Intraoperative Fluid Management and Blood Transfusion Essentials

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Body Fluid Distribution

- 25 L intracellular water
- 15 L interstitial water
- 5 L intravascular water
Perioperative Fluid “Stressors”

- NPO status pre-op, intra-op, and post-op
- Patient’s primary disease causes intravascular fluid depletion: trauma/bleeding, bowel disorders (obstruction, diarrhea), hyperglycemia with osmotic diuresis, diabetes insipidus, poorly controlled hypertension, chronic use of diuretics
Perioperative Fluid Stressors (cont)

- Patient’s primary disease causes intravascular fluid excess: poorly controlled congestive heart failure, renal failure overdue for dialysis, pre-eclampsia (can go either way – hypovolemia or hypervolemia)

- Postoperative nausea or vomiting delays resumption of p.o. fluid intake
Perioperative Fluid “stressors” (cont)

• Intraoperative fluid losses can be obvious or subtle
• Obvious: bleeding in surgical field
• Subtle: Evaporative losses from exposed peritoneal surfaces, sequestration of fluid in extravascular extracellular space (so-called “third spacing”), sympathectomy from spinal or epidural anesthesia
Calculating a Fluid Deficit

• Fluid requirement for normal adults:

\[ \text{Fluids/hour} = 60 \text{ ml} + (\text{Wt in Kg} - 20)\text{ml} \]

• Probably plateaus at 90-100 kg body wt, so not more than 140 ml/hr

• Deficit is calculated based on hours of NPO status:

8 hrs NPO for a 70 kg Pt: 8 X (60+60)+ 960 ml
Fluid Deficit (cont)

• So an 80 kg Pt who has been NPO for 8 hours is almost 1 L behind *before* anesthesia and surgery

• Replace prior to anesthetic induction? Probably OK, but most would replace half of it then, and replace the second half over the first hour thereafter (there’s no gold standard)
Maintenance Fluids

- Hourly basal Fluid Requirement is approximately 100-140 ml/hr for most adults
- Add in blood loss:
  - Crystalloid replacement (balanced salt solutions): 3-4 ml of crystalloid per 1 ml of blood loss
  - Colloid or blood product replacement: 1 ml of solution per 1 ml of blood loss
Third Spacing

• Controversial Subject
• Concept is that local trauma causes edema to develop, and that this edema fluid does not maintain the usual connection between interstitial and intravascular spaces
• Greatest third space losses: open laparotomies (4-6 ml/kg/hr possibly), open thorax with inflamed pleura (perhaps 2-4 ml/kg/hr)
Third Spacing (cont)

• Not a big consideration for superficial (breast, skin) or peripheral (hand, foot, knee) procedures: 0-2 ml/kg/hr

• Some believe that the third spacing concept is overrated and has given anesthesiologists an excuse for overloading patients with fluids
So is *third spacing* overrated?

- There probably is *some* 3rd spacing, but assumed third space formulas for fluid losses have been too high (e.g., maybe it peaks at 3-4 ml/kg/hr, and perhaps only when the bowel serosal surfaces are fully “exposed”)
  - Some have assumed as much as 8-10 ml/kg/hr under these conditions: TOO HIGH
- Recent studies suggest that conservative fluid management improves outcomes with colon and pulmonary resections (others yet to come?)
Rational Fluid Management Plan for a 70 kg man undergoing an open small bowel resection – NPO for 6 hours

- Fluid deficit: 110 ml/hr X 6 hrs = 660 ml
- Give approx 350 ml of LR pre-induction
- 1st hour: Maintenance (110 ml) plus remaining deficit (~300 ml) plus approx 4 ml/kg/hr 3rd space deficit (280 ml) = 690 ml
Rational Fluid Management Plan for a 70 kg man undergoing an open small bowel resection – NPO for 6 hours

- Second hour: Assume 100 ml blood loss:
  Maintenance (110 ml) plus 3\(^{rd}\) space loss (280 ml) plus 4 X 100 ml to replace blood loss = 790 ml

- If the bowel is not fully exposed to the room (it’s in a bag or it’s sequestered intra-abdominally), decrease the 3\(^{rd}\) space assumption

- Laparoscopic approach greatly decreases 3\(^{rd}\) spacing: probably 2 ml/kg/hr or less
And don’t forget:

Urine output counts in the fluid loss category: replace 1:1 with crystalloid
Crystalloids

- Approximately 25% remains intravascular 1 hour after administration
- Even less with D5W (<10%)
- Typically Normal Saline or “balanced salt solutions” are used intraoperatively in adults
- Balanced Salt Solutions: lactated Ringers (LR) or Normosol-R (similar to Plasmalyte)
# Crystalloid Composition

<table>
<thead>
<tr>
<th>Fluid</th>
<th>Na</th>
<th>Cl</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>D5W</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0.9% N.S.</td>
<td>154</td>
<td>154</td>
<td>0</td>
</tr>
<tr>
<td>L.R.</td>
<td>130</td>
<td>109</td>
<td>4.0</td>
</tr>
<tr>
<td>Normosol-R</td>
<td>140</td>
<td>108</td>
<td>5.0</td>
</tr>
</tbody>
</table>
## Crystalloidal Composition

<table>
<thead>
<tr>
<th>Fluid</th>
<th>Osm</th>
<th>pH</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>D5W</td>
<td>252</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>0.9% N.S.</td>
<td>308</td>
<td>6.0</td>
<td></td>
</tr>
<tr>
<td>L.R.</td>
<td>273</td>
<td>6.5</td>
<td>Lactate 28, Calcium 3</td>
</tr>
<tr>
<td>Normosol-R</td>
<td>294</td>
<td>6.6</td>
<td>Mg 3, Acetate 27, Gluconate 23</td>
</tr>
</tbody>
</table>
Which Crystalloid to Select?

- **D5W?** Seldom used, but makes sense as “background” maintenance for diabetics on insulin, children, and adults undergoing long cases (>6-8 hrs). Useless for intravascular volume replacement.

- **N.S.?** Makes sense if Pt is hyperkalemic, hyponatremic, hypochloremic, or if slight hyperosmolarity is desired (craniotomies), not so good if avoidance of metabolic acidosis is important.
Which crystalloid to select?

- **LR:** Workhorse solution in most ORs, avoid if hyperkalemic or hypercalcemic, tends to induce mild alkalosis
- **Normosol-R:** Similar to LR. Mg is a plus, absence of Ca allows mixing with citrated blood products
Special Situation: Burns

- Parkland Formula: 2 ml/kg/% BSA burn over first 8 hours (0.25 ml/kg/% burn/hr), same amount over next 16 hours (0.125 ml/kg/% BSA burn/hr)
- Calculation for 80 kg Pt with 50% BSA burn coming to OR for debridement 12 hours after injury:
  - 0.125 X 80 X 50 = 500 ml/hr for burn alone
- Don’t forget maintenance, blood loss, possible febrile state (increase fluids), and urine output!
Introduction to Transfusion

RBCs, FFP, and Platelet Concentrates
Therapeutic Dilemma

Anemia is bad
- Increases mortality
- Decreases Quality of Life
- Jeopardizes organ viability, especially in presence of limited collateral or vasodilatory reserve (critical coronary or carotid stenoses)

Transfusion is bad
- Independent association with increased mortality and morbidity
- Immunosuppression and enhanced inflammation may be the culprit – leukoreduction may help
- Immediate augmentation of $O_2$ transport may be limited (2,3 DPG deficit)
- Infectious complications
# Infectious Complications of Transfusion

<table>
<thead>
<tr>
<th>Infection</th>
<th>Risk (in most of USA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIV</td>
<td>1/800,000</td>
</tr>
<tr>
<td>HTLV 1 or 2</td>
<td>1/600,000</td>
</tr>
<tr>
<td>Hepatitis C</td>
<td>1/600,000</td>
</tr>
<tr>
<td>Hepatitis B</td>
<td>1/200,000</td>
</tr>
<tr>
<td>Cytomegalovirus</td>
<td>1/100*</td>
</tr>
</tbody>
</table>

* As high as 1/3 if immunosuppressed
Other infectious complications of transfusion

- Viruses: West Nile (1/26,000 estimate), Creutzfeldt-Jacob (rare)
- Bacteria: Unusual, but as high as 1/1000 in platelet concentrates and usually fatal
- Parasites: Malaria, babesiosis (like Malaria), and Chaga’s Disease with regional variation, even in USA, but rare overall
- One never knows what new and unsuspected virus is lurking in the blood supply. Hepatitis C went virtually undetected for almost a decade at an incidence of **4% per unit transfused!**
Immunologic Complications of Transfusion

Mild and relatively common
- Urticaria
- Febrile reactions
- “Generic” immuno-suppression – not necessarily mild – assoc. with cancer recurrence and infections

Serious and uncommon
- ABO/Rh incompatibility
- Non-ABO antibodies: hemolysis often delayed
- TRALI: can be fatal
- Anaphylaxis: usually recipient has an IgA deficiency
Metabolic Complications of Transfusion

- Citrate intoxication (FFP given very fast is most common cause): Rx Calcium chloride
- Hyperkalemia: older RBCs typically, Rx as hyperkalemia
- Hypokalemia, metabolic acidosis, metabolic alkalosis
- Hypothermia if RBC warming is ineffective – not an issue with FFP or platelets
Most Important Transfusion Predictor

Preoperative

Hgb/Hct
Anemia in Elective Surgical Patients
Goodnough LT, Anesth Analg 2005;101:1858-61

- Expert panel evaluating best practices
- **Recommendation 1**: Elective surgical Pts should have Hgb level tested a minimum of 30 days before scheduled surgery
- **Recommendation 2**: Unexplained anemia should be considered secondary to some other process, and elective surgery should be deferred until an appropriate diagnosis is made
Anemia Diagnostic Work-up

**PREOPERATIVE LABORATORY TESTING 30 DAYS**
PREOPERATIVELY:
COMPLETE BLOOD COUNT WITH DIFFERENTIAL

**Hemoglobin abnormal**
- male Hgb <13
- female Hgb <12

**MCV**
- 80-100
- <80
- >100

- Evaluation for anemia of chronic disease
- Reticulocyte count adequate?
- Creatinine >1.3 mg/dL
- Ferritin <12 ng/ml or Transferrin saturation <15%
- Test serum B12

- Nephrology/hematology evaluation for anemia of chronic kidney disease
- Rule out blood loss
- Rule out hemolysis

- Give iron supplementation.
- Consider gastrointestinal evaluation if iron deficiency confirmed.

**No further hematology workup**
So Goodnough et al. are recommending that we Diagnose and Treat anemia preoperatively!

• Does this seem like rocket science?
• Nuh-uh, but it is seldom done by surgeons and anesthesiologists. Why?
• Often impractical. Depends on
  – 1. Surgical urgency
  – 2. Access to patients pre-op
  – 3. Timing of access to patients pre-op
Clinical Settings Where Pre-op Dx/Rx of anemia works or doesn’t

It works
• Elective total joints
• Elective cardiac valve replacement/repair
• Spine fusions or scoliosis repairs
• Most radical hysterectomies or radical prostatectomies

It doesn’t work (or isn’t needed)
• Urgent CABG
• Fast-growing cancers, even though “elective”
• Procedures where transfusion is unlikely
ASA Practice Guidelines

- Transfusion rarely indicated when $\text{Hgb} \geq 10 \text{ g/dL}$
- Transfusion almost always indicated with $\text{Hgb} \leq 6 \text{ g/dL}$
- At levels between 6 and 10, it depends upon the situation
- Use of a universal “transfusion trigger” is not recommended
Don’t be Trigger Happy

Transfusion “trigger” isn’t just a numerical threshold: Consider “Patient Performance” markers: tachycardia, fatigue (if awake)

- Myocardial ischemia: ECG, TEE
- Increased susceptibility: LVH, CAD, Cerebrovasc. Dz, hyperthermia, hypermetabolic states (burns, sepsis)
- Evidence of global O$_2$ delivery failure: $\text{SvO}_2$/PvO$_2$, lactic acidosis
RBC Transfusion Modifiers

Primary anemia compensation is increased cardiac output, so this fails if

- The heart can’t increase CO (bad valve disease, severe diastolic dysfunction, dilated cardiomyopathy, etc.)
- You can’t maintain normovolemia: rapid blood loss
- In those situations, Hgb 8-9 may be a good “trigger point” for RBC transfusion
Bleeding/coagulopathy algorithm

Workup and initial therapy for coagulopathy

Type of bleeding: diffuse from wound or intravenous sites, or both, and from mucous membranes vs local petechiae, ecchymoses, or both

Rule out lack of surgical hemostasis

Correct hypothermia

Immediate PT, PTT, fibrinogen, platelet count

Decreased platelets or suspicion of thrombocytopenia

Transfuse 5–10 units of platelets, consider DDAVP

Increased PT, PTT
Normal platelet counts
Normal or increased fibrinogen levels

Fresh frozen plasma

Increased PT, PTT
Low platelets
Decreased fibrinogen

Fibrin split products + cryoprecipitate + platelets

Workup for disseminated intravascular coagulopathy fibrinolysis

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Indications for Fresh-frozen plasma

- Correction of microvascular bleeding with elevated PT or PTT (>1.5 x normal)
- Correction of congenital or acquired factor deficiencies that lack specific concentrates
- Urgent reversal of warfarin-induced anticoagulation
- Rare: exchange transfusion for autoimmune diseases, angioneurotic edema (C5a deficiency)
- **Nonindications**: Fixed ratio to RBC transfusion, malnutrition
FFP: So misunderstood
The Dr. Pepper of blood products

• Most overtransfused blood component
  – Problem exacerbated by lack of rapid turnaround on PT and PTT testing

• And yet when FFP is truly needed, many docs *underdose* it
  – Usual starting dose for microvascular bleeding with elevated PT is 10-15 ml/kg, i.e., 4-6 units in most adults
Fibrinogen concentration vs blood volumes lost (similar for other factors)

Implication: Critical deficiency (<100) seldom reached at < 1 BV
Platelet Transfusion Indications

- Nonsurgical Pt: Plt Count < 20,000 (some say 10,000)
- Surgical Pt: Plt Count < 50,000 pre-operatively or intraoperatively
- Platelet dysfunction (as in after cardiopulmonary bypass): potentially needed even if Plt count is 100,000, but seldom if higher than that
Platelet transfusion won’t help in

- Heparin-induced thrombocytopenia (a HYPERCOAGULABLE state exacerbated by Plts), TTP (ditto)
- ITP: The circulating antibodies just eat the transfused platelets: risk>>benefit
- MAY not help if there is unbound clopidogrel or abciximab in the plasma
Platelet transfusion dosing

- Usually start with 0.1 unit/kg: platelet count should increase by 10,000 per unit
- Check the size of a pooled platelet pack at your hospital (ranges from 4-8 units, and folks often mistakenly call this 1 “unit” of platelets locally)
- Single donor plateletpheresis: used for high-risk recipients, 1 pheresis is about the same as 6-8 pooled units of random donor platelets