Ultrasound in Neurosurgery: Pediatric Neurosurgery, Hydrocephalus, Endoscopy

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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
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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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
IOUS and post-op MRI

IOUS – greater extent of resection due to real-time feedback on tumor volume and location

Very good correlation between IOUS and post-op MRI
Types of probes

- Burrhole probe
- High frequency probe
  - Anterior fontanelle
Assessment of accuracy

**Objective**

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

**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

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

*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
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. Ultrasound-guided VC placement should become standard of care in VP shunt surgery.
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
MR Ventriculography

- 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)

*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

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
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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