

# FETAL CENTRAL NERVUS SYSTEM

## Contents:

- Normal neural development and anatomy
- Disease-hydrocephalus, neural tube defect, holoprosencephaly, agenesis of corpus callosum, destructive cerebral lesions, microcephaly, macrocephaly, choroid plexus cyst, vein of Galen aneurysm, arachnoid cyst, intracranial hemorrhage, periventricular leukomalacia
- Differential diagnosis
- Focus
- Pitfall

## Study target:

- to understand normal neural development and anatomy
- to memorize basic sonographic features of CNS anomaly
- to know pseudo-abnormalities

## .NORMAL NEURAL ANATOMY

### A. Development :

1. Neuralation(-3 weeks)
2. Diverticulation(4-8 weeks)
3. Mantle formation(9-term)

### Neuralation:

- neural plate-neural groove-neural tube(23 d-anterior neuropore, 25 d-posterior neuropore)

Diverticulation:

2 annular constriction(cephalic flexure,pontine flexure)

3 segmental dilatation

-forebrain(prosencephalon); at 7<sup>th</sup> weeks/ telencephalon,diencephalon

-midbrain(mesencephalon)

-hindbrain(rhombencephalon);metencephalon/pons,cerebellum

myelencephalon/medulla oblongata

Mantle formation:

Near internal limiting membrane-germinal cell-ependymal layer

Near outer limiting membrane-mantle layer(gray matter)

B.As gestational weeks

6<sup>th</sup> week:

- neural tube

7th Week:

- cephalic pole : sonolucent area(head discernible)

- fluid - filled rhombencephalic vesicle

-Rhombencephalon:8 to 10 weeks

cystic structure(posterior fossa, 4th ventricle)

3-4 mm <CYR DR et al>

8<sup>th</sup> Week:

-tortuous neural tube

-4 sonolucencies

telencephalon----lateral V----cerebral hemisphere

diencephalon----3<sup>rd</sup>. V-----thalamus

mesencephalon----aqueduct-----midbrain

metencephalon-----4<sup>th</sup>.V-----Pons,cerebellum

9wks gestation

- two cerebral hemisphere

- falx

- choroid plexus

11wks gestation

- the brightly echogenic choroid plexuses filling the large lateral ventricles
- cerebellum, foramen magnum

### C. Three screening planes

- transventricular plane:midline falx cerebri  
body of lateral ventricle with choroid plexus
- transthalamic plane:frontal horns of the lateral ventricle  
cavum septum pellucidum  
Sylvian cisterns
- transcerebellar plane:cerebellar hemisphere and vermis  
cisterna magna(2-10 mm)

### D. Anatomy

#### Ventricle

- Measurement- the width of atrium(inner to inner,perpendicular to the wall)
- normal range : less than 10mm(4 SD)
- ratio\_not used anymore
- choroid separation >3mm,ventricle<10mm:80% normal,20% abnormal  
<Hertzberg B.S et al>

#### pitfall: -upside ventricle

- change with time
- pseudohydrocephalus
- choroid plexus separation>3 mm
- left lateral V. slightly larger than right<Reliwen,1997>

#### Ventriculomegally:

- hydrocephalus-obstructive
- maldevelopment-surrounding brain
- destruction brain-infection, infarction

#### Cerebellum

- join 14 weeks, fissure-18 weeks
- planes includes:cavum.peduncles,cevrbellar hemispheres
- cerebellar diameter:increases with gestational age  
1 mm/week(15-21 weeks)  
accurate than HC,FL,AC in asymmetric IUGR; <Lee,1991>
- Hypoplasia in trisomy 18
- cerebellar vermis:closure by 17.5 weeks
- 4th ventricle and CM communicate at 14 weeks
- brighy echo(nerurus and deep gyri,sulci)

#### Cistern:

- dilatation of subarachnoid space(space between the cortex and the bony skull)
- 4 cisterns of mid brain:dorsal-quadrigeminal C  
lateral-ambient C  
ventral-interpeduncular C
- Cisterna Magna:5+-3mm

#### Choroid plexus:

- from ependymal cells
- first evidenced at 9 weeks

#### Corpus Callosum:

- connect the two cerebral himispheres
- fprming the floor of the interhemispheric fissure,the roof of the 3<sup>rd</sup>

V

- relatively late developing structure  
begins developing 13 week  
not evident until 18-20 weeks  
full development 28 weeks

#### Sulci,Fissures and Gyri

- after 26-28 weeks primary sulcus
- Lateral sulcus(insula)
- Calosal sulcus,cingulate sulcus(cingulate gyrus)

-not perfectly symmetric

Tentorium:

-an infolding of the dura that separates the contents of the post.fossa from the rest of the cranial vault

Germinal matrix: .active mitotic activity(zone of neuronal,glial proliferation )

.near ventricle(epindyma)

.highly cellular,rich blood supply

.involutes by 34 weeks

## .CNS ABNORMALITY

\* overall incidence of CNS abnormalities :> about 1 in 100

### A.Hydrocephalus

:Dilatation of the fetal lateral ventricles resulting from an increased quantity of cerebrospinal fluid and a subsequent increase in intraventricular pressure

Type ;Non communicating-intraventricular obstruction of the normal CSF flow  
Communicating-extraventricular cause

-Incidence; 0.3 0.5 per 1.000

33-43%:aqueductal stenosis

13% :Dandy Walker malformation

38% :communicating H.(Arnold-Chiari 2,absence of the arachnoid granulation)

-Progress: Occipital-temporal-frontal

-Ventriculomegaly:hydrocephalus-obstructive  
maldevelopment-surrounding brain  
destruction brain-infection,infarction

-Associated anomalies(70 to 85%)

.tip of iceberg;extracranial anomaly-face,heart,kidney,abdominal

wall, thorax, limbs)

.chromosomal anomaly : trisomy 21

#### Communicating Hydrocephalus

- form of enlargement of the the ventricles and subarachnoid system caused by an obstruction to CSF flow outside the ventricular system

.Non-communicating hydrocephalus

#### Aqueductal Stenosis

- m/c form of non-communicating H.
- caused by narrowing of the aqueduct of sylvius
- Primary(X-linked)-1,2%; ventriculomegaly in male fetus  
adducted thumb in mother
- secondary to intrauterine infection, hemorrhage within the ventricle, pressure by cranial mass
- Sonofindings:
  1. bilateral ventriculomegaly
  2. 3rd ventricle dilatation
  3. normal 4th ventricle

#### Dandy - Walker Malformation

- Common cause of non communicating H
- communicating with the 4th ventricle through a defect of the cerebellar vermis
- Diagnosis
  - \* enlarged cisterna magna
  - \* 10 mm ventricle
  - \* 4th ventricle
  - \* agenesis or hypoplasia of the cerebellar vermis
- Associated anomaly:encephalocele
  - ACC
  - aqueductal stenosis
  - VSD
  - infantile polycystic kidney

## Surgical Treatment of hydrocephalus

- ventriculostomy with endoscopy(3<sup>rd</sup> V.)  
success rate 75%

## B. Neural Tube Defect

### Classification:

- Acrania(Exencephaly)
- Anencephaly
- Cephalocele
- Iniencephaly
- Spina bifida

### Anencephaly

Incidence: 1 2 per 1000

- characterized by the absence of the cranial vault and telencephalon
- result from multifactorial influences(chromosomal, hyperthermia, folate deficiency)
- Diagnosis : midtrimester ( not possible until 11 or 12wks)
- acrania(exencephaly):embryonic precursor of anencephaly

### Cephalocele

- \*1 per 5000 to 10,000
- \* protrusion of the intracranial contents through a bony defect of the skull
- \* arises from the midline in the occipital area
- \* brain tissue inside the lesion
- \* Cranial meningocele : only the meninges protrude  
associated with microcephaly
- \* Massive encephalocele : associated with microcephaly
- \* Neonatal mortality rate : about 40%
- \* sonofindings:1.extracranial mass  
2.ventriculomegaly  
3.bony defect in the skull(occipital,parietal,frontal)
- \* prognosis:1.meningocele- mortality 11%(after surgical repair)

## 2.brain tissue herniated- mortality 71%

Associated with Meckel-Gruber syndrome(occipital cephalocele,bilateral Polycystic kidneys, polydactyly Warburg syndrome(cerebellar hypoplasia, Dandy-Walker cyst, Ocular abnormality)

## Iniencephaly

- defect in the occiput involving the foramen magnum
- retroflexion of the entire spine(occiput directed towards the lumbar region)
- open spinal defects

## Spina Bifida

- \* lumbar, thoracolumbar or sacrolumbar area : most affected(80%)
- \* Diagnosis : from the midtrimester(12 weeks after)
- \* transeverse view : vertebral arch defect  
sagittal view : assessing the severity and location of the lesion
- \* Two typical abnormal sign(95-100%)
  - ➔ banana sign(after 24 weeks-cerebellar absence)
  - ➔ lemon sign(90% more, 16-24 weeks)
- \* hydrocephalus : all cases
- Prognosis: associated with Anord-Chiari malformation
- Delivery: Never vaginal delivery
- Intra-uterine surgery
  - 22 to 24 weeks gestation
  - with omentum

## C.Holoprosencephaly

- ;Failure of the prosencephalon of differentiate into the cerebral hemisphere and lateral ventricles (4-8 weeks)
- \*the abnormal midline separation of the cerebral hemispheres and the diencephalic structures
- \*May affect orbitall and facial malformations(17%)
- \*Microcephaly in all three type

Alobar type: 1. Single common ventricle  
2. Fusion of thalamus. absent third ventricle  
3. Absent interhemispheric fissure  
4. Orbital anomaly (cyclopia to hypotelorism)  
5. Nasal anomaly (absent nose to a single nostril)  
6. Median facial clefts  
7. Chromosomal abnormality (50%) – trisomy 13, del 11q, del 13q, del 18p

Semilobar type: 1. Partial separation of the ventricles  
2. Partial fusion of the thalamus

Lobar type : 1. Division of the ventricles and thalamus  
2. septum pellucidum are missing  
3. Fused frontal horns

\*facial anomalies - cyclopia to severe hypotelorism  
median cleft lip and palate  
absence or extremely flattened of nose

incidence: - 1 / 250 voluntary terminations of pregnancy  
unknown / birth

#### D. Agenesis of the Corpus Callosum

; an anomaly of uncertain prevalence and clinical significance

- genetic factors are probably predominant
- abnormal karyotype ; trisomy 18, 8 ; 20%
- associated anomaly: 80%
- Sonographic findings;
- increased atrial width
- failure to visualize the Cavum septum pellucidum
- Lateral and superior displacement of the lateral ventricle
- Occipital horn dilation (tear drop sign)

- distension of the inter-hemispheric fissure
- Dilatation and upward displacement of the 3rd ventricle
- Steer sign\_angulated frontal and lateral ventricular horn
- Gyral pattern disarrayed(sunburst appearance)

## E.Destructive lesions

### .Congenital porencephaly

- presence of cystic cavities within the brain matter
- usually communicate with either the ventricular system, the subarachnoid space, or both.
- typically bilateral and symmetrical and is frequently associated with microcephaly
- pseudoporencephaly ; unilateral lesion is usually found

### .Hydranencephaly

- caused by internal carotid artery occlusion
- extreme form of pseudoporencephaly
- most of the cerebral hemispheres are replaced by fluid
- brain stem and rhombencephalic structures ; usually spared
- Differential Diagnosis ;
- severe HYDROCEPHALUS
- HOLOPROSENCEPHALY

### -Sonographic findings:

- 1.Brain tissue is replaced by fluid.
- 2.Falx is usually present, but may be absent
- 3.Choroid plexus may be observed
- 4.Macrocephaly
- 5.Hydroamnios

## F.Microcephaly

- 1 per 6,200 to 8,500
- clinical concern; mental retardation-85%
- BPD, H.C ; Below -3SD

- HC/AC ratio(Campbell)
- Causes:A.D inheritance
  - Chromosomal aberrations
  - Prenatal radiation
  - Maternal viral infection(CMV, rubella, toxoplasmosis)
  - Alcohol,heroin,mercury
  - Maternal PKU
  - Angelman syndrome,Brome syndrome
  - Chromosomal deletion(3p,4p,5p,11q,13q,18p,18q)
- Sonofindings:
  - 1.Small BPD,HC
  - 2.Head to abdomen disproportion
  - 3.disorganized brain tissue
  - 4.Intracerebral calcifications(parovirus, CMV)
  - 5.Ventriculomegaly
  - 6.VSD
  - 7.Polycystic kidney in Meckel-Gruber syndrome
  - 8.Limb disorder
  - 9.not diagnosed before 24 weeks.
- \* abnormal convolutional patterns ( macro / micro / a - gyria)
- \* pathologic microcephaly-small frontal lobe
  - (from the back of cavum to the inner calvarium)
  - <Goldstein,1988>
- Prognosis: -3 to -2SD (MR—18%)
  - 3SD over (MR--72%)

## G.Macrocephaly

- An abnormally large brain
- M/c nonspecific familial(A.D)
- a part of congenital anomalies / syndrome
  - Beckwith-Wideman syn.
  - achondroplasia
  - Osteopetrosis
  - Hunter syndrome

## Hurer syndrome

### H. Choroid plexus cysts

- Mid trimester; 1-3%
- Composed of cerebrospinal fluid and cellular debris, which trapped within the Neuroepithelial folds
- Resolve by 24 weeks.
- increased risk of chromosomal aberrations (4%-Kupfermenc, 2.5%-Shield) of 7 aneuploidy: 5(18+), 21+, 47XXY
- no correlations between size, bilaterality
- Normal Triple test with isolated CPC-risk of trisomy 18 (0.2%) in the absence of associated anomalies
  - > considered as normal anatomic variants
- DDx: subarachnoid cyst
  - corpus striatum (caudate N, internal capsule, lentiform N)
  - pseudocyst

### I. Vein of Gallen aneurysm

: midline vein located behind the third ventricle  
round, cigar shaped cyst behind the third ventricle  
color Doppler  
causes high output heart failure-hydrops fetalis, enlarged heart (95%)  
never diagnosed before 30 weeks

### J. Arachnoid cyst

: round, fluid filled and surrounded by a thin wall  
do not connect with the Ventricle  
external to the brain matter  
unilocular  
Primary treatment-endoscopy  
favorable outcome

### K. Porencephaly

: fluid filled area within the brain substance that communicates

with the Ventricles  
result of destruction of the brain(infection, ischemia, hemorrhage)  
internal to the brain matter  
No mass effect  
Frequent in monochorionic twin

#### L. Lissencephaly

:absence of cerebral gyri  
Type 1-4 layer of cortex, ventriculomegaly  
-ACC  
-slight microcephaly  
-Miller-Diecker syndrome  
Type 2-always Dandy-Walker malformation  
-ocular anomaly, muscular dystrophy  
Obstructive hydrocephalus

#### M. Intracranial hemorrhage

Fetal ICH-1.germinal matrix of caudate N of frontal horn  
2.subdural  
Sonographic findings:  
hyperechoic lesion  
focal echodense patch  
diffuse cerebral edema  
Secondary to maternal hemorrhage with hypertension  
Pancreatitis  
Seizure  
Isoimmune thrombocytopenia

#### Neonatal ICH

;results from sudden change in cerebral blood pressure  
perinatal asphyxia  
-most often in immature( <1.5Kg, < 32 weeks)  
-70% if assisted ventilation  
-first 3 days of life

## N. Periventricular leukomalacia (PVL)

: Coagulation necrosis of white matter dorsal and lateral to the external angle to the lateral ventricles <Volpe, 1989>

Location-external area of frontal horn  
optic radiations at trigone

results from rubella, CMV <Shackelford, 1983>

venous infarction <Volpe, 1989>

risky in IUGR, Pre-eclampsia, PROM

-Evolution

1. initially-normal or increased periventricular echogenicity

2. second, third weeks-multiple small cysts (necrosis, cavitation)

## . Differential Diagnosis

Where:	How :	If	: Then
Calvarium	Shape	bizzar	Anencephaly, Exencephaly Amniotic band syndrome Craniosynostosis
		Lemon	NTD
	Density	Cloverleaf	Thanatophoric dysplasia
		decreased	O.I, hypophosphatasia
Cerebrum	Size	increased	Macrocephaly
		decreased	Microcephaly
	Gyrus	decreased	Lissencephaly
	Sylvian fissure	delayed	Immature brain
Ventricle	Single		Holoprosencephaly
	Enlarged	macrocephaly	Hydrocephalus
		Microcephaly	Destructive

Anterior	CSP(18-37weeks)	absent	ACC,Holoprosencephaly
Posterior	Cerebellum	Banana shape	Arnold-Chiari type 2
		No vermis	Dandy-Walker syndrome
	CM	Communicated	Dandy-Walker syndrome
		Obstructed	NTD
Cyst	echogenic rim		CPC
	Between dura & parenchyma		Arachnoid cyst
	Central	color D	Vein of Galen cyst
	Communicating with V		Porencephaly
	Posterior, central		large CM
	Midline, upward		3 <sup>rd</sup> V in ACC
	Bilateral cleft		Schizencephaly
	Center, Doppler		Vein of Galen cyst

∩ : lateral hemisphere(lateral sulcus-insula)  
 ventricle  
 corpus callosum

### .Focus

Mild ventriculomegaly(10-15mm)

-Mahony(1988), 13 case, developmental delay 1/10(10%)

-Drugan(1989), 5 , 0/5

-Bromley(1991), 27 , 5/26(19%)

-Patel(1994), 44 , 6/34(18%)

-Alagappan(1994), 11 , 0/11

-Patrizi(1998), 4800000000 , 0/45

Total 148 12/131(9.2%)

,4 chromosomal anomalies(2.7%)

≥12mm :associated anomaly(56% vs 6%)

postnatal neurodevelopment(23% vs 3%) <Patrizia,1998>

Next step: Targeted sono

Visualization of Corpus Callosum

Echocardiogram

Serologic evaluation for congenital infection

### .Pitfalls in fetal CNS:

- early embryonic brain vesicle brain anomaly
- white matter hydrocephalus
- ventricle tilting choroid plexus cyst
- posterior deep tilting vermian agenesis
- fetal hair posterior nuchal mass
- prominent CSP third ventricle dilatation

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