Objectives

- Understand the current controversies of periop fluid therapy for major elective surgery
- Discuss the consequences of perioperative hypo- and hypervolemia
- Explain the benefits and limitations of fluid minimization and goal-directed fluid therapy
- Recommendations for perioperative fluid therapy for major elective surgery

Perioperative Fluid Therapy

- Fluid therapy for elective surgery ≠ Fluid therapy for emergent or trauma surgery
- Fluid therapy for major surgery ≠ Fluid therapy for mild-to-moderate surgery

Intravascular Volume Is Depleted in the Intraoperative Period?

- Preoperative fasting
- Bowel preparation
- Intraoperative losses
  - Blood loss
  - Evaporation
  - Third spacing
- General and regional anesthesia
  - Vasodilatation

Current Perioperative Fluid Therapy

- We have become desensitized to administration of high fluid volumes (5-6 liters for major surgical procedures)
- Patients typically gain 5 kg of body weight after major surgical procedure
Perioperative Crystalloid Administration and Postoperative Weight Gain


Perioperative Hypervolemia: Postoperative Morbidity and Mortality

- Perioperative hypervolemia increases postoperative morbidity and mortality
- Perioperative fluid overload is a contributory cause of postoperative complications and death
  - National Confidential Enquiry into Perioperative Death (http://www.ncepod.org.uk)

Postoperative Fluid Overload: Not a Benign Problem


Variation in Intraoperative Fluid Administration


Consider Fluids as Drugs, and Dose Them Appropriately!

“Poison is in everything, and no thing is without poison. The dosage makes it either a poison or a remedy.”

Paracelsus (Philippus Theophrastus Aureolus Bombastus von hohenhein), 16th century

Current Perioperative Fluid Therapy
### 4-2-1 Algorithm For Fluid Administration

<table>
<thead>
<tr>
<th>Time</th>
<th>Compensatory (ml)</th>
<th>Deficit (ml)</th>
<th>Maintenance (ml)</th>
<th>Blood Loss (ml)</th>
<th>Third Space (ml)</th>
<th>This Hour (ml)</th>
<th>Cumulative (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preinduction</td>
<td>350</td>
<td>220</td>
<td>110</td>
<td>0</td>
<td>0</td>
<td>680</td>
<td>680</td>
</tr>
<tr>
<td>Preinsection</td>
<td>-</td>
<td>220</td>
<td>110</td>
<td>0</td>
<td>0</td>
<td>330</td>
<td>1010</td>
</tr>
<tr>
<td>1st Hour</td>
<td>-</td>
<td>220</td>
<td>110</td>
<td>300</td>
<td>350</td>
<td>980</td>
<td>1990</td>
</tr>
<tr>
<td>2nd Hour</td>
<td>-</td>
<td>220</td>
<td>110</td>
<td>300</td>
<td>350</td>
<td>980</td>
<td>2970</td>
</tr>
<tr>
<td>3rd Hour</td>
<td>-</td>
<td>0</td>
<td>110</td>
<td>150</td>
<td>350</td>
<td>830</td>
<td>3800</td>
</tr>
<tr>
<td>Any Hour</td>
<td>-</td>
<td>0</td>
<td>110</td>
<td>0</td>
<td>200</td>
<td>330</td>
<td>4130</td>
</tr>
</tbody>
</table>

Kaye AD, Kavara AJ. In Miller RD Editor, Anesthesia, 6th Ed, 2005, pp. 1763-98

### Algorithm-Based Fluid Administration

- Non-anatomical “third space” does not exist
  - Brandstrup et al: Surg 2006; 139: 419-32
- Fluid volume accumulated in traumatized tissue is very small
- evaporative losses from abdominal cavity are small
  
  Brandstrup B. Best Practice & Research Clinical Anaesthesiology 2006; 20: 265-83

### Replacement of Blood Loss With Crystalloids

- Blood loss replaced with crystalloids in 1:3 ratio
- Increased survival of animals in hemorrhagic shock after resuscitation with 3X crystalloids
- Studies of goal-directed therapy suggest crystalloid-to-colloid volume ratios of 1.8-2
  - Perel P, Roberts I. Cochrane Database Syst Rev 2009; CD000567
- SAFE study: crystalloid vs. colloid ratio 1:1.4

### Crystalloids Versus Colloids: Exploring Differences in Fluid Requirements by Systematic Review and Meta-Regression

- Greater fluid volumes are required to meet the same targets with crystalloids than colloids with estimated ratio of 1.5

### Static Monitoring For Assessment of Intravascular Volume

---

*What gets us into trouble,*
*Is not what we don’t know.*
*It’s what we know for sure.*
*That just ain’t so.*

Mark Twain
Unreliable Indicators of Plasma Volume Status

- Heart rate
- Mean arterial blood pressure
- Central venous pressure
  - CVP or PAOP
- Urine output


No Association Between CVP and Blood Volumes

- 1500 simultaneous measurements of blood volume and CVP (r = 0.27).


Intraoperative Urine Output and Postoperative Acute Renal Failure

- Origin of the recommendation of urine output of >0.5 ml/kg/h unknown
- Reduced intraoperative urine output is neither a trigger nor a predictor of acute renal failure
- No correlation between urine output and ARF

Urine Output Reduced During Inhalation Anesthesia

- Crystalloids infused during inhalation anesthesia lead to fluid accumulation
- Ratio of interstitial fluid volume to urine output increases 6-fold


Urine Output: An Indicator if Intravascular Volume Status?

- Urine flow rate reliable indicator of changes in BV after blood withdraw (10ml/kg)
- No increase in urine flow after colloid administration (10 ml/kg)
  - "urine flow can act as an early sign of bleeding or hypovolemia, but not as a tool to define the end of resuscitation."

Shamir MY et al: Anesth Analg 2011; 112: 593-6

Crystalloids: An Iatrogenic Source of Multiple Organ Failure?

- Administration of crystalloids to achieve adequate urine output may cause multiorgan failure
  - "While renal failure is avoided, abdominal compartment syndrome resulting in multiple organ failure is increased"


Crystalloids: An Iatrogenic Source of Multiple Organ Failure?
Dynamic Monitoring For Assessment of Intravascular Volume

Goal Directed Fluid Therapy Using Dynamic Monitoring

- Static (HR, BP, CVP, PAOP) are single-point “snapshots”
- Dynamic indicators are predictors of fluid responsiveness
- Variation in PP, SBP, or SV, are ‘virtual’ preload challenges occurring during each respiratory cycle in ventilated patients

Volume Responsiveness to Guide Fluid Therapy

Hemodynamic Monitors

- Bioimpedance/Bioreactance
- Esophageal Doppler
- LiDCO rapid
- LiDCO plus
- PICCO
- PAC
- Tissue Oxygenation

NHS Improving Quality in collaboration with NHS England
Enhanced recovery care pathway
A better journey for patients seven days a week and better deal for the NHS
Progress review (2012/13) and level of ambition (2014/15)

Oesophageal Doppler and calibrated pulse contour analysis are not interchangeable within a goal-directed haemodynamic algorithm in major gynaecological surgery

Editor’s key points
- Stroke volume (SV) measurements on common care path do not correlate.
- SV in previous study, the patient after a fluid challenge.
- No method was associated with adequate haemodynamic control.
- No association with outcome endpoints.
- Oesophageal Doppler and pulse contour analysis are not interchangeable.
- Clinical equipoise exists between the two approaches.

Oesophageal Doppler and calibrated pulse contour analysis are not interchangeable within a goal-directed haemodynamic algorithm in major gynaecological surgery

Joshi, Girish, MB, BS, MD, FFARCSI

Fluid Therapy for Major Surgery
Nexfin Noninvasive Continuous Cardiac Output Monitor

Non-invasive Monitoring for Respiratory Variations: Pulse Oximetry

Systolic Pressure Variation: “Eyeball” Technique

The Ability of Anesthesia Providers to Visually Estimate Systolic Pressure Variability Using the “Eyeball” Technique

Systolic Blood Pressure Variation: Visual Estimation

Systolic Blood Pressure Variation: Visual Estimation

Visually True and Estimated Systolic Pressure Variation

Anesthesia providers (n=50) asked to visually examine 10 recorded arterial waveform tracings
- Estimate SPV as percentage
- Decision to administer or not to administer fluid bolus
- Fluid administration appropriate of SPV>14.5%
- Estimates of SPV within clinical limits in 82%
- Physician decisions to administer fluid were incorrect in 4.4% occasions

Limitations of Dynamic Indicators

- Spontaneous breathing
- Open chest
- Low tidal volumes <8 ml/kg
- High PEEP
- High respiratory rate
- Sustained cardiac arrhythmias
- Right ventricular failure
- Laparoscopic procedures
**Monitoring Truth**

No monitoring device, no matter how accurate or insightful its data will improve outcome, Unless coupled to a treatment, which itself improves outcome

Pinsky & Payen: Functional Hemodynamic Monitoring, 2004

---

**Fluid Minimization Therapy**

- Eliminate preloading
- Eliminate replacement of “third space”
- Eliminate replacement of urine output
- Use of colloids to replace blood loss
- Maintain postoperative weight gain < 1 kg
  - Body weight gain > 1 kg treated with furosemide


---

**Perioperative Fluid Therapy: Zero Balance Vs. Standard Practice**

- Individualized fluid therapy that adapts to changing patient needs during the periop period
- Goal: maximize tissue $O_2$ delivery with minimal cardiac $O_2$ consumption
  - Optimal goal remains to be determined
  - Stroke volume most commonly used
- Prevents subtle hypovolemia and hypervolemia that might lead to organ dysfunction, increase perioperative complications, and delay recovery

---

**Goal-Directed Fluid Therapy**

- Compared with traditional fluid therapy guided by static indicators, restrictive and goal-directed therapy
  - Early recovery of GI function
  - Reduced PONV
  - Decreased complications
  - Reduced critical care admission
  - Reduced ICU stay
  - Reduced hospital stay

**Perioperative Goal-Directed Hemodynamic Therapy**

- High-risk patients randomized to CO-guided hemodynamic therapy algorithm for IV fluid and inotrope (dopexamine) infusion during and 6 h after surgery (n=368) or to usual care (n=366)
- No difference in composite outcome of complications and 30-day mortality


**Cardiac Output-Guided Hemodynamic Therapy and Outcomes After Major GI Surgery**

- Randomized controlled trial (n=730) comparing CO-guided hemodynamic therapy algorithm for fluid and inotrope (dopexamine) infusion vs standard of care
- No difference between groups in primary outcome of composite of 30-day moderate-to-major complications
- No significant difference between groups for any secondary outcomes


**Cumulative Incidence of 180-day Mortality: Cardiac Output–Guided Hemodynamic Therapy Algorithm Intervention Vs. Standard Care**


**Stroke Volume Optimization and Perioperative Outcome**

- Elective bowel surgery
- Algorithm-driven SV optimization is of no benefit when superimposed on liberal baseline fluid regime
- NICE recommendation for intraop CO monitoring are not appropriate


**Goal Directed Fluid Therapy: Meta-analysis**

- Patients treated with GDT received a greater volume of colloids and smaller volume of crystalloids compared with patients not treated with GDT
- GDT is beneficial mainly when used outside ERAS programs and in patients undergoing colorectal surgery


**Goal For Fluid Therapy: Stroke Volume vs. Zero Fluid Balance**

- Double-blind, multi-center study (n=150) in patients undergoing elective colorectal surgery (lap and open)
  - Fluid therapy based on achieving max stroke volume
  - Zero balance (restricted approach)
- Postop weight increase similar (~ 1kg)
- Overall, major, minor cardiopulmonary, tissue healing complications, and LOS stay similar

Crystalloids Versus Crystalloids

Crystalloids Versus Crystalloids

Goal-Directed Fluid Therapy: Current Controversies

- Implementation of enhanced recovery protocols which include avoidance of preoperative mechanical bowel preparation, preoperative hydration/carbohydrate loading, aggressive ambulation may influence the need for minimally invasive (or non-invasive) CO monitors
- Role of these monitors in laparoscopic procedures controversial

Crystalloids Versus Colloids

Goal-Directed Fluid Therapy: Crystalloids Vs. Colloids

- High-risk patients undergoing colorectal surgery randomized to receive HES 6% (n=104) or crystalloid (n=98) for hemodynamic optimization using Lidco
- Crystalloid group received more fluids (3175 ml vs. 1875 ml) and higher 24-h fluid balance (+4226 vs. +3610)
- No difference in GI morbidity on POD 5
- No difference in overall complication rate


Normal Saline: Hyperchloremic Acidosis

Background: Several different crystalloid solutions are available for IV fluid administration but there is little information about their specific advantages and disadvantages. Methods: We performed a systematic search of MEDLINE, EMBASE, and COCHRANE up to May 12, 2013, selecting all prospective human studies that directly compared any two crystalloid solutions and reported any outcome. Results: From the 968 citations retrieved in the search, only 28 met the selection criteria. There was considerable heterogeneity among the studies. Several articles reported an increased incidence of hyperchloremic acidosis with the use of normal saline, and showed an increase in bicarbonate administration. Normal saline had a greater effect on plasma bicarbonate levels and serum bicarbonate concentrations than other crystalloid solutions. Conclusion: Different solutions have different effects on acid-base status, electrolyte levels, coagulation, renal, and hepatic function. Whether these differences have clinical consequences remains unclear.
Approaches to Optimize Intravascular Volume and Avoid Fluid Overload

Fluid Overload Avoided By Modifying Anesthetic Technique
- Avoid overdose of sedative-hypnotics, analgesics, which will mandate fluid administration to maintain blood pressure
- Avoid large tidal volumes and high peak pressures
  - Reduce venous return and cardiac output
  - Hypocapnia/alkalosis may reduce sympathetic output
  - Hypercapnia increases subcutaneous and colonic $O_2$ tension during abdominal surgery
- Fleischmann et al. Anesthesiology 2006;104:944-9

Summary
- Fluid therapy is often based on dogma and personal beliefs
- Patients commonly receive large amounts of crystalloids in the perioperative period
- Excessive fluids increase perioperative morbidity and mortality
- Avoid preop dehydration (encourage preop oral fluids and avoid bowel prep)
- Early optimization may be critical (proactive rather than reactive approach)

Fluid Minimization Approach
- Eliminate algorithm use (i.e., preloading and replacement of “third space”)
- Blood loss should be replaced with colloids or crystalloids based on volume responsiveness
- Avoid fluid administration based upon static indicators (HR, MAP, CVP)
- Role of CO monitors in modern practice remain questionable
- Need to follow postop, avoid weight gain > 1kg