An 8 month old 8 kg child is admitted after craniosynostosis surgery. He remains intubated because of the anesthesiologist concerns for the large blood loss during the case and continued hypothermia to 34 degrees. During the procedure the estimated blood loss was 500 cc and the patient received 300 cc of PRBCs and 800 cc of crystalloid (0.9NS). On arrival to the PICU the child is intubated, sedated on a propofol infusion and has the following VS:

T: 34.5, HR: 140, BP: 78/45, RR: 24 (ventilated at 24), O2 Sat: 100% on 100% oxygen

1. Given the size of this patient, the transfusion requirement for this case represents
   A. 0.5 blood volume transfused
   B. 1 blood volume transfused
   C. 2 blood volumes transfused

2. The coagulation profile for this patient is sent post op and you are now evaluating the results: PT: 18, INR: 1.8, PTT: 38 and the platelet count is 55,000. What is the most likely explanation for the observed coagulopathy?
   A. A dilutional coagulopathy complicated by the release of tissue thromboplastin
   B. A dilutional coagulopathy complicated by liver dysfunction
   C. A dilutional coagulopathy complicated by DIC

3. The coagulation profile for this patient is sent post op and you are now evaluating the results: PT: 18, INR: 1.8, PTT: 38 and the platelet count is 55,000. What is the most likely explanation for the observed coagulopathy?
   D. A dilutional coagulopathy complicated by the release of tissue thromboplastin
   E. A dilutional coagulopathy complicated by liver dysfunction
   F. A dilutional coagulopathy complicated by DIC
4. The initial laboratory studies for this child are as follows: pH: 7.24, pCO2: 45, 
P02: 110  BE: -10, Na: 144, K: 4.2, Cl: 114, Bicarb: 18, BUN 16, Cr. 0.4
A. This demonstrates a metabolic acidosis likely secondary to volume 
   depletion and a 10 cc bolus of 0.9 NS is indicated
B. This demonstrates a mixed metabolic and respiratory acidosis and the 
   appropriate intervention is an increase in the minute ventilation
C. This represents a non-gap metabolic acidosis and is likely secondary to 
   the infusion of 800 cc of 0.9NS during the operation. The appropriate 
   intervention is to reduce ongoing chloride infusion by changing the 
   intravenous fluid solution to Ringers Lactate.

5. At approximately 8 hours post op, you are called to the bedside because the 
   nurse noted that the child has new onset anisocoria. The right pupil is 5 mm, 
   the left pupil is 2 mm. The VS are BP: 125/60. HR: 110, RR: 22 all ventilated 
   breaths, Sat: 100% on 40% 02, and the CVP is 6. The nurse has already 
   drawn a blood gas and electrolytes and they are pending.
A. You should immediately call for a stat CT scan and notify neurosurgery of 
   the change in the neurologic exam
B. You should immediately get and electrocardiogram and notify 
   neurosurgery of the change in the neurologic exam
C. You should immediately check the intake and output balance and report 
   that balance and the change in the neurologic examination to 
   neurosurgery

6. The electrolytes drawn at the time the child had anisocoria revealed a serum 
   sodium of 126, repeated it is 124. The CT scan and the remaining electrolytes 
   were unremarkable.
A. You suspect the diagnosis of diabetes insipidus and give a bolus of 20 cc 
   per kg of 0.9NS and recheck the serum sodium
B. You suspect the diagnosis of cerebral salt wasting and give a bolus of 5 cc 
   per kg of 3% saline and recheck the serum sodium
C. You suspect the diagnosis of SIADH and give a 5 cc/kg bolus of 3% saline 
   and recheck the serum sodium
1-Answer: B
Discussion:
The approximate size of the blood volume in an 8 month old is 70 cc/kg or in this case 560 cc. Replacement of 300 cc of PRBCs, that has an HCT of 60-65 would be an approximate equivalent of 600 cc of cells with an HCT of 30 or approximately 1 blood volume. The additional crystalloid provides the diluting isotonic fluid that completes the transfusion as well as providing the “maintenance” fluids for the case.

2-Answer: A
Discussion:
Dilution of the coagulation factors and platelets occurs commonly in any transfusion in or about a one blood volume. Thrombocytopenia and low clotting factors are both seen and both deserve replacement in the bleeding or the at risk patient. In this patient, because of the risk of intracranial bleeding, transfusion of FFP and platelets are indicated. Dilutional coagulation abnormalities are compounded by the release of tissue thromboplastin is the post operative craniotomy patient and results in elevation of the PT/INR in excess of the aberration in the aPTT.

3-Answer: C
Discussion:
The anion gap is essential to calculate in any patient with a metabolic acidosis. It is a simple calculation: Na – (Cl + Bicarb) and should be 12 or less. Increased anion gap in this circumstance would likely be secondary to volume depletion. In this circumstance a non-anion gap acidosis is likely secondary to the volume of 0.9NS infused as each liter of 0.9 NS has 154 meq of Chloride. The gap on this child is 12 which is “normal” and the acidosis is therefore likely to the volume of normal saline given. This is known as a hyperchloremic metabolic acidosis.

4-Answer: A
Discussion:
In this child, given the risk of intracranial bleeding and the new unilateral pupillary dilatation, it is imperative to rule out a life threatening intracranial hemorrhage by CT scan. In the event of an intracranial bleed, the unilateral papillary dilatation is usually secondary to the compression of cranial nerve 3 by the uncus of the ipsilateral temporal lobe as a result of the mass effect of the bleed. The other possibilities include seizures, electrolyte abnormalities particularly hyponatremia that can produce seizures and regional or generalized edema.
5-Answer: C

Discussion: Serum sodium abnormalities are relatively common after cranial surgery. Hyponatremia occurs in the setting of SIADH and cerebral salt wasting (CSW). In SIADH, urine volume is generally low and the intravascular volume is normal or elevated. In CSW, urine volume is high and the patient is hypovolemic, often hypotensive and tachycardic. In the setting of diabetes insipidus (DI), the serum sodium is elevated and the urine volume is high. Again, in DI, the patient is often hypotensive and tachycardic because of volume depletion. In this patient, the serum sodium is low, and you do not know the urine volume. However, the CVP is 6 and the patient has a normal BP making CSW much less likely. Checking I and O’s and urine electrolytes will assist in the differentiation of these processes. Urine studies in CSW have a high (>100) sodium concentration. In DI, the hallmark of the urine is that it is very dilute, with a urine specific gravity of <1006. In SIADH, the urine osmolality exceeds serum osmolality and the urine sodium is usually between 50 and 75.

General Case Discussion:

Following craniotomy there are 6 key areas of focus for the clinician in the PICU:

1. Mental status/neurologic exam
2. Management of co-morbidities
3. Perioperative coagulation management
4. Perioperative acid-base management
5. Perioperative electrolyte management
6. Pain management

Mental status/neurologic exam: The postoperative patient needs to have mental status followed very closely particularly on the first post operative night. Any change in the exam should be carefully evaluated and reported to the managing surgeon. Intracranial hemorrhage, ischemia, seizures, and cerebral edema can be life threatening or result in permanent neurologic injury. A CT scan can help to define emergency situations that require reoperation and should be obtained urgently should a neurologic change occur.

Co-morbidities often accompany particularly children with craniosynostosis and need to be addressed on a case by case basis. Particular attention should be paid to the quality of the airway in children with craniosynostosis with associated syndromes as successful endotracheal intubation can be quite difficult.

Coagulation perturbations in the perioperative period are common when the blood loss incurred during repair meets or exceeds one blood volume. Thrombocytopenia and low clotting factors are both seen and both deserve replacement in the bleeding or the at risk patient. Dilutional coagulation abnormalities are compounded by the release of tissue thromboplastin is the post operative craniotomy patient and results in elevation of the PT/INR in excess of the aberration in the aPTT. In the patient presented, the increase in PT/INR and the low platelets are classic
coagulation abnormalities found in the craniotomy patient who has had significant intraoperative blood loss.

Acid base abnormalities are also common in the postoperative period after a procedure in which the patient has had significant blood loss. Under-resuscitation can certainly occur producing a typical anion gap acidosis from excess lactate production due to inadequate circulating blood volume and tissue hypoxia. In addition, a non-anion gap acidosis can also be seen following significant blood loss in the operating room secondary to the large chloride load of 0.9 NS when used as the primary replacement fluid. So-called normal saline contains 154 meq of Na and 154 meq of chloride per liter of fluid. When this is the intravenous replacement solution chosen, the elevation of serum chloride that occurs commonly causes an acidosis that has no associated anion gap. This abnormality is best addressed by decreasing the ongoing exposure to high chloride containing intravenous fluids. This is not a volume responsive acidosis as is the anion gap acidosis seen with elevations in serum lactate.

Perioperative electrolyte abnormalities can be life threatening as seen in the case presented. Most worrisome is hyponatremia which can lead to cerebral edema, seizures and in its extreme, rostral caudal herniation syndromes and death. There are several causes of hyponatremia in the perioperative craniotomy patient: the injudicious use of hypotonic fluids, the syndrome of inappropriate antidiuretic hormone (SIADH) and the occurrence of cerebral salt wasting (CSW). These are easily distinguished by examination of the patient’s I and O’s and serum and urine electrolytes. In the setting of SIADH, the patient has a normal or increased blood volume, relatively low urine output and a high urine specific gravity. Urine sodium values are usually between 50 and 75 meq/l. In CSW, intravascular volume is always low, and urine volume is always high. The patient can become quite hypotensive if he is under-resuscitated. Urine sodium values exceed 100 meq per liter. The first line treatment for SIADH is restriction of IVF’s. If the serum sodium is quite low or is under the targeted sodium identified by the surgical team, the replacement of sodium intravenously is also effective. Hypertonic saline solutions are often chosen to accomplish this. In CSW, intravenous sodium replacement is always required.