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Improving New Graduate Critical Care Nurse Practitioner Knowledge and Retention Using a Dedicated Orientation and Mentoring Program

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with an emphasis in Pediatric Care

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Abstract

Background: There has been a significant amount of research into the many challenges that nurse practitioners (NPs) face as they transition from school to practice, however, there is limited research on how to improve this transition. Regardless of the setting in which the NPs are working, novices NPs alike report feelings of being unprepared and experiencing high levels of stress, anxiety, fear, and frustration. New research suggests that a comprehensive NP orientation and residency programs may provide a way to integrate the new NPs into their practice environment successfully.

Method: Kern's Six Step Approach to Curriculum Development for Medical Education focusing on problem identification, needs analysis, goals/ objectives, and education strategies for implementation was used to guide the curriculum development of an orientation and residency program that increased unit specific knowledge and training and facilitating successful transition into their role as an advanced care provider.

Intervention: The pediatric critical care content and learning methods were identified through a review of orientation experiences a review of content by both new and experienced NPs in the PICU. A minimum six-month orientation and mentoring program was developed for implementation. Pre-and post-program evaluations were designed to identify individual needs, and knowledge gained.

Conclusion: While the culture may differ between hospital systems, the process of developing the SLCH PICU New APN Orientation and Mentoring Program is amenable to any specialty and, as such, has significant and positive implications for APN practice.

Introduction

Advanced practice registered nurses (APRNs) which include certified registered nurse anesthetists, certified nurse-midwives, clinical nurse specialists, and certified nurse practitioners represent an important role within our current healthcare system. Recent healthcare reform through the passage of the Affordable Care Act in 2010 and the 2011 revisions by the Accreditation Council for Graduate Medical Education have resulted in a decrease in continuity of care, an increase in the patient length of hospital stay, and subsequent increasing hospital cost (Yeager, 2010). New work hour limitation along with increasing patient loads and new expectations of continuous onsite coverage have created a shortage of physician providers. The coverage gaps caused by these changes have enabled the advanced practice nurse (APNs) to become a valued asset in the acute care settings and within specialty services in hospitals. Despite the value, APNs add to specialty clinical settings, gaps in training in these settings remain. There are very few programs specializing in pediatric acute and critical care leaving many nurse practitioners (NPs) with limited acute care training in their advanced practice education. Additionally, many acute care programs now focus on all patients with an acute process rather than focusing on patients with complex, high-acuity needs, like those seen in the critical care setting, further limiting the NP's exposure to the critical care processes (Harris, 2014). Subsequently, many NPs are entering the workforce with variable education levels and practice experiences. In total, these factors contribute to novice NPs' feelings of inadequacy, poor confidence in their ability to provide patient care, and limited knowledge of their patient population (Bahouth & Esposito-Herr, 2009; Cosme, 2015).

Mentorship has been identified as an important factor in improving NP transition into clinical practice and is more than just precepting; mentoring assists in the development of skills. Mentorship has been linked to improved job satisfaction and retention. Hill and Sawatzky (2011) found that a mentorship program where mentees can choose their mentors created the closest relationships and had the most positive outcomes. One company estimated that the

implementation of a mentoring program resulted in an annual cost savings of $328,000 as well as a decline in turnover from 20% to 12% in just one year (Gerhart, 2012). The goal of mentoring is to help provide a foundation of security to propel the APN in the trajectory of goal achievement in a streamlined and efficient manner. To accomplish this aim, a mentor must invest time, energy, and personal knowledge to develop a relationship and assist the mentee's growth and development (McKinley, 2004). Using a three-step mentoring framework developed by McKinley (2004), the mentor and mentee establish a relationship that supports the NP throughout the orientation process which includes:

1. Reflecting: Creation of the relationship, building a foundation and setting the expectation to ensure a successful mentoring relationship.
2. Reframing: Setting the work agreement and defining the agreed upon expectations. Encourages the connection and allows for a challenge of knowledge. Working toward accomplishing the learning goals and developing the relationship.
3. Resolving: Closing the formal mentorship and redefining the relationship moving forward. The mentor empowers the mentee to move forward.

As the role of NPs in delivering high quality, cost-effective care expands, successful transition to practice must be assured. The Affordable Care Act and Institute of Medicine recommend establishing programs for NPs at the time of entry into practice to improve the transition into clinical practice (Barnes, H. 2015). The New Hire NP Orientation and Mentoring Program developed for this project uses Kern's model of curriculum development as an overarching conceptual model to provide a framework for a transition into practice programs for NPs to address this recommendation for specialty-specific orientation and mentorship.

Literature Review

The role of the advanced practice nurse (APN) has continued to grow and evolve over the last 50 years, experiencing a momentous growth in the last ten years (Coruh, Roberson-Wiley, Wright, & Kritek, 2015). APNs play an essential role in serving to advance preventive care, increase patient access to care and provide a comprehensive impact on quality outcomes for hospitals (Woolforde, 2012). Current studies show that APNs spend more time interacting with

patients as well as time on care coordination (Coruh et al. 2015). Likewise, the use of APNs in the acute care setting has resulted in a reduction in ICU days, reduction in days spent on ventilators, and a lower rate of complications, with no change in mortality rates (Coruh et al. 2015). As research continues to show that APNs are delivering high quality, cost-effective care, it is important to ensure that the APN role transition is successful.

A comprehensive literature review was conducted using the following databases: PubMed and Cumulative Index to Nursing and Allied Health Literature (CINAHL) to obtain relevant articles on APN orientation programs from 2006 to 2016. Thirty (30) articles were retrieved of which five (5) were relevant. From the reference list of those articles, five (5) additional relevant articles were identified for a total of ten (10) articles reviewed.

While a substantial amount of information on the need for changes related to role transition, mentorship, and the orientation process exists, limited evidence into mechanisms for improvement were identified. More specifically, little evidence on or descriptive articles on the implementation of orientation programs for the APN exists. After searching the literature ten unduplicated articles were chosen because they addressed either the need for an APN orientation program or were trials of an APN/ MD orientation, mentoring, or residency programs.

Frameworks

Kern's Model for curriculum development was chosen as the overarching conceptual framework with a subset of theoretical frameworks used to guide the general needs analysis and the implementation stages in developing the APN orientation program (Thomas, Kern, Hughes, & Chen, 2016) [Figure 1]. Kern's Curriculum Development involves six steps - problem identification, a general and focused needs analysis for educational strategies, defined goals and objectives to guide program development, and analysis of implementation. Kern's cyclical method is ideal for the healthcare setting in that new problems identified in the evaluation, and feedback stages allow evaluation of the curriculum to meet the needs of the group.

Two sub-frameworks - Benner's framework (Benner, 1982), and the template (TempT) theory (Gobet, & Simon, 2000). - Were used to focus the general needs analysis on the APN role transition into practice. The theory of nursing expertise developed by Benner, derived from the Dreyfus Model of Skill Acquisition, is characterized by a decrease in abstract thought and an increase in concrete thought. This framework asserts that while developing skills, one progresses through five levels of proficiency from novice to expert. Due to subsequent research into Benner's theory and the belief by some that it does not always account for the development of expertise and intuition well when compared to empirical data the template (TempT) theory was also used.

The template theory (TempT) of expert intuition also focuses on the nurses' journey from novice to expert with five key features based on the acquisition of many perceptual patterns within the focus of intuition Gobet, & Chassy, 2008). Despite the differences, both theories are important for designing nursing education and training programs; with the importance of being able to detect subtle perceptual differences, acquiring skills in situ, and taking individual differences into account (Gobet, & Chassy, 2008). A graduate APN having had many nursing experiences, functions at an expert level, however, as many new APRN skills are introduced they may feel less like experts and more like a novice. After spending many years as an expert in clinical practice this sudden feeling of novice can be a difficult transition as they go from an expert RN to a novice APN (Yeager, 2010). Successful mentoring can ease this transition and offer support where needed.

The goal of mentoring is to help provide a foundation of security to propel the NP in the trajectory of goal achievement in a streamlined and efficient manner to help ensure the orientation process is a success. In the implementation stage is where McKinley's three-step mentoring framework was applied to ensure the success of the orientation process.

Also in the implementation stage, Kotter's 8 step change model (Kotter, 2012) provided an ancillary framework. Kotter's model includes creating a sense of urgency, recruitment of

powerful change agents, building a vision and effectively communicating it, removing obstacles, creating quick wins, and building on early momentum to make the proposed change part of organizational culture. Ensuring that changes become core to a group by anchoring these changes within the organization's culture is vital for success. Additionally, Kotter's eight (8) steps ensure careful planning and enables the building of a proper foundation so that successful implementation can be accomplished with ease creating a higher likelihood of success.

Specific Aim

Additional education provided through new graduate NP orientation and residency programs are a way to ease NP transition into practice and promote retention and satisfaction, as well as increase patient care quality through increased knowledge (Cosme, 2015). This project designed an orientation and mentoring program for new graduate NPs hired into the critical care areas at St. Louis Children's Hospital. There are only a small number of employees hired into these positions each year. The implementation and evaluation of this orientation and mentoring program will occur in the future with the expansion of the hospital and hiring of new critical care NPs.

Problem

There has been a significant amount of research into the many challenges that APRNs face as they transition from to school to practice. However, there is limited research on how to improve this transition (Bahouth, & Esposito-Herr, 2009). Regardless of the setting in which the APNs are working, novices APNs report feelings of being unprepared and experiencing high levels of stress, anxiety, fear, and frustration (Cosme, 2015).

Post-graduate education provided through a new-graduate nurse practitioner (NP) orientation program has been shown to ease APN transition into practice, promote job retention and satisfaction, and increase the quality of patient care through increased knowledge (Cosme, 2015). At St. Louis Children's Hospital, newly hired NPs demonstrate gaps in knowledge regarding pediatric critical care medicine, systems-based practice, and comfort transitioning to independent

practice. Currently, the orientation program in the Pediatric Intensive Care Unit (PICU) at St. Louis Children's Hospital is a six-month, in-unit program based on individual preceptors teaching and orientee's perceived needs, thus lacking any formal education process. The new NP works with three or more different preceptors without a formal plan or follow-up process. In summary, the current new hire PICU NP orientation at St. Louis Children's hospital lacks the evaluation, and formal education process necessary to provide new NPs with the skills needs to promote a successful transition into practice.

Methods

Needs Assessment

Novice and seasoned NPs perceptions about the current orientation process, perceived gaps in education, and preferred learning methods were determined through surveys and informal interviews. Problems identified through informal surveys were confusion in the learning process for the new NP as well as the instructors, delay in completion of training paperwork and miscommunication about what must be turned in, and feelings of anxiety, frustration, and even lack of confidence in knowledge acquired.

The previous institutional orientation in-unit program lacked a formal curriculum or explicit outcomes. New NPs worked with multiple preceptors with no formal mentoring. The informal educational process is based on the individuals perceived needs by the preceptor and/or orientee. Informal interviews with NP's from both the orientee and preceptor position identified specific curricular, content, and session- based goals and objectives that newly hired NPs demonstrated deficiencies in knowledge regarding pediatric critical care medicine, institutionally specific systems-based practices, and comfort transitioning to independent practice. A needs assessment was conducted via informal questionnaires using Survey Monkey. Nine of the eleven new and experienced NPs currently employed in the PICU completed the needs assessment survey. The following key content areas we identified as essential to the inclusion of the orientation curriculum: respiratory, cardiovascular, neuro- critical care, renal,

endocrine/metabolic, sepsis, and sedation/ analgesia. Additional problems identified included confusion in the educational and teaching process for the new NP as well as the role uncertainty for the instructors related to the education process, delays in completion of training paperwork, miscommunications about what paperwork must be turned in, and feelings of anxiety, frustration, and lack of confidence in the knowledge acquired during orientation.

Development of Educational Strategies/ Goals and Objectives

Content areas were sub-divided into professional requirements, knowledge-based requirements, and procedurally-based requirements. Professional requirements include content generally addressed during hospital orientation. Because hospital orientation is only required of NPs hired from outside the institution, all orientee's received information specific to the workflow and culture of the unit (Appendix A), credentialing, and a resource list. The knowledge requirements focus on the pathophysiology commonly exhibited by patients admitted to the pediatric intensive care unit, they are broadly organized by organ system, as seen in Appendix B, and then further sub-divided into seven modules (Appendix C) for targeted learning broken down into three-week sessions. Didactic sessions, will be held weekly for all NPs, tri-weekly modules (Appendix C) developed using readings and content from Pediatric Critical Care Study Guide Text and Review (Lucking, 2012) and relevant review articles plus PowerPoint lectures provided by pediatric critical care medicine faculty and content experts constitute the mainstay of knowledge instruction outside of the clinical environment. Experiential learning with direct observation and case-based readings with discussion provide guidance on clinical decision making and patient management. Finally, information gained from assessments provided on the first day of orientation (Appendix D and E) and case-based readings with discussion will guide the new hire NP and mentor dyad teaching sessions. Specific procedural content included all psychomotor skills required for the care of critically ill pediatric patients (Appendix B and F). Additional skills necessary for intensive care unit NPs, such as acute resuscitation leadership, are also addressed in the curricular content. Procedural instructional methods included simulation,

modeling and experiential learning with direct observation are required and documented on provided skills training form (Appendix G) and Orientation Weekly Review (Appendix H).

In preparation for implementation of the new orientation plan, an evaluation has been completed to evaluate for challenges and areas of weakness. The goals have been outlined and through team meetings it has been ensured that everyone has a clear understanding of the vision and their contribution.

Orientee Assessment and Program Evaluation

Knowledge outcomes will be assessed using multiple-choice questions following module completion and simulation checklists. Checklists completed during direct procedural observation will provide evidence of procedural competency (Appendix G). Mentors will meet with orientee on the last Friday of every month per outlined orientation calendar (Appendix I) at which time mentors will ensure completion of post-module assessments, attendance at required lectures, and documentation of at least one clinical experience of key pathophysiology (starred in Appendix B). At that time, mentors will review the post-module assessments and checklists with orientee to identify and fill any remaining knowledge gaps. Orientee's will be responsible for completing a 35 question post-orientation cumulative knowledge assessment developed using content from Society of Critical Care Medicine Self-Directed Virtual Critical Care Rounds. Successful completion of the orientation program requires completion of a cumulative knowledge assessment with a passing score of 80% and mentor approval based on completion of monthly meeting requirements.

A post-orientation self-evaluation quiz and knowledge assessment will be completed (Appendix E and F). These quizzes along with the individual module quizzes and the pre-implementation content review will be used to demonstrate achievement of knowledge and skills, as well as overall satisfaction with the course.

Evaluation

At the end of orientation two post-tests are administered: (a) knowledge survey, and (b) program/ process evaluation (Appendix J and K). Orientee's will be responsible for completing a [20] question post-orientation knowledge assessment for evaluation of content learned as well as the self-assessment survey to identify areas the orientee may still feel deficient in. Also, a post-orientation satisfaction and perceptions survey will be provided for program feedback. If the orientee is unable to complete the post-test with an 80% score, a meeting will be held with the APN manager to assess further actions needed to aid in proficiency and successful transition into practice. A one-year post orientation meeting with the manager, mentor, and orientee will be essential to address new areas of growth and development for the orientee. Throughout the development of this program communication with the PICU APN manager occurred to ensure direct buy-in and support of implementation. This course will be deemed successful if the new APN feels that they were mentored and that they have been fully supported to aid with the successful transition to practice. This feedback will be used to further model and develop the program so that the program can continue to grow and meet the needs of future new hire NPs.

Discussion

Limitations

Two significant limitations exist for this project. While the development of the New Graduate Critical Care Nurse Practitioner Orientation and Mentoring Program was based on a well-developed conceptual framework, Kern's Curriculum Development, the orientation program has yet to be implemented due to the small number of NP's hired into these positions. On-going use of the orientation and mentoring program will allow for future data collection to fully evaluate the success of the program. Second, several confounders may impact the post-test knowledge outcomes. Improved scores may be explained by natural maturation or the orientee and test-enhanced learning from the post-module assessments (Thomas, Kern, & Hughes, 2009). That said, natural maturation would occur in any orientation model so is assumed to equally confound knowledge and procedural growth in any orientation model. Test-enhanced learning is

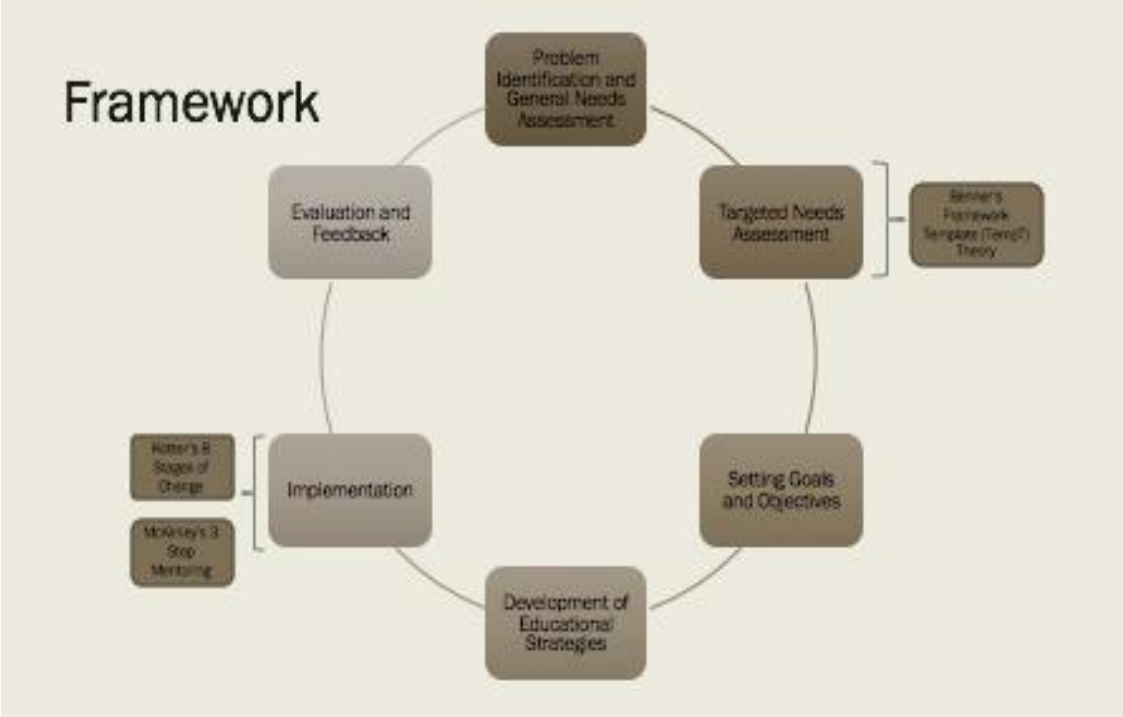
most likely during frequently repeated testing processes and, as such, is unlikely to be a significant confounder here.

Conclusion

The ability to provide competent care to acutely ill children requires an understanding of pathophysiology and procedural competency within the cultural context of a given specialty and hospital system. Many orientation programs use an apprenticeship-based model that is in which new-hire APNs gain and demonstrate expertise based on the patients to which they are exposed during the orientation time frame, and teaching is based on whomever the new-hire works with during the orientation period (Harden, Sowden, & Dunn, 1984). Administratively, this model succeeds because no specific arrangements for the mentoring need to be developed and monitored. In addition, teaching based on current experiences optimizes learning. The major limitation of this model lies in the inability to ensure global competency.

The development of an organized curriculum augmented by mentorship and patient-focused clinical teaching ensures both global competency as well as context-specific cultural understanding. The broad base of the New Graduate Critical Care Nurse Practitioner Orientation and Mentoring Program curriculum provides that new-hire APNs demonstrate foundational knowledge in all content areas. The module-specific knowledge assessments allow new-hire/mentor dyads to focus discussions and learning experiences on areas of weakness which can be clinically situated for optimal retention. Pathologies and procedures deemed critical for successful patient management require direct observation of and demonstration of proficiency ensuring adequate preparation prior to solo practice. Positive mentor/ mentee relationships can promote confidence and success in the transition to practice. While differences between hospital systems and clinical specialty may exist, the process of developing the New NP Orientation and Mentoring Program described in this study is highly generalizable.

Figure 1.


Framework
Problem Identification and General Needs Assessment
Targeted Needs Assessment
Setting Goals and Objectives
Development of Educational Strategies
Implementation
Evaluation and Feedback

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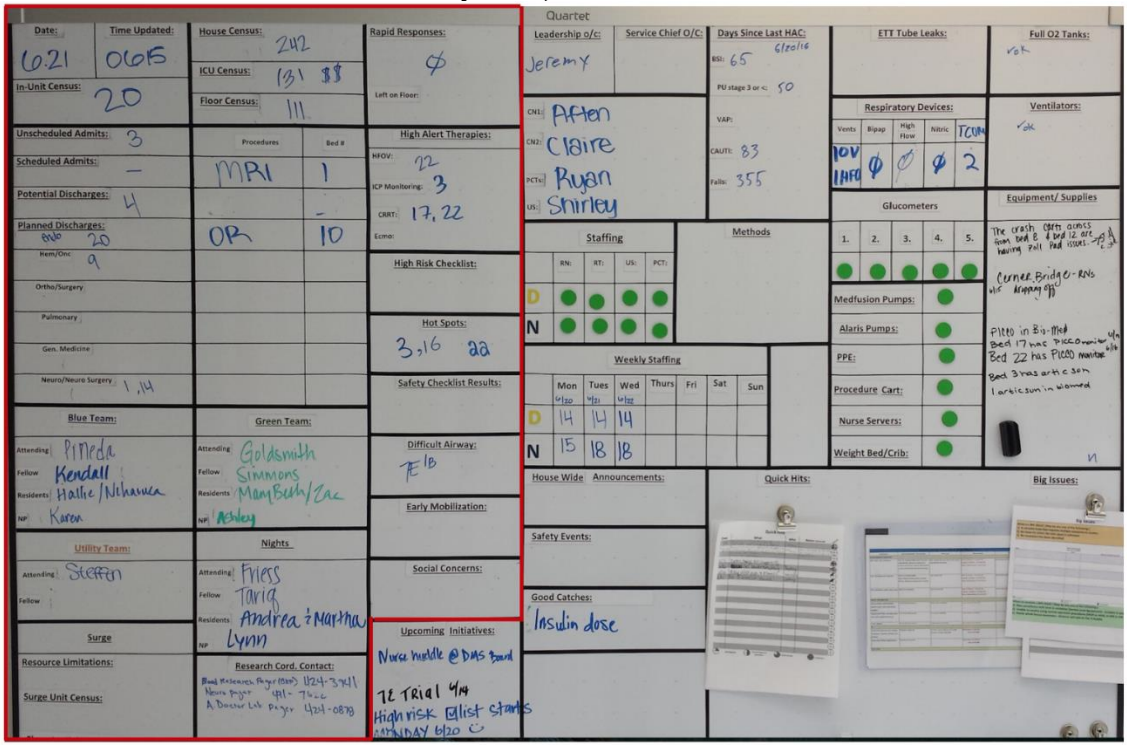
Appendix A

PICU Orientation

1. **Who**
   - ❖ Faculty: Brancato, Doctor, Duncan (CICU), Emke, Friess, Goldsmith, Guilliams (pediatric neurologist), Hartman, Kolovos, Lin, Malone, Pineda, Remy, Shoykhet, Spinella, Steed
   - ❖ Emergency Department and Anesthesia Fellows
   - ❖ Nurse Practitioners: Lara, Katy, Gina, Stephanie, Karen, Ashley, Lynn, Katherine, Julie, Mary, Lindsey
   - ❖ Pharmacist: Kara
   - ❖ Nutrition: Andrea
   - ❖ Social Work: Ashley and Meg
   - ❖ Pediatric and ED Residents

2. **When/Where**
   - ❖ **Teams**
     - o Green Team
       - ▪ Patients admitted for respiratory failure or sepsis
       - ▪ Composition: attending, fellow, NP, 2 residents
     - o Blue
       - ▪ Patients admitted for neuro-critical, post-surgical or trauma care
       - ▪ Composition: attending, fellow, NP, 2 resident
     - o Utility/Consult
       - ▪ Only present M-F
       - ▪ Responsible for: any issues that arise while Green and Blue teams are rounding, managing transports (with the fellows – see transport section of the binder for details), procedural sedation, and procedural oversight
       - ▪ Composition: attending and senior/resource fellow
     - o Overnights
       - ▪ Separate attending and fellow coverage overnight M-F
       - ▪ Responsible for all admissions, procedures, sedations, etc overnight
       - ▪ Composition: attending, fellow, NP, 2 residents (one for Green and one for Blue)
   - ❖ **Rounds**
     - o Weekdays (M-F)
       - ▪ Arrive no later than 6:00 to receive sign out from the night NP
       - ▪ The night fellow will sign out, in bed order, to both fellows
       - ▪ Following sign out, you should have time to review labs, vital sign trends, radiographs, talk with the overnight RN, and review your patient plans with the attending prior to rounds
       - ▪ Rounds start at 8 (teams round in parallel)
     - o Weekends
       - ▪ Rounds start at 7:30
       - ▪ One fellow covers entire unit so teams round in series – exact operation of this varies by attending so ask…
       - ▪ Anticipate being pulled out of rounds frequently as there is no UC attending or other fellow so plan to follow up with both attending's after rounds to review plans/patients/missed things

- Overnight
  - M-F sign out is at 4pm
  - No official overnight sign out on weekends
  - Only one fellow runs entire unit
  - Evening safety rounds
  - Sign out to daytime fellows starting at 5:45
  - Patient "huddle" at 6:30
    - Occurs M-F without fail; variable on weekends
    - Run the list of patients with the entire daytime team to ensure everyone has a one-line understanding of patient issue/reason for admission, most active concerns, and team assignment
  - Safety huddle at 6:45
    - Occurs 7 days/week
    - Ensures unit-based situational awareness
    - Run in the hallway
    - Joint process between all service lines (RN, RT, PCT, NP, Physician)



3. Other

- Admissions
  - Where they come from
    - ED
    - Transport
    - Floor
    - PACU
  - Admission orders
    - Triage based on acuity – if need things quickly, bring a resident to put in order while you're evaluating the patient vs a post-op that can wait 20 minutes
    - Surgery patients should have orders written by their surgery service but you need to review them for pediatric "appropriateness" of the order
- Transfer/Discharge
  - Anticipated bed placement decisions made prior to safety huddle. After rounds (occasionally prior to rounds if bed space is limited), patients ready for the floor receive bed placement confirmation from accepting unit via Tele-Tracking system and residents coordinate transfer of care (orders, sign-out, off-service notes).
- Getting your bearings (RNs, charge RNs, and PCTs will know if you can't remember)
  - 3 crash carts in the unit each with code meds, airway bag, defibrillator, portable suction
    - Outside of room 4 just before the double doors, across from room 12, and outside of room 24
  - 3 airway boxes (include items in crash cart in addition to LMAs)
    - Outside of room 3, outside of room 10, and outside of room 22
  - 1 difficult airway cart
    - Next to the crash cart outside of room 4
  - 1 surgical airway kit
    - In the cupboard outside of room 18
  - 1 scope cart (for emergency tracheolaryngoscopy)
    - In the hallway between the A and B side of the unit
  - 2 med storage machines (Pyxis machine)
    - One next to the RT desk outside of room 5 and one in the med room next to the tube station on the B side
  - Large supply Pyxis in the hallway connecting the sides of the unit, small "Neuro" Pyxis in the room off the hallway
  - Ultrasound machine and mayo tables are in the hallway next to the Neuro Pyxis
  - Procedure cart next to the crash cart outside room 24

Appendix B

PICU APN Orientation Competencies Assessment and Checklist

Name:

Start Date:

Competency/ Skill	Date Observed	Date Demonstrated	Preceptor Initial/ Date (Comments)
Documentation			
Admission History			
Off Service Note/ Discharge			
Procedure Notes:			
Arterial Line			
Central Line			
LP			
Chest Tube			
Intubation			
Patient Diagnosis:			
Pulmonary			
* Acute Respiratory Failure			
Hypoxemic Respiratory Failure & ARDS			
*Asthma (Status)			
*Pneumonia			
*Bronchiolitis			
Pleural effusion			
*Aspiration			
Cystic fibrosis			
Pulmonary embolism			
Pulmonary hypertension			

Competency/ Skill	Date Observed	Date Demonstrated	Preceptor Initial/ Date (Comments)
Multi-organ system Failure			
***Shock**			
Cardiogenic			
Distributive			
Hypovolemic			
Cardiovascular:			
*Rhythm & Conduction Disturbances			
Post-surgical management			
Pericarditis/ Myocarditis			
Hypertensive emergency			
ENT:			
*Tonsillectomy/ Adenoidectomy			
Airway reconstruction			
Mandibular distraction			
*OSA			
*Upper airway obstruction			
Foreign body			
Neuro/ Neurosurgical:			
Coma			
*Brain Tumor Resection			
Stroke			
*VP Shunt/ Revision (Hydrocephalus)			
*Cranial Biopsy (space occupying lesion)			
Craniosynostosis Repair			

Competency/ Skill	Date Observed	Date Demonstrated	Preceptor Initial/ Date (Comments)
*Craniotomy			
*Seizure Disorder (status)			
Cord Detethering			
*ICP placement and management			
Corpus Collosotomy			
Acute spinal trauma			
TBI			
Neuromuscular Disease			
Submersion Injury			
Infections Disease:			
*Sepsis			
*Septic Shock			
Hospital acquired infections			
*Meningitis			
Immunocompromised patients			
Metabolic/ Endocrine:			
*DKA/ hypoglycemia			
Acid/ Base Disturbances			
*Electrolyte Disturbances			
Disorders of thyroid function			
*Dehydration			
GI/ Surgery:			
Acute abdomen			
*Abdominal trauma			

Competency/ Skill	Date Observed	Date Demonstrated	Preceptor Initial/ Date (Comments)
Hepatic failure			
GI bleeding			
*Liver Transplant			
*Pre/ post op management			
NEC			
Hematologic:			
DIC			
*Sickle cell crisis/ acute chest syndrome			
Thrommbocytopenia			
Renal:			
*Acute renal failure			
Rhabdomyolysis			
*Renal Transplant			
HUS			
Oncology:			
Tumor lysis syndrome			
Hyperleukocytosis			
Superior vena cava syndrome			
***Intoxication/ Ingestion:**			
Alcohol			
Narcotics			
Tylenol			
Salicylates			
Hydrocarbon/ Carbon monoxide			

Competency/ Skill	Date Observed	Date Demonstrated	Preceptor Initial/ Date (Comments)
Resuscitation and Stabilization:			
Explain and preform airway management and resuscitation pharmacology			
Describe common causes of acute deterioration			
Functions appropriately in a CODE as part of the PICU team			
Functions appropriately as a RRT member and leader			
CPR			
Defibrillation/ Cardioversion			

Monitoring Devices:			
Arterial			
CVP			
PICCO			
ICP Monitoring			
EVD			
Cooling/ Heating Devices			
Intra-abdominal pressure monitor			
Therapies:			
Respiratory			
Modes of ventilation: (please list):			
HFOV			
Non-invasive ventilation: (please list)			
Nitric Oxide			
Positional therapy			

Nutrition			
Fluid, electrolyte, and caloric requirements			
TPN/ Modification			
Enteral nutrition			
Feeding intolerance			
Diagnostics and Procedures:			
CT			
Brain, Chest, Abdomen/ pelvis			
MRI			
Brain, Chest, Abdomen/ pelvis			
EEG			
Ultrasound			
Nuclear Med Studies			
Doppler			
ECHO			
Chest xray			
Airway Management			
Non-intubated			
LMA			
Intubation/ Extubations			
Line Insertion			
Arterial			
Central (please list)			
Chest tube			
12 lead EKG			

Case Management, Supportive Care, and Ethics:			
Comprehensive patient care			
Communicates with consultants			
Communicates with inter disciplinary team			
Provides communication and education to families			
Initiates and coordinates discharge planning as needed			
Recognizes and evaluates psychosocial needs of patients and families during illness and with recovery			
Provides supportive resources			
Demonstrates respect and sensitivity in dealing with critically ill children and families			
Discuss futility, withdrawal, and withholding care			
Define brain death and criteria for organ donation			
Discuss Do Not Resuscitate orders			

Source: Katherine Huffer, RN PNP-PC

Appendix C
Content Modules

Cardiovascular Module
Chapter 5: Assessment of Cardiovascular Function

Objectives:

- Describe physical Examination findings that aid in assessing the cardiovascular status of the critically ill child.
- Understand arterial and central pressure measurements/waveforms and how they are affected by various disease states.
- Describe the conservation of mass and Fick principles and how they relate to cardiac output measurement.
- Describe novel techniques used for the estimation of cardiac output in critically ill children.
- Identify and describe biochemical markers of cardiovascular function-specifically mixed venous, central venous saturations, lactate and brain natriuretic peptide measurements.

Chapter 29: Disorders of Cardiac Rhythm

Objectives:

- Review and understand the physiology of the cardiac action potential
- Identify and understand the various mechanisms that generate tachyarrhythmias (increased automaticity, reentrant tachycardias and triggered activity).
- Understand how antiarrhythmic medications alter cardiac conduction.
- Learn to identify and treat common pediatric tachyarrthymias.
- Describe the causes and treatment of bradycardia.
- Understand the natural history and treatment of common pediatric rhythm disorders.

Additional Reading Materials:

Nichols D.G and Cameron D.E. (2006). Arterial Pressure Monitoring. *Pediatric Arrhythmias*. New York: Elselvier-Mosby.

Link, M. S. (2012). Evaluation and Initial Treatment of Supraventricular Tachycardia. *The New England Journal of Medicine, 367(15),* 1438-1448.

Tobin, M. J. (1998). Arterial Pressure Monitoring. *Principles and Practices of Intensive Care Monitoring*. New York: McGraw-Hill.

Fuhrman, B.P. and Zimmerman, J. J. (2011). Echocardiography and Noninvasive Diagnosis. *Pediatric Critical Care.* Philadelphia: Elsevier Saunders.

Post-test Questions:

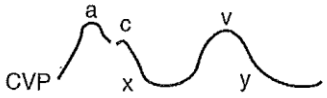
1. Which statement accurately reflects the utility of the physical assessment of the cardiovascular status of a child?
    a. Capillary refill time is independent of ambient temperature.
    b. Pulse pressure will be decreased in conditions characterized by low systemic vascular resistance.
    c. Tachycardia, in and of itself, is a sensitive and specific sign of hemodynamic instability.
    d. The peripheral skin to ambient temperature gradient (dTP-a) decreases during states of high systemic vascular resistance.

e. Urine output is influenced by many factors and therefore should not serve as a proxy for distal tissue perfusion.

2. Which statement is correct regarding arterial monitoring systems?
    a. Damping describes the interaction between the oscillatory energy of a wave and the electrical properties of the monitoring system.
    b. Due to the turbulent flow and the high oxygen tension found in arteries, infections associated with arterial catheters are extremely uncommon.
    c. Pressure monitoring devices must be leveled to the point at which the catheter enters the artery.
    d. The delivery of a small "fast flush" to the arterial catheter allows for quantification of excessive resonance within the system.
    e. The phlebostatic axis is the determined by locating the junction of the vertical line drawn down from the clavicle and the horizontal mid-axillary line.

3. In assessing a normal central venous pressure (CVP) waveform (Figure), the *a wave* represents which of the following?

FIGURE



    a. The decline in atrial pressure that occurs during atrial relaxation and ventricular systole.
    b. The displacement of the tricuspid valve toward the atrium during isovolumic ventricular contraction.
    c. The fall in atrial pressure that occurs as the tricuspid valve opens and the atrium is drained
    d. The increase in intra-atrial pressure observed during atrial contraction that occurs at the end of ventricular diastole.
    e. The rise in atrial pressure during the end of ventricular systole as the atrium fills with venous blood from the inferior and superior venous cava.

4. Which of the following FICK derived equations is correct?

A. $CO = \frac{DO_2}{C_{Ao}O_2 - C_{pa}O_2}$

B. $Q_{pul} = \frac{C_{Ao}O_2}{C_{pv}O_2 - C_{pa}O_2}$

C. $Q_{pul}(C_{pv}O_2) = \left[Q_{pul}(C_{pa}O_2)\right] + DO_2$

D. $Q_{syst}(C_{pv}O_2) = \left[Q_{syst}(C_{Ao}O_2)\right] - VO_2$

E. $Q_{syst} = \frac{VO_2}{C_{Ao}O_2 - C_{pa}O_2}$

5. Which statement regarding the use of themodilution to determine cardiac output is MOST correct?
    a. A fundamental assumption curing thermodilution is that the fluid injected into the right atrium will have complete and anatomically appropriate mixing prior to reaching the pulmonary artery.
    b. A high cardiac output state results in a large area under the thermodilution curve.
    c. Right heart cardiac output should equal left heart output even in the presence of a intracardiac shunt.
    d. The area under the thermodilution curve is determined by the change in flow over time.
    e. The area under the thermodilution curve is in the numerator of the Stewart-Hamilton formula used to calculate cardiac output.

6. A 12 year old girl with acute lymphoblastic leukemia is neutropenic and develops septic shock. Prior to arrival in the pediatric intensive care unit she is treated with antibiotics and is fluid resuscitated with 80ml/kg of isotonic intravenous crystalloid fluids. She has both central arterial and venous catheters placed that allow intermittent transpulmonary thermodilution and continuous pulse contour analysis for cardiac output determination. She appears toxic, flushed and has a hyperbrisk capillary refill. The following hemodynamic data are obtained:

HR: 150 bpm
BP: 100/34 mmHg
Cardiac Index (CI): 6.5L/min/m^2
CVP: 16mmHg
Stroke volume index (SVI) 51mL/beats/m^2
Stroke volume variation (SVV) <10% (normal <10%)
Systemic vascular resistance index (SVRI): 400 dynes-s/cm^5/m^2
Lactate: 9 mmol/L
$ScvO_2$: 88% (Right atrium)
SaO_2: 100%
Hemoglobin: 9.5mg/dL
The elevate $S_{CV}O_2$ (88%) is likely indicative of which of the following?
    a. Catheter tip positioning near the orifice of the coronary sinus

b. Drug toxicity
c. Inadequate oxygen uptake at the cellular level
d. Insufficient cardiac output to provide tissue perfusion
e. Successful resuscitation

7. Which of the following is true regarding the cardiac action potential?
    a. During hyperkalemia, calcium administration may be harmful by augmenting the calcium component of the resting potential.
    b. The high potassium concentration within the cardiac myocyte contributes to the resting action potential.
    c. The spreading wave of myocardial depolarization causes a negative deflection as ti moves toward a surface ECG lead.
    d. Sodium channel blockade with Class IB agents (lidocaine) results in prolongation of the action potential duration.
    e. Sympathetic augmentation decreases the inward calcium current and the slope of phase 4 depolarization.

8. Which one of the following mechanisms accounts for the most tachyarrhythmias (other than sinus tachycardia) in children?
    a. Ectopic foci
    b. Nodal Block
    c. Reentry
    d. Triggered activity
    e. Vagal Stimuli

9. A 2 month old female infant is being cared for in the pediatric intensive care unit for resolving viral bronchiolitis. You are called to the bedside to evaluate her for the sudden onset of a narrow complex tachycardia at a rate of 280 bpm. The infant is awake and interactive, although fussy and crying intermittently. Her blood pressure is 82/50 mmHg, her femoral pulses are readily palpable, and her capillary refill time is less than 2s. Prior to the event, she had a documented normal sinus rhythm with no evidence of a delta wave. Which of the following interventions is contraindicated?
    a. Application of a bag of ice to the infant's face without establishing peripheral intravenous catheter
    b. Placement of a peripheral intravenous catheter and administration of adenosine
    c. Placement of a peripheral intravenous catheter and administration of digoxin
    d. Placement of a peripheral intravenous catheter and administration of verapamil
    e. Placement of a peripheral intravenous catheter and await input from a cardiology consult

10. A 1 year old male is admitted to the pediatric intensive care unit following closure of a large, unrestricted ventricular septal defect. The infant is receiving mechanical ventilation support and his pulse oximeter is reading 100% consistently. He is receiving heavy sedation to maintain synchrony with the ventilator. Following endotracheal suctioning, he suddenly becomes cyanotic and bradycardic. Evaluation of his cardiopulmonary monitor

reveals a narrow complex junctional rhythm with a heart rate of 45bpm and a blood pressure of 62/30 mmHg. The pulse oximeter is reading in the 60s and the patient is clearly cyanotic. Of the following choices, which is the most likely explanation for his bradycardia?

a. Acute respiratory compromise resulting in bradycardia
b. Atrioventricular dissociation for the surgical procedure
c. Sinus node dysfunction secondary to his surgical procedure
d. Sinus node suppression form the required sedation
e. Vagally-induced bradycardia from the suctioning

11. Which of the following children is a LEAST risk for sudden cardiac event?
    a. A 15 yo, previously healthy female with scoliosis admitted following spinal fusion procedure having unifocal premature ventricular contractions
    b. A 5yo male with pre-excitation (Wolff-Parkinson-White Syndrome) noted on this baseline electrocardiogram
    c. A 13 yo female with syncope and a family history of Long QT syndrome
    d. A 12 yo male with a known cardiomyopathy having multifocal premature ventricular contractions
    e. A 8 yo female with known Long QT syndrome being started on methadone for chronic pain

12. Which of the following medications used in the treatment of supraventricular tachycardia binds to specific acetylcholine sensitive potassium channels resulting in a shortening of the action potential duration, nodal cell hyperpolarization and decreased automaticity?
    a. Adenosine
    b. Flecainide
    c. Digoxin
    d. Propranolol
    e. Sotalol

Competencies and checklist:

Complete reading for Chapter 5 and 29 and selected post-test questions.

- Identify differential diagnosis for tachycardic and bradycardic arrhythmias
- Arrhythmia identification

Complete PICCO article reading and review PICCO monitor interpretation at patient's bedside.
Review arterial line placement chapter and waveform trouble shooting at patient's bedside. Place initial line in SIM center with NP preceptor.
Review central line placement chapter and CVP waveform trouble shooting at patient's bedside. Place initial line in SIM center with NP preceptor.
Complete QT calculation interpretation exercise. Identify cause of prolonged QT.
Review defibulator set-up and knowledge of use on unit with charge Nurse or NP.
SWAN Overview
12 Lead EKG reading and interpretation- basic findings
ECHO interpretation-report interpretation

Associated pathways/clinical guidelines/protocols:

- PICCO Manual/Unit Guideline

Additional educational opportunities:

Shadowing Experiences:

- Spend day in cath lab with Cardiologist
- Spend day in ECHO Lab with Cardiology APN
- Spend day with Cardiology APN reading 12-lead EKGs
- Spend time with ECMO RN/perfusionist

Suggested lectures/guest topics:

- Standard hemodynamic monitoring in the PICU
- Cardiac output monitoring and management
- Anatomy and physiology of arrhythmias
- Problem solving ECG and treatment of arrhythmias

Taken from: Maffei, F. (2012) Assessment of Cardiovascular Function. In Lucking, S. E. *Pediatric critical care study guide: text and review*. (pp. 94-132). London: Springer.

Harmon, W. (2012) Disorder of Cardiac Rhythm. In Lucking, S. E. *Pediatric critical care study guide: text and review*. (pp. 583-606). London: Springer.

Endocrine & Metabolic Module

Chapter 35 Fluid Electrolytes and Acid Based Abnormalities

Objectives:

- Describe the major causes of dehydration and processes focusing on rehydration of the dehydrated patient
- Classify the causes of hypernatremia and hyponatremia and differentiate between potential therapies
- Describe the pathophysiology, diagnosis and treatment of patients with diabetes insipidus, SIADH, and cerebral salt wasting
- Describe the inherited causes of hypercalcemia and hypocalcemia and their potential treatment
    a. Discuss the ill effects associated with hypocalcemia
- Discuss the causes and management of hypokalemia and hyperkalemia in the PICU patient
    a. Discuss the potential ill effects associated with a low or high serum potassium
    b. Discuss the treatment of a low and high serum potassium in the PICU patient including when it is necessary to treat
    c. Recognize that because of the predominantly intracellular location of potassium, serum potassium is not a reliable indicator of total body potassium
    d. Identify groups of patients who are at risk for hypokalemia and hyperkalemia
    e. Review the ECG changes associated with hyperkalemia and describe how to use the ECG to diagnose increased serum potassium
    f. Describe the short-term and long-term treatment of hyperkalemia
- Describe the clinical correlates of high and low serum magnesium
    a. Define the treatment of hypomagnesemia
- Define the treatment of hypo- and hyper-phosphatemia
    a. Describe the clinical correlates of high and low serum phosphorus
- Describe the pathophysiologic effects caused by metabolic acidosis and alkalosis
    a. Describe the basis for classifying metabolic acidosis by: Acute versus chronic
    b. Presence or absence of abnormally large anion gap
    c. Describe the treatment of the acidosis with bicarbonate for each of the groups described above
    d. Identify the major causes of acute and chronic metabolic alkalosis
    e. Describe the general treatment of metabolic alkalosis including when acute treatment is indicated

Chapter 39 Critical Care Endocrinology

Objectives:

1. Recognize the signs and symptoms of endocrine/ metabolic disturbances
2. Understand the mechanisms important in maintaining glucose homeostasis
3. Identify the common causes of hypoglycemia in infants and children and how to evaluate and treat them.
4. Understand the pathophysiology of diabetic ketoacidosis and how to evaluate, manage and monitor the child who presents with diabetic ketoacidosis
5. Know how to treat the child with known or suspected adrenal insufficiency and understand the controversies surrounding diagnosing adrenal insufficiency in a critically ill child

6. Understand the biochemical and pathophysiological differences between thyroidal and non-thyroidal illnesses, and how to treat them
7. Recognize disturbances of osmoregulation encountered in patients with tumors of the central nervous system both pre and postoperatively

Chapter 40 Metabolic Crisis

Objectives:

1. Review the physiologic basis and patterns of inborn errors of metabolism.
2. Review the most common clinical and biochemical presentations of children with metabolic diseases.
3. Utilize screening laboratory tests to help guide the further diagnostic work up of a child with suspected metabolic disease.
4. Outline initial treatment strategies for managing a child during a metabolic crisis.

Additional Reading Material:

Moritz, ML & Ayus, J.C. (2004). Dysnatremias in the critical care setting. *Contrib Nephrol; 144*, 132-157.

Adrogue, H.J. & Madias, N.E. (1998). Management of life-threatening acid-base disorders: First of two parts. *New England Journal of Medicine; 338*(1), 26-34.

Adrogue, H.J. & Madias, N.E. (1998). Management of life-threatening acid-base disorders: Second of two parts. *New England Journal of Medicine; 338*(2), 107-111.

Post Test Questions:

1. A 10 kg child is admitted for isonatremic dehydration. Following an initial fluid bolus of 40 mL/kg, the remaining deficit should be replaced with what type of continuous intravenous fluids?
    - **a.** 0.2% normal saline
    - **b.** 0.2% normal saline with 40 mEq of sodium acetate added to each liter of fluid
    - **c.** 0.45% normal saline
    - **d.** 0.45% normal saline with 10 mEq of sodium acetate added to each liter of fluid
    - **e.** 0.9% normal saline

2. Which of the following is the single most important factor in the development of hospital acquired hyponatremia?
    - **a.** Arginine vasopressin (AVP) excess
    - **b.** Fluid retention
    - **c.** Hypotonic fluid administration
    - **d.** Renal disease
    - **e.** Subclinical volume depletion

3. A 5 kg infant with bronchiolitis is transferred to the pediatric intensive care unit actively seizing and is found to have a serum sodium of 123 mmol/L. Which of the following is the MOST appropriate therapy?

a. 0.9% normal saline bolus (10 mL/kg).
b. 3% normal saline bolus of 10 mL over 10 min.
c. 3% normal saline infusion at 5 mL/h.
d. intravenous lorazepam (0.5 mg).
e. intravenous mannitol (5 g) over 15 min.

4. A patient with nephrotic syndrome is found to have a total serum calcium level of 6.8 mg/dL with a serum albumin of 2.0 g/ dL. What is the corrected total serum calcium?
   a. 6.0
   b. 7.8
   c. 8.4
   d. 9.4
   e. 10.0

5. Hypokalemia is MOST likely to produce a serious arrhythmia in the setting of which of the following clinical conditions?
   a. cardiac disease
   b. hypocalcemia
   c. hyponatremia
   d. mitochondrial disease
   e. sepsis

6. A 7 year old male with a potassium level of 6.7 mmol/L has developed significant changes on his electrocardiogram consisting of peaked T-waves and prolongation of his QRS interval. Which of the following interventions is the MOST appropriate immediate course of action?
   a. Hemodialysis
   b. Inhaled beta-adrenergic agonist
   c. Intravenous calcium administration
   d. Intravenous insulin and dextrose infusion
   e. Sodium polysterene resin retention enema.

7. A patient with nephrotic syndrome also has diarrhea and is found to have a total CO 2 of 12 mmol/L, serum albumin of 1.0 g/dL and a calculated anion gap of 5 mmol/L. What is the corrected anion gap?
   a. 6
   b. 8
   c. 10
   d. 12
   e. 16

8. A four month old is admitted to the pediatric intensive care unit following cardiopulmonary arrest. Point of care blood testing reveals a pH 7.01, PaCO 2 32 mm Hg, PaO 2 347 mm Hg, base deficit (-27), hemoglobin of 9.7 g/dL, and an ionized calcium level of 1.05 mmol/L. The infant receives two 20 mL/kg fluid boluses of 0.9% normal saline, is treated with sodium bicarbonate (1 mEq/kg), and is started on an infusion of dopamine. Repeat point of care testing reveals a pH 7.21, PaCO 2 38 mm Hg, PaO 2 163 mm Hg, and a base deficit (-12). Assuming that no calcium was administered, and based solely on the blood gas result, the ionized calcium level on that point of care testing should MOST closely approximate which of the following?
   a. 0.73 mmol/L
   b. 0.85 mmol/L

c. 1.05 mmol/L
d. 1.20 mmol/L
e. 1.37 mmol/L

9. A 2 year old male presents with lethargy and a brief, self-limiting, generalized, tonic clonic seizure. His parents report that he has had an intercurrent viral illness for the past few days characterized by fever, anorexia, and upper respiratory symptoms. Point of care testing reveals a blood glucose level of 38 mg/dL. Urinalysis is strongly positive for ketones, but is otherwise unremarkable. D 25 W is administered as a 2 mL/kg bolus. Insulin levels drawn at the time of hypoglycemia are subsequently found to be less than 2 m IU/mL. Which of the following is the most likely diagnosis?
    a. Disorder of fatty acid oxidation
    b. B. Galactosemia
    c. C. Glycogen storage disease
    d. D. Hyperinsulinism
    e. E. Ketotic hypoglycemia

10. Which of the following statements is true concerning childhood hypoglycemia?
    a. Approximately one third of children under the age of 5 years with acute gastroenteritis are found to be hypoglycemic at presentation.
    b. Children with glycogen storage diseases are profoundly symptomatic with hypoglycemia as a result of their impaired ability to utilize lactate and ketones.
    c. Galactosemia is the most common cause of hypoglycemia in the neonatal age group.
    d. Hyperinsulinism is the most common cause of hypoglycemia in the preschool age group.
    e. Ketotic hypoglycemia is characterized by hypoglycemia following fasting with ketonemia and elevated serum insulin levels.

11. Which of the following interventions is associated with an increased risk of cerebral edema in children with diabetic ketoacidosis?
    a. Failure to administer an insulin bolus prior to initiating an insulin infusion
    b. Inadequate rate of fluid administration
    c. The administration of mannitol
    d. The use of 0.9% normal saline for intravenous fluid
    e. Treatment with intravenous sodium bicarbonate

12. Which of the following statements is true regarding adrenal insufficiency in critically ill children?
    a. A baseline serum cortisol level <25 m g/dL during a period of stress is consistent with adrenal insufficiency.
    b. A single dose of etomidate may increase the risk of adrenal insufficiency during pediatric critical illness.
    c. Failure of the serum cortisol level to rise more than 50 m g/dL 30 min after the administration of intravenous cosyntropin is consistent with adrenal insufficiency.
    d. The daily glucocorticoid maintenance dose for patients with known adrenal insufficiency is 25–50 mg/m 2 /day of intravenous hydrocortisone.
    e. There is strong evidence for a beneficial effect of glucocorticoid treatment on mortality in critically ill children.

13. Which of the following statements is true regarding diabetic ketoacidosis?

a. A fall or diminished rise in serum sodium during rehydration is linked to an increased risk of significant cerebral edema.
b. Cerebral edema is most likely to occur in an adolescent who has incurred previous episodes of diabetic ketoacidosis.
c. Low blood urea nitrogen levels have been associated with an increased risk of cerebral edema among patients with diabetic ketoacidosis.
d. Sodium bicarbonate is effective in ameliorating intracellular cerebral acidosis.
e. The development of hypernatremia during resolution of ketoacidosis is linked to an increased risk of significant cerebral edema.

14. A 6 month old male is admitted to the pediatric intensive care unit with a diagnosis of hypovolemic shock secondary to acute gastroenteritis with profuse diarrhea. Point of care blood testing reveals an ionized calcium level of 0.80 mmol/L (normal range 1.15–1.27 mmol/L). Further testing reveals a persistently low ionized calcium level with a normal vitamin D level and a low parathyroid hormone level. In addition to calcium supplementation, administration of which of the following is MOST likely to help correct the hypocalcemia?
a. Dextrose containing solution
b. Magnesium sulfate
c. Potassium chloride
d. Potassium phosphate
e. Sodium bicarbonate

15. The management of acute metabolic crisis due to organic acidemias may include all the following EXCEPT:
a. Dextrose infusion at 5–15 mg/kg/min
b. Sodium bicarbonate
c. Insulin infusion of 0.05–0.1 units/kg/h
d. TPN containing more than 3 g/kg/day of protein
e. L-carnitine

16. Glutaric aciduria type I may mimic abusive head injury as it may present with:
a. Diffuse retinal hemorrhages
b. Subdural hematoma
c. Bruising
d. Pathologic fractures
e. Severe diaper dermatitis

17. Children with mitochondrial disorders may present with the following symptoms:
a. Profound intestinal dysmotility and delayed gastric emptying
b. Stroke-like episodes
c. Generalized motor weakness
d. Pigmentary retinopathy
e. All of the above

18. An infant with a history of motor delay and severe seborrhea presents with progressive lethargy and vomiting. Initial laboratory analysis reveals marked acidosis with elevation of lactate and ketones as well as hyperammonemia. The most useful therapy in managing this infant is:
a. Administration of 0.025–0.1 mg/kg of glucagon
b. Hemodialysis
c. Administration of 100 mg/kg/day of L-carnitine

d. Administration of 10 mg/day of biotin
e. Supplementation with ribofl avin

19. A 9 week old 4.0 kg male infant is transported to the PICU for treatment of presumed sepsis. He had presented to the emergency department with progressive lethargy and poor feeding. He was found to be febrile to 38.1°C, tachypneic to 64 breaths/ min, tachycardic to 158 beats/min and had a blood pressure of 88/52 mmHg. He has palpable pulses and a capillary refill of 2 s. Blood, cerebrospinal and urine cultures are obtained. He is given broad spectrum antibiotics, a 20 mL/kg NS bolus and is transferred to the PICU due to obtundation, progressive tachypnea and severe acidosis. He has an unremarkable chest radiograph, head CT and complete blood count. Serum chemistries are: sodium of 145 mEq/L, chloride 98 mEq/L, glucose of 111 mg/dL and bicarbonate of 14 mEq/L. Serum lactate drawn from free fl owing arterial blood is 2.2 mMol/L, pH is 7.06, pCO2 23 mmHg and pO 2 90 mmHg on room air. He has made 22 mL of urine since his bolus. His urine has large amount of ketones. The most appropriate assessment and care plan is:

a. An organic acidemia should be suspected. Serum pyruvate, ammonia, amino acids and urine organic acids should be obtained. Prevention of catabolism, supportive care, serial electrolyte and glucose determinations and the continuation of antibiotics are all warranted.
b. A disorder of fatty acid oxidation should be suspected. Serum pyruvate, ammonia, amino acids, urine ketones and organic acids should be obtained. Prevention of catabolism, supportive care, serial electrolyte and glucose determinations are all warranted. Antibiotics should be discontinued.
c. A disorder of fatty acid oxidation should be suspected. Serum pyruvate, amino acids, ammonia, urine ketones and organic acids should be obtained. Prevention of catabolism, supportive care, serial electrolyte and glucose determinations are all warranted. Antibiotics should be continued.
d. A urea cycle defect should be suspected. Serum ammonia should be obtained. Prevention of catabolism, supportive care, serial electrolyte and glucose determinations, continuation of antibiotics and preparation for aggressive treatment of hyperammonemia are all warranted.
e. An inborn error of metabolism is unlikely. Placement of a central venous line, measurement of mixed venous saturation and continued antibiotics are warranted

20. A 12 week old 4.2 kg male infant is transported to the PICU for treatment of presumed meningitis. He presented with vomiting, poor feeding and progressive lethargy. He is found to be febrile to 38.3°C, tachypneic to 74 breaths per minute, tachycardic to 148 beats per minute and has a blood pressure of 108/52 mmHg. He is warm, has palpable pulses and a capillary refill of 2 s. He is difficult to arouse, has a full fontanel and moves all extremities with stimulation. Blood, cerebrospinal and urine cultures are obtained. He is given broad spectrum antibiotics. He has an unremarkable chest radiograph, head CT, complete blood count and serum glucose. Serum chemistries are: sodium of 138 mEq/L, chloride 108 mEq/L, and glucose of 131 mg/dL and bicarbonate of 20 mEq/L. His CSF demonstrates no cells, normal protein and glucose. Arterial lactate is 2.7 mMol/L, pH is 7.56, pCO 2 22 mmHg and pO 2 90 mmHg on room air. He has a 3 min generalized seizure that responds to lorazepam. An inborn error is suspected. The most correct assessment and care plan is:

a. An organic acidemia is most likely. Serum pyruvate, amino acids, ammonia and urine organic acids should be obtained. Pending definitive diagnosis, the prevention of catabolism, supportive care, serial lab testing and the continuation of antibiotics are all warranted.

b. A disorder of fatty acid oxidation is most likely. Serum pyruvate, amino acids, ammonia, urine ketones and organic acids should be obtained. Administration of glucose at a rate of 7–10 mg/kg/min should be initiated to prevent hypoglycemia and further fat catabolism
c. A urea cycle defect is most likely. Serum ammonia, pyruvate, amino acids, urine ketones and organic acids should be obtained. Aggressive treatment of hyperammonemia may be required.
d. A mitochondrial disorder is most likely. Pending definitive diagnosis, the prevention of catabolism, supportive care, serial lab testing and the continuation of antibiotics are all warranted. A muscle biopsy can be delayed but Co-enzyme Q should be administered.
e. A mitochondrial disorder is most likely. Pending definitive diagnosis, the prevention of catabolism, supportive care, serial lab testing and the continuation of antibiotics are all warranted. A muscle biopsy should be obtained in the next 24 h.

Competencies and checklist:

Review ABG's to practice diagnosing metabolic acidosis and alkalosis as well as classifying acute vs chronic and calculating and using anion gap.

Review ECG strips to practice using ECG to diagnose increased serum potassium.

Find sample electrolyte disturbances at the bedside and make treatment decisions

Additional educational opportunities:
Acid/base disturbances
DI/SIADH/CSW
Severe dehydration

Taken from: Moritz, M. (2012) Fluid/Electrolyte/Acid–Base Abnormalities. In Lucking, S. E. *Pediatric critical care study guide: text and review*. (pp. 734-764). London: Springer.

Lynshue, K. & Sperling, M. (2012) Critical Care Endocrinology. In Lucking, S. E. *Pediatric critical care study guide: text and review*. (pp. 851-869). London: Springer.

Bellino, P. (2012) Metabolic Crises. In Lucking, S. E. *Pediatric critical care study guide: text and review*. (pp. 870-895). London: Springer.

Neuro- Critical Care Module
Chapter 31: Cerebral Resuscitation and Traumatic Brain Injury

Objectives:

- Define the difference between primary and secondary brain injury
- Describe the cascade of events that occurs with global cerebral ischemia and reperfusion
- Identify the possible strategies for attenuating the poor outcomes associated global cerebral anoxia
- Describe the modalities currently available for clinical monitoring in brain injured patients and outline indicates for use of
- Discuss the management and its associated rationale of a pediatric patient with a severe head injury including respiratory, hematologic, and nutritional issues

Chapter 32: Neurological Diseases in Pediatric Critical Care Medicine

Objectives:

- Discuss the differential diagnosis of a child presenting with coma
- Describe a basic strategy for evaluating and treating a pediatric patient who presents with coma
- Discuss the differential diagnosis of neuromuscular weakness in an infant
- Discuss acquired disorders of neuromuscular weakness in older children
- Discuss causes, treatment, and outcome of status epilepticus in pediatric patients
- Understand the epidemiology, presentation, diagnosis, treatment, and outcomes of CNS infections in children
- Review the most commonly used guidelines for determining brain death in the pediatric patient

Additional Reading Materials:

Carney, N. A., Chesnut, R., & Kochanek, P. M. (2003). Guidelines for the acute medical management of severe traumatic brain injury in infants, children, and adolescents. *Critical Care Medicine, 31*. doi:10.1097/00003246-200306006-00001

Chapter 19. The role of anti-seizure prophylaxis following severe pediatric traumatic brain injury. (2003). *Critical Care Medicine, 31*. doi:10.1097/00003246-200306006-00020

Chapter 7. Intracranial pressure monitoring technology. (2003). *Critical Care Medicine, 31*. doi:10.1097/00003246-200306006-00008

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Gutmann, L., & Gutmann, L. (1999). Critical Illness Neuropathy and Myopathy. *Archives of Neurology, 56*(5), 527. doi:10.1001/archneur.56.5.527

Servillo, G., Bifulco, F., Robertis, E. D., Piazza, O., Striano, P., Tortora, F., . . . Tufano, R. (2006). Posterior reversible encephalopathy syndrome in intensive care medicine. *Intensive Care Med Intensive Care Medicine, 33*(2), 230-236. doi:10.1007/s00134-006-0459-0

Post test Questions:

1. A twelve year old male is involved in a motor vehicle accident. A computerized tomogram of the brain reveals a small subdural hematoma with multiple punctuate hemorrhages scattered throughout the frontal and parietal cortex. On clinical exam, he is intubated and hemodynamically stable. He opens his eyes minimally, but only to a firm sternal rub. He does not focus. Prior to the intubation, he moaned but made no discernible words. His pupils are equal and reactive. Which of the following is the best motor response that should still prompt consideration of placement of an intracranial pressure monitor?

a. Extension of his lower extremities in response to noxious stimuli
b. Flexion of his upper extremities in response to noxious stimuli
c. Moving all extremities spontaneously
d. Reaching across midline to resist a noxious stimuli
e. Withdrawing from a noxious stimuli

2. A five year old girl was involved in a motor vehicle collision where she sustained injury to her brain with multiple punctuate hemorrhages visualized on computer axial tomogram. She also incurred blunt trauma to her abdomen and has a markedly distended abdomen. She has developed marked acute respiratory distress syndrome requiring mechanical ventilation. After placement of a central venous catheter (tip in the superior vena cava), right radial arterial catheter, Foley catheter, and intra-ventricular intracranial pressure monitor, the following data are obtained:
Arterial blood pressure: 115 / 67 mm Hg (Mean 83 mm Hg)
Central venous pressure: 12 mm Hg
Intra-abdominal Pressure: 18 mm Hg
Mean Airway Pressure: 18 cm H 2 O
Intracranial Pressure: 22 mm Hg
The correct value of her cerebral perfusion pressure is which of the following?

a. 43 mm Hg
b. 61 mm Hg
c. 65 mm Hg
d. 71 mm Hg
e. 93 mm Hg

3. Normal cerebral blood flow values (mL/100 g brain/min) are highest at which age of life?

a. Newborns
b. Two years of age
c. Four years of age
d. Adolescence
e. Adulthood

4. The *primary* value of head computer axial tomography (CAT) immediately after an event associated with significant cerebral ischemia such as cardiac arrest or near drowning is which of the following?

a. A normal initial CAT scan of the brain portends a favorable prognosis.
b. Although likely to be normal, it establishes a baseline for comparison with future CAT scans.
c. An abnormal initial CAT scan indicates a higher probability of an unfavorable neurological outcome
d. It may be used to assess the possibility of trauma or intracranial hemorrhage as the cause of the cardiac arrest or near-drowning.

e. There is no value to a CAT scan of the brain in this setting.

5. In the setting of traumatic brain injury, epidemiologic data support maintenance of the PaO2 above which of the following values?
a. 45 mm Hg
b. 60 mm Hg
c. 75 mm Hg
d. 90 mm Hg
e. It varies based on the age of the patient.

6. Which of the following statements regarding the maintenance of body temperature following traumatic brain injury is currently recommended?
a. The induction of extreme hyperthermia should be attempted to optimize neurologic recovery (40–42°C) as first tier therapy.
b. The induction of extreme hypothermia should be attempted to optimize neurologic recovery (28–31°C) as first tier therapy.
c. The induction of moderate hyperthermia should be attempted to optimize neurologic recovery (38.5–39.5°C) as first tier therapy.
d. The induction of moderate hypothermia should be attempted to optimize neurologic recovery (32–34°C) as first tier therapy.
e. The maintenance of normo-thermia with particular attention to avoid any elevation of temperature should be attempted to optimize neurologic recovery.

7. Which statement regarding acute disseminated encephalomyelitis (ADEM) is true?
a. a causative organism is often identified using CSF culture or blood serologies
b. although the pathogenesis is incompletely understood, ADEM often follows immunization
c. CSF examination reveals a significant pleocytosis with lymphocyte predominance
d. morbidity secondary to refractory intracranial hypertension is common
e. pathologic features include immune-mediated myelin damage to brain and spinal cord reminiscent of multiple sclerosis

8. A 14 year old female on day 6 of induction chemotherapy (daunorubicin, L- asparaginase, vincristine and prednisone) for acute lymphocytic leukemia complains of headache and has a generalized tonic clonic seizure. She has had no hypoxia or poor perfusion and has normal electrolytes except for sodium of 133 mmol/L drawn 2 hours prior to the seizure. She has a WBC count of 3,000 cells/μL, hemoglobin 12 gm/dL and platelet count of 27,000/μl. She was noted to have moderate hypertension for the previous 36 hours that was attributed to volume loading and steroids. She is currently postictal and minimally arousable. Her vitals are: pulse 78 beats per minute, BP 159/99 mm Hg, RR 20 breaths per minute, pulse oximetry 100% on 60% face mask. Which of the following is the most likely pathogenesis of her neurologic deterioration?
a. acute encephalopathy secondary due to focal vasogenic edema caused by alterations in endothelial integrity and autoregulation
b. acute intracranial infection due to immune-compromise
c. hemorrhagic stroke due to thrombocytopenia
d. hyponatremia-induced seizure and prolonged postictal state
e. thrombotic stroke secondary to hypercoaguable state induced by L-asparaginase

9. A 16 year old male develops ascending weakness and areflexia approximately 2 weeks following a bout of gastroeneteritis. It is 4 days since the onset of his current symptoms and

Guillain Barre Syndrome is suspected. Which of the following is a true statement regarding the diagnosis of GBS?

a. confirmation of the diagnosis is largely based on ancillary testing
b. CSF analysis at day 4 will demonstrate a marked increase in protein and lymphocytes
c. electrophysiological studies demonstrate abnormal nerve conduction studies in the distribution of symptoms observed clinically
d. the differential diagnosis of Guillain Barre Syndrome includes tic paralysis, acute disseminated encephalomyelitis and transverse myelitis
e. the presence of anti-ganglioside antibodies is a relatively specific and sensitive ancillary test for GBS

10. Appropriate care of the child with new onset status epilepticus includes which of the following?

a. emergent MRI after airway, breathing, circulatory and seizure control
b. initial use of fosphenytoin in any seizure lasting greater than 15 minutes
c. initial use of high dose barbiturates in any seizure lasting greater than 15 minutes
d. use of benzodiazepines as the initial pharmacologic intervention to control seizures
e. use of combination phenytoin

Associated pathways/clinical guidelines/protocols:

Post op DI protocol
TBI protocol
Meningitis pathway
Sickle cell stroke protocol
Brain death protocol
Organ donation protocol

Competencies: (will create references, demonstrations/aids as well as mode of assessment ex: checklists, written test, demonstration, etc)

ICP set up and zeroing
CPP calculation
GCS review
Arctic Sun set up
Ventriculotomy set up /zeroing

Additional educational opportunities:

OR Experiences:

- Tumor resection
- Corpus callosotomy
- Strips/grids
- ICP monitor placement
- Ventric placement
- IMRIS case
- Decompressive craniotomy

Shadowing Experiences:

- Barb Miller, neurocritical care RN
- Neurology clinic
- Neuro rehabilitation
- EEG tech/reading room

- Neuro radiology
- Neurosurg clinic
- Neurosurg in patient PNP

Suggested lectures/guest lecturers:

- Dr. Pineda: TBI lecture regarding goals of therapy, protocol, outcome
- Neuro rehab team: assessment/candidates for neuro rehab, goals of therapy, outcome
- Neurosurgery faculty: corpus callosotomy procedure and post op care
- Neurosurgery faculty: tumor resection, goals of therapy
- Dr. Guilliams: stroke
- Neuro team member: seizure disorders/treatment
- Dr. Friess and Shoyket (current research)
- Barb Miller – arctic sun, ICP monitoring devices, pupillometer
- Neuroradiology – imaging review
- Midamerica Transplant
- Brain death lecture/exam

Taken from: Fink, E., Kochanek, P., & Clark, R. (2012) Cerebral Resuscitation and Traumatic Brain Injury. In Lucking, S. E. *Pediatric critical care study guide: text and review*. (pp. 643-667). London: Springer.

Bell, M., & Sharangpani, A. (2012) Neurological Diseases in Pediatric Critical Care Medicine. In Lucking, S. E. *Pediatric critical care study guide: text and review*. (pp. 668-689). London: Springer.

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Renal Module
Chapter 15: Renal Replacement Therapies

Objectives:

- Discuss the significance of renal replacement therapy in the care of critically ill children with acute renal failure.
- Describe the mechanics involved and advantages of and uses for peritoneal dialysis.
    - Catheter placement
    - Choice of dialysate
    - Discuss the relative and absolute contraindications to peritoneal dialysis
- Describe the advantages, disadvantages and uses of intermittent hemodialysis.
- Detail the mechanics involved with intermittent hemodialysis, and situations when hemodialysis should be used with caution
    - Hemodialysis equipment
- Describe the advantages and uses of continuous renal replacement therapy, the precautions, and the mechanic involved.
    - Continuous renal replacement therapy equipment
    - Anticoagulation strategies
- Discuss the indications, mechanics, and complications involved with plasmapheresis.
    - Vascular access

Chapter 36: Acute Kidney Injury

Objectives:

- Distinguish between pre-renal, intrinsic, and post-renal causes of acute kidney injury using appropriate laboratory tests and imaging studies.
- Describe the major manifestations of acute kidney injury in children.
- Discuss the management of the major perturbations of homeostasis caused by acute kidney injury and the controversies surrounding some of the traditional interventions such as diuretics and low-dose dopamine infusion.
- Discuss the indications for renal replacement therapy and the clinical issues that must be considered when choosing between different renal replacements modalities.
- Discuss interventions that may prevent or modify the course of acute kidney injury.

Additional Reading Material:

Kuiper, J.W., Groenvel, A.B.J., Slutsky, A.S., & et al. (2005). Mechanical ventilation and acute renal failure. *Critical Care Medicine, 33*, 1408-1415.
Uchino, S., Doig, G.S., Bellomo, R. & et al. (2004). Diuretics and mortality in acute renal failure. *Critical Care Medicine, 32*, 1669-1677.

Post Test Questions:

1. Which of the following statements is correct regarding trends in acute renal replacement therapy in children?
    a. As a result of concerns for central venous infection, the use of peritoneal dialysis as the initial modality for the treatment of acute renal failure is increasing.
    b. Due to the lack of pediatric specific equipment and the volume of extracorporeal blood, intermittent hemodialysis is not able to be used for small children.
    c. In contrast to adults, acute renal failure remains the only indication for pediatric renal replacement therapy.

d. Secondary to concerns of exacerbating hemodynamic instability, the use of continuous renal replacement therapy in the pediatric intensive care unit has decreased in recent years.
e. The use of continuous renal replacement therapy and intermittent hemodialysis has replaced peritoneal dialysis as the most common treatment for acute renal failure in children.

2. A 4 day old male presents with multiple organ dysfunction syndrome and encephalopathy. The infant is intubated, mechanically ventilated and started on a dopamine infusion for pulmonary and hemodynamic stabilization. Laboratory work up reveals severe hyperammonemia (ammonia level 1285 m mol/L). The Genetics service is consulted and suspects a urea cycle defect, most likely ornithine transcarbamylase deficiency. The therapy most urgently needed to improve his chance of successful outcome includes which one of the following?

a. Hemodialysis
b. Lactulose
c. Neomycin
d. Peritoneal dialysis.
e. Sodium benzoate and sodium phenylbutyrate

3. Which of the following is true regarding the use of continuous renal replacement therapy in children?

a. Continuous arterio-venous hemofiltration is used more frequently in children than continuous veno-venous hemofiltration because it is more effective at clearing inflammatory mediators.
b. The continuous nature of fluid removal in continuous renal replacement therapy results in less hemodynamic instability than experienced with intermittent hemodialysis.
c. The use of continuous renal replacement therapy is decreasing in children as the use of peritoneal dialysis increases.
d. The use of continuous veno-venous hemofiltration has been found to remove inflammatory mediators and improve outcomes in pediatric sepsis.
e. When the combined volume of the hemofilter and circuit is more than 10% of the blood volume of the child, the continuous veno-venous hemofiltration circuit may be primed with normal saline rather than blood.

4. A 7 year old child presents with paralysis of his lower extremities 10 days after an upper respiratory infection. He has a heart rate of 126 bpm and a blood pressure of 146/86 mm Hg with a weak, but adequate respiratory effort. As part of his diagnostic work-up, a lumbar puncture is performed which reveals less than 10 white blood cells/ m L and a protein level of 126 mg/dL. Which of the following therapies is most indicated in the treatment of his condition?

a. Continuous arterio-venous hemofiltration
b. Continuous veno-venous hemofiltration
c. Hemodialysis
d. Peritoneal dialysis
e. Plasmapheresis

5. Intermittent hemodialysis is effective in removing substances characterized by which of the following?

a. High protein binding
b. High water solubility
c. Large molecular weight
d. Negative electrochemical charge

e. Neutral electrochemical charge

6. A 13 year old, 55 kg male presents with acute kidney injury characterized by severe oliguria, azotemia, 15% total body fluid overload and hypertension. Vital signs reveal a heart rate of 65 bpm, a respiratory rate of 24 breaths/min, and a blood pressure of 148/89 mm Hg. Laboratory analysis reveals the following:
Sodium: 132 mmol/L, Potassium: 6.2 mmol/L, Blood urea nitrogen level: 118 mg/dL, Creatinine of 4.3 mg/dL, Hemoglobin 7.8 g/dL
Hemodialysis is successfully performed with a net fluid balance of (−) 500 mL and 2 units of packed red blood cells transfused. Shortly after the procedure, the adolescent complains of a headache, blurred vision and nausea that progresses to disorientation with vomiting. Post dialysis vital signs reveal a heart rate of 74 bpm, a respiratory rate of 20 breaths/min, and a blood pressure of 135/82 mm Hg. Laboratory analysis reveals the following:
Sodium: 137 mmol/L, Potassium: 3.4 mmol/L, Blood urea nitrogen level: 28 mg/dL, Creatinine: 2.3 mg/dL, Hemoglobin: 9.4 g/dL
The most likely explanation for the acute change in his clinical condition is which of the following?

a. Acute intracranial hemorrhage secondary to the anticoagulation required for the hemodialysis.
b. Acute intravascular volume depletion secondary to overzealous fluid withdrawal.
c. An acute thrombotic event secondary to acute hemoconcentration.
d. Central pontine myelinolysis from the acute increase in the sodium concentration.
e. Dialysis disequilibrium syndrome secondary to the rapid reduction of the elevated blood urea nitrogen level.

7. Citrate anticoagulation is frequently used for continuous renal replacement therapies. Citrate lock refers to accumulation of citrate when the rate of infusion exceeds the hepatic metabolism and the dialysate clearance. It is characterized by which of the following findings in the serum calcium level:

a. Decreasing total calcium and decreasing ionized calcium level
b. Decreasing total calcium and increasing ionized calcium level
c. Increasing total calcium and decreasing ionized calcium level
d. Increasing total calcium and increasing ionized calcium level
e. No change in either of the calcium levels

8. A 3 year old boy, who is neutropenic secondary to chemotherapy for acute lymphoblastic leukemia spiked a fever of 39°C. His baseline serum creatinine level is 0.4 mg/dL. At the time of his fever, he was mildly hypotensive for a brief period, but responded promptly to a single saline bolus. He is being treated with cefepime and gentamicin. Gentamicin levels have been within the therapeutic range. Eight hours after the febrile hypotensive episode, his creatinine is still 0.4 mg/dL and his urine output is 1 mL/kg/h. Given this information, you conclude that

a. given the mild nature of the hypotension, the risk of developing acute kidney injury is low.
b. he has not sustained any renal injury.
c. the normal gentamicin level is reassuring and that the dose is safe and does not require further monitoring.
d. the serum creatinine level should be monitored closely for several more days.
e. the urine output indicates normal renal function.

9. A 10 year old girl (Height 140 cm, Weight 35 kg) had open heart surgery 7 days ago. Her serum creatinine has peaked at 1.2 mg/dL for the past 3 days. Her estimated GFR is approximately
   a. 120 mL/min/1.73 M 2
   b. 90 mL/min/1.73 M 2
   c. 70 mL/min/1.73 M 2
   d. 50 mL/min/1.73 M 2
   e. 30 mL/min/1.73 M 2

10. Which of the following children with acute kidney injury has the best prognosis?
   a. A neonate with congenital heart disease
   b. A 2 year old male with typical, post diarrheal hemolytic uremic syndrome
   c. A 5 year old male who has received a bone marrow transplant
   d. A 10 year old female with sepsis
   A. A 17 year old male with Hodgkin lymphoma

11. A 5 year old male who has recently required resection of infarcted bowel has developed Gram-negative sepsis with the systemic inflammatory response syndrome and respiratory failure. His blood pressure is 58/30 mm Hg requiring substantial fluid resuscitation. His blood urea nitrogen level is 70 mg/dL, serum creatinine level is 3.0 mg/dL and his urine output is 0.3 mL/kg/h. After assuring adequate intravascular volume status, the best treatment option would be to
   a. administer a nitric oxide synthase inhibitor.
   b. administer repeated doses of a loop diuretic to improve urine flow.
   c. initiate an infusion of adenosine.
   d. initiate a low dose dopamine infusion to improve urine flow.
   e. initiate a norepinephrine infusion to support blood pressure.

12. In the patient described in question 4, oliguric kidney injury persists with significantly mismatched fluid balance with worsening edema, worsening ventilatory status, and marginal systemic blood pressures despite the use of pressor support and fluid boluses. The serum sodium level is 130 mmol/L and the serum potassium level is 6.2 mmol/L. Of the following options, the best choice for this patient would be
   a. continuous arterio-venous hemofiltration.
   b. continued medical management with sodium polystyrene sulphonate, diuretics, and sodium bicarbonate.
   c. continuous veno-venous hemofiltration.
   d. intermittent hemodialysis.
   e. peritoneal dialysis.

Associated pathways/clinical guidelines/protocols:
Sepsis Pathway
Competencies:
- Review CVVH and peritoneal dialysis competencies in folder

Additional educational opportunities:
Shadowing Experiences:
- Review CVVH machine with RN
- Dialysis clinic

Suggested lectures/guest lecturers:

- Dr. Tara Neumayr- AKI lecture
- Kira Giele, PNP- Dialysis lecture

Taken from: Schwaderer, A., & Lande, M. (2012) Renal Replacement Therapies and Other Extracorporeal Therapies. In Lucking, S. E. *Pediatric critical care study guide: text and review*. (pp. 322-332). London: Springer.

Varade, W, & Erkan, E. (2012) Acute Kidney Injury. In Lucking, S. E. *Pediatric critical care study guide: text and review*. (pp. 765-783). London: Springer.

Respiratory Module

Chapter 1: Fundamentals of Gas Exchange and the Assessment of Oxygenation and Ventilation

Objectives:

- Explain the alveolar gas equation and the alveolar/arterial oxygen gradient
- Define dead space, how it is quantified, and the compensatory mechanisms
- Define the distribution of ventilation and perfusion, how they are coupled, and common causes of their uncoupling
- Explain the hemoglobin/oxygen dissociation curve and carbon dioxide transport, and the differences between their transport mechanisms
- Describe the mechanics of, uses, and limitations of pulse oximetry, end-tidal carbon dioxide monitoring, and transcutaneous carbon dioxide monitoring

Chapter: 12 Conventional Mechanical Ventilation

Objectives:

- Describe the physiology of oxygenation and ventilation and the indications for initiation of mechanical ventilation
- Describe the changes in cardiopulmonary interactions with positive pressure ventilation
- Define different modalities of positive pressure ventilation and explain the differences between them
- Explain the relationships between minute ventilation and pCO2 and mean airway pressure and pO2

Chapter 13: Non-conventional Mechanical Ventilation

Objectives:

- Define and describe the types of noninvasive mechanical ventilation utilized in the critical care setting and the appropriate patient populations
- Understand the advantages and disadvantages of noninvasive mechanical ventilation
- Describe the indications for use of high frequency oscillatory ventilation (HFOV)
- Understand the advantages and disadvantages of HFOV
- Define and describe the different types of treatments and interventions used for improved airway and pulmonary compliance and pulmonary toilet

Additional Reading Materials:

Arnold JH. High-frequency ventilation in the pediatric intensive care unit. Pediatric Critical Care Medicine (2000). Vol. 1 No. 2, P. 93-99.

Carroll CL, Sala KA. Pediatric Status Asthmaticus. Critical Care Clinics. (2013). Vol. 29, P. 153-66.

Cheifetz IM, Venkataraman ST, Hamel DS. Chapter 21. Respiratory Monitoring. Rogers' Handbook of Pediatric Intensive Care, 4th ed. Philadelphia: Lippincott Williams & Wilkins (2008). P. 170-181.

Duval ELIM, Markhorst DG, Van Vught AJ. High Frequency Oscillatory Ventilation in Children: an Overview. Respiratory Medicine (2009). CME 2, P.155-161.

Haas CF, Bauser KA. Advanced Ventilator Modes and Technques. Critical Care Nurs Q (2012). Vol. 35, No. 1, P. 27-38.

Haitsma JJ. Physiology of Mechanical Ventilation. Crit Care Clin (2007). Vol 23, P. 117-34.

Martinon-Torres, F. Noninvasive Ventilation with Helium-oxygen in Children. Journal of Critical Care (2012). Vol 27, No 220, P1-9.

Randolph, A.G. Management of Acute Lung Injury and Acute Respiratory Distress Syndrome in Children. Critical Care Medicine (2009). Vol. 37, No 8. P. 2448-2454.

Stawicki SP, Goyal M, Sarani B. Analytic reviews: High-frequency Ventilation (HFOV) and Airway Pressure Release Ventilation (APRV): a Practical Guide. J Intensive Care Med (2009). Vol. 24, P. 215-29.

Venkataraman S. Mechanical Ventilation and Respiratory Care.

Ventre KM, Arnold JH. High Frequency Oscillatory Ventilation in Acute Respiratory Failure.

Paediatric Respiratory Reviews (2004). Vol. 5, P. 323-32.
ABG interpretation- http://www.thoracic.org/clinical/critical-care/clinical-education/abgs.php

Post test questions:

1. A twelve year old male with acute respiratory distress syndrome has required intubation for progressive hypoxemia. His initial ventilator settings are as follows:
Fraction of inspired oxygen: 1.0
Peak inspiratory pressure: 35 cm H 2 O
Peak end expiratory pressure: 12 cm H 2 O
Mean airway pressure: 22 cm H 2 O
Ventilator rate: 14 breaths per minute
His most recent arterial blood gas result revealed a pH 7.37, PaCO 2 40 mm Hg, PaO 2 100 mm Hg, and SaO 2 96%. The barometric pressure is 760 mm Hg, the partial pressure of water vapor is 47 mm Hg, and the respiratory quotient is assumed to be normal (0.8). Which of the following values most closely approximates the alveolar oxygen gradient?
   a. 538 mm Hg
   b. 563 mm Hg
   c. 573 mm Hg
   d. 610 mm Hg
   e. 663 mm Hg

2. A two month old infant with hypoplastic left heart syndrome status post Stage I Norwood Procedure is developing pulse oximetry evidence of increasing hypoxemia. Point of care arterial blood sampling reveals pH 7.38, PaCO 2 44 mm Hg, PaO 2 35 mm Hg, SaO 2 75%, and a hemoglobin 12.0 g/dL. Which of the following values best estimates the arterial oxygen content of this infant?
   a. 10.5 mL O 2 /dL.
   b. 11.2 mL O 2 /dL.
   c. 12.2 mL O 2 /dL.
   d. 14.2 mL O 2 /dL.
   e. 16.8 mL O 2 /dL.

3. A two year old male presents with profuse watery diarrhea and tachypnea. He is tachycardic and tachypneic on clinic exam with pulse oximetry readings of 85% and a good waveform which correlates with the heart rate. He is placed on increasing concentrations of oxygen, but he appears

dusky and his pulse oximetry readings and clinical exam remain essentially unchanged. Consequently, an arterial blood gas is performed which reveals pH 7.28, PaCO 2 34 mm Hg, PaO 2 189 mm Hg, and base deficit (–7). Which of the following diagnoses is most likely?

a. Carboxyhemoglobinemia
b. Malfunctioning pulse oximeter
c. Methemoglobinemia
d. Sickle cell disease
e. Ventilation perfusion mismatch

4. A sixteen year old trauma victim with a pulmonary contusion has developed evidence of acute respiratory distress syndrome. He currently is receiving mechanical ventilator support in the pressure regulated volume control mode with the following settings:
Fraction of inspired oxygen: 0.80
Inhaled tidal volume: 500 mL / exhaled tidal volume: 475 mL
Peak end expiratory pressure: 10 cm H 2 O
Mean airway pressure: 16 cm H 2 O
Ventilator rate: 16 breaths per minute
His pulse oximeter reading is 92% and his end tidal carbon dioxide is 30 mm Hg. An arterial blood gas reveals a pH 7.35, PaCO 2 45 mm Hg, PaO 2 65 mm Hg, and oxygen saturation 90%. The best estimate of the percent dead space ventilation is which of the following?

a. 2%
b. 5%
c. 15%
d. 20%
e. 33%

5. A five year old male is found unresponsive in a smoke-filled room at the scene of a house fi re. He is intubated at the scene and transported to the Emergency Department being ventilated with 100% oxygen. Upon arrival to the Emergency Department, he is found to have a pulse oximeter reading of 100%. Which of the following statements provides the best interpretation of the pulse oximetry reading?

a. Although the pulse oximetry reading accurately reflects a well oxygenated patient, the 100% oxygen should be continued to treat potential carboxyhemoglobinemia.
b. It is difficult to determine if the pulse oximetry value represents effective oxygenation because the pulse oximeter will inappropriately interpret carboxyhemoglobin to be oxyhemoglobin.
c. The ability to effectively oxygenate the patient with supplemental oxygen via conventional ventilation as reflected by the pulse oximeter reading obviates the need for hyperbaric oxygen.
d. The patient is well oxygenated and should have his fraction of inspired oxygen weaned to maintain a pulse oximetry level of 94 – 99% to minimize potential oxygen toxicity.
e. The pulse oximetry value likely overestimates the degree of oxygenation because the methemoglobin formed as a result of smoke inhalation has a very similar light absorption as oxyhemoglobin at 660 nm.

6. The capnogram depicted in the figure most likely represents which of the following clinical conditions?

a. Acute respiratory distress syndrome
b. Asthma
c. Compromised cardiac output
d. Pneumothorax

e. Pulmonary edema

7. A 14 year old 50 kg male develops postobstructive pulmonary edema following a near-hanging. He develops profound hypoxia and requires endotracheal intubation and mechanical ventilation at the referring institution. He arrives ventilated in a volume control mode. His settings are: FiO 2 80%, rate 16, tidal volume 400 mL, inspiratory time 1 s, PEEP 10 cm H 2 0. The PIP is measured at 34 cm H 2 0. He is lightly sedated but appears agitated. An arterial blood gas reveals: pH 7.58, PaCO 2 21 mmHg, PaO 2 98 mmHg. The following is the most likely cause of the hypocarbia:

a. high spontaneous rate causing excessive minute ventilation
b. high ventilator rate causing excessive minute ventilation
c. large tidal volume causing excessive minute ventilation
d. large tidal volume causing excessive PIP
e. short inspiratory time allowing prolonged expiration

8. Which of the following is most correct regarding the inspiratory time in mechanical ventilation?

a. Altering the inspiratory time in pressure controlled ventilation can effect minute ventilation but does not affect mean airway pressure
b. An inspiratory pause added at end expiration does not add to the total inspiratory time
c. Lengthening the inspiratory time in volume controlled ventilation can decrease the inspiratory flow and thus PIP
d. Longer inspiratory times help recruit alveoli with short time constants
e. Pressure support ventilation requires the inspiratory time be preset depending on the degree of airflow resistance or noncompliance

9. A 9-year-old, 30 kg girl with severe influenza infection develops ARDS and progressive hypoxia. Current ventilator settings are: SIMV-volume, FiO 2 100%, rate 16, tidal volume 200 mL, inspiratory time 1.4 s, PEEP 10 cm H 2 O. The PIP is measured at 40 cm H 2 O and the plateau pressure is 34 cm H 2 O. An arterial blood gas reveals: pH 7.28, PaCO 2 51 mmHg, PaO2 48 mmHg. Appropriate application of PEEP is best demonstrated by:

a. improved oxygenation with decreased PIP
b. improved oxygenation with increased PIP
c. improved oxygenation with decreased plateau pressure
d. pressure volume curve demonstrating a decrease in delta volume with no change in delta pressure
e. pressure volume curve demonstrating an increase in delta volume with increased delta pressure

4. Pressure support ventilation is a mode that is:

a. patient triggered (flow or pressure), flow limited and pressure cycled
b. patient triggered (flow or pressure), pressure limited and flow cycled
c. patient triggered (flow or pressure), time limited and time cycled
d. patient triggered (flow or pressure), volume limited and flow cycled
e. time triggered, pressure limited and flow cycled

10. A 16 year old with chronic renal disease and long standing hypertension presents with respiratory distress and hypertensive crisis. His admissions vitals are: temperature 38.7, pulse 108, respiratory rate 44, blood pressure 189/102 and oxygen saturation of 88% while breathing 100% FiO 2 . He appears mottled with cool extremities and poor pulses. His chest radiograph shows bilateral patchy infiltrates and cardiomegaly. He rapidly progresses to respiratory failure

and requires endotracheal intubation and positive pressure ventilation. Thirty minutes after intubation his vitals are pulse 90, ventilator rate 12 spontaneous rate 20, blood pressure 159/92 and oxygen saturation of 98% while on 60% FiO 2. He has improved color and has easily palpable pulses. He is comfortable with intermittent benzodiazepine sedation. Arterial lactate has declined to 3.5 mmol/L from 5.7 at admission. The most likely explanation for his hemodynamic improvement is

a. improved oxygenation due to the application of positive pressure
b. positive pressure reducing afterload to the right heart
c. positive pressure reducing afterload to the left heart
d. positive pressure reducing preload to the left heart
e. positive pressure reducing preload to the volume overloaded right heart

11. A 2 year old 12 kg female develops respiratory failure due to pneumococcal pneumonia and right sided empyema. She undergoes video-assisted thoracoscopic surgery and has a patent draining right chest tube. She is ventilated with SIMV-volume, FiO 2 40%, rate 16, tidal volume 90 mL, inspiratory time 1.2 s, PEEP 6 cm H 2 O. The PIP is measured at 24 cm H 2 O and the plateau pressure is 20 cm H 2 O. Her oxygen saturation is 98% and she appears comfortable on a low dose midazolam infusion and intermittent morphine. She develops acute hypoxia with oxygen saturation falling to 81%. Her lung exam is significant for equal but diminished breath sounds and no wheezing. The PIP is measured at 34 cm H 2 O and the plateau pressure is 23 cm H 2 O. Her perfusion is adequate and she is progressively agitated. The most appropriate initial intervention would be:

a. increase FiO 2 to 100% and administer a bronchodilator
b. increase FiO 2 to 100% and administer a neuromuscular blocker
c. increase FiO 2 to 100% and increase PEEP to 10 cm H 2 0
d. increase FiO 2 to 100% and reduce the tidal volume to 6 ml/kg
e. increase FiO 2 to 100% and suction the endotracheal tube

12. Which of the following maneuvers will not increase the mean airway pressure?

a. adding an inspiratory pause
b. increasing the inspiratory time
c. increasing the PIP
d. increasing the PEEP
e. increasing the minute ventilation by increasing the respiratory rate at fixed I:E ratio

13. Noninvasive positive pressure ventilation is most likely to be beneficial in which of the following patients:

a. a cooperative 7 year old with status asthmaticus.
b. a 14 year old with traumatic brain injury and facial trauma.
c. a 2 year old with pneumonitis following lye ingestion.
d. an anxious 8 month old with abdominal distention and gastroesophageal reflux-induced brady-dysrhythmias.
e. an obtunded, 14 year old with suspected encephalitis.

14. A 5 year old with acute hypoxemic respiratory failure is being supported with high frequency oscillatory ventilation requiring 100% oxygen. His most recent arterial blood gas reveals a pH of 7.38, a PaCO 2 of 52 mm Hg, a PaO 2 of 47 mm Hg and an oxygen saturation of 81%. Chest radiograph reveals no evidence of a pneumothorax and lung expansion to the eighth rib posteriorly. The most appropriate ventilator adjustment would be to:

a. adjust the I:E ratio.
b. increase the amplitude by 2 cm H 2 O.

c. increase the frequency by 2 Hz.
d. increase the mean airway pressure by 2 cm H 2 O.
e. partially deflate the endotracheal tube cuff.

15. In comparison to conventional ventilation, the use of high frequency percussive ventilation in pediatric patients with inhalational injury has been found to be associated with:
a. decreased lengths of mechanical ventilation.
b. decreased mortality.
c. decreased peak inspiratory pressures.
d. increased incidence of pneumonia.
e. lower PaO 2 /FiO 2 ratios.

Associated pathways/clinical guidelines/protocols

Asthma pathway
RSV/bronchiolitis pathway (DRAFT)
Respiratory treatments guideline
Empyema pathway
ETT care, taping & repositioning policy
Airway cuff pressure policy
ERT guideline
Transfer to 7E checklist

Additional reference materials

Ventilator scenarios
Ventilator waveforms
CO2 waveforms
Definitions and formulas

Additional clinical experiences:

Simulation center time for airway management
OR time for airway practice (40 hours)
Shadow RT for a day
Shadow Jodi Carter for a day (consider Ranken Jordan monthly rounds)
Shadow AIMS NP for a day
Demonstrate LMA, nasopharyngeal airway, oral airway placement
Demonstrate appropriate ETT size determination
Determine Initial oscillator settings

Lecture Topics:

A-a gradient, oxygen dissociation curve, ARDS
Airway management
Jodi Carter: home vents
HFOV
APRV

Competencies:

Complete the online blood gas interpretation quiz http://www.adamw.org/ned/apps/abg.cgi
Demonstrate appropriate ventilator settings- age, level of support required, mode
Respond to scenarios requiring ventilator manipulations (escalation or decreasing support)
Interpret ventilator waveforms

Demonstrate ETCO2 setup and waveform interpretation
Explain the process of weaning for extubation, understand NIFs, t-piece trials, PS
Demonstration of appropriate bag/mask ventilation technique

Taken from: Sullivan, J., & Nkromah, T. (2012) Fundamentals of Gas Exchange and the Assessment of Oxygenation and Ventilation. In Lucking, S. E. *Pediatric critical care study guide: text and review*. (pp. 1-18). London: Springer.

Tobias, J. (2012) Conventional Mechanical Ventilation. In Lucking, S. E. *Pediatric critical care study guide: text and review*. (pp. 262-284). London: Springer.

Dettorre, M. (2012) Non- Conventional Mechanical Ventilation. In Lucking, S. E. *Pediatric critical care study guide: text and review*. (pp. 285-298). London: Springer.

Sedation & Analgesia

Chapter 18: Sedation and Analgesia

Objectives:

- Emphasize the psychological and physiologic necessity of providing sedation and analgesia for patients in the PICU.
- Review the fundamental tenets of procedural sedation.
- Review the pharmacology, physiology and rationale for use of the major sedative agents and major narcotic agents in the PICU.
- Discuss non-narcotic analgesics available for use in the PICU.
- Describe the risk factors and treatment for the development of opioid and benzodiazepine dependence in the PICU

Chapter 19: Neuromuscular Blockade

Objectives:

- The indications for neuromuscular blockade in the Pediatric Intensive Care Unit (PICU) and the necessary co-administered therapies.
- The pediatric pharmacology of neuromuscular blockade.
- The physiology of the neuromuscular junction and how it is affected by neuromuscular blockade.
- The specific neuromuscular blocking agents used in the PICU including their pharmacokinetics, pharmacodynamics, and adverse effects.
- The interactions and adverse effects of neuromuscular blockade including ICU myopathy.
- The agents used for the reversal of neuromuscular blockade.

Additional Reading Material:

Franck, L. S., Scoppettuolo, L. A., Wypij, D., & Curley, M. A. (2012). Validity and generalizability of the Withdrawal Assessment Tool-1 (WAT-1) for monitoring iatrogenic withdrawal syndrome in pediatric patients. *Pain, 153*(1), 142-148. doi:10.1016/j.pain.2011.10.003

Whalen, L. D., Gennaro, J. L., Irby, G. A., Yanay, O., & Zimmerman, J. J. (2014). Long-Term Dexmedetomidine Use and Safety Profile Among Critically Ill Children and Neonates*. *Pediatric Critical Care Medicine, 15*(8), 706-714. doi:10.1097/pcc.0000000000000200

Post Chapter Questions

1. An 8 year old 30 kg boy is transported to the PICU from a community hospital with the presumptive diagnosis of sepsis. He is noted to have scattered purpuric lesions over his legs and abdomen. His vital signs are as follows: T 39.5 C, HR 160, RR 40, BP 76/32, SpO2 90% on 100% oxygen via NRB mask. He requires fluid resuscitation, inotropic support and mechanical ventilation. His hemodynamics have improved and current vitals are: 38.5 C, HR 128, RR 24, BP 96/52, SpO2 99%. He is given 3 mg IV versed and 60 mcg IV fentanyl to facilitate arterial line placement. He again becomes hypotensive to 71/34 and requires an additional 20 mL/kg NS to restore perfusion and blood pressure. Which statement is most correct?
    a. use of ketamine due to its direct positive inotropic effect would have avoided the hemodynamic instability seen after versed / fentanyl administration

b. use of ketamine for sedation and analgesia is contraindicated in sepsis due to causing adrenal suppression
c. use of versed and or fentanyl is contraindicated in patients with hemodynamic instability
d. versed and fentanyl in the doses given were unlikely to affect the child's hemodynamics and the likely cause for the hypotension was progressive cardiovascular dysfunction
e. when using benzodiazepines and opioids in the setting of hemodynamic instability, low initial doses should be used and subsequently titrated as tolerated

2. Which of the following medications can be used to treat mild to moderate pain and is not associated with platelet dysfunction?
a. ibuprofen
b. naproxen sodium
c. toradol
d. trisalicylate
e. salicylic acid

3. Which statement regarding the Mallampati classification is most correct?
a. Assignment of a Mallampati class is best done by asking the child to open his mouth fully, protrude his tongue and vocalize "ahh" to better visualize the tonsils
b. Mallampati classification has been used to help predict difficult intubation in adults based on visualization of pharyngeal structures
c. Mallampati classification has been validated as an accurate predictor of adverse airway events during procedural sedation in children
d. Mallampati classification predicts patients at risk for laryngospasm
e. Mallampati classification should be done while the patient is Supine

4. Kasai procedure is admitted to the PICU with respiratory distress secondary to respiratory syncytial virus pneumonia. She has moderate liver dysfunction and is awaiting liver transplantation. She is mechanically ventilated and agitated. Which statement regarding the choice of an appropriate benzodiazepine is most correct?
a. lorazepam hepatic metabolism occurs mainly by phase II reactions and is less affected by liver impairment than midazolam
b. lorazepam hepatic metabolism occurs mainly by phase I reactions and therefore is prone to multiple drug-drug interactions
c. midazolam and lorazepam both undergo hepatic phase I and phase II metabolism and are contraindicated in patients with moderate liver dysfunction
d. midazolam metabolism occurs mainly by phase II reactions and therefore is prone to multiple drug-drug interactions
e. midazolam metabolism occurs mainly by phase 1 reactions that produce several inactive metabolites that are renally excreted

5. Propofol is administered to facilitate a brain MRI in a 6 year old boy with a new onset seizure disorder. Which of the following correctly describes a potential adverse effect of propofol?
a. blood pressure is generally maintained but bradycardia is common due to direct vagal stimulation
b. endotracheal intubation is required during deep sedation with propofol due to commonly seen loss of airway reflexes and apnea
c. pain at the site of injection is common due to propofol's low pH.
d. peripheral compartment saturation is unlikely to occur during procedural sedation
e. propofol is contraindicated in children with seizure disorders due to its pro-epileptic effects

6. A 6 month old 5 kg girl with congenital CMV and chronic liver disease is brought to the PICU for management of second and third degree burns over her abdomen and chest sustained after an accidental hot water spill. She is in significant pain but remains alert and stable on 2L oxygen via NC. She is given two 1 mg doses of morphine 10 min apart and shortly thereafter becomes somnolent, hypopneic and SpO2 drops to 70%. She requires brief bag mask ventilation but quickly recovers. Which of the following statement is most correct regarding her respiratory decompensation?

a. due to the infant's immature CYP 450 metabolism, morphine quickly accumulated after her repeated dosing
b. infants are more prone to the respiratory depressant effects of morphine due to the presence of a higher density of m 2 receptors when compared to older children
c. Infants are more prone to the respiratory depressant effects of morphine due to a higher free fraction of available drug as protein binding is less in infants than in older children.
d. morphine-6-glucuronide, an active metabolite of the parent drug, is likely responsible for her respiratory depression
e. morphine-3-glucuronide, an active metabolite of the parent drug, is likely responsible for her respiratory depression

7. A 12 year old female with acute respiratory distress syndrome is requiring neuromuscular blockade to facilitate mechanical ventilation? The administration of which of the following medications is likely to decrease the effect of the block provided by a non-depolarizing neuromuscular blocking agent in this young girl?

a. Gentamicin
b. Inhaled anesthetic
c. Magnesium
d. Phenytoin
e. Solumedrol

8. A 15 year old male with acute myelogenous leukemia status post allogeneic hematopoietic stem cell transplant is admitted to the pediatric intensive care unit for mechanical ventilation. The young man has multiple organ dysfunction syndrome and exhibits evidence of significant renal and hepatic dysfunction. His pulmonary compliance is such that he requires neuromuscular blockade to facilitate ventilation with non-toxic inspiratory pressures. Which of the following medications is LEAST likely to have a prolonged effect because of his renal and hepatic dysfunction?

a. Atracurium
b. Pancuronium
c. Rocuronium
d. Tubocurarine
e. Vecuronium

9. An 8 month old infant is admitted to the pediatric intensive care unit following formation of a cavo-pulmonary shunt (Fontan procedure). The cardiovascular surgeon wishes to extubate him as soon as possible to minimize the deleterious effects of positive pressure on pulmonary blood flow. Consequently, you decide to administer neostigmine to reverse any residual neuromuscular blockade to facilitate successful extubation. Prior to administering the neostigmine, which of the following medications must also be given to the patient?

a. Atropine
b. Edrophonium
c. Epinephrine

d. Isoproterenol
e. Midazolam

10. Which of the following muscles is most resistant to neuromuscular blockade?
a. Adductor pollicis
b. Diaphragm
c. Geniohyoid
d. Masseter
e. Orbicularis occuli

Competencies and checklist:
WAT scores
SBS Goals
Associated pathways/clinical guidelines/protocols:
Non-Operating Room Anesthesia, "NORA" guidelines

Taken from: Lambert, R., Brink, L., & Maffei, F. (2012) Sedation and Analgesia. In Lucking, S. E. *Pediatric critical care study guide: text and review*. (pp. 382-405). London: Springer.

Eaton, M, & Stone, M. (2012) Neuromuscular Blockade. In Lucking, S. E. *Pediatric critical care study guide: text and review*. (pp. 406-426). London: Springer.

Sepsis Module

Chapter 2: Oxygen Delivery and Oxygen Consumption

Objectives:

- Detail how to calculate oxygen delivery and the interdependence of the lungs, heart, and blood on peripheral oxygen delivery
- Describe the mechanisms for measurement of oxygen consumption and the variables that can influence oxygen consumption in the PICU patient
- Define the use of the Fick equation in the evaluation of the adequacy of oxygen delivery
- Define the oxygen extraction ratio; describe how it varies with regional demands and disease states
- Describe the difference between aerobic and anaerobic metabolism touching on relevant metabolic pathways (Kreb's Cycle, Glyocolysis, Electron Transport, Oxidation of Fat, Synthetic Oxidative Pathways)
- Describe what ATP, NADP really do
- Describe the laboratory evaluation of the adequacy of circulatory function

Chapter 26: Circulatory Failure Shock

Objectives:

- Define shock and describe the pathophysiologic changes that occur with the different classifications of shock.
- Recognize the role of cardiovascular monitoring in circulatory failure.
- Understand the mechanistic principles of goal-directed therapies (including use of lactate levels and venous saturations) aimed at improving outcome in children with circulatory failure.
- Define and understand the pathophysiology of multiple organ dysfunction syndrome.

Chapter 27: Sepsis

Objectives:

- Discuss the epidemiology (including risk factors) of sepsis in the pediatric population.
- Discuss the inflammatory cascade triggered by bacterial organisms and the cellular responses to systemic infection including the roles of: Inflammatory cells, Endothelial cells, Cytokines and other mediators, and Coagulation system
- Understand the clinical signs and symptoms that result from generalized and organ specific inflammation and injury and the role of appropriate empiric antibiotic coverage, adequate fluid resuscitation and pharmacologic hemodynamic support.
- Discuss the treatment of sepsis, focusing on the underlying rationale for therapies including: Antibiotics, Inotropic support, Vasoactive agents, Corticosteroids, Monoclonal antibodies, and Cytokine inhibitors and analogues

Chapter 28: Multi-Organ Dysfunction Syndrome

- Describe the situations that may lead to multiple organ dysfunction syndrome and the presentation and course of multiple organ dysfunction syndrome in terms of individual organ pathophysiology.
- Discuss outcomes, and the criteria used to predict them, in multiple system organ failure.
- Plan a course of therapy in a patient with multiple organ dysfunction syndrome.

Additional Reading Material:

Farrell, D., & Nadel, S. (2016). What's New in Paediatric Sepsis. *Current Pediatrics Reports Curr Pediatr Rep, 4*(1), 1-5. doi:10.1007/s40124-016-0093-4

Singer, M., Deutschman, C. S., Seymour, C. W., Shankar-Hari, M., Annane, D., Bauer, M., . . . Angus, D. C. (2016). The Third International Consensus Definitions for Sepsis and Septic Shock (Sepsis-3). *Jama, 315*(8), 801. doi:10.1001/jama.2016.0287

Post-test Questions

1. Which statement is correct regarding the biochemical consequences of tissue hypoxia?
    a. Anaerobic metabolism is as equally efficient as aerobic metabolism in producing energy, but produces acid byproducts such as lactate.
    b. Elevated lactate levels can be readily buffered by the addition of sodium bicarbonate.
    c. Lactate is produced as a byproduct of anaerobic glycolysis during tissue hypoxia, but may also be produced in the absence of tissue hypoxia.
    d. Restoring tissue perfusion and oxygenation results in lactate being reconverted into glucose in the liver.
    A. The reduction in pH seen during states of tissue hypoxia is primarily due to the accumulation of lactate.

2. A 12 year old 50 kg male is admitted after correction of severe scoliosis via a combined anterior and posterior approach. Upon admission, he is mildly tachycardic to 108 bpm, normotensive and well perfused. His oxygen saturation is 99%, PaO 2 is 198 mm Hg on 30% FiO 2 and his hemoglobin is 10.9 g/dL. You are called to the bedside due to a steady increase in chest tube output. He is now tachycardic to 149 bpm, has a blood pressure of 96/58 mm Hg and is cool distally. His oxygen saturation is 87% and PaO 2 is 65 mm Hg on 30% FiO 2. Current hemoglobin is 7.6 g/dL. What percent decrease in arterial oxygen content has occurred?
    a. 10%
    b. 15%
    c. 30%
    d. 40%
    e. 50%

3. The above child is ordered a transfusion of packed red blood cells. While awaiting transfusion, he is placed on 100% FiO 2 resulting in an oxygen saturation of 99% and PaO 2 of 265 mm Hg. Which of the following is true regarding oxygen administration in this patient awaiting transfusion?
    a. Administration of oxygen will increase the arterial oxygen content from 9 to 11 mL/dL.
    b. Administration of oxygen will increase the arterial oxygen content from 9 to 13 mL/dL.
    c. Administration of oxygen will increase the arterial oxygen content from 10 to 12 mL/dL.
    d. Administration of oxygen will increase the arterial oxygen content from 10 to 13 mL/dL .
    e. Administration of oxygen will increase the arterial oxygen content from 10 to 14 mL/dL .

4. Which of the following is true regarding oxygen-hemoglobin dissociation curve?
    a. Fetal hemoglobin increases oxyhemoglobin dissociation in the capillary circulation thereby making more oxygen available at the tissue level.
    b. Hypoxemia increases oxyhemoglobin dissociation in the capillary circulation thereby making more oxygen available at the tissue level.
    c. Increased temperature decreases oxyhemoblobin dissociation in the capillary circulation thereby making less oxygen available at the tissue level.
    d. Severe acidosis decreases oxyhemoblobin dissociation in the capillary circulation thereby making less oxygen available at the tissue level.
    e. Severe alkalosis decreases oxyhemoblobin dissociation in the capillary circulation thereby making more oxygen available at the tissue level.

5. Which is the following is a true statement regarding physiologic determinants of oxygen delivery?

a. Arterial oxygen content can be maximized, yet a state of decreased oxygen delivery may persist.
b. Oxygen delivery is primarily determined by the rate of oxygen extraction.
c. The determinants of cardiac output and the determinants of arterial oxygen are different and have limited interdependence.
d. The fractional inspired oxygen content impacts arterial oxygen content, and therefore, oxygen delivery greater than the hemoglobin concentration.
e. Therapies aimed at improving oxygen delivery are primarily related to maintaining alveolar oxygenation.

6. Which of the following is most correctly matched?

a. Dobutamine 5 mcg/kg/min – decreased myocardial oxygen consumption
b. Low oxygen delivery – increased oxygen extraction
c. Mitochondrial poisoning – increased oxygen extraction
d. Neuromuscular blockade – increased oxygen consumption
e. Seizure – decreased oxygen consumption

7. Which statement best reflects the ability of the body to extract oxygen?

a. Baseline oxygen extraction varies among individual organs, but remains constant during changes in clinical conditions.
b. High oxygen extraction is reflected in a lower venous oxygen content.
c. The normal oxygen extraction ratio (O 2 ER) is approximately
d. 50% of the oxygen being delivered to the tissues. The excess in delivered oxygen allows for an increase during stress states, thereby, minimizing the need for anaerobic metabolism.
e. Organs with lower metabolic demand will consume less oxygen and consequently, will have a lower venous oxygen content.
f. The oxygen extraction ratio (O 2 ER) is determined by dividing the difference of the arterial and venous oxygen content by the cardiac output.

8. A 5 year old presents with pallor, a murmur, and a heart rate of 140 bpm. He is afebrile and his oxygen saturation via pulse oximetry is 97%. There is no history of acute blood loss and his mom explains that his symptoms have evolved over several weeks. Laboratory analysis reveals a white blood cell count of 12, 300 cells/ m L, hemoglobin of 4.5 g/dL, and a platelet count of 210,000/ m L. His red blood cell indices are microcytic and hypochromic. His electrolytes are unremarkable except for a bicarbonate of 18 mmol/l. His arterial blood gas reveals pH 7.32, PaCO 2 33 mm Hg, PaO 2 65 mm Hg, base deficit (−) 9, and an oxygen saturation of 97%. The most appropriate next course of action is which of the following?

a. Transfuse 15 mL/kg of packed red blood cells over 2 h.
b. Transfuse 5 mL/kg packed red blood cells over 4 h and administer a dose of sodium bicarbonate.
c. Transfuse 5 mL/kg packed red blood cells over 4 h and begin iron supplementation and erythropoietin.
d. Transfuse 5 mL/kg of packed red blood cells over 4 h and begin supplemental oxygen.
e. Transfuse 15 mL/kg of packed red blood cells over 4 h and monitor for signs of pulmonary edema utilizing furosemide if necessary.

9. A 14 year old multiple trauma victim with adult respiratory distress syndrome is admitted to the PICU. To optimize his care, you have placed an intravenous oximetric catheter with its tip in the superior vena cava to monitor venous oxygen saturation continuously. The patient is intubated, mechanically ventilated, and heavily sedated. His superior vena cava saturation has consistently been in the low 80 range, but has suddenly begun to decrease into the low 70s. His pulse oximeter is unchanged and continues to read 99%. His vital signs are stable except for a fever spike up to 39.8° Celsius and a 5–10 beat increase in his heart rate. He remains heavily sedated on a midazolam infusion. The most likely explanation for his sudden decrease in superior vena cava saturation is which of the following?

a. Acute occult blood loss
b. Decreased cardiac output
c. Fever
d. Migration of the catheter into the right atrium
e. Subclinical seizure

10. Hypoxemia is detected by special nerve chemical receptors located in the carotid and aortic bodies. When these chemoreceptors are triggered by hypoxemia (PaO 2 < 60 mm Hg, corresponding to SaO 2 < 93%), which of the following physiologic responses ensue?

a. Stimulation of the respiratory area of the medulla resulting in a decrease in minute ventilation, respiratory pauses, and potentially apnea.
b. Stimulation of the respiratory area of the medulla resulting in an increase in minute ventilation, a higher alveolar oxygen concentration (PAO 2), and ultimately, an increase in the arterial oxygen content.
c. Stimulation of the vasomotor center of the brainstem leading to decreased sympathetic tone and bradycardia.
d. Stimulation of the vasomotor center of the brainstem resulting in decreased sympathetic tone, decreased metabolic rate, and decreased oxygen consumption.
e. Stimulation of the vasomotor center of the brainstem resulting in increased sympathetic tone, increased systemic vascular resistance, and decreased cardiac output.

11. The statement that best describes physiologic alterations observed in shock is:

a. cardiogenic shock is more often the result of diastolic dysfunction than systolic dysfunction.
b. distributive shock is characterized by reduced cardiac output and pathologic vasodilation.
c. hemorrhagic shock produces an acute reduction in oxygen carrying capacity and may be complicated by multiple organ dysfunction syndrome.
d. increasing the partial pressure of oxygen often results in the greatest increase in oxygen carrying capacity.
e. septic shock often displays a predictable hemodynamic profile across multiple hosts.

12. Shock at the cellular level may be characterized by;

a. compromised oxidative phosphorylation and rapid accumulation of cytosolic ATP.
b. decreased activation of nuclear factor-κB activation.
c. failure of neutrophil apoptosis causing prolonged tissue inflammation.
d. low levels of poly (ADP-ribose) polymerase-1 activity leading to ATP depletion.
e. overproduction of nitric oxide leading to pathologic vasoconstriction.

13. The most correct statement regarding the monitoring of therapeutic interventions during shock is that:

a. decreased S c v O 2 can be indicative of inadequate oxygen delivery or decreased oxygen consumption, while increases of S cv O 2 in response to therapy can be indicative of effective therapy for shock.
b. due to the variable clinical examination findings in shock, serial examinations have been supplanted by more objective measures of shock such as lactate and mixed venous oxygen saturation determinations.
c. insertion of a pulmonary artery catheter is often necessary early in the treatment of septic shock.
d. mixed venous oxygen saturation is best measured from a pulmonary artery catheter with the tip in the pulmonary artery or alternatively by a central venous line with the tip at the inferior portion of the right atrium.
e. serial examinations and serial measurements of mixed venous oxygen saturation and lactate can serve as a guide for the severity, evolution, and resolution of shock.

14. A 6 year old, 20 kg boy recently diagnosed with acute lymphocytic leukemia is undergoing induction chemotherapy. He develops fever and is found to be neutropenic (absolute neutrophil count 410 cells / m L), anemic (hemoglobin 8.1 gm/dL) and thrombocytopenic (platelet count 108,000 / m L). In clinic, he is cool distally, has poor pulses and a delayed capillary refill of 5 seconds. He develops sustained tachycardia to 180 beats per minute and has a blood pressure of 85/67 mm Hg. He is given a 500 mL bolus of normal saline and is transferred to the PICU. Upon arrival to the PICU, he is agitated, poorly perfused and remains tachycardic (167 beats per minute). His blood pressure is 94/78 mm Hg. Central venous blood obtained from a broviac catheter (tip located at the superior portion of the right atrium) reveals a mixed venous oxygen saturation of 55% and a lactate of 3.4 mmol/L. He has made minimal urine since his admission. The most correct statement regarding his management is which of the following?

a. An additional 20 mL/kg normal saline should be administered while awaiting the arrival of packed red blood cells for transfusion.
b. Further volume resuscitation should be withheld pending results of a STAT echocardiogram.
c. No further volume resuscitation is required. He requires rapid initiation of inotropic support.
d. No further volume resuscitation is required. He requires rapid initiation of vasopressor support.
e. No further volume resuscitation is required. He requires rapid initiation of afterload reduction.

15. A 17 year old adolescent boy is transferred from an outlying facility to the PICU for treatment of refractory pneumonia. He had a 10 day viral prodrome consisting of low grade fever, progressive fatigue and dyspnea. His initial chest radiograph revealed bilateral basilar infiltrates. His current exam reveals tachypnea (34 breaths per minute), tachycardia (132 beats per minute) and blood pressure 110/91 mm Hg. He is cold distally and has a capillary refill time of 5 seconds. He is anxious and complains of chest pain. Repeat chest radiograph reveals diffuse bilateral infiltrates and cardiomegaly. Bedside ultrasound demonstrates no pericardial or pleural effusion. His oxygen saturation is 98% on 2 liters oxygen via nasal cannula. An arterial lactate is 7.8 mmol/L. Which of the following statements best describes the etiology and treatment of this patient?

a. He has become fluid overloaded from overzealous fluid administration and requires aggressive diuresis.

b. His pneumonia is now complicated by ARDS and septic shock. He requires endotracheal intubation and initiation of epinephrine at 0.1 mcg/kg/minute.
c. Myocarditis should be strongly suspected. He should undergo rapid endotracheal intubation and have an epinephrine infusion initiated at 0.5 mcg/kg/minute.
d. Myocarditis should be strongly suspected. Furosemide should be administered and a dopamine infusion initiated at 20 mcg/kg/minute.
e. Myocarditis should be strongly suspected. Milrinone should be initiated at 0.5 mcg/kg/minute while awaiting echocardiography.

16. A 16 year old female develops fever, rigors, diffuse erythema and syncope. In the emergency department, she is found to have tachycardia (162 beats per minute) and blood pressure 98/35 mm Hg. She is warm distally and has a capillary refill time of less than 1 second. She is anxious and complains of diffuse myalgias. She again becomes syncopal when sitting up. She is placed in the Trendelenburg position and is given three 20 mL/kg normal saline boluses over 1 hour. Her perfusion is unchanged and repeat blood pressure is 100/22 mm Hg. She is given an additional 20 mL/kg fluid bolus upon arrival to the PICU and has a central venous catheter placed. ST changes are noted on the bedside cardiac monitor. Which of the following statements best describes the etiology and treatment of this patient?

a. She has cardiogenic shock complicating sepsis and requires the institution of a milrinone infusion.
b. She has a distributive type of septic shock and requires more fluid resuscitation.
c. She has a distributive type of septic shock and requires the initiation of a high dose dopamine infusion.
d. She has a distributive type of septic shock and requires the rapid institution of a vasopressor such as norepinephrine.
e. She has overwhelming hypodynamic sepsis and requires the institution of an epinephrine infusion.

17. The correct statement regarding acid-base status and shock is that:

a. a bicarbonate infusion following volume resuscitation is often necessary to correct systemic acidosis.
b. increased anion gap metabolic acidosis is often due to bicarbonate loss.
c. initial measurements of arterial blood gases and lactate, in the setting of shock, are highly predictive of outcome.
d. multiple factors, other than insufficient oxygen delivery, can affect acid-base status and include liver dysfunction and infusions of normal saline.
e. shock can lead to increased dependence on aerobic metabolism, which results in overproduction of pyruvate.

18. In comparison to adults, children are more likely to present with which one of the following hemodynamic profiles?

a. High cardiac index with high systemic vascular resistance
b. High cardiac index with low systemic vascular resistance
c. Low cardiac index with high systemic vascular resistance
d. Low cardiac index with low systemic vascular resistance
e. Normal cardiac index with low systemic vascular resistance

19. Activation of the innate immune system in Gram-positive bacterial sepsis is mediated by:

a. Toll-like receptor 2 (TLR2)
b. TLR3
c. TLR4
d. TLR5

e. TLR6

20. Which of the following biologic effects is most accurately attributed to TNF- a?
    a. Induction of nitric oxide synthase (iNOS)
    b. Inhibition of adhesion molecules and chemokines that facilitate leukocyte-endothelial cell adhesion
    c. Inhibition of IL-1 b
    d. Inhibition of tissue factor
    e. Upregulation of protein C

21. Which of the following statements regarding IL-1 b is true?
    a. IL-1 b decreases tissue factor expression
    b. IL-1 b increases adhesion molecule expression
    c. IL-1 b inhibits monocyte activation and phagocytosis
    d. IL-1 b is the only agonist among the IL-1 family of proteins
    e. IL-1 b stimulates thrombomodulin secretion

22. Which of the following biologic mediators is an anti-inflammatory cytokine?
    a. IL-1 b
    b. IL-6
    c. IL-8
    d. IL-10
    e. TNF- a

23. Which of the following cytokines functions primarily as a chemokine?
    a. IL-1 b
    b. IL-6
    c. IL-8
    d. IL-10
    e. TNF- a

24. Which of the following statements best summarizes the biologic effects of Protein C?
    a. Antithrombotic and anti-inflammatory
    b. Antithrombotic and proinflammatory
    c. Antithrombotic, but without any effect on the inflammatory process
    d. Prothrombotic and anti-inflammatory
    e. Prothrombotic and proinflammatory

25. Once stable oxygenation and ventilation are assured, the most important priority in the patient with septic shock is:
    a. Adequate sedation and paralysis
    b. Fluid resuscitation with 20 mL/kg of isotonic fluid
    c. Initiation of inotropic support
    d. Placement of an arterial catheter
    e. Placement of central venous access

26. A 5 year old female is admitted to the pediatric intensive care unit with septic shock. She is well oxygenated on a 40% oxygen face mask. She has already received 60 mL/kg of 0.9% normal saline and has been started on a dopamine infusion at a rate of 5 mcg/kg/min. In monitoring her response to these interventions, which of the following should NOT be used as a therapeutic endpoint to monitor her progress?

a. Capillary refill time
b. Echocardiographically measured ejection fraction
c. Mental status
d. Serum bicarbonate level
e. Urine output ³ 1 mL/kg/h

27. A 12 year old male with acute lymphocytic leukemia is admitted to the pediatric intensive care unit with vancomycin resistant enterococcus bacteremia. His vital signs reveal a temperature of 39.6°C, a heart rate of 145 bpm, a respiratory rate of 20 breaths/min, and a blood pressure of 108/35 mm Hg. He is lethargic, but arousable. His pulses are bounding and his capillary refill is brisk. An arterial blood gas reveals a pH 7.31, a PaCO 2 33 mm Hg, a PaO 2 65 mm Hg, an oxygen saturation of 93%, and a base deficit of (−10). The oxygen saturation of venous blood sampled from the superior vena cava is 88%. Which of the following statements best describes his clinical condition?

a. The young man is bacteremic, but not in shock as evidenced by his bounding pulses, brisk refill, and normal systolic blood pressure.
b. The young man is in shock with inadequate oxygen extraction at the tissue level evidenced by the elevated superior vena cava saturation.
c. The young man has a primary metabolic acidosis, but has a normal oxygen extraction as oxygen saturation in the superior vena cava is normally higher than elsewhere in the body.
d. The young man has a primary metabolic acidosis, but is not in shock, evidenced by his high superior vena cava saturation.
e. The young man has a primary respiratory alkalosis that would benefit from supplemental oxygen therapy.

28. There is sufficient data to justify the use of which of the following adjuvant therapies in pediatric sepsis?

a. The administration of activated protein C to a child in septic shock without thrombocytopenia or coagulopathy
b. The administration of anti-TNF- a monoclonal antibodies to a septic patient to decrease the proinflammatory response
c. The administration of stress dose hydrocortisone to a septic patient whose serum cortisol level fails to increase sufficiently in response to a corticotropin stimulation test
d. The early initiation of high volume, continuous veno-venous hemofiltration to remove proinflammatory cytokines
e. The transfusion of packed red blood cells to maintain a hemoglobin ³ 12 g/dL in order to provide supranormal oxygen delivery

29. It has become clear that dysregulation of the coagulation cascade occurs in sepsis as reflected by activation of procoagulant pathways, consumption of clotting factors, alterations in fibrinolysis, and reduced anticoagulant activity. Which of the following components of coagulation is increased during sepsis?

a. Antithrombin III (AT III)
b. Plasminogen activator inhibitor type 1 (PAI-1)
c. Protein C
d. Protein S
e. Tissue factor pathway inhibitor (TFPI)

30. A 10 year old male is admitted in the PICU on day postoperative day 2 after undergoing exploratory laparotomy and drainage of abscesses secondary to a ruptured appendix. He develops altered mental status and hypotension. Vital signs are: temperature 40°C; heart rate 150 beats per minute, sinus rhythm; blood pressure 70/30 mm Hg, respiratory rate 30 breaths per minute, oxygen saturation 92% in 15L non-rebreather mask. Measurement of central venous pressure via a subclavian catheter is 1 mm Hg. On examination, he is drowsy, but arousable, with nasal flaring and intercostal retractions. His abdomen is slightly distended with two Jackson-Pratt drains containing serosanguinous fluid. His extremities are cool with a capillary refill of 3 seconds. After receiving 80 mL/kg of isotonic crystalloid solution, his blood pressure is 90/40 mm Hg, central venous pressure measurement is 4 mm Hg, and he has had no urine output. He has become more somnolent and is beginning to grunt while his oxygen saturations have dropped to 84% in 15L non-rebreather mask. What is the next best intervention?

a. administer 40 mL/kg of 5% albumin intravenously
b. administer 2 mg/kg intravenous furosemide
c. begin an infusion of milrinone
d. endotracheally intubate the child
e. obtain computerized tomography of the head to evaluate his altered mental status

31. Pediatric multiple organ dysfunction syndrome (MODS) is believed to approximate what percentage of a multidisciplinary PICU patient population?

a. 1%
b. 5%
c. 10%
d. 20%
e. 80%

32. A 17 year old female with a history of spina bifida and neurogenic bladder presents with a two-day history of fever. In the emergency department, she is febrile to 39.4°C, heart rate 140 beats per minute in a sinus rhythm, blood pressure is 80/30 mm Hg, respiratory rate 30 breaths per minute and oxygen saturations are 97% in room air. She has a clear sensorium, bounding pulses, no organomegaly, and her skin is flushed with brisk capillary refill. There is no urine in a Foley catheter. A fluid bolus and antibiotics are administered, and she is admitted to the pediatric intensive care unit for continuing care. Which of the following statement is true regarding her care?

a. acute kidney injury is the most likely explanation for her clinical condition
b. further fluid resuscitation should be restricted in order to prevent pulmonary edema
c. further fluid resuscitation is warranted
d. parenteral nutrition is superior to enteral nutrition in this setting
e. the infection focus is most likely pneumonia evidenced by her tachypnea

33. Pathologic specimens of organs involved in MODS typically reveal infiltration with:

a. histiocytes
b. macrophages
c. monocytes
d. neutrophils
e. red blood cells

34. Which of the following therapies is most indicated the care of pediatric MODS patients?

a. drotegcogin alpha (activated)
b. early use of continuous veno-venous hemofiltrtion

c. monoclonal antibody to tumor necrosis factor alpha
d. plasma filtration
e. supportive care

Competencies and checklist:
Sepsis Guidelines

Associated pathways/clinical guidelines/protocols:
ECMO Protocol

Taken from: Theodorou, G., &Theodorou, A. (2012) Oxygen Delivery and Oxygen Consumption in Pediatric Critical Care. In Lucking, S. E. *Pediatric critical care study guide: text and review*. (pp. 19-38). London: Springer.

Wong, H. (2012) Circulatory Failure/ Shock. In Lucking, S. E. *Pediatric critical care study guide: text and review*. (pp.535-553). London: Springer.

Lorts, A., Cornell, T., & Shanely, T. (2012) Sepsis. In Lucking, S. E. *Pediatric critical care study guide: text and review*. (pp. 552-570). London: Springer.

Kolovos, N., & Markovitz, B. (2012) Multiple Organ Dysfunction Syndrome. In Lucking, S. E. *Pediatric critical care study guide: text and review*. (pp. 571-582). London: Springer.

(Module content was developed with the assistance of the PICU NP team)

Appendix D

Critical Care Pre-test

1. What is the relationship between resistance to air flow and airway radius?
    a. Diseases affecting the respiratory tract decrease airway resistance
    b. Airway resistance is constant as related to the radius
    c. Resistance is inversely proportional to the radius
    d. All airway flow has the same resistance

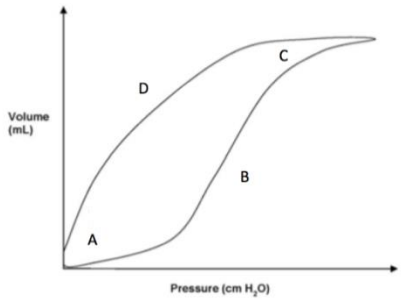
2. Which of the following methods is most reliable for confirming correct endotracheal tube placement?
    a. Listening
    b. Mist in the tubing
    c. Chest X-ray
    d. Capnography

3. An 8 month old male with RSV arrives to the PICU in respiratory distress. Initial blood gas reveals: pH 7.16, PaCO2 68, PaO2 108, and Bicarbonate 21. How is this blood gas interpreted?
    a. Acute respiratory acidosis
    b. Acute metabolic alkalosis
    c. Chronic respiratory acidosis
    d. Chronic metabolic acidosis

4. A 16 year old female is being evaluated in the EU for intermittent headache, blurry vision, and nausea. She has a history of systemic lupus erythematosus and chronic renal failure. She is non-compliant with all her medications. Her examination is notable for a BP of 174/108, vital signs are otherwise normal and she appears comfortable. Which of the following findings is most likely on a blood gas analysis?
    a. High pH
    b. Decreased HCO3
    c. Elevated PCO2
    d. Elevated HCO3

5. A 3 year old girl is admitted to the PICU with tachypnea and altered mental status. Significant lab values are: Sodium 139, Chloride 114, and Bicarbonate 12. ABG pH 7.10, PCO2 12, PaO2 150, Bicarbonate 9 mEq. What is your assessment of the lab values?
    a. Respiratory acidosis with elevated anion gap
    b. Metabolic acidosis with a normal anion gap
    c. Respiratory acidosis with normal anion gap
    d. Metabolic acidosis with an elevated anion gap

6. Match each area in the diagram with the appropriate zone or phase.



a. De-recruitment
b. Inspiratory phase
c. Over-distension
d. Expiratory phase

7. Which is the most common cause of hypoxemia in acute clinical presentation?
    a. V/Q mismatch
    b. Anemia
    c. CHD
    d. Apnea

8. Which of the following is the most accurate definition of shock?
    a. An acute decompensation and drop in blood pressure
    b. Acute onset of fever, hypotension, and tachycardia
    c. Acute inability of cardiovascular system to meet the body's metabolic needs.

9. A chest tube is being placed in a 16 year old male with a pleural effusion. Ketamine is given for sedation. What side effect is the patient most likely to experience?
    a. Hypotension
    b. Hallucinations
    c. Retro-grade amnesia
    d. Bradycardia

10. A 16 year old girl is brought to the EU by her friends after she passes out from drinking vodka. Per report this is her first time drinking. She moves and makes incomprehensible sounds too painful stimulation only. The most appropriate term to describe his level of consciousness is:
    a. Obtunded
    b. Lethargic
    c. Stuporous
    d. Coma

11. A 3 year old girl who was recently diagnosed with neuroblastoma has been on chemotherapy for 2 weeks. Because of infusion issues, she has to go to IR to get her catheter rewired. 10 hours following the procedure, she develops a fever, with a T max 39.1. Despite optimum treatment of her fever, her HR remains 180, and she is tachypneic and lethargic. Her cap refill is 1 sec, and BP is 66/26. What is the first line of treatment for this patient?
    a. Start norepi at 0.03 mcg/kg/min
    b. NS fluid bolus at 20 ml/kg

c. Start Dopamine at 5 mcg/kg/min
d. Remove the central line

12. A 6 year old boy with known sickle cell disease is admitted with history of acute onset overnight of abdominal pain. This is his 3rd admission over the past 5 months. He is afebrile and does not appear to be in respiratory distress. His pain is classified as severe. The ideal pain management at this time is?
    a. Scheduled morphine and ketorolac with pain consult and incentive spirometry
    b. Prn morphine and ketorolac and incentive spirometry
    c. Prn Tylenol and Motrin and incentive spirometry
    d. Scheduled Tylenol and Motrin with pain consult and incentive spirometry

13. What is the most important/ common cause of acute liver failure in infants?
    a. Hepatitis A
    b. Drug- induced
    c. Hepatitis B
    d. Metabolic disorder

14. A 13 year old girl with Type 1 DM presents to the EU with a 2 day history of abdominal pain and vomiting. Results of initial CMP are: Sodium 143, Potassium 4.8, Chloride 102, Bicarb 6, BUN 37, Creatinine 1.3, Glucose 600, and Calcium 9.5. Based on these values, what is the calculated anion gap?
    a. 16
    b. 35
    c. 48
    d. 8

15. In patients with DKA, the body's total potassium is:
    a. Increased
    b. Normal
    c. Decreased

16. A number of physiologic variables affect cerebral blood flow and contribute to ICP in severe TBI. Which of the following correctly indicates how each variable should be manipulated to minimize intracranial hypertension?
    a. ↓ PaCO2 ↑ PaO2, MAP 60-160, ↓ ICP
    b. ↓ PaCO2, ↓ PaO2, MAP 60-160, ↓ ICP
    c. ↑ PaCO2, ↓ PaO2, MAP 60-160, ↓ ICP
    d. ↑ PaCO2, ↑ PaO2, MAP 60-160, ↓ ICP

17. How does prone positioning improve oxygenation?
    a. It re-distributed fluid in the lung allowing expansion and alveolar inflation
    b. It removes pressure from the lungs allowing for fuller expansion
    c. Improves ventilation/ perfusion mismatching
    d. It doesn't work

18. Based on current epidemiology studies approximately what percentage of all children are considered to have asthma?

a. 30%
b. 20%
c. 8%
d. 50%

19. Which of the following is not part of the opiate toxidrome?
    a. Respiratory depression
    b. Bradycardia
    c. Miosis
    d. Diaphoresis

20. Shock is primarily a homeostatic imbalance of which of the following substrates?
    a. Carbon Dioxide
    b. Oxygen
    c. Glucose
    d. Blood

Taken from: Society of Critical Care Medicine. (n.d.). Retrieved January, 2017, from http://www.learnicu.org/Pages/default.aspx
Self-Directed Virtual Critical Care Rounds I & II

Appendix E

SLCH PEDIATRIC CRITICAL CARE ADVANCED PRACTITIONER GOALS AND OBJECTIVES

ORIENTATION

The critical care nurse practitioner orientation is an individualized process based on one's previous experiences and should be tailored to meet the needs of the particular orientee. The following goals were developed to establish a common knowledge base for all practitioners.

GOAL 1. Understand how to resuscitate and stabilize the critically ill child in the PICU setting.

Please evaluate your competency in managing the following situations
1=very unfamiliar with condition, no competency
3=moderately familiar with condition, competent with assistance
5= very familiar with condition, masterful clinical management with complete competency

_____ Explain and perform steps in resuscitation and stabilization, particularly airway management and resuscitative pharmacology.

_____ Describe the common causes of acute deterioration in the previously stable PICU patient.

_____ Functions appropriately in codes and resuscitations as part of the PICU team.

GOAL 2. Understand how to manage certain diagnoses commonly encountered in the PICU setting.

Please evaluate your competency in managing the following conditions
1=very unfamiliar with condition, no competency
3=moderately familiar with condition, competent with assistance
5= very familiar with condition, masterful clinical management with complete competency

Diagnosis	1	*2*	*3*	4	5
Multi-organ system failure:					
Shock					
Cardiogenic					
Distributive					
Hypovolemic					
Submersion injury					
Cardiovascular:					
Rhythm & Conduction Disturbances					
Post-op surgical management					

Pulmonary Hypertension					
Pericarditis/Myocarditis					
Pulmonary Embolism					
Hypertensive emergency					
ENT:					
Foreign body					
Obstructive sleep apnea					
Post-op ENT management					
Structural anomalies					
Upper airway obstruction					
Metabolic / Endocrine:					
Acid/base disturbances					
DI/SIADH/CSW					
Glucose management (i.e. DKA & hypoglycemia)					
Electrolyte disturbances					
Disorders of thyroid function					
Severe dehydration					
GI/Surgery:					
Acute abdomen					
Abdominal trauma					
Hepatic failure					
Upper/Lower GI bleeding					
Pre/post-op management					
Acute abdomen					
Abdominal trauma					
Hepatic failure					
Hepatic transplant					
NEC					
Hematologic:					
DIC					
Thrombocytopenia					
Sickle cell crisis					
Acute chest syndrome					
Infectious disease:					
Sepsis					
Meningitis					
Encephalitis					
Hospital-acquired infections					
Immunocompromised patient					
Neurologic:					
Coma					
Space occupying lesions					
Traumatic brain injury					
Acute spinal trauma					

Post-op neurosurgical management					
Status epilepticus					
Stroke					
Hydrocephalus & VP shunt infection/malfunction					
Neuromuscular disease					
Pulmonary:					
Acute respiratory failure					
Hypoxemic respiratory failure & ARDS					
Status asthmaticus					
Pneumonia					
Bronchiolitis					
Pleural effusion/empyema					
Aspiration					
Cystic fibrosis					
Renal:					
Acute renal failure					
Acid-base disturbances					
Rhabdomyolysis					
Renal transplant					
Oncology:					
Tumor lysis syndrome					
Hyper-leukocytosis					
Superior vena cava syndrome					
Common intoxications:					
Alcohol					
Narcotics					
Acetaminophen					
Hydrocarbon					
salicylates					
Carbon monoxide					

GOAL 3. Understand the application of physiologic monitoring and special technology and treatment in the PICU setting.

Please evaluate your competency in managing the following situations
1=very unfamiliar with condition, no competency
3=moderately familiar with condition, competent with assistance

Monitoring device	1	2	3	4	5
Arterial monitoring					
Central venous pressure monitoring					
PICCO Catheter					
NICCO monitor					
Oxygen utilization equations					

5= very familiar with condition, masterful clinical management with complete competency

GOAL 4. Discuss the indications, initiation, and modification of enteral and parenteral nutrition.

Please evaluate your competency in managing the following situations
1=very unfamiliar with condition, no competency
3=moderately familiar with condition, competent with assistance
5= very familiar with condition, masterful clinical management with complete competency

_____ Determine fluid, electrolyte, and caloric requirements for patients.

_____ Initiate TPN using computer-generated program.

_____ Modify TPN based on laboratory values.

_____ Discuss the pertinent laboratory data to evaluate the effectiveness of TPN.

_____ Determine readiness of patient for enteral nutrition using appropriate clinical assessment parameters.

_____ Initiate enteral feeding and evaluate feeding tolerance.

GOAL 5. Discuss the indications for the following diagnostic modalities:

Please evaluate your competency in managing the following situations
1=very unfamiliar with condition, no competency
3=moderately familiar with condition, competent with assistance
5= very familiar with condition, masterful clinical management with complete competency

_____ Radiographs – including interpretation

_____ CT scans

_____ MRI

_____ EEG

_____ Ultrasound

_____ Nuclear medicine studies

_____ Doppler studies

GOAL 6. Demonstrate competency of the following procedures (may occur after orientation):

Please evaluate your competency in managing the following situations

1=very unfamiliar with condition, no competency
3=moderately familiar with condition, competent with assistance
5= very familiar with condition, masterful clinical management with complete competency

_____ Airway management in non-intubated patient

_____ LMA insertion

_____ Intubation

_____ Extubation

_____ Lumbar puncture

_____ Arterial cannulation

_____ Internal jugular venous catheter insertion

_____ Femoral venous catheter insertion

_____ Chest tube placement

_____ Chest tube removal

_____ 12 Lead EKG Interpretation

_____ CXR Interpretation

_____ CT interpretation

_____ MRI interpretation

_____ CPR

_____ Defibrillation

GOAL 7. Develop case management skills for medically complex patients.

Please evaluate your competency in managing the following situations
1=very unfamiliar with condition, no competency
3=moderately familiar with condition, competent with assistance
5= very familiar with condition, masterful clinical management with complete competency

_____ Provides comprehensive patient care.

_____ Communicates with multiple consultants involved in patient management.

_____ Provides daily communication and education to family members.

_____ Initiates and coordinates discharge planning and needs.

GOAL 8. Demonstrate comprehensive and supportive care to patients and families.

Please evaluate your competency in managing the following situations
1=very unfamiliar with condition, no competency
3=moderately familiar with condition, competent with assistance
5= very familiar with condition, masterful clinical management with complete competency

_____ Communicate effectively in verbal and written form with health care team including

physicians, consultants, referring physicians, nursing staff, respiratory therapists, social worker, case manager, and auxiliary health care professionals.

_____ Recognize and evaluate the psychosocial needs of acutely ill children and their families, both during the immediate illness and the recovery.

_____ Identify and provide access to supportive resources.

_____ Demonstrate respect, sensitivity, and skill in dealing with death and dying with the child, family, and other health care professionals.

GOAL 9. Discuss ethical and medical-legal considerations in the care of critically ill children.

Please evaluate your competency in managing the following situations
1=very unfamiliar with condition, no competency
3=moderately familiar with condition, competent with assistance
5= very familiar with condition, masterful clinical management with complete competency

_____ Discuss concepts of futility, withdrawal, and withholding of care.

_____ Define brain death and describe criteria for organ donation.

_____ Describe the hospital policy for “Do Not Resuscitate” orders.

Appendix F

Procedural Content

- arterial line
- lumbar puncture
- central venous line
- chest tube
- intubation

Appendix G

APN SKILL TRAINING & MAINTENANCE
Pediatric Critical Care Medicine

Date _____

APN _____

Activity _____

Supervised by _____

To be filled out by activity supervisor:

Description of activity

_____

_____

_____

_____

_____

Assessment of APN performance (please check one)

☐ APN demonstrates limited understanding of concepts and is unable to complete this task. Remediation and improvement in fund of knowledge necessary before task should be attempted again.

☐ APN demonstrates limited understanding of concepts but with significant assistance is able to complete this task. Repetition of task will be required to demonstrate capability.

☐ APN demonstrates moderate understanding of concepts and furthers understanding with active questioning and interaction. Performs task with assistance but is unable to perform task independently

☐ APN demonstrates solid understanding of concepts and is able to complete task with minimal assistance. Questions and interactive learning during task demonstrates comfort with material and task.

☐ APN demonstrates mastery of concepts and task, demonstrates ability to troubleshoot unexpected events. APP ready to teach this task to others.

_____

APN Signature Activity Supervisor Signature

Appendix H
PICU NP Weekly Orientation Review

Name:_____
Dates:_____

Diagnosis of patients cared for:
_____
_____
_____

Skills/Knowledge gained this week:
_____
_____
_____

Procedures attempted/assisted with:
_____
_____
_____

OR cases observed:
_____
_____
_____

Goals for next week:
_____
_____
_____

Preceptors:
_____
_____

Please return form to Katherine weekly

Appendix I
PICU APN Orientation Calendar

Tentative (Example)

Month 1	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Week 1 **General Orientation**		Clinical Noon M&M Clinical APN Meeting		Clinical Noon Fellows Conference Clinical		Complete pre-test and pre-assessment	Clinical
Week 2 **Respiratory**	Clinical	Clinical Noon M&M Clinical APN Meeting		Clinical Noon Fellows Conference Clinical			
Week 3 **Respiratory**		Clinical Noon M&M Clinical APN Meeting		Clinical Noon Fellows Conference Clinical		Clinical	
Week 4 **Respiratory**		Clinical Noon M&M Clinical APN Meeting		Clinical Noon Fellows Conference Clinical	Complete Respiratory Quiz	Meet with Mentor and Sim	

Month 2	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Week 1 **Cardiovascular**		Clinical Noon M&M Clinical APN Meeting		Clinical Noon Fellows Conference Clinical			Clinical
Week 2 **Cardiovascular**		Noon M&M Cards APN APN Meeting	Cards APN	Noon Fellows Conference Cards APN	Cards APN	ECHO Tech	
Week 3 **Cardiovascular**	Clinical	Clinical Noon M&M Clinical APN Meeting		Clinical Noon Fellows Conference Clinical		Complete Cardiovascular Quiz	
Week 4 **Neuro- Critical Care**		Clinical Noon M&M Clinical APN Meeting		Clinical Noon Fellows Conference Clinical		Meet with Mentor and Sim	

Month 3	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Week 1 **Neuro-Critical Care**		Neurosurgery NP APN Meeting	Neurosurgery NP	Neurosurgery NP	Neurosurgery NP	Neurosurgery NP	
Week 2 **Neuro-Critical Care**		Clinical Noon M&M Clinical APN Meeting		Noon Fellows Conference		Complete Neuro Quiz	Clinical
Week 3 **Endocrine & Metabolic**	Clinical	Clinical Noon M&M Clinical APN Meeting		Clinical Noon Fellows Conference Clinical			
Week 4 **Endocrine & Metabolic**		Clinical Noon M&M Clinical APN Meeting		Clinical Noon Fellows Conference Clinical		Meet with Mentor and Sim	

Month 4	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Week 1 **Endocrine & Metabolic**		Clinical Noon M&M Clinical APN Meeting		Clinical Noon Fellows Conference Clinical		Complete Endocrine & Metabolic Test	Clinical
Week 2 **Renal**		Noon M&M OR APN Meeting	OR	Noon Fellows Conference OR	OR	OR	
Week 3 **Renal**	Clinical	Clinical Noon M&M Clinical APN Meeting		Clinical Noon Fellows Conference Clinical			
Week 4 **Renal**		Clinical Noon M&M Clinical APN Meeting		Clinical Noon Fellows Conference Clinical	Complete Renal Test	Meet with Mentor and Sim	

Month 5	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Week 1 **Shock & Sepsis**		Clinical Noon M&M Clinical APN Meeting		Clinical Noon Fellows Conference Clinical			Clinical
Week 2 **Shock & Sepsis**		Noon M&M Surgery NP APN Meeting	Surgery NP	Noon Fellows Conference Surgery NP	Ortho NP	Ortho NP	
Week 3 **Shock & Sepsis**	Clinical	Clinical Noon M&M Clinical APN Meeting		Clinical Noon Fellows Conference Clinical		Complete Shock & Sepsis Test	
Week 4 **Sedation & Analgesia**		Clinical Noon M&M Clinical APN Meeting		Clinical Noon Fellows Conference Clinical		Meet with Mentor and Sim	

Month 6	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Week 1 **Sedation & Analgesia**		Clinical Noon M&M Clinical APN Meeting		Clinical Noon Fellows Conference Clinical			Clinical
Week 2 **Sedation & Analgesia**		Clinical Noon M&M Clinical APN Meeting		Clinical Noon Fellows Conference Clinical		Clinical Complete Sedation & Analgesia Test	
Week 3	Clinical	Clinical Noon M&M Clinical APN Meeting		Clinical Noon Fellows Conference Clinical			
Week 4		Clinical Noon M&M Clinical APN Meeting		Clinical Noon Fellows Conference Clinical	Complete Post Assessment	Meet with Mentor and Sim	

Appendix J

Critical Care Post-test

1. Which of the following is true regarding upper airway anatomy?
a) An adult's larynx is funnel-shaped while a child's larynx is oval.
b) The narrowest portion of a child's upper airway is below the vocal cords.
c) In children, the cricoid cartilage does not form a complete ring.
d) An adult's glottis is more anterior in position than that of a child.

2. Which of the following oxygen delivery devices provides the highest percentage of O2 delivery?
a) Simple face mask
b) Face tent
c) Nasal Cannula
d) Non-rebreather mask

3. A six-month-old girl, born at an estimated 29 weeks' gestational age, has known BPD and CLD. She requires 0.25L of oxygen per minute via nasal cannula at home. She is on no home medications. Which of the following findings is most likely on a blood gas analysis?
a) Decreased pH (< 7.35), increased Pco2, decreased HCO3
b) Normal pH (7.35–7.45), decreased Pco2, decreased HCO3
c) Normal pH (7.35–7.45), increased Pco2, increased HCO3
d) Increased pH (> 7.45), decreased Pco2, increased HCO3

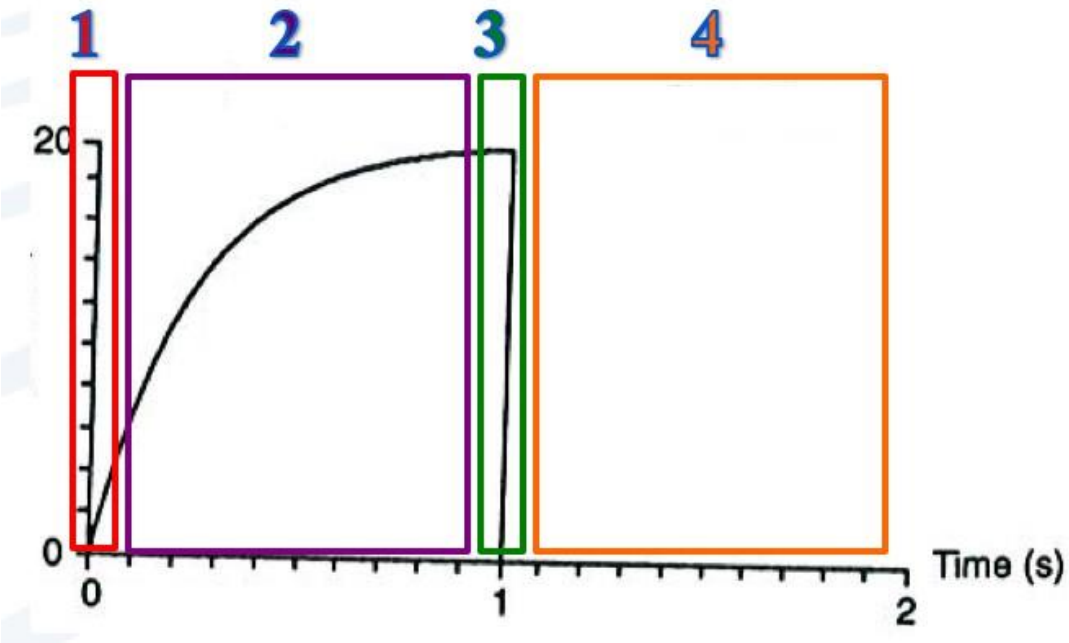
4. A 14-year-old girl required intubation for ARDS. Her FIO2is now 40%. An arterial blood gas reveals pH 7.31, Paco2 46 mm Hg, Pao295 mm Hg, and a base deficit of -1. Her saturations are 96% via pulse oximetry. Assuming she is at sea level and has a normal respiratory quotient, which of the following values most closely approximates the A-a gradient?
a) 144 mm Hg
b) 320 mm Hg
c) 90 mm Hg
d) 130 mm Hg

5. A 4-year-old boy presents in the PICU with hyponatremia and urine output <0.5 mL/kg/h. His most recent serum sodium level is 122 mEq/L. He has a generalized tonic-clonic seizure that is not responsive to lorazepam or fosphenytoin. The best next step would be to:
Give 3% saline IV to increase the sodium by 5mEq/L

6. A 14-year-old patient who has been receiving outpatient hemodialysis presents to the PICU with end-stage renal disease. He is noncompliant, receiving no hemodialysis for the past week. His lab results are significant for azotemia, elevated creatinine, and hyperkalemia (serum K+ 7.5 mEq/L). His EKG reveals peaked T-waves. You want to shift the potassium into the cell. Of the following choices, which is the best option?
a) Calcium chloride
b) Sodium polystyrene sulfonate
c) Glucose and insulin

d) Dialysis

7. Shown below is a depiction of the ventilator cycle on a time-versus-airway pressure graph. Which of the numbers above the graph represents the transition from inspiratory phase to expiratory phase?



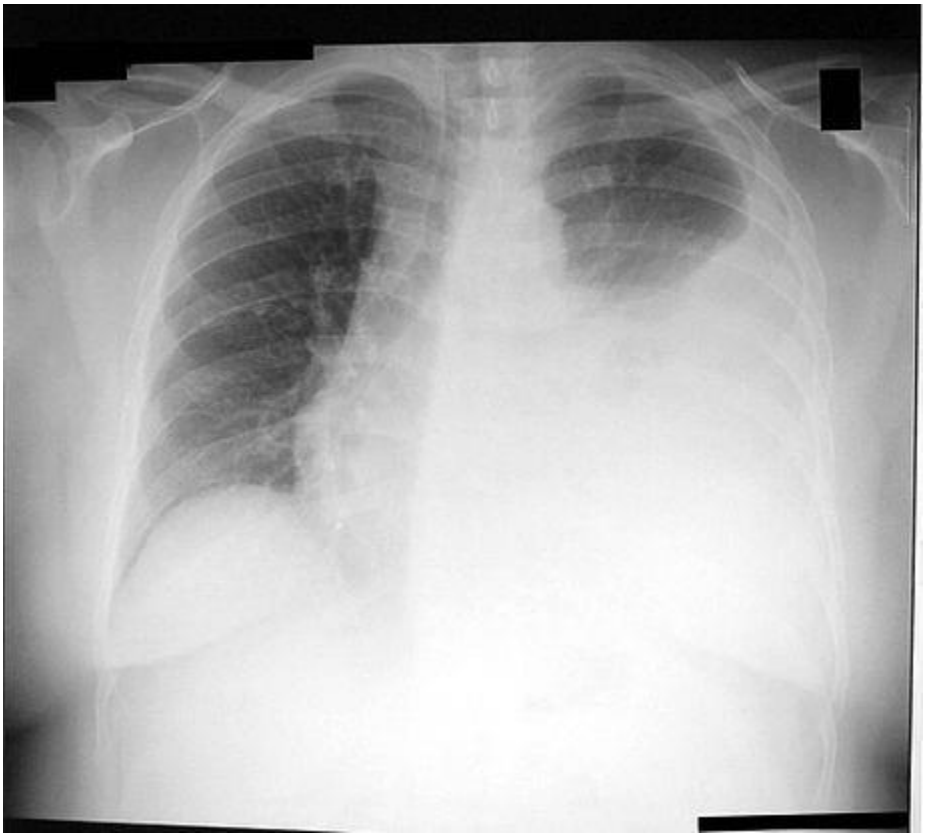
8. In which of the following ways does pressure control ventilation differ from volume control

a) In pressure control ventilation, the minute ventilation is consistent.
b) In volume control ventilation, the peak inspiratory pressure for each breath is consistent.
c) In volume control ventilation, the tidal volume for each breath is consistent.
d) In pressure control ventilation, the peak inspiratory pressure for each breath is variable.

9. A patient was intubated in the emergency department. The ABG results are:
pH 7.25 PCO2 66 mm Hg PaO2 58 mm Hg HCO3 22 mEq/L Base deficit -1 O2 saturation 84%
Her ventilator is set in volume-control mode with VT 8 mL/kg, rate 34 breaths per minute, inspiratory time 0.8 s, Fio2 100%, PEEP 12 mm Hg, measured peak inspiratory pressures 34-39 mm Hg, mean airway pressure 25 cm H2O. She is not receiving vasoactive medications.
Which of these statements represents the best next step in this patient's management?

a) Continue the current ventilator settings and recheck blood gas in 6-8 hours
b) Request a consultation for ECMO
c) Initiate high-frequency oscillatory ventilation
d) Wean the PEEP to more physiologic levels of 5-8 mm Hg

10. A 16-year-old boy with obesity presents with dyspnea, tachypnea and left-sided chest pain. Pulse oximetry reveals an oxygen saturation of 83% on room air. Which of the following is the most likely etiology of her hypoxemia?



a) Impaired alveolar diffusion
b) Alveolar hypoventilation
c) Low fraction of inspired oxygen
d) V/Q mismatch

11. Which of the following signs or symptoms is most likely to suggest impending respiratory failure?
    a) Subcostal retractions
    b) Nasal flaring
    c) Tachypnea
    d) Head bobbing

12. A 10-year-old girl with a peanut allergy takes a bite of a candy bar at school. Within minutes she feels flushed and dyspneic; she goes to the school nurse's office where she is noted to have angioedema and difficulty breathing. She appears very anxious. Which of the following is the nurse's most appropriate first course of action?
    a) Administer epinephrine through the girl's jeans.
    b) Take off the girl's jeans and then administer epinephrine.
    c) Call 911 and the girl's parents to notify them of the girl's condition.
    d) Call 911 and await EMS arrival before administering epinephrine.

13. A six-year-old girl is evaluated in the emergency department with warm shock due to presumptive septic shock. In the first hour, she has received four 20-mL/kg boluses of normal saline, without signs of volume overload, and empiric antibiotics. She is not dyspneic, and is saturating 98% on 2 liters of oxygen via nasal cannula. A NE infusion has been initiated and

rapidly escalated; despite this, she remains in hypotensive, warm shock. Which of the following is the most appropriate next step?
a) Start a dopamine infusion.
b) Perform endotracheal intubation.
c) Request an immediate echocardiogram.
d) Administer hydrocortisone, 2 mg/kg.

14. A three-month-old child with acute gastroenteritis presents with hypovolemic shock. Vital signs are: temperature 37°C, HR 188 beats/min, RR 58 breaths/min, BP 72/49 mm Hg, SpO2 92%. Breathing is non-labored, pulses are 1+ peripherally and 2+ centrally, and capillary refill is 5 seconds. The child is cool peripherally but warm centrally. Glucose is 98 mg/dL. You have ordered a 20 mL/kg bolus of normal saline to run over 10 minutes. Which of the following is the most appropriate next step to improve oxygen delivery?
    a) Start a norepinephrine infusion to increase the patient's SVR.
    b) Transfuse packed red blood cells.
    c) Administer oxygen via nasal cannula.
    d) Start an epinephrine infusion to increase heart rate and contractility.

15. A 10 month old male with a history of biliary atresia and failed Kasia is being intubated for respiratory failure due to Influenza A. When checking her most recent labs it is noticed that his Cr has doubled since admission. What is the preferred method for sedating this patient?
    a) Low-dose fentanyl infusion and monitoring of hepatic and renal function
    b) Intermittent doses of morphine, because it is neither renally metabolized nor excreted
    c) Intermittent doses of remifentanil, because it undergoes hydrolytic metabolism
    d) No sedation/analgesia, as the risk of all agents is too high

16. The solvent that makes Ativan potentially toxic to infants and that may cause severe metabolic acidosis is
    a) Ethyl acetate
    b) Toluene
    c) Polyethylene glycol
    d) Propylene glycol

17. A major disadvantage to etomidate is:
    a) Adrenocortical depression
    b) Cardiovascular collapse
    c) Urinary retention
    d) Renal insufficiency

18. A 4 year old female presents to the EU with altered mental status after a 2 day history of vomiting, diarrhea, and poor PO intake. Patent airway, intact gag reflex. Vital signs BP 80/45, HR 165, RR 42, Saturations 97% on RA; 1+ pulses and capillary refill is 4 sec. She is receiving a NS bolus via IV. Her modified GCS is 8. What is the next most appropriate intervention?
    a) Intubate the child based on the child's GCS of 8
    b) Check blood glucose level
    c) Obtain further history from the family
    d) Perform a STAT CT of the head

19. In the motor component of the GCS, which of the following responses to painful stimulation will result in the lowest motor score?

a) Withdrawal
b) Abnormal extension (decerebrate posturing)
c) Abnormal flexion (decorticate posturing)
d) Localization

20. A 2-week-old infant girl has been brought to the PICU after stage 1 repair of her hypoplastic left heart syndrome. Overnight, she develops tachycardia, low urine output, and progressive increase in blood lactate levels from 4 mmol/L to 6.5 mmol/L. The PICU team starts a milrinone infusion for the postoperative low cardiac output syndrome. Milrinone is believed to improve cardiac output through:
    a) Increase in myocardial contractility through phosphodiesterase inhibition
    b) Decrease in afterload through vasodilation
    c) Improvement in preload through lusitropy
    d) All of the above

21. In a patient with severe lung disease receiving positive pressure ventilation, which of the following is true?
    a) Central venous pressure correlates with right ventricle systolic volume
    b) Central venous pressure is affected by an increase in intrathoracic pressure from positive pressure ventilation
    c) Central venous pressure correlates with right ventricle function
    d) Central venous pressure correlates with left ventricle filling pressure or pulmonary artery occlusion pressure

22. A 2-year-old with sickle cell disease has had agitation, limping, and drooling for the past few hours. His current hemoglobin level is 10 g/dL with 58% sickle cells. Magnetic resonance imaging shows evidence of an acute stroke. He has had vaso-occlusive crises in the past but not stroke. The next best step is:
    a) Perform simple transfusion to decrease sickle cells below 30%
    b) Perform exchange transfusion to decrease sickle cells below 30%
    c) Perform simple transfusion to decrease sickle cells below 50%
    d) Order transcranial Doppler imaging to assess the severity of his acute stroke

23. Hepatorenal failure is usually associated with which of the following?
    a) Acute tubular necrosis
    b) Altered glomerular vasomotor function
    c) Cortical necrosis
    d) Increased intra-abdominal pressure
    e) Pigment injury to the tubules

24. Which of the following is most likely to be increased in severe liver failure?
    a) Factor II
    b) Factor VII
    c) Factor VIII
    d) Protein C
    e) Fibrinogen

25. Ketone bodies in diabetic ketoacidosis are produced by what reaction when free fatty acids are released from the adipose tissue?

a) Alpha-reduction
b) Alkalinization
c) Beta-oxidation
d) Acidification

26. Rhadomyolysis is associated with all of the following except:
    a) Elevated creatine kinase
    b) Elevated lactic dehydrogenase
    c) Hypernatremia
    d) Hyperkalemia

27. A 15-year-old morbidly obese girl was brought to the emergency department by her parents because of a 3-month history of excessive drinking and urination. Her initial glucose level was 1050 mg/dL. Venous blood gas measurements were: pH 7.29; P_{CO_2}, 41 mm Hg; Pa_{O_2}, 69 mm Hg; HCO_3-, 17 mEq/L; base excess, -5.9 mmol/L. She is severely dehydrated clinically, and urinalysis shows mild ketones and large amount of glucose. What is the most likely working diagnosis for this patient?
    a) Severe sepsis
    b) Diabetic ketoacidosis
    c) Hyperosmolar hyperglycemic syndrome
    d) Diabetes insipidus

28. A 17-year-old girl with type 1 diabetes mellitus presented to the emergency department with a 1-day history of abdominal pain and vomiting. Two large-bore intravenous lines have been placed. Her lab results are: sodium, 150 mEq/L; potassium, 4.4 mEq/L; chloride, 98 mEq/L; bicarbonate, 10 mEq/L; blood urea nitrogen, 44 mg/dL; creatinine, 1.3 mg/dL; glucose, 977 mg/dL; calcium, 9.8 mEq/L. Based on these results, the calculated serum osmolality is:
    a) 355 mOsm/kg
    b) 295 mOsm/kg
    c) 370 mOsm/kg
    d) 340 mOsm/kg

29. Which two physiologic processes are involved in the mechanics of renal replacement therapy?
    a) Diffusion and centrifugation
    b) Diffusion and convection
    c) Centrifugation and convection
    d) Centrifugation and counterpulsation

30. Which management strategy is most likely to make a significant impact on poor outcomes associated with acute kidney injury (AKI)?
    a) Stratification of AKI risk
    b) Early recognition of injury
    c) Use of targeted therapies for specific types of AKI
    d) Prevention of fluid overload
    e) All of the above

31. What is the role of systemic steroids in acute respiratory distress syndrome (ARDS)?
    a) Steroids should be given to all ARDS patients regardless of timing
    b) Steroids may be beneficial in the prevention of ARDS

c) Steroids may be beneficial in early ARDS, but results are conflicting
d) Steroids should never be given to any ARDS patients due to an increased mortality risk

32. A 7-year-old asthmatic was admitted to the PICU 12 hours ago; she is receiving methylprednisolone (1 mg/kg/dose) every 6 hours, scheduled ipratropium and continuous albuterol at 20 mg/h. Over the past 2 hours, she has become increasingly somnolent, does not arouse to voice cues and has saturation of 87% on a non-rebreather mask (15 L, FIO_2 1.00). What is the next most appropriate intervention?
    a) Get a STAT chest radiograph
    b) Obtain a STAT blood gas measurement
    c) Prepare for endotracheal intubation
    d) Increase albuterol to 40 mg/h

33. Hypoxemia in a patient with severe asthma exacerbation is most often due to which of the following?
    a) Increased alveolar diffusion gradient
    b) Hypoventilation
    c) Ventilation/perfusion mismatching
    d) Lobar pneumonia

34. Hemodialysis is effective for which of the following compounds?
    a) Those with a high volume of distribution and high molecular weight
    b) Those with low protein binding and high molecular weight
    c) Those with a low volume of distribution, low protein binding and low molecular weight
    d) Those with a low volume of distribution, high molecular weight and low protein binding

35. All of the following drugs/toxins are causes of increased anion gap except:
    a) Salicylates
    b) Iron
    c) Cyanide
    d) Phenobarbital
    e) Theophylline

36. Which of the following electrolyte abnormalities is a complication of tumor lysis syndrome?
    a) Hypophosphatemia
    b) Hyperkalemia
    c) Hypercalcemia
    d) Hyponatremia

Taken from: Society of Critical Care Medicine. (n.d.). Retrieved January, 2017, from http://www.learnicu.org/Pages/default.aspx
Self-Directed Virtual Critical Care Rounds I & II

Appendix K

Post Orientation and Mentoring Program Satisfaction Survey

1. How effective was the teaching within the core curriculum of the orientation and mentoring program?

2. Do you feel the course materials covered were relevant to the environment, and were you satisfied with the information provided?

3. Do you feel you were well supported by your mentor? Please list one thing you felt the excelled at and one thing you were hoping to receive/ attain from them but did not.

4. Do you feel like this program equipped you with the required materials to successfully transition into your role as a Nurse Practitioner in the PICU?

5. Overall how satisfied were you with the orientation and mentoring program? What is one thing you thought benefited you the most? What is one thing you wish would have been provided but was not?

6. Overall do you feel more confident in your abilities as an advanced provider after completing the curriculum?