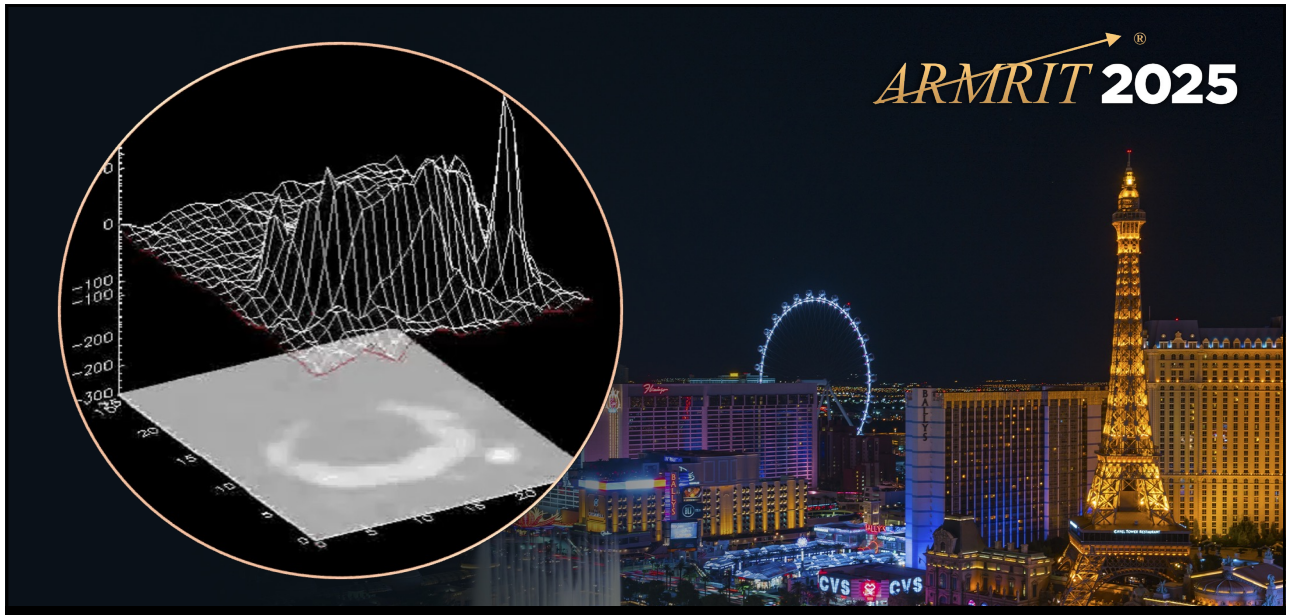


1

CREDIT CLAIMING

- You must be in attendance for **the duration of this session** to claim credit
- Stay tuned at the end of this session for the following information:
  - The credit claiming website
  - The access code assigned to this session
  - Instructions on how to claim credit and download your certificate of completion

2

ACCREDITATION

MRI Technologists
This course has been approved for one (1) ARRT Category A CE credit(s) by AHRA

Radiology Administrators
This course meets all CRA renewal credit criteria and has been approved for one (1) continuing education credit in the following CRA domain(s): Operations Management (OM).

This CE activity may be available in multiple formats or from different CE sponsors. ARRT does not allow self-learning CE activities (e.g., Internet courses, home study programs, directed readings) to be repeated for CE credit in the same CE biennium.

Some organizations may not allow CE credit to be awarded for completing the CE activity a second time even if the CE activity is presented in a different format such as: a lecture, home study, or webinar. You should check with the organization requiring the CE credit for information specific to your professional credential requirements.

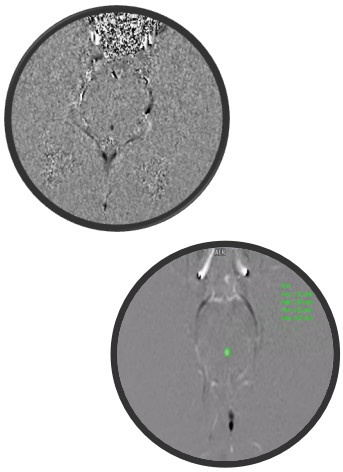
3

DISCLAIMER & DISCLOSURES

- All information in this presentation is for illustration only and is not intended to be relied upon by the reader for instruction as to the practice of medicine.
- This material does not substitute for that duty and is not intended to be used for any purpose in that regard.
- This presentation content was prepared by the speaker and not by Siemens Healthineers North America.

WHY CSF FLOW IMAGING ?

- Evaluates CSF Circulation Disorders
  - *Hydrocephalus, Chiari, Syringomyelia, ETV, Arachnoid Cyst*
- Assessment of flow patterns and blockage
- Pre & Post Surgical CSF Quantification
- Distinguishes between conditions
  - *Hydrocephalus vs. Brain Atrophy*
  - *Syringomyelia vs. Hydromyelia*



ARMRIT

5

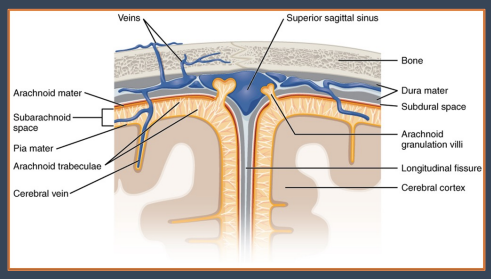
CSF Anatomy

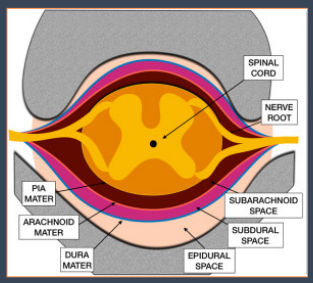
Cerebrospinal Fluid (CSF) - Is the clear fluid that surrounds Brain and Spinal Cord.

- Primary is to protects, waste removal, and nourishes the brain and spinal cord.

Meninges - Is a layered unit of membranous connective tissue that covers the Brain and Spinal Cord.

- Primary is to protect and support the CNS





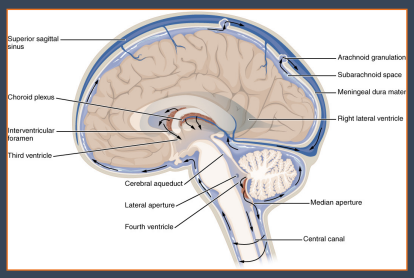
6

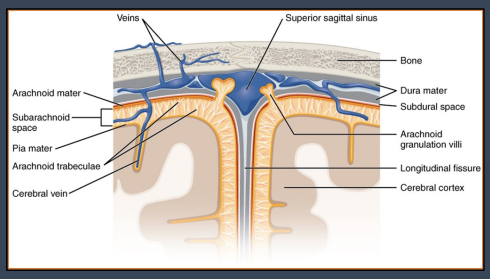
Ventricular System Anatomy

The primary function is to produce, circulate and absorb CSF

- *Lateral Ventricles*
  - *Foramen of Monro*
- *Third Ventricle*
  - *Aqueduct of Sylvius*
- *Fourth Ventricle*
  - *Magendie & Luschka Foramen*
  - *Central Canal*

Choroid Plexus





THE MENINGES

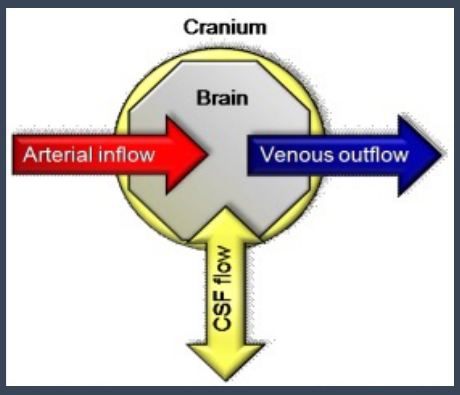
The Ventricular System | Neuroanatomy | OSF | Geeky Medics

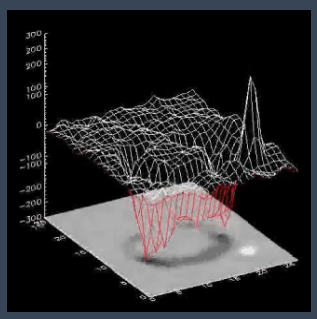
Meninges - Physiopedia

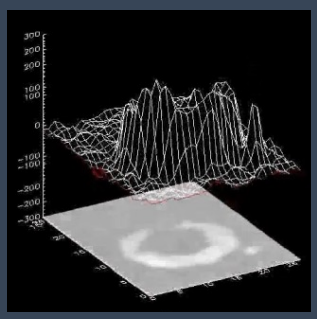
7

Cerebrospinal Fluid Circulation

Craniospinal CSF flow is driven by the difference between arterial inflow and venous outflow and is modulated by the intracranial compliance.





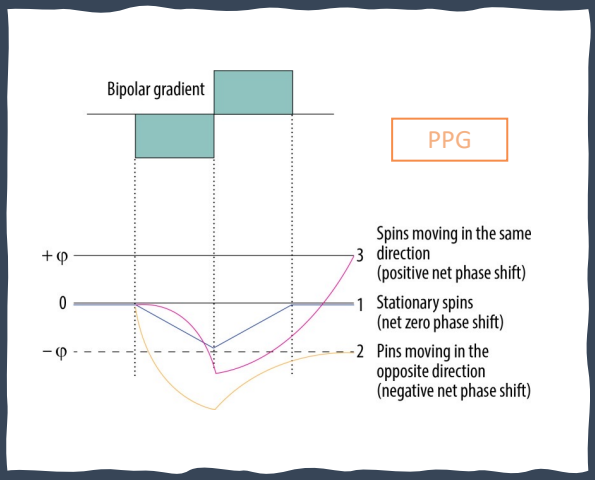


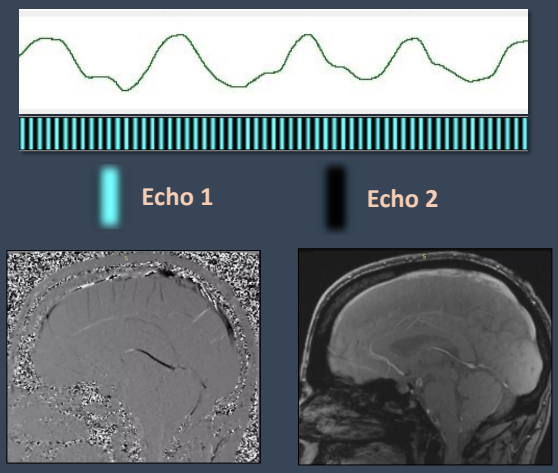
Images courtesy of Noam Alperin PhD

8

CSF FLOW Sequence

PHASE CONTRAST (CSF Flow)

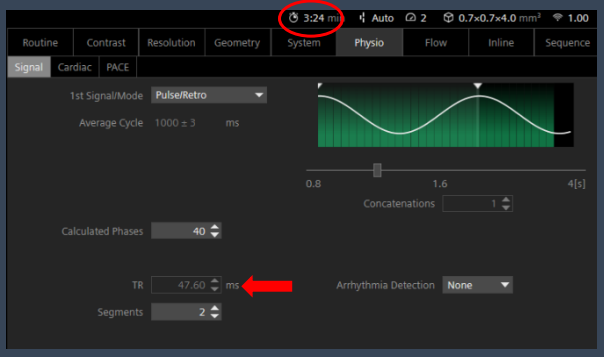


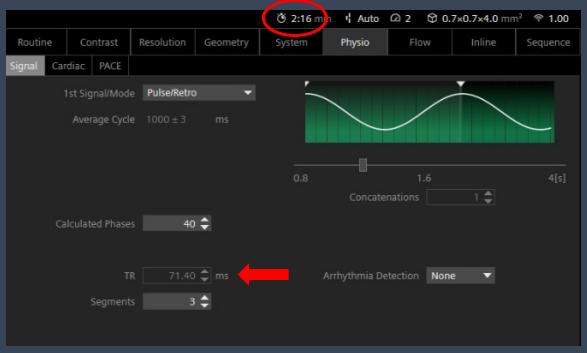


9

PARAMETERS (PC-CSF Flow)

- *TR (Temporal Resolution)*

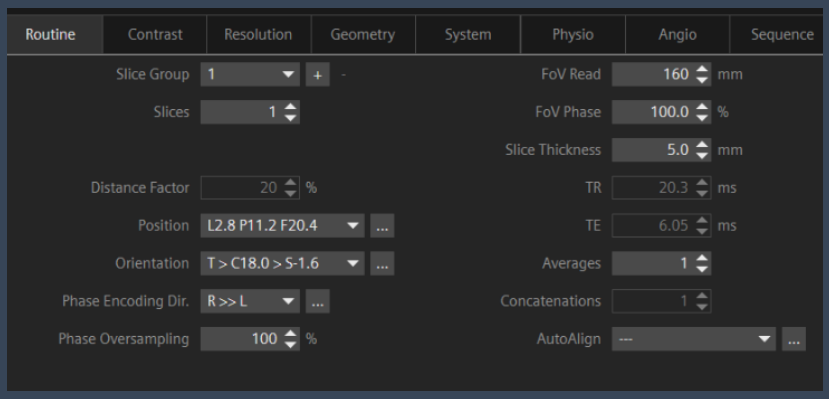


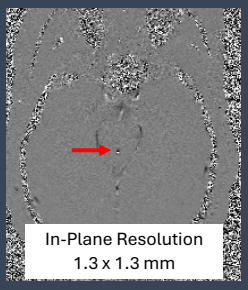


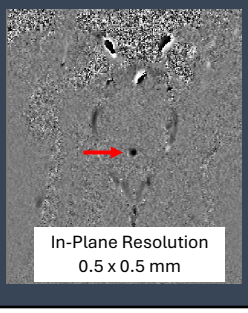
10

PARAMETERS (PC-CSF Flow)

- *FOV ,Matrix ,Slice Thickness (Spatial Resolution)*



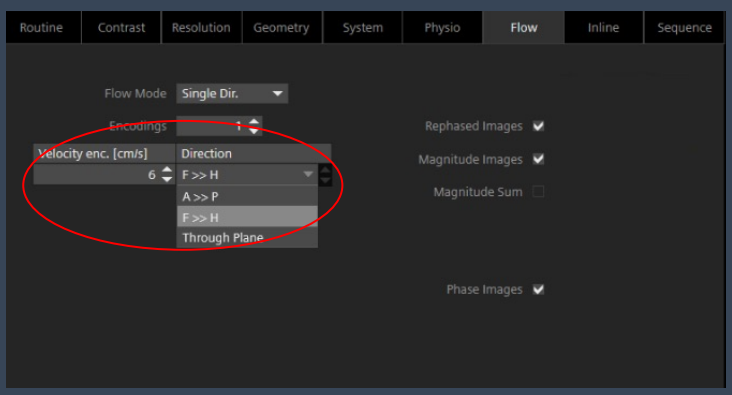


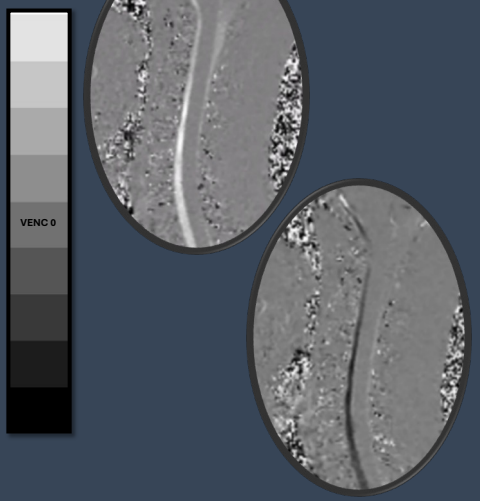


11

PARAMETERS (PC-CSF Flow)

- *VENC (Velocity Encoding)*

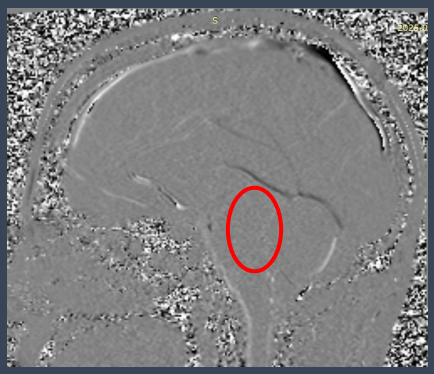




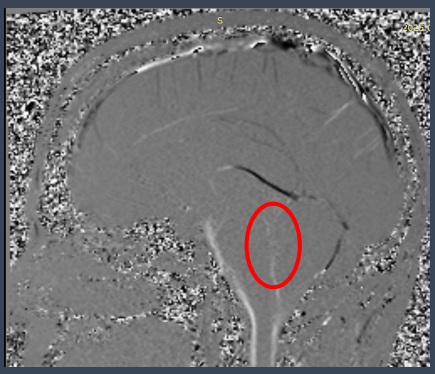
12

PARAMETERS (PC-CSF Flow)

- *VENC (Velocity Encoding)*



VENC 20 cm/s

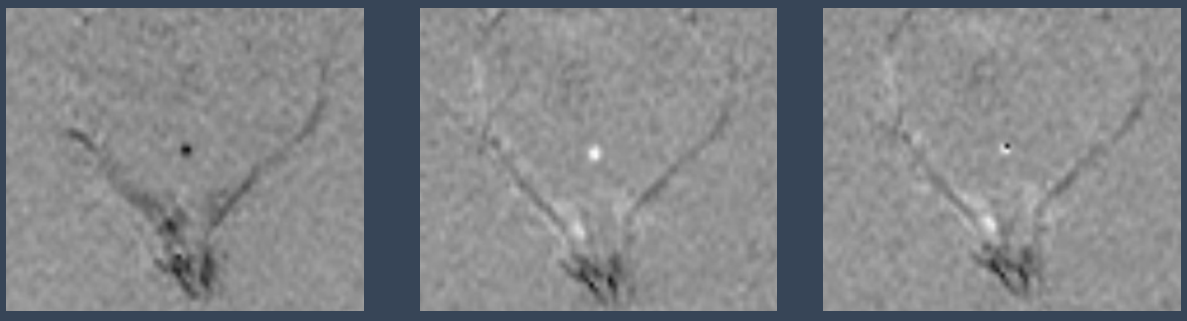


VENC 8 cm/s

13

PARAMETERS (PC-CSF Flow)

- *VENC (Aliasing)*



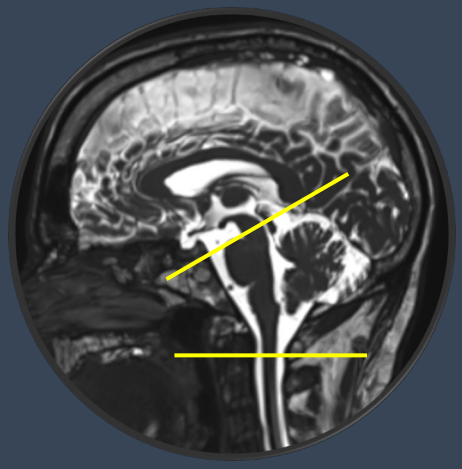
Aliasing

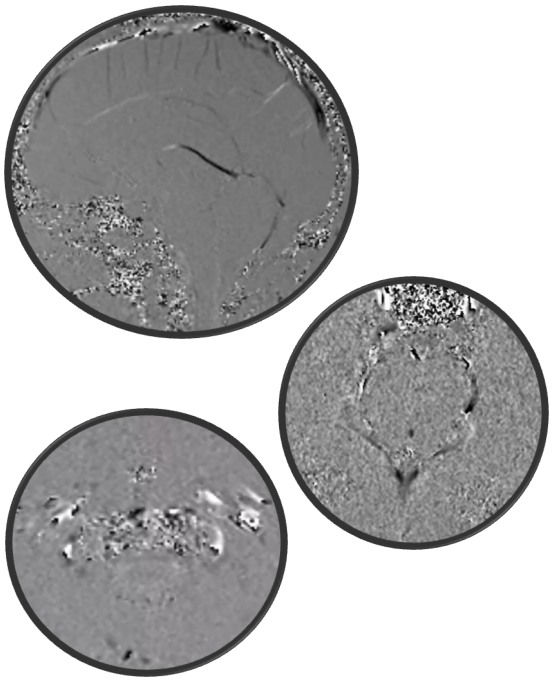
– VENC 8 cm/s +

14

CSF Flow (PC-PPG)

Qualitative

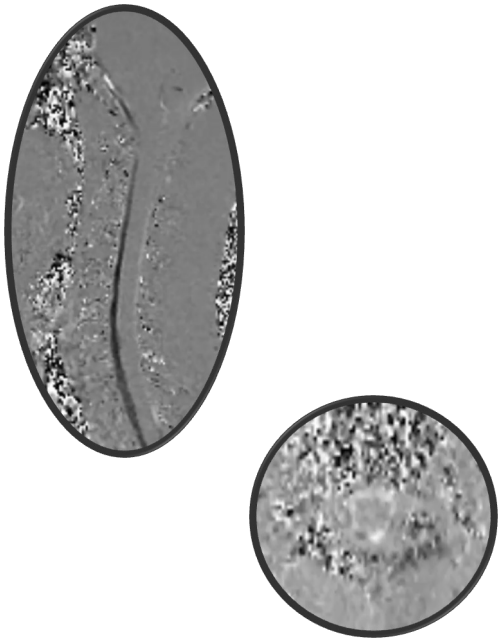




15

CSF Flow (PC-PPG)

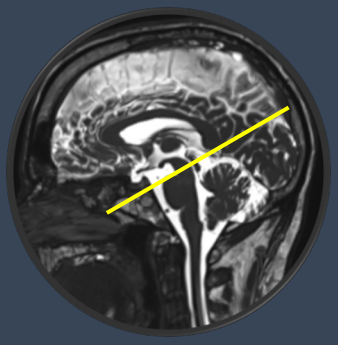
Qualitative

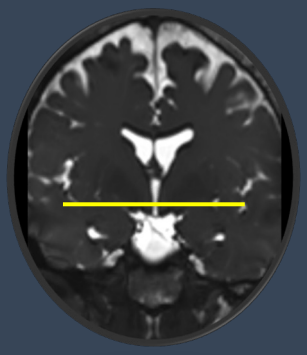


16

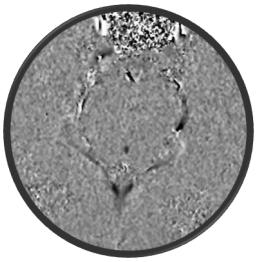
CSF Flow (PC-PPG)

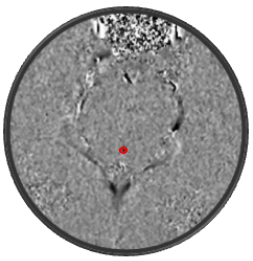
Quantitative





Aqueduct Stenosis

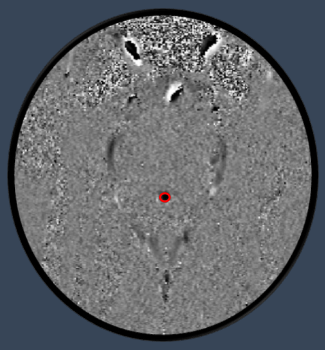


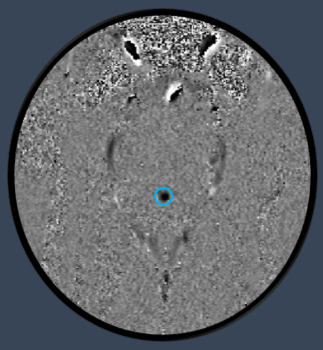


CSF Flow	
Peak Velocity	7.451 cm/s
Forward Volume	0.045 ml
Reverse Volume	0.015 ml
Stroke Volume	0.030 ml
Absolute Volume	0.060 ml

17

Post Processing





CSF Flow	ROI 1	ROI 2
Peak Velocity	6.863 cm/s	6.414 cm/s
Forward Volume	0.058 ml	0.042 ml
Reverse Volume	0.034 ml	0.026 ml
Stroke Volume	0.046 ml	0.034 ml
Absolute Volume	0.092 ml	0.068 ml

18

CSF Disorders

Hydrocephalus

Happens when the cerebrospinal fluid (CSF) builds up(Ventricles), putting pressure on the brain and leading to damage. Causing symptoms such as headache, blurred vision, sickness and difficulty walking.

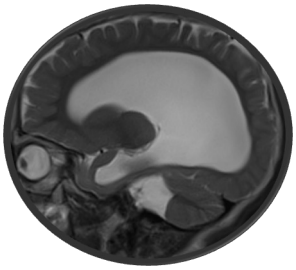
- ***Congenital Hydrocephalus***
- ***Acquired Hydrocephalus***
- ***Normal Pressure Hydrocephalus (NPH)***

19

HYDROCEPHALUS

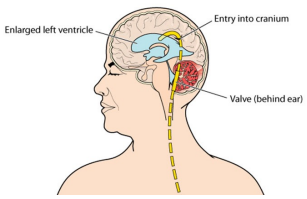
VP Shunt

Acts as a drainage system to bypass the patient's existing CSF absorption mechanisms. It consists of a long, flexible thin tube with a valve that keeps fluid from the brain flowing in the right direction and at the correct rate.

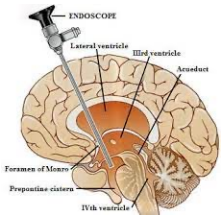


Endoscopic Third Ventriculostomy (ETV)

Is a procedure aims to internally bypass the existing CSF pathway and no implantable device is needed. A hole in the bottom of one of the ventricles or between the ventricles to enable cerebrospinal fluid to flow out of the brain, circulate and absorb.



What is a VP Shunt Used For?



Endoscopic Third Ventriculostomy. My journey following brain surgery –

20

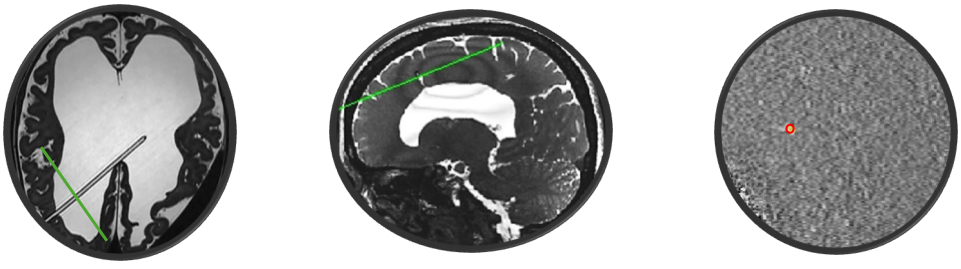
VP SHUNT

21

CSF Flow-Shunts

MRI as a one-stop destination for evaluation of CSF shunt malfunction

Eman Ahmed Hamed, Shaimaa Abdelsattar Mohammad, Shrouk M. Awadallah, Assem Mounir Metwalli Abdel-Latif & Abeer Maghawry Abd-Elhameed

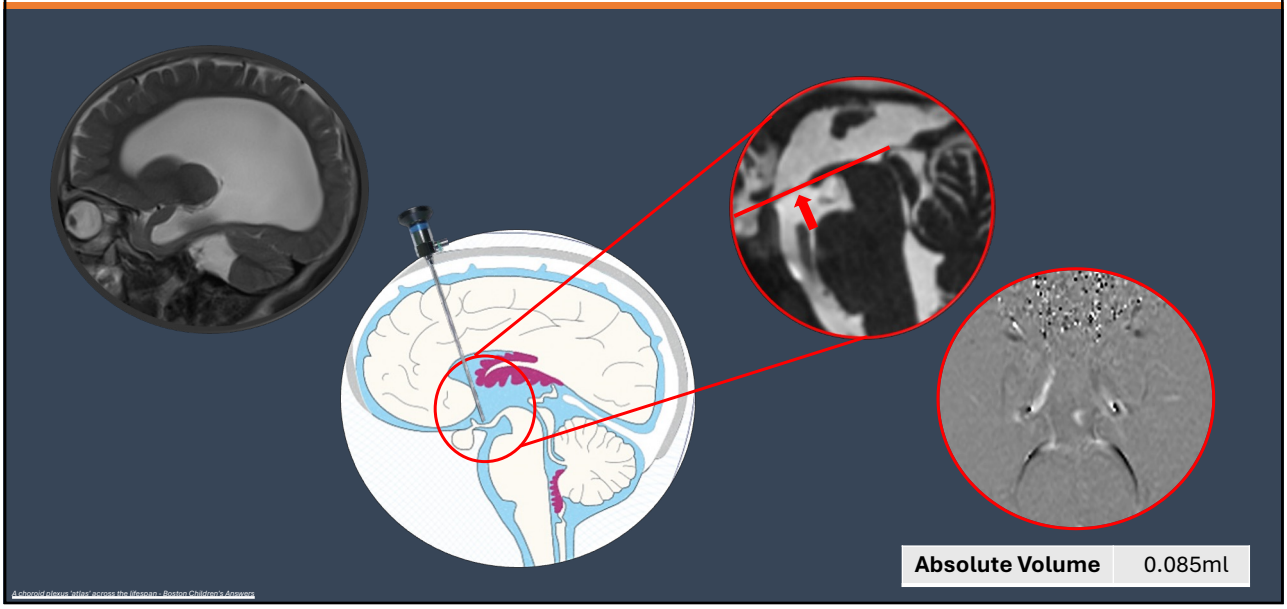


Stroke Volume	0.00017ml

Images courtesy of Noam Alperin PhD

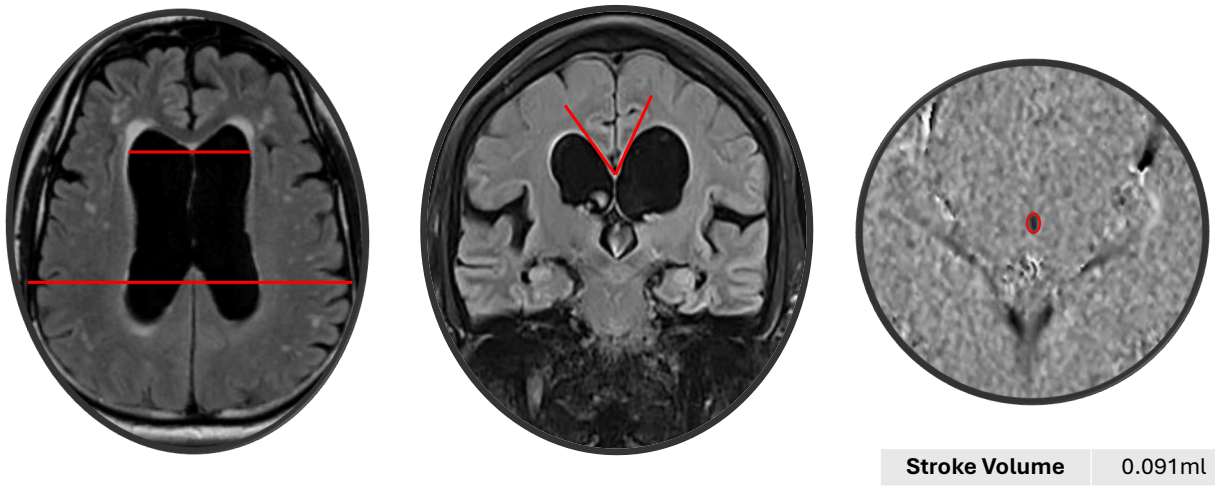
22

ETV (3rd Ventricle)



23

HYDROCEPHALUS (NPH)



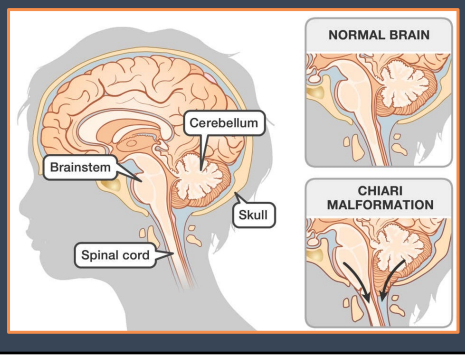
24

CSF Disorders

Chiari Malformation

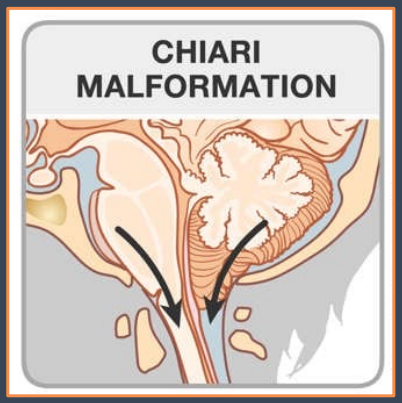
Is a condition the cerebellar tonsils of the brain descend through the magnum foramen. Causes compression of the brain stem and disruption of the flow of cerebrospinal fluid (CSF).

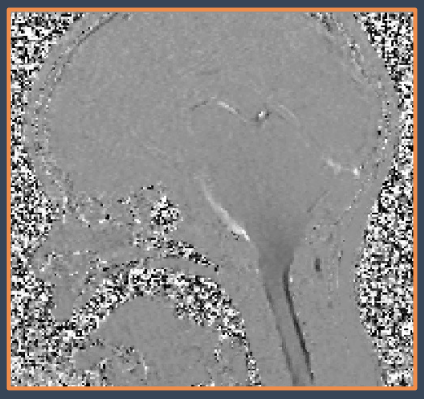
Results in increased pressure inside the brain (causing symptoms)



25

Chiari Malformation





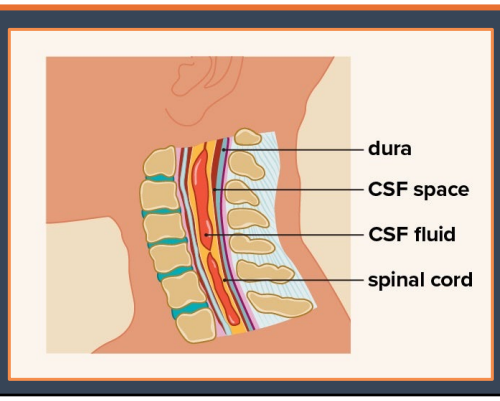
26

CSF Disorders

Syringomyelia

- Is a disorder in which a cyst or cavity (syrinx) is formed within the spinal cord around the central canal.

Results in increased pressure inside the spinal cord causing the cord to expand (causing symptoms)



27

Syringomyelia



28

Syringomyelia

29

Post Op

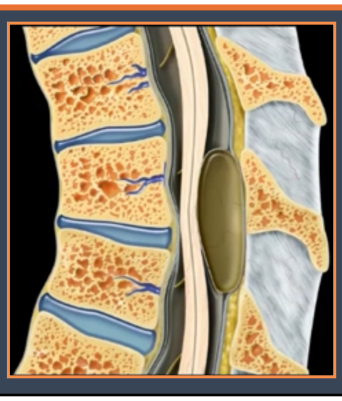
30

CSF Disorders

Arachnoid Cyst

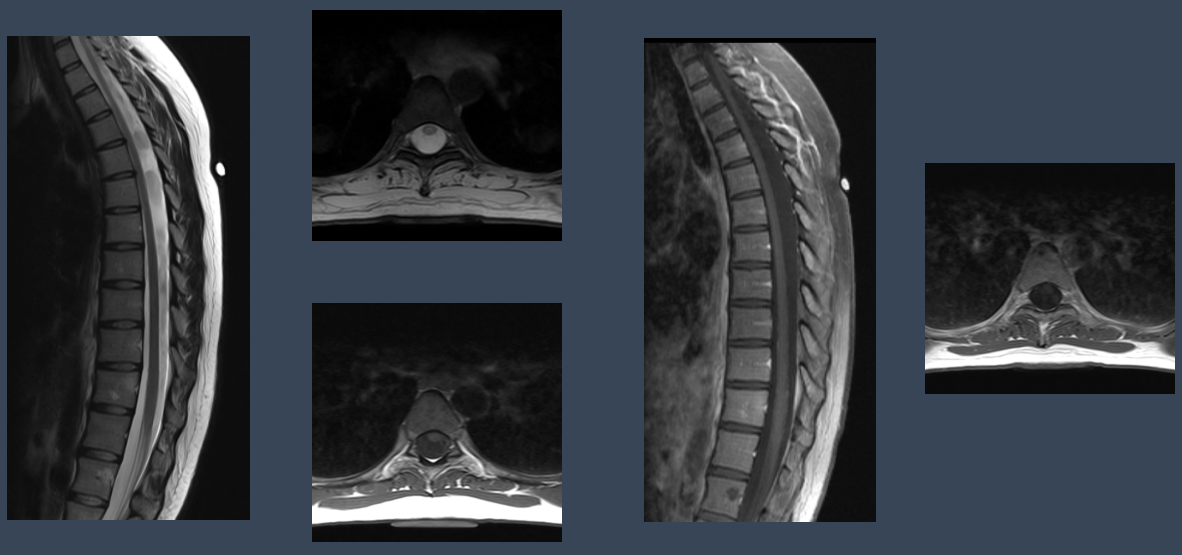
- Are sacs filled with spinal fluid that are located between the spinal cord and the arachnoid membrane.

Results in symptoms such as back pain, tingling, numbness in the legs and bladder issues.



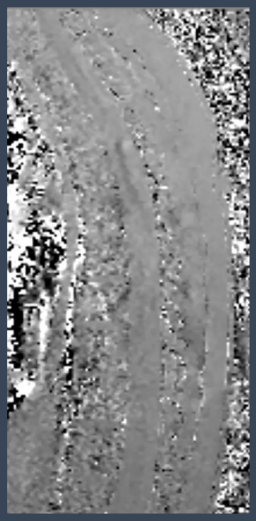
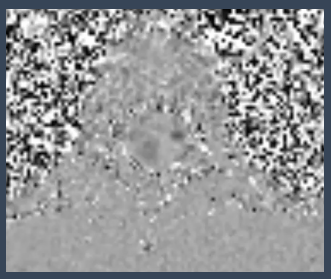
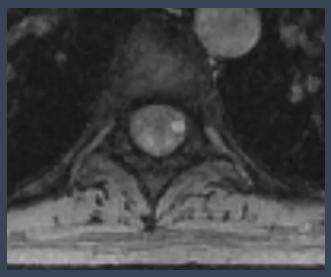
31

T-Spine CSF Flow



32

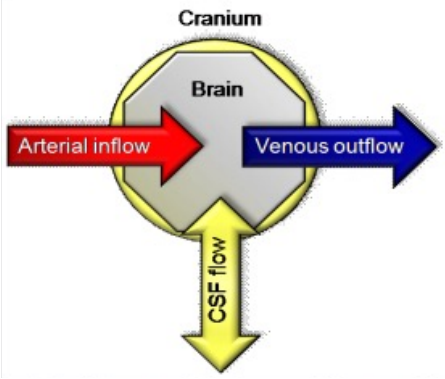
Arachnoid Cyst

33

Intracranial Pressure (MR-ICP)

Flow Imaging (PC-Cine)



Normal ICP Ranges from 7mmHg to 15mmHg (Supine)

Images courtesy of Noam Alperin PhD

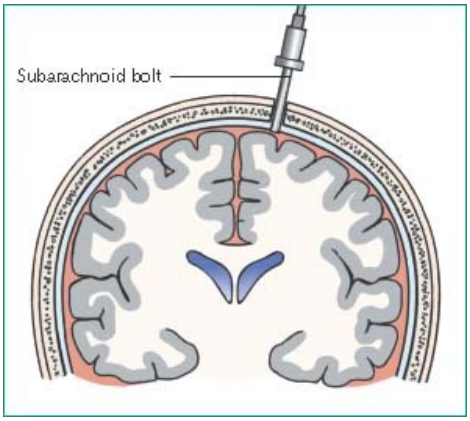
34

Intracranial Pressure (ICP)

- *ICP monitoring -* Is a test that can help determine if high or low cerebrospinal fluid (CSF) pressure is causing symptoms .

- *Neurosurgeon -* Inserts a catheter into the brain (Invasive).

- *ICP Device-* Is connected to a monitor that displays the pressure reading.



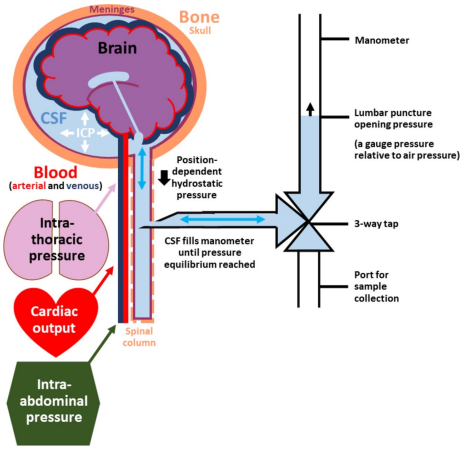
35

Intracranial Pressure (ICP)

- *Lumbar Puncture-* Is a procedure that can measure intracranial pressure (ICP) by measuring the pressure of cerebrospinal fluid (CSF).

- *Neurosurgeon -* Inserts a needle into your lower back.

- *Manometer -* Is connected to the needle that displays the pressure.

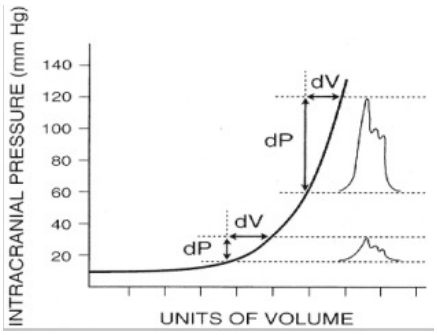


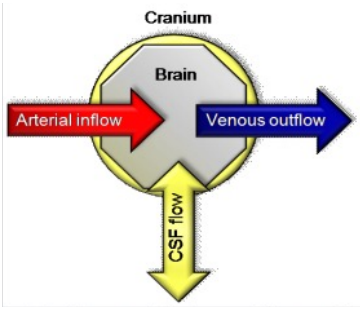
36

Intracranial Pressure (ICP)

- *MR-ICP –* Uses MRI to measure noninvasive intracranial pressure(ICP). It measure Blood Flow(Arterial & Venous) and CSF Flow at the level of C2.

- *Neuro Radiologist –* Review images(PC-Flow) and Post Processing values.





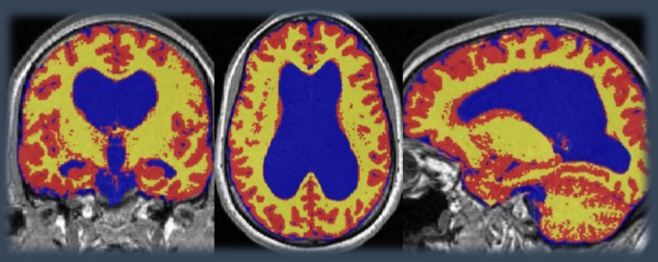
Images courtesy of Noam Alperin PhD

37

Intracranial Pressure (MR-ICP)

Brain (ICP) – *Quantitative*

3D T1 Brain MRI (Isotropic)



Volumes	
Grey Matter	532ml
White Matter	498ml
Intracranial	1431ml

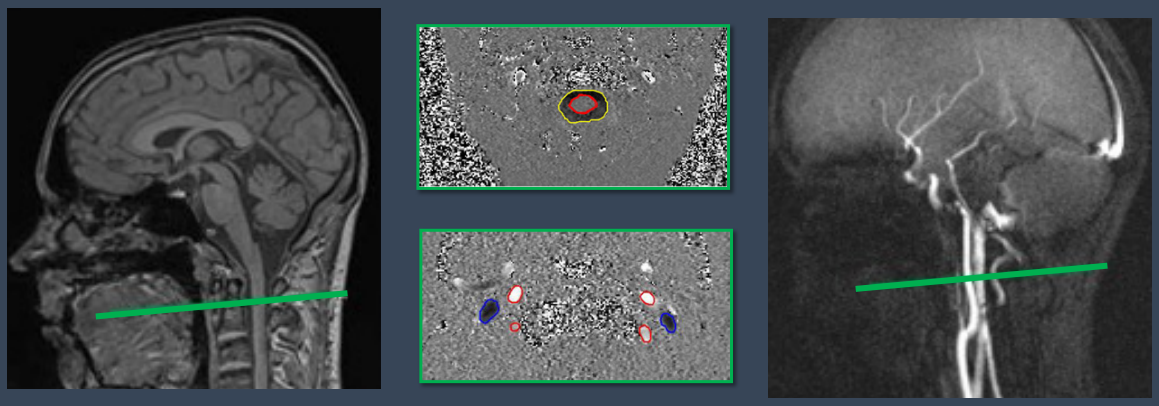
Images courtesy of Noam Alperin PhD

38

Intracranial Pressure (MR-ICP)

Brain (ICP) – *Quantitative*

- C2 (Phase Contrast-Different *VENC*)



Images courtesy of Noam Alperin PhD

39

Noam J. Alperin, PhD
Sang H. Lee, BA
Francis Loth, PhD
Patricia B. Raksin, MD
Terry Lichtor, MD, PhD

Index terms:
Animals
Brain, volume, 10.368, 10.436, 10.82
Cerebrospinal fluid, flow dynamics, 10.368, 10.436, 10.82
Cerebrospinal fluid, MR, 10.12144
Magnetic resonance (MR), experimental studies, 10.12144
Magnetic resonance (MR), phase imaging, 10.12144
Magnetic resonance (MR), volume measurement, 10.12144

Radiology 2000; 217:877–885

Abbreviations:
CSF = cerebrospinal fluid
ICP = intracranial pressure

[1] From the Departments of Radiology (N.J.A., S.H.L.), Bioengineering (N.J.A., S.H.L.), and Mechanical Engineering (F.L.), University of Illinois at Chicago, 1740 W Taylor, Chicago, IL 60612; the Department of Neurosurgery, Rush-Presbyterian-St Luke's Medical Center, Chicago, Ill (P.B.R.); and the Department of Neurosurgery, Cook County Hospital, Chicago, Ill (T.L.). From the 1999 RSNA scientific assembly. Received February 25, 2000; revision requested April 3; revision received May 3; accepted May 5. N.J.A. and F.L. supported in part by National Institutes of Health grant RR14242-01. N.J.A. supported in part by a seed grant from the Department of Radiology at the University of Illinois at Chicago. **Address correspondence to** N.J.A. (e-mail: *alperin@uic.edu*).

MR–Intracranial Pressure (ICP): A Method to Measure Intracranial Elastance and Pressure Noninvasively by Means of MR Imaging: Baboon and Human Study[1]

PURPOSE: To develop a noninvasive method for intracranial elastance and intracranial pressure (ICP) measurement.

MATERIALS AND METHODS: Intracranial volume and pressure changes were calculated from magnetic resonance (MR) imaging measurements of cerebrospinal fluid (CSF) and blood flow. The volume change was calculated from the net transcranial CSF and blood volumetric flow rates. The change in pressure was derived from the change in the CSF pressure gradient calculated from CSF velocity. An elastance index was derived from the ratio of pressure to volume change. The reproducibility of the elastance index measurement was established from four to five measurements in five healthy volunteers. The elastance index was measured and compared with invasive ICP measurements in five patients with an intraventricular catheter at MR imaging. False-positive and false-negative rates were established by using 25 measurements in eight healthy volunteers and six in four patients with chronically elevated ICP.

RESULTS: The mean of the fractional SD of the elastance index in humans was 19.6%. The elastance index in the five patients with intraventricular catheters correlated well with the invasively measured ICP (R^2 = 0.965; $P < .005$). MR imaging–derived ICPs in the eight healthy volunteers were 4.2–12.4 mm Hg, all within normal range. Measurements in three of the four patients with chronically elevated ICP were 20.5–34.0 mm Hg, substantially higher than the normal limit.

CONCLUSION: MR imaging–derived elastance index correlates with ICP over a wide range of ICP values. The sensitivity of the technique allows differentiation between normal and elevated ICP.

40

MR-ICP

Comparing invasive with MRI-derived Intracranial Pressure measurements in healthy elderly and brain trauma cases: A Pilot Study

Ritambhar Burman, BE[1], Ashish Shah, M.D[2], Ronald Benveniste, M.D.[2], George Jimsheleishvili, M.D.[2], Sang H Lee, MS[3], David Loewenstein, PhD[4], Noam Alperin, PhD[1,3]

[1]University of Miami, Biomedical Engineering Department, Coral Gables, FL 33146, USA.

[2]University of Miami, Department of Neurological Surgery, FL 33136, USA.

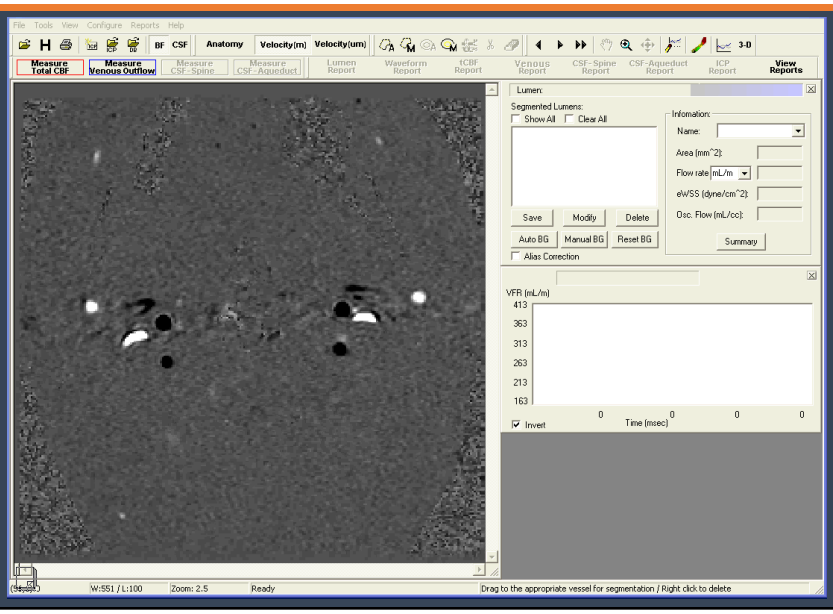
[3]University of Miami, Radiology Department, Miami, FL 33136, USA.

[4]University of Miami, Department of Psychiatry and Behavioral Sciences, FL 33136, USA.

MR-ICP and Invasive ICP were positively correlated (r=0.95, p<0.001)

41

MR-ICP



Images courtesy of Noam Alperin PhD

42

ACKOWLEDGEMENT

- ***Noam Alperin PhD,*** *University of Miami*
- ***Chariff Sidanni MD****, University of Miami*
- ***Pradip M. Pattany PhD****, University of Miami*
- ***Siemens Applications Team****, Siemens Healthineers*
- ***Jim Coffin ARMRIT (President)***

43

SUMMARY

- *Review anatomy and pathologies of Cerebral Spinal Fluid (CSF).*
- *Discuss the key parameters such as Temporal, Spatial Resolution and Velocity Encoding (VENC).*
- *Differences and benefits of qualitative and quantitative techniques of CSF Flow.*
- *Post Processing tips for proper quantifications*
- *New role of flow imaging to evaluate ICP.*

ARMRIT®

44

REFERENCES

- www.physio-pedia.com/Meninges
- www.sciencedirect.com/topics/medicine-and-dentistry/spinal-meninx
- The Ventricular System | Neuroanatomy | CSF | Geeky Medics
- www.aboutkidshealth.ca/chiari-malformation
- www.healthline.com/health/neurological-health/syringomyelia
- Imaging of cerebrospinal fluid flow: fundamentals, techniques, and clinical applications of phase-contrast magnetic resonance imaging
- Endoscopic Third Ventriculostomy- My journey following brain surgery –
- What is a VP Shunt Used For?
- A choroid plexus 'atlas' across the lifespan - Boston Children's Answers
- Intracranial Pressure Monitoring | Nurse Key
- How to use lumbar puncture manometry in children | ADC Education & Practice Edition

Eduardo D Campuzano BS,RT (R)(MR)(CT),ARMRIT,MRSO(MRSC)

- MRI Applications Manager
  Southeast Zone ,USA
- *Siemens Healthineers*
  - Phone: (786) 650-5030
  - E-mail: eduardo.campuzano@siemens-healthineers.com

CREDIT CLAIMING INSTRUCTION

You must complete a brief evaluation of each session you attended to claim continuing education credit. To "unlock" each session's individual evaluation, you will need the **access code (case sensitive)** provided below to open the session's corresponding evaluation. Once that session's evaluation is unlocked and completed, you can download a certificate of completion for that session.

Credit claiming will open on Monday, September 29, 2025.

1. Go to **ce.ahclearning.com/ARMRITcreditclaim25**.
2. Select this session's title from the list. On the page that appears, click the "Add to Cart" tab.
3. On the next page, enter the code for this session in the space provided and click "Unlock."
   The code for this session is squirrel.
4. Click "Take Course."
5. Click "Start Course" or "Resume Course" to access the session evaluation.
6. Complete the evaluation and click "Submit."
7. Download your certificate.