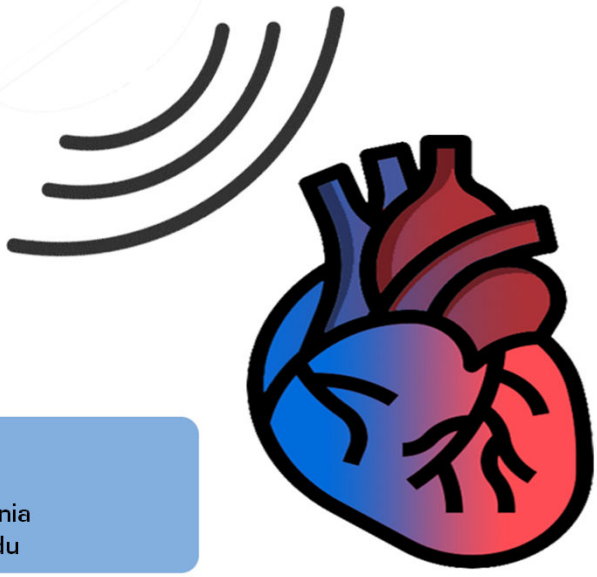
Cardiogenic Shock in 2025

Cutting Edge Techniques to Nail the Diagnosis!



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1

Disclosures

Research Funding

- NIH: NHLBI
- Reprieve Cardiovascular
- Avive AED

Conflicts of Interest: None

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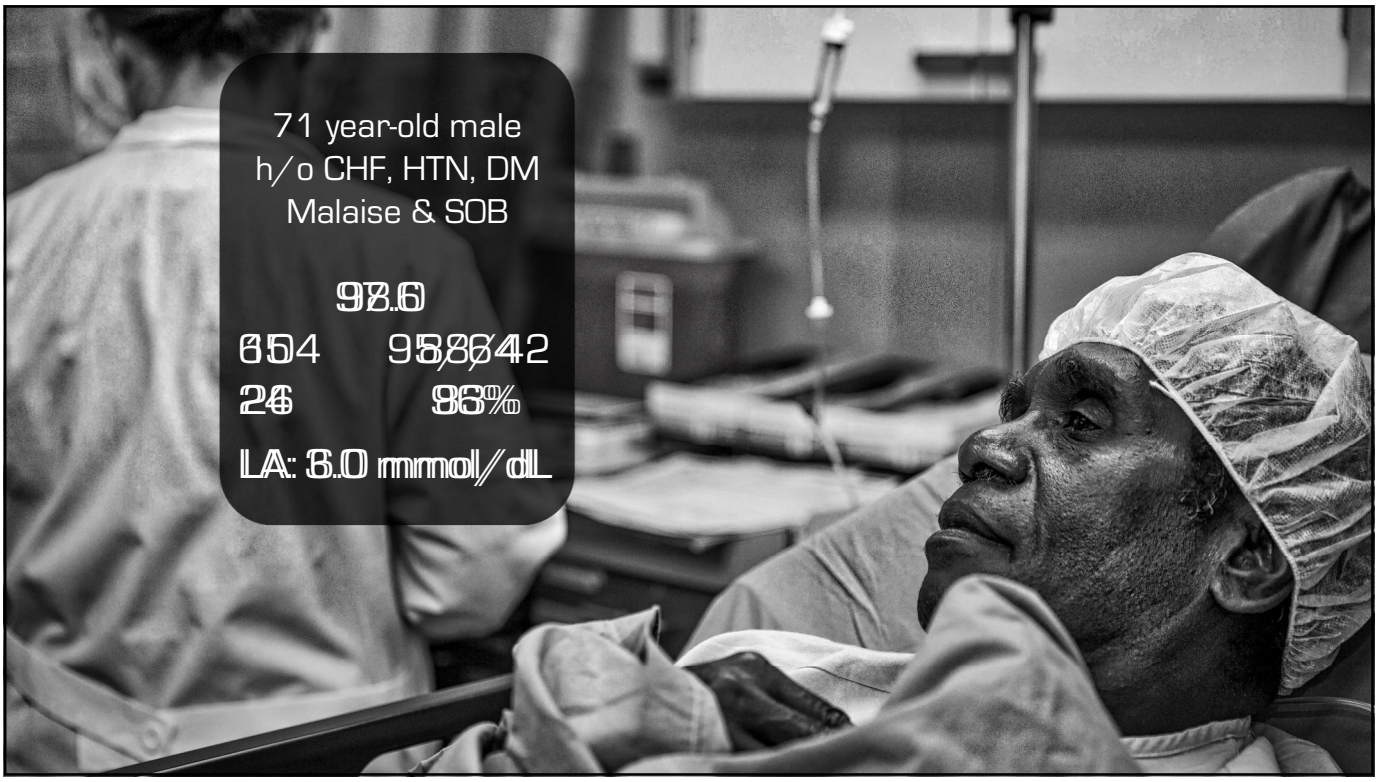

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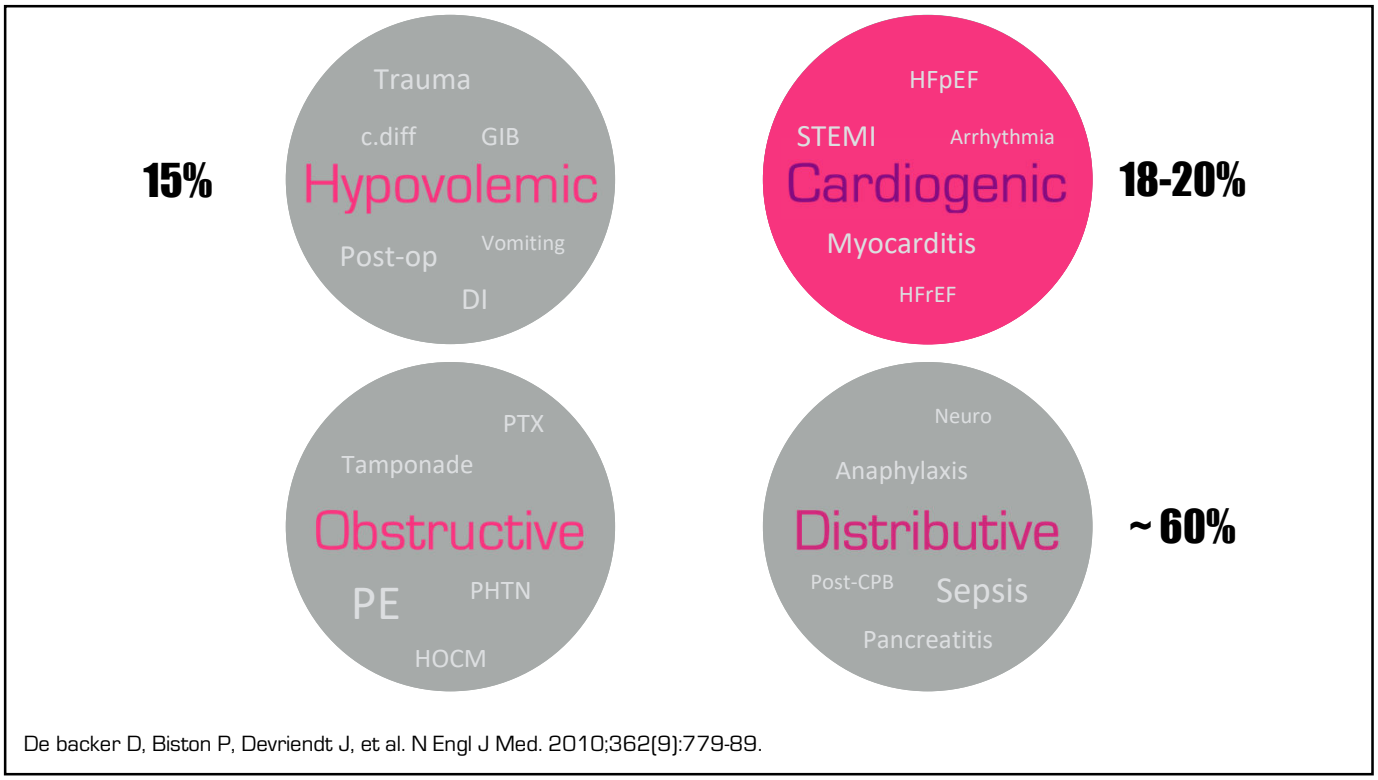

De backer D, Biston P, Devriendt J, et al. N Engl J Med. 2010;362(9):779-89.

4

3x in cardiogenic shock presenting to ED over last 15 years

AMI-CS Mortality 39%

ADHF-CS Mortality 42%

Morici N, et al. Cath Cardio Int, 2023; Jentzer JC, et al. JACC 2019.
Osman M, et al. JAHA, 2021
Bertaina M, et al. ESC HF, 2023

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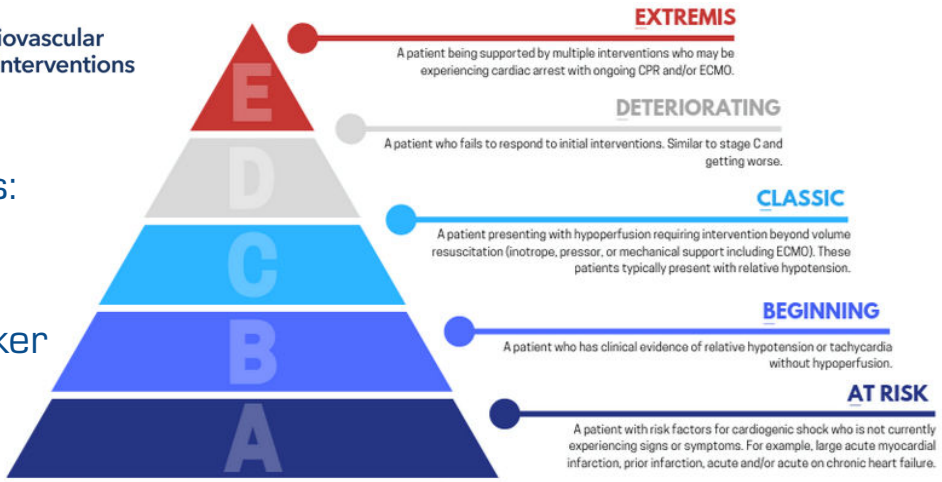
Time - How is CS recognized?

SCAI
Society for Cardiovascular Angiography & Interventions

CS diagnosis requires:
- Physical Exam
- Hemodynamic
- Biochemical Marker



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Time - How is CS recognized?

Physical Exam

Intensive Care Med (2019) 45:190–200
https://doi.org/10.1007/s00134-019-05527-y

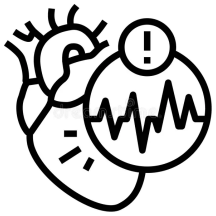
ORIGINAL

The diagnostic accuracy of clinical examination for estimating cardiac index in critically ill patients: the Simple Intensive Care Studies-I

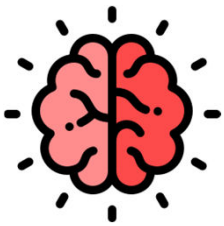
Bart Hiemstra[1*], Geert Koster[1], Renske Wiersema[1], Yoran M. Hummel[2], Pim van der Harst[2]

Capillary Refill Time
PPV: 49%

280 patients
CI < 2.2 L/min/m²



Atrial fibrillation
PPV: 46%



Altered Mental Status
PPV: 42%

Hiemstra (2019). Intensive Care Medicine.

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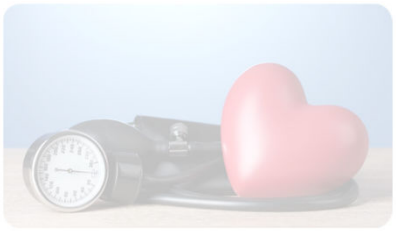
Time - How is CS recognized?

Hemodynamic Criteria

ORIGINAL

The diagnostic accuracy of clinical examination for estimating cardiac index in critically ill patients: the Simple Intensive Care Studies-I

280 patients
CI < 2.2 L/min/m^2



Biomarkers???

HR > 100 bpm
PPV: 40%

SBP < 90 mmHg
PPV: 32%

Hiemstra (2019). Intensive Care Medicine.

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Reducing time to CO Normalization

Greenwood et al. 2025. Under Review

Inclusion:
- Dx of Cardiogenic shock (inotrope started <24h)
- Admitted to Penn HVICU (623 patients)

Exclusion: STEMI, HFpEF, home inotropic tx, heart txpx, OHCA

Eligible cohort: 138 patients

Shock Start 'Time 0': Meeting SCAI C criteria

Characteristics	Early Inotrope < 8 hours (n = 87)	Late Inotrope ≥ 8 hours (n = 51)	*p-value*
Age, years	61 ± 15	59 ± 16	0.394
Gender, male (%)	61 (53)	26 (65)	0.189
Race n, (%)			
White	26 (30)	22 (43)	0.115
Black	54 (62)	27 (54)	0.293
Other	7 (8)	1 (2)	0.344
Comorbidities n, (%)			
Non-ischemic Cardiomyopathy	51 (59)	21 (41)	0.048
Ischemic Cardiomyopathy	24 (28)	14 (27)	0.986
Diabetes	28 (33)	12 (24)	0.279
Chronic Kidney Disease	29 (34)	13 (25)	0.334
LVEF %	20 [14 - 28]	20 [15 - 30]	0.340
APACHE II Score	18.5 ± 9.4	20.5 ± 8.1	0.207
Hospital LOS (days)	19 [14-30]	20 [14-30]	0.637

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Reducing time to CO Normalization

Time - How was CS recognized?

Greenwood et al. 2025. Under Review

1. CRT was rarely measured
2. Abn Lactate trigger
3. Hypotension assoc. with *delayed* inotropic support

SCAI Shock C Criteria	Early Inotrope < 8 hours (n = 87)	Late Inotrope ≥ 8 hours (n = 51)	*p-value*
Physical exam criteria, n (%)			
Peripheral exam; cool extremities	**29 (34)**	**8 (16)**	**0.022**
Was CRT measured? Yes	19 (22)	14 (27)	0.456
Altered mental status	13 (15)	6 (12)	0.601
Invasive or non-invasive mechanical ventilation	15 (17)	6 (12)	0.387
Urine output < 30 mL/hr	5 (6)	5 (10)	0.375
Volume overload	70 (80)	44 (86)	0.384
Biochemical markers, n (%)			
Lactate > 2 mmol/dL	**62 (71)**	**25 (49)**	**0.009**
> 50% decrease in GFR	40 (46)	20 (39)	0.439
Abnormal liver function tests	25 (29)	18 (35)	0.422
Elevated B-natriuretic peptide	59 (68)	35 (69)	0.921
Hemodynamic criteria met first, n (%)			
SBP < 90 or MAP < 60 mmHg	**50 (57)**	**43 (84)**	**0.001**
Cardiac Index < 2.2 L/min/m²	**34 (39)**	**12 (24)**	**0.061**

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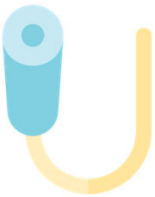
Reducing time to CO Normalization

Time - How was CS recognized?



Greenwood et al. 2025. Under Review

Delayed inotropic support:

1. Longer time to CO measurement
2. Received vasopressor 1st
3. Increased mortality

	< 8 hours (n = 87)	≥ 8 hours (n = 51)	*p-value*
Diagnostic investigations			
Time to cardiac output measurement (hrs)	6.5 [1.0-20.8]	18.5 [8.5-24.2]	< 0.001
Transthoracic Echocardiography	15 [3-24]	19 [11-36]	0.053
Pulmonary Artery Catheter	16 [2-46]	25 [16-45]	0.042
Vasoactive requirements			
Vasopressor plus inotrope, n (%)	30 (34)	34 (67)	< 0.001
Vasopressor started prior to inotrope, n (%)	10 (11)	23 (45)	< 0.001
Vasoactive-Inotropic Score (VIS, first 24 hrs)	2.5 [1.3-9.2]	7.1 [1.3-21.3]	0.014
Perfusion metrics			
Peak Lactate mmol/L	3.6 [2.1-5.3]	2.6 [1.4-5.8]	0.475
Initial SvO_2 %	53 ± 13	52 ± 12	0.661
Outcome(s)			
28-day mortality	15 (17)	17 (32)	0.031
VA-ECMO	8 (9)	5 (10)	0.906

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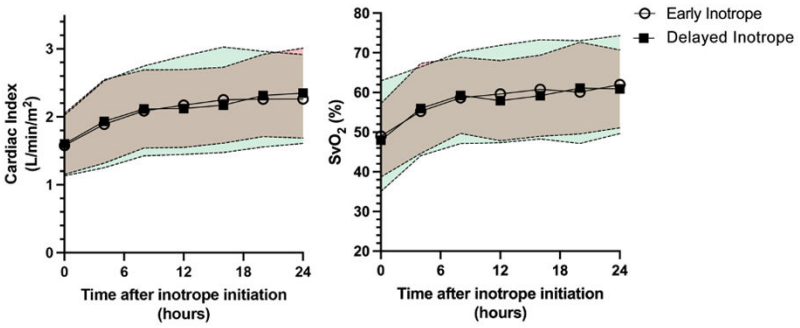
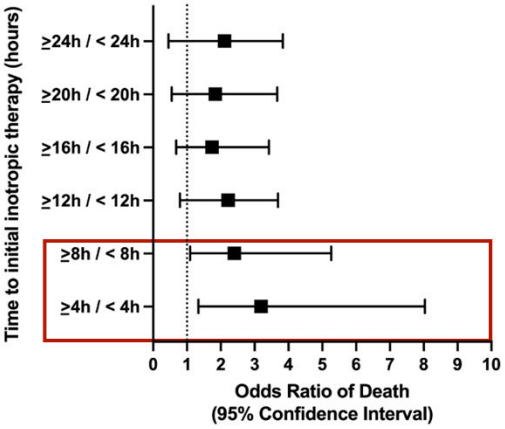
Time - Outcomes

Greenwood et al. 2025. Under Review





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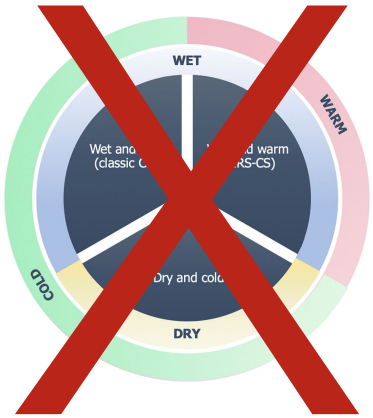
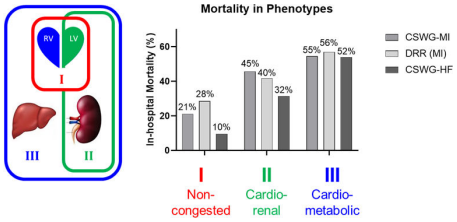
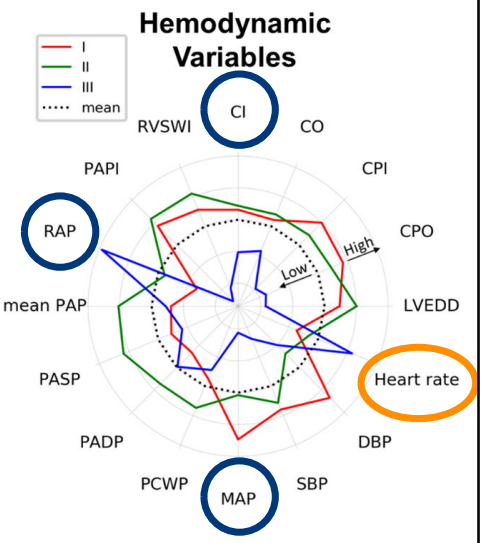
What is a hemodynamic profile?







Zweck E, Thayer KL, Helgestad OKL, et al. Phenotyping cardiogenic shock. JAHA 2021

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FREE

EGLS

FEER

Boyd: ECHO

POCUS

FALLS

FEEL-RESUS

FATE

RUSH: H I M A P

B L E E P

ACES

BEAT

RUSH: Tank Pump Pipes

Elmer/Noble

Trinity

15

Doppler Echocardiography in Advanced Systolic Heart Failure

A Noninvasive Alternative to Swan-Ganz Catheter

Pier Luigi Temporelli, MD; Francesco Scapellato, MD; Ermanno Eleuteri, MD; Alessandro Imparato, MD; Pantaleo Giannuzzi, MD

1. Inpatient ADHF patients (LVEF < 35%)
2. Cardiology Echocardiographers
3. Performed in an ECHO lab
4. 43 patients

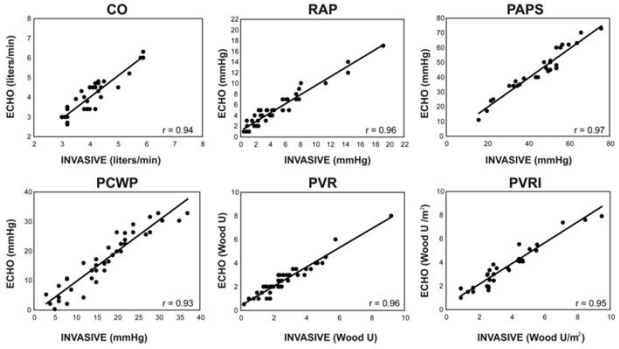
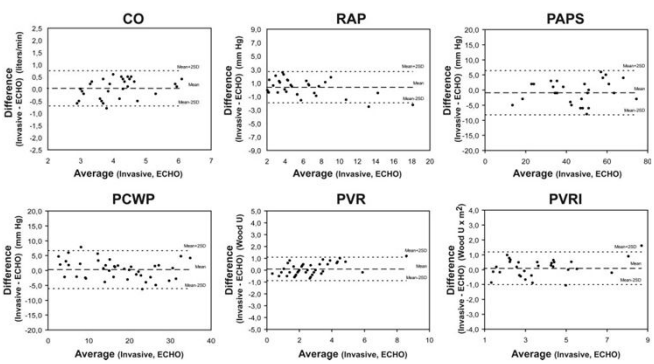


Figure 2. Plots showing correlation between invasive and noninvasive echocardiographic determinations of hemodynamic variables. Lines represent the linear fitting of the regression between invasive and noninvasive determinations. CO, cardiac output; RAP, right atrial pressure; PAPS, pulmonary artery systolic pressure; PVR, pulmonary vascular resistance; PVRI, pulmonary vascular resistance index; PCWP, pulmonary capillary wedge pressure; ECHO, echocardiography.

Limitations

1. Stable outpatients
2. Predominantly normal/high CI patients
3. Complex measurements, not ED relevant



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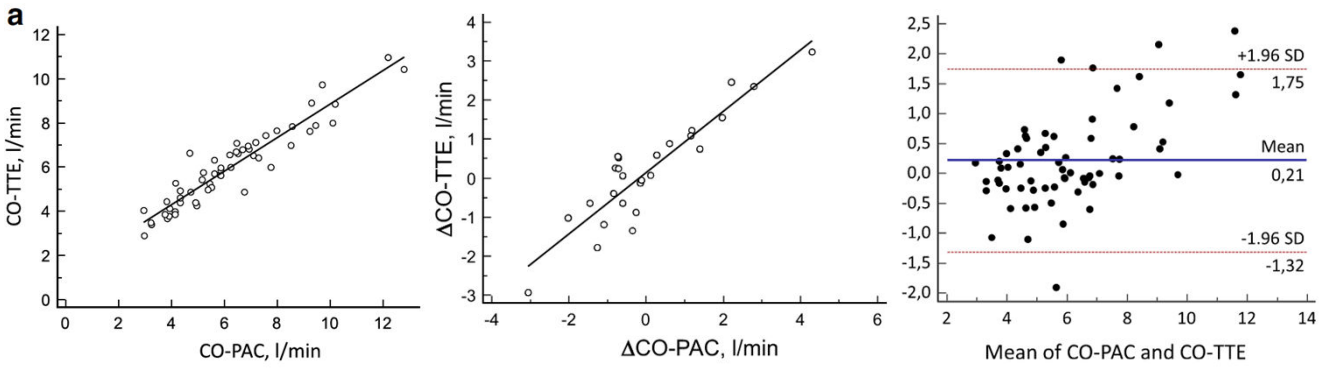
RESEARCH Open Access

Transthoracic echocardiography: an accurate and precise method for estimating cardiac output in the critically ill patient

Pablo Mercado[1,2], Julien Maizel[1], Christophe Beyls[1], Dimitri Titeca-Beauport[1], Magalie Joris[1], Loay Kontar[1],

Limitations

1. General ICU patients
2. Predominantly normal/high CI patients
3. Paralyzed
4. DID NOT examine RAP, SVR, or report RV Function



Bias: 0.2 L/min
Percent Error: 25%
Note: Acceptable < 30%

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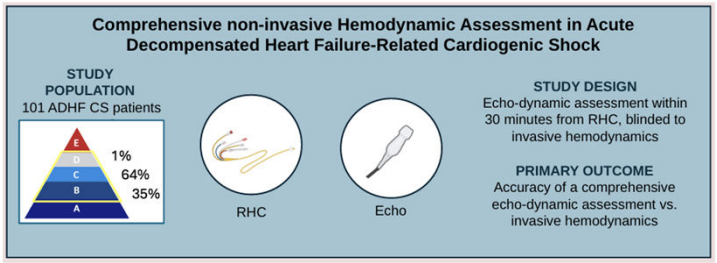
What is a hemodynamic profile?

ESC European Society of Cardiology
European Heart Journal: Acute Cardiovascular Care (2024) 13, 646–655 https://doi.org/10.1093/ehjacc/zuae087
ORIGINAL SCIENTIFIC PAPER
Techniques in Acute Cardiology and Intensive Care

Comprehensive non-invasive haemodynamic assessment in acute decompensated heart failure-related cardiogenic shock: a step towards echodynamics

Simone Frea [1], Carol Gravinese [1], Paolo Boretto [1]*, Giulia De Lio[1],



Accuracy of Echo Based HD Parameters

Cardiac Index (r=0.88)
- Sen: 97%
- Spec: 73%

CVP (r=0.86)
- Sen: 90%
- Spec: 83%

Would add RV function (TAPSE)

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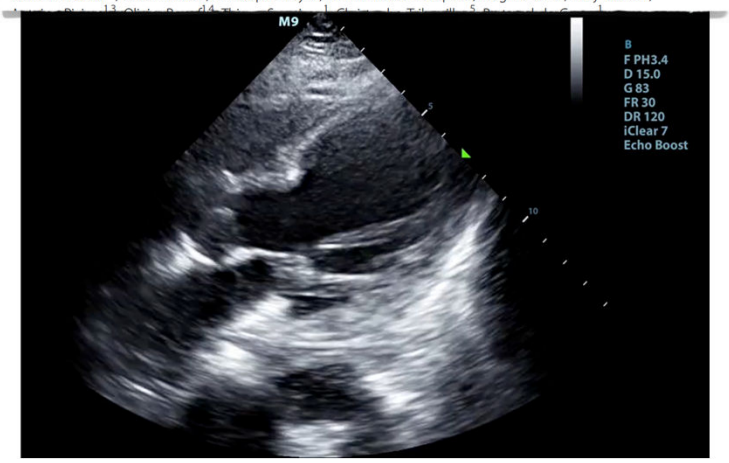

CRITICAL CARE

Inclusion

1. General ICU patients
2. Intubated with PAC in place
3. Sinus rhythm
4. Paralyzed
5. Two non-echocardiographers (duplicate measures)
6. 26 patients

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Is IVC Ultrasound a Waste of Time?

Journal of the American Society of Echocardiography
Volume 20, Issue 7, July 2007, Pages 857-861

Original article

Reappraisal of the Use of Inferior Vena Cava for Estimating Right Atrial Pressure

J. Matthew Brennan MD, John E. Blair MD, Sascha Goonewardena MD, Adam Ronan MD, Dipak Shah MD, Samip Vasaiwala MD, James N. Kirkpatrick MD, Kirk T. Spencer MD

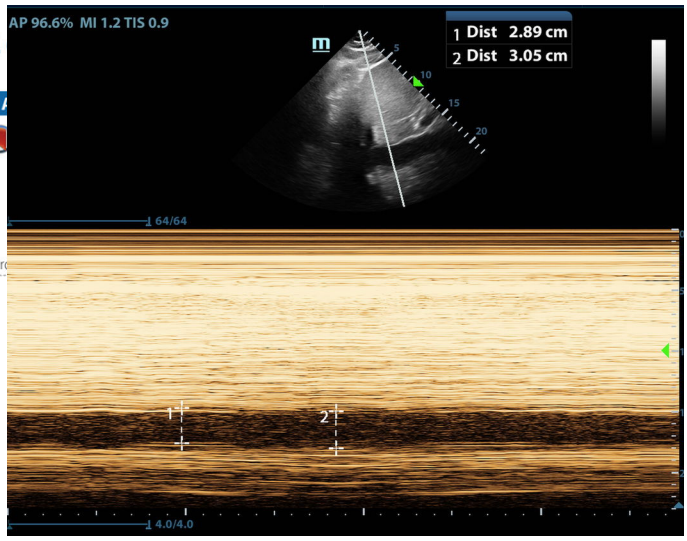
CRITICAL

Open

y

ness in spontaneously breathing patients?

Emmanuel Lorne[2,3], Melanie Levrard



Reasonable estimate of RAP

Excellent NPV

Diameter > 2 cm + < 50% variability

CVP > 10 mmHg

Beware: TVR, high IAP, high resp drive

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Right Atrial Pressure (or Central Venous Pressure)

IVC size (cm)	Inspiration Effect	CVP (mmHg)
Small < 1.5	Collapse	0 - 5
Normal 1.5 – 2.5	↓ ≥ 50%	5-10
Normal 1.5 – 2.5	↓ ≥ 50%	10-15
Dilated > 2.5	↓ ≥ 50%	15-20
Dilated + Hepatic veins	No collapse	> 20

From Otto CM and Pearlman AS: Textbook of Clinical Echocardiography

IVC diameter	RAP
IVC <2.1 >50%	3 mmhg
IVC <2.1 <50%	8 mmhg
IVC >2.1 >50%	8 mmhg
IVC >2.1 <50%	15 mmhg

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Updated 2/22/2023

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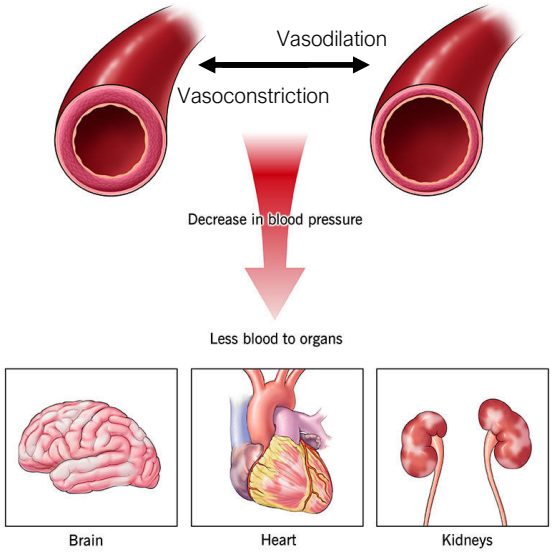
Systemic Vascular Resistance Index (SVRi)

$$80 * \frac{MAP - CVP}{\text{Cardiac Index}}$$

Safety Check for starting inotropic support

Normal: 1900 - 2400 dynes/sec/cm^5 *m^2



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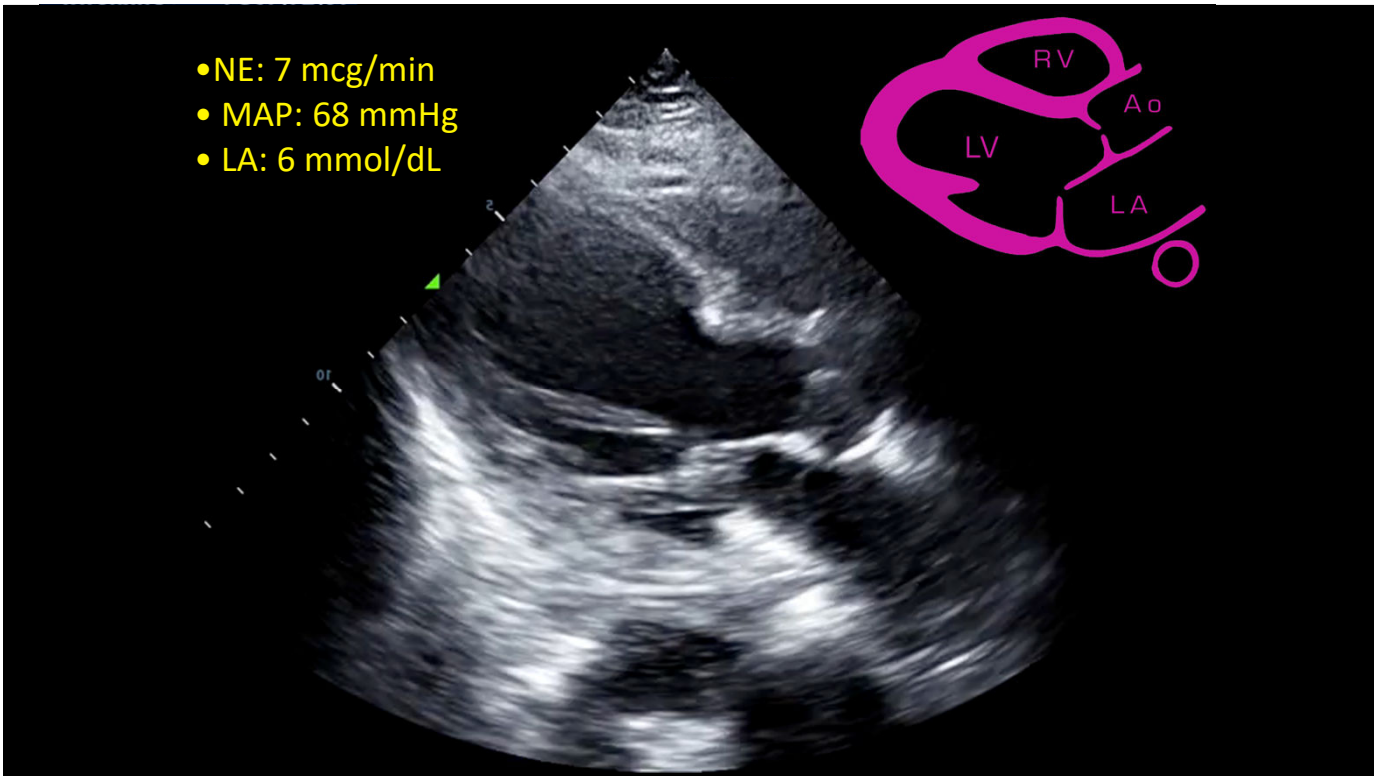
How to measure Cardiac Output
< 2 minutes

23



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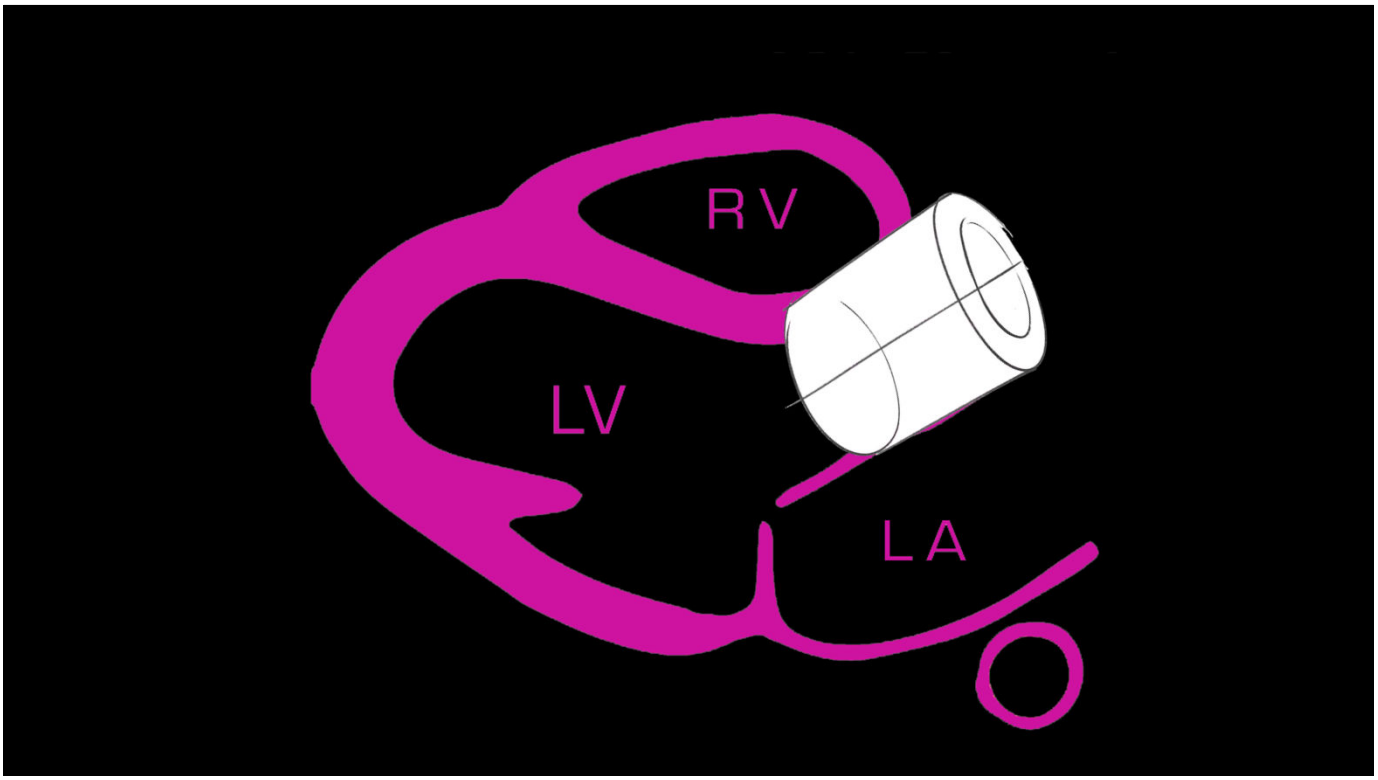
EF Doesn't Matter

Cardiac Index
+
Perfusion

25



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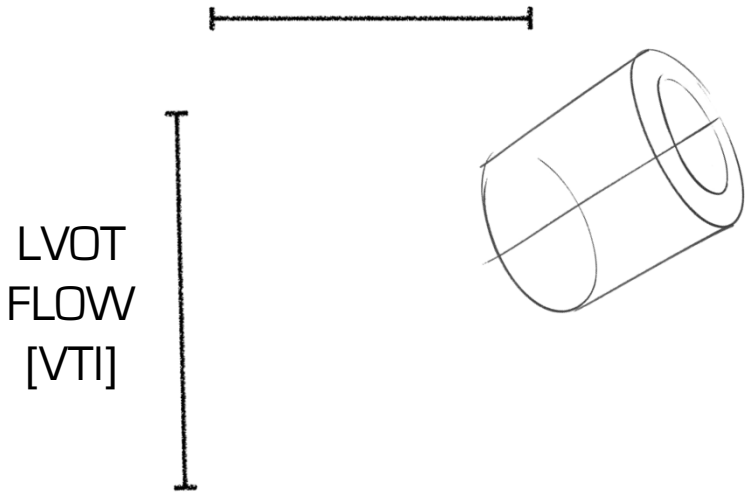
AVA = Use LVOT diameter



27

Stroke Volume = AVA * LVOT VTI

Cardiac Output = SV * HR

Cardiac Index = CO/BSA

Threshold: > 2.2 L/min/m^2

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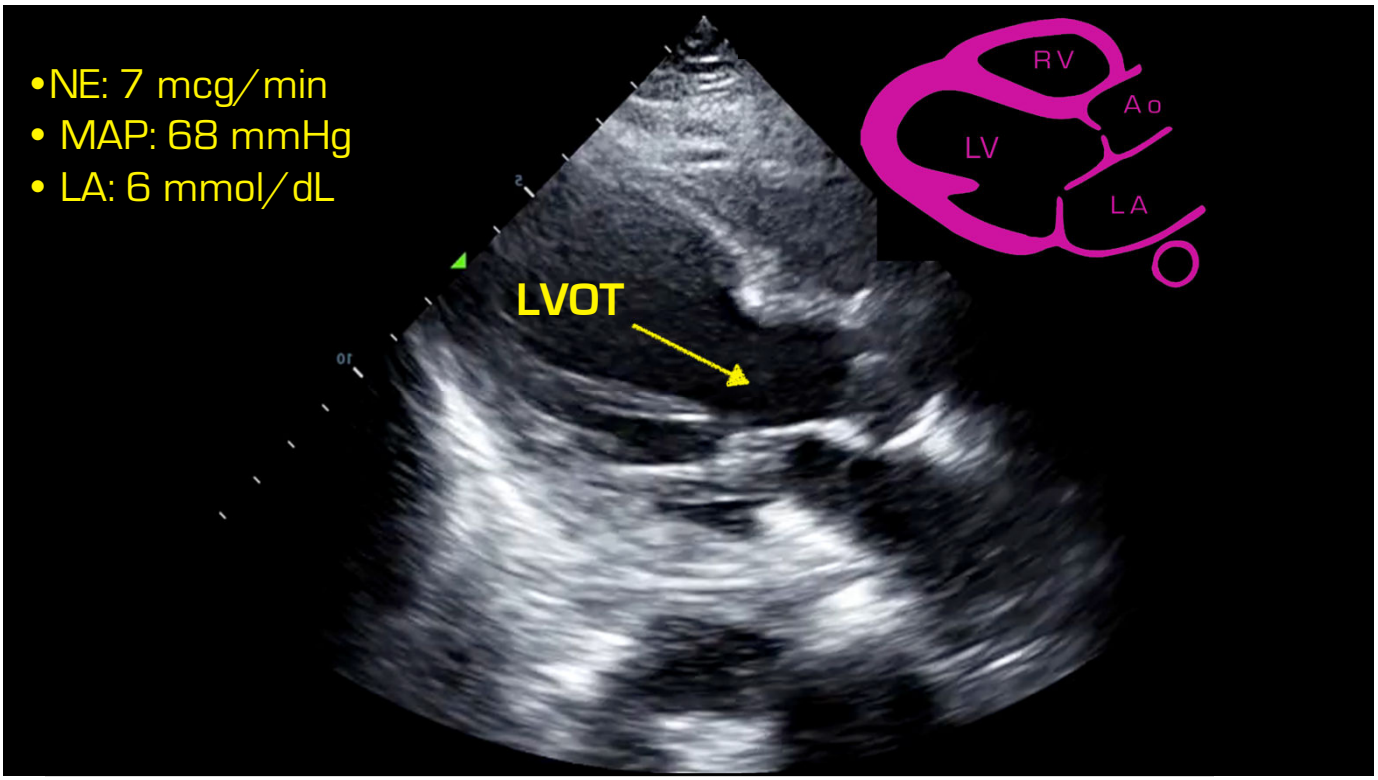
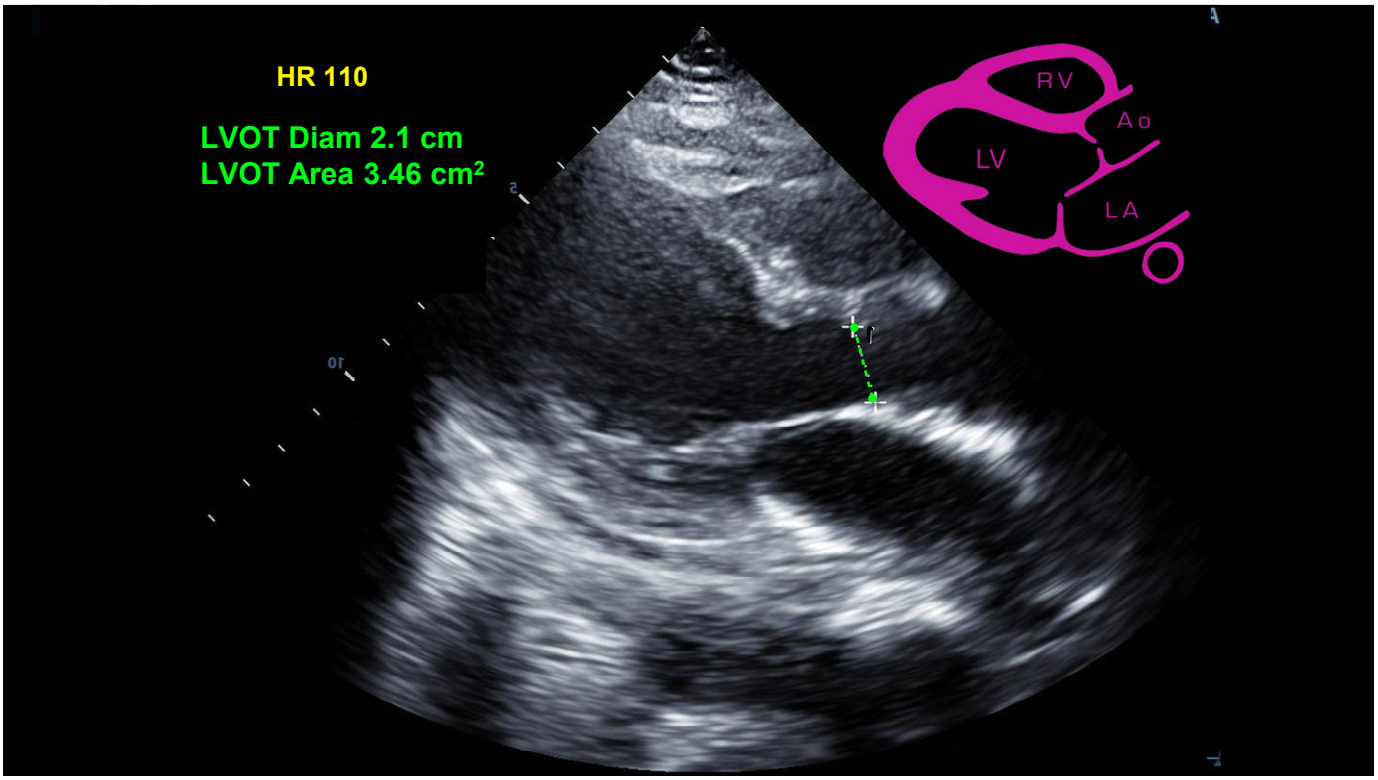

•NE: 7 mcg/min
• MAP: 68 mmHg
• LA: 6 mmol/dL
LVOT
RV
Ao
LV
LA

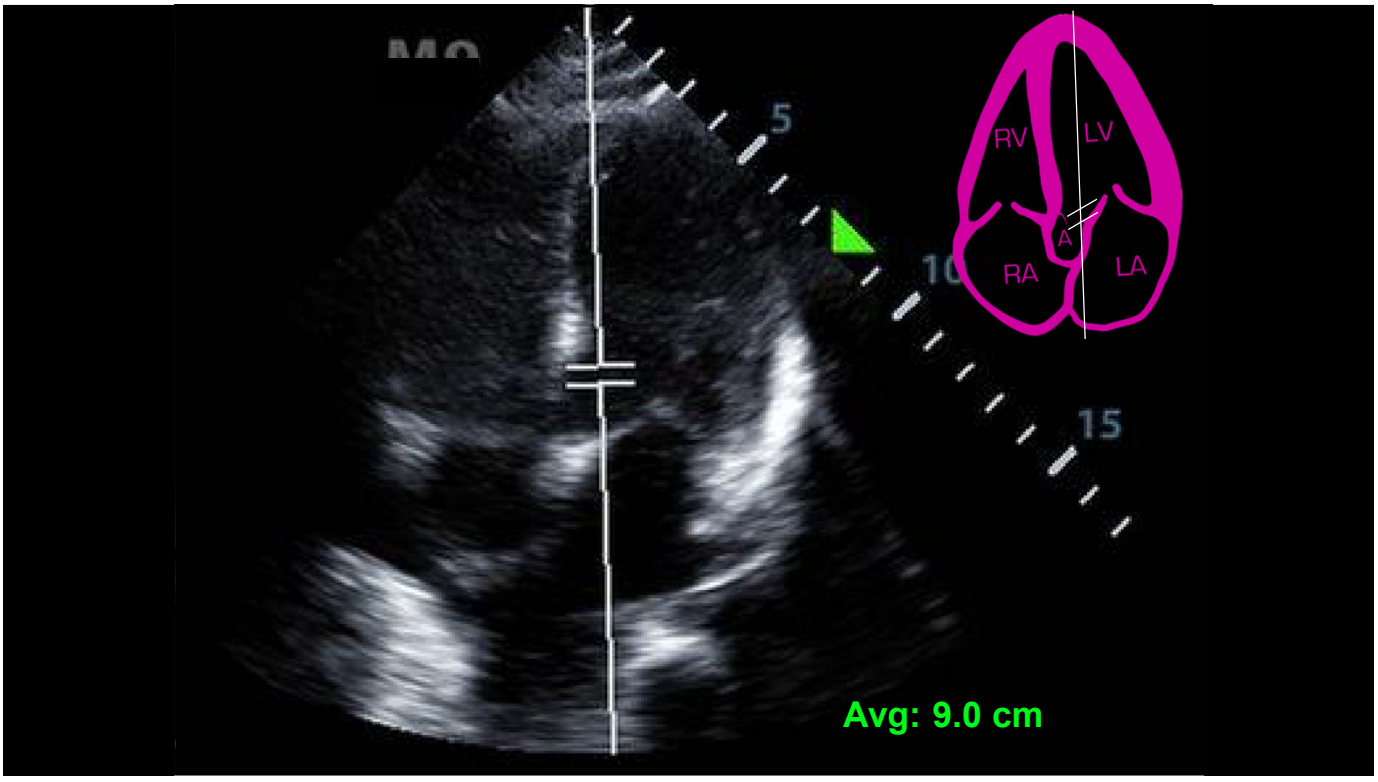
29


HR 110
LVOT Diam 2.1 cm
LVOT Area 3.46 cm²
RV
Ao
LV
LA

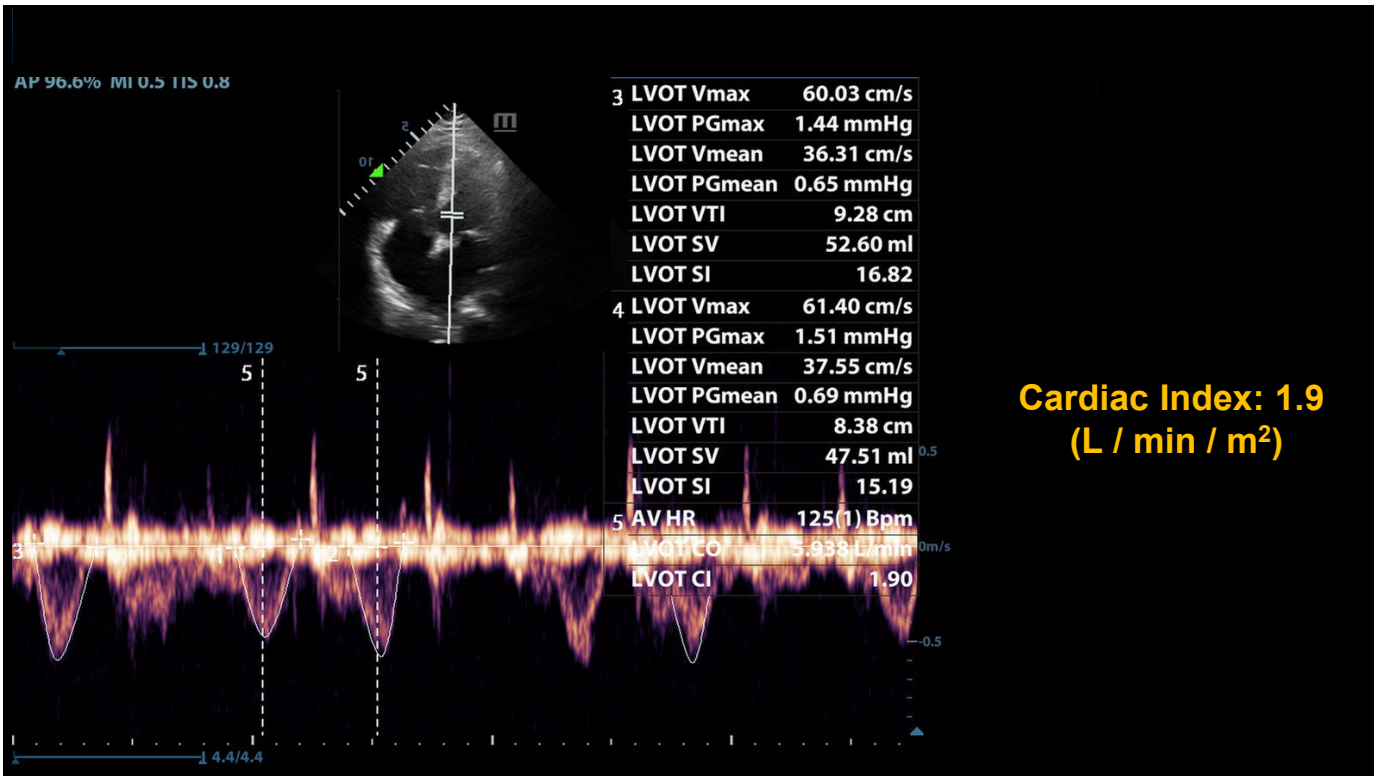
30


PW
C
M
B
Update
Measure
Caliper
Angle
Gain
Zoom
Freeze

31


5
10
15
RV
LV
A
RA
LA
Avg: 9.0 cm

32



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Stroke Volume = AVA * LVOT VTI

Cardiac Output = SV * HR

Cardiac Index = CO/BSA

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TAPSE
(TAP - SEE)

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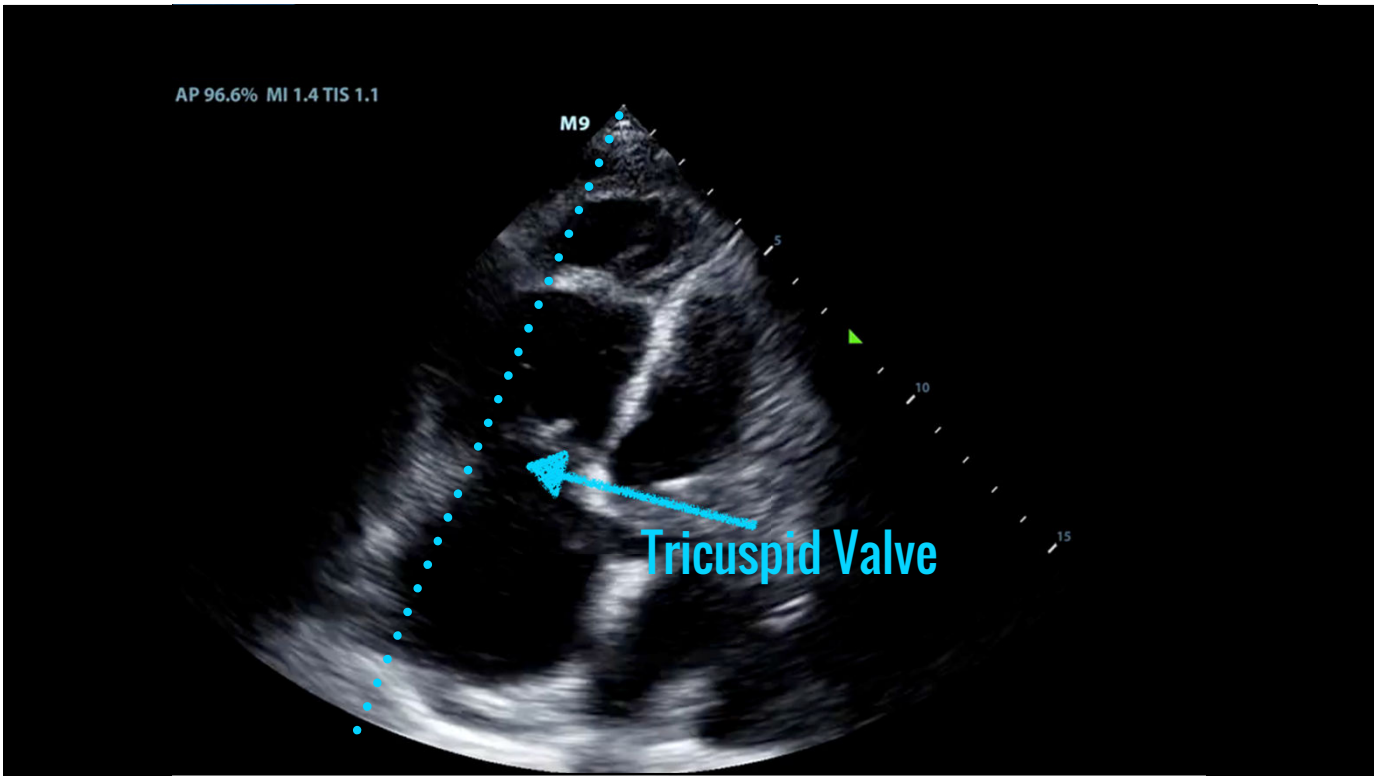

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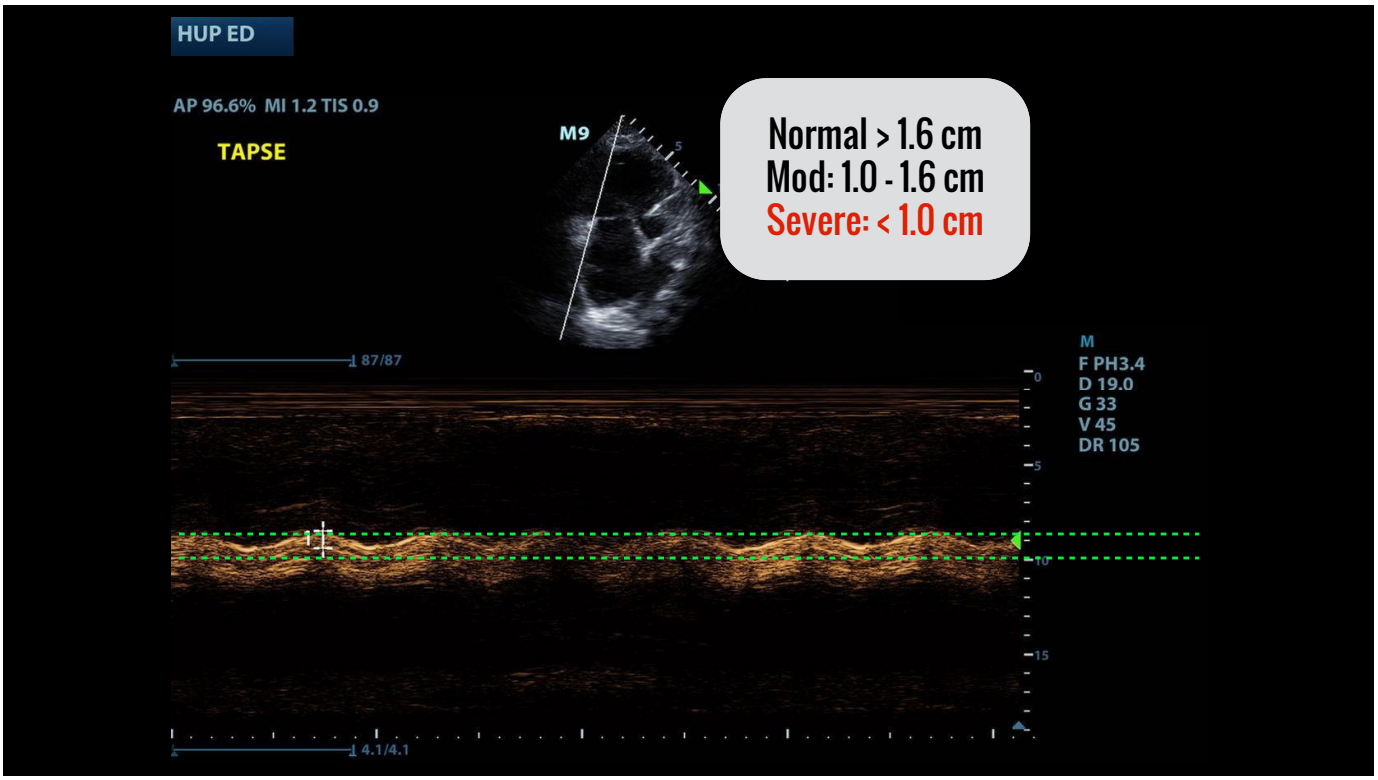

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$t_{+5\ min}$: 88/48

Intervention?

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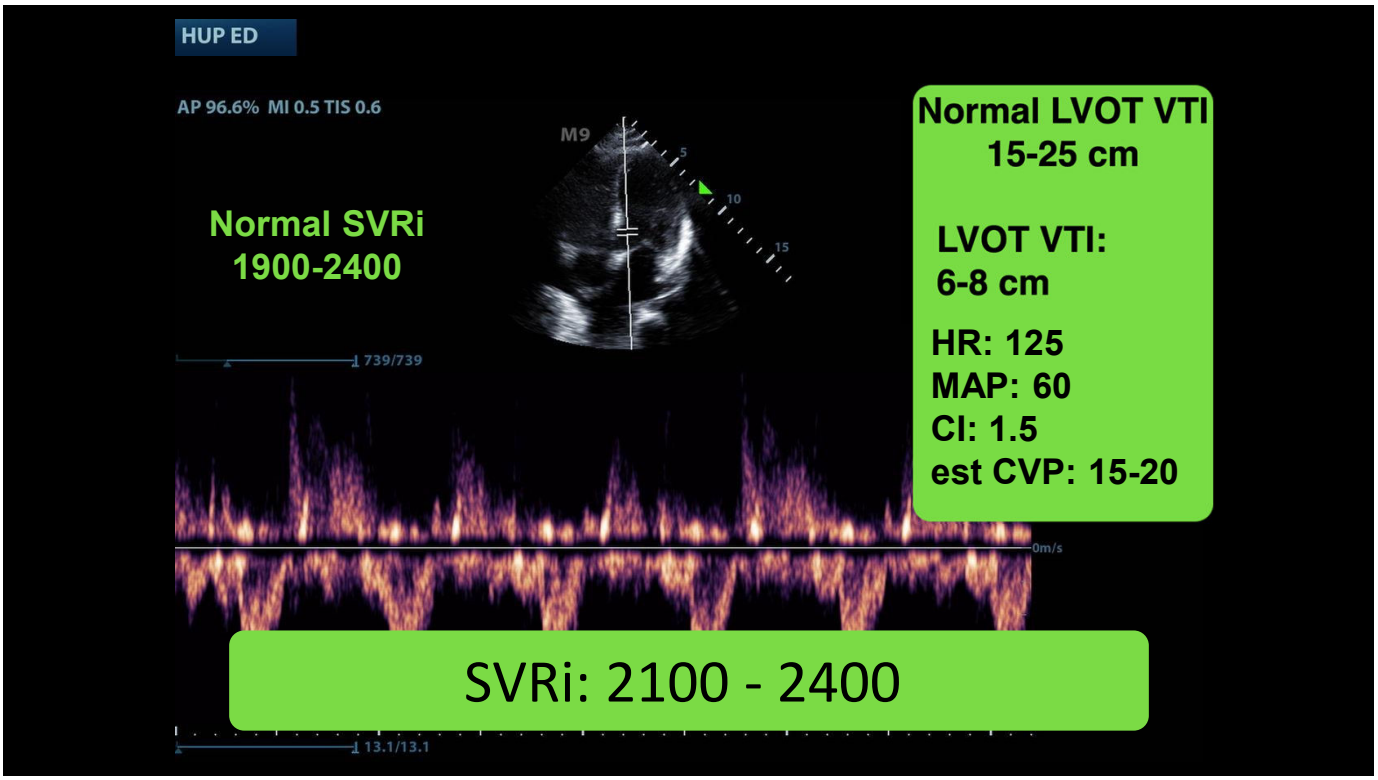
HUP ED
AP 96.6% MI 0.5 TIS 0.6
M9
Normal SVRi
1900-2400
Normal LVOT VTI
15-25 cm
LVOT VTI:
6-8 cm
HR: 125
MAP: 60
CI: 1.5
est CVP: 15-20
739/739
0m/s
SVRi: 2100 - 2400
13.1/13.1

39

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Step 1- Reducing time to CO Normalization

a.) Can we identify the correct CS phenotype in the ED?

AMI-CS

ADHF-CS
HFpEF

ADHF-CS
LVEF ≤ 30%*
or BiV failure

* Independently associated with inpatient mortality (OR 2.15, 95% CI: 1.40–3.29)

FRENSHOCK Registry. ESC Heart Failure 2022; 9: 408–419

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Step 1 - Time to CO Normalization

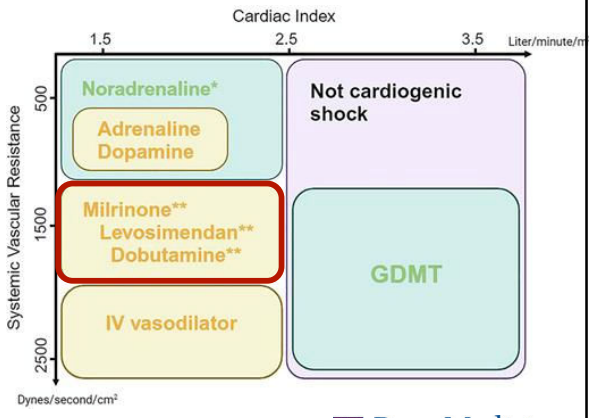
Patient Identification

Compare ED POCUS to Gold Standard

- Spontaneously breathing suspected "SCAI C" patients (LVEF < 30%)
- Planned RHC or PAC in place
- Measurement in duplicate

- Important measurements:
  - CO/CI: LVOT VTI
  - estimated RAP/CVP
  - RV function: TAPSE
  - Estimated SVR

- Imaging QI
- Analysis: Regression, agreement/bias
- Outcome: relationship with PAC/RHC



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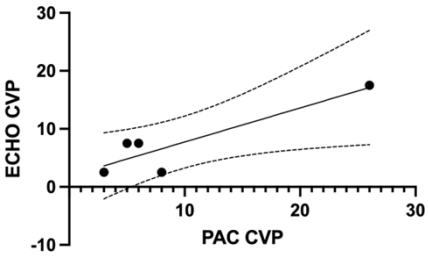
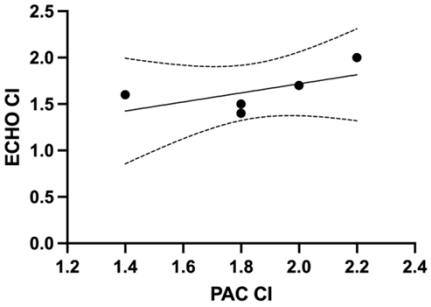
Preliminary Data

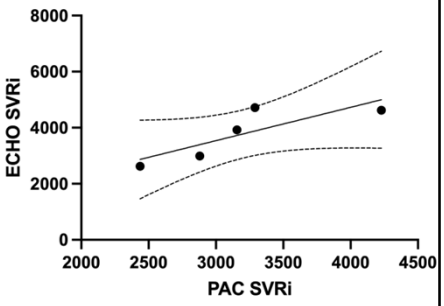
(5 subjects with ADHF-CS)



$R^2 = 0.802$



$R^2 = 0.396$



$R^2 = 0.693$

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APPLICATIONS OUTSIDE OF CARDIOGENIC SHOCK

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$t_{+5\ min}$: 88/48

Intervention?

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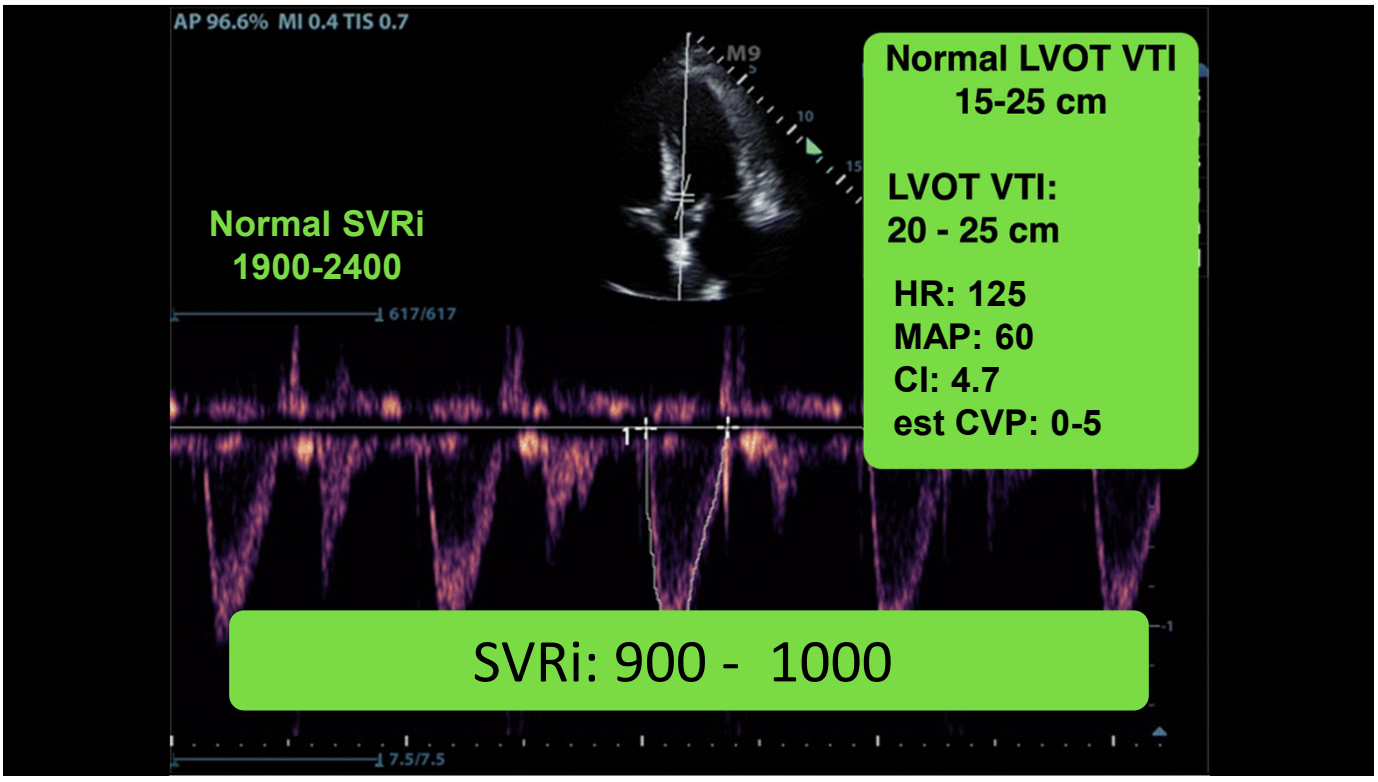

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The FLAT IVC does NOT always equal hypovolemia

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QUESTIONS?

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