Goal Directed Fluid Therapy: A Modern Approach to Perioperative Fluid Management
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Disclosure

- Fresenius Kabi:
  - Speaker’s honoraria
1999 UK Confidential Enquiry into Perioperative Deaths

- Errors in fluid management (usually fluid excess): most common cause of perioperative morbidity, mortality

Why do we give so much fluid?

- preop fasting
- surgical blood loss
- evaporation
- urinary excretion
- vasodilation caused by anesthesia, epidural
- transfer to “third space”
- transcapillary leak of albumin caused by inflammatory mediators

Many liters of fluid during a standard operation

Hahn RG. Anesth Analg 2007;105:304
“Standard” management grossly overestimates iv fluid requirements

- **Maintenance:**
  4:2:1 rule

- **Deficit:**
  Maintenance x hr fasting

- **3rd space losses:** 10-15 mL/kg/hr

- **Blood loss:**
  3:1 replacement with crystalloid
“Standard” fluid management

- 90 kg male, APR, NPO x 8 hr, 6 hr surgery, EBL 1500 mL
- Using standard formula this patient should get 12 L crystalloid intraop
How much harm does excess fluid really cause?
Aggressive fluid strategies adversely affect every system and organ.

Prowle JR et al. Nat Rev Nephrol 2010;6:107
Why are patients sensitive to large volumes of crystalloid? 

- clearance of crystalloid during anesthesia and surgery is 10-20% of that in awake volunteers  
- crystalloid leaves the plasma space, equilibrates with interstitial space after 20-30 min

Hahn RG. Anesth Analg 2007;105:304
Body water components

- ECF: 20%
- ICF: 40%
- Minerals, protein, glycogen, fat: 40%

Plasma volume: 4.3%
Interstitial fluid: 15.7%

Colloids
Crystalloid: 75-80% leaves vasculature after 20 minutes
5% Dextrose
What happens to all that crystalloid?

Preoperative measured blood vol.

Crystalloids

Colloids

Blood loss

Urine

Postop measured blood vol.

Total perioperative fluid balance

Perioperative output

1,700 mL

Perioperative input

1,700 mL

Standard infusion 12 mL/kg/h crystalloid; blood loss replaced 1:1 with colloid.

Can a healthy person die of pulmonary edema?

- 13 patients, death from pulmonary edema within 36 hr postop
- average 7 L +ve fluid balance in first 24 hr
- 10/13: ASA I
- average age: 38 yr

Arieff AI. Chest 1999;115:1371-1377
Current perioperative fluid therapy

- Anesthesiologists 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 procedures

Perioperative weight gain and mortality

More +ve fluid balance = worse outcomes

For major surgery, all experts agree...

- 1-2 mL/kg/hr maximum crystalloid during OR
- average 100 mL/hr
What happens when you restrict perioperative fluids?
## Fluid restriction and postop complications

- 141 patients for elective colorectal resection
- Based on 90 kg person, 500 ml blood loss:

<table>
<thead>
<tr>
<th></th>
<th>Restricted Regimen</th>
<th>Standard Regimen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preloading</td>
<td>No preloading</td>
<td>500 mL colloid</td>
</tr>
<tr>
<td>Third space loss</td>
<td>No replacement</td>
<td>NS 7 mL/kg h first hr; 5 mL/kg 2nd + 3rd hr, then 3 mL/kg/hr = 1350 mL NS</td>
</tr>
<tr>
<td>Fluid loss for fast</td>
<td>500 mL D5W, minus po intake during fast</td>
<td>500 mL N/S</td>
</tr>
<tr>
<td>Blood loss</td>
<td>500 mL colloid</td>
<td>1500 mL N/S</td>
</tr>
<tr>
<td>Total in</td>
<td>1000 mL</td>
<td>3850 mL</td>
</tr>
</tbody>
</table>

Complications related to IV fluid, weight gain on day of operation

Liberal vs restricted: Intraabdominal surgery

- Ringer’s lactate only
- liberal: av. 3900 mL
- restrictive: av. 1400 mL
- blood loss both groups replaced 3:1

Nisanevich V et al. Anesthesiology 2005;103:25
Liberal vs restricted: Intraabdominal surgery

- Ringer’s lactate only
- liberal: av. 3900 mL
- restrictive: av. 1400 mL
- blood loss both groups replaced 3:1

Nisanevich V et al. Anesthesiology 2005;103:25
Even cutting down on IV fluids postop speeds GI recovery!

- colon resection, postop IV fluid 2/3-1/3
- “standard” at 125 mL/hr vs “restricted” at 85 mL/hr
- standard group had:
  - 3 kg weight gain
  - more complications
  - 3 day longer hospital stay

Lobo DN at al. Lancet 2002;359:1812
So too much crystalloid is harmful in major surgery...what about too little?
GI complications are the leading cause of delayed discharge

Bennett-Guerrero E et al. Anesth Analg 1999;89:514
GI complications

- **Major:**
  - hemorrhage
  - abscess
  - gastric/bowel obstruction
  - infection
  - fistula
  - anastomotic leak
  - GI infarction
  - anything requiring reoperation

- **Minor:**
  - severe nausea and vomiting requiring rescue antiemetic
  - ileus
  - diarrhea
  - abdominal distension
  - pancreatitis

Why are GI complications so common?

- healthy patients: 25-30% loss of blood volume with no change in BP or HR
- splanchnic perfusion falls with only 10-15% decrease in blood volume
- gut hypoperfusion often outlasts hypovolemia
- no simple clinical monitor

The trouble with blood volume assessment

- no direct beside measurement
- clinical surrogates used:
  - VS (BP, HR), examination (chest)
  - U/O
  - lab: Hg, serum and urinary Na⁺
  - ongoing losses (EBL, NG, etc.)
  - fluid balance charts
  - CXR (pulmonary congestion)
The trouble with blood volume assessment

- surrogate measures: **accurate prediction of volume status <50% of the time**, even by experienced clinicians
- HR, BP, U/O, CVP, labs values
  - lack specificity in identifying volume deficit
  - do not correlate with CO
  - lead to over- or under-transfusion of fluids
- best measure of adequacy of GI perfusion is gastric pH

McGee S et al. JAMA 1999;281:1022
PAOP and CVP fail to predict ventricular filling volume, cardiac performance, or the response to volume infusion in normal subjects.

A

RV\text{DVI (mL/m}^2\text{)}

CVP (mm Hg)

B

ΔRV\text{DVI (mL/m}^2\text{)}

ΔCVP (mm Hg)

C

LV\text{DVI (mL/m}^2\text{)}

PWP (mm Hg)

D

ΔLV\text{DVI (mL/m}^2\text{)}

ΔPWP (mm Hg)

Cardiac filling pressures are poor measures of preload and volume responsiveness.

“...very poor relationship between CVP and blood volume as well as the inability of CVP/ΔCVP to predict the hemodynamic response to a fluid challenge ...

- CVP should not be used to make clinical decisions regarding fluid management...

- ...Based on the results of our systematic review, we believe that CVP should no longer be routinely measured in the ICU, operating room or emergency department.”

**Figure 1.** Fifteen hundred simultaneous measurements of blood volume and CVP in a heterogenous cohort of 188 ICU patients demonstrating no association between these two variables ($r = 0.27$). The correlation between ΔCVP and change in blood volume was 0.1 ($r^2 = 0.01$). This study demonstrates that patients with a low CVP may have volume overload and likewise patients with a high CVP may be volume depleted. Reproduced with permission from Shippy et al.\textsuperscript{11}
“All great truths begin as blasphemies”

George Bernard Shaw
1856 - 1950
Too much, too little or just right?

![Graph showing the relationship between perioperative administered fluid volume and post-operative morbidity and factors influencing shift of the curve.](image)

- **Bowel ischemia**
- **Bowel edema**

**Fig. 2.** Relationship between perioperative administered fluid volume and post-operative morbidity and factors influencing shift of the curve (arrow). Boxes indicate the risk of complications associated with deviation from normovolaemia. Modified from Bellamy. SIRS, systemic inflammatory response syndrome; PONV, post-operative nausea and vomiting.

The answer: Goal-Directed Therapy (GDT)

- The gold standard for perioperative fluid management in critical illness, or during major surgery with significant fluid shifts and blood loss
Goal-Directed Therapy (GDT)

- intensive monitoring and aggressive management of perioperative hemodynamics in high risk patients to optimize oxygen delivery
- early reports in the literature first appeared around 2000
- standard of care:
  - most major centres in US
  - NICE* guidelines in UK for surgical patients
  - almost all current periop fluid literature

*NICE: National Institute for Health and Clinical Excellence
Goal-Directed Therapy (GDT)

- Target specific values for cardiac index, $O_2$ delivery, $O_2$ consumption
- Use fluids and inotropes
- ↓ mortality and morbidity

Shoemaker WC et al. Chest 1988;94:1176-86
Early Goal-Directed Therapy in the Treatment of Severe Sepsis and Septic Shock

Emanuel Rivers, M.D., M.P.H., Bryant Nguyen, M.D., Suzanne Havstad, M.A., Julie Ressler, B.S., Alexandria Muzzin, B.S., Bernhard Knoblich, M.D., Edward Peterson, Ph.D., Michael Tomlanovich, M.D., for the Early Goal-Directed Therapy Collaborative Group

ABSTRACT

Background Goal-directed therapy has been used for severe sepsis and septic shock in the intensive care unit. This approach involves adjustments of cardiac preload, afterload, and contractility to balance oxygen delivery with oxygen demand. The purpose of this study was to evaluate the efficacy of early goal-directed therapy before admission to the intensive care unit.

Early hemodynamic assessment on the basis of physical findings, vital signs, central venous pressure,6 and urinary output7 fails to detect persistent global tissue hypoxia. A more definitive resuscitation strategy involves goal-oriented manipulation of cardiac preload, afterload, and contractility to achieve a balance between systemic oxygen delivery and oxygen demand.2 End points used to confirm the achievement of such a balance (hereafter called resuscitation end points) include normalized values for mixed venous oxygen saturation, arterial lactate concentration, base deficit, and pH.8 Mixed venous oxygen saturation has been shown to be a surrogate for the cardiac index as a target for hemodynamic therapy.9 In cases in which the insertion of a pulmonary-artery catheter is impractical, venous oxygen saturation can be measured in the central circulation.10
Goal-directed therapy (GDT): What goals can we target?

- stroke volume (SV)*
- cardiac index (CI)
- stroke volume variation (SVV)
- oxygen delivery or consumption**
- mixed venous oxygen saturation (SvO2)
- gastric mucosal pH
- stroke distance (esophageal doppler)

*most commonly used goal
**ideal goal
Goal-directed therapy (GDT): What operations? Which patients?

- expected blood loss >500 mL
- examples:
  - major abdominal--gen surg, gyn, urologic
  - orthopedic: major spine, hip (esp revision)
  - major head and neck oncology
  - cardiac, thoracic
  - trauma
  - patients at high risk of complications (poor LV)
  - uncertain preoperative volume status
  - ICU: sepsis, burns, etc.
Frank-Starling curve of ventricular function
It’s all about oxygen delivery!
<table>
<thead>
<tr>
<th>Device</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Esophageal Doppler</td>
<td>Simple to use</td>
<td>Mathematical assumptions about aortic size might be erroneous</td>
</tr>
<tr>
<td></td>
<td>Does not require access to the circulation</td>
<td>Only measures descending aortic blood flow</td>
</tr>
<tr>
<td></td>
<td>Many clinical studies proving utility</td>
<td>Occasional difficulty in obtaining optimal probe position</td>
</tr>
<tr>
<td></td>
<td>Reliable</td>
<td>Learning curve</td>
</tr>
<tr>
<td></td>
<td>Can use as a monitor of volume</td>
<td></td>
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<tr>
<td></td>
<td>responsiveness in goal directed therapy</td>
<td></td>
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<tr>
<td>Thoracic electrical</td>
<td>Completely noninvasive</td>
<td></td>
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<tr>
<td>bioimpedance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Partial non-rebreathing</td>
<td>Easy to set up</td>
<td>Difficult to set up</td>
</tr>
<tr>
<td>systems</td>
<td>Does not require access to the circulation</td>
<td>Numerous mathematical assumptions</td>
</tr>
<tr>
<td></td>
<td>Provides for continuous CO measurement</td>
<td>Not useful for patients with dysrhythmias</td>
</tr>
<tr>
<td></td>
<td>Simple to use</td>
<td>“Noise” from OR limits use</td>
</tr>
<tr>
<td></td>
<td>Only require arterial line</td>
<td>Requires hemodynamic stability</td>
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<tr>
<td></td>
<td>Can be used in goal directed therapy</td>
<td>Have not been reported for use in goal directed therapy</td>
</tr>
<tr>
<td></td>
<td>Validated in clinical studies under many</td>
<td>Have not been reported for use in goal directed therapy</td>
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<tr>
<td></td>
<td>different conditions</td>
<td></td>
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<tr>
<td></td>
<td>Continuous CO measurements</td>
<td>Changes in dead space or V/Q matching may erroneously change CO measurement</td>
</tr>
<tr>
<td></td>
<td>Can be used to measure stroke volume and stroke</td>
<td>Requires access to the circulation</td>
</tr>
<tr>
<td></td>
<td>volume variation</td>
<td>Requires high fidelity arterial tracing</td>
</tr>
<tr>
<td>Arterial pulse contour</td>
<td></td>
<td>Requirement for calibration (some systems)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Need to re-calibrate during periods of hemodynamic instability (some systems)</td>
</tr>
<tr>
<td>Lithium dilution</td>
<td>Ease of set up</td>
<td></td>
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<tr>
<td></td>
<td>Only require arterial line</td>
<td></td>
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<tr>
<td></td>
<td>Continuous CO measurements</td>
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<td></td>
<td>Can be used to measure stroke volume and stroke</td>
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<tr>
<td></td>
<td>volume variation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Can be used with goal directed therapy</td>
<td></td>
</tr>
<tr>
<td>Trans-pulmonary thermodilution</td>
<td>Can use pre-existing arterial line or central</td>
<td>Requires access to the central circulation</td>
</tr>
<tr>
<td>techniques</td>
<td>line</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Continuous CO measurements</td>
<td>Radial artery not suitable</td>
</tr>
<tr>
<td></td>
<td>Provides estimation of extravascular lung water</td>
<td>Not truly a noninvasive technology</td>
</tr>
<tr>
<td></td>
<td>Can be used with goal directed therapy</td>
<td>Limited use in the OR</td>
</tr>
</tbody>
</table>

CO = cardiac output, OR = operating room.
GDT technologies:
Esophageal doppler
GDT technologies: Oesophageal doppler

Summary of velocity-time graph

- Peak velocity
- Mean acceleration
- Stroke distance = marker of stroke volume

markers of ‘contractility’

Flow time
Cycle time
Time
GDT technologies:
Fluid administration algorithm

Measure stroke volume

200-250 ml fluid over 5-10 minutes

Stroke volume increase >10%?

No

Monitor stroke volume for clinical signs of fluid loss

Yes

Stroke volume reduction >10%

Yes

No
Doppler-optimized fluid therapy

- RCT, elective colorectal surgery
- Standard fluid therapy vs esophageal doppler monitoring
- Postop care similar in both groups

Fig. 1 Fluid administration algorithm. FTc, descending aortic corrected flow time; SV, stroke volume

Results: GDT group had decreased

- time to tolerate diet (median 3 vs 4 days, \( p=0.003 \))
- incidence of unplanned ICU admission (0 vs 12%, \( p=0.012 \))
- major complications (0 vs 12%) and overall complications (25% vs 45%, \( p=0.07 \))
- time to fitness for discharge (median 7 vs 9 days, \( p=0.005 \))

Doppler-optimized fluid therapy

- no difference in intraop colloid use or crystalloid use between groups
- most of the volume in the study group was administered in the first quarter of the operating time (i.e., first 40 min)


Fig. 3 Cardiac index measured at 10-min intervals during surgery from induction of anaesthesia. Values are mean(s.d.), Mann–Whitney U test
Functional intravascular volume deficit in patients before surgery

Volume of colloid to establish maximal cardiac stroke volume

Goal-directed fluid therapy:

“The right fluid, for the right patient, at the right time”
Goal directed fluid technologies: 
Pulse contour analysis

- requires high-fidelity arterial line
- simple, no manual calibration
- monitor SV, SVI, CO, CI, SVV
- when used with CVP gives ScvO₂
- updates every 20 sec: real time cardiac output
FloTrac: Stroke Volume Variation (SVV)

- Requires mechanical ventilation $V_T$ 8mL/kg
- Affected by PEEP
- Not valid during arrhythmias (e.g., a fib)
- Normal value <13%
Fluid management algorithm using FloTrac-Vigileo monitor
Simplified Physiologic Protocol

Developed by W.T. McGee, MD, MHA, Tufts University Medical School

Figure 1

Volume Responsive: SVV > 13%

Yes

Volume Challenge

No

SVI Normal (40-50)

Pressor

SVI Low (<40)

Inotrope

SVI High (>50)

Diuretic

Figure 2

Volume Responsive: SVV > 13%

Yes

Volume Challenge

No

SVI Normal (40-50)

Pressor

SVI Low (<40)

Inotrope

SVI High (>50)

Diuretic

Possible Therapeutic Considerations Based on Clinical Findings

- **Pressor**
  - In the appropriate clinical setting (i.e., hypotension without bradycardia)

- **Inotrope**
  - No further response to volume (i.e., SVI does not improve) clinical pulmonary congestion and/or hypotension

- **Diuretic**
  - Volume overload (i.e., clinical pulmonary congestion and high A-a gradient)

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Improving Perioperative Outcomes: Fluid Optimization with the Esophageal Doppler Monitor, a Metaanalysis and Review

Tuong D Phan, MBBS, FRCA, Hilmy Ismail, MD, FFARCS(I), FRCA FANZCA, Alexander G Heriot, MD, FRCS, FRACS, Kwok M Ho, MPH, FANZCA, FJFICM

Table 1. Summary of Studies and Risk of Bias Classification

<table>
<thead>
<tr>
<th>First author, year</th>
<th>Risk of bias*</th>
<th>Type of operation</th>
<th>n</th>
<th>Intervention†</th>
<th>Colloid</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conway, 2002²¹</td>
<td>B</td>
<td>Major bowel</td>
<td>57</td>
<td>SV &gt; 10%, ftc &lt; 0.35</td>
<td>HES</td>
<td>LOS, diet, critical care days</td>
</tr>
<tr>
<td>Gan, 2002²³</td>
<td>A</td>
<td>Major gynecologic, general, urology</td>
<td>100</td>
<td>SV &gt; 10% ftc &lt; 0.35</td>
<td>200 mL 6% HES</td>
<td>LOS, diet, complications</td>
</tr>
<tr>
<td>Wakeling, 2005¹⁹</td>
<td>A</td>
<td>Colorectal</td>
<td>128</td>
<td>SV &gt; 10%</td>
<td>250 mL Haemacel or Gelofusine</td>
<td>LOS, diet, endotoxin, complications</td>
</tr>
<tr>
<td>Noblett, 2006³³</td>
<td>A</td>
<td>Colorectal</td>
<td>103</td>
<td>ftc &lt; 0.35 SV &gt; 10%</td>
<td>3 mL/kg initial bolus, then 3 mL/kg colloid</td>
<td>LOS, diet, morbidity, critical care days, cytokines</td>
</tr>
<tr>
<td>Sinclair, 1997²²</td>
<td>B</td>
<td>PFF</td>
<td>40</td>
<td>ftc &lt; 0.35, SV &gt; 10%</td>
<td>3 mL/kg HES</td>
<td>LOS, hemodynamics</td>
</tr>
<tr>
<td>Venn, 2002²⁰</td>
<td>A</td>
<td>PFF</td>
<td>90</td>
<td>ftc &lt; 0.35, SV &gt; 10%</td>
<td>200 mL Gelofusine</td>
<td>LOS, complications</td>
</tr>
<tr>
<td>Mythen, 1995¹⁷</td>
<td>C</td>
<td>Cardiac</td>
<td>60</td>
<td>CVP &lt; 3, rise in SV</td>
<td>200 mL 6% HES</td>
<td>LOS, pH, complications, ICU days</td>
</tr>
<tr>
<td>McKendry, 2004²⁵</td>
<td>A</td>
<td>Postoperative cardiac</td>
<td>170</td>
<td>svi &gt; 10% fluid loss</td>
<td>200 mL colloid or blood</td>
<td>LOS, complications</td>
</tr>
<tr>
<td>Chytra, 2007¹⁸</td>
<td>C</td>
<td>Trauma</td>
<td>162</td>
<td>SV &gt; 10%, ftc &lt; 0.35</td>
<td>HES, Gelofusine</td>
<td>LOS, ICU days, infection, lactate</td>
</tr>
</tbody>
</table>

CVP, central venous pressure; diet, time to establishment of oral intake; ftc, flow corrected time (sec); HES, hydroxyethyl starch; LOS, length of stay; PFF, proximal femoral fracture; pHi, gastric intraluminal pH; SV, stroke volume change, eg >10%; svi, stroke volume index.

*Cochrane Handbook of Systematic Reviews.¹⁴

¹¹Main triggers for fluid administration in the protocol group.
Decreased length of stay with GDT

Decreased time to resume full diet with GDT

Decreased morbidity with GDT

### Average increased volume colloid 700 mL

- Supports the hypothesis that subclinical hypovolemia causes postoperative bowel dysfunction
- Preventable by using GDT

# Major gastrointestinal complications

<table>
<thead>
<tr>
<th>Study</th>
<th>Treatment</th>
<th>Control</th>
<th>Weight (%)</th>
<th>Odds ratio M-H, random, 95% CI</th>
<th>Odds ratio M-H, random, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High risk of bias trials</strong></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Bender and colleagues⁴</td>
<td>1</td>
<td>0</td>
<td>1.9</td>
<td>3.18 (0.13, 79.83)</td>
<td></td>
</tr>
<tr>
<td>Boyd and colleagues⁷</td>
<td>3</td>
<td>9</td>
<td>10.3</td>
<td>0.30 (0.08, 1.18)</td>
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<tr>
<td>Chytra and colleagues¹²</td>
<td>2</td>
<td>4</td>
<td>6.5</td>
<td>0.50 (0.09, 2.81)</td>
<td></td>
</tr>
<tr>
<td>Conway and colleagues¹³</td>
<td>5</td>
<td>9</td>
<td>12.4</td>
<td>0.44 (0.13, 1.53)</td>
<td></td>
</tr>
<tr>
<td>Lobo and colleagues³⁹</td>
<td>3</td>
<td>5</td>
<td>7.5</td>
<td>0.49 (0.10, 2.43)</td>
<td></td>
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<tr>
<td>Shoemaker and colleagues⁵³</td>
<td>2</td>
<td>3</td>
<td>5.7</td>
<td>1.46 (0.23, 9.28)</td>
<td></td>
</tr>
<tr>
<td><strong>Subtotal (95% CI)</strong></td>
<td>260</td>
<td>295</td>
<td>44.3</td>
<td>0.53 (0.27, 1.02)</td>
<td></td>
</tr>
<tr>
<td><strong>Total events</strong></td>
<td>16</td>
<td>30</td>
<td></td>
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</tr>
<tr>
<td><strong>Heterogeneity:</strong></td>
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<tr>
<td>$\tau^2 = 0.00$</td>
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<tr>
<td>$\chi^2 = 3.11$, df = 5 (P = 0.68); $I^2 = 0%$</td>
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<tr>
<td><strong>Test for overall effect:</strong></td>
<td></td>
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<td></td>
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<tr>
<td>$Z = 1.89$ (P = 0.06)</td>
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<tr>
<td><strong>Low risk of bias trials</strong></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Lopes and colleagues⁴⁰</td>
<td>4</td>
<td>8</td>
<td>8.7</td>
<td>0.31 (0.07, 1.36)</td>
<td></td>
</tr>
<tr>
<td>Noblett and colleagues⁴⁶</td>
<td>0</td>
<td>2</td>
<td>2.1</td>
<td>0.20 (0.01, 4.19)</td>
<td></td>
</tr>
<tr>
<td>Pearse and colleagues⁴⁸</td>
<td>9</td>
<td>13</td>
<td>22.1</td>
<td>0.61 (0.24, 1.57)</td>
<td></td>
</tr>
<tr>
<td>Wakeling and colleagues⁵⁹</td>
<td>1</td>
<td>2</td>
<td>3.3</td>
<td>0.49 (0.04, 5.57)</td>
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</tr>
<tr>
<td>Wilson and colleagues⁶⁰</td>
<td>7</td>
<td>14</td>
<td>19.6</td>
<td>0.19 (0.07, 0.51)</td>
<td></td>
</tr>
<tr>
<td><strong>Subtotal (95% CI)</strong></td>
<td>286</td>
<td>238</td>
<td>55.7</td>
<td>0.34 (0.19, 0.62)</td>
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</tr>
<tr>
<td><strong>Total events</strong></td>
<td>21</td>
<td>39</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Heterogeneity:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\tau^2 = 0.00$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\chi^2 = 3.12$, df = 4 (P = 0.54); $I^2 = 0%$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Test for overall effect:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$Z = 3.55$ (P = 0.0004)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total (95% CI)</strong></td>
<td>546</td>
<td>533</td>
<td>100.0</td>
<td>0.42 (0.27, 0.65)</td>
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</tr>
<tr>
<td><strong>Total events</strong></td>
<td>37</td>
<td>69</td>
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<td></td>
</tr>
<tr>
<td><strong>Heterogeneity:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\tau^2 = 0.00$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\chi^2 = 7.13$, df = 10 (P = 0.71); $I^2 = 0%$</td>
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<td></td>
</tr>
<tr>
<td><strong>Test for overall effect:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$Z = 3.91$ (P &lt; 0.0001)</td>
<td></td>
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</tr>
</tbody>
</table>
### Minor gastrointestinal complications

<table>
<thead>
<tr>
<th>Study</th>
<th>Treatment</th>
<th>Control</th>
<th>Weight (%)</th>
<th>Odds ratio M-H, random, 95% CI</th>
<th>Odds ratio M-H, random, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High risk of bias trials</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Lobo and colleagues(^{39})</td>
<td>1 19</td>
<td>0 18</td>
<td>2.9</td>
<td>3.00 (0.11, 78.53)</td>
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</tr>
<tr>
<td>Shoemaker and colleagues(^{53})</td>
<td>1 28</td>
<td>1 60</td>
<td>3.9</td>
<td>2.19 (0.13, 36.26)</td>
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</tr>
<tr>
<td><strong>Subtotal (95% CI)</strong></td>
<td>47</td>
<td>78</td>
<td>6.8</td>
<td>2.50 (0.30, 21.03)</td>
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</tr>
<tr>
<td><strong>Total events</strong></td>
<td>2</td>
<td>1</td>
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<tr>
<td>Heterogeneity: (\tau^2=0.00; \chi^2=0.02), df = 1 ((P=0.88)); (I^2=0)%</td>
<td></td>
<td></td>
<td></td>
<td>Test for overall effect: (Z=0.84 (P=0.40))</td>
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<tr>
<td><strong>Low risk of bias trials</strong></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Gan and colleagues(^{23})</td>
<td>7 50</td>
<td>18 50</td>
<td>29.2</td>
<td>0.29 (0.11, 0.78)</td>
<td></td>
</tr>
<tr>
<td>Noblett and colleagues(^{46})</td>
<td>3 51</td>
<td>12 52</td>
<td>16.6</td>
<td>0.21 (0.05, 0.79)</td>
<td></td>
</tr>
<tr>
<td>Pearse and colleagues(^{48})</td>
<td>2 62</td>
<td>4 60</td>
<td>10.0</td>
<td>0.47 (0.08, 2.65)</td>
<td></td>
</tr>
<tr>
<td>Wakeling and colleagues(^{59})</td>
<td>9 64</td>
<td>29 64</td>
<td>37.3</td>
<td>0.20 (0.08, 0.47)</td>
<td></td>
</tr>
<tr>
<td><strong>Subtotal (95% CI)</strong></td>
<td>227</td>
<td>226</td>
<td>93.2</td>
<td>0.25 (0.14, 0.43)</td>
<td></td>
</tr>
<tr>
<td><strong>Total events</strong></td>
<td>21</td>
<td>63</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heterogeneity: (\tau^2=0.00; \chi^2=0.94), df = 3 ((P=0.82)); (I^2=0)%</td>
<td></td>
<td></td>
<td></td>
<td>Test for overall effect: (Z=4.99 (P&lt;0.00001))</td>
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</tr>
<tr>
<td><strong>Total (95% CI)</strong></td>
<td>274</td>
<td>304</td>
<td>100.0</td>
<td>0.29 (0.17, 0.50)</td>
<td></td>
</tr>
<tr>
<td><strong>Total events</strong></td>
<td>23</td>
<td>64</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heterogeneity: (\tau^2=0.02; \chi^2=5.24), df = 5 ((P=0.39)); (I^2=5)%</td>
<td></td>
<td></td>
<td></td>
<td>Test for overall effect: (Z=4.36 (P&lt;0.00001))</td>
<td></td>
</tr>
</tbody>
</table>

Why is GDT not used routinely?

- Fears about uncontrolled implementation?
- (cost of PA catheter, cordis/central line kit, CXR?)
Why is GDT not used routinely?

I’m looking for funding for GDT monitoring

It helps the floor not the OR

It’s for the OR not the floor

Show me the money!

Traditional silos getting in the way?
Why is GDT not used routinely?

- lack of immediate results (not intraop or early postop)
- lack of user-friendly equipment, lack of training/knowledge
- no large-scale RCTs, only systematic reviews
- skepticism about clinical effectiveness

Poor Adoption of Hemodynamic Optimization During Major Surgery: Are We Practicing Substandard Care?

Timothy E. Miller, MB ChB, FRCA, Anthony M. Roche, MB ChB, FRCA, MMed (Anaes), and Tong J. Gan, MD, MHS, FRCA

Anesth Analg 2011;112:1274
Successful implementation of GDT

- concern about postop complications related to fluid
- campaign to adopt GDT (esoph. doppler) in 3 large hospitals in England
- consultant anaesthetist, divisional manager, audit facilitator at each site
  - business case prepared with support from NHS Technology Adoption Centre to overcome unequal spread of costs vs. benefits
- clinician and manufacturer training support for anaesthetists

Kuper M et al. BMJ 2011;342:d3016
Successful implementation of GDT

- compared patient outcomes
  ~650 matched pairs 12 months before and after implementation
- use of GDT ↑ from 11% to 65% of eligible operations
- LOS reduced 3.7 days
  - 1 complication (pulmonary edema)
- [www.ntac.nhs.uk/HowToWhyToGuides/DopplerGuide](http://www.ntac.nhs.uk/HowToWhyToGuides/DopplerGuide)

Kuper M et al. BMJ 2011;342:d3016
GDT vs restrictive fluid balance

- 150 pts elective colorectal surgery (laparoscopic and open)
- randomized to (A) GDT to max SV, or (B) zero fluid balance, normal body wt
- no difference in complications:
  - major
  - minor
  - cardiopulmonary
  - tissue-healing

Brandstrup B et al. Eur J Anaesth 2010;27:4
Summary

- hypovolemia is common, unrecognized and potentially avoidable
- standard monitoring methods of fluid management have failed us
- crystalloid excess is not the answer
- GDT improves patient outcomes
- fluids must be individualized
- the right fluid, for the right patient, at the right time
- our nursing colleagues must be champions for GDT!