrant VP shunt to left frontal-to-atrial shunt.

Confirmation of findings



Radionuclide Shuntogram:

Historical Perspective:

1. Di Chiro and associates (Evaluation of surgical and spontaneous cerebrospinal fluid shunts by isotope scanning. *Journal of neurosurgery* 24: 743-748, 1966).
2. Wil B. Nelp and associates (Radionuclide Assessment of CSF Shunt Function in Children, *JNM* 1973 Sept;14(9): 683-686

Suggested Articles

1. Krasnow A. The Lost Art of Cerebral Spinal Fluid Nuclear Medicine Annual 2004.
2. Sivaganesan. Neuroimaging of ventriculoperitoneal shunt complications in children; September 2012, Volume 42, issue 9, pp 1029–1046.
3. Behnia F., Gross JA. Ragucci M et. al Nuclear medicine and the emergency department patient: an illustrative case-based approach. La radiologia medica. January 2015, volume 120, issue 1, pp 158–170.
4. Uvebrant et al. Evaluation of CSF shunt function in hydrocephalic children using 99m Tc-DTPA., Childs Nervous System, 1992 March;8(2) 76-80.
5. Vassilyadi et al. Radioisotope shuntograms at Children's Hospital of Eastern Ontario, et al, Childs Nervous System, 2006 Jan; 22(1): 43-9.
6. Reilly PL et. al. Isotope Transport studies and shunt pressure measurements as a guide to shunt function; British Journal of Neurosurgery, 1989; 3(6);681-90.
7. May CH et al. Evaluation of shunt function in hydrocephalic patients with radionuclide 99mTc pertechnetate; Childs Nervous System 1999 May; 15(5):239-44, discussion 245.
8. Oliver Vernet Radionuclide Shuntogram: Adjunct to Manage Hydrocephalic Patients;JNM, March 1996, vol 37, No. 3, 406-410.

Suggested Articles

- 9. Ouellette D., et al. Additive value of Nuclear Medicine Shuntograms to Computed Tomography for Suspected Cerebrospinal Fluid Shunt Obstruction in the Pediatric Emergency Department, *Ped Emer Care.* (2009) 25:12.
- 10. O'Brien DF., et al., A critical analysis of normal radionuclide shuntograms in patients subsequently requiring surgery. *Childs Nerv Syst* (2003) 19:337-341.
- 11. Courtney Pendleton BS, et al. Harvey Cushing's use of a transplanted human vein to treat hydrocephalus. *J Neurosurg Pediatrics* 5:423-427, 2010
- 12. Goeser et al. Diagnostic Imaging of VP shunt complications and malfunctions. *Radiographics* 1998 18:635-51.
- 13. Lewis, DH. Benefit of Tomography in the Scintigraphic Localization of Cerebrospinal Fluid Leak. *J Nucl Med* 1991 32:2149-2151
- 14. MacDonald A, Burrell S. Infrequently performed studies in nuclear medicine: part 2. *JNMT* 2009 37:1-13