FLUID MANAGEMENT
Fluid Responsiveness

Fluid Loss

- Water loss by evaporation 40-800mL/day
- Open abdomen ~ 1L/h 70kg person
- GI losses (i.e. illness, bowel obstruction, fistula)
- Hemorrhage
- Endothelial Injury (sepsis, trauma, burns, inflammatory states)
- Iatrogenic

Why do we give fluids?

Goal of Fluid Resuscitation

"Increase preload, aka the stressed venous volume, leading to an increased stroke volume and cardiac output"

BUT

- Only ~50% of hemodynamically unstable patients are fluid responsive
- Hemodynamic response to a fluid challenge is usually small & short lived - without lasting effect on cardiac index/output, BP, UOP
- Over resuscitation is not benign

Fluid administration is not benign....

Hypervolemia:
Soft tissue edema
Intestinal edema/ileus
Pulmonary Edema
Prolonged Ventilation
ARDS
Heart failure
Damaged glycoccalyx
Abdominal Compartment
End organ damage
Reduced wound healing
Mortality

Hypovolemia:
Reduced tissue perfusion
End organ damage
Mortality

What does fluid responsive mean?

- Fluid responsive = SV increases by >10% following a fluid challenge

(really need invasive or non-invasive cardiac monitoring system to determine)

- **Need 2 things to increase SV:**

1) Bolus increases the stressed blood volume -> causing the mean systemic pressure to increase enough to increase the gradient for venous return

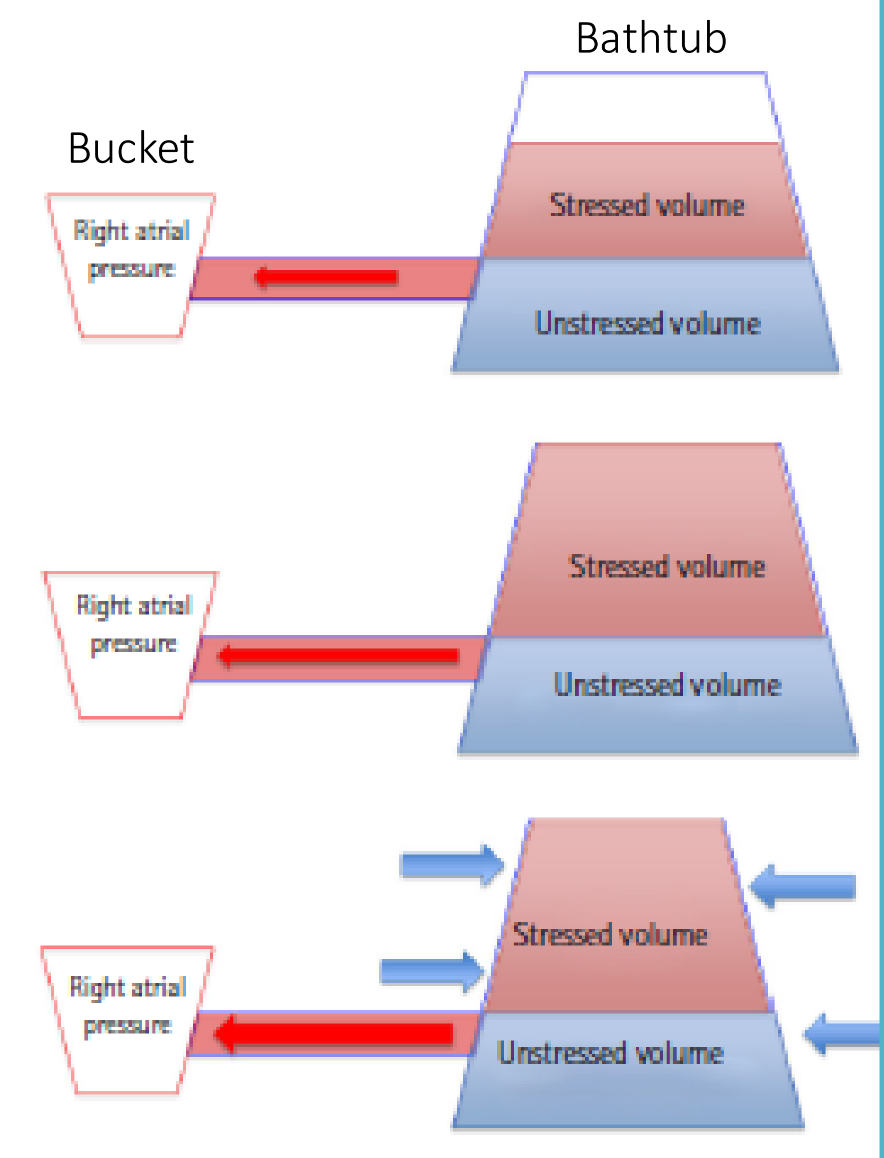
2) Both ventricles on the ascending limb of the Frank-Starling Curve

Stressed v Unstressed Blood Volume

Unstressed blood volume (UBV): Blood volume in the venous system that doesn't create significant pressure; physiologically inert until recruited.

Stressed blood volume (SBV): The volume beyond the UBV that causes distending pressure in the veins, determining mean systemic pressure (MSP) and venous return.

How does UBV & SBV work?

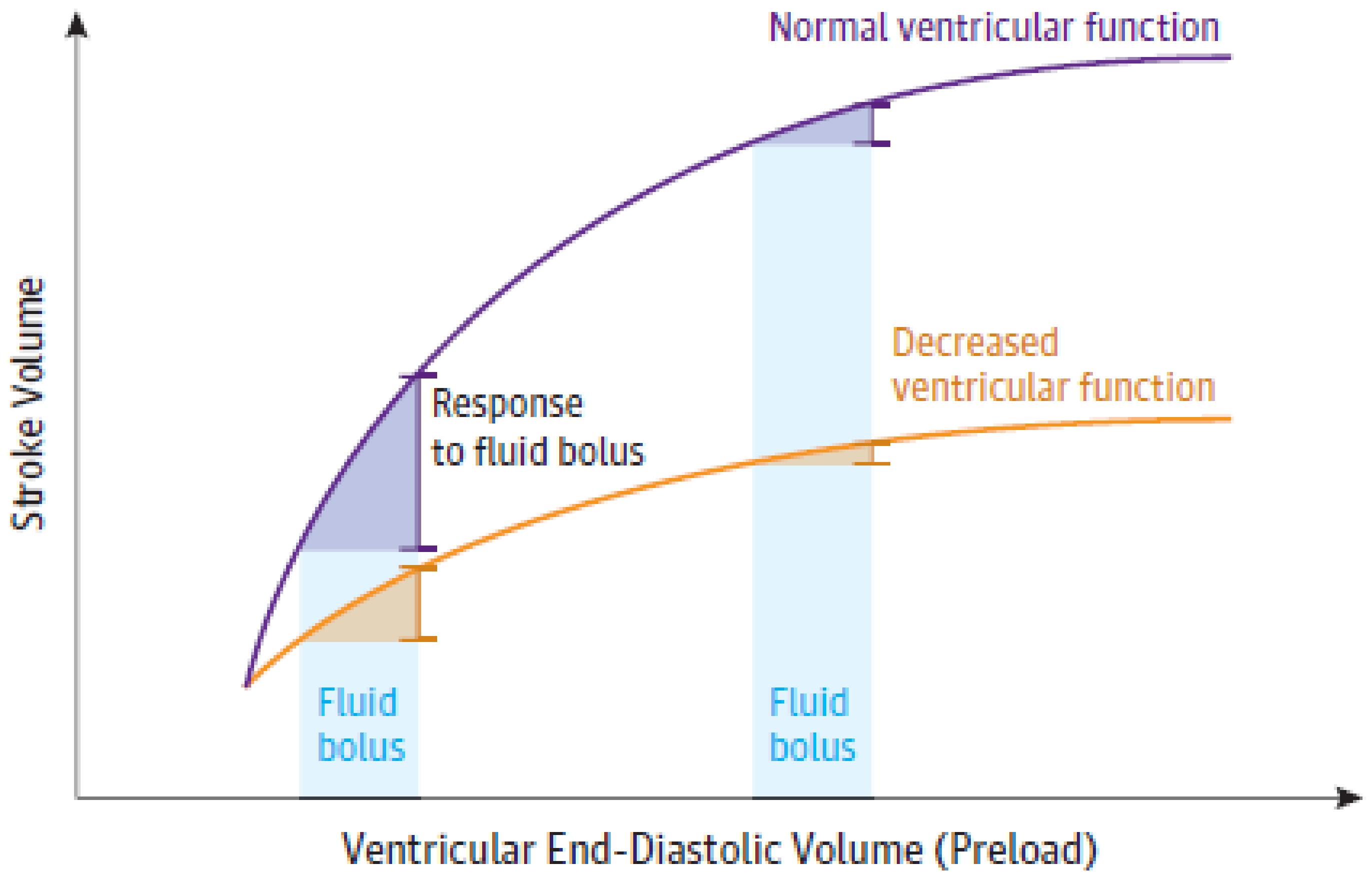


Tub will drain to the level of the drainpipe but no farther. The remainder of the water in the system is considered the unstressed volume

Fluid bolus augments venous return by , increasing both the total volume and stressed volume

Alternatively vasopressors can augment venous return by compressing the walls of the tub (reducing compliance), increasing the stressed volume without increasing total volume

Figure 1. Effect of Increase in Preload on Stroke Volume of Ventricles With Normal and Decreased Contractility



Frank-Starling curves illustrate that the effect of a given increase in preload on stroke volume is dependent both on ventricular contractility and on baseline preload.

What Do We Have In the Toolbox?

Static

Vs

Dynamic

Tests

What’s the difference?

Examples

Static parameters	Dynamic parameters
Clinical examination • Heart rate • Blood pressure	**Arterial pressure** • Systolic pressure variation • Pulse pressure variation • Stroke volume variation
Preload pressure • Central venous pressure • Pulmonary artery occlusion pressure	**Plethysmography** • Plethysmographic amplitude variation • Plethysmographic variability index
Thermodilution and ultrasound dilution • Global end-diastolic volume index • End-diastolic volume • Ejection fraction	**Cardiac preload challenge** • Abdominal compression • Passive leg rising test • End-expiratory occlusion test • Mini-fluid challenge test
Echocardiography and Doppler • Left ventricular end-diastolic area • Stroke volume index • Corrected flow time	**Echocardiography and Doppler** • Respiratory variation in aortic blood flow peak velocity • Respiratory variation in the inferior vena cava diameter • Stroke distance variation • Velocity–time integral

Static Measures: Exam/Labs

Vital Signs:

HR (increased) – hypovolemia?

BP (decreased, ideally w increased HR) – compensation not enough to sustain perfusion

RR (increased) – metabolic acidosis from hypoperfusion (resp comp)

UOP (<1ml/kg/h) – hypovolemia, hypo-intravascular volume

Physical Exam:

Reduced cap refill

Weak, rapid pulse

Cool, clammy skin

Dry membranes

Skin turgor

Labs:

BUN/Cr (increased)

Lactic acidosis

Hct (low – hemorrhagic hypo, high – hemoconcentrated/hypovolemic)

ABG

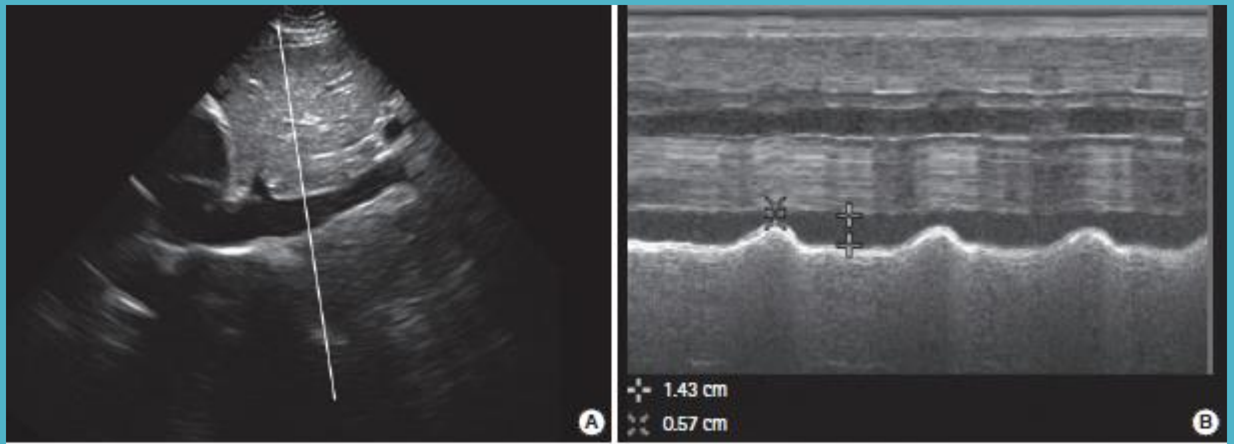
Static Measures: CVP

- Fails to reliably predict CO response to a fluid bolus
- Testing CVP to guide fluid challenge in sepsis = CVP <8 mm Hg predics fluid responsiveness only 47%
- CVP ability to accurately predict CO response to a fluid bolus = AUC of 0.56 (like flipping a coin)
- Should not be used in isolation
- Trending can be of use – pattern overtime improves efficacy
- Can result in fluid overload
- Higher ≠ better

  Elevated CVP's – associated with increased risk organ failure/AKI

Dynamic Measures: IVC Collapsibility

- Mechanically Ventilated: Δ in IVC diameter **>15% between inspiration & expiration** indicates preload responsiveness
- Measurements should be taken 1-2 cm distal to the hepatic veins
- Using cine-loop with manual measurement at a fixed anatomical point helps avoid errors
- Sensitivity ~ 75%, Specificity ~82%
- **BUT:** require specific conditions - ventilated in VC 8mL/kg IBW, sinus rhythm, no ventilator dyssynchrony, normal right ventricular function & RV-to-LV coupling



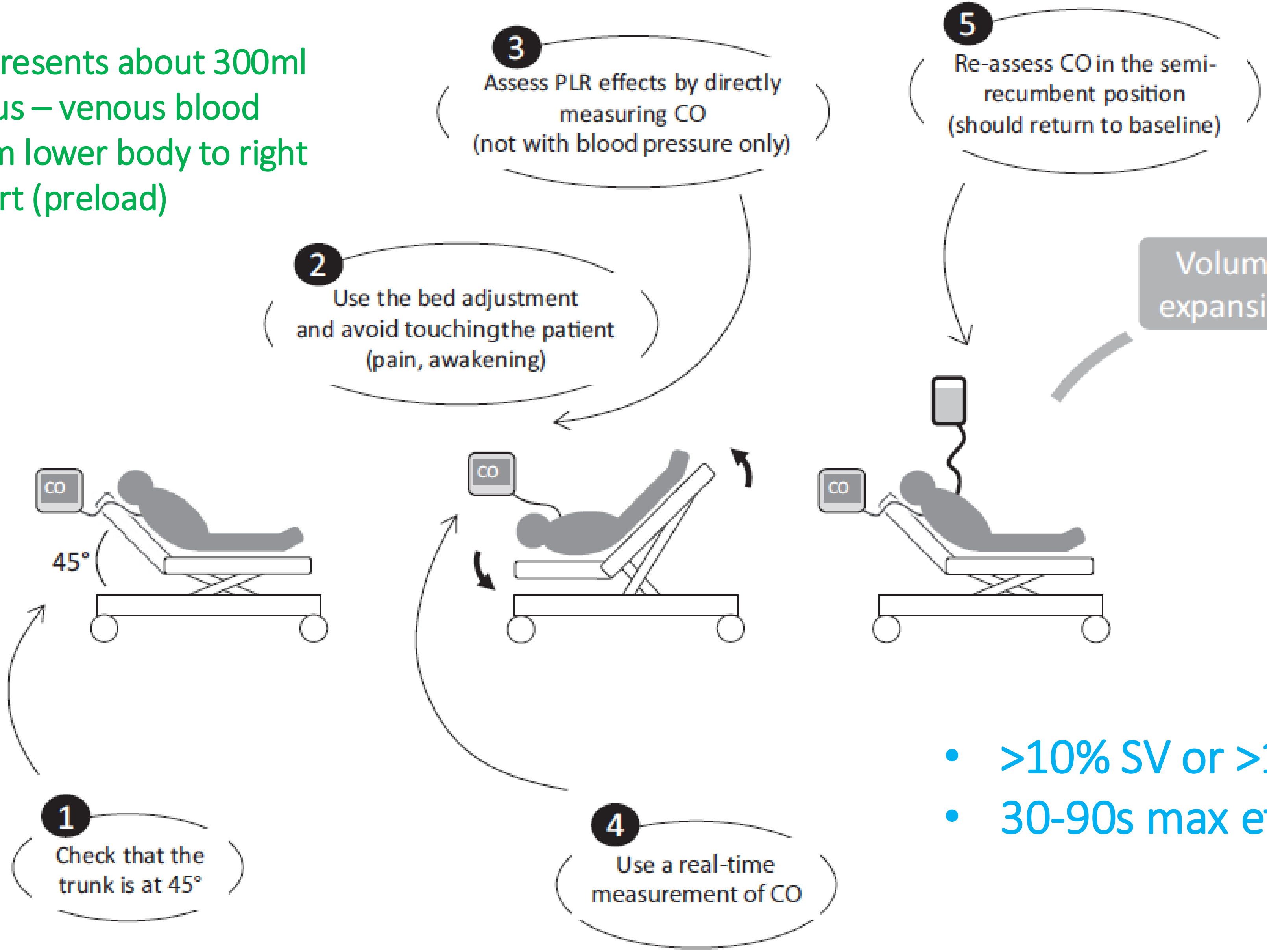
Dynamic Measures: SVV/PPV

- **Pulse Pressure Variation (PPV):** % of change between the highest PP & lowest PP over a respiratory cycle
- **Stroke Volume Variation (SVV):** % of change in stroke volume during a respiratory cycle
- **>10-15% suggest fluid responsiveness**
- Demonstrate accuracy in mechanically ventilated patients receiving controlled ventilation (PPV/SVV AUC ~ 0.87)
- **BUT:** require specific conditions - controlled mechanical ventilation with TV ≥8 mL/kg, PEEP<10, sinus rhythm, absence of spontaneous breathing efforts, normal thoracic/abdominal compliance
- SVV requires min-invasive cardiac monitoring technology (Flotrac, Vigileo)

Dynamic Measures: Passive Leg Raise (PLR)

- Awake or intubated
- Represents ~300ml bolus – venous blood from lower body to right heart (preload)
- >10% SV or >15% CI = possible fluid response (30-90s max effect)
- **One of the most accurate methods for predicting fluid responsiveness, positive likelihood ratio of 11 and specificity of 92%**
- Does NOT require controlled mechanical ventilation, though may be less reliable in patients with intra-abdominal hypertension
- Most broadly applicable test in patients with arrhythmias, spontaneous breathing, altered lung compliance, low TV ventilation
- **Ideally need CO measurement, less accurate using blood pressure**
- Requires moving patient & raising leg

- Represents about 300ml bolus – venous blood from lower body to right heart (preload)



- >10% SV or >15% CI fluid response
- 30-90s max effect

Figure 1 The best method for passive leg raising, indicating the five rules to be followed. CO, cardiac output; PLR, passive leg raising.

Dynamic Measures: Mini Fluid Challenge

- Small bolus 100-250ml
- Rapidly infused over 1-5 minutes
- Responsive test = increased SV or CO 10%
- High predictive value of fluid responsiveness (AUC 0.9)
- Similar to PLR - applicable test in patients with arrhythmias, spontaneous breathing, altered lung compliance, low TV ventilation
- Requires continuous cardiac output monitoring (to get the accuracy stated above)

Dynamic Measures: A couple more examples

End-expiratory occlusion test (EEOT) - end expiratory pause (15-30s) – temporarily augments venous return – increases preload – on release of hold monitor for change in CO

- Responsive - >5% increase CO

Tidal Volume Challenge - Increase ventilator tidal volume from 6 mL/kg to 8 for 60s

- Responsive - ΔPPV of > 2%, or a final PPV>11% at the higher volume

Both need continuous cardiac monitoring

There is no perfect test

Dynamic test out perform static BUT typically require specific conditions to obtain reported accuracy

Need to look at the big picture

Clinical context

Patient dynamics

Risk v benefit

Use your clinical tools as adjuncts – not the rule

Approach to Resuscitation

What is the cause?

Is it volume?

Is it the pump?

Is it the tub (vasculature compliance, vascular leak, …)?

Is it a combination?

Approach needs to be tailored to etiology & patient factors…

Approach to Resuscitation

- Hypovolemic (GI loss, dehydration, absolute fluid loss)
  - *Isotonic Crystalloid*
    - *LR, plasmalyte*
    - *NS (in specific situations) – hyperchloremic acidosis, possible higher AKI risk*

- **Hypovolemic hemorrhagic**
  - *1:1:1 RBC:plasma:plt (+/- cryo, fibrinogen) and/or whole blood*
  - *Calcium*
  - *Vasopressor*

Approach to Resuscitation

- **Septic Shock**
- *Typically distributive – vasodilation – increased vascular/venous compliance – reduced stressed volume - resulting in relative hypovolemia*
- *Can also have absolute hypovolemia (depending on etiology)*
- *Surviving sepsis guidelines:*

Approach to Resuscitation

Septic Shock

- *Surviving sepsis guidelines:*
- 30 mL/kg crystalloid fluids recommended in 1st 3h
- Albumin - no clear benefits over balanced crystalloids. Weak recommendation - after infusing "large volume crystalloid" to improve blood pressure
- Add vasopressors if initial fluid resuscitation not adequate
- Lactate does not need to normalize BUT levels approaching normal suggest successful resuscitation

Approach to Resuscitation

Cardiogenic

- *Need to fix the pump – inotropes & vasopressor*
- *Hypovolemic – may need fluid (typically isotonic crystalloid)*
- *Hypervolemic –diuresis*