INTRAOPERATIVE ULTRASOUND IN NEUROSURGERY

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

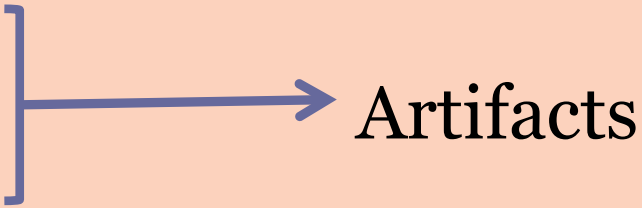


Image Buildup

- *Frequency* :
  High frequency(10MHz)- 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

Terminology

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

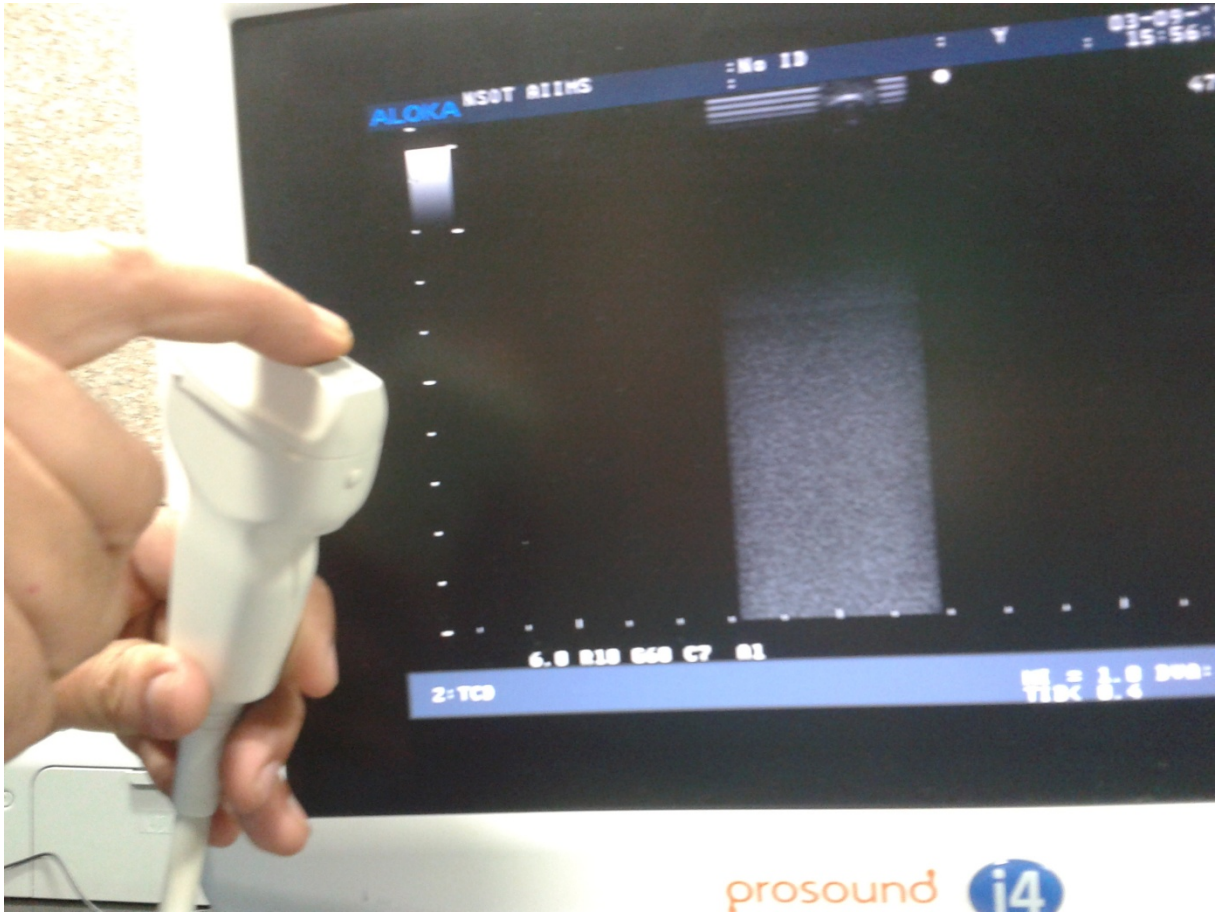
Transducers- suited in NSx

- 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 hypoehoic

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

Cranial Uses

- Resection control
- To delineate tumor vascularity
- Localizing site for biospy
- 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

Resection control

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

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 indentifies 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

Other procedures : Biopsy

- Free hand
- USG transducer mounted biospy 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), 1st January, 1996 enacted
- Amendment 2003
- Restricted use of USG for prenatal diagnosis of sex

THANK YOU