Pediatric US for the General Radiologist

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General Principles

- US is a valuable tool in pediatrics:
  - Patients have little body fat
  - There is no ionizing radiation involved - ALARA principle
  - Inexpensive and quite mobile technology
  - Word of caution:
    - Extremely operator dependent!
    - Appropriate transducers should be used

Specific Applications

- Neuro Imaging
  - Brain
  - Spine
- Abdomen:
  - Normal patterns in children
  - Pyloric stenosis
  - Intussusception
  - Appendicitis
- Musculoskeletal:
  - Hips - DDH, joint effusion
Neurosonography

- Neonatal head US
  - Feasible before fontanel closure (9-15 months)

- Spinal sonography
  - Feasible before 3 months of age, when posterior elements ossify

Imaging Guidelines Rational

- Clinical care decisions
  - Germinal matrix hemorrhage

- Long term neurological outcome
  - Periventricular leukomalacia (PVL)
  - Low pressure ventriculomegaly
  - More recently, white matter ischemic changes (MR)

AAN Guidelines - Preterm Infant

- Routine screening cranial US done on all infants of < 30 weeks’ gestation,
  - once between 7-14 days,
  - repeated between 36-40 weeks post-menstrual age.

(Increasing use of MRI on very low birth weight infants with abnormal US results)
Indications for Cranial US

- Asymptomatic newborns ≤ 33 weeks or ≤ 1500g: US at 7 days
  - Normal blood pressure, hematocrit, arterial gasometry
  - 5 min Apgar ≥ 6/7
- Symptomatic newborn, any gestational age
  - Initial US
  - Repeat one week later
- Any newborn
  - Before surgery
  - Before indomethacin therapy

US - Initial Examination of Choice

- Hemorrhage
- Hydrocephalus
- Congenital anomalies

Technique - Neonatal Head US

- 8-10 MHz real-time sector transducer
- Anterior fontanel used as acoustic window
  - Closure begins at about 9 months and ends by 15 months
- Images obtained in coronal and sagittal planes
**Cranial US - Technique**

- Use of coronal suture or squamosal portion of temporal bone
  - Extracerebral fluid collections
  - Vascular structures of the circle of Willis
- Use of posterior fontanel
  - Posterior fossa lesions: Arnold-Chiari, Dandy-Walker

**Standard Imaging Planes**

**Coronal**

- Frontal horns anterior to the foramen of Monroe
- Foramen of Monroe
- Posterior aspect of 3rd ventricle through the thalami
- Quadrigeminal cistern
- Trigones of lateral ventricles
- Parietal and occipital cortex

**Sagittal**

- Midline
- Caudothalamic groove
- Body of lateral ventricles
- Sylvian fissure on each side
Normal Variants

- Brain parenchyma appearance varies with age and fetal maturity
- Cavum septum pellucidum and vergae
- Lateral ventricles
  - Asymmetry is a normal finding, occurring in 40% of prematures and 20% of term infants
  - Slit-like ventricles are not a reliable sign of edema in the first weeks of life

US Normal variant - Cavum septum pellucidum

Brain Sulcal Development

- 20 weeks - calcarine fissure
- 24 weeks - parieto-occipital fissure
- 28 weeks - calloso-marginal and cingulate sulci
- 30 weeks - cingulate sulcus is branched
- 8-9th month gestation - sulci bend, branch and anastomose
Hypoxic Ischemic Brain Injury

- Pattern of injury depends on:
  - Brain maturity at time of injury
    - Preterm newborn
    - Term newborn
  - Severity/duration of hypoperfusion

Findings in premature newborns

- Mild to moderate ischemia:
  - Germinal matrix bleed
  - Periventricular leukomalacia
  - Both
- Severe hypoxia/ischemia:
  - Thalamus
  - Anterior vermis
  - Dorsal brain stem

Germinal Matrix

- Highly vascular structure
- Very active until the end of 2nd trimester
- Capillaries consist of only endothelium, sensitive to vascular pressure changes
- Capillary rupture leads to hemorrhages of variable severity
Germinal Matrix Bleed - Grading System

- Gr I - Subependymal hemorrhage
- Gr II - Intraventricular extension, without ventricular dilation
- Gr III - Ventricle dilated with blood
- Gr IV - Periventricular venous infarction
  - unilateral, hemorrhagic, triangular lesion, caused by thrombosis of medullary veins

Significance of GMH

- Grades 1 and 2 - little neurological sequelae
- Grade 3 -
  - poorer neurodevelopmental outcome
  - iron-induced white matter injury
- Grade 4 -
  - 5-8% of premature low birth newborns
  - Worse neurodevelopment outcome
  - May result in hemiplegia, severe motor damage

US - Gr I bleed
US - Grade II IVH

- Premature triplets
- Initial study, Grade II bleed on left side

US - Grade III IVH

- Premature newborn
- 2nd week of life
- Bilateral bleeds 48h later

US - Bilateral Bleeds
Anatomic Sequelae of IVH

- Ventriculomegaly
- Obstructive hydrocephalus
- Measure distance between lateral walls of lateral ventricles at the level of 3rd ventricle, for consistency

US – Gr 4 bleed

US – Post hemorrhagic hydrocephalus
Hypoxic - Ischemic Injury

- Prematures - periventricular leukomalacia (PVL)
- Term-infants -
  - selective neuronal necrosis,
  - focal/multifocal ischemic cerebral necrosis,
  - status marmoratus of basal ganglia and thalamus,
  - watershed cerebral injury

US - PVL

- White matter injury of prematurity
  - Areas of focal necrosis in deep white matter (cystic variety)
  - More diffuse injury to oligodendrocytes
- Most common in watershed zones:
  - Periventricular white matter adjacent to the trigone and foramen of Monroe
- ? Toxic injury to premyelinating oligodendrocytes
  - cerebral ischemia
  - hypoperfusion
  - both
US - Encephalomalacia

Congenital/Developmental Anomalies

- Chiari malformation
- Holoprosencephaly
- Dandy-Walker malf.
- Absent corpus callosum
- Vein of Galen malf.
- Hydranencephaly
- Porencephaly

- Gray matter heterotopia
- Schizencephaly
- Lissencephaly
- Pachygyria
- Dysgenesis of corpus callosum
- Neurocutaneous syndromes, etc

Agenesis of Corpus Callosum
US – Absent corpus callosum and Dandy Walker

US - Holoprosencephaly

Vein of Galen Malformation
Spinal Dysraphism (SD)

- Most common CNS abnormality (myelomeningocele 2:1000 live births)
- Abnormal embryological development causes defective neural tube closure
- Importance of maternal folate ingestion (before and after conception)

Importance of Screening for SD

- Early detection of closed or occult SD
- Cord damage is caused by rapid growth of vertebral column, leading to cord ischemia and neural dysfunction
- Intradural lipoma causes direct cord compression
**SUS - Timing**

- SUS is optimal during the first 3 months of life, due to the lack of ossification of posterior arch of spine
- Usually not feasible after 6 months of life, unless there is a posterior spinal defect
- Open defect is *absolute* contraindication

**Neonatal SU Screening (SUS) - Indications**

- Infants with associated syndromes
  - Anorectal, urogenital malformations, inclusive VATER
- Newborn with cutaneous markers for SD

**Cutaneous Stigmata**

- Low Risk:
  - Simple midline cysts:
    - < 5mm diameter,
    - within 2.5cm of the anus,
    - in the midline,
    - no other associated lesions
**Cutaneous Stigmata**

- **High Risk**:
  - Atypical dimples
    - > 5mm in diameter,
    - > 2.5cm above the anus
  - Flat lesions
    - hemangomas, cutis aplasia
  - Upraised lesions
    - hairy patches, skin tag/tail
  - Multiple cutaneous stigmata

**SUS vs MRI**

- **Current guidelines**:
  - SUS done as screening modality
  - MRI performed in infants with abnormal US, or known anomalies

- New development – 3D SUS

**SUS - Technique**

- Patient lays prone on a pillow
- Use a 7.5 to 10 MHz linear array transducer
- Images acquired in sagittal and axial planes along the entire spine
- Use dual screen, start over the sacrum
- Identify 1st sacral segment by dorsal tilt or other method
Identification of L₅-S₁

- Lordotic transition between L – S spine
- Count vertebral bodies - S₅ is the lowest calcified vertebra
- On axial images, L₅ is at the top of iliac spine
- The T₁₂ ribs project at the level of L₂
- In case of doubt, place metallic marker at the level of conus, radiograph

Normal L-S US

Normal Spine Trans L₁-₄
SUS- Normal Findings

- Normal cord is tubular and hypoechoic, walls are hyperechoic
- Central echo complex (not central canal, but interface between myelinated ventral white commissures and central end of anterior median fissure) is hyperechoic
- Cord diameter is widest in cervical and lumbar levels

Conus Medularis Position

- Fetus (19th week) - L2/L3
- Premature infants - L2/L4
- Infants up to 3 months - as low as L3
- After 3 months - above L3

Tethered cord/meningocele
REFERENCES

Abdominal US

Normal findings in children

- Neonatal kidneys:
  - As echogenic as the liver
  - Lucent pyramids may simulate hydronephrosis
- Normal adrenal
  - "Oreo cookie" appearance
  - Decrease in size during first few months

Normal pelvis in children

- Uterus
  - Large in newborn period
  - Decreases in size, cervix > fundus
  - Puberty leads to cervix = fundus, fundus > cervix, endometrial stripe
- Ovaries
  - Normal follicular cysts are better seen with high resolution transducers
  - Size: pre-pubertal - 1 x 1 x 1 cm
    post-pubertal - 1 x 2 x 3 cm
    if more than 12 cc, abnormal
**Pyloric Stenosis**

- Infant with history of **projectile, non bilious, vomiting**
- **Technique**: Linear array, high resolution transducer, distended stomach, child in right oblique decubitus
- **Measurements**
  - Thickness > 3mm
  - Length > 17 mm

**Pyloric Stenosis**

- If vomit is non bilious, not an emergency
- Hydrate the child, perform the study during regular hours
- If positive, no need for UGI

**Intussusception**

- Child between 1-3 y, colicky abdominal pain; "currant jelly" stools
- Get US for dx, plain film for free air, IV fluids, monitoring
- Surgery consult
- Attempt reduction w contrast or air
Differential Diagnosis

• Colitis
• Constipation

CT - colitis

Appendicitis

• Presentation - abdominal pain, fever.
• Technique - RLQ examination, graded compression with linear array transducer, use color Doppler.
• Findings -
  - appendix measuring 6 mm or more in transverse diameter, hyperemic, position is quite variable.
  - Secondary signs include free fluid, edema, appendicolith
US - Appendicitis

Appy – US/CT

Hip US

- Indication: DDH
- Not for screening populations, but patients with risk factors
- Technique:
  - High resolution linear array transducer
  - Axial and coronal scans
  - Dynamic maneuvers
Sonographic Hip Types

• Alpha angle:
  - I - Normal > 60°
  - 2A - Physiologic Immaturity, < 3 months old, between 50 - 59°
  - 2B - Delayed ossification, > 3 months old, between 50 - 59°

Hip US - Normal

US - Lt hip DDH
Hip Effusion

- Linear array transducer
- Scan along the femoral neck plane
- DX:
  - Asymmetric appearance with more than 2mm difference
  - Internal echoes
- Drainage can be done under US or fluoro guidance

Reference

- Society for Pediatric Radiology website
  www.pedrad.org
Thank you!