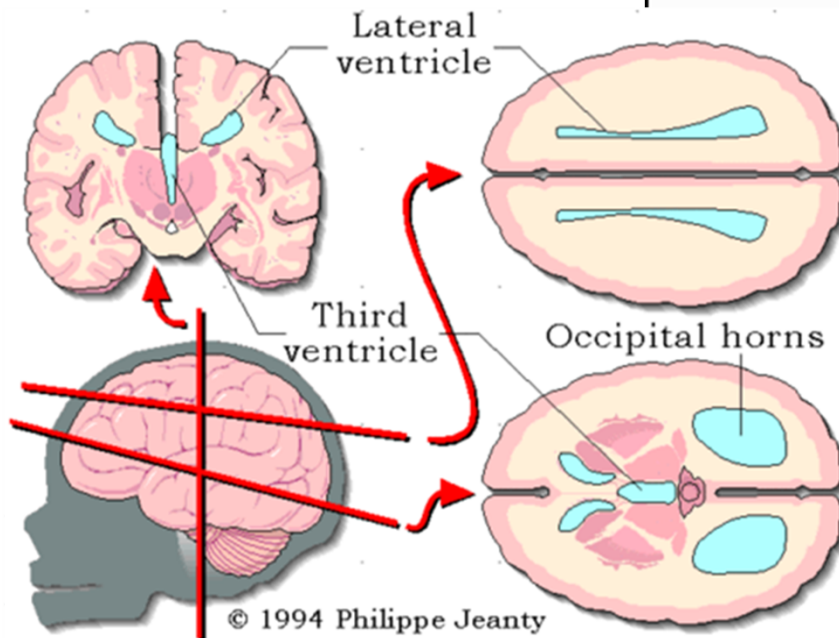
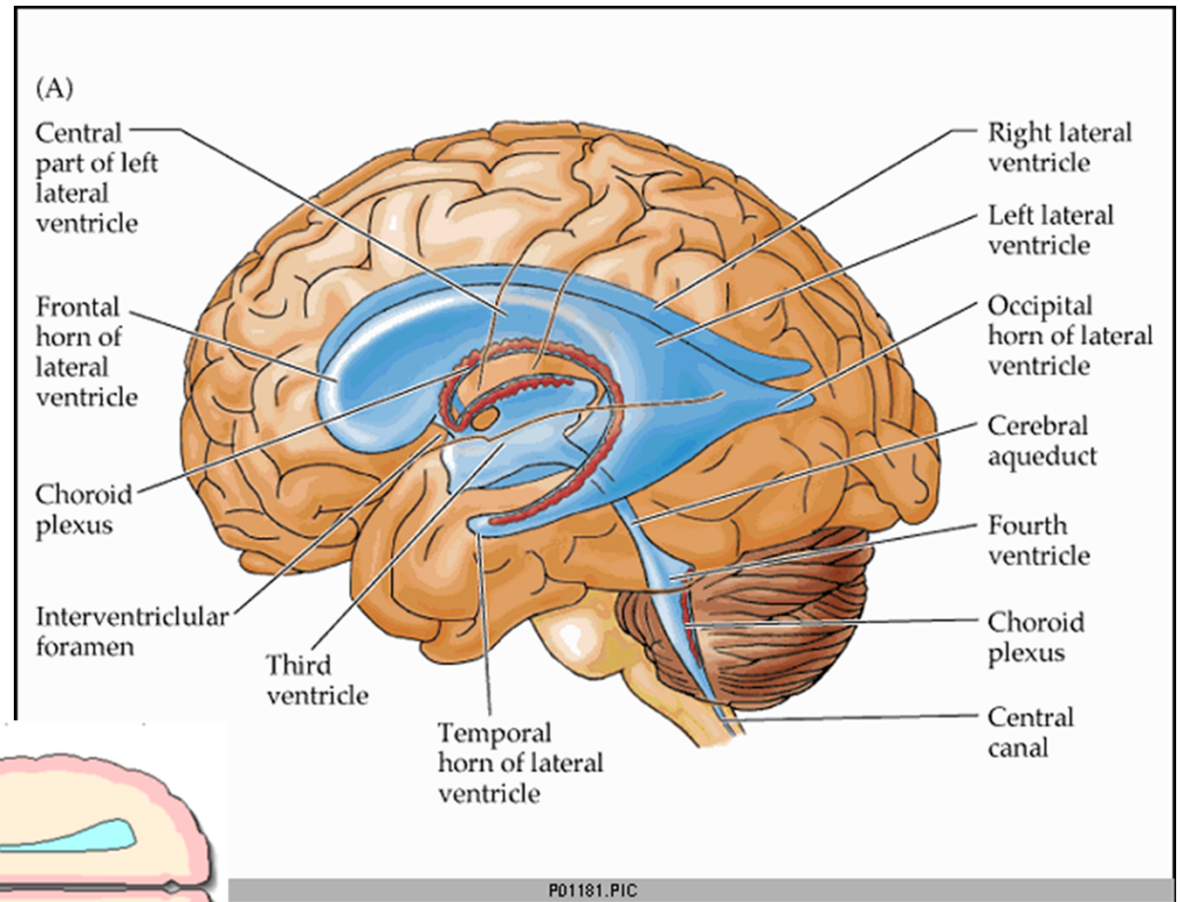
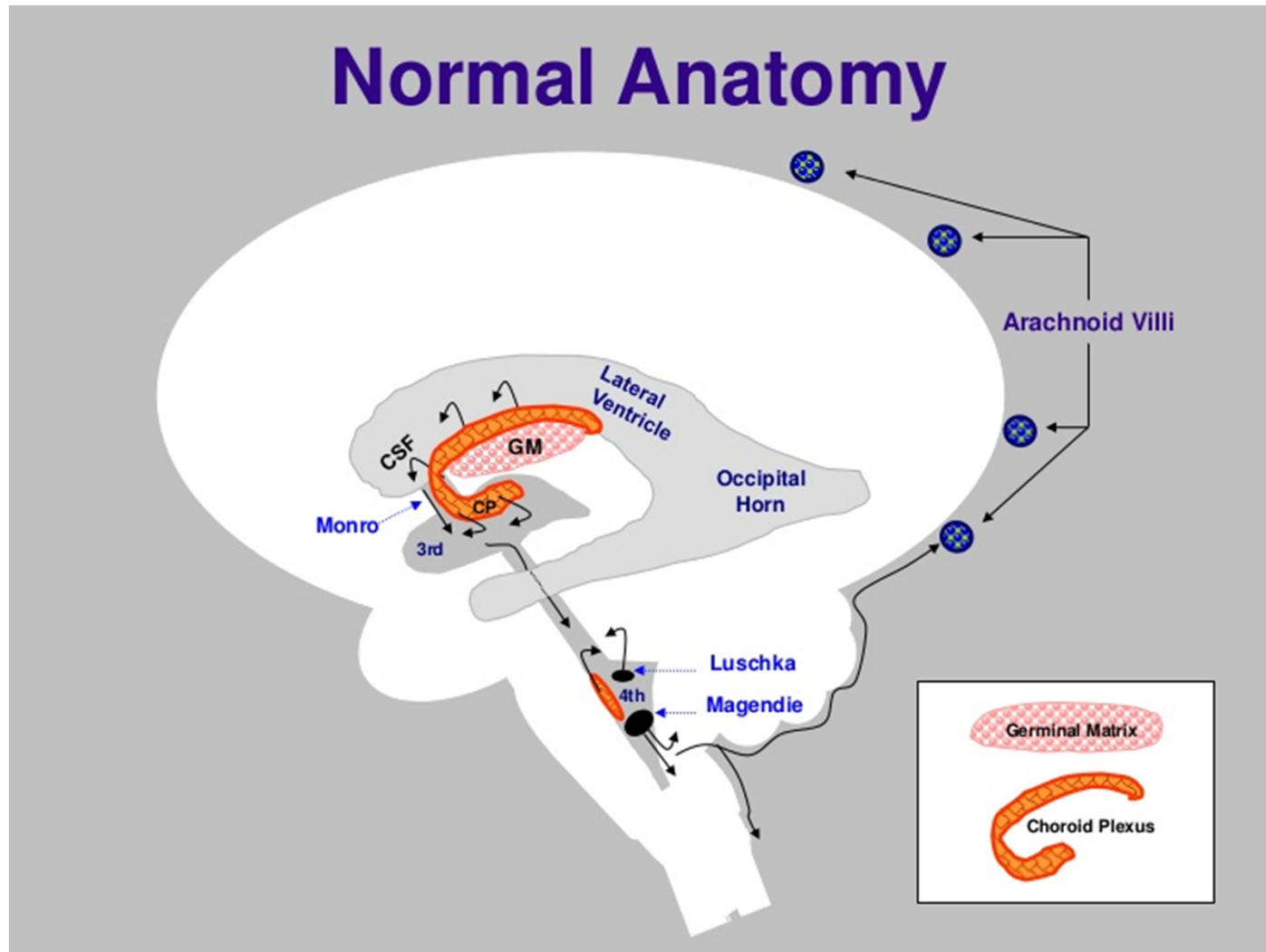


# Anatomy!!

- Ventricles
- Intraventricular Foramen
- Cerebral aqueduct
- Choroid plexus
- Germinal matrix



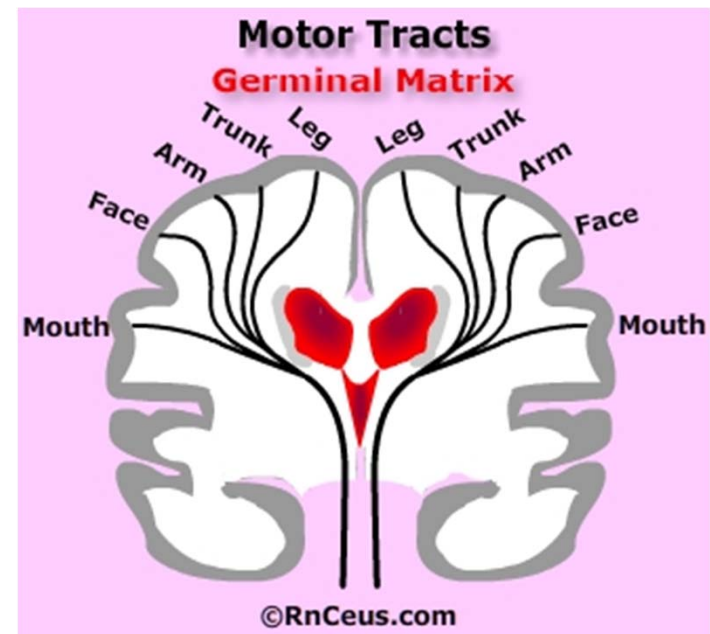
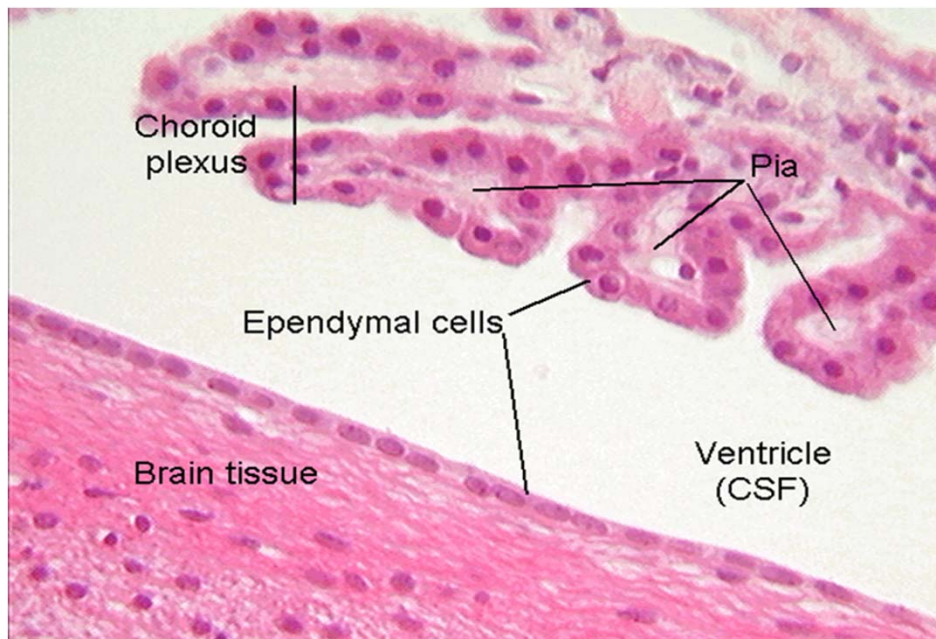
# Anatomy!!



Introductory sentence Arial – 21pt font

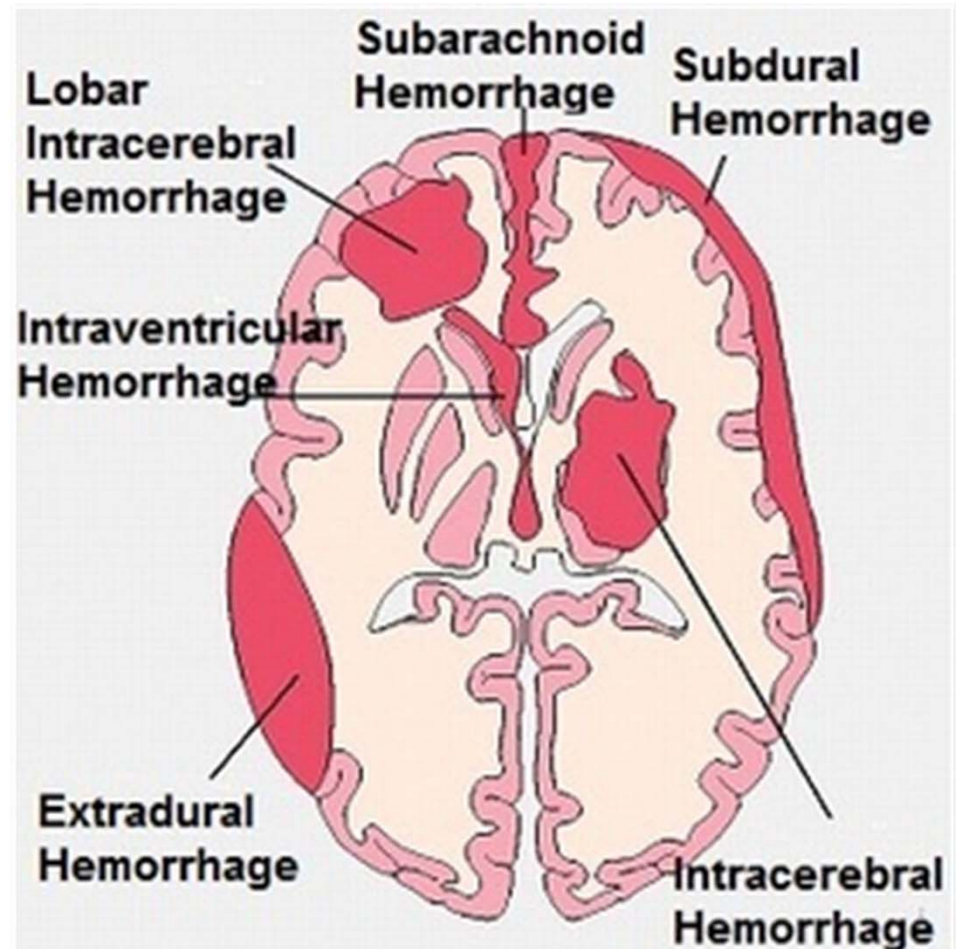
# Germinal Matrix

- Highly vascularized and poorly supported
  - Involutes over time
    - 23-24 weeks 2.5 mm width
    - 32 weeks 1.4 mm width
    - 36 weeks involute



# Intra-Cranial Hemorrhage (ICH) & Intra-Ventricular Hemorrhage (IVH)

- ICH
- IVH
  - Most common and serious form of neonatal ICH
  - Most common in GA <32 weeks and/or <1500 grams
  - Risk decreases as GA increases



# Periventricular-Intraventricular Hemorrhage (IVH)

- Occurs once germinal matrix hemorrhage extends into the lateral ventricle
- Risk factors: prematurity (less than 34 weeks), respiratory failure, increasing arterial blood pressure, perinatal asphyxia
- Incidence:
  - 10 to 15% of infants with hemorrhages
  - 30 to 40% of preterm infants <30 weeks or <1500 grams
  - Higher risk if <28 weeks
  - 2 to 3% of term infants

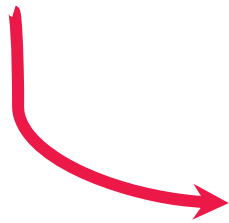


So why  
are  
preemies  
at high  
risk?!



# Fetal Brain Development

This is what we are working with...



23 weeks gestation



30-32 weeks gestation



40 weeks gestation

# Pathogenesis

Thought to be caused by capillary bleeding.

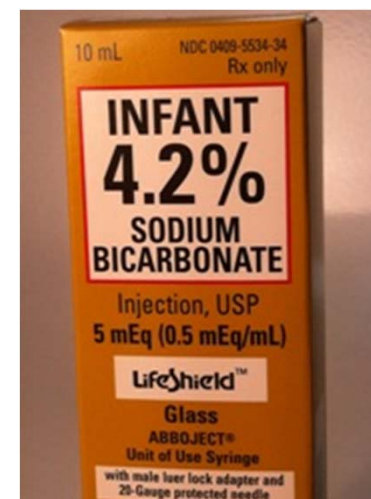
- Major factors:
  - Intra-vascular factors
    - Loss of cerebral autoregulation
    - Abrupt alterations in cerebral blood flow and pressure
  - Vascular factors
    - Germinal matrix-vulnerable to hypoxia
    - Reperfusion injury
  - Extravascular factors
    - Poor vascular support in cerebral tissue



# IVH Risk Factors

Abrupt changes in cerebral circulation

- Rapid changes in PaCO<sub>2</sub>
- Rapid changes in aortic pressure
  - Rapid infusion of volume expander
  - Excessive increase in vasopressor infusion
  - Noxious procedures
    - suctioning, PIV insertion, CT insertion, loud noises, aggressive handling
- Large PDA with left-to-right shunt
- Elevated venous pressure from tension pneumothorax or excessive ventilator pressures



# IVH Timing and Progression

- May begin in utero, but usually begins after birth
- Hemorrhages may be small at first, then progress to larger hemorrhages later
- Most large or progressive IVH's begin in the first week of life
  - **Why is this important to the bedside nurse?**



# Symptoms of IVH

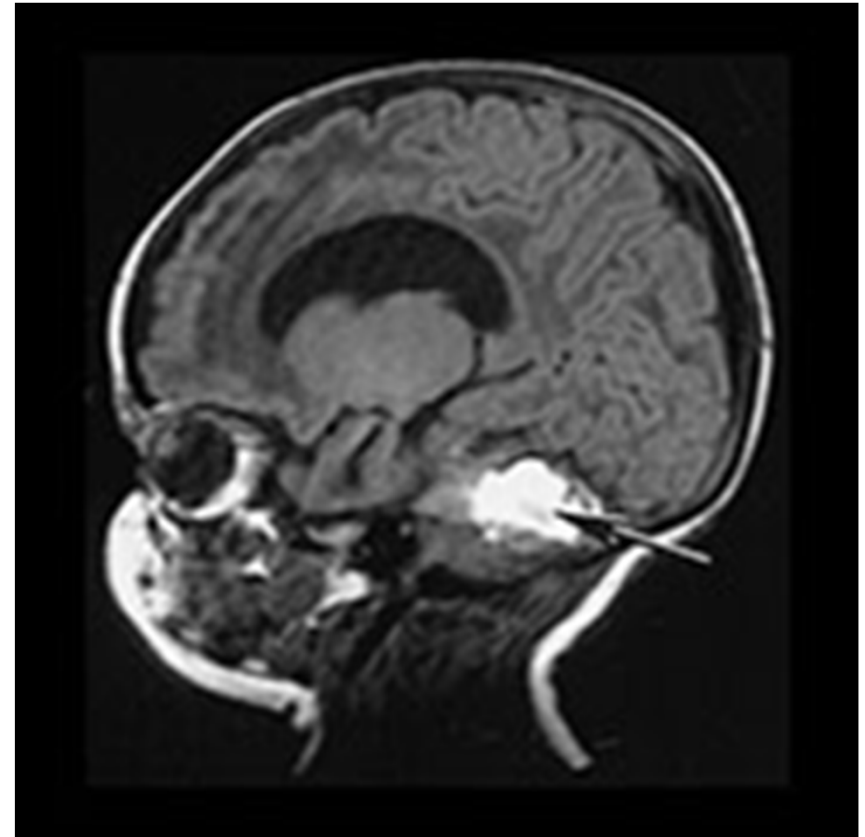
- Majority are asymptomatic
  - Dx is cranial ultrasound
    - 4<sup>th</sup> day 90% detected
    - Serial ultrasounds
- Symptomatic (common)
  - Changes in LOC, movement, tone, respirations, and eye movement
- Symptomatic (uncommon) catastrophic deterioration
  - Stupor, coma, decerebrate posturing, generalized tonic seizures, quadraparesis

# Acute/ Catastrophic Presentation

- Clinical signs include:
  - Bulging anterior fontanelle/split sutures
  - Decreasing hematocrit
  - Bradycardia
  - Hypotension (or reactive hypertension)
  - Temperature instability
  - Glucose intolerance or hypoglycemia
  - Metabolic acidosis

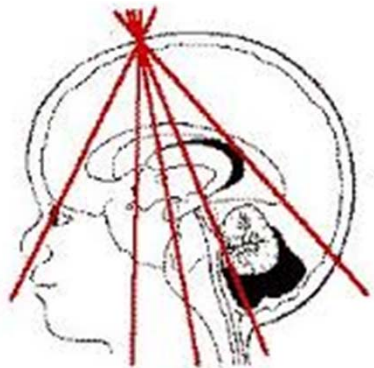
# Intracerebellar Hemorrhage

- Diagnostic:
  - Cranial ultrasound
  - CT to define the hemorrhage
  - MRI for definitive diagnosis
- Outcome:
  - More favorable in term than preterm infants
  - Probable neurologic deficits



# Surveillance for Intracranial Hemorrhage in ELBW Infant

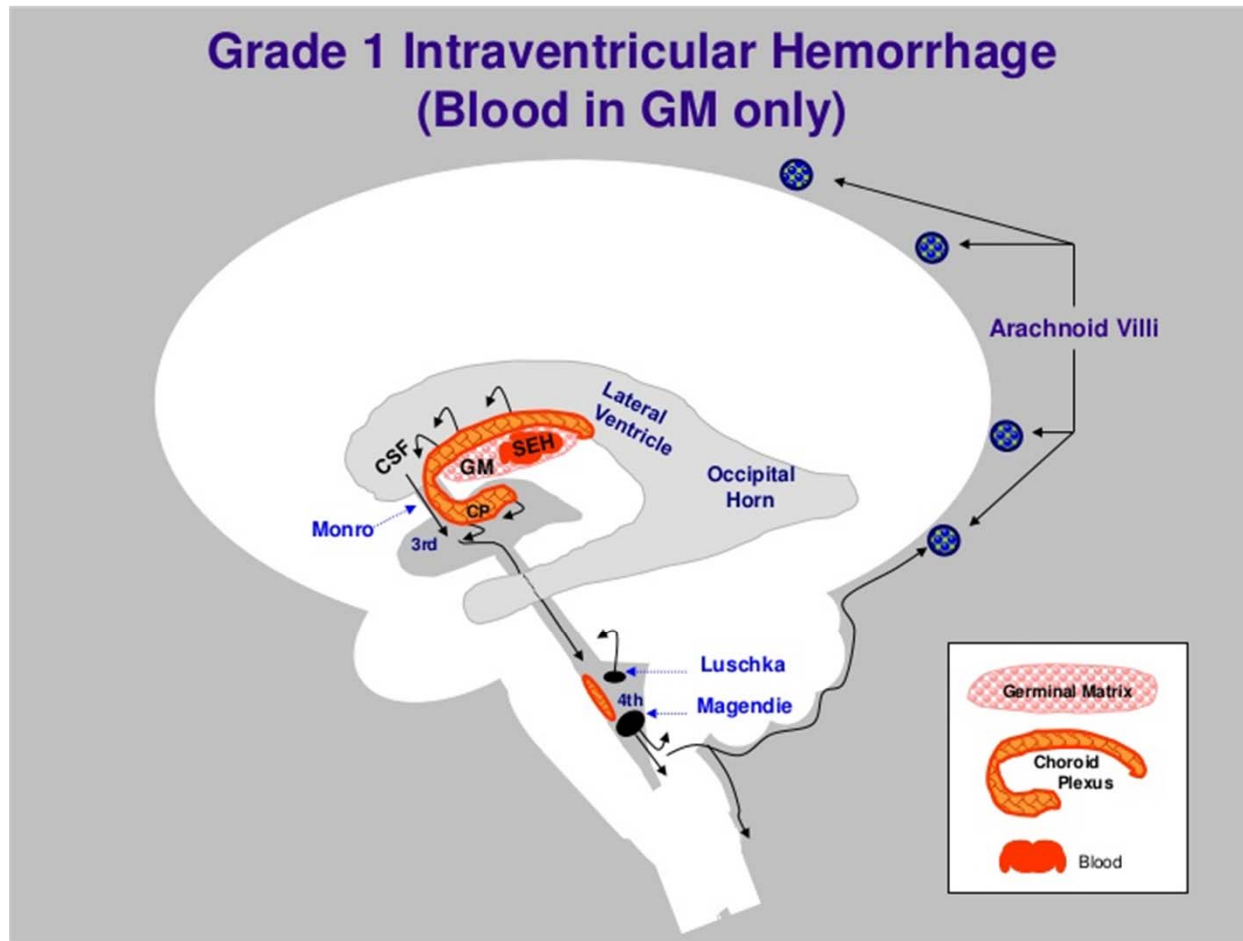
- Stable neonate
  - HUS at end of the first week of life
  - If HUS normal repeat at 1 month of age
  - Repeat HUS sooner if infant has a predisposing event or deteriorates
    - Weekly head circumference measurements



# IVH

- Diagnostic:
  - Cranial ultrasound (serial) – Papile Classification (1988):
    - Grade I: Subependymal hemorrhage in the periventricular germinal matrix.
    - Grade II: Partial filling of the lateral ventricles without ventricular dilation.
    - Grade III: Intraventricular hemorrhage with dilation
    - Grade IV: Intraventricular hemorrhage with parenchymal involvement or extension of blood into the cerebral tissue
  - LP to rule out septic shock or meningitis

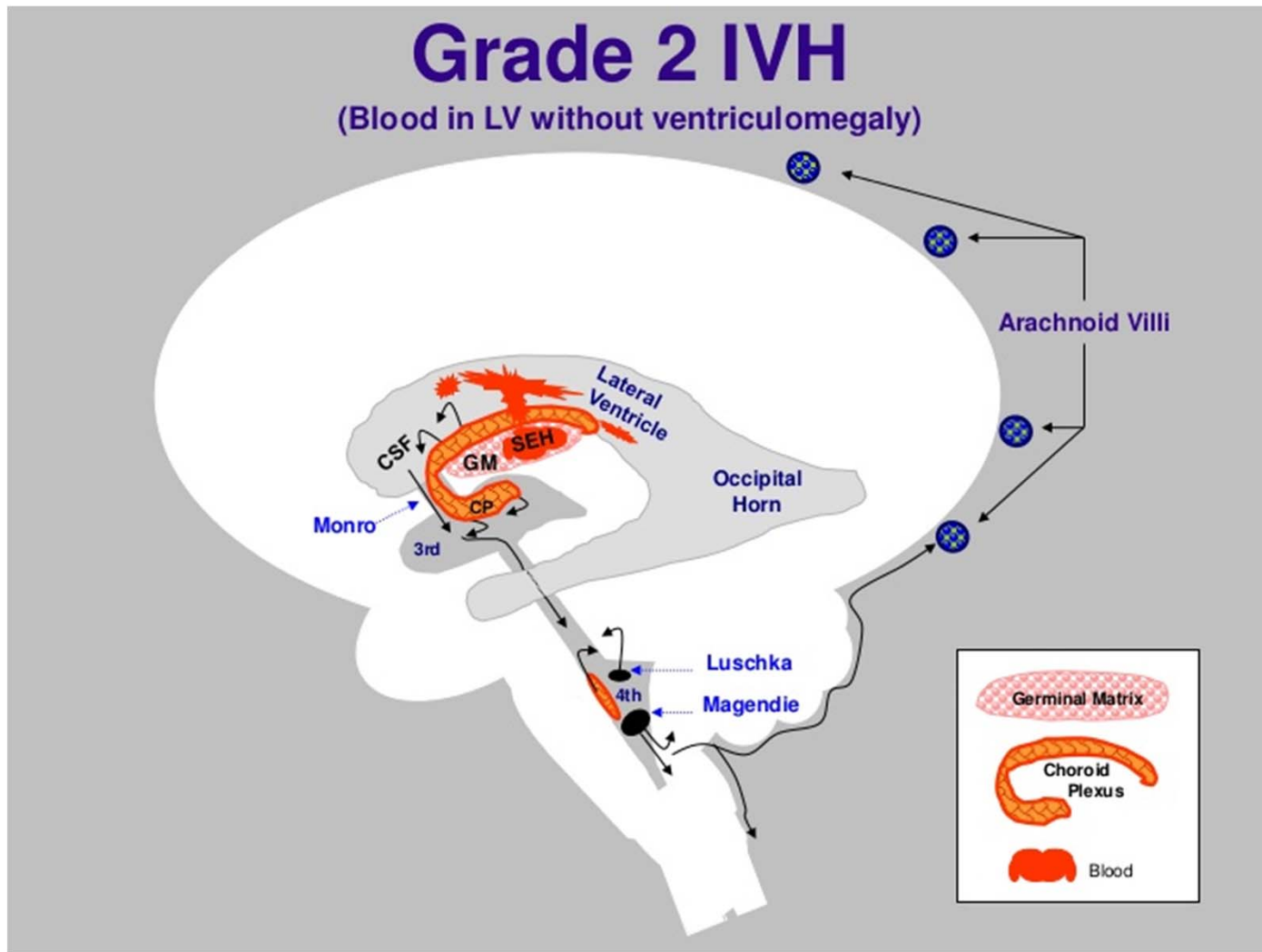
# Grade I IVH



<http://www.slideshare.net/PediatricHomeService/brain-injury-in-preterm-infants>

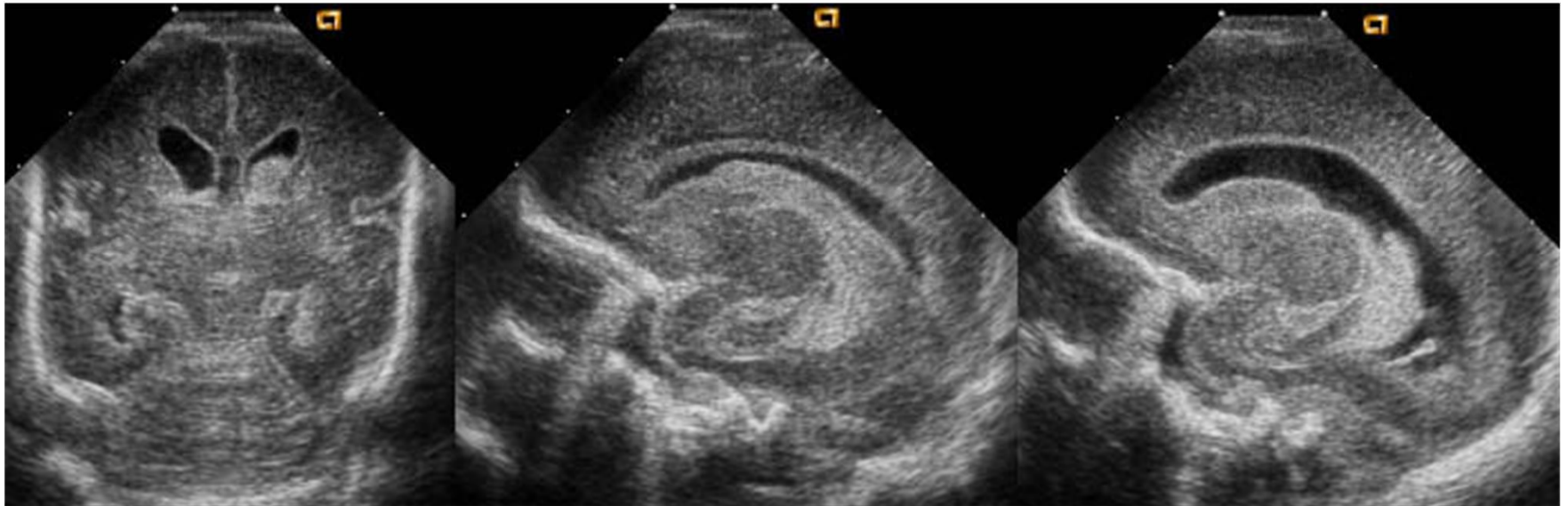


# Grade II IVH



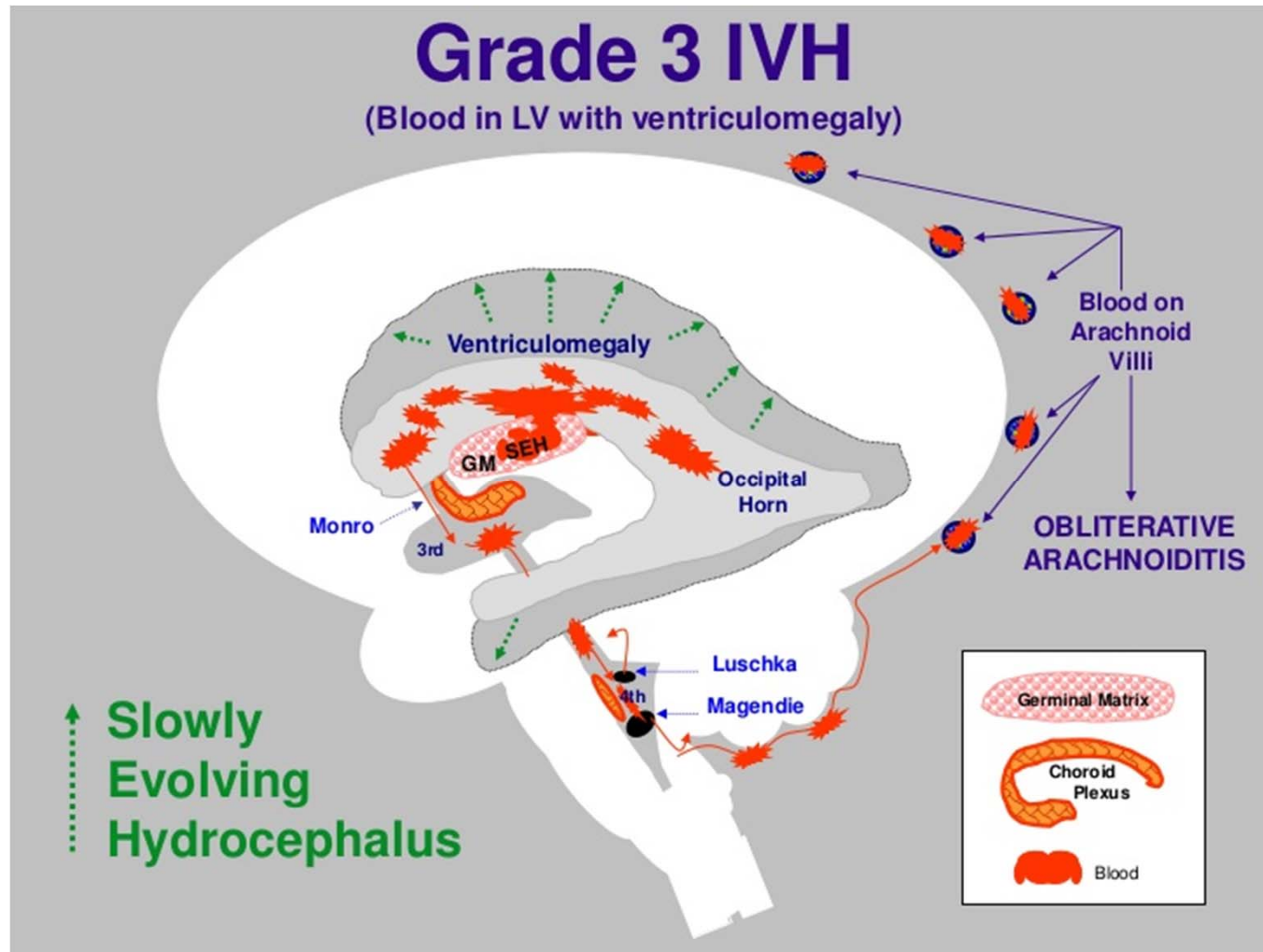
<http://www.slideshare.net/PediatricHomeService/brain-injury-in-preterm-infants>

# Grade II IVH



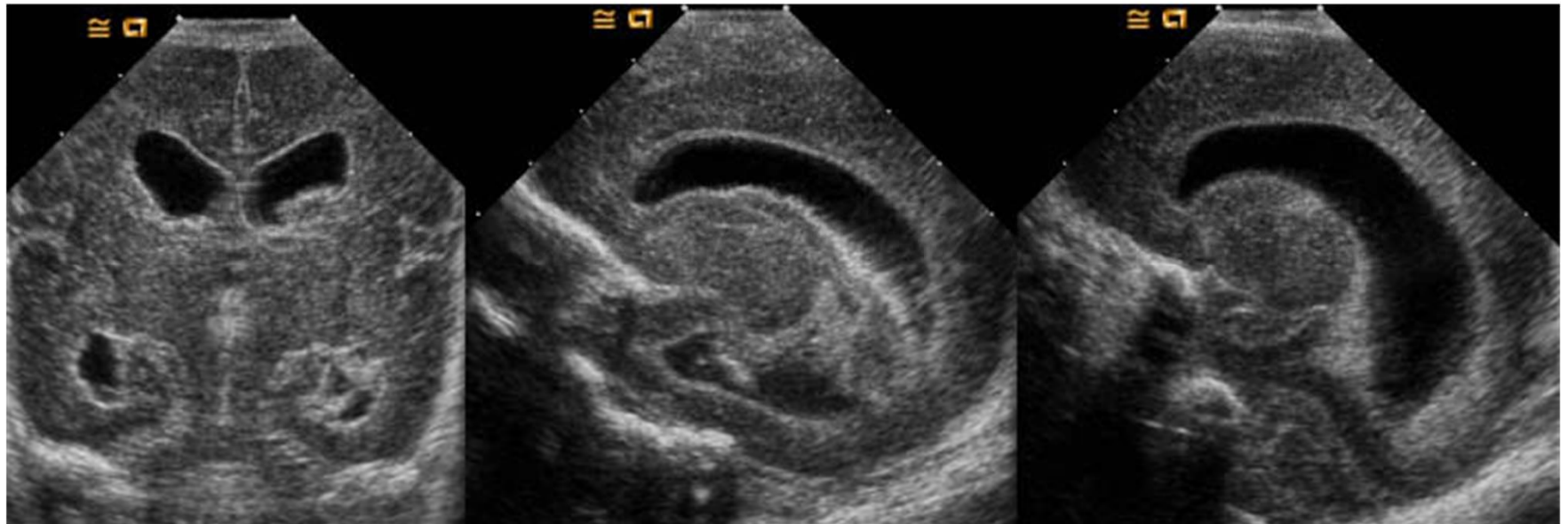
<http://pediatriceducation.org/2005/03/14/>

# Grade III IVH



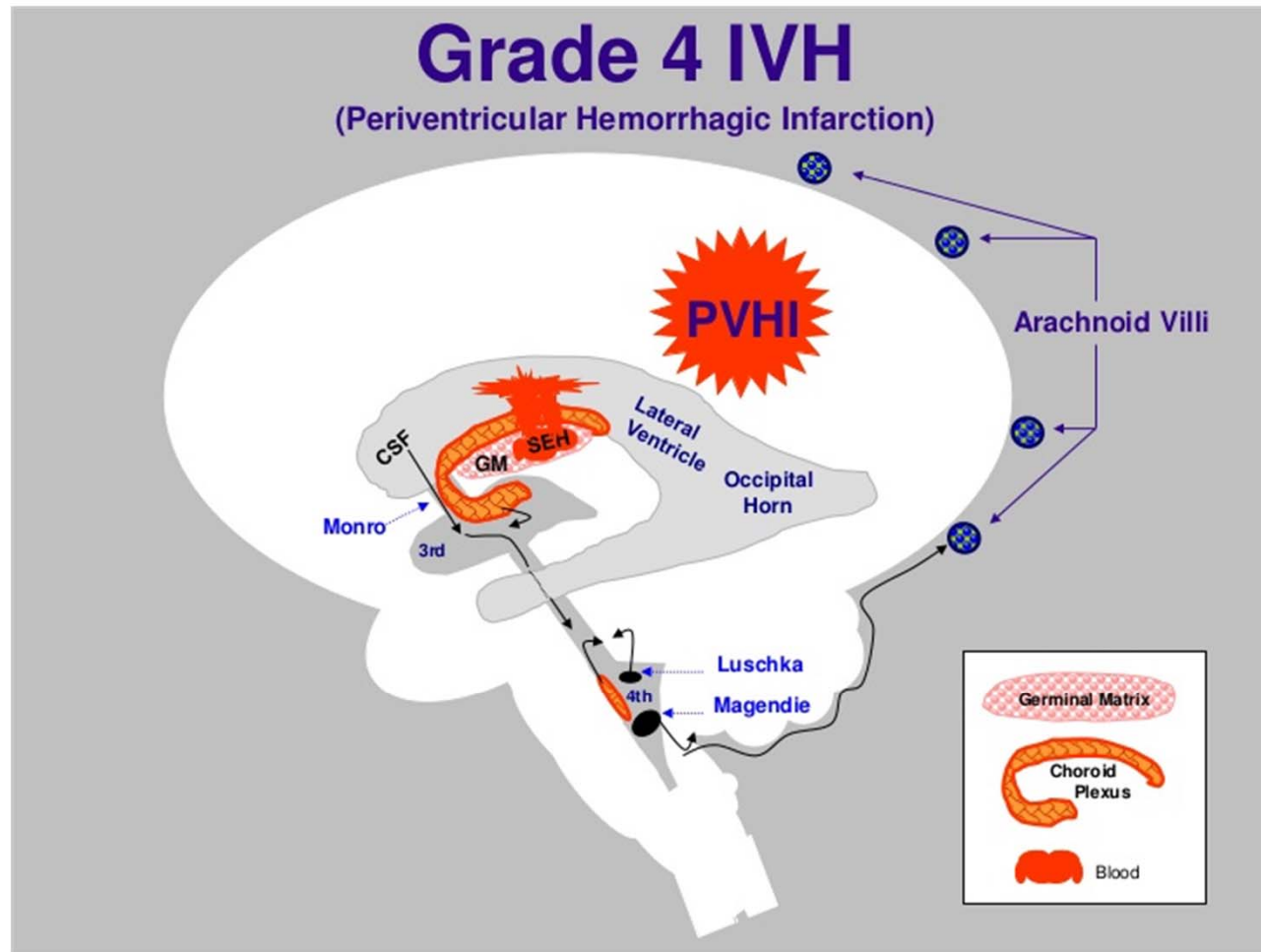
<http://www.slideshare.net/PediatricHomeService/brain-injury-in-preterm-infants>

# Grade III IVH



<http://pediatriceducation.org/2005/03/14/>

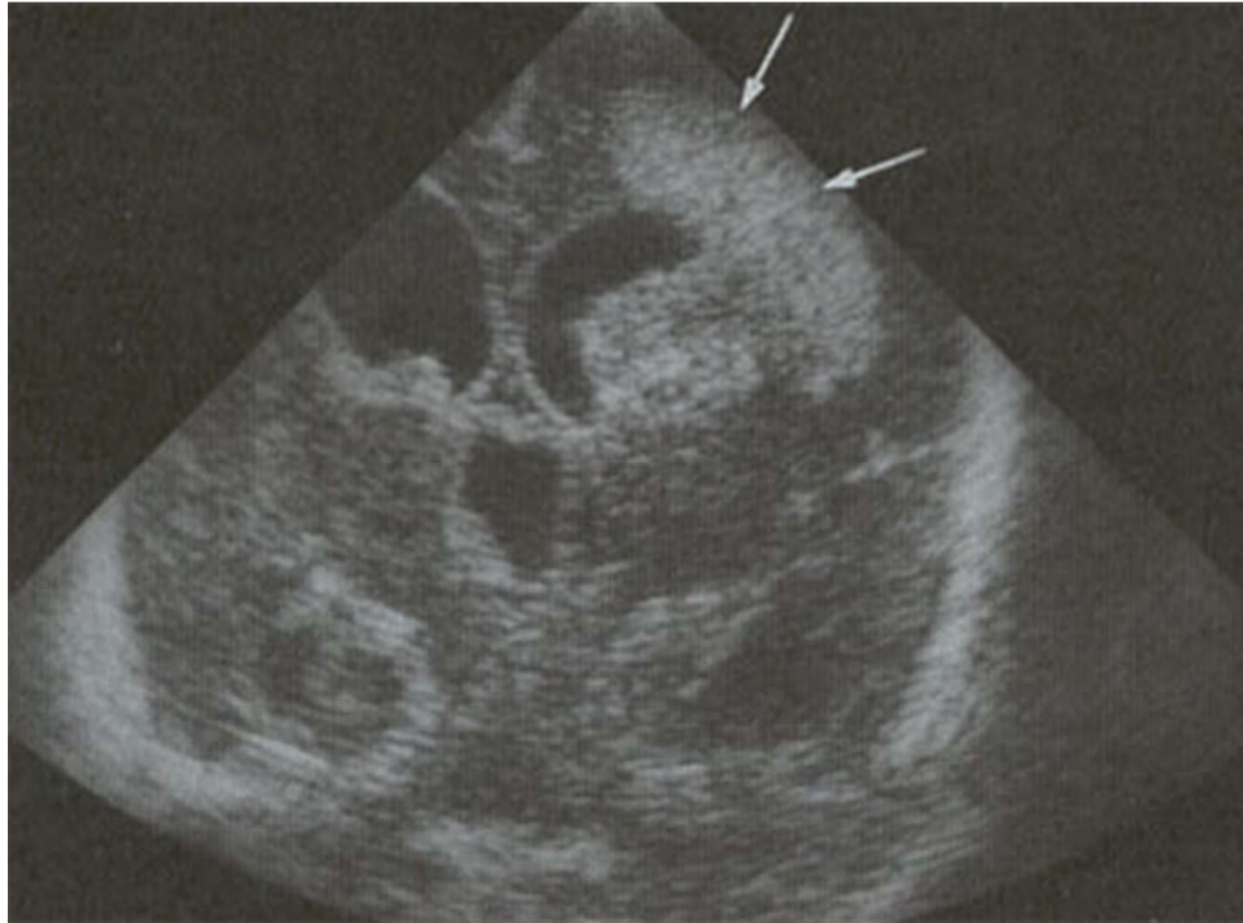
# Grade IV IVH



<http://www.slideshare.net/PediatricHomeService/brain-injury-in-preterm-infants>

[http://www.nrdaddy.com/lectures/ivh\\_pvl/ivhgrad\\_4a.htm](http://www.nrdaddy.com/lectures/ivh_pvl/ivhgrad_4a.htm)

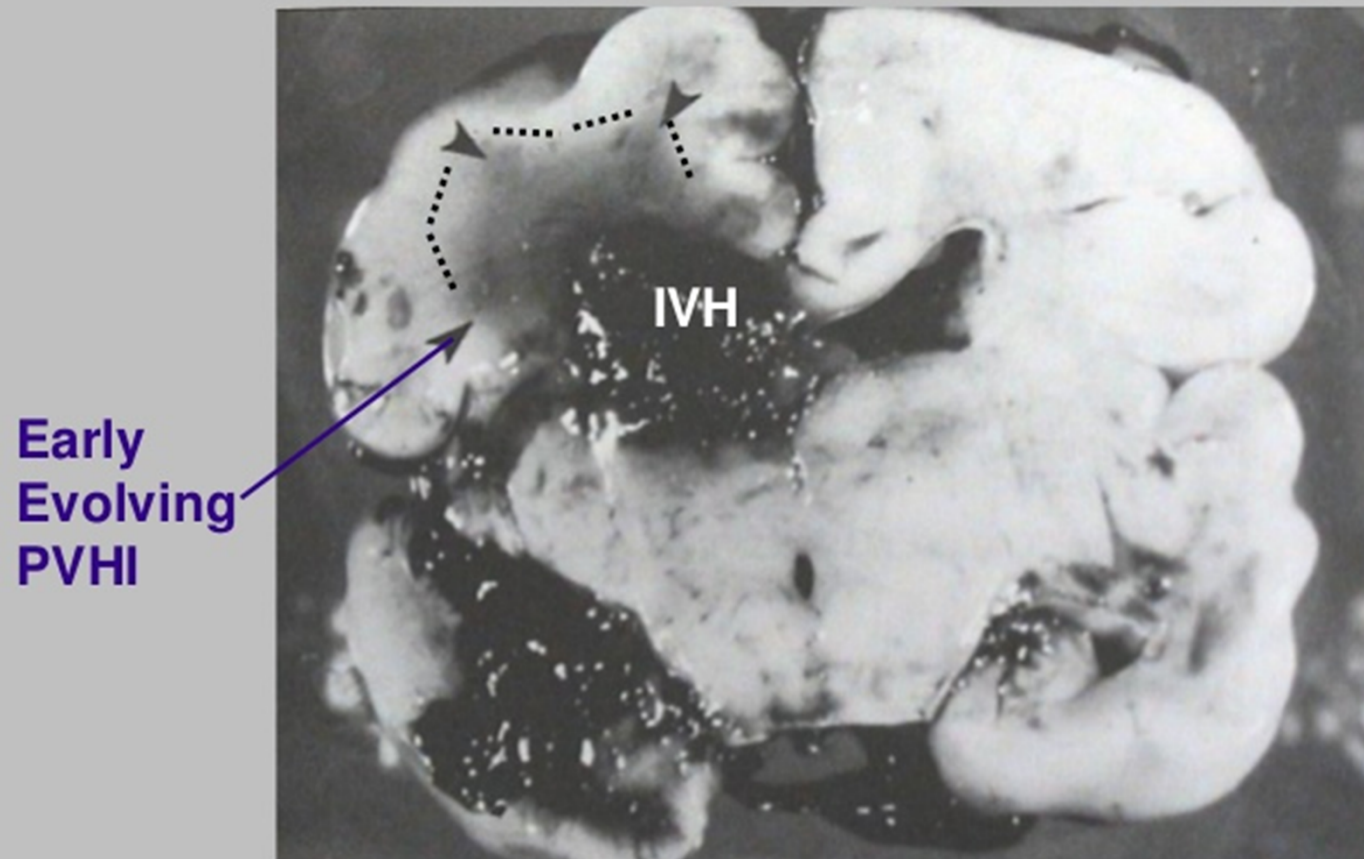
# Grade IV IVH



<http://www.slideshare.net/PediatricHomeService/brain-injury-in-preterm-infants>

[http://www.nrdaddy.com/lectures/ivh\\_pvl/ivhgrad\\_4a.htm](http://www.nrdaddy.com/lectures/ivh_pvl/ivhgrad_4a.htm)

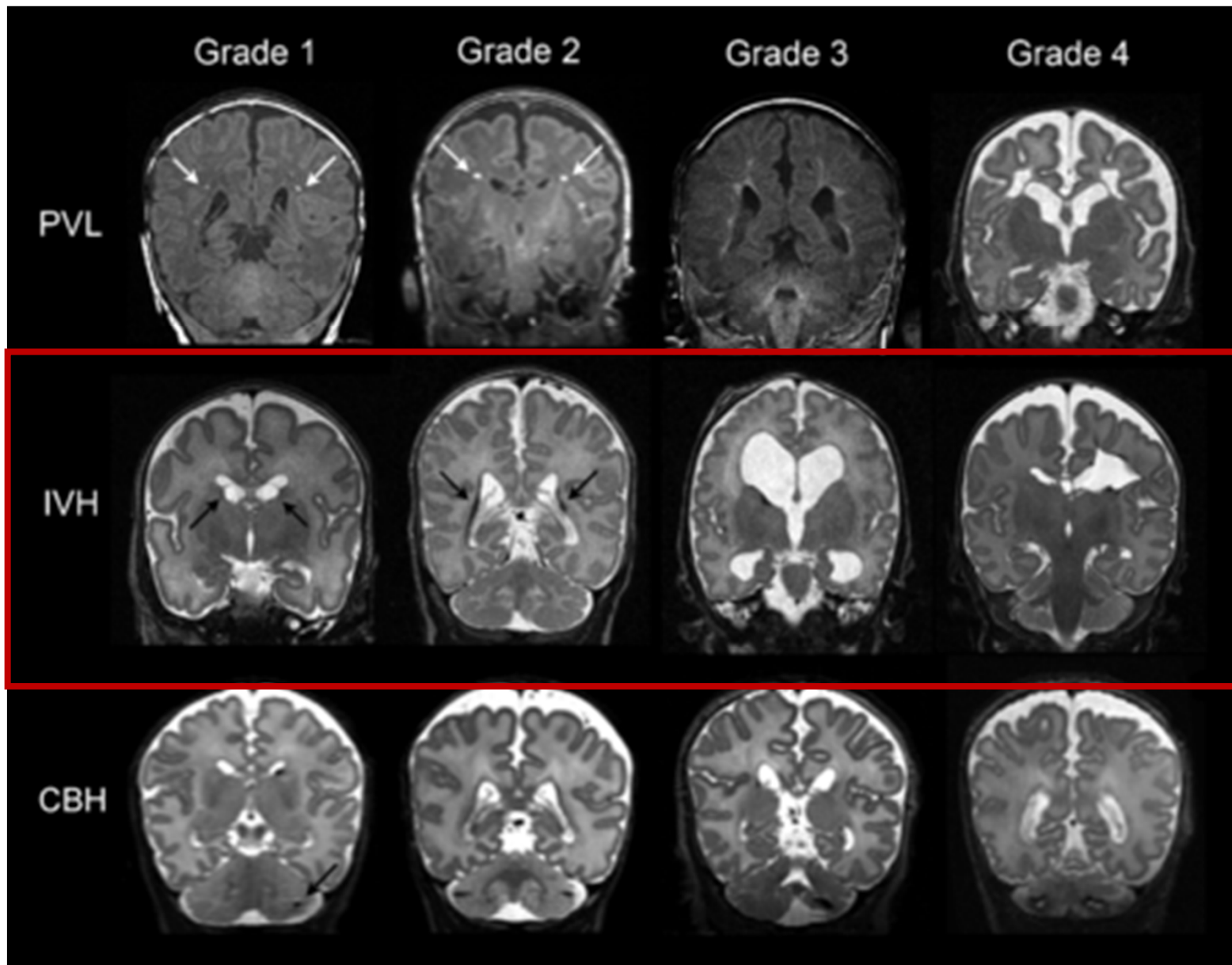
# Periventricular Hemorrhagic Infarction



**Coronal Section**

<http://www.slideshare.net/PediatricHomeService/brain-injury-in-preterm-infants>

[http://www.nrdaddy.com/lectures/ivh\\_pvl/ivhgrad\\_4a.htm](http://www.nrdaddy.com/lectures/ivh_pvl/ivhgrad_4a.htm)







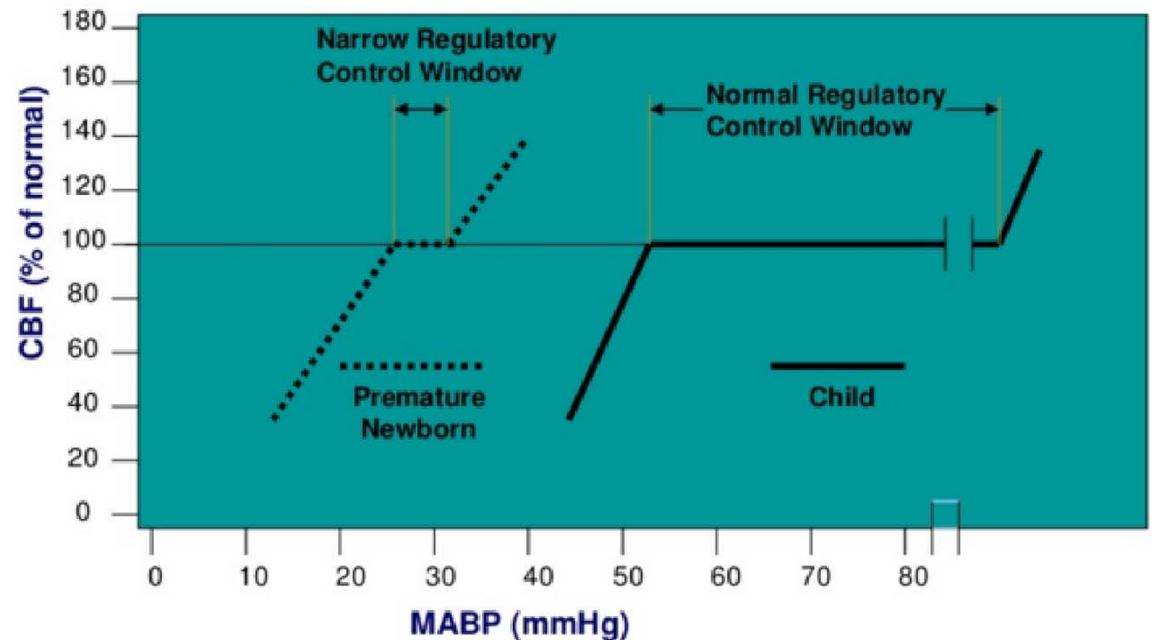
# IVH Outcomes



- Small (Grade I)
  - Neurodevelopmental disability similar to premature infants without IVH
- Moderate (Grade II-III)
  - Neurodevelopmental disability in 40%
  - Mortality 10%
  - Progressive hydrocephalus in 20%
- Severe (Grade PVHI)
  - Major neurodevelopmental disability in 80%
  - Mortality rate 50-60%
  - Hydrocephalus common in survivors

# Periventricular Leukomalacia (PVL)

- Ischemic, necrotic periventricular white matter lesions of arterial origin
- Risk factors: systemic hypotension, recurrent apnea with bradycardia
- Pathophysiology
- Incidence



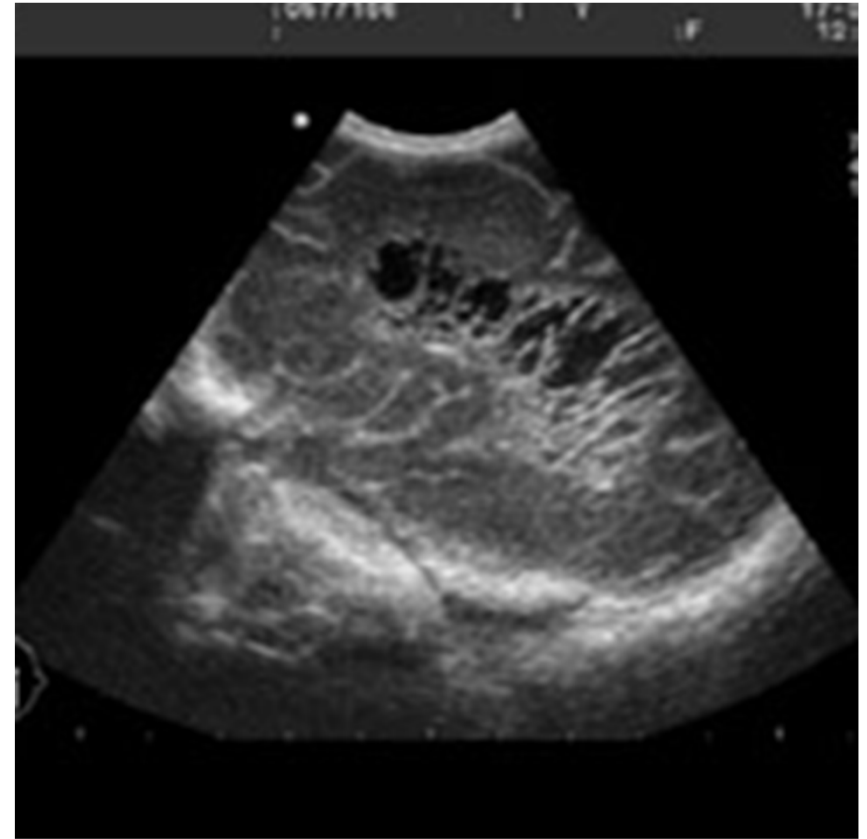
# PVL

- Clinical presentation:
  - Acute phase: hypotension and lethargy
  - 6 to 10 weeks later:
    - Irritable
    - Hypertonic
    - Increased arm flexion and leg extension
    - Frequent tremors
    - Abnormal Moro reflex

# PVL

- Diagnostic:
  - Cranial ultrasound
  - CT
  - MRI
  
- Initial presentation: PV echodensities
- Later: PV cystic changes

# Periventricular Leukomalacia



<http://www.armobgyn.com/en/Neurosonography.htm>

# Periventricular Hemorrhagic Infarction (3 weeks of age)



- Cyst Formation**
- tissue necrosis
  - clot retraction

**Parasagittal View**

<http://www.armobgyn.com/en/Neurosonography.htm>

# Periventricular Hemorrhagic Infarction (2 months of age)



Porencephalic  
cyst

Parasagittal View

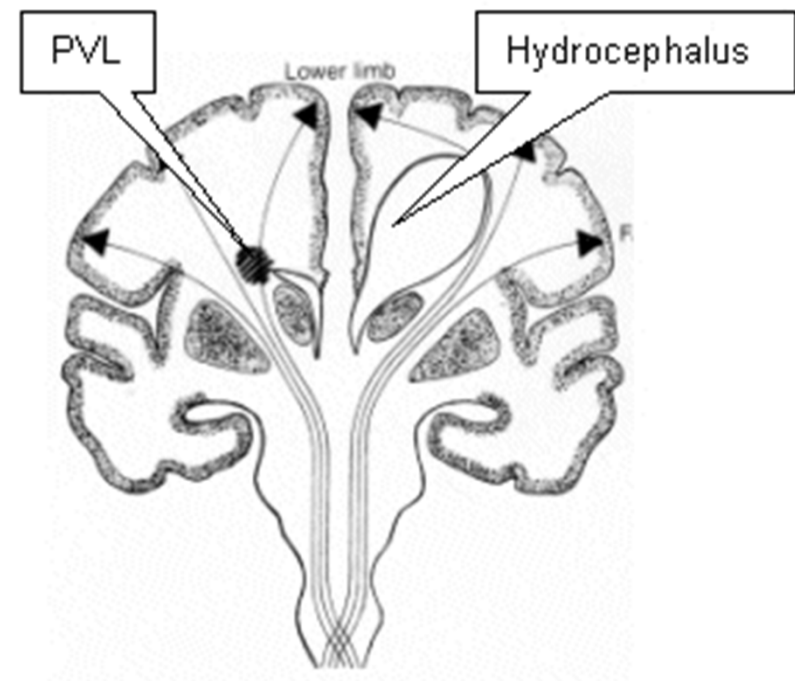
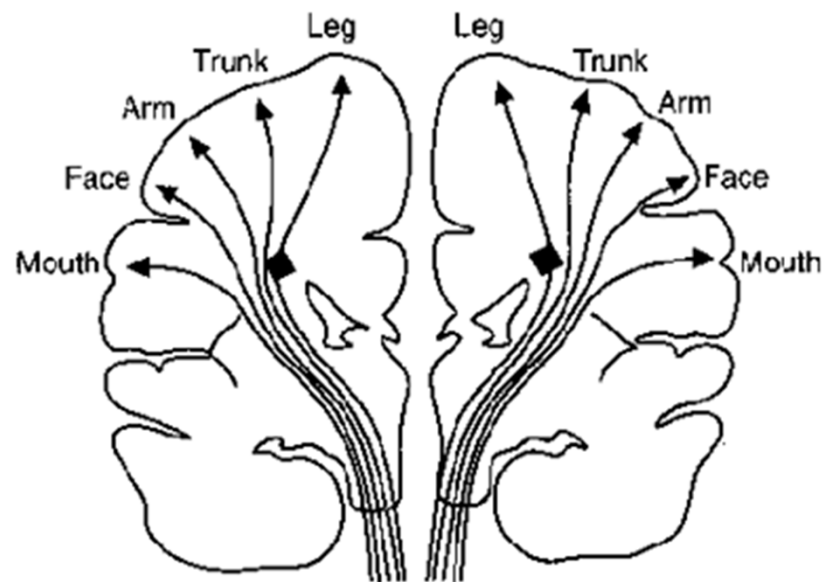
<http://www.armobgyn.com/en/Neurosonography.htm>



# PVL

- Outcome:
  - Based on location and extent of the injury
  - Major motor deficits
  - Significant upper arm involvement is associated with intellectual deficits
  - Visual impairment
  - Lower limb weakness

# PVL Outcome



[http://www.nrdaddy.com/lectures/ivh\\_pvl/prog4.htm](http://www.nrdaddy.com/lectures/ivh_pvl/prog4.htm)

[http://www.perinatal.nhs.uk/reviews/cp/cp\\_causes.htm](http://www.perinatal.nhs.uk/reviews/cp/cp_causes.htm)

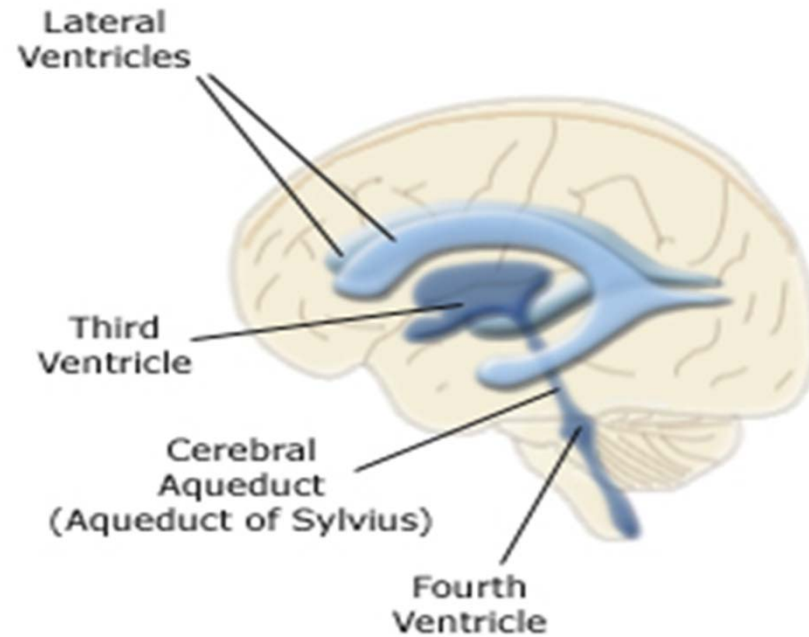
m4

# Posthemorrhagic Hydrocephalus

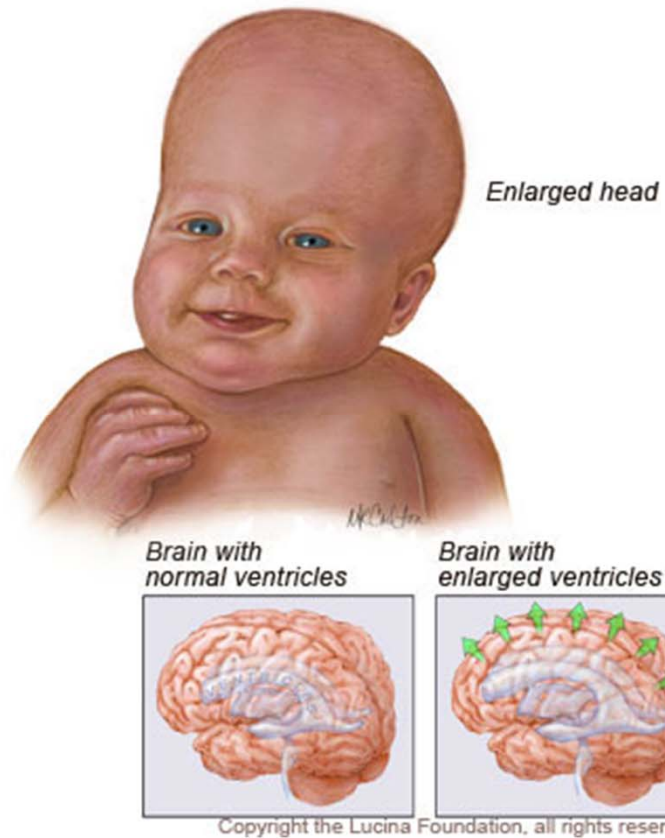
- Progressive dilation of the ventricles after IVH caused by injury to the periventricular white matter; inhibition of CSF flow
- Two types:
  - Acute
  - Chronic (subacute)
- Incidence:
  - Acute dilation in up to 50% of infants with IVH (generally resolves)
  - Slightly more than 50% of severe cases will result in progressive ventricle dilation

# Post Hemorrhagic Hydrocephalus

- Frequent complication of GM-IVH
  - Clot obstructing CSF flow at the level of the aquaduct of Sylvius



# Hydrocephalus



<http://www.spinabifida.net/hydrocephalus-in-children-adults-facts-treatment-symptoms.html>

# Hydrocephalus

- Clinical presentation:
  - Rapid increase in head size
  - Episodic apnea and bradycardia
  - Lethargy
  - Increased ICP
  - Tense, bulging anterior fontanel
  - Separated cranial sutures
  - Ocular movement abnormalities

# Hydrocephalus

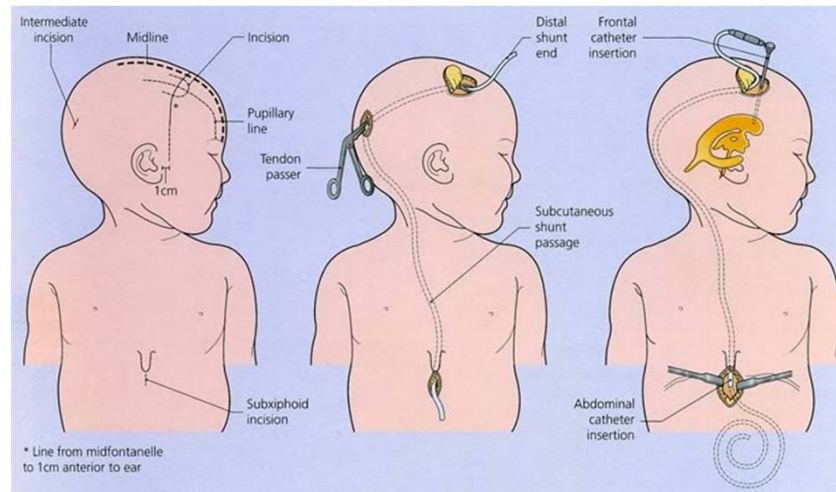
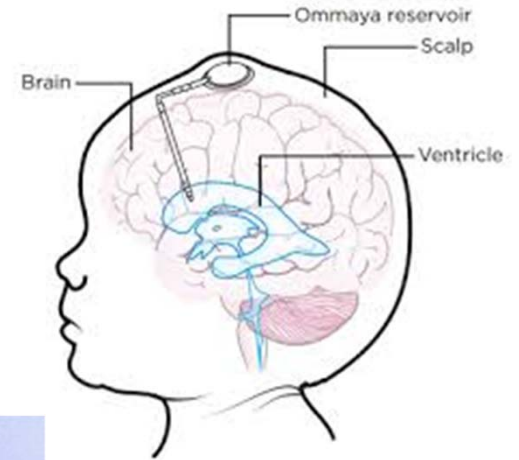
- Diagnostic:
  - Measure weekly OFC
  - CT
  - Cranial ultrasound
  - MRI
- Outcome:
  - Poor outcomes if decompression is not successful with shunt placement
  - Motor and cognitive deficits

# Post Hemorrhage Ventricle Device

## External Ventricular Drain/Reservoir/Shunt/



- EVD
- Ommaya reservoir
- Ventriculoperitoneal (VP) shunt



Willows Vision Appeal, (2015). Willow's Story. Retrieved 10 November 2015, from <http://www.willowsvisionappeal.com/willows-story.html>  
Mskcc.org, (2015). About Your Ommaya Reservoir Placement Surgery for Pediatric Patients | Memorial Sloan Kettering Cancer Center. Retrieved 10 November 2015, from <https://www.mskcc.org/cancer-care/patient-education/about-your-ommaya-reservoir-placement-surgery>  
Seattlechildrens.org, (2015). Hydrocephalus Treatment | Seattle Children's Hospital. Retrieved 10 November 2015, from <http://www.seattlechildrens.org/medical-conditions/brain-nervous-system-mental-conditions/hydrocephalus-treatment/>



# Patient Care and Management

- Prevent preterm birth
- Promote in utero transport
- Promote a no stressful intrapartum course
- Provide efficient resuscitation with expedient intubation
- Cluster care activities and promote appropriate handling
- Minimize noxious stimuli
- Avoid events associated with wide swings in arterial and venous pressures (i.e.: seizures, apnea, etc.).
- Prevent blood pressure swings – slow volume replacement

# Patient Care and Management

- Avoid over ventilation leading to pneumothorax
- Use inline suctioning devices
- Use noninvasive monitoring devices
- Monitor and maintain normal pH
- Correct abnormal clotting
- Be alert to signs of hemorrhage (changes in LOC, etc.)



**Your Baby is premature...**  
**What YOU can do to help your baby!**

**What you may see during your stay, especially during the first 5 days of life:**

- Care providers touching and moving my baby with extreme care with gentle calm movements...*your baby needs your touch* and will benefit most by using *soft gentle touch*
- You will notice the cover over your baby's isolette (unless under phototherapy lights) as we will try to *limit the light and noise* as best we can..the quiet is best for your baby and we encourage you to help your baby's visitors understand this when visiting. *Soft voices* and avoiding conversations held across your baby's bed will help
- Care Providers will try to limit the times they are disturbing your baby by grouping cares with other team members so that your baby can rest...*your baby needs your attention and holding*, we want you to hold your baby as soon as you can and Kangaroo Care is encouraged, the longer length of time you hold your baby the better it is for your baby, try to stay for at least 1 hour so your baby has time to rest
- *Positioning* is important to your baby especially during the first few days of life..we will try to keep your baby's head in correct position to allow for the best blood flow to your baby's brain
- **IMPORTANT:** You are an important part of your baby's care team...*changing diapers, taking temperatures, calming your baby, holding your baby, are all things you can do to help.* Your nurse will show you how to change your baby's diaper in a manner that is safest for a very preterm baby....*Do Not Lift Feet Up Towards The Head*, we would like you to slide diapers in from the side so feet are never above infants head..this is best for your baby and after some coaching you will be a pro at it!

Educate  
and  
support  
the  
parents

# Neuroprotection in the NICU

- IVH Bundles
- Antenatal steroids and Magnesium Sulfate
- Delayed Cord Clamping
- The “Golden” Hour / CPQCC Delivery Room Toolkit
- Neutral head positioning
- NIDCAP
- Developmental care

# IVH Bundles

## IVH BUNDLE AUDITS

Date & time audit initiated (**Day 1 of Life**): \_\_\_\_\_

**[DAY SHIFT]**

Admitting RN starts the form by filling in these on their shift

Patient Sticker: \_\_\_\_\_

Please place a **Y**, **N**, or **N/A** in the box following each goal. For any **N (no)**, where a goal hasn't been met please, be sure to explain in the appropriate Doc Flowsheet.

### GOALS

Day of Life      **1**      **2**      **3**      **4**      **5**

❖ Midline position, head aligned with torso w/ gradual position changes	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
❖ No prone positioning	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
❖ Head of bed elevated 15 to 30 degrees	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
❖ Cares clustered	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
❖ BP mean equal to, or greater than gestational age	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
❖ Neutral thermal regulation between 36.5-37.5	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
❖ No bath given	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
❖ CO2 levels maintained between 45 and 60	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
❖ Provider notified for CO2 <45 or >60	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
❖ No PICC line insertion	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
❖ IVH handout discussed with parents, documented under Education	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

The RN completing the form fills in these on their shift and turns into clerks

Date & time audit completed (**Day 5 of Life**): \_\_\_\_\_

lospitals

# Potentially Better Practices to Prevent Brain Injury

1. Antenatal steroids & magnesium
2. Optimize management and delivery at center with a NICU
3. Early management by a Neonatologist/NNP
4. Minimize pain and stress
  1. Avoid pain and stress
  2. Developmental Care
5. Optimal positioning (midline)
6. Treat hypotension
7. Judicious indomethacin use
8. Optimize respiratory management
9. Limit sodium bicarbonate use
10. Use post-natal dexamethasone judiciously



# Delayed Cord Clamping (DCC)

- ACOG Committee Opinion, Number 684, January 2017
  - **DCC in vigorous term and preterm infants for at least 30-60 seconds after birth**
  - DCC increases hemoglobin levels at birth and improves iron stores
  - Improves transitional circulation
  - Decreases need for pRBC transfusion
  - Lowers incidence of NEC and IVH
  - Does not increase risk of postpartum hemorrhage
  - What is done in your center?

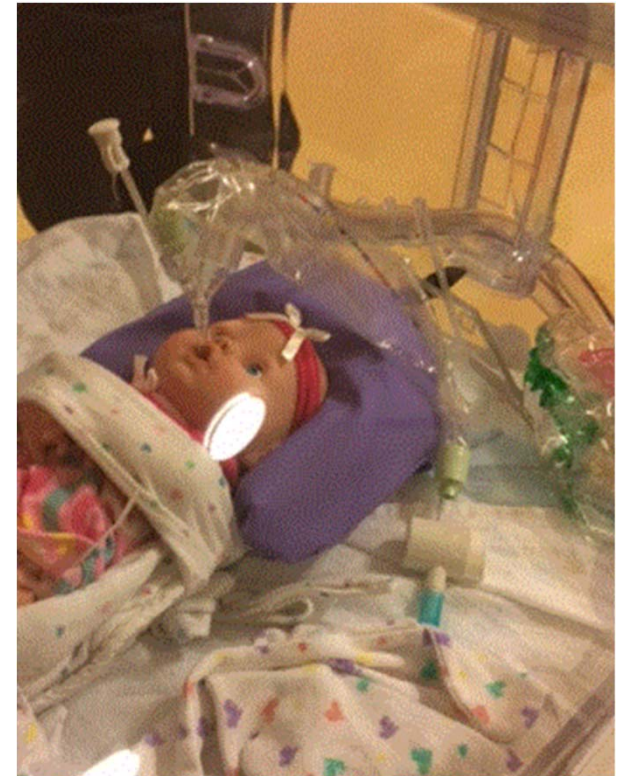
# The “Golden” Hour (Delivery Room Toolkit)

- Based on principles from cardiovascular and emergency medicine
- First hour of life is a time of critical transition and adaptation
- Management has been shown to impact long term outcomes
- Structured focus on thermoregulation, minimizing energy consumption, and respiratory support
- Measurable data points include: time to admission, admission temperature, admission glucose, initiation of IV fluids with glucose and amino acids
- What does your “Golden” hour look like?



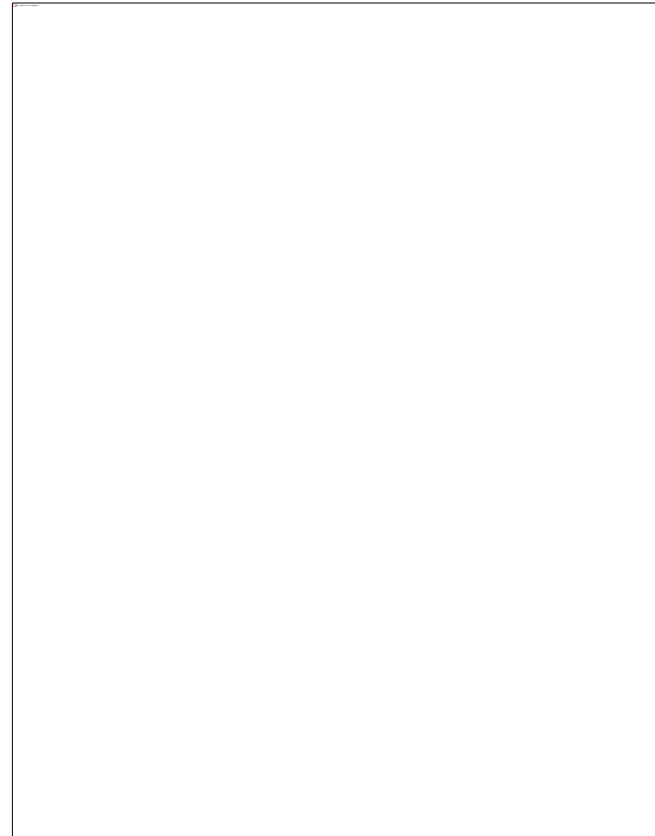
# Neutral Head Positioning

- First studied in adults in the 1980s
- Infants less than 32 weeks are positioned in neutral midline position with the head of the bed tilted upward for 72 hours
- Goal: to reduce alterations in cerebral blood flow associated with turning of the head from side to side in efforts to reduce the incidence of IVH
- Thoughts?
- Key stakeholders? Equipment needs?
- How is this audited?



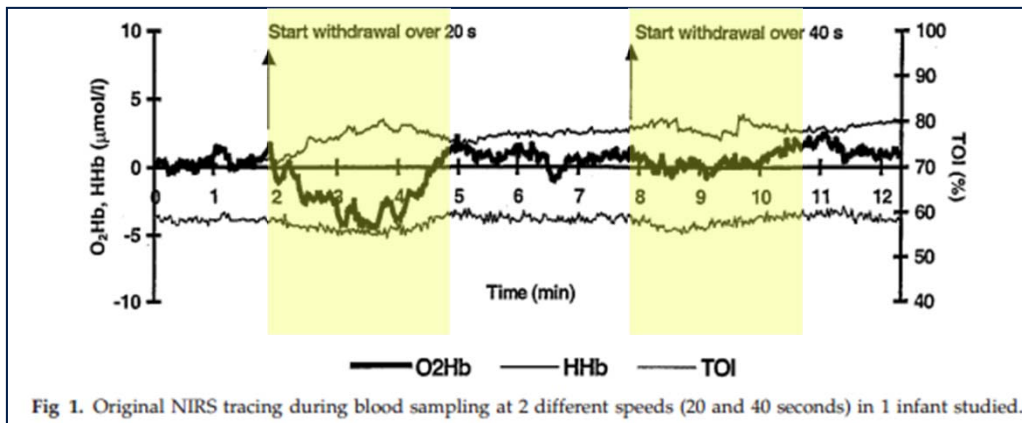
# Cerebral blood flow

- ELBW's have impaired cerebral autoregulation
  
- Everyday ICN tasks that affect Cerebral Blood Flow (CBF)
  - Diaper changes
  - Suctioning
  - Blood sampling
  
- Can we prevent harm to our patients?



# Blood Sampling

- Evidence has shown blood sampling techniques from UACs affect cerebral blood flow and oxygenation
- 20 second vs. 40 second push-pull



# Permissive hypotension

- Current practice
- Preterm infants with a  $MAP < GA$  often have no clinical signs of shock
  - Presumably have adequate tissue oxygen delivery
  - May not need treatment.

# Permissive hypotension

- Numerical blood pressure value lower than gestational age should not be used as the only indicator for treating early period hypotension
- Hemodynamic status should be included in assessment
- unstable vital signs, impaired perfusion, skin color, capillary refill rate, urine output, blood lactate level, and acidosis

# Treatment for hypotension

- Treat the cause!
  - Normal Saline
  - PRBCs
- Medications
  - Dopamine
  - Hydrocortisone

# Reperfusion injury

- Tissue damage caused when blood supply returns to the tissue after a period of ischemia or lack of oxygen
- Absence of oxygen and nutrients from lack of blood supply during ischemic insult
- Restoration of circulation results in inflammation and oxidative damage rather than restoring normal function

# Premature Infants- Developmental Consequences

Evolution of developmental delay is evident by term equivalents:

Compared to full term infants:

- Poor orientation ( $p < .001$ )
- Poor tolerance of handling ( $p < .001$ )
- Poor self regulation ( $p < .001$ )
- More sub-optimal reflexes ( $p < .001$ )
- More stress ( $p < .001$ )
- More hypertonicity ( $p < .001$ )
- More hypotonia ( $p < .001$ )
- More excitability ( $p = .007$ )

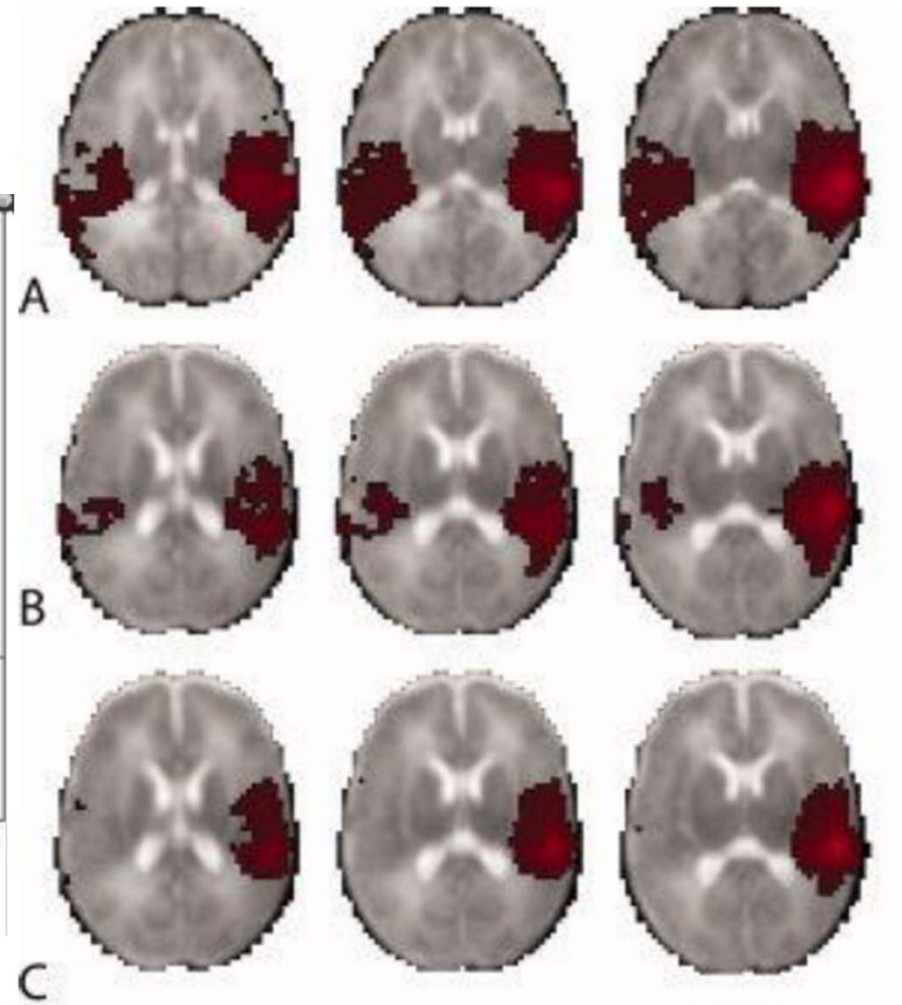
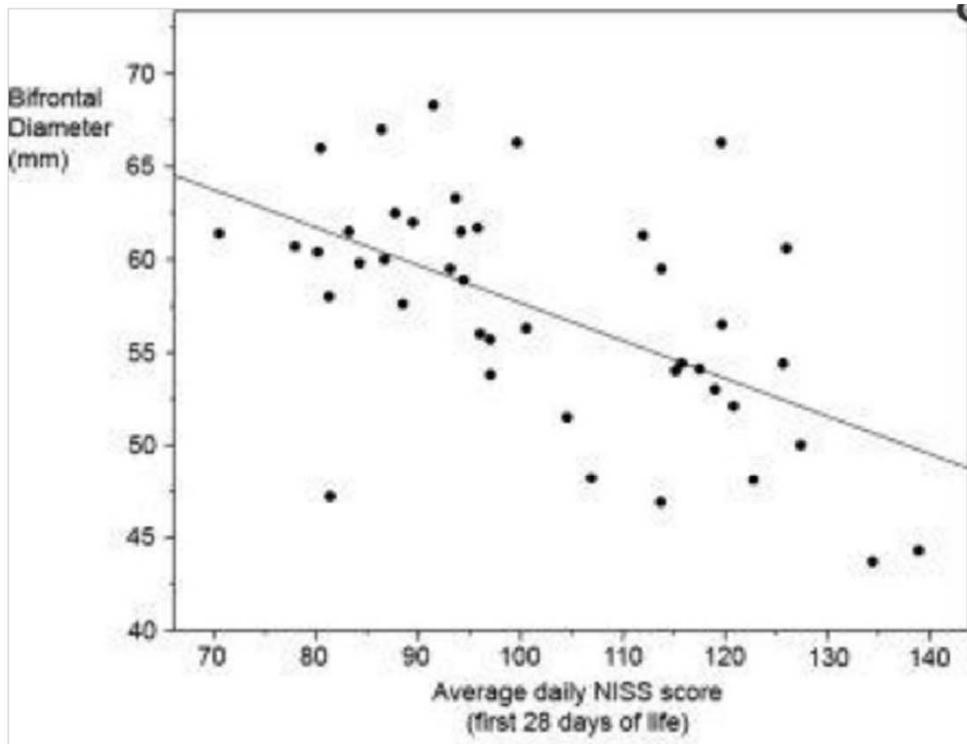


## Appendix A

NICU Infant Stressor Record Sheet (<28 weeks).

Acute Items						Chronic Items	
INSTRUCTIONS: Enter the time that the procedure was performed (eg: 9:15 am)						Name: _____	
						Date: _____	
<b>extremely stressful (score 5)</b>	7am–9am	9am–11am	11am–1pm	1pm–3pm		<b>extremely stressful (score 5)</b>	
Multiple attempts inserting IV, IA, UAC/UVC							
Intubation							
Insertion pneumothorax chest drain							
Eye examination							
<b>very stressful (score 4)</b>						<b>very stressful (score 4)</b>	
Suctioning of ETT tube						having asystemic infection	
Suctioning of nose and mouth						HFO/Jet vent without sedation	
Removing infant from incubator/bed (unwrapped)							
Insertion of IV, IA, UAC/UVC							
Insertion of percutaneous long line							
Insertion of nasal CPAP tube							
Lumbar puncture							
Surgery							
Heel pricks							
<b>moderately stressful (score 3)</b>						<b>moderately stressful (score 3)</b>	
Nappy changes						nursed in radiant warmer	
Position changes						local infection	
Removal of IV						HFO/Jet vent with sedation	
Receiving nasal CPAP						Hudson Prong CPAP	
Insertion of Hudson Prong						fasting for surgery	
Insertion of nasogastric tube						recovering from surgery	
Gavage feed						pneumothorax chest drain	
Removing infant from incubator/bed (wrapped)						conventional ventilation w/o sedation	
Cardiac echocardiogram							
Ultrasound							

# NISS scores



58 Smith, G., Gutovich, J., Smyser, C., Pineda, R., Newnham, C., & Tjoeng, T. et al. (2011). Neonatal intensive care unit stress is associated with brain development in preterm infants. *Annals Of Neurology*, 70(4), 541-549. <http://dx.doi.org/10.1002/ana.22545>

# Offsetting stress with POSITIVE experiences

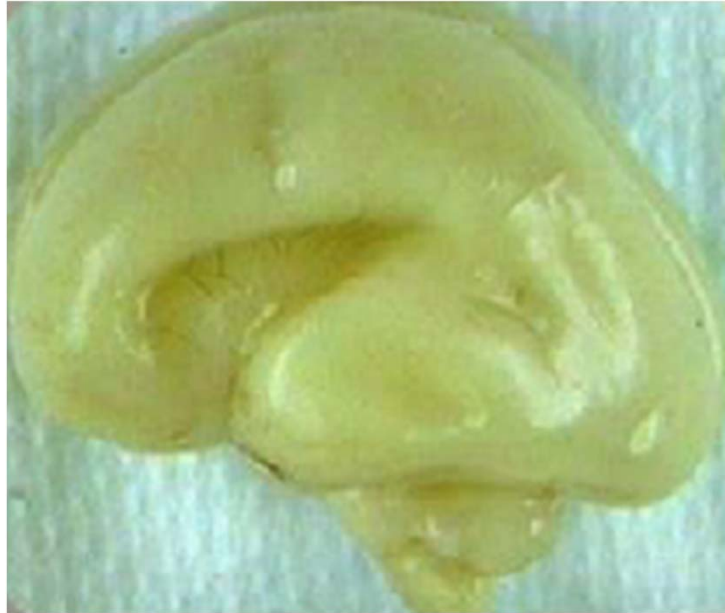
- Stressful experiences in NICU are inevitable
- How do we provide positive experiences?
  - Tactile
  - Vestibular
  - Gustatory
  - Olfactory
  - Auditory
  - Visual
- How do we document this?

# Take home points...

## **Premature infants are born at a critical time in their development**

- Interventions aim to:
  - Minimize Pain and Stress
  - Offer Positive Sensory Experiences
  - Protect Sleep
  - Promote Family Bonding

# Take care of this brain



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QUESTIONS??