Dynamic MR Imaging (MR fluoroscopy): Clinical Applications in Pediatric Neuroradiology

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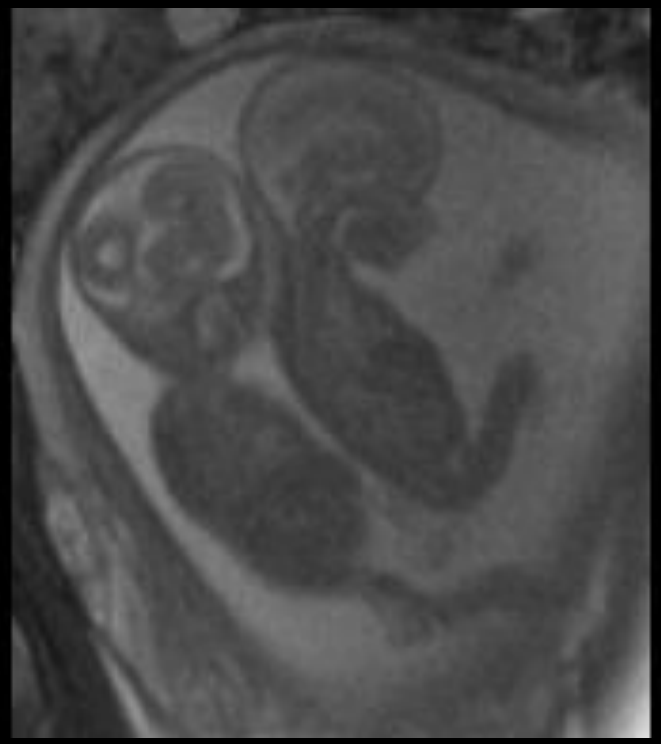
Purpose:

To describe the **technique** and present the **varied applications** of Dynamic MR Imaging (MR fluoroscopy) in pediatric neuroradiology

In fetuses



In children

Click on image to start cine

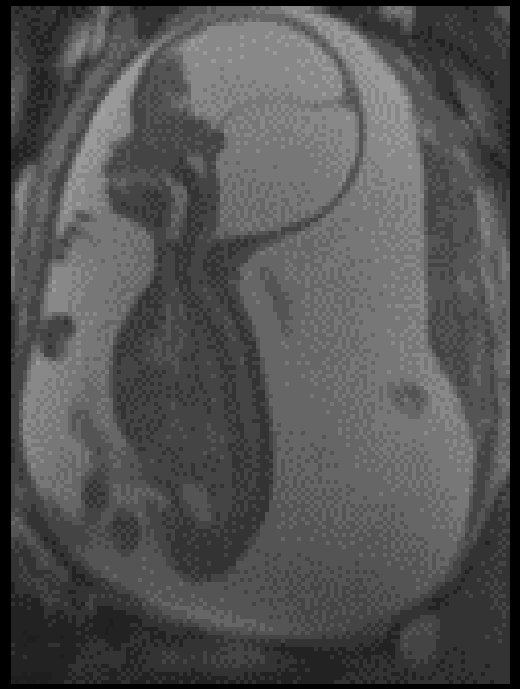
Background:

Dynamic imaging modalities:

- Nuclear medicine
- Ultrasound
- Conventional fluoroscopy (ionized radiation exposure)
- **Cine MRI "fluoroscopy"** (no radiation exposure)

Cine MRI - "fluoroscopy":

- near real-time temporal resolution
- short acquisition time
- organization of images in a sequential-loop
- **lack of ionized radiation**



Background:

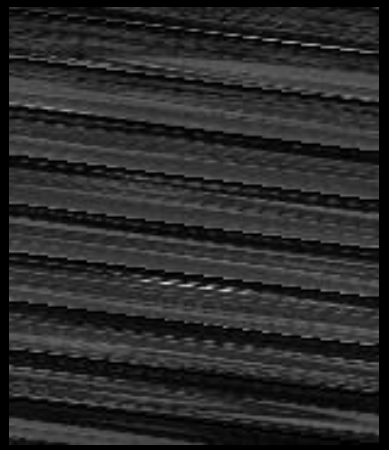
Cine MRI – "fluoroscopy":

- Rapidly evolved from research and "Work in progress" to use in clinical practice as routine imaging sequences

- **Growing list of indications** for dynamic MR imaging studies in **children**
  - Assessment of CSF flow pattern
  - Cervical spine imaging to assess stability
    - Fusion/segmentation anomalies
    - Stenosis
    - Trauma
  - Swallowing patterns
  - And more…

Let me out of here!!

Background:

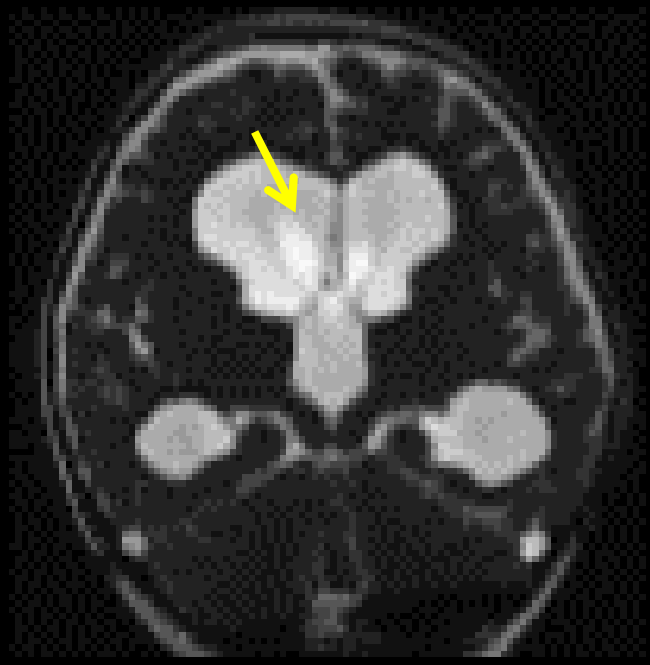


Cine MRI – "fluoroscopy":

- Used with increasing frequency for **prenatal imaging**
  - Assessment of CSF flow in suspected obstruction
  - Assessment of swallowing mechanism in fetuses with
    - head and neck lesions
    - facial cleft
  - Assessment of motor function in fetuses with spinal dysraphism

Real time MR techniques

- Sequences differ slightly in different manufactures
- **Any sequence sensitive to flow may be employed**
- 1.5 and 3.0 Tesla Magnets



Real time non-invasive MR techniques

True FISP Cine and HASTE with arrangement in cine loop

Parallel imaging with 2D/3D True FISP; no breath holding; 5-35 sec acquisition time

CSF flow, swallowing assessment

SPACE (CUBE, VISTA) High-resolution 3D T2-weighted sequence

Sampling perfection with application optimized contrast using different flip angle evolution

Passive flexion and extension of cervical spine

Cine to-and-fro CSF Phase-contrast Imaging

Low velocity encoding (VENC) parameter to sensitize the sequence to slow **CSF flow**

The acquisition plane depends on the particular flow being evaluated

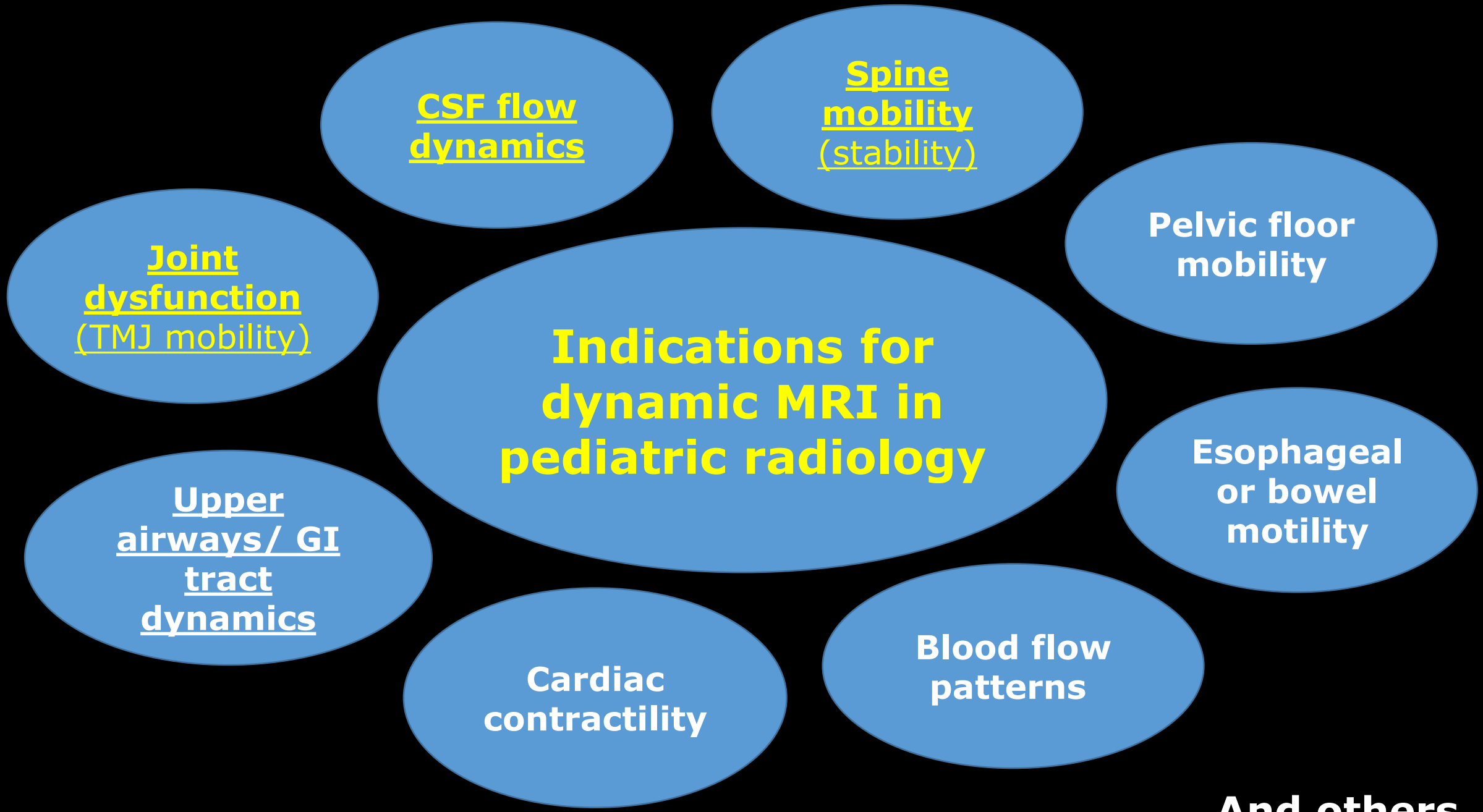
Steady-state free precession MRI (SSFP)

Respiration-induced non-contrast MRI spin labeling Excellent assessment of **CSF motion** associated with respiration

The acquisition plane may be applied in any plane and in any direction

Real time MR techniques - Siemens

Parameters	Fetal cine True FISP 1.5 Tesla Magnet	Fetal cine True FISP 3.0 Tesla Magnet	Swallowing Cine HASTE	Swallowing Cine 3D True FISP
Slice thickness	3	3	5	1.5
Averaging	1	1	1	1
TR	4.30	4.30	900	4.9
TE	1.89	2.15	87	2.1
Flip Angle	90	90	107	42
Base Resolution	256	256	320	256
Phase Resolution	80	80	80	80
Bandwidth	558	476	401	558
RF Pulse Type	Normal	Normal	Normal	Normal
Gradient Mode	Fast	Fast	Fast	Fast


Indications for dynamic MRI in pediatric radiology
CSF flow dynamics
Spine mobility (stability)
Joint dysfunction (TMJ mobility)
Pelvic floor mobility
Upper airways/ GI tract dynamics
Esophageal or bowel motility
Cardiac contractility
Blood flow patterns
And others…

CSF flow dynamics

- Assessment of various pathologic entities causing **alteration of cerebrospinal fluid (CSF) flow** in the brain and spine
  - Chiari deformity
  - Hydrocephalus
    - Cerebral aqueduct stenosis or compression
    - Ventricular outflow obstruction
  - Intra-cranial cysts or mass
  - Spinal stenosis

- Assessment of **effectiveness of endoscopic neurosurgical procedures** performed to change route of flow of CSF
  - Endoscopic third ventriculostomy (**ETV**)
  - Arachnoid cyst **fenestration**

Normal pattern of CSF flow

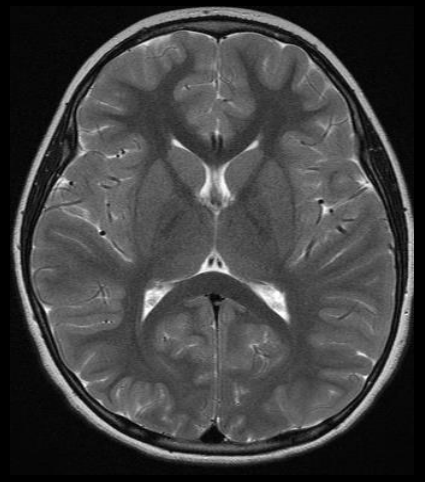
Normal flow through the:

- cerebral aqueduct
- craniocervical junction
- posterior fossa

24 weeks fetus

Axial T2WI

3 year old child



Axial T2WI

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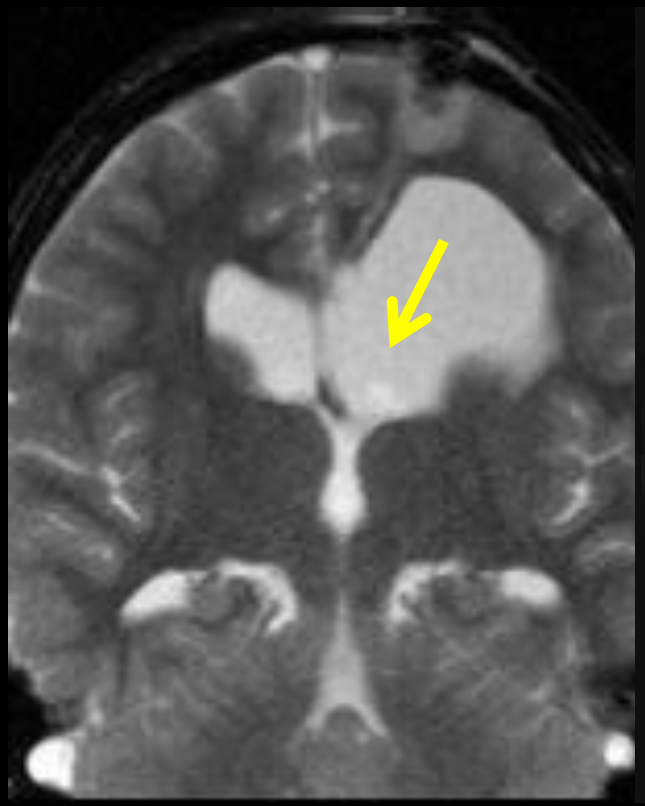
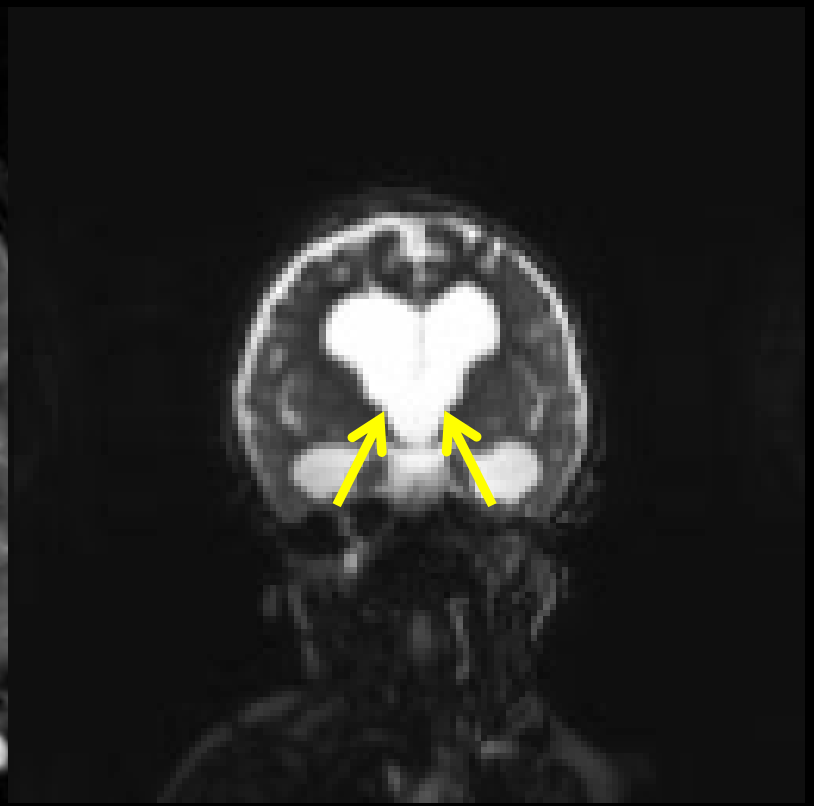
Patterns of intracranial CSF flow

Foramen of Monro (arrow)





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Sagittal T2WI

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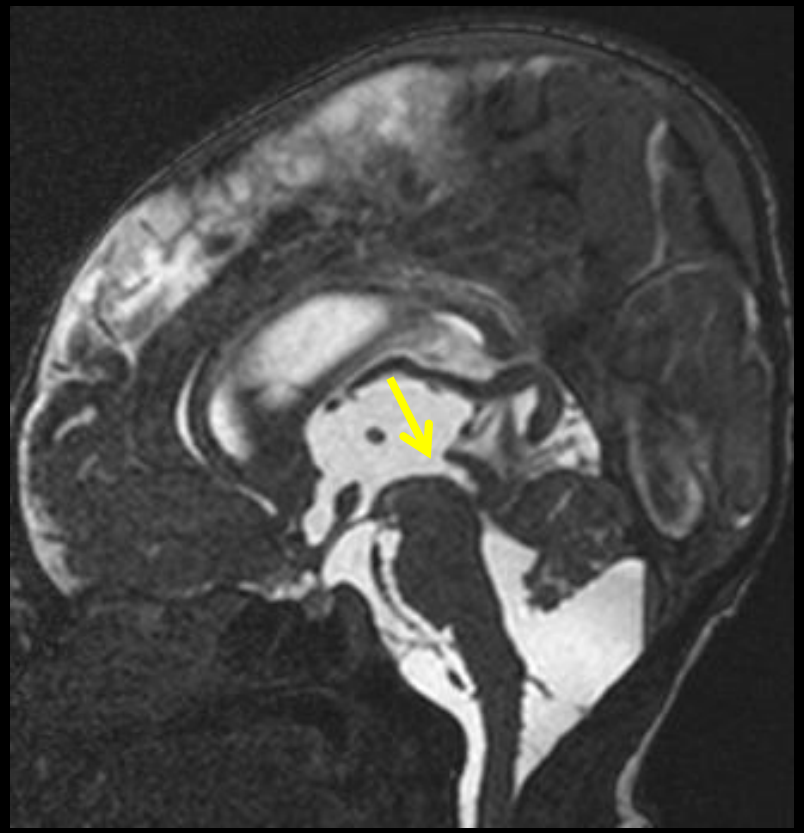
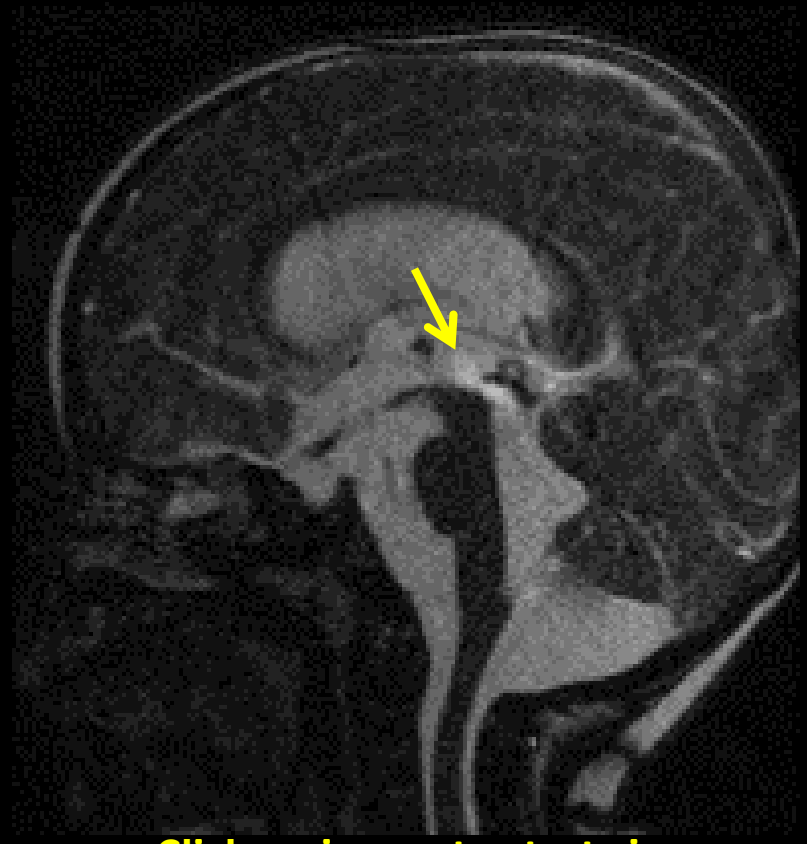
Patterns of intracranial CSF flow

Sylvian Aqueduct (arrow)



Sagittal T2WI



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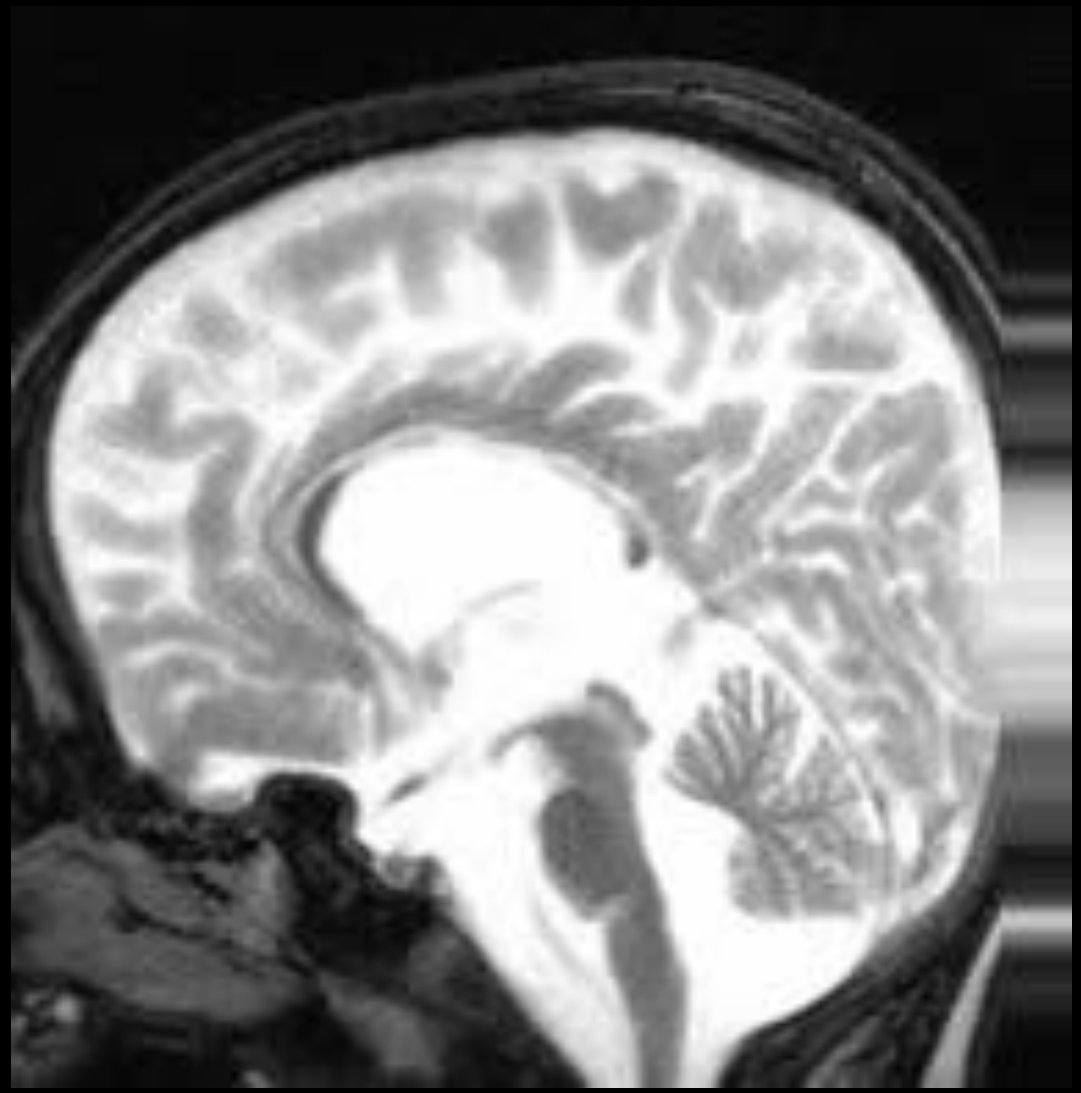
Patterns of intracranial CSF flow

Periventricular leukomalacia (PVL) and adhesions cause distorted "**blizzard**" type of CSF flow in the:

- ventricles
- pre-pontine cistern
- foramen of Magendie



Endoscopic third ventriculostomy

- Designed to **divert CSF flow** with less morbidity
- Almost equally effective to VP shunting

- **MR** = accepted **gold standard** for **stoma effectiveness evaluation**
- Direct visualization of the flow by **cine** = most reliable sign of patency

- **Cine** to-and-fro **CSF Phase-contrast Imaging** with **low** velocity encoding (**VENC**) parameter (5cm/sec) to sensitize the sequence to slow CSF flow **or true FISP cine**

Patency of fenestration site

Patient with tectal glioma, status post ETV

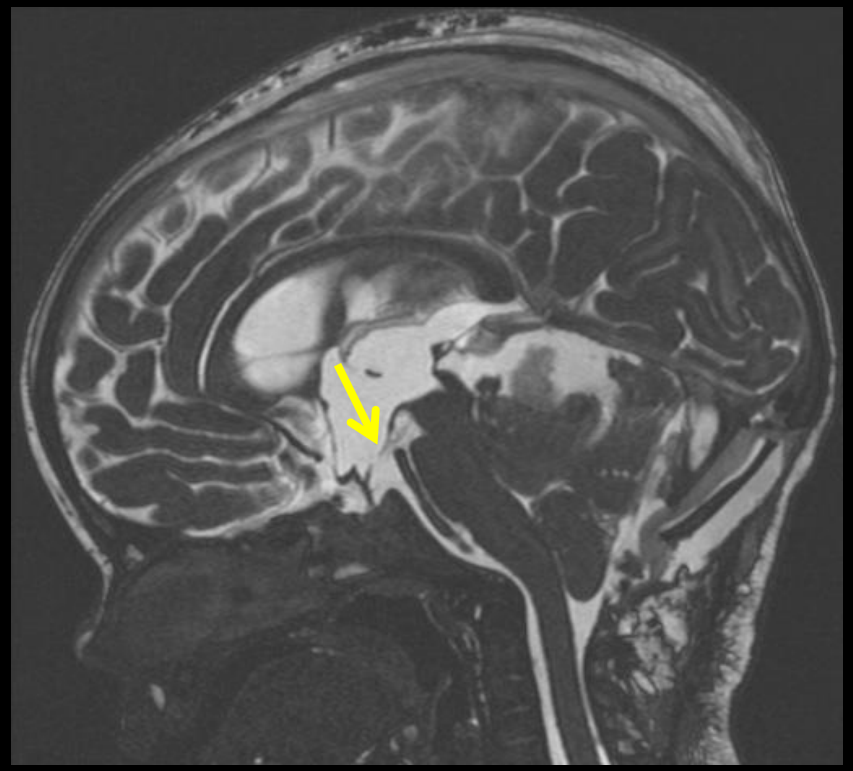
Low **third ventricle floor** touching **basilar artery tip** (**arrow**)

Attention must be paid to the position of the presumed site of stoma placement and its relationship to the tip of the basilar artery

Patency of fenestration site

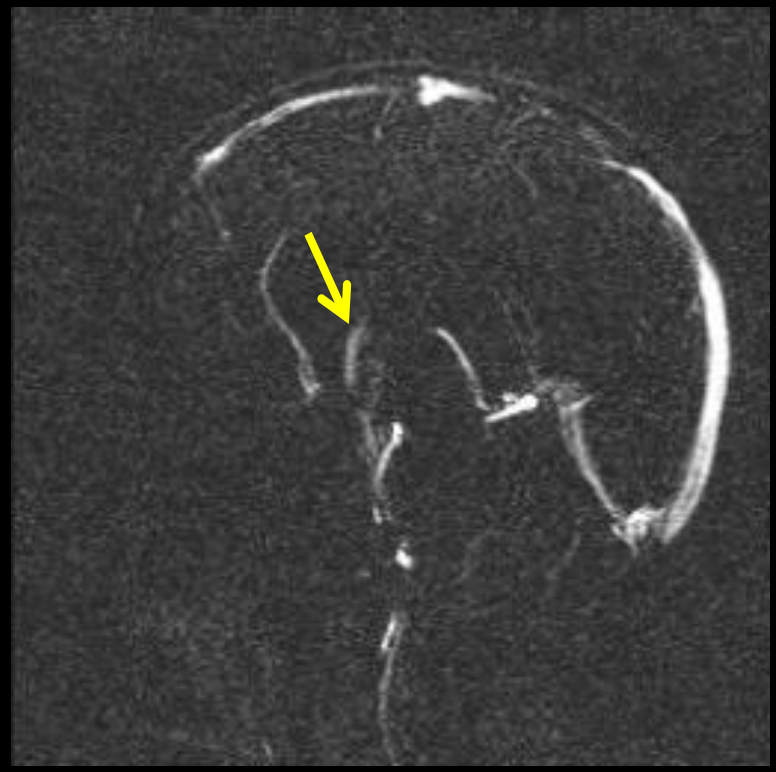
Patient with **posterior fossa tumor, status post ETV**

ETV fenestration site (**arrow**)



Sagittal CISS 3D image

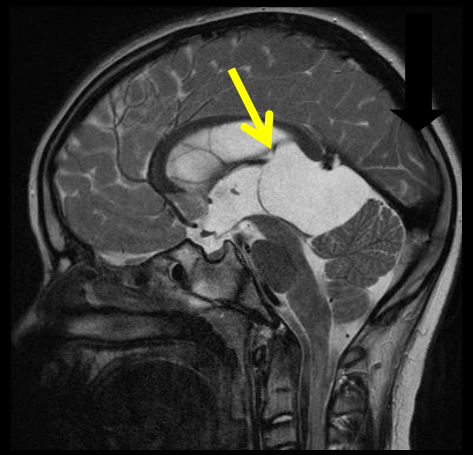
Jet flow from the 3rd ventricle floor to the pre-pontine cistern (**arrow**)



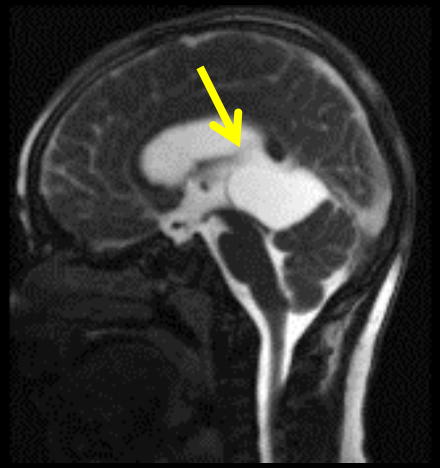
Patency of fenestration site and ETV

Large arachnoid cyst (AC), compressing the cerebral aqueduct. Status post fenestration of anterior wall of AC and ETV.

AC (**arrow**)



Sagittal T2WI



Click on image to start cine

Phase contrast flow study* shows multi-directional jets (**arrows**) through both defects and foramen of Monro

Click on images to start cine

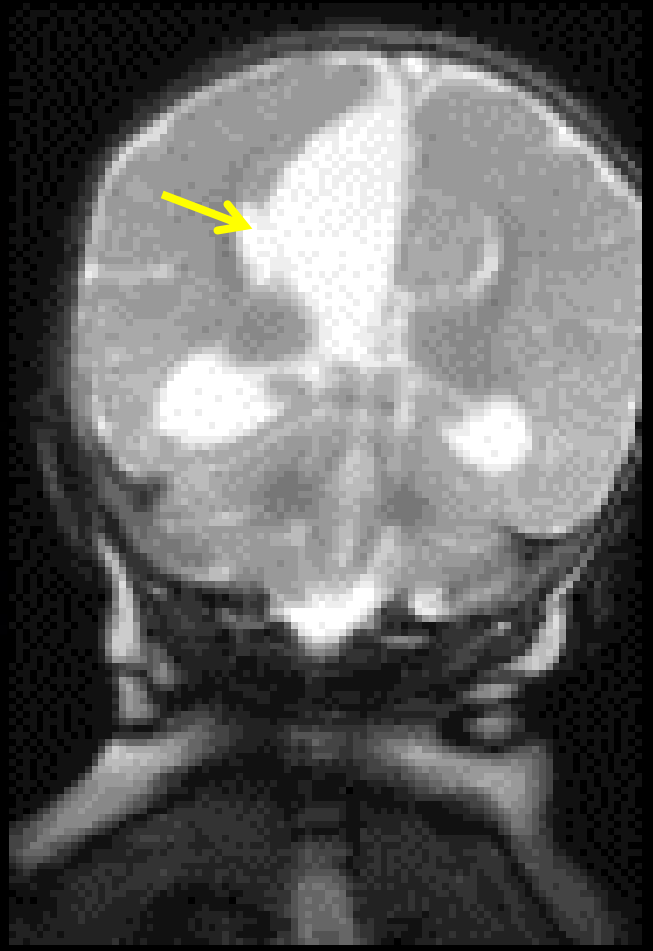
* With low velocity encoding (VENC) parameter (5cm/sec) to sensitize the sequence to slow CSF flow.

Non-functional stoma versus patent stoma

Non-functional stoma
No CSF flow through ETV

Click on image to start cine

Status post fenestration of parasagittal arachnoid cyst



Click on images to start cine

Dynamic cine MRI for spinal anomalies

- Mobile components:
  - cerebrospinal fluid
  - cerebellar tonsils
  - spinal cord itself

- Dynamic cine MRI shows **physiologic longitudinal** and **transverse motion** of the spinal **cord**

Evaluation of spinal CSF flow dynamics

- **Spinal cord movement may be affected by various pathologies, including:**
  - Down’s syndrome
  - Os odontoideum
  - Basilar invagination
  - **Chiari I deformity**
  - Syringohydromyelia
  - Cervical stenosis
  - Trauma

Evaluation of spinal CSF flow dynamics

- Imaging in **functional positions** with **flexion/extension** maneuvers
- Images acquisition with patient **actively** flexing and extending his neck = limited by patient comfort

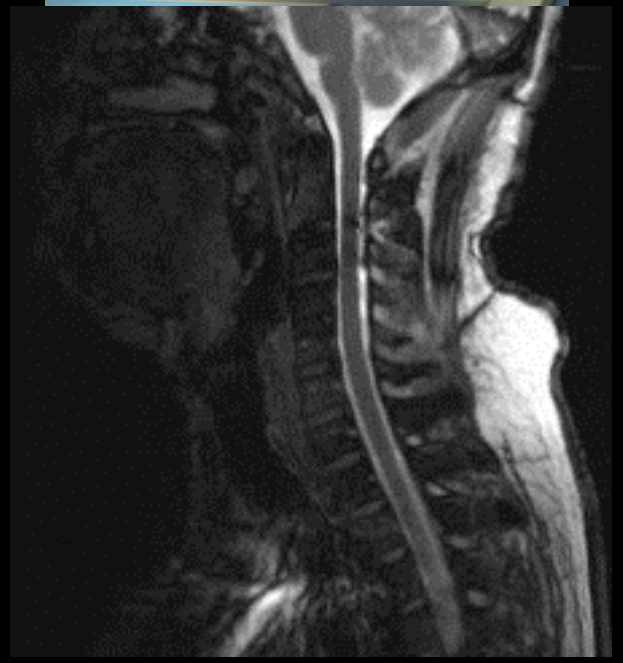
- **Special dynamic flexible coils (or house-made devices)**
  - May be used in **sedated** (even under GA) patients
  - **Easy** to perform, short acquisition time
  - May help to avoid sedation in certain patients

House-made device: inflatable cuff (sphygmomanometer)

1. Placed under neck of patient
2. Remotely inflated and deflated during examination by technologist

Dynamic MRI for cervical spine - Normal

Neutral position



Flexion

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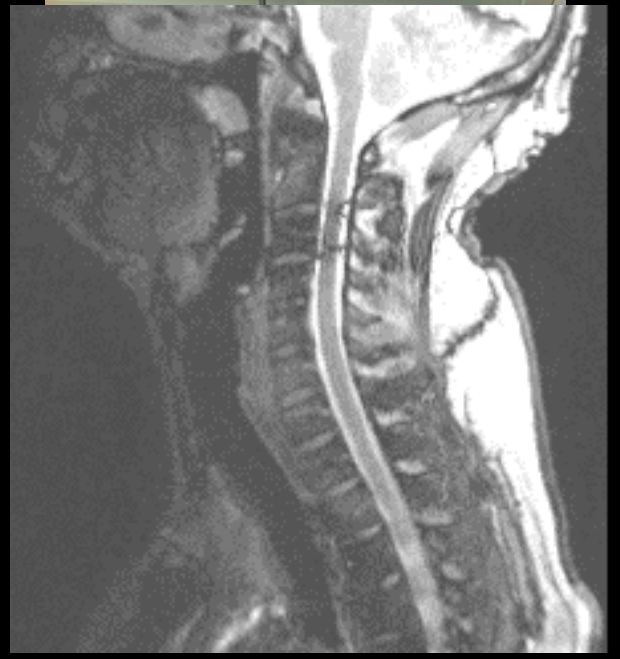

Extension

Dynamic MRI for cervical spine

Trauma

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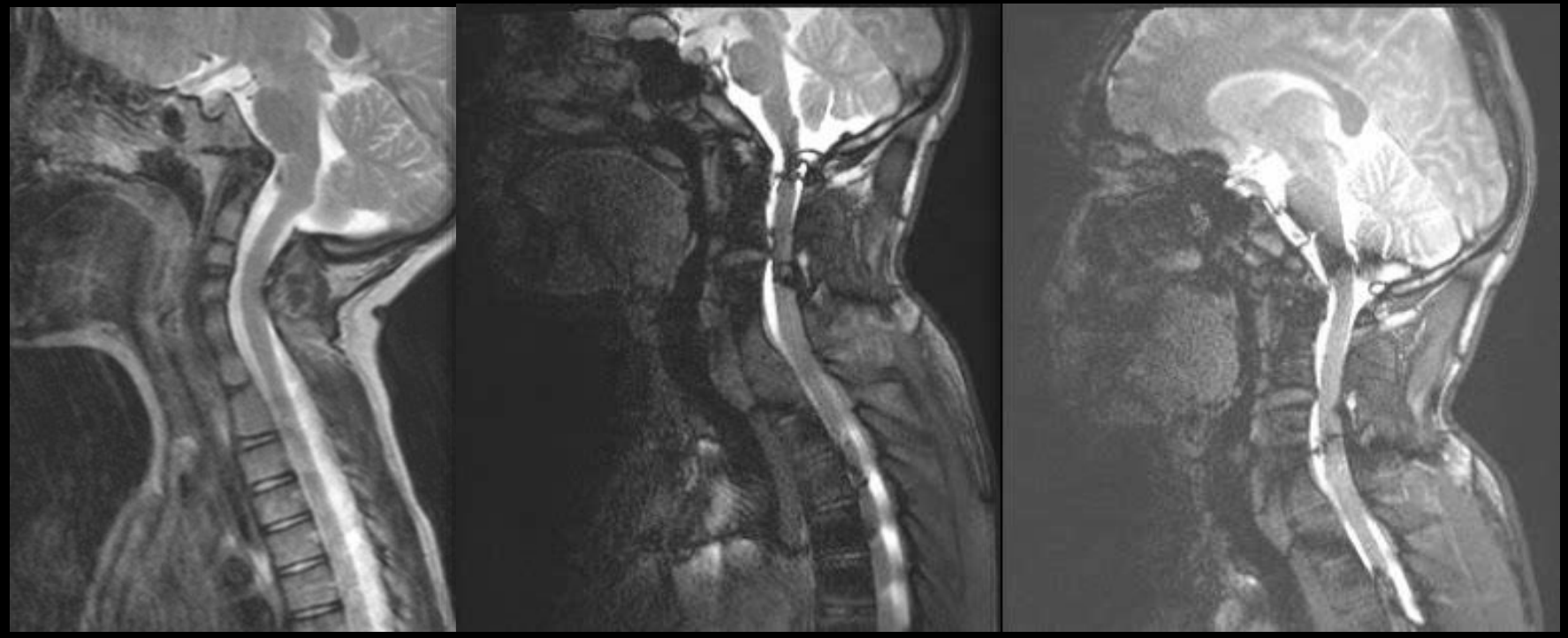
No abnormal motion/instability
No compromise of the CSF space

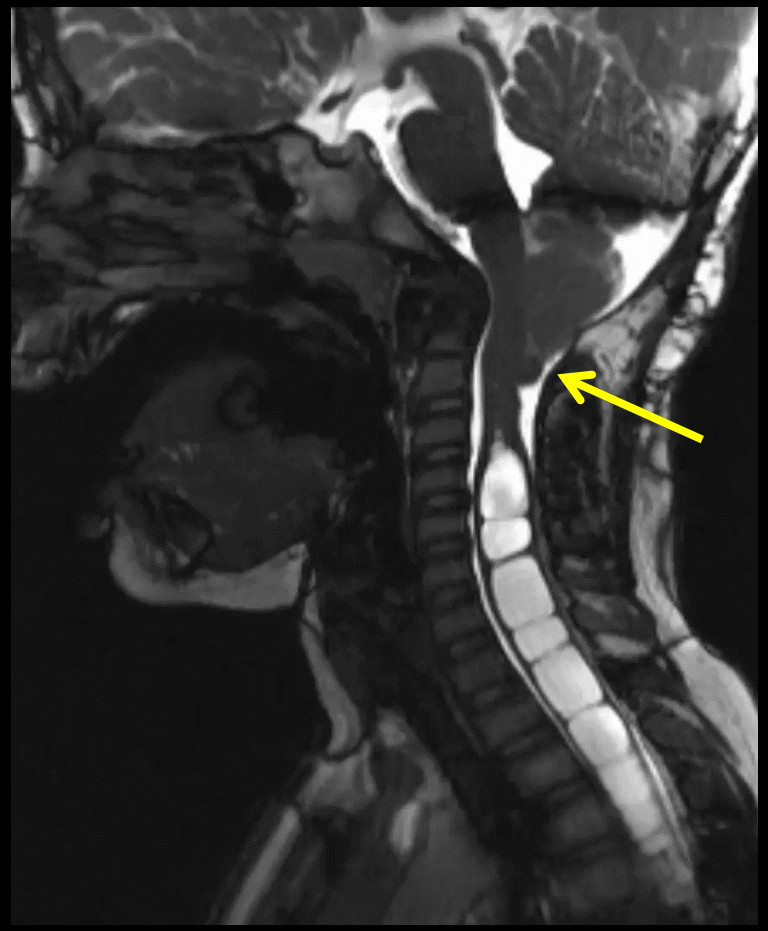
Fusion anomalies



Click on images to start cine

No abnormal motion/instability
Effacement of CSF (anterior column) with flexion

CSF flow pattern in patients with Chiari I



Increased mobility, pulsatile movements, notably of the cerebellar tonsils (arrow)

Patient with Chiari I deformity and syringohydromyelia

Increased pulsatile movements of hindbrain-spinal cord axis in patients with foramen magnum obstruction

These pulsatile movements, together with a one-way valve mechanism in the syrinx cavity act as a **"vacuum-pump"** to **enlarge the syrinx**

Evaluation of the upper airways dynamics

- **Indications include:**
  - Children with suspected **velopharyngeal dysfunction or incompetence (VPI)**
  - Suspected dynamic airway compression
    - dynamic evaluation of tracheal collapsibility in patients with tracheomalacia during coughing (Valsalva)
  - Swallowing dynamics in neonate
  - Swallowing patterns in fetuses with head & neck pathology

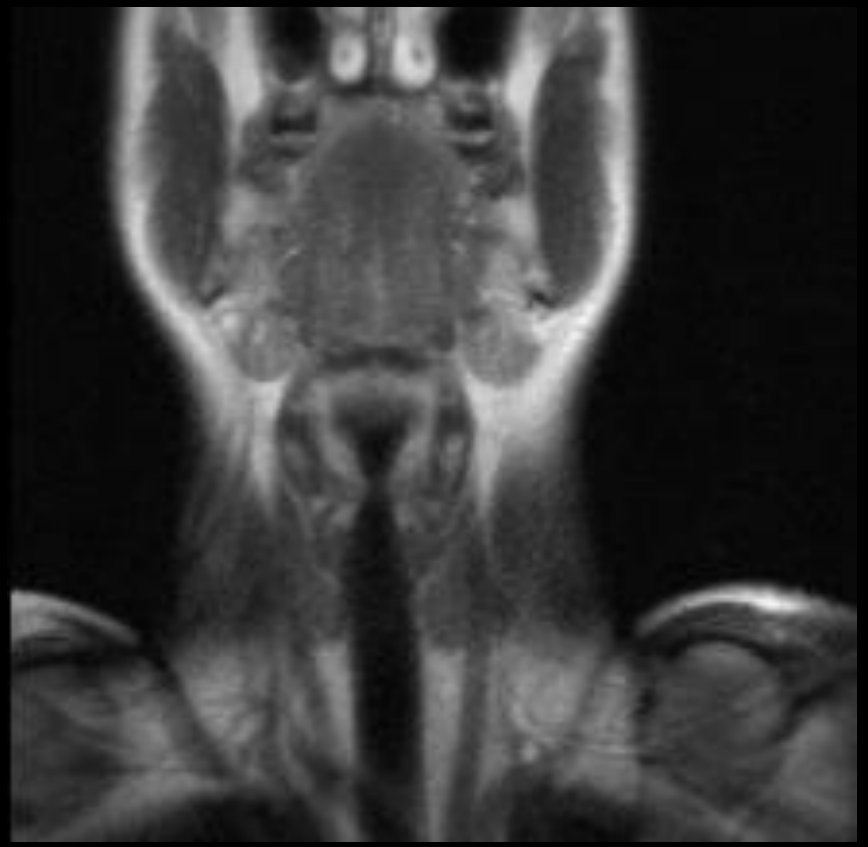
Velopharyngeal incompetence (VPI)

- **Inability to achieve adequate closure of the velopharyngeal port (during swallowing and phonation), notably with:**
  - sleep apnea
  - 22q11.2 deletion
  - cleft

- Assessment usually performed with:
  - Cephalometric Radiographs
  - Videofluoroscopy
  - Nasoendoscopy

- MR fluoroscopy is a valuable addition for VPI assessment

Normal velopharyngeal closure and normal motion of soft palate



At Rest

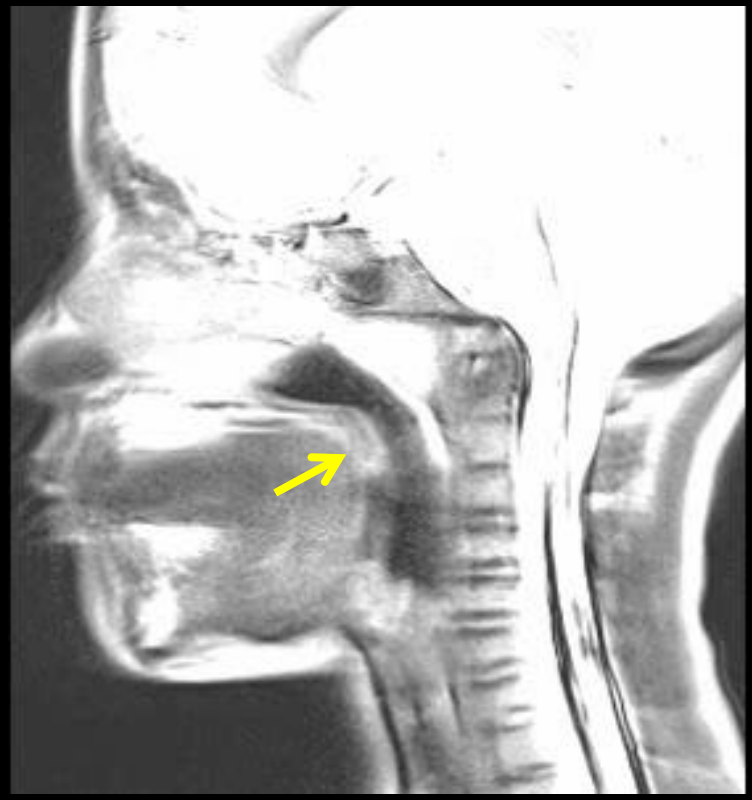
Phonation: e-e-e

Click on images to start cine

Patient with 22q11.2 deletion syndrome: snoring, sleep apnea, VPI

Incomplete closure

Soft palate does not reach the posterior pharyngeal wall



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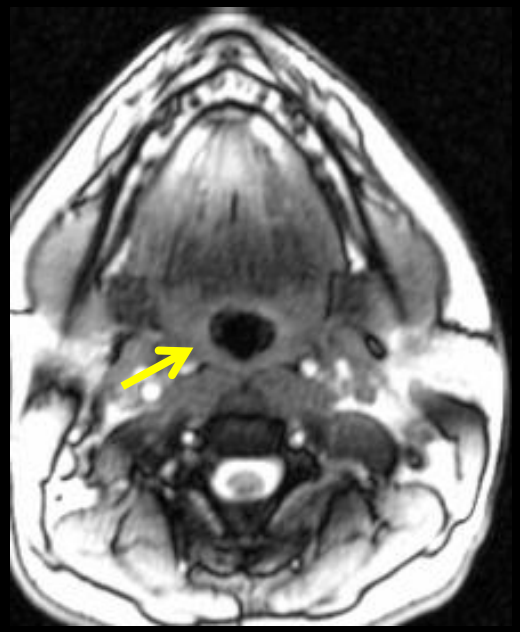
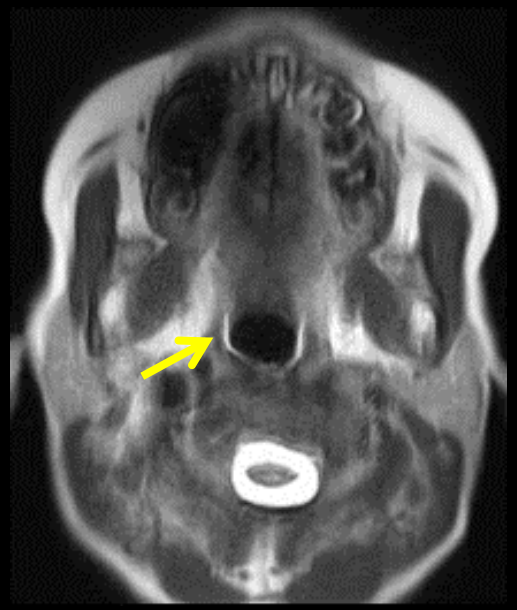
Normal and abnormal velopharyngeal closure (on axial images)

22q11.2 deletion syndrome

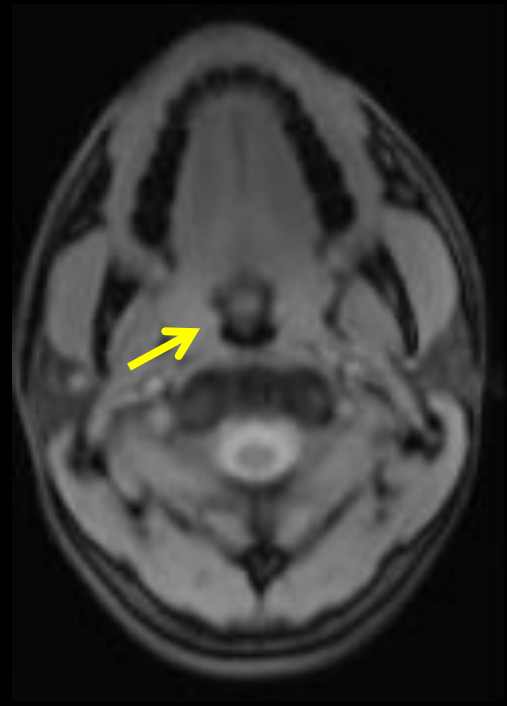


Severe VPI



Moderate VPI

Normal volunteer

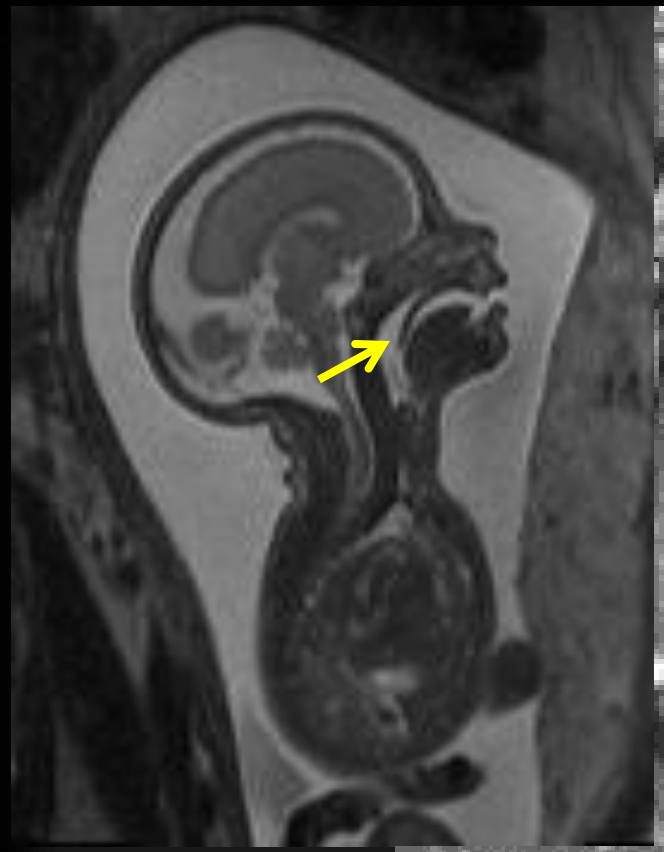


Normal **complete** closure

Click on images to start cine

Fetal swallowing

- Fetal swallowing movements detected as early as 11 wks of GA (demonstrated by US)
- Increased coordination with increasing gestational age
- Various phases of fetal swallowing are identifiable

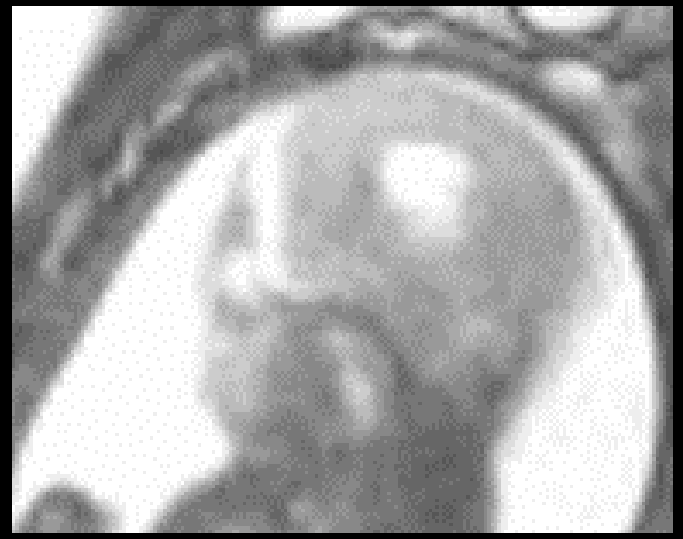


Sagittal T2WI
Soft palate **(arrow)**

Click on images to start cine

Spectrum of pathologies with abnormal pattern of fetal swallowing

- Giant neck masses
  - **venolymphatic malformations**
  - **teratomas**
- Cleft lip and palate
- Micrognatia
- Esophageal atresia
- Swallowing patterns in fetuses with head & neck pathology differ from those in fetuses with variety of other entities, not involving head and neck
- Some lesions in the fetal neck could lead to fetal maldevelopment

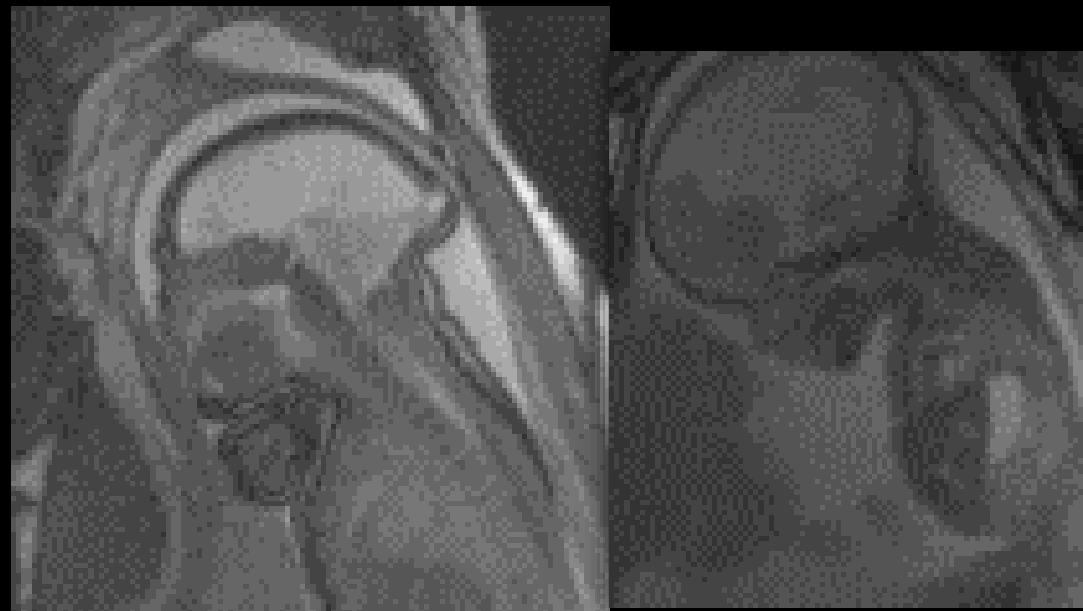


Normal pattern of fetal swallowing

Normal motion of fetal tongue and soft palate

Normal motion of hypopharynx and AEF

What exact mechanism regulates fetal swallowing is unknown



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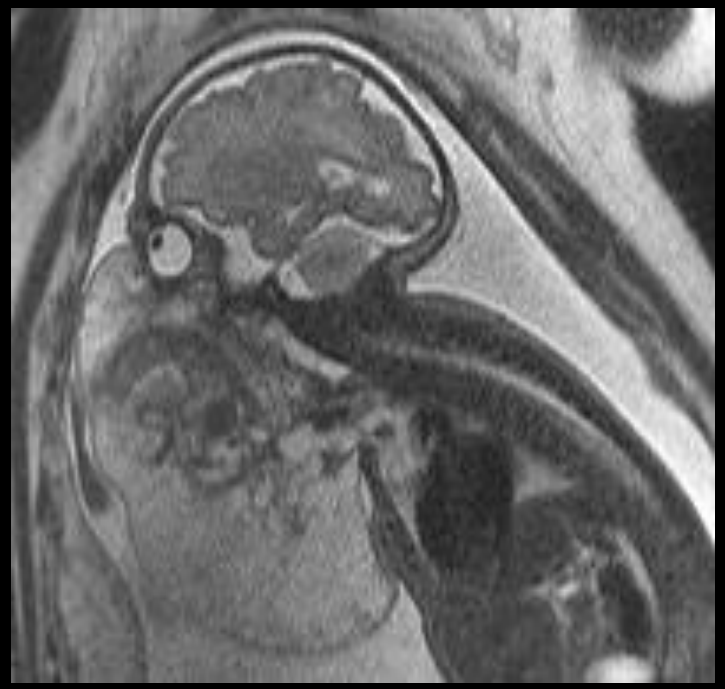
Craniofacial lesion, causing swallowing impairment

28 weeks fetus



Sagittal T2WI
Large, soft venolymphatic malformation

CINE

Partial obstruction to swallowing mechanism

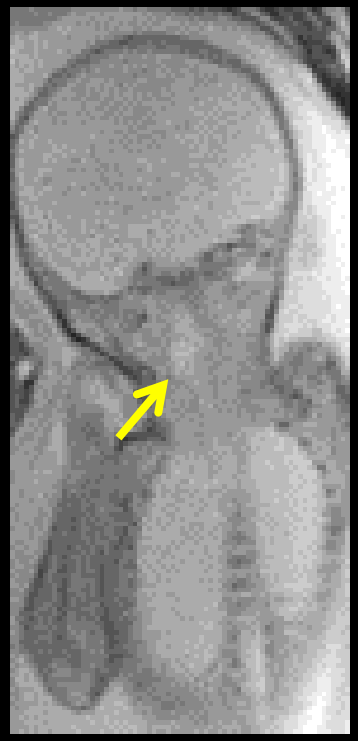
Abnormal patterns of fetal swallowing

Click on images to start cine

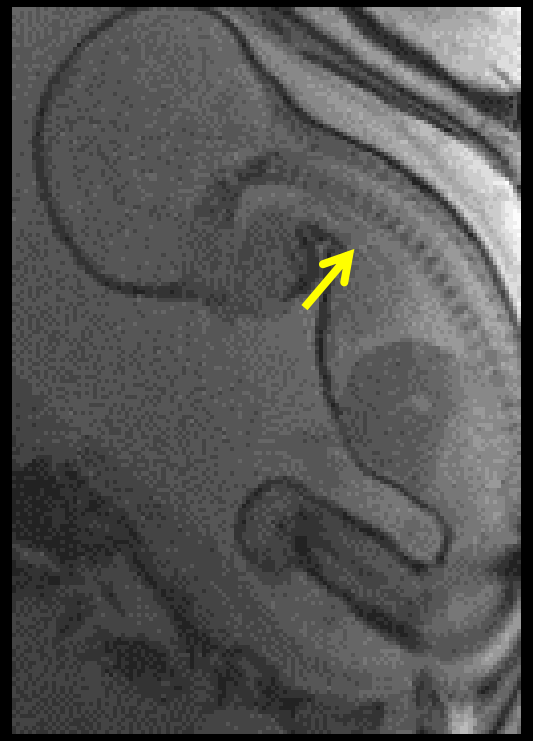
Large epidermoid cyst in floor of the mouth, causing impaired swallowing

Large, soft venolymphatic malformation, causing impaired swallowing

Abnormal patterns of fetal swallowing



Fetal laryngocele (**arrow**)



Esophageal atresia with blind pouch (**arrow**)

Pattern of swallowing for childbirth planning

???

Compression of upper GI tract structures may cause polyhydramnios and accelerated labor

Glossoptosis, causing impaired swallowing
In severe cases, glossoptosis can result in airway obstruction during or immediately after delivery, and may therefore require EXIT procedure.

Vaginal delivery

C-Section

Ex Utero Intrapartum Therapy (EXIT procedure)

Conclusion: Dynamic Real Time MRI

- Proves to be a valuable tool in assessment of intracranial CSF flow dynamics and evaluation of effectiveness of endoscopic neurosurgical procedures performed to change route of flow of CSF
- Easily obtainable and tolerable by the patients
- Desirable alternative of endoscopic procedures in evaluation of the upper airways
- Avoids radiation exposure
- May help to avoid sedation
- Demonstrates functional impairment of numerous fetal fluids flow dynamics
- Provides clinically significant prognostic information for pre and postnatal planning
  - Helps to guide parental counseling and delivery planning

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THE END – THANK YOU!