Goal-Directed Fluid Therapy: A New Way of Thinking

Ji Su Jenny Kim & Logan D. MacLean
SRNA, BSN, CCRN
DNP Candidates
Goal-Directed Fluid Therapy Therapy Map

- History of Fluid Management
- Significance of Fluid Management
- Fluid Compartment Physiology
- Traditional Theories of Fluid Management
- Fluid Management Indicators & Interventions
Why Should I Care?
Goal-Directed Fluid Therapy Map

- History of Fluid Management
- Significance of Fluid Management
- Fluid Compartment Physiology
- Traditional Theories of Fluid Management
- Fluid Management Indicators & Interventions
Hypovolemia  Hypervolemia
Hypovolemia Complications

- Low cardiac output
- Decreased tissue perfusion
- Shock/organ failure

## Why Should I Care?

<table>
<thead>
<tr>
<th>Surgical Procedure</th>
<th>Anesthetics</th>
<th>Patient-related</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgical procedure</td>
<td>Excessive fluid administration</td>
<td>Age &gt; 65 yr</td>
</tr>
<tr>
<td>Vascular</td>
<td>Blood transfusion (&gt;4 units)</td>
<td>ASA physical status &gt; 2</td>
</tr>
<tr>
<td>Thoracic</td>
<td>Residual neuromuscular blockade</td>
<td>History of respiratory disease</td>
</tr>
<tr>
<td>Upper abdominal</td>
<td>Intraoperative hypothermia</td>
<td>OSA</td>
</tr>
<tr>
<td>Neurosurgery</td>
<td>Use of NG tube</td>
<td>Preoperative SpO2 &lt; 96%</td>
</tr>
<tr>
<td>Head and neck</td>
<td>Inadequate ventilator settings</td>
<td>History of CHF</td>
</tr>
<tr>
<td>Emergency procedure</td>
<td>Recent respiratory infection (&lt;1 mo)</td>
<td></td>
</tr>
<tr>
<td>Reintervention</td>
<td>Partial or total functional dependency</td>
<td></td>
</tr>
<tr>
<td>Surgical duration &gt; 2h</td>
<td>Active smoking</td>
<td></td>
</tr>
<tr>
<td>Open laparotomy &gt; laparoscopy</td>
<td>Alcohol abuse</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Preoperative sepsis</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Weight loss &gt; 10% in the last 6 months</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Preoperative anemia (&lt;10g/dl)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Obesity</td>
<td></td>
</tr>
</tbody>
</table>

Goal-Directed Fluid Therapy Map

- History of Fluid Management
- Significance of Fluid Management
- Fluid Compartment Physiology
- Traditional Theories of Fluid Management
- Fluid Management Indicators & Interventions
Fluid Compartments

(a) Distribution of body solids and fluids in average lean adult female and male

(b) Exchange of water among body fluid compartments
Fluid Compartments

30L Intracellular fluid (ICF)
12L Interstitial fluid
3L Extracellular fluid (ECF)
Plasma (intravascular fluid)
Fluid Compartments

Intracellular fluid (ICF) with 30L, 12L, and 3L.

Interstitial fluid with Na+, K+, and protein.

Extracellular fluid (ECF) with water and Na+.

Plasma (intravascular fluid) with 3L.
Fluid Compartments

30L Intracellular fluid (ICF)
12L Interstitial fluid
3L Plasma (intravascular fluid)

Na+, K+, protein

Water

Extracellular fluid (ECF)
Endothelial Glycocalyx

Endothelial Glycocalyx

Endothelial Glycocalyx

- Inhalational Agents (sevoflurane)
- Plasma proteins
- Hydrocortisone
- Etanercept (TNF-a receptor)
- Antithrombin III
- Antioxidants

- Ischemia/Reperfusion
- Sepsis/Inflammation
- Hypervolemia
- ANP
- Hyperglycemia
- Surgical Stress

Protect → Destroy

Goal-Directed Fluid Therapy Map

- History of Fluid Management
- Significance of Fluid Management
- Fluid Compartment Physiology
- Traditional Theories of Fluid Management
- Fluid Management Indicators & Interventions
### Intra-Operative Fluid Replacement

80kg pt undergoing Exploratory Laparotomy; NPO for past 10 hours

<table>
<thead>
<tr>
<th>Hours</th>
<th>Fluid Deficit</th>
<th>Maintenance</th>
<th>Insensible Losses</th>
<th>EBL</th>
<th>Urine Output</th>
<th>Hourly Total</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hour 1</td>
<td>600</td>
<td>120</td>
<td>640</td>
<td>100 (300)</td>
<td>150</td>
<td>1,810</td>
<td>1,810</td>
</tr>
<tr>
<td>Hour 2</td>
<td>300</td>
<td>120</td>
<td>640</td>
<td>300 (900)</td>
<td>50</td>
<td>2,010</td>
<td>3,820</td>
</tr>
<tr>
<td>Hour 3</td>
<td>300</td>
<td>120</td>
<td>640</td>
<td>50 (150)</td>
<td>30</td>
<td>1,240</td>
<td>5,060 mls</td>
</tr>
</tbody>
</table>
### Maintenance Fluids/Insensible Losses

#### Maintenance Requirements for Different Surgeries

<table>
<thead>
<tr>
<th>Surgical Trauma</th>
<th>Fluid Volume</th>
<th>Example Surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superficial</td>
<td>1-2 mL/Kg/hr</td>
<td>Peripheral surgery</td>
</tr>
<tr>
<td>Minimal</td>
<td>3-4 mL/Kg/hr</td>
<td>Head and neck, hernia, knee surgery</td>
</tr>
<tr>
<td>Moderate</td>
<td>5-6 mL/Kg/hr</td>
<td>Major surgery without exposed abdominal contents</td>
</tr>
<tr>
<td>Severe</td>
<td>8-10 mL/Kg/hr (or more)</td>
<td>Major abdominal, especially with exposed abdominal contents</td>
</tr>
</tbody>
</table>

# Intra-Operative Fluid Replacement

80kg pt undergoing Exploratory Laparotomy; NPO for past 10 hours

<table>
<thead>
<tr>
<th>Hours</th>
<th>Fluid Deficit</th>
<th>Maintenance</th>
<th>Insensible Losses</th>
<th>EBL</th>
<th>Urine Output</th>
<th>Hourly Total</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hour 1</td>
<td>600</td>
<td>120</td>
<td>640</td>
<td>100 (300)</td>
<td>150</td>
<td>1,810</td>
<td>1,810</td>
</tr>
<tr>
<td>Hour 2</td>
<td>300</td>
<td>120</td>
<td>640</td>
<td>300 (900)</td>
<td>50</td>
<td>2,010</td>
<td>3,820</td>
</tr>
<tr>
<td>Hour 3</td>
<td>300</td>
<td>120</td>
<td>640</td>
<td>50 (150)</td>
<td>30</td>
<td>1,240</td>
<td>5,060 mls</td>
</tr>
</tbody>
</table>
“Fundamentals”

1. **Preoperative fasting** patients are hypovolemic due to ongoing insensible perspiration and urinary output

2. **Insensible perspiration** increases dramatically during surgery due to exposure

3. An unpredictable fluid shift towards the “**third space**” requires generous substitution

4. **Hypervolemia is harmless** because the kidneys regulate the overload
Intra-Operative Fluid Replacement

80kg pt undergoing Exploratory Laparotomy; NPO for past 10 hours

<table>
<thead>
<tr>
<th>Hours</th>
<th>Fluid Deficit</th>
<th>Maintenance</th>
<th>Insensible Losses</th>
<th>EBL</th>
<th>Urine Output</th>
<th>Hourly Total</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hour 1</td>
<td>600</td>
<td>120</td>
<td>640</td>
<td>100 (300)</td>
<td>150</td>
<td>1,810</td>
<td>1,810</td>
</tr>
<tr>
<td>Hour 2</td>
<td>300</td>
<td>120</td>
<td>640</td>
<td>300 (900)</td>
<td>50</td>
<td>2,010</td>
<td>3,820</td>
</tr>
<tr>
<td>Hour 3</td>
<td>300</td>
<td>120</td>
<td>640</td>
<td>50 (150)</td>
<td>30</td>
<td>1,240</td>
<td>5,060 mls</td>
</tr>
</tbody>
</table>
Intra-Operative Fluid Replacement

80kg pt undergoing Exploratory Laparotomy; NPO for past 10 hours

<table>
<thead>
<tr>
<th>Hours</th>
<th>Fluid Deficit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hour 1</td>
<td>600</td>
</tr>
<tr>
<td>Hour 2</td>
<td>300</td>
</tr>
<tr>
<td>Hour 3</td>
<td>300</td>
</tr>
</tbody>
</table>

- **Pre-op fasting for 10hrs = No differences between theoretical and actual plasma volumes using indocyanine green (2008)**

- **Pre-op fasting for >8hrs = No differences between pre and post fasting plasma volumes using transthoracic echocardiography (2014)**


# Intra-Operative Fluid Replacement

80kg pt undergoing Exploratory Laparotomy; NPO for past 10 hours

<table>
<thead>
<tr>
<th>Hours</th>
<th>Fluid Deficit</th>
<th>Maintenance</th>
<th>Insensible Losses</th>
<th>EBL</th>
<th>Urine Output</th>
<th>Hourly Total</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hour 1</td>
<td>600</td>
<td>120</td>
<td>640</td>
<td>100 (300)</td>
<td>150</td>
<td>1,810</td>
<td>1,810</td>
</tr>
<tr>
<td>Hour 2</td>
<td>300</td>
<td>120</td>
<td>640</td>
<td>300 (900)</td>
<td>50</td>
<td>2,010</td>
<td>3,820</td>
</tr>
<tr>
<td>Hour 3</td>
<td>300</td>
<td>120</td>
<td>640</td>
<td>50 (150)</td>
<td>30</td>
<td>1,240</td>
<td>5,060 mls</td>
</tr>
</tbody>
</table>
## Maintenance Fluids/Insensible Losses

### Maintenance Requirements for Different Surgeries

<table>
<thead>
<tr>
<th>Surgical Trauma</th>
<th>Fluid Volume</th>
<th>Example Surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superficial</td>
<td>1-2 mL/Kg/hr</td>
<td>Peripheral surgery</td>
</tr>
<tr>
<td>Minimal</td>
<td>3-4 mL/Kg/hr</td>
<td>Head and neck, hernia, knee surgery</td>
</tr>
<tr>
<td>Moderate</td>
<td>5-6 mL/Kg/hr</td>
<td>Major surgery without exposed abdominal contents</td>
</tr>
<tr>
<td>Severe</td>
<td>8-10 mL/Kg/hr (or more)</td>
<td>Major abdominal, especially with exposed abdominal contents</td>
</tr>
</tbody>
</table>


## Maintenance Fluids/Insensible Losses

### Maintenance Requirements for Different Surgeries

<table>
<thead>
<tr>
<th>Surgical Trauma</th>
<th>Fluid Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superficial</td>
<td>1-2 mL/Kg/hr</td>
</tr>
<tr>
<td>Minimal</td>
<td>3-4 mL/Kg/hr</td>
</tr>
<tr>
<td>Moderate</td>
<td>5-6 mL/Kg/hr</td>
</tr>
<tr>
<td>Severe</td>
<td>8-10 mL/Kg/hr</td>
</tr>
</tbody>
</table>

Evaporation/fluid loss through exposure:

0.5-1 ml/kg/hr

---


Fluid Resuscitation

Classical Approach
- 3:1 ratio

Recent Findings
- 1.3:1 to 2:1 ratio

The efficacy and safety of colloid resuscitation in the critically ill (2011)

Crystalloids versus colloids: exploring differences in fluid requirements by systematic review and meta-regression (2015)


# Intra-Operative Fluid Replacement

80kg pt undergoing Exploratory Laparotomy; NPO for past 10 hours

<table>
<thead>
<tr>
<th>Hours</th>
<th>Fluid Deficit</th>
<th>Maintenance</th>
<th>Insensible Losses</th>
<th>EBL</th>
<th>Urine Output</th>
<th>Hourly Total</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hour 1</td>
<td>600</td>
<td>120</td>
<td>640</td>
<td>100 (300)</td>
<td>150</td>
<td>1,810</td>
<td>1,810</td>
</tr>
<tr>
<td>Hour 2</td>
<td>300</td>
<td>120</td>
<td>640</td>
<td>300 (900)</td>
<td>50</td>
<td>2,010</td>
<td>3,820</td>
</tr>
<tr>
<td>Hour 3</td>
<td>300</td>
<td>120</td>
<td>640</td>
<td>50 (150)</td>
<td>30</td>
<td>1,240</td>
<td>5,060 mls</td>
</tr>
</tbody>
</table>
Goal-Directed Fluid Therapy Map

- History of Fluid Management
- Significance of Fluid Management
- Fluid Compartment Physiology
- Traditional Theories of Fluid Management
- Fluid Management Indicators & Interventions
Indications and Interventions

- Scientific Method
- Traditional Indicators
- Advanced Indicators
- Pharmacokinetic Indicator: Volume Effect
- Crystalloid vs. Colloid
Scientific Method

1. Target: Normovolemia

2. Indication: Intravascular Hypovolemia

3. Therapy: Volume Replacement

4. Outcome Variable: Blood Volume
Scientific Method

1. Target
   - Normovolemia

2. Indication
   - Intravascular Hypovolemia

3. Therapy
   - Volume Replacement

4. Outcome Variable
   - Blood Volume
Traditional Indicators

- BP, HR, CVP
- Urine output
- Not sensitive or specific

![Graph showing arterial blood pressure and heart rate variations with mean values and standard deviations.]

Blood volume:
- 3959 ± 387 ml
- 3501 ± 499 ml
- 3934 ± 500 ml

Hct:
- 0.35 ± 0.04
- 0.28 ± 0.04
- 0.25 ± 0.04

---

Advanced Flow Measurements

- Frank Starling Curve
- Pulse Pressure Variation (PPV)
- Stroke Volume Variation (SVV)
- Limitations

Indications and Interventions

 ✓ Scientific Method
 ✓ Traditional Indicators
 ✓ Advanced Indicators

 ● Pharmacokinetic Indicator: Volume Effect
 ● Crystalloid vs. Colloid
Volume Effect

- Percentage of infused solution that
  - 1) remains within circulatory compartment and
  - 2) does not cause interstitial edema

![Diagram of fluid compartments](image)
Volume Effect

- Percentage of infused solution that
  - 1) remains within circulatory compartment and
  - 2) does not cause interstitial edema

- Calculation Methods
  - Hematocrit Dilution (98% existing data)
  - Acute Normovolemic Hemodilution (ANH)
Volume Effect: Hematocrit Dilution

- Initial hct

- Initial blood volume * initial Hct = Red Cell Volume

- Intravenous volume therapy

- New Hct

- Calculation of increase in blood volume
Volume Effect: Hematocrit Dilution

- Initial hct 0.40

- Initial blood volume * initial Hct = Red Cell Volume

- Intravenous volume therapy

- New Hct

- Calculation of increase in blood volume
Volume Effect: Hematocrit Dilution

- Initial hct 0.40

- Initial blood volume * initial Hct = Red Cell Volume
  
  \[ 5 \text{ L} \times 0.40 = 2 \text{ L RCV} \]

  \[ 5 \text{ L} - 2 \text{ L} = 3 \text{ L Plasma} \]

- Intravenous volume therapy

- New Hct

- Calculation of increase in blood volume
Volume Effect: Hematocrit Dilution

- Initial hct 0.40

- Initial blood volume * initial Hct = Red Cell Volume
  
  5 L * 0.40 = 2 L RCV

  5 L - 2 L = 3 L Plasma

- Intravenous volume therapy 1 L Colloid

- New Hct

- Calculation of increase in blood volume
Volume Effect: Hematocrit Dilution

- Initial hct  0.40

- Initial blood volume * initial Hct = Red Cell Volume

  \[ 5 \text{ L} \times 0.40 = 2 \text{ L RCV} \]

  \[ 5 \text{ L} - 2 \text{ L} = 3 \text{ L Plasma} \]

- Intravenous volume therapy  1 L Colloid

- New Hct  0.35

- Calculation of increase in blood volume
Volume Effect: Hematocrit Dilution

- Initial hct  0.40

- Initial blood volume * initial Hct = Red Cell Volume
  5 L * 0.40 = 2 L RCV

  5 L - 2 L = 3 L Plasma

- Intravenous volume therapy  1 L Colloid

- New Hct  0.35

- Calculation of increase in blood volume
  \[
  \frac{2 \text{ L RCV}}{0.35} = \frac{x \text{ L Plasma}}{0.65}
  \]

  \[x = 3.7 \text{ L Plasma}\]
Volume Effect: Hematocrit Dilution

- Initial hct 0.40

- Initial blood volume * initial Hct = Red Cell Volume
  
  \[ 5 \text{ L} \times 0.40 = 2 \text{ L RCV} \]

- Intravenous volume therapy 1 L Colloid

- New Hct 0.35

- Calculation of increase in blood volume
  
  \[ \frac{2 \text{ L RCV}}{0.35} = \frac{x \text{ L Plasma}}{0.65} \]

  \[ x = 3.7 \text{ L Plasma} \]
Volume Effect: Hematocrit Dilution

- Initial hct 0.40
- Initial blood volume * initial Hct = Red Cell Volume
  \[5 \text{ L} \times 0.40 = 2 \text{ L RCV}\]
  \[5 \text{ L} - 2 \text{ L} = 3 \text{ L Plasma}\]
- Intravenous volume therapy 1 L Colloid
- New Hct 0.35
- Calculation of increase in blood volume
  \[
  \frac{2 \text{ L RCV}}{0.35} = \frac{x \text{ L Plasma}}{0.65}
  \]
  \[x = 3.7 \text{ L Plasma}\]

Volume Effect of 1L Colloid 70%
Endothelial Glycocalyx

- Inhalational Agents (sevoflurane)
- Plasma proteins
- Hydrocortisone
- Etanercept (TNF-α receptor)
- Antithrombin III
- Antioxidants

- Ischemia/Reperfusion
- Sepsis/Inflammation
- **Hypervolemia**
- ANP
- Hyperglycemia
- Surgical Stress

Volume Effect

● Percentage of infused solution that
  ○ 1) remains within circulatory compartment and
  ○ 2) does not cause interstitial edema

● Calculation Methods
  ○ Hematocrit Dilution
  ○ Acute Normovolemic Hemodilution (ANH)
Acute Normovolemic Hemodilution (ANH)

Induction of General Anesthesia

20 min
Equilibration

5 min
Measurement 1

45 min
Hemodilution

30 min
Equilibration

5 min
Measurement 2

20 min
Albumin Infusion

30 min
Equilibration

5 min
Measurement 3

End of Protocol and Start of Surgery

Acute Normovolemic Hemodilution (ANH)

Induction of General Anesthesia

20 min  Equilibration
5 min   Measurement 1
45 min  Hemodilution
30 min  Equilibration
5 min   Measurement 2
20 min  Albumin Infusion
30 min  Equilibration
5 min   Measurement 3

End of Protocol and Start of Surgery

Acute Normovolemic Hemodilution (ANH)

Induction of General Anesthesia

20 min
Equilibration

5 min
Measurement 1

45 min
Hemodilution
Blood Loss: - 1L

LR: + 3L

30 min
Equilibration

5 min
Measurement 2

20 min
Albumin Infusion

30 min
Equilibration

5 min
Measurement 3

End of Protocol and Start of Surgery

Acute Normovolemic Hemodilution (ANH)

Induction of General Anesthesia

20 min
Equilibration

5 min
Measurement 1
BV: 4L
Blood Loss: -1L
LR: +3L

45 min
Hemodilution

30 min
Equilibration

5 min
Measurement 2
BV: 3.5L

20 min
Albumin Infusion

30 min
Equilibration

5 min
Measurement 3

End of Protocol and Start of Surgery
Acute Normovolemic Hemodilution (ANH)

Induction of General Anesthesia

20 min
Equilibration

5 min
Measurement 1

45 min
Hemodilution
Blood Loss: -1L
LR: +3L

30 min
Equilibration

5 min
Measurement 2

20 min
Albumin Infusion

30 min
Equilibration

5 min
Measurement 3

End of Protocol and Start of Surgery

Volume Effect of LR
17%

Acute Normovolemic Hemodilution (ANH)

- BV: 4L
- Blood Loss: -1L
- LR: +3L
- BV: 3.5L

Volume Effect of LR 17%

(a) Distribution of body solids and fluids in average lean adult female and male
(b) Exchange of water among body fluid compartments
Acute Normovolemic Hemodilution (ANH)

Induction of General Anesthesia

20 min  Equilibration

5 min  Measurement 1

45 min  Hemodilution

30 min  Equilibration

5 min  Measurement 2

20 min  Albumin Infusion

30 min  Equilibration

5 min  Measurement 3

End of Protocol and Start of Surgery

Acute Normovolemic Hemodilution (ANH)

**Induction of General Anesthesia**

- **20 min**
  - Equilibration

- **5 min**
  - Measurement 1

- **45 min**
  - Hemodilution

- **30 min**
  - Equilibration

- **5 min**
  - Measurement 2

- **20 min**
  - Albumin Infusion

- **30 min**
  - Equilibration

- **5 min**
  - Measurement 3

**End of Protocol and Start of Surgery**

**BV:** 4.1 L

**Blood Loss:** - 1.4 L

**6% HES:** + 1.7 L

Acute Normovolemic Hemodilution (ANH)

Induction of General Anesthesia

20 min
Equilibration

5 min
Measurement 1
BV: 4.1 L
Blood Loss: -1.4 L
6% HES: +1.7 L

45 min
Hemodilution

30 min
Equilibration

5 min
Measurement 2
BV: 4.3 L

20 min
Albumin Infusion

30 min
Equilibration

5 min
Measurement 3

End of Protocol and Start of Surgery

Acute Normovolemic Hemodilution (ANH)

Induction of General Anesthesia

20 min  Equilibration
5 min   Measurement 1  BV: 4.1 L
45 min  Hemodilution  Blood Loss: -1.4 L
30 min  Equilibration  6% HES: +1.7 L
5 min   Measurement 2  BV: 4.3 L
20 min  Albumin Infusion
30 min  Equilibration
5 min   Measurement 3

End of Protocol and Start of Surgery

Volume Effect of Colloid (ANH) 98%

Acute Normovolemic Hemodilution (ANH)

Induction of General Anesthesia

- **20 min**
  - Equilibration

- **5 min**
  - Measurement 1

- **45 min**
  - Hemodilution

- **30 min**
  - Equilibration

- **5 min**
  - Measurement 2

- **20 min**
  - Albumin Infusion

- **30 min**
  - Equilibration

- **5 min**
  - Measurement 3

**End of Protocol and Start of Surgery**

**Volume Effect of Colloid (ANH)**

- **BV:** 4.1 L
- **Blood Loss:** -1.4 L
- **6% HES:** +1.7 L

**Volume Effect (Hct dilution)**

- **98%**
- **127%**
Acute Normovolemic Hemodilution (ANH)

Volume Effect of Colloid (ANH) 98%

Vs.
Volume Effect (Hct dilution) 127%
Acute Normovolemic Hemodilution (ANH)

Induction of General Anesthesia

- 20 min: Equilibration
- 5 min: Measurement 1
- 45 min: Hemodilution
- 30 min: Equilibration
- 5 min: Measurement 2
- 20 min: Albumin Infusion
- 30 min: Equilibration
- 5 min: Measurement 3

End of Protocol and Start of Surgery

Volume Effect of LR
17%

Volume Effect of Colloid (ANH)
98%

Scientific Method

1. Target
   - Normovolemia

2. Indication
   - Intravascular Hypovolemia

3. Therapy
   - Volume Replacement

4. Outcome Variable
   - Blood Volume
Scientific Method

1. Target
   - Normovolemia

2. Indication
   - Intravascular Hypovolemia

3. Therapy
   - Volume Replacement

4. Outcome Variable
   - Blood Volume
Volume Loading (VL)

**Induction of General Anesthesia**

- **20 min**
  - Equilibration

- **5 min**
  - Measurement 1

- **45 min**
  - Hemodilution

- **30 min**
  - Equilibration

- **5 min**
  - Measurement 2

- **20 min**
  - Albumin Infusion

- **30 min**
  - Equilibration

- **5 min**
  - Measurement 3

**End of Protocol and Start of Surgery**

**BV:** 4.2 L

---


Volume Loading (VL)

Induction of General Anesthesia

20 min  Equilibration
5 min  Measurement 1  BV:  4.2 L
45 min  Hemodilution  Blood Loss:  ---
30 min  Equilibration  Albumin:  + 1.4 L
5 min  Measurement 2
20 min  Albumin Infusion
30 min  Equilibration
5 min  Measurement 3

End of Protocol and Start of Surgery
Volume Loading (VL)

**Induction of General Anesthesia**

- **20 min**
  - Equilibration

- **5 min**
  - Measurement 1
  - BV: 4.2 L

- **45 min**
  - Hemodilution
  - Blood Loss: ---
  - Albumin: +1.4 L

- **30 min**
  - Equilibration

- **5 min**
  - Measurement 2
  - BV: 4.7 L

- **20 min**
  - Albumin Infusion

- **30 min**
  - Equilibration

- **5 min**
  - Measurement 3

**End of Protocol and Start of Surgery**

---

Volume Loading (VL)

Induction of General Anesthesia

20 min
Equilibration

5 min
Measurement 1

45 min
Hemodilution

30 min
Equilibration

5 min
Measurement 2

20 min
Albumin Infusion

30 min
Equilibration

End of Protocol and Start of Surgery

Volume Effect of Colloid (VL) 38%

Volume Loading (VL)

20 min
Equilibration

5 min
Measurement 1

45 min
Hemodilution

30 min
Equilibration

5 min
Measurement 2

20 min
Albumin Infusion

30 min
Equilibration

End of Protocol and Start of Surgery

Volume Effect is Context Sensitive

Volume Effect of Colloid (ANH) 98%

Volume Effect of Colloid (VL) 38%

Indications and Interventions

✓ Scientific Method
✓ Traditional Indicators
✓ Advanced Indicators
✓ Pharmacokinetic Indicator: Volume Effect

● Crystalloid vs. Colloid
Why Should I Care?

- Hypervolemia and hypovolemia are not benign.

- Evidence challenges traditional theories of fluid replacement and indicators.

- Integrity of the EGL has many implications for perioperative fluid therapy (namely, hypervolemia, surgical stress, ischemia).

- Volume effect is context sensitive. Proper indications matter.
THANK YOU!