Advanced imaging of cerebrospinal fluid

-Time spatial labeling inversion pulse technique (Time-SLIP)-

S Yamada[1], S Matsumoto[2], M Miyazaki[3], T Yamaoto[4], M YUi[4], T Shiodera[5], T Takeguchi[5], J. Gordon McComb[6].

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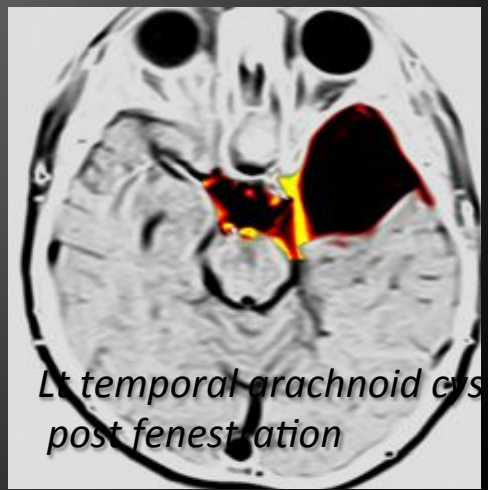
Conflict of Interest

S Yamada: *Employee : Toshiba Rinkan Hospital*

S. Matsumoto
M. Miyazaki
T. Yamaoto
M. Yui *Employee: Toshiba medical systems*

T. Shiodera
T. Takeguchi *Employee: Toshiba Corp.*

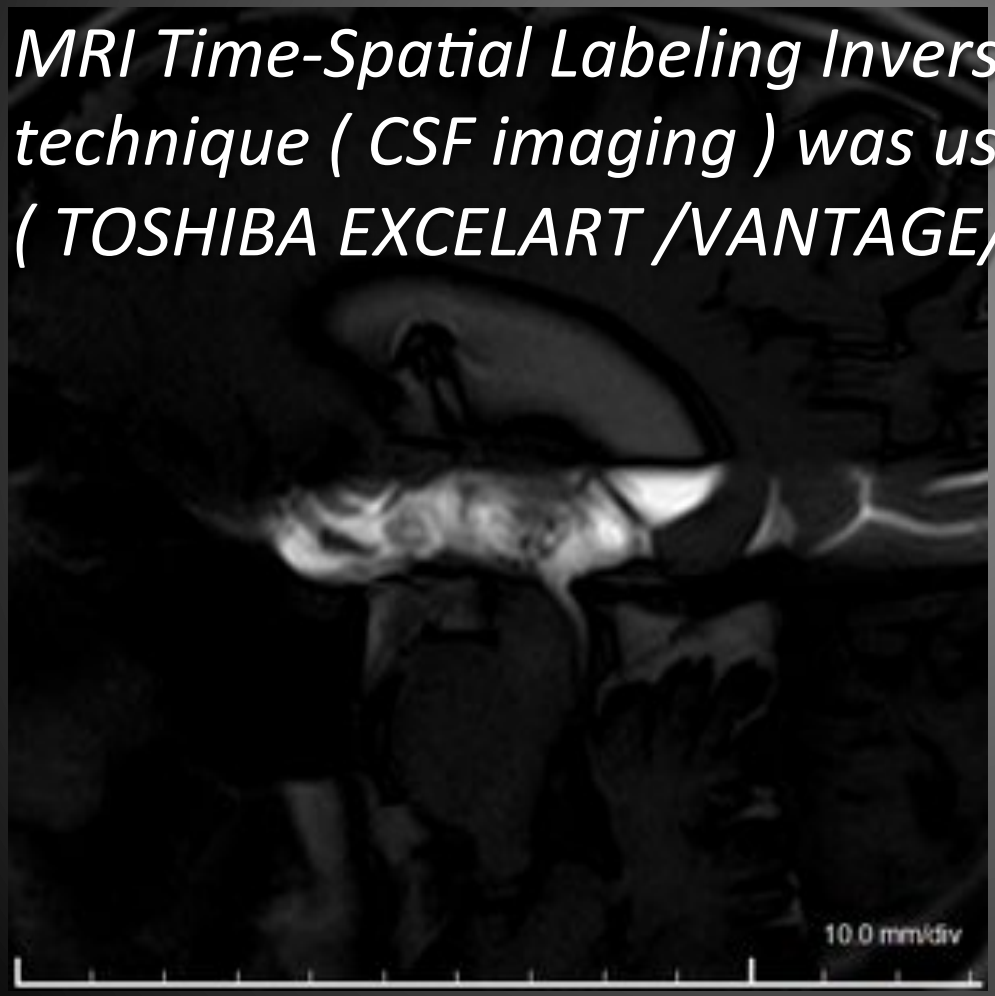
J. Gordon McComb[6] *No Conflict of interest*

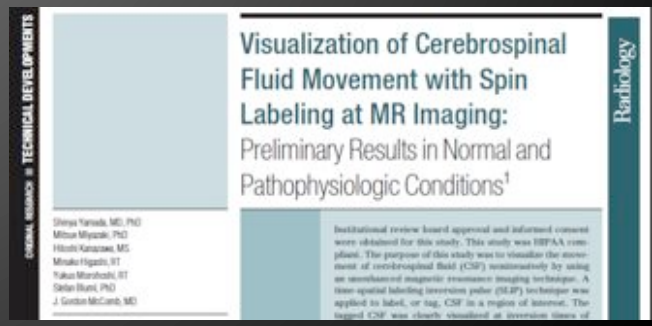


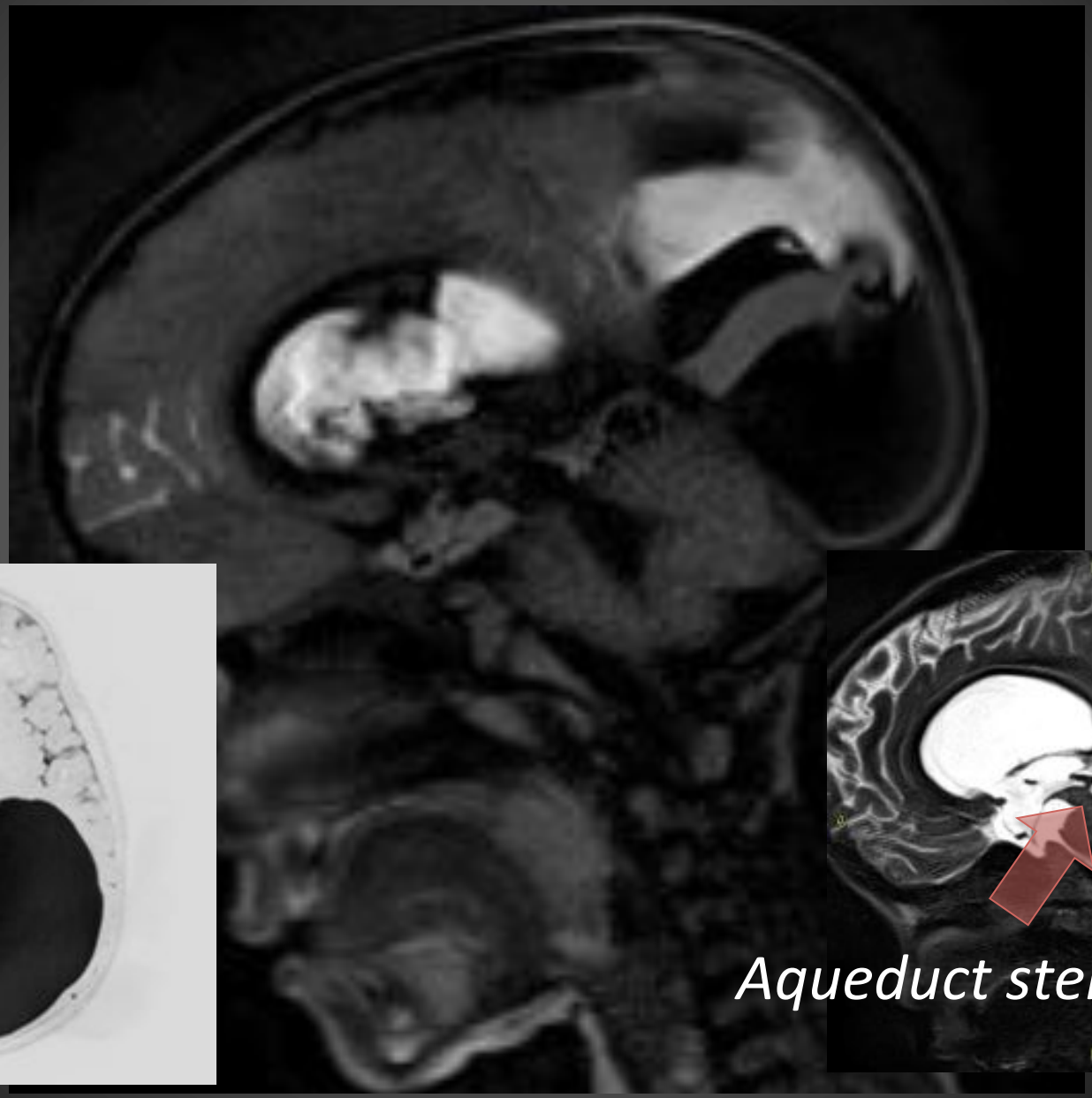
CSF Dynamics imaging

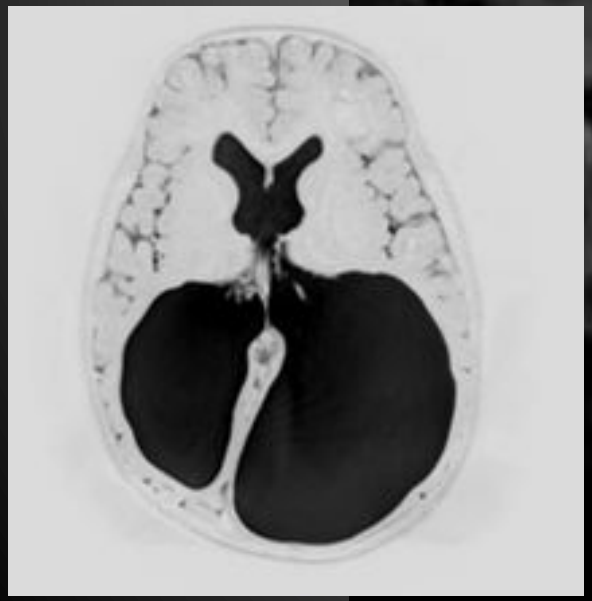
Technique

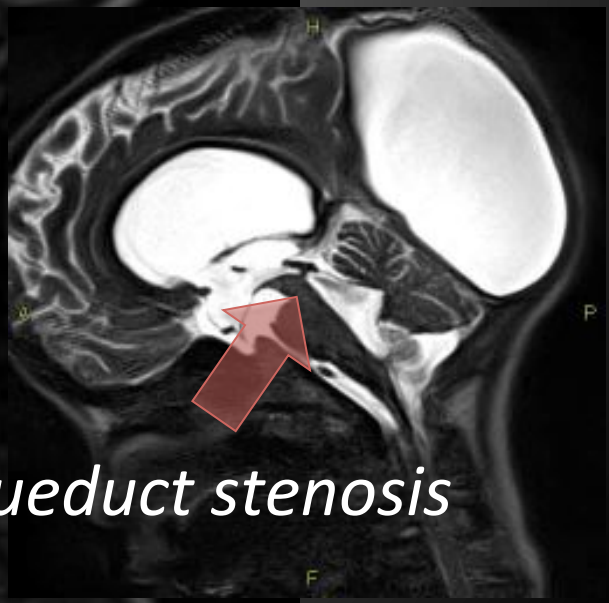
MRI Time-Spatial Labeling Inversion Pulse (Time-Slip) technique (CSF imaging) was used in this study.
(TOSHIBA EXCELART /VANTAGE/TITAN)





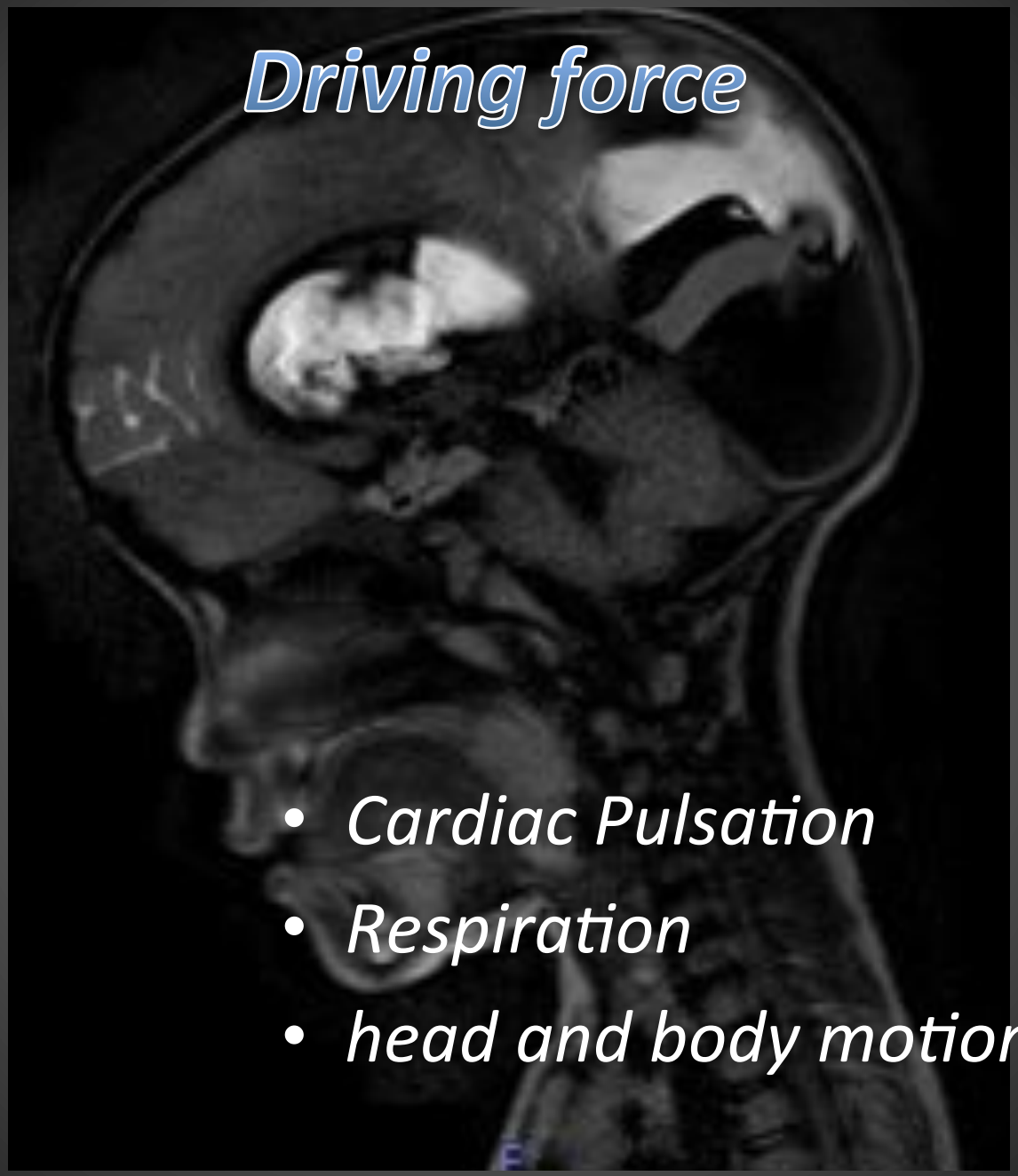






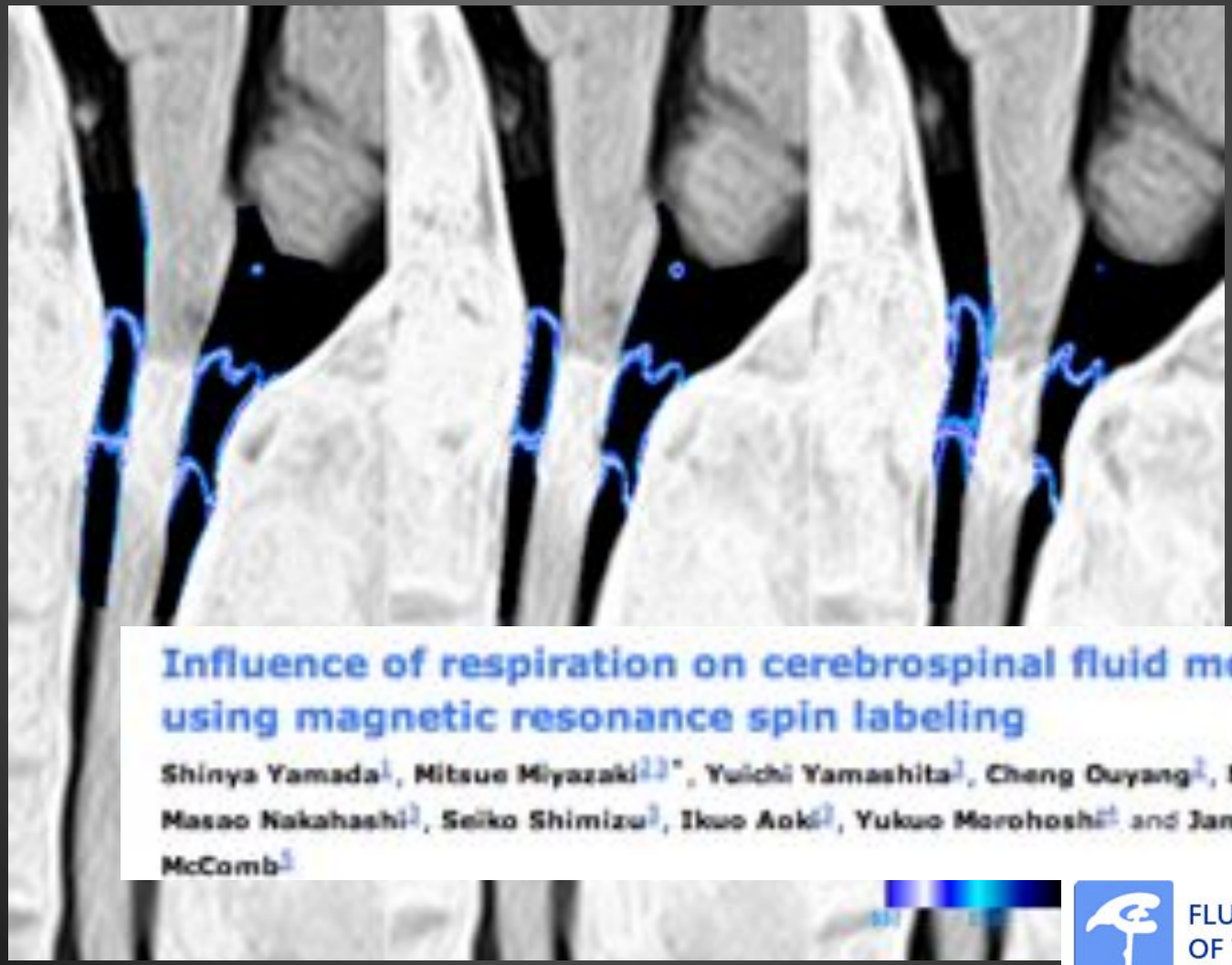
Aqueduct stenosis

Driving force



- *Cardiac Pulsation*
- *Respiration*
- *head and body motion*

Cardiac Pulsation (during breath hold)

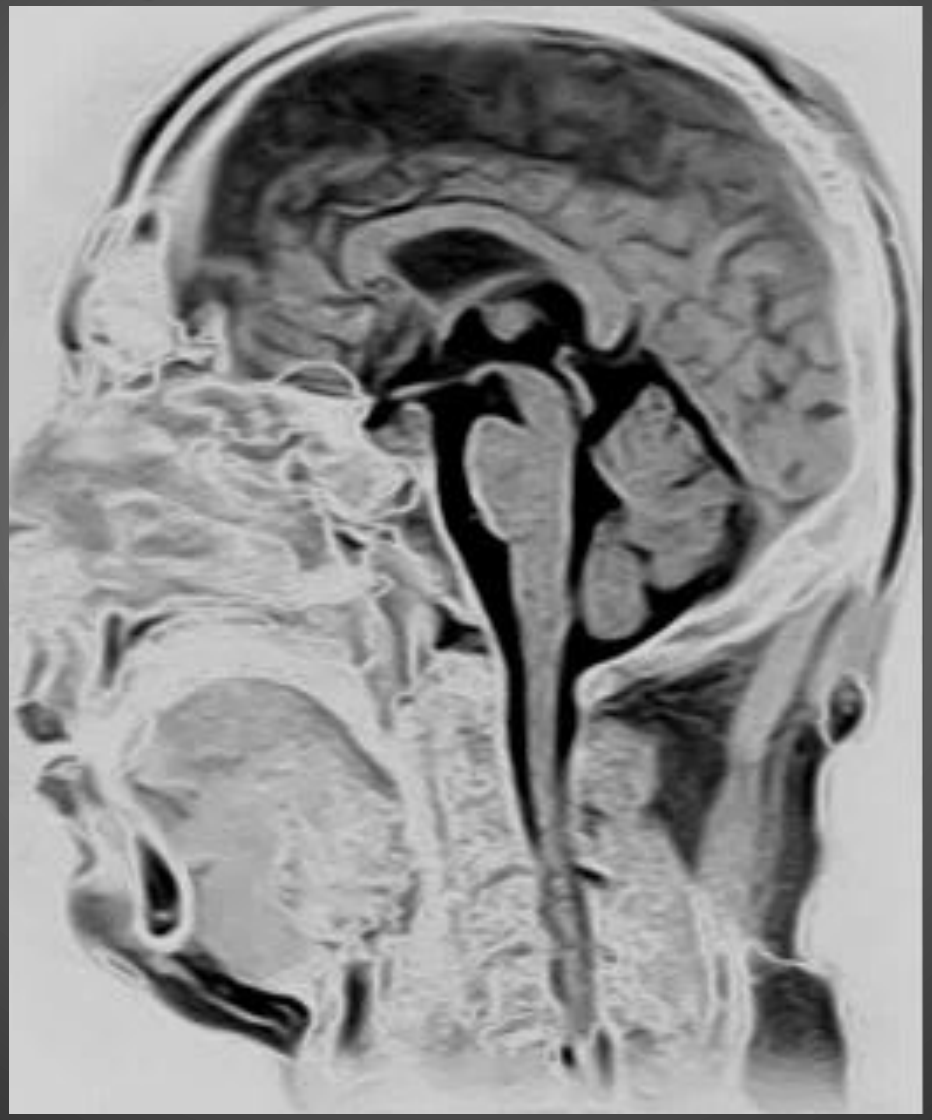


Influence of respiration on cerebrospinal fluid movement using magnetic resonance spin labeling

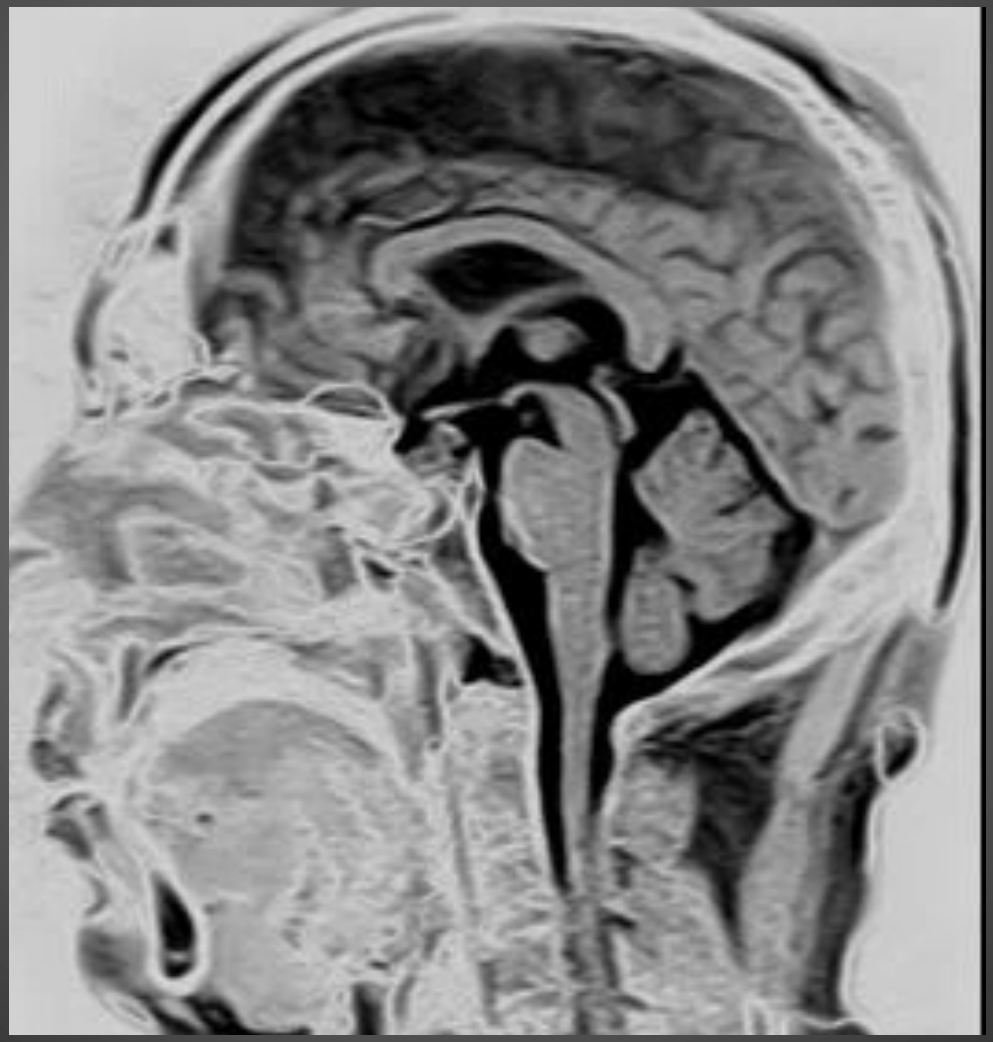
Shinya Yamada[1], Mitsue Miyazaki[1,2]*, Yuichi Yamashita[1], Cheng Ouyang[1], Masao Yui[1], Masao Nakahashi[1], Seiko Shimizu[1], Ikuo Aoki[1], Yukuo Morohoshi[1] and James Gordon McComb[1]

FLUIDS AND BARRIERS OF THE CNS

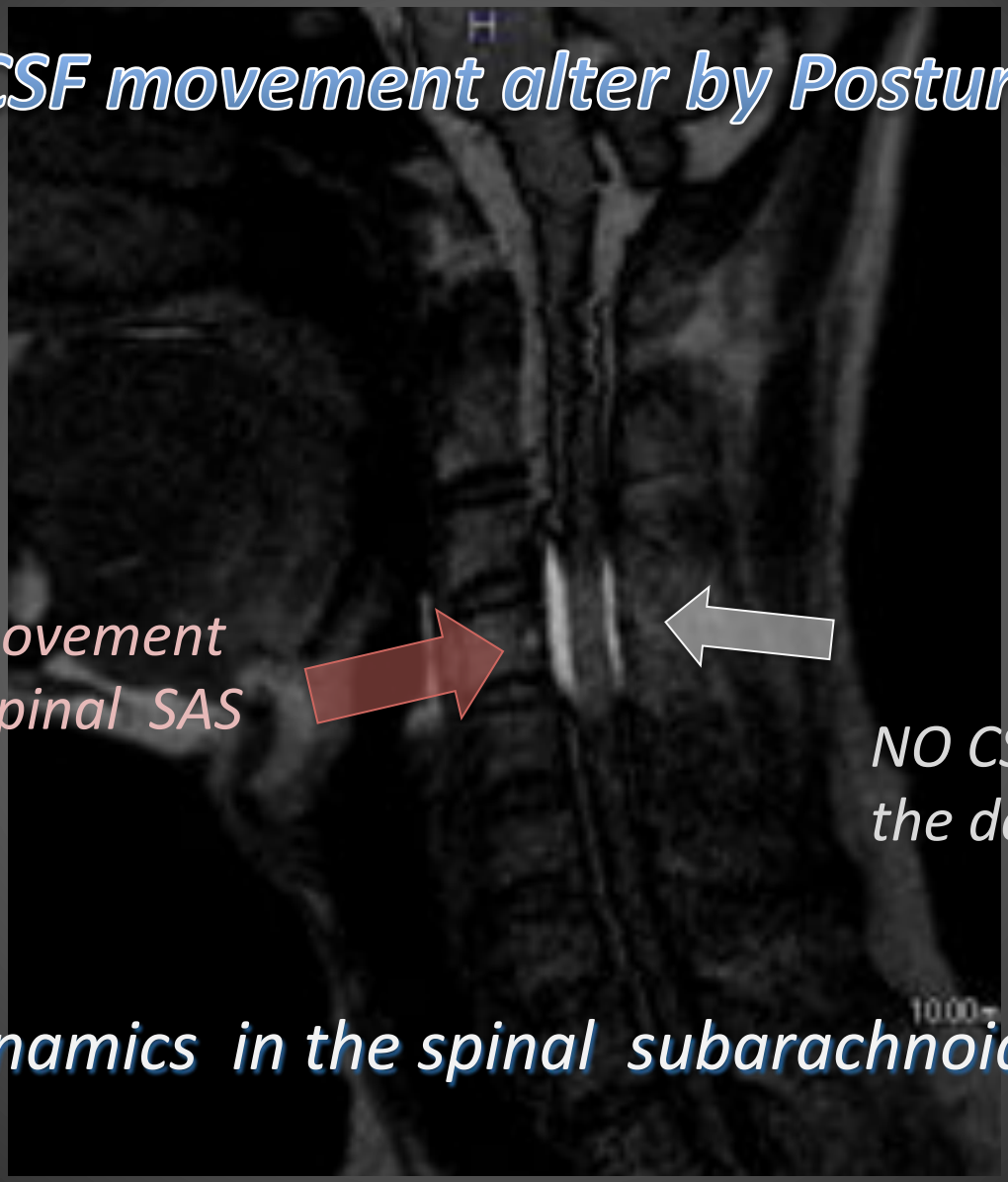
Deep Breath (inhalation)



Deep Breath exhalation



Does CSF movement alter by Posture ?



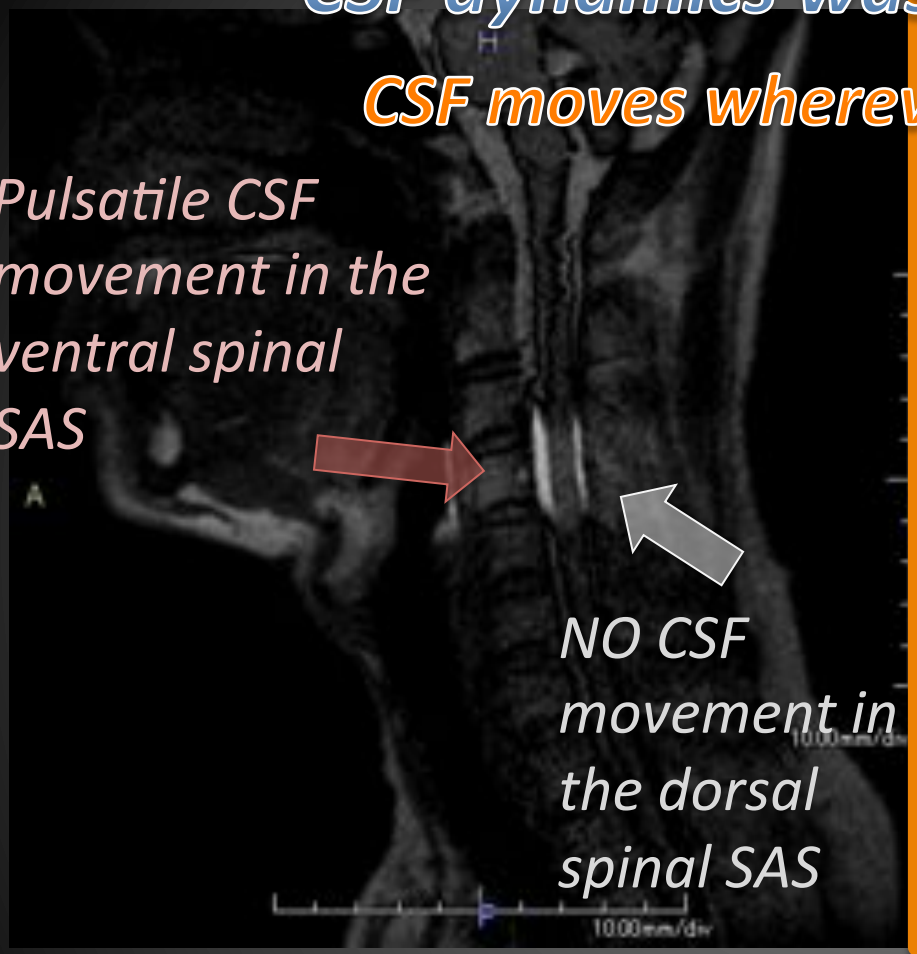
Pulsatile CSF movement in the ventral spinal SAS

NO CSF movement in the dorsal spinal SAS

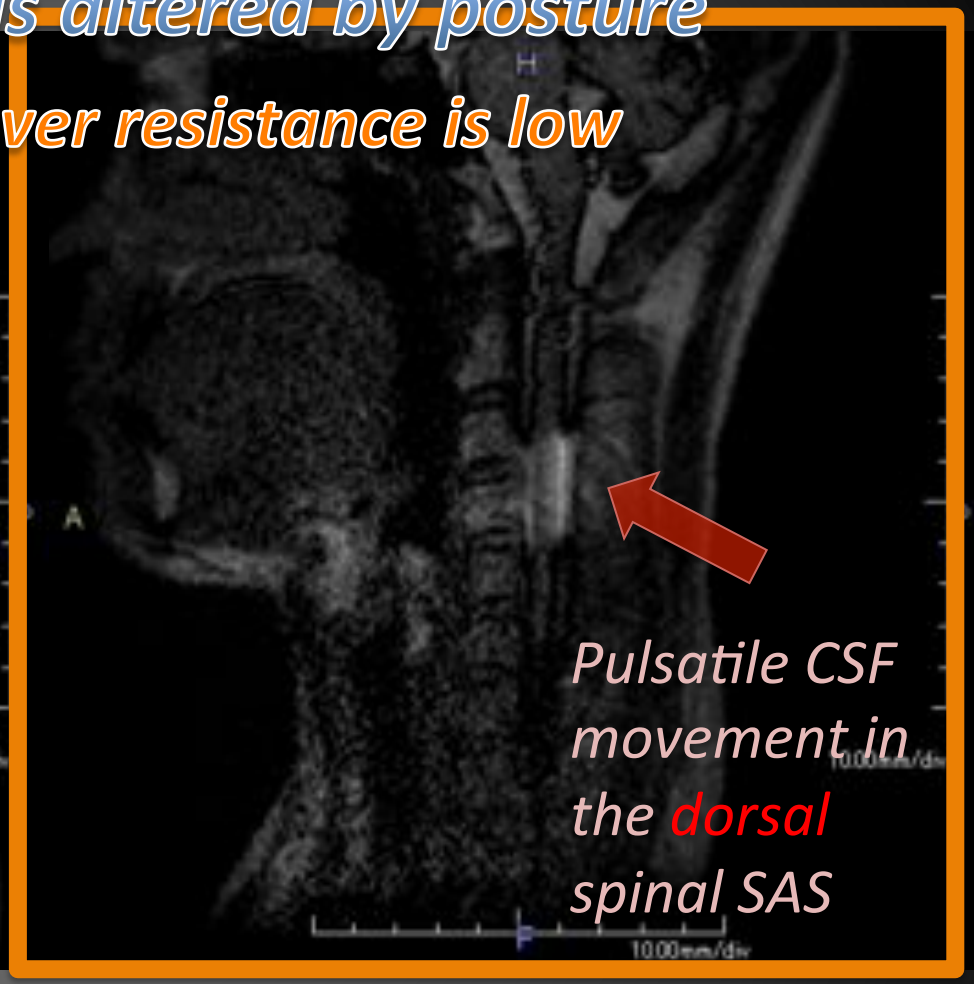
CSF dynamics in the spinal subarachnoid space

CSF dynamics was altered by posture

CSF moves wherever resistance is low

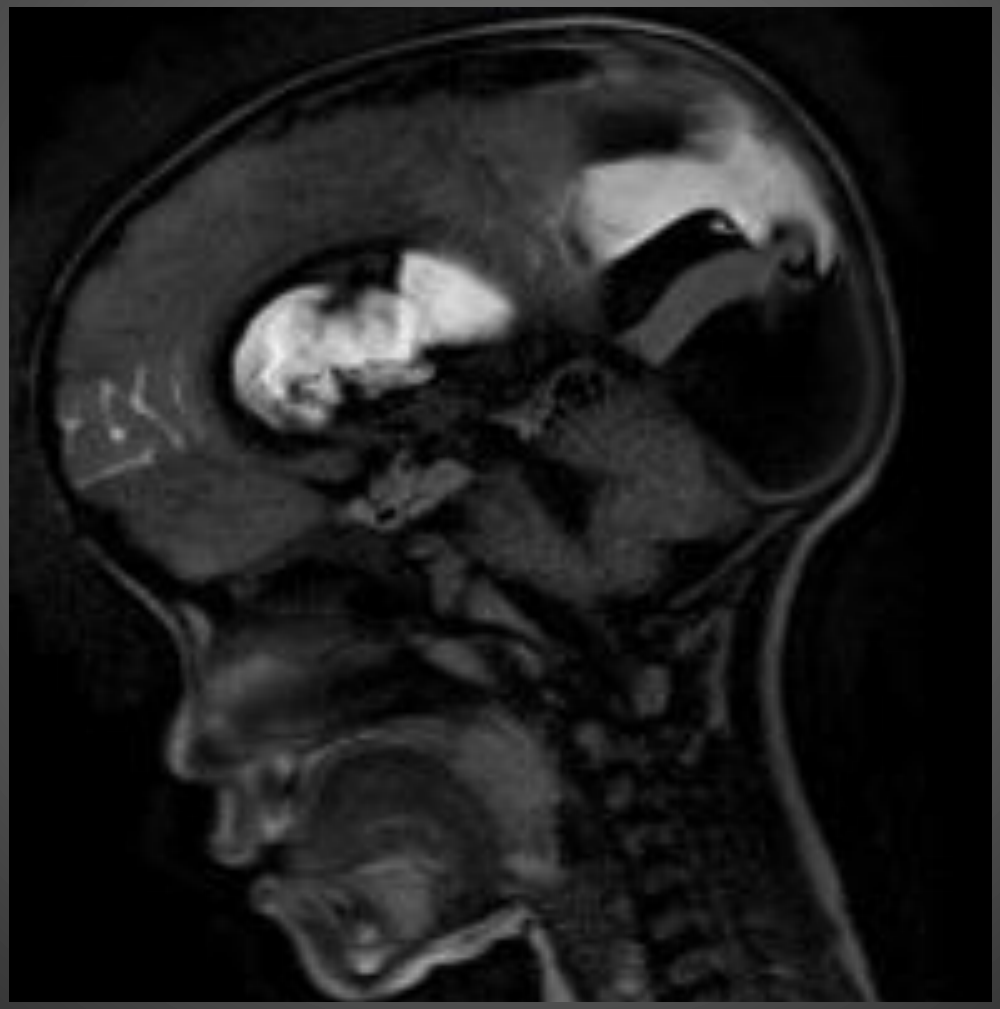


Supine position

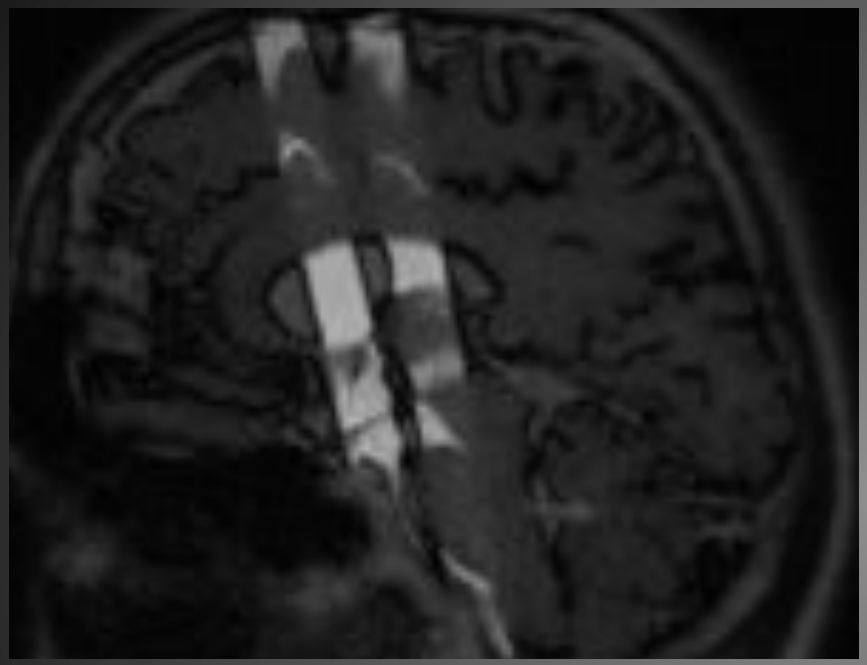


Prone position

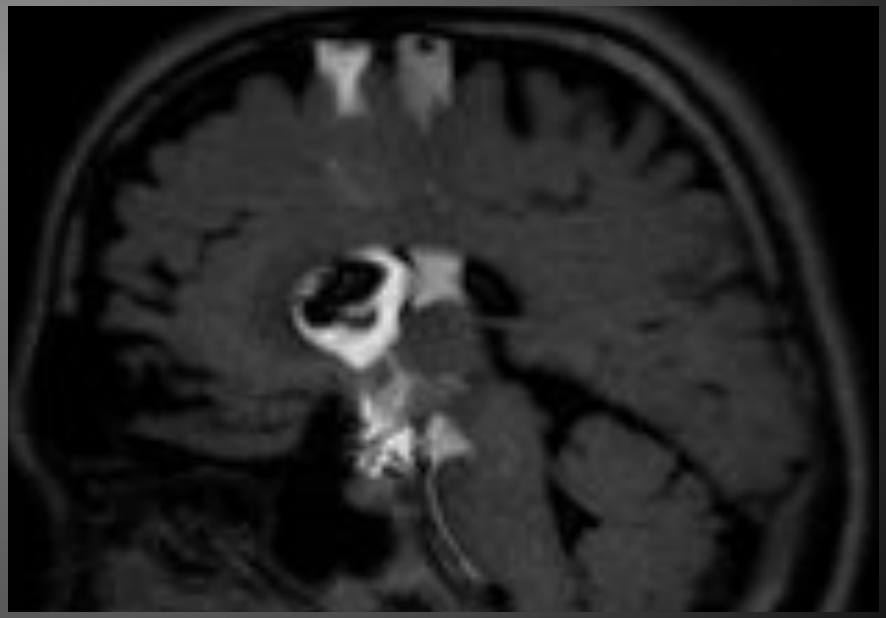
- *Head motion (inertia)*



Head motion produces additional CSF movement.

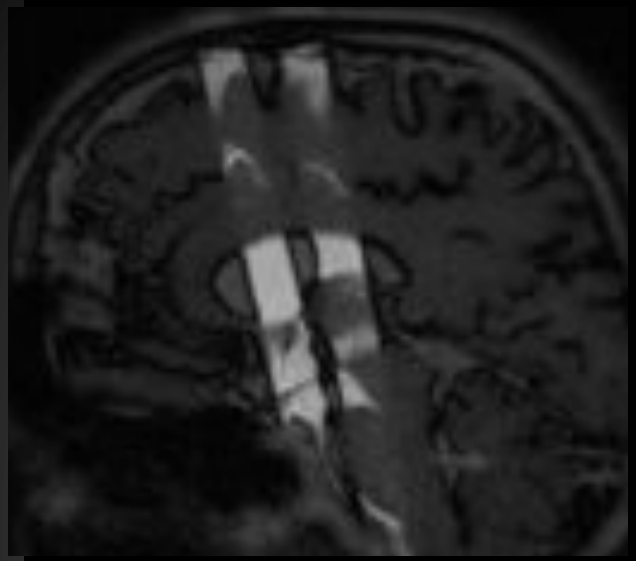


head stationary



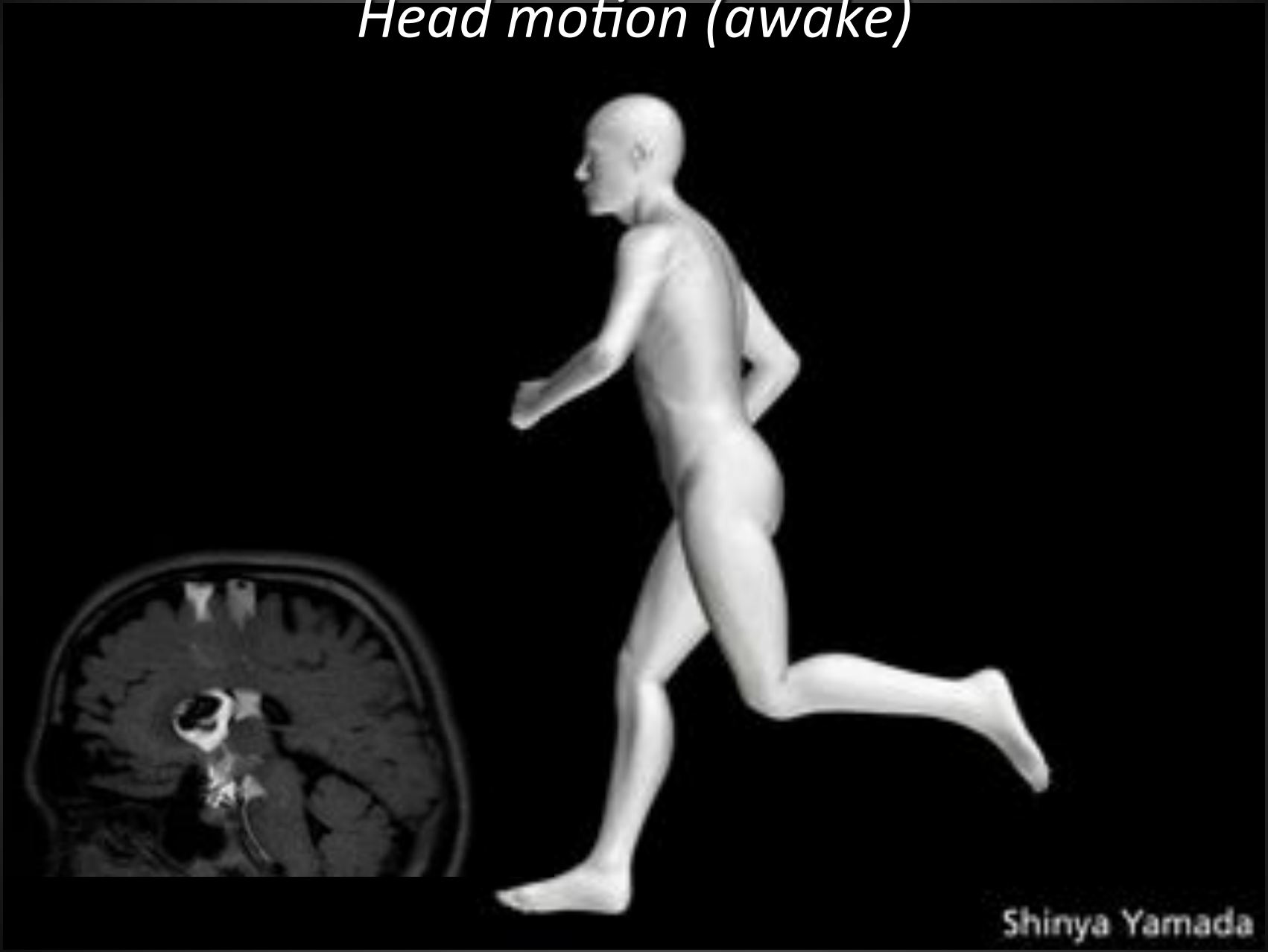
head motion

Head Stationary (sleep)



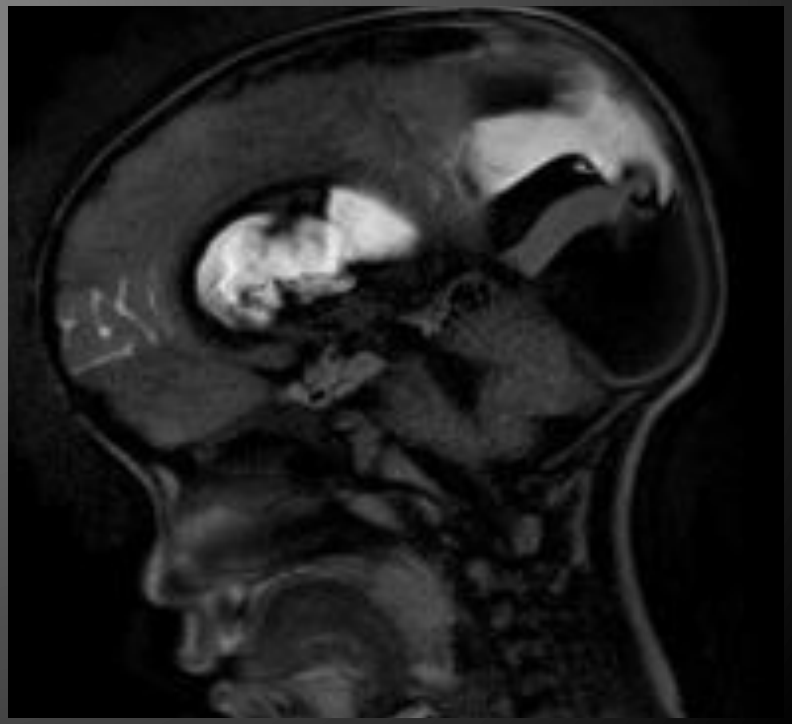
Shinya Yamada

Head motion (awake)



Conclusions:

Significant amount CSF was moved by cardiac pulsation, respiration and head inertia.



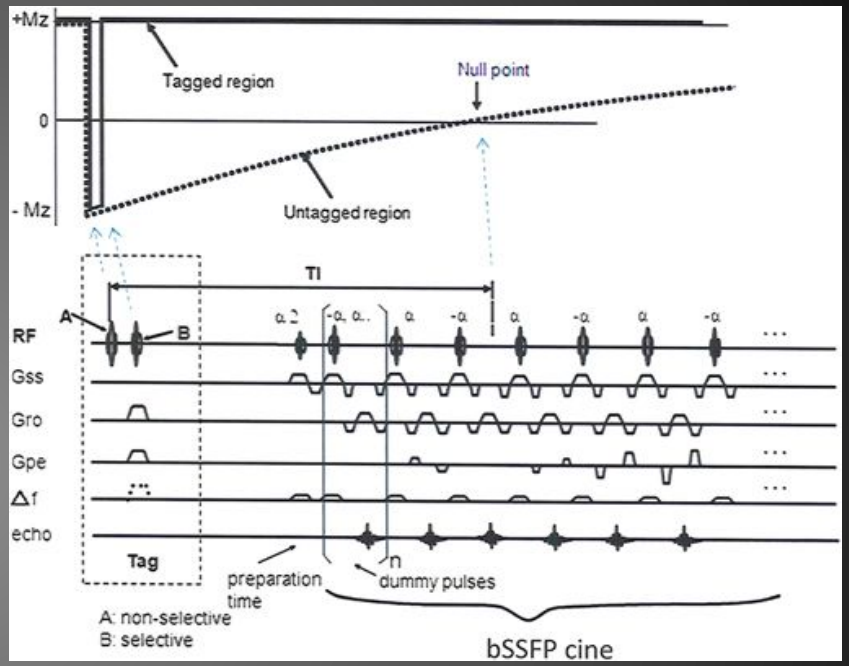
Time-SLIP: Technical Developments

CSF driving forces are more than one

Real Time CSF Dynamics Imaging

Material and Method

MRI Time-Slip technique with b-SSFP was used in this study. (TOSHIBA EXCELART / VANTAGE/TITAN)

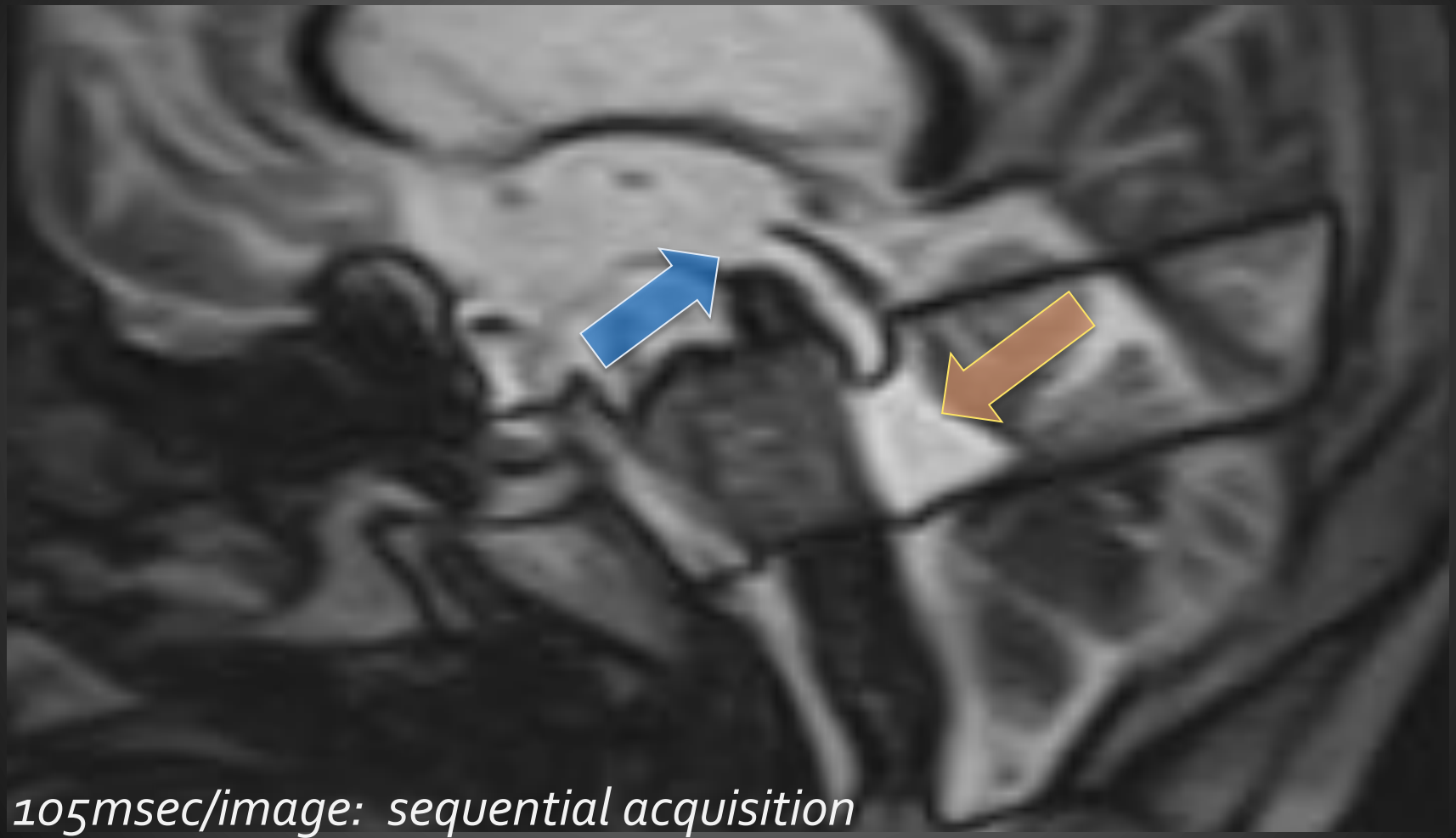


Gate Free Time-SLIP Real Time Imaging

105msec/frame: approximately 50images/5sec

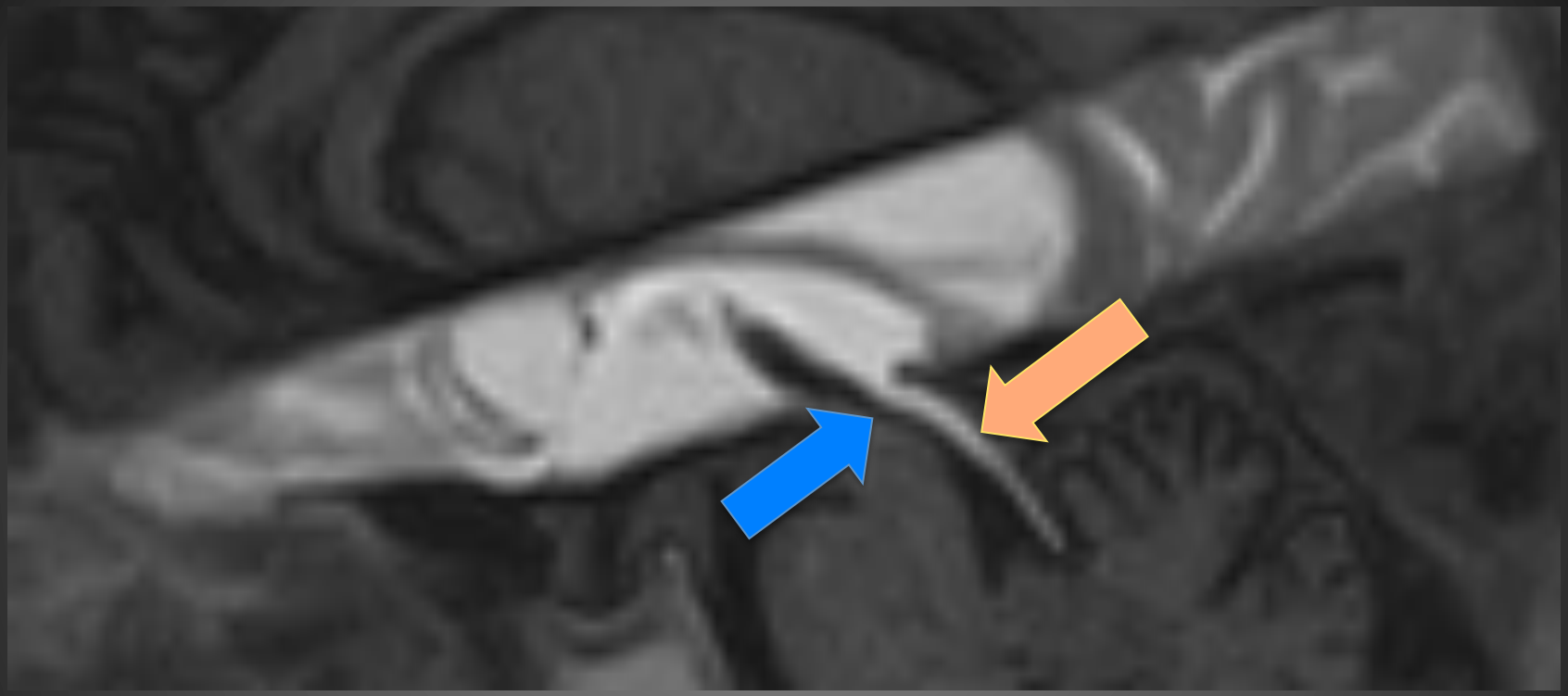
Spin magnetization (top) and sequence diagram (bottom). The sequence diagram (bottom) shows Time-SLIP with two-dimensional cine bSSFP. The corresponding magnetization states (top) of signals covered by the non-selective pulse (A) and the selective tagged pulse (B) are presented. An initial non-selective pulse (A) inverts all magnetizations within a radiofrequency coil, followed by a selective pulse (B) that restores the magnetization at + Mz in a plane that can be placed freely in any orientation. The untagged background signals, receiving only the non-selective inversion recovery (IR) pulse return to + Mz by following T1 recovery relaxation, as shown in the dotted line. After waiting, a TI, cine bSSFP read-out is acquired. When the untagged signals reach a null point, the tagged signals and the untagged signals have maximum contrast and thus they are well differentiated.

Real time CSF Dynamics Imaging

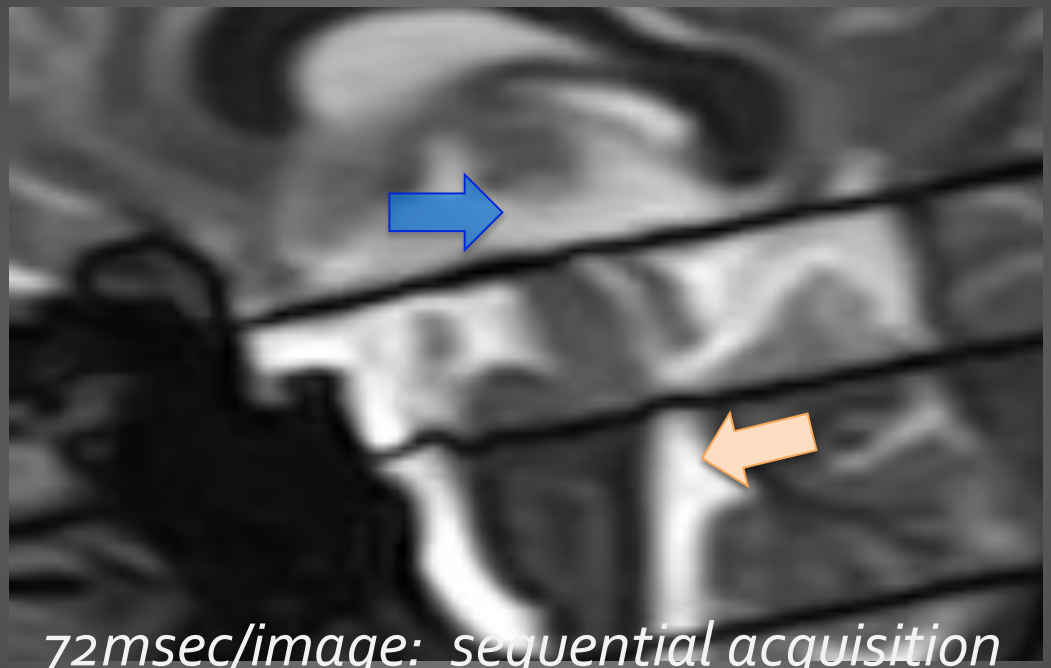


105msec/image: sequential acquisition

Simultaneous bidirectional CSF movement in the aqueduct ?



Simultaneous bi-directional CSF movement in the aqueduct

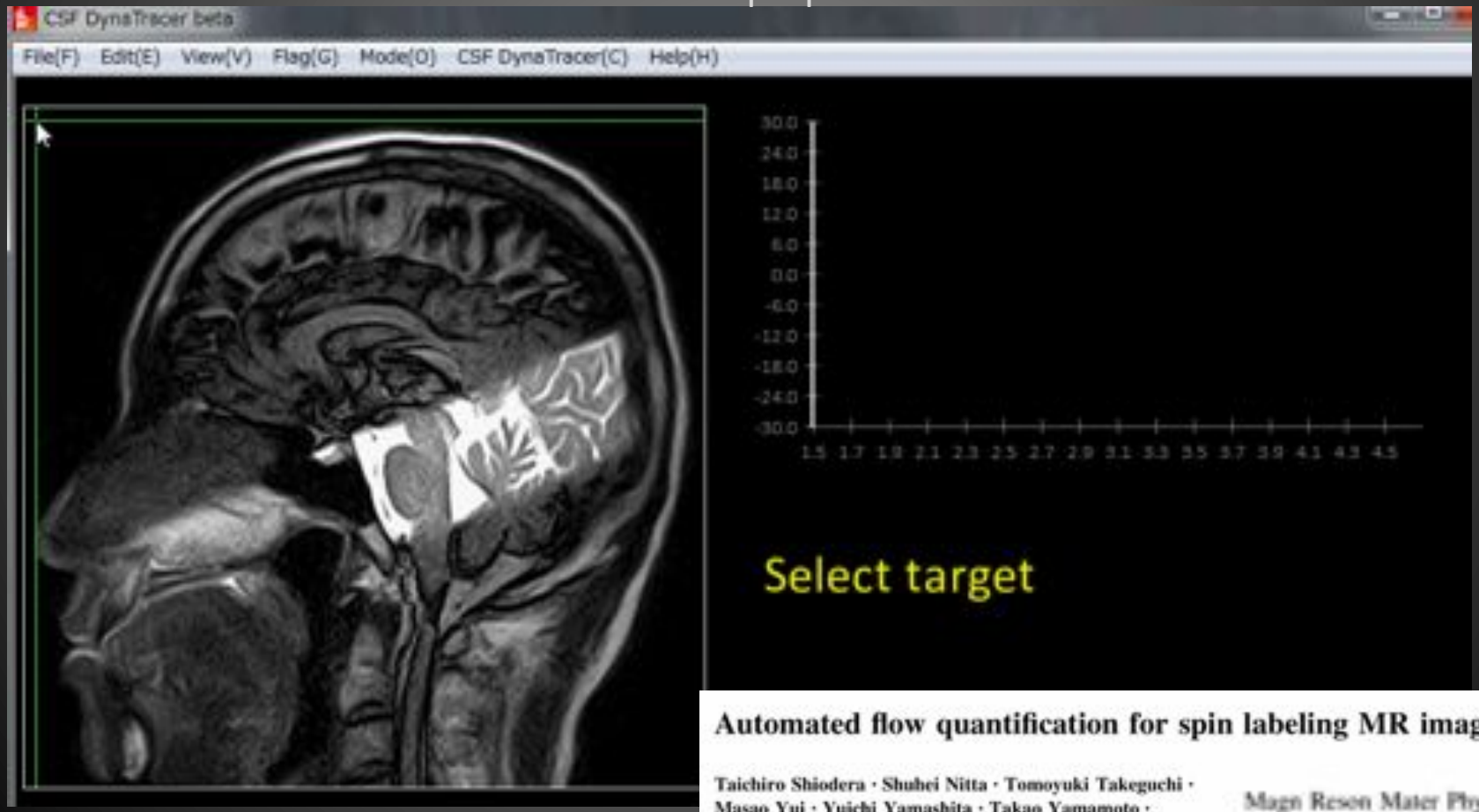


72msec/image: sequential acquisition

Real Time CSF Dynamics Imaging

Automated quantification of CSF dynamics (Dynatracer)

algorisms for three different lesions : foramen Monro
aqueduct of Sylvius
prepontine cistern

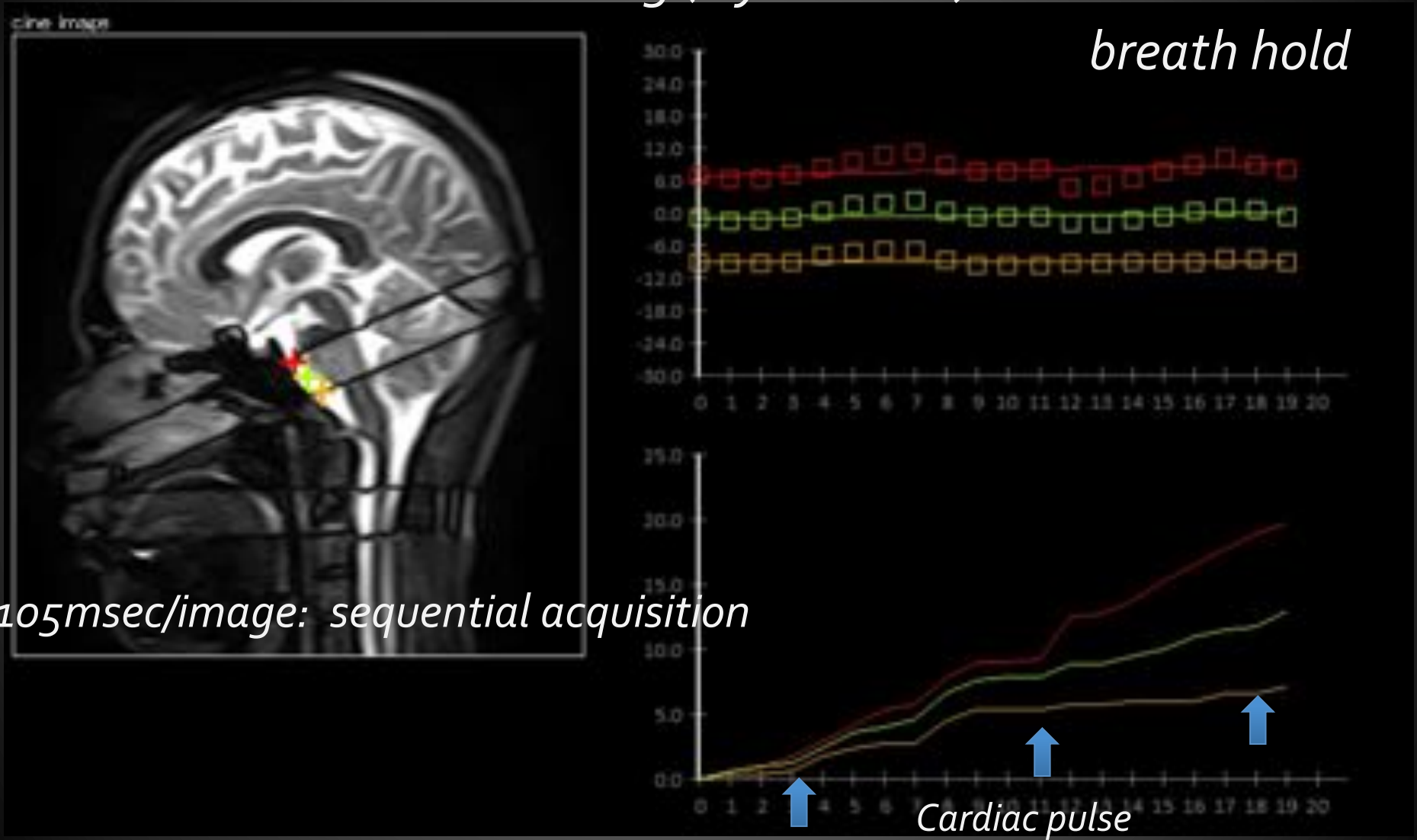


Automated flow quantification for spin labeling MR imaging

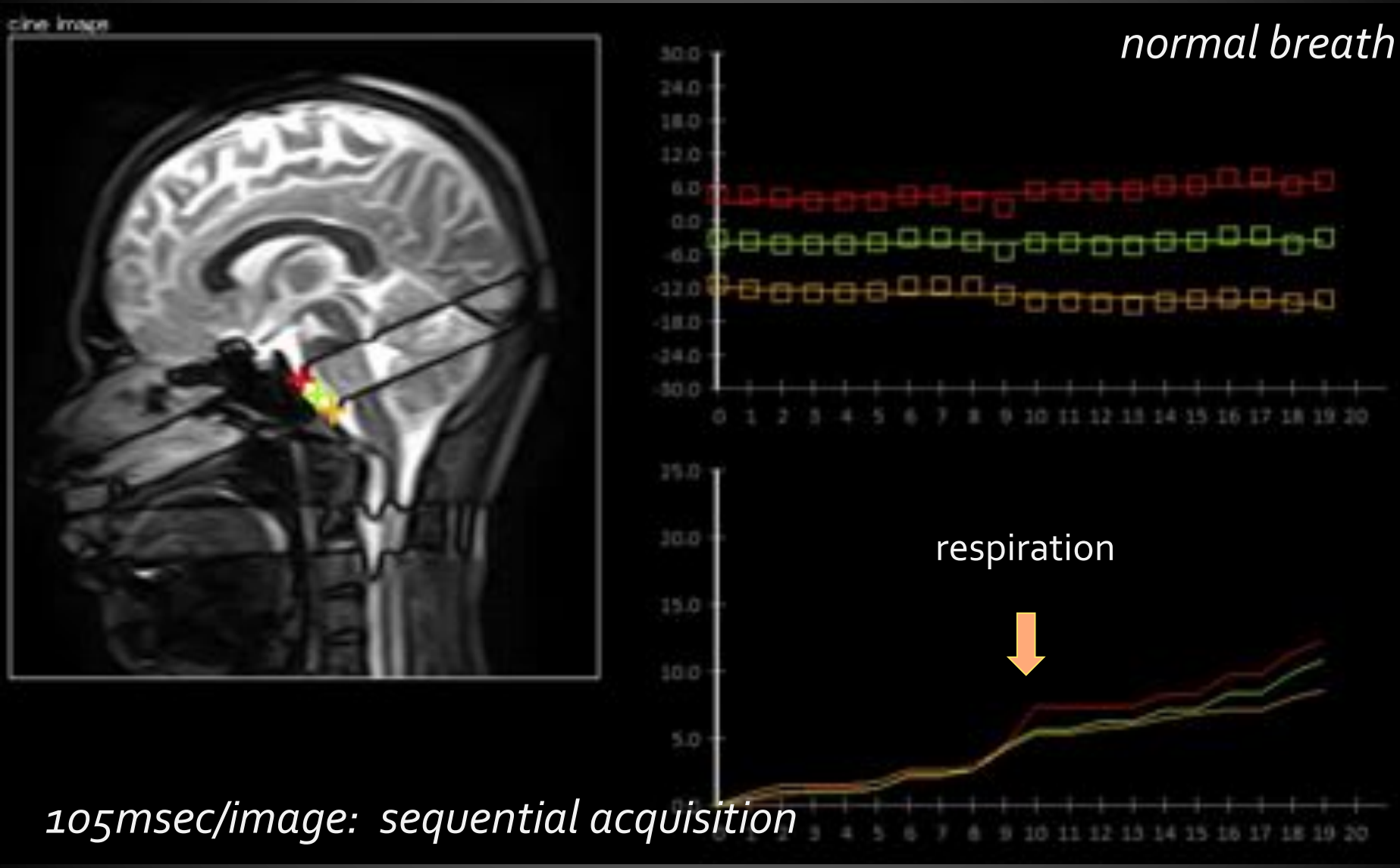
Taichiro Shiodera · Shuhei Nitta · Tomoyuki Takeguchi · Masao Yui · Yuichi Yamashita · Takao Yamamoto · Shinya Yamada

Magn Reson Mater Phy
DOI 10.1007/s10334-013-0416-1

Real Time Imaging autotracing (Dynatracer)

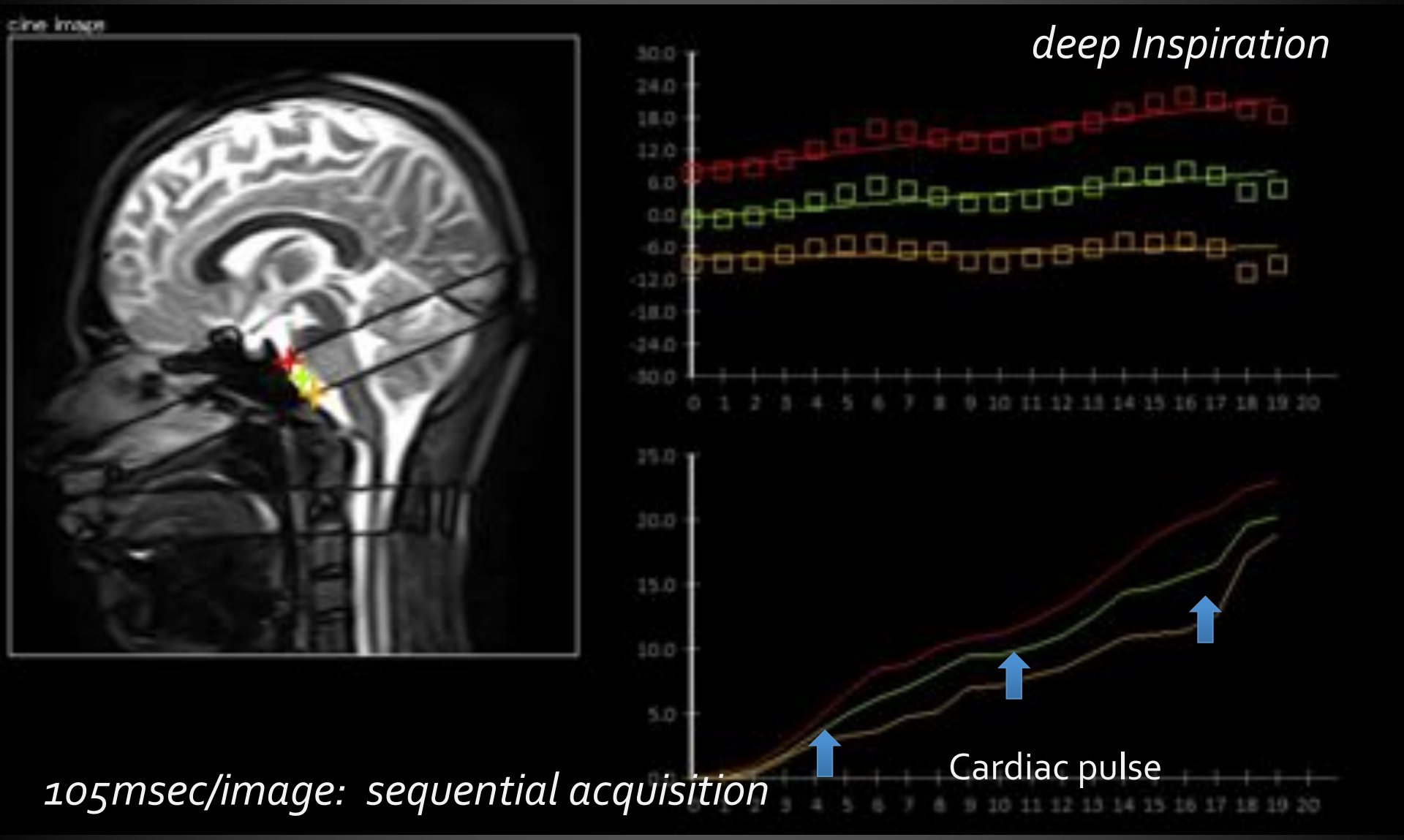


Real Time Imaging



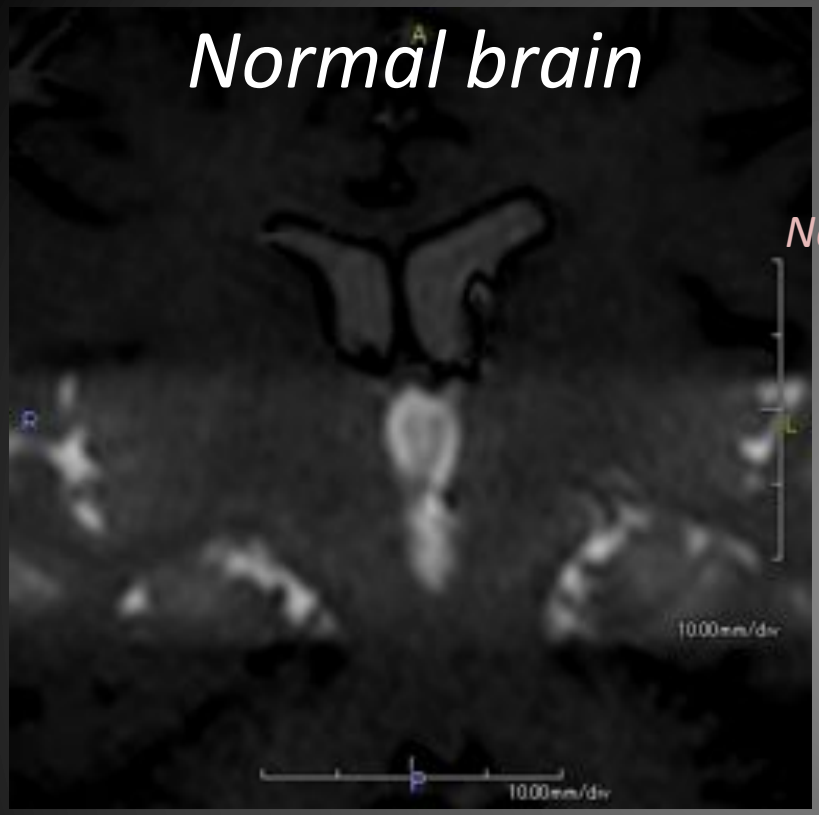
105msec/image: sequential acquisition

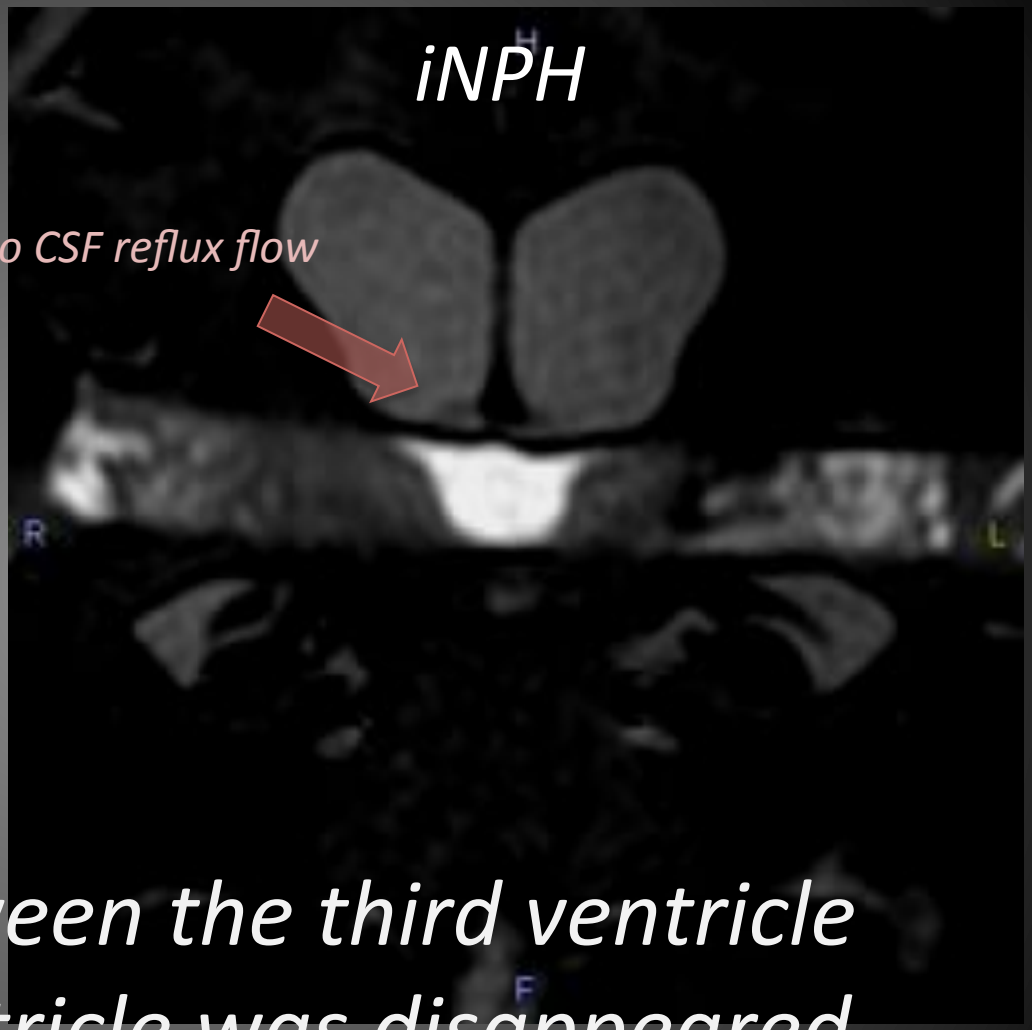
Real Time Imaging



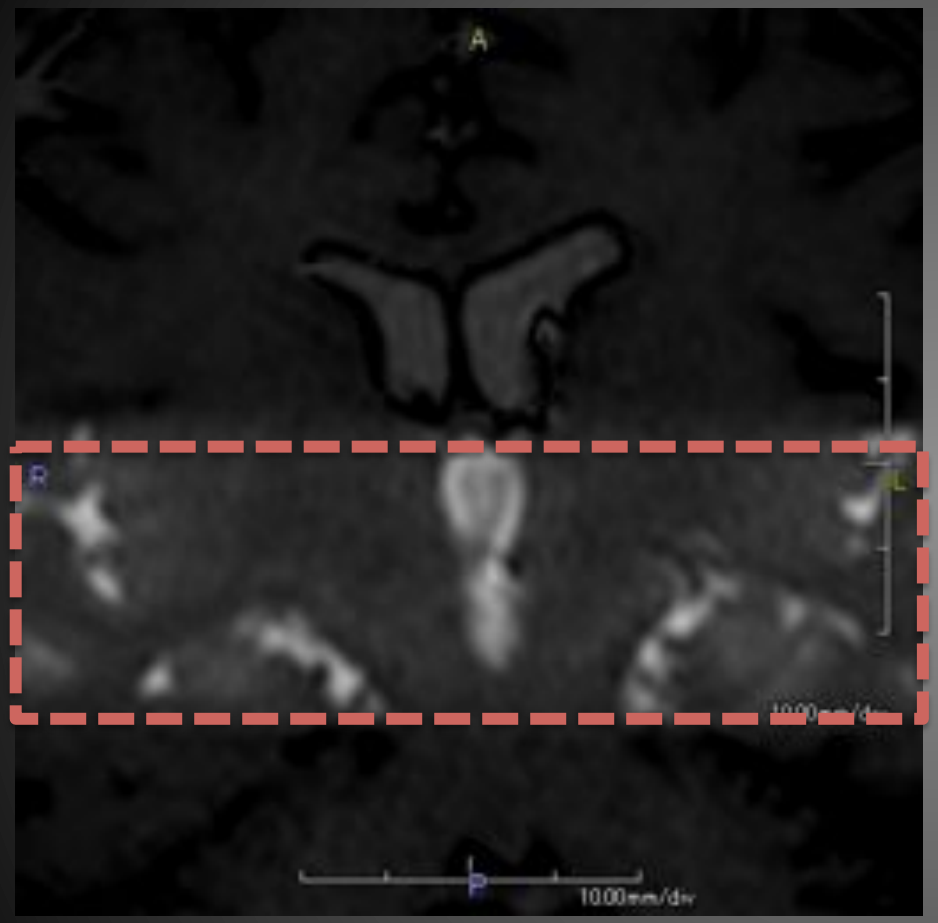
105msec/image: sequential acquisition

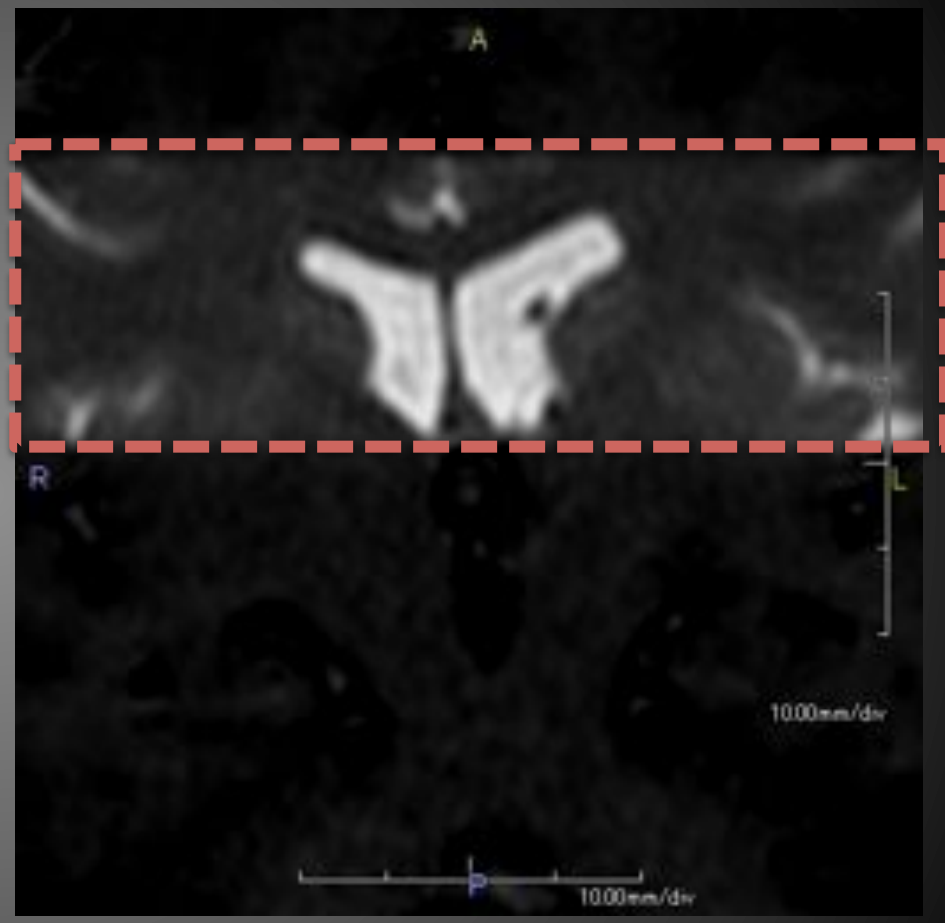
Utility of Time-SLIP method
CSF dynamics in Hydrocephalus





CSF exchange between the third ventricle and the fourth ventricle was disappeared.


A
R
L
10.00mm/div


A
R
L
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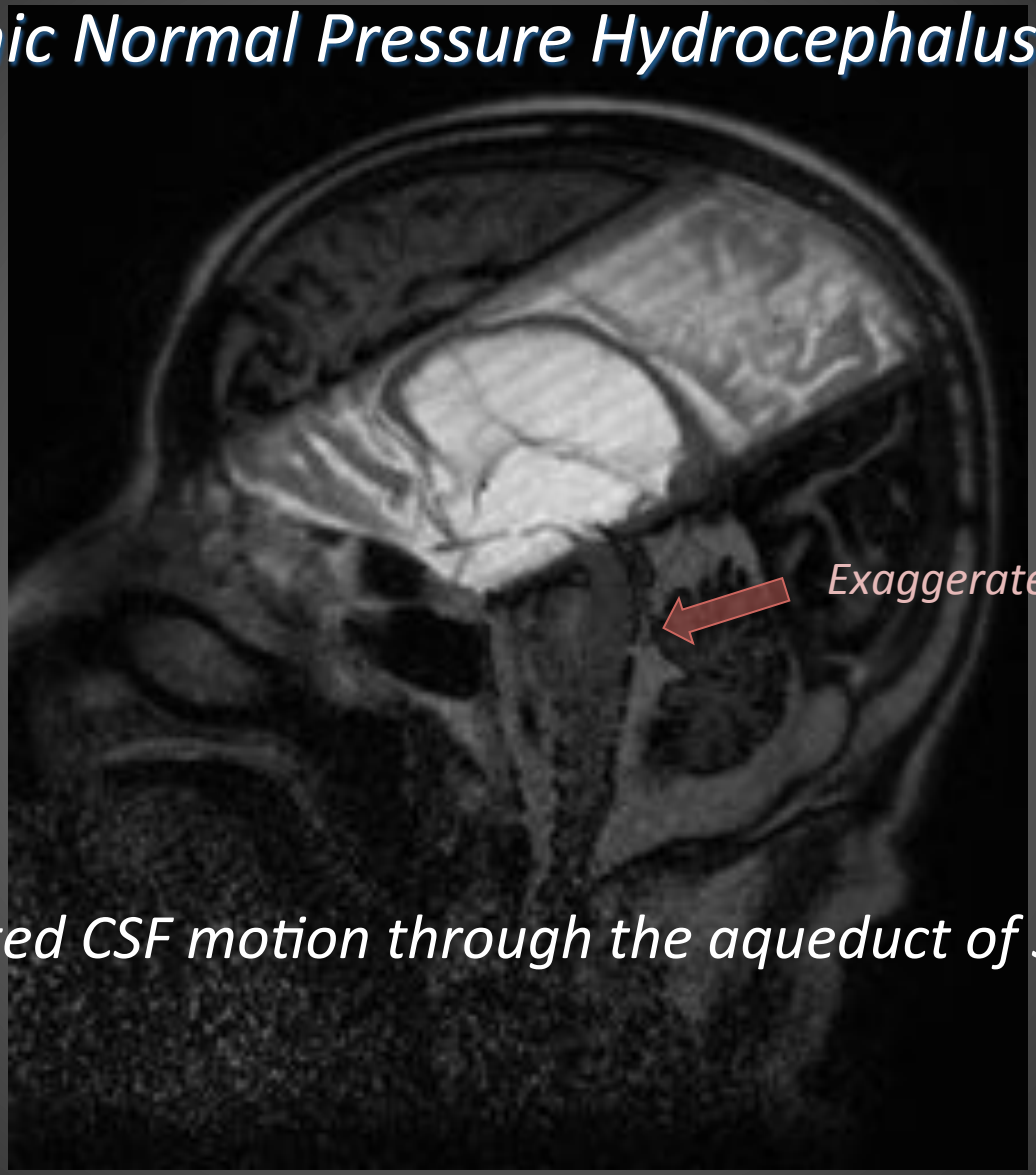
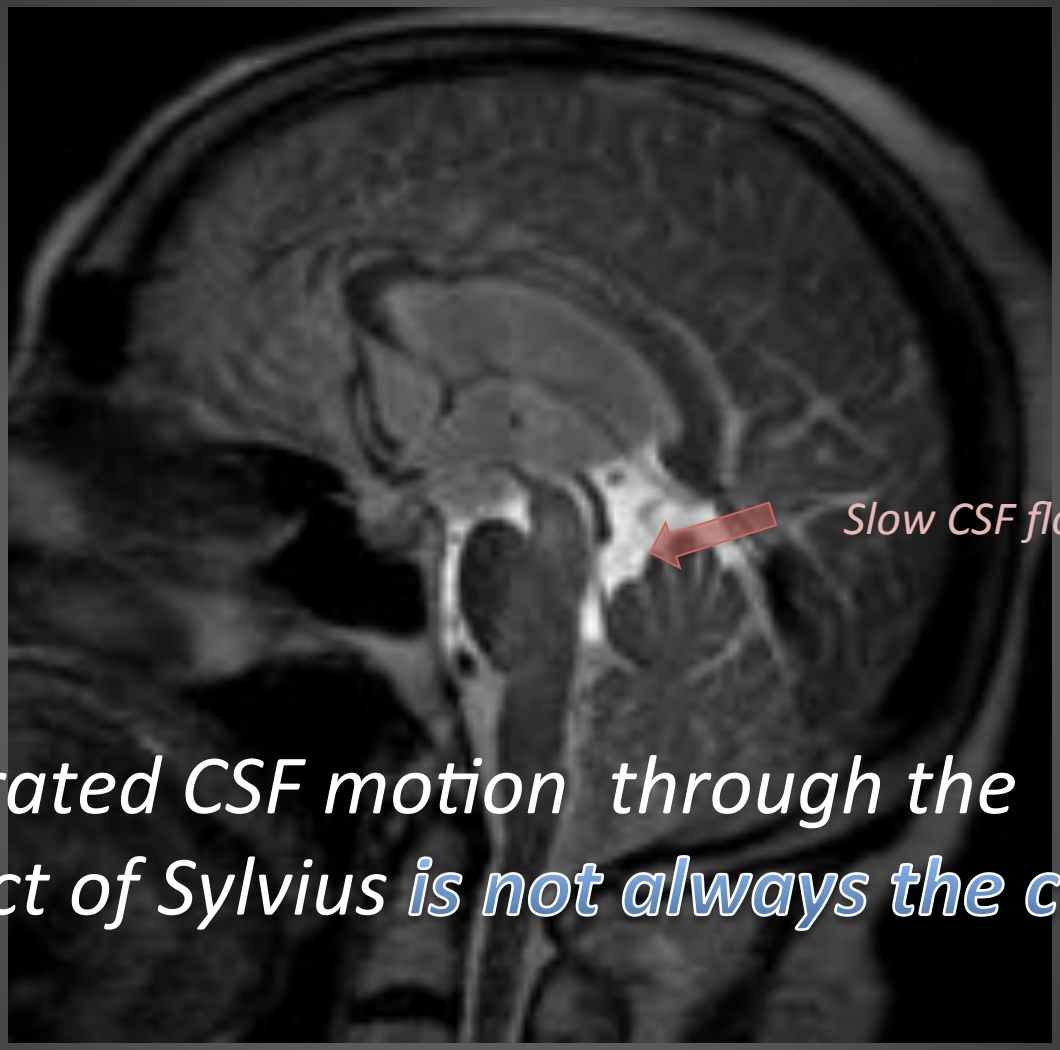
10.00mm/div

Idiopathic Normal Pressure Hydrocephalus (iNPH)



exaggerated CSF motion through the aqueduct of Sylvius in iNPH

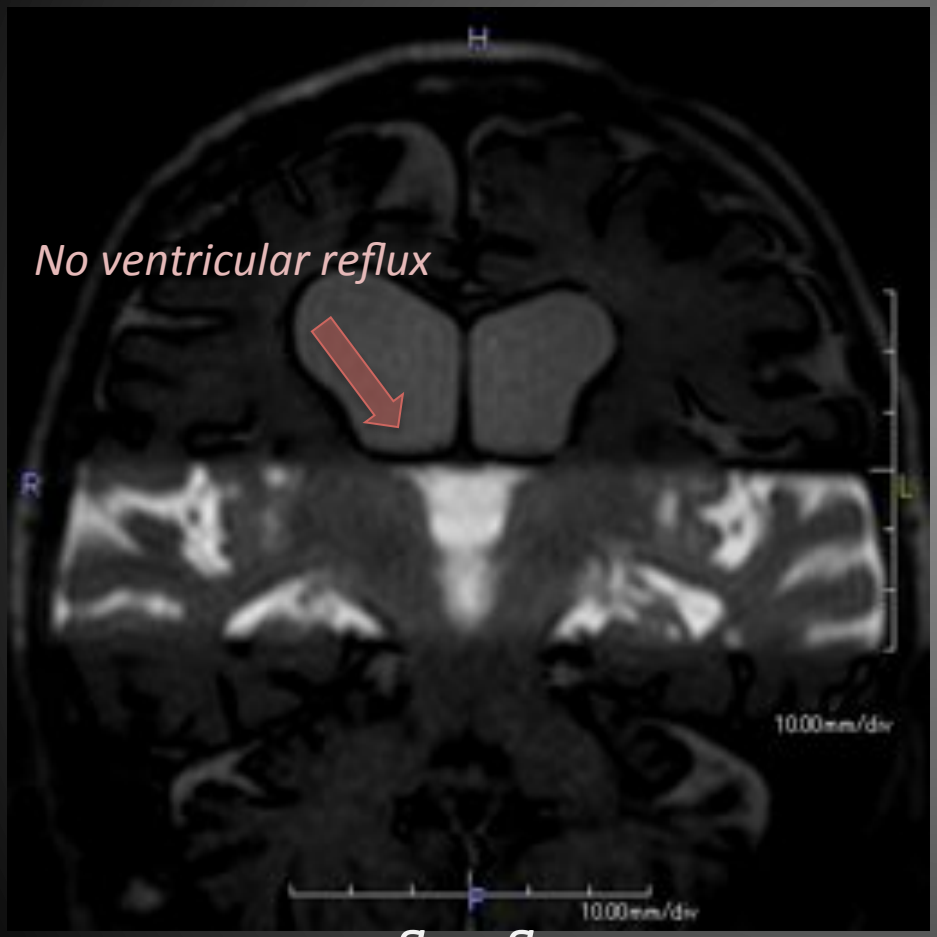
iNPH



exaggerated CSF motion through the aqueduct of Sylvius ***is not always the case in iNPH.***

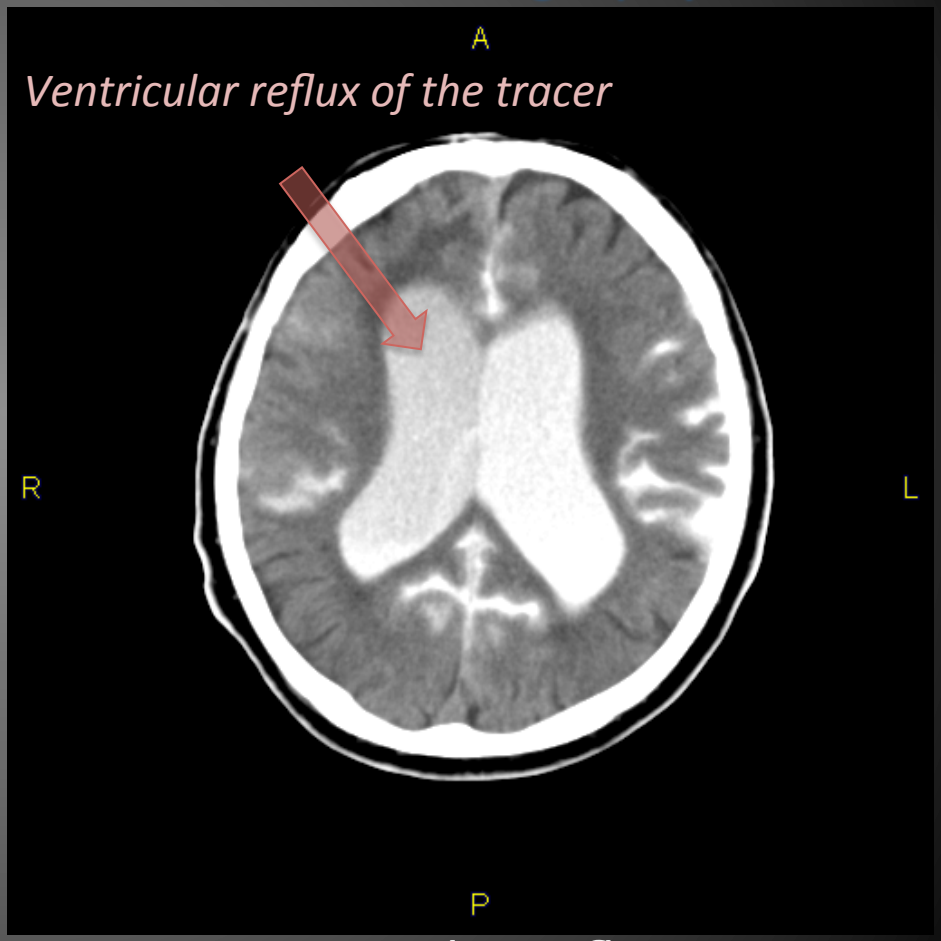
communicating hydrocephalus

Time-Slip



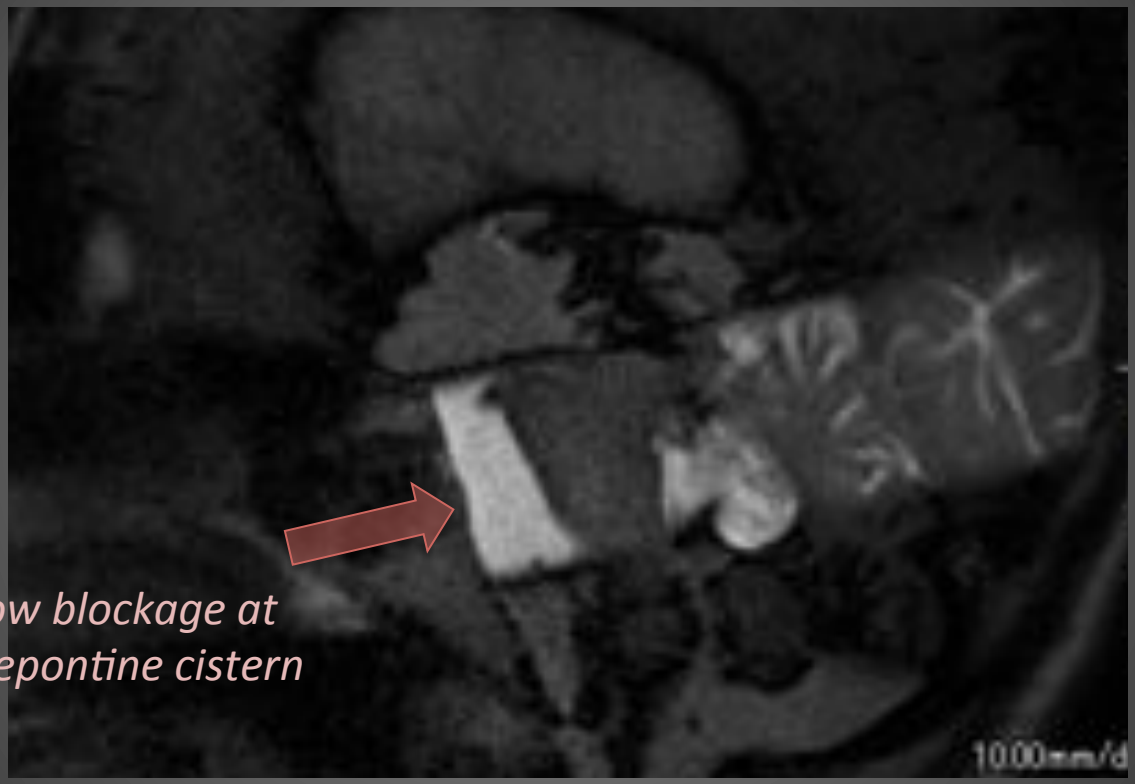
no reflux flow

Metrizamide CT Cisternography



ventricular reflux

Extra-ventricular intra-cisternal obstructive hydrocephalus

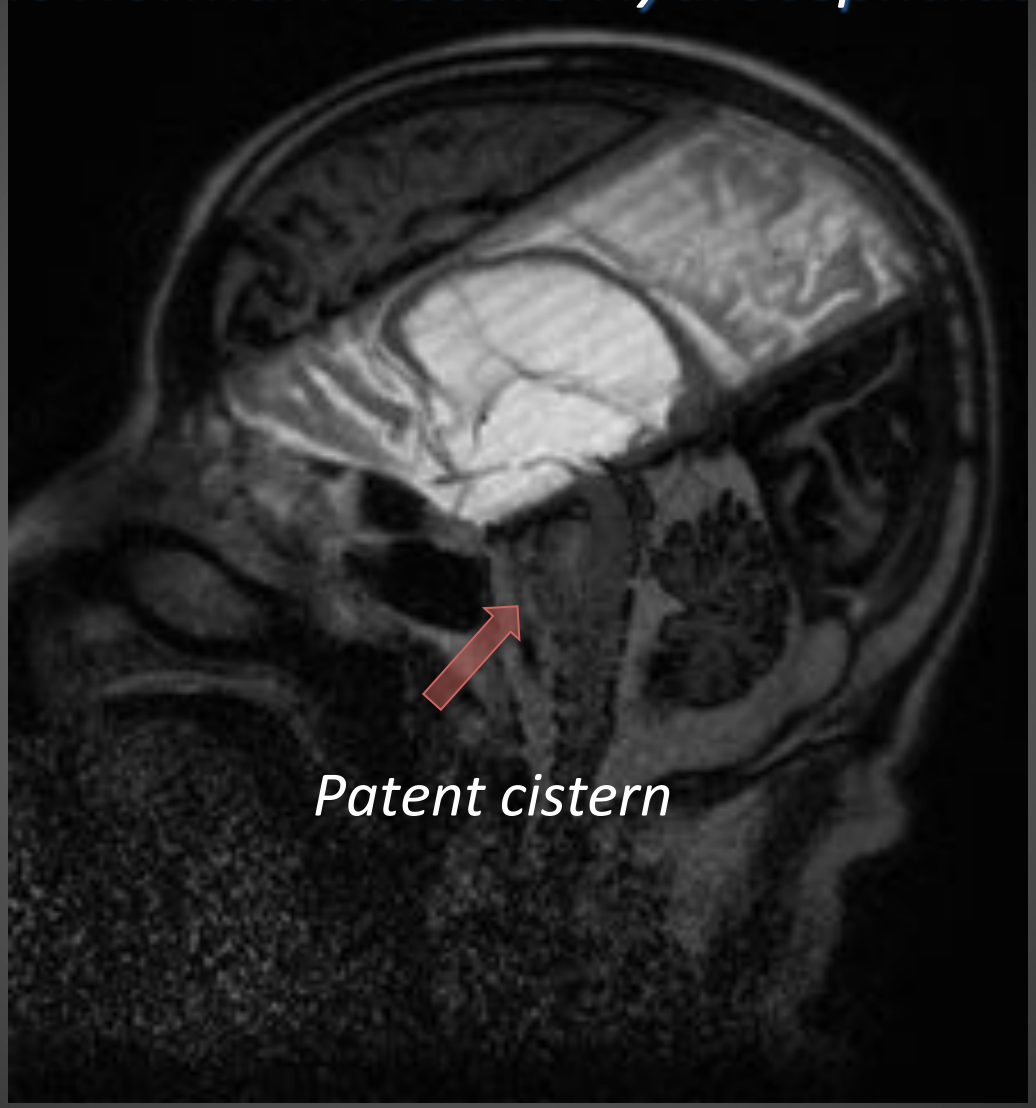


CSF flow blockage at the prepontine cistern

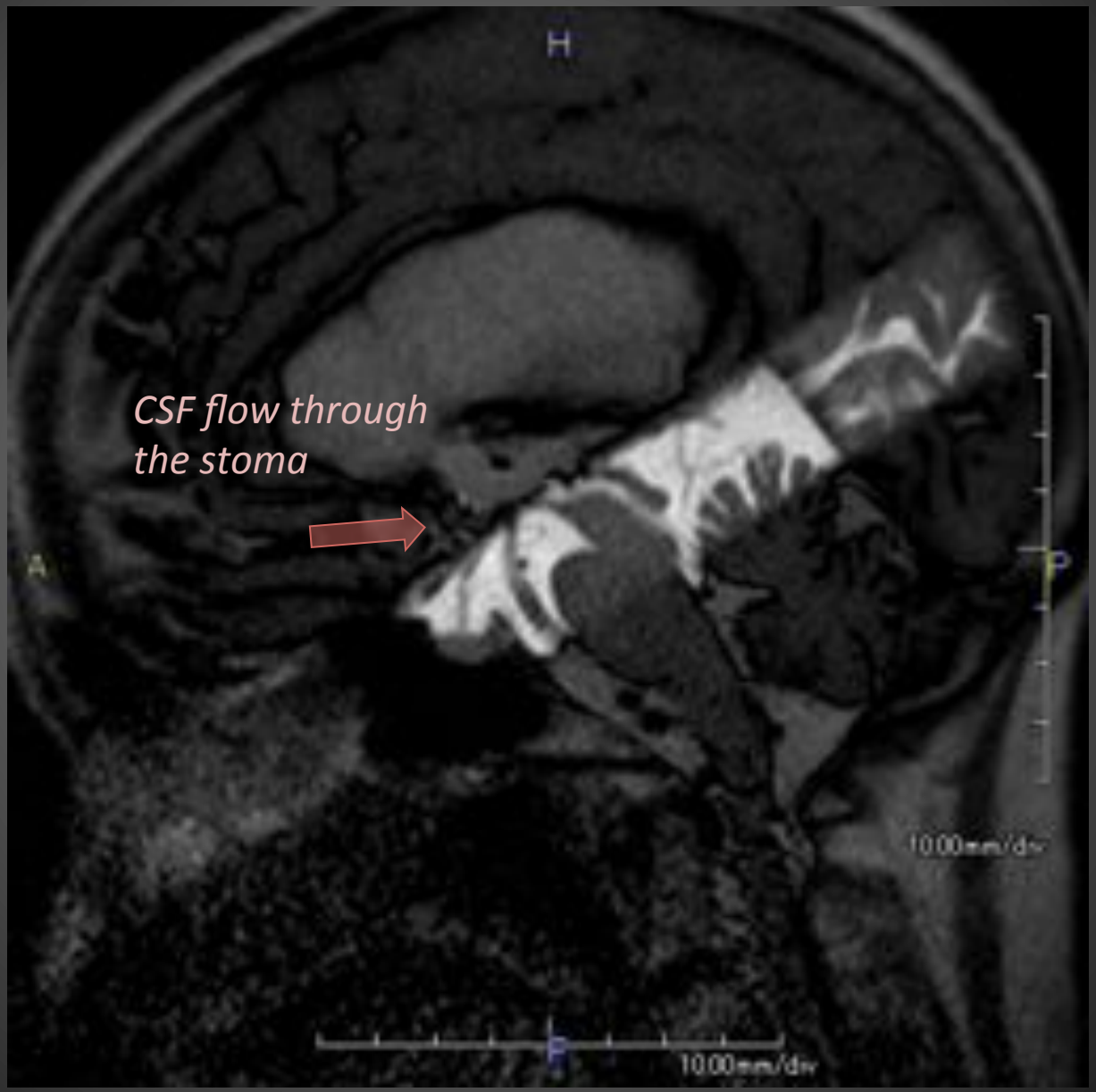
Communicating Hydrocephalus Secondary to Subarachnoid Hemorrhage

Except for a terminology

Idiopathic Normal Pressure Hydrocephalus (iNPH)



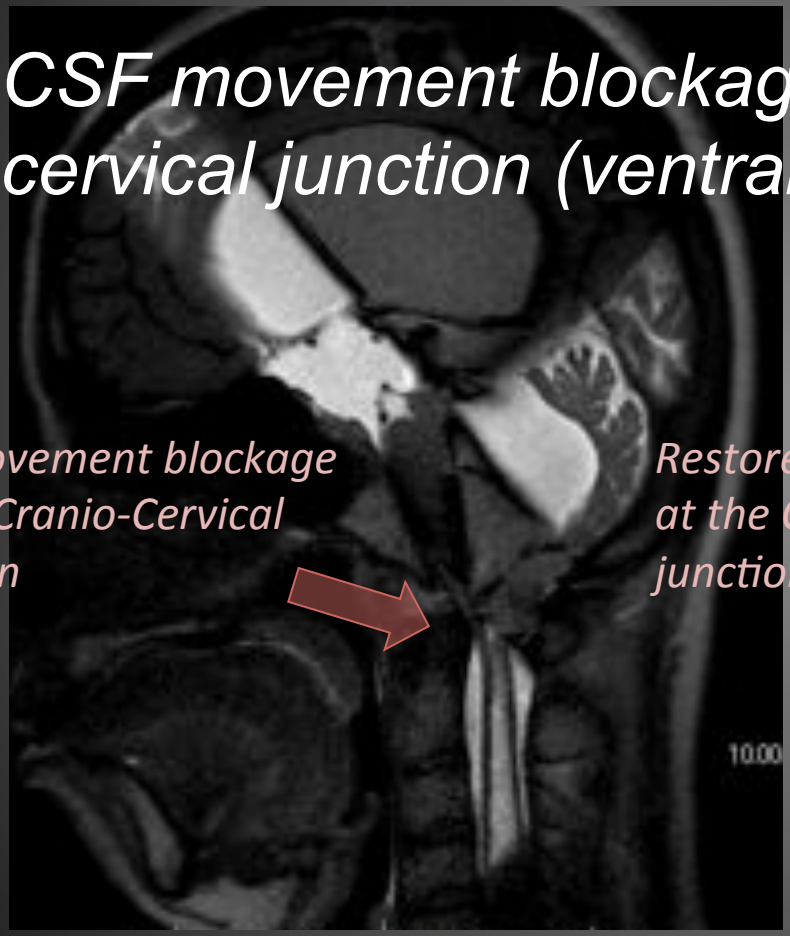
Endoscopic Third Ventriculostomy



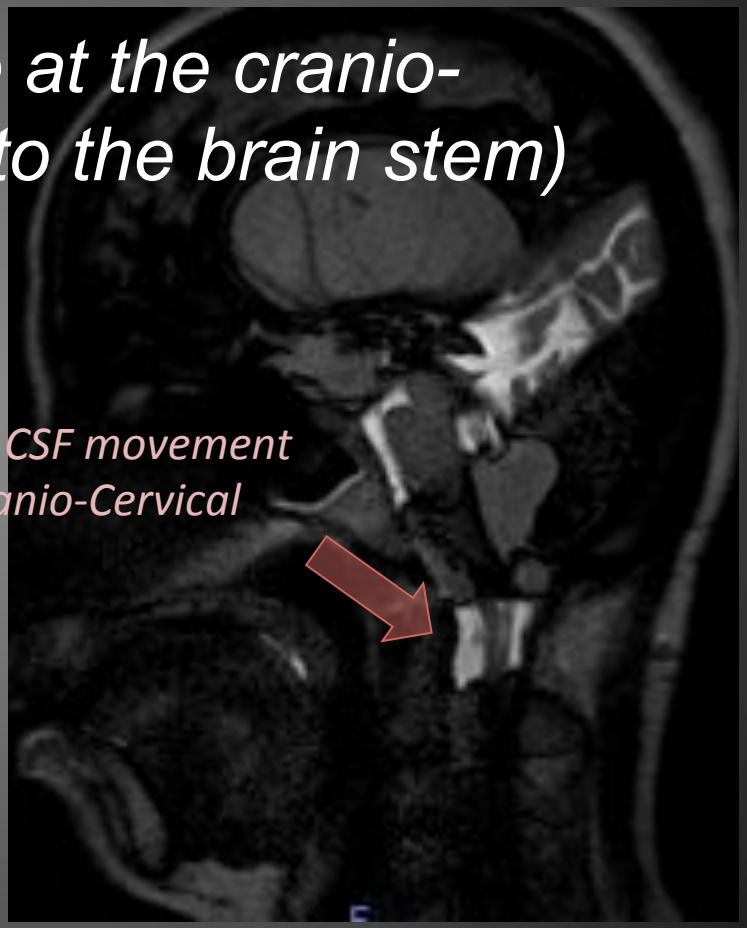
CSF flow through the stoma

Hydrocephalus associated with Syringomyelia

CSF movement blockage at the cranio-cervical junction (ventral to the brain stem)



CSF movement blockage at the Cranio-Cervical junction

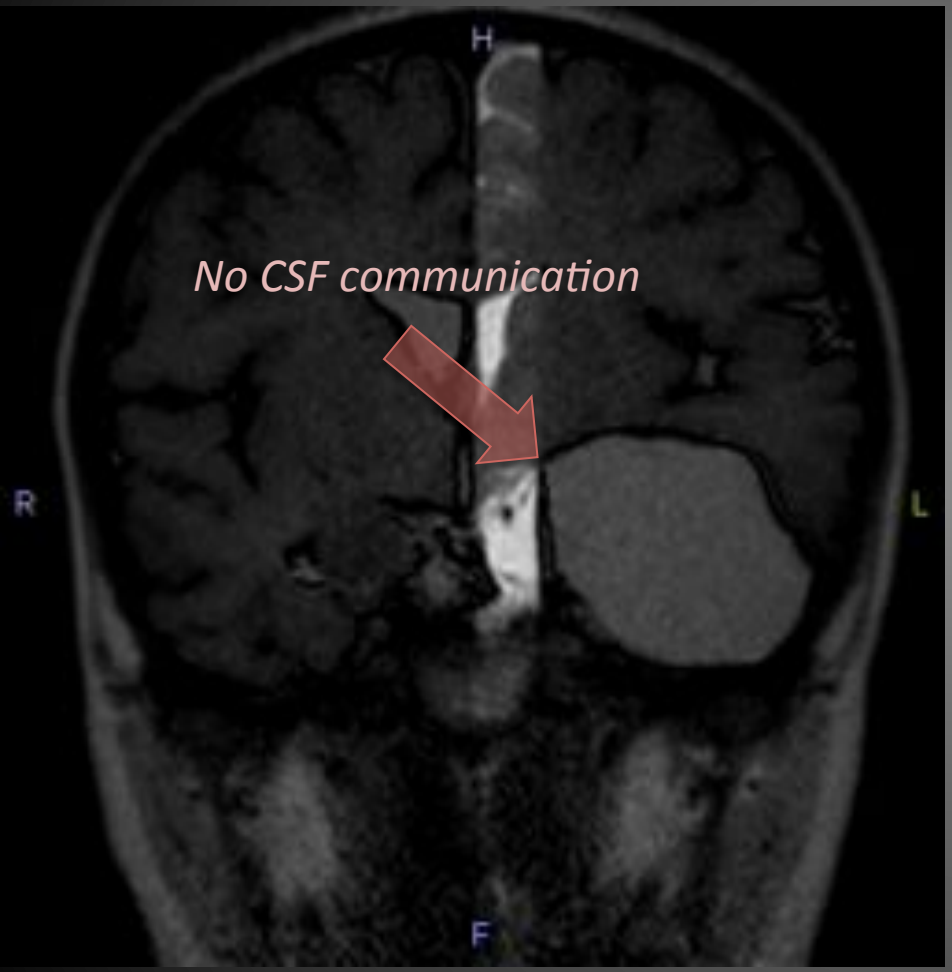


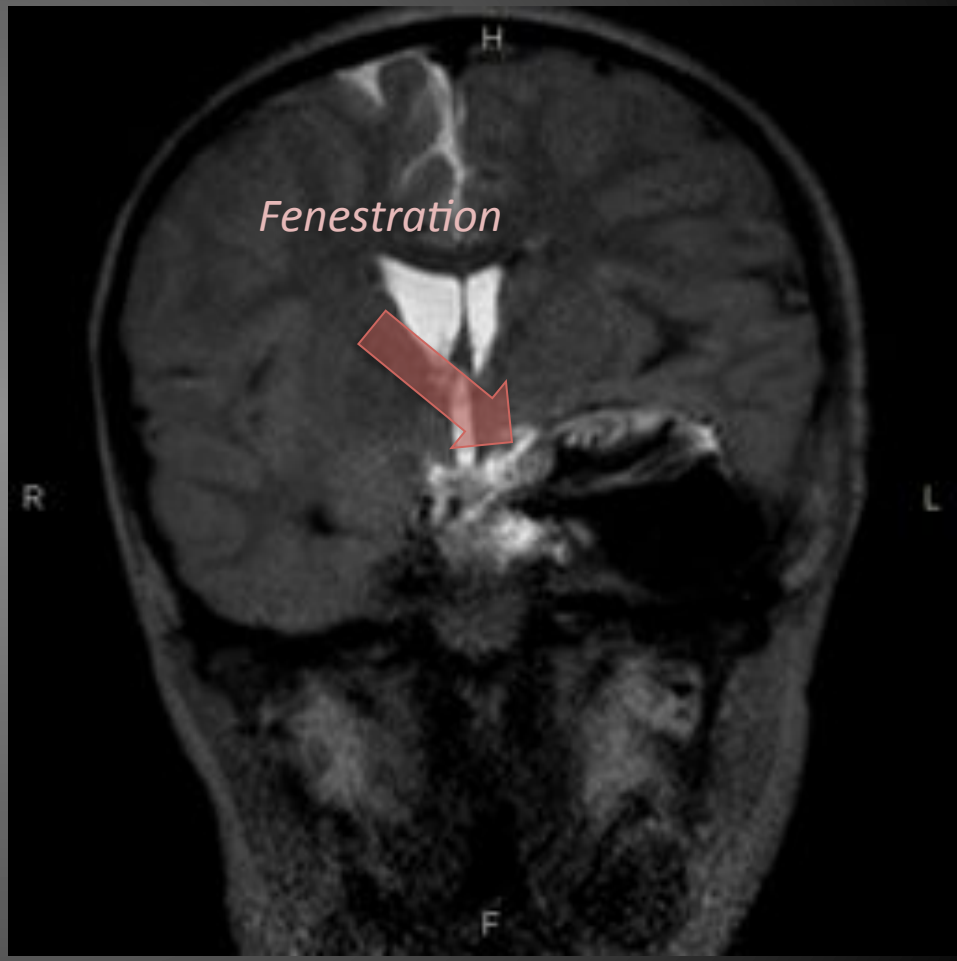
Restored CSF movement at the Cranio-Cervical junction

Pre OPE

Post OPE

Temporal arachnoid cyst

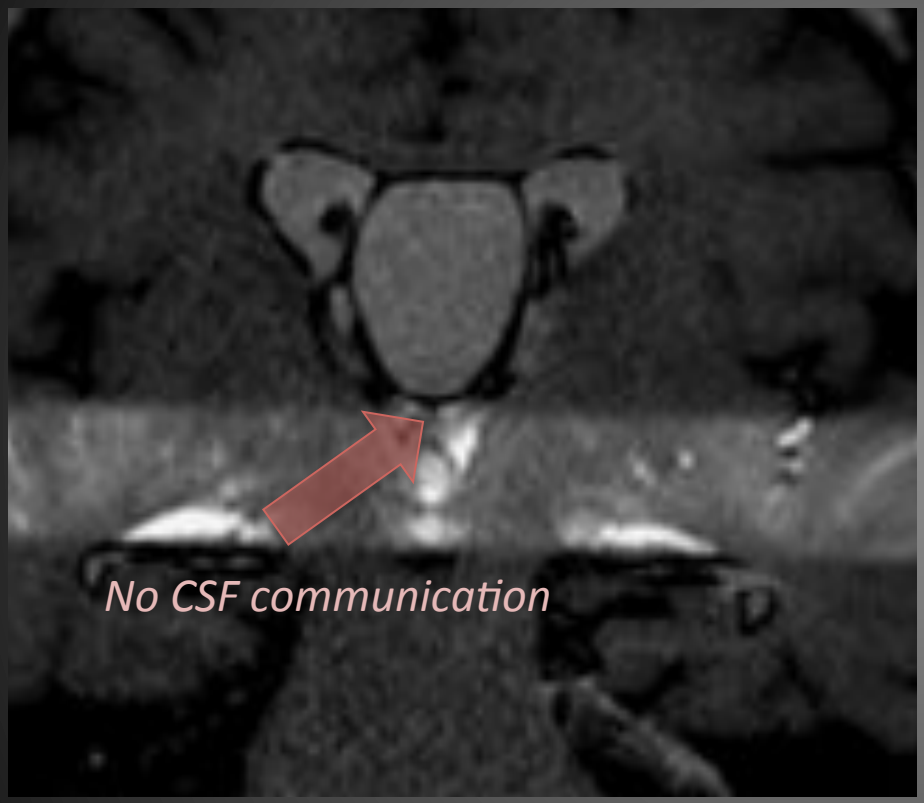


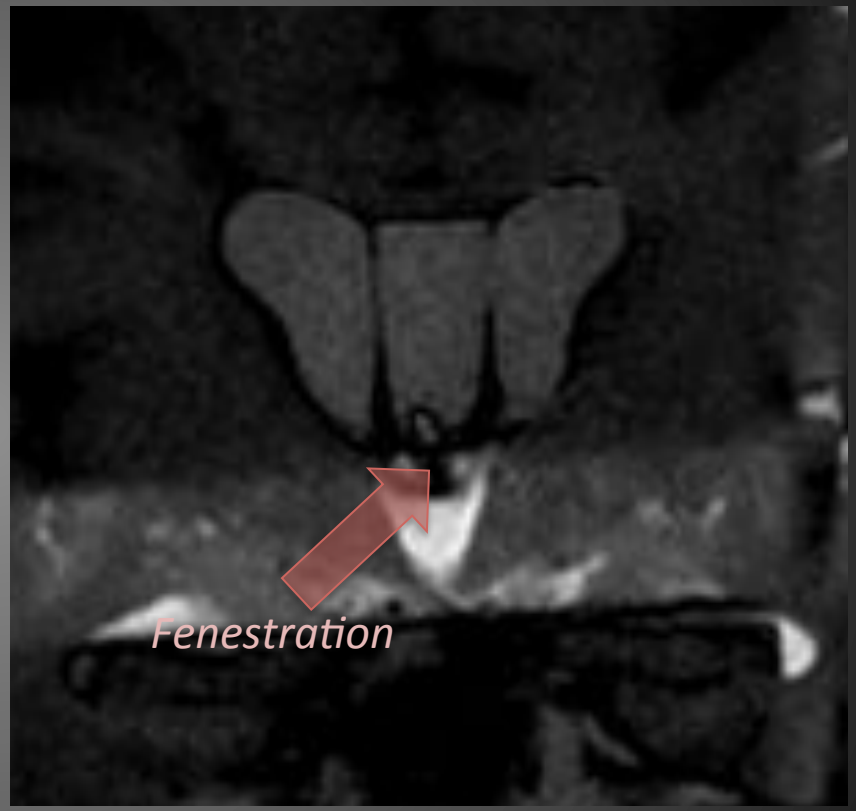


Pre op.

Post fenestration

Expanding (symptomatic) Cavum Septi Pellucidi (CSP)

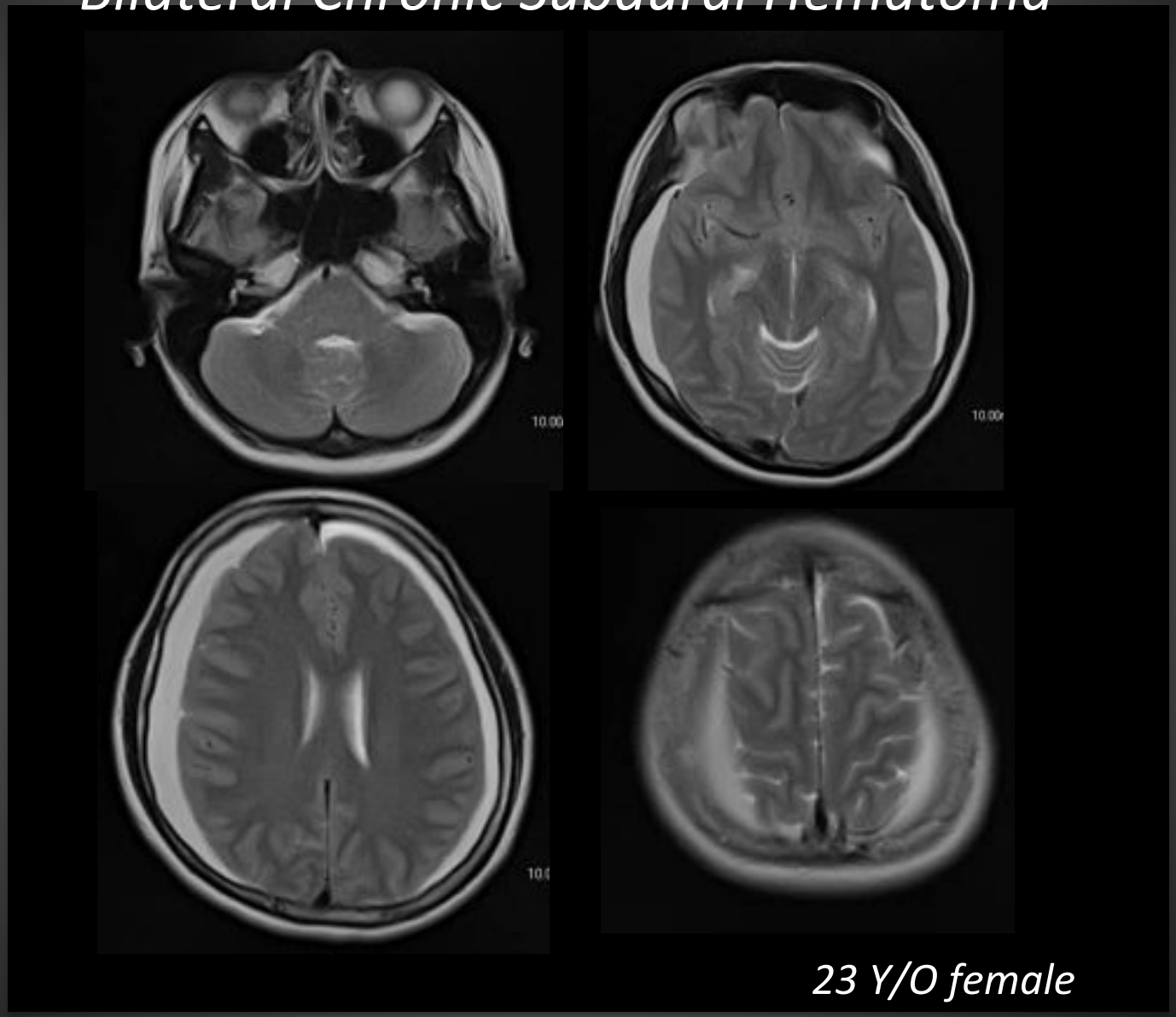




Pre op.

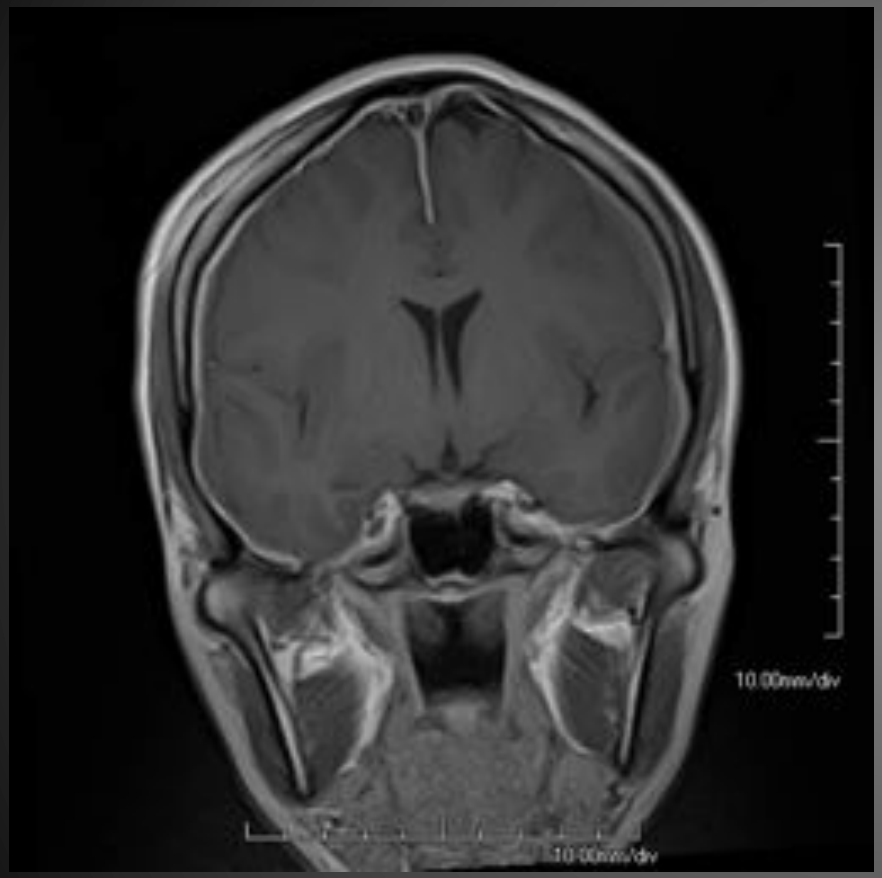
Post endoscopic fenestration

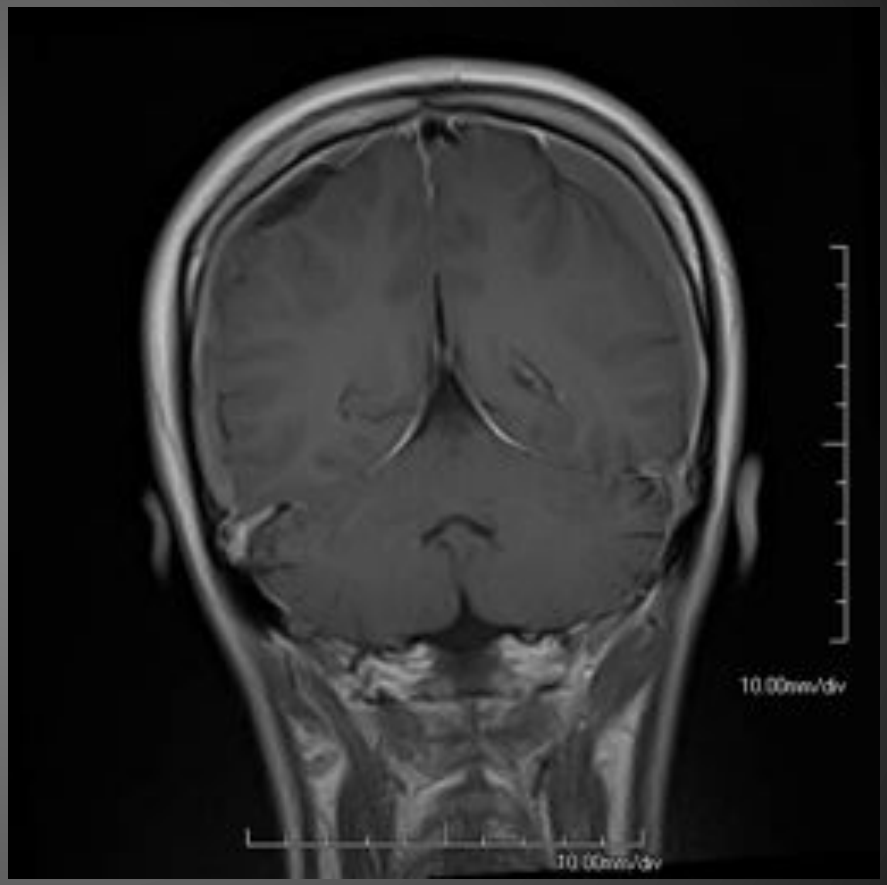
Bilateral Chronic Subdural Hematoma



23 Y/O female

Spontaneous Intracranial Hypotension (SIH)



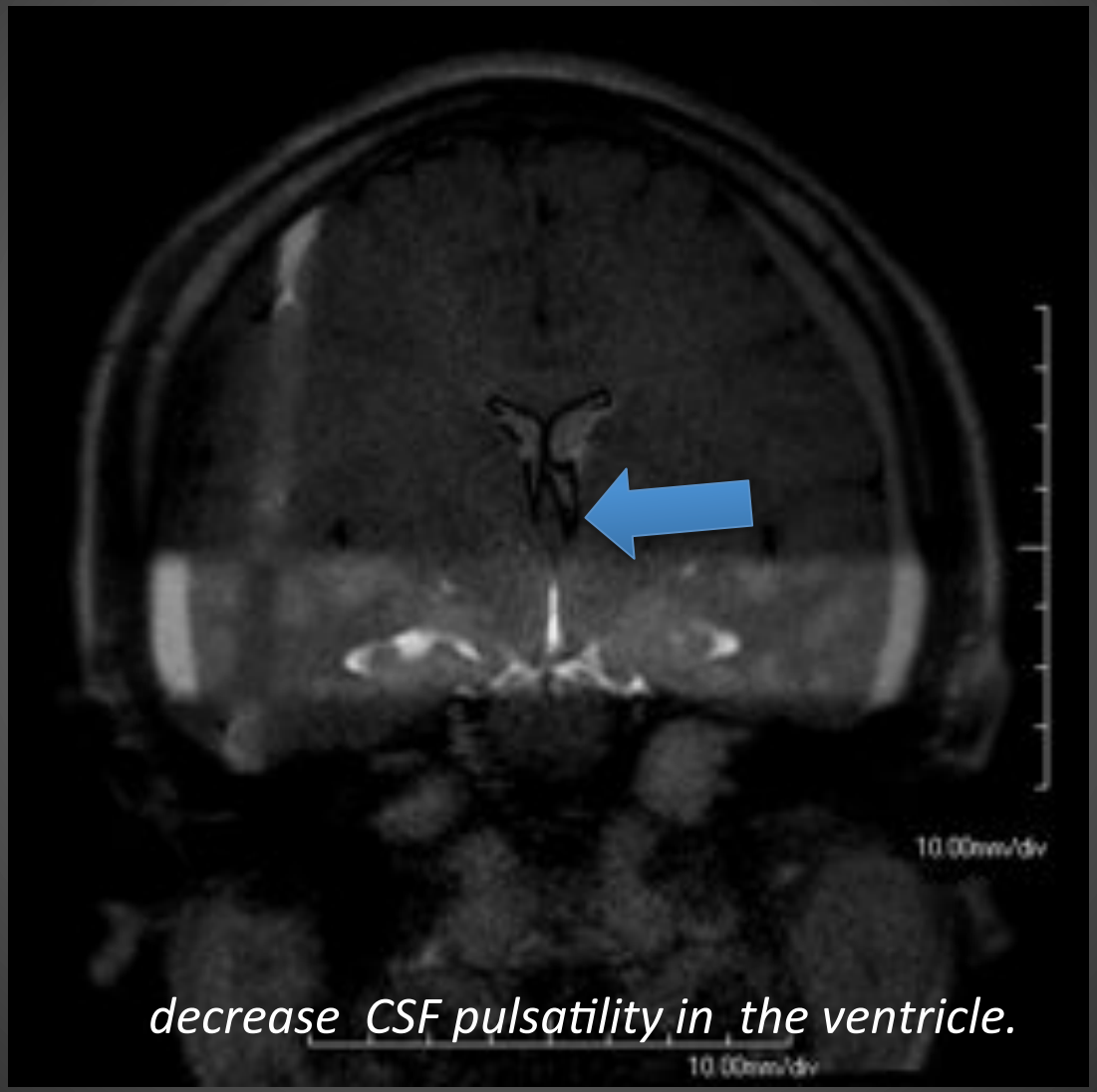


Gd (+)

CSF Dynamics in SIH

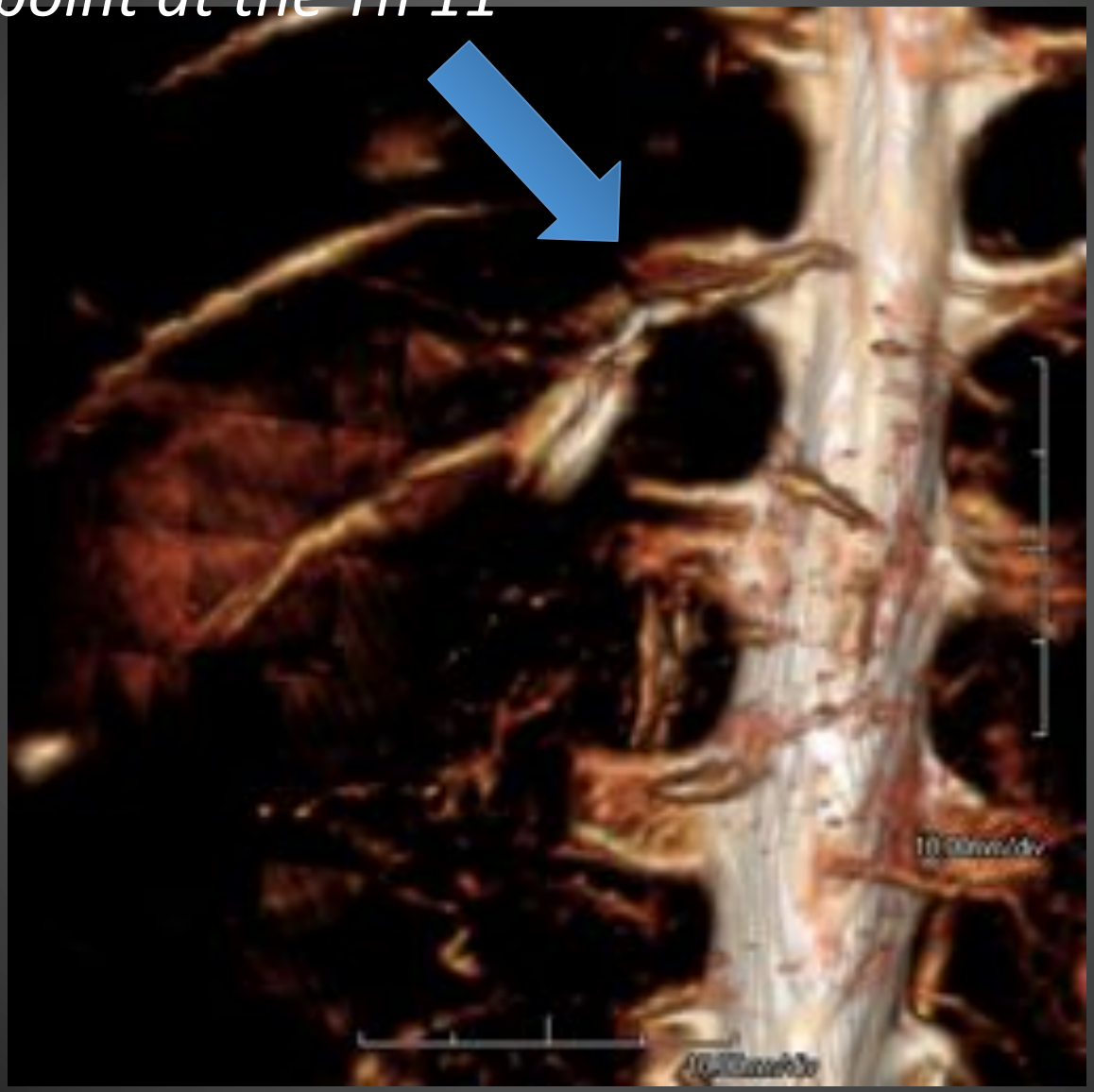
decrease CSF pulsatility in the ventricle.

CSF Dynamics in SIH

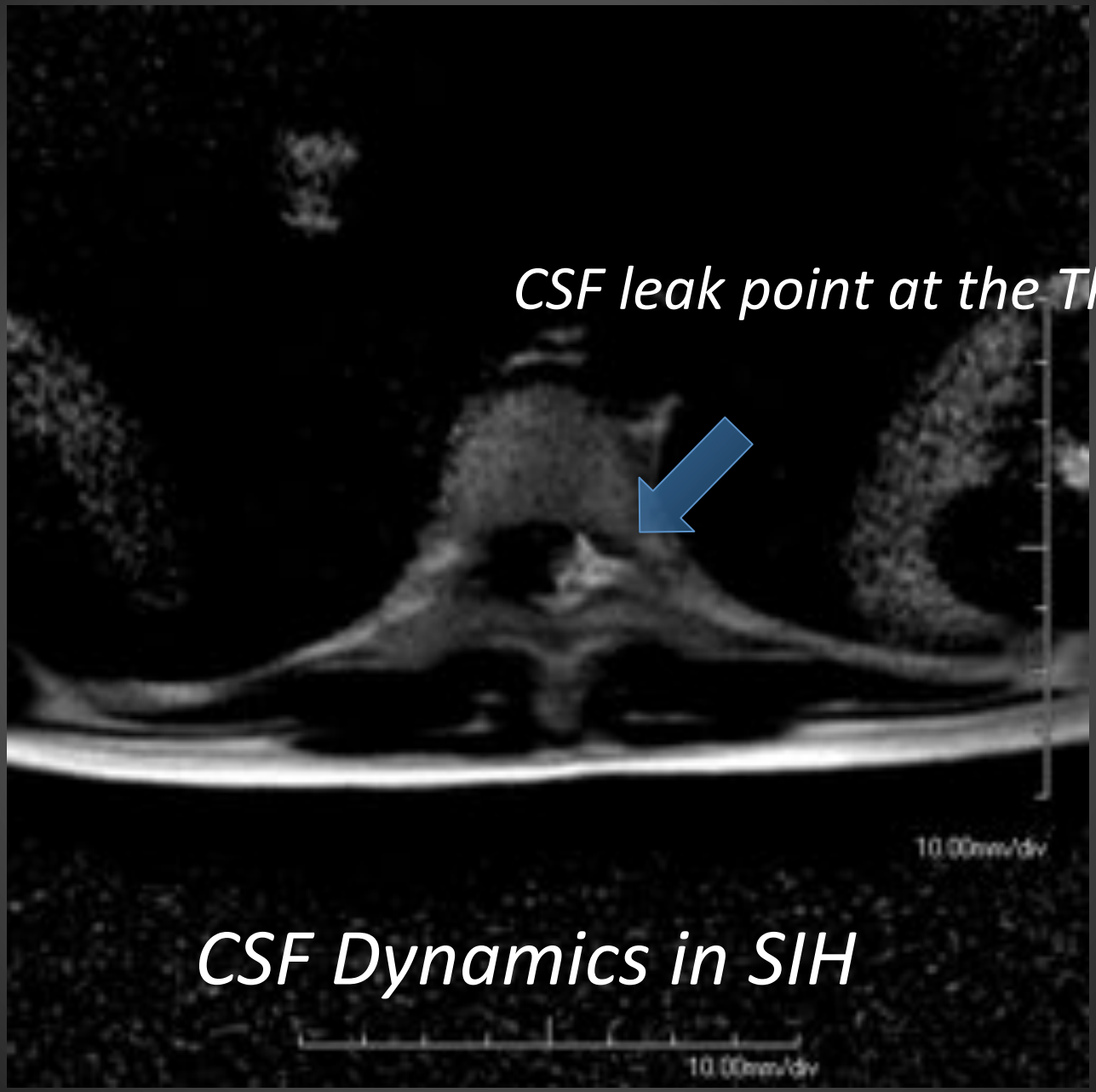


decrease CSF pulsatility in the ventricle.

CSF leak point at the Th 11

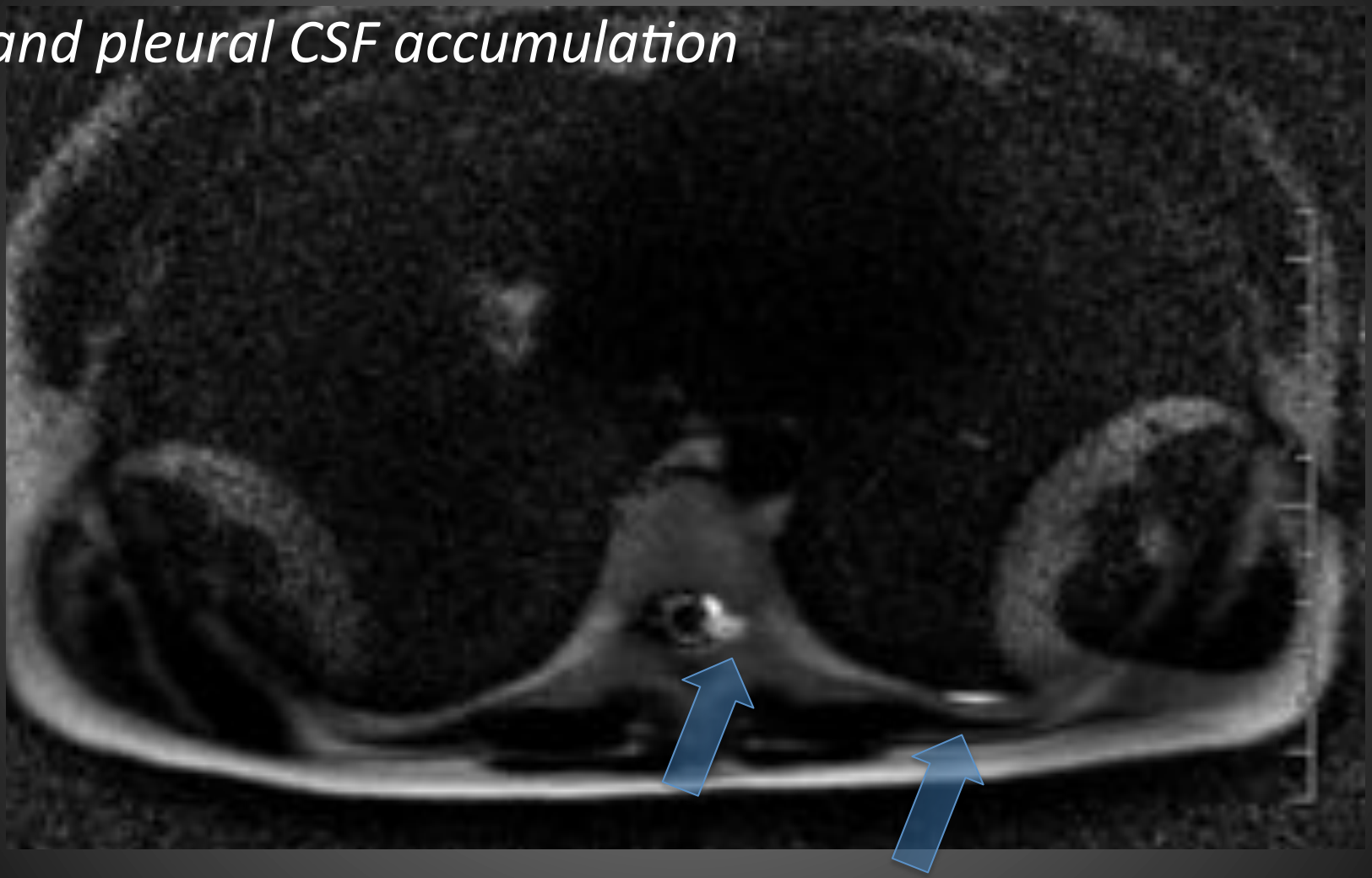



CSF leak point
10.00mm/div
10.00mm/div



CSF Dynamics in SIH

Synchronized CSF motion at the leak point nerve sleeve and pleural CSF accumulation

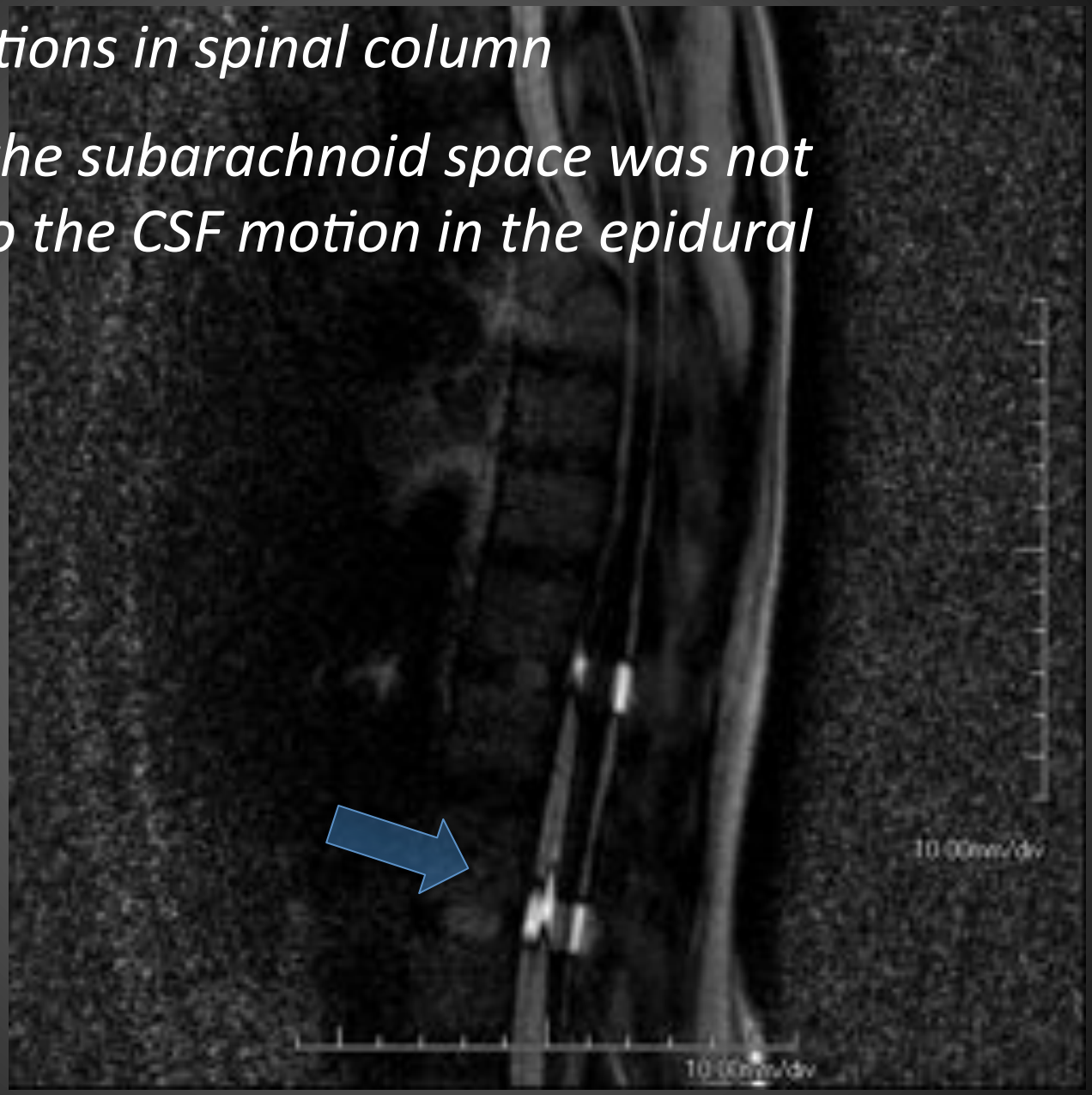


CSF Dynamics in SIH

T2 Sagittal

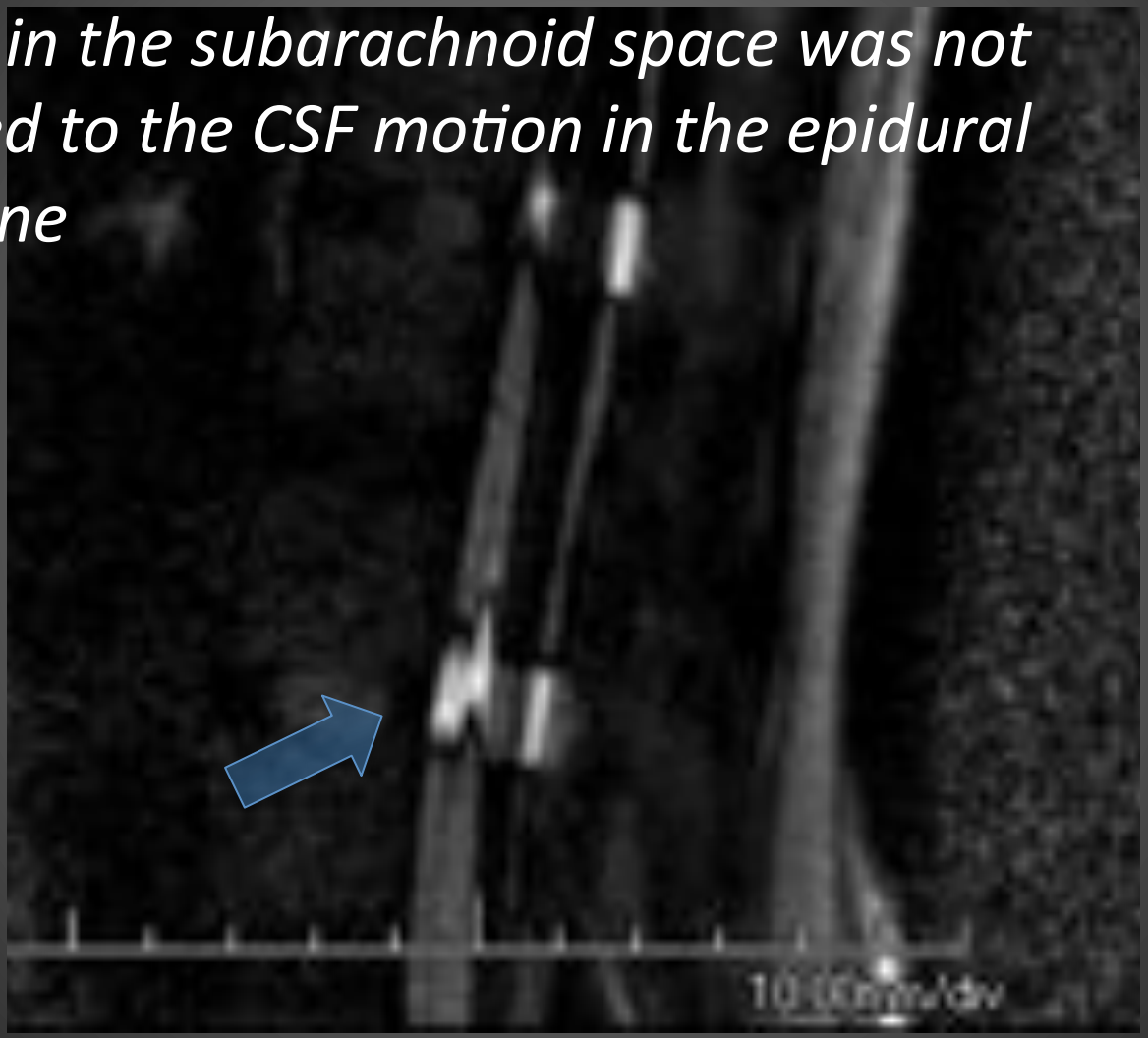
Double CSF motions in spinal column

CSF motion in the subarachnoid space was not synchronized to the CSF motion in the epidural space in spine



Double CSF motions in spinal column

CSF motion in the subarachnoid space was not synchronized to the CSF motion in the epidural space in spine



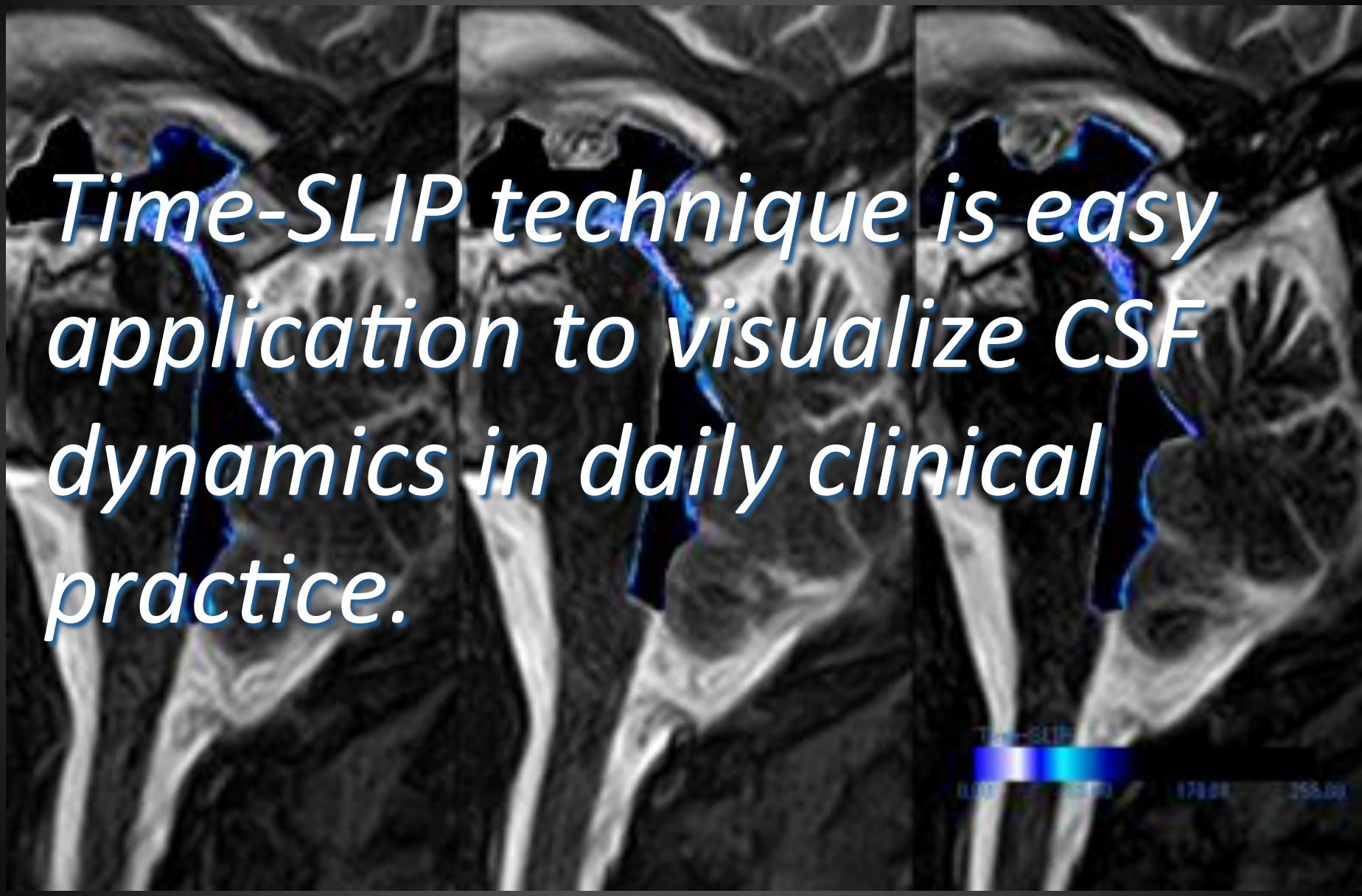
Multiple layer CSF motions ?? in spinal column

Subarachnoid space

(Subdural space ?)

(Venous Component ?)

Epidural space


Time-SLIP technique is easy application to visualize CSF dynamics in daily clinical practice.