

# **Clinical Investigation of Cerebrospinal Fluid Movement in Normal and Hydrocephalic Brains Using a Non- contrast Time-Spatial Labeling Inversion Pulse Technique**

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# **Disclosure: Conflict of Interest**

**Shinya Yamada has no conflict to disclose.**

**Mitsue Miyazaki is an employee of Toshiba Medical systems.**

**Yuichi Yamashita is an employee of Toshiba Medical systems.**

**Hitoshi Kanazawa is an employee of Toshiba Medical systems.**

**Seiko Shimizu is an employee of Toshiba Medical systems.**

**Ikuo Aoki is an employee of Toshiba Medical systems.**

**Yukuo Morohoshi has no conflict to disclose.**

**J. Gordon McComb has no conflict to disclose.**

# INTRODUCTION

- The ideal tracer to study CSF movement is CSF itself.
- Using time-spatial labeling inversion pulse (time-SLIP) it is possible to repeatedly visualize CSF movement non-invasively in the clinical setting.

# Introduction

- Can pulse label a variable volume of CSF in any orientation and in any place in the CNS.
- Acquisition time is short, averaging 3 minutes per scan.



# Introduction

- Repeated studies are readily doable and can assess CSF movement under normal physiological conditions as well as in altered states.

# Technique

- The method described was originally derived from arterial spin labeling of blood flowing in vessels.

# Technique

- With modifications it became possible to mark (tag) any given volume of blood repeatedly in any orientation.

# Technique

- This technique, referred to as time-spatial labeling inversion pulse (time-SLIP) was further modified to visualize CSF pulsatile and turbulent flow.

# Technique

- A non-selective inversion recovery pulse inverts all signals in a field of view from initial longitudinal magnetization (+M<sub>z</sub>) to (-M<sub>z</sub>).

# Technique

- Immediately after the initial inversion, a second spatially selective inversion pulse is applied to invert (tag) only the magnetization in the region of interest.

# Technique

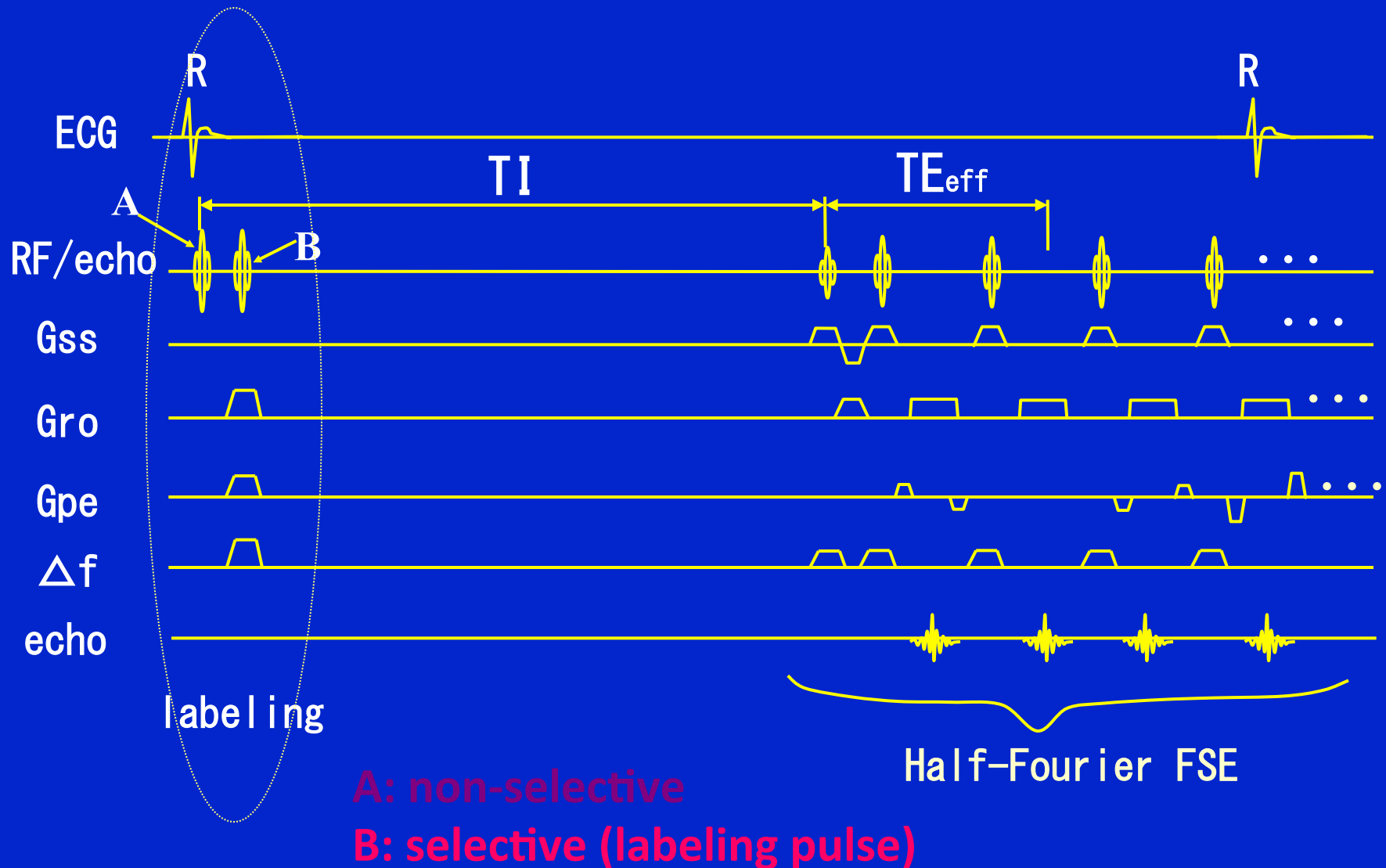
- The magnetization in the marked region is restored to  $+M_z$  whereas the magnetization elsewhere is  $-M_z$ .

# Technique

- This produces a contrast between tagged and untagged CSF that can be visualized from 1000-4500ms.



# Pulse sequence (2D Time-SLIP)



# Technique

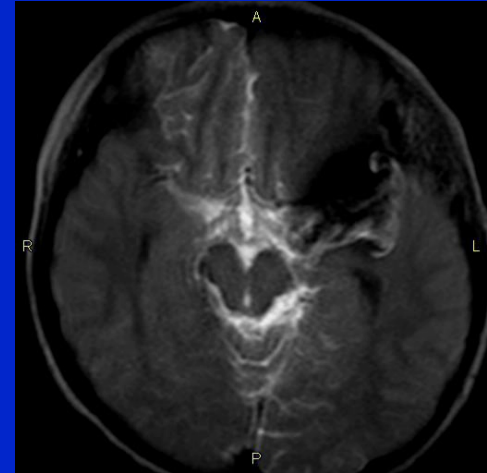
- The tagged area is freely selectable and can be viewed as to volume, orientation and location and can be repeated at will.

# Material and Methods

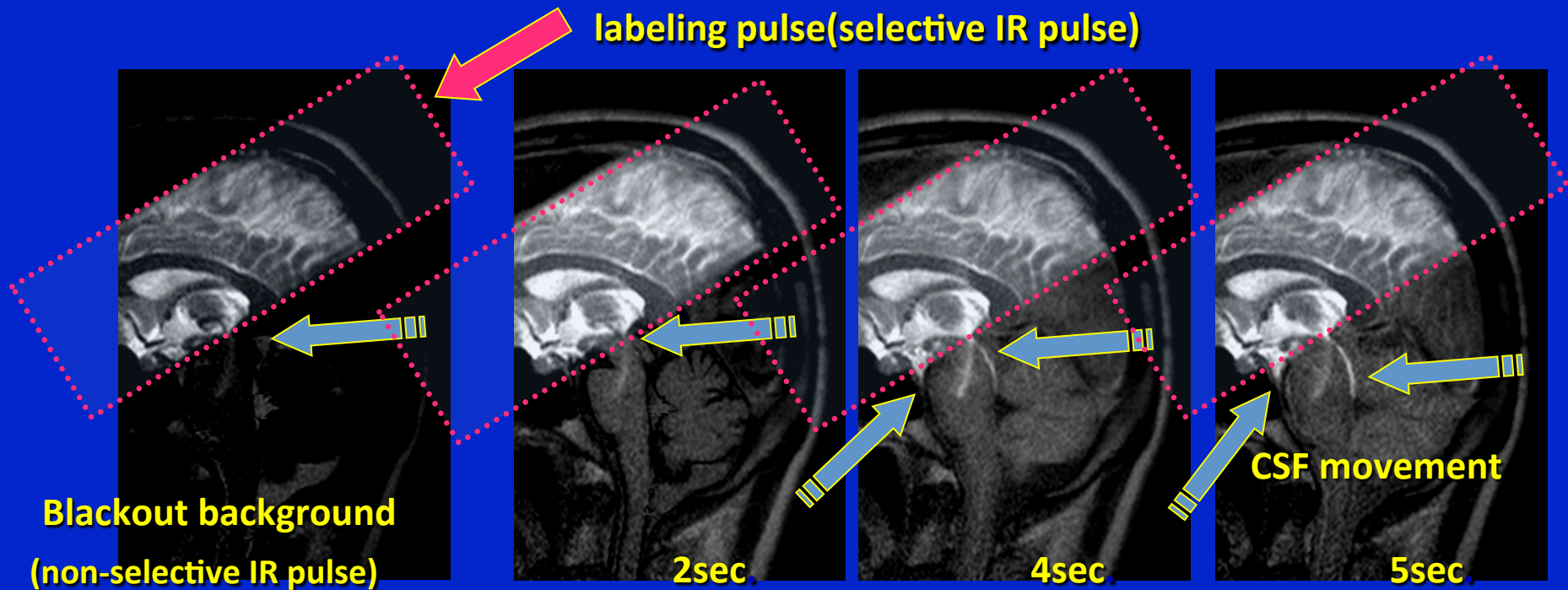
Normal Volunteers : 10 (m-6 f-4)

Hydrocephalic Patients: 17 (m-7, f-10)

Non-Communicating	5
Post-SAH	7
Post-Trauma	2
Idiopathic NPH	3



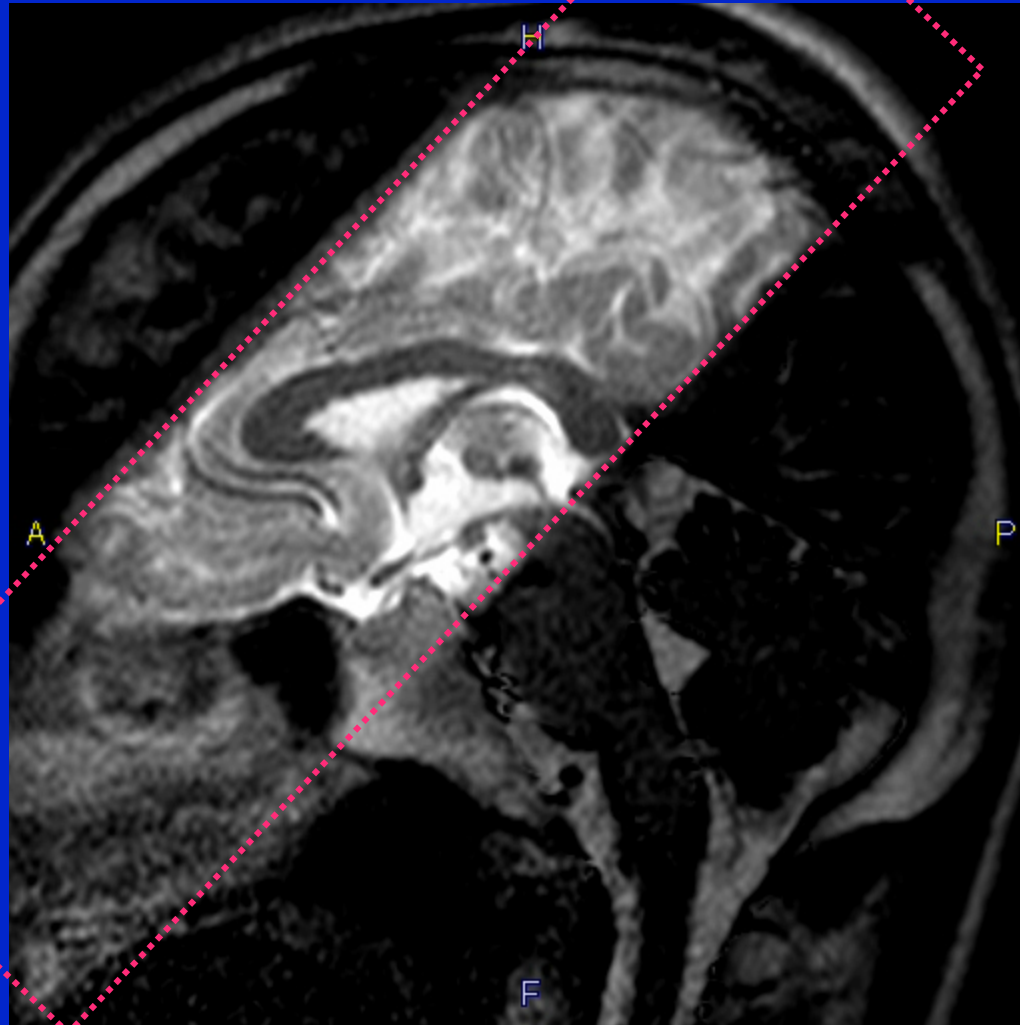
Reference: MRI visualization of cerebrospinal fluid movement with spin labeling: Preliminary results in normal and pathophysiological conditions. *Radiology* 249:644-652, 2008. Yamada S, et.al.



## CSF Pulsatile Flow Inversion Recovery

- A tracer study without using tracer.
- IR pulse labels CSF as an internal tracer.

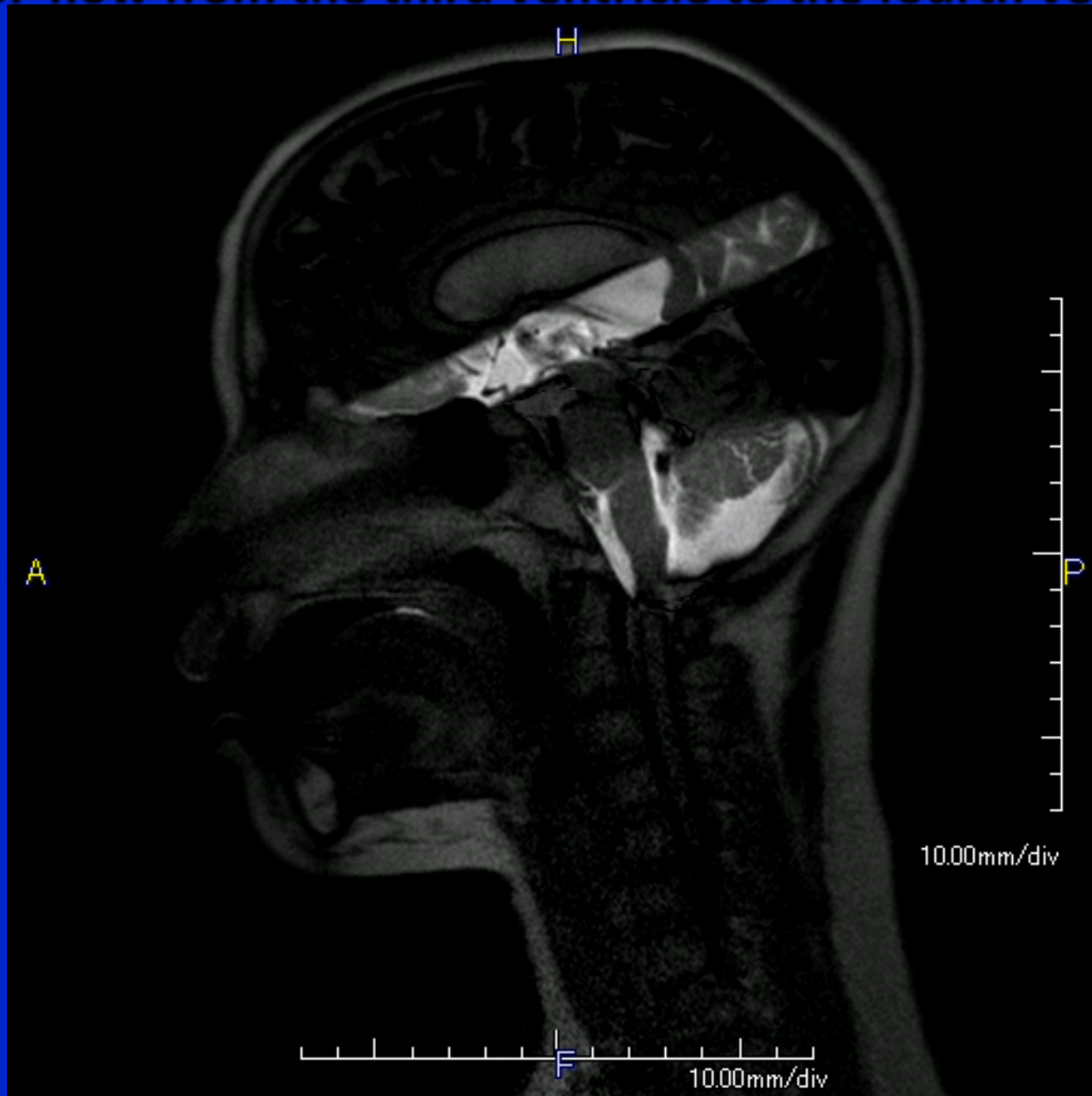
# CSF flow from third ventricle to the fourth ventricle



• • labeling pulse

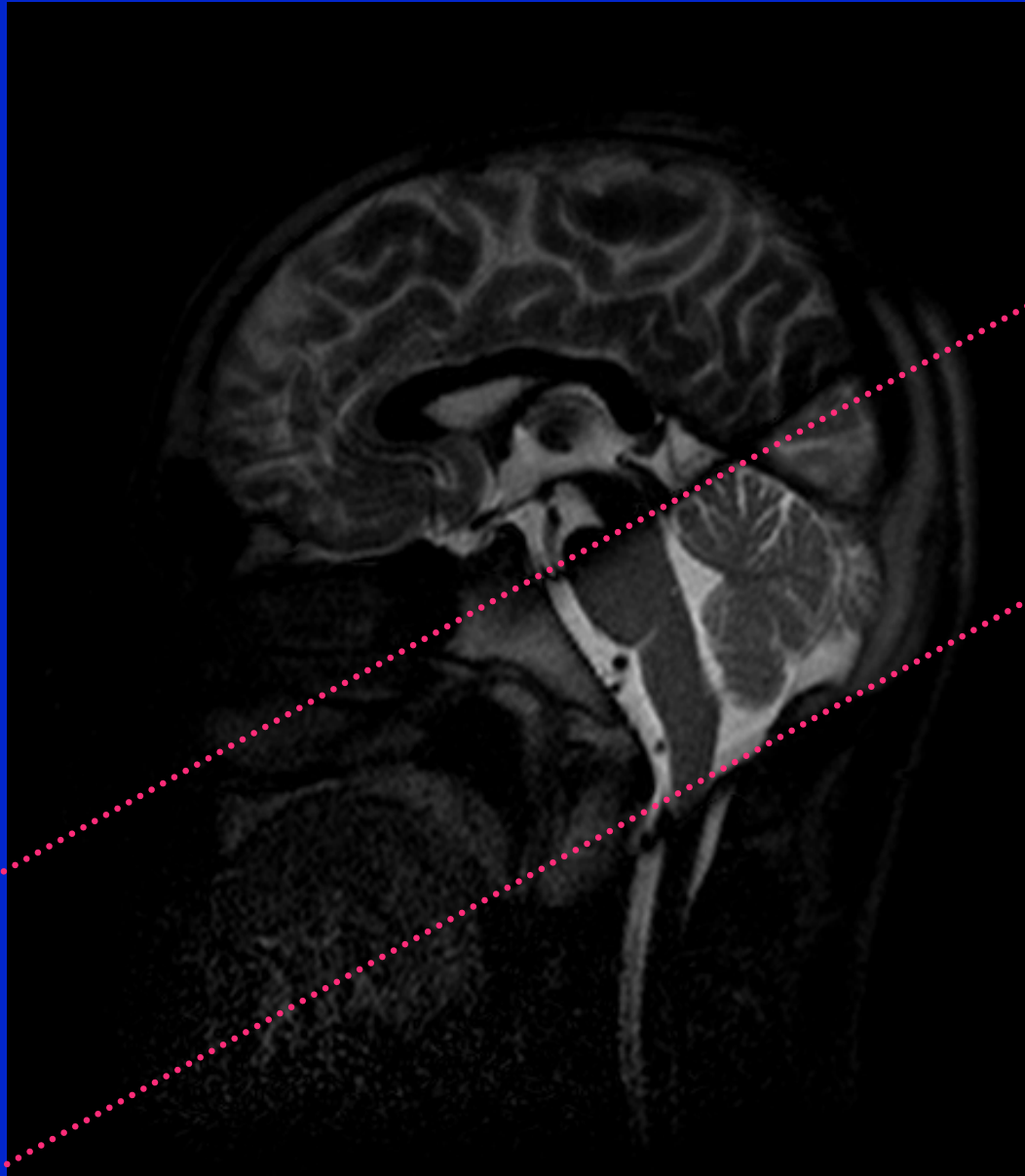
normal volunteer

# CSF flow from the third ventricle to the fourth ventricle



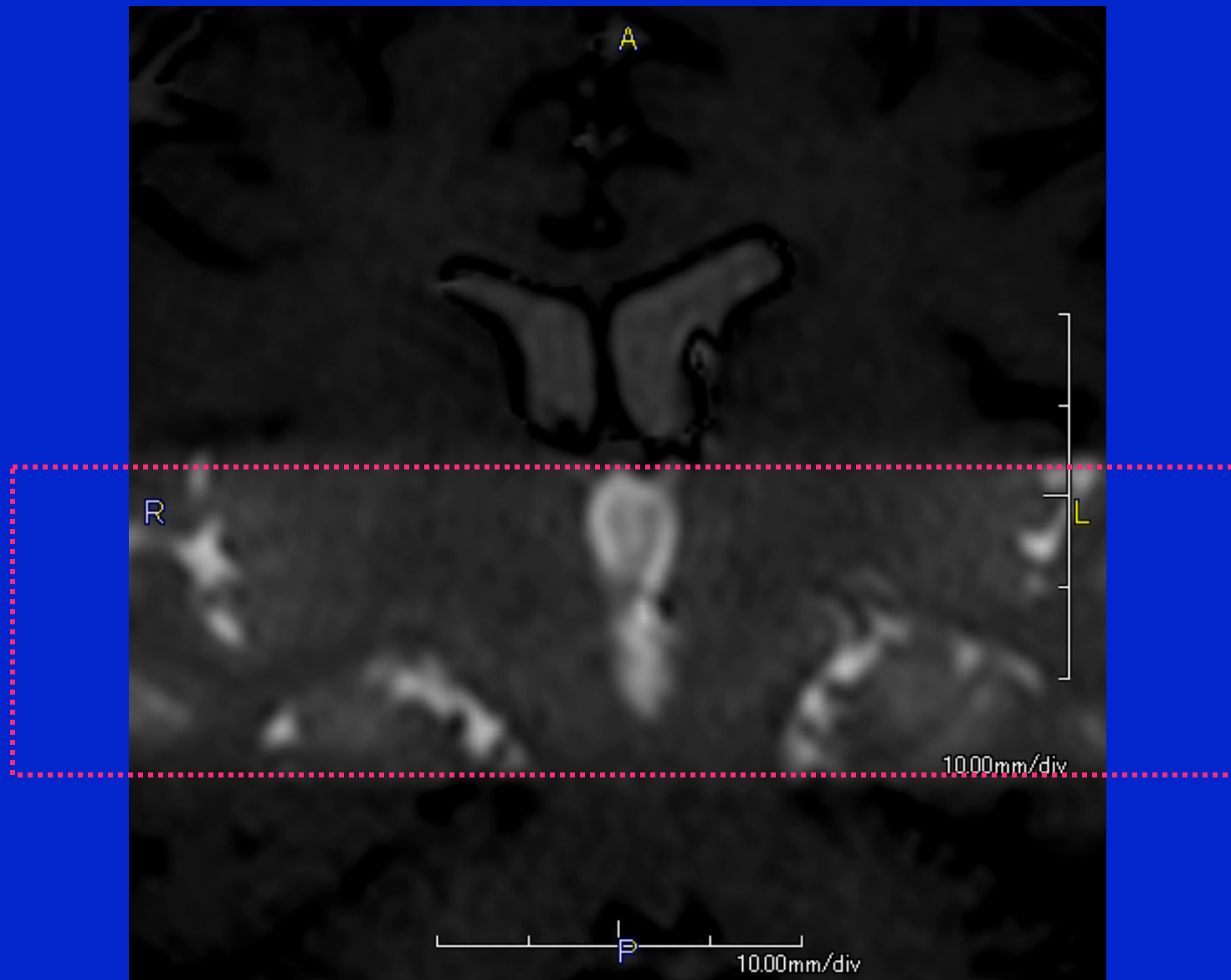
normal volunteer

# Reflux CSF flow from the fourth ventricle back into the third ventricle



normal volunteer

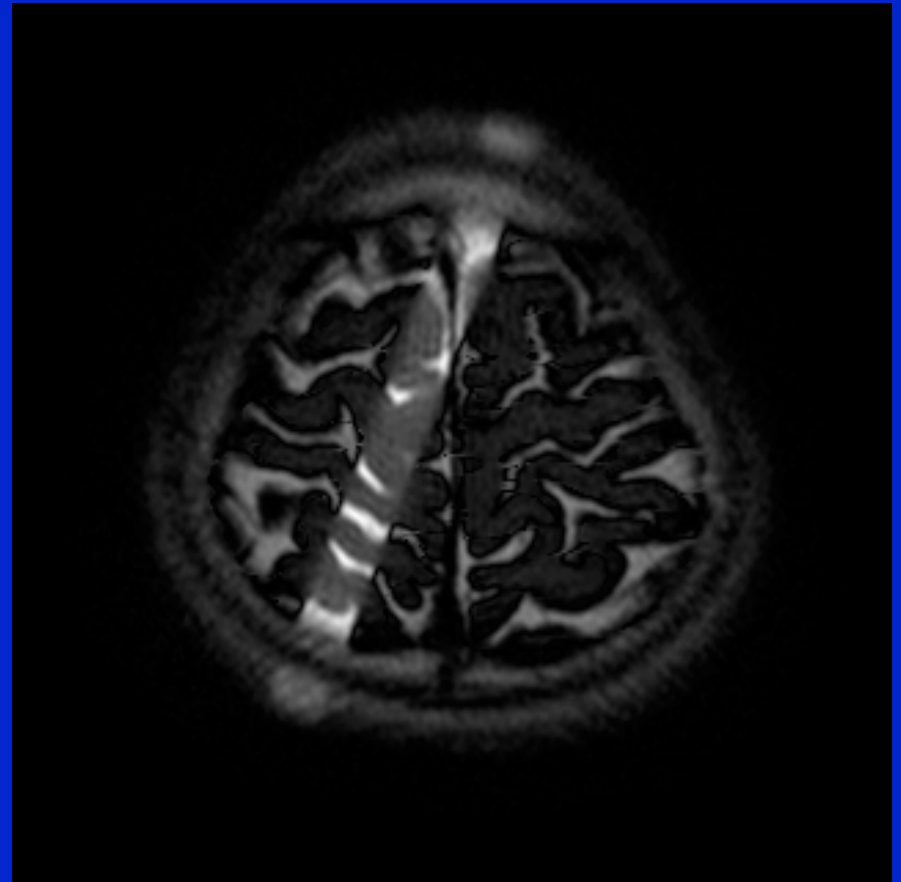
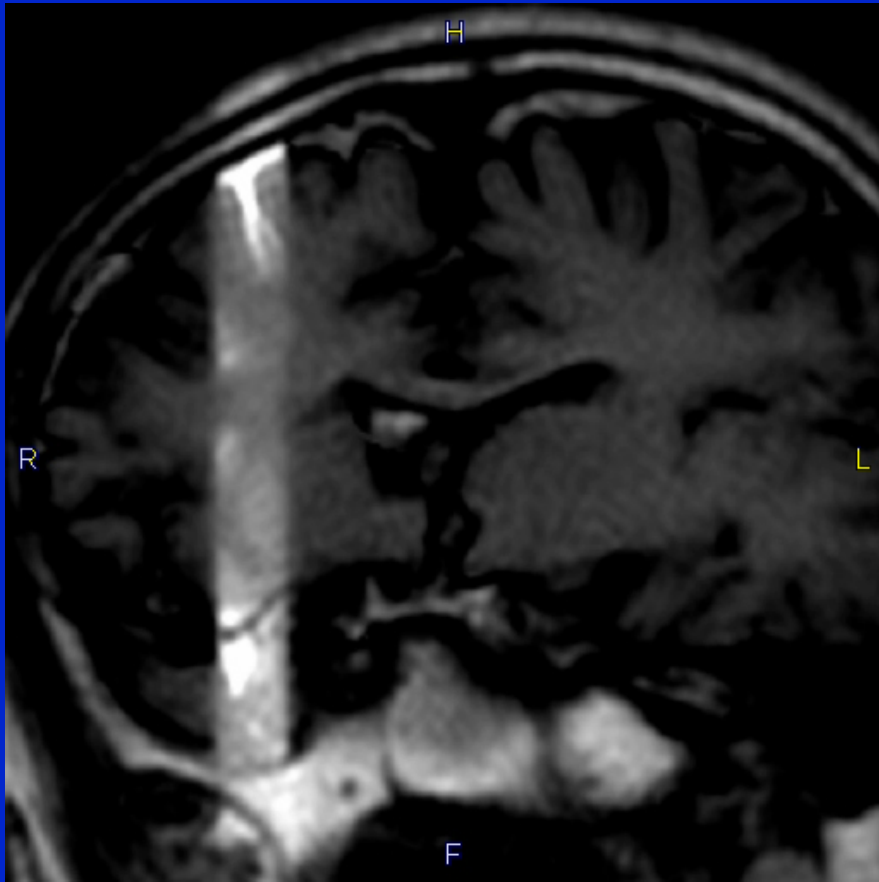
## CSF reflux flow into the lateral ventricles



normal volunteer

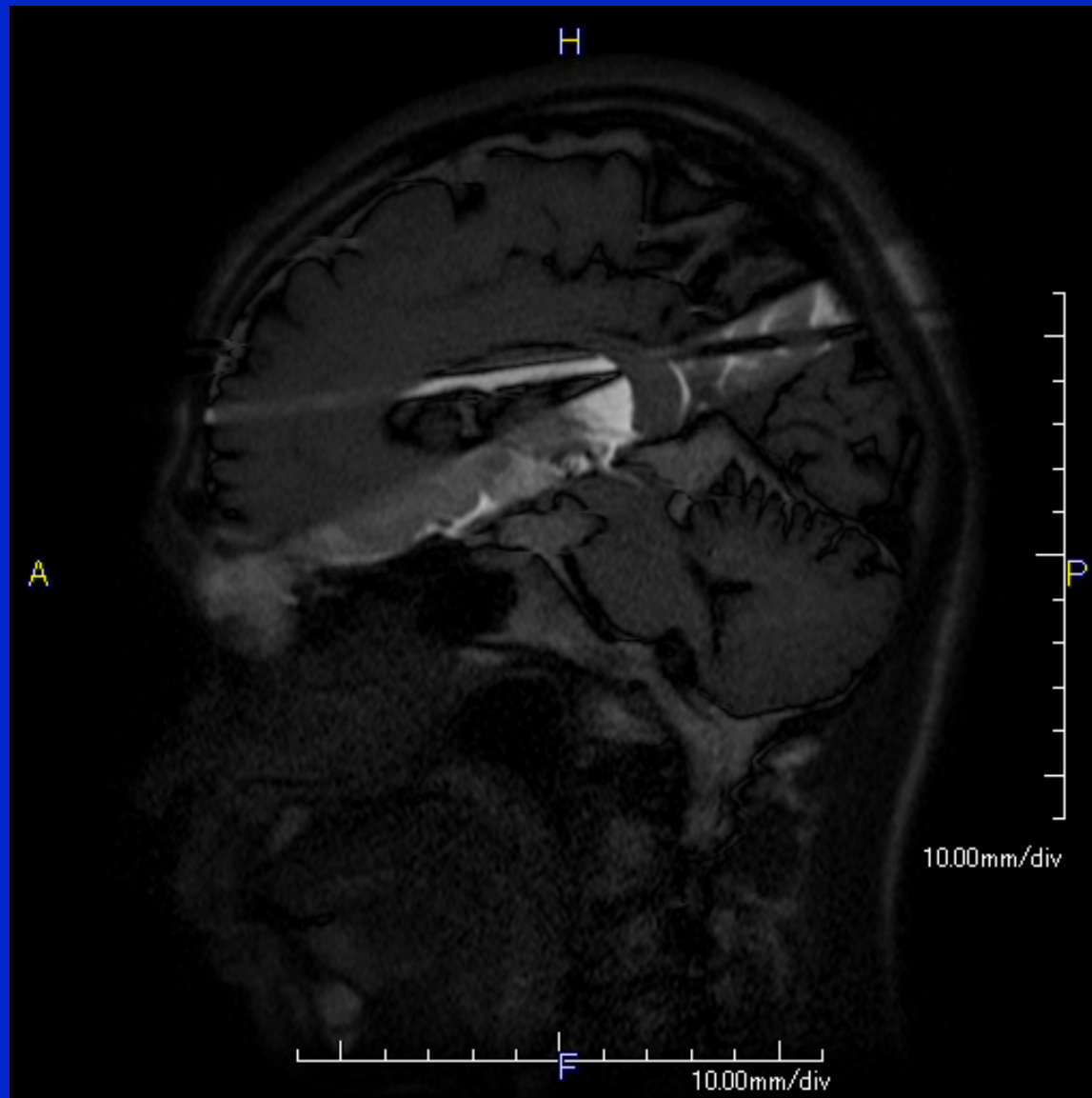


## CSF flow in the Sylvian fissure and convexity of the brain



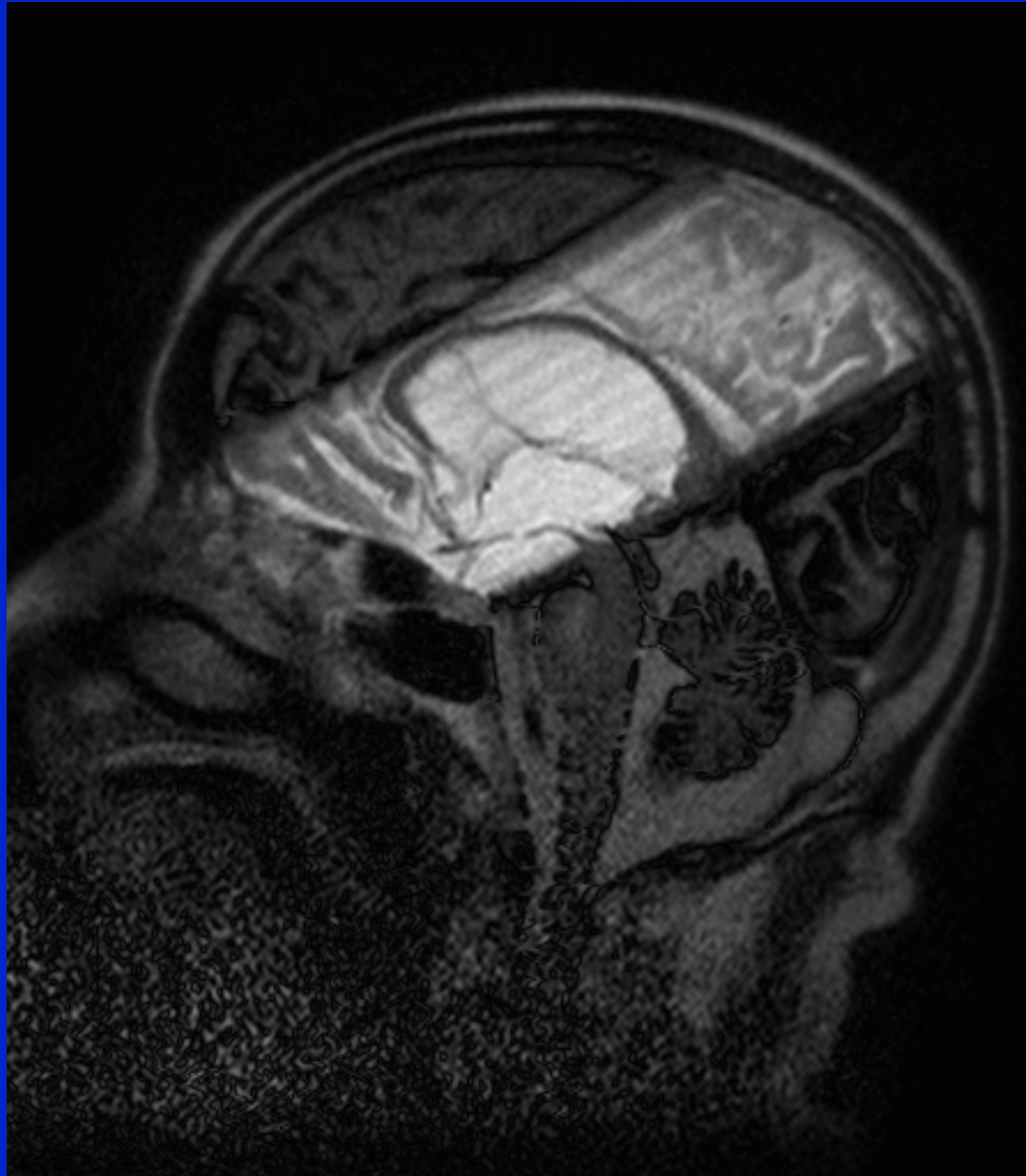
normal volunteer

## CSF flow at the aqueduct, foramen of Monro and lateral ventricle

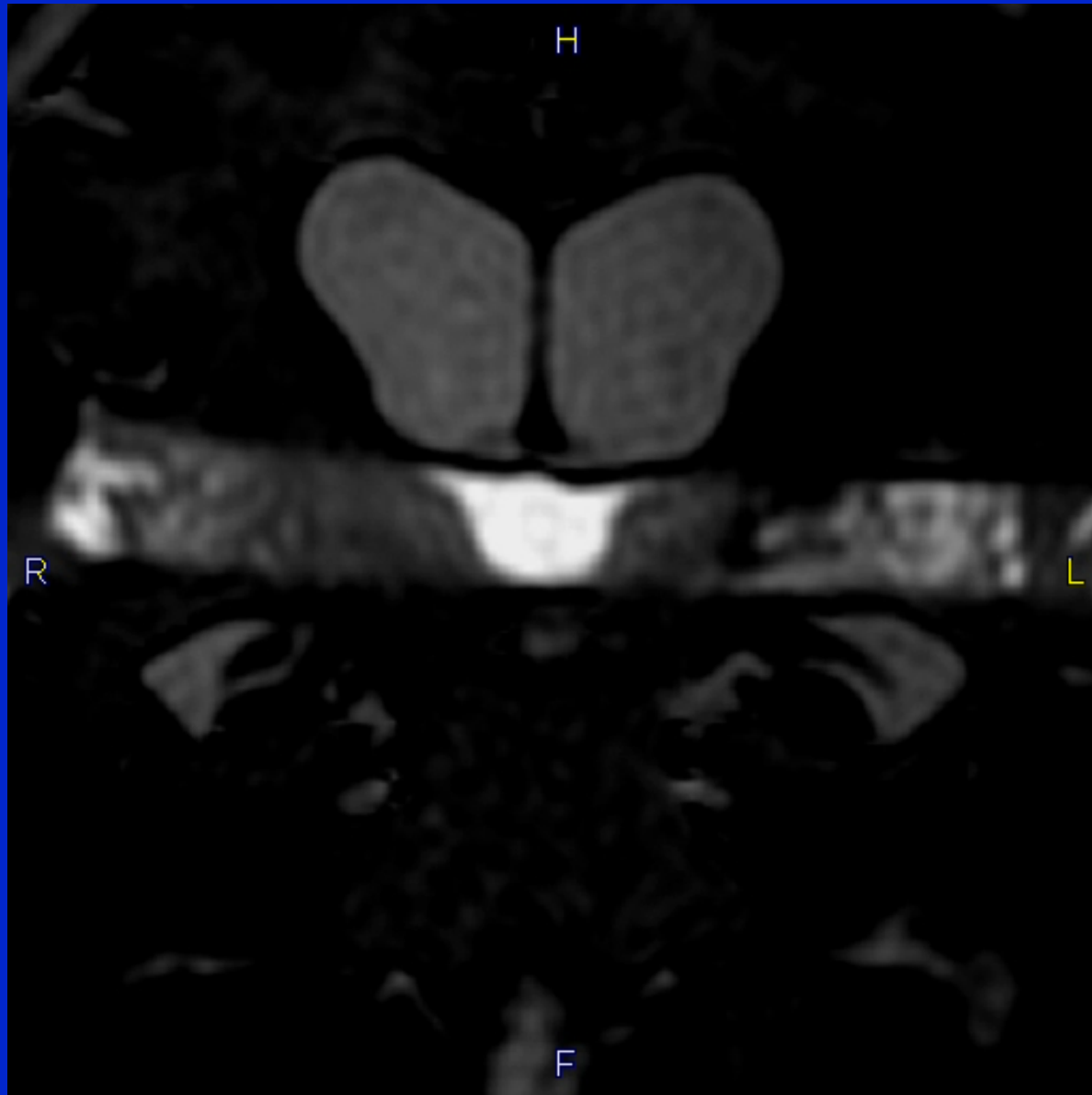


normal volunteer

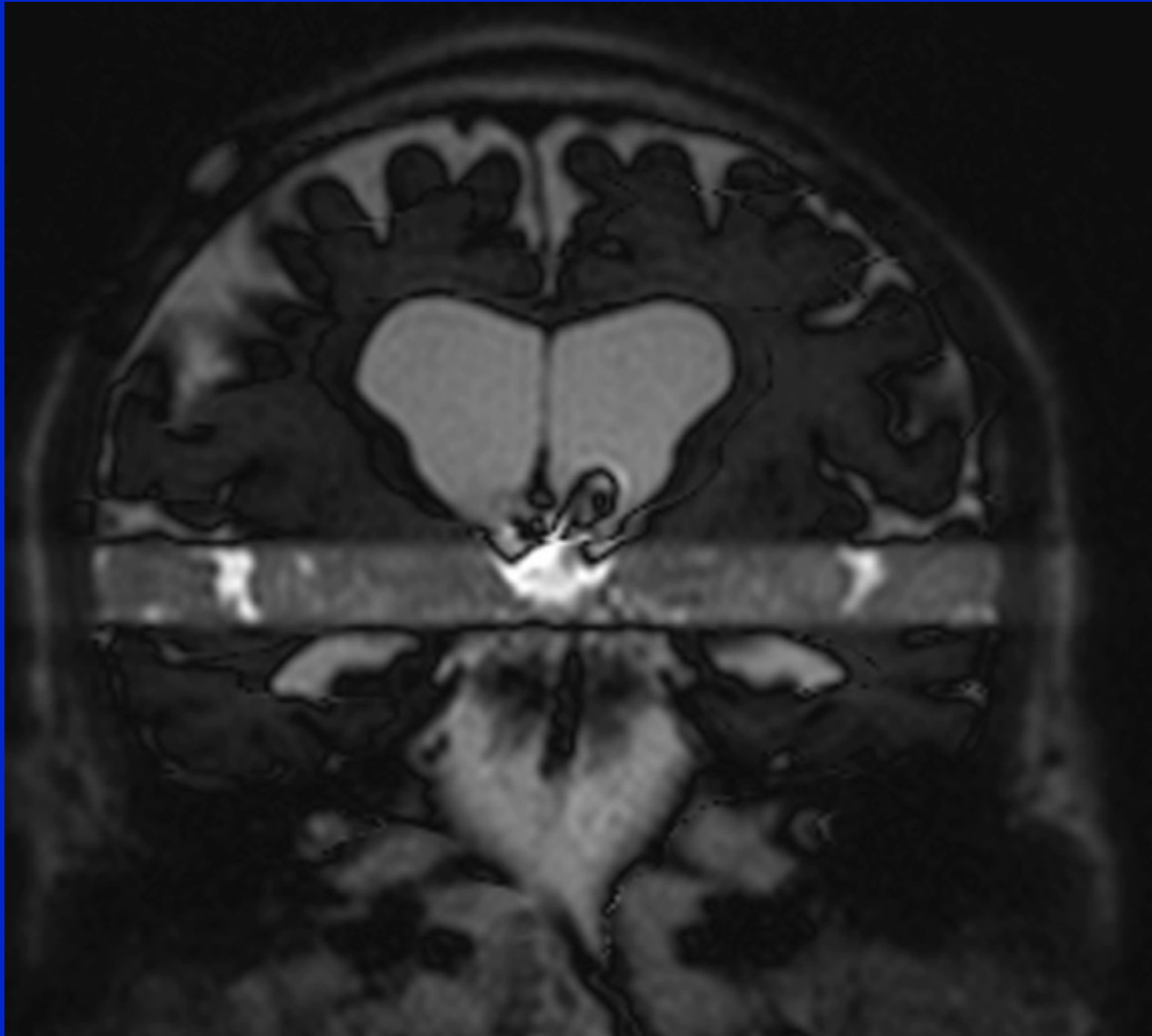
## Hydrocephalus (iNPH)



## Hydrocephalus (iNPH)

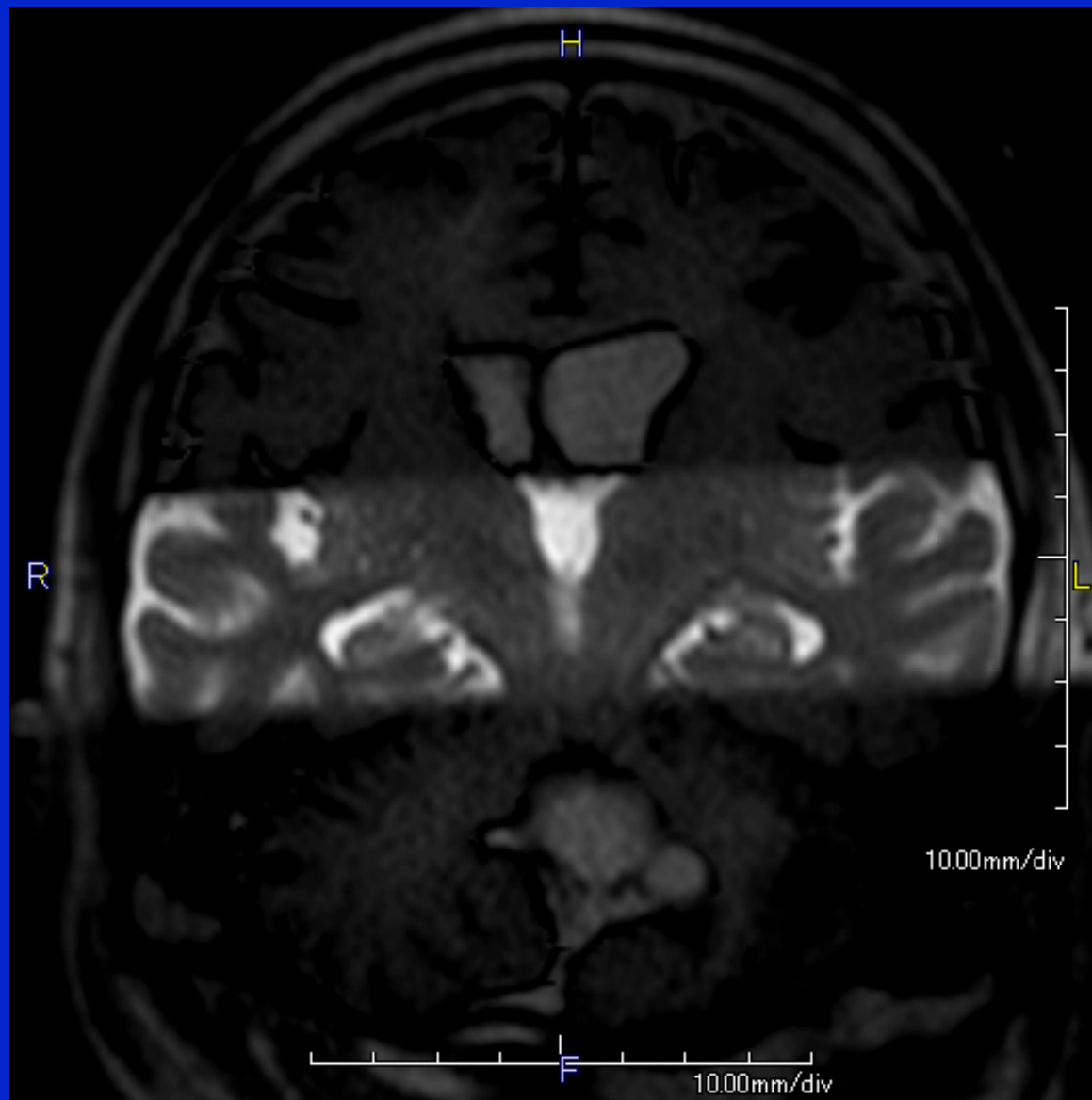


**Hydrocephalus (iNPH)**  
**After insertion of a ventriculo-peritoneal shunt**



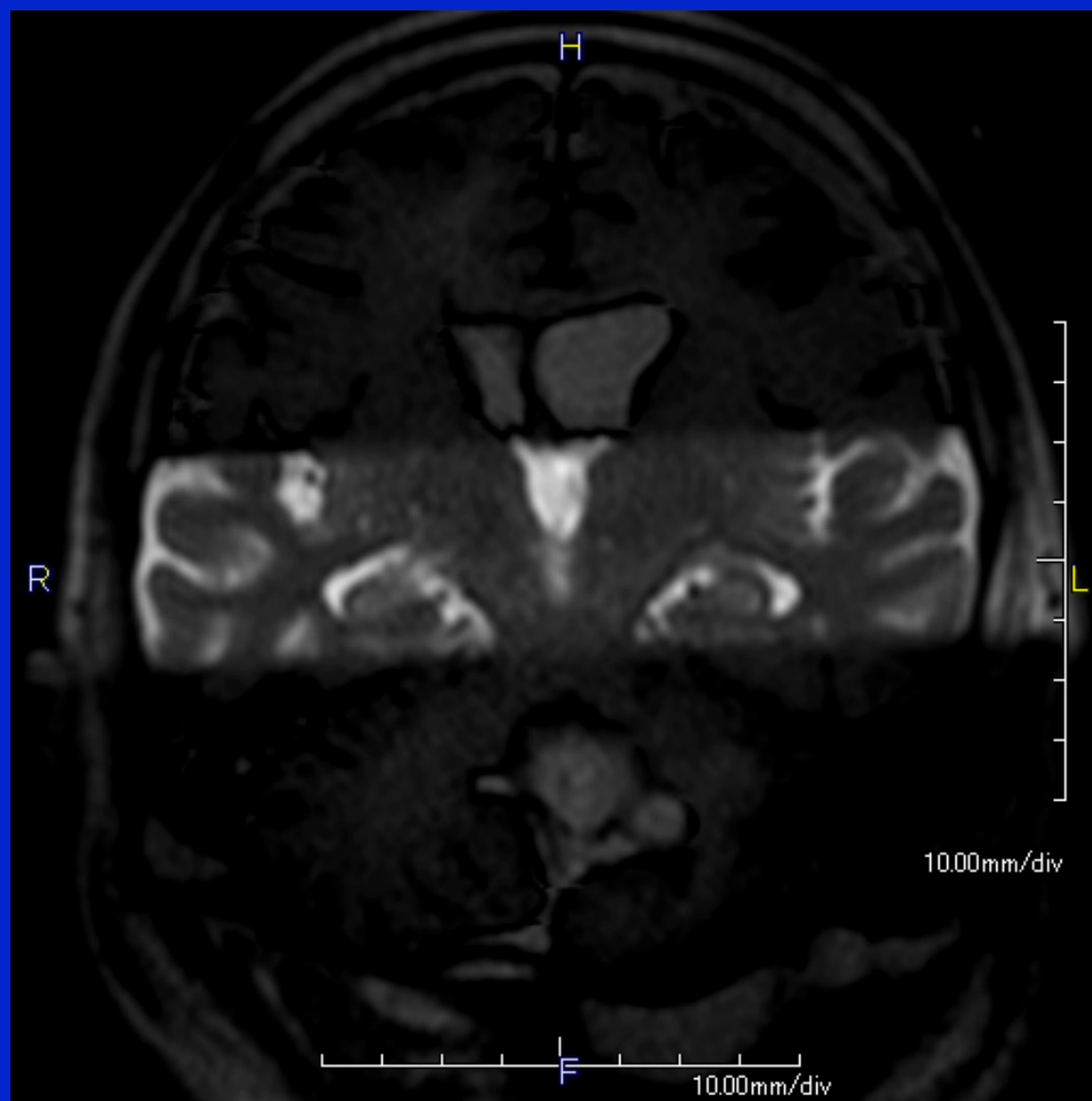
# Non-Communicating Hydrocephalus

A ventriculostomy, placed at the time of surgery, was clamped prior to acquiring these images



## Non-Communicating Hydrocephalus

Same patient, but after aspirating 5cc of CSF via the ventriculostomy



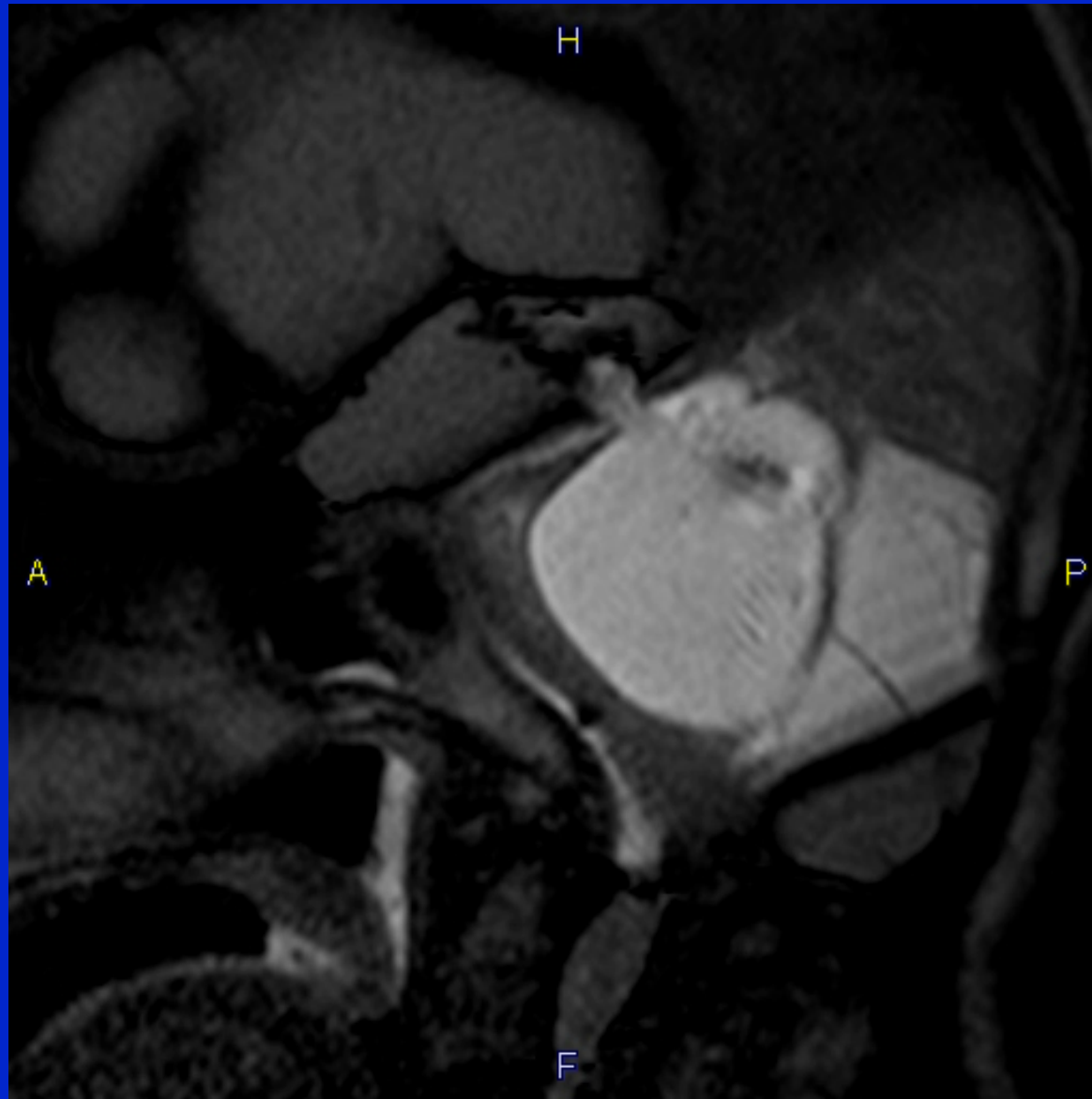


## Communicating Hydrocephalus after subarachnoid hemorrhage

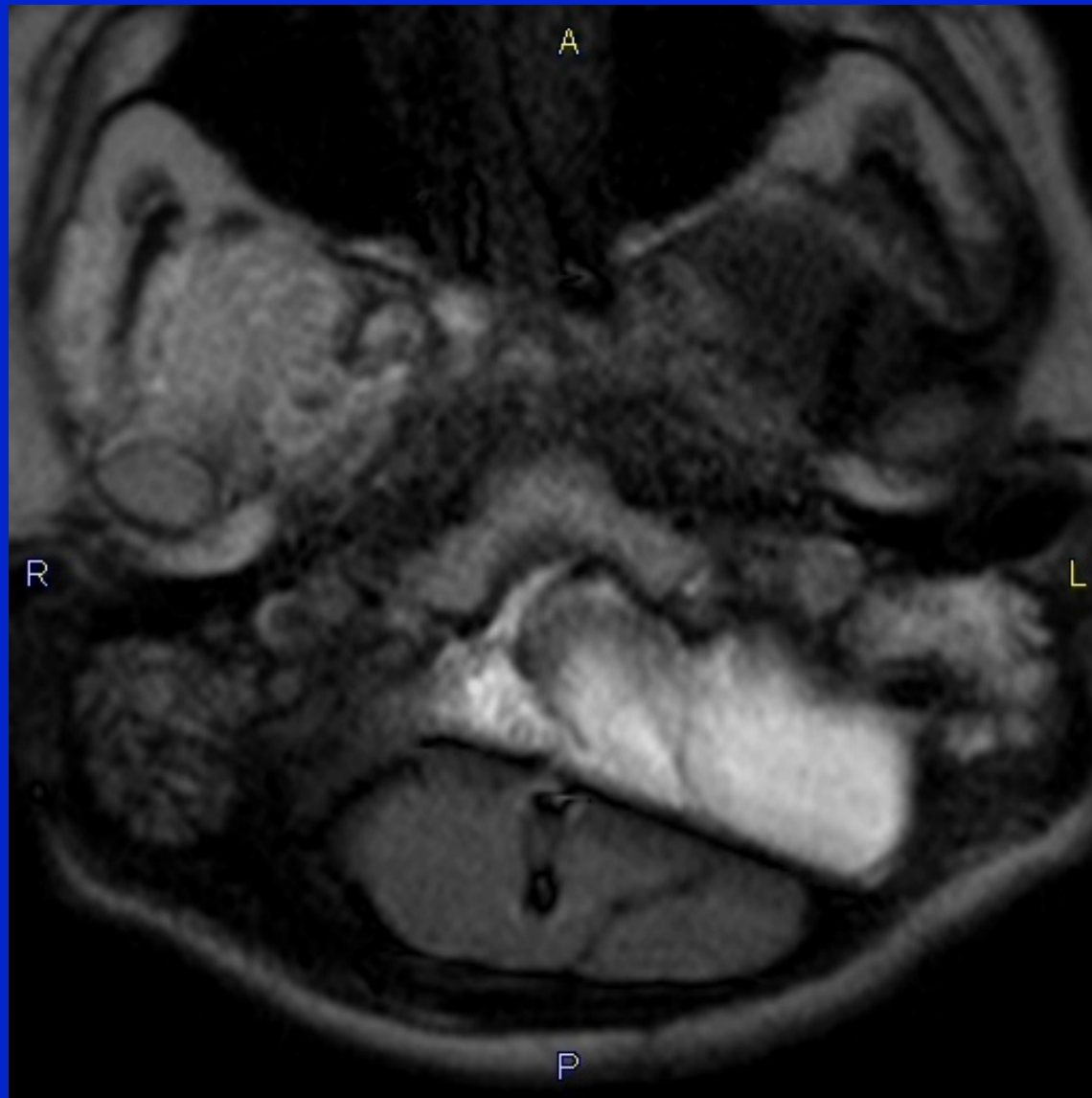




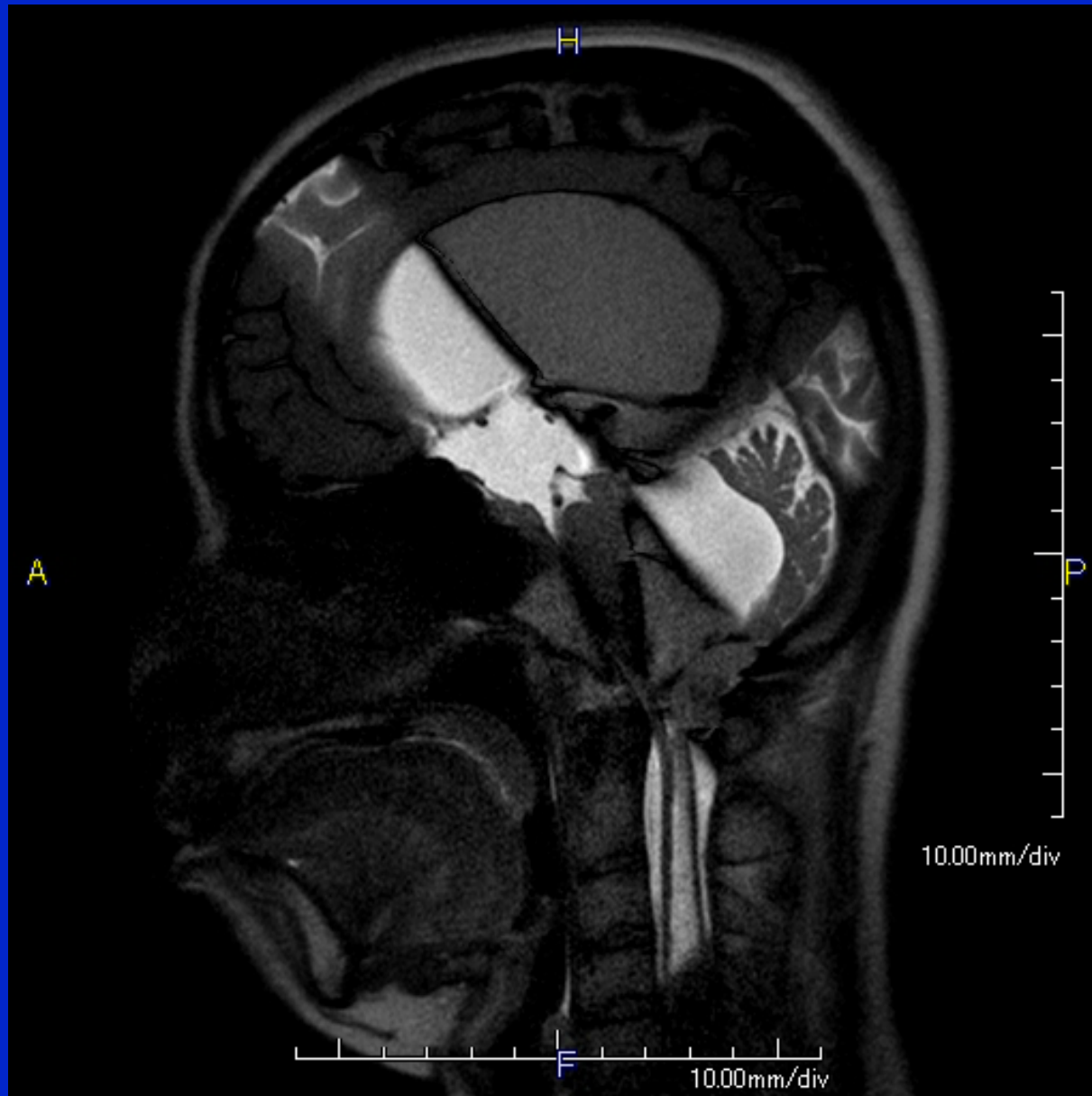
# Post-traumatic Hydrocephalus



# Post-traumatic Hydrocephalus

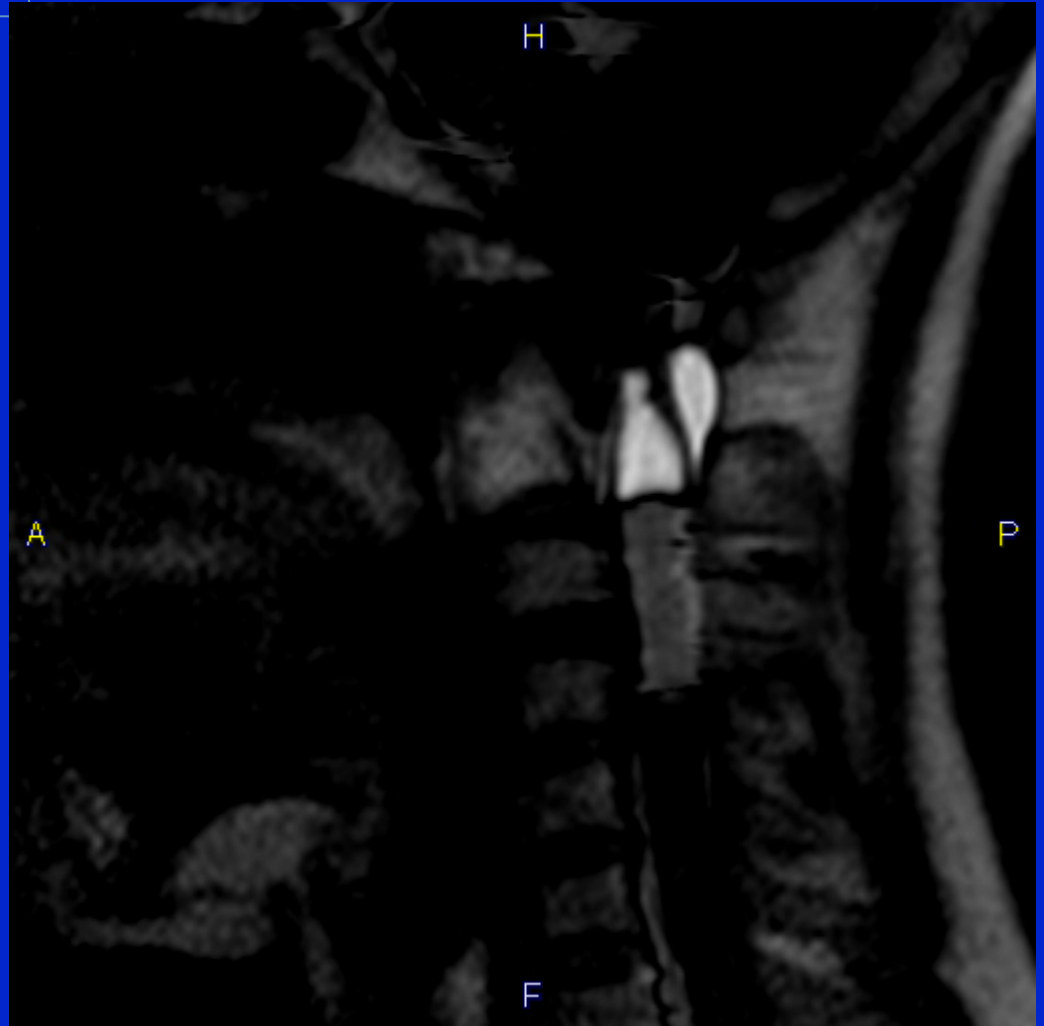
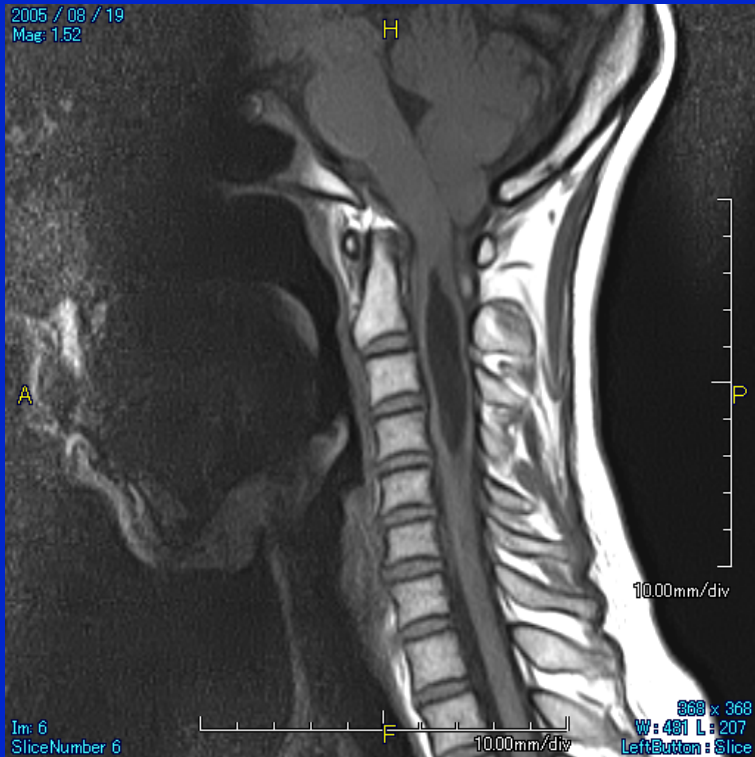


# Hydrocephalus associated with syringomyelia



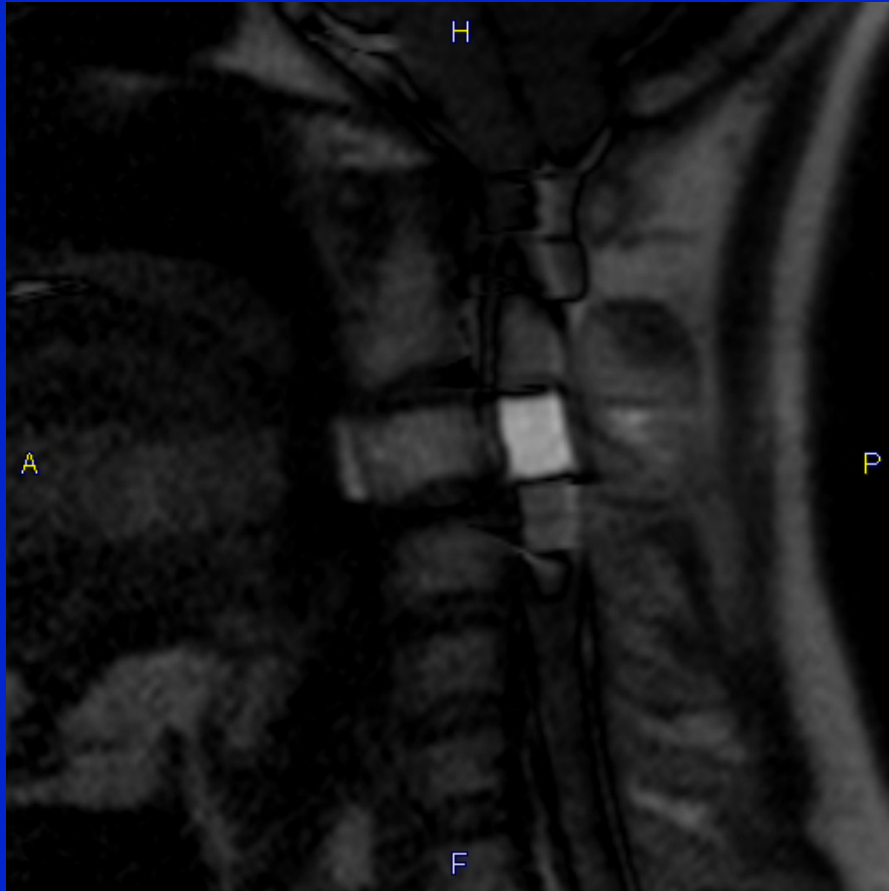
# SYRINGOMYELIA

## Chiari I malformation

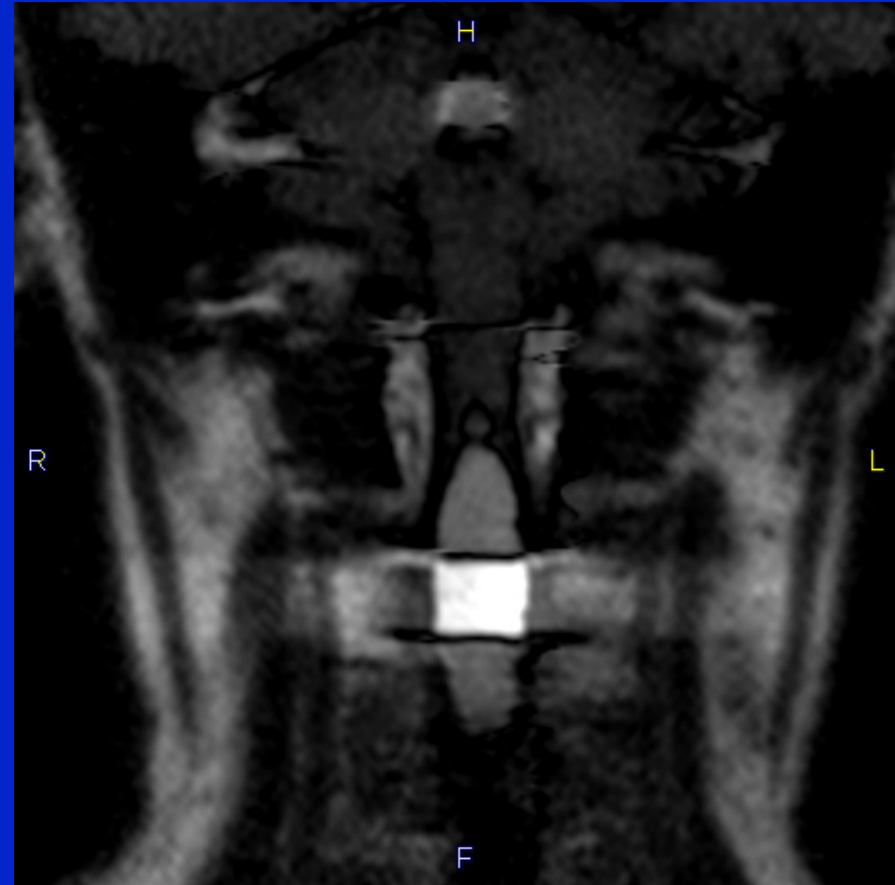


**CSF flow  
at the Cranio-cervical junction**

# CSF Flow in the Syrinx

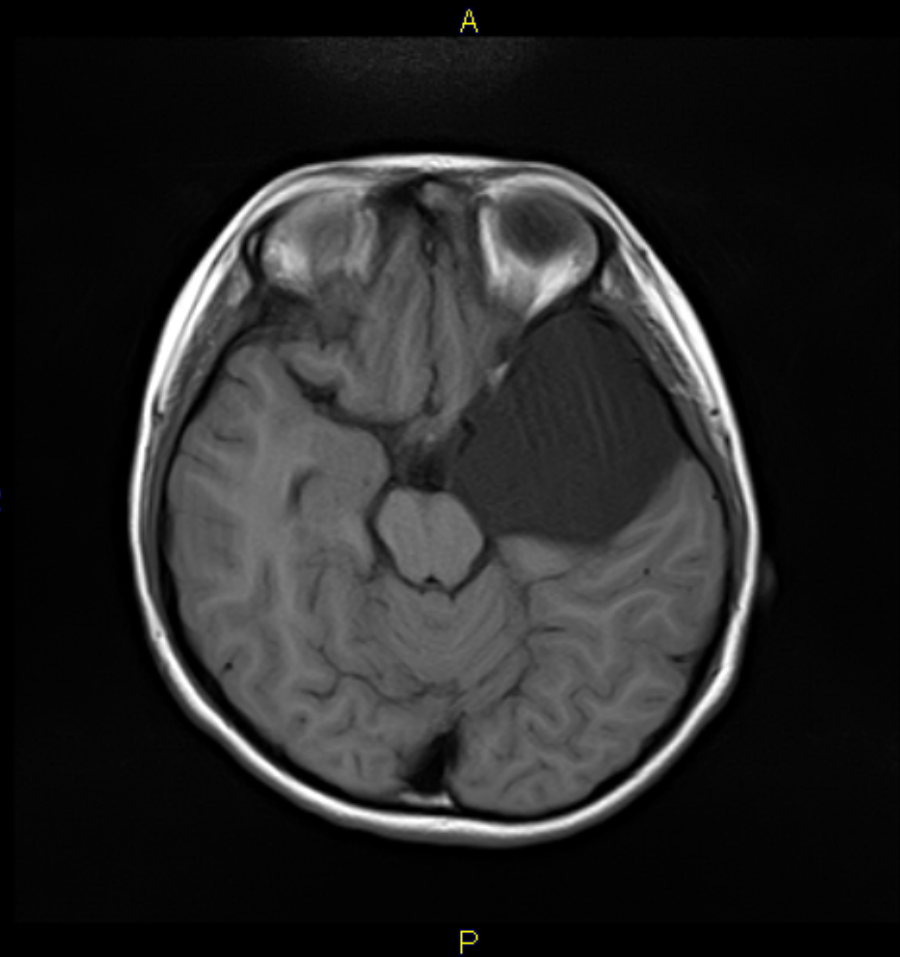
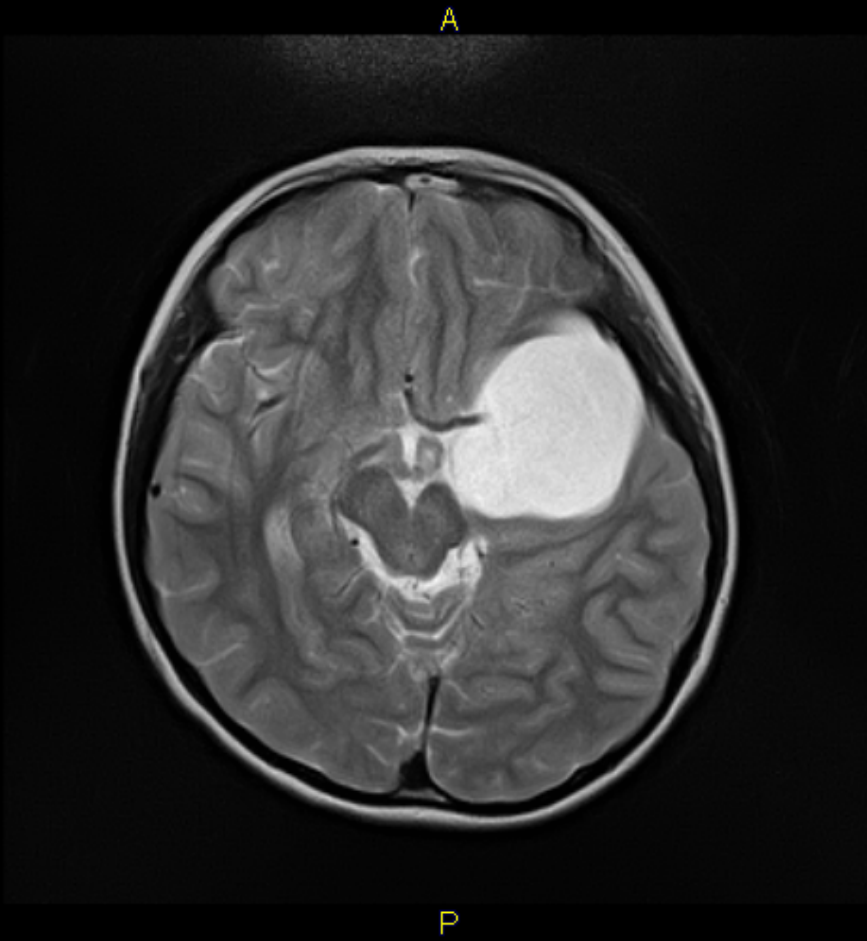


**Sagittal view**



**Coronal view**

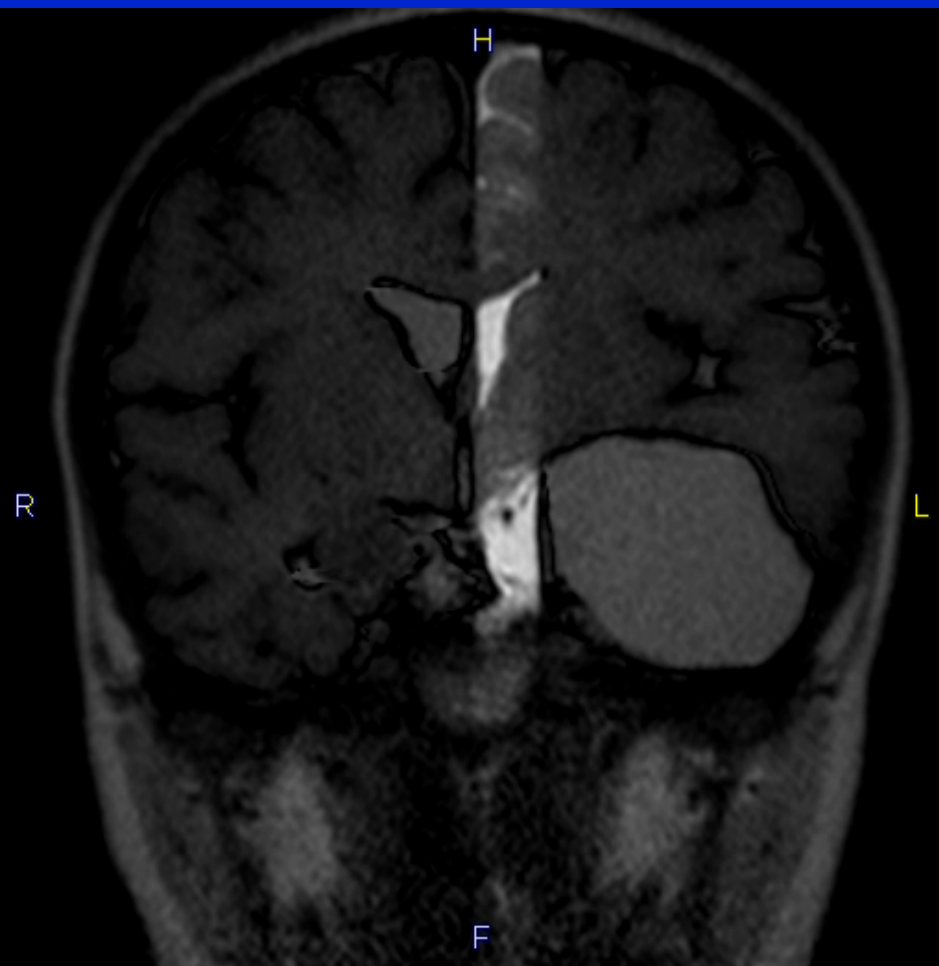
# Lt. Temporal Arachnoid Cyst



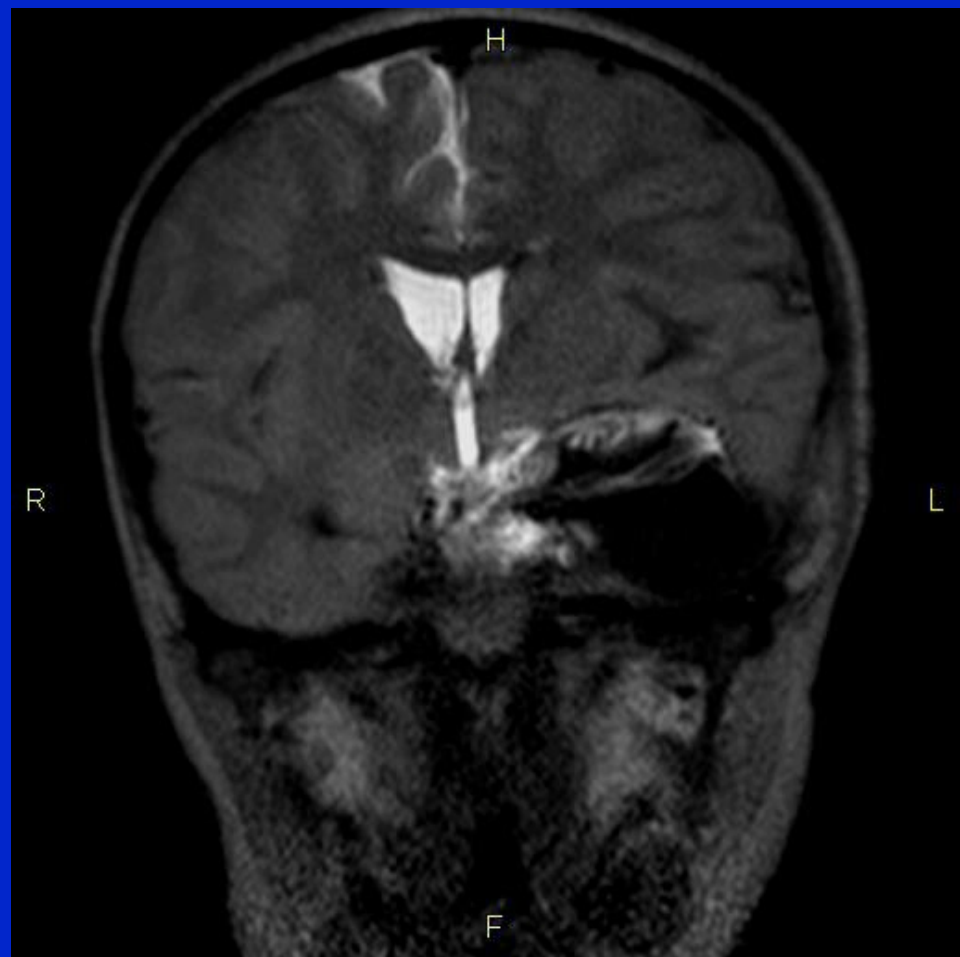
**7 Y/O Male**



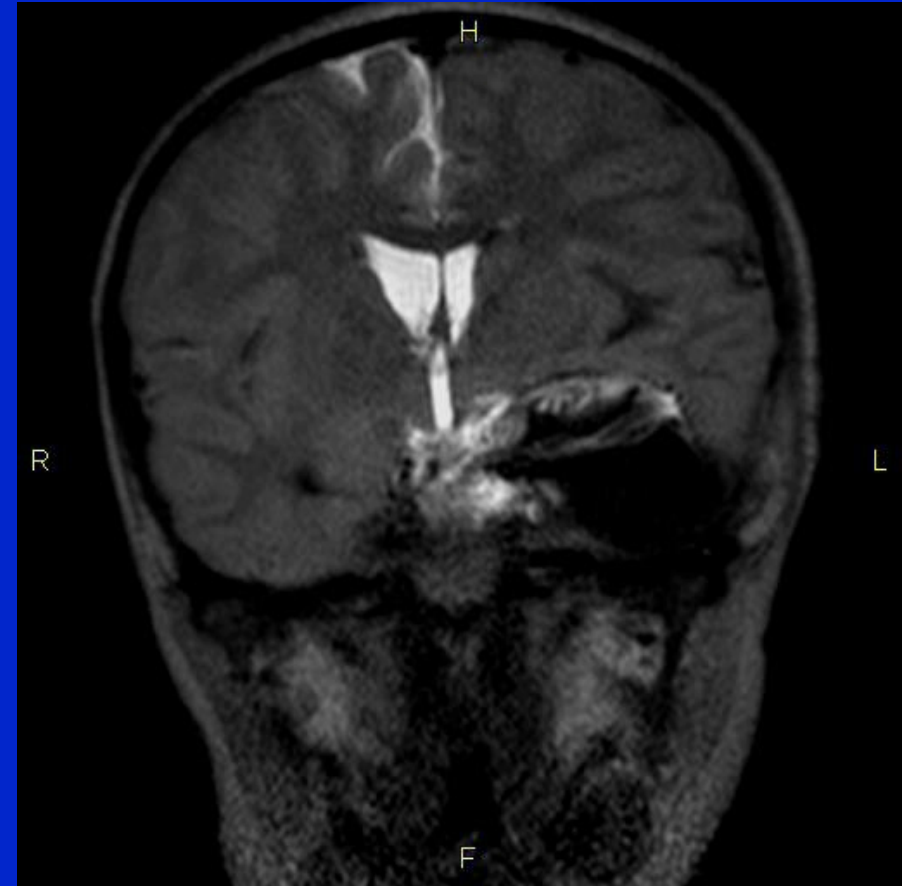
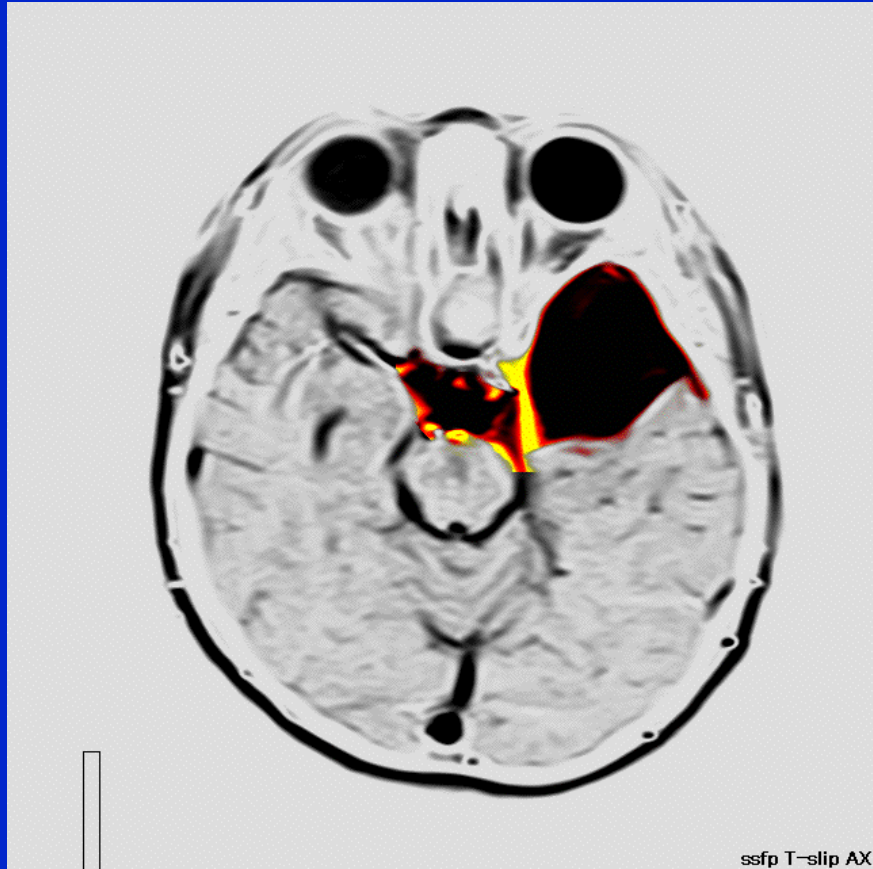
Pre Op.



PostOp.



## Post Op





# SUMMARY

- **Time-SLIP technique enables observation of pulsatile and turbulent CSF flow under normal and pathophysiologic conditions.**
- **Will enable further understanding of hydrocephalus and its treatment.**