NURSERY NOTES
UNIVERSITY OF COLORADO HOSPITAL
DEPARTMENT OF PEDIATRICS
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This handbook is a guide developed for residents training in Pediatrics, not as a definitive management resource.
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INTRODUCTION

Welcome to the University of Colorado Neonatal Intensive Care unit. The Nursery Notes are designed as a quick reference guide for NICU issues. Should you need further information, there are a variety of Neonatal texts available on the unit for your use.

WORK SCHEDULE-Once you’ve pre-rounded on your patients, you will meet with the Senior Resident or NNP to discuss your patients before rounds with the Attending. OB Board rounds are at 0700 on Monday, 0730 the remainder of the week. You will carry a delivery pager and attend all high-risk deliveries. Level III infants require a long note each day. Once patients are more stable (off Vent and IVF’s) their daily note can be done on the blue “Feeder/Grower” notes. On weekends a modified routine is in place, when on call, you do not have to pre-round on your patients, just arrive at 0700 for sign out.

WELL BABY NURSERY-The Level 1 nursery is covered by the PL2 throughout the day and the NICU Intern on call during the evening. When you are on call, the PL2 will sign out the well baby nursery to you. You are responsible for admission exams and paperwork for all infants born prior to midnight.

ORDERS-Physician orders are kept in the black books at the patient bedside, or in chart rack of the back nursery. Please inform the nurse of any orders and leave the black book open at the bedside. The RN’s do not accept verbal orders. There are no standing orders or lab orders for more than 24 hours in advance. Please place your physician number as well as “ml” or “mg” /kg/day on any orders.

RADIOLOGY-Write the orders for the XRAY in the black order book. Complete the XRAY request and fax it to the appropriate radiology department. After hours you must call #26100 and let them know you have faxed a request. Most requests are “priority 2” unless the situation is life threatening.

PHARMACY-Medication orders must include patient weight, total dose to be given and dose/kg ordered. All antibiotic orders have an “automatic stop order” (ASO) after 48 hours. Should you want your patient to continue antibiotic therapy, you must then write to have the antibiotics continue as well as order levels. TPN orders are due to the pharmacy by 9:30am. We use the infant’s birth weight for the first week for all calculations.

INFECTION CONTROL-Universal precautions are observed at all times. University scrubs are required to attend C-Sections. A three-minute scrub at the start of the day and routine hand washing when returning to the unit and/or between patients is required. Use the patient’s individual stethoscope, located at the bedside. Food and drinks are not allowed in the patient areas. You must put on gloves prior to examining patients.

CONSULTS/CONSENTS-You are responsible for filling out the consult and phoning the appropriate department. Obtain consent for all invasive procedures and transports. Telephone consent will need an additional witness.

PHYSICAL THERAPY-The PT’s will assess for PT needs and begin therapy as indicated once the infant is stable.

SOCIAL WORK-The social worker is available to provide assessments, counseling, resource coordination, and D/C planning. She will also handle any child protective service issues. Please include the social worker in family care conferences and D/C planning.

CASE MANAGER-The case manager will help with insurance issues and discharge planning. Please notify the case manager of any family care conferences, planned discharges, or transfers.
PRENATAL TESTING

NONSTRESS TEST- Minimum of 20 Min. non-invasive monitoring
  Reactive NST- ≥ 2 accelerations of fetal heart rate (FHR) 15 beats/min above baseline lasting at least 15 secs.

  Nonreactive NST- FHR does not meet above criteria during prolonged period (i.e. 1 hr.) Low specificity-must follow with more definitive testing (i.e. CST or Biophysical Profile)

CONTRACTION STRESS TEST- Assesses fetal risk for uteroplacental insufficiency.
  Negative (normal)- No late decels during contractions, baseline FHR is normal. associated with a very low perinatal mortality in the week following the test.

  Positive (abnormal)- Late decelerations occur with at least 2 of 3 contractions during a 10 minute interval. Can signify poor fetal outcome, and depending on GA, delivery is recommended.

  Equivocal (suspicious)- A late deceleration occurs with 1 of 3 contractions over a 10-minute interval. Prolonged fetal monitoring is recommended.

BIOPHYSICAL PROFILE- A test to assess fetal well being. A non-stress test along with ultrasound is used to evaluate fetal breathing movements, tone, and amniotic volume. A score of 8-10 is considered normal, 4-6 possible fetal compromise, and 0-2 predicts high perinatal mortality.

FETAL DOPPLERS- Used primarily to assess IUGR fetus.
  “Brain sparing”- increased flow in the middle cerebral artery due to hypoxia
  Umbilical artery- progression from decreased diastolic flow to absent end diastolic flow to reversed end diastolic flow indicative of increased hypoxia and academia in the fetus.

FETAL SCALP pH - Used during labor to assess fetal acid-base status.
  pH 7.20: Fetus is not acidotic, no intervention required
  pH 7.10-7.19: Fetus is pre-acidotic, repeat sampling in15-20 minutes.
  pH <7.10: Fetus may be acidotic, delivery is indicated.

TESTS OF FETAL LUNG MATURITY
  Lecithin:Sphingomyelin (L:S) Ratio-
    2:1 Lungs are mature (98% accuracy)
    1.5-1.9:1 50% will develop respiratory distress syndrome
    <1.5:1 73% will develop respiratory distress syndrome

  Phosphatidylglycerol (PG)-
    Appears in amniotic fluid at ~35 weeks, reported as present or absent, present is a marker of lung maturation.

  TDx Fetal Lung Maturity (FLM)-
    Surfactant: Albumin concentration in amniotic fluid assesses lung maturity.
    >70 mg/g: Lungs are likely mature
PREDELIVERY COUNSELING

Any pre-delivery counseling should be discussed with the attending, fellow, PL3 or NNP. Care should be taken to provide accurate and appropriate information to parents. Any language barriers, education level and personal beliefs should be taken into consideration when discussing neonatal issues.

Initial discussions should be simple and straightforward, mentioning typical neonatal issues they can expect should their baby deliver prematurely. It can be helpful to parents to mention some of the common management problems and procedures.

The Palliative care team is available to counsel families with more complex diagnosis’, life-threatening anomalies or if there is hospice care needs to be discussed.

Mortality and morbidity statistics vary somewhat among centers. The numbers given below represent current national statistics and can be used as a framework for counseling.

<table>
<thead>
<tr>
<th>GA</th>
<th>% Survival</th>
<th>BW</th>
<th>% Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td>20%</td>
<td>500-600</td>
<td>20%</td>
</tr>
<tr>
<td>24</td>
<td>33-50%</td>
<td>600-700</td>
<td>40-50%</td>
</tr>
<tr>
<td>25</td>
<td>60-75%</td>
<td>700-800</td>
<td>65%</td>
</tr>
<tr>
<td>26</td>
<td>80%</td>
<td>800-900</td>
<td>80%</td>
</tr>
<tr>
<td>27</td>
<td>85%</td>
<td>900-1000</td>
<td>90%</td>
</tr>
<tr>
<td>28</td>
<td>&gt;90%</td>
<td>1000-1500</td>
<td>95%</td>
</tr>
<tr>
<td>29-32</td>
<td>&gt;95%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note that there is a considerable increment in survival as you go from 23 to 28 weeks or up to 1000 grams. Keep in mind as well that survival is enhanced by a complete course of antenatal steroids and dates later in a week; eg: 24 5/7 Severe IUGR and infection diminish the chances for survival.

Morbidity:
HMD incidence is 80% @ < 28 weeks or 1000g, 50% @ 1000-1250g and 28-29 weeks, 25 –30% @ 1250-1500g and 30-32 weeks. After 33 weeks gestation, the incidence drops considerably. Chronic lung disease occurs in 25-30% of survivors < 1000g. At Denver’s altitude, almost all babies born at < 26 weeks gestation will go home on supplemental oxygen.

Severe ICH occurs in 25% of infants born @ less than 26 weeks and 500-750g. At 26-28 weeks and 750-1000g the rate is 15%. Severe hemorrhage is rare after 28 weeks gestation. Severe neurodevelopmental handicap occurs in 5-10% of survivors at 28-32 weeks gestation and increases to 25% at 23-25 weeks gestation. In those infants ≤ 25 weeks gestation, another 25% suffer lesser disabilities. Note: 50% of survivors in this group have some degree of developmental handicap.

The incidence of ROP is 80% in the 500-750g group, 50% @ 750-1000g, and 35% @ 1000-1250g. The incidence drops off considerably after 1250g. Need for laser treatments is limited primarily to those infants born before 27 weeks GA.

Please write a note in the mother’s chart after counseling, especially in those infants of borderline viability status so all providers are clear about the proposed plan.
DELIVERY ROOM MANAGEMENT

A. ROUTINE RESUSCITATION

MEDICATIONS FOR RESUSCITATION

<table>
<thead>
<tr>
<th>Drug</th>
<th>Concentration</th>
<th>Route</th>
<th>Administration</th>
<th>Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epinephrine</td>
<td>1:10,000</td>
<td>IV, ET</td>
<td>Rapid bolus</td>
<td>0.1-0.3 ml/kg</td>
</tr>
<tr>
<td>Normal saline</td>
<td></td>
<td>IV</td>
<td>Over 5-10 min</td>
<td>10 ml/kg</td>
</tr>
<tr>
<td>Sodium bicarb</td>
<td>0.5 mEq/ml</td>
<td>IV</td>
<td>Over 2 min</td>
<td>2 mEq/kg</td>
</tr>
<tr>
<td>Naloxone</td>
<td>1.0 mg/ml</td>
<td>IV, ET, IM, SC</td>
<td>Rapid</td>
<td>0.1 mg/kg</td>
</tr>
</tbody>
</table>
APGAR SCORES

<table>
<thead>
<tr>
<th>POINTS</th>
<th>0</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart Rate</td>
<td>Absent</td>
<td>&lt;100</td>
<td>&gt;100</td>
</tr>
<tr>
<td>Respiratory Effort</td>
<td>Absent</td>
<td>Slow, irregular</td>
<td>Good, regular, crying</td>
</tr>
<tr>
<td>Muscle Tone</td>
<td>Limp</td>
<td>Some flexion</td>
<td>Active motion</td>
</tr>
<tr>
<td>Response to Stimulation</td>
<td>No response</td>
<td>Grimace</td>
<td>Cough, cry</td>
</tr>
<tr>
<td>Color</td>
<td>Blue or pale</td>
<td>Pink with acrocyanosis</td>
<td>Completely pink</td>
</tr>
</tbody>
</table>

DR CLINICAL PEARLS

- ETT Size: <1000gms 2.5 ETT Placement: <1000 6cm
  1000-2000 3.0 1000-2000 7cm
  2000-3000 3.5 2000-3000 8cm
  >3000 3-5- 4.0 3000-4000 9cm
  >4000 10cm

DELIVERY ROOM MANAGEMENT OF < 28 WEEK GESTATION NEONATES

- The most experienced Person (NNP, Fellow or Attending) intubates infant shortly after birth
- Use Neopuff ventilator breaths of ~22/6 for ventilation. Avoid manual breaths unless bradycardia or persistent cyanosis despite pressures up to 30/6. Adjust pressures as needed to obtain adequate chest rise and equal breath sounds.
- Administer Infasurf (3 ml/kg per ETT) as soon as stable (in first 5-10 minutes)
- Pulse-Oximeter to be placed by RT ASAP. O2 to be weaned by placing blender on tank. Keep saturations 90-94%
DELIVERY ROOM SURPRISES AND EMERGENCIES

- ~10% of deliveries require resuscitation

Airway Obstruction
- Should be suspected if inadequate chest rise after readjusting mask, suctioning, repositioning and using higher pressures.
- Possible causes of airway obstruction include: secretions, meconium, choanal atresia, Pierre robin, hypoplastic mandible, enlarged tongue, thyroglossal cysts, floppy epiglottis, laryngeal web or spasm, tracheomalacia, tracheal stenosis or cyst, bronchiostenosis, bronchiomalacia, goiter, vascular ring, aberrant vessels, hemangioma, cystic hygroma, teratoma.
- Treatment is to initially vigorously suction to try to clear airway. If this is not effective, will have to bypass obstruction with oral airway or endotracheal tube.
- If partial lower airway obstruction present after bypassing upper airway will generally need to use long slow breaths (long inspiratory time and low rate) to ventilate.

Pulmonary Disorders Causing Immediate Severe Respiratory Distress
- Pulmonary Hypoplasia- Associated with severe Oligohydramnios or Congenital Diaphragmatic Hernia
- Congenital Chylothorax- Usually unilateral but if bilateral may need emergent thoracentesis.
- Bilateral Pleural Effusions associated with Fetal Hydrops.

Congenital Diaphragmatic Hernia
- ~1:2200 births
- 80% left sided
- 16-22% with associated cardiovascular abnormalities.
- Scaphoid abdomen, Severe cyanosis, Bradycardia
- If suspected intubate immediately and place an NG tube so as not to distend intestines in chest
- Mortality 20 - 60%
- Surgery often delayed 3-5 days for stabilization.
- Pulmonary Hypertension very common requiring Nitric Oxide and High Frequency Ventilation.
- Pneumothorax very common

Fetal Hydrops
- Mortality Rate > 50%
- Most common cause = CHF
- Other causes include Obstructed lymphatics, Severe anemia, Chromosomal disorder, Infection and Twin-Twin Transfusion
- May require emergent thoracentesis, pericardiocentesis, paracentesis and fluid resuscitation in the delivery room
- Much less common since RhoGAM available to prevent Rh sensitization.
- Includes > 5mm Skin Thickening & 2 or more of following: Fetal Ascites (> 50ml seen on u/s); Pleural Effusion; or Pericardial Effusion Abnormally Thick Placenta > 6 cm.

Subgaleal Hemorrhage
- Collection of blood between galea aponeurotica and periostium of skull
- Fluctuating mass straddling cranial sutures
- May spread to posterior neck and displace ears anteriorly
- Loose connective tissue can accommodate up to 260 ml blood causing pallor, hypotonia and hypovolemic shock
• Often 2nd midforceps or vacuum deliver
• ~ 4 / 10,000 births
• Treatment = Blood and FFP after initial fluid resuscitation
• ~ 25% Die

Gastroschisis

• Defect of abdominal wall to the right of the umbilicus usually including colon and small bowel
• No membranous sac; Increased AFP.
• 1:2000, M=F, Increased in young mothers and low socioeconomic status. On uprise.
• Usually isolated defect without other anomalies or abnormal chromosomes
• 90% survival; 3-4 wk ileus; 1/3 further surgery

Omphalocele

• Membranous Sac composed of peritoneum, and amnion cover with variable herniated abdominal viscera (Stomach, liver, spleen)
• If cephalic including heart (Ectopia cordis) = Pentalogy of Cantrell
• If caudal including bladder = Cloacal Exstrophy
• ~ 50% associated with other anomalies - i.e. cardiac defects, neural tube defects or Beckwith-Wiedemann
• ~ 1/3 associated with chromosomal anomalies - i.e. Trisomy 13, 18, 21
• All affected infants need chromosomes and echocardiogram
• 80% one-year survival if no other anomalies

Gastroschisis / Omphalocele Initial Management

• Gastric Decompression with > 10 fr catheter to LIS
• Cover with warm moist gauze, outer layer of dry gauze and Saran wrap or bowel bag
• Support viscera on front of abdomen to avoid kinking and venous congestion
• May need 10-20ml/kg NS fluid boluses as needed for perfusion and 120-150+ml/kg/d fluid maintenance and temperature support
• Peripheral IV and Arterial Line for ABG’s and BP monitoring - Will have Broviac placed in Surgery
• Ampicillin and Gentamicin or Cefotaxime (Claforan)
• Much greater urgency for operative repair with Gastroschisis than Omphalocele
WELL BABY NURSERY GUIDELINES

FOR A DETAILED ORIENTATION, PLEASE REFER TO THE LEVEL 1 ORIENTATION PACKET

EXAM: A cursory exam should be completed in the delivery room to include the heart, lungs, abdomen, and any obvious anomalies. Once in the WBN, allow the infant to transition for 2-4 hours prior to the admit exam. All infants born before midnight should be examined by the personnel on call that evening. Abnormal physical exam findings as well as prenatal imaging should be reported to the Attending, NICU Fellow or NNP.

PRENATAL HISTORY/LABS: Review prenatal history and maternal hospital course.

- IF THERE ARE NO PRENATAL LABS DOCUMENTED ON THE NEWBORN RECORD, MATERNAL CHART OR PENDING IN THE COMPUTER, CALL OB’S AND REQUEST THEY BE ORDERED AND BE SURE TO FOLLOW-UP.

- BLOOD TYPE: If mother is type O, or Rh-negative, cord bloods will automatically be sent for infant’s blood Type and Coombs.

- RPR/VDRL: Infants born to mothers who received adequate penicillin treatment (3 doses; 1 week apart) during pregnancy are at minimal risk. The infant should be treated if maternal treatment was inadequate, unknown, or given during the last 4 weeks of pregnancy. Refer to AAP Red Book for more details.

  Untreated or inadequately treated mothers will require further infant evaluation.
  1. Physical Exam
  2. Blood for VDRL, a titer at least 4 fold higher in the infant than in the mother = active infection
  3. Antitreponemal IgM
  4. CSF examination
  5. Penicillin therapy, see Red Book for current recommended dosing (page 555)
  6. Long bone XRAYS
  7. Penicillin therapy, see Red Book for current recommended dosing (page 555)
  8. Repeat quantitative NTA tests at 3, 6, and 12 months. Most infants will develop a negative titer with adequate treatment; a rising titer requires further investigation.

- RUBELLA: Non-Immune mothers are at risk for exposure during pregnancy. The fetal infection rate varies according to the timing of maternal infection during pregnancy. Congenital rubella has a wide spectrum of presentations, ranging from acute disseminated infection to deficits and defects not evident at birth. If there is suspicion of rubella exposure, nasopharyngeal cultures should be completed. There is no specific treatment for rubella. Children with congenital rubella should be considered contagious until they are at least 1 year old, unless nasopharyngeal and urine cultures are repeatedly negative for the virus.

- HbsAG: If maternal HbsAG status is unknown, test the mother as soon as possible and the infant should receive the Hepatitis B vaccine within 12 hours of birth. If the mother is found to be HbsAG positive, the infant should receive Hepatitis B immune globulin (HBIG) within 7 days of birth.

  If maternal HbsAG is positive, the infant should be given the Hepatitis B vaccine and HBIG within 12 hours of birth. Additionally, the Hepatitis B vaccine is given at birth, 1 month, and 6 months of age.

- HEPATITIS A: Intrauterine transmission is rare, most infants are asymptomatic with mild abnormalities of liver function. Immune globulin (IG) is given to the newborn only if mother’s symptoms began between 2 weeks prior to delivery and 1 week after delivery.
**HEPATITIS C:** Perinatal transmissions occur in about 5% of infants born to mothers who carry the virus. No prevention strategies exist.

**HIV:** Infants born to HIV mother should receive the following:
1. Plasma PCR for HIV-RNA or
2. Whole blood PCR for HIV-DNA
3. CBC with slide eval
4. Liver function tests
5. Zidovudine syrup (10mg/ml) 2mg/kg orally every 6 hours
6. If unable to tolerate orally, then Zidovudine 1.5mg/kg IV every 6 hours
7. Start Zidovudine within 8-12 hours of birth
8. Consult the CHIP program prior to D/C #303/764-8233
9. D/C with a 6 week supply of meds
10. Appointment with CHIP program within 1-2 weeks of D/C

**CHLAMYDIA:** Infants born to mothers’ known to have untreated chlamydial infection should not be empirically treated secondary to the increased risk of pyloric stenosis with EES administration in infants. Any eye drainage requires a Chlamydia FA and PO erythromycin for 14 days if the FA is positive.

**GROUP B STREP: GBS** positive mothers with adequate antibiotic treatment (2 doses completed with treatment onset 4 hours prior to delivery) require just additional observation and more frequent vital signs. Infants born to positive mothers (without adequate treatment) who are asymptomatic may just be observed for 24 hours prior to D/C. Infants born to positive mothers typically are symptomatic within 24 hours and require:
1. CBC with slide eval
2. Blood Cultures
3. CXR
4. Antibiotic administration

If GBS status is unknown, management of infants is based on evidence of risk factors. If the infant has any of the following, they will require additional observation and more frequent vital signs for 24 hours prior to D/C.
1. PTL or PPROM < 37 weeks gestation
2. ROM ≥ 18 hours
3. Maternal temperature during labor

If symptomatic, a full septic work-up as above. Documented chorioamnionitis merits close observation for 48 hours.

**GONORRHEA:** Infant’s born to mothers with GC infections usually do not develop infection. However, since there have been reported cases, infants should receive a single injection of Ceftriaxone. See Red Book for current dosing recommendations.

**HSV:** Primary maternal infection poses the highest risk to the infant. The following should be followed if infant was delivered vaginally or by C/S with ROM ≥ 6 hours:
1. Obtain blood for HSV-PCR and culture
2. CSF for HSV-PCR and culture
3. Surface cultures from conjunctiva, throat, feces, urine, and nasal pharynx.
4. After lab specimens obtained, start IV Acyclovir 60mg/kg/day divided every 8 hours
5. See Red Book for current recommendations

With secondary maternal infections, infants should be cultured only if clinical signs of HSV infections exist.
Infants born to mothers with secondary infection and active lesions should be cultured and started on therapy only if culture positive or symptoms appear.

**VARICELLA:** Infant’s of mothers who develop Chicken Pox within 5 days prior or 48 hours after delivery, should receive the Varicella-Zoster Immune Globulin (VZIG) within 96 hours of birth.

**MATERNAL ILLICIT DRUG EXPOSURE:** Tox Screen on urine and meconium should be obtained. Contact social worker on unit for follow-up.

**NOTIFICATION OF ATTENDING:**

1. Any infant not following the typical WBN course
2. Any patient you have concerns about
3. Clinical jaundice at ≤24 hours old
4. Mother treated with antibiotics prior to delivery
5. Any unusual physical findings
6. Known anomaly on prenatal ultrasound
7. Hypoglycemia x 2 or requiring a gavage feed
8. Heart murmur present at discharge
9. ABO incompatibility

**DISCHARGE CRITERIA:**

1. Uncomplicated antepartum, intrapartum, and postpartum course for mother and baby are considered routine.
2. Routine D/C may occur at 20-24 hours of age
3. Normal, stable vital signs for at least 12 hours prior to D/C
4. Thermal homeostasis (axillary temperature 36.1-37 C in open crib)
5. Respiratory rate < 60/minute
6. Heart rate 100-160 beats/minute
7. Infant has voided and stooled, if circumcised there is no excess bleeding for ≥1-2 hours
8. Baby is feeding well
9. Infants who are jaundiced at ≤24 hours of age should have a Total Bili sent and be discussed with Attending/Fellow/NNP prior to D/C
10. Document that infant is NOT jaundiced for all ABO and Rh set-ups
11. Heart murmur noted at D/C must be carefully documented and evaluated by supervisor, document all pulses and 4 extremity blood pressures.
12. Infants D/C at 20-48 hours should have follow-up in 2-3 days either in home or by PCP especially when breastfeeding.
13. First Newborn State Screen obtained
14. Mother has adequate knowledge to care for her newborn and training is documented
15. Other support is available for mother and baby for the first few days after D/C
16. Maternal and infant laboratory data obtained has been reviewed as normal or negative
17. Family, environmental and social risk factors assessed.
18. Predischarge bilirubin risk assessment or bilirubin measurement.

**CLINICAL PEARLS:**

1. All maternal charts should be reviewed for missing information not provided on the newborn Record (i.e. missing labs, complications, pertinent ultrasound findings, substance abuse).
2. If maternal Hepatitis B status is unknown, the infant needs to receive the Hep B vaccine within 12 hours of life. This includes mothers that received PNC but their charts are unavailable.
3. Maternal Hep B and RPR status should be known prior to D/C, if pending the result must be followed up in the “prenatal lab” book.
4. Consider use of Sweet-Ease for circumcision, the policy is in the nursery.
5. Follow-up for patients potentially being D/C’d on the weekend should be arranged on Friday prior to clinic closures.
FLUIDS, ELECTROLYTES AND NUTRITION

There is much that is not known about optimal feeding in neonates, with little definitive data in the literature to recommend specific strategies. Local and national nutritional feeding practices vary widely. The following recommendations are based on assessment of the current literature with a “reasonable practice” suggested.

**Daily Fluid Requirement Estimates (ml/kg/day)**

<table>
<thead>
<tr>
<th></th>
<th>&lt;750g</th>
<th>750-1250g</th>
<th>1250-1500g</th>
<th>&gt;1500g</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOL#0</td>
<td>100-150</td>
<td>80-130</td>
<td>80-100</td>
<td>80-90</td>
</tr>
<tr>
<td>DOL#1</td>
<td>120-150</td>
<td>100-140</td>
<td>100-130</td>
<td>100-120</td>
</tr>
<tr>
<td>DOL#2</td>
<td>130-150</td>
<td>120-150</td>
<td>120-150</td>
<td>120-140</td>
</tr>
<tr>
<td>DOL#3</td>
<td>≥150</td>
<td>150</td>
<td>150</td>
<td>150</td>
</tr>
</tbody>
</table>

- Start with the lower number and increase to the upper number based on the infant’s hydration status. For infants <1000g, fluid requirement may be higher than listed.
- Initially start with Stock TPN (D10W and 2g amino acids/100ml), and add electrolytes after 24-48 hours
- Increase 10-20ml/kg/day to max 150ml/kg/day
- There is some evidence that lower fluid intake decreases the incidence of BPD, so there is currently a national trend for greater fluid restriction
- An open warmer increases an infants fluid requirements, so get micro preemies to an isolette ASAP; added mist and saran wrap are other alternatives

**Assessment of Hydration Status**

- This is especially important in the micro preemies in the first few days of life (to help prevent lung disease and the development of a PDA)
- A number of factors are involved in assessing overall hydration status
  - Weight – checked 2-4x/d in the micro preemies
    - Bed scales may not be as reliable, especially on a single weight, so follow trends
    - Ideal weight in the first 5-6 days of life is 5-10% below birth weight
    - Don’t make fluid decisions based on a single weight alone
  - Urine output – reassess every 4-6 hours; infant may need fluid boluses above maintenance fluids to keep up with UOP
  - Sodium
    - In the first few days of life this is a good reflection of fluid status
    - Follow serum Na 2-3x/day in the micro preemies
    - In the first few days Na generally reflects hydration status more than Na status
    - If serum Na >145, increase fluid intake (unless Na intake very high, then decrease Na intake)
  - Hct may be helpful as a sign of dehydration if it is increasing
  - Less helpful, but important, is your physical exam (skin turgor, mucous membranes, eyes, and AF)
### Electrolyte Requirements (meq/kg/day)

<table>
<thead>
<tr>
<th></th>
<th>&lt;750g</th>
<th>750-1250g</th>
<th>1250-1500g</th>
<th>&gt;1500g</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOL#0</td>
<td>None</td>
<td>None</td>
<td>None</td>
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</tr>
<tr>
<td>DOL#1</td>
<td>Na 0-1</td>
<td>Na 0-1</td>
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<td>DOL#3</td>
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<td>Na 3</td>
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<tr>
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<td>K 1-2</td>
<td>K 1-2</td>
<td>K 2</td>
<td>K 2</td>
</tr>
</tbody>
</table>

- As a general rule, add electrolytes at 24-48 hours of life, after checking lytes and making sure UOP is adequate
- To add lytes to fluid (other than your TPN orders) it is written as i.e. 3meqNa/100ml fluid + 2meqK/100ml fluid; often the Na is NaCl and the K is KAcetate
- Infants <1000g may have higher Na requirements, so follow lab values closely

### Neonatal TPN

<table>
<thead>
<tr>
<th>Energy (kcal/kg/d)</th>
<th>&lt;750g</th>
<th>750-1250g</th>
<th>1250-1500g</th>
<th>&gt;1500g</th>
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</thead>
<tbody>
<tr>
<td>Starting rate</td>
<td>&gt;40-50</td>
<td>&gt;40-50</td>
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<td>50-60</td>
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<tr>
<td>Goal rate</td>
<td>80-100</td>
<td>80-100</td>
<td>80-100</td>
<td>80-100</td>
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<tr>
<td>Amino acids (g/kg/d)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Starting rate</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Increase/day</td>
<td>1</td>
<td>1</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Maximum rate</td>
<td>4</td>
<td>4-3.5</td>
<td>3.5-3.2</td>
<td>3.2-3.0</td>
</tr>
<tr>
<td>Glucose (mg/kg/min)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Starting rate</td>
<td>6-8</td>
<td>6-8</td>
<td>6-8</td>
<td>6-8</td>
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<tr>
<td>Increase/day</td>
<td>2-3</td>
<td>2-3</td>
<td>2-3</td>
<td>2-3</td>
</tr>
<tr>
<td>Goal rate</td>
<td>10-12</td>
<td>10-12</td>
<td>10-12</td>
<td>12</td>
</tr>
<tr>
<td>Lipids (g/kg/d)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Starting rate</td>
<td>0.5-1.0</td>
<td>1.0-1.5</td>
<td>1.0-2.0</td>
<td>2.0-3.0</td>
</tr>
<tr>
<td>Increase/day</td>
<td>0.5-1.0</td>
<td>0.5-1.0</td>
<td>0.5-1.0</td>
<td>0.5-1.0</td>
</tr>
<tr>
<td>Maximum rate</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

- TPN is given over 24 hours; ideally this also includes intralipids though this is often not possible given interruption by meds, so IL is commonly given over 20 hours.
- It can be started DOL#0 with total fluids as indicated in the daily fluid req’d chart. Since other drips are often used write full desired TPN in a smaller volume.
- **Energy/Calories**
  - Calories are provided from glucose (3.4kcal/g) and lipid (2kcal/ml)
  - A minimum of 40-50kcal/kg/d is required just to prevent protein wasting; often not achieved in first few days but give as much as tolerated
- **Amino acids**
  - Start at 3g/kg/day but can consider starting at 4 if patient is very stable
  - To achieve fetal protein accretion rates, younger preemies need more AA/kg
  - The AA preparation is currently trophamine plus cysteine supplementation
  - Infants with sepsis, on steroids or who are critically ill often need the AA amount reduced and follow for protein intolerance
  - There are poor markers for AA/protein intolerance, but following BUN and acidosis daily while increasing AA to max can be useful
• **Glucose**
  - Glucose intakes are best thought of in terms of the glucose infusion rates or GIR
  - Glucose infusion rates (mg/kg/min) are calculated as follows
  - \[ \text{Glucose (mg/kg/min)} = \left(\%\text{glucose} \times \text{rate (ml/hr)} \times 0.167\right) / \text{Weight (kg)} \]
  - Glucose rate (ml/hr) = \left(\text{glucose req’d (mg/kg/min)} \times \text{weight (kg)} \times 0.06\right) \times \% \text{glucose}
  - Begin with GIR of 6-8mg/kg/min (D10% at 80ml/kg will provide 5.5mg/kg/min).
  - Generally, infants >1000g will tolerate 2-3mg/kg/min per day (2.5-5%) increases in GIR. The ELBW <1000g may require a slower stepwise increase of 1-2mg/kg/min per day.
  - Glucose should be started at an infusion rate of 6-8mg/kg/min and increased to 10-12mg/kg/min (50-60% of non-protein caloric intake) as tolerated.
  - The goal is to keep blood glucose <150-200mg% and prevent glucosuria
  - Dextrose solutions >12.5% require a central line
  - If there is hyperglycemia (in first few days of life) on <6-8mg/kg/min, consider adding insulin and appropriate glucose to provide adequate CNS energy.
    - Start insulin at 0.05-0.1units/kg/hour (using insulin or albumin for IV priming) mixed at 0.1ml/hr=0.025units/kg/hour. Adjust insulin infusion rate by 0.1ml/hr to keep glucose 150-250mg%; discontinue for levels <100mg% and follow glucose every 4 hours once target range is achieved.
    - Before beginning insulin, rule out other causes of hyperglycemia i.e. infection, IVH, steroids, etc.

• **Fats/Intralipids**
  - Administered as 20% intralipids (2kcal/ml)
  - Essential fatty acid deficiency can be prevented with 0.5-1.0g/kg/day minimum IL intake
  - The maximum rate is typically 3g/kg/d or 45-55% of total calories from fat, but you may need to go up to 4g/kg/d to achieve this. Infuse over 20 hours.
  - Want to keep triglycerides(TG) <150mg/dl; monitor random TG levels while advancing to goal amount; if modestly elevated levels (>200mg/dl), hold IL for 24 hours and then resume at a lower infusion rate
  - May need to decrease lipid amount in infants with PPHN, severe lung disease, severe infection, steroid use and near exchange bilirubin levels

• **Other additives**
  - Heparin is added to all TPN at 1 unit/ml
  - EPO, iron, Vit E – see heme section
  - Trace elements and MVI – as per TPN order form
  - Consider eliminating calcium when infusing through a peripheral line
  - Zinc, chromium and selenium are excreted primarily in the urine and should be omitted in infants with decreased renal function (Cr >1.2)
  - Copper and Manganese are excreted primarily via the biliary system and should be omitted or cut in half if cholestatic liver disease exists (DB>2)

• **TPN labs**
  - Daily TPN labs for the first 3-5 days include electrolytes, glucose, BUN, and TG until at goal TPN, and then weekly is okay
  - Additionally check Ca, Mg and Phos in the first few days with the micro preemies
  - Weekly TPN labs include lytes, BUN/Cr, LFTs (with fractionated bilirubin), Ca, Mg, Phos, alkphos, and albumin

**ENTERAL FEEDS**
- Minimum enteral nutrition, also called trophic or priming feeds, does not have any well defined standards or rules
• Early minimum enteral feeds has led to decreased days to regain birth weight, greater weight gain by hospital discharge, increased small intestinal maturity and motility, decreased hospital costs, and doesn’t appear to increase the risk of NEC, but the best way to get there is not clear
• All infants can start trophic feeds on DOL #0-1 unless there are GI contraindications, a hypoxic event, high pressor support or sepsis, then feeds are begun after 24 hours if stable.
• Trophic feeds generally begin at 1-2ml/kg every 6-12 hours (usually as a bolus feed over 15-30min) and either stay at that rate or advance as tolerated. The trophic feed total should remain at less than 10-20 ml/kg/d. Length of time of trophic feeds depends on GA/BW of the baby. For micro preemies (1000 gm and 27-28 w or severe IUGR) 5-7 days. For bigger, more stable infants 3-5d.
• There are two general categories for feed advancement
  o Slow advancement for those with a high risk of NEC (i.e. those infants <1250g, with birth asphyxia, high oxygen requirements or systemic illness); consists of increases of 10-20ml/kg/d
  o Rapid advancement for those with a low risk of NEC (i.e. >32-34wk gestation and stable younger preemies); consists of increases of 25-35ml/kg/d
• If starting nutritive feeds in a stable baby >30weeks gestation, start at 20ml/kg/d and increase 20-40ml/kg/d as tolerated to goal
• Goal feeds for infants >32weeks gestation is 120kcal/kg/day and infants <1250g may need 140-150kcal/kg/day
• The initial feeding should ideally be breast milk (no dilution), and if not available, 20kcal preemie formula; usually 20kcal formula is used to full volume and then the caloric intake can be increased to 22 or 24 kcal; if >24kcal formula/breast milk is needed, use MCT oil to get to 26kcal and discuss with nutrition
• Use a preemie or transitional formula for all infants <34-36 weeks gestation
• Most preemie formulas provide adequate vitamins and minerals; term formulas often do not; thus in preemies who are solely on breast milk or on term formulas, consider a MVI and Fe supplement
• 15-20g/kg/d is the ideal daily weight gain regardless of gestational age
• To check for feeding intolerance, one can follow gastric aspirates (a significant aspirate is >1/2 the feed or >3-5ml/kg or any bilious aspirate), abdominal size, heme checking stools, or observing for loops of bowel on PE; if the baby looks well but is having residuals, consider continuous drip feeds instead of bolus feeds
• Base all calculations on BW for the first 7 days.
• For TPN plus enteral feeds, write a full TPN as if the child is npo. This will balance enteral and parenteral calories

HYPOGLYCEMIA

Definition
• Hypoglycemia is defined as a plasma glucose <45mg/dl in a term or premature infant. There is much controversy over the exact number, so interpret the number with the clinical status of the infant.

Etiology
• Due to a relative hyperinsulinemia (IDM or infant of a mother on terbutaline); usually presents early at < 1 hour of life
• Due to decreased stores of glucose in preemies or SGA/IUGR infants; usually presents at 4-8 hours of life
• Another category/risk factor is an ill baby – asphyxia, sepsis, polycythemia, etc
• Hormonal abnormalities (hypopituitarism); carbohydrate metabolism defects (galactosemia, glycogen storage disease)

Clinical Findings
• Irritability; jitteriness
• Lethargy, CNS depression
• hypothermia
• Poor feeding
• Seizures
• Respiratory distress (apnea or cyanosis)
• Usually asymptomatic initially so screen any at risk infant

Management

**Bedside Glucose Test <20mg/dl (even if asymptomatic) or <40 and symptomatic**
- Confirm by stat central serum level, but do not wait to initiate therapy
- Give IV glucose 2ml/kg D10W ASAP
- Maintain IV glucose at 6-8 mg/kg/min D10W (see formula below)
- Repeat blood sugar in 30 min
- Once IV glucose infusion started, follow blood sugar every 1-2 hrs until >45 x 3
- If <40 with symptoms, or <25, repeat 2ml/kg D10W bolus and increase glucose infusion rate by 10-15%
- IDM infants are hyperinsulinemic so increase glucose infusion rate by increasing fluid rate; these large infants can handle an increased fluid load; repeat D10W boluses will compound the hypoglycemia by leading to glucose spiking followed by insulin spiking driving down the glucose level even further
- When blood sugar >45 for several hours, taper glucose infusion by 5-10% every 4-6 hours
- Okay to feed if infant is vigorous

**Bedside Glucose Test 20-40mg/dl and asymptomatic**
- Confirm by stat central serum level
- Early feeding of formula can be given by nipple or gavage (15ml), keep in mind that a term infant that won’t nipple is symptomatic
- Repeat blood sugar in 1 hour
- If glucose remain low (after 1-2 feeds), provide IV glucose at 6mg/kg/min
- Maintenance glucose is 5-7 mg/kg/minute for a normal newborn:
  \[
  \text{IV rate needed (ml/hr)} = \frac{6 \times \text{wt (kg)}}{x} \times (\text{mg/kg/min desired}) \times \% \text{ glucose in IV}
  \]
- If infant is requiring >10mg/kg/min of glucose, consider central line for >D12.5%, glucagon or hydrocortisone. Insulin level and further w/u for pathologic causes should be considered for prolonged hypoglycemia (3-5 days)

HYPERGLYCEMIA

**Definition**
- Hyperglycemia is defined as serum blood glucose level >125mg/dl in term infants and >150mg/dl in preterm infants
- Find out if glucose is being spilled in the urine because once the urinary glucose level is 1+ or greater, there is an increased chance of osmotic diuresis and subsequent dehydration
- Check how much glucose the patient is receiving. Normal maintenance glucose therapy is 6mg/kg/min

**Etiology**
- Too much exogenous glucose in IVFs
- Inability to metabolize glucose may occur with prematurity, secondary to sepsis/stress, or severe encephalopathy
- Medications such as steroids and caffeine
- Inability of extremely preterm infant to handle even a normal glucose load

**Labs**
- Serum glucose level
- Urine dipstick test for glucose
- CBC with diff, blood and urine culture are indicated if sepsis is suspected
- Electrolytes and daily weights to follow losses and dehydration with associated osmotic diuresis
- Consider insulin level if concern about transient neonatal diabetes (rare)
Management
• Calculate mg/kg/min of dextrose infused first and adjust dextrose concentration as needed; can’t use <D5W because it is too hypo-osmolar
• Consider insulin infusion starting at approximately 0.05 units/kg/hour and recheck blood glucose one hour after start of infusion and adjust as needed. In general, you need about 1 unit of insulin for every 3-5 grams of glucose infused.
• Will need a site to obtain frequent glucose measurements. Begin to decrease insulin infusion when BG is <200: discontinue insulin infusion when BG <100.
• Decrease any causative medications

HYPERKALEMIA
• Definition
  • K > 6.0 meq/dl
  • See if sample was hemolyzed as that falsely elevates K (common with heel stick)
• Etiology
  • Falsely elevated K caused by hemolyzed sample
  • Excess K administration
  • RBC hemolysis (IVH, sepsis, Rh incompatibility)
  • Renal failure and renal immaturity (ELBW infant)
  • Acidosis - drives K out of the cell
  • Tissue necrosis (check for S/Sx of NEC)
  • Medications (Digoxin, K-sparing diuretics, Indomethacin, etc.)
  • Adrenal insufficiency (CAH or adrenal hemorrhage)
• Evaluation
  • Recheck stat serum K
  • Check for any ECG changes (widened QRS, peaked Ts, PVCs, arrhythmia) - based on true ECG and not read off a monitor
  • Check UOP, BUN/Cr
  • Check what type of IVFs patient is receiving (maintenance K is 1-3 meq/kg/d)
• Therapy
  • Stop all K containing fluids or supplements
  • Maintain normal pH
  • Maintain normal serum calcium concentration
  • If no ECG changes and K 6.5-7.5
    • Lasix 1mg/kg IV
    • Kayexelate 1g/kg/dose as an enema and repeat every 4-6 hrs prn
  • If ECG changes exist or K>7.5
    • Give 10% Ca chloride (20 mg/kg) to decrease myocardial excitability
    • Give NaBicarb 1-2 mEq/kg if acidotic
    • Give glucose and insulin to drive K into the cells; give 0.5g/kg/hr of dextrose IV with regular insulin 0.2 units/kg/hr and watch for hypoglycemia. Usual ratio is 1 unit insulin to 3 grams glucose.
    • Dialysis if above interventions fail
HYPOKALEMIA

- Definition
  - K < 3.5meq/dl
- Etiology
  - Inadequate K administration
  - K wasting medications (diuretics, Amph B, gentamycin)
  - Increased intracellular uptake of K (alkalosis, Insulin therapy, albuterol)
  - GI tract losses
  - Hypercalcemia and/or Hypomagnesia
  - Renal tubular defects
- Evaluation
  - Recheck central K
- Treatment
  - Increase supplementation and correct over time, avoid bolus correction if at all possible
  - Maintain normal pH, calcium and magnesium levels

HYPOCALCEMIA

Definition
- Serum calcium <7mg/dl
- Ionized Ca is a better value to use (<1.0) since total Ca varies with serum albumin

Etiology
- Calcium levels normally drop in the first three days of life
- Very common especially in preemies (50% of the time)
- Risk factors for hypocalcemia include:
  - infants with poor enteral intake
  - infants of diabetic mothers – get an increase in insulin and calcitonin secretion
  - infants with perinatal stress – effects of corticosteroids and catecholamines
  - infants with alkalosis – iCa is inversely proportionate to serum pH
  - infants receiving blood transfusions, (especially exchange transfusions) – the citrate complexes with calcium
  - infants receiving diuretics especially furosemide that causes hypercalciuria
  - infants receiving excessive phosphate intake
  - infants with insufficient magnesium
  - congenital hypoparathyroidism (DiGeorge Syndrome)

Clinical Findings
- Acute hypocalcemia infants may present with apnea, irritability, slight tremors, tetany, seizures, cardiac dysfunction with prolonged Q-T intervals and arrhythmias
- Chronic hypocalcemia infants may present with rickets characterized by apnea, bone demineralization, increased alkaline phosphatase, and fractures

Laboratory Findings
- Total and ionized calcium are low
- Serum magnesium levels <1.5mg/dl can accompany hypocalcemia
- Elevated alkaline phosphatase levels can be an early sign of rickets
- Spot urinary calcium/creatinine rations >0.21-0.25 are indicative of hypercalciuria
- XRAY studies of ribs and long bones checking for bone demineralization and rickets
- ECG may show prolonged Q-T intervals or arrhythmias
Management

- Reserve IV calcium therapy for those infants with profound (<0.8-1.0 iCa) or symptomatic hypocalcemia as replacement therapy has its risks (IV infiltration with soft tissue injury, precipitation in TPN, vascular compromise when infused through arterial lines, bradycardia or cardiac arrest with rapid or excessive infusion)
- Primary at risk group is critically ill infants with unstable CV status
- IV calcium is given as 10% Ca gluconate at 100mg/kg IV (over 1 hour) every 6 hours
- If a central line is available, the treatment of choice is an IV bolus of CaCl at 20mg/kg by slow IVP
- For infants with poor enteral intake, Ca, Phos, and Vit D need to be given parenterally by day 3 of life
- If there are urinary losses due to loop diuretic therapy, substitute a thiazide diuretic

Rickets

- Chronic disorder of calcium metabolism with bone demineralization and elevated Alk phos
- Rare in infants >30 weeks gestation
- Rare in infants on an appropriate preemie formula or fortified breast milk which provide the extra calcium needed
- Lab evaluation for high risk babies (VLBW, BPD, chronic stress, malnutrition, diuretics) includes checking Alk phos, Ca, and Phos at 4 weeks and following these labs monthly if positive
- Management includes appropriate special care preemie formulas, daily Vit D, and Ca and Phos supplements if low

Hypotension/Shock

- Definition
  - Inadequate tissue perfusion
  - A helpful mnemonic is mean arterial blood pressure (MAP) should be at least the same number as the gestational age in infants who are < 30 weeks gestation

<table>
<thead>
<tr>
<th>Birth Weight (g)</th>
<th>Mean Pressure</th>
<th>Systolic (mmHg)</th>
<th>Diastolic (mmHg)</th>
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</thead>
<tbody>
<tr>
<td>501-750</td>
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<td>50-62</td>
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<tr>
<td>751-1000</td>
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<td>23-36</td>
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<td>1001-1250</td>
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<td>26-35</td>
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<td>1251-1500</td>
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<td>1501-1750</td>
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<td>46-58</td>
<td>23-33</td>
</tr>
<tr>
<td>1751-2000</td>
<td>36-48</td>
<td>48-61</td>
<td>24-35</td>
</tr>
</tbody>
</table>

- Etiology
  - Hypovolemic shock
    - Antepartum blood loss (abruption, placenta previa, twin-twin transfusion, fetomaternal hemorrhage)
    - Postpartum blood loss - coagulation d/o, Vit K deficiency, birth trauma with organ injury (intracranial bleed, subgaleal bleed, IVH, pulmonary hemorrhage, subcapsular liver bleed, etc.)
  - Septic shock
  - Cardiogenic shock (birth asphyxia, metabolic problems, CHD, SVT, bradyarrhythmias)
  - Neurogenic shock (birth asphyxia, IVH)
  - Adrenal insufficiency – especially in micropreemie
  - NEC
- Clinical findings
  - Look for signs of intra- and extracranial, intra-abdominal and pulmonary bleeding
  - Look for signs of sepsis
  - Check perfusion - pulses, capillary refill time (nl <2 sec), fontanel
  - Invasive BP monitoring with arterial access can be useful
- Laboratory findings

Normal BP values in neonates
- CBC with diff and cultures – evaluate for infection; Hct important to evaluate for blood loss (allow adequate time for equilibration with an acute bleed)
- Coagulation studies if concern for DIC
- Electrolytes, glucose, Ca to screen for metabolic problems
- ABG to assess for hypoxia and/or acidosis
- Kleihauer-Betke test if concern for fetomaternal transfusion; this test detects the presence of fetal RBCs in mother’s blood; a smear of maternal blood is fixed and incubated in an acidic buffer causing adult Hgb to be eluted from the RBCs; fetal Hgb resists elution; after the slide is stained, fetal Hgb cells, if present, appear dark, whereas maternal RBCs appear clear
- CXR to evaluate lungs and heart
- Cranial U/S if suspicious for IVH
- Head CT if concern for other intracranial bleeds (i.e. subdural)
- ECG if arrhythmia suspected
- Echo if concern for myocardial dysfunction/CHD
- Therapy
  - Determine underlying etiology and target treatment
  - Consider UVC to follow CVP (normal 4-6 mmHg) to help decide if infant needs volume and/or inotropic agents
  - Use UAC for accurate BP monitoring
  - If known blood loss (Hct<40), transfusion is needed
  - Volume should be given as 10ml/kg boluses of NS or LR over 30 minutes; give 2-3 boluses, then start pressors; in some situations with 3rd space losses (sepsis, NEC, etc.), more boluses may be needed
  - If no response to volume expansion/replacement, start an inotropic agent like dopamine
    - Begin dopamine at 3-5mcg/kg/min and increase to 20mcg/kg/min as needed for adequate perfusion/pressure
    - If dopamine is maxed out, consider the addition of dobutamine and/or epinephrine
  - Pressors for newborn include:

<table>
<thead>
<tr>
<th>Agent</th>
<th>Site of Action</th>
<th>Dose(mcg/kg/min)</th>
<th>Effect</th>
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<tbody>
<tr>
<td>Dopamine</td>
<td>DA receptors</td>
<td>1-3</td>
<td>Renal vasodilator</td>
</tr>
<tr>
<td></td>
<td>β</td>
<td>3-10</td>
<td>Inotrope, some vasodilation</td>
</tr>
<tr>
<td></td>
<td>α &gt; β</td>
<td>10-20</td>
<td>Peripheral vasoconstriction, PVR↑</td>
</tr>
<tr>
<td>Dobutamine</td>
<td>Selective β1,</td>
<td>1-20</td>
<td>Inotrope, +/-vasodilation (β2), PVR↓, weak α activity</td>
</tr>
<tr>
<td></td>
<td>Mild β2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isoproterenol</td>
<td>β1 and β2</td>
<td>0.05-2.0</td>
<td>Inotrope, increase HR, vasodilation, PVR↓</td>
</tr>
<tr>
<td></td>
<td>Nonselective β</td>
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<td></td>
</tr>
<tr>
<td>Epinephrine</td>
<td>β &gt; α</td>
<td>0.05-1.0</td>
<td>Inotrope, tachycardia, renal flow↓, PVR↑</td>
</tr>
<tr>
<td>Norepinephrine</td>
<td>α &gt; β</td>
<td>0.05-1.0</td>
<td>Profound vasoconstrictor, PVR↑↑, mild inotrope</td>
</tr>
</tbody>
</table>
- Ensure adequate respiratory support
- Initiate empiric antibiotics with IV ampicillin and gentamicin if concern for sepsis; if foreign bodies present, consider adding vancomycin too
- Consider corticosteroids as many preemies are adrenally suppressed and stressed
  - Indications for shock steroids (2mg/kg dexamethasone) include CAH, micropreemies, fulminant sepsis, and hypotension non-responsive to above pressor therapy
  - Stress doses include hydrocortisone 1-2 mg/kg IV every 8 hours
  - Replacement therapy 1 mg/kg/day divided every 12 hours
**RESPIRATORY**

**Commonly Used Abbreviations**

- TTN - Transient Tachypnea of the Newborn
- PPHN - Persistent Pulmonary Hypertension of the Newborn
- PFC - Persistent Fetal Circulation
- HMD - Hyaline Membrane Disease
- RDS - Respiratory Distress Syndrome
- A's & B's - Apnea and Bradycardia
- AOP - Apnea of Prematurity
- BPD - Bronchopulmonary Dysplasia
- CLD - Chronic Lung Disease
- PIE - Pulmonary Interstitial Emphysema
- CDH - Congenital Diaphragmatic Hernia
- PVR - Pulmonary Vascular Resistance
- SVR - Systemic Vascular Resistance
- PCA - Post Conceptual Age
- UAC - Umbilical Arterial Catheter
- PAL - Peripheral Arterial Line
- HFV - High Frequency Ventilation
- HFOV - High Frequency Oscillatory Ventilation
- CPAP - Continuous Positive Airway Pressure
- NCPAP - Nasal Continuous Positive Airway Pressure
- HFNC - High Flow Nasal Cannula
- NC - Nasal Cannula
- PIP - Peak Inspiratory Pressure
- MAP - Mean Airway Pressure
- \( P \) or Amp - Amplitude on High Frequency Ventilation
- IT or Ti - Inspiratory Time
- FiO\(_2\) - Inspired Oxygen Concentration
- TCM - Transcutaneous PO\(_2\) and CO\(_2\) monitor

### Differential diagnosis:

<table>
<thead>
<tr>
<th>Non cardiopulmonary</th>
<th>Cardiovascular</th>
<th>Pulmonary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypothermia</td>
<td>Left sided outflow tract obstruction</td>
<td></td>
</tr>
<tr>
<td>Hypoglycemia</td>
<td>Hypoplastic left heart</td>
<td></td>
</tr>
<tr>
<td>Polycythemia</td>
<td>Aortic stenosis</td>
<td></td>
</tr>
<tr>
<td>Metabolic acidosis</td>
<td>Coarctation, interrupted aortic arch</td>
<td></td>
</tr>
<tr>
<td>Drug intoxications</td>
<td>Cyanotic lesions</td>
<td></td>
</tr>
<tr>
<td>CNS insult</td>
<td>TOGV</td>
<td></td>
</tr>
<tr>
<td>Metabolic acidosis</td>
<td>TAPVR</td>
<td></td>
</tr>
<tr>
<td>Drug intoxications</td>
<td>Right sided outflow tract obstruction</td>
<td></td>
</tr>
<tr>
<td>CNS insult</td>
<td>TTN</td>
<td></td>
</tr>
<tr>
<td>Metabolic acidosis</td>
<td>Pneumonia</td>
<td></td>
</tr>
<tr>
<td>Drug intoxications</td>
<td>HMD</td>
<td></td>
</tr>
<tr>
<td>CNS insult</td>
<td>Pulmonary hypoplasia</td>
<td></td>
</tr>
<tr>
<td>Metabolic acidosis</td>
<td>Pneuorthorax</td>
<td></td>
</tr>
<tr>
<td>Drug intoxications</td>
<td>Pleural effusions; Congenital chylothorax</td>
<td></td>
</tr>
<tr>
<td>CNS insult</td>
<td>Mass lesions (CDH, cystic adenomatoid malformation)</td>
<td></td>
</tr>
</tbody>
</table>

*Respiratory signs can be a manifestation of many conditions usually cardiopulmonary in origin, but don't forget the non-cardiopulmonary causes.*
Evaluation of term newborns with cyanosis
Compliments of John Kinsella

**History and Risk Factor Assessment**

<table>
<thead>
<tr>
<th>Prenatal:</th>
<th>Delivery:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prenatal ultrasound study results</td>
<td>History of positive pressure ventilation in DR</td>
</tr>
<tr>
<td>History and duration of oligohydramnios</td>
<td>Meconium stained amniotic fluid</td>
</tr>
<tr>
<td>History of fetal tachy/bradyarrhythmia</td>
<td>Hemorrhage</td>
</tr>
<tr>
<td>Maternal illness, drugs, medications</td>
<td>Trauma</td>
</tr>
<tr>
<td>History of fetal distress</td>
<td>Apgar score</td>
</tr>
<tr>
<td>Risk factors for infection</td>
<td></td>
</tr>
</tbody>
</table>

**Physical Exam**

- **Respiratory distress**
  - Retractions, grunting, nasal flaring
  - Suggests lung parenchymal disease

- **No significant respiratory distress**
  - Tachypnea alone
  - Suggests hypoxemia caused by cyanotic heart disease without lung disease

**Role of Pulse oximetry**

*Preductal/postductal SaO₂*

- **Preductal SaO₂ = Postductal**
  1. Intrapulmonary shunt (PVR < SVR)
  2. Cyanotic CHD with L-R PDA: (ductal dependent Qp: eg: PS, TA, or Ebstein’s)
  3. PPHN: extrapulmonary shunt @ foramen ovale: (PVR > SVR with closed DA)

- **Preductal SaO₂ > Postductal**
  1. PVR > SVR with R-L PDA: PPHN with MAS, RDS, CDH or Idiopathic
  2. Ductal dependent Qs: HPLHS, AS, IAA, coarctation
  3. Anatomic pulmonary vascular disease: alveolar capillary dysplasia pulmonary venous stenosis TAPVR with obstruction

- **Preductal SaO₂ < Postductal**
  1. TOGV with pulm hypertension
  2. TOGV with coarctation
Response to Supplemental Oxygen
Heart disease vs. PPHN vs. parenchymal disease

Acute response to high FiO₂ (hood, mask)

Minimal or transient change in SaO₂
Cyanotic heart disease, PPHN

Marked improvement in SaO₂
Parenchymal lung disease, CHD with ductal dependent systemic blood flow

CXR and Laboratory Evaluation

Chest radiograph
ABG, CBC, 4 extremity BP

Hypoxemia out of proportion to CXR
CHD with ductal dependent pulmonary blood flow, PPHN with clear lung fields and R-L shunt

ABG: assess respiratory and metabolic status
CBC: for infection
BP: to R/O coarctation and IAA

Role of echocardiography

R-L shunting at PDA and/or PFO with normal LV function:
Consider iNO use after lung recruitment

Anatomic abnormalities:
Ductal dependent systemic blood flow:
HPLHS, critical AS, coarct, IAA

Functional abnormalities:
LV dysfunction with mitral insufficiency; L-R atrial shunt with R-L ductal shunt = pulm venous hypertension
? RV dependent systemic BF
COMMON CAUSES OF RESPIRATORY DISTRESS

1. TTN (Transient Tachypnea of the Newborn)

**Epidemiology:**
- Usually near term infants
- Common after C/S

**Etiology:**
- Delayed resorption of fetal lung fluid

**Clinical Findings:**
- Usually self-limited with variable length (4 ->72h)
- Mild cyanosis, grunting, flaring, retracting and tachypnea usually improving after first few hours
- Rare to progress after initial few hours
- Very rare to require intubation unless coexisting etiology (i.e. HMD, pneumonia, PPHN)

**CXR:**
- Prominent perihilar streakiness with fluid in the fissure
- Occasionally can also have patchy infiltrates clearing within 48 hours - difficult to distinguish between pneumonia and meconium aspiration

**Management**
- Support with oxygen
- Watch for evidence of co-existing pneumonia, PPHN

2. PPHN (Persistent Pulmonary Hypertension; Previously called PFC-Persistent Fetal Circulation)

**Epidemiology**
- Most commonly affects near term infants with co-existing risk (CDH, TTN, Hypoxia, Cold Stress, Pneumonia, Sepsis, Meconium Aspiration, Perinatal Asphyxia, Pulmonary Hypoplasia)
- Can affect premature infants with sepsis, pneumonia, severe RDS, or CLD

**Etiology:**
- Increase in PVR postnatally. May be acute from asphyxia or hypoxia, chronic from structural changes with increased muscular wall thickness or from pulmonary hypoplasia related to decrease in number of branching vessels in the pulmonary vascular bed.

**Clinical Findings**
- Labile oxygen saturations. When PVR > SVR (Suprasystemic Pulmonary Pressures) R to L shunting will occur either at the ductal or atrial level. Monitoring Pre-ductal (Right Hand) and Post-ductal (i.e. either foot) saturations can be helpful. If Pre-ductal > 10% higher than post-ductal and CHD ruled out with labile course PPHN is most likely etiology. CHD should be ruled out with an echocardiogram.

**CXR**
- Can be consistent with co-existing condition (i.e. TTN, pneumonia, and meconium aspiration, CDH).
- In unusual circumstances there is no associated parenchymal disease with a CXR that is radiolucent with decreased pulmonary blood flow. Typically the CXR is consistent with the primary underlying parenchymal lung disease.

**Lab Evaluation**
- Evaluating Pre- and Postductal saturations and/or PO2 can be helpful in evaluating for right to left shunt consistent with suprasystemic pulmonary pressures. Following ABG's including pH can be helpful with management as PPHN can worsen with acidosis as well as hypoxia.

**Echocardiogram**
- To rule out congenital heart diseases as well as potentially quantify the degree of pulmonary hypertension.
**Management**

- Fully recruit the lungs by increasing PIP, PEEP, Tidal Volume, or using HFV initially with a higher MAP. HFV is usually the most effective mode to recruit the lungs.
- Initially increase oxygen to keep Sats > 95% and PO2 > 80 if possible.
- Mild respiratory alkalosis (pH 7.40-7.45) with PCO2's in the 30's is sometimes beneficial if worsening or not responding with normal PCO2's. Severe alkalosis may have neurodevelopmental consequences.
- Avoidance of acidosis is beneficial. Sodium bicarbonate can only be used if there is adequate ventilation with PCO2's <60-70 or tissue acidosis will be worsened.
- Sedation with Fentanyl, Versed or Ativan is often helpful.
- Maintaining Mean BP higher i.e., >45-50 for term infants can help prevent R to L shunting.
- Nitric Oxide starting at 20 PPM for term infants or 5 PPM for preterm infants may be helpful for persistent shunting after above treatment measures have been tried.
- ECMO is a consideration if all else fails.

**3. HMD (Hyaline Membrane Disease) or RDS (Respiratory Distress Syndrome)**

**Epidemiology:**

- 80% of < 1000 grams (< 28 weeks)
- ~ 50% of 1001-1250 grams (~28-29 weeks)
- 25-30% of 1251-1500 grams (~30-32 weeks)
- ≤25% of ≥ 33 weeks.

**Etiology**

- Surfactant deficiency, inhibition of surfactant function and immature lungs.
- Lung maturation is accelerated by antenatal steroids, maternal hypertension, IUGR, PPROM, Chorioamnionitis. Diabetes and hydrops delay it.

**Clinical Findings**

- Tachypnea, retraction flu, grunting, cyanosis on room air.
- Symptoms usually present at birth, peak by 2-3 days and improve after 72 hours.
- Surfactant can alter the typical clinical course.

**CXR**

- Reticulogranular (ground glass)
- Air bronchograms
- Hypoexpansion

**Management**

- < 1000 grams or < 27 weeks, consider prophylactic administration of surfactant (Infasurf 3 ml/kg or Survanta 4 ml/kg divided into 2 aliquots) in the delivery room with controlled ventilation initially of ~ 22/6. Improved control of pressures can be achieved by utilizing the Neopuff in the delivery room.
- Consider rescue surfactant for any infant requiring intubation with a typical HMD CXR. The earlier it's given the more effective it will be.
- Consider repeat doses ≥ 6-8 hours after initial Infasurf or Survanta ≥ 6 hours after initial dose for a max of 4 doses/48 hours for FiO2 requirement > 40% or high ventilator settings if patient responded to previous doses. This should be discussed with the team. Usual uncomplicated RDS requires 2-3 doses. Babies with complicated RDS (? pneumonia, asphyxia) should be retreated with a lower threshold (≥30 % FiO2).
• If a preterm infant is vigorous and breathing spontaneously, a therapeutic option may be to recruit and maintain lung volume with nasal CPAP initiated in the delivery room. It is important the CPAP be continuously applied with the mask followed by prongs upon return to the unit to maintain the lung distention. This early intervention helps avoid recruitment/derecruitment cycles that may cause early lung damage. This early intervention may obviate the need for surfactant administration and mechanical ventilation.

4. Meconium Aspiration Syndrome (MAS)

**Epidemiology**
- Incidence of meconium stained amniotic fluid only 1.6% for 34-37 wks. And 30% for 42 wks. Very rare < 34 weeks - (May actually be bilious reflux from intestinal obstruction.)
- Overall average of meconium stained amniotic fluid is ~ 12% of all deliveries.
- ~ 4% of infants with meconium stained fluid will have secondary meconium aspiration.
- Risk factors for meconium aspiration include: Postterm pregnancy, pre-eclampsia or maternal hypertension, maternal diabetes, abnormal fetal heart rate, IUGR, oligohydramnios, maternal smoking or chronic maternal respiratory or cardiovascular disease.

**Etiology**
- Passage of meconium is often secondary to fetal distress.
- Deep irregular breathing or gasping related to distress during labor or delivery can than lead to aspiration of the meconium stained fluid.

**Clinical Findings**
- Initial presentation at birth may be upper airway obstruction.
- After birth, the meconium may migrate distally causing decreased lung compliance and increased expiratory large airway disease.
- Significant and usually asymmetrical air trapping often present related to ball-valve phenomenon.
- A “barrel chest” or over inflated appearance of the chest may be seen.
- Air leak risk is 21-50% when air trapping is present.
- With distal migration of meconium, chemical pneumonia occurs causing bronchiolar edema and surfactant inactivation.
- PPHN is commonly associated with MAS.

**CXR**
- Coarse irregular patchy infiltrates.
- Frequent asymmetrical hyperinflation.
- Associated pneumothorax or pneumomediastinum may be present.

**Management**
- Infants with meconium stained amniotic fluid who are not vigorous at birth should be intubated and their trachea suctioned using a meconium trap aspirator.
- Definition of vigorous per NRP 2006 guidelines include good muscle tone, normal respiratory effort and a HR > 100. The thickness of the meconium does not contribute to the decision making pathway.
- Infants with borderline criteria for intubation/ventilation after delivery room may benefit from intubation for pulmonary toilet.
- Watch closely for associated PPHN and manage as described previously.
- Make sure there is not another underlying cause of the MAS, which may need treated such as pneumonia/sepsis or perinatal asphyxia.
Ventilation

- If PPHN present also see PPHN section.
- Air trapping and airway edema component usually managed best with conventional ventilation using low rates (20-25) with long inspiratory times (0.5-0.7) and moderately high pressures. Increasing PEEP may actually help stint airway open and improve ventilation.
- If possible, maintain a higher PaO2 (80-90) to minimize PPHN.
- High Frequency Ventilation (HFV) is only used if patient fails conventional ventilation management, as the disease is usually asymmetrical with air trapping, which can be worsened with HFV.
- If HFV used the oscillator (SensorMedics 3100A) should be used because it has an 'active' expiratory phase and the ability to lower the Hertz (Hz) or rate both of which may help with ventilation and limiting air trapping.

5. Air Leak Syndromes (Pneumothorax, Pneumomediastinum, Pneumopericardium, Pulmonary Interstitial Emphysema [PIE])

Epidemiology

- Spontaneous pneumothorax occurs in ~ 1 % of all live births.
- PIE is predominately seen very low birth weight infants on the ventilator early in their course.
- Pneumothorax, pneumomediastinum and pneumopericardium are predominately seen in infants on the ventilator especially with underlying MAS.

Etiology

- Probably begins with alveolar overdistension, then dissection of into the perivascular or interstitium of the lung, which is PIE.
- Once PIE has developed, it can progress to pneumothorax, pneumomediastinum, or pneumopericardium.
- Don't forget that a term newborn with 'symptomatic' spontaneous pneumothorax may have underlying pneumonia also.

Clinical Findings

- PIE can be asymptomatic or with only slowly worsening course.
- Pneumothorax may be asymptomatic or associated to respiratory distress, asymmetrical lung sounds, shifted heart sounds, barrel chest from increased AP diameter, and hypotension (with 'tension' pneumothorax).
- Pneumomediastinum may be asymptomatic or associated with increased respiratory distress or hypertension (especially in posterior pneumomediastinum).
- Pneumopericardium can be associated with abrupt tachycardia, hypotension or sudden death.

CXR

- Pneumomediastinum: look for thymus outline; air does not surround the heart
- PIE: diffuse interstitial air; “clearing “ of an HMD x-ray
- Pneumothorax: shifted mediastinum; no lung markings evident
- Pneumopericardium: air shadow surrounds the heart

Management

- If a pneumothorax is suspected, immediately transilluminate the chest. If present the pneumothorax lights up with diminished transillumination on the contralateral side.
- Obtain CXR
- If symptomatic, a thoracentesis can be done, if the air accumulates again, then a chest tube is placed anteriorly and connected to 10-20 cm H2O suction
- In PIE, the disease will spontaneously regress over time.
- Position infant with the affected side down or dependent.
- HFOV can be initiated.
6. Apnea and Bradycardia (A's & B's)

Definitions
- Apnea is absence of respiratory air flow for \( \geq 20 \) seconds in preterm infants or \( \geq 15 \) seconds in term infants.
- Bradycardia is HR < 100 beats per minute.
- Periodic breathing is 3-10 second period of respiratory pauses without associated bradycardia, cyanosis or consequences. Common in newborn period and not harmful.
- Central Apnea is characterized by absence of air flow with no respiratory effort. Most common type in term infants.
- Obstructive Apnea is characterized by continued respiratory effort with no air flow. Pharynx is most likely level of obstruction especially in very premature infants. The longer the apneic episode, the more likely there is an obstructive component.
- Mixed Apnea is combination of central and obstructive apnea. Most common type in premature infants.

Epidemiology
- Apnea of Prematurity affects 25% of <2500 grams; > 50% < 1500 grams; 85% < 1000 grams.
- Peaks 1-14 days of age then declines and almost always resolves by 44 weeks gestation.
- If infants born at > 28 wk gestation, resolves in most cases by 37 weeks post-conceptional age.
- In those < 28 wk gestation can last longer (see figure 1 below).
- Spells that require intervention end ~ 1 week before "self-resolving "spells (see figure 2 below.)
- Unusual < 24 hours of age. Onset is later and can peak later in previously ventilated infants.
- Onset unusual past 34 weeks gestation.
**Differential Diagnosis**

- Most common cause is Apnea of Prematurity.
- Unusual course i.e. onset < 24 hours, peaking past 14 days or occurrence in near term infants is concerning for other possible causes such as NEC, Sepsis or Infection, IVH, Seizure, Anemia, Polycythemia, Temperature Instability, Hypoxia, Metabolic abnormality (hypoglycemia), misplaced (esophageal) OG tube.
- Apnea of Prematurity (AOP) is gradual in onset. Sudden severe A & B's suggest other etiology.
- Gastroesophageal reflux (GER) can also be a cause of A & B's. May need to evaluate or treat for this in an older infant who has persistent or new onset A & B's (after an A & B free period). Episodes are more common the first hour after feeds and sometimes have bradycardia out of proportion to apnea secondary to vagal response.

**Evaluation**

- If unusual course consider: CXR (check OG placement, look for atelectasis, pneumonia etc.), CBC (R/O anemia, look for evidence of infection), CRP? Blood culture, Head Ultrasound, Abdominal XRAY (R/O NEC), glucose, lytes? Calcium, ?EEG depending on the clinical presentation. Should also check vital signs, pulse oximeter and consider CBG or ABG.

**Treatment**

- Prone position with head elevated may decrease episodes. Make sure head isn't hyperflexed.
- If possibly feeding related consider delivering feeds over 1-2 hours or trying continuous feeds. Transpyloric feedings is also an option.
- Supplemental oxygen may help if associated with hypoxia.
- High flow Nasal Cannula (HFNC) or NCPAP may help if there is an obstructive component: NCPAP of 6 = HFNC L/min. = 0.92 + (0.68 x Wt in KG). For 1000 grams = 1.6 liters, For 1500 grams = 2.4 liters.
- Consider Caffeine when ~ ≥ 10 episodes / 24 hours or episodes requiring interventions, or prophylactically in ≤ 1000 gram infants for extubation.
- **Caffeine Citrate** - dose; load = 20mg/kg, maintenance = 5-7.5 mg/kg/dose every 24 hours.
- **Caffeine and Theophylline** have similar therapeutic effect on apnea. Caffeine has the advantage of a longer half-life with easier dosing and wider safety margin with fewer side effects.
- Consider stopping meds when without A's and B's for 5-7 days or only having occasional self-resolving events.
- Caffeine should be stopped at least 5-7 days prior to discharge unless patient is going to be discharged on caffeine. In most infants, can stop at 34-35 weeks PCA.
  - Caffeine citrate is the only FDA approved medicine to treat AOP and is the drug of choice.

**Discharge Criteria**

- Patient should be without A's and B's requiring intervention and off caffeine for at least 7 days prior to discharge and without Self-resolving A's & B's for 5 days prior to discharge. Episodes during feedings do not count.
- Home monitor may be considered with discharge ≥ 37 weeks with self-resolving events < 5 days, but no episodes requiring intervention for ≥ 7 days prior to discharge. This needs to be discussed with the attending. Home monitor should be continued until 44 weeks gestation or 1 week after caffeine stopped.
- Rate of death from SIDS is 3-4 x's higher in premature infants but timing does not correlate with apnea of prematurity. Apnea of prematurity resolves by 44 weeks gestation and SIDS peaks at ~ 46 weeks in extremely premature infants and 52 weeks in term infants. Spells in the nursery do not predict SIDS.
7. Chronic Lung Disease (CLD) or Bronchopulmonary Displasia (BPD)

**Definition**
- Oxygen requirement at 36 weeks gestation.

**Epidemiology**
- Mortality has decreased with surfactant and antenatal steroids but not the incidence of CLD. Incidence at 36 weeks: 60% 500-750 gm; 39% 751-1000 gm; 21% 1001-1250 gm and 12% of 1251-1500 gm.
- The 'new' chronic lung disease is less severe than the 'old fashioned BPD' with a generally more diffusely hazy and less cystic CXR.
- May be partially secondary to maldevelopment of the lung secondary to interrupted normal development of very premature lungs.
- Other causes of CLD are ventilator damage related to volutrauma and barotrauma, low lung volume injury from inadequate pEEP, oxygen toxicity, infection, inflammation, pulmonary edema and PDA.

**Prevention**
- Avoid overdistention and hyperventilation with the ventilator never allowing PCO2 < 30 and consider permissive hypercarbia with PCO2 of 45-60.
- Wean aggressively after surfactant given after birth. Most <1000 gram premature infants start on settings of ~ 22/6 (Pressures) x 30 (rate) 1.00 (FiO2) at birth and wean to ~ 16/5 x 20 .30 by ~ 30 minutes of age.
- Wean O2 aggressively keeping saturations in low 90's and PO2's < 80 unless PPHN sensitive to oxygen saturations.
- Exhale as soon as safely able, but support with NCPAP or HFNC as needed to prevent atelectasis and secondary low lung volume injury.
- Watch closely for evidence of PDA and treat early if present. Consider prophylactic Indomethacin 0.1 mg/kg/dose 1 x daily for 5 days in < 1000 gms.
- Avoid fluid overload, which may contribute to pulmonary edema and PDA.
- Current research trials are underway to study whether Nitric Oxide or physiologic replacement Hydrocortisone may be effective in preventing CLD by decreasing the inflammatory component of pathogenesis.

**Treatment**
- Very controversial and attending dependent.
- If infant still on the ventilator, tidal volume ventilation with pressure support or HFV may help to decrease injury, allow healing and more even ventilation.
- Optimal nutrition is of utmost importance with ideal weight gain of 15-30 gm / day.
- Steroid use needs to be discussed with attending because of concern of long term developmental problems especially associated with long courses of high dose Decadron. Short courses (6 doses @ 0.1-0.2 mg/kg/day divided BID) may be considered for infants on very high ventilator settings and FiO2.
- Inhaled steroids, nebulized budesonide (pulmicort), diuretics (Furosemide &/or Hydrochlorothiazide &/or Spironolactone), and bronchodilators (Albuteral &/or Ipatropium) may be beneficial. Routine Lasix use especially ≥ 1-2 x’s daily can cause nephrocalcinosis &/or rickets and should be avoided if possible or accompanied by Hydrochlorothiazide.
- Gastroesophageal reflux (GER) is very common in infants with CLD and often will need treated with Zantac, Prilosec (Omeprazole), lansoprazole (Prevacid) and rarely a Nissan and GT.
- Infants with CLD will need Synagis during RSV season (usually Nov. - April) for 1-2 years as per the AAP guidelines.
**Discharge Criteria**

- Need to pass Room Air Challenge, keeping saturations $\geq 80\%$ for $\geq 40$ minutes. Premature infants can have a biphasic response to hypoxia becoming apneic after a short period of tachypnea.
- If $\geq 37$ weeks gestation and otherwise ready for discharge but can't pass the room air challenge, can be discharged home on pulse oximeter if approved by attending.
- If unable to pass RA challenge and has symptoms consistent with more severe CLD, may need EKG &/or Echo prior to discharge to evaluate for PPHN or RVH.
- If being discharged home to a higher altitude O2 will need to be increased at discharge.

### Nasal Cannula Conversion Table

<table>
<thead>
<tr>
<th>Flow Rate</th>
<th>FiO2</th>
<th>100%</th>
<th>80%</th>
<th>60%</th>
<th>40%</th>
</tr>
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<tbody>
<tr>
<td>*1/32 L = 31 ml</td>
<td></td>
<td>24%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*1/16 L = 62.5ml</td>
<td></td>
<td>27%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*1/8 L = 125ml</td>
<td></td>
<td>31%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>**1/4 L = 250ml</td>
<td>34%</td>
<td></td>
<td>31%</td>
<td>26%</td>
<td>22%</td>
</tr>
<tr>
<td>**1/2 L = 500ml</td>
<td>44%</td>
<td></td>
<td>37%</td>
<td>31%</td>
<td>24%</td>
</tr>
<tr>
<td>**3/4 L = 750ml</td>
<td>60%</td>
<td></td>
<td>42%</td>
<td>35%</td>
<td>25%</td>
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<tr>
<td>**1 L = 1000ml</td>
<td>66%</td>
<td></td>
<td>49%</td>
<td>38%</td>
<td>27%</td>
</tr>
</tbody>
</table>

* Measured mean hypopharyngeal oxygen concentrations in 13 infants (1580-4020 gms)
** Measured mean hypopharyngeal oxygen concentrations 10 infants (1780-4090 gms)

Important to note there was significant variability between infants mostly depending on the infant’s weight. The smaller infants < 1500 grams had much higher oxygen concentrations with the same flow.

### Altitude Effect on Oxygen Requirement

| FiO2 Required to Maintain the Same Partial Pressure of Inspired O2 (PiO2) |
|-----------------------------|-----------------|-----------------|-----------------|-----------------|
| Sea Level                   | 5,000 ft.       | 7,500 ft.       | 10,000ft        | 12,500 ft.      |
| 24% (~1/32 L)               | 26% (~1/16 L)   | 29% (~1/8 L)    | 32% (~1/4 L)    |
| 27% (~1/16 L)               | 30% (~1/8 L)    | 33% (~1/4 L)    | 37% (~1/2 L)    |
| 29% (~1/8 L)                | 32% (~1/4 L)    | 36% (~1/2 L)    | 39% (~1/2 L)    |
| 32% (~1/4 L)                | 36% (~1/2 L)    | 40% (~1/2 L)    | 44% (~1/2 L)    |
| 38% (~1/2L)                 | 42% (~1/2 L)    | 46% (~3/4 L)    | 51% (~3/4 L)    |
| 41% (~1/2 L)                | 45% (~3/4 L)    | 51% (~3/4 L)    | 56% (~3/4 L)    |
| 44% (~1/2 L)                | 54% (3/4 L)     | 59% (~3/4 L)    | 66% (~1 L)      | 73% (> 1 L)     |

* Oxygen requirement has been calculated using the alveolar gas equation and atmospheric pressure for each altitude. The approx. NC requirement is derived from the above data for approx. 1500 gram - 4000 gram infants. Since this can vary between infants, a pulse oximeter study should be done when the baby arrives at the altitude.

### 5. Ventilator Management

**Indications for Mechanical Ventilation**

- Clinical respiratory failure
- Consider delivery room intubation and surfactant in < 1000 grams.
- Premature infant with RDS and FiO2 ~ > .50. Generally, the sooner the infant is intubated and given surfactant the better they respond.
- pH < 7.25, pCO2 ~ 60-65, Prolonged apnea.
- NCPAP may be tried first if infant does not need surfactant or not rapidly deteriorating.
### Endotracheal Tube and Laryngoscope Blade Size

<table>
<thead>
<tr>
<th>Weight / Gestation</th>
<th>ETT Size</th>
<th>Laryngoscope Blade Size</th>
<th>Depth of ETT at Lip</th>
<th>Common Initial Vent Settings</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1000 gms / &lt; 28 wks</td>
<td>2.5 mm</td>
<td>Miller 00 or 0</td>
<td>6-7 cm</td>
<td>~ 20-22/5-6 x 30, 100% O2, IT ~ 0.4 ~16/5-6 x 20, 30% by 30 min.</td>
</tr>
<tr>
<td>1000-2000 gms/ 28-34 wks</td>
<td>3.0 mm</td>
<td>Miller 0</td>
<td>7-8 cm</td>
<td>~ 20-22/5-6 x 30 , IT 0.4-0.5</td>
</tr>
<tr>
<td>2000-3000 gms/34-36 wks</td>
<td>3.5 mm</td>
<td>Miller 0</td>
<td>8-9 cm</td>
<td>~ 20-24/5-6 x 30, IT ~0.5</td>
</tr>
<tr>
<td>&gt; 3000 gms / &gt; 36 wks</td>
<td>3.5 - 4.0 mm</td>
<td>Miller 0 or 1</td>
<td>9-10 cm</td>
<td>~20-26/5-6 x 30, IT ~0.5</td>
</tr>
</tbody>
</table>

### Types of Ventilation

**Conventional Ventilation** - Can be primarily pressure control or volume control.

- **Pressure Control** - Machine delivers set pressure for each breath.
- **Volume Control** - Machine delivers set tidal volume (5-8 ml/kg usually used initially) for each breath. The **Siemens** or **Drager** ventilators can be set in volume control or pressure control.

Other Possible Conventional Ventilator Modes

- **Pressure Regulated Volume Control (PRVC)** - Tidal volume is set and the machine selects a pressure and holds it for the set inspiratory time measuring the tidal volume delivered and then automatically adjusts the pressure level up or down to keep the patient tidal volume constant. Has decelerating flow wave, which is supposed to be more comfortable for patient and less injurious to the lungs. An upper limit of pressure to be delivered can be set and the inspiratory pressure will be automatically regulated between PEEP and 5 cm H2O below the upper pressure limit. Can be beneficial with rapidly changing compliance and ideally will limit lung injury by limiting pressure and volume delivered. May not work well if a significant ETT air leak is present. It is available on the **Siemens** and **Drager**. Every breath is augmented, so this is essentially an assist control mode.

- **Pressure Support (PS)** - A set inspiratory pressure above the PEEP is delivered with each spontaneous, nonventilated breath. So if the PEEP is 5 and PS 8, 13 cm H2O will be delivered with each spontaneous breath. This mode can be by itself or combined with volume control or pressure control. It is available on the **Siemens** and **Drager** and can be especially helpful when trying to wean the rate on the ventilator. Usually used with a preset IMV.

- **Synchronized Intermittent Mandatory Ventilation (SIMV)** - Synchronizes delivered breaths with patients breath improving oxygenation, decreasing agitation and need for sedation, shortening time on ventilator.

### Ventilator Parameters with Conventional Ventilation (CV)

- **Peak Inspiratory Pressure (PIP)** - Maximal inspiratory pressure attained during respiratory cycle. Preset with pressure control mode. Usual settings range 14-26cmH2O with [common initial setting of 18-22](#) and adjustment as needed to for gentle chest rise.

- **Positive End-Expiratory Pressure (PEEP)** - Airway pressure maintained continuously between breaths to prevent atelectasis. Commonly set at 5-6.

- **Rate** - Number of ventilator breaths per minute. Often initially set at 30-40 and adjusted as needed to maintain PCO2's ~ 45-55 depending on the disease process.

- **Inspired Oxygen Concentration (FiO2)** - Adjusted to keep saturations in low 90's (92-94%) except with sometimes with PPHN higher saturations may be beneficial.

- **Inspiratory Time (Ti or IT)** - Length of time the ventilator spends in the inspiratory phase. Increased ITs increase mean airway pressure (MAP) and usually increase oxygenation but too long of IT's can cause damage. Usual IT 0.3-0.4 sec.

- **Tidal Volume (TV)** - Volume of gas delivered during inspiration. TV and Rate affect minute ventilation, which affects PCO2. Can be set in volume control modes. Typical TV is 5-8 ml/kg.
**High Frequency Ventilation (HFV)-**
- Much smaller tidal volumes at very high frequencies.
- Better oxygenation with less barotrauma or injury to the lungs
- Best with diffuse homogeneous disease or airleak syndromes such as pulmonary interstitial emphysema (PIE)
- Also used freq. with pulmonary hypoplasia, PPHN and congenital diaphragmatic hernia (CDH) or any severe lung disease failing conventional ventilation.
- Can rapidly decrease PCO2. Ideal to place a transcutaneous CO2 monitor (TCM) prior to placing on HFV.

**High Frequency Oscillatory Ventilation (HFOV)- SensorMedics 3100A**
- Active instead of passive expiratory phase.
- Much more powerful than the HFFI especially with > 2kg infants.

**Ventilator Parameters for High Frequency Ventilation**
- **Frequency (Hz)** Usually set at 10 Hz. In SensorMedics 3100A, (Hz range = 3-15) lowering Hz can significantly increase TV and improve ventilation which may be helpful with meconium aspiration syndrome, RSV, and Pneumonia. CLD when air trapping is a problem.
- **Amplitude** (Amp or Δ P) - Mainly affects ventilation (PCO2). Usually initially set this at ~ the same level as the previous PIP and adjust as needed for adequate chest 'jiggle' and to maintain normal PCO2's. TCM is very helpful with this transition to trend the PCO2's.
- **Mean Airway Pressure (MAP)** - Mainly affects oxygenation. Initially start ~ 2-5 cmH20 higher than MAP on CV and adjust as needed for proper oxygenation and expansion on CXR. Frequent CXR's can be helpful since both over and underexpansion can lead to hypoxia and hypercarbia. MAP can also effect PCO2.
Effects of Ventilator Setting Changes on PaCO2 and PaO2

<table>
<thead>
<tr>
<th>Ventilatory Setting Changes</th>
<th>PaCO2</th>
<th>PaO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase PiP</td>
<td>Decreases</td>
<td>Increases</td>
</tr>
<tr>
<td>Increase TV</td>
<td>Decreases</td>
<td>Increases</td>
</tr>
<tr>
<td>Increase PEEP</td>
<td>Can Increase</td>
<td>Increases</td>
</tr>
<tr>
<td>Increase Rate</td>
<td>Decreases</td>
<td>Min. Increase</td>
</tr>
<tr>
<td>Increase Inspiratory Time (IT)</td>
<td>No Change</td>
<td>Increase</td>
</tr>
<tr>
<td>Increase FiO2</td>
<td>No Change</td>
<td>Increase</td>
</tr>
<tr>
<td>Increase Flow on Vent.</td>
<td>Min. Decrease</td>
<td>Min. Increase</td>
</tr>
<tr>
<td>Increase Amplitude (ΔP)- HFV</td>
<td>Decrease</td>
<td>No change</td>
</tr>
<tr>
<td>Increase MAP - HFV</td>
<td>Min. Decrease</td>
<td>Increase</td>
</tr>
</tbody>
</table>

Extubation

- HFV usually transitioned to CV prior to extubation.
- PIP often weaned to 18-22 or lower for micropremies prior to extubation.
- MAP usually ≤ 7-8.
- PEEP usually not weaned prior to extubation.
- Rate usually weaned to 10-15.
- FiO2 requirement usually < 0.4 - 0.5.
- TV usually constant ~ 5-8 ml/kg and not weaned prior to extubation.
- PS usually weaned to ≤ 6-8.
- Small premies or infants with significant lung disease may benefit from being extubated to NCPAP of 5-7.
- NCPAP can also be provided through the ventilator with SIMV. This is sometimes called BiPAP and common initial settings are 16-18/6 x 12. Limit use to 72 hours.
- Other infants are usually placed on humidified hood for ~ 1-2 days and then weaned to NC.
- Loading with Caffeine citrate may enhance success in infants extubated @ < 1000g.

6. Nitric Oxide (NO)

- Potent endothelial-derived vasodilator secondary to cyclic GMP increases.
- Produces vasodilation only in vascular bed of well ventilated regions of the lung.
- Can improve intrapulmonary shunting or VQ mismatch.
- Very expensive: $125/hour = $3000/day.
- Indications for use include suprasystemic pulmonary pressures with R-L shunting at ductal level and Pre/Post ductal O2 Sat difference usually > 10 % difference.
- Ideal to obtain echocardiogram and recruit lungs with ventilator (often HFOV) prior to use.
- If Pre-ductal Saturation < 80% may consider emergent use prior to above.
- Starting dose = 20 ppm for ≥ 34 weeks decreasing to 5 ppm after ~ 4 hours. Starting dose for < 34 weeks = 5 ppm. Check at least one methemoglobin ~ 6-12 hours after starting.
- Typical course < 5 days (CDH &/or Severe Pulmonary hypoplasia may be exceptions).
- Consider weaning off if FiO2 < 0.60 and PO2 >60.
- Usually can stay off NO if FiO2 increase < 15% ≥ 60 minutes after being off.

7. Extra Corporeal Membrane Oxygenation (ECMO or Bypass)

- Rarely used if HFOV and NO used properly.
- Primarily used at TCH only after maximal medical therapy has failed usually cardiac failure is a major component.
- Criteria ≥ 34 weeks and > 2 kg; reversible lung disease; no major intracranial hemorrhage;
- Catheters placed in R internal jugular vein with tip in R atrium and R common carotid artery with tip to aortic arch.
CONGENITAL HEART DISEASE

♦ Overall incidence is 1% (8-12/1000 live births).
♦ 50% of these infants present in the first two weeks of life.
♦ Not all present in neonatal period (VSD, ASD) and not all heart defects will present with a murmur (Transposition of Great Arteries, Total Anomalous Pulmonary Venous Return).
♦ In the neonate CHD presents in 3 ways;
   A-Cyanotic
   B-Poor cardiac output
   C-Congestive heart failure with respiratory distress (usually later presentation than A or B)

A) CYANOSIS
- Occurs when 3-5 gm/dl of Hgb is desaturated
- Is best seen in mucous membranes and nail beds (not acrocyanosis or circumoral cyanosis)
- If cyanosis occurs without respiratory distress CHD should be strongly suspected.
- Most common heart lesions presenting in the first two weeks of life with cyanosis (respectively):
  Days 0-6:
  1) Transposition of the Great Arteries
  2) Right sided outflow tract obstructions:
     - Pulmonary Atresia
     - Critical Pulmonic Stenosis
     - Tricuspid Atresia
  3) Obstructed Total Anomalous Pulmonary Venous Return
  4) Truncus Arteriosus
  Days 7-13:
  1) Transposition of the Great Arteries
  2) Tetralogy of Fallot
  3) Unobstructed Total Anomalous Pulmonary Venous Return

Evaluation of the cyanotic infant should include:
1. Family History; a previous affected sibling increases incidence to 3% and an affected mother may increase the risk to as high as 13-18% as in the case of mother with AS.
2. Obstetric and Prenatal History including TORCH infections, maternal medications used during pregnancy (cardiac teratogenic medications such as anticonvulsants, alcohol, and lithium…), findings on prenatal ultrasounds, and maternal medical problems that may predispose to neonatal heart problems (i.e. diabetes mellitus, SLE.).

Important Physical exam findings:
1. Dysmorphic features may represent chromosomal abnormalities (i.e. trisomy 21) and an increased risk for CHD.
2. Cyanosis and pulse oximetry saturations both preductal (R upper ext) and postductal (either leg). If differential cyanosis (pre>post) is found it suggests pulmonary hypertension or ductal dependent systemic blood flow (critical aortic stenosis, interrupted aortic arch, and critical coarctation of the aorta). If reverse cyanosis is seen (pre<post) then one should suspect Transposition of the Great Arteries with pulmonary hypertension or Transposition of Great Arteries with Coarctation of the Aorta.
3. Perfusion, pulse quality and blood pressures obtained in R arm (preductal) and either leg (postductal). A >15mm systolic difference upper vs. lower is significant for a potential COA.
4. Respiratory rate and work of breathing.
5. Cardiac exam for: precordial activity, PMI, murmur quality, location, systolic/diastolic, S1, S2 quality. Single S2 suggests a single valve closing as seen in pulmonary atresia, aortic atresia, Truncus Arteriosus, and transposition of the great arteries (one valve closer to stethoscope).
6. Abdomen should evaluated for hepatomegaly as a sign of cardiac failure (a late finding)
Technical evaluation includes:

1. EKG

2. CXR: Very important as congenital heart disease can be divided into lesions with increased pulmonary blood flow lesions versus those with decreased pulmonary blood flow lesions;
   - Decreased PBF (R heart abnormalities)
     1) Pulmonic stenosis
     2) Severe Tetralogy Of Fallot
     3) Tricuspid atresia
     4) Ebstein’s anomaly (also see massive cardiomegaly)  
   
   - Increased to normal PBF
     1) D- Transposition of Great Arteries
     2) Total Anomalous Venous Return
     3) Truncus Arteriosus
     4) Coarctation Of the Aorta
     5) Interrupted Aortic Arch
     6) Hypoplastic Left Heart Syndrome

3. Hyperoxia test: Can be performed in patients to help delineate between CHD and pulmonary disease. A patient with CHD may have room air saturations of 85% that does not increase when placed in 100% FIO2 suggesting intracardiac shunting. To evaluate obtain a preductal ABG on RA followed by a preductal ABG on 100% FIO2 (should be on for 10-15 minutes prior to obtaining ABG). CHD should be strongly suspected if PaO2 remains below 100mm Hg despite 100% FIO2.

4. Echocardiogram and cardiac catheterization are gold standards for diagnosis of CHD.

B) POOR CARDIAC OUTPUT

- Structural causes occur secondary to left heart obstruction:
  - mitral atresia, aortic stenosis, COA, interrupted aortic arch

- Nonstructural causes;
  - sepsis, cardiomyopathy, myocarditis, brady and tachy arrhythmias.

C) CONGESTIVE FAILURE with respiratory distress

- Structural causes occur because of pulmonary blood flow>> systemic blood flow:
  1) Truncus Arteriosus
  2) Endocardial cushion defects (atrioventricular septal defects)
  3) Single ventricle physiology
  4) Patent Ductus Arteriosus in full term infants

- Other structural abnormalities can cause pulmonary venous congestion:
  1) Total Anomalous Pulmonary Venous Return (especially with obstruction).

- Nonstructural:
  1) Arterial-Venous Malformations
  2) Anemias
D) DUCTAL DEPENDENT CONGENITAL HEART DISEASE

- Heart lesions that require ductal patency to provide pulmonary blood flow (right heart lesions) or systemic blood flow (left heart lesions):
  - Pulmonary Atresia
  - Aortic Atresia
  - Hypoplastic Left Heart Syndrome
  - Critical Coarctation of the Aorta
  - Interrupted Aortic Arch
  - Severe Ebstein’s Anomaly
  - D-TGA with intact ventricular septum and minimal atrial level shunt (poor mixing)

- These patients should be started on PGE continuous infusion at starting dose of 0.025-0.05 mcg/kg/min to maintain ductal patency. If patency is not achieved may increase to max dose 0.3 mcg/kg/min (very rare to need this increased dose).

-Side Effects of PGE include:
  - Apnea (that may require intubation and mechanical ventilation)
  - Fever
  - Irritability
  - Seizure
  - Hypotension
  - Diarrhea

ARRHYTHMIAS

All varieties can occur in the fetus and neonate. The most common are premature atrial contractions, premature ventricular contractions, sinus tachycardia, and sinus bradycardia. Many arrhythmias are benign whereas others can cause hemodynamic instability or occur in the presence of structural heart disease.

Most Common Benign Arrhythmias

A) Premature Atrial Contractions (PAC)
- occur in up to 30% of newborns
- on EKG see an early P wave (may even be lost in preceding T wave)
- in hemodynamically stable infants they do not warrant further investigation.
- it may take them several months to resolve.
- NOTE; always check central line placement in the presence of PACs as they may indicate irritation caused by a catheter in the right atrium.

B) Premature Ventricular Contractions (PVC)
- are ventricular depolarizations causing QRS complexes with different morphology than sinus beats. Normally the QRS is wider and not preceded by a P wave.
- can be benign, however if there are persistent electrolyte abnormalities, structural heart disease, or long QT syndrome should be ruled out.
- if not associated with these abnormalities then they may be expected to disappear over several months.

C) Sinus tachycardia
- occurs with fever, anemia, pain, hypovolemia and sepsis.
- in neonates the heart rate may be as high as 230 and still be sinus rhythm.

D) Sinus Bradycardia
- sustained heart rates less than 70 beats per minute are abnormal in the neonate.
- many infants have nonsustained bradycardic episodes during activities such as crying, bathing, defecation and with vagal stimulation which occurs during intubations, naso/orogastric tube placements, or with gastroesophageal reflux.
Most Common Pathological Neonatal Arrhythmias

A) Supraventricular Tachycardia (SVT)
- occurs with a narrow (normal) QRS complex and an absent P wave (or morphology different than sinus)
- should be suspected if heart rates are fixed and greater than 200 beats per minute.
- all infants with suspected SVT should have evaluations for structural heart disease as they are present in 8%-25% of patients with SVT. Also occurs with myocardial irritation as seen with myocarditis or misplaced catheter.
- most infants are asymptomatic with SVT however if it is sustained or in the presence of structural heart disease an infant may become symptomatic and require intervention. Vagal maneuvers (application of ice or very cool cloth to the infants face) or medicating with adenosine at 50ug-100ug/kg dose via IV (note half life is only seconds, thus give by quick IV push followed by normal saline) can stop the rhythm. If administering adenosine also get rhythm strip concurrently as it aids in diagnosing underlying arrhythmia and directing further treatment.

B) Complete Heart Block
- ventricular rate is slower than and independent from atrial rate (usually 50-100 vs. atrial rate of 120-160 beats per minute)
- can occur with maternal Lupus or Sjogren’s syndrome if anti-Ro or anti-La antibodies are present during gestation and have affected the fetal conduction system.
- may also be associated with underlying structural heart disease.
- most infants are asymptomatic
- if symptomatic patients will require long term ventricular pacing or medical therapy acutely (isoproterenol).

PATENT DUCTUS ARTERIOSUS
PDA is a unique problem in the premature infant recovering from hyaline membrane disease. In premature infants the pulmonary vascular resistance drops much quicker than in full-term infants (hours to days vs. weeks in full-term infants). This results in a large left to right shunt that steals systemic blood flow resulting in inadequate end-organ perfusion. It also causes increased pulmonary blood flow that worsens lung compliance and leads to greater ventilator dependence thus increasing the risk of chronic lung disease.

Incidence is inversely related to birthweight
- <1kg = 60%
- 1-1.5kg = 25%
- 1.5-2.0kg = 10%

Clinical Symptoms and Signs:
- **murmur** (can be continuous, but normally is heard in systole at left upper sternal border). Not uncommonly, no murmur is heard because PA and systemic pressures are equal with no flow across PDA or there is not enough turbulence to cause a murmur (a large PDA). Least sensitive of physical exam findings
- **tachycardia**.
- **widened pulse pressure or low diastolic pressure** (<26), sometimes refractory hypotension is the only sign in the micropremie
- **bounding peripheral pulses** (“palmar pulses” or “calf pulses”)
- **hyperactive precordium**
- **hepatomegaly**
- blood gases initially showing **worsening ventilation** and later followed by **worsening oxygenation**.
- CXR revealing **increasing heart size** and **pulmonary vascular engorgement or edema**.
**Diagnosis**

- Occasionally a patient will present with “classic” signs and symptoms of a PDA and thus treatment may be begun.
- More frequently subtle signs and symptoms may be present (just a murmur or just widened pulse pressure) and that requires a cardiology consultation and echocardiography for diagnosis.
- With Echo size of PDA can be estimated, Doppler and color flow mapping delineates ductal flow (i.e. left to right), and can show increased left atrium and left ventricular size.

**Treatment**

- If PDA is determined to be small and hemodynamically insignificant no specific treatment is necessary, just careful monitoring for worsening signs and symptoms.
- If PDA is hemodynamically significant (left to right shunting with above signs and symptoms) but without cardiorespiratory collapse Indomethacin IV should be used at a dose of 0.2mg/kg/dose q 12 hours times three doses or 0.2mg/kg for first dose then followed by 0.1 mg/kg/dose q 12 hours times two more doses.
- If PDA is causing profound cardiorespiratory embarrassment surgical ligation of PDA is indicated or if the PDA has not closed with two “rounds” of Indomethacin therapy ligation is indicated (less than 30% of cases require ligation).
- Also treat with relative fluid restriction (age, weight and case specific)

Relative Contraindications to Indomethacin

- Creatinine >2mg/dl
- BUN > 30mg/dl
- Urine output <0.6 ml/kg/hour for last eight hours
- Platelets <60,000
- Evidence of bleeding diathesis
- Evidence of necrotizing enterocolitis or hematochezia
- Pulmonary hypertension with right to left ductal blood flow

Side Effects of Indomethacin

- Platelet dysfunction
- Acute Renal Failure
- Decreased Mesenteric Blood Flow

**MURMURS**

50% of full-term newborns have been found to have an innocent murmur in the first weeks of life with the incidence even higher in the premature infant.

There are four common innocent murmurs in the neonatal period:
1. **Pulmonary Flow Murmur**
   - is heard best at the ULSB at transmits to back, both axilla, and both sides of the chest.
   - murmur is grade 2/6 in intensity and soft in quality
   - murmur is not transient but lasts weeks to months with most disappearing by 6 months of age.

2. **Transient systolic murmur of tricuspid regurgitation**
3. **Peripheral Pulmonic Stenosis**
4. **Vibratory Innocent systolic murmur**

**Pulmonary Flow Murmur**

- starts with S1 (regurgitant) and is heard best at LLSB and has a VSD quality (somewhat harsh and 2/6 intensity).
- it disappears in 1-2 days.
**Peripheral Pulmonic Stenosis**

- is a very common murmur heard in the nursery
- systolic murmur grade 2/6 in intensity with soft to harsh quality heard throughout precordium and radiates to both axilla and the back.
- murmur may be heard intermittently
- usually disappears by several months of age.

**Vibratory innocent systolic murmur**

- counterpart to older children’s Stills murmur
- best heard LLSB or near the apex
- vibratory in quality and sometimes difficult to distinguish from VSD but is ejection type (not starting at S1 like a VSD does.)

**FREQUENTLY USED CARDIAC MEDICATIONS**

**Prostaglandin E1** - used for maintaining ductal patency, usual starting dose 0.025 – 0.05 mcg/kg/minute via constant infusion mixed in D5W or D10W.

**Indomethacin** - used for closing a persistent PDA with dosing regimen of
  1. 0.2mg/kg IV q 12 hours times 3 doses
  2. 0.2mg/kg IV x's one dose followed by 0.1 mg/kg/dose q 12 hours x's two doses.

**Adenosine** - used for persistent stable SVT, slows AV nodal conduction rate. Initial dose 50-100 mcg/kg/dose given rapidly via IV as half life is seconds and administration should be followed by normal saline to “clear” the IV. Also should have continuous rhythm strip during administration for diagnostic and therapeutic reasons.

**Dopamine** - is first line agent behind volume expansion in the neonate with hypotension. Usual starting dose is 5 mcg/kg/minute with range up to 20 mcg/kg/minute given constant IV infusion and mixed in D5W or D10 W.

**Dobutamine** - is second line agent behind dopamine for persistent hypotension. Usual starting dose is 5 mcg/kg/minute and can be increased to 20 mcg/kg/minute. Mixed in D5W or D10W.
GASTROSESOPHAGEAL ISSUES

GE REFLUX

A. Pressure of lower esophageal sphincter is about half of normal adult pressures.
B. Poor coordination of esophageal motility.
C. Most normal infants have some regurgitation.
D. Usually temporary, not associated with adverse clinical consequences, and will resolve with age.
E. Presence of persistent regurgitation, poor weight gain, or aspiration may be indications for therapy.
F. Treatment.
   1. Medical.
      a. Upright position, thickened feeds, Reglan, acid blockers.
      b. Symptomatic reflux in a child with neurologic impairment decreases the success of medical therapy.
   2. Surgical.
      a. Indications – failure to thrive, recurrent pneumonia, anemia caused by esophageal bleeding, or persistent vomiting despite medical therapy; a large hiatal hernia, paraesophageal hernia, or esophageal stricture of ulceration.
      b. Procedures – Nissen fundoplication, Thal repair.
      c. Complications.
         1. SBO 5-7%.
         2. Wrap displacement into chest 2-8%.
         3. Disruption of wrap 3-10% - higher in neurologically impaired.

TRACHEOESOPHAGEAL FISTULA

Incidence – 1 in 4500 live births.
A. Usually isolated, but is part of the VATER association.
B. Classification.
   1. Esophageal atresia with distal TEF – 85%.
   2. Esophageal atresia without TEF and TEF without esophageal atresia (H-type) – 5-7%.
   3. Esophageal atresia with proximal TEF, esophageal atresia with proximal and distal TEF – rare.
C. Symptoms.
   1. Esophageal Obstruction.
   2. Secondary respiratory complications including pneumonia.
   3. Polyhydramnios.
   4. Copious oral secretions with coughing and choking.
   5. Intermittent cyanosis.
   6. Abdominal distention with communication of the trachea and distal esophagus.
   7. Gasless abdomen with no distal TEF or pure esophageal atresia.
D. Diagnosis – placement of NG tube with XRAY studies, then proceed to fluoroscopic contrast study.
E. Management.
   2. Surgical – Three types: primary, delayed primary, staged.
ABDOMINAL WALL DEFECTS

Omphalocele
1. Partial or complete arrest of migration and fusion of the craniocaudal and lateral infolding the normally results in an intact umbilical ring.
2. Higher incidence of associated defects – cardiac, neurologic, genitourinary, skeletal, or chromosomal found in 65%.
3. Cardiovascular malformations in 15-25%.

Gastroschisis
1. Smaller, lateral defect of the abdominal wall.
2. Normal umbilical cord attachment without a covering sac.
3. Ischemic compromise of the herniated intestine is possible as well as atresias.

Early management.
1. Prenatal diagnosis has improved over time.
2. Mode and timing of delivery are controversial.
3. Defect wrapped in warm, fluid impermeable dressing.
4. Patients have excessive heat, fluid, protein losses.
5. Broad spectrum antibiotic coverage.
6. Early use of appropriate TPN.

Surgical correction.
1. Individualized in accordance with presence of intact sac, size and nature of herniated viscera, associated anomalies.
2. Primary repair is preferable but not always possible.

CONGENITAL DIAPHRAGMATIC HERNIA

A. Diaphragmatic defect occurs by failure of closure of the pleuropertitoneal canal.
B. Left sided in 85%. Bilateral is 1% and usually fatal.
C. Usually presents with severe respiratory compromise and intestinal obstruction.
D. Severity related to timing and degree of prenatal visceral herniation.
E. Immediate management includes intubation, nasogastric decompression, attention to cardiac and pulmonary status, and delayed surgical repair until pulmonary vasoreactivity has diminished.

INTESTINAL OBSTRUCTION

A. Duodenal atresia
1. Responsible for greater than 50% of all duodenal obstruction.
2. Pathogenesis is failure of recannalization of the GI tract during the second month of fetal life.
3. High rate of coexisting anomalies. 30% have trisomy 21. Also associated with malrotation, congenital heart disease, TEF, and renal anomalies.
4. Presents with polyhydramnios, bilious or non bilious emesis in first 24 hours, upper abdominal distention. Meconium is normally passed. X – rays show double bubble.
5. If air is present distally upper and lower contrast studies may be needed to differentiate duodenal stenosis from malrotation.
6. Surgical correction is required.

B. Malrotation
1. Results in variable clinical symptoms and is potentially lethal.
2. Complications due to intestinal obstruction or vascular compromise.
3. Sudden onset of bilious vomiting in a previously healthy neonate is suggestive of malrotation and volvulus and requires immediate confirmation and action.
4. UGI contrast study reveals abnormal position of duodenojejunal junction, or obstruction beyond the second portion of the duodenum, or a corkscrew appearance of the jejunum.
5. Contrast enema reveals abnormal caecum position.
6. Surgical intervention is indicated in all infants with symptomatic malrotation.
7. Fluid resuscitate, NPO with gastric decompression, and antibiotics.

C. Jejunoileal atresia
1. Clinical presentation – bilious vomiting, abdominal distention, failure to pass meconium, polyhydramnios (especially in jejunal atresia).
2. Radiographs.
   a. Plain films show multiple air fluid levels in dilated loops.
   b. Contrast enema shows microcolon.
3. Etiology is in utero mesenteric vascular occlusion.
4. Classification.
   a. Type I – Intraluminal diaphragm occlusion (20%).
   b. Type II – Cord-like atresia with intact mesentery (35%).
   c. Type III – a) atresia with intestinal discontinuity and mesenteric defect (35%)
      b) atresia with extensive mesenteric defect with the distal blood supply being the ileocolic artery – apple peel deformity (11%).
   d. Type IV – multiple atresias (6%).
5. Surgical correction depends on length and location of atresias.

MECONIUM SYNDROMES

A. Meconium ileus
1. Most common manifestation of cystic fibrosis in the newborn.
2. Hyperviscous secretions of the small intestine result in meconium with a low water content.
3. Two clinical subtypes.
   a. Simple meconium ileus (2/3).
      1. Mid-ileal obstruction with proximal dilated intestine. Symptoms occur within 24-48 hours and consist of failure to pass meconium, abdominal distention, bilious vomiting, and presence of palpable rubbery loops of bowel.
      2. Imaging.
         a. Radiographs show multiple dilated loops of bowel with absence of air fluid levels. A coarse granular appearance of air within meconium is characteristic.
         b. Contrast enema shows a small unused colon.
   b. Complicated meconium ileus (1/3).
      1. Associated with volvulus, intestinal necrosis, perforation, meconium peritonitis, or intestinal atresias.
      2. Signs of bacterial or chemical peritonitis superimposed on intestinal obstruction.
4. Treatment with hypertonic contrast enema. Prior to this therapy the diagnostic contrast enema should exclude other causes. Complications such as volvulus, atresia, perforation, and peritonitis should be excluded. IV antibiotics and fluid resuscitation should be administered.
5. Surgical therapy for those that fail non surgical management and for any complicated meconium ileus.

B. Meconium plug syndrome
1. Represents a spectrum on neonatal colonic dysmotility, including small left colon syndrome. It appears to be a functional obstruction resulting from diminished colonic motility.
2. IDM babies make up half of the patients with meconium plug syndrome.
3. Obstruction may be relieved with rectal stimulation. A contrast enema may cause evacuation. Rarely surgical intervention may be necessary.

C. Meconium peritonitis
1. Occurs after in utero perforation of the intestine.
2. A complication of meconium ileus, intestinal atresia, volvulus, internal hernia, congenital peritoneal bands, in utero intussusception, gastrochisis.
3. Four clinical varieties.
   a. Meconium pseudocyst – represents accumulation of meconium for a prolonged period with containment.
   b. Adhesive meconium peritonitis – widespread contamination of peritoneal cavity by meconium several days to weeks before birth.
   c. Meconium ascites – results when perforation occurs a few days before birth.
   d. Infected meconium peritonitis – results when intestinal perforation is not sealed.

4. Most cases require surgery.
   a. Indications include intestinal obstruction, persistent peritonitis, an enlarging abdominal mass, abdominal wall cellulitis, and sepsis.
   b. Specific surgery is dependent on primary disease.

HIRSCHPRUNGS DISEASE

A. Congenital absence of the parasympathetic innervation to the distal intestine.
B. May involve the entire intestinal tract, but is usually confined to the rectum and sigmoid colon.
C. Presents with failure to pass meconium, especially in a full term healthy infant. Also, obstruction, distention, bilious vomiting.
D. May be complicated by acute bacterial enterocolitis – progressive distention, vomiting, large amounts of often bloody stools.
E. Diagnosis suggested by presentation and contrast enema, but confirmed by rectal biopsy.
F. Requires surgical repair.

Imperforate Anus

A. Includes a wide range of abnormalities.
B. VATER association should be excluded, including abdominal and pelvic ultrasound.
C. Surgical correction is dependent on anatomy.
D. Generally associated with a fistula to bladder, urethra, vagina, perineum

NECROTIZING ENTEROCOLITIS

Definition
- Necrotizing enterocolitis is an acquired neonatal disorder due to intestinal injury in a gut with immature protective mechanisms that predominately affects preterm infants

Differential Diagnosis of bloody stool
- NEC, intestinal infection, volvulus, intussusception, anal fissure, milk intolerance/allergic colitis, DIC, hemorrhagic disease of the newborn, swallowed maternal blood

Pathogenesis/Etiology
- The etiology of NEC has not been clearly established, but appears to represent a common pathologic response that is triggered by a variety of risk factors acting singly or in combination
- Such risk factors include prematurity, hypoxia, gut ischemia, infection, hypertonic feedings, rapid advancement of feeding, polycythemia, milk-protein allergy, immunologic immaturity of gut, exchange transfusions, and indwelling umbilical catheters
  - Common risk factor: >90% of infants with necrotizing enterocolitis have been fed
  - Peak incidence of necrotizing enterocolitis: 19-21 days of life.

Clinical Findings
- Abdominal distension (the most frequent early sign), tenderness and/or discoloration
- Vomiting/bilious vomiting
- Increased gastric residuals (can be bilious)
- Heme positive stools; usually grossly bloody with mucus
• Temperature instability
• Increased A&Bs
• Decreased UOP
• Poor perfusion
• Hypotension

Laboratory Findings
• CBC – increased or decreased WBC with relative bandemia; thrombocytopenia
• Blood cultures are positive in 35% of cases, GNR most common
• Stool screening for occult blood
• Chem 7 – increased glucose secondary to stress; decreased Na due to 3rd spacing; increased K due to necrotic bowel, hemolysis, decreased UO
• Arterial blood gas – metabolic or combined acidosis or hypoxia may be seen
• Consider DIC screen
• Stool cultures for rotaviruses and enteroviruses should be obtained if diarrhea is an epidemic in the nursery

XRAY Findings
• Need a 3 way of the abdomen or at least a flat plate and left lateral decubitus to adequately look for free air above the liver. Can consider cross-table lateral if infant unstable.
• Bowel wall edema, abnormal bowel gas pattern, pneumotosis intestinalis (indicating air within the subserosal bowel wall), portal venous gas, pneumoperitoneum/free air
• A large distended immobile intestinal loop on repeated XRAY suggests a gangrenous loop of bowel
• Gasless abdomen may indicate perforation and peritonitis

Management
• Bowel rest/NPO with NG decompression; start TPN once fluids/lytes are stable
• IVF resuscitation; replace 3rd space GI losses with NS boluses and follow UOP closely, may require 50-100ml/kg of volume replacement
• Correction of anemia, thrombocytopenia, DIC if needed
• Septic work-up with blood, urine and +/- CSF prior to antibiotics, depending on severity of clinical illness
• Broad spectrum antibiotics are begun empirically; typically start with ampicillin and gentamicin or cefotaxime IV and add anaerobic coverage (clindamycin or Flagyl) if peritonitis or perforation is suspected; if all cultures are negative and the infant has improved clinically, antibiotics can be stopped after 3 days, otherwise they are continued for 10-14 days with confirmed disease
• Monitor for GI bleeding by checking gastric aspirates and stool for blood, Zantac in TPN
• Follow VS, PE, and labs
• Serial abdominal films (AXR should be done every 6-8 hours during acute phase to monitor for perforation)
• Notify surgery team; surgical indications include pneumoperitoneum, abdominal wall cellulitis, fixed loop on serial AXRs, abdominal mass, portal venous gas, and/or progressive deterioration on maximum medical support
• When to reinitiate feeds after NEC is not clearly established; general recommendations include:
  • Waiting 3-5 days after mild medically treated NEC
  • Waiting 7-10 days after last abnormal X-ray, depending on severity of the clinical illness
• Start with small amounts (i.e. 20ml/kg/day) and advance slowly as tolerated. May need to start with elemental formula or breastmilk
• Limit spread of infection throughout nursery

Prognosis
• 10-20% mortality
• Strictures can occur in 25-35% of survivors after either medical or surgical therapy usually presenting 1-4 months after diagnosis. All surgically diverted infants need a distal study to rule out stricture prior to reanastamosis.
RENAL FUNCTION

- Nephrogenesis is not complete until 34 weeks gestation
- Urine output (UOP)
  - 92% of all infants urinate within the first 24 hours of life; 98% by 48 hours
  - First two days UOP = 0.6-1.2 ml/kg/hr
  - Next 4 weeks UOP = 1.5 ml/kg/hr, depending on intake
- Normal newborn kidneys cannot maximally concentrate urine secondary to immature countercurrent system and immature response to ADH (max 600-700mOsm/L)
- Creatinine (Cr)
  - Reflects Mom’s Cr on DOL 1-2
  - Should be stabilized to <0.6 by 1 week of age
  - Levels up to 1.0 are acceptable in preemies
- Glomerular Filtration Rate (GFR)
  - Cr is the most useful parameter to estimate GFR
  - Doubling of the Cr represents a 50% decrease in GFR
  - Prior to 34 weeks, GFR is low and there is glomerulotubular imbalance with limited ability to conserve glucose, phosphate, sodium, bicarbonate and amino acids which can lead to electrolyte problems

Acute Renal Failure (ARF)

- Potentially reversible reduction in filtration function
- Anuria or oliguria (<0.5ml/kg/hr) can exist
- Changes in serum creatinine are the most reliable indicator of the degree of altered renal function
- Etiology
  - Prerenal failure due to decreased renal perfusion (most common cause) secondary to hypovolemia, hypoxia or hypotension
  - Intrinsic renal failure or renal parenchymal injury due to acute tubular necrosis, nephrotoxins, congenital anomalies, DIC, renal vein thrombosis, renal artery thrombosis, hemolysis, medullary or cortical necrosis and structural anomalies (aplasia, dysplasia, polycystic kidney disease)
  - Postrenal failure secondary to obstruction of urinary outflow due to a blocked urinary system or a neurogenic bladder
- Clinical findings
  - Irritability, pallor, emesis, poor feeding and lethargy, although nonspecific, are suggestive of uremia
  - Assess overall fluid/hydration status and UOP
  - Look for Potter’s facies
  - Look for signs of pulmonary hypoplasia (small lung/volumes, barrel shaped thorax)
  - Try and palpate for enlarged kidneys or bladder
- Work-up
  - Initial labs include BUN/Cr, electrolytes, U/A, and consider CBC
  - If concern for neurogenic bladder – consider passing catheter to check residuals
  - Perform a diagnostic fluid challenge of 10ml/kg NS IV and repeat once as needed, if no signs of volume overload exist
  - If no response to fluid bolus, given 1mg/kg of furosemide
  - If still no increase in UOP, perform an U/S to check for obstruction or consider a diagnosis of intrinsic renal failure
- Complications or concurrent problems
  - Hyperkalemia, circulatory collapse, sepsis, metabolic acidosis, hypertension, hypervolemia, hyperphosphatemia, hypocalcemia and osmolar disequilibrium
- Management
  - Find the specific cause and treat that
  - Keep strict I/Os and frequent weight checks
  - Adjust fluids so patient is only receiving insensible fluid losses (50-70 ml/kg/d in preterm infants; 30 ml/kg/d in term infants) plus fluid output (urine and GI losses)
  - Follow electrolytes especially K, and ensure that IVFs do not contain K
  - Restrict protein to <2g/kg/d; often PM 60/40 formula is used
  - If phosphate rising – consider binders like aluminum hydroxide and follow Ca closely (may need to be replaced)
  - Peritoneal dialysis in rare occasions

Hematuria
- Definition – presence of gross or microscopic blood (>3 RBC/hpf) in the urine
- Pathophysiology/Etiology
  - Perinatal asphyxia
  - UTI
  - Trauma
  - Coagulopathy
  - Renal vein thrombosis (RVT) – may have association with maternal diabetes
  - Renal artery thrombosis (RAT) – usually in association with HTN? h/o UAC
  - Acute tubular necrosis (ATN)
  - Polycystic disease
  - Cortical or medullary necrosis
  - Urinary tract obstruction
  - Acute interstitial nephritis (AIN) – usually drug related
  - Neonatal glomerulonephritis (most commonly caused by syphilis)
  - neoplasms – rare cause
- Work-up
  - U/A and culture
  - BUN/Cr
  - CBC
  - Coagulation studies
  - Imaging study
- Management
  - Directed at underlying cause

Urinary Tract Infection (UTI)
- Definition
  - Catheterization - >1000-10,000 cfu/ml of single organism
  - Suprapubic aspiration (bladder tap) - >10 cfu/ml
- Pathophysiology
  - In infants <1 yr, an associated urinary tract abnormality often exists
  - The primary organisms are GN rods especially E coli
  - In neonates, UTIs are frequently acquired by hematogenous spread
  - Risk factors include indwelling catheters, systemic sepsis with hematogenous seeding, urinary tract obstruction, neurogenic bladder, and uncircumcised males
- Clinical findings
  - Signs of sepsis, lethargy, irritability, poor feeding, vomiting, jaundice, FTT
- Lab findings
  - U/A may show WBCs, nitrites or bacteria
  - Positive urine culture
  - Leukocytosis on CBC
• Serum bilirubin may be elevated

Management
• Ampicillin plus gentamicin initially until urine culture results known
• If meningitis is diagnosed or suspected, include a 3rd G cephalosporin

Urinary tract evaluation
• Young children with UTIs have a relatively high incidence of anatomic abnormalities and increased risk of renal scarring in the subpopulation with reflux
• An ultrasound evaluates for major anomalies and obstruction
• A voiding cystourethrogram (VCUG) evaluates for reflux and for posterior urethral valves (in males); if this is not done while on antibiotics, prophylactic antibiotics (Penicillin or Amoxicillin) are often given until the study is performed

Hypertension (HTN)
• Definition
  • Refer to table in text book or Harriet for specific age/weight values
  • In full-term infants - systolic BP>90 and diastolic BP>60
  • In preterm infants – systolic BP>80 and diastolic BP>50
  • Ensure that a manual BP is taken in addition to any UAC readings
  • BP should be higher in the legs than in the arms (o/w ? coarctation of the aorta should be suspected when leg pressures are 15-20 points lower than arms, and/or pulses hard to palpate)
  • BP cuff should approximate 2/3 length of the arm
• Differential diagnosis
  • Vascular causes
    • Coarctation of the aorta
    • RAT, RVT
    • Congenital renal artery stenosis
    • Aortic thrombosis
  • Renal causes
    • Polycystic kidney
    • Hypoplastic kidney
    • Obstructive uropathy
    • Renal insufficiency
    • Multicystic kidney
    • Renal tumors
  • Other causes
    • Fluid and electrolyte problems
    • Medications
    • Increased ICP
    • Neural crest tumors
    • Pain or agitation
    • BPD
    • Endocrinopathies (Cushing’s disease, primary hyperaldosteronism, hyperthyroidism, CAH)
• Clinical findings
  • Check femoral pulses
  • Examine abdomen for renal masses
  • Check for symptoms of CHF
• Lab findings
  • Assess renal function with BUN/Cr, electrolytes, U/A and Cx
  • Other studies including renin, VMA, etc can be ordered based on suspicion
  • Radiologic studies include abdominal U/S and echo initially
- Management
  - Find and treat underlying cause
  - Correct any fluid overload and follow volume status
  - Maintenance agents include a diuretic, ACE-I, B-blocker, or alpha-antagonist
Disabilities at 6-7 years of Age Dependant on Birth Weight

1. Frequency of major disabilities (CP, MR) increases as the gestation decreases: 5-10% at 30-34 weeks; 20-25% at 24-25 weeks.
2. Lesser handicaps also increase at lower gestational age.

Cerebral Palsy
- Chronic nonprogressive disability of cerebral origin characterized by aberrant control of movement or posture, starting in the neonatal period.
- **Paraplegia** - Weakness of both legs without any involvement of the arms; Rare - suggests either an abnormality of the spinal cord or peripheral nerves
- **Spastic Quadriplegia** - Partial or complete weakness of all limbs. May be asymmetrical involving mostly right or left side and termed hemiplegia. Developmental delay is usually profound, often with microcephaly, visual disturbances and seizures.
- **Spastic Diplegia** - Most common CP associated with prematurity. All four limbs affected with legs much more severely affected than arms.

Periventricular Leukomalacia
- Necrosis of white matter secondary to hypoxic-ischemic injury. Periventricular area is most vulnerable 'watershed area' in premature infants. Perisagittal area is most vulnerable 'watershed area' in term infants.
- Incidence is 5-10% of < 1500 grams by ultrasound and as high as 70% by MRI.
- Presence of this on ultrasound correlates highly with cerebral palsy.
- Cerebral palsy can still occur with absence on ultrasound.
Intraventricular Hemorrhage (IVH)
- Occurs in 20%-30% of all VLBW (<1500 gram infants). Inversely related to gestational age.
- < 28 Weeks = 3x higher incidence of bleeds with 2x higher risk of severe bleeds compared to 28-31 weeks.
- Most hemorrhages occur in first 2 postnatal days and almost all by 1 week.
  
  **Mild Intraventricular Hemorrhage**
  Grade 1 - Isolated germinal matrix hemorrhage.
  Grade 2 - Intraventricular hemorrhage without dilation of ventricle
  *Neuro Outcome* - Not at increased risk for handicap including motor disability, learning, and behavior problems.

  **Moderate Intraventricular Hemorrhage**
  Grade 3 - Intraventricular hemorrhage with acute ventricular dilation
  *Neuro Outcome* ~ 40% develop diplegia or quadraplegia; ~ 50% need special education; possible ventricular peritoneal shunt (<10%).

  **Severe Intraventricular Hemorrhage**
  Grade 4 - Intraventricular Hemorrhage with parenchymal hemorrhage
  *Neuro Outcome* - Most die. ~ 80% of survivors have significant disability often contralateral hemiparesis

*Note:* Children born at ≤ 28 w GA are at increased risk for handicap even with a normal cranial ultrasound.

Cranial Ultrasound Screening Guidelines for IVH and PVL
- At any time for neurological concerns
- ≤ 28 6/7 weeks at ~10 days and 4-6 weeks
- 29-32 weeks at 4-6 weeks
- If ≥ Grade 3 bleed found, repeat CUS Q 1-2 weeks until stable or resolving.

'Watershed' - most vulnerable areas of the Brain
- Term infants- parasagittal area
- Preterm infants - periventricular
Perinatal Asphyxia - Hypoxic Ischemic Encephalopathy (HIE)

**Definition**
- Evidence of significant birth depression such as: Profound metabolic or mixed acidemia (pH < 7.00 &/or Base deficit ≥ 16) on cord or arterial gas in the first hour of life or low apgar score (≤ 5), or continued resuscitation > 10 min.
- Evidence of encephalopathy or neurologic manifestation (seizures, lethargy, hypotonicity, coma or irritability).
- Evidence of multiorgan dysfunction.

**Significance**
- Incidence ~ 2-4/1000 term infants and up to 60% of very low birth weight infants.
- 20-60% of babies with HIE die.
- ~ 25% of survivors exhibit permanent neuropsychological handicaps such as cerebral palsy, mental retardation, learning disabilities or epilepsy. This incidence varies dependent on the severity of encephalopathy.

**Neurologic Outcome Based on Sarnat Stages**
- Stage 1 (mild) - Total=79. 0% experienced neurologic handicap (CP, MR, epilepsy, deafness or blindness), death or reading disabilities without other neurologic deficits at 3.5 years and 8 years.
- Stage 2 (mod)- Total=119. 6% died. 20% had neurologic handicaps and 35% reading disabilities without other neurologic handicaps.
- Stage 3 (severe) - Total=28, 100% of survivors with neurologic handicaps. 75% died by 3.5yrs.

**SARNAT STAGES - CLINICAL STAGING OF HYPOXIC-ISCHEMIC ENCEPHALOPATHY**

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>STAGE 1</th>
<th>STAGE 2</th>
<th>STAGE 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level of Consciousness</td>
<td>Alert</td>
<td>Lethargy</td>
<td>Coma</td>
</tr>
<tr>
<td>Muscle Tone</td>
<td>Normal or Hypertonia</td>
<td>Hypotonia</td>
<td>Flaccidity</td>
</tr>
<tr>
<td>Tendon Reflexes</td>
<td>Increased</td>
<td>Increased</td>
<td>Depressed or Absent</td>
</tr>
<tr>
<td>Myoclonus</td>
<td>Present</td>
<td>Present</td>
<td>Absent</td>
</tr>
<tr>
<td>Seizures</td>
<td>Absent</td>
<td>Frequent</td>
<td>Frequent</td>
</tr>
<tr>
<td>Complex Reflexes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suck</td>
<td>Active</td>
<td>Weak</td>
<td>Absent</td>
</tr>
<tr>
<td>Moro</td>
<td>Exaggerated</td>
<td>Incomplete</td>
<td>Absent</td>
</tr>
<tr>
<td>Grasp</td>
<td>Normal or Exaggerated</td>
<td>Exaggerated</td>
<td>Absent</td>
</tr>
<tr>
<td>Oculocephalic (doll's eye)</td>
<td>Normal</td>
<td>Overactive</td>
<td>Weak or absent</td>
</tr>
<tr>
<td>Autonomic Function</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pupils</td>
<td>Dilated, reactive</td>
<td>Constrictive, reactive</td>
<td>Variable or fixed</td>
</tr>
<tr>
<td>Respirations</td>
<td>Regular</td>
<td>Periodic, variable</td>
<td>Apneic</td>
</tr>
<tr>
<td>Heart Rate</td>
<td>Normal or tachycardia</td>
<td>Bradycardia</td>
<td>Bradycardia</td>
</tr>
<tr>
<td>EEG</td>
<td>Normal</td>
<td>Low voltage</td>
<td>Very low voltage, Burst suppression or isoelectric</td>
</tr>
</tbody>
</table>

**Other Systemic Complications of Perinatal Asphyxia (End Organ Damage)**
- Acute Tubular Necrosis
- Hepatic Necrosis; hypoglycemia
- Cardiomyopathy
- Necrotizing Enterocolitis
- Meconium Aspiration Syndrome
- Persistent Pulmonary Hypertension
- DIC; Adrenal Insufficiency and SIADH
Initial Management of Perinatal Asphyxia

- **Respiratory**: Often require ventilation, possible HFV, &/or NO
- **Cardiac**: Arterial line, often require pressors and initial boluses, consider ionized calcium.
- **Hematology**: CBC, DIC panel? PRBC’s, ?FFP, watch for jaundice.
- **Renal**: Foley catheter placement, fluid restriction (60-80 ml/kg/d), limit potassium, Check Bun/Cr and frequent electrolytes, consider high dose Lasix for no UO > 12-24 hrs.
- **Liver**: Initial LFTs, may need to limit protein (can have high ammonia) and supplement albumin.
- **Intestines**: First organ to have blood supply limited with asphyxia. Initially should be NPO and then slow initiation and advancement of feeds.
- **Endocrine**: At risk of SIADH and Adrenal insufficiency. Watch electrolytes and I’s/O’s carefully. If hypotension persists or is out of proportion to cardiac status, consider sending cortisol level and replacement or stress hydrocortisone.

If the infant survives after perinatal asphyxia - all organs but the brain usually fully recover.

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### Treatment with cerebral and systemic hypothermia to rectal temperature of 33-35 degrees celsius starting by 6 hours after perinatal asphyxia and continuing for 48-72 hours is approved as a treatment modality. This has shown the greatest promise in infants with moderate (stage 2) encephalopathy.

- Decreases Oxygen Consumption of Brain by 6-7% and Cerebral Energy Utilization Rate by 5.3% per Degree Celsius Decrease Below Normal Body Temperature.

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### Current Guidelines for Management of Perinatal Asphyxia

- Attempt to maintain normal temperature during and after resuscitation avoiding overheating which may be very detrimental.
- Treat maternal fever during labor aggressively.
- Consider immediate referral of asphyxiated infants to a center offering hypothermia.
- Avoid Hypotension, Hypoglycemia, Severe Hypocarbia, and Recurrent Hypoxia Postnatally as they may exacerbate the Insult.
- Rigorous Recognition and Treatment of Even Subtle or Subclinical Seizures Postnatally May be Beneficial.

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### Neonatal Seizures

**Overall Most Common Causes of Early Seizures (1st 3 days) by Frequency**

1. Hypoxic Ischemic Encephalopathy (HIE)
2. Bleed (Intraventricular - premature infant; Subarachnoid, Subdural, Epidural or Parenchymal - near term infants.)
3. Infection

**Differential Diagnosis of Seizures by Time of Onset**

#### 24 Hours

1. Hypoxic Ischemic Encephalopathy
2. Bacterial Meningitis and Sepsis
3. Subarachnoid Hemorrhage
4. Intraventricular Hemorrhage
5. Subdural or Epidural Hemorrhage
6. Intracranial Parenchymal Hemorrhage
7. Cerebral Infarct
8. Direct Drug Effect
9. Pyridoxine Deficiency
10. Hypoglycemia
11. Transplacentally Acquired HSV

#### 24 to 72 Hours

1. Drug Withdrawal
2. Hypocalcemia / Hypoparathyroidism
3. Inborn Error of Metabolism/ Urea Cycle Defects
4. Cerebral Dysgenesis
**72 Hours to 1 Week**
1. Cerebral Dysgenesis
2. Cerebral Infarct
3. Benign Familial Neonatal Convulsions
4. Hypoparathyroidism/ Hypocalcemia
5. Kernicterus
6. Inborn Error of Metabolism (Urea Cycle Defects, Ketotic Hyperglycemia)
7. HSV
8. Tuberous Sclerosis

**1 Week to 4 Weeks**
1. Cerebral Dysgenesis
2. HSV
3. Neonatal Adrenoleukodystrophy
4. Inborn Error of Metabolism (Ketotic Hyperglycinemias, Fructose Dymetabolism, Gaucher Disease Type II, GM1 Gangliosidosis Type I)

*Many of Neonatal Seizures are Subtle or Subclinical and Difficult to Recognize*

<table>
<thead>
<tr>
<th>Clinical seizure type</th>
<th>Frequency (%)</th>
<th>Consistent EEG correlation</th>
<th>Poor EEG correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subtle</td>
<td>30%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bicycling</td>
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<td>+</td>
<td></td>
</tr>
<tr>
<td>Oral-buccal-lingual</td>
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<td>+</td>
<td></td>
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<tr>
<td>Tonic eye deviation</td>
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<td>Autonomic phenomena</td>
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<td>Complex movements</td>
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<td>Clonic</td>
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<tr>
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<tr>
<td>Multifocal</td>
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<tr>
<td>Tonic</td>
<td>20%</td>
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<tr>
<td>Focal</td>
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<tr>
<td>Generalized</td>
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<td>+</td>
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<tr>
<td>Myoclonic</td>
<td>25%</td>
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</table>

*Treatment of Seizures*
- Ativan 0.1 mg/kg IV or 0.2 mg/kg nasally, sublingually or rectally.
- Phenobarbital 20-40 mg/kg IV or orally load. 3-5 mg/kg/day maintenance dose.
- Dilantin 15-20 mg/kg IV load. 4-8 mg/kg/day maintenance dose.

*Prognosis of Neonatal Seizure*
- Overall > 50% of infants with neonatal seizures have normal development.
- ~ 50% of neonates with seizures 2º HIE have normal development.
- ~ 90% of neonates with seizures from subarachnoid hemorrhage have normal development.
- < 10% of neonates with seizures from intracerebral hemorrhage from hemorrhagic infarct have normal development.
- 2-26% of neonates with seizures have epilepsy with mean age of onset of 13 months. 68% of those with moderately to severely abnormal background on EEG developed epilepsy.
- Majority of neonates with normal EEG background have normal development.
HEMATOLOGY

Transfusions

The transfusion of blood products to neonates (infants up to 28 days of age) is common. Most frequently, Pack Red Blood Cells are transfused to:
- Restore Circulating Blood Volume
- Increase Oxygen-Carrying Capacity
- Replace blood removed for labs

The need for erythrocyte transfusion must be balanced against potential risks to the baby for whom special screening, preparation and administration of blood products are required in addition to usual blood-banking procedures.

Minimizing the Risks:
Many risks of erythrocyte transfusion to neonates have been effectively eliminated through usual blood donor screening and blood banking practices. Of the numerous risks one is of particular importance — cytomegalovirus (CMV) infection.

- CMV: CMV infection has been reported in premature neonates receiving CMV-positive blood. Very premature babies appear to be at highest risk of serious illness associated with such transfusion-acquired infection. The incidence of CMV infection may be eliminated with the use of saline-washed frozen erythrocytes and leukocyte filtration.

- Additional risks:

  Transfusion Associated Viral Infection (one unit exposure):
  - EBV: 1:333,333
  - HIV: 1:420,000
  - Hep B: 1:200,000
  - Hep C: 1:6,000
  - HTLV: 1:50,000

  Other Metabolic/Hemodynamic concerns:
  - Hyperkalemia
  - Volume Overload
  - Iron Overload

Indications for transfusions (Strict):

- Shock due to blood loss (Vasa preva, Premature cord separation, Feto-maternal transfusion)

Indications for transfusions (relative):

- Transfuse if hematocrit < 20%
  - Asymptomatic infant, if reticulocytes <100,000/ul (< 2% corrected retics)
- Transfuse if hematocrit < 25%
  - Oxygen requirement < 40%
  - On CPAP or IMV with Mean airway pressure < 8 cm H2O
  - Significant apnea and bradycardia while on methylxanthines (>9 episodes in 12 hours or 2 episodes in 24 hours requiring mask and bag ventilation)
  - if pulse > 180 beats/min or respiratory rate > 80/min and persists for 24 h
  - Weight gain < 10g/d over 4 days despite adequate calories
  - Sepsis or Elevated Serum Lactate (>2.5mEq/L)
- Transfuse if hematocrit < 35%
  - Oxygen requirement > 40%
  - Intubated or CPAP with mean airway pressure > 8 cm H2O
Additional Info:
- Capillary Hematocrit will be higher (up to 10 points) than central sample
- Congenital heart disease patients often require higher hematocrits
- Iron supplements after 1 – 2 months of age (2-4mg/kg/day) if HCT < 30%, retics < 4%
- To prevent exposure to multiple donors, babies have unit assigned to them upon admission; keep track of the date of expiration (if patient may be a candidate for PRBC near the date of expiration; give the PRBCs before they expire)

Transfusion administration:
- HCT < 30%: Give 10ml/kg PRBC over 4 hours x 2 aliquots 12 hours apart; check HCT after 2nd aliquot
- HCT > 30%: Give 10 – 15ml/kg PRBC over 4 hours; check HCT after transfusion
- Consider Lasix mid-transfusion or after transfusion if volume status dictates (Lasix is not always indicated!!!)

Erythropoietin (EPO):
- Infant expected to receive multiple early transfusions (ELBW patients)
  - Consider 200 U/Kg/d and 1mg/Kg/d of Fe Dextran in TPN for 2 weeks
- After 2 weeks of age, consider 300U/kg MWF SQ for 2 weeks together with 6-8mg/kg/d Iron (elemental) if HCT <35% and/or the infant is at high risk for a late transfusion;
  - Anticipated High Phlebotomy Losses
  - Severe Chronic Lung Disease
  - S/P Severe Hemolytic Disease of the Newborn
  - Jehovah’s Witness
- NOTE: If infant still has blood available from initial unit, would transfuse rather than using EPO.
- Alternatively, can plan for a single late transfusion with the existing unit of blood or plan for use of rescue EPO at 400U/kg/d for 7-10 days along with Iron for HCT <25% or <28% with symptoms and an inadequate reticulocytes response.

Transfusions (non-PRBC)

Fresh Frozen Plasma (FFP): is indicated to correct deficiency of multiple clotting factors in bleeding patients or in patients at risk for bleeding due to an invasive procedure.
- Factor Deficiencies may be secondary to Liver Synthetic Dysfunction, Vitamin K Deficiency, Massive Bleeding, or Disseminated Intravascular Coagulopathy.
- Corrects Deficiencies of: Anti-thrombin III, Factors II, V, VII, IX, XI, Protein C and S
- The Maximal Effect Declines 2 Hours After Transfusion
- Typical dose: 10-15ml/kg/dose

Cryoprecipitate: Indicated primarily for the correction of fibrinogen deficiency (congenital or acquired).
Platelets: The normal circulating platelet count for all ages ranges from 150,000 to 400,000. Average lifespan of a platelet is 7-10 days. The bleeding time is prolonged in thrombocytopenic patients, particularly those with counts <100,000. Severe thrombocytopenia may present with pinpoint purpura known as petechiae. Prolonged bleeding at venipuncture sites or incisions may occur. There is no direct link between bleeding risk and absolute platelet count. In general, the risk for spontaneous bleeding increases with platelet counts <20,000. Consider the possible etiologies:

- Increased platelet destruction:
  - Isoimmune Thrombocytopenia: Accounts for 20% of Neonatal Thrombocytopenia, incidence of 1:1000 births. Results from placental passage of maternal antibodies directed against paternally inherited antigens present on fetal platelets. Typically involves IgG antibodies (analogous to Rh hemolytic disease of the newborn). The most frequently implicated antigen: PI A1 (75% of cases). Suspect this in the face of isolated thrombocytopenia at birth. May be severe with platelet counts <10,000 on day of life 1. Confirmed with laboratory testing. Treatment of choice is administration of IVIG.
  - Autoimmune thrombocytopenia (maternal ITP)
  - Infectious processes: Sepsis, CMV disease (congenital)
  - Giant Hemangioma (Kasabach-Merrit Syndrome)
  - Disseminated Intravascular Coagulopathy (with or without sepsis)

- Underproduction of platelets:
  - Congenital Infections
  - Sepsis
  - Syndromes:
    - Fanconi’s Anemia
    - Wiskott-Aldrich
    - TAR (Thrombocytopenia with absent radii)

Platelets: provision of 10ml/kg of normally concentrated platelets will increase platelet count by 50,000/mm3

- Hemorrhagic complications rare with counts > 10,000/mm3

Pre-surgery requirements typically > 50,000/mm3 but may be >100,000/mm3. In preterm infants at risk for IVH, consider keeping counts > 50,000/mm3.

BLEEDING ABNORMALITIES

Hemorrhagic Disease of the Newborn (A.K.A.: Vitamin K Deficiency):

- Newborns are relatively vitamin K deficient for a variety of reasons:
  - Low Vitamin K stores at birth
  - Poor placental transfer of Vitamin K
  - Low Vitamin K levels in breast milk
  - Gut sterility

- Most common sites of bleeding:
  - Umbilicus, Mucous membranes, GI tract, Circumcisions, Venipunctures, areas of trauma
  - Intracranial bleeding (less common) main cause of mortality and long-term morbidity

- Statistics:
  - Frequency: 0.25-1.7%
  - No racial or sex predilection
  - Age of onset:
    - Early (First 24 hours of life): Rare and almost always associated with maternal medications that interfere with Vitamin K (Anti-epileptics, Anti-coagulants, Antibiotics). Postnatal vitamin K has no effect in preventing early onset disease
    - Classic (2 – 7 days of life): Typically found in breastfed infants. Prevent with postnatal Vitamin K
    - Late Onset (after 2 weeks of life): Associated with breast feeding, as well as, hepatitis, CF, Celiac disease, α-1 Antitrypsin disease. Most severe (high incidence of ICH).
• Lab Evaluation:
  o Include prothrombin time (PT), activated partial thromboplastin time (aPTT), fibrinogen levels, and a platelet count in the initial work-up for bleeding in a newborn. A thrombin clotting time (TCT) is optional.
  ▪ Prolonged PT is the first laboratory test to be abnormal
  ▪ Vitamin K direct assays are not useful (levels are normally low in all newborns)
  ▪ Typically have normal platelet counts and fibrinogen levels.
  ▪ Vitamin K brings a halt to the bleeding and corrects the elevated PT and PTT
• Treatment:
  o Prevent with postnatal Vitamin K
    ▪ Vitamin K 1mg IM (>1500g birthweight)
    ▪ Vitamin K 0.5mg IM (<1500g birthweight)
  o If bleeding, obtain lab studies and give Vitamin K if suspect deficiency
  o For severe bleeding, give FFP

Polycythemia: Defined as a red cell mass 2 standard deviations above normal for age and gestation. For a term infant the upper limit of normal for Hb 20gm/dl and HCT 65%. Whole blood viscosity increases with increases in RBC mass. Infants with HCT above 65% are at risk for hyperviscosity syndrome: Listlessness, hypoglycemia, respiratory distress, systemic thrombosis. Also, often associated with exaggerated hyperbilirubinemia. Patients with HCT >70% should be considered for a partial volume exchange transfusion (using normal saline). Treatment should be done for any infant with symptoms. Partial Volume Exchange Transfusion is accomplished by using the following formula:

\[
\frac{PVH(\%) - DH(\%) \times BV(mL/kg) \times Wt(kg)}{PVH(\%)}
\]

PVH = Peripheral Venous Hematocrit
DH = Desired Hematocrit
BV = Blood Volume
Wt = Weight

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HYPERBILIRUBINEMIA

Etiology/Pathophysiology of Hyperbilirubinemia

- 60% of all newborns experience jaundice
- Metabolism:
  - Bilirubin is derived from the catabolism of proteins that contain heme, and usually from the breakdown of hemoglobin from RBCs. In the RES, heme is oxidized to biliverdin and then reduced to bilirubin, which is relatively insoluble in water but very lipid soluble. Bilirubin circulates bound to albumin in equilibrium with its unbound fraction that readily cross the blood brain barrier and causes neurotoxicity.
  - Bilirubin is made more water soluble in the liver by conjugation with glucuronic acid to produce conjugated bilirubin (CB) or direct bilirubin. Some CB is excreted in the urine, but most is excreted as bile, which gets metabolized by intestinal bacterial flora and excreted in the feces.
  - The danger of indirect or unconjugated hyperbilirubinemia (UB) is the fear of kernicterus – yellow staining of the brain affecting the basal ganglia, hippocampus, and the cerebral and bulbar nuclei ultimately resulting in chorioathetoid cerebral palsy, absent upward gaze, and higher frequency hearing loss.
  - Phototherapy works by bypassing the hepatic system and producing photoisomers of bilirubin that are more water soluble. These can then be cleared directly in bile or urine without conjugation in the liver.
- Causes
  - Physiologic jaundice due to immature hepatic glucuronyl transferase
  - Excess bilirubin production from RBC breakdown
    - Intravascular = hemolysis or polycythemia
    - Extravascular = bruising or cephalohematoma
  - Decreased removal of bilirubin through the gut
    - Decreased meconium evacuation = increased enterohepatic recirculation
    - Decreased bile flow due to liver disease or cholestasis
  - Sepsis/viral infection
  - Breastfeeding jaundice – occurs in the first week after birth and implies inadequate hydration or caloric intake
  - Breastmilk jaundice – there are unidentified factors in the normal mature human milk that cause increased reabsorption of UB from the gut; can last for 3-4 weeks (up to 3 months)

Clinical Findings

- Jaundiced skin and scleral icterus
- Any visible jaundice by 24 hours of age indicates hemolysis until proven otherwise
- Approximation of TB based on inferior border of jaundice:
  Caution: Errors can occur, especially in babies with dark skin.
  
<table>
<thead>
<tr>
<th>Location</th>
<th>Approximation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>5</td>
</tr>
<tr>
<td>Chest</td>
<td>10</td>
</tr>
<tr>
<td>Umbilicus</td>
<td>15</td>
</tr>
<tr>
<td>Legs</td>
<td>25</td>
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</tbody>
</table>
- Check the infant’s intake, output and weight change since birth
- Look for pallor, plethora, bruising, cephalohematomas and hepatosplenomegaly

Lab Findings

- Term infants peak between 3-5 days
- Preterm infants peak at 5-6 days
- Concept of rate of rise of bilirubin is important and can be useful
- The only condition, in which the rate of rise has been proven to be predictive is Rh hemolytic disease, so it is crucial to think about this in Rh disease, but can be helpful in any case.
- You can calculate how fast the Bili level has risen over a period of time and ask yourself “If this rate of rise continues, when will the Bili reach the predicted exchange level?” and decide at what level phototherapy should be initiated to prevent an exchange transfusion
Work-Up

- First step is to determine whether the jaundice is pathologic or not (i.e. is it evident at <24hrs, is TB increasing at >1mg/dl/hr, is there true hemolysis, is there HSM)
- Check maternal ABO, Rh typing and serum screen for “irregular” isoimmune antibodies
- Check cord blood type, Rh and direct Coombs
- Check TB for first screen (fractionated not needed initially)
- Consider CBC, diff, retic and blood smear based on history, risk factors and exam
- For persistent jaundice at 2-3 weeks of age, a more comprehensive evaluation including fractionated Bili, LFTs, TFTs, ammonia, PT/PTT, sweat test, alpha-1 antitrypsin level, blood and urine cultures and imaging studies of the liver (US or HIDA) should be considered.

Work-Up and Diagnosis of Unconjugated Hyperbilirubinemia

Conjugated $\rightarrow$ Hyperbilirubinemia $\rightarrow$ Unconjugated

**Extrahepatic obstruction**
- Genetic and metabolic disorders
- Intrahepatic cholestasis

**Coombs Test**
- Positive
- Negative

**Isoimmunization**
- Rh, ABO, minor blood grps
- Maternal autoimmune hemolytic anemia

**Hemoglobin**
- NL/low
- High

**Retic count**
- High
- Normal

**Twin-twin transfusion**
- Maternal-fetal transfusion
- Delayed cord clamping
- SGA infant

**Management**
- Remember the goal of therapy is to prevent kernicterus
- If there is any clinical jaundice at <24hrs, place the baby under phototherapy while awaiting lab results and follow TB every 4-6 hours, until level is controlled
- Several factors are considered when determining the bilirubin level above which kernicterus may be possible (i.e. the exchange level):
  - Gestational age (preemies have a less mature blood brain barrier)
  - Degree of illness (babies who are sick can have a damaged blood brain barrier)
  - Evidence of hemolysis or not
• A common guideline to determine the Bili level at which double volume exchange transfusion should be performed was established for hemolytic disease: at term exchange at 20; then subtract 0.5 for each week <38wks
• See the following charts on guidelines for initiating phototherapy and exchange transfusion in sick and healthy infants
• Phototherapy
  • Goal is to avoid an exchange transfusion
  • ANSWER THE QUESTION: Based on rate of rise (i.e. etiology), at what level must phototherapy begin (or continue) to prevent reaching exchange level?
  • Since it takes phototherapy about 24 hours to halt the rise of Bili at the usual rate of rise for exaggerated physiologic jaundice (which is 5 per day), usually phototherapy is started at 5 less that the exchange level
  • In the presence of hemolysis, which has a much greater rate of rise, phototherapy must be started at a much lower level
  • Increase fluids 20% for each bank of lights added
  • Dual therapy utilizing the Bili blanket and conventional phototherapy is most effective
• Exchange transfusion
  • To remove infants’ sensitized and destroyed RBCs and circulating antibodies
  • Double-volume exchange replaces 85% of the circulating RBC volume
  • Decreases the Bili level by ½ and corrects anemia
  • Indications
    • Bili levels rising >1mg/dl/hr
    • Bili at 20 in term baby with hemolysis; lower in preterms with hemolysis
    • Bili at 25-30 in the term infant without hemolysis; it may be indicated at lower Bili levels in the face of sepsis, anemia, acidosis, hypoxia or hypoproteinemias
    • Cord blood bilirubin >4.5 and Hgb<11
  • Technique of a simple 2 volume exchange
    • Infant blood volume is 80ml/kg and you need 2x the blood volume for exchange
    • Type and cross match to mother’s blood
    • Need a UVC (+/- UAC) to withdraw blood as equal volumes are infused
  • IVIG can be used in infants with hemolytic disease and a rapid rate of bilirubin rise.

![Guidelines for Exchange Transfusion in Infants ≥ 35 Weeks](image)

Figure 4: The risk factors listed for this figure are factors that increase the likelihood of brain damage at different bilirubin levels. Infants are designated as “higher risk” because of the potential negative effects of the conditions listed on albumin binding of bilirubin, the blood-brain barrier, and the susceptibility of the brain cells to damage by bilirubin.
Outpatient Management

- Before discharge, every newborn needs to be assessed for the risk of subsequent severe hyperbilirubinemia. This can be done with clinical criteria/or by measuring a bilirubin level (see below).
- Use of hour specific bilirubin measurement (in the absence of a positive direct coombs) can be used to assess the risk of developing clinically significant hyperbilirubinemia. Approximately 40% of infants in the high-risk zone develop significant hyperbilirubinemia, 13% of those in high-intermediate risk; 2% in low-intermediate risk.
**Major risk factors**
- Predischarge bilirubin in the high risk zone
- Jaundice observed at < 24 h
- Blood group incompatibility
- GA of 35-36 w
- Previous sib needing phototherapy
- Cephalohematoma or bruising
- Exclusive breastfeeding
- East Asian Race

**Minor risk factors**
- Predischarge bilirubin in the high intermediate risk zone
- GA 37-38 w
- Visible jaundice prior to discharge
- Previous sib with jaundice
- Macrosomic in an IDM
- Maternal age ≥ 25 y
- Male sex

*Figure 1–2. Risk designation of term and near-term newborns based on their hour-specific bilirubin values. (Reproduced, with permission, from Bhutani VK et al: Predictive ability of a predischarge hour-specific serum bilirubin test for subsequent significant hyperbilirubinemia in healthy term and near-term newborns. Pediatrics 1999;103[6].)*
METABOLIC DISORDERS

I. Presentations.
   A. Before birth – rare.
      1. Placental protection – Placenta usually provides effective dialysis of toxic materials.
      2. Acute fatty liver of pregnancy and HELLP are associated with LCHAD deficiency.
      3. Hydrops fetalis, ascites, and prenatally diagnosed dysmorphic features are other possible presentations.
   B. Deterioration after a symptom free period.
      1. Acute parenchymal liver disease – jaundice, hepatomegaly, clotting disorders.
      2. Acid – Base disorders.
         a. Severe, unexplained, or persistent metabolic acidosis.
         b. Lactic acidosis may also be secondary to hypoxia, cardiac disease, infection, and convulsions.
         c. Mild respiratory alkalosis in a non-ventilated patient suggests hyperammonemia.
      3. Cardiac disease – cardiomyopathy, arrhythmias, pericardial effusions.
      5. Hypoglycemia – severe, persistent, unexplained.

II. Diagnostic investigations – best to obtain samples when symptomatic.
   A. First line – CBC, BUN, lytes, anion gap, glucose, blood gas, ammonia, lactate, pyruvate, LFTs, urine for reducing substances and ketones, CSF lactate especially with neurologic symptoms.
   B. Second line – urine organic acids and amino acids, plasma amino acids, uric acid, carnitine, and acyl carnitine profile.
   C. Complete characterization usually requires enzyme assays, DNA analysis, or family studies.

III. General treatment.
   A. Stop any nutrients possibly contributing to symptoms.
   B. Provide IV or oral glucose to prevent catabolism.
   C. Insulin to correct any associated hyperglycemia and reduce catabolism.
   D. Correct tissue perfusion, dehydration, acidosis, hypothermia, and anemia.
   E. Treat hyperammonemia with sodium benzoate, sodium phenylbutyrate, arginine, and/or dialysis.
   F. Specific therapies are dependent on final diagnosis.

IV. Studies to obtain if death is inevitable.
   A. Blood spot on a screening card.
   B. Lithium heparin and EDTA blood samples.
   C. Freeze urine in sterile containers.
   D. Prepare for skin, liver, and muscle biopsy.
ENDOCRINE

Congenital Adrenal Hyperplasia
21-OH Deficiency

Etiology
- The adrenal cortex synthesizes three classes of hormones: glucocorticoids, mineralocorticoids and sex steroids; a deficiency in one of the enzyme pathways can result in disregulation of the hormone end products
- 21-OH deficiency accounts for more than 90% of CAH cases resulting in deficient cortisol, increased ACTH, adrenal hyperplasia and increased adrenal androgens
- Classification includes classic (severe) simple virilizing or salt-wasting forms and nonclassic (mild) forms
- Inheritance is autosomal recessive

Clinical Findings
- Simple virilizing type findings
  - Males are normal at birth, then show precocious sexual development at 6 mo-5 years
  - Females usually show some evidence of masculinization at birth—ambiguous genitalia and nonpalpable testes, increased pigmentation of nipples, genitalia and/or skin creases
- Salt-wasting type findings
  - Approximately 75% of patients with the classic type also have a defect in aldosterone synthesis and a salt wasting crisis may occur
  - May exhibit hypovolemic hyponatremic shock shortly after birth
  - Failure to regain birthweight and progressive weight loss
  - Anorexia, vomiting and dehydration
  - Cardiac dysrhythmias with cyanosis and dyspnea
  - Death can occur within a few weeks without treatment
- Non-classic type findings
  - Presents later in childhood with signs of androgen excess, including precocious puberty, tall stature, advanced bone age, acne, hirsutism, amenorrhea or infertility

Laboratory Findings
- Electrolyte abnormalities including hyponatremia, hypochloremia, hyperkalemia and metabolic acidosis in the salt-wasting type
- Increased baseline and ACTH stimulated 17-OHP
- Increased serum androgens and urinary metabolites
- Increased plasma renin activity is seen in the salt-wasting form
- Pelvic ultrasound to identify female sex organs
- Tested for on Colorado NBS

Management
- Glucocorticoids are administered to decrease ACTH secretion, suppress the hyperplastic adrenal gland and stop overproduction of adrenal androgens preventing progressive virilization; usually hydrocortisone 10-20mg/m²/d is given orally in 3 divided doses; increased doses given during periods of stress
- Those with the salt-wasting type require a mineralocorticoid and sodium supplementation in addition to the glucocorticoid; usually given as florinef (0.05-0.3mg daily) and NaCl (1-3g); if the patient presents with a salt-losing crisis, high doses of hydrocortisone (50-100mg/m²/d in 3-4 divided doses) are required

Newborn Screening
- Measures 17-OHP levels (markedly elevated in classic 21-OH deficiency)
- Elevated levels should be confirmed with serum 17-OHP level and check electrolytes
- Does not reliably detect the nonclassic form
Hypothyroidism

Etiology
- Incidence is 1/3500-1/4500
- 2:1 ratio in females to males
- Increased incidence in Down syndrome (1/140)

Clinical findings
- Early signs include LGA, large fontanel, temperature instability, mottling of the skin, hypotonia, lethargy, poor feeding, prolonged jaundice
- Late signs usually appearing after 6 weeks include puffy eyelids, coarse hair, hoarse cry, constipation, dry skin, decreased activity, hypothermia, umbilical hernia, enlarged tongue

Laboratory findings
- Part of Colorado newborn screen
- Preemies often have a false positive newborn screens (low T4, NL TSH)
- Work-up for an abnormal screen includes repeating serum FreeT4, TSH
  - If all are normal, there is no diagnosis/problem
  - Low T4, High TSH indicates Primary Hypothyroidism
  - Low T4, Low TSH indicates Secondary Hypothyroidism
  - If T4 is low, TSH normal, T3RU increased
    - Dx is TBG (thyroid-binding globulin) deficiency and no therapy is needed
  - If T4 is low, TSH is normal and T3RU is normal or low
    - Dx is unclear - consider secondary (TSH deficiency) or tertiary (TRH deficiency) hypothyroidism or “euthyroid sick” syndrome seen with chronic disease, depression, newborn RDS, prematurity, etc
  - If T4 is low, TSH is elevated and T3RU is low
    - Dx is primary hypothyroidism and thyroxine therapy is needed

Management
- Thyroxine: 10-12 mcg/kg/d
- Steady state is achieved at 40 days
- Follow up T4, TSH, T3RU or FT4 in 4 weeks, then at 3 month intervals for 2 years
- Goal is T4 at upper limit normal, with suppression of elevated TSH
- Monitor linear growth, dental development, bone age
- Use in premature infants with transient hypothyroidism is controversial and not recommended at this time
INFECTIOUS DISEASES

Rule-out Sepsis

- Incidence - sepsis occurs in 1-10/1000 live births; increased incidence in LBW and preemies
- Etiology
  - May be acquired prenatally, at delivery, or postnatally
  - Bacteria are usually from the vaginal flora including group B streptococci (GBS), E.coli, other GN enterics, enterococcus, Listeria, Staphylococcus, anaerobes and H. influenzae
  - Organisms associated with nosocomial sepsis include Staph (especially coag negative staph), GNRs (Pseudomonas, Klebsiella, Serratia, and Proteus), enterococcus and fungus
  - Viral agents include HSV, enterovirus, and CMV
- Risk factors
  - PROM > 18 hours
  - Maternal peripartum fever (>38.0) or infection (chorioamnionitis, UTI, GBS colonization)
  - Prematurity (<37wks) – the single most significant factor correlated with sepsis
  - LBW
  - Meconium stained amniotic fluid
- Clinical findings
  - Early onset infections usually present with respiratory distress, shock, acidosis and a fulminant course typically within the first 24h of life, but may be within the first 5d. The organism is usually acquired during the intrapartum period from the genital tract.
  - Late onset infections may occur as early as 5d of age but more commonly after the first week of life. Bacteria may be acquired from the maternal genital tract as well as from human contact or from contaminated equipment. Presentation may vary from an identifiable focus to subtle clinical signs including temp instability, altered perfusion, vasomotor instability, A&amp;Bs, jaundice, lethargy, hypo/hyperglycemia, and poor feeding.
- Laboratory findings
  - CBC with diff
    - Sepsis more likely if WBC <5000 or >30,000, ANC<1500 (ANC=wbc (%segs+%bands)), I:T (immature:total) neutrophil ratio >0.2, thrombocytopenia
  - Blood culture - not completely reliable in the face of intrapartum antibiotic therapy
  - CRP is an acute phase reactant that can be helpful (>1.0 is considered positive)
    - It typically begins to elevate (in response to an infection) after a latency period of 6-8 hours, can double every 8 hours, peaks at 36-48 hours, and stabilizes 1-2 days after effective antimicrobial therapy
    - Can obtain CRP at time of evaluation and again at 36-48h of illness
  - Tracheal aspirate if infant intubated
  - U/A and Cx by catheterized or suprapubic tap specimen for late onset infections, usually if &gt; 3 days of age; most bacteriuria in the first 72 hours of life is secondary to bacteremia, so urine cultures are not mandatory in the early neonatal infection w/u
  - Lumbar puncture is recommended for infants who become ill at &gt; 48-72 hrs, those with CNS signs including apnea or seizures.
    - Meningitis is suggested when CSF wbc>25, protein>250, glucose<30
  - CSF and blood can be sent for PCR and viral culture for HSV and enterovirus, if suspected
  - CXR should be obtained if any signs/symptoms of respiratory distress
  - Examination of placenta can be useful
• Management
  • Once cultures obtained, start broad-spectrum antibiotics, usually ampicillin & gentamicin
  • Ampicillin covers enterococcus, GBS, Listeria
  • Gentamicin provides synergy with ampicillin for better GBS coverage and covers GN enterics (Klebsiella, Proteus, E.coli, Enterobacter, Citrobacter, Serratia)
  • For courses of gentamicin >72h, or very ill infant, obtain gentamicin peak & trough
  • Cefotaxime (or a 3rd generation cephalosporin) may be used in place of gentamicin
  • If infant >5-7d or central line in place, consider Vancomycin and Ceftazidime (for S. aureus and Pseudomonas coverage); obtain Vanco levels if longer therapy anticipated
  • If wound/abdominal infection or NEC, add anaerobic coverage (Clindamycin or Flagyl)
  • If concerned about HSV infection (see TORCHES below) – start Acyclovir
  • If concerned about fungal sepsis – start Amphotericin B
  • For fungal prophylaxis in preemies with indwelling catheters use nystatin po QID
  • IVIG, GCSF and shock steroids may be of some use in fulminant early neonatal sepsis
  • Prognosis - mortality is 13-50%; higher rates in preemies and those with early disease

Identification of Bacteria

Gram stain

Gram-negative
- Cocci
  - Neisseria
  - Curved or spiral
  - Vibrio
  - Campylobacter
- Bacilli
  - Lactose fermenter
- Coccobacilli
  - Hemophilus
  - Moraxella
  - Acinetobacter
  - Bordetella
  - Brucella

Gram-positive
- Bacilli
  - Listeria
  - Corynebacteria
- Cocci
  - Chains or pairs
  - Clusters
  - Nonenteric
  - Streptococci
  - Beta
  - Grp A
  - Grp B
  - Grp C
  - Grp D
  - Staph
  - S. viridans
  - Enterococci

- Hemolysis
- Queilung pos
- Strep pneumo
- Coagulate pos
- Coag Neg

Oxidase
- E coli
- Enterobacter
- Citrobacter
- Klebsiella
- Pseudomonas
- Aeromonas
- Shigella
- Yersinia
- Proteus
- Serratia
- Citrobacter
Viral Infections/TORCHES

- Background information
- Agents (Toxoplasmosis, Others, Rubella, CMV, HSV/HIV, Enterovirus, Syphilis)
- Modes of transmission include:
  - Transplacental transfer via umbilical cord flow or direct spread to the amniotic fluid
  - Ascending transmission from the cervix and uterus to the amniotic fluid
  - Intrapartum exposure to maternal vaginal secretions and blood
  - Postpartum exposure to maternal respiratory secretions or milk
- Routes of transmission

<table>
<thead>
<tr>
<th>Virus</th>
<th>Congenital (trimester)</th>
<th>Intrapartum</th>
<th>Postpartum</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMV</td>
<td>+++ (1,2,3)</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>HIV</td>
<td>+++ (1,2,3)</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>HSV</td>
<td>+</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>VZV</td>
<td>+ (1)</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Parvovirus</td>
<td>+++ (1,2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enterovirus</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Rubella</td>
<td>+++ (1)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Risk of vertical transmission

<table>
<thead>
<tr>
<th>Microorganism</th>
<th>Incidence of infection in newborns / live births in US</th>
<th>Risk vertical transmission</th>
<th>Risk fetal/neonatal death</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMV</td>
<td>1/100</td>
<td>30-40%</td>
<td>33% if symptomatic</td>
</tr>
<tr>
<td>HIV</td>
<td>1/3,000</td>
<td>25-40%*</td>
<td></td>
</tr>
<tr>
<td>HSV</td>
<td>1/3,000 – 1/20,000</td>
<td>30-50% (1st infection)</td>
<td></td>
</tr>
<tr>
<td>VZV</td>
<td>1/10,000</td>
<td>10-20%</td>
<td>20-30%</td>
</tr>
<tr>
<td>Parvovirus</td>
<td>Unknown</td>
<td>33%</td>
<td>1-9%</td>
</tr>
<tr>
<td>Enterovirus</td>
<td>50/1,000</td>
<td>30-50%</td>
<td></td>
</tr>
<tr>
<td>Rubella</td>
<td>1/100,000</td>
<td>80% (&lt;12wk)</td>
<td></td>
</tr>
</tbody>
</table>

* Markedly reduced with maternal treatment with Zidovudine during pregnancy

- Toxoplasmosis
  - Etiology
    - Toxoplasma gondii is a protozoan parasite
    - Maternal infection occurs through infected cat feces or undercooked meat
    - The highest risk of transmission of symptomatic disease occurs in the first trimester
    - Frequency in the US is 1/1,000 – 1/10,000 live births
  - Clinical findings
    - Asymptomatic at birth in 70-90% of cases
    - Several months to years later, visual impairment, learning disabilities, or mental retardation will be apparent in a large percentage
    - For infants symptomatic at birth, signs include a maculopapular rash, generalized lymphadenopathy, HSM, jaundice, thrombocytopenia and hydrops
    - Secondary to intrauterine meningoencephalitis, CSF abnormalities, hydrocephalus, microcephaly, chorioretinitis, seizures and cerebral calcifications can develop
  - Diagnosis
    - Prenatal diagnosis by detecting Toxoplasma IgM or IgA, or parasite in fetal blood
    - Postnatal diagnosis by isolating Toxoplasma gondii from placental or cord tissue
    - Also diagnostic are Toxoplasma IgM or IgA assay within the first 6 months of life, or persistently positive IgG titers beyond the first 12 months of life

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- PCR can also be performed on the peripheral WBCs, CSF, and amniotic fluid
- Work-up should include ophthalmologic and auditory examinations, LP and head CT
- Treatment
  - Symptomatic or asymptomatic congenital infection is treated with pyrimethamine and sulfadiazine for up to 1 year

**Others (VZV/Varicella)**

- Risk factors
  - If the mother never had varicella before and was exposed to a child with chickenpox within 21 days of delivery, the newborn is at risk for developing congenital varicella
  - If the mother had not developed a rash before delivery, it is unlikely that she was able to provide antibodies to the newborn, and the illness will be more severe (pneumonitis, CNS involvement, hepatitis); 10-20% of infants whose mother have varicella within 5 days before delivery, develop varicella; disseminated VZV infection occurs in 25% of these children with 30% of those dying
  - If the mother had a rash and the duration of her illness was at least 5-7 days, it is likely that she developed antibodies and her newborn infant will be protected, developing only a minor varicella illness, or neonatal zoster
- Diagnosis
  - Maternal history with a characteristic clinical presentation in the newborn within 5-10 days of life
  - Isolation of the virus from vesicular fluid
  - Demonstration of VZV Ag in skin lesions (DFA test)
  - PCR can also be used
  - Demonstration of a fourfold rise in VZV Ab titer by ELISA
- Clinical presentation
  - Vesicles, pneumonia, encephalitis, hepatitis
- Treatment
  - Supportive
  - Strict isolation until all lesions are crusted
  - Acyclovir in severe infections or potentially severe infections
- Prevention
  - Delay delivery 5-7 days after onset of maternal illness to allow passive transfer of protective antibody
  - If delay not possible, the neonate should receive VZIG (125 units) if the mother has onset of varicella from 5 days before to 2 days after delivery; these infants should be in strict respiratory isolation for 28 days after VZIG, since treatment will prolong the incubation period; VZIG doesn’t reduce the clinical attack rate, but causes milder disease
  - Avoid direct contact between the infant and maternal skin lesions

**Varicella embryopathy or congenital varicella syndrome**

- Occurs in maternal VZV infection in the first 20 weeks of pregnancy and can cause direct fetal damage, including spontaneous abortion, stillbirth, and congenital anomalies; occurs in 2-5% of cases
- Anomalies include cutaneous scars, limb hypoplasia, muscle atrophy, malformed digits, psychomotor retardation, microcephaly, cataracts, chorioretinitis, and microophthalmia

**Others (Parvovirus)**

- Etiology
  - Primary mode of spread is via respiratory secretions from exposure to a child with erythema infectiosum (fifth disease, or slapped cheek disease)
  - Greatest period of contagion in children is during the first few days of illness, before the characteristic slapped cheek rash appears
  - Incubation period is 4-14 days
  - 20% of infected individuals may not have symptoms, and 50% may not have a rash
• Parvovirus infection in adults is manifested by fever, rash and acute symmetrical peripheral polyarthritis
• Severe fetal disease is likely to occur only with acute maternal infection during the first 18 weeks of gestation
• Pathogenesis
  • Transplacental transfer of B19 virus leads to infection of RBC precursors causing arrest of RBC production and severe anemia leading to CHF and fetal hydrops
• Clinical manifestations
  • Asymptomatic infection
  • Mild anemia
  • Non-immune hydrops fetalis
  • Fetal demise
  • Myocarditis
  • Extramedullary hematopoeiesis and hepatosplenomegaly
• Diagnosis
  • Measurement of specific IgG and IgM Ab by ELISA
  • PCR
  • Characteristic intranuclear inclusions in erythroid cells
• Treatment
  • No antiviral therapy available
  • IVIG of no benefit to the fetus
  • Intrauterine fetal PRBC transfusion

• **Rubella** – congenital rubella syndrome
• Etiology
  • Acquired during the first 12 weeks of gestation
  • Effective rubella vaccine in 1969 dramatically reduced the number of cases in US
• Clinical manifestations
  • IUGR, HSM, jaundice, purpuric rash, sensorineural hearing loss, cataracts, cloudy cornea, cardiac lesions (PDA, PAS, coarctation, septal heart defects), myocarditis, microcephaly, encephalitis, meningitis, behavior disorder, mental retardation, growth retardation
  • Occurrence of congenital defects is 50% or greater if infection during the 1st month of gestation, 20-30% if during the 2nd month, and 5% if during the 3rd or 4th month
• Laboratory findings
  • Hyperbilirubinemia, thrombocytopenia, elevated LFTs, metaphyseal lucencies of long bones (distal femur/proximal tibia), CSF lymphocytic pleocytosis and elevated protein, intracranial calcifications
• Diagnosis
  • Isolation of rubella virus from urine, nasopharynx, conjunctival scrapings, blood, CSF
  • Rubella specific IgM Ab by ELISA (birth-2 months)
  • Persistent elevation of specific IgG (beyond 6-12 months)
  • Long bone films may show metaphyseal radiolucentcies
• Treatment
  • No specific antiviral therapy
  • Isolation from susceptible pregnant women
  • Infants with congenital rubella syndrome are infectious up to 1 year after birth by shedding of the virus in their respiratory secretions, stool and urine
  • Mothers not immune to rubella should be immunized after delivery
• **CMV** (congenital cytomegalovirus infection)
  - Risk factors
    - Intimate personal contact with individual who is shedding the virus
    - Exposure to blood products
    - Exposure to infected breast milk
    - Higher risk for seroconversion in people around day care
  - Clinical findings
    - Petechiae/purpura, HSM, jaundice, microcephaly, IUGR, prematurity, chorioretinitis
    - Clinical presentations vary from an asymptomatic infant shedding the virus to a full blown multisystemic infection
    - 1-2% of all newborns are infected with CMV; only 0.1% have symptomatic disease
    - 20-30% of symptomatic infants die and 90% of survivors develop sequelae
    - Rate of transmission and severity of disease are greater with primary maternal infection (30-40%)
  - Laboratory evaluation
    - CBC with diff reveals anemia and thrombocytopenia
    - Elevated LFTs and bilirubin (conjugated as well)
    - CSF for cell count, protein, glucose and CMV culture
    - CT of head shows intracranial calcifications, typically periventricular
    - Chorioretinitis on ophthalmologic exam
    - Hearing loss on BAER
  - Diagnosis
    - Based on clinical characteristic and positive urine (or saliva) culture or PCR for CMV in the first 2 weeks of life
    - A negative urine culture in the first 2 weeks of life differentiates congenital from postnatally acquired CMV infection
  - Therapy
    - Ganciclovir has been used to treat some congenitally infected infants, but it is not recommended routinely because of insufficient efficacy data
  - Sequelae
    - Hearing loss (60-70% - most important cause of deafness in children), mental retardation, cerebral palsy, language and learning disabilities, visual disturbances

• **HIV**
  - Principal cause of pediatric HIV infection today is vertical transmission from HIV infected mothers
  - Transmission rates are 15-40%; CS and maternal/infant zidovudine decrease to 2%
  - 20% of infected infants develop AIDS in the first year of life
  - Diagnosis is based on any combination of two positive tests (HIV culture, HIV DNA PCR or p24 antigen), with the first one usually done during the first 48 hours of life (do not use umbilical cord blood)
  - Treatment
    - Maternal Zidovudine 2nd and 3rd trimesters reduces the rate of transmission
    - Antiretroviral therapy (often triple therapy) is recommended for infected infants
  - Follow up
    - HIV cultures and PCR at birth, 2 and 6 months
    - ELISA and Western blot at 9, 12, 18 and 24 months

• **HSV** (Herpes Simplex Virus)
  - Etiology
    - HSV-2 (or genital HSV) causes most neonatal infections (75%), with 20-30% due to HSV-1
    - HSV-1 and HSV-2 are transmitted from person to person through contact with infected skin lesions, mucous membranes, and secretions with an incubation period from 1-26 days
  - Transmission
    - Vertical transmission occurs in utero (4%), perinatally (85-90%), postnatally (10%)
• HSV is shed asymptomatically in the majority of infected mothers with only 2/3 of those with positive HSV cultures having genital lesions
• Neonatal HSV infection is more common if the mother has a primary infection

• Risk factors for transmission
  • Primary maternal infection
    • Accounts for 70-80% of neonatal HSV infections
    • Infants born vaginally have a 30-50% chance of becoming infected
    • There is a higher virus concentration, no transplacental antibodies to the infant and longer viral excretion in primary infection
  • Recurrent maternal infection
    • Risk decreases to 3-5% if symptomatic, and 0.05% if mother is asymptomatic
    • Cervical shedding is infrequent, lower virus concentration exists and passage of transplacental antibodies are around to decrease transmission
  • Other risk factors include cervical vs. perineal skin lesions, multiple vs. single lesions, high titer of virus in vaginal secretions, PROM (4-6h or greater), prematurity, skin trauma (scalp electrodes)
  • C/S is performed if maternal clinical infection apparent

• Clinical Manifestations
  • SEM (skin, eye and mouth) infection (45%)
    • Presents in the 1st or 2nd week of life (about 10 days)
    • Clusters of vesicles appear on any part of the body, often the presenting part or on areas of trauma, and progress to involve other sites
    • Classic lesions: vesicular with cloudy or pustular fluid on an erythematous base
    • Low mortality
    • Recurrence in 90% of patients
    • 20-30% develop neurologic sequelae if untreated
    • Ocular manifestations include keratoconjunctivitis and chorioretinitis
  • CNS infection (35%)
    • Presents in the 2nd to 3rd week of life (days 10-17)
    • Only 60% develop skin lesions
    • Untreated mortality 50%, treated 18%
    • Symptoms include seizures, A& Bs, poor feeding, temp instability, cranial nerve abnormalities
    • At least 2/3 develop neurologic impairment
  • Disseminated infection (20%)
    • Presents in the 1st week of life
    • Involves any organ, commonly lungs, liver, adrenal glands and brain
    • Seizures can occur of day 1 of life; pneumonia appears later (10 days)
    • Clinical picture of sepsis
    • Untreated mortality >80%, with therapy 50-6%; highest mortality if pneumonitis is present (80% with therapy)

• Laboratory Evaluation
  • Spinal tap: CSF with lymphocytic pleocytosis, high protein, +/- RBCs
  • HSV DFA of vesicle scrapings
  • Viral cultures of skin lesions, oropharynx, conjunctivae, CSF, blood
  • CSF PCR has a sensitivity of 75% and specificity of 100% for CNS infection
  • CBC with diff, LFTs, BUN/Cr
  • CXR if respiratory symptoms
  • Ophthalmologic exam
  • Neuro imaging – head CT may be normal
  • EEG - typically temporal lobe involvement
Treatment
- Infants born to mothers with a history of herpes and no lesions can be observed
- In infants born to mothers with a genital lesion that is a known recurrence and infant is asymptomatic, often cultures plus observation alone is done, treatment is based on symptomatology or positive cultures
- In infants born to mothers with a known primary genital lesion, and thus associated risk to the infant is 33-50%, most often cultures are obtained and empiric Acyclovir at birth is begun; others support no treatment initially if infant is asymptomatic, and obtain cultures at 24-48h and observe
- Acyclovir 60 mg/kg/day IV q 8hr
- Duration is generally 14-21 days for proven disease; length depending on severity of disease
- If ocular involvement, add topical ophthalmic drug: 1-2% trifluridine, 1% iododeoxyuridine or 3% vidarabine
- CS can prevent intrapartum transmission with active lesions if done before 6 hours of ruptured membranes.

Enterovirus
- Etiology
  - Usually mother has a viral respiratory or GI illness before or after the delivery
  - Time of year for seasonal epidemics is usually summer and fall
  - Congenital infection occurs usually perinatally from the mother during delivery or from other sources in the postnatal period, in infants less than 7 days of age
  - The timing of maternal infection in relation to delivery is an important determinant of outcome; maternal infections more than 5-7d prior to delivery should induce maternal IgG Ab that protect the newborn against disease but not necessarily infection
- Clinical manifestations
  - Asymptomatic, pneumonia, hepatitis, myocarditis, meningoencephalitis, meningitis
- Diagnosis
  - Isolation of the virus from stool, CSF, respiratory secretion, blood or tissues
  - PCR for EV CSF testing
- Treatment
  - Supportive
  - IVIG and pleconaril have been used in life-threatening neonatal infections

Syphilis
- Etiology
  - Treponema pallidum, a spirochete
  - Congenital syphilis is contracted from an infected mother via transplacental transmission at any time during pregnancy or at birth
- Clinical findings
  - Infants may not have signs of disease or they may present up to 2 years of age
  - Stillbirth, IUGR, hydrops fetalis, prematurity
  - HSM, lymphadenopathy, persistent rhinitis
  - Osteochondritis, mucocutaneous lesions, rash
  - Hemolytic anemia, thrombocytopenia
  - Untreated infants, regardless of whether they have early manifestations, may develop late manifestations, which usually appear after 2 years of age and involve the CNS system, bones, joints, teeth, eyes, and skin
- Diagnosis
  - An infant should be evaluated for congenital syphilis if born to a mother who has a positive nontreponemal test, confirmed by a positive treponemal test, and who has one or more of the following:
    - Was not treated
    - Had treatment but course was poorly documented
• Received inadequate doses or duration of treatment
• Was treated with nonpenicillin regimen (i.e. erythromycin)
• Was treated <1 month before delivery
• Had insufficient serologic f/u to ensure she responded appropriately to treatment by demonstrating a 4-fold or greater decrease in titers 3 months after therapy
• Laboratory work-up
  • Quantitative nontreponemal and treponemal tests on infant’s serum (not on cord blood) as well as on seropositive mothers to enable comparison of titer results
  • Examine CSF for protein, cell count, and VDRL test
  • CBC with platelet count
  • Other clinically indicated tests (i.e. CXR, LFTs)
  • Long bone radiographs for diaphyseal periostitis, osteochondritis
  • Pathologic exam of the placenta or umbilical cord using specific fluorescent antitreponemal Ab staining if available
  • An infected infant’s test may be reactive or nonreactive, depending on the timing of maternal and fetal infection, thus screening maternal blood is important

• **Guide for interpretation of the syphilis serology of mothers and their infants**

<table>
<thead>
<tr>
<th>Nontreponemal test (VDRL, RPR, ART)</th>
<th>Treponemal test (MHA-TP, FTA-ABS)</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mother</td>
<td>Infant</td>
<td>Mother</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>+</td>
<td>+</td>
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<td>+</td>
<td>+ or -</td>
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<td>+</td>
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<td>+</td>
</tr>
<tr>
<td>-</td>
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<td>+</td>
</tr>
</tbody>
</table>

ART (automated regain test); MHA-TP (microhemagglutination test for T. pallidum)

• **Treatment**
  • Parenteral PCN G remains the preferred drug for treatment of syphilis at any stage
  • Recommendations for PCN G and duration of therapy vary, depending on stage of disease and clinical manifestations (see chart below)
  • Follow nontreponemal serologic tests at 3, 6, and 12 months after treatment or until results become nonreactive
  • Nontreponemal Ab titers should decline by 3 months of age and should be nonreactive by 6 months of age if infant adequately treated or not infected
  • Infants with congenital neurosyphilis (positive CSF VDRL) or abnormal CSF findings need repeated CSF exams at 6 month intervals until CSF normal
<table>
<thead>
<tr>
<th>Clinical Status</th>
<th>Evaluation</th>
<th>Antimicrobial Therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proven or highly probable diseasea</td>
<td>CSF analysis for VDRL, cell count, and protein</td>
<td>Aqueous crystalline penicillin G, 100,000–150,000 U/kg per day, administered as 50,000 U/kg per dose, IV, every 12 h during the first 7 days of life and every 6 h thereafter for a total of 10 days OR Penicillin G procaine, 50,000 U/kg per day, IM, in a single dose for 10 days</td>
</tr>
<tr>
<td>Normal physical examination and serum quantitative nonneutrophilic titer the same or less than fourfold the maternal titer:</td>
<td>CSF analysis for VDRL, cell count, and protein</td>
<td>Aqueous crystalline penicillin G, IV, for 10 days OR Penicillin G procaine, 50,000 U/kg per day, IM, in a single dose for 10 days OR Penicillin G benzathine, 50,000 U/kg, IM, in a single dose</td>
</tr>
<tr>
<td>(a) (i) Mother was not treated or inadequately treated or has no documented treatment; (ii) mother was treated with erythromycin or other nonpenicillin regimen; (iii) mother received treatment ≥4 weeks before delivery</td>
<td>CBC and platelet count</td>
<td>Long-bone radiography</td>
</tr>
<tr>
<td>(b) (i) Adequate maternal therapy given ≥4 wk before delivery; (ii) mother has no evidence of reinfection or relapse</td>
<td>None</td>
<td>Clinical, serologic follow-up, and penicillin G benzathine, 50,000 U/kg, IM, in a single dose</td>
</tr>
<tr>
<td>(c) Adequate therapy before pregnancy and mother's nonneutrophilic serologic titer remained low and stable during pregnancy and at delivery</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

IV indicates intravenously; IM, intramuscularly; CSF, cerebrospinal fluid; and CBC, complete blood cell.
1 If more than 1 day of therapy is missed, the entire course should be restarted.
2 Abnormal physical examination, serum quantitative nonneutrophilic titer that is fourfold greater than the mother's titer, or positive result of darkfield or fluorescent antibody test of body fluids.
3 Penicillin G benzathine and penicillin G procaine are approved for IM administration only.
4 A complete evaluation (CSF analysis, bone radiography, CBC) is not necessary if 10 days of parenteral therapy is administered but may be useful to support a diagnosis of congenital syphilis. If a single dose of penicillin G benzathine is used, then the infant must be evaluated fully, the full evaluation must be normal, and follow-up must be certain. If any part of the infant’s evaluation is abnormal or not performed or if the CSF analysis is uninterpretable, the 10-day course of penicillin is required.
5 Some experts would not treat the infant but would provide close serologic follow-up.
6 Some experts would treat with penicillin G benzathine, 50,000 U/kg, as a single IM injection if follow-up is uncertain.
MINOR ACUTE ISSUES

EARS – Neurosensory Hearing Loss
- Incidence – 1-5% of NICU population
- Risk factors
  - Prematurity (<32wks, <1500g)
  - Family history
  - Congenital infection
  - Exchange level hyperbilirubinemia
  - Severe birth asphyxia
  - Ototoxic drugs
  - Craniofacial anomalies
  - Meningitis
  - Prolonged assisted ventilation
- Screening
  - 1994 Joint Committee of Infant Hearing asked for universal detection
  - All infants are currently getting a Brainstem Auditory Evoked Response (BAER) done prior to discharge to screen for possible hearing loss
  - If the BAER is abnormal, further audiologic evaluation should be done

IMMUNIZATIONS
- Preterm infants should be immunized at the normal chronological age with the same vaccine doses as term infants
- 2 month immunizations include DTaP, IPV, HIB, HepB, and Prevnar. RotaTeq now added – 1st dose at 6-12 weeks of age at time of nursery discharge.
- Infants whose mothers are positive for HBsAg, HBcAg or HbeAg need both HBIG and HepB vaccination in the first 12 hours of life

  Synagis
  - Synagis is a recombinant humanized monoclonal antibody; it is administered IM on a monthly basis at doses of 15mg/kg (0.15ml/kg)
  - It is treatment for the prevention of serious lower respiratory tract infection caused by RSV; it is not approved for the treatment of RSV disease
  - Candidates for RSV prophylaxis
    - Infants born < 28 weeks gestation who are < 12 months at the onset of RSV season
    - Infants born at 29-32 weeks gestation who are < 6 months at the onset of the RSV season
    - Infants born at 32-35 weeks gestation who are < 6 months at the onset of RSV season and who have at least two environmental risk-factors (child care attendance, school age siblings, exposure to environmental air pollutants, congenital airway anomalies, neuromuscular disease)
    - Infants with significant respiratory conditions that require daily respiratory medications/therapy who are < 2yo at the onset of RSV season

NEWBORN STATE SCREEN FOR COLORADO
- Cystic fibrosis
- Hypothyroidism
- PKU
- Hemoglobinopathies
- Expanded metabolic screen (amino acid disorders, fatty acid oxidation disorders, organic acid disorders.
RETINOPATHY OF PREMATURITY

- Definition
  - Developmental abnormality of the normal vascularization of the maturing retina
  - Important cause of visual impairment and can result in permanent blindness

- Incidence of ROP among preemie survivors
  - The incidence of ROP and the severity of disease are inversely proportional to BW and gestational age
  - BW (grams) % with ROP (all stages)
    - 500-750 81%
    - 750-1000 53%
    - 1000-1250 35%
    - 1250-1500 14%
  - approximately 17% of all infants who develop ROP progress to stage III
  - of infants <28 weeks, 61% have ROP and 21% have stage III or above
  - of infants 29-32 weeks, 33% have ROP and 5-9% have stage III or above

- Etiology
  - The precise etiology and pathogenesis is unknown, but is believed to be multifactorial
  - Postulated causes include hypoxia, hyperoxia, vascular immaturity, dietary deficiencies

- Classification by location, extent and stage
  - Location designated at Zone I, II, III
  - Extent of disease specified as hours of the clock
  - Staging of the disease refers to the level of abnormal vascular response
    - Stage I: a demarcation line is present between vascular and avascular retina
    - Stage II: a ridge is formed as the demarcation line becomes raised
    - Stage III: extraretinal neovascularization occurs as vessels proliferate over the ridge into the vitreous
    - Stage IV: retinal detachment
    - Plus Disease: may occur at any stage when the vascular changes are so marked that the posterior veins are enlarged and the arterioles tortuous. When ROP is in Zone I or posterior Zone II and “Plus” disease is present, progression may be very rapid

- Screening
  - Infants less than 1500 grams or 32 weeks and infants between 1500-2000g with an unstable clinical course
  - Initial screening is based on age. Infants are screened at 4 weeks of age for those born at ≥ 27 weeks. Those born at ≤ 26 weeks are seen at 31 weeks PCA (e.g. 26 weeks @ 5 weeks, 25 weeks @ 6 weeks).
  - Repeat exam at least every two weeks until vascularization has progressed into the outer retina (zone 3), ROP has resolved, or it progresses to the point that it requires intervention
• Complications
  • Retinal detachment
  • Severe myopia/amblyopia
  • Blindness
  • Strabismus
  • Glaucoma
  • Cataracts

• Management/Prognosis
  • Retinal ablation via laser therapy
  • 90% of cases of stage I and II disease and 50% of stage III+ disease regress spontaneously
DISCHARGE PLANNING

- Maintain temperature in open crib
- Nippling full volume feeds
- Gaining weight appropriately
- Medications discontinued in a timely manner to observe infant appropriately
- No acute illness present
- Initial Newborn State Screening completed
- Hearing screening completed
- Room air challenge passed if on O2
- PCP identified
- Family discharge teaching complete
- Arrangements for equipment and supplies have been made
- Any social issues addressed/discussed with Social Worker

CIRCUMCISION

- Residents must be checked out by Attending, Fellow or PL3 or NNP prior to performing procedure
- See Well Baby Guidelines for protocols
- Informed consent signed
- Circumcision performed before 1700
- Infant may be discharged 1-2 hours after procedure if no excessive bleeding

ROOM AIR CHALLENGE

- The room air challenge involves watching the infant on a pulse-oximeter while awake, asleep and feeding while on room air
- Oxygen saturation must not be less than 80% after 40 minutes in room air
- Oxygen requirement must not be greater than ¾ lpm for discharge criteria
- Infants weaned to room air should be tested 40 minutes and 4 hours after weaning
- Perform within 3 days of discharge

MONITOR GUIDELINES

- Home monitor may be considered with discharge ≥ 37 weeks PCA with self-resolving events < 5 days, but no episodes requiring intervention for ≥ 7 days prior to discharge. This needs to be discussed with the attending. Home monitor should be continued until 44 weeks PCA or 1 week after caffeine stopped.
- Rate of death from SIDS is 3-4 x’s higher in premature infants but timing does not correlate with apnea of prematurity. Apnea of prematurity resolves by 44 weeks PCA and SIDS peaks at ~46 weeks in extremely premature infants, and ~52 weeks PCA interm infants. Spells in the nursery do not predict SIDS.
PROCEDURES

Remember to obtain consent for LP, PICC, and chest tube (if non-emergent)

Intubation
- ETT size
  - <1000g = 2.5
  - 1000-2500g = 3.0
  - >2500g = 3.5
  - For older kids (16 + age (years)) / 4
- Laryngoscope blade (Miller)
  - No. 0 for infants <3000g
  - No. 1 for infants >3000g
- ETT placement
  - 1-2-3-4 = 7-8-9-10; meaning a 1kg infant = 7cm at the lip, etc.
  - Confirm placement by XRAY (want about ½ cm above carina)

UVC
- Size – 5.0 F and double lumen if available
- Length – distance from umbilical cord to xyphoid + 1 cm + length of the cord
- Placement
  - For emergent situations, advance 3-4 cm – just until blood return obtained
  - For long term access or CVP measurement, place tip above the diaphragm in the IVC or RA (should correspond to T8-9)
  - Verify with XRAY (AP and lateral)
  - Can be left in place up to 14 days, but preferably out by 7 days of age
- Fluids
  - Usually TPN or maintenance fluids with 1.0 unit heparin/ml
- Indications
  - Emergent vascular access for fluids, medications, and/or blood draws
  - CVP monitoring
  - Exchange transfusions
  - Long-term central venous access in LBW infant (while awaiting PICC)
- Contraindications
  - Omphalitis, omphalocele, NEC, peritonitis
- Complications
  - Infections, thromboembolic events, catheter malpositioned, arrhythmias

UAC
- Size – 3.5F for VLBW (<1.2kg), o/w 5.0F for most larger infants
- Length - distance from the symphysis to the umbilicus x 2 plus length of the cord
- Placement
  - Ideal is a high position about the level of T8
  - Verify with XRAY (AP and lateral)
- Fluids
  - Usually ½ NS with 1.0 unit heparin/ml
  - Never run <D5W or <1/2 NS due to hypo-osmolarity
- Indications
  - Frequent or continuous measurement of arterial gases for pO2
  - Continuous monitoring of arterial BP
  - Exchange transfusion
  - Access for frequent blood sampling in VLBW infants
• Contraindications
  • Same as UVC
  • Evidence of local vascular compromise in LE or buttocks

• Complications
  • Cath toes, thrombosis, embolization, infection, hemorrhage

Thoracentesis
• Equipment
  • 21 or 23G butterfly needle
  • Stopcock
  • 20ml syringe
  • Assemble completely and break the seal on the syringe prior to procedure

• Approach
  • 3rd ICS in midclavicular line anterior chest (for pneumothorax)
  • 4th ICS in posterior axillary line lateral chest (for fluid removal)

• Technique
  • Clean area with betadine and alcohol
  • Insert needle perpendicular to chest wall just above the rib on lower margin of the ICS (to avoid vessels)
  • and aspirate continuously on the syringe
  • Make sure stopcock is open to chest and off to room
  • Stop advancing needle immediately as soon as air is released into syringe
  • Continue to aspirate intermittently, expelling excess gas into room via stopcock (after turning it off to the baby)

Chest Tube
• Equipment
  • Prepackaged chest tube tray usually contains sterile drapes, gauze pads, suture materials, hemostats, scalpel, 1% lidocaine, 3ml syringe and 25G needle.
  • Chest tube size – No. 10F for infants < 2000g and No. 12F for >2000g

• Approach
  • Infant is usually supine with arm at a 90 degree angle
  • If chest tube needed for pneumothorax, remember air collects in the uppermost chest areas, so place the tube anteriorly
  • For anterior approach, the site is the 4th to 6th ICS at the anterior axillary line
  • For pleural effusions, remember that fluid collects in the most dependent chest areas, so place the tube posteriorly and laterally
  • For posterior placement, the site is the 4th, 5th, or 6th ICS at the posterior axillary line; the nipple is the landmark for the 4th ICS

• Technique
  • Clean area with betadine and alcohol
  • Infiltrate site with 1% lidocaine (first superficially and then down to the rib)
  • Make a small incision with a No. 15 or No. 11 scalpel in the skin over the rib just below the ICS where the tube should be inserted
  • Insert a closed, curved hemostat into the incision and spread the tissues down to the rib
  • Using the blunt tip of the hemostat, puncture the pleura just above the rib (may hear rush of air) and spread gently (remember the intercostal nerves and vessels lie below the ribs)
  • Insert the chest tube through the opened hemostat
  • Depth of insertion is typically 2-3cm for preterm infants and 3-4cm for term infants (ensure that the tube holes are within the pleural cavity)
  • Connect tube to a water-seal vacuum system (Pleur-evac) with 10cm of suction pressure; water seal prevents air from being drawn back into the pleural space
  • Secure tube and close skin incision with silk sutures
  • Obtain a CXR to verify placement and check for residual fluid or air

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Radial Arterial Puncture
- Equipment
  - 23 or 25G needle
  - 1-3 ml syringe
  - 1:1000 heparin or precoated syringe if submitting a blood gas sample
- Technique
  - Perform the Allen test to check collateral circulation and patency of ulnar artery
    - Elevate arm and occlude the radial and ulnar arteries at the wrist
    - Rub the palm to cause blanching
    - Release pressure on the ulnar artery
    - Normal color should return to the palm in <10sec
    - If normal color does not return for >15sec or not at all, then the collateral circulation is poor and this radial artery should not be used
  - Take the infants hand in your left hand and extend the wrist
  - Palpate the radial artery with the index finger of your left hand
  - Clean the site with betadine and alcohol
  - Aim your needle at a 30 degree angle and advance with bevel up until a flash returns
  - The volume of blood taken shouldn’t exceed 3-5% of total blood volume (80ml/kg)
  - Withdraw needle and apply firm pressure for about 5 minutes
RESOURCES

Neonatology Handbook by Gomella
AAP 2006 Redbook
Harriet Lane Handbook

Websites:
www.neonatology.org
www.aap.org  Academy of Peds homepage
www.ncbi.nlm.nih.gov/PubMed  For literature searches
www.pedinfo.org  Index of pediatric internet sites
www.medbioworld.com Link to pediatric and neonatal journals
http://neonatal.peds.washington.edu