Title: Cardiac arrest during emergency craniotomy for a 6 day old neonate with elevated ICP and impending herniation from an intracranial mass.

Moderators:

1. Naiyi Sun, MD Clinical Assistant Professor, Stanford University School of Medicine
2. Brenda Golianu, MD Associate Professor, Stanford University School of Medicine

Goals:

1. Identify the intraoperative concerns associated with anesthesia of a neonate with an intracranial mass.

2. Understand the anesthetic management of intracranial hypertension and strategies to optimize cerebral perfusion pressure.

3. Identify the complications associated with transfusion of a neonate.

4. Develop an approach to manage a neonate in cardiac arrest associated with hyperkalemia.

5. Develop an approach to deliver bad news to parents.

Case Stem:

A 6-day-old 3.4 kg term infant presents to the emergency room with seizures, vomiting, and poor feeding. She was discharged from the hospital 2 days earlier on DOL 4 following an uneventful birth. Brain MRI imaging reveals a 5x5 cm. right temoral parietal intraparenchymal bleed with an associated mass, midline shift and herniation of the cerebellar tonsils.

1. *Discuss significance of the MRI findings.*
2. *What physical examination signs would you expect?*

Physical Examination:

In the NICU, baby is already intubated with a 3-0 endotracheal tube and on mechanical ventilator support. She is hypertensive with a blood pressure of 115/77 and heart rate of 89. On physical examination, she is found to be unresponsive to stimulus with asymmetric pupils and absence of the gag reflex.

1. *Should you treat the patient's hypertension and bradycardia?*
2. *What are the treatment options for elevated intracranial pressure?*

Following drainage of CSF with a ventricular tap performed at bedside, an emergency craniotomy for tumor resection is planned due to concern for further herniation.

1. *What additional studies do you want for this patient prior to proceeding?*
2. *What lab studies are needed?*
3. *What monitors do you need for the surgery?*
4. *Does the patient need a central line for the procedure? If so, where would you place it?*
5. *What should you tell the parents regarding anesthetic risks for this surgery?*
6. *Any additional considerations?*

Intraoperative Course:

The patient is transported intubated from NICU to the OR. The monitors are placed and surgical preparation proceeds.

1. *How will you maintain anesthesia?*
2. *What are your goals of ventilator management for this patient?*
3. *What are the intraoperative concerns for a neonate with a large intracranial mass undergoing resection?*
4. *What maintenance IV fluid would you use?*
5. *How much blood should be available?*
6. *How is blood intended for a neonate treated differently compared to an older child?*

Two hours into the tumor resection, the patient starts to develop progressive intraoperative hypotension with brisk oozing of blood from the tumor bed.

1. *What is your differential diagnosis for hypotension during surgery?*
2. *What lab tests do you want to send?*
3. *What blood products do you want to prepare?*
4. *How do you want to treat the intraoperative hypotension?*
5. *What do you tell the surgeons?*

Diffuse intravascular coagulation (DIC) is strongly suspected. Transfusion of a large volume of blood products and initiation of vasopressors are required to maintain a borderline blood pressure. During the resuscitation, the patient suddenly develops ventricular tachycardia, which degenerates to ventricular fibrillation.

1. *What do you do next?*
2. *What is the differential diagnosis for etiologies for intraoperative ventricular fibrillation?*
3. *What is the mostly likely cause of VT/VF in this scenario?*

After initiation of CPR, electrical shocks are delivered with only transient conversions back to sinus rhythm. ABG shows pH 7.3/CO2 32/HCO3 16/K 7.8

1. *What are the risk factors for development of hyperkalemia following transfusion?*
2. *What are the therapies to lower potassium level during anesthesia?*

Therapies to lower the potassium level are implemented. After 15 minutes of resuscitation, a stable sinus rhythm with stable hemodynamics is achieved and the patient is deemed stable enough for transfer back to the neonatal ICU for further care.

Postoperative Care:

A multidisciplinary family meeting is arranged to discuss the prognosis of the patient.

1. *What factors should be considered in goals of care for this patient?*
2. *Who should be present for the family meeting?*

Discussion:

Pre-anesthetic Assessment:

Brain tumors are the most common solid tumors in children. However, congenital brain tumors are extremely rare and histologically different from those in the older pediatric population. Malignant histology is common and is associated with poor outcomes despite advances in neuroimaging and adjuvant therapy.

The anesthesiologist's primary concern for pediatric patients with intracranial mass is whether they have any signs and symptoms of raised intracranial pressure (ICP). The normal ICP in children is less than 15 mmHg. In term neonates normal ICP is even less at 2-6 mm Hg. In infants, signs and symptoms of elevated ICP can develop late and are ominous. They include bulging fontanelles, decreased level of consciousness, papilloedema, and pupillary dilation. These symptoms may progress to Cushing's triad (hypertension, bradycardia, and irregular ventilation), which may signify impending herniation.

Hyperventilation can be used to reduce ICP immediately. Arterial partial pressure of carbon dioxide (PaCO2) and cerebral blood flow (CBF) have a linear relationship. Another strategy to decrease ICP is to elevate the head in the midline position to maximize cerebral venous drainage. Patients with intracranial hypertension associated with tumor can be started on dexamethasone to decrease tissue swelling around the tumor. Mannitol or furosemide may be administered to decrease cerebral volume. The surgeon can also place a ventricular drain to remove CSF in order to decrease intracranial volume and pressure to decrease risk of herniation.

Monitoring should include standard ASA monitors plus arterial catheter due to the potential for sudden and severe hemodynamic changes. The arterial transducer should be zeroed at the level of the head if the head and heart positions are different so that CPP can be accurately assessed. Careful estimation of intravascular volume is crucial in this case and having central venous access may help in monitoring volume status and replacement of volume. In small infants with elevated ICP, the femoral vein may be preferred thereby avoiding the trendelenburg position during catheter insertion and the risk of accidental carotid puncture. In the first few days of life, the umbilical artery and vein can also be cannulated.

Maintenance of Anesthesia:

For maintenance of anesthesia, anesthetics that decrease ICP and CMRO2 and maintain CPP are most desirable. All potent inhalational agents are cerebral vasodilators, which increase CBF and ICP. However, low concentrations of volatile anesthetic combined with mild hyperventilation minimally affect CBF and ICP. Maintenance of anesthesia can be accomplished with inhalational anesthetics, intravenous infusions, or a combination of these drugs. There are no outcome studies in humans showing differences in these anesthetic techniques.

Potential intraoperative complications during craniotomy for tumor resection include cardiac arrhythmias and acute blood pressure changes during surgical exploration. VAE is a potential serious complication because patients are frequently positioned with 10 to 20 degrees head-up to improve venous drainage. Blood loss is often difficult to estimate during neurosurgery because it is frequently absorbed by the operative drapes. Massive hemorrhage is a rare event, but when it occurs it can be sudden and catastrophic. Therefore, all patients should have secure, large-bore intravenous access and blood products should be available.

Blood Transfusion in Neonates:

Leukoreduction filters remove approximately 99.9% of WBC from PRBCs, which reduces febrile non-hemolytic transfusion reactions, prevents alloimmunization, and reduces the risk of CMV infections. Irradiation prevents transfusion associated graft vs. host disease (TA-GVHD) in susceptible recipients. Leukoreduced PRBCs should be used in all neonates. In addition, most blood banks will also irradiate leukoreduced PRBCs prior to neonatal transfusion. CMV negative PRBCs reduce the transmission of CMV in seronegative recipients. CMV –seronegative PRBCs should be used in high risk populations, although many centers use CMV-negative PRBCs in all neonates.

Hyperkalemia after massive transfusion:

Hyperkalemia associated with cardiac arrest may be a serious complication of massive blood administration. Hyperkalemia occurs after transfusion due to

leakage of intracellular potassium from RBCs after prolonged storage. Risk factors identified as contributors for hyperkalemia after transfusion include longer storage age of the RBC product, speed and volume of RBC products transfused, age and size of patient, method of transfusion, and presence of comorbidities.

The recent attention surrounding these reactions resulted in an advisory from Wake up Safe to the pediatric anesthesiology community in 2011. Wake Up Safe recommends the following guidelines:

- Transfusion with "fresh" red cell products (< 7 day from collection) in cases where massive transfusion is anticipated.
- If irradiation of red cell product is indicated, transfuse the irradiated blood as soon as possible after irradiation.
- If red cell product with relatively high potassium levels are the only readily available option, use these measures to reduce the chances of transfusion-associated hyperkalemia:
    - Avoid hypovolemia associated low cardiac output state.
    - Request the Blood Bank to wash the red blood cell products.
    - Transfuse blood slowly, if possible, through > 23 gauge peripheral IV rather than via a central venous catheter.
    - Check serum electrolytes frequently during massive transfusion.

Hyperkalemia should be suspected when T waves increase in height or appear "peaked". If not treated promptly, it can progress to wide complex ventricular arrhythmias. Intraoperative treatment of hyperkalemia includes hyperventilation, bicarbonate administration, calcium, and a combination of glucose and insulin.

Giving bad news:

Breaking bad news is one of the physician's most difficult tasks, yet our medical education typically offers little preparation in it. The family medicine literature offers the following simple pneumonic, ABCDE, to provide some guidance:

- **A**dvance preparation – arrange adequate time in a private location, Social work and /or clerk should be invited if available. Discuss and review the intraoperative events with the surgeon before speaking to the family to prevent conflicting stories. Prepare emotionally.
- **B**uild a therapeutic relationship – introduce yourself to everyone, warn the family that bad news is coming, use touch when appropriate.
- **C**ommunicate well - determine the family's knowledge and understanding of the situation, proceed at the family's pace, avoid medical jargon and euphemisms, allow for silence and tears, and answer questions.
- **D**ealing with patient and family reactions – assess and respond to emotional reactions and empathize with the family. Be aware of the cognitive coping strategies (denial, blame, intellectualization, disbelief, and acceptance). Be empathetic.

- **E**ncouraging/validating emotions – inquire about the family's emotional and spiritual needs and what support systems they have in place. Offer referrals as needed.

References:

1. Bhananker SM, Ramamoorthy C, Geiduschek JM, et al. Anesthesia-Related Cardiac Arrest in Children: Update from the pediatric Perioperative Cardiac Arrest Registry. Anesth Analg. 2007;105(2):344-350.

2. Cote CJ, Lerman J, Anderson BJ. (Eds.) A Practice of Anesthesia for Infants and Children, 5th Edition. Philadelphia: Elsevier Saunders. 2013: 511-517.

3. Lee AC, Reduque LL, Luban NLC, et al. Transfusion-associated hyperkalemic cardiac arrest in pediatric patients receiving massive transfusion. Transfusion. 2014;54:244-254.

4. Shamji MF , Vassilyadi M, Lam CH, et al. Congenital tumors of the central nervous system: The MCH Experience. Pediatr Neurosurg. 2009; 45(5):368-374.

5. Sloan SR. Neonatal transfusion review. Pediatr Anesth. 2011; 21(1):25–30.

6. Tyler DC. The Pediatric Anesthesia Quality Improvement Initiative Wake Up Safe. Hyperkalemic Statement. 2011. Available from: http://wakeupsafe.org/fidnings.iphtml.

7. Vandekieft GK. Breaking bad news. Am Fam Physician. 2001;64(12):1975-1979.