Perioperative Fluid Management
A. Scott Keller
October 22, 2016
Or…
“Mr. Anesthesiologist, please don’t drown my patient!”
Disclosures

No relevant financial disclosures.
Learning Objectives

• Describe perioperative fluid physiology.
• Estimate perioperative fluid requirements.
• Explain when diuretics are needed postoperatively.
• Discuss the limitations of using urine output to determine intravascular volume in the perioperative period.
Perioperative fluid management is not a new concern...
WG Maddock: Water Balance in Surgery

“It is difficult to lay down hard and fast rules to cover the proper administration of saline solutions to all patients.”

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Chicago, Illinois

January 2, 1937
Paging On-Call (That’s You!)

• 8:00 PM--You’ve just taken sign out for the night shift at Outside Hospital.

• 8:05 PM--You’re reviewing patient notes, including Mr. Hip, a 67-yo male s/p left revision THA this morning.

• 8:10 PM--Mr. Hip’s nurse pages you about his low urine output: “Can you come see this patient?”
First Case: Low Urine Output

• Urine output of 100 cc in last 6 hours.

• BP 80/40, HR 100, T 37.4, RR 16, weight 106 kg (pre-op weight 100 kg).

• NAD, no pain, but mild nausea and no oral intake, urine is amber colored, lungs are clear.

• He took his usual atenolol 25 mg before surgery, no other chronic meds.

• Labs: Hgb 9 (13), creat 1.0 (1.0).
First Case: Low Urine Output

• Review of his chart shows EBL of 1000 cc.

• His total intra-op fluids were 7300 cc in and 1300 cc out.

• 6 liters positive fluid balance!!!

• He is still receiving NS at 140 cc/hr.
What is the most appropriate initial treatment?

A. Call the anesthesiologist and yell at him/her for drowning your patient.

B. Give furosemide 40 mg IV STAT.

C. Monitor for another 12 hours because decreased urine output is expected in the immediate post-op period.

D. Give fluid bolus of 500 cc over 1 hour, repeat if necessary.

E. Check a UA and consult Nephrology.
Second Case: Low Urine Output

- Urine output of 100 cc in last 6 hours.
- BP \textbf{130/70}, HR 100, T 37.4, RR 16, weight 106 kg (pre-op weight 100 kg).
- NAD, no pain, but mild nausea and no oral intake, urine is amber colored, lungs are clear.
- He took his usual atenolol 25 mg before surgery, no other chronic meds.
- Labs: Hgb 9 (13), creat 1.0 (1.0).
Second Case: Low Urine Output

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D. Give fluid bolus of 500 cc over 1 hour, repeat if necessary.

E. Check a UA and consult Nephrology.
Pre-Test Questions—Test Your Knowledge!
Question #1: Which one of the following is true?

A. Most IV crystalloid “leaks” out of the intravascular space into the interstitium.

B. Induction of anesthesia causes relative intravascular hypervolemia.

C. It is best to avoid IV fluids post-op since patients get sufficient fluid during surgery.
Question #2: All of the following are true except

A. Urine output (UOP) is expected to **decrease** during surgery.

B. UOP generally **increases** around POD 2.

C. Low UOP post-op means acute kidney injury.

D. Perioperative urine output does **not** correlate with intravascular volume status.
Question #3: Which is the best scenario to give furosemide?

A. Post-op low urine output.
B. Post-op lower extremity edema.
C. Post-op pulmonary edema.
D. Always continue furosemide perioperatively if patient takes it chronically.
The Job of the Anesthesiologist
The Job of the Anesthesiologist

- Induce unconsciousness/amnesia.
- Provide analgesia.
- Maintain a quiescent surgical field.
- Optimize hemodynamic function and organ/tissue perfusion.
- Avoid volume excess, including lung fluid accumulation.
Things That Worry the Anesthesiologist

• Underlying medical conditions
  • CAD and CHF.
  • Aortic stenosis.
  • Asthma.
  • Pulmonary hypertension.
  • Renal insufficiency.

• Response to the surgical procedure
  • Effects of anesthesia.
  • Sympathetic stimulation.
  • Blood loss and fluid shifts.
Fundamental Difficulty

• Usual physiologic response to hypovolemia in a conscious person is vasoconstriction and tachycardia.

• These responses can compensate and mask underlying intravascular depletion until 10-20% blood loss.

• These mechanisms are blunted or abated by anesthesia, making estimates of volume loss more complex—static measures aren’t accurate.
Fundamental Difficulty

• So how can we monitor and maintain intravascular volume?
• The short answer—it’s complicated.
• We’ll talk about the longer answer.
• For Mr. Hip, we need to determine if he has too much or too little fluid and what to do about it.
First, let’s look at some physiology…
Review of Physiology

• Cardiac output = SV x HR.
• SV is a function of preload, afterload, and contractility.
• Blood pressure is a function of CO and SVR.
• Reduced tissue perfusion can be due to low cardiac output or vasoconstriction of organs.
Reduced tissue perfusion can be seen with hypovolemia, euvolemia, or hypervolemia!
Frank-Starling’s Law

- Normal Range, SV Increases with EDV
- More Blood in Heart Means More Gets Pumped Out!
- Maximum EDV, Maximum SV
- Too Much Volume = Decreased SV

Stroke Volume vs. End-Diastolic Volume
So what does this mean?

• The foundation for cardiovascular function:
  • Maintenance of proper intravascular volume
  • Maintenance of ventricular preload (end diastolic volume) and SV.

• The anesthesiologist must carefully control the volume and preload/SV during the surgical procedure, and avoid extravascular excess.
More Physiology (!)
Starling Forces Inside Capillary

Blood Flow

Capillary

Hydrostatic Pressure

Oncotic Pressure

Excess Fluid Enters Lymphatics

Lymphatic Vessel

To Venous Circulation
Distribution of Body Fluid: Normal

- Intracellular Fluid Volume: 66%
- Extracellular Fluid Volume: 34%
  - ISFV: 75%
  - PV: 25%
- Third-Spaced Fluid: Negligible
What if the patient has an injury or surgery?
Third Spacing

• Analogous to hitting your thumb with a hammer—local tissue swelling.
Distribution of Body Fluid: Acute Injury

Intracellular Fluid Volume
Extracellular Fluid Volume
Third-Spaced Fluid

ISFV
PV

Site of Injury
More About Third Spacing

• Likely mechanism is tissue trauma and increased vascular permeability ("leakiness") due to surgical inflammation (release of IL6, IL8, TNF-α).

• Mostly a temporary phenomenon that persists for 1-3 days with subsequent fluid mobilization (may take longer in elderly patients).

• Lymphatics are initially overwhelmed, then can catch up and remove fluid.
More About Third Spacing

- Where exactly is the “third space?”
- No one really knows! (Is it real?)
- Tracer methods to look for blood or fluid extravasation and shifts have been inconsistent.
- The third space may simply be the interstitium or sequestered fluid.

What if we give IV fluids?
IV Fluids and Third Spacing

- Most IV crystalloid “leaks” out of the intravascular space into the interstitium.
- Thus, the more IV fluid given to replete the vascular space, the more third-spacing (or at least shifting from the intravascular space to the interstitium) will occur!
More About IV Fluid Therapy

- Crystalloid (NS, LR) replacement
  - 3:1 if small blood loss
  - But geometric increase in transcapillary leakage with higher blood loss (less alb)
    - 5:1 if 35% blood loss!
    - 16:1 if 75% blood loss!!

- Blood, colloid
  - Replace 1:1

Distribution of Body Fluid: IV Fluid Infusion

Blood pressure improves as PV increases...

Intracellular Fluid Volume

Extracellular Fluid Volume

PV

ISFV

Third-Spaced Fluid

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### Blood vs IV Fluids

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<thead>
<tr>
<th>Fluid</th>
<th>Na mEq/L</th>
<th>Cl mEq/L</th>
<th>K mEq/L</th>
<th>Ca mEq/L</th>
<th>Bicarb mEq/L</th>
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<td>100</td>
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<td>290</td>
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<tr>
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<td>154</td>
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<td>0</td>
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<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>50</td>
<td>308</td>
</tr>
</tbody>
</table>

Note: Calcium 5 mEq/L x 1L/10dL x 40 mg/mmol x 1mmol/2mEq = 10 mg/dL
IV fluids are IV drugs!

- “The selection, timing, and doses of intravenous fluids should be evaluated as carefully as they are in the case of any other intravenous drug, with the aim of maximizing efficacy and minimizing iatrogenic toxicity.”

Controversy: Crystalloid vs Colloid

• Crystalloids are solutions of crystalline substance such as NaCl, KCl, or glucose in water.

• Colloids are expensive suspensions of macromolecules (not solutions) in a water- or saline-based medium (albumin, hetastarch, dextran).

• Colloids theoretically stay in vascular space, but no consistent benefit.
Controversy: Crystalloid vs Colloid

• Only about 20-25% of LR and NS stay in circulation (about 1-4 h) vs 70-100% of albumin 5% (12-24 h) and 100-200% of hetastarch (8-36 h).*

• High volumes of NS can cause hyperchloremic NAGMA.*

• Cl⁻ vasoconstricts, may ↓ splanchnic and renal blood flow, LR may be best crystalloid in many situations, but may cause hyponatremia.

*Am J Respir Crit Care Med 2004;170:1247-1259
Perioperative Fluid Theory
A Tough Act

- The anesthesiologist has to ensure enough fluid to maintain intravascular volume and SV…
- …while avoiding volume excess.
- This is especially critical for underlying medical conditions like heart failure and CKD.
- Remember that static measures aren’t helpful to assess volume.
Five Phases of the Perioperative Period

• Pre-op dehydration phase.
• Shock phase causing absolute hypovolemia in extracellular space
  • Vasoconstriction.
  • Shunting of blood to vital organs.
  • Decreased capillary hydrostatic pressure.

Five Phases of the Perioperative Period

• Relative and absolute hypovolemic phase (as a consequence of vasodilatation, fluid sequestration from increased capillary permeability, and blood loss).

• Diuresis phase (“mobilize fluid”).

• Equilibrium phase (POD 2).

Dehydration vs Hypovolemic vs Relative Volume Depletion

• Dehydration: loss of free water, leads to ↑ [Na+].
• Hypovolemia: loss of both water and electrolytes/proteins, or blood.
• Relative volume depletion: dilation of blood vessels without necessarily losing fluid.
Controversy—Different Strategies to Replace Intravascular Volume Losses

- **Liberal/traditional fluid**
  - Typically formula-based.
  - Idea is to maintain hemodynamics and perfusion above all else.

- **Restrictive/zero balance fluid**
  - New thinking over last decade.
  - Idea is to minimize tissue edema while optimizing perfusion.

- **Goal-directed therapy/Hybrid**
  - Use intraoperative TEE to monitor SV.
What about fluids for hip surgery patients?

• “Five studies including a total of 403 participants provided no evidence that fluid optimization strategies improve outcomes for participants undergoing surgery for proximal femur fracture.

• Further research powered to test some of these outcomes is ongoing.”

Perioperative Fluid Losses

• Pre-operative losses.
• Intraoperative losses.
• Postoperative losses.
• Fluids need to be given to compensate for these losses.
Intraoperative Fluid Losses

• Induction of anesthesia (relative loss)
  • Causes decreased venous return
    • Decreased SVR (vasodilation).
    • Reduced myocardial contractility.
  • Effects are from inhalation, IV anesthetic agents, and spinal anesthesia.
  • Also can be due to positive pressure ventilation and many muscle relaxants.
Intraoperative Fluid Losses

- Other factors that alter venous return and vascular tone (relative loss)
  - Patient positioning.
  - Surgical packing and retraction.
  - Patient temperature.
  - Orthopedic bone cement (causes significant vasodilation).
Intraoperative Fluid Losses

- Direct fluid requirements
  - Maintenance fluids.
  - Insensible losses (evaporation from the surgical exposure and respiratory losses).
  - Bleeding.
  - Fluid shifts ("third spacing").
Maintenance Fluids

• Estimate as 1 cc per kg per hour plus 40 cc per hour (one approach).
• For a 100 kg patient, this is 140 cc per hour.
• The patient’s NPO time should be compensated with additional real-time maintenance fluid.
Compensation for Third Spaced Fluid and Insensible Losses

- Different surgeries have different estimated compensation requirements (cc/kg/h):
  - Minimal trauma, 2–4 cc/kg/h
  - Moderate trauma, 4–6 cc/kg/h
  - Extensive trauma, 6–12 cc/kg/h

This Formula-Based Approach May Not Always Be Best

Other Concerns

- Transient intra-op hypotension may require fluid boluses and/or vasopressors
  - Excessive bleeding.
  - Bone cement.
  - Change in patient position.
  - Release of tourniquet (inrush of blood plus lactic acidosis).
  - Marrow fat emboli during reaming.
Other Indications for Fluid Administration

- Medications.
- Need for coagulation factor transfusion.
- Endotoxin and sepsis.
- Allergic or anaphylactic reactions.
- Electrolyte imbalance.
- Acid-base balance.
- Nutrition and glucose requirements.
What about the need for fluids after surgery?

The Role of the Hospital Provider
Postoperative Fluid Losses

• Continued capillary leakage for 24-36 hours (postoperative inflammation).
• Ongoing bleeding.
• Surgical drains.
• Poor po with nausea and vomiting.

Postoperative Fluid Losses

- Evaporative losses.
- NG tube.
- Urine output.
- Diarrhea.

How to determine post-op intravascular volume?
Usual Assessment of Intravascular Volume: Exam

- **Too little:**
  - Blood pressure and heart rate.
  - Orthostatics.
  - Dry mucous membranes.
  - Loss of skin turgor.
  - Dark urine color, decreased output.

- **Too much:**
  - Lung crackles.
  - Jugular venous pressure/AJR.
  - S3.
  - Peripheral edema.
Usual Assessment of Intravascular Volume: Tests

• Laboratory studies
  • Serum sodium.
  • BNP.
  • BUN:creatinine ratio.
  • Urine indices (electrolytes, osm, SG).

• Imaging studies
  • CXR.
  • Chest CT.
Are these helpful post-op?

• Exam findings may **not** be helpful
  • BP and HR increased due to surgical stress, pain, anxiety.
  • Orthostatics not reliable if bedbound.
  • Mucous membranes not helpful if NPO.
  • Urine output not always helpful, as we’ll see.
What about weight?

• Many authorities suggest this is best way to assess volume changes.

• 10% gain above preoperative weight, has been associated with increased morbidity, length of ICU stay, and postoperative mortality.*

• Personal experience--many sources of error, but can be helpful.

Use of Echocardiography to Estimate Intravascular Volume

https://web.stanford.edu/group/ccm_echo/cardio/cgi-bin/mediawiki/index.php/IVC
Use of Echocardiography to Estimate Intravascular Volume

https://web.stanford.edu/group/ccm_echo_cardio/cgi-bin/mediawiki/index.php/IVC
What about post-op urine output?
Profound Quotes from Smart People

“Intraoperative oliguria, defined as urine output less than 0.5 ml/kg/h, was not associated with renal failure.”

“Intraoperative urine formation depends on a number of factors and is an insensitive and unreliable method for assessing postoperative risk of renal dysfunction.”

“Low hourly urine flow (<0.5 mL/kg/hr) is a marker in some widely used criteria to diagnose AKI but is not a meaningful assessment to make this diagnosis in the immediate perioperative period.”

“Postoperative oliguria should be expected and accepted, as urine output does not indicate overall fluid status.”

“Our findings support the hypothesis that ARF is not prevented by striving toward a predefined urine output target.”

"…fluid administration solely for the purpose of increasing urine output is not indicated and may lead to fluid overload."

GP Joshi. Intraoperative fluid management. UpToDate 2016.
Say what?!?
Urine Output

• Multiple factors may affect urine output
  • Intravascular depletion (↓)
  • Natural Na and water conservation (↓)
  • AKF (↓)
  • Diuretics (↑)
  • Hyperglycemia (↑)
  • Volume overload (↑)
Response to Blood Loss and Hypovolemia

• Anti-Diuretic Hormone--natural protective measure to conserve Na and water.
• Helps the body to maintain cardiac output and organ perfusion.
Anti-Diuretic Hormone

- Stimulated by volume contraction, hypotension, pain, N/V, opioids, and...

**SURGICAL STRESS AND POSITIVE-PRESSURE VENTILATION**

- Also, two very common drugs potentiate the renal action of ADH...

**NSAIDs AND ACETAMINOPHEN**
Anti-Diuretic Hormone

• The result of ↑ ADH is…
  
  DECREASED URINE OUTPUT.

• So how useful is measurement of urine output to determine intravascular volume status?

• May be a reasonable surrogate marker if you understand the timing of expected fluid shifts.
Expected Urine Output

- Decreases during surgery and immediately following surgery (↑ ADH).
- Should increase over the next 12-24 hours post-op as surgical stress resolves and hormonal mechanisms normalize.
- Should increase significantly with fluid mobilization around day 2-3 as inflammation/capillary permeability subsides (longer in elderly patients).
Expected Urine Output

- Multiple factors can change this:
  - Large intra-op blood loss.
  - Patient took diuretic pre-op.
  - Prolonged hypotension.
  - Acute kidney injury/failure (ATN most common).
  - Massive tissue trauma with on-going hemorrhage and third spacing.
  - Low albumin (acute phase reactant vs poor nutrition).
For postoperative patients with decreased urine output…

• Best treatment is to give fluids only if clinical volume depletion or true oliguria, or else risk for pulmonary edema (more later).

• Otherwise, may need to limit free water to minimize hyponatremia related to ADH.

• Periodically check creatinine.

• No need for concern unless creat is increasing—no kidney failure if creat is normal unless remains oliguric/anuric.
In immediate postop setting, low urine output does not equal acute kidney failure!
For postoperative patients with decreased urine output…

• Remember, post-op patients are trying to conserve Na and water with increased ADH.

• No need to check urine output every hour, just monitor over 6-12 hour period.
However…

• Caution if true oliguria (<400 cc in 24 hours).

• Change in creat can lag behind insult, so be aware of possible AKI/AKF.
  • Preop risk factors (CKD, DM)?
  • Periop insults (hypotension, volume loss)?

• May consider checking NGAL if concern and risk factors for AKI/AKF (see Appendix).
What about furosemide?

• For patients who chronically take furosemide, I usually hold it the day of and the day after surgery (unless acute HF).

• Do not routinely give furosemide just because of low urine output.

• Even if intravascular volume depletion, furosemide can increase urine output!

• Monitor creat, BUN, and bicarb when giving furosemide to help determine if intravascular depletion.
What if low urine output makes you nervous?

- If low UOP despite normal vitals and creat, can give tiny doses of furosemide 5 mg IV to counter effects of ADH.
- No evidence that furosemide improves outcomes in AKF*, but does not appear to increase mortality.**
- May be useful in patients at risk for fluid overload as they begin to mobilize third-spaced edema.

*KM Ho and DJ Sheridan, Meta-Analysis of Frusemide to Prevent or Treat Acute Renal Failure. BMJ 2006.

When to give furosemide?

- Pulmonary edema is major indication
  - Arieff and colleagues suggest that fluid retention >67 mL/kg/day can lead to pulmonary edema within the initial 36 hours post-op.*

- Also in post-op hypertension despite usual meds and adequate pain control (if evidence of intravascular volume overload).

When to give furosemide?

• Patients with conditions like heart failure, chronic kidney disease, and mitral stenosis are at higher risk to develop pulmonary edema.

• Patients with cardiac ischemia/AMI post-op may also develop pulmonary edema.
When to give furosemide?

• These high-risk patients may need cautious diuresis beginning 18-24 hours post-op, especially as they begin to “mobilize” the third-spaced fluid 1-3 days post-op (use caution in patients with severe aortic stenosis).

• Fortunately, most healthy patients will “auto-diurese” the extra fluid with no problems.
Back to our patient, Mr. Hip…
Intra-op Fluid Therapy (Crystalloid)

- NPO compensation is 140 cc for 8 hours = 1120 cc. Replace ½ the deficit in the first hour, then ¼ over each of the next two hours.
- Intra-op maintenance for a 3 hour surgery is 140 cc x 3 = 420 cc.
- Blood loss (3:1) = 3 liters NS or LR (could consider 1:1 colloid instead).
- Medications = 260 cc.
Intra-op Fluid Therapy (Crystalloid)

• Compensation for hypotension at induction, with bone cement, and transient episodes = 1000 cc (could consider phenylephrine also).

• Fluid for third spacing and insensible losses = 500 cc/h for three hours = 1500 cc.

• Total intra-op fluid administration = 1120 + 420 + 3000 + 260 + 1000 + 1500 = 7300 cc!

• Net = 7300 – 1300 (EBL + UOP) = 6000 cc!
Intra-op Fluid Therapy

• Almost all of the fluid given in this case was "appropriate" to compensate for pre-op and intra-op losses.

• The fluid was necessary to maintain adequate tissue perfusion with the goal of being euvolemic.
Answer to the First Case

• Mr. Hip is **hypotensive** in the setting of surgery with low urine output.

• He took his usual atenolol, plus he may have effects of anesthesia and opioids.

• Despite being 6 L fluid positive, concern for intravascular volume depletion, possibly bleeding.
What is the most appropriate initial treatment?

A. Call the anesthesiologist and yell at him/her for drowning your patient.
B. Give furosemide 40 mg IV STAT.
C. Monitor for another 12 hours because decreased urine output is expected in the immediate post-op period.
D. Give fluid bolus of 500 cc over 1 hour, repeat if necessary.
E. Check a UA and consult Nephrology.
Answer to the Second Case

• Mr. Hip is normotensive in the setting of surgery and low urine output.

• This most likely represents the effect of increased ADH.

• He does not need any specific treatment at this time.

• He should be closely monitored to make sure his UOP improves as expected.
What is the most appropriate initial treatment?

A. Call the anesthesiologist and yell at him/her for drowning your patient.
B. Give furosemide 40 mg IV STAT.
C. Monitor for another 12 hours because decreased urine output is expected in the immediate post-op period.
D. Give fluid bolus of 500 cc over 1 hour, repeat if necessary.
E. Check a UA and consult Nephrology.
Post-Test Questions—What Have You Learned?
Question #1: Which one of the following is true?

A. Most IV crystalloid “leaks” out of the intravascular space into the interstitium.

B. Induction of anesthesia causes relative intravascular hypervolemia.

C. It is best to avoid IV fluids post-op since patients get sufficient fluid during surgery.
Question #2: All of the following are true except

A. Urine output (UOP) is expected to decrease during surgery.
B. UOP generally increases around POD 2.
C. Low UOP post-op means acute kidney injury.
D. Perioperative urine output does not correlate with intravascular volume status.
Question #3: Which is the best scenario to give furosemide?

A. Post-op low urine output.
B. Post-op lower extremity edema.
C. Post-op pulmonary edema.
D. Always continue furosemide perioperatively if patient takes it chronically.
Take-Home Point #1

• The goal of perioperative fluid management is to maintain tissue perfusion without excess extravascular fluid.
Take-Home Point #2

• Basic physiologic principles, including the Frank-Starling curve, govern intravascular volume status
  • CO = SV x HR.
  • Frank-Starling curve.
  • Starling forces inside capillaries.
  • Distribution of body fluids and third-spacing.
Take-Home Point #3

• Urine output is not an accurate gauge of intravascular volume, but may be a reasonable surrogate based on timing of expected fluid shifts.
Finally…

- The need for post-op fluid restriction and diuresis is NOT evidence of excess fluid administration, but rather of altered time- and disease-related pathophysiology.

- “You have to give what the patient is asking for in the moment and then deal with the consequences. Most kidneys are smarter than most humans.”

--David Morris, MD.
Remember…

• Anesthesiologists do NOT intentionally “drown” our patients!

• In your preop evaluation, do not say “avoid fluid overload”—the anesthesiologists know this!
Summary of What I Do

• Monitor hemodynamics and pulmonary status, may need IVF.

• Calculate ins and outs, check weights.

• Watch urine output to make sure trend is as expected.

• Monitor creatinine.

• If chronically on a diuretic, resume around POD 1-2 as allowed by hemodynamics.

• May need diuretic if pulmonary edema or HTN.
As hospital-based providers, we should understand and acknowledge the work of our anesthesia colleagues, and we should provide appropriate post-op monitoring.
Minnesota Fluid Theory
With your excellent medical care, we can get our patients back in the game...
Thank you for your attention!
Questions?

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Appendix
NGAL

• Urine NGAL: Neutrophil Gelatinase-Associated Lipocalcin.

• Produced and secreted by kidney tubule cells at low levels.

• Amount produced and secreted into the urine increases dramatically after ischemic, septic, or nephrotoxic injury of the kidneys.
NGAL

• Analogous to troponin—can detect kidney injury within 2 hours after ischemic injury associated with cardiac surgery or after contrast-induced nephropathy.

• Elevation precedes increase in creat by 12 to 24 hours.

• Highly predictive of the subsequent development of acute kidney injury.
NGAL

• So, if decreased urine output and concerning history (CKD, prolonged hypotension during surgery, severe sepsis, contrast dye or other nephrotoxic meds like NSAIDs, etc):
  • Consider checking NGAL.
  • Make sure volume replete.
  • Treat as if AKI/AKF while closely monitoring (kidney diet, adequate blood pressure, avoid nephrotoxic meds, adjust med dosages).
Excellent Reviews of Perioperative Fluid Management


• GP Joshi. Intraoperative fluid management. UpToDate 2016.
Controversy: Crystalloid vs Colloid


• “Among ICU patients with hypovolemia…colloids vs crystalloids did not result in a significant difference in 28-day mortality.”
Controversy: Crystalloid vs Colloid


- “In patients with severe sepsis, albumin replacement in addition to crystalloids, as compared with crystalloids alone, did not improve the rate of survival at 28 and 90 days.”
• Hydroxyethyl Starch Solutions: FDA Safety Communication - Boxed Warning on Increased Mortality and Severe Renal Injury and Risk of Bleeding June 11, 2013
  
  • Do not use HES solutions in critically ill adults.
  • Avoid if pre-existing renal dysfunction.
  • Discontinue at first sign of AKI or coagulopathy.
  • Need for renal replacement therapy has been reported up to 90 days after HES administration. Monitor renal function for at least 90 days in all patients.
  • Avoid use in open heart surgery with CPB due to excess bleeding.
Additional References and Further Reading


Additional References and Further Reading


