Pediatric CCRN Certification Review Course

Presented by:
Kathryn Roberts, RN, MSN, CRNP, CCRN, CCNS

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Pediatric CCRN Exam
Exam Overview & Preparation
Kathryn E. Roberts, RN, MSN, CRNP, CCRN, CCNS

- **CCRN® Exam**
  - Administered by the AACN Certification Corporation
  - Conducted in cooperation with Applied Measurement Professionals, Inc (AMP)
  - Computer based exam
  - Paper & Pencil version at NTI, Trends
  - 150 multiple choice questions
    - 125 scored; 25 not scored
  - 3 hours
  - Able to change answers
    - First answer usually the best!
  - Pass/Fail
  - Based on Role Delineation Study & the Synergy Model

- **CCRN® Exam Test Plan (Blueprint)**
  - Clinical Judgment = 80%
    - Pulmonary – 18%
    - Cardiovascular – 14%
    - Multisystem – 11%
    - Neurology – 14%
    - GI – 6%
    - Endocrine – 5%
    - Hematology – 3%
    - Renal – 6%
    - Behavioral/Psychosocial – 3%
  - Professional Caring & Ethical Practice = 20%
    - Advocacy/Moral Agency – 2%
    - Caring Practices – 4%
    - Collaboration – 4%
    - Systems Thinking – 2%
    - Response to Diversity – 2%
    - Clinical Inquiry – 2%
    - Facilitation of Learning – 4%

- **Eligibility**
  - Current, unrestricted RN license
  - 1,750 hours in direct bedside care during previous 2 years (875 hrs. in past 12 months)
  - Recommended experiences (not required)
Renewal
- Certification is for a period of 3 years
- Approx. 90 days before their expiration date, certificants will receive a “CCRN Renewal Handbook”
  - 432 hours of direct bedside care of acutely ill/critically ill patients w/i 3 yr period
  - 144 hrs accrued in last 12 months
  - Synergy CERPs: 60 Cat A; 10 each B & C

Application Fees (computer exam)
- AACN members
  - $220
- Non-members
  - $325

Application Process
- Complete Exam Application
- Submit verification of clinical practice requirements
- AACN Cert Corp notifies AMP that you are eligible
- AMP sends you a confirmation postcard
- Call AMP to schedule an appointment
- Take the Test!

Test Preparation
- Take a class
- STUDY – identify areas that you need to focus on
- Review books/questions
- Study groups
- Audiotapes
- Practice, practice, practice

The night before
- Don’t drink alcohol
- Don’t stay up late studying
- Don’t drink caffeine
- Lay out clothes
The day of........

- Do not attempt a major review
- No caffeine (±)
- Eat breakfast (±)
- Wear comfortable clothing
- Wear layers
- Arrive 30-45 minutes early
  - Know how to find the test center....

Taking the Exam

- Wear a watch
- Answer at least 50 questions in the 1st hour
- Don’t spend longer than 2 minutes on a question
- No penalties for guessing
- Read questions carefully
- Do NOT “read into” the question
- Try to eliminate 2 choices
- DON’T think of atypical patients

Questions....

Analyzing Questions

- Look for the answer with a broader focus
- Look for the qualifying words
- Look for the negative words
- Avoid answers with “absolute” words.
- Example: Broad Answer

1. Cindy is diagnosed with Kawasaki’s disease. While reviewing her clinical exam, the nurse should note which of the following characteristics of this disease?

   a. Fever >5 days, unresponsive to antibiotics
   b. Fever > 5 days, unresponsive to antibiotics, rash, oral mucosal changes
   c. Bilateral conjunctivitis
   d. Cervical lymphadenopathy

Qualifying Words

- First
- Best
- Most
• Initial
• Better
• Highest Priority
• Example: Qualifying Words

2. A child is admitted after sustaining a head injury. The *most important* aspect of the nurse’s continuing neurological assessment is:

   a. Level of consciousness
   b. Pupillary response
   c. Motor response
   d. Assessment of the cranial nerves

   o **Negative Words**
     • Not
     • Least
     • Except
     • Inconsistent
     • All but
     • Atypical
     • Incorrect
     • False
     • Unlikely
     • Inappropriate
     • Unrealistic
     • Contraindicated

   o **Absolute Words**
     • Always
     • Every
     • Only
     • All
     • Never
     • None
     • Example: Absolute & Negative Words

3. For the patient in renal failure, potential metabolic derangements include all of the following except:

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a. Metabolic acidosis  
b. Hyperkalemia  
c. Hypocalcemia  
d. Metabolic alkalosis

o **What to do when you haven’t got a clue??**  
  - Avoid selecting an answer that you also don’t understand!  
  - Remember that nursing care is similar in many situations  
  - Select the answer that seems most logical  
  - Example: Clueless

4. George Green, age 13, is diagnosed as having a pheochromocytoma. Appropriate initial nursing care would include:

   a. Administration of large doses of xylometazoline to help control disease symptoms.  
   b. Close monitoring of George’s vital signs, especially blood pressure  
   c. Preparing George and his parents for imminent death  
   d. Have the parents discuss the condition with the doctor before informing George of the disease because of the protracted recovery period after treatment.

o **The Jeopardy Question**  
  - Especially long questions with a lot of information  
  - Real question is found at the very end  
  - Example: Jeopardy Question

5. A 12 year-old male patient with status asthmaticus is admitted to the ICU. Physical examination reveals paradoxical respirations, 44 breaths per minute; sinus tachycardia at 160 BPM; and blood pressure, 85/50mmHg. The patient has a gray, ashen appearance, is diaphoretic, and cannot speak. No audible sounds are heard on chest auscultation. Arterial blood gas levels on a 50% rebreather mask include:

   - pH 7.25  
   - PaCO2  
   - 80 mmHg;  
   - Pa O2 45 mmHg  
   - HCO3, 26 mEq/L

   The patient’s arterial blood gas levels indicate:

   a. Respiratory acidosis with metabolic compensation  
   b. Respiratory acidosis with severe hypoxemia
c. Combined respiratory and metabolic acidosis
d. Respiratory alkalosis with severe hypoxemia

- Example: The Wade

6. Postoperatively, a 10 y/o cardiovascular patient has a mediastinal chest tube and multiple invasive lines. The patient is now unstable, with decreased capillary refill time, CVP of 15 mm Hg, tachycardia and agitation. The patient’s BP is decreased, with a change in 10 mmHg in systolic pressure with inspiration. The most probable etiology is:
  a. Pericardial tamponade
  b. Excessive chest tube drainage
  c. CHF
  d. Misplacement of the CVP measuring device

Good Luck!!!!!

Recommended References

Pediatric - Clinical Judgment


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**Professional Caring and Ethical Practice**


14% of the Exam:
- Acute spinal cord injury
- Brain death
- Congenital neurological abnormalities
- Encephalopathy
- Head trauma including shaken baby
- Hydrocephalus
- ICP monitoring
- Intracranial hemorrhage/intraventricular hemorrhage
- Neurologic infectious diseases
- Neuromuscular disorders
- Neurosurgery
- Seizure disorders
- Space-occupying lesions
- Spinal fusion
- Stroke

Components of the Central Nervous System
- Cerebral Cortex (lobes)
- Basal ganglia
- Thalamus
- Hypothalamus
- Cerebellum
- Brainstem
- Pons
- Midbrain
- Medulla Oblongata

Meninges
- P Pia Mater Inner Vascular
- A Arachnoid Middle Feathery
- D Dura mater Outer Tough
- PAD – meninges protect the brain and spinal cord
- Subarachnoid space – located between the arachnoid and pia & contains CSF
- **Cerebrospinal Fluid**
  - Formed – Choroid plexus of the lateral, 3rd & 4th ventricles
  - Reabsorbed – Arachnoid villae

- **Peripheral Nervous System - Cranial nerves**
  - Olfactory
  - Optic
  - Oculomotor
  - Trochlear
  - Trigeminal
  - Abducent
  - Facial
  - Vestibulocochlear
  - Glossopharyngeal
  - Vagus
  - Spinal Accessory
  - Hypoglossal

- **Cranial sutures**
  - Posterior fontanel – closes at 2 months
  - Anterior – closes at 16 – 18 months
  - Severe elevation in ICP can reopen the sutures up to age 12

- **Autonomic Nervous System & Cerebral Metabolism**
  - Oxygen: 20% of CO delivered to brain
    - Require constant O2 delivery
    - Dependent on aerobic metabolism
  - Glucose: minimal stores
    - Require constant, consistent delivery
    - Hypo- & hyperglycemia detrimental

- **Cerebral Blood Flow**
  - CBF varies with age
  - Determinants:
    - Arteriolar radius
    - MAP
    - Blood viscosity
  - Cerebral Perfusion Pressure (CPP)
    - CPP = MAP – ICP
    - Child > 50 mm Hg
    - Adolescent > 60 mm Hg
o **Relationship b/w Intracranial Pressure & Volume**
  - Rigid skull w/ 3 volume compartments
  - If any one or more of the compartments increase, there must be a reciprocal change in one or more of the other compartments

o **Hydrocephalus**
  - Excess of CSF
  - Communicating: decreased absorption of CSF or blockage outside of the ventricular system
  - Non-communicating: obstruction w/i the ventricular system
  - Congenital or acquired
  - Key Clinical Manifestations
    o Varies with how rapidly ICP increases
    o Acute:
      - Cerebral hypertension
      - Rapid deterioration
    o Slowly progressing:
      - Increased HC
      - Poor feeding
      - Setting-sun sign
      - “Cracked pot” sounds
      - N/V
      - Headache
      - Unsteady gait
      - Alt in school performance
      - Behavioral changes
  - Management
    o Correct the cause
    o Surgical placement of shunting device
    o Ventriculoperitoneal shunt

o **VP Shunt**
  - Drain excess CSF from ventricles to peritoneum to decrease ICP

o **Stroke**
  - Acute Ischemic Stroke (AIS)
    o Incidence: 0.2/100,000 children/yr to 7.9/100,000 children/yr
    o Mortality: 0.6/100,000 children/yr
    o Morbidity: >50% with neurologic or other deficits
  - Etiology: embolus, thrombus or occlusion
  - Risk Factors
    o Cardiac
• Hematologic
• Infectious
• Arteriopathies
• Vasculopathies
• Other

• Treatment
  o Maintain normal oxygenation
  o Control systemic HTN
  o Normalize serum glucose
  o Control fever
  o Anticoagulation (controversial)
  o Aspirin for prevention of future AIS

  o Intraventricular Hemorrhage
    • Often develops in first few days of life in preterm infants
    • Risk Factors:
      o Hypernatremia
      o Blood transfusions
      o Shock
      o Acidosis
    • S/S: Change in LOC, shock, acidosis, seizures, bradycardia, apnea
    • Dx: Ultrasound

Questions....

1. CSF is formed by the:

   a. Choroid plexus
   b. Cerebral ventricles
   c. Arachnoid villae
   d. Pia mater

2. A sympathomimetic drug would be expected to produce which of the following symptoms in addition to any desired effects?

   a. Pupil constriction
   b. Bronchodilation
   c. Bradycardia
   d. Increased bladder tone
3. The mechanism of the development of hydrocephalus is most commonly related to:
   
a. Increased flow of CSF  
b. Increased re - absorption of CSF  
c. Obstructed flow of CSF  
d. Decreased production of CSF  

4. What is the best place to level the ICP transducer?
   
a. A reference point that approximates the lateral ventricles  
b. A reference point that approximates the left atrium  
c. A reference point located at the angle of Louis  
d. A reference point located at the lower mandible

- **Increased Intracranial Pressure**
  - Clinical Manifestations
    
    o Altered/diminished LOC  
    o Lethargy/ irritability  
    o Tense, bulging fontanel  
    o ↑ Head Circumference  
    o Emesis  
    o High pitched cry  
    o Cushing’s triad  
    o Widening pulse pressure  
    o Hypertension  
    o Bradycardia  
    o Abnormal respiration/ apnea  
    o Papilledema - LATE

- **Intracranial Hemodynamics**
  - ICP = 4 – 15mm Hg  
  - CPP = MAP – ICP
    
    o Maintain above 50 mm Hg to ensure adequate cerebral oxygenation (child)  
    o > 60 mm Hg in adolescent/adult

- **Increased ICP**
  - Management
    
    o Mild hyperventilation  
    o Cerebral vasoconstriction in response to decreased PaCO2  
  - Diuretics
    
    o Mannitol / Lasix – reduce cerebral blood volume
• Hypothermia
• Sedation
  o Barbiturates
• Nursing Interventions
  o ↑ HOB – Promote cerebral venous drainage
  o Maintain head midline
  o Restrict fluids – ¾ maintenance
  o Cluster care
  o Limit stimulation

  o **Intracranial Pressure Monitoring**
    • Many types of systems
    • Intraventricular
    • Subarachnoid bolt

  o **ICP Waveforms**
    • A - Plateau waves
      o Usually range in amplitude from 50 – 100 when pt has an acute spike in ICP
    • B – Waves
      o Low – amplitude waves 20 – 50 mm Hg that flux during the respiratory cycle
    • C – Wave
      o Rhythmic, low – amplitude
      o Clinical significance is unknown

  o **Traumatic Brain Injury**
    • Goal: Maintain CPP
    • S/S: Increased ICP & based upon location of trauma
    • Diagnosis: Skull X – rays, CT, MRI
    • Tx: Based upon symptoms
    • Treat ↑ ICP

  o **TBI Injury Mechanisms**
    • Fractures: usually linear
    • Concussion: Blow to head with or without shearing & + LOC
    • Contusion: Bruise on the brain
    • Coup: Injury to the side of the head that was struck
    • Contrecoup: Injury to the opposite side of brain that was struck
    • Skull Fractures
    • Linear:
      o Bones remain in alignment and meninges not torn
    • Depressed:
• One or more pieces are indented damaging underlying brain tissue
  • Compound:
    o Open and Depressed - Scalp laceration and depressed skull fracture – allowing for foreign bodies to pass into skull cavity
  • Basilar:
    o Fracture in the posterior base of skull

• **Diffuse Axonal Injury (DAI)**
  • Cause: mechanical shearing following deceleration causing tearing of axons
  • Mild: Coma state for 6 – 24 hours
  • Moderate: Coma state more than 24 hours with little or no brain stem involvement
  • Severe: Coma more than 24 hours

• **Secondary Brain Damage**
  • Hematomas
  • Cerebral Swelling
  • Infection
  • Herniation
  • Ischemia
  • Brain Death

• **Hematomas**
  • Epidural = Arterial Bleed
    o Blood accumulates above the dura
    o Brief LOC followed by rapid deterioration
    o Talk and die phenomena
    o Common finding to have pupil dilation ipsilateral the injury
  • Subdural = Venous Bleed
    o Blood accumulates below the dura or between the dura and arachnoid layers
    o Bleed can be acute, subacute, or chronic

**Questions…**

5. After receiving a blow to the head, an 8 year old is diagnosed with having an epidural bleed. This type of bleed is associated with:
   a. Arterial bleeding
   b. Venous bleeding
   c. Bleeding into the brain tissue
   d. Intraventricular bleeding

6. After returning from surgery for evacuation of the epidural bleed, the critical care nurse would first assess this child’s__________.
a. Systemic perfusion  
b. Orientation  
c. Presence of reflexes  
d. Pupillary response

7. What is the initial independent nursing intervention that should be used to maintain cerebral perfusion?

   a. Mannitol/ Lasix  
   b. Maintain head midline  
   c. Transfuse with PRBC  
   d. Sedate with Morphine

- **Brain Death**
  - Irreversible cessation of cerebral blood flow  
  - Differences in confirmation process from state to state  
  - Ad Hoc Task Force for the Determination of Brain Death in Children  
    - Irreversible cause  
    - Physical examination  
    - Pupillary light response  
    - Oculovestibular reflex  
    - Dolls’ eyes  
    - Apnea test  
    - EEG  
    - Cerebral Blood Flow study

- **Spinal Cord Injuries**
  - Complete or incomplete injury  
  - SCIWORA more common in peds  
    - Spinal Cord Injury Without Radiographic Abnormality  
  - Most common cause:  
    - Motor vehicle accidents  
  - Treatment:  
    - Steroids immediately to minimize the neurological damage  
    - Spinal fusion with traction may be necessary
**Encephalopathy**
- Any neurological disorder of unknown or non–infectious cause
- Etiologies:
  - Lead poisoning, hypoxia event, HTN, metabolic disorders, herpes, chicken pox, vaccinations
- S/S:
  - Decreased LOC, irritability, seizures, motor and sensory defects, H/A, hyperventilation
- DX: LP negative, Good Hx and PE
- Treatment: Supportive, decrease ICP

**Neurologic Infectious Diseases**
- Meningitis
  - Bacterial CSF analysis
    - ↑ WBC
    - ↑ protein
    - ↓ glucose
    - + Gram stain
    - + bacterial culture
  - Viral CSF analysis
    - SI ↑ WBC
    - Normal or sl ↑ protein
    - Normal glucose
  - Gram stain
  - Bacterial culture
- Bacterial Meningitis
- Age Related Pathogens
  - Newborn: E Coli, Group B Strep (GBS), Listeria, Enterobacter
  - > 2 mos & children: GBS, Strep pneumoniae, Nisseria meningitidis, H flu
- Signs and Symptoms
  - Fever
  - Photophobia
  - Headache – frontal / occipital regions
  - Nuchal rigidity
  - Neck pain
  - Altered LOC
  - Kernigs sign
  - Brudzinski’s sign
  - Non – specific rash
  - Other: seizures, sensorineural deafness, focal neuro signs
• Management of Meningitis
  o IV Antibiotics (bacterial)
  o Isolation for 1st 24 hours after initiation of Antibiotics
  o ± Steroids
  o CT/ MRI – r/o hydrocephalus or empyema
  o Monitor for SIADH/ DI

  o Seizures
  • “an uncontrolled, time-limited alteration in behavior that results from abnormal
electrical discharge from cortical neurons”
  • Status Epilepticus – prolonged seizure or multiple consecutive seizures w/o regaining
consciousness
  • Types:
    o Partial (focal / local) - begin focally from a single location within one hemisphere
    o Simple partial
    o Complex partial
    o Partial as a secondary result of generalized seizures
    o Generalized (convulsive or nonconvulsive)
    o Absence (AKA Petit mal) – staring, “spacey”
    o Myoclonic – sudden, brief, generalized muscle contractions.
    o Febrile seizures – elevation of temperature greater than 101.8 F - effecting
children ages 6mo – 6 yr
    o Myoclonic infantile spasms – head bobbing or body jerking affects ages 3 – 8 mo
    o Clonic
    o Tonic
    o Tonic – Clonic (AKA Grand Mal)

  • Management
    o Anticonvulsants
    o Protection/Support
    o Airway – oxygenation & ventilation
    o CV – hemodynamics and perfusion
    o Assess for aura presence and type
    o Length
    o Incontinence
    o LOC
    o Presence of post – ictal phase

  • Medication management
    o Diazepam/ Ativan initial treatment
      ▪ Onset minutes, half – life 7 minutes
      ▪ SE: hypotension, laryngospasm, respiratory depression
    o Phenytoin
      ▪ Onset 15 – 20 minutes
- Therapeutic level – 15 – 20
- SE: Cardiovascular collapse if administered rapidly

**Questions....

8. After a drowning event and rewarming to 36 C, your patient remains unresponsive, with fixed and dilated pupils. The family is approached with the potential diagnosis of brain death. A diagnosis of brain death is confirmed by:
   a. Apnea testing
   b. Cold calorics
   c. EEG
   d. Pupillary light response

9. A 5 year old boy is admitted after being involved in a MVA in which he did not wear a seat belt. C/O numbness and tingling in his legs and feet, and has decreased sensation. Preliminary diagnostic studies are normal. The CC nurse plans care to include:
   a. Removing the cervical collar
   b. D/C log rolling to turn the patient
   c. Administration of anti – anxiety medications
   d. Continuation of spinal cord protective measures

10. Which of the following CSF results represent untreated bacterial meningitis?
    a. Decreased leukocyte count, elevated protein, and decreased glucose
    b. Decreased leukocyte count, decreased protein, and decreased glucose
    c. Increased leukocyte count, decreased protein, and increased glucose.
    d. Increased leukocyte count, elevated protein, and decreased glucose.

11. On arrival to PICU your patient has a grand mal seizure. spO2 drops to 85%. The nurse should immediately:
   a. Administer Oxygen
   b. Administer Valium
   c. Intubate
   d. Insert a bite block

12. Which of the following explains the mechanism of most neonatal seizures?
   a. Increase of inhibitory control
   b. Loss of inhibitory control
   c. Increase of excitatory centers
   d. Loss of excitatory centers
Types of Spinal Abnormalities
- Myelomeningocele
  - Required surgical closure within 48 hours of birth
  - Monitor for hydronephrosis and neurogenic bladder
  - Associated with hydrocephalus
  - Associated with Arnold–Chari malformation
- Meningocele
- Spina Bifida
  - Cause: results in failure of the neural tube to close in wks 3 – 6 of embryological development
  - Etiology: radiation, maternal diabetes, vitamin deficiencies, multi-factorial inheritance
  - Degree of neurological impairment dependent on level of lesion
  - Lesions are commonly located in the lumbar sacral regions
  - L5 – S1 Ambulation possible
  - L3 – L4 Ambulation possible with assistance
  - L1 – L2 Paraplegia
  - S/S:
    - Tuft of abnormal hair
    - Dimple
    - Hemangioma
    - Lipoma over lumbar or sacral regions
- Arnold Chari Malformations
  - Cerebellar tonsils slip into the space where the SC travels into the skull thus obstructing CSF flow

Space Occupying Lesions
- Primary brain tumors are the most common form of cancer in children ages 5 - 10
- Classification depends on location, degree of malignancy, and histology features.
  - Supratentorial: occur in either cerebral hemisphere above the tentorium cerebelli
  - Infratentorial: occur in the brainstem below the tentorium cerebelli
- Management
  - Control ICP
  - Surgical excision
  - Control post-op complications
  - Radiation
  - Chemotherapy

Arteriovenous Malformation (AVM)
- Management
  - Varies w/ size & location of AVM & pt condition

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13. J. is a 6 year old boy, admitted to PICU after craniotomy and resection of a medulloblastoma. The patient is hemodynamically stable & intubated. His dressing is dry and intact, and his neuro exam is within normal limits. Medulloblastomas are most frequently located in the:

   a. Cerebral hemispheres
   b. Chiasmal region
   c. 4th Ventricle
   d. Posterior fossa

14. The most common complication seen in a child with a medulloblastoma is:

   a. Cerebral aneurysm
   b. Cerebral edema
   c. Obstructive hydrocephalus
   d. Quadriplegia

15. J. has an uneventful postoperative course. Follow-up plans include chemotherapy and radiation. In general, chemotherapy has been less effective in treating central nervous system tumors than neoplasia in other parts of the body because:

   a. Children are usually not diagnosed until the tumor is in an advanced stage
   b. Intrathecal catheters are not available for children
   c. The blood–brain barrier provides a physiologic barrier for many chemo agents
   d. There are not enough trained pediatric neurologists who specialize in oncology
16. Which of the following may be a contraindication to performing a lumbar puncture?

- a. Increased ICP
- b. Suspected infection
- c. Intracranial hemorrhage
- d. Post-ictal state

17. When receiving a transfer report from the ER, the C.C. nurse is told the patient is agitated and has a + Brudzinski’s sign. This indicates:

- a. Increased ICP
- b. Meningial irritation
- c. Encephalitis
- d. IVH

**Key References**


Pulmonary Review
Kathryn E. Roberts, RN, MSN, CRNP, CCRN, CCNS

Pulmonary Review Part 1

- **CCRN Test Plan: 18% of the exam**
  - ALI/ARDS
  - Acute pulmonary embolus
  - Acute respiratory failure, hypoxemia
  - Acute respiratory infections
  - Air-leak syndromes
  - Aspirations
  - Bronchopulmonary dysplasia
  - Congenital anomalies
  - Pulmonary hypertension
  - Pulmonary trauma
  - Pulmonary pharmacology
  - Asthma
  - Thoracic trauma
  - Ventilator management and ABG interpretation

- **Pediatric Considerations**
  - Fixed number of airway branches
  - Decreased alveolar number & size
  - Smaller intrathoracic airways
  - Cylindrical chest wall
  - Immature respiratory center
  - Upper Airway Development
    - Obligatory nose breathers
    - ↑resistance leads to increased WOB
    - Larynx
    - Epiglottis – anterior, cephalad, longer, flaccid
    - Cricoid cartilage – narrowest point
    - Vocal cords – more rigid
  - Trachea
    - Infants 4-5 cm
    - Adolescents 7 cm
  - Thoracic Cavity
    - Poorly developed diaphragm
- Compliant chest wall

- **Physiologic Principles**
  - Gas exchange
  - Pulmonary compliance & resistance
  - Pulmonary vascular pressures & resistance
  - Oxyhemoglobin curve
  - Control of breathing
  - V/Q match & mismatch
  - Intrapulmonary shunting

- **Gas Exchange & Transport**
  - Alveolus - functional unit of gas exchange
  - Simple diffusion
  - Network of pulmonary capillaries
  - Type I (gas exchange) and Type II (surfactant) epithelial cells

- **Compliance & Resistance**
  - Compliance
    - Distensibility of the lungs
    - Surfactant
    - Elasticity
  - Resistance
    - Obstruction to airflow
    - Poiseuille’s law
    - Role of upper airway
  - Pulmonary Vascular Pressures & Resistance
    - Change from fetal to adult circulation
    - Gravity dependent pulmonary blood flow
    - Ventilation-perfusion matching
    - PVR

- **V/Q Match**
  - V/Q ratio = air to blood ratio; indicates whether or not air and blood come together in normal amounts
  - Normal = 0.8
  - “Mismatch” occurs when there is a change in this relationship

- **Intrapulmonary Shunt**
  - P/F ratio is a means of determining the presence and degree of a shunt
    - \( P = \text{PaO2} \)
    - \( F = \text{FiO2} \)
    - \( \text{PaO2/FiO2} \) normally is > 286 mmHg
  - A decreased ratio indicates the presence of a shunt
  - The process is reversible
Oxyhemoglobin-Dissociation Curve
- Left shift: increases binding of oxygen to Hgb
- Right shift: unloading of oxygen from Hgb
- Fetal O2-Hgb curve shifts to the Left

Acute Respiratory Failure
- Inability of the respiratory system to meet the demands of the body for oxygen
  OR
- Inability to provide adequate elimination of carbon dioxide
- Etiology
  - Impaired Integrity of Lung Tissue
  - Increased Airway Resistance
  - Respiratory Compromise
  - Alterations in CNS Function
  - Upper Airway Disorders
  - CV or Hematologic Disorders
- Clinical Manifestations
  - ↑ WOB
  - ↓ lung volume
  - Upper airway obstruction
  - Lower airway obstruction
  - ↓ air entry
  - Compromised perfusion
  - Alterations in LOC
- Management
  - Prevention, Prevention, Prevention.....
  - Non-invasive monitoring
  - Invasive monitoring
  - Supplemental oxygen
  - Mechanical ventilation

Questions

1. PEEP is intended to do which of the following?
   a. Increase functional residual capacity
   b. Decrease functional residual capacity
   c. Increase venous return to the heart
   d. Increase cardiac output
2. In an infant with bronchopulmonary dysplasia (BPD), factors that impair the release of oxygen by negatively affecting oxyhemoglobin dissociation include:
   a. Hyperthermia
   b. Metabolic acidosis
   c. Respiratory acidosis
   d. Hypothermia

3. The normal V/Q ratio is 0.8. An increased ratio (>0.8) indicates:
   a. Ventilation is greater than normal in relation to perfusion
   b. Decreased ventilation as a result of air trapping
   c. Decreased perfusion from a low cardiac output
   d. Increased perfusion and ventilation

4. Increased pulmonary vascular resistance can be attributed to:
   a. Respiratory and metabolic alkalosis
   b. Pulmonary vasoconstriction secondary to acidosis
   c. Hypoplasia of lung tissue as seen in diaphragmatic hernias
   d. Both B & C

5. You notice that your intubated, mechanically ventilated 2-month old infant with RSV bronchiolitis has a sudden decrease in his spO2 from 98% to 82%. Your first priority is to:
   a. Administer a sedative agent
   b. Increase the FiO2 and ventilator rate
   c. Reposition the endotracheal tube
   d. Assess the patency of the endotracheal tube

- **Complications Associated with Intubation/Mechanical Ventilation**
  - Oxygen toxicity
  - Acute Lung Injury (ALI)
  - Barotrauma
  - Atelectasis
  - Pneumonia
  - \( \downarrow \) Cardiac Output

- **Acute Respiratory Distress Syndrome (ARDS)**
  - Most severe form of Acute Lung Injury
  - Non-cardiogenic pulmonary edema
  - \( \text{PaO2/FiO2} < 200 \)
  - Bilateral pulmonary infiltrates
• Pathophysiology
  o Local or systemic insult activates systemic stress response
  o Neutrophils induce injury
  o Development of ↑ alveolar capillary membrane permeability
  o Development of pulmonary edema & PVR
  o Pulmonary Hypertension
  o Bronchoconstriction
  o Hypovolemia
  o Increased Pulmonary Vascular Resistance
  o Reduced FRC & Decreased Compliance
• Management: Goals
  o Support optimal oxygen delivery
  o Manage inciting injury
  o Minimize oxygen consumption
  o Provide optimal fluid and nutritional support
  o Surveillance for infectious diseases
• Ventilation Therapies
  o Volume control ventilation
  o Pressure control ventilation
  o PEEP
  o Permissive Hypercapnia
  o High Frequency Ventilation
  o ECMO
  o Nitric Oxide
  o Prone Positioning
  o Rotation Therapy
  o Surfactant
• Optimize Oxygenation & Minimize O2 Consumption
  o Increase cardiac output
  o Ensure normal preload
  o Reduce afterload
  o Support cardiac contractility
  o Maintain adequate Hgb
  o Maximize oxygen delivery
  o Decrease activity
  o Maintain comfort
  o Normothermia
- **Optimize Fluid & Nutrition**
  - Maintain CVP → normal renal function
  - Diuretics
  - Increased protein needs
  - Early enteral nutrition
- **Infectious Disease**
  - Increased risk for nosocomial infections
  - Monitor Temp & WBC
  - Universal precautions
  - Gastric decompression

  - **Acute Pulmonary Infections**

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</table>
Epiglottitis | H-flu  
| Beta-hemolytic streptococcus  
| Pneumococci  
| 2-6 years | Abrupt fever  
| Drooling  
| Dysphagia  
| Dysphonia  
| Distress  
| Stridor  
| Tripod position  
| “Thumb sign” on x-ray  
|  
| OR for laryngoscopy & intubation  
| Maintain comfort  
| Maintain oxygenation & ventilation  
| Sedation  
| Monitor for pulmonary edema  

Bronchiolitis | Viral  
| 2-6 months | Fever  
| URI Symptoms  
| Apnea  
| Cyanosis  
|  
| Prevention  
| Supplemental O2  
| Mechanical ventilation  
| Fluids & Nutrition  
| RSV Antibody test  

Questions
6. Which of the following therapies would be most valuable in aiding the management of a child requiring a PEEP of 15 cm water?
   a. ECMO therapy
   b. Placement of a thoracostomy tube
   c. Placement of a pulmonary artery catheter
   d. High frequency ventilation
7. Which of the following are not considered to be potential complications of the management of pediatric ARDS?
   a. Barotrauma, oxygen toxicity, secondary infections & SIADH
   b. Diminished cardiac output, air leaks, acute lung injury & pneumothorax
   c. Diminished cardiac output, tracheal ulcerations & DI
   d. Oxygen toxicity, MOSF, pressure ulcers & pneumonia

8. Which of the following clinical manifestation is an indication of the need for an artificial airway in a 2 y/o child with laryngotracheobronchitis?
   a. Elevated temperature
   b. Increased mucous production
   c. Metabolic acidosis
   d. Persistent agitation/lethargy

9. The most important objective in caring for the patient with epiglottitis is to:
   a. Keep the child quiet & comfortable
   b. Administer racemic epinephrine
   c. Place the child in a supine position
   d. Administer antibiotics

10. A 10 month old w/ bronchiolitis is intubated due to an acute deterioration in her respiratory status. Post-intubation ABG is as follows:
    - pH 7.29
    - pCO2 65
    - pO2 80
    - HCO3- 22
    - O2 sat 95%

   This blood gas reflects:
   a. Respiratory acidosis
   b. Respiratory alkalosis
   c. Metabolic acidosis
   d. Metabolic alkalosis
Pulmonary Review
Part II

- Pneumothorax/Air Leak Syndromes
- Asthma/Status Asthmaticus
- Acute Pulmonary Embolus
- Pulmonary Hypertension
- Bronchopulmonary Dysplasia
- Congenital Diaphragmatic Hernia
- Tracheo-esophageal Fistula

- Air Leak Syndromes
  - Etiology
    - Pneumothorax: collection of air in the pleural space
    - Postoperative causes
    - Chest tube removal
    - Mechanical ventilation
    - Upper airway trauma
    - Thoracic trauma
  
  - Pathophysiology
    - Size, pressure & extent of pneumothorax
    - Cardiorespiratory dysfunction
    - Loss of vital capacity, total lung capacity, functional residual capacity
    - Intrapulmonary shunting with ventilation-perfusion mismatching in the collapsed lung
  
  - Clinical Manifestations
    - ↑ HR, ↑RR, intercostal retractions, chest wall asymmetry, grunting, flaring, paleness to cyanosis
    - ↓ intensity or change in pitch of breath sounds
    - ↑ PIP’s in the ventilated child
    - ↓spO2
    - ↓ cardiac function
    - Sudden cardiorespiratory collapse
• Chest Radiographs
  ▪ Absent pulmonary vascular markings
  ▪ Uniformly translucent area without lung markings
  ▪ Free pleural air accumulates in the non-dependent portions of the chest
  ▪ Evidence of subcutaneous air along the mediastinum, bronchi

  o Tension Pneumothorax
    • Clinical Manifestations
      ▪ Agitation
      ▪ Hypotension
      ▪ Unilateral chest wall movement
      ▪ Decreased breath sounds on the affected side
      ▪ Cardiac compromise
      ▪ Shifting of heart sounds
      ▪ Tracheal deviation
      ▪ Mediastinal shift
      ▪ Sudden cardiorespiratory collapse

  o Open Pneumothorax
    • “Sucking chest wound”
    • Flail chest wall movements
    • Severe respiratory distress,
    • Hypoventilation
    • Hypercapnia
    • Hypoxia
    • Atelectasis
    • Increased work of breathing

• Tracheobronchial Injury
  • Subcutaneous emphysema
  • Dyspnea
  • Sternal tenderness
  • Hemoptysis
**Air Leak Syndromes: Management**
- Prevention, prevention, prevention.....
- Rapid recognition
- Direct care
- Chest tube (pneumothorax)
- Positive pressure ventilation (open pneumothorax)
- Needle thoracentesis (tension pneumothorax)
- Supportive care
- Pain management

**Status Asthmaticus**
- Severe asthma episode refractory to 1st line management
- Characterized by:
  - Airway inflammation
  - Mucosal edema
  - Airway plugging
  - Bronchospasm
  - Status Asthmaticus
- Pathophysiology
  - Cellular mediators
  - Neurogenic factors
  - Pulmonary function
  - Abnormalities of gas exchange
- Clinical Manifestations
  - ↑ Respiratory Effort
  - ↓ Cardiac Output
  - Respiratory Acidosis
  - Altered LOC
- Management
  - Diagnostic studies
  - Restore airway patency
  - Reverse bronchospasm
  - Control inflammatory response
  - Decrease secretions
  - ± Intubation & mechanical ventilation
• Pharmacology/Medications
  o Inhaled β2-agonists
  o Anticholinergics
  o Corticosteroids
  o Systemic β2-agonists
  o Magnesium Sulfate
  o Mucolytics
  o Antibiotics

  o **Acute Pulmonary Embolus (PE)**
    • Relatively rare in pediatrics
    • High morbidity & mortality
    • May be underdiagnosed
    • Management derived from adult practice
    • Sickle Cell Disease

• Pathophysiology
  o Free floating thrombus
  o Extension of existing pulmonary thrombus
  o Size & location
  o V/Q mismatch
  o Potential for right heart failure
  o Reflex bronchoconstriction

• Populations at Risk
  o Sickle cell disease
  o Nephrotic syndrome
  o Cancer
  o Chemotherapy
  o Inherited hypercoagulable state
  o Vasculitis

• Management
  o Anticoagulation
  o Thrombolysis
  o Supportive care
  o CV support (e.g. Dopamine)
  o Antibiotics
  o PRBCs
  o Surgical care
    ▪ Embolectomy
    ▪ Vena caval filters
Questions....

11. Which one of the following is the first action to take in the case of a patient with a suspected tension pneumothorax?
   a. Obtain the child’s blood pressure
   b. Assist with intubation
   c. Call for a chest radiograph
   d. Prepare for a needle thoracostomy

12. For a patient with status asthmaticus, CXR will reveal:
   a. Hyperinflation
   b. Foreign-body aspiration
   c. Perihilar infiltration
   d. An elevated diaphragm

13. A 12 y/o male is admitted to the PICU following an acute asthma attack. He has received multiple albuterol treatments. The following measurements are obtained:
   - BP 130/78
   - HR 68
   - RR 48
   - FiO2 0.6
   - O2 Sat 88%

   Based on his history, which of the following physical findings would you expect to find:
   a. Wheezing & agitation
   b. Coughing & grunting
   c. Pleural rub & wheezing
   d. Stridor & bronchospasm

14. The use of an inhaled beta2-adrenergic agonist in the management of a child with status asthmaticus would include which of the following medications?
   a. Isoproterenol (Isuprel)
   b. Methylprednisolone (Solu-Medrol)
   c. Albuterol (Ventolin)
   d. Ipratropium bromide (Atrovent)
15. Intubation and positive pressure ventilation are high risk therapies in the pediatric asthmatic patient because of the risk of:

a. Infections  
b. Oxygen toxicity  
c. Pneumothorax  
d. Ventilator dependence

16. A full term infant is admitted to the PICU with a history of meconium aspiration. A pulse oximetry reading on the right finger is 99% while the pulse oximetry reading is 65% on the right foot. The probable rationale for this discrepancy is:

a. Poor systemic perfusion  
b. Coarctation of the aorta  
c. Artifact from a moving child or probe malfunction  
d. Persistent pulmonary hypertension

- **Pulmonary Hypertension**
  - Etiology
    - Functional vasoconstriction w/normal pulmonary vasculature  
    - Hypertrophy of distal vascular pulmonary smooth muscle  
    - Hypoplastic alveoli & associated vessels  
    - Functional obstruction to pulmonary blood flow  
  - Mean pulmonary artery pressure of more than 25 mm Hg at rest or more than 30 mm Hg during exercise  
    - WHO, 2003  
  - PHTN: Classification/Etiology
    - Pulmonary artery hypertension  
    - PHTN with left heart disease  
    - PHTN associated with respiratory disorders &/or hypoxemia  
    - PHTN due to chronic thrombotic/embolic disease  
    - Miscellaneous  
  - Clinical Manifestations
    - Vary with disease progression  
    - Related to presence and degree of R→L shunting  
    - Wide swings in O2 saturations & PaO2  
    - Preductal PaO2 > post-ductal PaO2  
    - Cyanosis  
    - Hypoxemia  
    - Acidosis
• Management
  o Hyperoxegenation
  o Hyperventilation
  o IV Vasodilators
  o HFOV
  o INO
  o ECMO
  o Decrease stimuli
  o Maximize cardiac output
  o Nutrition
  o Infection control
  o Family support
• Vasoconstrictors:
  o Alveolar hypoxia
  o Acidosis
  o Hypothermia
  o Hyperinflation
  o Agitation
• Vasodilators:
  o Oxygen
  o Alkalosis
  o Normothermia
  o Sedation
  o iNO
  o Calcium channel blockers
  o IV Prostacyclines

  o Bronchopulmonary Dysplasia
    • Etiology
      o Unresolved chronic lung injury of infancy
      o Respiratory distress
      o Oxygen dependency
      o Risk factors:
        • O2 toxicity
        • Positive pressure ventilation
        • Chronic inflammation
        • Overhydration
    • Pathophysiology
      o ↑ airway resistance
      o ↓ compliance
      o Rapid, shallow respirations
• Respiratory fatigue  A’s & B’s
  • Bronchospasm
  • Atelectasis
  • PHTN  right heart failure

• Clinical Manifestations
  • Barrel chest
  • Tachypnea, rapid shallow respirations, retractions
  • Hypoxemia & hypercarbia
  • Respiratory acidosis
  • Crackling, wheezing, rales
  • Fluid intolerance
  • RV failure
  • Failure to thrive
  • “BPD SPELLS” or bronchospasm: agitation, irritability, duskiness, increased work of breathing

• Diagnostic Findings
  • ABG: hypoxemia, hypercarbia, compensated respiratory acidosis
  • ECG: right ventricular hypertrophy
  • CXR: scattered infiltrates, atelectasis, “ground glass”

• Management
  • Maintain adequate oxygenation & ventilation
    ▪ permissive hypercapnia
    ▪ intubation/mechanical ventilation - SLOW weaning
    ▪ ± tracheostomy
    ▪ supplemental O2
    ▪ Treatment of residual lung disease
    ▪ Bronchodilators
    ▪ Inhaled anticholinergics
    ▪ Anti-inflammatory agents
    ▪ Diuretic therapy
  • Growth & development
    ▪ Nutrition/↑ caloric needs
    ▪ GERD
  • Monitor for respiratory failure
  • Discharge planning
  • Supplemental O2
  • Pulmonary toilet
  • Prevention of infection
  • Technical skills

Peds CCRN.Webinar.Pulmonary
Congenital Diaphragmatic Hernia (CDH)

- Full term infants
- Herniation of abdominal contents
- Heart is displaced to the right
- G & D of both lungs affected
- Pathophysiology
- Pulmonary hypoplasia
  - R→L shunting
  - Pulmonary hypoplasia
  - ↓ number & size of conducting airways
  - ↓ total lung volume
  - ↓ number & size of conducting airways
  - ↓ Type II pneumocytes
  - Ipsilateral lung w/ decreased compliance & increased resistance
  - ↑ resistance to blood flow
  - PPHN
- Clinical Manifestations
  - Tachypnea
  - Retractions
  - ↓ or absent breath sounds
  - PMI shifts
  - ↑ chest diameter
  - Scaphoid abdomen
  - Pulmonary HTN
  - Hypoxemia
  - Cyanosis
  - CXR – gas-filled bowel loops
- Pre-Operative Management
  - Adequate oxygenation & ventilation
    - Intubation & mechanical ventilation
    - ↓ oxygen demands
    - Positioning
  - Correction of acidosis
  - Adequate perfusion
  - Nutrition
  - Support
  - Abdominal or Thoracic approach
  - Surgical repair
    - Primary repair
    - Patch repair
• Post-Operative Management
  o Adequate oxygenation & ventilation
    ▪ Intubation & mechanical ventilation
    ▪ ↓ oxygen demands
    ▪ Positioning
  o Correction of acidosis
  o Adequate perfusion
  o Nutrition
  o Infection surveillance
  o Family support

o Tracheoesophageal Fistula (TEF)
  • Pathophysiology
    o EA with distal TEF (87%)
    o Isolated EQ (8%)
    o Isolated TEF (4%)
    o EA with proximal TEF (1%)
    o EA with double TEF (1%)
  • Clinical Manifestations
    o Congenital defect
    o Prenatal history - polyhydraminos
    o Post-natal history - profuse oral secretions, bubbly oral secretions, regurgitation of saliva, severe coughing spells, and respiratory distress with the first feeding
    o Associated anomalies:
      ▪ Other midline defects
        • Cardiac
        • GI
        • Musculoskeletal
        • Urinary tract
  • Pre-Operative Management
    o Maintain oxygenation & ventilation
    o Decompression
    o No pacifiers
    o Prone positioning
    o F & E balance
    o Neutral thermal environment
    o Evaluation for other anomalies
  • Operative Management
    o Primary repair
Esophageal Atresia with distal TEF
- Staged repair
- Isolated TEF

- Post-Operative Management
  - Maintain hemodynamic stability
  - Optimize oxygenation & ventilation
  - Gastric decompression
  - Pain management
  - Prevention of infection
  - Nutrition
  - Parent support

**Questions...**

17. A long-term complication for the child with BPD is:
   a. Cor pulmonale
   b. Barotrauma
   c. Cystic Fibrosis
   d. Cardiomyopathy

18. The *primary objective* in the treatment of an infant with PHTN is to:
   a. Maintain the pH level < 7.40
   b. Dilate the pulmonary vascular bed
   c. Dilate the systemic vascular bed
   d. Constrict the pulmonary vascular bed

19. Which of the following factors does not enhance or increase pulmonary vasodilation?
   a. Alveolar hypoxia
   b. Alkalosis, respiratory &/or metabolic
   c. Inhaled nitric oxide
   d. Sedation
20. An infant is admitted to the PICU with a history of prematurity, RDS, mechanical ventilation for four weeks with decreasing oxygen requirements. The infant is now six months of age, living at home but still requiring oxygen support and albuterol nebulizations. The history suggests the presence of Bronchopulmonary Dysplasia (BPD). Which of the following statements are NOT true of BPD?

a. Ventilation-perfusion mismatching in BPD is due to increased airway resistance, edema and inflammation result in alveolar hypoventilation, hypercapnea, and hypoxemia.
b. Prematurity, oxygen therapy, and prolonged ventilation contribute to the development of BPD.
c. Diuretic therapy and fluid restriction are often instituted secondary to the development of congestive heart failure.
d. Normalization of arterial blood gases, especially PaCO₂, is the goal of mechanical ventilation.

21. Which complication is most common in infants with CDH?

a. Alveolar-arterial ratio mismatch
b. Inhibition of surfactant delivery
c. Left-to-right shunting through patent ductus arteriosus
d. Severe pulmonary hypertension

**KEY References**


Peds CCRN Review:
The Synergy Model and Developmental Considerations
Kathryn E. Roberts, RN, MSN, CRNP, CCRN, CCNS

What is Synergy...?
☯ Synergy is a practice model developed by AACN
☯ Links clinical practice with outcomes
☯ Recognized the unique contribution that nurses make to outcomes and quality of care
☯ Recognizing the additional components that comprise critical care nursing, 20% of the exam is based on...

Breakdown of Exam Components
☯ Clinical Judgment 80%
☯ Professional Caring and Ethical Practice 20%

Professional Caring And Ethical Practice
☯ Advocacy/Moral Agency 2%
☯ Caring Practices 4%
☯ Collaboration 4%
☯ Systems Thinking 2%
☯ Response to Diversity 2%
☯ Clinical Inquiry 2%
☯ Facilitator of Learning 4%

Why Synergy?
☯ All patients and their families have similar needs but experience them across continuums from health to illness.
☯ The dimensions of a nurse’s practice are driven by these needs.
☯ When nurse competencies stem from patient needs and the characteristics of the nurse and patient synergize, optimal patient outcomes can result.

☯ Other nursing models:
  • Did not look at individual patient needs
  • Did not consider the family
  • Did not look at the nurse

Peds CCRN Webinar.Synergy/Development
• Needed to look at practice based on patient and family needs
• Needed to look at nurse competencies that matched the needs of the patient

Patient Characteristics

☯ Stability
  • Ability to maintain a steady-state equilibrium

☯ Complexity
  • Intricate entanglement of two or more systems

☯ Predictability
  • Able to expect a certain trajectory of illness

☯ Resiliency
  • Capacity to return to optimal function using compensatory & coping mechanisms

☯ Vulnerability
  • Susceptibility to stressors that may adversely affect outcomes

☯ Participation in decision-making
  • Capacity to engage in decision-making

☯ Participation in care
  • Capacity to engage in care

☯ Resource availability
  • Resources that a patient, clinical unit or system brings to a situation

Nurse Characteristics

☯ Clinical judgment
  • Clinical reasoning. This includes clinical decision-making, critical thinking & a global grasp of the situation coupled with nursing skills acquired by integrating formal & experiential knowledge

☯ Clinical inquiry
  • Ongoing process of questioning and evaluating practice & providing informed practice

☯ Caring practices
  • Constellation of nursing activities that respond to the uniqueness of patients, families & colleagues. Caring practices create a compassionate & therapeutic environment aimed at promoting comfort & preventing suffering.

☯ Response to diversity
  • Sensitivity to recognize, appreciate & incorporate differences when providing care

☯ Advocacy/moral agency
  • Working on another’s behalf & representing the concerns of patients, families & colleagues. Serves as a
moral agent in identifying & helping to resolve ethical concerns within clinical settings.

Facilitation of learning
• Ability to use one’s self to facilitate patient, family, staff & system learning

Nurse Characteristics

Collaboration
• Working with others to promote & encourage each person’s contributions

Systems thinking
• Appreciating the care environment from a perspective that recognizes the holistic interrelationships that exist within & across healthcare systems

Synergy:

- Need to look at patient characteristics and nurse competencies
- Importance of nurse competencies will vary depending on the patient’s characteristics
- **Synergy results when a patient’s needs and characteristics are matched with the nurse’s competencies**

How Synergy is used in the exam

- Will not be questioned on Synergy terminology
- Synergy theory applied to scenarios
- Reflects what nurses do
- Usually answer is common sense

Developmental Considerations

- General concepts of childhood development
- Erikson’s stages of psychosocial development
- Freud’s theory of personality development
- Piaget’s stages of cognitive development
Infancy: 0 – 12 months
- Psychosocial: Trust versus mistrust
- Personality: Oral stage
- Cognitive: Sensorimotor stage

Toddlers: 1 – 3 years
- Psychosocial: Autonomy versus doubt and shame
- Personality: Anal stage
- Cognitive: Sensorimotor stage progresses to preoperational stage
- Concept of death: temporary event

Preschool (3 – 5 years)
- Psychosocial: Initiative vs Guilt
- Personality: Phallic stage
- Cognitive: Preoperational
- Concept of death: temporary and feared

School-age 6 – 12 years
- Psychosocial: Industry vs Inferiority
- Personality: Latency Period
- Cognitive: Concrete operational (7-11 y)
- Concept of death: temporary to permanent

Adolescents: 12 – 18 years
- Psychosocial: Identity vs Role confusion
- Personality: Genital stage
- Cognitive: Formal operational
- Concept of death: permanent & inevitable but very distant

Questions....

1. Members of the nursing staff are developing written patient family education materials for a group of patients/families with diverse reading abilities. It would be most effective for the staff to:
   a. Design individual handouts for each patient.
   b. Develop a computer-based education series.
   c. Write the materials at a fourth-grade reading level.
   d. Limit text and provide color pictures.

2. The nursing staff is resisting being assigned to a disruptive patient. An appropriate resolution would be to:
a. Request the physician to transfer the patient
b. Rotate the patient assignment among staff
c. Confront the family and demand an end to the disruptive behavior
d. Hold a nursing team conference to discuss possible alternatives.

3. A patient recalls a near-death experience (NDE) that occurred during resuscitation and wishes to tell the nurse about it. What is the optimal response by the nurse?

a. Let the patient know that NDE’s are often hallucinations
b. Compare the patient’s story to the actual resuscitation events
c. Encourage the patient to describe the NDE to his family
d. Make time to listen actively while the patient tells the story.

4. A nurse manager feels that the number of blood culture samples that have been reported by the laboratory as being contaminated is excessive. The most appropriate action for the nurse manager would be to:

a. Observe the staff as they obtain blood culture samples
b. Track the number of blood cultures drawn and the number that are reported as contaminated.
c. Hold a staff meeting and discuss the problem
d. Develop a poster demonstrating the correct procedure

5. An alert teenager is emergently intubated during an episode of pulmonary edema. When family members come to visit the patient, they cry out, “Talk to me; talk to me!” The nurse should tell the family that:

a. They must not excite the patient while visiting
b. Communication is not a priority at this time
c. The patient is too exhausted to converse with them
d. The breathing tube temporarily prevents the patient from speaking.

6. A 2 YO end stage liver failure patient has been declared brain dead. The parents decide to discontinue feedings and donate their daughter’s organs. In response to the parents’ request, the most appropriate action by the nurse would be to:

a. Contact the organ procurement agency.
b. Convene a multidisciplinary care conference.
c. Tell the parents that their daughter’s condition precludes organ donation.
d. Discontinue feedings per the parents’ request.

7. The parents of a patient who transferring out of the ICU says, “Why can’t he just stay a few days longer? He just doesn’t feel strong enough.” Which of the following is the most appropriate response?
a. “There’s a very sick patient who needs this bed”
b. “You sound concerned about leaving the ICU.”
c. “Most people do just fine after transfer”
d. “Your insurance limits the time you can stay in the ICU”

8. A patient’s family expresses anxiety regarding the meaning of numbers on the patient’s monitor, and asks the nurse for clarification. The nurse’s most appropriate response would be:

a. “The numbers indicate when the patient is having problems”
b. “The numbers help us determine the best treatment”
c. “Which numbers on the monitor concern you?”
d. “What don’t you understand about the monitor?”

9. The aunt of a trached, mechanically ventilated patient is to be taught how to suction. When developing a teaching plan, the nurse must first:

a. Obtain written information about the procedure
b. Determine a schedule for demonstrating the technique
c. Assess the knowledge and skills the aunt needs to learn.
d. Encourage the daughter to observe the procedure on other patients

10. A patient is in critical condition in the CCU following an acute myocardial infarction. His significant other has been at the bedside providing reassurance and support since his admission 12 hours ago. His estranged wife arrives and demands that the significant other not be allowed to visit or be given condition updates. The nurse should:

a. Ask the physician to write an order to allow the significant other to have visitation privileges
b. Request a multidisciplinary care conference to discuss visitation and communication of patient status
c. Contact the hospitals’ medical-legal department and request that the hospital attorney speak to the wife
d. Encourage the patient to express his desire to spend time with his significant other to his wife
11. Numerous consultants are involved in ordering conflicting therapies for a patient. The nurse should:
   a. Ask consultants to collaborate before ordering therapies
   b. Prioritize and complete therapies in order of importance
   c. Try to balance the conflicting therapies as well as possible
   d. Request a patient care conference

12. A survey reveals that all of a hospital’s nurses feel that the routine 4am chest x-rays cause an interruption in children’s sleep patterns. The best strategy for addressing this issue would be to:
   a. Assemble a work group to discuss the current hospital policy
   b. Reschedule all non-emergent 4am chest x-rays during daytime hours
   c. Request an in-service for the radiology department on the effects of sleep deprivation in children
   d. Send the results of the survey to hospital administration

13. When caring for a 15-YO patient, the nurse would:
   a. Address worries about the future
   b. Use games as a teaching strategy
   c. Encourage the patient to talk about life experiences
   d. Allow the patient’s peers to visit.

14. Which of the following age groups is most likely to incorporate “imaginary friends” into their play?
   a. Pre-schoolers
   b. School-agers
   c. Toddlers
   d. Adolescents

**Key References:**


Pediatric Potpourri
Kathryn E. Roberts, RN, MSN, CRNP, CCRN, CCNS

Pediatric Potpourri

- Ingestions
- Abuse
- Burns
- Behavioral/Psychiatric Concerns

Poison/Toxin Exposure

- Poison exposure – inappropriate contact with a potentially harmful substance
- Ingestion
- Inhalation
- Ocular
- Dermal
- Parenteral injection
- Acute vs Chronic

Pediatric Exposures

- 2008 (AAPCC Annual Report)
- 1,613,969 cases (0-19 yrs)

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• 3114 “major” effect
• 118 deaths

Most common exposures

• <6 years of age
  o Cosmetics/personal care products
  o Cleaning substances
  o Analgesics
  o Foreign bodies
  o Topical preparations
  o Cough & cold preparations
  o Plants
  o Pesticides
  o Vitamins
  o Antimicrobials

• 6 – 19 years
  o Analgesics
  o Cough & cold preparations
  o Antidepressants
  o Foreign bodies
- Bites & envenomations
- Cosmetics/personal care products
- Cleaning substances
- Sedatives/hypnotics/ antipsychotics
- Stimulants & street drugs
- Antihistamines

Risk factors by age
- Infants
- Toddlers
- School age children
- Pre-teens & teenagers

Fatalities
- Analgesics
- Sedatives/hypnotics/ antipsychotic medications
- Antidepressants
- Stimulants and street drugs
- Cardiovascular drugs
- Alcohols
• Anticonvulsants
• Antihistamines
• Gases and fumes
• Muscle relaxants

General Management Principles

• History
• Assessment
  o Clinical
  o Laboratory
• Prevent absorption
  o Ocular
    ▪ Irrigation
  o Dermal
    ▪ Irrigation
  o GI
    ▪ Ipecac – NOT recommended
    ▪ Gastric lavage
    ▪ Whole bowel irrigation
    ▪ Activated charcoal
- Cathartics
  - Enhance elimination
    - Ion trapping
    - Extracorporeal measures
- Antidotes
  - Acetaminophen: N-acetylcysteine
  - Digoxin: Digoxin immune Fab
  - Isoniazid: Pyridoxine
- Supportive care
- Symptom management
  - Range from fluids & monitoring to ECMO
- Prevent future episodes
- Evaluate contributing factors
  - Developmental factors
  - Psychosocial considerations
  - Psychiatric considerations

Two Examples:
- Acetaminophen
  - Rapidly absorbed from GI tract & metabolized in the liver
Toxic dose related to body weight

- Delayed symptoms
- Progress to hepatic encephalopathy, hepatic failure, and death in some cases

Treatment:
- N-acetylcysteine

- Calcium channel blockers
  - Absorbed from GI tract
  - Toxic dose varies
  - Cause conduction delays, decreased cardiac output and hypotension...can lead to cardiac collapse
  - Treatment: aggressive GI tract decontamination

Abuse/Neglect

- Incidence (2006):
  - 3,300,000 referrals (6 million children) to CPS in the US
  - 905,000 determined to be victims of abuse or neglect
  - 1530 children died

- Types of Child Abuse
  - Physical Abuse
• Physical Neglect
• Sexual Abuse
• Munchausen Syndrome by Proxy

• Non-accidental Trauma
  o A leading cause of morbidity and mortality in children
  o Higher ICU admission rates
  o Increased morbidity and increased medical costs as compared to accidental injuries
  o Missed diagnoses may lead to repeat injury or death

• Physical Abuse
  o Any inflicted injury that results in or risks significant physical injury to the victim
  o Morbidity
    ▪ Physical sequelae
    ▪ Mental health consequences
    ▪ Violence
    ▪ Criminal behavior
    ▪ Substance abuse
    ▪ Self-injurious/suicidal behavior
    ▪ Depression
- Anxiety
- Abused becomes the Abuser

- Clinical Presentation in the ICU
  - Traumatic Brain Injury
  - Skeletal Trauma
  - Abdominal Trauma
  - Chest Trauma
  - Burns
  - Asphyxiation/Suffocation
  - Near Drowning

- History – “Red Flags”
  - Unexplained or poorly explained etiology of injury
  - Injuries incompatible with history provided
  - Changing history
  - Significant delay in seeking treatment

- Abuse & Neglect: Risk Factors
  - Child
• < 3 y/o
  • Learning or developmental disabilities
  • Hx of unexplained or repeated injuries
  • Prolonged crying/colic
  • Multiple absences from school
    ○ Parent
      • Unwanted pregnancy
      • Environmental stressors
      • Adolescent or single parent
      • Inappropriate delay in obtaining help for child
      • Hx of domestic violence
      • Hx of substance abuse
      • Unwillingness to provide information
      • Disinterest in child

• Physical Exam
  ○ Characteristics of Intentional Injuries
  ○ General appearance
  ○ Injuries in various stages of healing
  ○ Multiplanar injuries

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- Obvious pattern to injuries
- Assaultive locations of injuries
- Burns
- Fractures
- Bruising

- Traumatic Brain Injury
  - Intentional TBI – leading cause of death from non-accidental trauma
  - Most common ICU presentation of non-accidental trauma
  - 4 in 100,000 children < 5 yrs affected annually (Conway, 1998)
  - Physical abuse – leading cause of serious TBI in infants

- Shaken Baby Syndrome
  - Who?
    - Children ≤ 36 months of age
    - Majority of cases < 12 months of age
  - How?
    - Caffey (1972) “Whiplash Shaken Baby Syndrome”
    - Deceleration forces
  - Striking of the head against a surface
• Intracranial trauma
  • Subdural hematoma (± cerebral edema)
  • Subarachnoid hemorrhage
  • Retinal hemorrhage(s)
  • Rib fracture(s)
  • Metaphyseal fracture(s) of the long bones
  • Hx of previous abuse – typically not an isolated event

• Clinical Manifestations
  • Apnea
  • Lethargy
  • Cyanosis
  • Seizures
  • ↓ pO’s
  • Irritability
  • Hyper- vs. Hypotonicity
  • Retinal hemorrhage(s)
  • Hx of Fall
  • Skull fractures

  • Differential Diagnosis
- Accidental trauma
- Birth trauma
- Coagulopathies
- Osteogenesis Imperfecta
- Glutaric aciduria type I

- Skeletal Trauma
  - Presence of older, healing fractures
  - Highly specific injuries
  - Multiple fractures
  - Infants – rib fractures
  - Fracture of mid to distal 1/3 of clavicle/scapula
  - Skull fractures with no history of witnessed trauma

- Differential Diagnosis
  - Accidental injury
  - OI
  - Osteomyelitis
  - Infantile rickets
  - Congenital syphilis
Abdominal Trauma

- 2-5% of physical abuse
- 40-60% of inflicted abdominal trauma result in death
- Damage to multiple organs
  - Liver
  - Duodenum
  - Kidneys
  - Pancreas
  - Mesentery
- Present to ICU w/:
  - Fever
  - Sepsis
  - Hypotension
  - Hypovolemic shock
- Need rapid assessment/ rapid resuscitation
- Accidental v Non-Accidental
  - One organ affected
  - History consistent w/ injury
  - ± abdominal bruising

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- Multiple organs affected
- History inconsistent w/ injury
- ± abdominal bruising

Burns
- 6-20% of pediatric abuse
- ICU admission rates variable
- Immersion burns
  - Non-splash, near linear demarcation
  - “glove” demarcation
- Uniform contact burns
- Bilateral burns

Asphyxiation/Suffocation
- Anoxic damage with minimal clinical findings
- Petechiae – skin & mucous membranes without medical cause
- Unexplained acute neurological deterioration
- What about SIDS?
  - “Distinguishing Sudden Infant Death Syndrome from Child Abuse Fatalities”

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• Sudden Infant Death Syndrome
  o Complete autopsy is done; autopsy findings are compatible with SIDS
  o No gross or microscopic evidence of trauma or significant disease process
  o No evidence of trauma on skeletal survey
  o Other causes of death are adequately ruled out
  o No evidence of current alcohol, drug, or toxic exposure
  o Thorough death scene investigation and review of the clinical history are negative

• Suffocation/Asphyxiation
  o Previous recurrent cyanosis, apnea, or ALTE while in the care of the same person
  o Age at death > 6 months
  o Previous unexpected or unexplained deaths of 1 or more siblings
  o Simultaneous or nearly simultaneous death of twins
  o Previous death of infants under the care of the same unrelated person
  o Discovery of blood on the infant’s nose or mouth in association with ALTEs

“Keys” to Diagnosis of Non-Accidental Trauma

• Physical exam inconsistent w/ Hx or initial Dx
• Multiple injuries in various stages of healing
• Unexplained acute neurological deterioration
• Unexplained shock, cardiac arrest or unconsciousness

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Questions...

1. An unconscious 5-month-old is admitted. The parent reports the baby fell off the table during a diaper change by an older sibling. What findings would indicate further inquiry of the history?
   a. a reddened or bruised area on the skull
   b. poorly reactive pupils
   c. retinal hemorrhage
   d. a linear skull fracture

2. When assessing a suspected victim of child abuse, documentation of the physical examination should include:
   a. Evaluation of the consistency of the injury with the reported mechanism of injury
   b. Bruising or other injuries in various stages of healing
   c. Thorough description of all injuries
   d. All of the above

3. A 2-year-old is experiencing manifestations of digoxin (Lanoxin) toxicity. BP is 94/60, capillary refill time is 2 seconds and the electrocardiogram reveals AV block with a heart rate of 60. The critical care nurse would anticipate which of the following interventions?
   a. Performance of cardioversion
   b. Administration of Atropine
   c. Performance of vasovagal maneuvers
   d. Monitoring of HR and rhythm and perfusion status

4. In caring for a patient with salicylate intoxication, the critical care nurse would anticipate which of the following as a primary treatment measure?
   a. Administration of protamine sulfate
   b. Administration of glucose
   c. Transfusion of packed RBCs
   d. Replacement of fluid and electrolytes

5. A 3 year old girl is found with an open bottle of her mother’s prenatal vitamins with iron. The color of the tablet coating can be seen in the child’s mouth. 20 tablets cannot be accounted for. Following the ingestion of iron, GI decontamination may include all of the following except
   a. Whole bowel irrigation
   b. Activated charcoal

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c. Ipecac syrup
d. Gastric lavage

6. The best initial treatment for the child with suspected carbon monoxide poisoning is:
   a. Intubation and mechanical ventilation
   b. Hyperbaric oxygenation
   c. Administration of 100% oxygen
   d. Cool, humidified room air

Burns

- Incidence declining
  - Highest risk: \( \leq 4 \) years of age
  - Most common type: scald burns

- Mechanism of Injury
  - Occurs as the result of heat necrosis of cells
  - Causes coagulation necrosis of tissue (surface area and depth)
  - Extent determined by:
    - Heat intensity
    - Duration of exposure
    - Tissue(s) involved

- Classification
  - Functional
    - Zone of hyperemia
    - Zone of stasis
    - Zone of coagulation
Descriptive

- 1st degree
- 2nd degree
- 3rd degree

Types of Injuries

- Thermal
  - Direct heat, exposure to chemicals, contact with electrical current
- Scald
  - Hot liquids
- Electrical
  - Contact with high-voltage electricity
- Chemical
  - Direct contact with caustic chemicals
- Contact
  - Hot, solid objects

Initial Management/Treatment

- Minimize extent and depth
- Eliminate the source
- Stop the burning process
- Rapid primary assessment
• Emergency Department
  
  o ABCDE
  
  o Hx, mechanism of injury
  
  o Extent of the burn (% of TBSA)
  
  o Dx studies
  
  o Wound care

• Systemic Responses to Burns
  
  o Early hypofunction followed by hyperfunction
  
  o Proportional to extent of burn injury
  
  o CV
  
  o Pulmonary
  
  o Hematologic
  
  o Systemic Responses to Burns
  
  o GI
  
  o Renal
  
  o Metabolic
  
  o Immune and Inflammatory
  
  o Hypothermia

• Fluid Resuscitation

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o Initiate in infants with burns ≥ 10% of BSA & older children with burns ≥ 15% of BSA

o Goal: restore & maintain intravascular volume

o Multiple formulas to calculate fluid deficit

  - Parkland Burn Resuscitation Formula:
    - First 24 hours post-burn
      o 4ml Lactated Ringers x wt in kg x burn surface area
      o Give half of the calculated amount in the first 8 hours post-burn and the remaining over the next 16 hours
      o Plus daily maintenance volume as needed to maintain appropriate urine output
    - Second 24 hours post-burn
      o 25% Albumin: 0.1ml x wt in kg x % burn surface area
      o D5W: 1ml x wt in kg x % burn surface area
      o Plus daily maintenance volume as needed to maintain appropriate urine output

  - Maintenance fluids

  - Wound assessment & care
    - Cleansing
    - Hydrotherapy
    - Debridement
    - Topical preparations
    - Excision
    - Coverage

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- Autograft

- Special considerations
  - Eyes
  - Nose
  - Lips
  - Ears

- Pain management

Behavioral/Psychiatric Concerns
- Complications associated with psychotropic medications
- Behavioral/Psychosocial emergencies
- Behavioral restraint

Complications of Psychotropic Medications
- Extrapyradimal Symptoms (EMS)
- Neuroleptic Malignant Syndrome (NMS)
- Acute Dystonia
- Serotonin Syndrome
- Extrapyradimal Symptoms (EPS)
- Parkinsonian-like tremor
- Muscular Rigidity
- Akinesia

**Treatment:**
- Anti-muscarinic meds (e.g. Cogentin)
- Anti-histaminergic meds (e.g. Benadryl)

### Neuroleptic Malignant Syndrome

- NMS can develop after initiation of or increased dose of a neuroleptic medication (e.g. Haldol).
- Rare, but life threatening event

**Clinical Manifestations:**
- Fever
- Muscle Rigidity
- Change in mental status/altered LOC
- Diaphoresis
- Tremor
- Autonomic instability

**Treatment of NMS**
- Close monitoring of VS

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- Stop neuroleptic medications
- IV hydration
- Treat hyperthermia
- Monitor CK closely
- Monitor fluids and electrolytes

**Acute Dystonia**

- Oculogyric crisis
- Blephorospasm Torticollis
- Opisthotonus
- Macroglossia
- Buccolinguial crisis
- Laryngospasm
- Spasticity
- Treatment of Acute Dystonia
  - IM or IV Cogentin
  - IM or IV Benadryl
  - Acute dystonia is most often reversible with the above treatment
Serotonin Syndrome

- Rare, but serious event
- Excess presence of serotonin in the CNS.
- Increase (or overdose) of a serotonergic agent
- Combination of serotonergic medications

**Clinical Manifestations:**
- Confusion/disorientation
- Restlessness/agitation
- Myoclonus
- Hyperreflexia
- Diaphoresis
- Tremor/shivering N/V/HA

**Treatment of Serotonin Syndrome**
- Discontinue serotonergic meds
- Fluids
- Monitor VS and electrolytes

**Common Diagnostic Tests**
- CBC
- Serum electrolytes
- Renal and liver function tests
o Thyroid Function tests
o Serum B12 and Folate
o HIV/Syphilis serology
o Urinalysis
o Drug screen
o Heavy metals

Suicide

• Risk Factors:
  o History of attempts
  o Hopelessness
  o Psychiatric Illness
  o Impulsivity
  o Severe anxiety/panic
  o Acute drug/alcohol intoxication
  o Chronic drug/alcohol use
  o Recent loss
  o Chronic physical illness
• Nursing Interventions:
  
  o Listen for statements of intent/thoughts of self-harm
  
  o Assess intent, lethality, access to means (i.e. weapons)
  
  o Provide 1:1 monitoring of patient
  
  o Assess for and remove objects in environment that could be used as a means of harm
  
  o Inform SW, medical and psychiatric team

Violence

• Risk Factors:
  
  o Drug/alcohol intoxication
  
  o Psychotic illness
  
  o History of violence
  
  o Impulse dyscontrol
  
  o History of arrest
  
  o Organic brain damage

• Interventions:
  
  o Make team members aware of risk
  
  o Do not intervene alone!
  
  o Assess for and remove objects in environment that could be used as a means of harm
harm
  o Remain calm, clear and concise
  o Restraints according to hospital policy
  o 1:1 observer
  o Medications

Use of Restraints

• What is a restraint?

• What about medications?

• What is NOT a restraint?
  o Safety devices routinely used in the course of pediatric care delivery
  o Standard practices involving devices that limit mobility or temporary immobilization, related to medical, dental, diagnostic or surgical procedures and the related post-procedure care processes
  o Adaptive support devices
  o Forensic/correctional devices used for security purposes
  o Medications used for treatment purposes
• Restraint Monitoring
  o Restraints can have negative physical and psychological consequences.
  o Be creative in finding alternatives to restraint
  o Always use the least restrictive measure
  o Discontinue restraints at the earliest possible time
  o Monitor patients’ for and document:
    ▪ Vital signs
    ▪ Skin integrity
    ▪ Circulation
    ▪ Continued need for restraint
    ▪ Hygiene and comfort

**Questions...**
6. A child is admitted to the PICU following a house fire. On assessment, the bedside nurse notices singed nasal hairs & eyebrows, wheezing and an altered level of consciousness. At this time, the primary nursing action should be to assess:
   a. Neurologic status
   b. Respiratory effort
   c. Skeletal injury
   d. Extent of burn injury

7. In the emergent phase of burn care, the primary type of shock related to a burn injury is:
   a. Septic
   b. Cardiogenic
   c. Hypovolemic
   d. Distributive
8. The 1\textsuperscript{st} priority in treatment of a chemical burn injury would be:
   a. Removing all patient clothing and locating a neutralizing agent
   b. Removing all patient clothing and brushing a powdered chemical from the skin
   c. Removing all patient clothing, brushing a powdered chemical from the skin and locating a neutralizing agent
   d. Removing all patient clothing, brushing a powdered chemical from the skin and performing extensive irrigation of the burn with tap water

9. In the immediate post-burn injury period, the preferred route of medication administration would be:
   a. Oral (pO)
   b. Subcutaneous (SC)
   c. Intramuscular (IM)
   d. Intravascular (IV)

10. Which of the following would not be considered a restraint?
    a. Administration of Haldol during a psychotic episode
    b. Administration of Midazolam to an agitated, intubated, mechanically ventilated patient
    c. Application of an immobilizer to stop a child from pulling at his endotracheal tube
    d. Application of leather restraints to a violent adolescent who has just attacked his mother

11. You are caring for an adolescent receiving Haldol. Over the course of your shift, he becomes increasingly confused, develops tremors, and is diaphoretic, tachycardic and febrile to 40°C. You contact the medical team because you are concerned that your patient has developed:
    a. Acute dystonia
    b. Sepsis
    c. Serotonin syndrome
    d. Acute neuroleptic malignant syndrome

12. You recognize that this is considered a medical emergency and know that your patient will require close monitoring for the development of:
    a. Acute renal failure
    b. Cardiovascular collapse
    c. Acute respiratory failure
    d. All of the above
Key References:


Renal Review
Kathryn E. Roberts, RN, MSN, CRNP, CCRN, CCNS

Renal Review

- Acute Renal Failure
- Chronic Renal Failure
- Life-threatening Electrolyte Imbalances
- Hemolytic Uremic Syndrome (multisystem)

Key Concepts

- Normal hourly UOP is small; small compromise in UOP may indicate a significant compromise in renal perfusion/function
- UOP will decrease if CO and RBF are compromised
- Renal failure may be present in a child with low, normal or high UOP
- F & E imbalances can develop rapidly in infants/children. All sources of fluid intake/output must be monitored closely; essential to replace excessive fluid losses
- S/Sx of inadequate intravascular volume/shock in the infant/child may be subtle

Renal Anatomy

- Kidneys
- Ureters
Heme/Imm Review

- Hematology, anatomy & physiology
- Blood products and plasma
- Coagulopathies
- Hematologic/Oncologic/Immunologic Emergencies**

Hematopoiesis

- Process by which blood cells are formed
  - Embryonic/fetal: multiple sites
  - At birth – occurs in the red bone marrow of all bones

Blood Component Therapy

- Whole Blood
- Packed Red Blood Cells
- Platelets
- Fresh Frozen Plasma
- Granulocytes
- Cryoprecipitate
- Factor VIII
• Albumin – 5% and 25%

Immunity

• Passive
  o Natural: acquired via natural contact w/ antibody transplacentally or via colostrum & breast milk
  o Artificial: acquired through the administration of antibody or antitoxin

• Active
  o Natural: acquired via natural infection; exposed to antigen & immune response mounted
  o Artificial: acquired via inoculation w/ a variant antigen

Immune Disorders

• Immunodeficiency: a permanent state of impaired immune function that is usually genetic or congenital in nature

• Immunosuppression: a state of impaired immune function that can be intentional or unintentional in nature
Questions....

1. All of the following are potential complications of blood component administration except ___________.
   a. Acute hemolytic reaction
   b. Infection
   c. Anemia
   d. Coagulopathy

2. 20 minutes after initiation of a PRBC transfusion, your patient becomes hypotensive, anxious, dyspneic & begins to shake uncontrollably. You suspect that which of the following is occurring:
   a. Citrate toxicity
   b. Acute hemolytic transfusion reaction
   c. Acute non-hemolytic transfusion reaction
   d. Anaphylaxis

3. Your 1st intervention will be to:
   a. Notify the physician
   b. Treat shock and/or respiratory distress
   c. Stop the transfusion
   d. Keep vein open w/ an infusion of 0.9% NaCl

4. Which of the following electrolyte disturbances are frequently associated with a large-volume blood transfusion?
   a. Hypernatremia & hyperphosphatemia
   b. Hypocalcemia & hypophosphatemia
   c. Hyperkalemia & hyponatremia
   d. Hypocalcemia & hyperkalemia

5. A neutropenic patient is admitted showing signs of respiratory infection. Blood & sputum cultures are obtained. The RN should anticipate:
   a. Starting antibiotics immediately
   b. Placing the patient in strict isolation immediately
   c. No intervention until a causative organism is identified
   d. Transbronchial biopsy

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Case Study

- A.H. is an 8 month old male with a severe respiratory infection which has led to ARDS. He was transferred to your facility from an OSH where he was intubated and had an arterial and central line placed. His PMH includes multiple episodes of oral thrush and diaper rash. He has had pneumonia twice since birth. Both episodes responded to antibiotic therapy. Prior to developing ARDS he was diagnosed and treated for an ear and throat infection. He received a 10 day course of ampicillin. He did not respond to the ampicillin. In fact his symptoms worsened.
  - Diagnostic studies:
    - Respiratory culture is positive for PCP.
    - Blood cultures are negative from all sites.
    - CBC has a WBC count of 0.5 with decreased lymphocytes on the differential.
    - Immunoglobulin levels are low.
    - HIV is negative with a viral load of < 50.

6. Which is the most likely diagnosis based on these findings?

   a. HIV
   b. DiGeorge syndrome
   c. Congenital TORCH
   d. SCIDS

Congenital Immunodeficiency Disease

- β-lymphocyte disorders
- T-lymphocyte disorders
- Phagocyte dysfunction disorders
- Complement disorders
- Combined β- and T- lymphocyte disorders

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Severe Combined Immunodeficiency (SCID)

- Most severe combined - and T- lymphocyte disorder
- Immunologic emergency
- Survival requires stem cell transplant
- Autosomal recessive mutations or de novo mutations
- Unusual frequency of common infections
- Infection not present @ birth
- Diagnostic studies:
  - WBC
  - Decreased total lymphocyte count
  - Decreased absolute lymphocyte count
  - Cell-mediated immunity
  - Erythrocyte & leukocyte enzymes
  - CXR – small or absent thymus

- SCID: Management
  - Stem cell transplantation
  - Isolation
  - Meticulous skin/mucosal care
  - IVIG
  - Enzyme replacement therapy
Gene therapy

SCID: Complications
- Infection
- Failure to thrive/malnutrition
- Graft vs Host Disease

Coagulopathies
- Disseminated Intravascular Coagulopathy
- Idiopathic Thrombocytopenia Purpura
- Heparin Induced Thrombocytopenia

Idiopathic Thrombocytopenic Purpura (ITP)
- Also called “immune thrombocytopenic purpura”
- Isolated thrombocytopenia
- Development of antibodies to own platelets
- Increased peripheral platelet destruction
- Diagnosis of exclusion
- Exact cause is unknown
- Normal bone marrow
- ITP: Diagnosis
  - Exclude other causes of platelet destruction or decreased production

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• Hx: prev healthy child w/ recent viral illness

• Exam: bruises, petechiae

• Laboratory findings:
  - ↓ Platelet count
  - Nml PT/PTT

• ITP: Management
  - Steroids
  - IVIG
  - Immunosuppression
  - Splenectomy if non-responsive to medical treatment
  - Platelet transfusion

• Monitor for complications:
  - Intracranial bleeding, GI tract & renal bleeding

Heparin Induced Thrombocytopenia (HIT)

• Complication of heparin exposure

• Antibody mediated

• Low platelet count

• High risk of thrombosis

• Suspect HIT when......
  - Patients are receiving heparin (any form)
o Unexplained platelet decrease by 50% of baseline OR

o Thrombocytopenia with or without thrombosis

- HIT: Management

- Hold heparin therapy held whenever possible

- Review of the patient’s care for heparin exposure includes, but not limited to, use of heparin via:

  o Heparin coated catheters;

  o Heparin and low molecular weight heparin (e.g., enoxaparin) therapy for venous thromboembolism prophylaxis or treatment of thrombosis;

  o Heparin infusions for prevention of thrombosis or anticoagulation therapy;

  o Heparin flushes and locks for peripheral and central venous catheters;

  o Heparin as a carrier for arterial, central venous and intracardiac lines;

  o Heparin in parenteral nutrition

  o Heparin as the priming agent and anti-clotting agent in closed systems (circuits) used for dialysis, plasmapheresis, Extracorporeal Membrane Oxygenation (ECMO) and cardiopulmonary bypass.
Oncologic Emergencies

- Tumor Lysis Syndrome
- Hyperleukocytosis
- Spinal cord compression
- Superior vena cava syndrome
- Hyponatremia (Endocrine)
- DIC (Multisystem)
- Sepsis (Multisystem)

Tumor Lysis Syndrome

- Most common metabolic emergency
- Metabolic triad:
  - Hyperuricemia, hyperkalemia, hyperphosphatemia
- Secondary complications:
  - Acute renal failure
  - Hypocalcemia
- Pathophysiology
  - Rapid release of intracellular contents
  - Large tumor burden
  - Rapid cell turnover
  - Rapid response to tumor therapy

Peds CCRN Webinar. Hemelm
o ALL, AML, high-grade lymphoma, after initial chemotherapy

• Management
  o Prophylactic:
    ▪ Limit potassium & phosphate intake
    ▪ Hydration
    ▪ Alkalinization
    ▪ Reduction of uric acid
    ▪ ECG monitoring
  o Emergent:
    ▪ Goal: maintain normal end-organ function
    ▪ Treat hyperkalemia
    ▪ Treat hyperphosphatemia
    ▪ Treat hypocalcemia
    ▪ ± dialysis

Hyperleukocytosis
• Most common hematologic emergency
• Peripheral leukocyte count > 100 x 10⁹ L (>100,000/mcL)
• More common in AML, ALL, ANLL
• Poor prognostic indicator
• Pathophysiology

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- Increased viscosity
- Thrombi in microvasculature
- Dyspnea & hypoxia
- Focal neurologic deficits, ataxia, agitation, confusion, delirium, stupor

- Management
  - Goal: decrease peripheral leukocyte count & control complications
  - Avoid PRBC transfusions
  - Leukopheresis or exchange transfusion

Spinal Cord Compression

- Impingement of the spinal cord or cauda equina
- Intramedullary mass (primary CNS tumor)
- Compression of the thecal sac (tumor in the epidural space)

- PAIN
- MRI – best dx test
- Rapid intervention needed
- Corticosteriods
- Radiation therapy
- Surgery
- ± Chemotherapy
- Analgesia
SVC Syndrome

- Occurs as result of SVC obstruction
- External compression
- Internal thrombosis
- ~10% of pediatric patients with mediastinal mass
- Thrombosis – unusual in peds
- Clinical manifestations
  - Cough
  - Hoarse voice
  - Chest pain
  - Dyspnea
  - Orthopnea
  - Late: headache, confusion, vision changes, syncope
- Supportive medical treatment
  - Local radiation
  - Thrombus
  - If catheter present – remove
  - Short term anticoagulation
Questions....

7. The 1st priority of management for a patient with SCIDS is:

   a. Stem cell transplant
   b. Treatment of the ARDS/PCP
   c. Bone marrow transplant
   d. IVIG therapy

Amy is a 22-mos old female who was admitted to the PICU 2 weeks ago with RSV. She was nasally intubated & mechanically ventilated soon after admission. Her respiratory status has significantly improved and she was extubated 2 days ago. She has had some minor bleeding from her nares but is otherwise doing well. The team is considering transferring her to the floor later today. 2 hours into your shift, you notice that the bleeding from Amy’s nares has increased and that she has 2 large bruises on her chest and petechiae on all extremities.

You immediately notify the critical care MD & send off the following labs: CBC, Coags, & D-dimer.
Lab findings are significant for:
CBC – decreased platelet count
PT/PTT – normal
D-dimer – normal

8. Based on this information, you suspect that Amy may have developed which of the following?
   a. Disseminated Intravascular Coagulopathy (DIC)
   b. Thrombotic Thrombocytopenic Purpura (TTP)
   c. Idiopathic Thrombocytopenic Purpura (ITP)
   d. Hemolytic Uremic Syndrome (HUS)

9. The triad of electrolyte disturbances most frequently seen in Tumor Lysis Syndrome is:

   a. Hypercalcemia, hypophosphatemia, hyperkalemia
   b. Hyperphosphatemia, hyperuricemia, hypocalcemia
   c. Hypophosphatemia, hypokalemia, hypocalcemia
   d. Hyperphosphatemia, hyperkalemia, hyperuricemia

Peds CCRN Webinar. Hemelmm
Key References:


GI Review

- 6% of the Pediatric CCRN Exam
- Acute abdominal trauma
- Acute GI hemorrhage
- Bowel infarction /obstruction/ perforation
- Gastro-esophageal reflux
- GI abnormalities
- GI surgeries
- Hepatic failure/coma
- Malnutrition and malabsorption

Acute Abdominal Trauma

- Most common potentially lethal injury to children
- Anatomic differences contribute to injury
- Body surface area allows for greater distribution of injury
- Anterior organs with less subcutaneous fat
- Smaller blood volume

Blunt Abdominal Trauma

- Compression of solid or hollow viscous organs against the spine
- Rapid acceleration and deceleration
- Increased abdominal pressure
- contusion
- laceration
- hemorrhage
- Can result in lethal injury without sign of trauma

Penetrating Abdominal Trauma

- Usually caused by gunshot or stab wound
- Major vascular injuries are common
- Onset of peritonitis may be immediate

Abdominal Trauma - Clinical Manifestations

- Signs are often subtle
- Rebound tenderness
- Pain
- Guarding
• Increased abdominal girth
• Rigidity
• Grunting respirations
• Pallor
• Hypotension
• Cullen’s sign
• Turner’s sign
• Kehr’s sign

Abdominal Trauma - Diagnostic Studies
• CT scan
• Diagnostic peritoneal lavage
• CBC and coagulation studies
• Chest and abdominal x-rays
• Urinalysis
• Nuclear scan is the gold standard for hepatic and splenic injuries
• Ultrasound

Abdominal Trauma - General Management
• ABC’s and vital signs
• Serial abdominal girths
• NG tube
• Serial hematocrits
• Indications for surgery:
  o massive bleeding
  o penetrating trauma
  o certain blunt injuries

Acute Abdomen
• Acute abdomen refers to sudden onset of abdominal pain and tenderness
• Any acute abdomen needs to be evaluated for surgical intervention!!

Acute Abdomen - Causes
• Abdominal inflammation
• Obstruction
• Perforation
• Hemorrhage

Acute Abdomen - Physiology
• Leakage of GI contents
• Upper GI tract perforations
• Lower GI tract perforations
• Peritoneal injury

Acute Abdomen - Clinical Manifestations
• Signs and symptoms of obstruction:
  o abdominal distension, loss of bowel sounds, vomiting & fever
• Signs and symptoms of perforation:
  o respiratory distress and acidosis
• Third spacing
• Signs and symptoms of peritonitis:
  o pain, guarding, & rebound tenderness

Acute Abdomen - Management
• Ongoing assessment & monitoring
• Gastric decompression
• Intravascular volume replacement & maintenance
• Pharmacologic maintenance
• Diagnostic studies
  o x-ray
  o CT scan
  o radionucleotide studies
  o deep peritoneal lavage
  o CBC
  o Electrolytes
• Nutrition
• Maintain intravascular volume
• Pain management
• Monitor for manifestations of respiratory distress
• Elevate HOB to 30-45 degrees
• NG tube placement for decompression and drainage
• Surgical intervention

Acute Abdomen - Potential Complications
• Decompensated shock
• Perforation
• Infarction
• Death

Acute GI Bleed - Causes
• Lower GI Bleed

Peds CCRN Webinar.GI
• Neonates: swallowed maternal blood, milk allergy, hemorrhagic disease of the newborn, NEC, colitis, volvulus, and intussusception
• Infants: the above, anal fissures, juvenile polyps, and hemolytic uremic syndrome
• Preschool age: the above, Henoch-Schonlein purpura, and inflammatory bowel disease
• School age child and adolescent: infections, colitis, inflammatory bowel disease, polyps, angiodysplasia, Henoch-Schonlein purpura, hemolytic-uremic syndrome, hemorrhoids, and rectal trauma

• Upper Gi Bleed
  • Neonates and infants: swallowed maternal blood, esophagitis, stress ulcer, esophageal varices, hemorrhagic newborn disease, reflux, portal hypertension, trauma, and pyloric stenosis
  • Preschool age children: the above, foreign body, caustic ingestion, and trauma
  • School age and adolescent child: esophagitis, gastritis, stress ulcer, peptic ulcer disease, portal hypertension, trauma, and nasopharyngeal lesions

Acute GI Bleed - Physiologic Response
• Early gastrointestinal bleeding
  • >15% loss of blood volume
• Stimulation of autonomic CV response
  • >20% loss of blood volume
• Decreased SBP & metabolic acidosis
  • Severe hemorrhage

Acute GI Bleed - Clinical Manifestations
• Signs of acute blood loss (sudden, acute bleed)
• Weakness and faintness (slow onset bleed)
• Acute bleeding presents as hematemesis, melena or hematochezia
• Chronic (occult) bleeding presents as trace amounts of blood in normal appearing stools or gastric secretions

Acute GI Bleed - Diagnostic Studies
• Laboratory tests including ABG, CBC, FSP, PTT, pancreatic enzymes & LFT’s
• Upper/Lower GI
• Abdominal x-ray
• Endoscopy
• Radionucleotide studies
• Angiography

Acute GI Bleed - Management

Peds CCRN Webinar.GI
- Signs and symptoms of respiratory distress
- Fluid resuscitation
- Monitor coagulation studies
- Monitor electrolytes
- Monitor fluid balance
- Monitor for further signs of bleeding
- Assess for S/Sx of perforation
- Administer room temperature saline lavage
- Monitor for gastric pH < 4
- Prevent stress ulcers & ↑ cytoprotection
- Vasopressin or somatostatin

**Questions....**

R, an 8 yr old girl who suffered blunt abdominal trauma from a soccer injury is being transferred to the PICU from the general pediatric unit. She has been in the hospital for 24 hours without significant problems, but 2 hours ago, R started to experience mild discomfort in her epigastric region and the discomfort has increased in severity since then. R rates her pain as 5 on a pain scale of 1-10. She is admitted to the PICU to assess the possibility of pancreatitis.

1. One of the most frequent causes of pancreatitis in children is:
   a. Alcoholism
   b. Gallstones
   c. Blunt abdominal trauma
   d. Vascular disease

2. The RN observes for a positive Cullen’s sign in R. This is indicative of:
   a. Impending disseminated intravascular coagulopathy
   b. Hemorrhagic pancreatitis
   c. Necrotic bowel process
   d. Sepsis

3. Which of the following is considered a “classic sign” of splenic rupture?
   a. Cullen’s sign
   b. Kehr’s sign
   c. Battle sign
   d. Turner’s sign

Hepatic Failure & Coma

Peds CCRN Webinar.GI
• Portal hypertension
• Fulminant hepatitis
• Biliary atresia
• Hyperbilirubinemia
• CMV
• EBV
• Reye’s Syndrome
• Drug induced hepatic failure

Hepatic Failure
• Multifactorial pathophysiology
• Fulminant hepatic failure
  o encephalopathy develops within 8 weeks of the onset of liver disease in patients with no previous liver dysfunction

Hepatic Failure - Clinical Manifestations
• Hepatosplenomegaly
• Varices
• Ascites
• Malnutrition
• Pruritis
• Telangiectasis
• Jaundice
• Hepatic encephalopathy
• Renal failure
• Coagulopathy

Hepatic Encephalopathy Staging
• Stage I
  o Normal LOC, periods of lethargy & euphoria
• Stage II
  o Disorientation, increased drowsiness, agitation
• Stage III
  o Marked confusion; sleeping most of the time
• Stage IV
  o Coma

Hepatic Failure - Management
• Management of encephalopathy:
  o Control ICP
• Monitor for neurologic dysfunction

Peds CCRN Webinar.GI
- Decrease serum ammonia
- Management of hepatorenal syndrome
- Management of portal hypertension
- Management of coagulopathy
- Management of ascites

Portal Hypertension
- Obstruction of the normal flow of blood through the portal system, liver sinusoids, and the hepatic vein
  - Extrahepatic portal hypertension
  - Intrahepatic portal hypertension
  - Suprahepatic portal hypertension
- Caused by anything that obstructs blood flow within the portal venous system, liver, or inferior vena cava

Portal Hypertension - Complications
- Congestion of the splenic and mesenteric circulations
- Development of collateral vessels
- Sequestration of blood in the splanchnic circulation

Portal Hypertension - Clinical Manifestations
- Splenomegaly
- Hemorrhoids
- Dilated abdominal veins
- Esophageal varices
- Acute upper GI bleeding
- Ascites
- Anemia, thrombocytopenia, leukopenia

Portal Hypertension - Diagnostic Studies
- Liver function tests
- Liver biopsy
- Barium Swallow
- Esophagoscopy
- Splenoportography

Portal Hypertension - Management
- Fluid/blood Resuscitation
- Saline lavage
- Vasopressin therapy
- Endoscopic sclerotherapy

Peds CCRN Webinar.GI
• Sengstaken-Blakemore tube (?)
• Supportive care
  o avoid rectal temperatures
  o keep patient calm
  o soft foods only
  o active type and screen

Portal Hypertension - Surgical Management
• Goal is to decompress the hypertensive portal system
• Portacaval shunt

Biliary Atresia
• Congenital defect of unknown cause
• Incidence: 1 per 8,000 to 13,000 white infant births
• Absence or obstruction of the intrahepatic and extrahepatic ducts of the biliary system
• When fibrosis develops the bile flow is obstructed
• Eventually cirrhosis occurs
• Bile cannot drain from the liver to the duodenum
• Direct/conjugated hyperbilirubinemia
• Progression to portal hypertension and cirrhosis

Biliary Atresia - Clinical Manifestations & Dx
• Persistent Jaundice
• Gray colored stools
• Dark colored urine
• Pruritis
• Laboratory studies to differentiate from other types of neonatal jaundice
• Radionucleotide scanning

Biliary Atresia - Management
• Determined by location of the atresia
• Kasai procedure
• Post-operative laparotomy care
• Liver transplant

Post-operative Complications
• Infection
• Ascites
• Portal hypertension
• Cirrhosis
• Liver failure
Inoperable Biliary Atresia
- Supportive care
- Control progression of ascites, pruritis, fat malabsorption, hepatic encephalopathy
- Phenobarbital – promote biliary drainage
- Cholestyramine – removal of bile salts

Hepatitis
- Inflammation of the liver
- Most frequent cause of hepatic failure
  - Hepatitis A
  - Hepatitis B
  - Hepatitis C
  - Hepatitis D

Hepatitis - Clinical Manifestations
- Pre-icteric stage lasts one week and includes symptoms of fever, chills, anorexia, malaise, abdominal pain, nausea, vomiting, joint pain, hepatomegaly, lymphadenopathy
- HAV has nonspecific viral symptoms
- HBV presents with urticaria, arthralgia, and arthritis preceding full blown illness
- Icteric state has a duration of 2-6 weeks and includes weakness, fatigue, pallor, jaundice, dark urine, pale-colored stool, pruritis, and palmer erythema
- Post-icteric stage includes the resolution of jaundice and normalization of stool and LFT values

Congenital GI Abnormalities
- Early diagnosis important
- Adequate surgical repair
- Prevention & tx of post-op complications
- Polyhydramnios
- Failure of air to pass through the GI tract

<table>
<thead>
<tr>
<th>Associated with Respiratory Distress</th>
<th>Associated with Abdominal Wall Defects</th>
<th>Associated with Obstructive or Bleeding Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diaphragmatic Hernia Tracheoesophageal Fistula</td>
<td>Omphalocele Gastrochisis</td>
<td>Malrotation with volvulus Hirshprung’s disease</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Imperforate anus &amp; intestinal atresia</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Intussusception</td>
</tr>
</tbody>
</table>

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Congenital GI Abnormalities

- Omphalocele
  - Abdominal organs herniate into the umbilicus
  - Covered w/ protective sac
- Gastrochisis
  - Abdominal organs herniate
  - NO protective sac
  - Abdominal wall defect

Clinical Manifestations

- Same S/Sx (other than initial presentation)
- Temperature instability
- Dehydration
- Hypoglycemia
- Respiratory distress
- SHOCK

Management

- Prevent/Treat SHOCK
- Omphalocleles – cover w/moist sterile gauze
- Gastrochisis – cover w/warm, sterile saline sponges & plastic bag/wrap

Pre-Op Management

- NPO
- NG tube to low sxn
- IVF or TPN
- Neutral thermal environment
- Close monitoring of serum glucose levels

Volvulus

- Most common in infancy
- Abnormal movement of intestines around the mesenteric artery
- Obstruction of the duodenum and strangulation of the mesenteric artery

Volvulus - Clinical Manifestations
Peds CCRN Webinar.GI
• Bilious emesis
• Melena or currant jelly stools
• Abdominal distention
• Visible peristalsis
• Variable x-ray findings

Volvulus - Management
• NPO
• IV hydration
• IV antibiotics
• Surgical repair
• Post-op:
  o TPN
  o Management of F & E imbalances

Intussusception
• Healthy infants
• Preceded by gastroenteritis
• Telescoping of intestinal segments
• Venous then arterial obstruction
• Compromised blood supply

Intussusception - Clinical Manifestations
• Paroxysmal severe abdominal pain
• Bloody stools
• Signs of obstruction:
  o Bilious emesis
  o Abdominal distention
  o “sausage-shaped” mass in RUQ

Intussusception - Management
• IV fluids
• NPO
• Barium enema
• Surgical correction
• Post – op
  o IV hydration
  o IV Abx
  o Monitor for infection
  o Pain management

Peds CCRN Webinar.GI
Questions....

S is a 7-month old boy who was diagnosed with Hepatoblastoma 4 months ago. He has been hospitalized for a liver biopsy, radiation Tx, Hickman central line placement and chemotherapy. S undergoes a 2nd laparotomy for partial excision of the tumor mass and a visceral angiogram for chemoembolization of the residual mass. He returns to the PICU postoperatively.

S’s lab results on admission to PICU:
- Alk phos: 39 U/L
- Bili direct: 0.4 mg/dL
- Bili total: 1.6 mg/dL
- LDH: 425 U/L
- SGOT: 35 U/L
- Albumin: 4.1 g/dL
- Total protein: 5.2 g/dL
- Glucose: 50 mg/dL

4. S’s admitting orders include starting an IV solution of glucose. The rationale for this is that:
   a. Patients with liver failure are kept NPO because eating interferes with ventilation.
   b. Gluconeogenesis is no longer completed because of liver failure.
   c. Appetite stimulation is greatly decreased because of hepatic encephalopathy.
   d. Decreased bile production compromises digestion and absorption

5. Acute pancreatitis can best be defined as:
   a. Infection of the head of the pancreas
   b. An autodigestive process
   c. An overproduction of bile
   d. Ischemia to the pancreas

6. Laboratory tests in a patient with pancreatitis reveal an amylase of 325 units/dL & a glucose concentration of 562 mg/dL. Hyperglycemia is caused by:
   a. Dehydration leading to hyperconcentration of glucose
   b. Fat necrosis
   c. The starvation response
   d. Hypersecretion of glycogen

7. Third spacing in the patient with pancreatitis results from:
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a. Release of pancreatic enzymes
b. Hemorrhagic process in the small bowel
c. Bowel necrosis
d. Azotemia

8. Respiratory failure with liver failure is probably caused by:
   a. Fluid overload
   b. Pulmonary bleeding
   c. Cerebral ischemia
   d. Overwhelming sepsis

9. Surveillance of ammonia levels is valuable for patients with hepatic failure, because ammonia levels are:
   a. A predictor of GI bleeding
   b. A nonspecific indicator of GI function
   c. Responsible for fluid shifts from the intracellular space to the extracellular space
   d. An indicator of the amount of ammonia detoxified by the liver

Additional Info – NOT covered in lecture

LFT's - A Quick Review

Ammonia
- Deamination of amino acids during protein metabolism
- In hepatic failure ammonia is left in its toxic form
- Increased levels reflect synthetic dysfunction
- Increased levels can occur in acute or chronic hepatic failure
- Elevated levels may alter the neurologic status

Bilirubin
- By-product of the heme portion of the breakdown of the hemoglobin molecule
- Indirect or unconjugated bilirubin is the fat-soluble bilirubin that is bound to albumin for transport to the liver
- Direct bilirubin is excreted into the hepatic ducts and the GI tract

AST & ALT
- Alanine aminotransferase (ALT) and Aspartate aminotransferase (AST)
- Both catalyze the reversible transfer of an amino group between two acids
• Both increase with cell destruction
• Following cell necrosis the enzyme level peaks and then decreases, ominous if decreases rapidly
• ALT is more hepatic specific than AST

Alkaline Phosphatase
• Derived from the epithelium of the intrahepatic bile ducts
• Increased levels with inflammation or obstruction of the hepatobiliary tree

Hirschsprung's Disease
• Lack of GI tract innervation
• Interruption of peristalsis

Hirschsprung's Disease - Clinical Manifestations
• Newborn:
  • failure to pass meconium
  • Signs of intestinal obstruction
• Child:
  • Constipation
  • “Ribbon-like” stool
  • Abdominal distention
  • Visible peristalsis

Hirschsprung's Disease - Management
• IV hydration
• NPO
• NG tube placement
• Surgical correction with colostomy
• Pain management (post-op)

Key References:


• Bladder
• Urethra
• Nephron

Normal Urine Output
• Adolescent - 0.5 ml/kg/hr
• Child - 1.0 ml/kg/hr
• Infant - 2 ml/kg/hr

Functions of the Renal System
• Formation of Urine
• Waste Excretion
• Erythrocyte Production
• Maintenance of Blood Pressure
• Water & Sodium Balance
• Electrolyte Balance
• Acid-Base Balance

Developmental Limitations
• Inability to excrete excessive sodium
• Decreased serum bicarbonate concentrations
• Inability to concentrate urine
• Decreased Glomerular filtration rate (GFR)
• Decreased Renal blood flow (RBF)

Acute Renal Failure
• Definition: the abrupt cessation of kidney function, with or without oliguria, resulting in accumulation of fluid & waste products
• BUN > 80 mg/dL
• Cr > 1.5 mg/dL

• 3 Categories:
  o Prerenal
    o Renal/Intrarenal/Intrinsic/ATN
    o Postrenal

Prerenal ARF
• Decreased renal perfusion
• Decreased Renal Blood Flow - decreased Glomerular Filtration Rate - decreased Urine Output

• Causes
  o Altered cardiac function
  o Vasodilation

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• Altered vascular volume
• Altered renal blood supply

• Physiologic Responses
  o Autoregulation (Intrarenal)
  o Alterations in: (Extra renal)
  o Cardiac output
  o Systemic vascular tone
  o ADH
  o Distribution of systemic blood flow
  o Systemic blood pressure

• Clinical Presentation
  o Oliguria vs. Nonoliguria
  o Acid-base disturbances
  o Azotemia

• Lab Values
  o Increased BUN
  o Increased Creatinine
  o Increased BUN/Creatinine Ratio
  o FENa < 1%
  o USG > 1.020

• Immediate Management

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Early Recognition
Assess & Maintain Intravascular Volume
Discontinue K+ containing fluids
Diuretics
Avoid nephrotoxic agents

Intrinsic Renal Failure

Acute Tubular Necrosis (ATN)
• Describes numerous conditions which produce renal parenchymal damage involving the glomerulus or tubular epithelium
• Nephrotoxic vs. Ischemic
• Causes
  o Immune-Related
  o Vascular
  o Interstitial Nephritis
  o Renal Trauma
  o Nephrotoxins
• 3 phases
  o Oliguric Phase
  o Diuretic Phase
  o Recovery Phase

• Oliguric Phase
• Abrupt decrease in UOP < 1ml/kg/h
• Increased BUN/Cr
• USG < 1.018
• Decreased Urine osm
• Urine Na > 10 mEq/L

• Oliguric Phase - Potential Complications
  • Hypervolemia
  • Electrolyte Imbalances
  • Acid-base Imbalances

• Diuretic Phase
  • 5 – 7 days
  • BUN increases then decreases
  • Fluid imbalance
  • Electrolyte imbalance
  • Acid-base imbalance

• Recovery Phase
  • 2-4 months
  • Lasts longer in children than in adults
  • BUN normalizes
  • Variable level of recovery

• Intrinsic Renal Failure - Immediate Management
- Supportive care
- Improve renal perfusion
- Remove cause
- Prevention of complications

Postrenal Failure

- Results from anatomical obstruction of the urinary tract
- Congenital problem
- Uncommon in children

• Causes
  - Ureteral
  - Bladder
  - Urethral

• Clinical Manifestations
  - Abdominal or flank pain
  - Palpable mass
  - Failure to thrive

• Immediate Management
  - Decompression of urinary collecting system
  - Removal of obstruction
  - Urinary diversion

PedsCCRNWebinar.Renal
Questions....

1. In prerenal failure, oliguria is the body’s compensatory mechanism to:
   
a. Conserve bicarbonate to alter the acid-base balance  
b. Increase the GFR  
c. Restore the intravascular volume to increase tissue perfusion  
d. Maintain the patency of the ductus ateriosus  

2. Potential complications during the oliguric phase of acute renal failure include:
   
a. Serum K+ = 4.0 mEq/L  
b. Serum osmolality = 260 mOsm/L  
c. Congestive heart failure  
d. Urine output = 1ml/kg/hr  
3. Common laboratory findings associated with acute renal failure include an increase in the blood urea nitrogen (BUN) level, as well as which of the following changes in the concentrations of potassium and creatinine?  
a. ↑ Potassium ↑ Creatinine  
b. ↓ Potassium ↑ Creatinine  
c. ↑ Potassium ↓ Creatinine  
d. ↓ Potassium ↓ Creatinine

Acute Renal Failure - General Management

• Maintain Intravascular Volume
• Maintain Electrolyte Balance
• Maintain Acid-Base Balance
• Maintain Respiratory Status
• Maintain Neurological Status
• Maintain Adequate Nutrition
• Prevent Infection
• Maintain Hematologic Function

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Intravascular Volume

- Goal: achieve & maintain normal intravascular fluid volume
- Strict I & O
- Hypovolemia – fluid administration
- Hypervolemia – fluid restriction & diuretics
- Hypertension

Electrolyte Balance (see table)

- Hyperkalemia
- Hyponatremia
- Hypocalcemia
- Hyperphosphatemia
- Hypo- or Hypermagnesemia

Hyperkalemia (>5 mEq/L)

Clinical Manifestations

- Muscle weakness
- Confusion
- Ascending paralysis
- Nausea
• Diarrhea

• Altered cardiac function
  - Tall, peaked T waves
  - Widened QRS & prolonged PR interval
  - Ventricular arrhythmias
  - Cardiac arrest

Hyperkalemia - Management
• Monitor for clinical signs
• ECG monitoring
• Discontinue K-containing fluids/meds
• Insulin 0.1 u/kg + Glucose 0.5 g/kg
• Ca Glu 100 mg/kg
• Na Bicarb 1-2 mEq/kg
• Albuterol
• Lasix
• Kayexalate 1-2 g/kg
• Hemodialysis
Hyponatremia - Clinical Manifestations

- Lethargy
- Disorientation
- Seizures
- Coma
- Muscle twitching, tremors, weakness
- Abdominal cramps
- Nausea/vomiting
- S/Sx consistent w/ hypovolemia
  - Altered skin integrity
  - Rapid, weak pulse
  - Hypotension
- S/Sx consistent w/ hypervolemia
  - Edema
    - Rapid, bounding pulse
  - Hypertension

Hyponatremia - Management

- Treatment of underlying cause
- ± Hypertonic saline (3%)
- Frequent Neuro assessments

PedsCCRNWebinar.Renal
• Monitor serum Na

Hypocalcemia - Clinical Manifestations

• Tingling sensation
• Chvostek’s sign
• Trousseau’s sign
• Muscle cramps
• Lethargy
• Seizures
• Hypotension
• Prolonged QT interval

Hypocalcemia = Management

• Treat/control underlying cause
• Monitor for S/Sx
• ECG monitoring
• IV calcium supplements
• Monitor serum Mg levels!

Acid-Base Balance

• Metabolic acidosis most common
• Evaluate patient’s ability to compensate
• Pros & cons of Bicarb administration

Respiratory Status
• Complications often R/T fluid retention
• Pulmonary edema or infection
• ARDS

Neurologic Status
• Mild myoclonus or twitching
• Seizures
• Uremic encephalopathy

Nutrition
• Small, frequent enteral feedings
• Parenteral nutrition
• “Nephro” solutions

Infection
• Patients at increased risk for infection
• Minimized ability to fight infection
• Prophylactic antibiotics NOT recommended

Hematologic Function
• Anemia
• Platelet dysfunction
• Bleeding disorders
• Leukocytosis

Pharmacology and ARF
• Ability to clear meds is altered
• RRT may alter therapeutic levels
• Some meds may enhance renal output
• Drugs Requiring Dosage Adjustments
  • Acetominophen
  • Acyclovir
  • Amikacin
  • Amphotericin B
  • Ampicillin
  • Ceftazidime
  • Cefuroxime
  • Digoxin

PedsCCRNWebinar.Renal
• Diphenhydramine
• Gentamycin
• Imipenem
• Penicillin G
• Piperacillin
• Ranitidine
• Tobramycin
• Vancomycin

• Drugs Which Enhance Renal Output
  • Loop Diuretics
    ▪ Furosemide
    ▪ Bumetanide
  • Osmotic Agents
    ▪ Mannitol
    ▪ Thiazides
    ▪ Metolazone
  • K+‐Sparing Agents
    ▪ Spironalactone
  • Adrenergics
    ▪ Dopamine
Renal Replacement Therapy

- Peritoneal Dialysis: removes fluid slowly over 2-3 days thru diffusion
- Continuous Venovenous Hemofiltration: slow continuous removal of fluids thru Ultrafiltration
- Hemodialysis: rapidly restores and corrects F/E balance thru Ultrafiltration and diffusion

Chronic Renal Failure

- poor appetite
- vomiting
- bone pain
- headache
- stunted growth
- malaise
- high urine output or no urine output
- recurrent urinary tract infections
- urinary incontinence
- pale skin
- bad breath
- hearing deficit
- detectable abdominal mass

PedsCCRNWebinar.Renal
• tissue swelling
• irritability
• poor muscle tone
• change in mental status

Chronic Renal Failure
• Medications
• Diuretic therapy
• Diet restrictions
• Dialysis
• Kidney transplantation

Hemolytic Uremic Syndrome (HUS)
• Acute Renal Failure
• Hemolytic Anemia
• Thrombocytopenia
• Causes:
  • Infectious Disease
  • Medications
  • Hereditary Traits
• Incidence

PedsCCRNWebinar.Renal
• 6 mos to 4 yrs of age
• April – September
• 2-4 cases per 100,000 children < 5 yrs
• ?? increased occurrence

• Pathophysiology
  • Vascular Endothelial Damage
  • Widened Sub endothelial Space
  • Fibrin Deposits
  • Thrombosis of Arterioles
  • Renal Ischemia

• Clinical Manifestations
  • Renal – Acute Renal Failure
  • Heme – thrombocytopenia, hemolytic anemia
  • GI – perforation, obstruction, stricture, intussusception
  • CNS, Pulmonary, Adrenal, Cardiac involvement also possible

• Clinical Assessment
  • Pale
  • Lethargic
  • Irritable
  • Abdominal pain or tenderness
  • Hemorrhagic manifestations
• ± Seizures
• ± Oliguria
• ± Anuria

• Management
  • Rapid recognition
  • Supportive Care
  • Treat the complications

Renal Trauma
  • Children more vulnerable than adults:
    • Increased kidney size R/T abdominal size
    • Incomplete development of abdominal wall muscles
    • Lack of protection by lower ribs
  • Blunt Trauma
    ▪ Direct compression
    ▪ Deceleration injury
  • Penetrating Trauma –

• Clinical Manifestations
  ▪ Blood @ urethral meatus
  ▪ High-riding prostate
- Gross hematuria
- Ecchymosis or hematoma
- Abd/flank pain

• Management
  - Penetrating – surgical intervention
  - Blunt – close observation & monitoring
  - Long-term follow-up

**Questions...**

4. Hyponatremia is a common electrolyte imbalance associated with Acute Renal Failure. Which of the following is a potential result of a significantly decreased serum Na+ level?

a. Cerebral edema  
b. USG = 1.015  
c. SBP = 80 mmHg  
d. Serum K+ = 5.0 mEq/L

5. Classic signs of Hemolytic Uremic Syndrome include:

a. Chronic renal failure, oliguria & pernicious anemia  
b. Chronic renal failure, leukopenia & hemolytic anemia  
c. Thrombocytopenia, hemolytic anemia & acute renal failure  
d. Acute renal failure, positive Coombs’ test & anemia

6. You receive orders for all of the following interventions for your patient with symptomatic hyperkalemia. Your 1st priority would be:

a. Initiation of continuous venovenous hemofiltration  
b. Administration of insulin & glucose  
c. Administration of 20cc/kg NSS fluid bolus  
d. Administration of Kayexalate
Key References:


# Table 1. Electrolyte Imbalances

<table>
<thead>
<tr>
<th>Electrolyte Imbalance</th>
<th>Causes</th>
<th>Clinical S&amp;Sx</th>
<th>ECG Findings</th>
<th>Management</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hyponatremia</strong></td>
<td>Vomiting/diarrhea, NG suction, ↓ Na intake, fever, excessive diaphoresis, ↑ water intake, burns &amp; wounds, renal disease, DKA, Malnutrition</td>
<td>Lethargy, Muscle cramps, N/V, Disorientation, Seizures, Coma</td>
<td>N/A</td>
<td>Treat underlying cause, Frequent neuro assessments, Fluid replacement, 3% saline, Monitor Na levels</td>
</tr>
<tr>
<td>$Na^+ &lt; 135\ mEq/L$</td>
<td>$Na^+ &gt; 145\ mEq/L$</td>
<td>$Na^+ &gt; 145\ mEq/L$</td>
<td>N/A</td>
<td>Treat underlying cause, Frequent neuro assessments, Strict I&amp;O, Slow correction of fluid deficit, Monitor lab data</td>
</tr>
<tr>
<td><strong>Hypernatremia</strong></td>
<td>↑ Na intake, renal disease, fever, ↑ insensible water loss, Diabetes insipidus, Hyperglycemia</td>
<td>Irritability/agitation, Dry, sticky mucous membranes, Flushed skin, Lethargy/confusion, Seizures, Coma, Muscle weakness, Muscle twitching, Intense thirst</td>
<td>N/A</td>
<td>Treat underlying cause, Frequent neuro assessments, Monitor ECG, Frequent neuromuscular assessments, $K^+$ replacement, Monitor acid-base status</td>
</tr>
<tr>
<td><strong>Hypokalemia</strong></td>
<td>↓ K intake, Starvation, Malabsorption syndromes, GI losses</td>
<td>Muscle weakness, cramping, stiffness, paralysis, hyporeflexia, Hypotension, Lethargy</td>
<td>Flattened, inverted T waves, Presence of U-waves, PVC’s</td>
<td>Determine &amp; treat cause, Monitor ECG, Frequent neuromuscular assessments, $K^+$ replacement, Monitor acid-base status</td>
</tr>
</tbody>
</table>
| **K⁺ < 3.5 mEq/L** | • Diuresis  
| • Nephritis  
| • Alkalosis | • Irritability  
| • Tetany  
| • N/V  
| • Abdominal distention  
| • Paralytic ileus  
| • Irregular, weak pulse |

| **Hyperkalemia** | • ↑ K intake  
| • Renal disease/failure  
| • Adrenal insufficiency  
| • Metabolic acidosis  
| • Severe dehydration  
| • Burns  
| • Crushing injuries  
| • Hemolysis | • Muscle weakness  
| • Ascending paralysis  
| • Hyperreflexia  
| • Confusion  
| • Apnea  
| • N/V  
| • Diarrhea  
| • ↓ cardiac function |

| **K⁺ > 5.0 mEq/L** | • Tall, peaked T waves  
| • Widened QRS  
| • Prolonged PR interval  
| • Ventricular arrhythmias  
| • Asystole | • Determine & treat cause  
| • Monitor ECG  
| • Administer IV fluids  
| • D/C K⁺ containing fluids/meds  
| • Ca Glu 100mg/kg  
| • Insulin 0.1u/kg + Glucose 0.5g/kg  
| • Na Bicarb  
| • Kayexalate  
| • Dialysis  
| • Monitor serum K levels  
| • Evaluate acid-base status |

| **Hypocalcemia** | • ↓ dietary Ca  
| • Vitamin D deficiency  
| • Renal insufficiency  
| • Diuretics  
| • Hypoparathyroidism  
| • Alkalosis  
| • ↓ serum protein  
| • NM irritability  
| • Tingling sensation  
| • Chvostek’s sign  
| • Trousseau’s sign  
| • Tetany  
| • Muscle cramps  
| • Lethargy  
| • Seizures  
| • Hypotension | • Prolonged QT interval  
| • Treat/control cause  
| • Monitor ECG  
| • IV calcium supplements  
| • Monitor Ca & Mg levels |

| **Ca < 8mg/dL** | • Acidosis  
| • Prolonged immobilization  
| • Kidney disease | • Lethargy  
| • Stupor  
| • Coma  
| • Seizures |

| **Ca < 1.15** | • Shortened QT interval  
| • Bradycardia  
| • Cardiac arrest  

| **Hypercalcemia** | • Treat underlying cause  
| • Monitor ECG  
| • IV fluids  
| • Loop diuretics |
| Ca > 10.5 mg/dL | iCa > 1.34 | Anorexia | N/V | Constipation | NM hypotonicity | Hyperparathyroidism | Excessive administration | Hyperparathyroidism | Excessive administration | Hyperparathyroidism | Excessive administration | Hyperparathyroidism | Excessive administration |
|-----------------|------------|-----------|-----|--------------|----------------|-------------------|---------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| Mg < 1.4 mEq/L  | Hypomagnesemia | • ↓ intake (NPO) | • Malabsorption syndromes | • ↑ renal excretion | • NM excitability | • Tetany | • Confusion | • Dizziness | • Headache | • Seizures | • Coma | • Respiratory depression | • ↑ HR | • ↑ intake (NPO) | • Malabsorption syndromes | • ↑ renal excretion | • NM excitability | • Tetany | • Confusion | • Dizziness | • Headache | • Seizures | • Coma | • Respiratory depression | • ↑ HR |
| Hypermagnesemia | Mg > 2.5 mEq/L | • Chronic renal disease | • ↓ GFR/↑ excretion | • ECF deficit | • ↑ administration of Mg containing drugs | • Lethargy | • Muscle weakness | • ↓ swallow | • ↓ gag | • ↓ HR | • ↓ BP | • Prolonged PR | • Prolonged QRS | • Prolonged Qt | • AV block | • Treat cause | • Monitor ECG | • Administer Ca Glu | • IV hydration | • Dialysis |
|                 |             | • PVC’s | • V-tach | • V-fib | • Treat cause | • IV Mg replacement | • Monitor ECG | • Neuromuscular assessments | • Treat cause | • Monitor ECG | • Administer Ca Glu | • IV hydration | • Dialysis |
Peds CCRN: Cardiovascular Part I
Kathryn E. Roberts, RN, MSN, CRNP, CCRN, CCNS

Overview – 14% of the Exam

- Acute heart failure/ pulmonary edema
- Acute inflammatory disease
- Cardiac surgery
- Cardiac trauma
- Cardiogenic Shock
- Cardiomyopathies
- Cardiovascular pharmacology
- Conduction defects, blocks & pacemakers
- Congenital heart defects/diseases
- Dysrhythmias
- Hemodynamic monitoring
- Hypertensive crisis
- Hypovolemic shock & volume deficit
- Pulmonary hypertension

Cardiac Physiology - General Principles

- Cardiac output
- Stroke volume
- Preload
- Afterload
- Compliance
- Contractility
Cardiac Output

- Cardiac Output (CO) = HR x SV
  - volume of blood ejected from the LV / min
- Good CO = good tissue perfusion
- Varies from 200ml/kg/min in a neonate to 100ml/kg/min in adolescents to adults
- Influenced by:
  - Preload
  - Afterload
  - Compliance
  - Contractility

- Stroke volume
  - The volume of blood ejected from the LV with each contraction / ventricular beat
  - 60-75% of ventricular volume
Preload

- The volume of blood in the ventricles at the end of diastole and prior to contraction

- Determined by:
  - cardiac fiber length & stretch
  - volume of blood returned from the systemic and pulmonary circulation

- The Frank-Starling Law
  - “...the force of contraction of the cardiac muscle is proportional to its initial length...the more the diastolic volume or fiber stretch at the end of diastole the greater the force of the next contraction during systole”

- Venous blood return directly affects CO and can be significant

- Alterations of Preload
  - Variations in volume
  - Systemic HTN or pulmonary HTN
  - Excessive PEEP
  - Dysrhythmias
  - Vasopressors / Inotropes
  - Volume Administration
    - crystalloids
    - colloids
    - blood
  - Innate Mechanisms
    - renin angiotensin
- ADH
- aldosterone
- catecholamines
  - Diuretics
  - ANP/BNP
  - Vasodilators
  - Afterload Reduction

**Afterload**

- Workload the ventricles must overcome – the systemic pressure
- Measured by SVR and PVR: \[ SVR = (MAP - CVP) \div CO \]
- MAP is average pressure in the aorta: \[ MAP = (CO \times SVR) + CVP \]
- MAP is dependent on the volume in the system and the elastic properties of the arterial walls
- Increase Afterload
  - Systemic HTN
  - Pulmonary HTN
  - Polycythemia
  - Outflow obstructions
  - Vasoconstrictors
  - Heart Failure
• Decrease Afterload
  o Sepsis
  o Vasodilators
  o Anaphylaxis
  o Physiologic factors

Compliance
• Ventricular function: ability of the ventricles to relax and distend (fill) during diastole
• Relationship between end-diastolic pressure and end diastolic volume
• Good compliance: large volume of fluid creates only a small change in ventricular pressure
• Poor compliance: small fluid volume can produce a large pressure change or “stiff” ventricle
• Factors Affecting Compliance
  o Decreased Compliance
    ▪ Myocardial hypoxemia and acidosis
    ▪ CHF
    ▪ Ventricular hypertrophy
    ▪ Pericardial tamponade
    ▪ High PEEP
    ▪ Positive Inotropy
  o Enhanced Compliance
    ▪ Afterload reducers
Contractility

- Squeeze generated by the myocardial muscle
- Echocardiography estimates
- Cardiac catheterization directly measures
- Atrial contraction accounts for 10 - 40% of LV filling depending on HR
- Shortening fraction (SF) → % change in ventricular diameter during systole and diastole; normal ~ 28 - 44%
- Indication of the myocardial ability to maintain contraction
- Ejection fraction (EF) → % of volume change with systole; normal ~ 50-70%
- Factors Influencing Contractility
  - Electrolyte imbalances
  - Sympathetic stimulation / catecholamines
  - Physiological depressants
  - Pharmacological agents
  - Inotropic agents

Autonomic Nervous System

- Sympathetic stimulation causes the release of norepinephrine
- Parasympathetic stimulation causes the release of acetylcholine → acts on the right and left vagus nerve
• **Alpha (α)–Adrenergic**
  - Cardiac fiber stimulation results in arterial vasoconstriction

• **Beta (β)–Adrenergic**
  - Stimulation increases SA node discharge causing an increase in inotropy, chronotropy and AV conduction time
  - β1 increases inotropy, chronotropy and rennin secretion
  - β2 smooth muscle relaxation, bronchodilation

• **Vasoactive** → raise or lower HR and BP

• **Vasopressors** → typically act to raise BP

• **Inotropic** → work through α and receptors to vasodilate, vasoconstrict and / or enhance contractility

• **Chronotropic** → change HR by affecting nerves controlling the heart OR by changing the rhythm from the SA node

**Questions....**

1. Poor cardiac output is indicated by:
   - Cold, pale & mottled extremities
   - Cyanotic lips, gums & nail beds
   - Increased urinary output
   - Cyanotic extremities

2. Stimulation of the sympathetic nervous system has which effect on the cardiovascular system?
   - Decreases stroke volume & increases blood pressure
   - Increases stroke volume & decreases blood pressure
   - Slows conduction through the AV node
   - Increases stroke volume and HR
3. An MD prescribes Dopamine for a patient. This drug improves CV function by:
   a. Increasing SVR
   b. Inotropic & chronotropic actions
   c. Decreasing afterload
   d. Improving renal perfusion

4. Vasodilators are prescribed to help improve cardiac function by:
   a. Increasing SVR
   b. Inotropic & chronotropic actions
   c. Decreasing afterload
   d. Improving renal function

Left Heart Failure

• LV is unable to completely empty during systole

• Pathophysiology → decrease in CO secondary to a decrease in contractility

• Causes include:
  o LV infarction
  o valvular disease

• Backflow of blood from the LV to the LA

• PAP, PCWP, and CVP are all increased

• Clinical Manifestations
  o Respiratory
    ▪ Pulmonary venous congestion
    ▪ Pulmonary edema
    ▪ Fluid retention
    ▪ Dyspnea
- Rales
- Frothy sputum
- Decreased saO2, paO2

  - Cardiac
    - Cardiomegaly with ↓ myocardial function
    - Poor myocardial and peripheral perfusion
    - Tachycardia
    - Hypotension
    - S3 sound

  - Late Signs
    - Acidosis
    - Decreased GFR

Right Heart Failure

- Right heart failure usually occurs as a progression of left heart failure

- Primary causes include
  - pulmonary HTN
  - RV infarct
  - cardiomyopathy

- Increased myocardial 02 demand
- Increased HR
- Increased PA pressures
• Decreased CO

• Pulmonary vasculature resistance in response to hypoxia

• Clinical Manifestations
  o Jugular venous distension
  o Hepatojugular reflux
  o Dependant pitting edema
  o Hepatomegaly
  o Anorexia, nausea
  o Weight gain
  o Increased CVP
  o Increased PVR
### Summary of Clinical Manifestations

<table>
<thead>
<tr>
<th>LEFT Heart Failure</th>
<th>RIGHT Heart Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>• dyspnea</td>
<td>• jugular venous distension</td>
</tr>
<tr>
<td>• tachycardia</td>
<td>• hepatojugular reflux</td>
</tr>
<tr>
<td>• S3 sound</td>
<td>• dependant pitting edema</td>
</tr>
<tr>
<td>• crackles, frothy sputum,</td>
<td>• hepatomegaly</td>
</tr>
<tr>
<td>• oliguria</td>
<td>• anorexia, nausea</td>
</tr>
<tr>
<td>• decreased SaO2, PaO2</td>
<td>• weight gain</td>
</tr>
<tr>
<td>• increased PAWP, SVR</td>
<td>• increased CVP</td>
</tr>
<tr>
<td>• decreased CO</td>
<td>• increased PVR</td>
</tr>
</tbody>
</table>

- **Diagnosis of Congestive Heart Failure**
  - Hx, PE, lab findings, CXR
  - Listen for split heart sounds and murmrs
  - Pulmonary sounds / Respiratory status
  - Diminished peripheral pulses
  - Increased liver size (palpable at or below costal margin)
  - EKG and Echocardiogram changes

- **Laboratory Findings**
  - Dilutional anemia and hyponatremia
  - Decreased UO
- Albumin in the urine
- Hypoglycemia
- Increased WBC count
- Polycythemia
- Iron deficiency anemia

- Treatment of Heart Failure
  - Maximize cardiac performance
  - Decrease myocardial oxygen demand
  - Improve cardiac contractility
  - Optimize preload
  - Decrease afterload
  - Maximize Cardiac Performance
    - Inotropic agents
    - Reduce preload
      - Diuretics, sodium & fluid restriction
      - Venous dilation with nitroglycerin & morphine(?)
    - Decrease afterload
      - Nipride, ACE inhibitors, IABP in extreme cases
      - Treatment of Heart Failure (con’t)
  - Decrease Myocardial Oxygen Demand
    - Bedrest
• Anxiolytic medications
• Beta-blockers
• Dysrhythmia management
• Pain Management
  ▪ Enhance Contractility
    • Digoxin
    • Dobutamine
    • Amrinone, Milrinone
    • Ventricular assist device (VAD)

Acute Inflammatory Diseases

Layers of the Heart
• Epicardium
• Pericardium
• Myocardium
• Endocardium

Pericarditis
• Inflammation of the two layers of the pericardium, producing an effusion and fibrin deposits in the pericardial sac
• Causes:
- Infection from surgery, trauma, drugs, collagen disease

- Hallmark symptoms:
  - Pericardial friction rub
  - Muffled heart sounds
  - Decreased CO & BP

- Signs/symptoms of cardiac tamponade

- Treatment: Tx the infection, remove the fluid collection

- Cardiac supportive care

Myocarditis

- Inflammatory disease of the myocardium

- Viral infection, ingestion of toxins, drugs or hypersensitive immune reactions

- Acute and chronic

- Extension of endocarditis

- Symptoms: fever, tachycardia, Hx of bacterial/viral illness, myalgia, dysrhythmia, CHF, systolic murmur, pulsus alternans

- Treatment: CV support, treating infection, antiarrythmics

Endocarditis

- Inflammation of the valve, endocardium or endothelium

- Occurs in valvular or structural heart lesions, CHD, from intracardiac catheters, prosthetic valves, or post-surgical children

- Usually bacterial (S. Aureus, S. Epi, S. Viridans)
• Symptoms: fever, HA, malaise, arthralgia, new or changing murmur, systemic emboli, splinter hemorrhages, Osler’s nodes, Janeway’s lesions
• Treatment: ≈ 6 weeks IV antibiotics, bed rest, management of CHF
• Prevention for susceptible patients

Diagnosis of Acute Inflammatory Disease

• CXR
• ECG
• Echocardiogram
• Laboratory studies
• Cardiac catheterization
• Pericardiocentesis

Kawasaki Disease

• A leading causes of acquired heart disease in children in the US
• Etiology unknown
• Incidence: 80% are children ages 1-5yrs
• Pathophysiology involves acute, diffuse, vasculitis of the medium size arteries and small vessels of the body → particularly the coronary arteries; potential for coronary artery aneurysm
• Diagnosis
• No definitive laboratory or diagnostic test

• Diagnosis is based on CDC criteria
  
  o Fever >5 days, unresponsive to antibiotics
  
  o Bilateral conjunctivitis
  
  o Oral mucosal changes (strawberry tongue)
  
  o Peripheral extremity changes (erythema)
  
  o Rash
  
  o Cervical lymphadenopathy

• Clinical Manifestations and Complications
  
  o Aseptic meningitis
  
  o Increased ESR
  
  o Leukocytosis
  
  o Elevated liver enzymes
  
  o Thrombocytosis
  
  o Anemia
  
  o ECG and Echocardiography changes
  
  o Aneurysm
  
  o Infarction

• Management and Treatment
  
  o IVIG
    1. Within the first 10 days of symptoms
    2. High dose: 2 gm/kg, q 8-12 hours
- Decreases the acute phase of the illness
- Hemodynamic monitoring for CHF
- Pre-med with Benadryl
  - Aspirin therapy
    - High dose (80-100mg/kg/day) for 2-4 days for inflammation, fever reduction
    - Anti-platelet doses after fever has been reduced
    - Low dose aspirin during the convalescent phase
  - Antithrombotic therapy
  - Surgical intervention - if aneurysm is present

Cardiomyopathy
- Disease of heart muscle
- Idiopathic or related to systemic disease that affects cardiac muscle
- Three types:
  - Dilated
  - Hypertrophic
  - Restrictive (rare in peds)

- Dilated Cardiomyopathy
  - Massive cardiomegaly and LV dilation
- Referred to as “congestive” cardiomyopathy
  - Decreased SV and EF

**Hypertrophic Cardiomyopathy**
- Increased myocardial mass, particularly in the LV with decreased ventricular cavity size
- Blood flow is obstructed → hypertrophic tissue → LVOFTO
- Big, thick, ugly heart

**Restrictive Cardiomyopathy**
- Defect of the anatomy in the endocardium
- Related to fibrosis and scarring
- Results in minimal contractile movement
- Normal systolic function but decreased diastolic function

**Clinical Manifestations**
- Cardiomegaly noted on CXR
- Symptoms: Asymptomatic initially → may present as a murmur; poor perfusion, CHF, low CO, decreased UO, decreased LOC, syncope, thromboembolic events, arrhythmias, can progress to shock

**Management**
- Fluid restriction, Na+ restriction, decrease cardiac workload, DVT prophylaxis
- Transplantation

**Diagnosis**
PedsCCRN Webinar.CV Part I
- CXR
- ECG → conduction delays, ST segment and T wave changes
- ECHO → evaluate function
- Viral titers
- Cardiac Catheterization

- Treatment Modalities: Nursing and Medicine
  - Dilated cardiomyopathy
    - Positive inotropic agents
    - Diuretics
    - Vasodilators
    - Afterload reduction
  - Hypertrophic
    - β adrenergic agonists
    - Calcium channel blockers
    - Diuretics and inotrope with caution
    - Pacing
    - Surgical resection
  - Restrictive
    - None specific
    - CHF
    - Symptoms treatment → options include diuretics, digitalis, vasodilators, and antiarrhythmics
- Lifestyle changes

**Questions:**

5. A patient with CHF would likely exhibit all of the following except:
   
   a. Increased urine output  
   b. Decreased cardiac output  
   c. Hepatomegaly  
   d. Cardiomegaly

6. An adrenergic response to CHF is typically manifested by:
   
   a. Polyuria  
   b. Warm, dry skin  
   c. Tachycardia  
   d. Poor feeding

A 6-year male with a previous history of Kawasaki’s disease is admitted to the PICU with dyspnea and restlessness. His HR on admission is 160. A 12-lead EKG is performed at the bedside and reveals depressed, flattened ST segments and the presence of Q waves.

7. The critical care nurse should suspect that this patient has developed:
   
   a. A recurrence of his Kawasaki’s disease  
   b. Pulmonary Embolus  
   c. Pericarditis  
   d. Myocardial infarction
Key References:


Overview
- Fetal Circulation
- Ductal Circulation
- Congenital Heart Disease

Fetal Circulation
- Placenta the site of gas exchange
- Cardiac development @ 4-7 weeks gestation
- PVR elevated in the fetus
- Falls after week 1 of life

Fetal Neonatal

Intracardiac shunts No intracardiac shunts
- High PVR Low PVR
- Low SVR High SVR
- Low cardiac output High cardiac output
- Gas exchange in the placenta Gas exchange in lungs

2 Anatomical Shunts
- Ductus Arteriosus
  1. Constricts in response to increased paO2
2. Also influenced by placental prostaglandins
3. Functionally closed @ 12-24 hours after birth
4. 1-2 weeks for anatomic closure

- Foramen Ovale
  1. Opening in mid-atrial wall
  2. Fetus – R to L shunt
  3. Neonate – L to R shunt
  4. Functional vs anatomic closure
  5. “Intermittent” PFO

Shunting.....

- LEFT to RIGHT
  1. Oxygenated blood from systemic to pulmonic
  2. Body receives oxygenated blood
  3. Acyanotic

- RIGHT to LEFT
  1. De-oxygenated blood from pulmonic to systemic
  2. Body receives de-oxygenated blood
  3. Cyanotic

- Vascular Resistance to Flow
  1. PVR: pulmonary vascular resistance
Increased = vasoconstriction
Decreased = vasodilation

2. SVR: systemic vascular resistance
   - Increased = vasoconstriction
   - Decreased = vasodilation

Suspect CHD in a newborn when......

3. Murmur AND cyanosis
4. Crying worsens cyanosis
5. Failed hyperoxia test
6. Abnormal weight loss, poor feeding w/tachypnea
7. Discordant upper & lower pulses
8. “Septic appearing” infant
9. Infant has been diagnosed w/ a syndrome:
   - Trisomy 21 (Down’s Syndrome) - AVSD
   - Trisomy 18 (Edward’s Syndrome) – VSD, HLHS
   - 45X (Turner’s Syndrome) – VSD, CoA, AS, HLHS
   - William’s Syndrome – Supravalvular Stenosis
   - DiGeorge Syndrome – IAA
   - Noonan’s Syndrome – Valvular PS
Classification of CHD

- Acyanotic with increased pulmonary blood flow
- Acyanotic with ventricular outflow obstruction
- Cyanotic with decreased pulmonary blood flow
- Cyanotic with increased pulmonary blood flow

More CHD Terminology

- ATRESIA
- STENOSIS
- HYPOPLASTIC
- SEPTAL
- ANOMALOUS
- TETRALOGY

Acyanotic with Increased Pulmonary Blood Flow

- Ventricular Septal Defect
  1. Most common
  2. Left to right shunt
  3. Amount & direction of shunting determined by:
     ▪ systemnic and pulmonary circulations
     ▪ Size of VSD

PedsCCRN Webinar.CV Part II
• Associated lesions

4. Clinical symptoms develop as shunting increases

5. Congestive heart failure (CHF)

6. Long term – PHTN

7. Surgical repair:
   ▪ CP bypass
   ▪ Patch or suture closure
   ▪ Usually an uncomplicated post-op course

8. Delayed repair can result in PHTN

9. Watch for arrhythmias

• Atrial Septal Defect

  1. 3rd most common

  2. Females > males

  3. 3 separate locations

  4. Shunting determined by compliance of RV & LV AND size of defect

  5. Indications for closure:
     ▪ RV volume overload
     ▪ Arrhythmias
     ▪ Paradoxical emboli
     ▪ Elevated PVR
• Atrioventricular Septal Defect

6. Associated with Trisomy 21
7. Large defect in AV septum
8. 3 components
   - Deformity of tricuspid and mitral valve - Common AV valve
   - Atrial septal defect
   - Ventricular septal defect
9. Surgical repair at infancy:
   - VSD closed with patch
   - Mitral valve repaired
   - ASD closed with patch
10. Post-op course is variable
    - PHTN and arrhythmias are 2 important potential complications

• Patent Ductus Arteriosus

11. Higher incidence in premature infants
12. Left to right shunting
13. Closure:
   - Indomethacin
   - Surgical ligation
Acyanotic w/ Ventricular Outflow Obstruction

- Aortic Stenosis (AS)
  - Aortic valve commisures fused
  - Thickened, domed, stenotic opening
  - Severity of symptoms is related to degree of narrowing
  - The narrower the opening, the more severe symptoms
- Critical Aortic Stenosis is the most severe form of congenital aortic stenosis
  - Dependent on the PDA for adequate systemic circulation
  - As the PDA begins to close, the LV has to attempt to meet systemic circulation needs
  - In severe obstruction, CV collapse is possible
  - Early surgical intervention required
    - Goal is to relieve the obstruction
    - Balloon valvotomy
    - Surgical approach via sternotomy and fissures are incised
    - Post-op course related to degree of LV dysfunction

- Coarctation of the Aorta
  - Constriction of the descending aorta
  - Variable symptoms depending on degree of arch hypoplasia
  - Open PDA in newborn often allows for adequate perfusion of lower extremities
- Critical CoA
  1. Present with shock
  2. PGE₁
  3. Post-operative HTN common

- Pulmonary Stenosis
  - RV outflow tract obstruction
  - 2nd most common form of CHD
  - Abnormal pulmonary valve
  - Fusion of commisures
  - Repair:
    1. Balloon valvuloplasty or surgical intervention if that is not successful

Questions

1. A 3-year old girl is admitted to the ICU following repair of her coarctation of the aorta. Her vital signs are:

Vital signs: Arterial blood gas:
- HR  80 (sinus rhythm)  pH   7.35
- Arterial BP  155/84  pCO₂  42
- RR   18  pO₂   96
- CVP  10  HCO₃  25

She is comfortable and sleeping soundly. The most likely cause of her hypertension is:
  a. Inadequate pain control
  b. Expected systemic response to an aortic incision
  c. Fluid volume overload
  d. Diminished baroreceptor sensitivity to changes in arterial pressure
2. Medications used in the management of a PDA include:
   a. Digoxin
   b. Milrinone
   c. Indomethacin
   d. Prostaglandin

3. Congenital heart defects that result in increased pulmonary blood flow place an infant at greatest risk for:
   a. Stroke
   b. Hypoxemia
   c. Congestive heart failure
   d. Syncopal events

Cyanotic w/ Decreased Pulmonary Blood Flow

• Tetralogy of Fallot

• 4 defects:
  o Pulmonary stenosis/Right ventricular outflow obstruction (RVOT)
  o Right ventricular hypertrophy
  o Overriding aorta
  o VSD

• Wide spectrum of severity – the more severe the RVOT obstruction, the more severe the symptoms

• Variable degrees of cyanosis
  o The infamous “Tet Spells”
    ▪ Begins with irritability & hyperpnea
- Followed by prolonged period of intense cyanosis, leading to syncope
- Comfort & calm
- Knee-to-chest position
- Supplemental oxygen
- Morphine
- IV fluids (10-20 ml/kg 0.9% NaCl)
- Sodium bicarbonate

Post-op considerations:

- Complicated repair
  - A degree of RV failure common post-op
  - Need AV synchrony, adequate preload & maintenance of low pulmonary vascular pressures
  - Watch for bleeding

- Tricuspid Atresia
  - Rare
  - Tricuspid valve is not patent
  - PFO or ASD
  - Typically have hypoplastic RV and RVOT
Cyanotic w/ Increased Pulmonary Blood Flow

- Transposition of the Great Arteries (TGA)
  - Aorta arises from the RV
  - Pulmonary artery arises from the LV
  - Parallel pulmonary and systemic circulations – dependent on some type of shunt for survival
  - Cyanotic blood recirculation
  - Stabilize neonate
  - PGE1
  - Vasoactive support
  - Balloon septostomy – to create an ASD to allow for shunting of flow
  - Surgical repair – arterial switch operation (CPB)
    - Lengthy, complicated repair
    - Myocardial dysfunction can be seen

- Truncus Arteriosus
  - Rare; occurs when conotruncal septation fails to separate during fetal development into the aorta and pulmonary arteries
  - Single-valved vessel located above RV and LV
  - Large VSD
  - Associated with DiGeorge Syndrome
• Total Anomalous Pulmonary Venous Return
  
  o Rare
  
  o Can be total or partial
  
  o 3 subtypes of total
    
    ▪ Supracardiac to the innominate vein
    
    ▪ Intracardiac to the coronary sinus
    
    ▪ Infracardiac below the diaphragm (hepatic, portal or umbilical venous systems)
  
  o Severity of cyanosis increases with obstruction to pulmonary venous return
  
  o Immediate surgical repair

• Hypoplastic Left Heart Syndrome
  
  o 4% of CHD
  
  o Mitral stenosis/atresia
  
  o Aortic stenosis/atresia
  
  o CoA
  
  o Hypoplastic left ventricle
  
  o HLHS: Stage I Palliation
    
    ▪ Creation of a BT or central shunt
    
    ▪ Creation of common atrium
• Creation of a “neo-aorta” using the PA
  ○ HLHS: Stage II Palliation
    ▪ SVC is connected to the PA
    ▪ Bi-Directional Glenn Anastamosis:
      ▪ Pulmonary blood flow changes from parallel to (more normal) in-series flow
      ▪ Reduce the volume load on the RV

  ○ HLHS: Stage III Palliation
    ▪ Baffle created
    ▪ May fenestrate
    ▪ More “normal” series circulation versus parallel circulation

Pre- & Post-operative Considerations: The Family
• Fetal diagnosis
• Reality shock
• Multidisciplinary team effort
• “Fragile” child post-op
• Multiple surgeries and long term follow-up
• Medications
• Feeding issues
• Growth and development

PedsCCRN Webinar.CV Part II
• Pre- & Post-operative Considerations: The Family

• Support groups

• Genetic counseling

• Social work consults

• Spirituality/religious counseling

• Bereavement counseling

• Family dynamics: parents, siblings

• Education: newborn care, defect, pre/post surgery, home care

Peri-operative Interventions

• Repair vs Palliation

• Cardiopulmonary Bypass

• Myocardial Protection

• Hypothermia & Circulatory Arrest

• Aortic cross clamping

• Cardioplegia

Post-Operative Care: General Principles

• Hemorrhage & Clotting
  
  o Post-operative Bleeding

  o CT drainage decreases rapidly

PedsCCRN Webinar.CV Part II
- Hourly assessment
- Amount & characteristics
- Monitor for TAMPONADE!!

**Hemodynamic Assessment**

- HR & Rhythm
- Continuous ECG monitoring
- Rhythm disturbances are not uncommon
- JET & Atrial ectopic tachycardia
- Ventricular arrhythmias
- Heart block/conduction delays
- Causes:
  - Surgical sequelae, anesthesia, CPB/hypothermia, conduction system damage, catecholamines, metabolic derangements
- Hemodynamic Assessment:
  - Systemic Arterial BP
  - Indwelling arterial catheter
  - Beat to beat assessment of BP
  - Accuracy of non-invasive BP
  - affected by vascular tone & hemodynamics
  - High potential for low CO & perfusion
  - Timely recognition is essential!
- Atrial Pressures
- RAP or CVP
- Systemic venous return
- Right heart preload
- Right heart function
- RVEDP
  - ↓ indicates hypovolemia
  - ↑ can indicate RV failure or PHTN
- LAP
- Pulmonary venous pressure
- Left heart preload
- Left heart function
- LVEDP
  - ↓ indicates hypovolemia
  - ↑ indicates LV failure or increasing LV afterload
- Ventilation
  - Airway protection & gas exchange
  - Typically have “healthy” lungs
  - Volume or pressure control ventilation
  - Careful suctioning
  - Close monitoring of ABG’s
- Impact of single ventricle physiology

- Fluid & Electrolyte Status
  - IVF choice variable
  - ± sodium restriction
  - CPB patients – 50% maintenance x 24 hrs
  - Monitor ALL sources of I & O
  - Monitor closely for lyte imbalances
  - Monitor glucose levels
  - Monitor renal function & UOP

- Acid – Base Status
  - Monitor closely
  - Acidosis is BAD
  - Adversely affects myocardial function
  - Metabolic acidosis
  - Indication of inadequate tissue perfusion
  - Sodium Bicarbonate vs Tromethamine

- Pharmacologic Support
  - Pharmacologic Support
  - Catecholamines
  - Afterload Reducers
  - Vasodilators
Diuretics

Arrhythmias & Pacing

- Temporary pacing wires may be placed intra-op

- Monitor:
  - Local/systemic infection
  - Bleeding after removal
  - Oversensing/undersensing
  - Non-capture

- Identify the cause of the arrhythmias !!

A Few More General Management Principles

- Thermal regulation
- Feeding & nutrition
- Wound care
- Infection Prophylaxis
- CNS assessment
- Pain management
Questions....

4. 2 cardiac anomalies associated with Tetralogy of Fallot are:

   a. PDA & interrupted aortic arch
   b. ASD & patent foramen ovale
   c. VSD & pulmonary stenosis
   d. TGA & aortic stenosis

5. In the child with Tetralogy of Fallot, what are the goals of nursing interventions if the child has a “TET” spell?

   a. Decrease systemic blood flow & increase pulmonary vascular resistance
   b. Increasing pulmonary blood flow & relaxing the infundibulum
   c. Decrease pulmonary blood flow & increase SVR
   d. Increase systemic blood blow & relax the left ventricular outflow tract

6. A newborn is admitted with the Dx of TGA. Pulse oximetry reveals a saturation of 46%. No murmur is heard. Until a Balloon Septostomy can be performed, which one of the following should be administered to the patient?

   a. Indomethacin
   b. Digoxin
   c. Tolazoline
   d. Alprostadil

7. A 10-day old infant presents with tachycardia, tachypnea, poor feeding & is noted to have spO2 of 65% on RA. The baby is noted to be cyanotic with poor peripheral pulse, delayed capillary refill and a BP of 50/34. The infant is intubated and placed on 100% O2 without improvement in oxygen saturations. The ABG is as follows:

   pH 7.27 pCO2 30 pO2 44 HCO3 16

The most likely diagnosis for this baby is:

   a. Hypoplastic Left Heart Syndrome
   b. Diaphragmatic Hernia
   c. Tetralogy of Fallot
   d. Ventricular Septal Defect
8. Emergent management of the patient with suspected cardiac tamponade should include:
   a. Pleuricentesis
   b. Dialysis
   c. Pericardiocentesis
   d. Thoracentesis

**Key References:**


http://www.nhlbi.nih.gov/health/dci/Browse/Heart.html
Shock, SIRS, MSOF
Kathryn E. Roberts, RN, MSN, CRNP, CCRN, CCNS

Shock
• Definitions:
  o Acute disruption of circulatory function resulting in decreased tissue perfusion
  o Inadequate oxygen & substrate delivery to meet metabolic requirements of the cells
  o Diminished cellular energy production

• Clinical Criteria
  o Hypotension after 20 ml/kg crystalloid
  o Tachycardia
  o End-organ perfusion abnormalities
  o Lactate production
  o Evidence of altered oxygen extraction
  o Evidence of systemic inflammation

Tissue Perfusion: Components
• Blood volume
• Cardiac pump
• Vascular tone
• Adequate oxygenation
• Cellular function
Shock: Classifications

- Cardiogenic
- Cardiovascular - obstructive
- Distributive
- Hypovolemic
- Septic

Hypovolemic Shock - Physiology

- Decreased intravascular volume
- Decreased preload
- Decreased cardiac output

Hypovolemic Shock - Etiology

- Caused by:
- External fluid losses
- Internal fluid losses
  - < 1 year
    - Gastroenteritis/ Diarrhea
  - > 1 year
    - Hemorrhage from trauma
Hypovolemic Shock - Other causes:

- Hyperthermia
- Burns
- Nephrotic syndrome
- Diuretic phase of ATN
- Diabetes Insipidus

Hypovolemic Shock: Clinical Assessment

- Severity of fluid losses

<table>
<thead>
<tr>
<th>Clinical Manifestations</th>
<th>Mild Fluid Deficit</th>
<th>Moderate Fluid Deficit</th>
<th>Severe Fluid Deficit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mental Status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infants and young children</td>
<td>Thirsty, alert, restless</td>
<td>Thirsty, restless or lethargic but irritable to touch</td>
<td>Lethargic, somnolent</td>
</tr>
<tr>
<td>Older children and adults</td>
<td>Thirsty, alert, restless</td>
<td>Thirsty, alert</td>
<td>Usually conscious, apprehensive</td>
</tr>
<tr>
<td>Radial pulse</td>
<td>Normal rate and strength</td>
<td>Rapid and weak</td>
<td>Rapid, feeble, sometimes impalpable</td>
</tr>
<tr>
<td>Heart Rate</td>
<td>Normal or mild tachycardia</td>
<td>Tachycardia</td>
<td>Severe tachycardia that may progress to bradycardia</td>
</tr>
<tr>
<td>---------------------</td>
<td>-----------------------------</td>
<td>-------------</td>
<td>----------------------------------------------------</td>
</tr>
<tr>
<td>Respiration</td>
<td>Normal</td>
<td>Normal to rapid</td>
<td>Deep and rapid</td>
</tr>
<tr>
<td>Fontanel &amp; Eyes</td>
<td>Normal</td>
<td>Slightly depressed</td>
<td>Severely sunken</td>
</tr>
<tr>
<td>Systolic blood</td>
<td>Normal</td>
<td>Orthostatic hypotension</td>
<td>Severe hypotension</td>
</tr>
<tr>
<td>pressure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skin elasticity</td>
<td>Pinch retracts immediately</td>
<td>Pinch retracts slowly</td>
<td>Pinch retracts very slowly (&gt;3 sec)</td>
</tr>
<tr>
<td>Tears</td>
<td>Present</td>
<td>Present or absent</td>
<td>Absent</td>
</tr>
<tr>
<td>Mucous membranes</td>
<td>Moist</td>
<td>Dry</td>
<td>Very dry</td>
</tr>
<tr>
<td>Urine output</td>
<td>Normal</td>
<td>Oliguria</td>
<td>Oliguria or anuria</td>
</tr>
<tr>
<td>Body weight loss (%)</td>
<td>3–5</td>
<td>6–9</td>
<td>≥10</td>
</tr>
<tr>
<td>Estimated fluid deficit (mL/kg)</td>
<td>30–50</td>
<td>60–90</td>
<td>≥100</td>
</tr>
</tbody>
</table>

- **Causes of hemorrhage**
  - # 1 = traumatic injury
  - Spleen, mesentery, liver, long bones and scalp lacerations
  - Post-surgical bleeding
  - GI bleeding, esophageal varices, Mallory-Weiss syndrome
Coagulopathies

Distributive Shock - Physiology

- Abnormality in vascular tone
- “Relative” hypovolemia
- Maldistribution of intravascular volume
- Decreased preload
- Decreased cardiac output

Distributive Shock - Etiology

- Anaphylaxis
- Drug toxicity
- Neurologic injury (above T1 & brainstem)
- Loss of sympathetic vascular tone
- Hyperthermia
- Infection
- Adrenal insufficiency
- Pancreatitis
- Systemic Inflammatory Response Syndrome

Septic Shock - Physiology

- Infection triggers a systemic inflammatory response
• Characteristics of:
  o Hypovolemic
  o Distributive
  o Cardiogenic Shock

Septic Shock - Etiology
• Gram negative bacteria
• Gram positive bacteria
• Anaerobic bacteria
• Other organisms
• Virus
• Fungus
• Rickettsiae
• Neonate
  o Group B beta hemolytic strep
  o Enterobacter
  o Listeria monocytogenes
  o Staph aureus
  o Herpes Simplex Virus

• Infant/Child
Late onset group B beta hemolytic strep

Haemophilus influenza

Neisseria meningitidis

Strep pneumoniae

Staph aureus

Enterobacter

• Immune Compromised Child
  
  Candida albicans

  Pseudomonas

  Enterobacter

  Staph aureus

  Staph epidermidis

Cardiogenic Shock - Physiology

• Myocardial dysfunction

• Inability to meet the metabolic demands of the tissues

• Decreased cardiac output

Cardiogenic Shock - Etiology

• Congenital heart disease &/or sequellae of repair

• Cardiomyopathy
• Myocardial ischemia

• Kawasaki’s

• Hypoxemia

• Anomalous coronary arteries

• Severe tachycardia

• High dose beta agonists

• The “itis’s”

• Valvular disease

• Hypoglycemia

• Hypothermia

• Altered electrolytes

• Dysrhythmias

• Myocardial depressant factors

Cardiovascular-Obstructive Shock -

• Obstruction to cardiac output

• Pulmonary embolism

• Thrombus

• Valvular stenosis

• Aortic coarctation

• Great vessel trauma

Peds CCRN Webinar.Shock,SIRS,MOSF
Hemodynamic Definitions of Shock (ACCM, 2009)

- Cold or Warm
- Fluid Refractory/Dopamine Resistant
- Catecholamine Resistant
- Refractory

Stages of Shock

- Compensated
  - Vasoconstriction
- Uncompensated
  - Compensatory mechanisms fail......MSOF
- Irreversible
  - “Refractory”

Question

1. You are caring for a patient in the early stages of hypovolemic shock. You would expect which of the following hemodynamic findings:

   a. Decreased HR
   b. Increased pulmonary occlusion pressure
   c. Decreased MAP
   d. Increased systemic vascular resistance

2. You are caring for a patient with septic shock. The patient is intubated & mechanically ventilated with normal ABG results. She has received a total of 30 ml/kg of isotonic fluids for persistent hypotension without improvement & remains febrile with a temperature of 40.3
C rectally. You expect the next intervention to be:

a. Consult with the MD about adjusting the ventilator settings  
b. Place a rectal probe and begin external cooling.  
c. Start a Dopamine infusion at 5 mcg/kg/min  
d. Repeat a fluid bolus of 20 ml/kg

3. The primary feature of uncompensated shock is:

a. Improved cellular function  
b. Lactic acid production  
c. Alteration in body temperature  
d. Organ system failure

4. A 12 year old fell 20 feet from a tree, striking his chest. She presents with severe shortness of breath. No breath sounds are auscultated on the right side, and crepitus is palpated on the right side of her chest. His heart rate is 138 and there is no palpable blood pressure. She is most likely experiencing:

a. Hypovolemic shock  
b. Distributive shock  
c. Obstructive shock  
d. Cardiogenic shock

Blood Pressure Regulation

- Neural

- Baroreceptors, volume receptors and chemoreceptors
  - vasoconstriction

- Humoral

- Catecholamines, renin-angiotensin and vasopressin
  - vasoconstriction and fluid retention

- Autotransfusion
• Hydrostatic pressure
  o fluid shifts into vascular space

The Physiology of Shock: Oxygen Delivery

• Why maintain blood pressure?
  o Substrate and oxygen delivery to cells
  o Oxygen is required for cellular energy production
  o Inadequate oxygen delivery results in cell injury, death and an inflammatory response

Aerobic Metabolism

• ATP is derived from cellular respiration, which requires oxygen to catalyze chemical reactions
• Under normal conditions, cells produce energy from oxidative phosphorylation, using glycolysis, the citric acid cycle and the electron transport chain = 36 ATP

Anaerobic Metabolism

• The citric acid cycle and electron transport chain cannot function in states of oxygen deprivation
• In the absence of oxygen, pyruvate formed during glycolosis is converted to lactate via an alternative pathway (substrate level phosphorylation) = 2 ATP
• Lactate accumulation causes acidosis
Role of the adrenal glands

- Cortisol regulates catecholamine synthesis, responsiveness of adrenergic receptors & cell membrane stability
- High dose hydrocortisone - intractable shock in patients at risk for adrenal insufficiency
  - Known to take steroids
  - Neurologic abnormalities (Hypopituitarism)
  - Prolonged critical illness / adrenal hemorrhage

Physiology of Shock: Cellular Injury

- **Hypoxic-ischemic injury**
- Decreased cell energy production and loss of structural integrity of cells
- Cell membrane breakdown
- Intracellular edema
- Cell death
- Release of toxic substances and activation of inflammatory response

- **Reperfusion injury**
- Xanthine oxidase produced during hypoxic-ischemic insult to cells, converts available oxygen on reperfusion to superoxide anion = free radical
- Cytotoxic
- Activates inflammatory response
States of Dysoxia

- Inability of cells to utilize oxygen for energy production
- Severe cellular injury / wide-spread irreversible cell damage (ominous)
- Poisonings (uncouple the electron transport chain or block oxygen hemoglobin binding / release)
- Metabolic diseases (mitochondrial disorders)
- Hypothyroidism
- Sick Euthyroid

Assessment of the Shock State

- Perfusion
  - HR, BP, urine output
  - Invasive hemodynamic monitoring (CVP, a-line)
  - Physical exam (color, skin temperature, pulse quality)
- Oxygen delivery and consumption
  - Respiratory function, blood gases, pH / base deficit, SvO2, a-vDO2, lactate, CBC
  - Cellular function (oxygen utilization)
- Evaluation of individual organ systems
- Oxygen Delivery and Consumption
  - Components of O2 delivery (DO2):
    - Cardiac Index (CI)
• Cardiac Output (CO), based on heart rate and stroke volume, for body surface area

  o Arterial blood O2 content (CaO2)
    ▪ determined by Hgb
    ▪ % Hgb saturated with O2 (SaO2)
    ▪ partial pressure of arterial blood O2 (PaO2)

  o Components of O2 consumption (VO2):
    ▪ Cardiac index (CI) and the arteriovenous oxygen difference (a-vDO2)
      • a-vDO2 is the difference between the arterial blood O2 content (CaO2) and the venous blood O2 content (CvO2)
    ▪ CvO2 determined by Hgb,
      • % Hgb saturated with O2 (SvO2)
      • partial pressure of venous blood O2 (PvO2)

Treatment of Shock States

• Treat the underlying cause

• Administer fluid

• Crystalloids

• Colloids

• Inotropic and / or vasoactive medications

• Correct severe acidosis with bicarbonate
• Serial examinations and laboratory studies

• Fluid Administration
  o Establish IV access!
  o Crystalloid
  o 20 ml/kg increments
  o Blood products
  o Maintain Hgb > 10ml/dL

• Pharmacologic Management of Shock
  o Dopamine
  o Dobutamine
  o Epinephrine
  o Norepinephrine
  o Nitroprusside
  o Esmolol
  o Milrinone

• Correcting Acidosis: Bicarbonate
  o Correct respiratory acidosis with ventilation!!
  o Metabolic acidosis with base deficit > 6 mEq/L give ...
    ▪ 1 - 2 mEq/kg NaHCO3 or ...
    ▪ 0.3 x kg x base deficit = mEq NaHCO3 (1/2 correct)
- Dilute 0.5 mEq/ml solution for neonates
  - Follow Na+, Ca++ and K+ carefully
    - As pH increases / K+ decreases
    - As pH increases / Ca++ decreases

Systemic Inflammatory Response Syndrome (SIRS)
- Inflammatory reaction to illness / injury, particularly hypoxic-ischemic injury ie: SHOCK
- Local reaction at site of an injury or infection progressing to a systemic response
- Endotheliopathy
- Capillary leak
- Vasomotor paralysis
- Leukocyte infiltrations
- Coagulopathy
- Myocardial depression
- Immunocompromise

Stages of SIRS
- Stage I
  - Inflammatory response of local environment
- Stage II
  - Initial systemic response
• Stage III
  o Massive systemic inflammatory response
    o Ensuing Shock state
• Stage IV
  o Immunosupression

Endotheliopathy
• Endothelium is injured
• Contributes to cellular breakdown and further precipitates the inflammatory response
• Increased membrane permeability
• Nitric oxide production → Vasodilation
• Managing Endotheliopathy
  o Stop the inciting insult
  o Fluid resuscitate
  o Increase plasma oncotic pressure
  o Colloid administration
  o Promote vasoconstriction
  o Alpha agonists
Systemic Inflammatory Response: Myocardial Depression

- Myocardial depression
  - Release of Myocardial Depressant Factor (MDF)
  - Nitric oxide
  - TNF-a
  - IL-1B
  - Endotoxins

Managing SIRS

- No established treatments to manipulate the immune response at the present time - Treat the underlying cause!!

- Examples of experimental therapies
  - nitric oxide synthetase inhibitors
  - monoclonal antibodies to tumor necrosis factor and interleukins
  - arachidonic acid inhibitors
  - complement inhibitors
  - coagulation modulators (antithrombin III, protein C, plasminogen activators)

Systemic Inflammatory Response: Coagulation

- Coagulation cascade

- Triggered by inflammatory response (TNF-a and complement)

- Hageman Factor XII turned on
- Coagulation = clot formation
- Fibrinolytic systems triggered in response
- Fibrin breakdown = bleeding
- Platelet aggregation stimulated
- Platelet consumption = thrombocytopenia

Systemic Inflammatory Response: DIC
- Hemorrhage and thrombosis
- Exaggerated intravascular coagulation
- Fibrinogen converted to fibrin
- Thrombosis
- Compensatory anti-thrombotic mechanisms are stimulated
- Fibrin broken down to fibrin split products
- Bleeding
- Clotting factors are depleted
- Factors V and VIII
- Inhibitors of coagulation are depleted
  - tissue factor pathway inhibitor
  - antithrombin III
  - heparin cofactor II
  - protein C
- Bleeding

- Laboratory findings
  - decreased fibrinogen
  - increased fibrin split products
  - prolonged PT and PTT
  - thrombocytopenia

- Treatment
  - Heparin in early thrombotic phase (controversial)
  - Activated protein C (experimental)
  - Clotting factors = FFP / cryoprecipitate

Multiple Organ System Failure (MOSF)

- Failure of two or more organ systems due to shock / SIRS
- Hypoperfusion of organs contributes to dysfunction
- Endotheliopathy common final pathway of organ system dysfunction = profound cellular dysfunction
- Initiating event causing hypoperfusion of organ systems and a systemic inflammatory response
- Resuscitation / reperfusion injury
  - Illa. Hypermetabolic state / cells have increased oxygen and substrate requirements
o IIIb. Acute Respiratory Distress Syndrome contributes to oxygen debt
o IV. Multiple organs fail due to persistent deficit in delivery of oxygen and substrates to cells

Assessment

• Cardiovascular
  o Tachycardia, hypotension, dysrhythmias
  o ECHO = poor myocardial function
  o Metabolic acidosis / lactatemia

• Respiratory
  o Meets criteria for Acute Lung Injury or Acute Respiratory Distress Syndrome

• Neurologic
  o Glasgow Coma Score of 4 or less

• Renal
  o Anuria / oliguria
  o Elevated Blood Urea Nitrogen and creatinine

• Hematologic
  o Anemia, neutropenia, thrombocytopenia

• Hepatic
  o Elevated liver enzymes
  o Bilirubinemia
  o Coagulopathy
Questions

5. Which of the following interventions will decrease oxygen consumption?
   a. Increasing the rate of the Dobutamine infusion
   b. Administration of a blood transfusion
   c. Medicating the patient with Ativan for agitation
   d. Repositioning the patient

6. To verify a diagnosis of DIC, a significant laboratory finding is an elevation in:
   a. Fibrin split products
   b. Prothrombin time
   c. Fibrinogen
   d. Platelet count

7. A 4-month old was admitted with a 24 hour Hx of vomiting and diarrhea. She is lethargic, pale, cool & clammy. No peripheral pulses can be palpated & she has weak central pulses. Her capillary refill time is > 5 seconds. The child is in:
   a. Compensated hypovolemic shock
   b. Stable hypovolemic shock
   c. Uncompensated hypovolemic shock
   d. Partially compensated hypovolemic shock

8. The child is placed on high flow oxygen and an IV is inserted. An initial fluid bolus is ordered. The child weighs 7 kg. Which of the following is the most appropriate fluid to be administered to this infant?
   a. 140 ml 0.9% NaCl
   b. 240 ml 0.9% NaCl
   c. 140 ml D5W
   d. 300 ml D5W

9. The parents of a 15-month old state that she has a high fever & vomiting and is now extremely irritable. Her mother states that she has “bruises” on her leg but has no history of recent trauma.

   The child’s vital signs are HR 160 RR 38 BP 84/62 & rectal temperature of 40 C.
   This child is most likely experiencing:
   a. Hypovolemic shock
   b. Cardiogenic shock
   c. Septic shock
   d. Obstructive shock
10. Malaki, an 11 year old boy with a history of leukemia, received a bone marrow transplant 80 days ago. He has a 12-hour history of fevers to 39.5 C, progressive tachycardia and poor urine output. He is admitted to the PICU with a diagnosis of septic shock. Malaki’s initial assessment in the PICU reveals restlessness, dilated pupils, brisk capillary refill, full, bounding pulses and vital signs of 38.8C – 170 – 44 – 98/40. Malaki is experiencing the initial stage of what type of shock?

   a. Maldistributive  
   b. Obstructive  
   c. Cardiogenic  
   d. Low-flow

11. After he has been in the PICU for 2 hours, Malaki exhibits decreased responsiveness to procedures, poor capillary refill, weak pulses, tachycardia to the 180’s and hypotension with a MAP of 40. Based on these findings, he is in what stage of shock:

   a. Compensated  
   b. Uncompensated  
   c. Irreversible  
   d. Low-flow

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Endocrine Review
Kathryn E. Roberts, RN, MSN, CRNP, CCRN, CCNS

5% of the exam
- Hormones and anatomy & physiology
- Syndrome of inappropriate secretion of antidiuretic hormone (SIADH)
- Diabetes insipidus
- Acute hypoglycemia
- Diabetic ketoacidosis
- Inborn errors of metabolism

Endocrine System: Functions

- Regulation of:
  - Water & electrolyte balance
  - Energy production & utilization by the cells
  - Glucose homeostasis
  - Metabolic rate
  - Growth & sexual maturation
  - Circulatory function

Endocrine System: Problems

- Overproduction of a hormone
- Underproduction of a hormone
  - Nonfunctioning receptors – cause target cells to lose sensitivity to hormones

Function #1: Water & Electrolyte Balance

- 4 Major Hormones involved:
- Antidiuretic Hormone
- Natriuretic Hormones
- Mineralocorticoids
- Adrenal Hormones

- Antidiuretic Hormone (ADH, Vasopressin)
  - Regulates fluid balance
  - Increase renal collecting ducts’ permeability to water
  - Stimulated by changes in:
    - plasma osmolality
    - ECF volume
    - changes in ABP
  - Vasoconstrictor effect on blood vessels

Problem: Syndrome of Inappropriate Antidiuretic Hormone (SIADH)

- ADH secretion despite
  - Serum hypo-osmolality
  - Hyponatremia
  - Euvolemia

- Etiology
- Traumatic Brain Injury
- Hypoxic Brain Injury
- Other

### Pathophysiology
- ↑ ADH secretion leads to H2O retention & increased intravascular volume
- ↓ serum osmolality
- ↓ serum Na+

### Clinical Manifestations
- Weight gain
- ↓ urine output
- Mental Status changes
- Headache
- Seizures
- Nausea/vomiting

### Diagnostic Studies
- Serum Na+ < 130 mEq/L
- Serum osm < 280 mOsm/kg
- BUN < 10 mg/dL
- Urine osm > 600 mOsm/kg
- USG > 1.030

### Management
- Restrict fluids
- Hypertonic saline
- Loop diuretics
- Monitor Serum Na & osm
- Monitor UOP
- Monitor USG
- Monitor Urine osm
- Monitor I & O
- Serial weights
- Hemodynamic status

Problem: Diabetes Insipidus

- Deficit of ADH
  - ↓ ability to concentrate urine
  - ↓ ability to conserve water
  - ↑↑↑↑ diuresis
  - ↓ urine osmolality

- Etiology
  - Traumatic Brain Injury
  - Brain Tumor
  - Neurosurgical procedures
• Pituitary and/or hypothalamic lesions

• Pathophysiology
  o Neurogenic
    ▪ ADH deficiency
    ▪ Failure to synthesize ADH
    ▪ Failure to secrete ADH
    ▪ Combination of the two
  o Nephrogenic
    ▪ No ADH deficiency
    ▪ Normal secretion of ADH
    ▪ Renal system resistant to effects of ADH

• Clinical Manifestations
  o Altered mental status
  o Seizures
  o Coma
  o Weakness
  o Twitching
  o THIRST
  o ↑↑↑ UOP
  o Dilute urine
  o Sx of hypovolemia

• Diagnostic Studies
- Serum osm > 285 mOsm/kg
- Serum Na+ > 145 mEq/L
- Water deprivation test
- Imaging studies
- Urine osm < 200 mOsm/kg
- Urine Na+ < 30 mEq/L
- Urine SG < 1.010

Management

- Replace fluid deficit
- Replace ongoing losses
- ADH replacement
- Monitor serum Na+
- Monitor serum Osm
- Monitor UOP
- Monitor USG
- Monitor urine Osm
- Serial weights

- Synthetic Vasopressin (Pitressin)

- Continuous Infusion
  - 0.0005 u/kg/hr (max 0.01 u/kg/hr)

- IM/SC:
  - 2.5 - 10 units 2-4x/day

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• 1-Deamino-8-D-Arginine Vasopressin (DDAVP)

• Oral:
  o 0.05 mg BID

• Intranasal:
  o 5-40 mcg/day 1-3 times/day

• IV/SC:
  o 2-4 mcg/day in 2 divided doses OR
  o 1/10 of maintenance Intranasal dose

**Question**

1. Which parameters signal the development of SIADH?
   a. Decreased serum sodium; decreased serum osmolality
   b. Increased serum sodium; increased serum osmolality
   c. Decreased serum sodium; increased serum osmolality
   d. Increased serum sodium; decreased serum osmolality

2. In a patient being treated for SIADH, which one of the following sodium levels would indicate reversal of this syndrome?
   a. 119 mEq/L
   b. 128 mEq/L
   c. 135 mEq/L
   d. 152 mEq/L

3. Which of the following findings is indicative of diabetes insipidus (DI)?
   a. Serum sodium 150 mEq/L
   b. CVP 10 mm Hg
   c. Urine specific gravity 1.032
   d. Serum osmolality 280 mOsm/L

4. A child with a closed head injury has developed SIADH. Which of the following laboratory results would this patient exhibit?
a. Serum Na+ 122; serum Osm 262
b. Serum Na+ 134; serum Osm 280
c. Serum Na+ 144; serum Osm 282
d. Serum Na+ 158; serum Osm 295

5. Which of the following actions would be appropriate after the administration of desmopressin (DDAVP) to a patient with Diabetes Insipidus?

a. Decreasing fluids
b. Increasing fluid
c. Increasing sodium intake
d. Decreasing sodium intake

Mineralocorticoids

- Aldosterone
  - Mineralocorticoid secreted by adrenal cortex
  - Regulates H2O and sodium balance
  - Produced via the Renin-Angiotensin system.
  - Stimulated by:
    - ↓ MAP
    - Na+ depletion
    - Increased K+ concentration
  - Renal retention of Na+ & H2O in exchange for excretion of K+ & H-

Adrenal Hormones

- Glucocorticoids (cortisol)
• Secreted by the adrenal cortex

• Triggered by stress responses

• Conserves Na+ & H2O

• Increases serum glucose levels

• Influences catecholamine production & sensitivity

• Catecholamines

  • Epinephrine & Norepinephrine

  • Secreted by the adrenal medulla

  • Maintain MAP

  • Act on adrenergic receptors

  • ↑ vascular tone, HR & myocardial contractility

Problem: Adrenal Insufficiency/Crisis

• Etiology

• Primary
  o Intrinsic disease of the adrenal gland

• Secondary
  o Communication issues b/w hypothalamus, pituitary gland & adrenal gland, or hypothalamic-pituitary-adrenal axis

• Clinical Manifestations
  o Hyponatremia

  o Hyperkalemia
- Hypovolemia
- Decreased myocardial contractility
- Vasodilation
- Capillary leak
- Hypoglycemia

**Management**
- High dose corticosteroids
- Corticotropin Releasing Hormone (CRH)
- Adrenocorticotropic Hormone (ACTH)
- Fludrocortisone

**Function #2: Energy Production/Glucose Homeostasis**

- 5 Hormones that regulate energy production
  - Insulin
  - Glucagon
  - Epinephrine
  - Cortisol
  - Growth Hormone

- **Insulin**
  - Anabolic hormone
  - Secreted by the β-islet cells of the pancreas in response to serum glucose
  - Increases glucose uptake by the cells

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• Stimulates:
  ▪ Glycogenesis (formation of glycogen)
  ▪ Protein synthesis
  ▪ Formation of adipose

• Glucagon
  ▪ Counter-regulatory hormone to insulin
  ▪ Secreted by pancreas in response to ↓ serum glucose
  ▪ Stimulates:
    ▪ Glycogenolysis (glycogen breakdown)
    ▪ Gluconeogenesis (glucose production)

• Growth Hormone
  ▪ Secreted by the anterior pituitary gland
  ▪ Stimulates:
    ▪ Protein synthesis
    ▪ Gluconeogenesis
    ▪ Lipolysis
  ▪ Release triggered by stress response

Problem: Hypoglycemia

• Etiology
  ▪ Common in sick neonates & young infants
  ▪ Inadequate glycogen stores
- Hyperinsulinism (transient or persistent)
- Hypopituitarism
- Adrenal insufficiency
- Liver failure
- Inborn errors of metabolism

- Clinical Manifestations
  - Serum glucose ≤ 60 mg/dL
  - ↓ level of consciousness
  - Seizures
  - Tremors
  - Hypotonia
  - Apnea
  - Tachycardia
  - Diaphoresis
  - Anxiety

- Acute Management
  - No IV access:
    - Oral carbohydrate
    - Glucagon
  - IV access:
    - 0.2 – 2 g/kg dextrose
    - 5 – 20 ml/kg D10
Problem: Diabetic Ketoacidosis

- Pathophysiology of Diabetes
- Glucose unable to enter cells
- Cannot be used as energy by cells
- Rising serum glucose levels
- Alternative metabolic pathways activated
- Fat & protein metabolized for fuel
- Results in a cellular energy deficit
- Hyperglycemia ( > 300 mg/dL)
- Acidosis (pH < 7.30; HCO3 < 15 mEq/L)
- Ketonuria/Ketonemia

- Clinical Manifestations
  - Severe hyperglycemia
  - Serum glucose ≥ 180 mg/dL or 10 mmol/dL
  - Ketoacidosis
  - Electrolyte abnormalities
    - Hyperkalemia
    - Hyperphosphatemia
    - Hypernatremia
- Hyperosmolarity with osmotic diuresis
- Dehydration $\rightarrow$ hypovolemic shock
- Altered mental status (& signs of elevated ICP)
- Tachycardia
- Hypotension – later sign
- Poor peripheral perfusion
- Tachypnea
- Acetone breath
- Abdominal tenderness
- Signs of concurrent infection

- **Management**
  - Airway, Breathing
  - Circulation
  - Fluid & salt replacement
  - Volume resuscitate if in shock
  - Decrease blood sugar
  - Correct electrolyte imbalances
  - Family teaching

- **Volume Resuscitation**
  - Bolus with normal saline
  - Brisk 10 - 20 ml/kg for circulatory failure – proceed as needed to regain circulation, but exercise great caution (avoid > 40ml/kg)
- Without ongoing circulatory collapse, bolus 5-20 ml/kg over 1-2 hours
- Calculate volume deficit and replace
- Typically 10-20% dehydration
- Administer ≥ 0.45% saline at maintenance plus deficit correction over next 24-72 hours
- Establish vascular access
- Insulin Administration
  - 0.1 U/kg/hr regular insulin
  - IV bolus not typically necessary
- Glucose should be added once serum glucose levels are 250-300 mg/dl
  - Add 5% dextrose when serum glucose reaches 300 mg/dl
  - Add 10% dextrose when serum glucose reaches 200 mg/dl
- Potassium & Phosphate Management
  - Replace K+ & PO4- as needed by adding to IV bag
  - Avoid single dose administration
  - Add 20 to 60 mEq/liter of IVF as needed
- May present with hyperkalemia secondary to acidosis.
- Treat severe hyperkalemia with calcium and consider bicarbonate
  - Cerebral Edema and DKA
    - Considered to be a complication of treatment
    - Typically occurs during the first 24 hours of treatment
    - Incidence - 0.7-1%
Underlying mechanism is unclear

Clinically apparent cerebral edema fatal in 40 – 90% of cases and majority of deaths in DKA attributable to cerebral edema

Risk Factors

- Younger age
- ↑ duration of symptoms
- ↑ serum Na+ during tx
- pH < 7.0 and use of bicarbonate
- serum glucose > 800 mg/dl
- rapid correction of glucose

Treatment

- Immediate recognition & intervention
- Reduce IVF rate
- ± Mannitol
- Hypertonic (3%) saline
- ± Intubation & ventilation

Questions

6. A child being treated for DKA becomes lethargic, is difficult to arouse and has vomited twice in the past hour. These occurrences could be interpreted as indications of:

   a. Exhaustion due to lack of sleep
   b. The development of hypoglycemia
   c. Decreased intestinal motility
   d. Increased ICP

7. A child in DKA has a glucose of 350. One hour later the glucose is 250. The critical care nurse
would anticipate the administration of:

a. Potassium chloride  
b. Sodium bicarbonate  
c. Dextrose solution  
d. Subcutaneous insulin

8. Early signs of hyponatremia include all of the following except:

a. Abdominal cramping  
b. Hyperactive reflexes  
c. Deteriorating level of consciousness  
d. Diarrhea

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