Ultrasound in Neurosurgery:

Pediatric Neurosurgery, Hydrocephalus, Endoscopy

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UNIVERSITEIT VAN PRETORIA
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Faculty of Health Sciences
Fakulteit Gesondheidswetenskappe
Lefapha la Disaense tša Maphelo

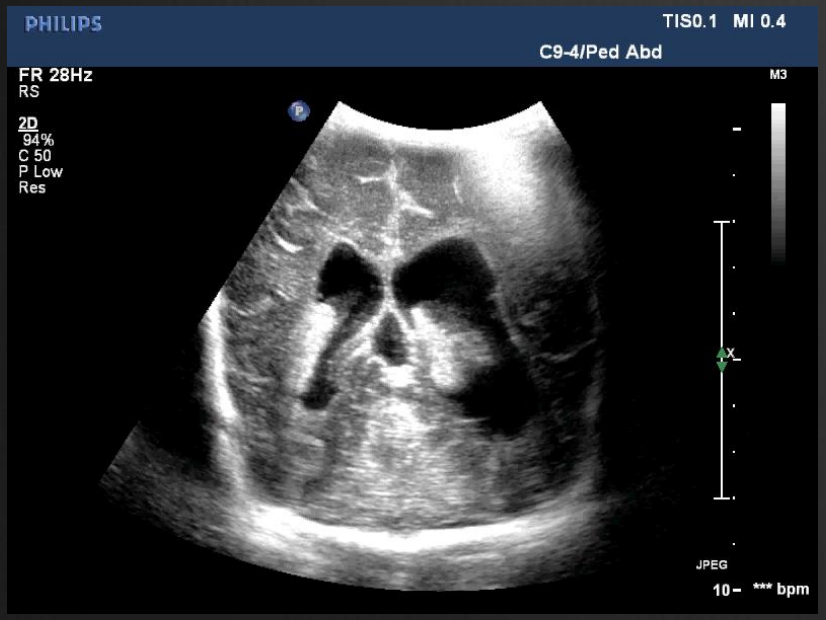
Ultrasound in Neurosurgery

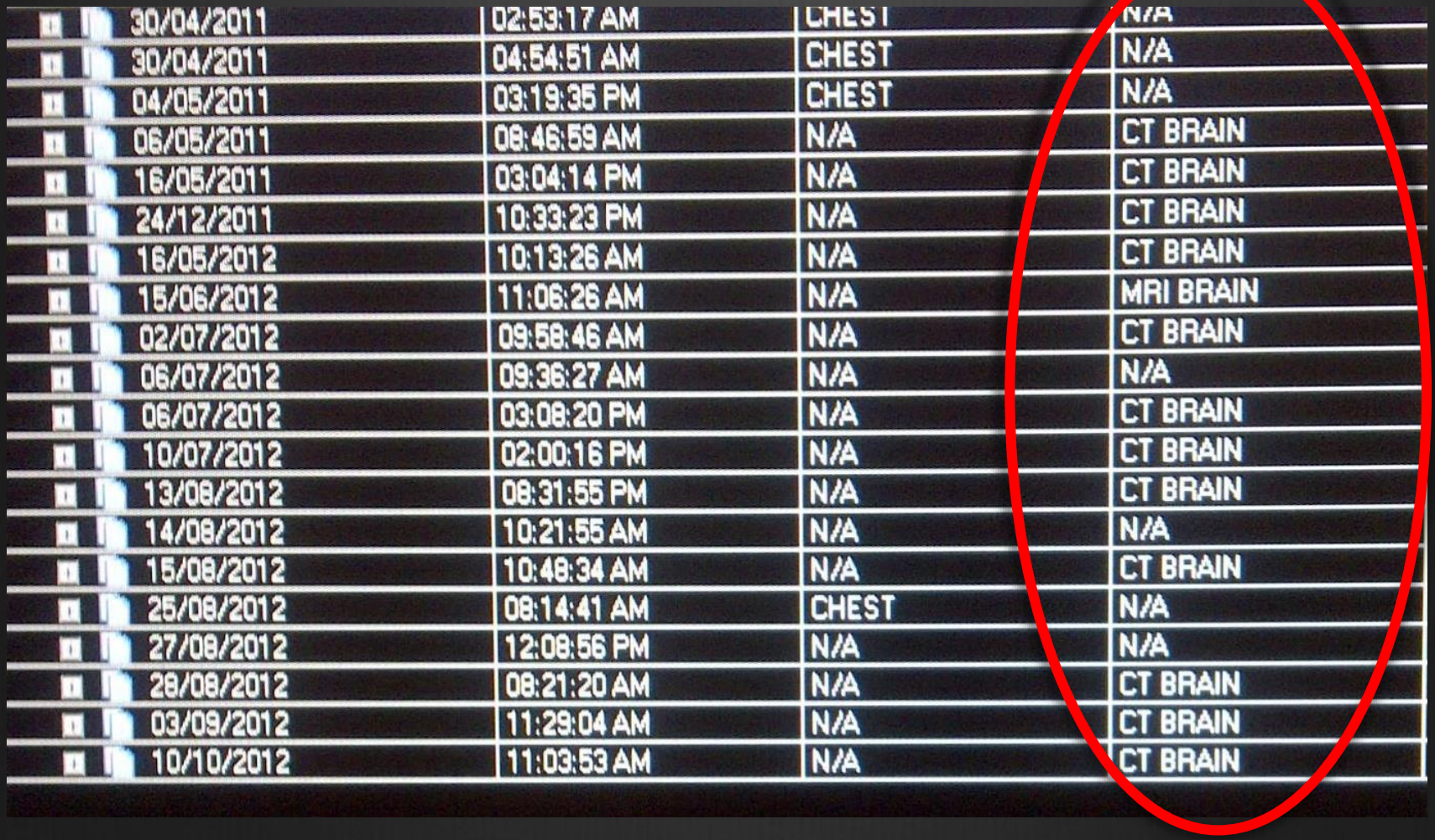
- **Diagnostic**
  - Bedside
    - Craniosynostosis
    - Hydrocephalus
    - Tumors
  - Raised ICP
- **Intra-operative Navigation**
  - Tumors
  - Hydrocephalus
    - V/P Shunts
    - Multiloculated
    - Endoscopy
  - Chiari malformation
  - Vascular
  - Peripheral nerve surgery
- **Surgical tool**
  - CUSA, piezosurgery
- **Therapeutic modality**
  - High Intensity Focused Ultrasound (HIFU)
    - Tumors
    - Functional
    - Blood Brain Barrier
- **Neuromodulation**
  - Sonogenetics


Red Cross War Memorial
Children's Hospital

Bedside diagnosis

- Decrease the amount of CT scans
  - Initial/early diagnosis in neonates
  - Follow-up assessment of ventricular size
  - Insertion of V/P Shunt





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30/04/2011	04:54:51 AM	CHEST	N/A
04/05/2011	03:19:35 PM	CHEST	N/A
06/05/2011	08:46:59 AM	N/A	CT BRAIN
16/05/2011	03:04:14 PM	N/A	CT BRAIN
24/12/2011	10:33:23 PM	N/A	CT BRAIN
16/05/2012	10:13:26 AM	N/A	CT BRAIN
15/06/2012	11:06:26 AM	N/A	MRI BRAIN
02/07/2012	09:58:46 AM	N/A	CT BRAIN
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28/08/2012	08:21:20 AM	N/A	CT BRAIN
03/09/2012	11:29:04 AM	N/A	CT BRAIN
10/10/2012	11:03:53 AM	N/A	CT BRAIN

6 month old - 15 CTs in 5 months !

Courtesy: Dr. T. Kilborn

What does this mean?

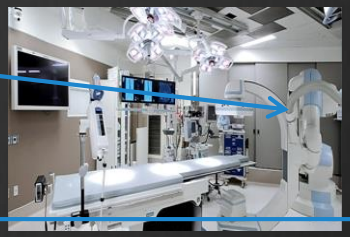
- Effective dose (mSv) calculates the dose absorbed.
- CXR = 0.01 – 0.02 mSv (1 day background)
- SXR = 0.1 mSv (5 days background)
- CT Head = 2mSv (8 months background).

1 CT Head = 100 CXR's

1/3 have at least 3 scans

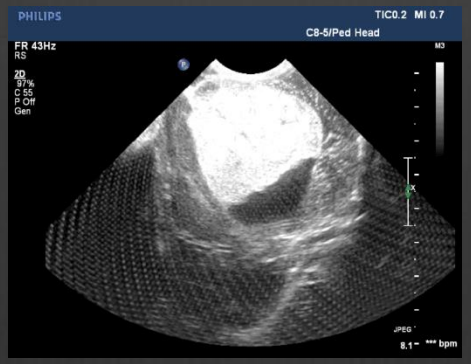
Modern Neurosurgery Theatre

- **Neuronavigation systems**
  - Frame-based and frameless systems
- Minimally invasive techniques
  - Microsurgery
  - Endoscopy
  - Endovascular
  - Novel ablation techniques
- Intra-operative image-guidance
  - Intra-operative MRI / CT
  - Fluorescence guidance
  - Intra-operative Ultrasound (IOUS)
- Intra-operative monitoring techniques
  - Cortical mapping and neurophysiological monitoring (IONS)

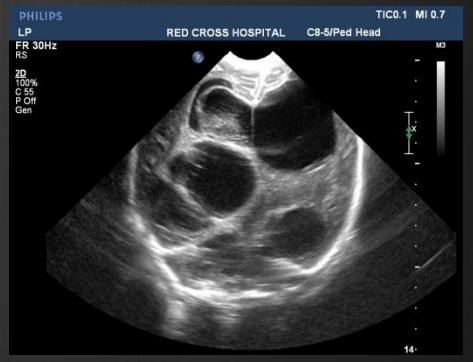


In my practice

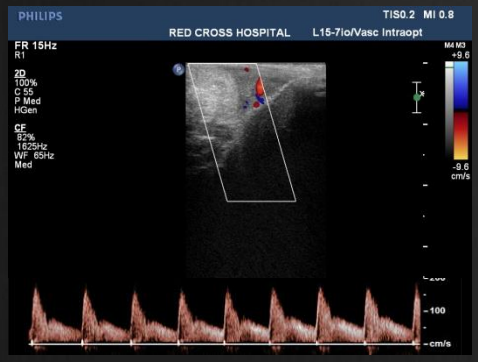
Ventricular catheter placement in hydrocephalus (n=127)



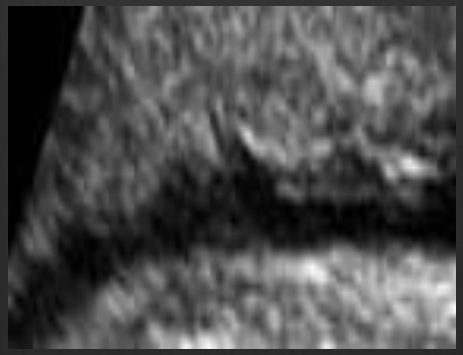
Intra-axial Neoplasm resection (n=102)



Endoscopic fenestration and catheter placement in multiloculated hydrocephalus (n=56)



Vascular– (n=9)



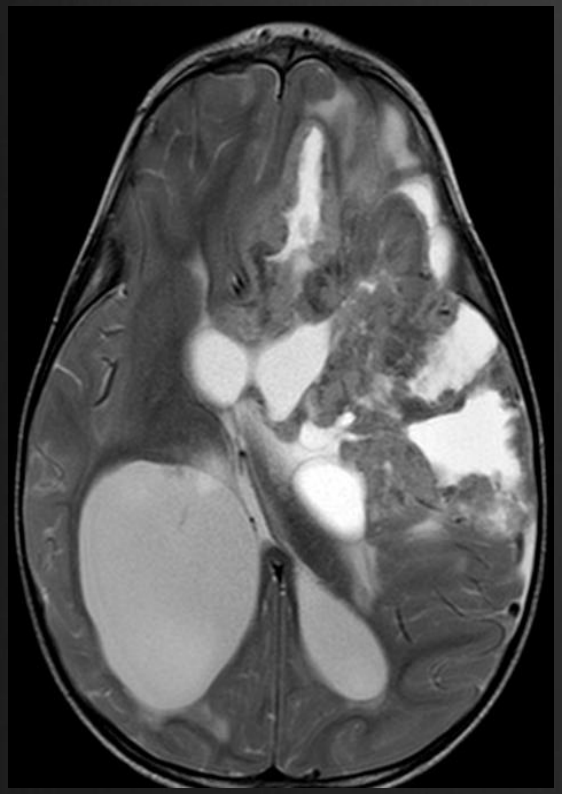
Chiari I malformation (n=16)

Intramedullary spinal cord tumor (n=8)

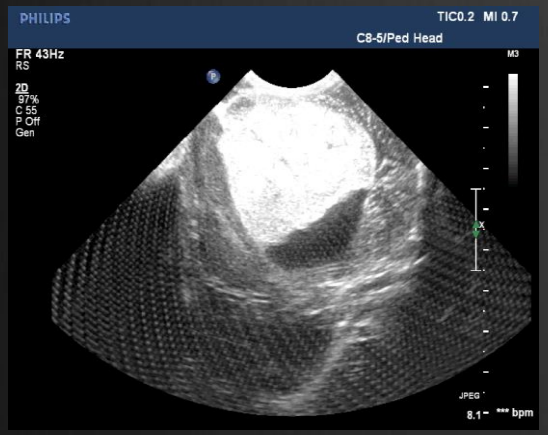
Necessities for U/S usage

- **Dural window**
  - Surgical window – fontanelle or craniotomy
- **Sterility**
- **Image quality**
  - Spatial resolution – probe frequency and probe size
  - Acoustic coupling
- **Image display**
  - Orthogonal, dual anyplane and stereoscopic
- **Probe**
  - Linear / phase array probes
- **User Experience**

Benefit of intra-operative imaging



Tumors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C8-5/Ped Head
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C 55
P Off
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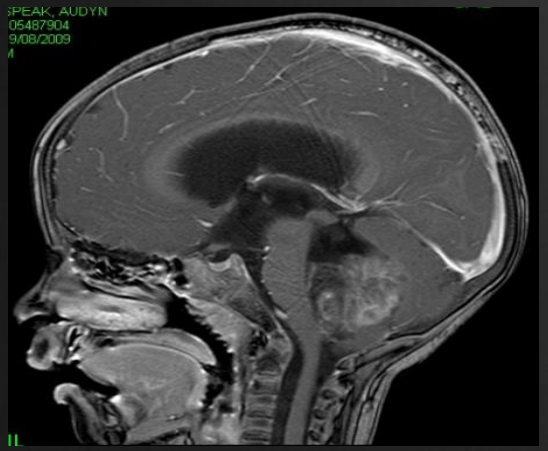
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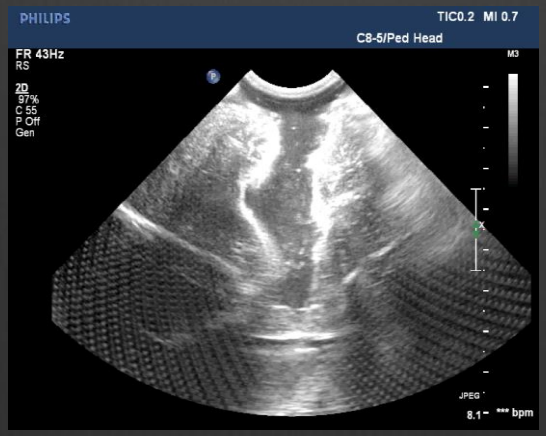
PHILIPS
TIC0.2 MI 0.7
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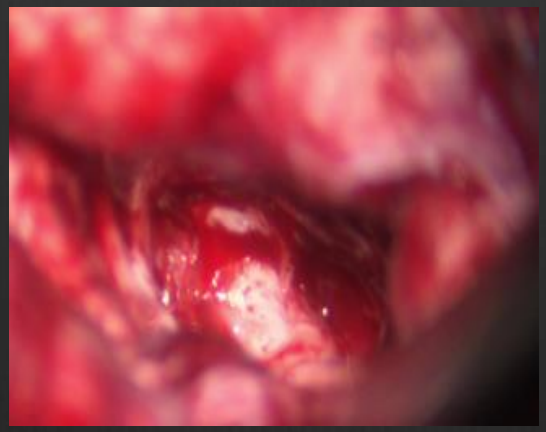

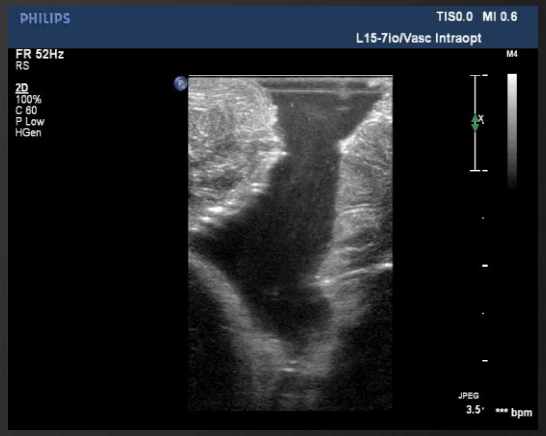
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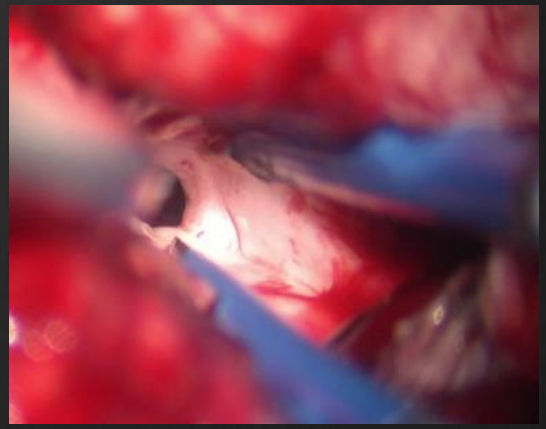
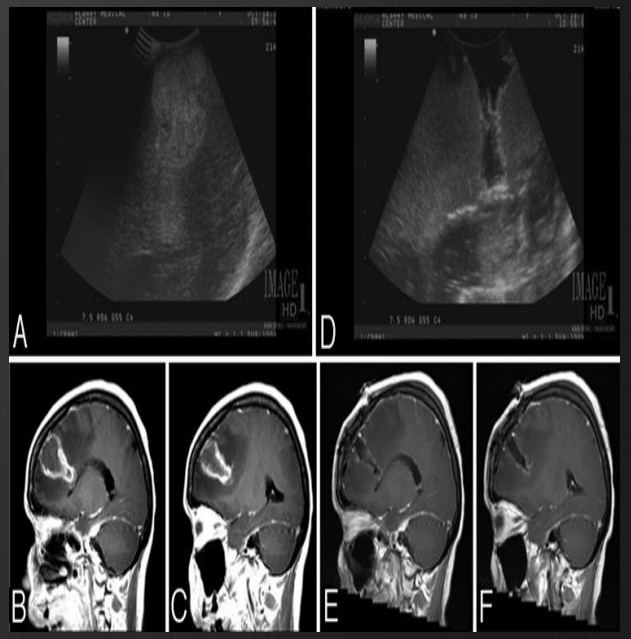


IOUS and post-op MRI

- IOUS – greater extent of resection due real time feedback on tumor volume and location
- Very good correlation between IOUS and post-op MRI

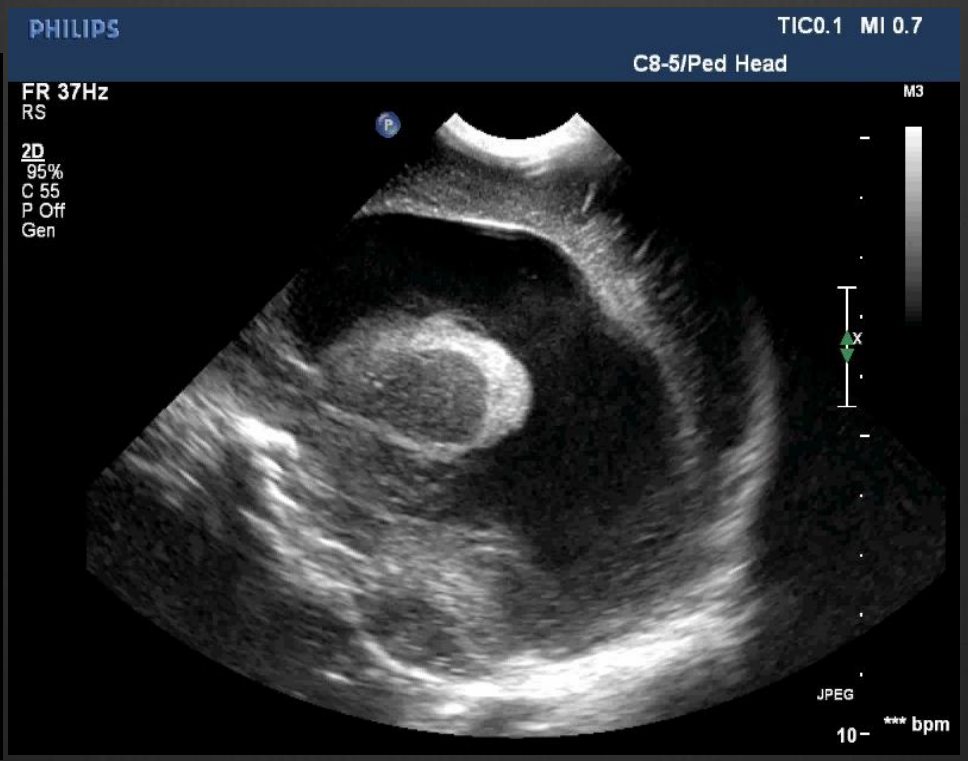


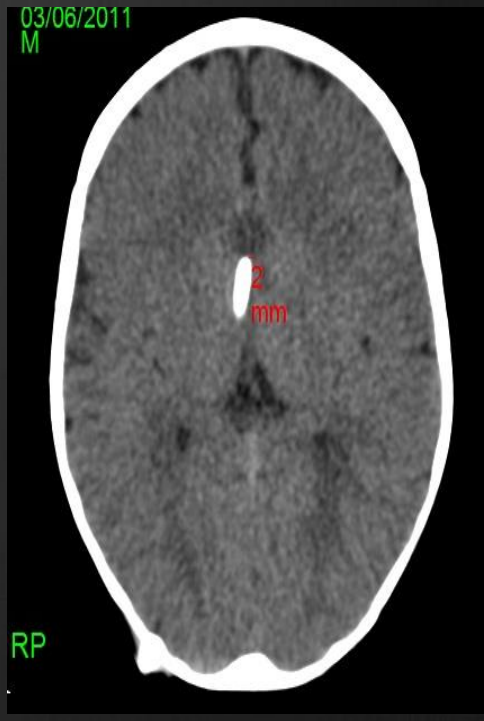
JNS PEDIATRICS
CLINICAL ARTICLE
J Neurosurg Pediatr 18:578–584, 2016

Correlation between intraoperative ultrasound and postoperative MRI in pediatric tumor surgery

Heather Smith, BA, AmiLyn Taplin, MD, Sohail Syed, MD, and Matthew A. Adamo, MD

Hydrocephalus





Types of probes

- Burrhole probe
- High frequency probe
  - Anterior fontanelle

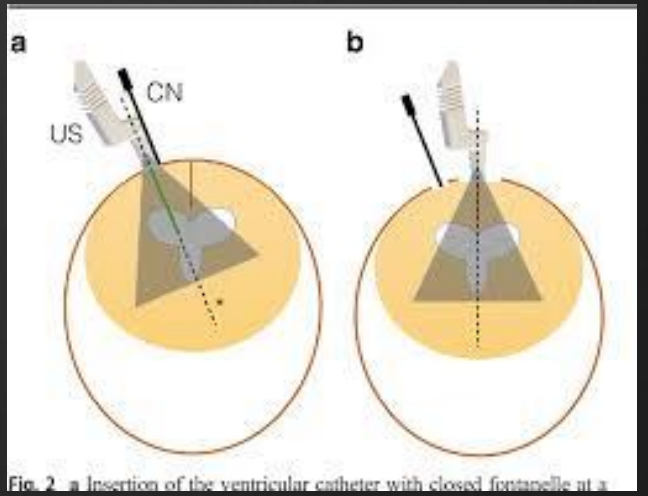


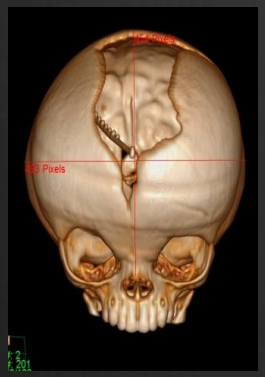
Fig. 2 a Insertion of the ventricular catheter with closed fontanelle at a

Assessment of accuracy

- Objective*

Accuracy 3D : $\sqrt{AP^2 + RL^2 + CC^2}$

AP



RL

CC

*Accuracy is defined as the Euclidean distance between the ipsilateral FOM and the catheter tip

- Subjective*

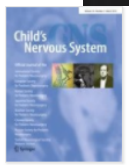
1) Catheter tip floating in CSF equidistant from the ventricular walls, away from choroid and a straight trajectory from the burrhole

2) Catheter tip touching ventricle wall or choroid

3) Part of catheter tip within parenchyma or failure to cannulate the targeted ventricle completely

*__Hayhurst et al__
Effect of electromagnetic-navigated shunt placement on failure rates.
J. Neurosurg. 2010

Ultrasound-guided placement of ventricular catheters in first-time pediatric VP shunt surgery



Zeitschrift: Child's Nervous System › Ausgabe 3/2018

Autoren: Marcel Kullmann, Marina Khachatryan, Martin Ulrich Schuhmann

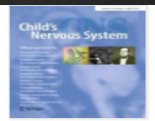
Imaging variable		Ultrasound-guided		Standard
Catheter grade				
1) **Optimal**		n=21 (23)		n=12 (25)
		92%		48%
2) **Acceptable**		n=1 (12)		n=5 (15)
		8%		33%
3) **Needs revision**		n=0 (12)		n=3 (15)
		0%		33%

Conclusion

Ultrasound-guided VC placement is as precise as frameless navigated placement. The optimal VC position was associated to a significant lower VC obstruction rate. The frontal position was superior to the occipital. Intraoperative US guidance is fast with almost no extra time and no extra cost. US-guided VC placement should become standard of care in VP shunt surgery.

*

Ultrasound-guided placement of ventricular catheters in first-time pediatric VP shunt surgery

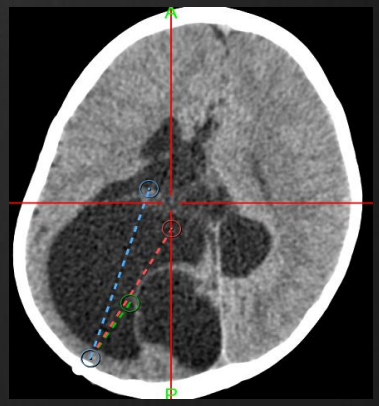


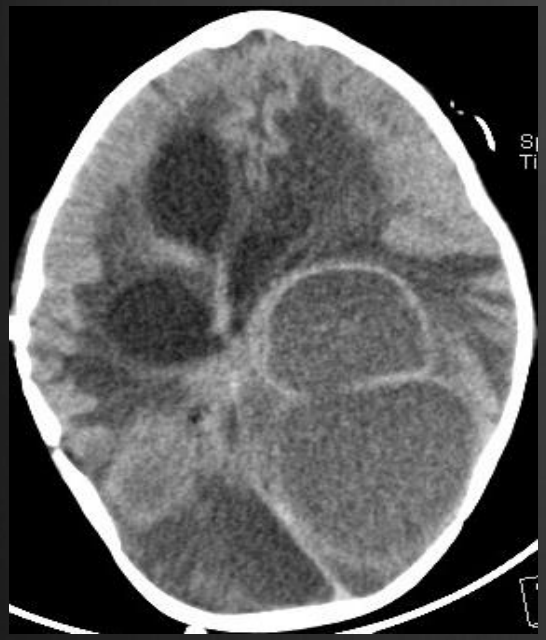
Zeitschrift: Child's Nervous System > Ausgabe 3/2018

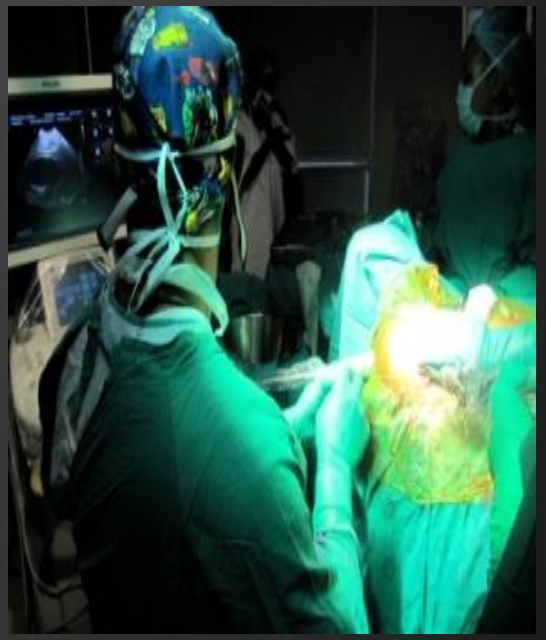
Autoren: Marcel Kullmann, Marina Khachatryan, Martin Ulrich Schuhmann

Image-guided Neuroendoscopy

- Real-time intra-operative imaging
  - Ultrasound guidance
  - Intraventricular contrast injection
  - Neuronavigation combined with intra-operative MRI
- Stereotactic-guidance (Neuronavigation)
  - Frameless (electromagnetic)
  - Combined with intraoperative MRI

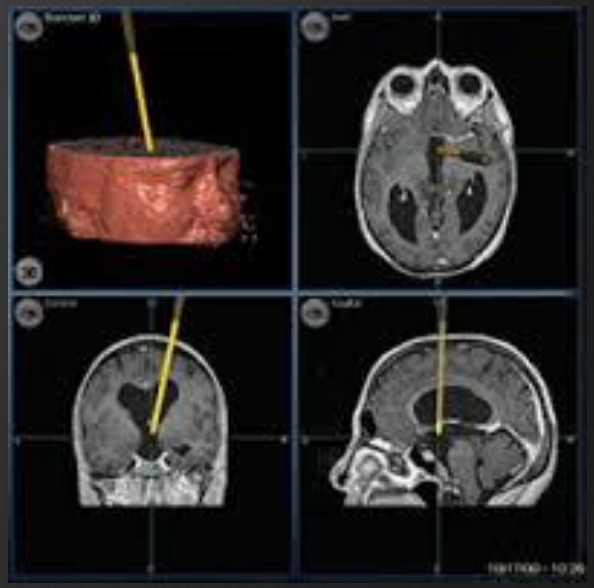






Electromagnetic neuronavigation guided neuroendoscopy

- 16 children (29 navigated procedures)
- Refines operative planning and intraoperative orientation
- Multiple procedures are often necessary
- High complication rate



J Neurosurg Pediatrics (2010)
Navigated endoscopic surgery for multiloculated hydrocephalus in children
Mattias Schulz, Georg Bohner, Hannah Knaus, Hannes Haberl, Ulrich-Wilhelm Thomale

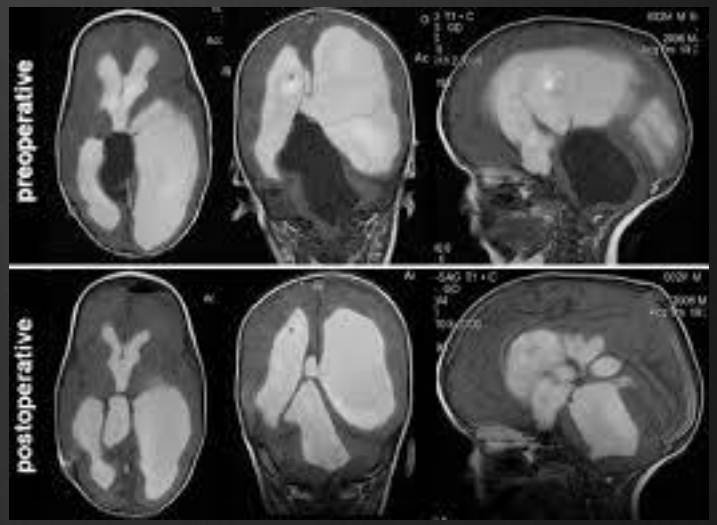
Neuronavigation and intra-operative MRI

- 5 infants
  - Helpful in redefining targets
  - Documenting brain and CSF shift
  - Combination of the two modalities provides visually controlled real-time navigation

J Neurosurg Pediatrics 2011
Combined intraoperative magnetic resonance imaging and navigated neuroendoscopy in children with multicompartmental hydrocephalus and complex cysts: a feasibility study
Dimitrios Paraskevopoulos, Naresh Biyani, Shlomi Constantini, and Liana Beni-Adani

MRVentriculography

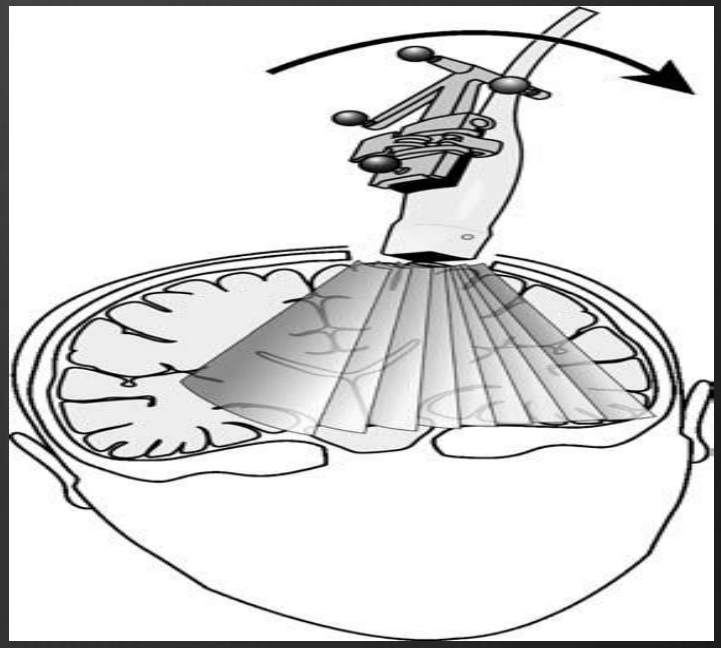
- 18 patients
- Injection of the lateral ventricle with contrast
- Pre and post-operatively
- Accurately defines anatomy, site of obstruction and efficacy of procedure(post-op)



J.Neurosurg. Ped 11:697-703, 2013
Role of magnetic resonance ventriculography in multiloculated hydrocephalus
Gandhoke G, Frassanito P, Chandra N, Ojha B, Singh A

Ultrasound guided Neuroendoscopy

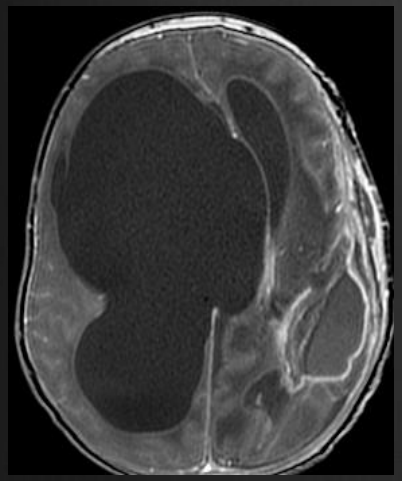
- 6 (10) patients
- Treated cystic lesions
  - Safe guidance of the scope
  - Permanent visual control of surrounding brain tissue
  - Real time imaging to check position of the tip during fenestration
  - Saline flush to confirm fenestration
  - Recommended combination usage

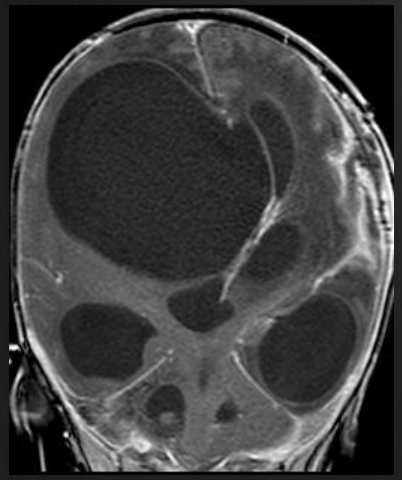


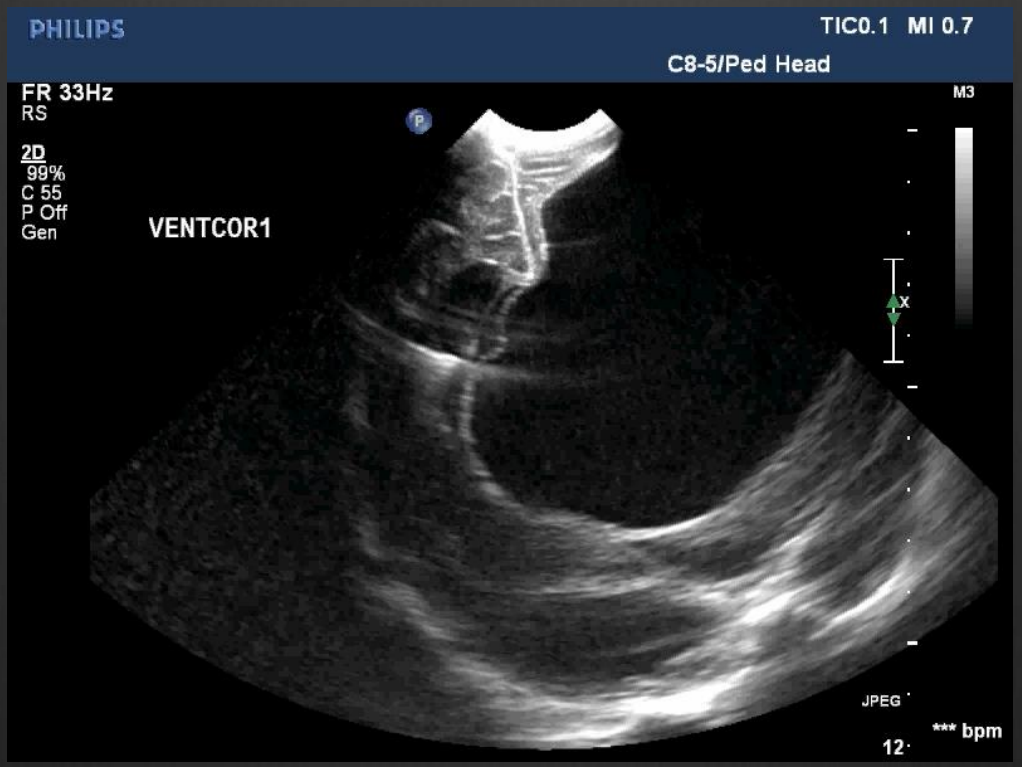
J Neurosurg 96:628–632,2002

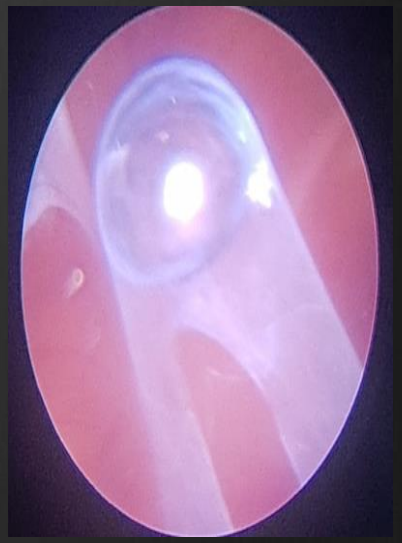
A new method of ultrasonic guidance of neuroendoscopic procedures
MARTIN STROWITZKI, M.D., MICHAEL KIEFER, M.D., AND WOLF-INGO STEUDEL, M.D.

Inadequate fenestration

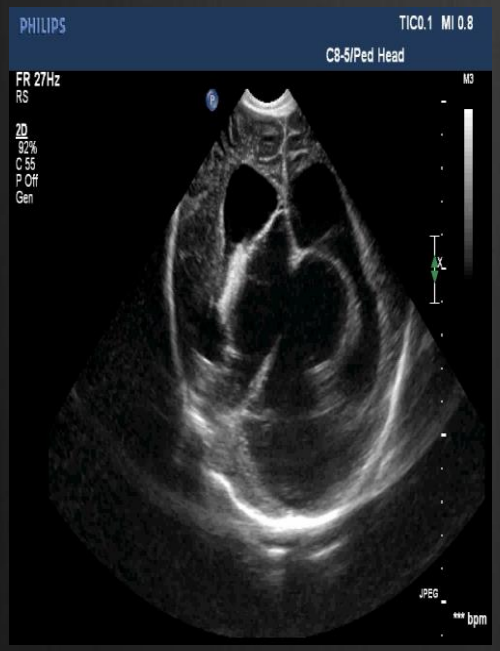


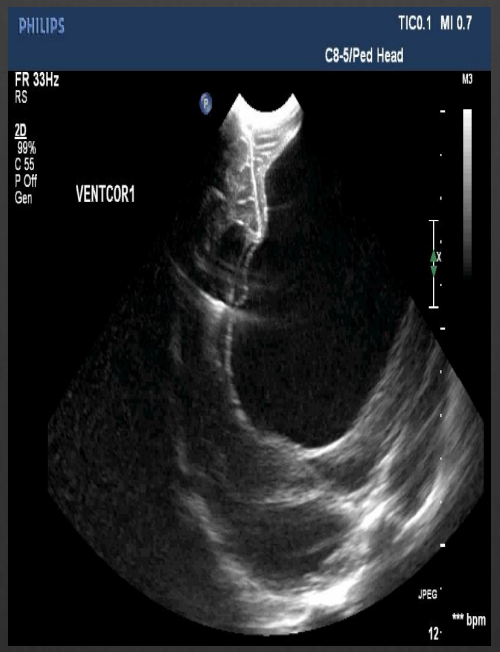


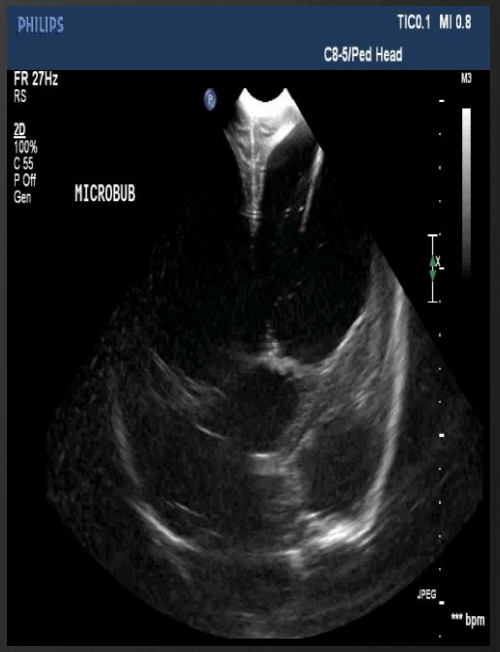




Multiloculated Hydrocephalus

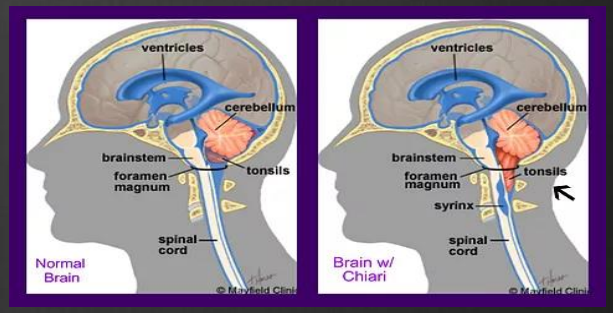


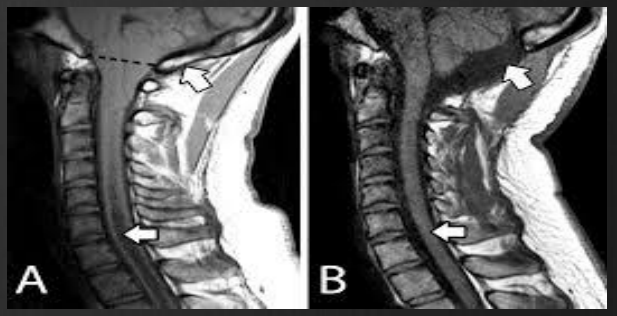




Chiari Deformity

- Herniation of the hindbrain below the level of the Foramen Magnum
- Usually >5mm, associated with syringomyelia, hydrocephalus
- Cine MRI
  - CSF flow across CCJ





Childs Nerv Syst (2015) 31:1371–1376
DOI 10.1007/s00381-015-2699-1

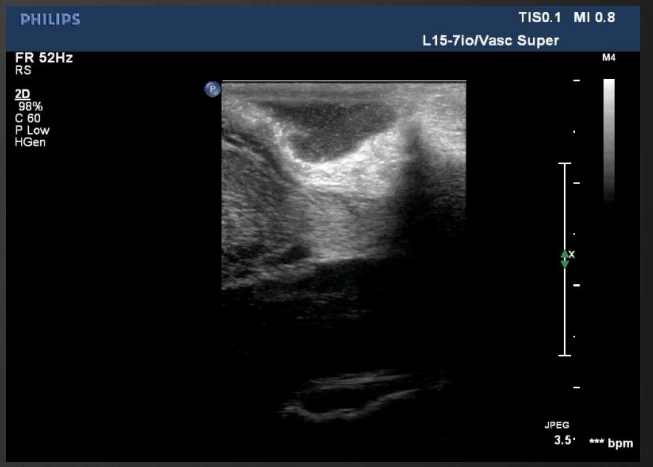
ORIGINAL PAPER

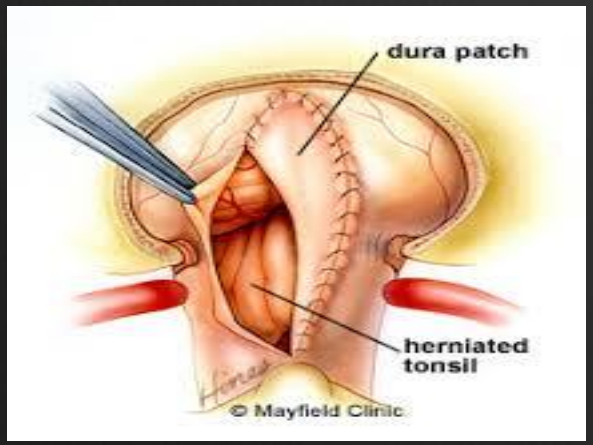
Management of Chiari I malformation in children: effectiveness of intra-operative ultrasound for tailoring foramen magnum decompression

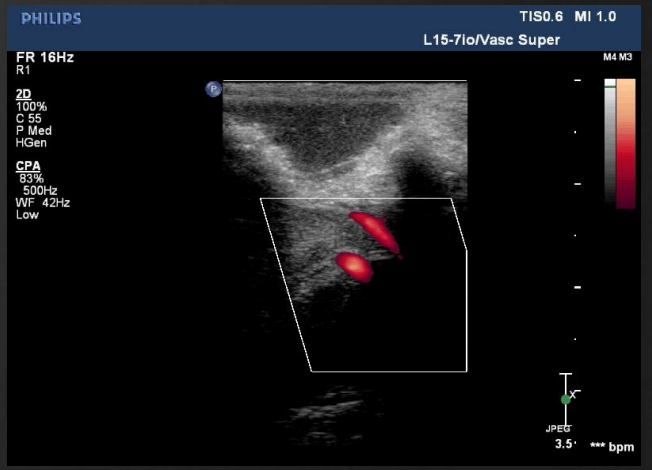
Ganesalingam Narenthiran[1] - Christopher Parks[1] - Benedetta Pettorini[1]

Chiari Deformity

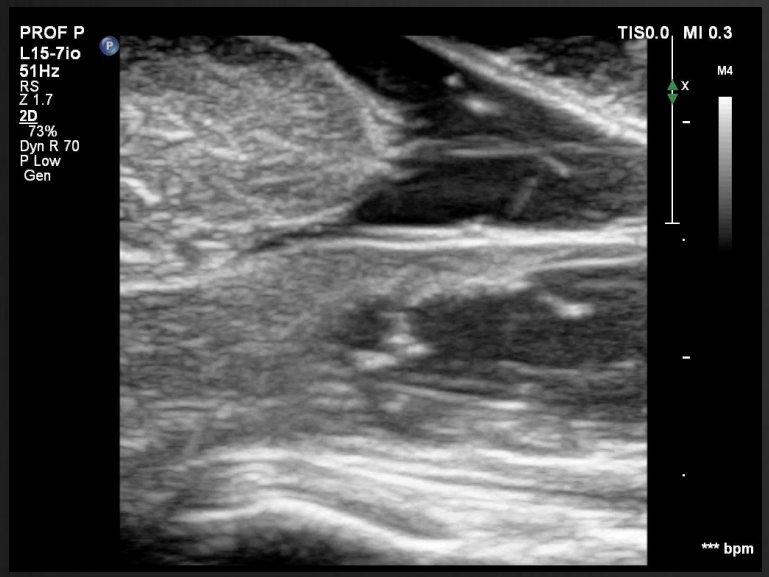
- Surgical options
  - Bony decompression
  - Duroplasty
  - Tonsil coagulation
  - CCJ fusion
- Success is based on ***restoring CSF flow*** across CCJ
- Morbidity related to ***dural opening***







Chiari I Deformity + Syrinx



“ That it will ever come into general practice, I am extremely doubtful; because it’s beneficial application requires much time and gives a good bit of trouble to the patient and the practitioner"

J.Forbes, 1823
Preface to the First English edition of Laennec’s “Treatise”

Summary

- Ultrasound is safe, cost-effective, portable and non-invasive with diverse applications, especially in pediatric neurosurgery
  - Diagnostic
  - Navigation
  - Surgical adjunct
  - Therapeutic and neuromodulation
- Incredible diagnostic and therapeutic potential within the next few years, both as 2D and 3D
- Certainly worth making the effort to integrate this modality into our routine practice

Thank you !

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