Intraoperative Ultrasound in Neurosurgery

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MYTHS

- Image Quality: ?inferior to MR
- Minimally invasive surgery incompatible: ?need for bigger craniotomies
- No use at end of surgery?, decline in image quality
- US interpretation ?difficult than MR
History

- French et al. – 1950
  (A Mode – experimental studies on brain tumor)

- Leksell - 1954, SDH localization, later Echoencephalogram

- Wild and Reid – 1978
Physical Principles

- Reflection - most important for image buildup
- Absorption
- Scattering

Artifacts
Image Buildup

- **Frequency**: High frequency (10 MHz) - high resolution, less penetration and vice versa

- **Focus**: Beam – narrowing - higher resolution

- **Depth**: Deeper gives more overview.

AIM – to achieve resolution 25 um at 50 MHz
Machine considerations

- Modes *ABCD
- Storing features
- Transducers *
- Financial considerations
Modes

- **A Mode**: Amplitude mode, depth measurement
  - Uses:
    - Seldom used
    - Focused beam for calculi Rx

- **B Mode**: Brightness mode (real-time gray scale display >18fps)
  - Uses:
    - Real time imaging
    - Widely used
Modes

C Mode – Color mode
- All moving particles encoded with different red and blue shades
- Velocity and direction dependent
Uses: Blood flow/vessels detection

D Mode – Doppler/power/angio mode
- Amplitude of moving structures
Uses: Small/slow flow vessels display
1. Echogenicity

Depends on – Reflections of tissue

- Anechogenicity: No echogenicity (ventricle)
- Low Echogenicity: Normal white matter
- High Echogenicity: Glioma
- Hyperechogenicity: calcifications/bone- meningiomas
Terminology

2. Homogeneity

Homogenous - low grade gliomas
Inhomogeneous - high grade glioma

3. Demarcation
Infiltrative v/s Non infiltrative tumors and extent of resection.
Artifacts

- BLURRED IMAGE
  Source: Bubbles trapped at contact surfaces
  1. Brain- sheath
  2. sheath- probe interface

- REVERBERATIONS
  Source: brain spatulas,

- SHADOWING
  Source: calcifications

- Increased ECHOGENICITY
  Source: cysts in front of structures
Transducers

• Linear array and Convex array- Not useful (convex interface and poor resolution)

• Phased array- widely used

BEST- small phased rectangular acoustic lens and area of contact 20-25 mm
Transducers- suited in NSx

- Phased array
- Burrhole transducer
- Convex array
Sterilization

- Not suited
- Sterile sheath to be used
Getting started

First locate sulci/interhemispheric fissure to gain orientation
Applications

- Mass Lesions localization
- Inflammatory and Infectious disorders
- AVM
- Burrhole /guided biopsies
- VP shunt
- Aneurysm
- Neuronavigation
MASS LESION LOCALISATION- cranial

- All tumors Hyper echoic, except- cystic components and Lymphoma(iso to hypo echoic)

- Surrounding parenchyma and vasogenic edema – relatively hypoechoic

- PITFALLS- Chronic edema /radiation changes may change echogenicity. Wrong orientation over gyrus
Cranial Uses

- Resection control
- To delineate tumor vascularity
- Localizing site for biopsy
- Minimally invasive hematoma drainage
- Aspiration of abscess and cysts
- Patency of arterial bypasses
MASS LESION LOCALISATION - cranial

- Vascularity assessment - Colour duplex sonography – B mode with color mode

High grade glioma, in relation to vessels
Preop MR and intraop US-Thalamic tumor Pericallosal artery(red) demonstrated by Power/Doppler mode
Resection control

Thalamic tumor in sagittal and coronal planes, with gradual excision. At end of resection residual seen and was resected further to achieve sonographic total excision.
MASS LESION LOCALISATION - Spinal

**Normal spine**
- **Dura**: Echogenic ring with surrounding anechoic CSF
- **Spinal cord**: homogeneous low-level echoes, demarcated from CSF by bright echogenic line
- **Central canal**: echogenic structure
- **Nerve roots**: echogenic
MASS LESION LOCALISATION- Spinal

Mass Lesions characteristics:

- Cyst/syrinx- anechoic
- IM tumor- complex cystic and solid
- IM neoplasms - inhomogenous hyperechoic (glioma, metastases)
- Calcifications enhance echogenicity (ependymoma, astrocytoma, dermoid)
Mass Lesions characteristics:

- Focal cord expansion and obliteration of the central canal

- Extramedullary lesions are generally hyper-echoic (disk, hematoma, meningioma, neurofibroma, bone, cyst abscess)
Spinal Uses

- Syrinx - localize site of needle insertion/perforation
- Tumor biopsy
- Myelotomy in avascular planes
- Tumor resection
Neuronavigation

• 3D USG: By tilting the ultrasound probe over the area of interest, a collection of 2D ultrasound images is acquired, forming a 3D ultrasound image volume

• Camera identifies position of the patient reference frame and the US probe and enables display with corresponding preop MR

• Time taken ~ 1 min
Neuronavigation

Accuracy of 3D US
- Preop MR may not predict intraop brain shifts
- Image to patient registration is not needed for navigation based on intra-operative US
- Acquisition is performed in the same coordinate system as navigation is executed.
- New 3D images can be acquired in order to compensate for brain shift
Anaplastic astrocytoma: corresponding MR and US pics
Corresponding slices of MR vs US in localization of brainstem cavernoma
Other procedures: Biopsy

- Free hand
- USG transducer mounted biopsy probe
- Diagnostic yields of 85-100% reported in literature-
- Depth and nature of pathology
- Most hyperechoic region to be chosen
Other procedures: VP shunt

- Special burrhole transducer < 12mm diameter
- *use of separate burrhole/ larger burrhole, in open fontanelle*
Cavernoma

- Hyperechogenicity
- Inhomogeneous- microcalcification, cysts, thrombosis
- Demarcation- may be be sharp (cause- iron ring)
- Difficult to identify flow in cavernoma
Venous anomaly

- Criteria:
  - slow flow (<5 cm/s)
  - flow away from lesion

Other cerebrovascular parameters:
- Peak systolic flow (AVM > 300 cm/s), diastolic flow
- Resistance index (<0.6- AVM)
Other procedures: AVM

- Intra-operative 2D colour-duplex-sonography for localizing deep-seated AVMs,
- Identifying feeders and draining vessels and for re-section control
- Colour Doppler: measure the cerebrovascular resistance and differentiate between feeding vessels and en passant vessels.
Other procedures : AVM

- Stereoscopic display or a 3D rendering of the vessels may be helpful to understand the tortuous architecture of the feeding vessels.

- Image quality and details inferior to MR.

- ROLE- to estimate shifts and correction and vessels of nidus.
Other procedures: Aneurysms

- 2D US for peripheral aneurysms
- Flow evaluation in distal vessels pre and post clipping (systolic flow, RI)
- PITFALL: Power Doppler of smaller vessels generates smeared image for navigation
- ROLE: not clearly defined and needs improvement
Other procedures: decompression

- USG to assess need for duraplasty in Chiari I patients after foramen magnum decompression

- ROLE: ? Paradigm shift
  CSF related complications v/s No duraplasty

Recurrence rates of symptoms twice in moderate and severe cases in bony decompression only patients-

*Mcgirt et al. JNS- pediatrics, July(1) 2008*
LIMITATIONS

• Operator Dependent

• Requires knowledge of neuroradiologic abnormalities that are not routinely evaluated by sonography.

• Difficulties in distinguishing a tumour from normal tissue and lesion obscuration by chronic edema.

• CT stereotaxis and real-time MRI fusion images.
Future

- 1.5D probe
  - thinner image planes at a wider depth range.
  - improve the quality of both tissue imaging and angiography based on power Doppler
Future

- **Contrast:**
  - Thin-shelled micro bubbles (size ~ RBCs) very strong scatterers of ultrasound
  - Size 1-4 um, coupled to galactose, albumin (*albunex, levenist*)
  - Administered iv
  - Increase signal to noise ratio
Future

- Strain imaging:
  - Elasticity of brain tissue.
  - Tissue motion of arterial pulsations can US strain images of brain tumors (histologic clue)
  - Adjunct to B mode
  - STATUS- under evaluation
Future

- **HIFU**
- Under evaluation for tumor
- MR guided
USG AIIMS

- B- K medical, equipped with linear(vascular), burrhole, convex array

Surgeries
- Foramen magnum decompression
- Intracranial tumor excision
- Spinal IM tumor localization
- Biopsy
USG - INDIA: PNDT act

- The Pre-natal Diagnostic Techniques Regulation and Prevention of Misuse) Act (1994), 1\textsuperscript{st} January, 1996 enacted
- Amendment 2003
- Restricted use of USG for prenatal diagnosis of sex
THANK YOU