Neonatal Neurosonography –
The Premature Infant

Harris L. Cohen, MD, FACR

University of Tennessee Health Science Center
LeBonheur Children’s Hospital
Memphis, Tennessee
Harris L. Cohen MD FACR

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- The Premature Infant

DISCLOSURE:
Neither I nor my spouse have any relevant financial interests, arrangements, or affiliations with a commercial interest.
In a Limited Amount of Time
We Will:

- Discuss a few methods in head US technique
- Review some normal intracranial US anatomy
- Note some current axioms of head US evaluation and diagnosis in the premature infant, discussing:
  - Intracranial Hemorrhage (IVH / IPH) &
  - Periventricular Leukomalacia (PVL)
Technique: Windows to the Brain

◆ The Key Window for Insonation is the Anterior Fontanelle

from Cohen, Blitman, Sanchez in Fetal and Neonatal Neurosonography
Timor Trisch, Monteagudo, Cohen (ed 2)
There are other helpful Windows to the Brain

Posterior Fontanelle View

All skull openings are useful
Posterior Fontanelle Sonography

- Correa et al, from 1999-2001 looked at 164 cases w/ post fontanelle sono added to anterior images
- Their results:
  - Grade II hemorrhage dx increased by 32%.
  - They noted 2 cerebellar hemorrhages & 1 abscess
  - Did not help PVL diagnosis

Posterior Fontanelle Views

No ventriculomegaly or hemorrhage
Mastoid Fontanelle View

Wikipedia 2014
The Mastoid Fontanelle View:

- Sagittal and transverse planes are obtained using a small convex high frequency linear array placed posterior to the ear in the mastoid area.
- Has predominantly helped us evaluate:
  - Cerebellum for hemorrhage
  - The 4th ventricle and its relationship to the cisterna magna (Dandy Walker Complex analyses)
  - as well as Pericerebellar arachnoid cysts, transverse sinus vascular flow (via Doppler), +
Looking at the Cerebellum

- Routine midline sag view
- Mastoid view highlighting near field cerebellum
Mastoid View Images

Foramen of Magendie

Blake’s Pouch Cyst
Mastoid View Images

No hemorrhage & normal sized lateral ventricles

Left cerebellar hemorrhage & dilated lateral ventricles
Use of Doppler

- Routine imaging of ACA for reconfirmation of corpus callosum presence on sagittal view
- Vessels of circle of Willis. Transcranial best for MCA analysis at 0 degree angle
- Can be used for hydrocephalus, mineralizing vasculopathy, Galenic or other AVM, flow in superior sagittal sinus and other venous structures, arachnoid cyst vs vessel
MCA Tributaries in Sylvian Fissure
Anterior Cerebral artery turns superior to CC, if corpus callosum is present
Linear Array Transducers and their higher frequency are used for High Resolution analysis of superficial structures.

Normal SSS flow

Confirmed by MR

Used mostly for analysis of color flow in superior sagittal sinus.
Thrombosis can be seen for a variety of reasons including: Polycythemia and Dehydration

SSS = Superior Sagittal Thrombosis
Transducer Choices

• Excellent Near Field Resolution using higher frequency transducers (e.g., 7.5 MHz)
• Better Far Field Penetration provided by lower frequency transducers (e.g., 3.5 - 5 MHz)

- Transducer shapes need to fit fontanelles and adequately image through sutural openings.

High frequency linear arrays transducers are great for SSS thrombosis analysis at vertex but limited for curved skull areas or transverse sinuses cerebellum. We use small high frequency curved linear array transducers.
Coronal Plane

Look For:
- Anchor sign
- C Callosum
- Caudate head
- Thalamus
- Frontal horn
- Sylvian fissure

Angling to obtain images from frontal orbits ➔
frontal horns ➔ body of lateral vents to occipital area
Coronal Plane

through bodies of Lateral Ventrices
Midline Images

Look For:

An additional fine point

- Corpus callosum (→)
- Cavum septum pell (csp)(vergae and v interposit)
- Gyri and sulci (>)
- 3rd ventricle
- Cerebellar vermis (v)
- 4th ventricle (4)
(Near) Parasagittal Plane

Look for:
- Lateral ventricle (➔)
- Head of caudate [C]
- Thalamus (T)
- Gyri & Sulci

In order to see entire lateral ventricle body need to have anterior image somewhat medial in position and posterior somewhat lateral
Peripheral (Far) Parasagittal Plane

More gyri = older premature

To Right Sylvian Fissure (➔)
Peripheral (Far) Parasagittal Plane

Less Gyri = Younger Premature
Number of Gyri and Sulci and Coverage of Sylvian Fissure…vary with age.
24 week gestation (young premie) with few gyri – the “toast” sign

Does not suggest lissencephaly
Indications for Neonatal Cranial US in Prematures (Caffey 11th ed)

- Screening
  - Intracranial hemorrhage (<1000-1250g, <28 weeks)
  - Hypoxic ischemic encephalopathy including PVL (focal white matter necrosis)
  - Birth trauma (if cannot be transported to CT)
  - Prenatally detected abnormality
Indications for Neonatal Cranial US in Prematures (Caffey 11th ed)

• Follow-up
  – **Intracranial Hemorrhage** (and development of posthemorrhagic hydrocephalus)
  – Hydrocephalus
  – Extraaxial collections

• Initial Evaluations for: seizures, congenital abnormality, macrocephaly, cns infection, suspected superior sagittal sinus thrombosis
IVH

• A great concern for the Premature Infant

• Particularly, if:
  – <1500 grams and/or
  – <32 weeks gestational age

• Key to IVH is bleeding in the subependymal germinal matrix. A highly cellular richly vascularized (gelatinous) area with active cell proliferations
Why? Impaired Autoregulation

- The subependymal area consists of 1 cell thick blood vessels and neuroblasts destined to eventually reach the cortex. The neural tissue is at risk for hemorrhage.
- The brain of premature infants cannot change vascular inflow pressure to protect itself from changes in neonatal blood pressure.
- Such (premature infant) brains are pressure passive & therefore at greater risk for injury
Papile Classification
Germinal Matrix [GM] Hemorrhage

- Grade I - hemorrhage limited to GM area
- Grade II - intraventricular w/o dilatation
- Grade III - intraventricular extension with ventricular dilatation
- Grade IV - intraventricular extension with associated periventricular infarction

1979 classification with change to Grade IV in late 1980’s
Evolution of Hemorrhage as Imaged by Diagnostic Ultrasound

• Acute hemorrhage is **echoless**
• Immediately after fibrin deposition it is homogeneously **echogenic**
• with time….the hemorrhage becomes heterogeneous and eventually **hypoechoic**
Grade I Hemorrhage (Subependymal)

Hemorrhage (arrows) is typically between the head of the caudate nucleus and the thalamus.
When hemorrhage resolves, cysts (arrows) are typically seen in their place .... between the head of the caudate nucleus and the thalamus.
When the echogenicity of hemorrhage is seen within the ventricle, one must consider Grade II IVH or greater.

Note choroid is never anterior to the Foramen of Munro.
Grade II IVH

Intraventricular hemorrhage with less than 50% ventricular dilation

Clot in 3rd vent
Very low birth weight infant born at 25 weeks with Grade 2 IVH. Now seen at 2 months of age.
Clot looks like Choroid After Fibrin Deposition

Initially it can be separated by knowing that:

Clot has no color flow and living Choroid Plexus does

Echogenic structure is choroid-- it has contained vascular flow
Clot not Choroid
Since it extends anterior to foramen of Monro

Grade III IVH

Hemorrhagic debris in occipital horn lateral ventricle

IVH with acute (greater than 50%) ventricular dilation
Grade 4 IVH

Right frontal horn is dilated, filled with clot. It extends anterior (yellow line) to white line anterior to left frontal horn.

Clot (c) fills the right ventricle. Large echogenic area is seen just superior to ventricle.

White Matter Infarction
When the white matter infarct contents resorbs, one may be left with a Porencephalic Cyst.
Echogenic Infarct in the Periventricular White Matter

Seen superior and lateral to lat vent

Patient C – sag, late

Patient B – sag, early

Seen superior to lat vent
Posthemorrhagic Hydrocephalus

- Clot actually blocking outflow from ventricles, or
- Inflammation/irritation of pachionian granulation (at vertex) by hemorrhage, may ➔

- Posthemorrhagic hydrocephalus (communicating or noncommunicating types)

- 1/3 will improve, 1/3 will stay the same and 1/3 will worsen.
Posthemorrhagic Hydrocephalus

Old Clot – Peripheral echogenicity, echopenic center
Dependent debris in ventricle (arrow)
Cerebellar hemorrhage

Often Requires Mastoid View To See
Neonatal Hypoxic-Ischemic Brain Disease I

• Cerebral white matter disease is a better predictor of poor neurologic outcome than is IVH
  – Insults are not truly periventricular since discrete foci of coagulation necrosis are found throughout the white matter of the brain. Better called Focal Necrosis of White Matter and only some of the areas are cystic. Most remain solid area of coagulation necrosis

• Most often seen dorsal and lateral to the external angles of the lateral ventricles  (Caffey)
Neonatal Hypoxic-Ischemic Brain Disease II

- **PVL** is seen predominantly in prematures
  - **US**: acute necrosis appears echogenic and becomes cystic in 1-3 weeks. 50-70% may be missed by US compared to autopsy.
  - **MRI**: Diffuse extensive high signal intensity (DEHSI) lesions seen on MR (esp DWI sequences)
    - Increased free radicals due to excessive nitrous oxide production (dt excess glutamate activation) which can damage oligodendrocytes
  - Inflammation \(\rightarrow\) accelerated cell death or apoptosis
Periventricular Leukomalacia: What is Seen by Ultrasound
Patient was long term in Nursery .. Developed seizures

Periventricular Leukomalacia

Most common in Watershed zones
In Summary

This was a brief review of head ultrasound in prematures. US is a fine tool for the analysis of the premature brain within the safe confines of the isolette and NICU.

THE END

Basic techniques and diagnostic axioms were reviewed.

Key imaging abnormalities in the premature - IVH and (to a lesser extent) PVL - were discussed.

I left out a lot that could fit into a 20 minute talk but which are well in ultrasound’s scope: perinatal identification of CNS anomalies, infections, infarctions etc.
The Routine Exam

◆ Consists of:
   • **Coronal** Views through the Anterior Fontanelle
     (angling to right and to left may help with poor contact with anterior fontanelle)
   • **A Sagittal Midline View** and
   • **R & L Parasagittal Views**
     – angling from Midline ➔ Sylvian Fissures
   • **Additional views** (post fontanelle, mastoid)
Near Parasagittal Plane
(some added info)

More gyri = older premature
Less Gyri = Younger premature
Things to Consider Before Calling Something Abnormal

- **Periventricular white matter** – if concerned because of degree of echogenicity or asymmetry– wait 10 days to see if cysts develop
- **Periatrial w mattter echogenicity** may be an anisotropic effect i.e. only seen where sound crosses at 90 degrees, consider different angle of approach
- **Extraaxial fluid** – commonly seen. We see more now that CTs are reconstructed in sagittal and coronal planes. Concept of normal effusions of infancy
• Key to IVH is bleeding in the subependymal germinal matrix. A highly cellular richly vascularized (gelatinous) area with active cell proliferations.

• It obviously can occur in fetuses as well.
Non Germinal Matrix Hemorrhage

- Not all IVH has a subependymal origin
- Hemorrhage originating from the **Choroid plexus** was once thought a common cause
- It is now thought to be far less usual as a primary cause
  - occurring most often in Full Term Infants
  - thought to be due to elevated venous pressures of asphyxia or mechanical causes
tf724 lebroh twin 1 25 wks
tf724 lebroh twin 1 25 wks

SAGITTAL

MIDLINE
28 week day 8 and day 22 gr 1 bilat inf cerebellar echoless tube
23.3 weeks 510 grams 713 grade 4 over time
32 week gestation 2do on 7/5 17do on 7/20 1020g wallerian
25 week 760 gram 10 day old evolving seh, also 4th vent dil on mastoid view, clot in rt lat vent posteriorly
Dw variant hydro
27w 1mo tf 3975 Dw variant hydrocephalus prior tf 3975 27w 1mo 3v hydro dw variant
tf3939 gr4 n cerebellum pv infarc 28-33 9 and 17 2 mo later
tf3939 gr4 n cerebellum pv infarc 28-33 9 and 17 2 mo later
tf3939 gr4 n cerebellum pv infarc 28-33 9 and 17 2 mo later
27 weeker 3do toast sign tf3778
Mastoid view aids 4th ventricular clot id not seen on sag
Mastoid view aids 4th ventricular clot id not seen on sag
Germinal Matrix [GM] Hemorrhage: Tips for making the diagnosis

- Use the *orthogonal* view
- Consider *other* US windows
- Differentiate choroid plexus from clot (Doppler may help as will tincture of time)
- Look for *fluid debris levels*
- Be aware of normal structures
See the grey older clot surrounding the homogeneously echogenic choroid (ch)
Cerebellar Hemorrhage

• Use of the posterior fontanelle and posterolateral (mastoid) fontanelle views have aided diagnostic imaging

• These techniques place the transducer closer to the subtentorial pathology than does using the anterior fontanelle
Transcranial Head US

8mo closed fontanelles “large head”

Premie w/ overlapping sutures
Cerebellar Hemorrhage

• A type of intraparenchymal hemorrhage seen occasionally in premature infants
• May be underdiagnosed
• Said to be found in 10-25% of low birth weight infants at autopsy
• 70-85% of affected had difficult deliveries
  – prolonged or precipitous
  – forceps or breech
• Best seen with Mastoid & Post Font views
24 weeks gestation

Sylvian fissure is squarer: Less brain to compress it to its typical Y shape in older premies

Try to ignore the germinal matrix hemorrhages on this image
Neonatal Hypoxic-Ischemic Brain Disease II

• PVL seen predominantly in premarutes
• Necrosis (axonal destruction) occurs in the periventricular regions
• Glial injury with hypertrophic astrocytes occurs throughout the white matter
• On US: acute necrosis appears echogenic and becomes cystic in 1-3 weeks. 50-70% may be missed by US compared to autopsy.
• MRI (esp DWI sequence) is helpful

Caffey 11th ed Chapter 31
Pathophysiology of Neonatal Brain Disease (Volpe)

• **Increased free radicals** due to excessive nitrous oxide production (dt excess glutamate activation) damage oligodendrocytes

• **Inflammation** ➔ accelerated cell death or apoptosis

◆ Periventricular white matter injury

• Cystic lesions seen on US or

• Diffuse extensive high signal intensity (DEHSI) lesions seen on MR (esp DWI sequences) are typical in prematures
Neonatal Hypoxic-Ischemic Brain Disease III

- Cystic white matter necrosis occurs in 3-5% of very low birth weight (<1500g) infants
- **Diffuse noncystic form** is seen in 20-50%, and is better noted by MRI

Caffey 11th ed Chapter 31
Number of Gyri and Sulci and Coverage of Sylvian Fissure...vary with age.
Normal Findings
Symmetrical periventricular white matter is usually normal and not echogenic PVL
Prominent periatrial echogenicity is usually normal white matter appearing of increased echogenicity by anisotropic effect of sound beam crossing the insonated white matter at 90 degrees