Assessing Fluid Responsiveness in the MICU

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Last updated: March 23, 2022

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A Common Scenario

- Middle of the night in MICU.
- Patient who has been in the ICU for several days with shock has increasing vasopressors requirements.
- Senior (or fellow?) tells you to "go ultrasound the IVC".

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- Patient who has been in the ICU for several days with shock has increasing vasopressors requirements.
- Senior (or fellow?) tells you to “go ultrasound the IVC”.
- Why?

The Goal

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  - Abbreviations
    - CO = cardiac output, HR = heart rate, SV = stroke volume, DO_2 = delivered oxygen, CaO_2 = oxygen content of the blood, Hgb = hemoglobin, SpO2 = pulse oximetry-derived oxygen saturation
  - **Formula / Definitions**
    - $DO_2 = (CO) \cdot (CaO_2)$

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    - $DO_2 = (HR \cdot SV) \cdot (1.34 \cdot [Hgb] \cdot SpO_2)$
- if ↑SV, we (may) ↑CO and (may) get ↑DO_2
- Notice all the "mays" in there.

Physiology

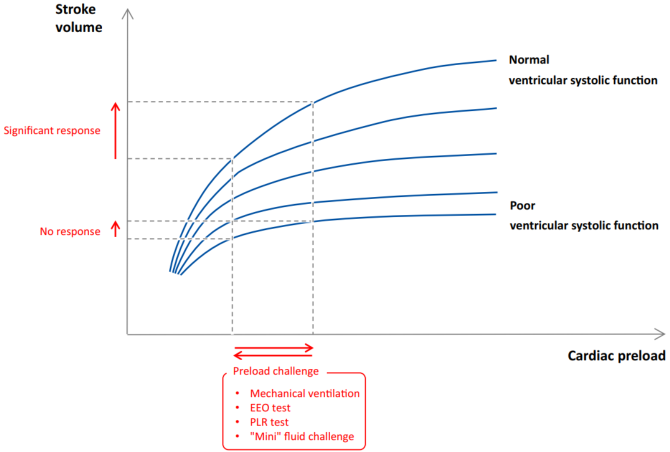

Fig. 1 Frank–Starling relationship. The slope of the Frank–Starling curve depends on the ventricular systolic function. Then, one given level of cardiac preload does not help in predicting fluid responsiveness. By contrast, dynamic tests include a preload challenge (either spontaneous, induced by mechanical ventilation or provoked, by passive leg raising, end-expiratory occlusion or fluid infusion). Observing the resulting effects on stroke volume allows for the detection of preload responsiveness. *EEO* end-expiratory occlusion, *PLR* passive leg raising

Some Thoughts

- Fluid responsiveness $\neq$ patient should be get fluids!
  - e.g., no shock

Some Thoughts

- Fluid responsiveness $\neq$ patient should be get fluids!
  - e.g., no shock
- However, if $\downarrow$ CO and requires correction:
  fluid responsiveness $\implies$ $\uparrow$SV (and usually $\uparrow$CO, unless HR falls) if fluids are given

Assessing Shock

Overview

Rule out acutely life-threatening causes:

- ECG for possible acute MI as a cause of cardiogenic
- CBC/exam to assess for hemorrhagic – send type/screen
- Infectious workup if sepsis is suspected, early antibiotics

BP = CO X SVR

CO = HR X SV

SV from preload, contractility, afterload

	Preload	Pump Function	Afterload	Tissue perfusion	Treatment
Measure	Wedge	CO/CI	SVR (Limbs)	MvO2 sat	HYPOTHESIS
Hypovolemic - Dry or Bleeding	↔ (early) or ↓ (late)	↔ (early) or ↓ (late)	↑(cool)	>65% (early) or <65% (late)	Volume and/or blood
Cardiogenic	↑	↓	↑(cool)	<65%	Improve CO
Distributive – SIRS, Septic, Neurogenic	↔ (early) or ↓ (late)	↑ (↓ possible)	↓(warm)	>65%	Volume, peripheral pressor
Obstructive – PE, PH, tension PTX	↔ (early) or ↓ (late)	↔ (early) or ↓ (late)	↑(cool)	>65%	Treat obstruction
Obstructive - Tamponade	↑	↓	↑(cool)	<65%	Relieve tamponade

Assessing Shock

Distributive

Type	Pathophysiology	Example Causes	Special Consideration for Treatment
Septic	Cytokine mediated vasodilation and/or ↑ permability	Pneumonia, Urinary tract infection, Meningitis, Catheter related, abscess, Peritonitis, Septic arthritis, Cellulitis, Gastrointestinal Can include fungal like candidemia	**Early empiric ANTIBIOTICS** after cultures drawn, Vasopressors, Fluids, Stress dose steroids, source control
Inflammatory - SIRS	Cytokine mediated vasodilation and/or ↑ permability	Infections, Pancreatitis, Burns, Crush, Air/Fat Embolism, post-ROSC, obstructive pyelo post-procedure	Vasopressors, Fluids
Neurogenic	Loss of neural tone of arteries	Traumatic brain injury, spinal cord injury	Vasopressors, relieve ongoing neuro damage
Anaphylaxis	Allergic IgE release, often bronchospasm	Bees, drugs, contrast, latex	**Epinephrine**, Fluids
Toxin or Drug Overdose	Direct effect on vessels from drug or toxin	Toxic shock syndrome (Strep, Ecoli), Opiates, Scorpion, Transfusion reaction	Anti-toxin if available, Narcan, stop transfusion
Endocrine	Mineralcorticoid deficiency with poor vascular tone, often myxedema and ↓ Contractility	Addisonian crisis	**Replace mineralcorticoids**

Strategies

Overview

Static	**Dynamic**

Strategies

Overview

Static	**Dynamic**
vital signs	passive leg raise
CVP / PCWP	end-expiratory occlusion test
"one off" lactate / VBG	IVC ultrasound
pulse pressure variation	mini fluid challenge

Strategies

Overview

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pulse pressure variation	mini fluid challenge

Strategies

Overview

Heart-Lung Interaction	**Independent**
pulse pressure variation	passive leg raise
end-expiratory occlusion test	mini fluid challenge
IVC ultrasound	

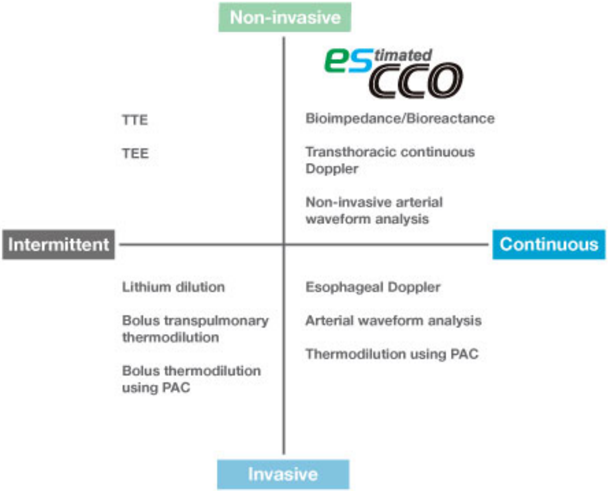
Monitoring Cardiac Output

Who do we know if we've helped?

- **All** of these methods need a way to monitor cardiac output
- Most of these methods used *non-invasive cardiac output monitoring (NICOM)* in studies
- We don't have NICOM systems at Brown

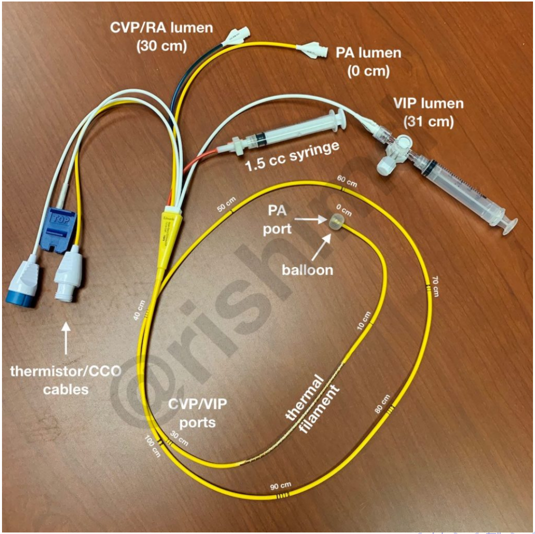
Monitoring Cardiac Output

Overview



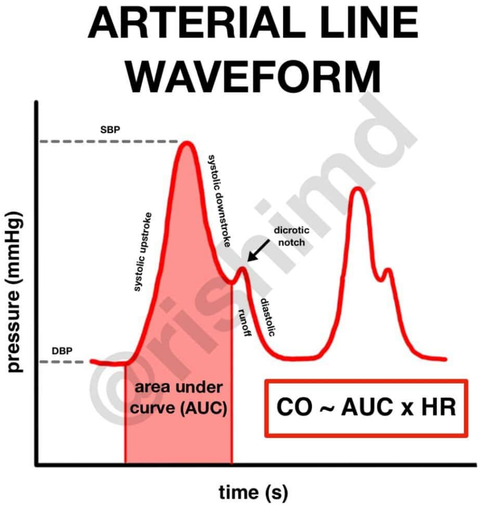
Monitoring Cardiac Output

Invasive Monitoring



Monitoring Cardiac Output

Less Invasive Monitoring

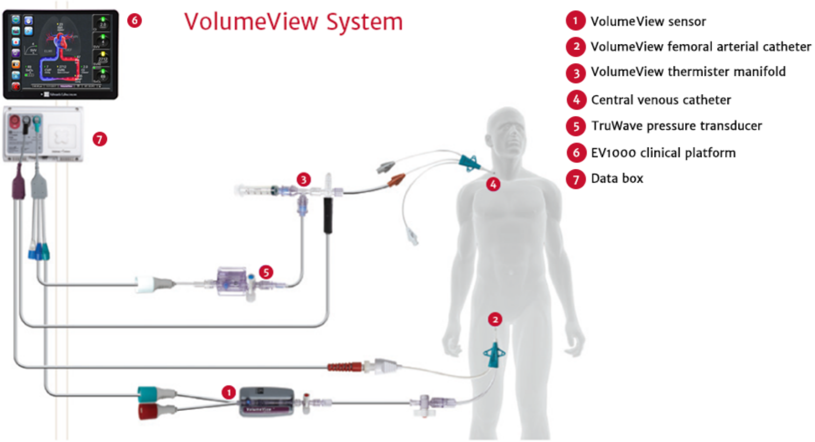


Monitoring Cardiac Output

Less Invasive Monitoring

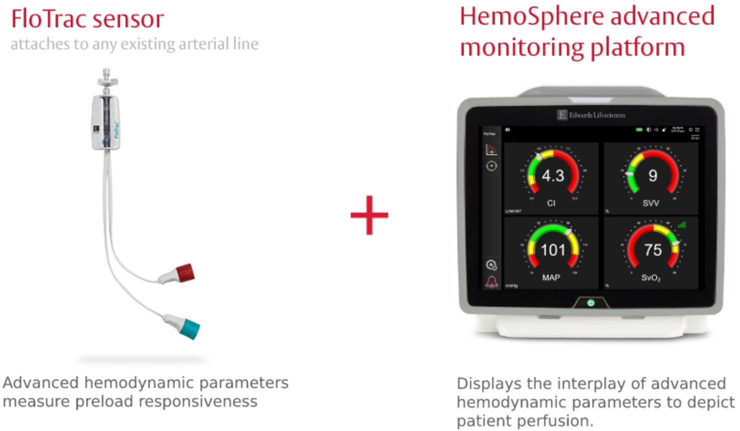
Monitoring Cardiac Output

NICOM



Monitoring Cardiac Output

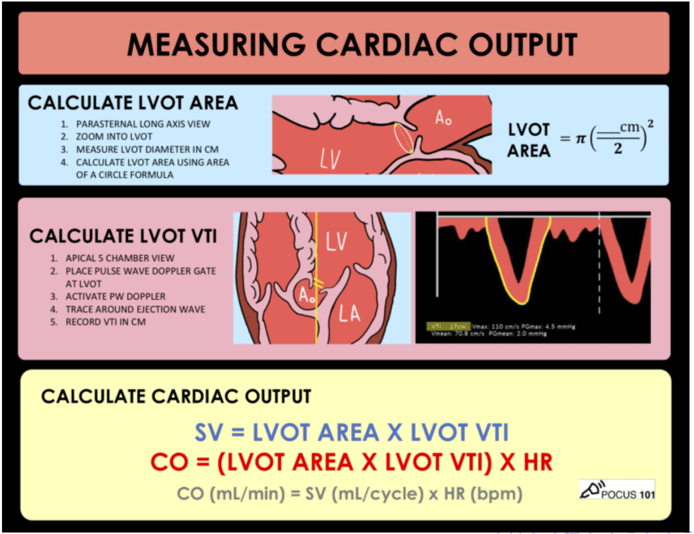
NICOM

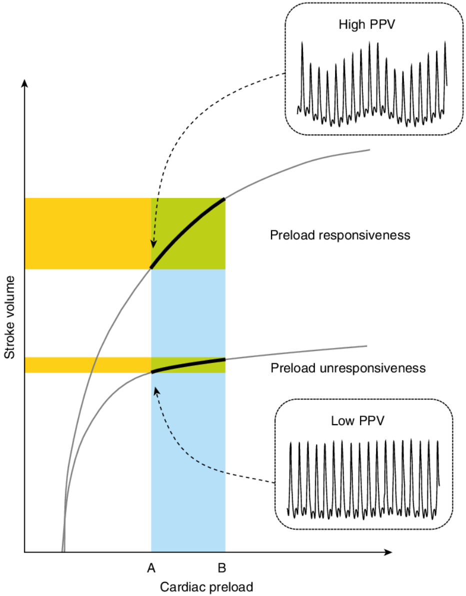


Monitoring Cardiac Output
NICOM

Monitoring Cardiac Output

NICOM




High PPV
Preload responsiveness
Preload unresponsiveness
Low PPV
Stroke volume
A
B
Cardiac preload

Source: [1]

Pros / Cons

Pulse Pressure Variation

Pros	**Cons**
validated in intubated patients	not validated in non-intubated patients
	doesn't work in arrhythmias
	not valid in tamponade

Method

Pulse Pressure Variation

- $PPV = \frac{PP_{max} - PP_{min}}{\frac{PP_{max} - PP_{min}}{2}} = \frac{\Delta PP}{PP_{mean}}$
- Area under the curve $PPV = 0.82$ [2]

Table 3 Operative performance of predictors of fluid responsiveness

Predictor of fluid responsiveness	Sensibility	Specificity	AUC	Threshold (%)	DOR	I^2 (%)
First group						
PPV	0.74 (0.66–0.81)	0.77 (0.70–0.83)	0.82	10	11.70 (6.73–20.37)	56
Tidal volume challenge	0.90 (0.76–0.97)	0.87 (0.31–0.99)	0.92	3	82.95 (12.37–556.12)	8
SVV	0.83 (0.75–0.88)	0.85 (0.78–0.90)	0.90	12	28.82 (12.43–66.84)	63
Second group						
ΔIVC	0.77 (0.65–0.86)	0.87 (0.70–0.95)	0.86	16	24.13 (9.71–59.67)	0
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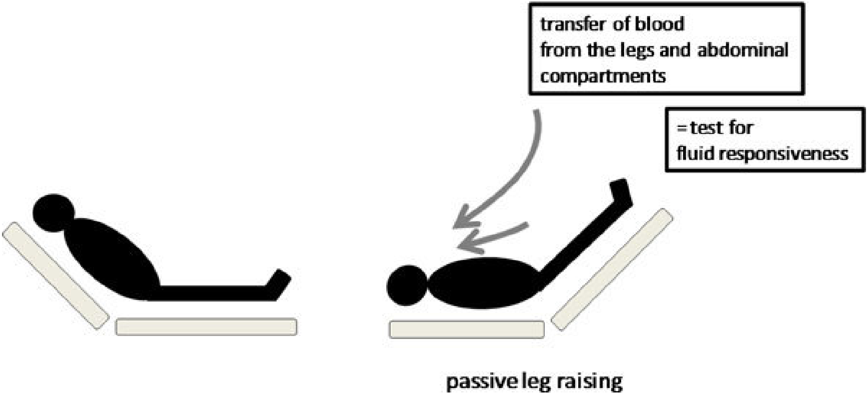
Mini-fluid challenge	0.84 (0.76–0.90)	0.76 (0.68–0.83)	0.84	1	15.57 (8.02–30.25)	9
PLR	0.83 (0.61–0.94)	0.80 (0.68–0.88)	0.84	13	31.65 (4.16–240.93)	74
EEOT	0.82 (0.73–0.89)	0.89 (0.82–0.94)	0.92	5	39.35 (14.80–104.60)	51

Values are expressed as pooled value (95% confidence interval). AUC, area under curve; I^2, inconsistency; DOR, diagnostic odds ratio; EEOT, end expiratory occlusion; PLR, passive leg raising; PPV, pulse pressure variation; SVV, stroke volume variability. Values are expressed as pooled data (95% confidence interval)


transfer of blood
from the legs and abdominal
compartments
= test for
fluid responsiveness
passive leg raising

Source: [3]

Pros / Cons

Passive Leg Raise

Pros	**Cons**
valid in intubated patients	body habitus
valid in non-intubated patients	no legs!
valid in arrhythmias	neurological injury
may be more reliable than PPV [4]	no-turn patients

A prior Brown faculty member studied this, showing favorable outcomes when using PLR to guide resuscitation in septic shock [5]

The Evidence

Passive Leg Raise

- Multiple studies showing good prediction ($AUR = 0.84$) [2, 6]

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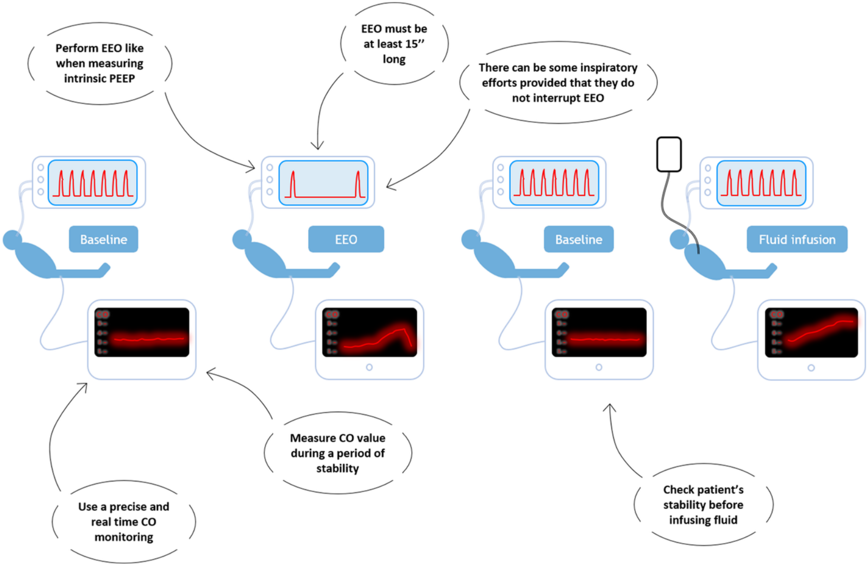
Perform EEO like when measuring intrinsic PEEP
EEO must be at least 15'' long
There can be some inspiratory efforts provided that they do not interrupt EEO
Baseline
EEO
Baseline
Fluid infusion
Use a precise and real time CO monitoring
Measure CO value during a period of stability
Check patient's stability before infusing fluid

Source: [7]

Pros / Cons

End-Expiratory Occlusion Test

Pros	Cons
valid in intubated patients	requires significant sedation
valid in $\downarrow$TV ventilation	can't do it in non-intubated patients
valid in arrhythmias	respiratory stability

The Evidence

End-Expiratory Occlusion Test

- One meta-analysis found Area under the curve of $EEOT = 0.92!$[2]

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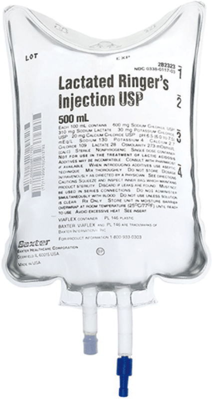
- Multiple other studies have assessed it [7]

Method

Mini-Fluid Challenge

- Rapidly infusion 100 cc of IV fluid
- Monitor stroke volume in real time



Pros / Cons

Mini-Fluid Challenge

Pros	Cons
less fluid overload	Requires precise cardiac output monitoring
Good evidence it's predictive	Still requires giving fluid

The Evidence

End-Expiratory Occlusion Test

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IVC Ultrasound

The Most Common Resident Assessment

- This seems to me the one we use the most.
- What is it? How do we do it?

IVC Ultrasound

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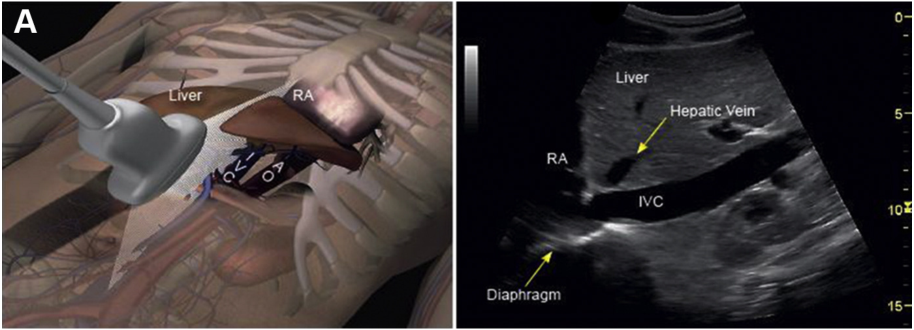

Images source [8]

Why / how it works

- if intra-abdominal pressure $\geq$ right atrial pressure, then IVC collapses
- Sniff test example
    - acutely increases abdominal pressure

Why / how it works

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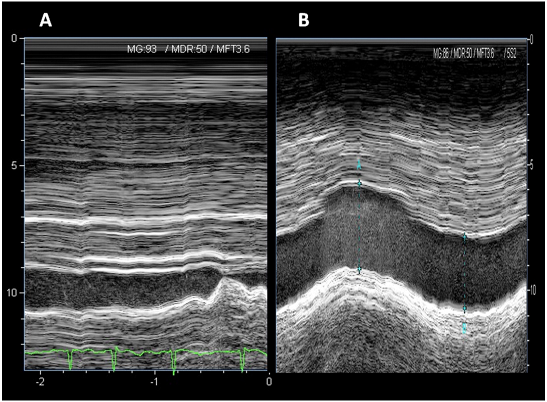
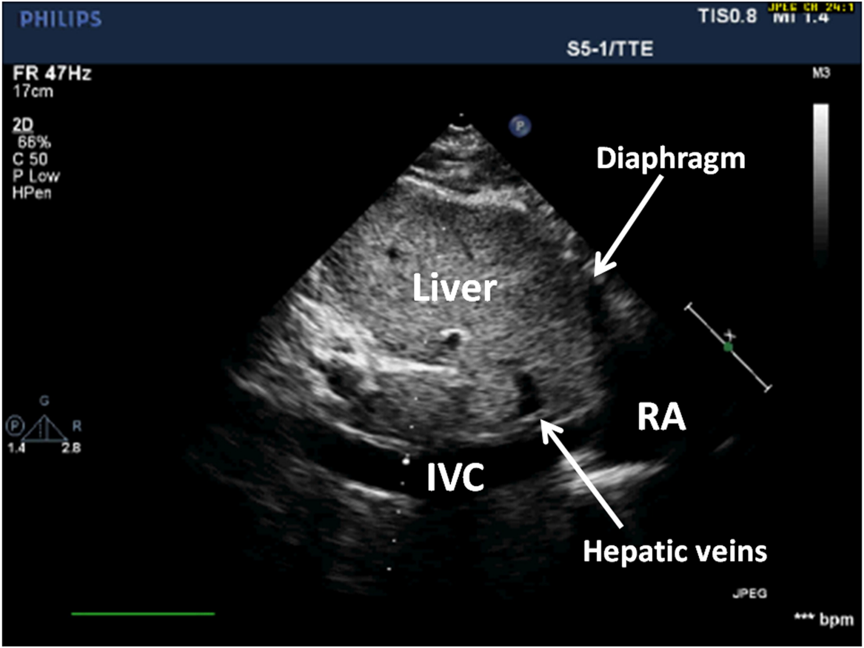
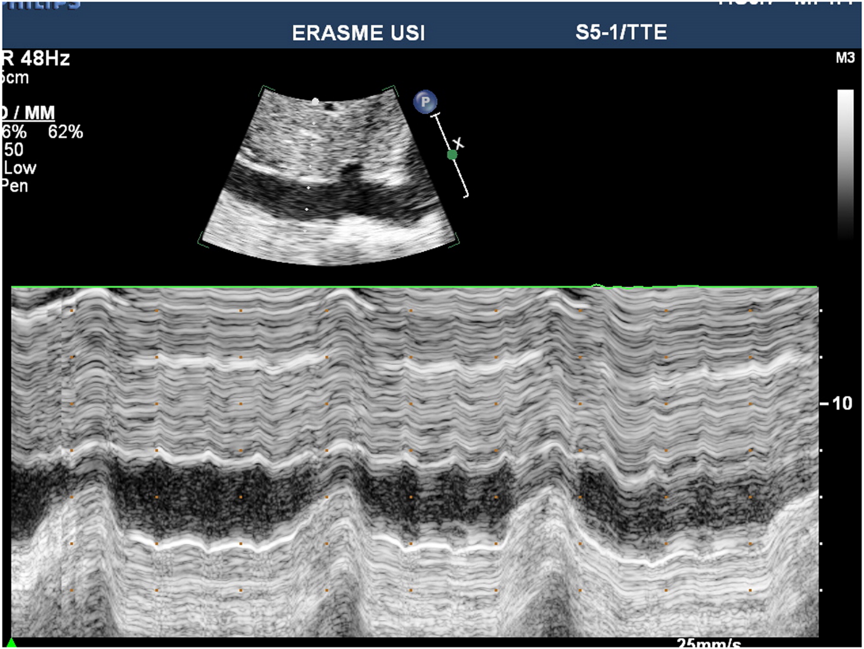
  - acutely increases abdominal pressure




PHILIPS
TIS0.8
MI 1.4
S5-1/TTE
FR 47Hz
17cm
2D
66%
C 50
P Low
HPen
M3
Diaphragm
Liver
RA
IVC
Hepatic veins
JPEG
*** bpm


ERASME USI
S5-1/TTE
R 48Hz
cm
/ MM
6% 62%
50
Low
Pen
M3
P
X
10
25mm/s

Pros / Cons

IVC Ultrasound

Lots of limitations (source:[9]):

Pros / Cons

IVC Ultrasound

Lots of limitations (source:[9]):

Pros	**Cons**
valid in intubated patients	inconsistencies in non-intubated patients
easy to administer	not valid in ↑ PEEP and/or ↓ TVs
	can't use in several heart issues
	can't use with increased abdominal pressure
	IVCs don't uniformly collapse
	inspiration can laterally displace IVC

Quality of Evidence

IVC Ultrasound

- PubMed has indexed 3 systematic reviews [10–12]
  - Long2017: "Respiratory variation in IVC diameter has **limited ability to predict fluid responsiveness**, particularly in spontaneously ventilating patients. A negative test cannot be used to rule out fluid responsiveness."
  - Orso2020: "Ultrasound evaluation of the diameter of the IVC and its respiratory variations **does not** seem to be a reliable method to predict fluid responsiveness."
  - Kim2021: "Our results suggest that the **diagnostic accuracy ... is acceptable**."
    - Sensitivity 0.75, specificity 0.83, positive likelihood ratio 4.37, negative likelihood ratio - 0.30, Area under the curve 0.86
- caveat: first two had spontaneously breathing patients

Quality of Evidence

IVC Ultrasound

- PubMed only has 2 RCTs looking at fluid responsiveness using ultrasound and IVC variation
  - both in patients before and after getting spinal anethesia
  - mixed results ([13, 14])

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Conclusions

- Remember to evaluate type of shock
- Fluid responsiveness $\neq$ patient should be get fluids!
- Remember this limitations of each method
  - Passive leg raise has fewest limitations
  - For intubated patients, EEOT and mini-fluid challenge are good
  - IVC ultrasound isn't bad either
- Don't forget to monitor cardiac output!

Post-Lecture Survey

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[1] Jean-Louis Teboul et al. “Arterial Pulse Pressure Variation with Mechanical Ventilation”. In: American Journal of Respiratory and Critical Care Medicine 199.1 (Jan. 2019), pp. 22–31. ISSN: 1073-449X. DOI: 10.1164/rccm.201801-0088CI. URL: https://www.atsjournals.org/doi/10.1164/rccm.201801-0088CI.

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