# IS THE IVC ALL THAT IT'S CRACKED UP TO BE?

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## DISCLOSURES

- No financial disclosures

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## OBJECTIVES

1. Review indications of IVC imaging
2. Discuss how to obtain IVC imaging
3. Describe the appropriate location for measurements
4. Identify challenges with use of the IVC
5. Review IVC in select clinical applications
   - Define Collapsibility Index & Distensibility Index
6. Case Examples

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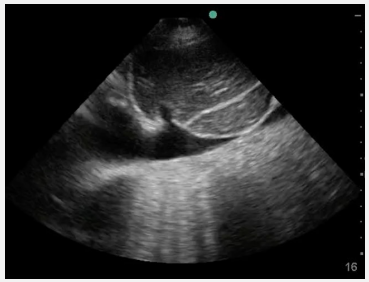
## INDICATIONS

- Undifferentiated shock protocols
- Volume status assessments
- Supplement physical exam
  - Narrow differentials
- Guiding treatment (ex CHF)
- Education
  - Great intro into POCUS training and physiology concepts
- Others

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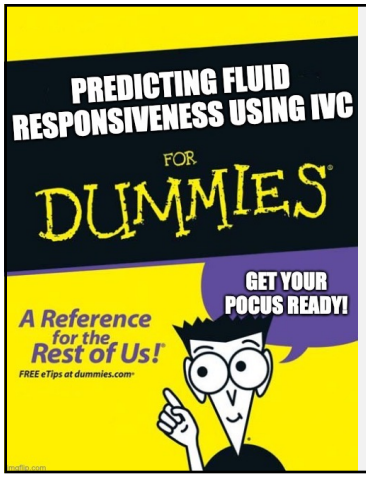


## WE REALLY WANT TO USE IVC…

- Everyone has an IVC
- Easy to train providers
- Easy to obtain images
- Predictable*
- Noninvasive
- Repeatable
- Fast
- Not nursing intensive
- "Cheap"
- POCUS more available as devices become smaller and less expensive

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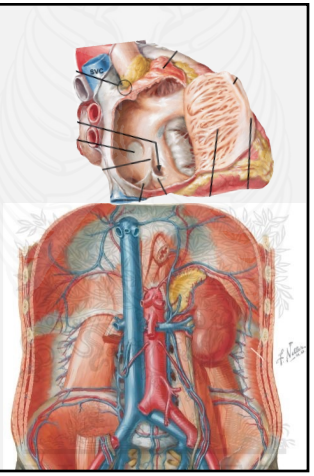
## IVC IMAGE ACQUISITION

- Positioning: supine (some studies semirecumbent)
- Phased array (or curvilinear)
- Cardiac Preset (Or abdominal)
- Indicator for EM caudal (Cardiology cephalad)
- Subxiphoid area and rock your beam up into the chest to visualize the RA with IVC and hepatic vein
- If not finding it fan laterally and slide laterally
- Measure IVC ~2cm back from atrial-caval junction or ~1cm from hepatic vein/IVC jxn
- Inspiratory sniff/deep breath

Note if not working can slide further laterally and evaluate transhepatically



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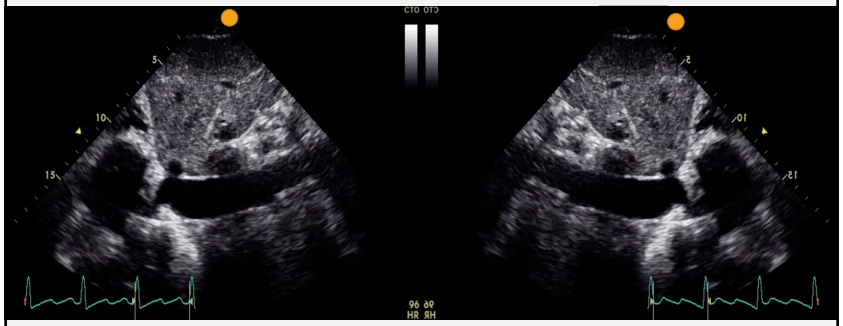

Some Emergency Medicine

Cardiology

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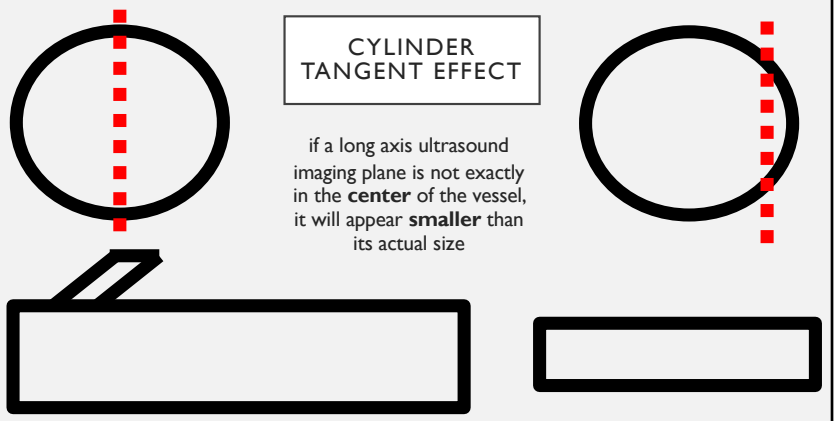
## CYLINDER TANGENT EFFECT

if a long axis ultrasound imaging plane is not exactly in the **center** of the vessel, it will appear **smaller** than its actual size



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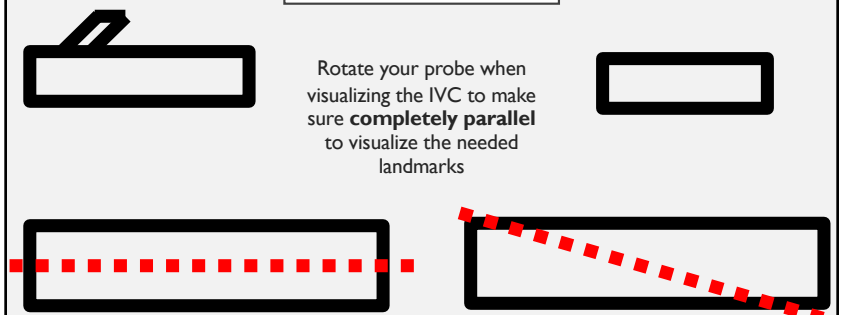
## ANOTHER OBLIQUE EFFECT

Rotate your probe when visualizing the IVC to make sure **completely parallel** to visualize the needed landmarks



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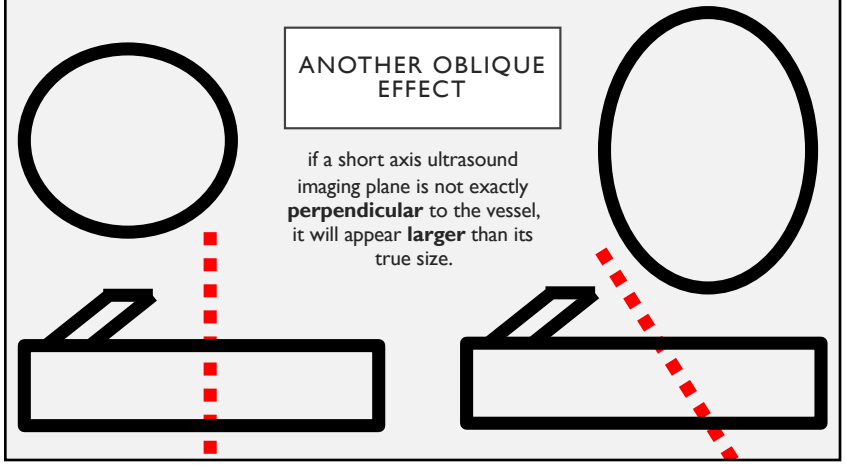
## ANOTHER OBLIQUE EFFECT

if a short axis ultrasound imaging plane is not exactly **perpendicular** to the vessel, it will appear **larger** than its true size.



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## THE AORTA EFFECT

You literally are measuring the **aorta…**

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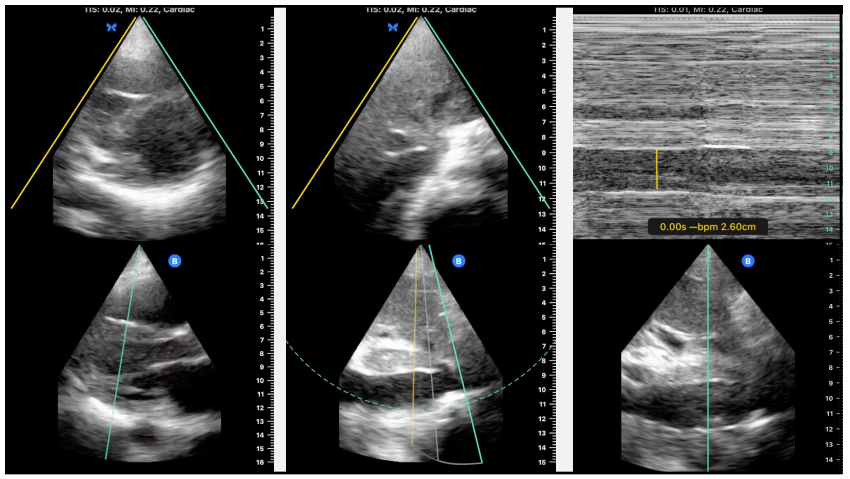


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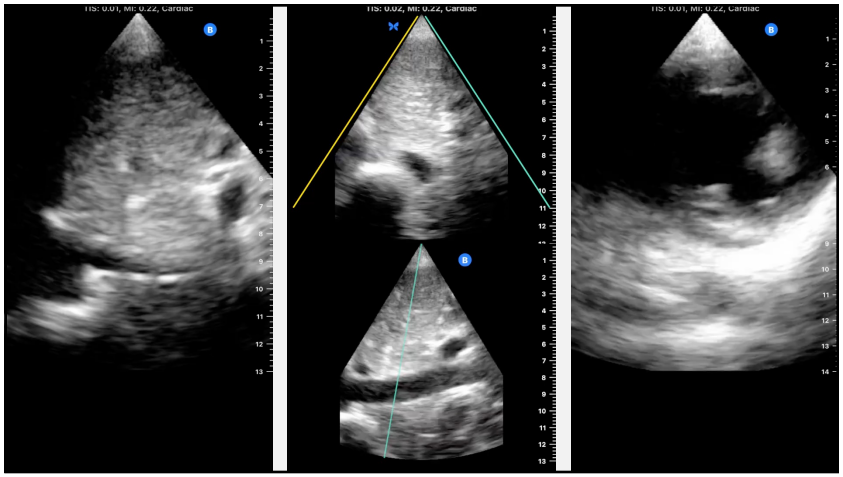

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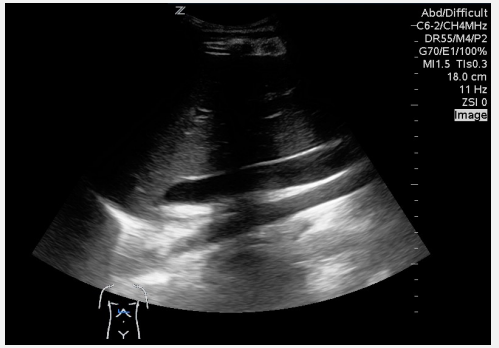
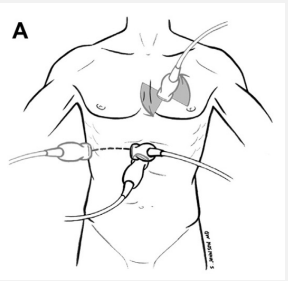
## CORONAL BACKUP




Kaptein MJ, Kaptein EM. Inferior Vena Cava Collapsibility Index: Clinical Validation and Application for Assessment of Relative Intravascular Volume. Adv Chronic Kidney Dis. 2021 May;28(3):218-226. doi: 10.1053/j.ackd.2021.02.003. PMID: 34906306.

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## INVASIVE POSITIVE PRESSURE VS SPONTANEOUS BREATHING

Spontaneous Breathing:

Exp→ MAX

Insp→ MIN

- Sniff test/deep inspiration vs quiet breathing
- Spont Inspiration→ neg intrathoracic pressure→ increase venous return → IVC collapse

Positive Pressure Ventilation:

Exp→ MIN

Insp→ MAX

- IVC: assessment of capacitance for dilation
- Positive pressure inspiration → pos intrathoracic pressure→ decreased venous return→ IVC distension

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## IVC MEASUREMENTS

Inner wall to inner wall
~2cm from the atrial-caval junction

or

1cm from the hepatic vein

Measure both IVC Max and IVC Min

Table 1
IVC Measurement Sites

| Reference | IVC Measurement Site |
|---|---|
| Barbier[7] | Just upstream of the origin of the suprahepatic vein |
| Blehar[9] | Immediately inferior to the confluence of the hepatic vein inlet |
| Brennan[4] | Within 2.5 cm of the caval–RA junction |
| Brennan[10] | Within 2 cm of the caval–RA junction |
| Feissel[8] | Approximately 3 cm from the RA |
| Grant[2] | Actual measurements in centimeters were not recorded |
| Kircher[11] | Within 2 cm of the caval–RA junction |
| Lichtenstein[12] | Left renal vein |
| Lyon[6] | 2 cm distal of the IVC–hepatic vein junction |
| Minutiello[13] | Within 2 cm of the right atrium origin of the IVC |
| Mintz[14] | Inferior to the junction of the hepatic veins |
| Mitaka[15] | Few centimeters inferior to the hepatic vein junction with the RA |
| Moreno[16] | IVC diameter was measured below the level of the hepatic veins and a few centimeters inferior to its junction with the RA |
| Natori[17] | Not defined |
| Sakurai[3] | Site distal of the IVC–hepatic vein junction |
| Simonson[18] | Successive 10-mm IVC measurements starting at the diaphragm and continuing to 60 mm from the caval–RA junction |
| Tamaki[19] | Slightly peripheral point from hepatic inlet |

IVC = inferior vena cava; RA = right atrium.

Wallace DJ, Allison M, Stone MB. Inferior vena cava percentage collapse during respiration is affected by the sampling location: an ultrasound study in healthy volunteers. Acad Emerg Med. 2010 Jan;17(1):96-9

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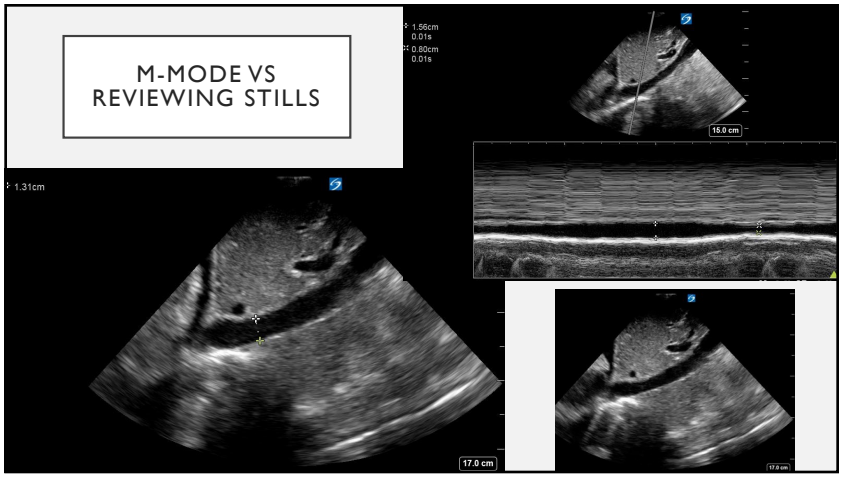
## M-MODE VS REVIEWING STILLS

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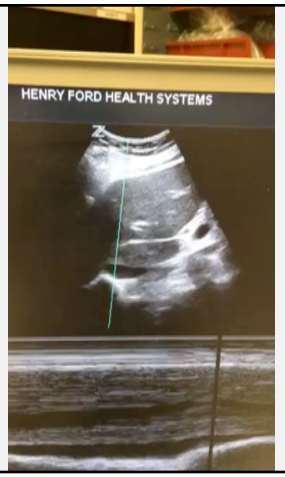
## RESPIROPHASIC VARIATION & MMODE




Courteously Dr Suszanksi
Henry Ford Hospital

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## IVC CHALLENGES

Variables that can affect IVC measurements:

- PPV vs Spontaneous breathing
- Cylinder tangent effect
- Diaphragmatic excursion/ deep vs shallow breathes
- Variation in IVC shape
- Variation in location of measurements
- Supine/semirecumbent/sitting
- Inadvertent measurement of the aorta
- Extrinsic compression
- Elevated intraabdominal pressure
- Transplant/cirrhosis
- Cardiac: Pulm HTN/Tricuspid Regurg/etc

Obstacles to adequate images:

- Bowel Gas
- Obesity
- Surgical wounds
- Abdominal pain

Biggest problem with IVC:

- Heterogeneity of the literature
- Multiple indices/calcs

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IS THE IVC ALL THAT IT'S CRACKED UP TO BE?

## DEPENDS ON WHAT QUESTION YOU ARE TRYING TO ANSWER…

1. IVC in Tamponade
2. IVC in Fluid Responsiveness
3. IVC in SOB/CHF Assessments
4. IVC in RUSH Exam/POCUS Protocols

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## IVC & TAMPONADE

**Inferior Vena Cava Plethora With Blunted Respiratory Response: A Sensitive Echocardiographic Sign of Cardiac Tamponade**

RONALD B. HIMELMAN, MD, BARBARA KIRCHER, MD, DON C. ROCKEY, MD, NELSON B. SCHILLER, MD, FACC
*San Francisco, California*

- 1988
- N=115 pts with mod-large pericardial effusions; 33 pts w tamponade
- "Thus, plethora in pericardial effusion is
  - 1) associated with elevated right heart filling pressures;
  - 2) more sensitive but less specific for tamponade than right heart chamber collapse or jugular venous distension; and
  - 3) of prognostic importance."

**Table 2.** Sensitivity and Specificity of Echocardiographic Signs in the Detection of Cardiac Tamponade

| | No. of Patients | Plethora (%) | R | RVC (%) | RAC or RVC (%) |
|---|---|---|---|---|---|
| Overall | 115 | | | | |
| Sensitivity | | 97 | | 48 | 64 |
| Specificity | | 40 | | 84 | 57 |
| | | | | | |
| Sensitivity | | 100 | 67 | 62 | 71 |
| Specificity | | 37 | 56 | 73 | 44 |
| Surgical | 37 | | | | |
| Sensitivity | | 91 | 33 | 25 | 50 |
| Specificity | | 65 | 96 | 92 | 92 |

Abbreviations as in Table 1.

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## IVC & FLUID RESPONSIVENESS

- All measure IVCexp and IVCinsp diameters
- IVC pre and post bolus (some crystalloid some colloid)
- IVC pre and post PLR
- IVC pre and post blood loss w/blood donation model
- IVC pre and post hemodialysis
- IVC w/ & w/o CO/SV eval
- IVC spontaneous and/or mechanical ventilation
- IVC w/ CVP/invasive monitoring
- IVC w/ POCUS (CV, Lung)

- Look at:
  - cIVC = max – min / max
  - dIVC= max – min / min
  - deltaIVC= max – min / mean
  - abs size IVC = exp and insp diameters

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## IVC & CVP

- Step 1: >2.1 cm or < 2.1cm
- Step 2: >50% resp collapse or <50% resp collapse

| | IVC <2.1cm | IVC >2.1cm |
|---|---|---|
| < 50% Collapse w sniff | *CVP 8? (5-10)* | CVP 15 (10-20*) |
| >50% Collapse w sniff | CVP 3 (0-5) | *CVP 8? (5-10)* |

Rudski LG, Lai WW, Afilalo J, Hua L, Handschumacher MD, Chandrasekaran K, Solomon SD, Louie EK, Schiller NB. Guidelines for the echocardiographic assessment of the right heart in adults: a report from the American Society of Echocardiography endorsed by the European Association of Echocardiography, a registered branch of the European Society of Cardiology, and the Canadian Society of Echocardiography. J Am Soc Echocardiogr. 2010 Jul;23(7):685-713; quiz 786-8. doi: 10.1016/j.echo.2010.05.010. PMID: 20620859.

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## CVP

- Nagdev *et al.* 2010: Annals of Emergency Medicine
  - Prospective, n=73 pts in ED who needed a CVC
  - Caval Index (aka Collapsibility Index) = Max-Min / Max
  - **cIVC >50% c/w CVP<8mmHg**
  - **Sens 91%, Spec 94%, PPV 87%, NPV 96%**
  - Mix intubated and spont breathing*
- Stawicki *et al.* 2009: J Am Coll Surg
  - Prospective, n=83 pts in SICU w CVC
  - Collapsibility Index cIVC = Max-Min / Max
  - IVC-CI appears to correlate best with CVP in the setting of low (<0.20) and high (>0.80) collapsibility ranges.
    - **cIVC <20%, mean CVP 12mmHg, In this group→ <5% CVP <7mmHg & >40% CVP >12mmHg**
    - **cIVC >60%, mean CVP 7.3mmHg, In this group→ >60% CVP <7mmHg**
  - 45% pts mechanically ventilated; some with elevated intraabdominal pressures suspected

**Emergency Department Bedside Ultrasonographic Measurement of the Caval Index for Noninvasive Determination of Low Central Venous Pressure**

Arun D. Nagdev, MD
Roland C. Merchant, MD, MPH, ScD
Alfredo Tirado-Gonzalez, MD
Craig A. Sisson, MD
Michael C. Murphy, MD
From the Department of Emergency Medicine, Warren Alpert Medical School of Brown University, Providence, RI.

**Intensivist Use of Hand-Carried Ultrasonography to Measure IVC Collapsibility in Estimating Intravascular Volume Status: Correlations with CVP**

S Peter Stawicki, MD, Benjamin M Braslow, MD, FACS, Nova L Panebianco, MD, James N Kirkpatrick, MD, Vicente H Gracias, MD, FACS, Geoffrey E Hayden, MD, Anthony J Dean, MD

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CHEST Special Feature

**Does Central Venous Pressure Predict Fluid Responsiveness?***

**A Systematic Review of the Literature and the Tale of Seven Mares**

*Paul E. Marik, MD, FCCP; Michael Baram, MD, FCCP; and Bobbak Vahid, MD*

- Marik *et al.* 2008 CHEST
  - Systematic Review:
    - (1) the relationship between CVP and blood volume
    - (2) the ability of CVP to predict fluid responsiveness
    - (3) the ability of the change in CVP (deltaCVP) to predict fluid responsiveness.
  - "*Conclusions:* **This systematic review demonstrated a very poor relationship between CVP and blood volume as well as the inability of CVP/deltaCVP to predict the hemodynamic response to a fluid challenge.** CVP should not be used to make clinical decisions regarding fluid management."

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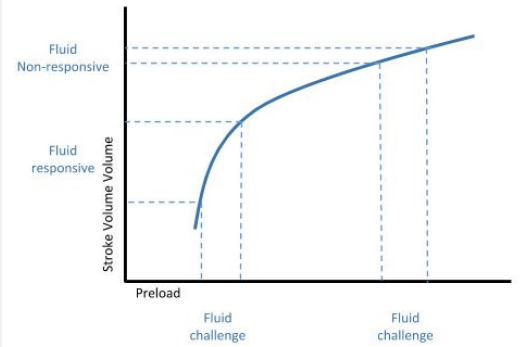
## FLUID RESPONSIVE

- CO or SV increase 10-15% when given a volume bolus (typically ~300mL)
- Many ways of measuring CO: LVOT VTI common in IVC literature + others
- Passive Leg Raise: Auto bolus ~300mL
- In acute circulatory failure ~50% of pts will be fluid responsive
  - *Obvious next question, can we find only the FR patients and give them fluids?




[Peer-Reviewed, Web Publication] Cohen B, Wilson D. (2019, Aug 5). Fluid Responsiveness. [NUEM Blog. Expert Commentary by Morales-Nebreda L]. Retrieved from http://www.nuemblog.com/blog/fluid-responsiveness

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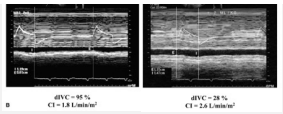
## DISTENSIBILITY INDEX

- **Intubated→ Distensibility Index (dIVC)**
  - dIVC = IVCmax – IVCmin / IVCmin
  - >12-18% Fluid Responsive
- Barber *et al.* 2004 Intensive Care Medicine
  - Prospective, ICU, n=23, ACF 2/2 sepsis on vent
  - **dIVC >18% → sens 90% spec 90% for FR**
- Huang *et al.* 2018 Critical Care
  - Meta-analysis, n=603, intubated circulatory shock
  - Heterogeneity between studies, TV ~8ml/kg[8]
  - Pooled sens 69% pooled spec 80%; Pooled AUROC 0.82
  - Conclusions: The findings of this study suggest that the ΔIVCD performed **moderately well in predicting fluid responsiveness in patients with circulatory shock receiving mechanical ventilation**. (Note: doesn't rule out FR[8])

Christophe Barbier
Yann Loubières
Christophe Schmit
Jan Hayon
Jean-Louis Ricôme
François Jardin
Antoine Vieillard-Baron

**Respiratory changes in inferior vena cava diameter are helpful in predicting fluid responsiveness in ventilated septic patients**




Pre and post volume expansion

Value of variation index of inferior vena cava diameter in predicting fluid responsiveness in patients with circulatory shock receiving mechanical ventilation: a systematic review and meta-analysis

Haijun Huang†, Qinkang Shen, Yafen Liu, Hua Xu and Yixin Fang

**Table 1** Characteristics of studies included in this meta-analysis

| First author/year of publication | Country | Sex (M/F) | Age in y (mean ± SD) | Cases | Tidal volume (ml/kg) | Index test | Reference standard measurement | Reference standard threshold | Reference standard device |
|---|---|---|---|---|---|---|---|---|---|
| Barbier 2004 [14] | France | 15/5 | 63 ± 15 | 20 | 8.5 | $(D_{max} - D_{min})/D_{min}$ | CI | > 15% | TTE |
| Feissel 2004 [15] | United States | 22/17 | 65 ± 15 | 39 | 8–10 | $(D_{max} - D_{min})/(D_{max} + D_{min})*2$ | CO | > 15% | TTE |
| Charbonneau 2014 [16] | France | 26/18 | 58.5 | 44 | 8–10 | $(D_{max} - D_{min})/D_{min}$ | CI | > 15% | TTE |
| Theerawit 2016 [17] | Thailand | 11/18 | 62.6 ± 15.9 | 29 | 8 | $(D_{max} - D_{min})/(D_{max} + D_{min})*2$ | CO | > 15% | PCA |
| Lu 2017 [18] | China | 33/16 | R: 55.7 ± 12.6 N: 55 ± 12.8 | 49 | 8–10 | $(D_{max} - D_{min})/D_{min}$ | CI | ≥ 10% | TTE |
| Vignon 2017 [19] | France | 37*/16† | 65 ± 13 | 540 | 8 | $(D_{max} - D_{min})/D_{min}$ | SV | > 10% | TTE |

*Abbreviations: CI* Cardiac Index, CO Cardiac output, $D_{max}$ and $D_{min}$ Maximum (inspiration phase) and minimum (expiration phase) diameter of inferior vena cava over a complete respiratory cycle, respectively, N Nonresponder, PCA Pulse contour analysis, R Responder, SV Stroke volume, TTE Transthoracic echocardiogram*

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## DISTENSIBILITY INDEX

- **Intubated→ Distensibility Index (dIVC)**
  - dIVC = IVCmax – IVCmin / IVCmin
- Si *et al.* 2018 Critical Care and Resuscitation
  - Meta-analysis, n=753, mechanically ventilated pts
  - **Conclusion:** ΔIVC shows limited ability for predicting fluid responsiveness in distinct ventilator settings.
    - In patients with **TV ≥8 mL/kg and PEEP ≤5 cm H2O**, ΔIVC >16% was an accurate predictor of fluid responsiveness. (Pooled Sens 80%, pooled spec 94%)
    - In patients with **TV <8 mL/kg or PEEP >5 cm H2O**, ΔIVC was a poor predictor. Thus, intensivists must be cautious when using ΔIVC. (Pooled Sens 66%, pooled spec 68%)

**Does Respiratory Variation in Inferior Vena Cava Diameter Predict Fluid Responsiveness in Mechanically Ventilated Patients? A Systematic Review and Meta-analysis**

Xiang Si, MD,* Hailin Xu, PhD,* Zimeng Liu, MD,* Jianfeng Wu, PhD, MD,* Daiyin Cao, MD,† Juan Chen, MD,* Minying Chen, MD,* Yongjun Liu, MD,* and Xiangdong Guan, PhD, MD*

**Table 2. Diagnostic Performance of ΔIVC for Predicting Fluid Responsiveness**

| Study | TP | FP | FN | TN | Threshold (%) | Sensitivity (%) | Specificity (%) | AUROC (95% CI) |
|---|---|---|---|---|---|---|---|---|
| TV ≥8 mL/kg and PEEP ≤5 cm $H_2O$ | | | | | | | | |
| Barbier et al (2004)[14] | 9 | 1 | 1 | 9 | 18 | 90 (55–100) | 90 (55–100) | 0.91 (0.84–0.98) |
| Feissel et al (2004)[15] | 14 | 1 | 2 | 22 | 12 | 88 (62–98) | 96 (78–100) | NA |
| Monnet and Pinsl (2010)[21] | 12 | 0 | 5 | 12 | 16 | 71 (44–90) | 100 (74–100) | 0.90 (0.73–0.99) |
| Sobczyk et al (2015)[20] | NA | NA | NA | NA | NA | NA | NA | NA |
| Sobczyk et al (2016)[7] | 20 | 3 | 4 | 8 | 18 | 83 (63–95) | 73 (39–94) | 0.74 |
| de Oliveira et al (2016)[9] | 6 | 0 | 3 | 11 | 16 | 67 (30–93) | 100 (72–100) | 0.84 (0.63–1.0) |
| TV <8 mL/kg or PEEP >5 cm $H_2O$ | | | | | | | | |
| Machare-Delgado et al (2011)[22] | 8 | 8 | 0 | 9 | 12 | 100 (63–100) | 53 (28–77) | 0.81 (0.64–0.98) |
| Baker et al (2013)[23] | NA | NA | NA | NA | NA | NA | NA | 0.46 (0.22–0.69) |
| Charbonneau et al (2014)[16] | 10 | 7 | 16 | 11 | 21 | 38 (20–59) | 61 (36–83) | 0.43 (0.25–0.61) |
| Vanas et al (2015)[24] | 2 | 2 | 1 | 10 | 18 | 67 (9–99) | 83 (52–98) | NA |
| Vignon et al (2016)[25] | 95 | 75 | 77 | 175 | 8 | 55 (47–63) | 70 (64–76) | 0.64 |
| Theerawit et al (2016)[17] | 12 | 3 | 4 | 10 | 10.7 | 75 (48–93) | 77 (46–95) | 0.69 (0.48–0.90) |

Abbreviations: ΔIVC, inferior vena cava diameter; AUROC, area under the receiver operating characteristic curve; CI, confidence interval; FN, false negative; FP, false positive; NA, not available; PEEP positive end-expiratory pressure; TN, true negative; TP, true positive; TV, tidal volume.

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## COLLAPSIBILITY INDEX

ORIGINAL RESEARCH

EMA

Bedside sonographic measurement of the inferior vena cava caval index is a poor predictor of fluid responsiveness in emergency

**Table 1.** Comparison of participants by caval and cardiac index

| | All participants ($n = 26$) | Fluid responders ($n = 9$) | Non-responder ($n = 17$) | $P$-value |
|---|---|---|---|---|
| Participant characteristics | | | | |
| Age (years) | 47 | 32.6 ± 9.0 | 52.2 ± 22.6 | 0.03 |
| Female | 17 (65.4%) | 5 (55.5%) | 12 (70.6%) | |
| Male | 9 (34.6%) | 4 (44.5%) | 5 (29.4%) | |
| Vital signs | | | | |
| Heart rate (bpm) | 84.9 | 71.1 ± 9.0 | 91.1 ± 18.5 | 0.03 |
| SBP (mmHg) | 114.1 | 123 ± 12.8 | 110 ± 27.3 | 0.06 |
| Measurements | | | | |
| Cardiac index (L/m²/min) | 2.98 | 2.91 ± 0.36 | 2.88 ± 0.91 | 0.91 |
| Cardiac index % change (%) | 11 ± 21 | 20.0 ± 14.3 | −4.3 ± 18.3 | <0.01 |
| Initial caval index (%) | 15.8 | 14.9 ± 12.0 | 16.2 ± 17.3 | 0.69 |
| Caval index change (cm) | 0.22 ± 0.19 | 0.25 ± 0.21 | 0.21 ± 0.19 | 0.66 |
| Dynamic caval index (%) | 0.5 ± 10.9 | 2.1 ± 10.4 | −0.3 ± 11.4 | 0.31 |

SBP, systolic blood pressure.

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## COLLAPSIBILITY INDEX

Respiratory variations of inferior vena cava diameter to predict fluid responsiveness in spontaneously breathing patients with acute circulatory failure: need for a cautious use

Laurent Muller[1*], Xavier Bobbia[1], Mehdi Toumi[1], Guillaume Louart[1], Nicolas Molinari[2], Benoit Ragonnet[3], Hervé Quintard[4], Marc Leone[5], Lana Zoric[1], Jean Yves Lefrant[1] and the AzuRea group

- Muller *et al.* 2012 Critical Care
  - Prospective, ICU, n=40, cIVC predicted FR in spont breathing patients with ACF
  - AUROC curve for **cIVC was 0.77** (95% CI 0.60, 0.88), the present study shows that cIVC cannot reliably (inferior limit of CI < 0.75) predict fluid responsiveness in spontaneously breathing patients with ACF.
  - Conclusions
    - In spontaneously breathing patients with ACF, despite its apparent simplicity, cIVC should be interpreted with caution.
    - A high **cIVC value (> 40%) is usually associated** with fluid responsiveness while low values (< 40%) do not exclude fluid responsiveness.

COMMENTARY

Respiratory variation in inferior vena cava diameter: surrogate of central venous pressure or parameter of fluid responsiveness? Let the physiology reply

Laurent Bodson[1,2] and Antoine Vieillard-Baron[3,4]

In conclusion, as re-emphasized by Muller and colleagues [1], it seems **hazardous to manage fluids** in a spontaneously breathing patient by using IVC respiratory variations only, until further data are published.

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## COLLAPSIBILITY INDEX

Does inferior vena cava respiratory variability predict fluid responsiveness in spontaneously breathing patients?

Norair Airapetian[1,2], Julien Maizel[1,3], Ola Alyamani[2], Yazine Mahjoub[2,3], Emmanuel Lorne[2,3], Melanie Levrard[2], Nacim Ammenouche[2], Aziz Seydi[2], François Tinturier[2], Eric Lobjoie[2], Hervé Dupont[2,3] and Michel Slama[1,3*]

- Airapetian *et al.* 2015 Critical Care
  - Prospective, ICU, n=59, cIVC in spont breathing patients looking for FR, no sniff
  - cIVC + CO: baseline, after PLR, after 500cc Bolus
  - 49% FR (>10% increase CO)
  - cIVC >40% for FR → sens 31% spec 97% PPV 90%
  - Conclusions:
    - In SBP with suspected hypovolemia, vena cava size and respiratory variability do not predict fluid
  - In contrast, a **cIVC >42 % may predict** an increase in CO after fluid infusion.

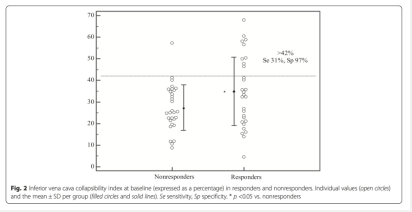


**Fig. 2** Inferior vena cava collapsibility index at baseline (expressed as a percentage) in responders and nonresponders. Individual values (*open circles*) and the mean ± SD per group (*filled circles* and *solid lines*). *Se* sensitivity, *Sp* specificity. * $p < 0.05$ vs. nonresponders.

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DOES RESPIRATORY VARIATION IN INFERIOR VENA CAVA DIAMETER PREDICT FLUID RESPONSIVENESS: A SYSTEMATIC REVIEW AND META-ANALYSIS

**Elliot Long,*†‡ Ed Oakley,*†‡ Trevor Duke,†‡§ and Franz E. Babl*†‡, on behalf of the Paediatric Research in Emergency Departments International Collaborative (PREDICT)**

*Department of Emergency Medicine, The Royal Children's Hospital, Parkville, Victoria, Australia; †Murdoch Childrens Research Institute, Parkville, Victoria, Australia; ‡Department of Paediatrics, Faculty of Medicine, Dentistry, and Health Sciences, University of Melbourne, Melbourne, Victoria, Australia; and §Paediatric Intensive Care Unit, The Royal Children's Hospital, Parkville, Victoria, Australia

- Long *et al.* 2017 SHOCK
  - Meta-analysis, 17 studies, n=533, IVC studies looking at predicting fluid responsiveness, both mechanically ventilated and spont breathing*
  - Mean threshold cIVC >42% and dIVC >16%
    - Respiratory variation in IVC diameter performs **moderately well** in predicting fluid responsiveness, with a pooled AUROC of 0.79 (SE 0.05)
    - A positive IVC ultrasound is **moderately** predictive of fluid responsiveness, with a **pooled specificity of 0.73** (95% CI: 0.67 – 0.78)
    - A negative IVC ultrasound, however, could not be used to rule out fluid responsiveness, with a **pooled sensitivity of 0.63** (0.56 – 0.69).
  - **Its clinical utility, particularly in spontaneously ventilating patients, is limited and should be interpreted in clinical context.**

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## COLLAPSIBILITY INDEX

**Accuracy of Ultrasonographic Measurements of Inferior Vena Cava to Determine Fluid Responsiveness: A Systematic Review and Meta-Analysis**

Daniele Orso, MD[1], Irene Paoli, MD[1], Tommaso Piani, RN[2], Francesco L. Cilenti, RN[1], Lorenzo Cristiani, RN[1], and Nicola Guglielmo, MD[1]

- Orso *et al.* 2020 Journal of Intensive Care Medicine
  - Meta-analysis, 20 Caval Index studies, mechanical ventilation and spont breathing included
  - **cIVC pooled sens 72% pooled spec 75% pooled AUROC 0.71**
- Conclusions:
  - In summary, **the extreme heterogeneity** of the studies considering the role of IVC to predict fluid responsiveness **makes difficult to evaluate the usefulness of IVC diameter** and the caval index assessed by US.
  - For the obtained data so far, US evaluation of the diameter of the IVC and its respiratory variations **does not seem to be a reliable method to predict the fluid responsiveness**.

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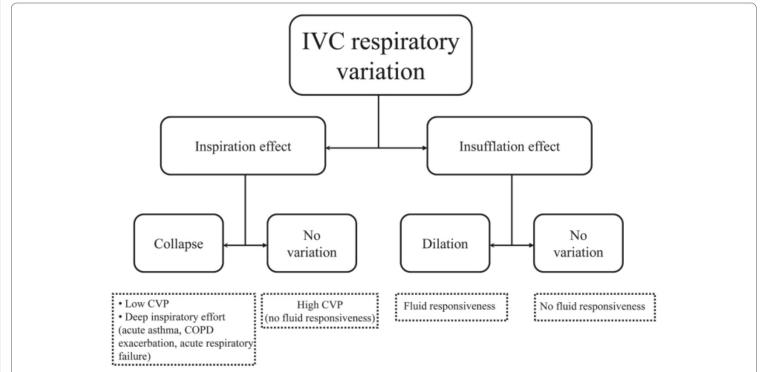


**Figure 1. Diagnostic algorithm for interpretation of inferior vena cava (IVC) respiratory variation according to type of ventilation.** COPD, chronic obstructive pulmonary disease; CVP, central venous pressure.

Bodson L, Vieillard-Baron A. Respiratory variation in inferior vena cava diameter: surrogate of central venous pressure or parameter of fluid responsiveness? Let the physiology reply. Crit Care. 2012 Nov 28;16(6):181.

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- Blehar *et al.* 2009 AJEM
- Prospective, ED, n= 46, measure cIVC as diagnostic tool for CHF chief complaint SOB
  - cIVC CHF (9.6%) than without CHF (46%), p<0.001, AUROC 0.96.
- Receiver operating characteristic curve analysis showed optimum cutoff of **15% variation or less of IVC diameter with 92% sensitivity and 84% specificity for the diagnosis of CHF**.
- Darwish *et al.* 2020 AIUM
- Meta-analysis, 27 articles, n=1472, eval IVC in CHF vs nonCHF
  - The combined mean IVC-CI values were 61.6% (95% CI, 48.4%–74.7%) for the control group and 30.5% (95% CI, 26.4%–34.6%) for the AHF group. (P<0.0001)
- **Conclusion:**
  - Bedside IVC US showed that a statistically significant difference existed in the IVC parameters between patients with and without AHF. Based on mean calculations, an **IVCexp of greater than 2.0 cm and an IVC-CI of less than 30% are reasonable cutoffs to suggest that a patient with acute dyspnea is more likely to have AHF than a non-AHF condition**. Given the high degree of heterogeneity across the studies and the high risk of bias, larger randomized studies are warranted to explore the use of IVC US in patients with HF.

## IVC & SOB/CHF

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## IVC & RUSH

**Diagnostic Accuracy of Rapid Ultrasound in Shock (RUSH) Exam; A Systematic Review and Meta-A nalysis**

*Mojtaba Keikha[1], Mohammad Salehi-Marzijarani[2], Reihane Soldoozi Nejat[3], Hojat Sheikh Motahar Vahedi[4], Seyed Mohammad Mirrezaie[5*]*

- 2018 Meta-analysis
- **Conclusion:** This meta-analysis suggests that RUSH protocol has generally good role to distinguish the states of shock in patients with undifferentiated shock referred to the emergency department.

**Table 2.** accuracy measures of RUSH protocol among [illegible] several types of shock

| | Sensitivity | Specificity | Positive LR | Negative LR | DOR | AUC |
|---|---|---|---|---|---|---|
| All shock | 0.87 (0.80-0.92) | 0.98 (0.96-0.99) | 19.9 (11.49-32.06) | 0.23 (0.15-0.34) | 210.49 (94.83-467.23) | 0.98±0.01 |
| | $I^2$=46.7% | $I^2$=30.8% | $I^2$=4.1% | $I^2$=18.4% | $I^2$=0.00% | |
| | | | (3.24-29.78) | 0.04 (0.01-0.20) | 250.54 (41.21-1523.4) | 0.99±0.01 |
| ic Shock | $I^2$=0.00% | $I^2$=43.7% | $I^2$=63.7% | $I^2$=0.00% | $I^2$=0.00% | |
| Cardiogenic Shock | 0.89 (0.73-0.97) | 0.97 (0.92-0.99) | 22.29 (7.92-62.77) | 0.17(0.06-0.46) | 209.77 (43.94-1001.5) | 0.98±0.02 |
| | $I^2$=0.00% | $I^2$=14.3% | $I^2$=0.00% | $I^2$=32.7% | 0.00% | |
| Obstructive Shock | 0.94 (0.73-1.00) | 0.98(0.93-1.00) | 33.07 (9.69-112.92) | 0.08(0.02-.38) | 476.42 (55.13-4114.8) | NC |
| | $I^2$=2.20% | $I^2$=0.00% | $I^2$=0.00% | $I^2$=0.00% | $I^2$=0.00% | |
| Distributive Shock | 0.73 (0.50-0.89) | 1.00 (0.97-1.00) | 51.32 (10.17-258.96) | 0.31 (0.17-0.56) | 170.36 (26.77-1083.7) | 0.97±0.02 |
| | $I^2$=0.00% | $I^2$=0.00% | $I^2$=0.00% | $I^2$=0.00% | $I^2$=0.00% | |
| Mixed Shock | 0.70 (0.47-0.87) | 0.99 (0.95-1.00) | 40.49 (9.97-164.39) | 0.33 (0.19-0.59) | 130.95 (24.12-710.68) | 0.99±0.03 |
| | $I^2$=0.00% | $I^2$=0.00% | $I^2$=0.00% | $I^2$=0.00% | $I^2$=0.00% | |

NC: Not computable

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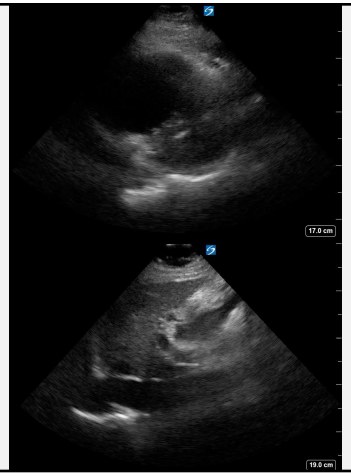
DILATED IVC >2.1CM
NO RESP VARIATION
CVP 10-20+

- Differential:
  - CHF/Cardiogenic Shock
  - Obstructive Shock (tamponade, tension PTX, PE)
  - PulmHTN
  - Valvular Heart Disease (Tricuspid Regurg)
  - Volume Overloaded



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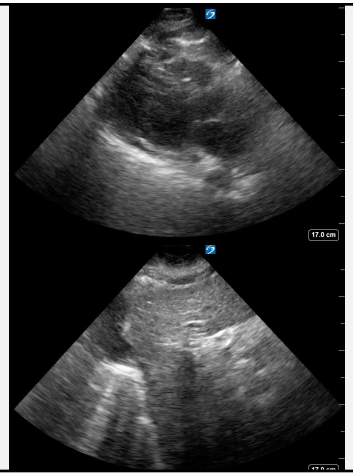
SMALL IVC <2.1CM
>50% RESP VARIATION
CVP 0-5

- Differential:
  - Hypovolemic/Hemorrhagic Shock
  - Distributive Shock
  - Extrinsic Compression
  - Elevated intraabdominal pressures



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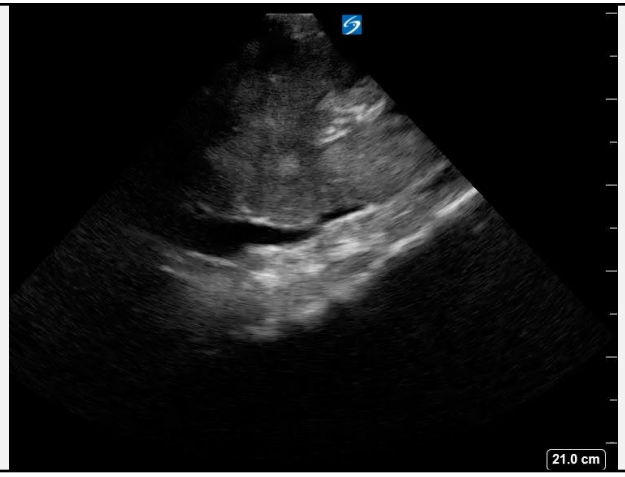


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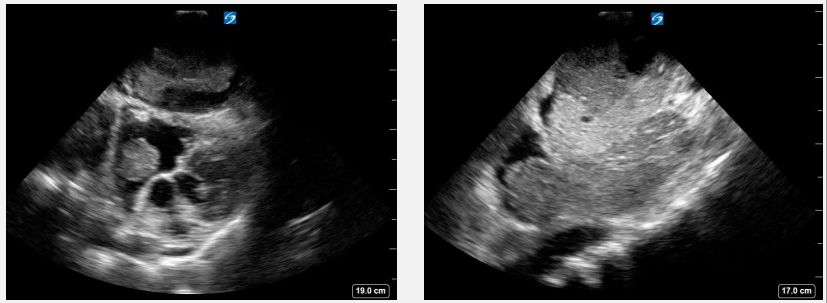

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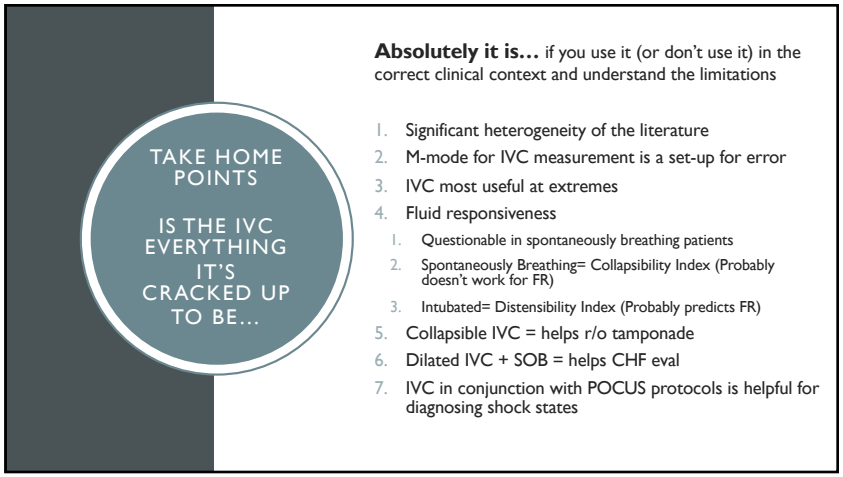


**Absolutely it is…** if you use it (or don't use it) in the correct clinical context and understand the limitations

1. Significant heterogeneity of the literature
2. M-mode for IVC measurement is a set-up for error
3. IVC most useful at extremes
4. Fluid responsiveness
   1. Questionable in spontaneously breathing patients
   2. Spontaneously Breathing= Collapsibility Index (Probably doesn't work for FR)
   3. Intubated= Distensibility Index (Probably predicts FR)
5. Collapsible IVC = helps r/o tamponade
6. Dilated IVC + SOB = helps CHF eval
7. IVC in conjunction with POCUS protocols is helpful for diagnosing shock states

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