Apport de l’échocardiographie pour l’évaluation hémodynamique

Daniel De Backer

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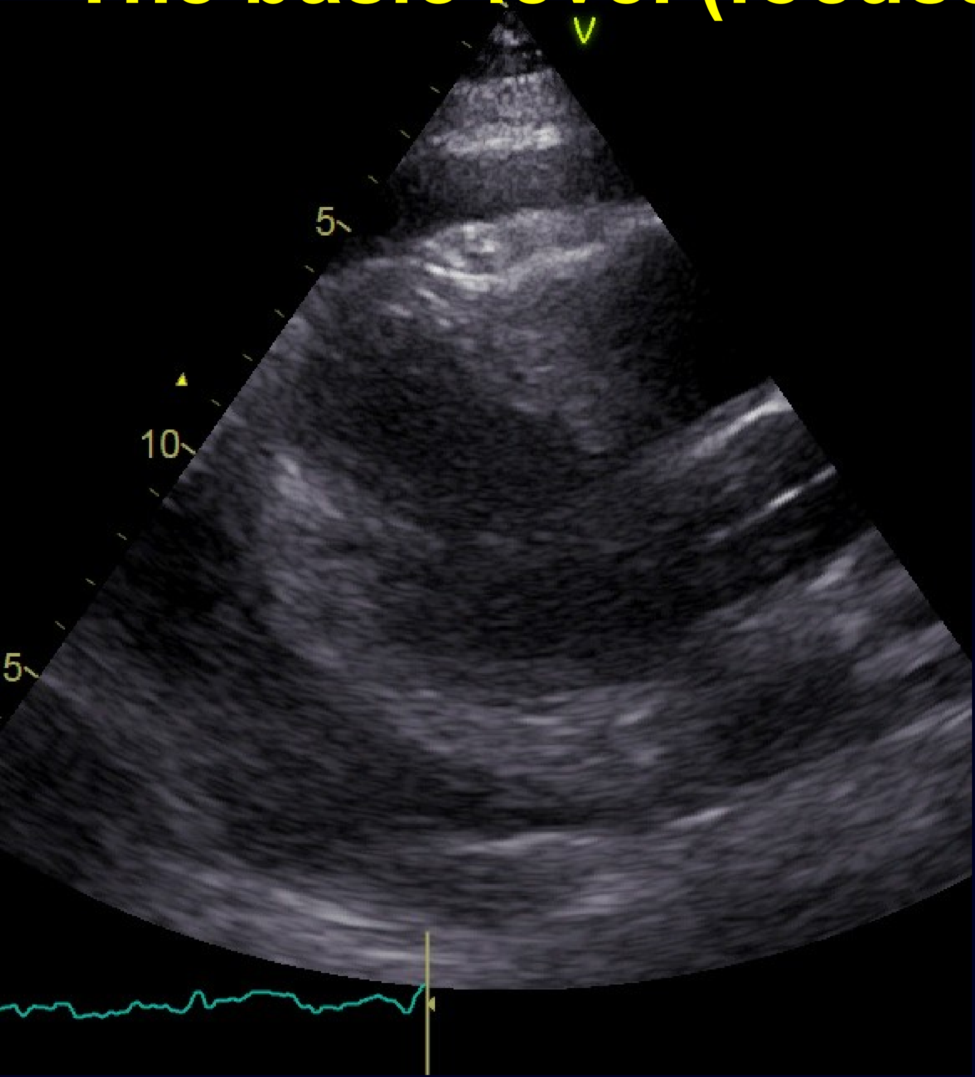
Professor of Intensive Care, Université Libre de Bruxelles
Past-President European Society of Intensive Care Medicine
Past Co-Chair of European Diploma of Advanced Echocardiography (ED

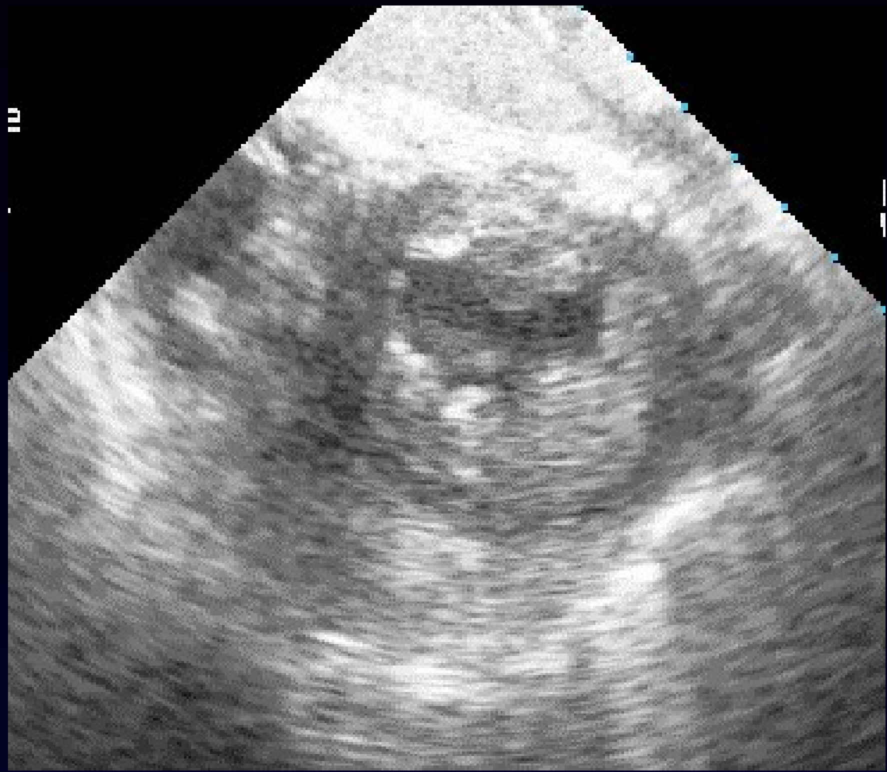
Critical care echocardiography

1- Focused evaluation

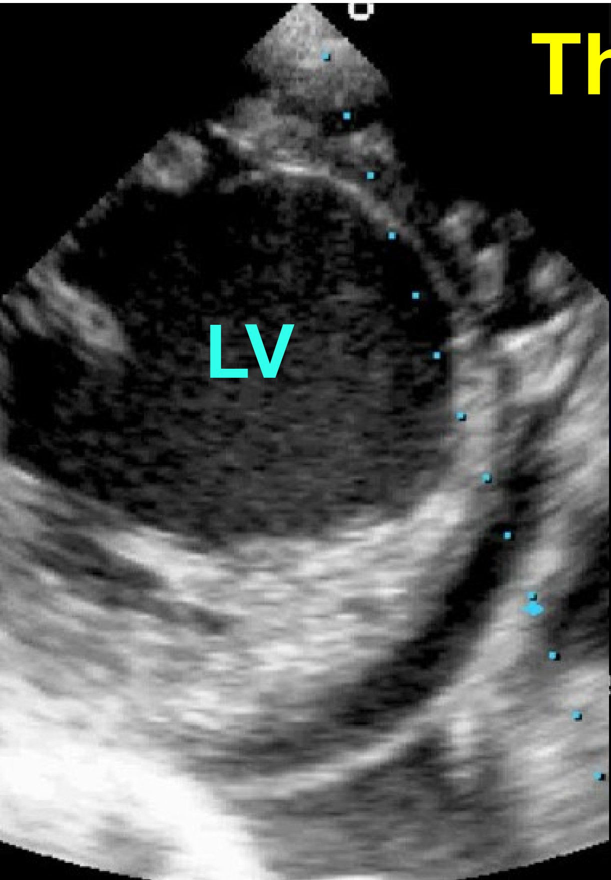
- Mostly 2 D evaluation
- Diagnosis based on pattern recognition

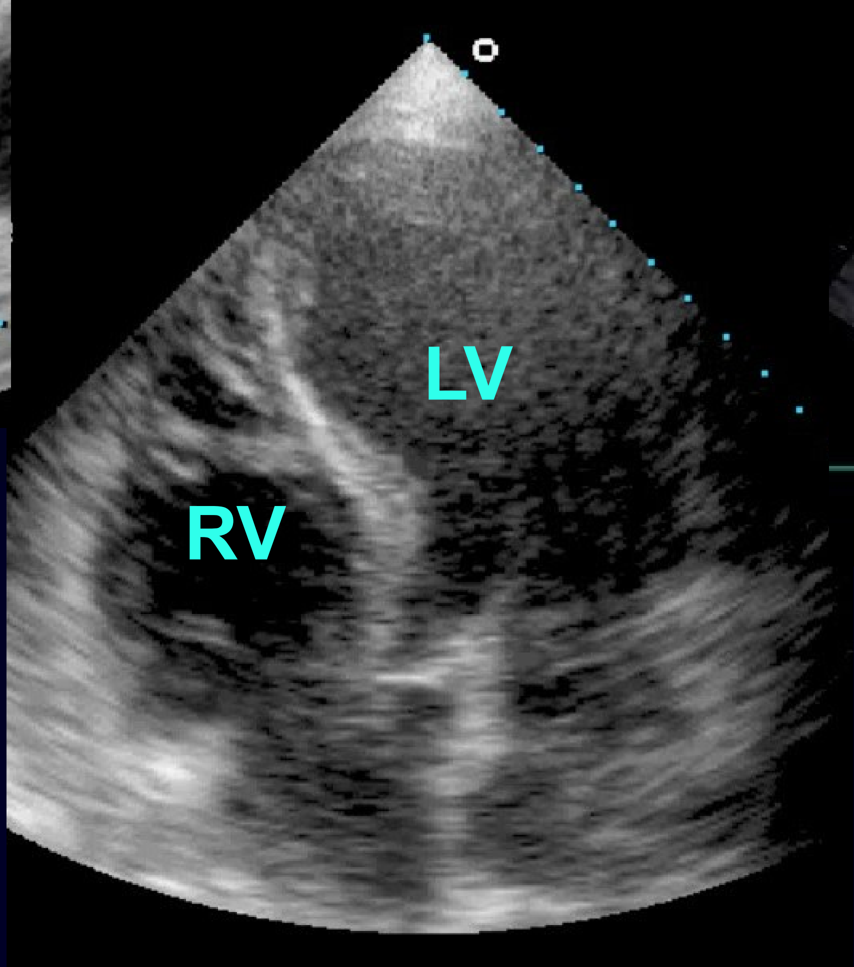
The basic level (focused exam): all about pattern recognit

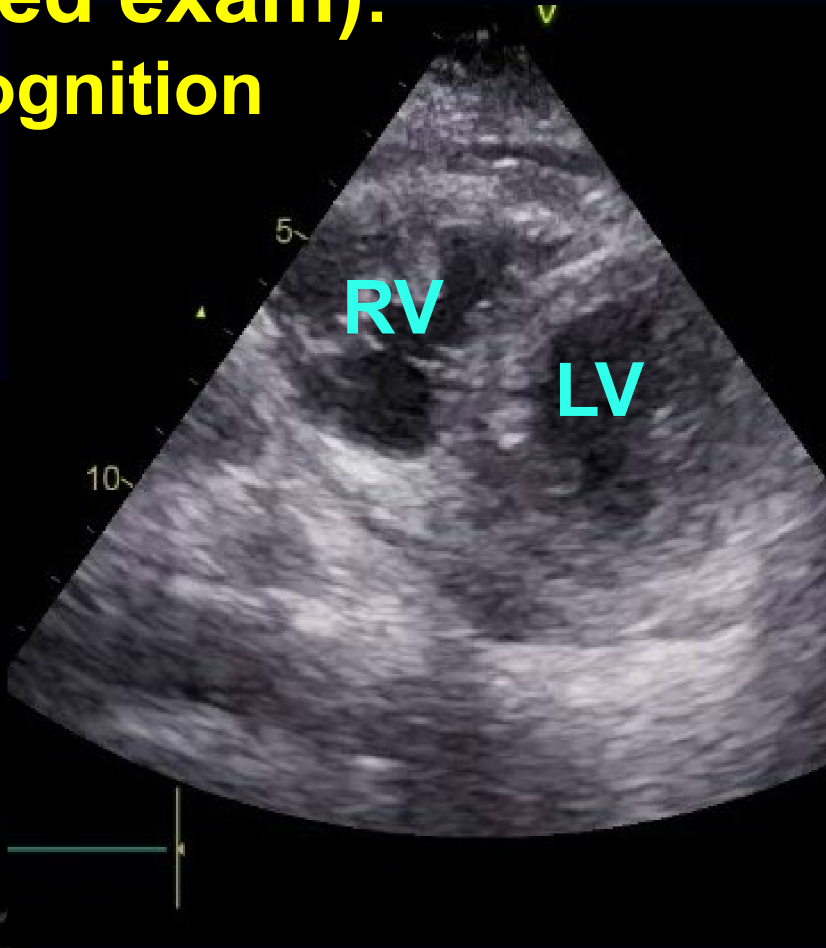




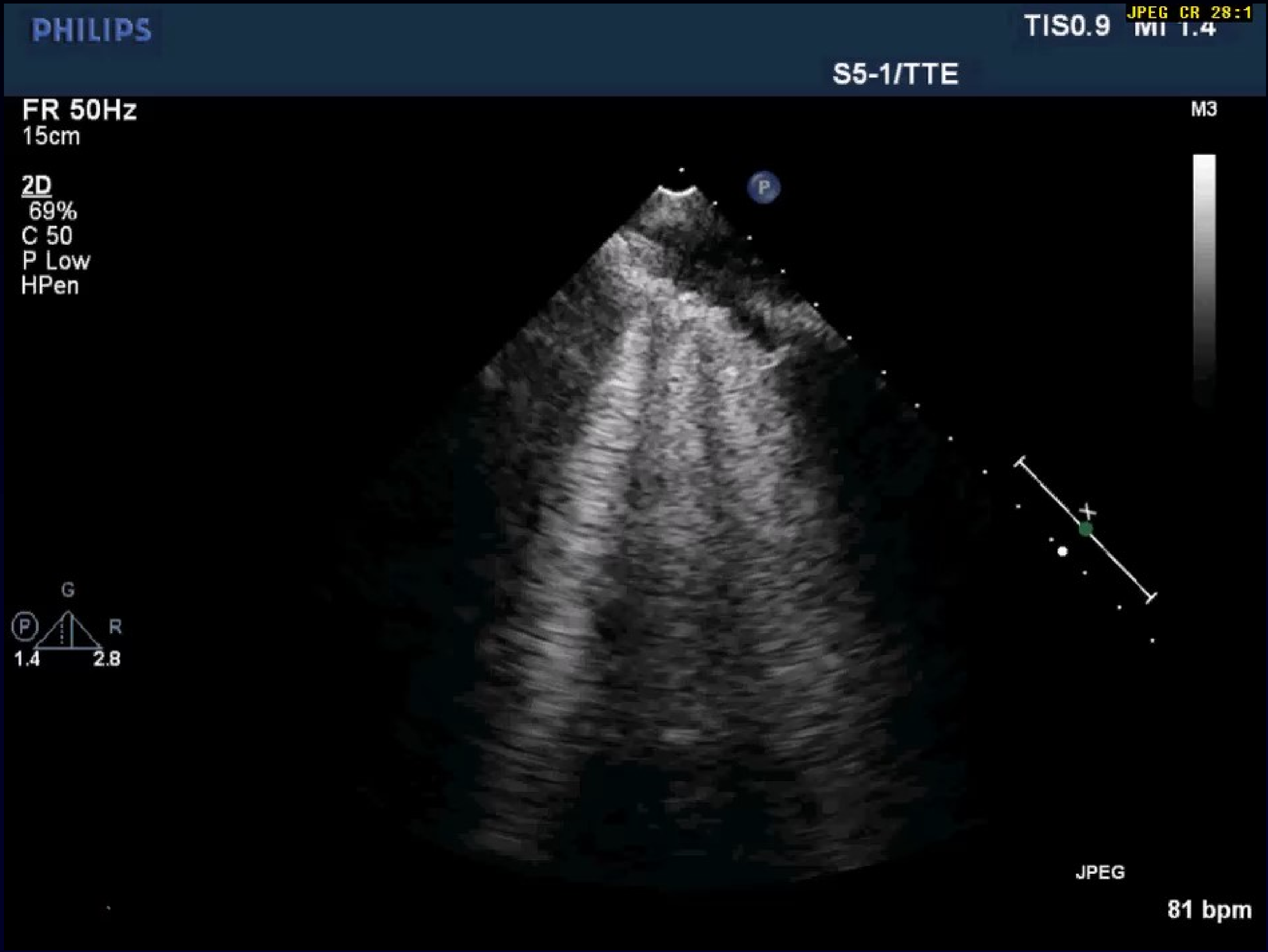
The basic level (focused exam):
all about pattern recognition







B Lines



PHILIPS
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C 50
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1.4
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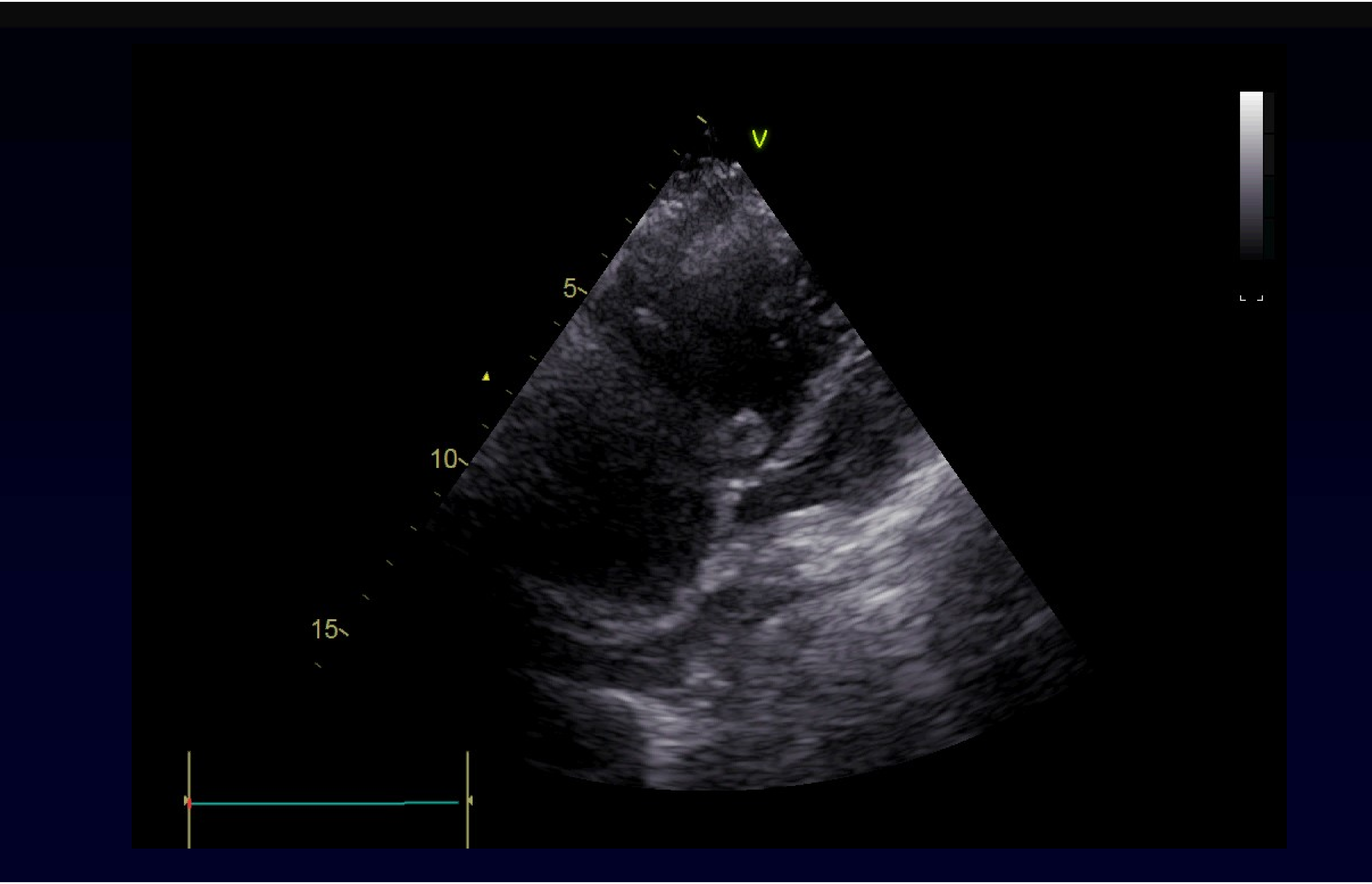
JPEG
81 bpm


V
5
10
15

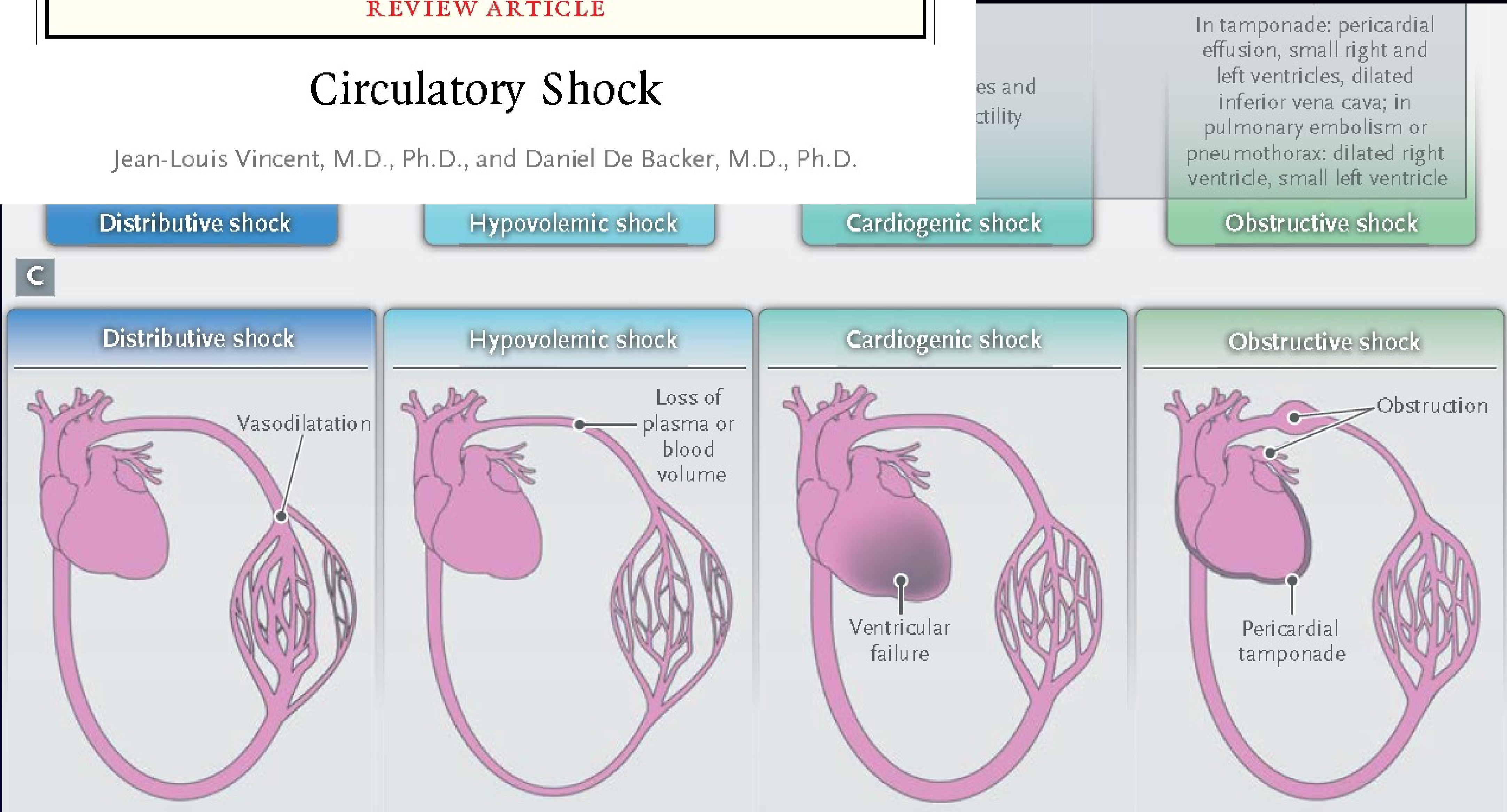
Vincent and De Backer NEJM 2013

The NEW ENGLAND JOURNAL of MEDICINE

REVIEW ARTICLE

Circulatory Shock

Jean-Louis Vincent, M.D., Ph.D., and Daniel De Backer, M.D., Ph.D.



Volpicelli et al
ICM 2013

Ultrasounds in shock

Table 5 Statistic analyses comparing data of preliminary ultrasound diagnoses in patients with undifferentiated hypotension with final clinical diagnoses

	Number of cases	Cohen *k*	95 % CI	*P*	Ra
Analysis 1	108	0.710	(0.614–0.806)	<0.0001	0.768
Analysis 2	108	0.838	(0.761–0.914)	<0.0001	0.870
Analysis 3	92	0.971	(0.932–1.000)	<0.0001	0.978

Time to diagnosis: 4.9±1.3 min

108 hypotensive patients in ED

dside POCUS during ward emergencies associated with improved diagnosis d outcome: an observational, prospective, ntrolled study

Zieleskiewicz L et al
Crit Care 2021

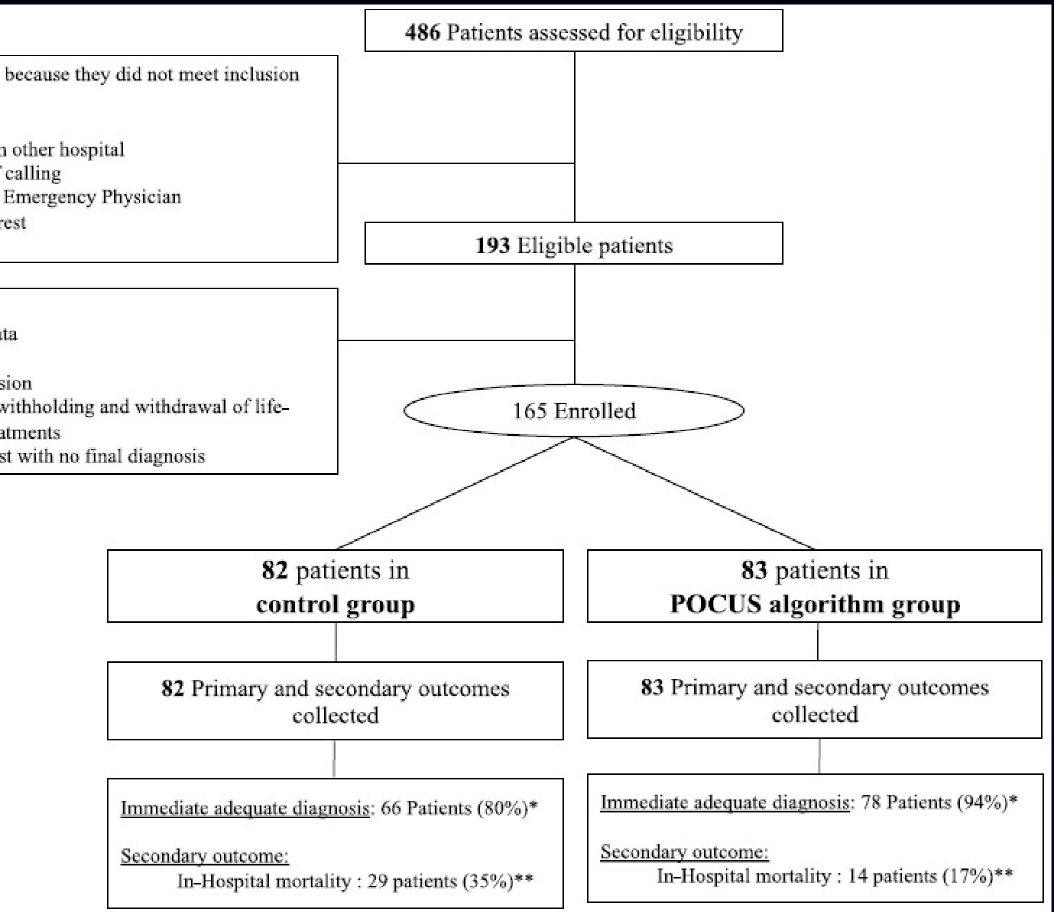


Table 4 In-hospital and ICU mortality rates in P group versus control group[a]

	Control group $n=82$	POCUS group $n=83$
In-ICU mortality		
General	* 17 (25)	* 7 (11)
Circulatory	7/23 (30)	1/17 (6)
Respiratory	10/44 (23)	6/45 (13)
In-hospital mortality		
General	29 (35)	14 (17)
Circulatory	12/26 (46)	3/22 (14)
Respiratory	17/56 (30)	11/61 (18)

* Patients admitted in ICU: control group $n=67$ and POCUS group $n=6$

[a] Data are expressed as no. (%) of participants

Intensive Care Med (2014) 40:1795–1815
DOI 10.1007/s00134-014-3525-z

CONFERENCE REPORTS AND EXPERT PANEL

Maurizio Cecconi
Daniel De Backer
Massimo Antonelli
Richard Beale
Jan Bakker
Christoph Hofer
Roman Jaeschke
Alexandre Mebazaa
Michael R. Pinsky
Jean Louis Teboul
Jean Louis Vincent
Andrew Rhodes

Consensus on circulatory shock and hemodynamic monitoring. Task force of the European Society of Intensive Care Medicine

No.	Statement/recommendation	GRADE level of recommendation; quality of evidence	Type of statement
13.	We recommend further hemodynamic assessment (such as assessing cardiac function) to determine the type of shock if the clinical examination does not lead to a clear diagnosis	Ungraded	Best practice
14.	We suggest that, when further hemodynamic assessment is needed, echocardiography is the preferred modality to initially evaluate the type of shock as opposed to more invasive technologies	Level 2; QoE moderate (B)	Recommendation

Critical care echocardiography

1- Focused evaluation

2- Full hemodynamic evaluation

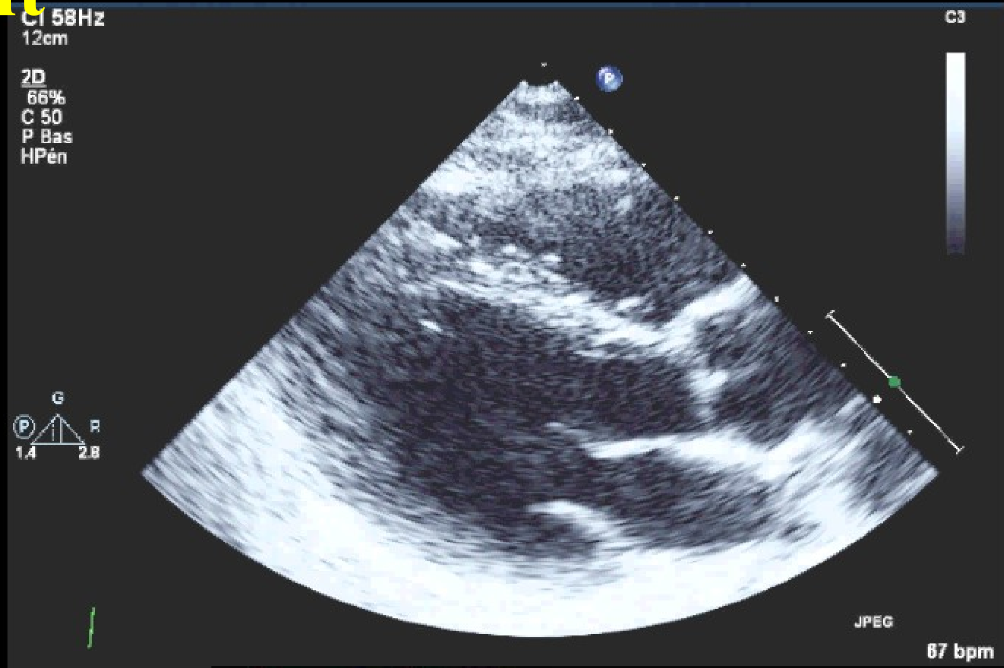
- Use of Doppler signals
- Analysis of heart-lung interactions

What should we measure ?

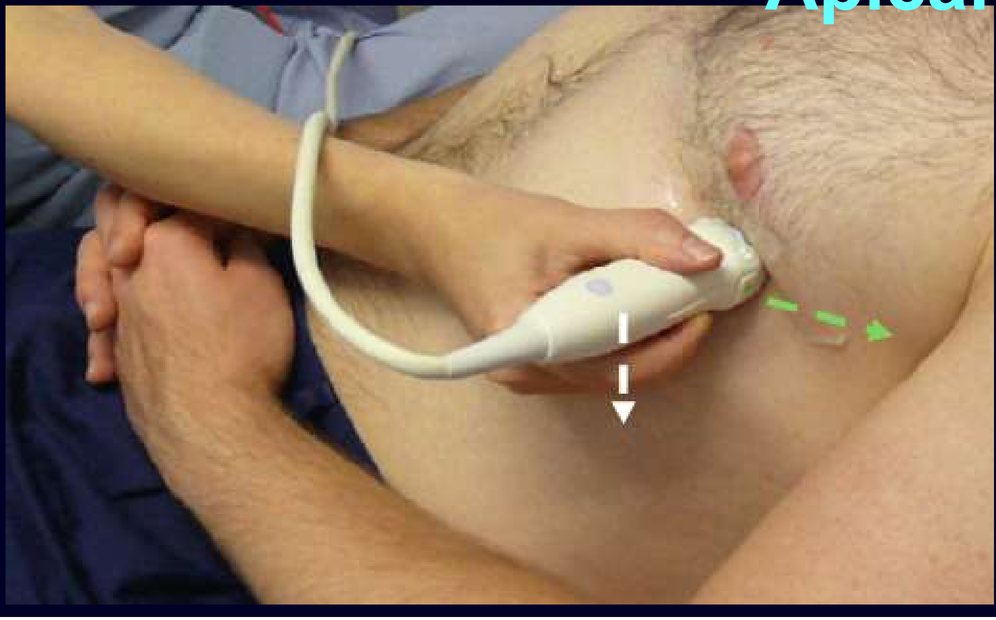
- Cardiac output
- Contractility
- Preload dependency / LV and RV preload
- Pulmonary artery pressure
- Morphologic evaluation
(pericardial effusion, valves, regional contraction, PFO)

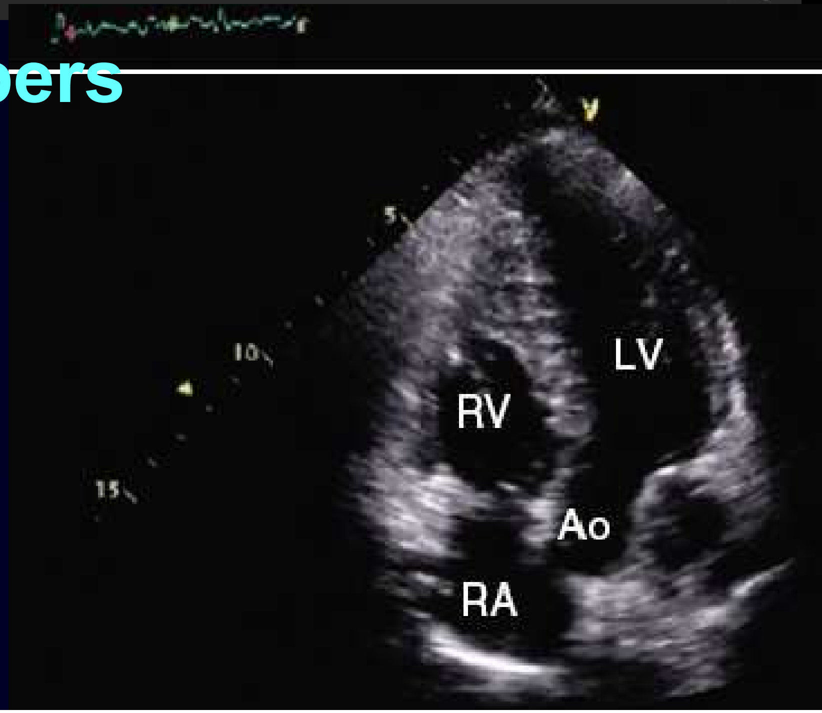
Measurement of cardiac output

PARASTERNAL LONG AXIS

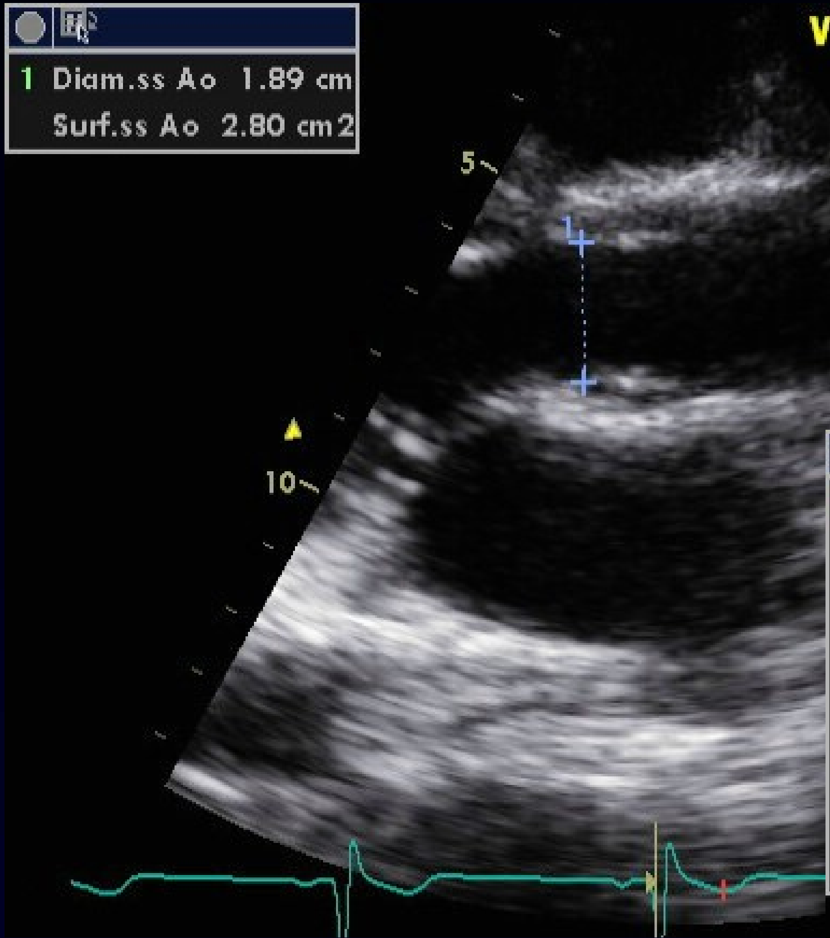


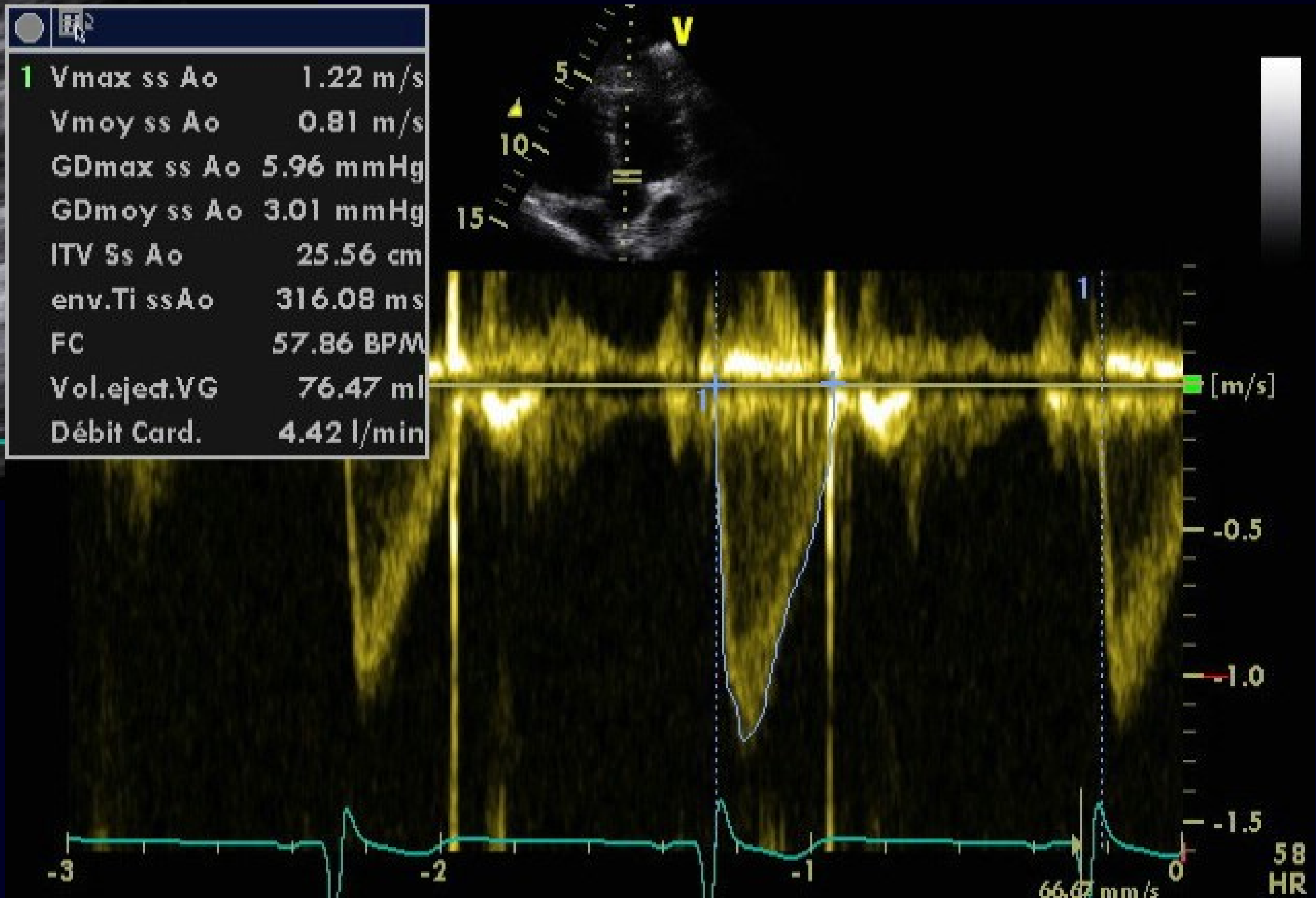
Apical 5 chambers





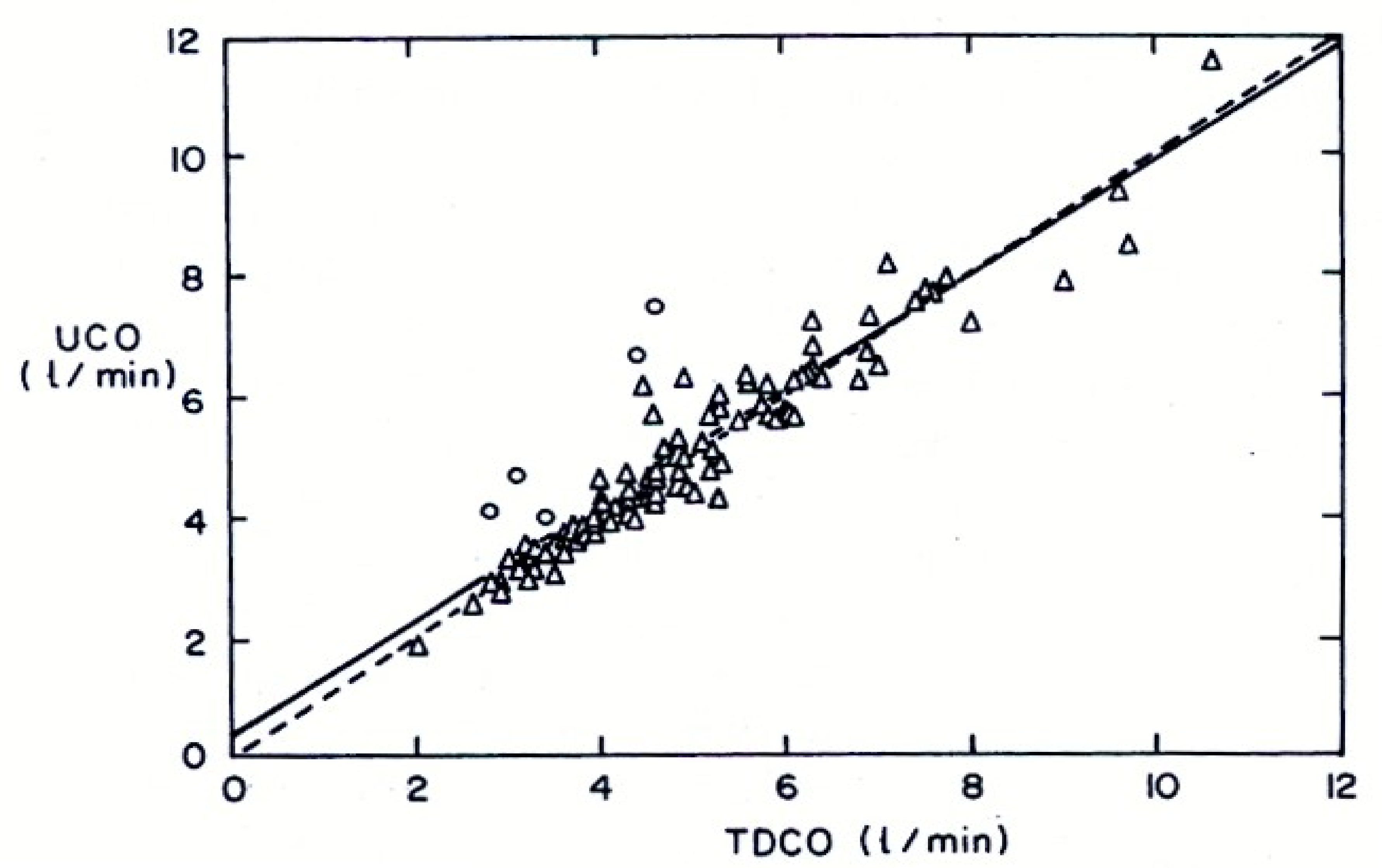
Measurement of cardiac output





Cholley B et al
Hemodynamic monitoring using echocardiography in the critically ill
Eds: De Backer et al
Springer 2011

Huntsman et
Circulation 19

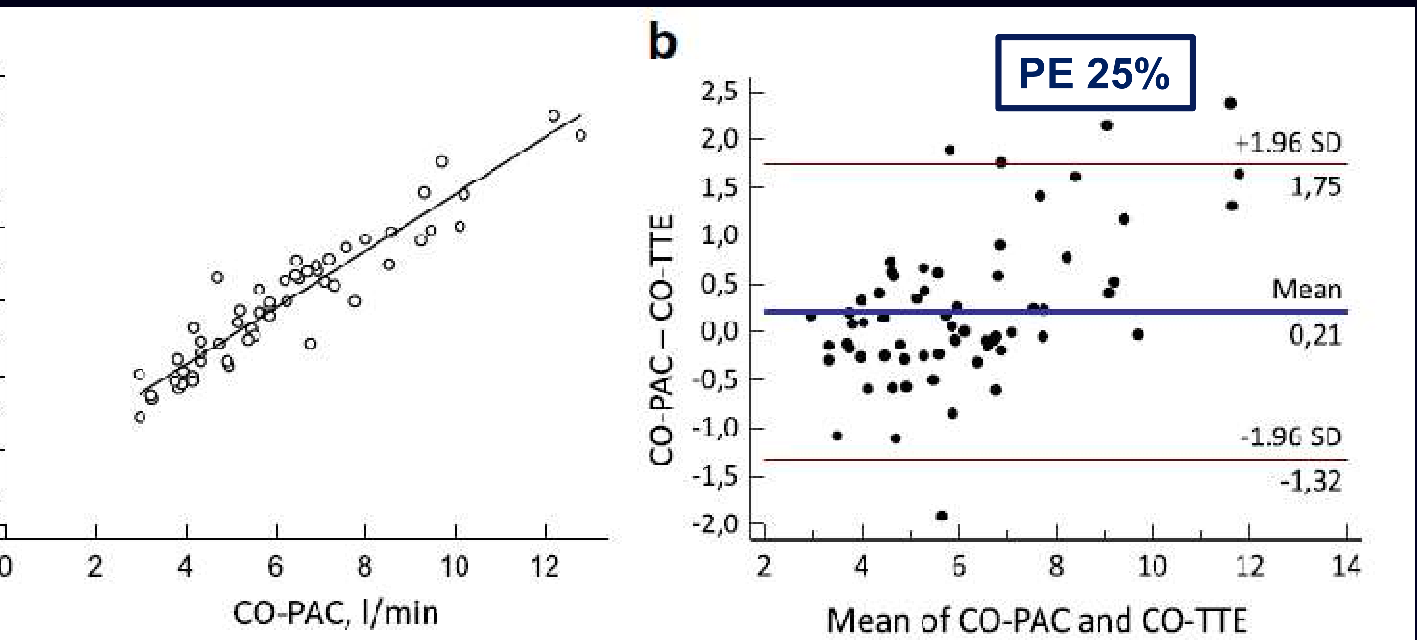


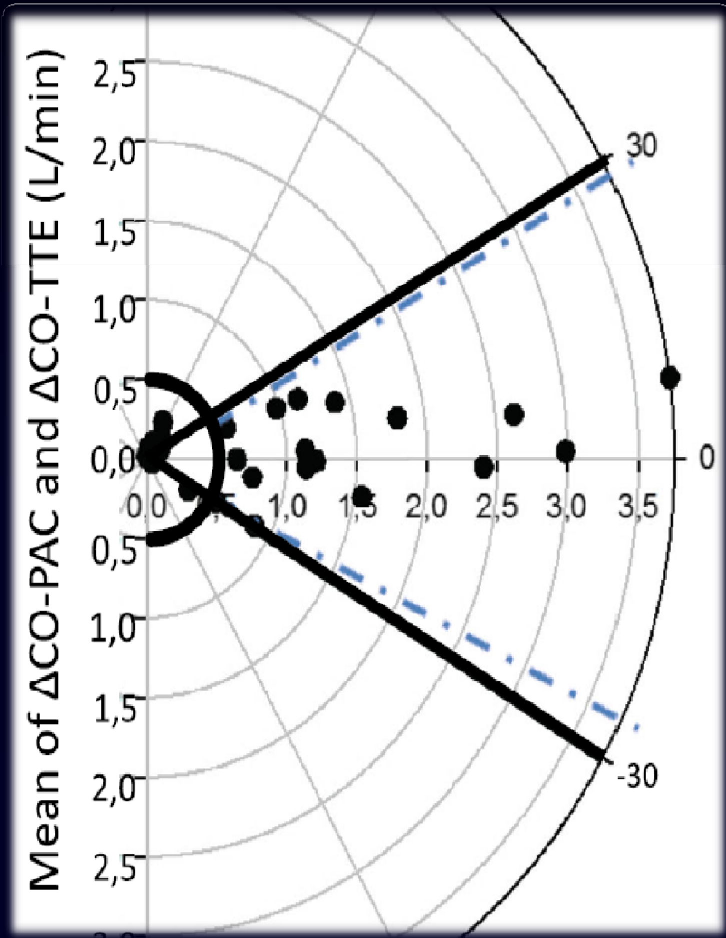
RESEARCH Open Access

Crit Care 2017

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], Antoine Riviere[1,3], Olivier Bonef[1,4], Thierry Soupison[1], Christophe Tribouilloy[5], Bertrand de Cagny[1] and Michel Slama[1,6*]





easurement of LVOT

⇒LVOT area: $\pi D^2/4$

A small error is elevated to the square !

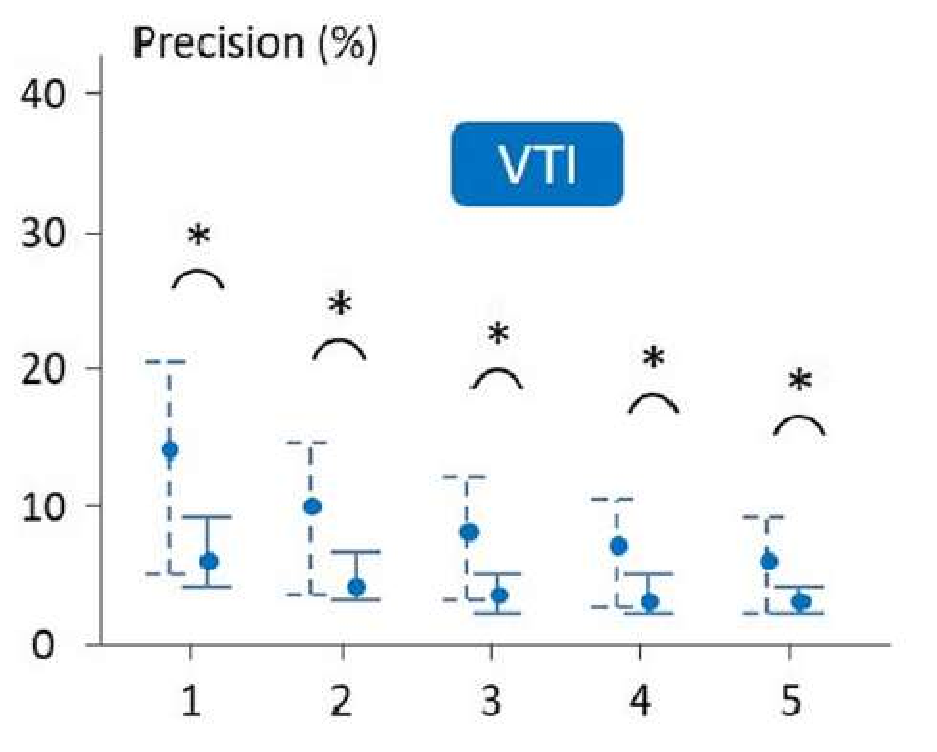
VTI	HR	LVOT	$\pi D^2/4$	CO
17	100	1.7	2.27	3.86
17	100	1.8	2.54	4.33
17	100	1.9	2.84	4.82
17	100	2.0	3.14	5.34
17	100	2.1	3.46	5.89

=> Always use same LVOT value or use VTI

What is the lowest change in cardiac output that transthoracic echocardiography can detect?

Mathieu Jozwiak[1,2*], Pablo Mercado[1,2], Jean-Louis Teboul[1,2], Anouar Benmalek[3], Julia Gimenez[1,2], François Dépret[1,2], Christian Richard[1,2] and Xavier Monnet[1,2]

Crit Care 2019



Lowest significant change:

- 11[5-18]% same oper
- 14 [8-26]% diff oper

N=100 ICU pts (16 in AF)

How to evaluate cardiac function with echo ?

LV systolic

- Ejection fraction
- S wave Mitral annulus
- MAPSE
- dP/dT
- Strain rate

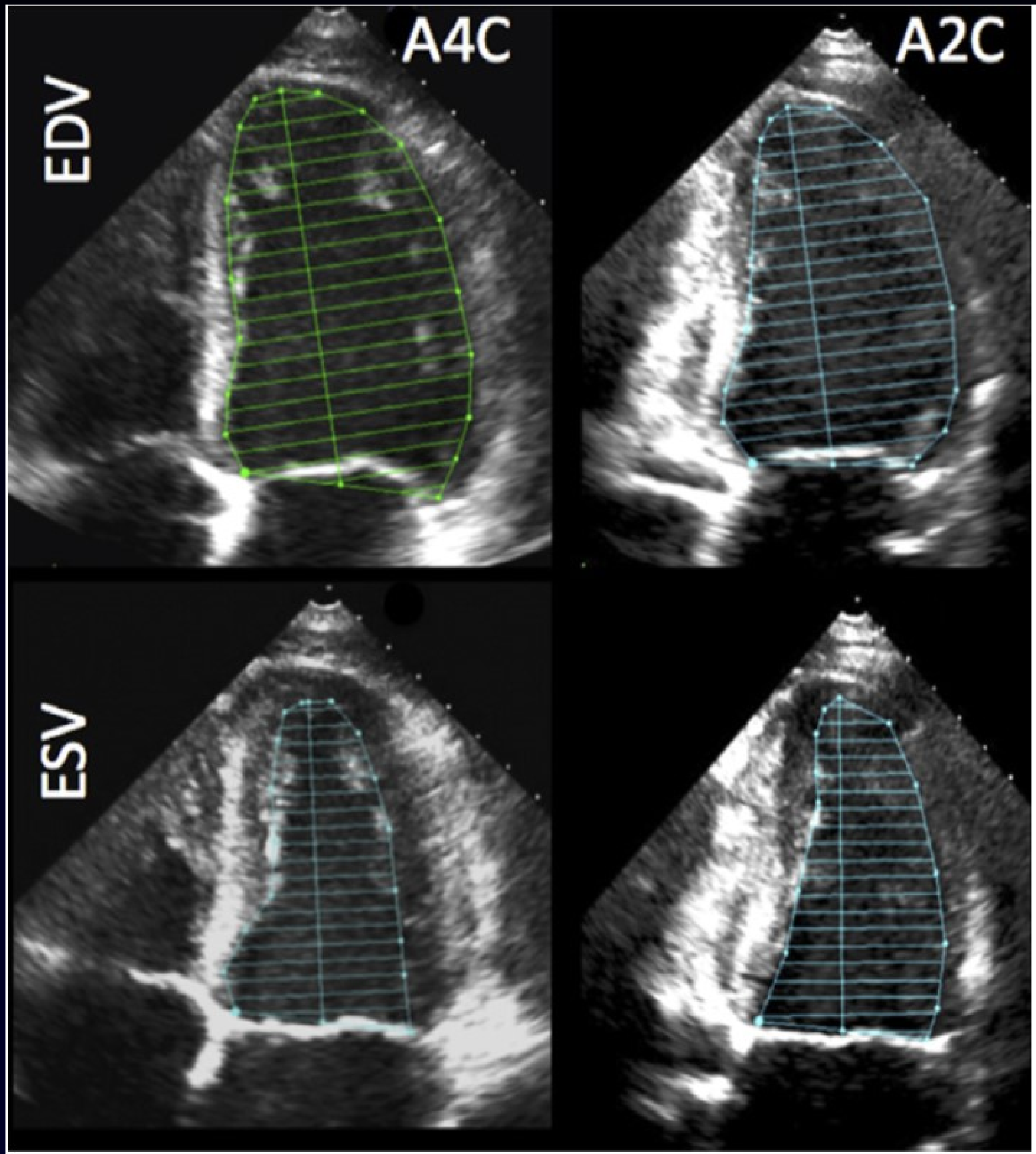
LV diastolic

- Mitral annulus E and A
- Strain rate

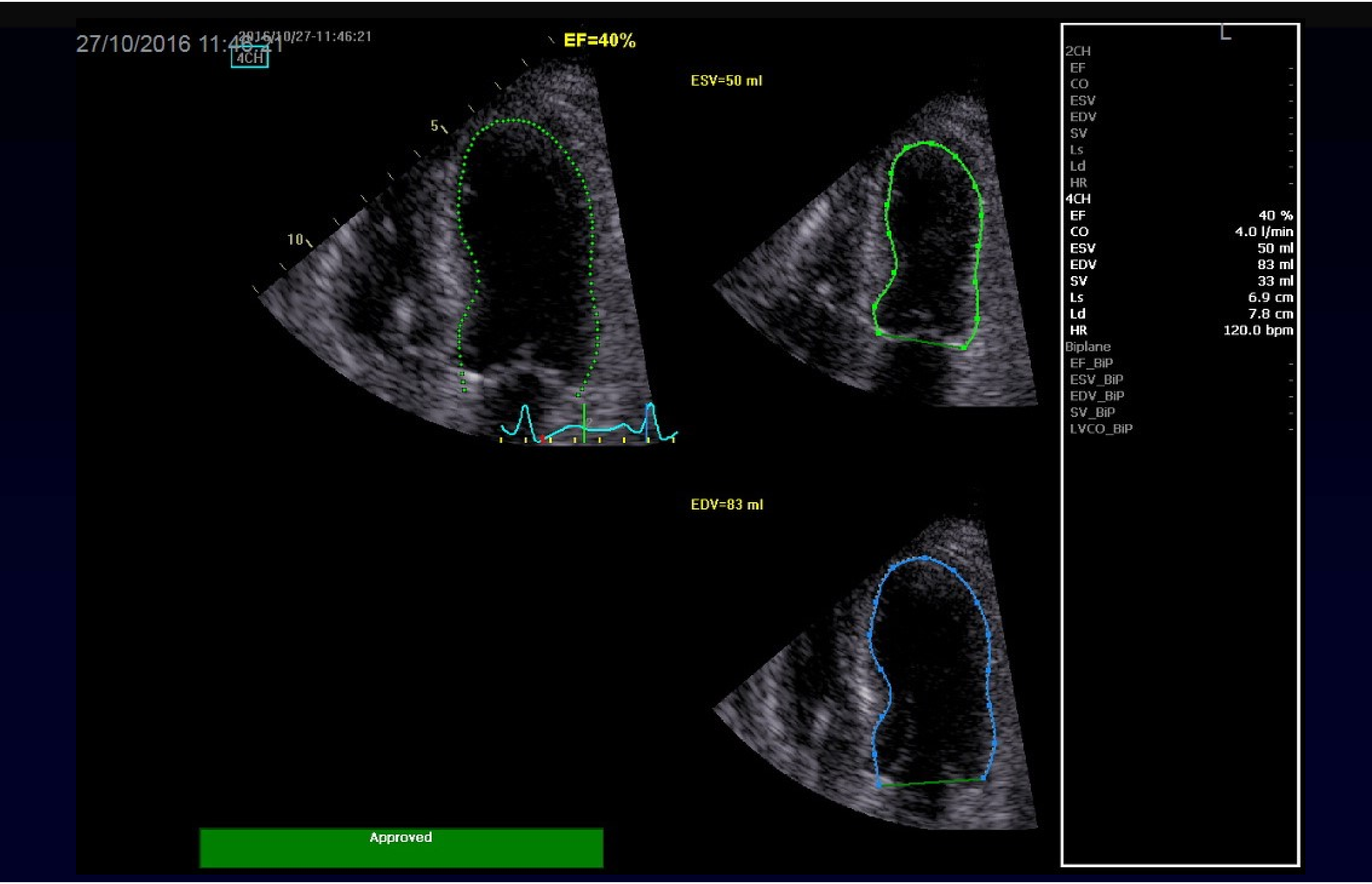
GUIDELINES AND STANDARDS

Recommendations for Cardiac Chamber Quantification by Echocardiography in Adults: An Update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging

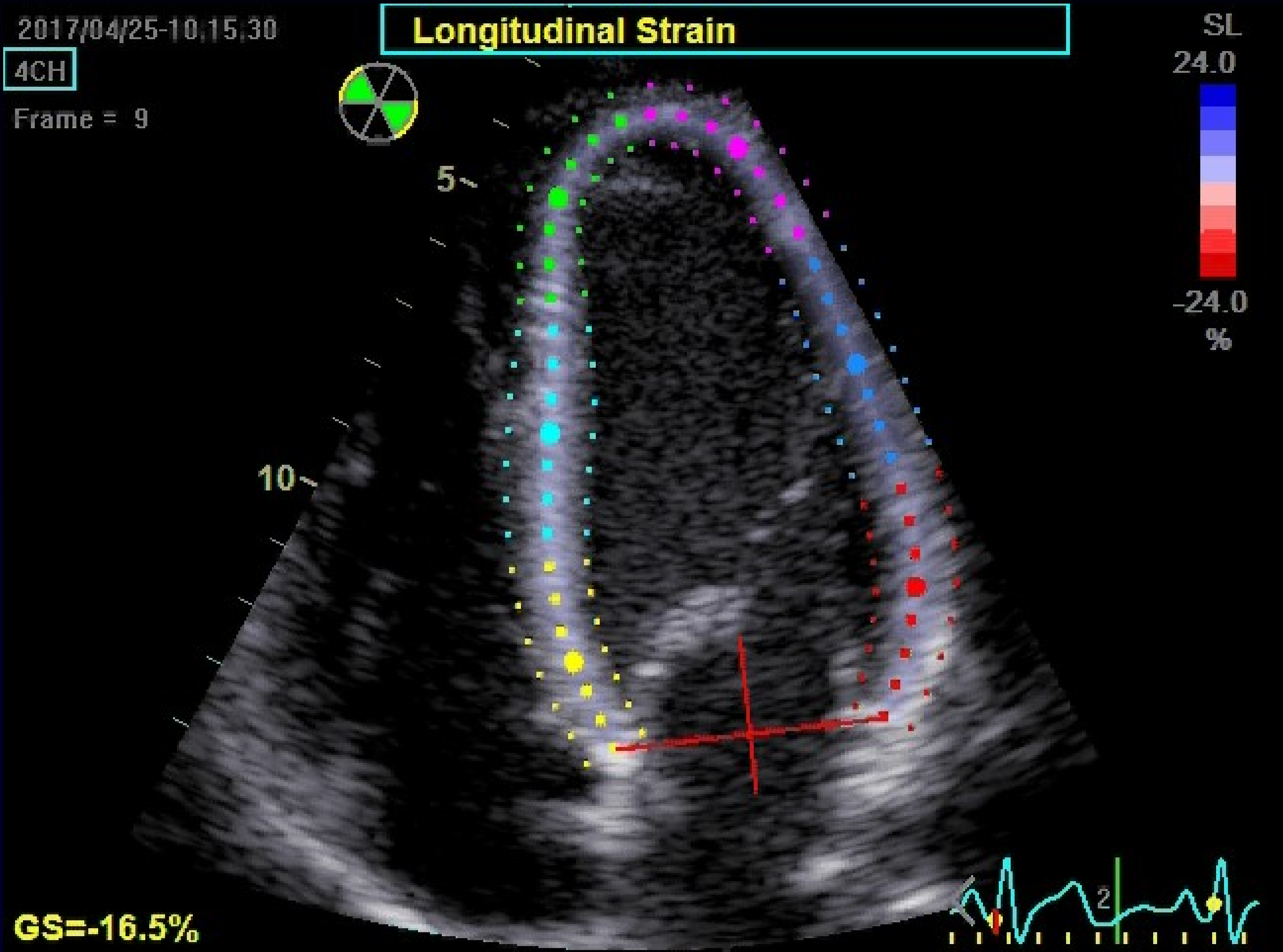
Roberto M. Lang, MD, FASE, FESC, Luigi P. Badano, MD, PhD, FESC, Victor Mor-Avi, PhD, FASE, Jonathan Afilalo, MD, MSc, Anderson Armstrong, MD, MSc, Laura Ernande, MD, PhD, Frank A. Flachskampf, MD, FESC, Elyse Foster, MD, FASE, Steven A. Goldstein, MD, Tatiana Kuznetsova, MD, PhD, Patrizio Lancellotti, MD, PhD, FESC, Denisa Muraru, MD, PhD, Michael H. Picard, MD, FASE, Ernst R. Rietzschel, MD, PhD, Lawrence Rudski, MD, FASE, Kirk T. Spencer, MD, FASE, Wendy Tsang, MD, and Jens-Uwe Voigt, MD, PhD, FESC, *Chicago, Illinois; Padua, Italy; Montreal, Quebec and Toronto, Ontario, Canada; Baltimore, Maryland; Créteil, France; Uppsala, Sweden; San Francisco, California; Washington, District of Columbia; Leuven, Liège, and Ghent, Belgium; Boston, Massachusetts*



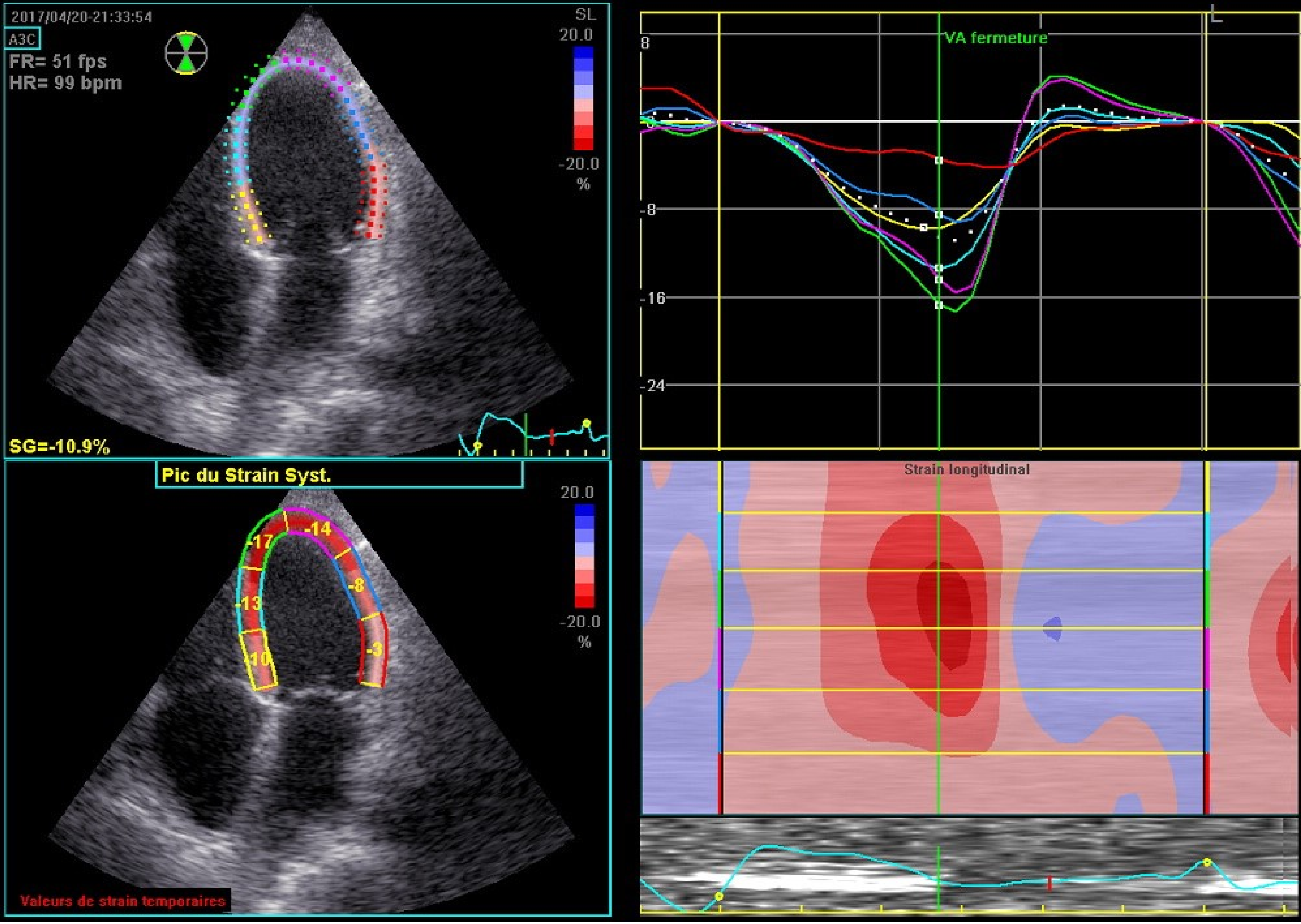
Lang R. et al. J Am Soc Echo 2015


27/10/2016 11:46:21
2016/10/27-11:46:21
4CH
EF=40%
ESV=50 ml
EDV=83 ml
Approved
2CH
EF -
CO -
ESV -
EDV -
SV -
Ls -
Ld -
HR -
4CH
EF 40 %
CO 4.0 l/min
ESV 50 ml
EDV 83 ml
SV 33 ml
Ls 6.9 cm
Ld 7.8 cm
HR 120.0 bpm
Biplane
EF_BiP -
ESV_BiP -
EDV_BiP -
SV_BiP -
LVCO_BiP -

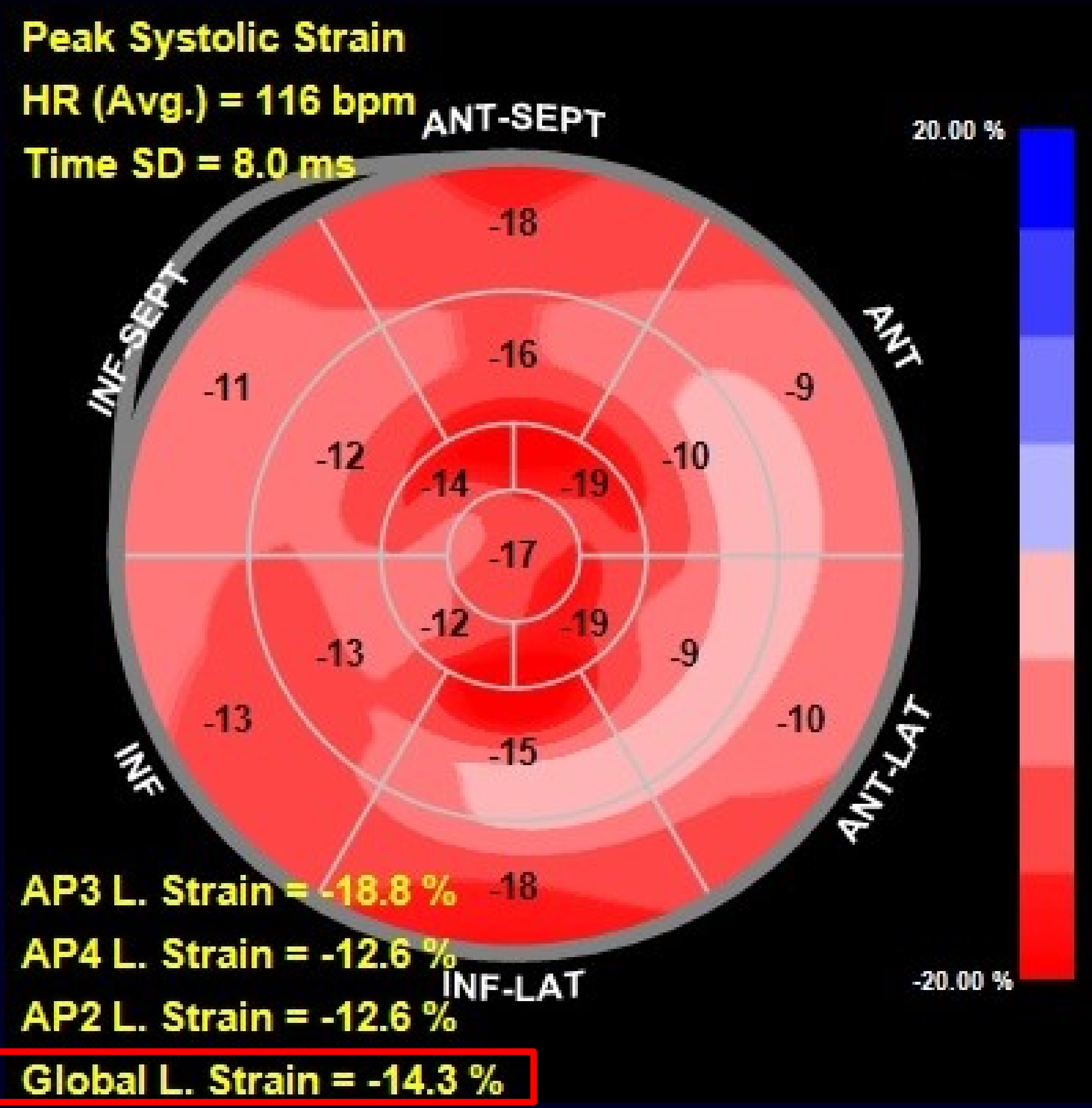
rain (speckle tracking)

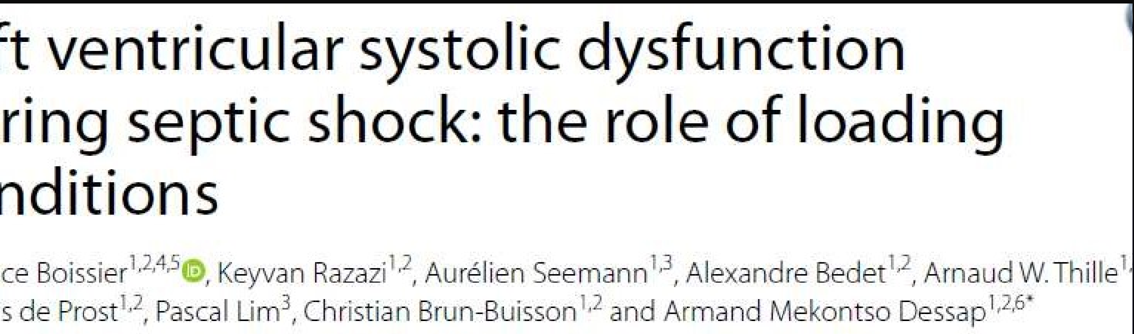


rain (speckle tracking)



ull's Eye Display & lobal Longitudinal Strain (GLS)



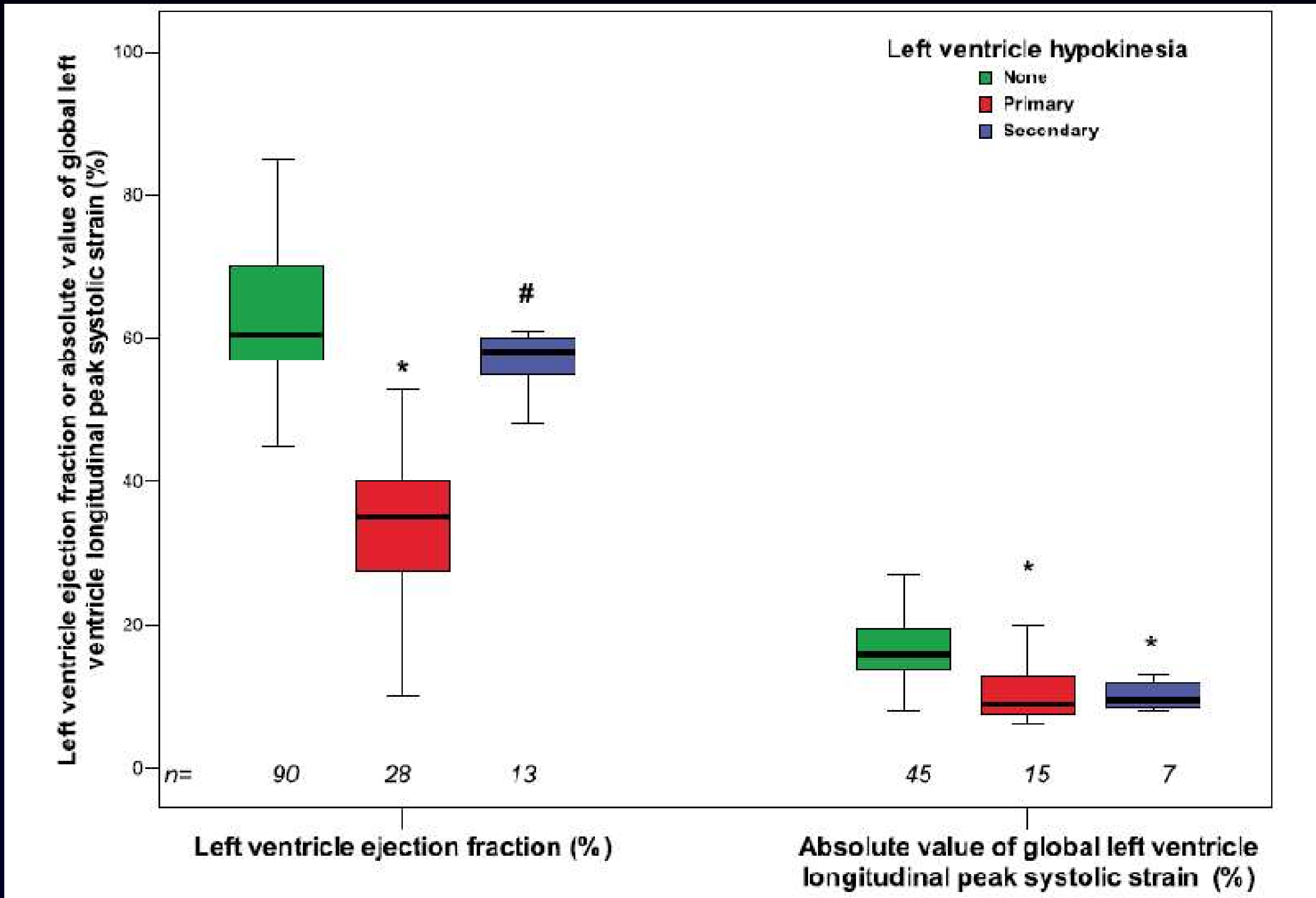


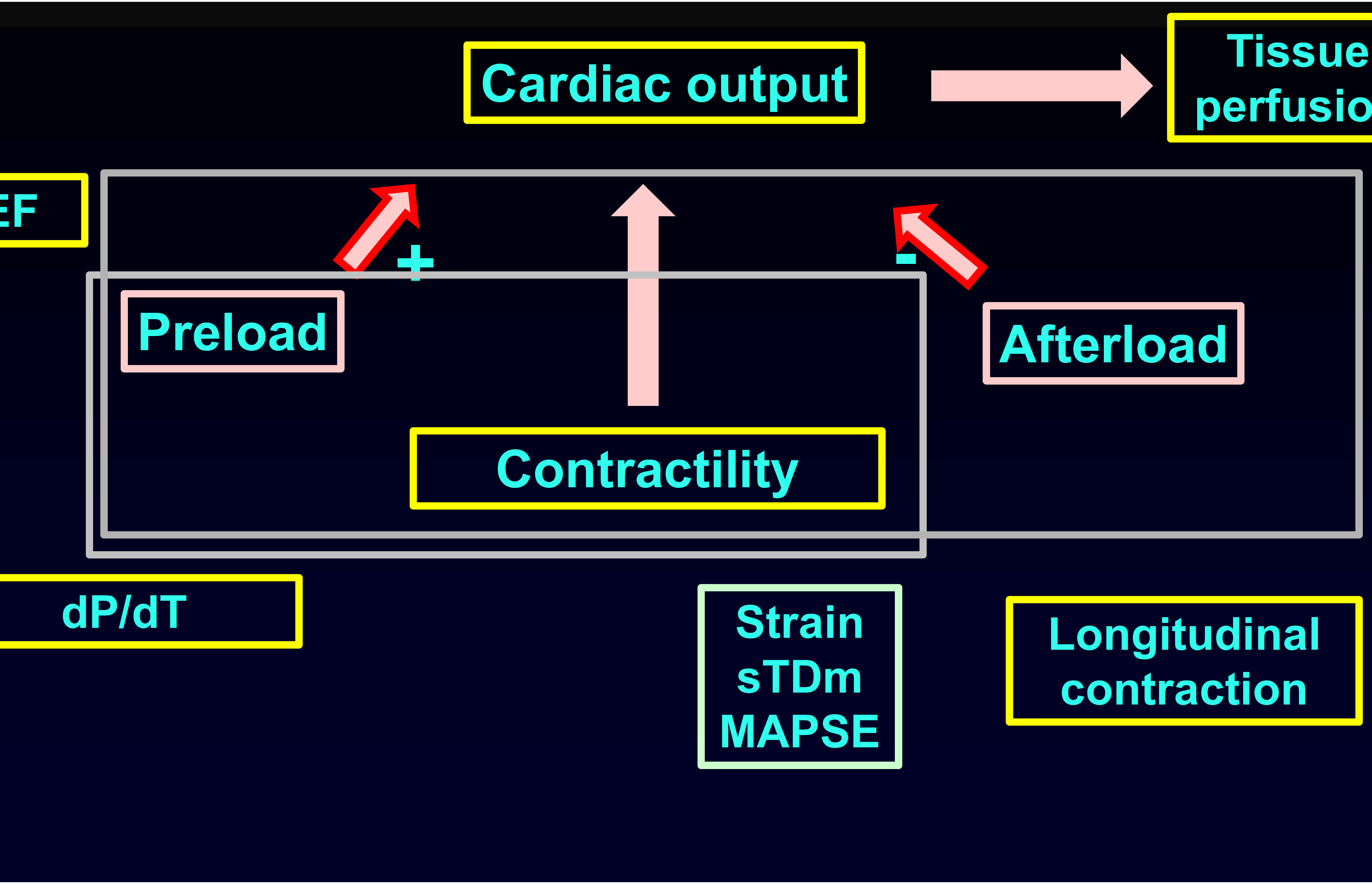
ft ventricular systolic dysfunction
ring septic shock: the role of loading
nditions

ce Boissier[1,2,4,5], Keyvan Razazi[1,2], Aurélien Seemann[1,3], Alexandre Bedet[1,2], Arnaud W. Thille[1,
s de Prost[1,2], Pascal Lim[3], Christian Brun-Buisson[1,2] and Armand Mekontso Dessap[1,2,6*]

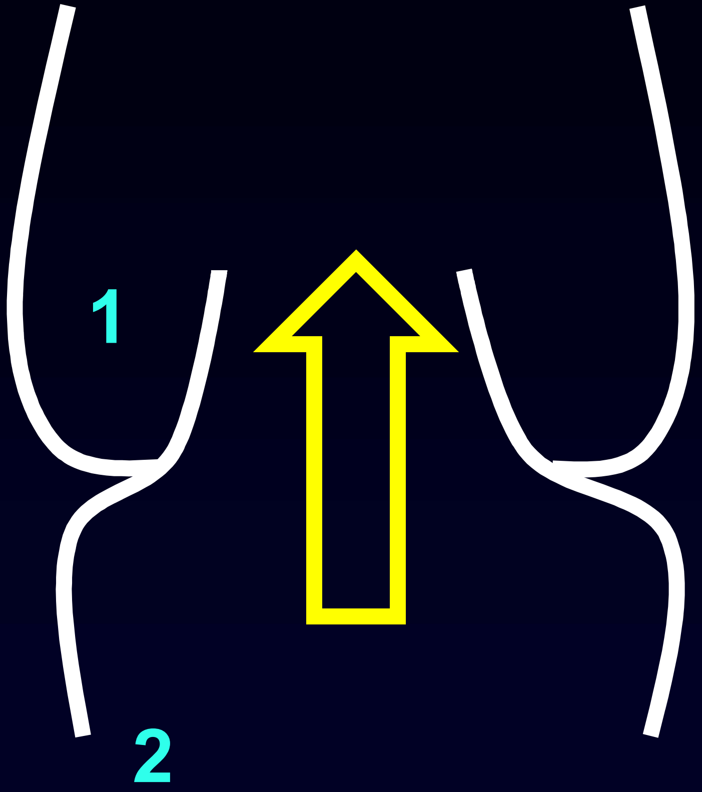
Boissier F et al
ICM 2017

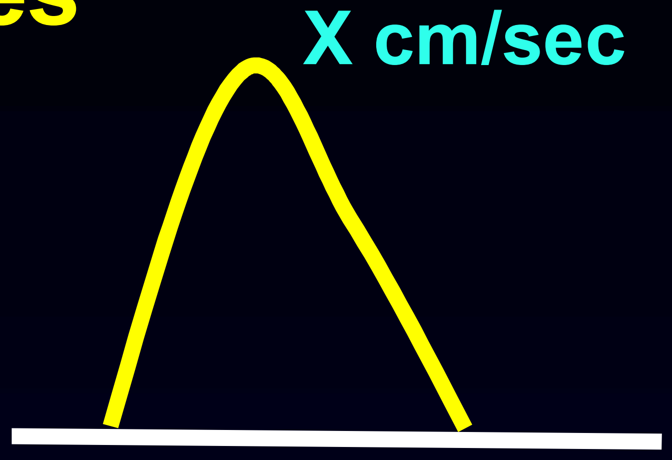
Early detection of LV dysfunction with strain




Cardiac output
Tissue
perfusio
EF
+
-
Preload
Afterload
Contractility
dP/dT
Strain
sTDm
MAPSE
Longitudinal
contraction

Measurements of pressures

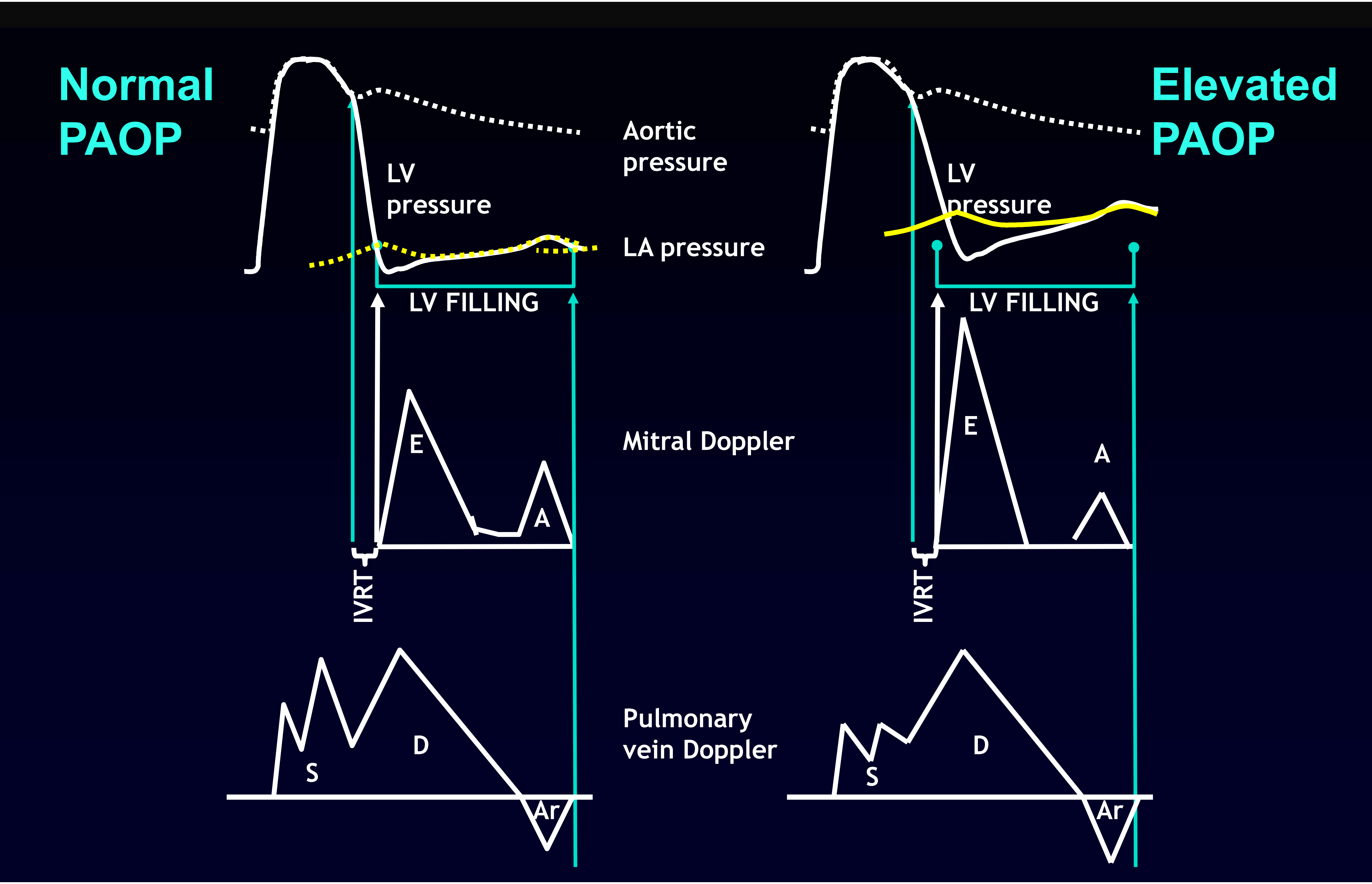




$$\boxed{P2 - P1 = 4X^2}$$

- PAP (tricuspid)
- PAOP (mitral)

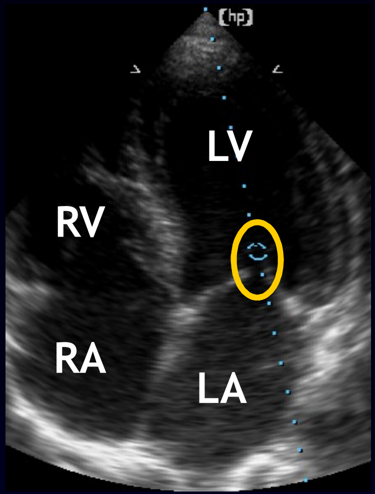

Preload



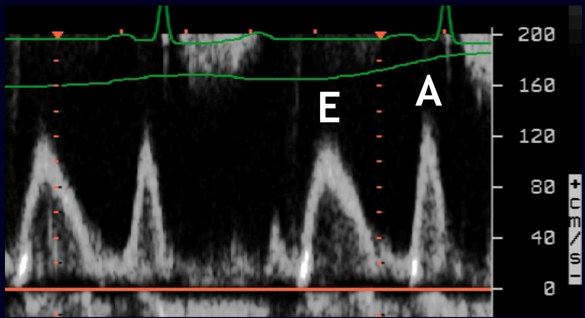
Normal PAOP
Elevated PAOP
Aortic pressure
LV pressure
LA pressure
LV FILLING
Mitral Doppler
E
A
IVRT
Pulmonary vein Doppler
S
D
Ar

Evaluation of PAOP

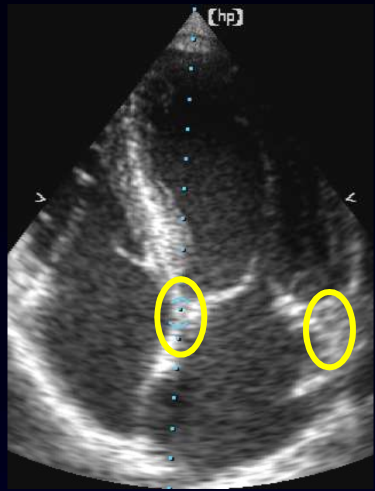
Mitral Doppler



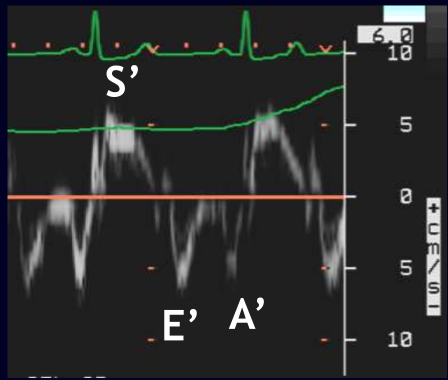
Depends:
- ➢ Preload
- ➢ diastoly



Tissue Doppler imaging (mitral ring)



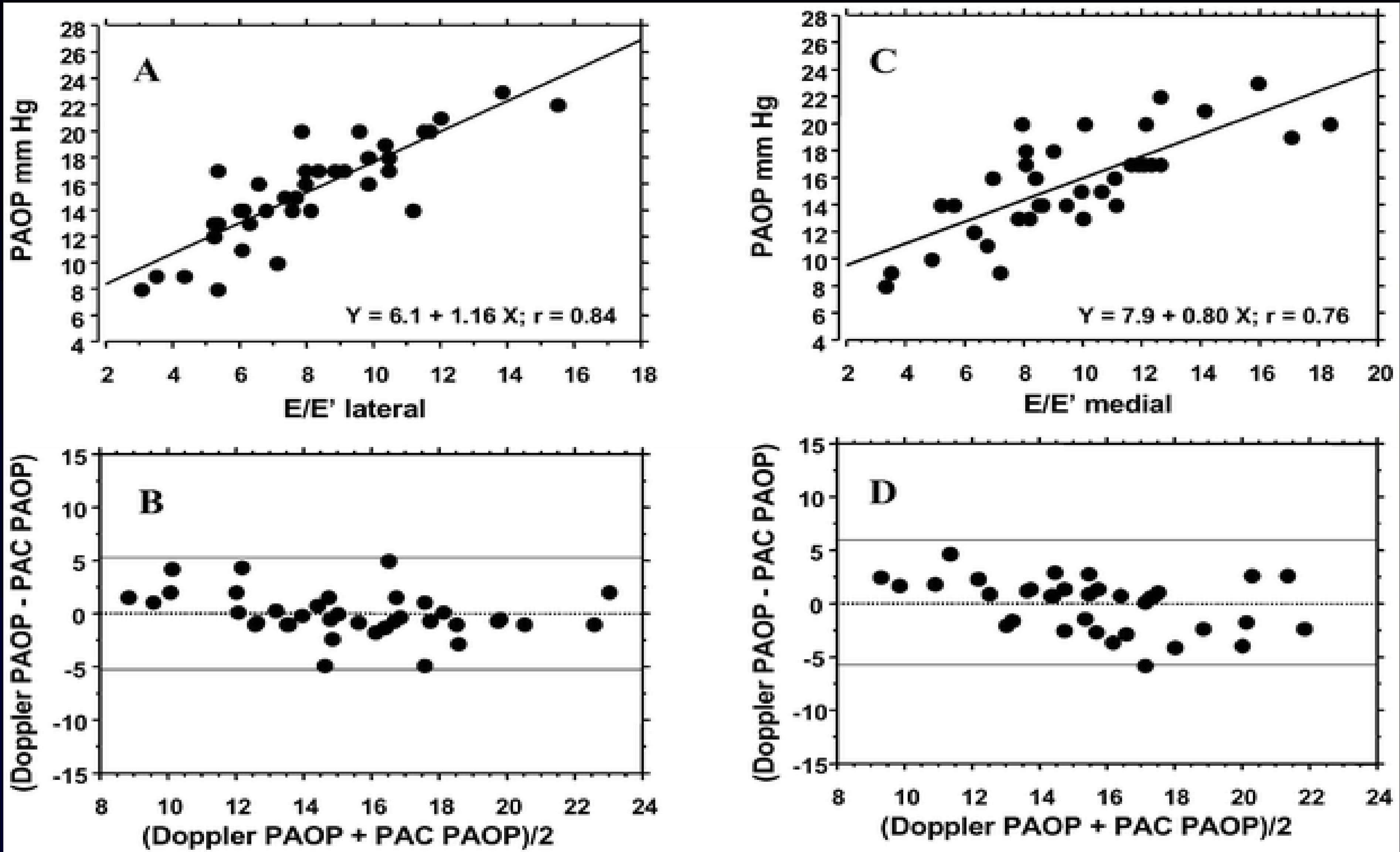
Depends:
- ➢ ~~Preload~~
- ➢ diastoly



Mitral E/A and E/Ea ratios

Vignon P et al
Hemodynamic monitoring using echocardiography in the critically ill
Eds: De Backer et al Springer 2011

E/Ea



ICU, mechanical ventilation

Combes A Int Care Med 2004

The large limits of agreement do not really allow quantitative measurements of PAOP

- semi-quantitative measurements
- trends over time

hich cut-off??

- E/Ea ≤ 5.5 => PAOP ≤ 8 Bouhemad et al Anesth 2003
- E/Ea ≤ 7.5 => PAOP ≤ 15 Combes et al ICM 2004
- E/Ea ≤ 8 => PAOP ≤ 18 Vignon et al Crit Care 2008

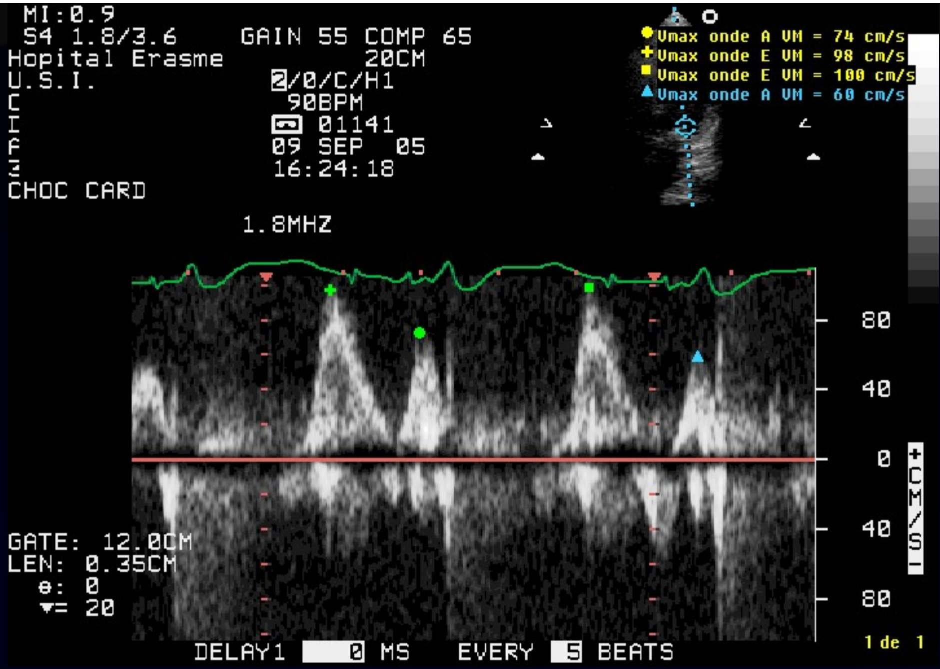
- E/Ea ≥ 8.5 => PAOP ≥ 18 Lamia et al CCM 2009
- E/Ea ≥ 10 => PAOP ≥ 18 Nagueh et al JACC1997
- E/Ea ≥ 15 => PAOP ≥ 18 Ommen et al Circ 2000

=> E/Ea ≤ 7.5 => PAOP low
=> E/Ea between 7.5 and 13 => grey zone
=> E/Ea ≥ 13 PAOP elevated

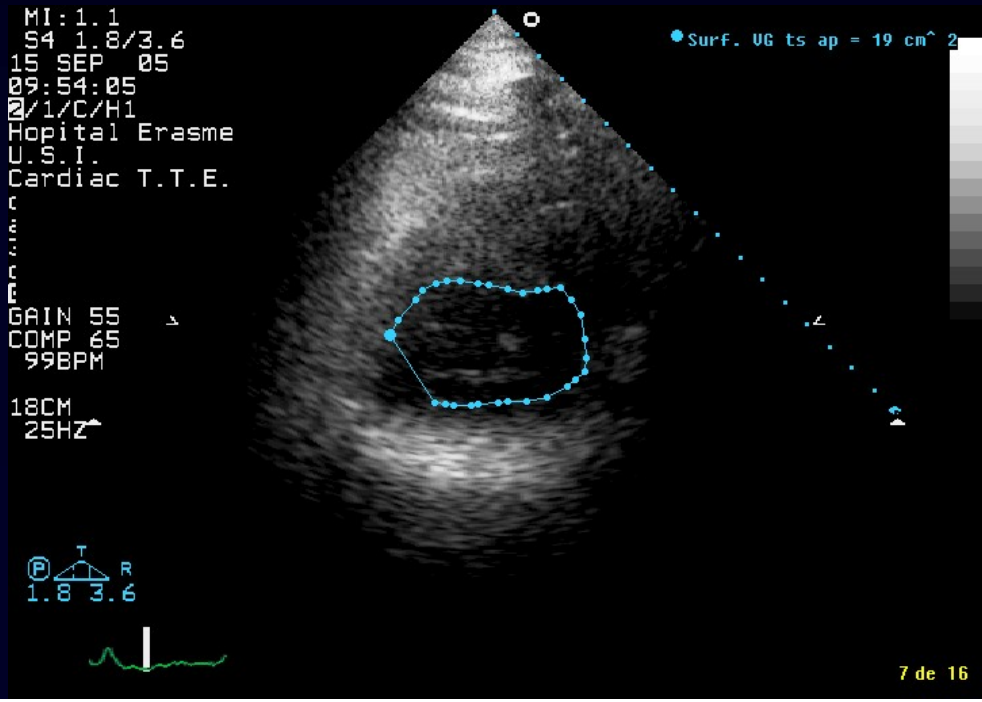
Echographic assessment of fluid responsiveness

How to detect patients who may benefit from fluids

reload assessment

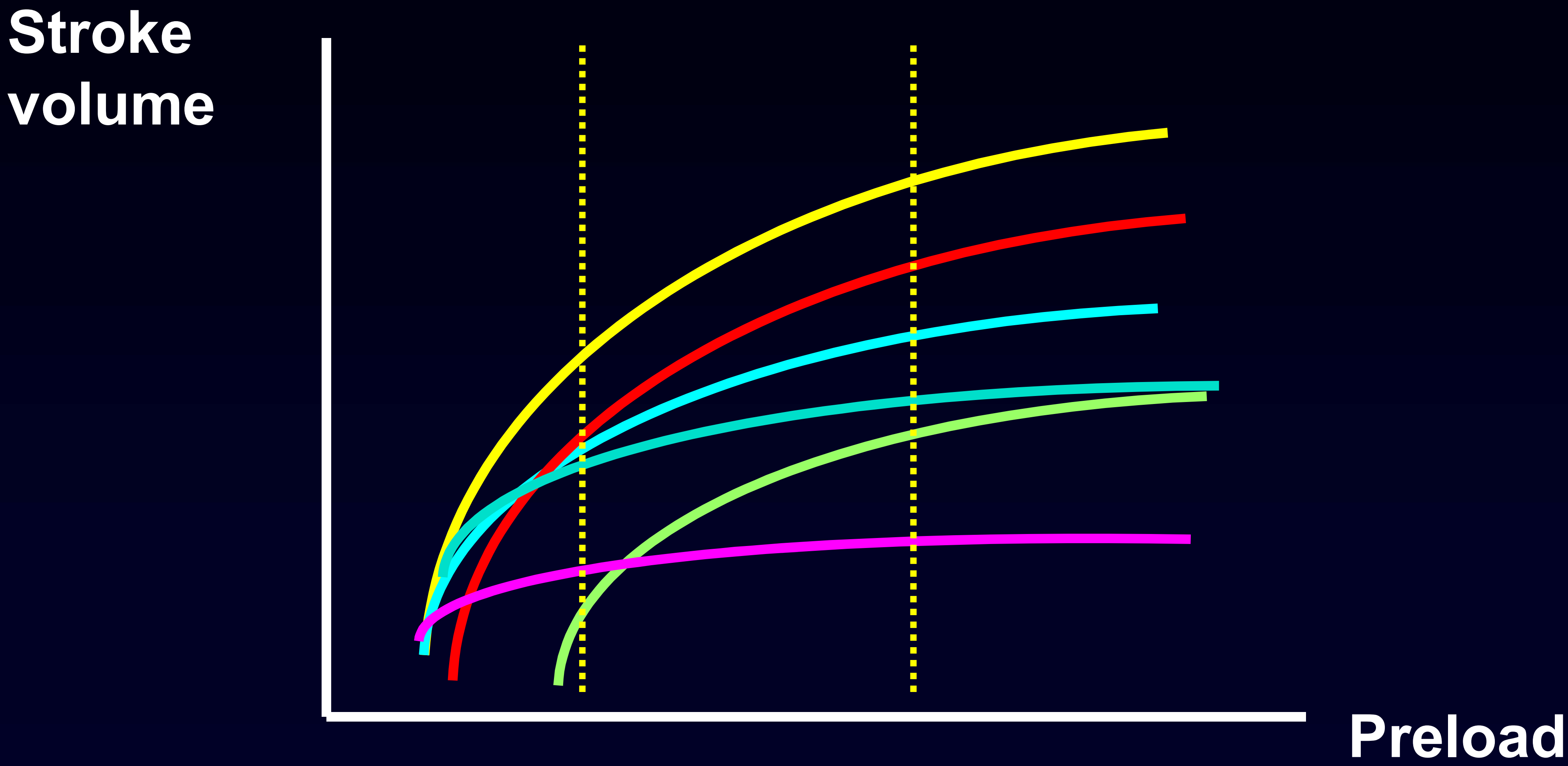


- Evaluation of filling pressures:
  - Mitral flow + mitral TDI (PAOP)



- Evaluation of volumes
  - LV area
  - LV volume (Simpson)

TARLING RELATIONSHIP



All indices of preload poorly predict fluid responsiveness !

DDE

Preload measurements

↓

Preload responsiveness measurements
(functional hemodynamics)

FUNCTIONAL HEMODYNAMICS

Heart-lung interactions

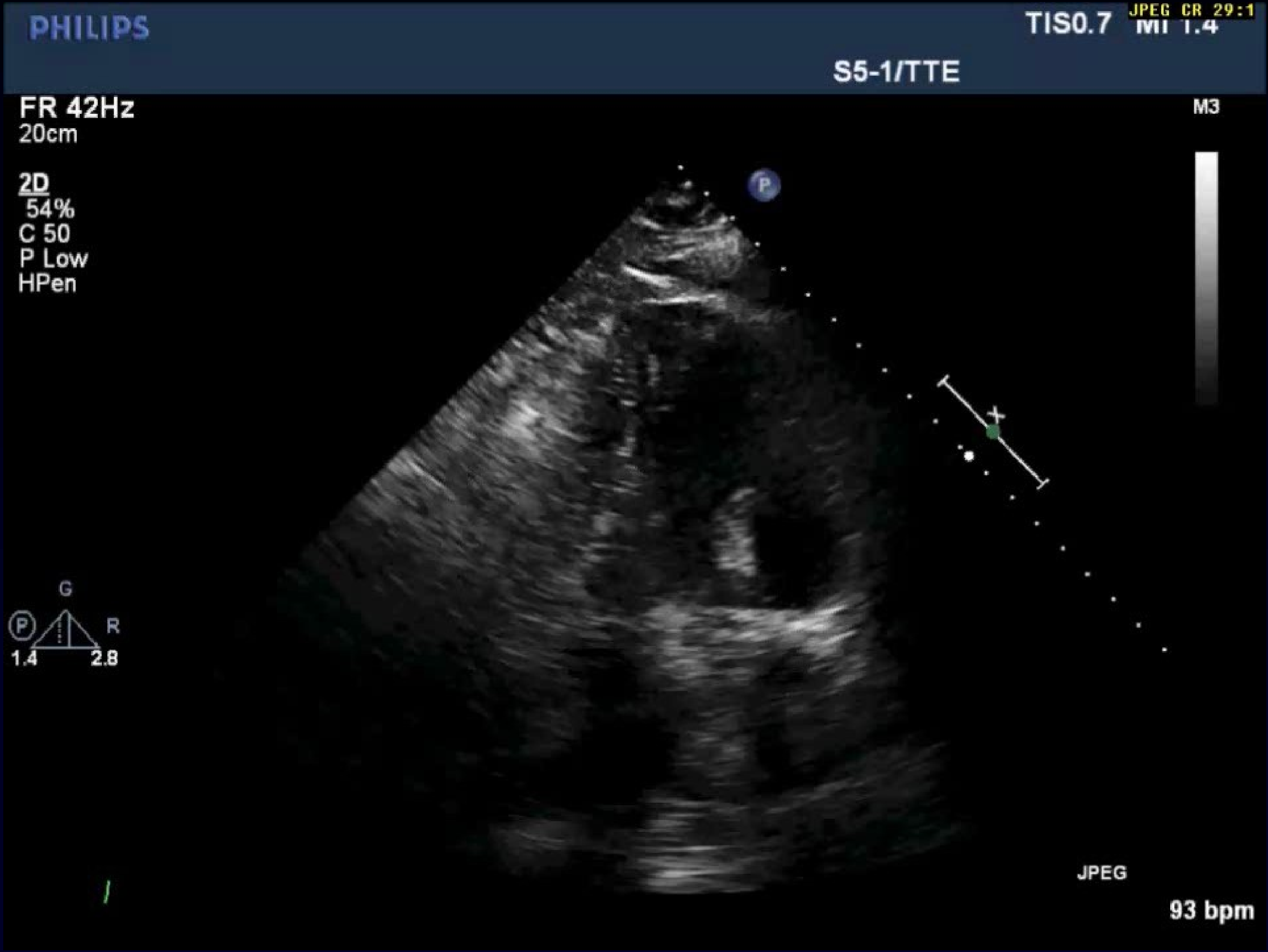
- Respiratory variations in stroke volume
- Respiratory variations in vena cava size

External maneuvers

- Expiratory pause
- Passive leg raising test

Old Egypt illustration of heart and lungs
Sarcophagus Cairo Museum

A SPECIAL LOOK AT THE RIGHT VENTRICLE…


PHILIPS
TIS0.7 MI 1.4
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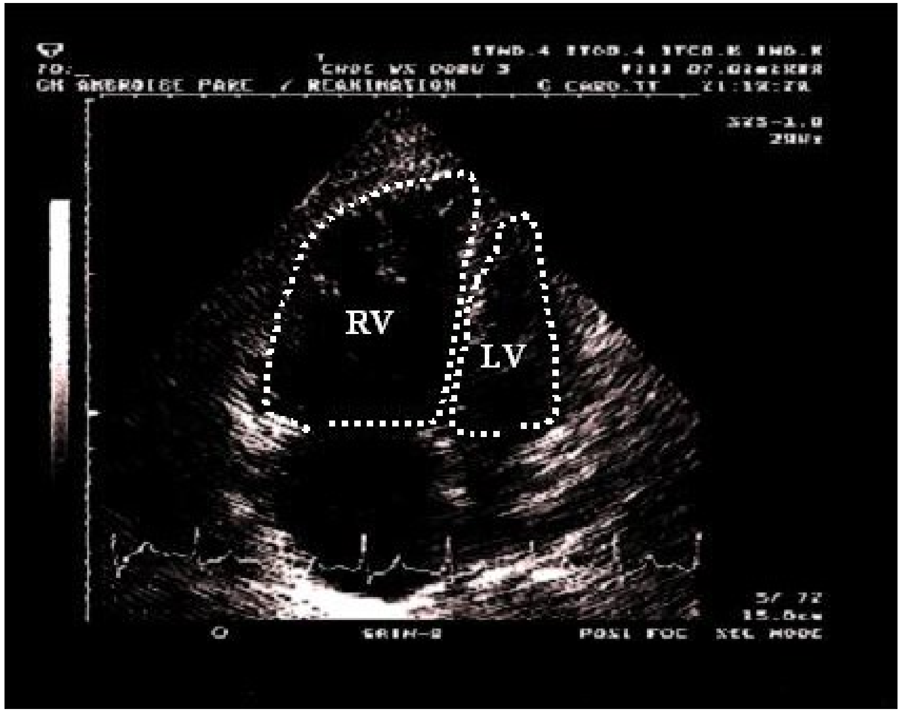
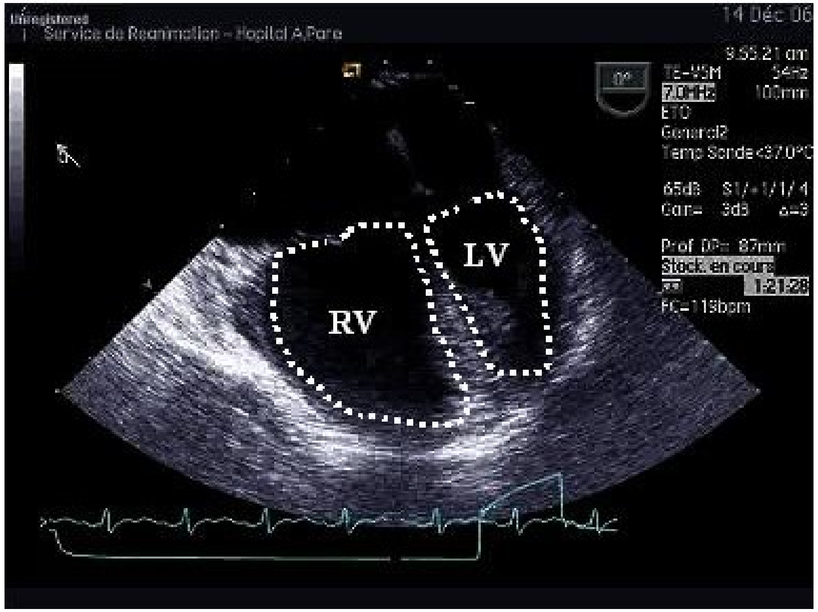
S5-1/TTE
FR 42Hz
20cm
2D
54%
C 50
P Low
HPen
M3
G
R
1.4
2.8
JPEG
93 bpm

Evaluation of RV dilation

Jardin
Chest 1997





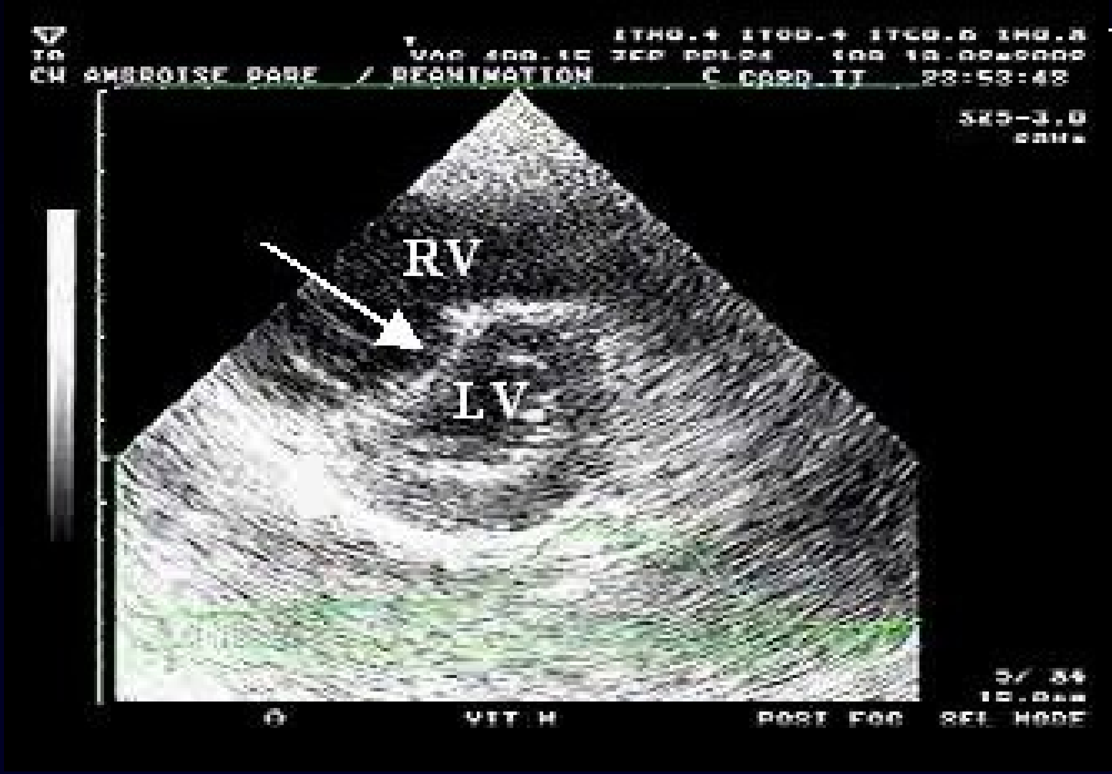
No dilation: RVTDA / LVTDA < 0.6

Moderate dilation : RVTDVA / LVTDA 0.6 - 1

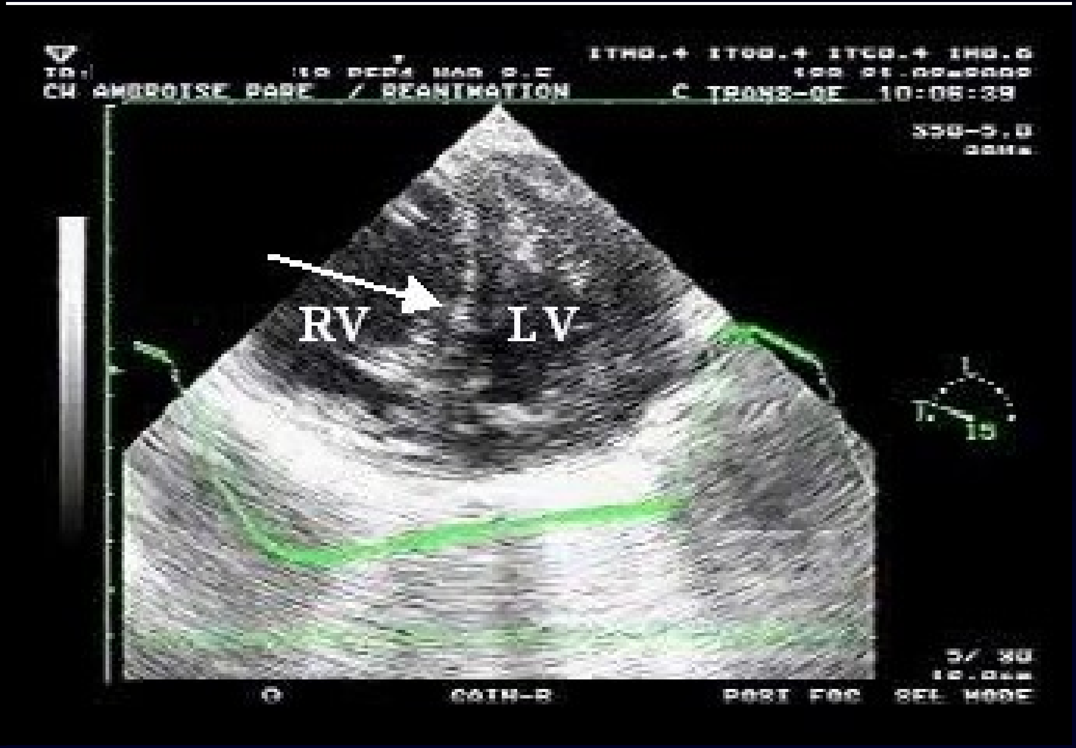
Major dilation: RVTDA / LVTDA > 1

Paradoxical septal movement

TTE

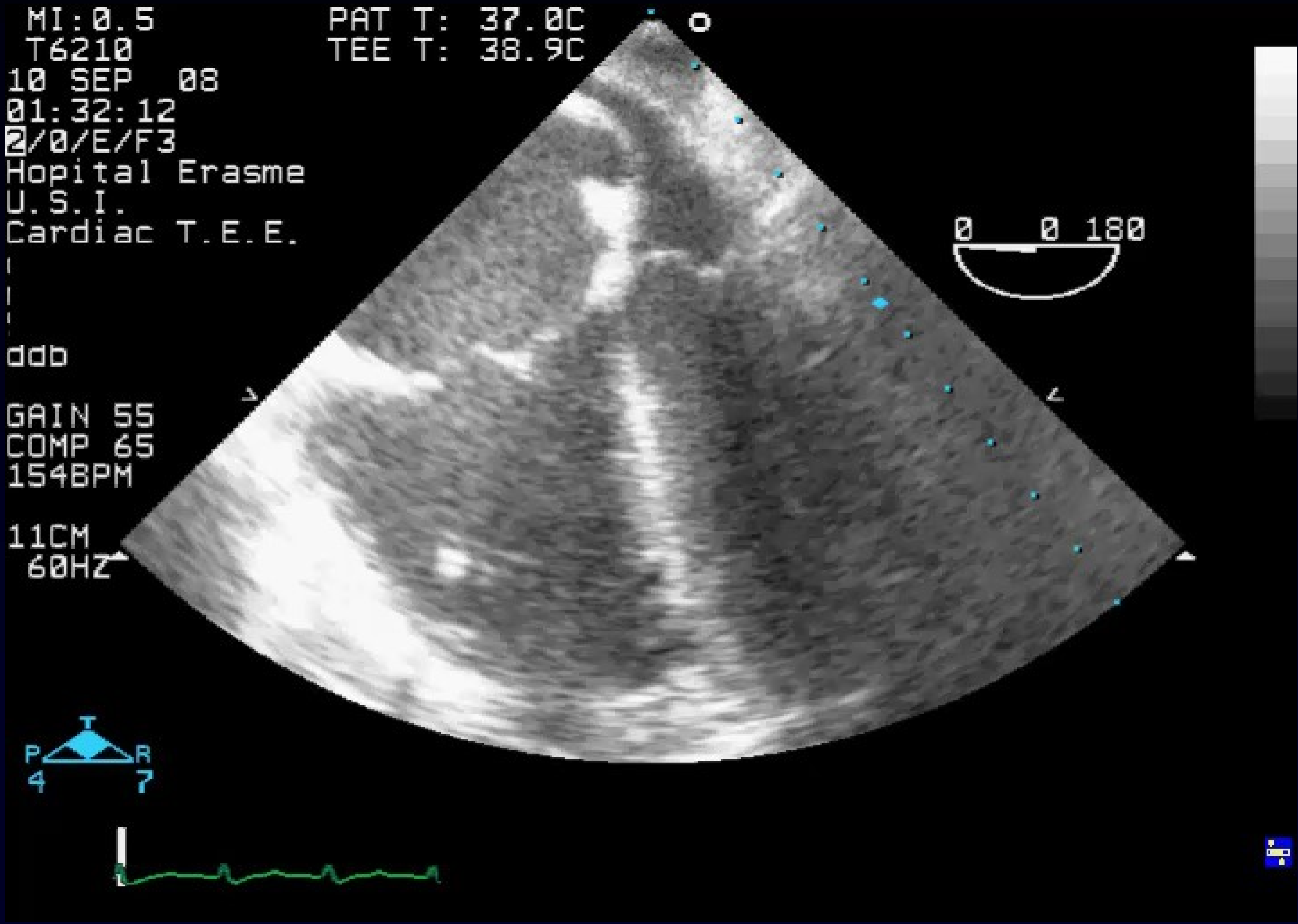


TEE



Kaplan A et al
Hemodynamic monitoring using echocardiography in the critically ill
Eds: De Backer et al
Springer 2011

Bulging of IV septum into LV during inspiration

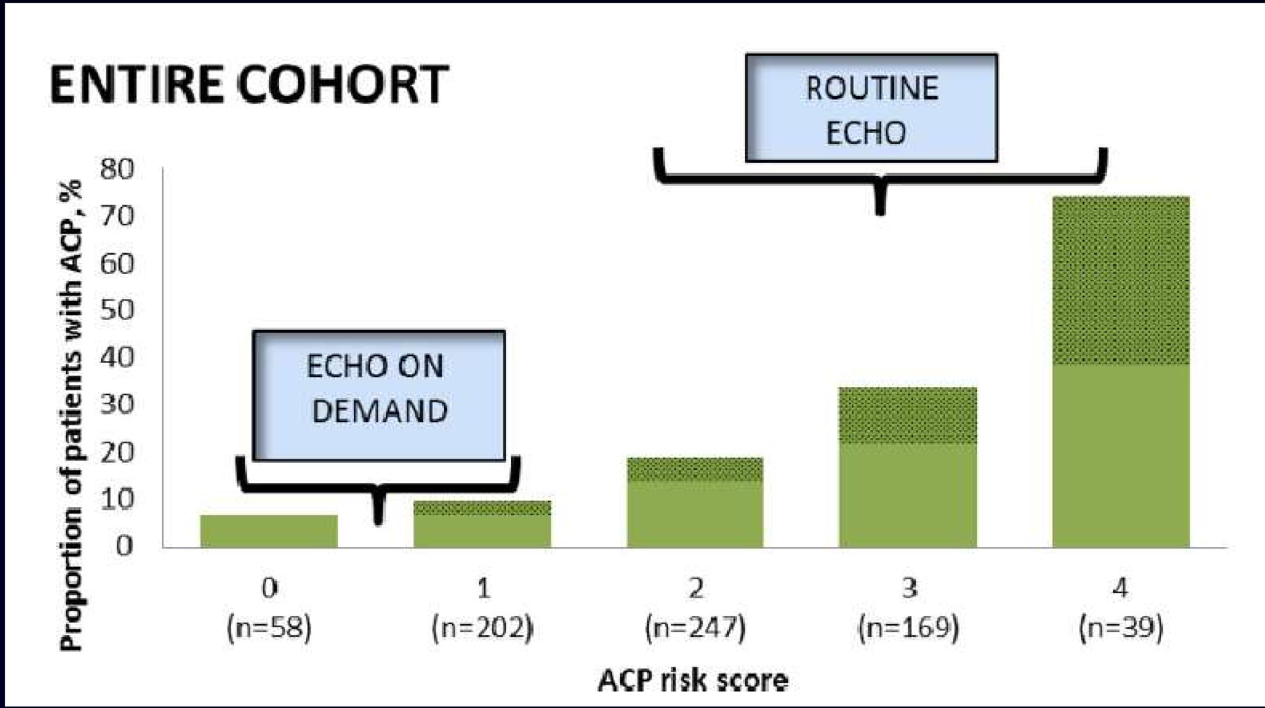


MI:0.5
T6210
10 SEP 08
01:32:12
2/0/E/F3
Hopital Erasme
U.S.I.
Cardiac T.E.E.
ddb
GAIN 55
COMP 65
154BPM
11CM
60HZ
PAT T: 37.0C
TEE T: 38.9C
0 0 180
P
R
4
7

ACP in ARDS: incidence and risk factors

Menkontso-Dessap A et al
ICM 2016

Parameter	Score
Pneumonia as cause of ARDS	1
Driving pressure $\geq$18 cmH_2O[a]	1
PaO_2/FiO_2 ratio <150 mmHg	1
$PaCO_2$ $\geq$48 mmHg	1
Total score	0–4



<5% 8% 15% 33% 75%

N= 752

Caution
(fluids/ventilation

RV dysfunction

- RV dilation / loss of triangular shape
- flattening of IV septum
- stroke volume usually preserved

RV failure (acute cor pulon

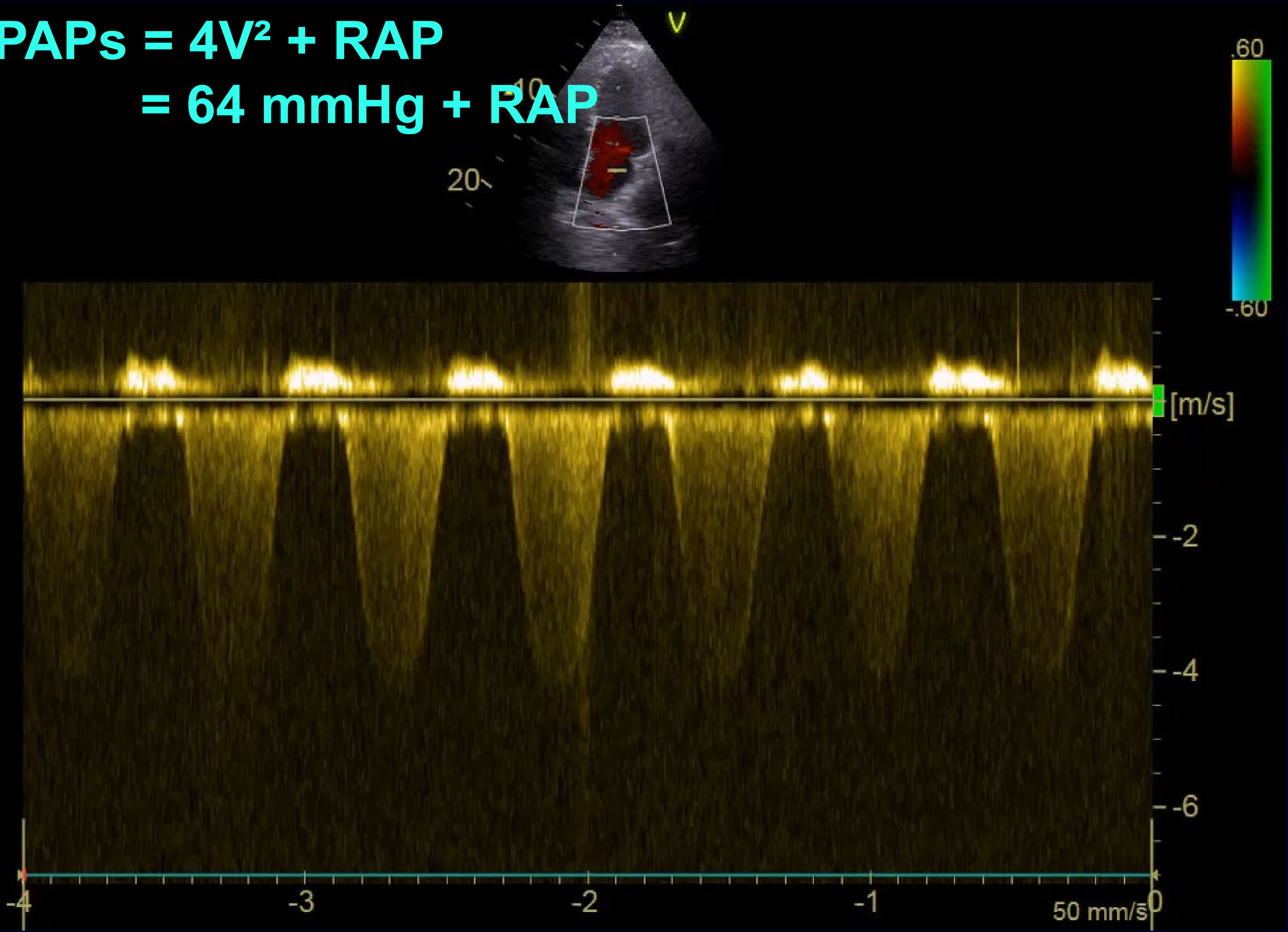
- RV dilation
- paradoxical septal move
- decreased stroke volum

Action needed
uid removal/ventilation/Prone…)

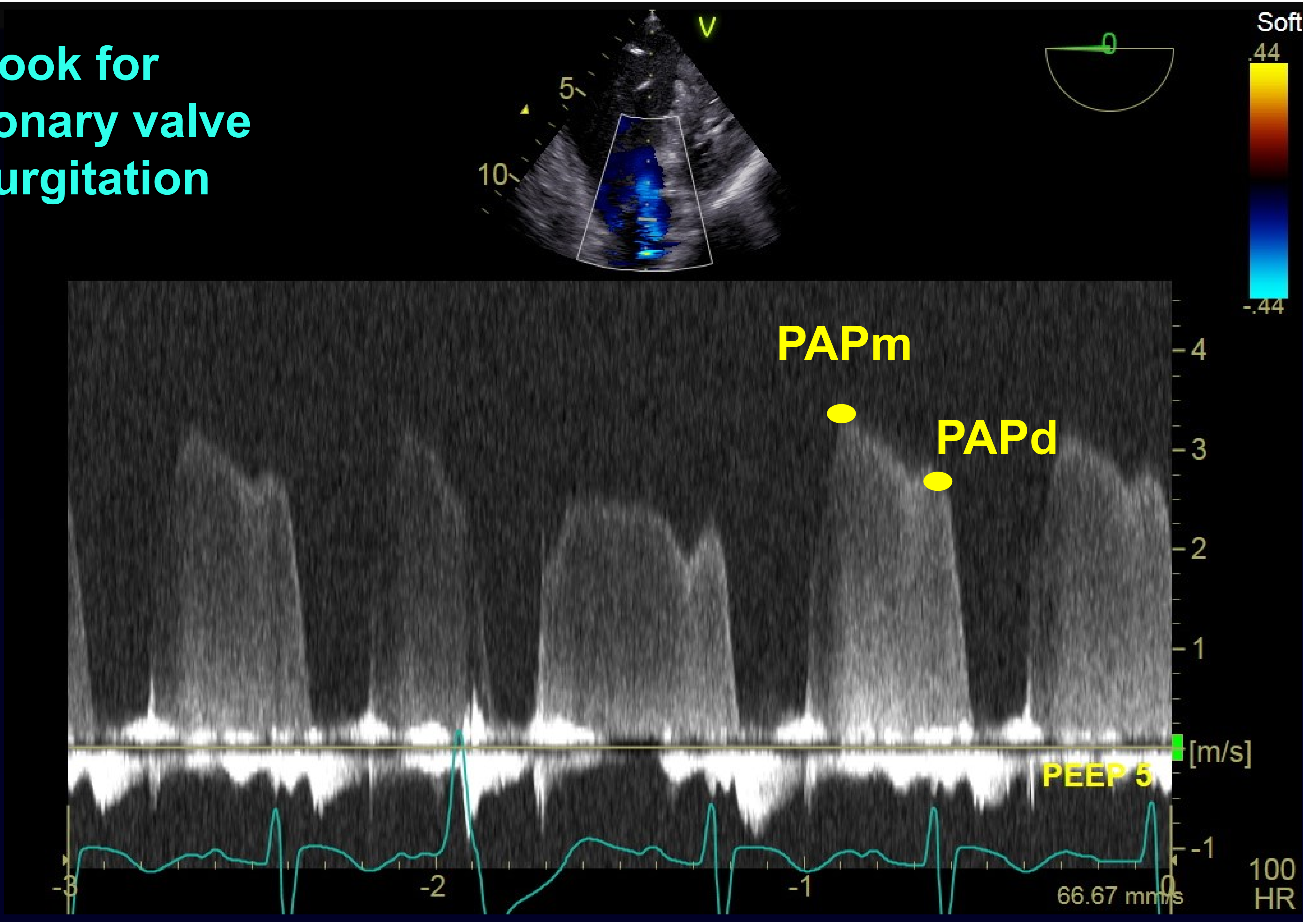
Echocardiographic evaluation of RV is not solely looking at the RV….

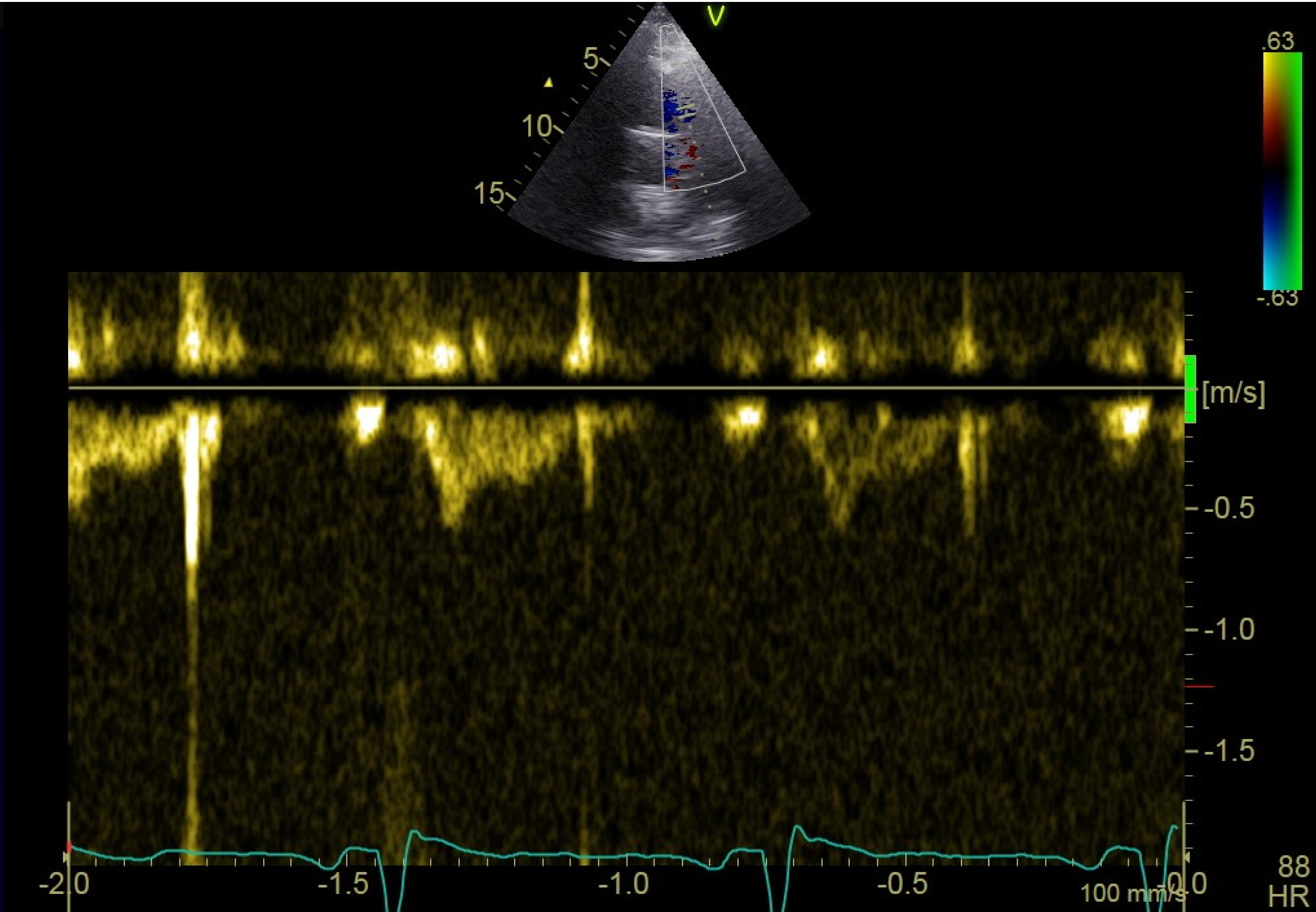
PAPs = $4V^2$ + RAP

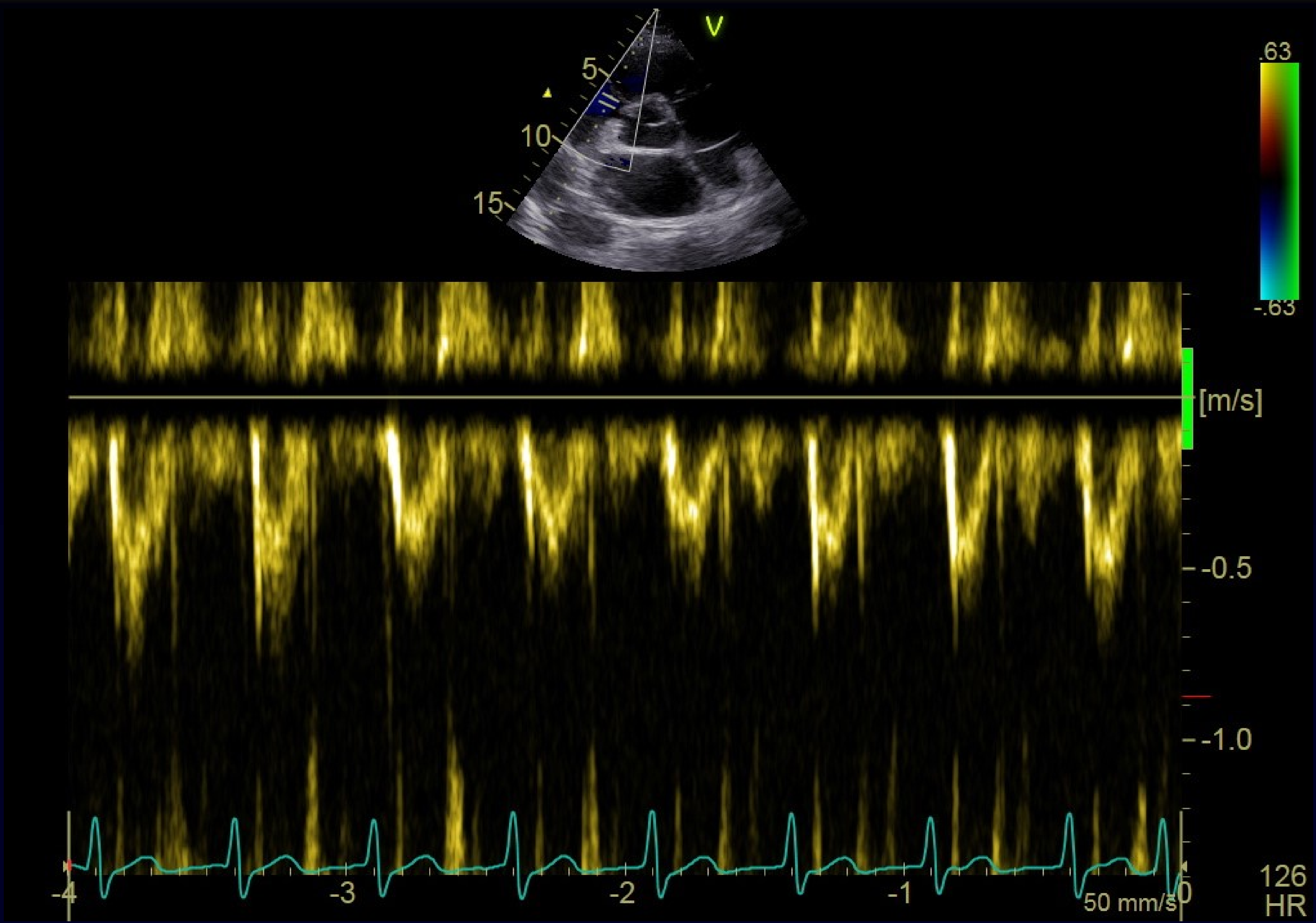
= 64 mmHg + RAP



Look for
lmonary valve
egurgitation




5
10
15
V
.63
-.63
[m/s]
-0.5
-1.0
-1.5
-2.0
-1.5
-1.0
-0.5
0.0
100 mm/s
88
HR


V
.63
-.63
5
10
15
[m/s]
-0.5
-1.0
-4
-3
-2
-1
0
50 mm/s
126
HR

How to evaluate RV function with echo ?

RV

- Dimension
- Shape (D shape)
- IV septum
- Tricuspid annulus
  - TAPSE
  - S wave
- Strain rate

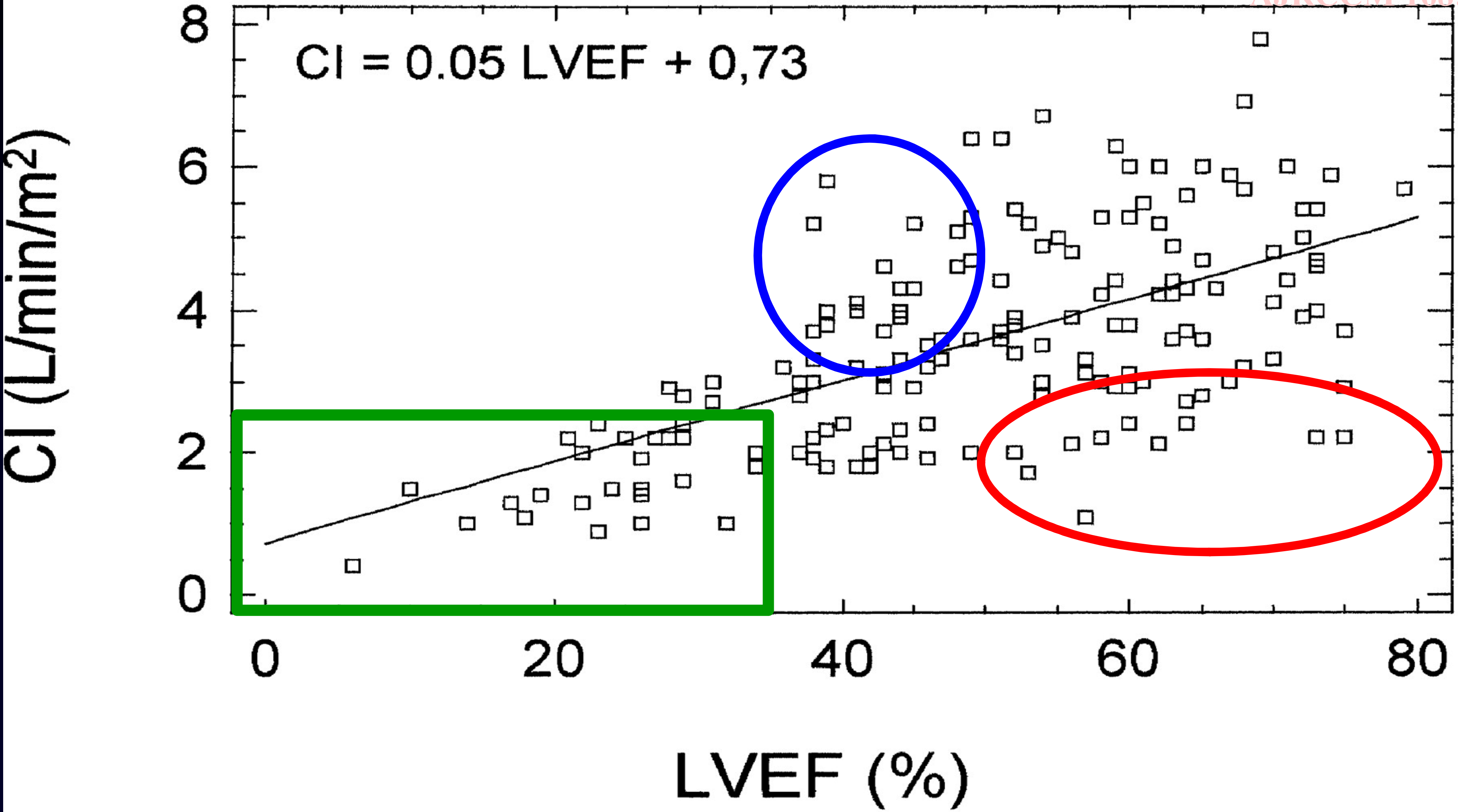
PA

- Clots
- PA pressure from
  - Tricuspid regurgitation
  - Pulm V regurgitation
- PA acceleration time
- PA flow morphology

ECHO GUIDED HEMODYNAMIC MANAGEMENT IN SEPTIC SHOCK

easuring LV EF or CI alone can be misleading

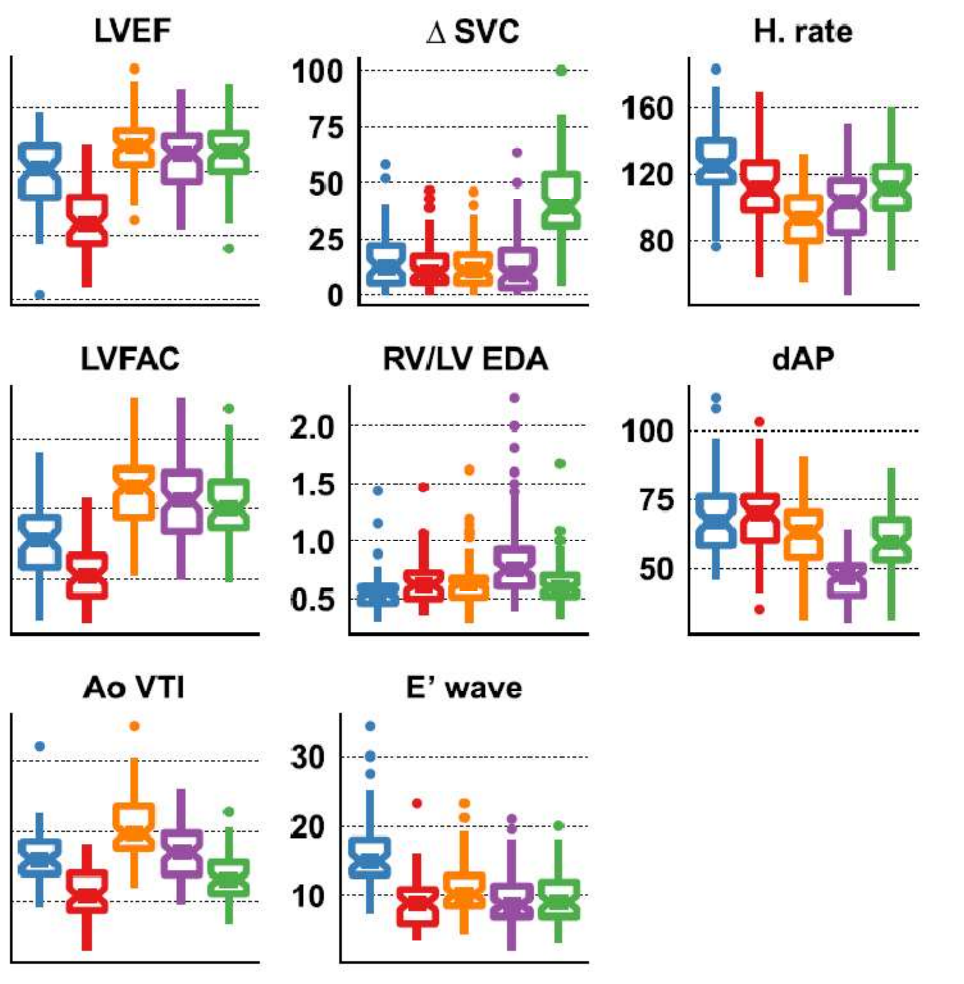
Vieillard-Baron et al
AJRCCM 168:1270;2



tients with septic shock

rdiovascular clusters in septic shock mbining clinical and echocardiographic rameters: a post hoc analysis

Geri G et al
ICM 2019



360

- **Well resuscitated 61(17%)**
- **LV systolic dysf 64**
  LVEF <40% & Ao VTI <14cm & LVFAC <33%
- **Hyperkinetic 84(23%)**
  Ao VTI >20cm & Heart rate <106bpm & LVFAC >58%
- **RV failure 81(23%)**
  RV/LV EDA >0.8 & sABP <100mmHg & dABP <51mmHg
- **Still hypovolemic 70(19%)**
  Ao VTI < 16 cm & E wave < 67 cm/s & SVC > 39 %

De Backer D et al Crit Ca

ERAPEUTIC APPROACH

Cardiac output

CRT / Lactate / ScvO2 / Pv

Cardiac output → Inadequate

Cardiac output → Adapted

Inadequate → Preload dependency → Volume

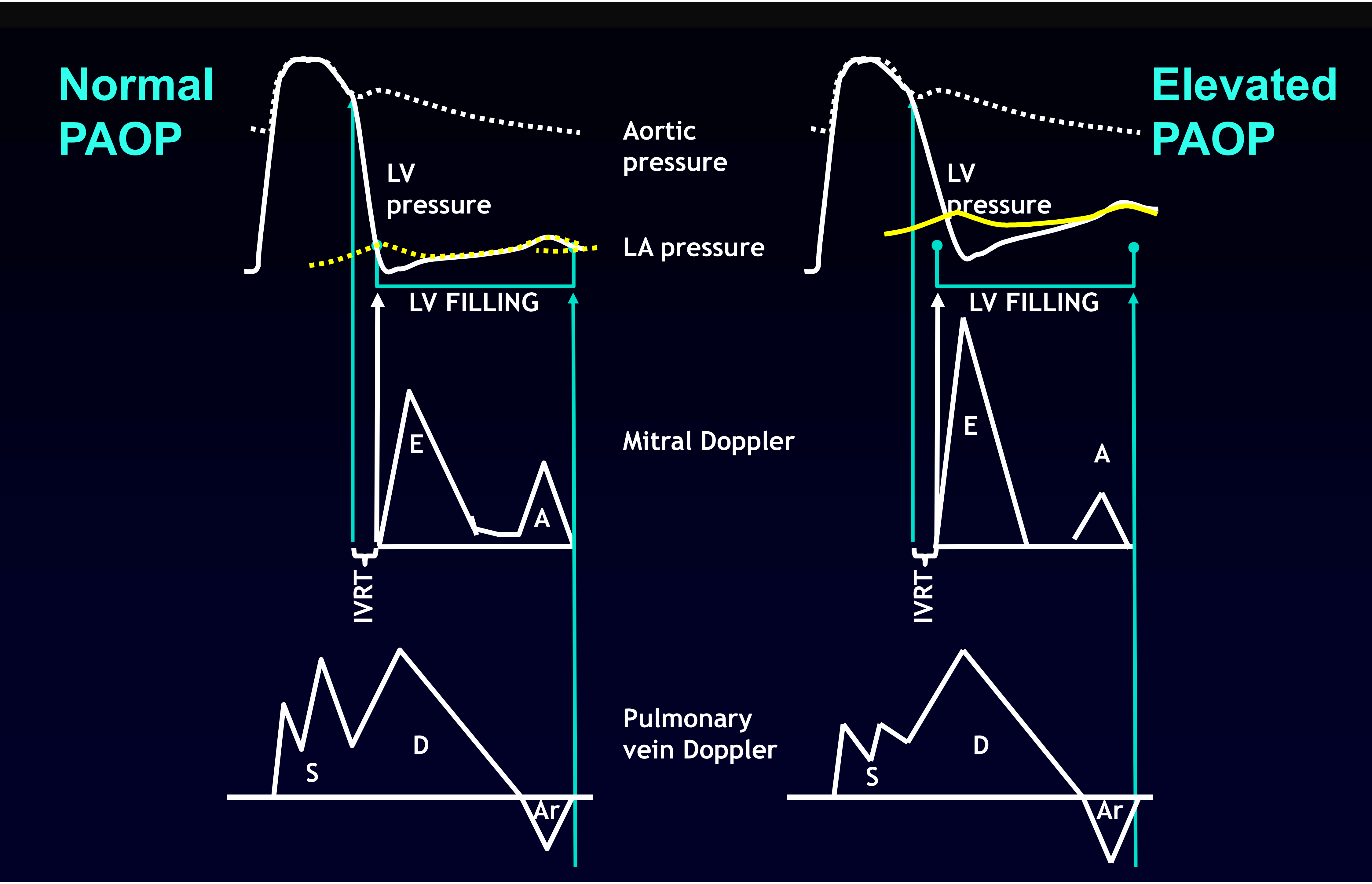
Preload dependency → LVOT obstruction → Volume ± ↓ inotropes and vasopres

LVOT obstruction → LV dysfunction → inotropes

LV dysfunction → RV function → Adjust ventilator ± iNO ± restrict flu

DIAGNOSIS IN RESPIRATORY FAILURE

Hydrostatic versus non hydrostatic cause of pulmonary edema ?



Normal PAOP
Elevated PAOP
LV pressure
Aortic pressure
LA pressure
LV FILLING
E
A
IVRT
Mitral Doppler
S
D
Ar
Pulmonary vein Doppler

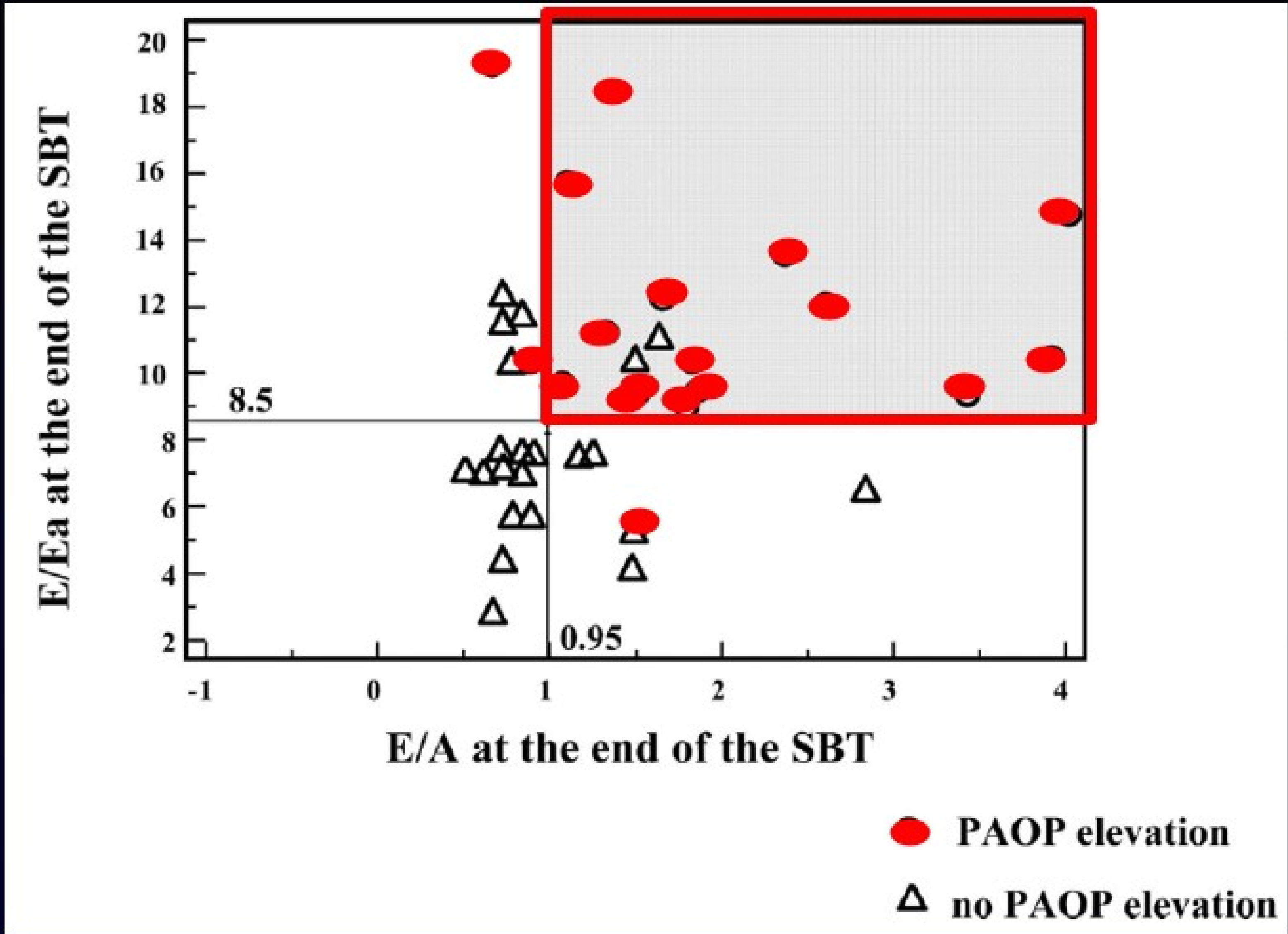
OP and EVLW B-lines provide different information

PAOP reflects the current
ydrostatic pressure (i.e.
iving force contributing to
pulmonary edema)

- EVLW B-lines reflect the extend
of water flooding in the lungs,
independently of its origin.

9 pts failed SBT

Lamia B et al
CCM 27:1696



E/A> 0.95 + E/Ea >8.5 predict elevated PAOP
(Se 82% and Sp 91%)

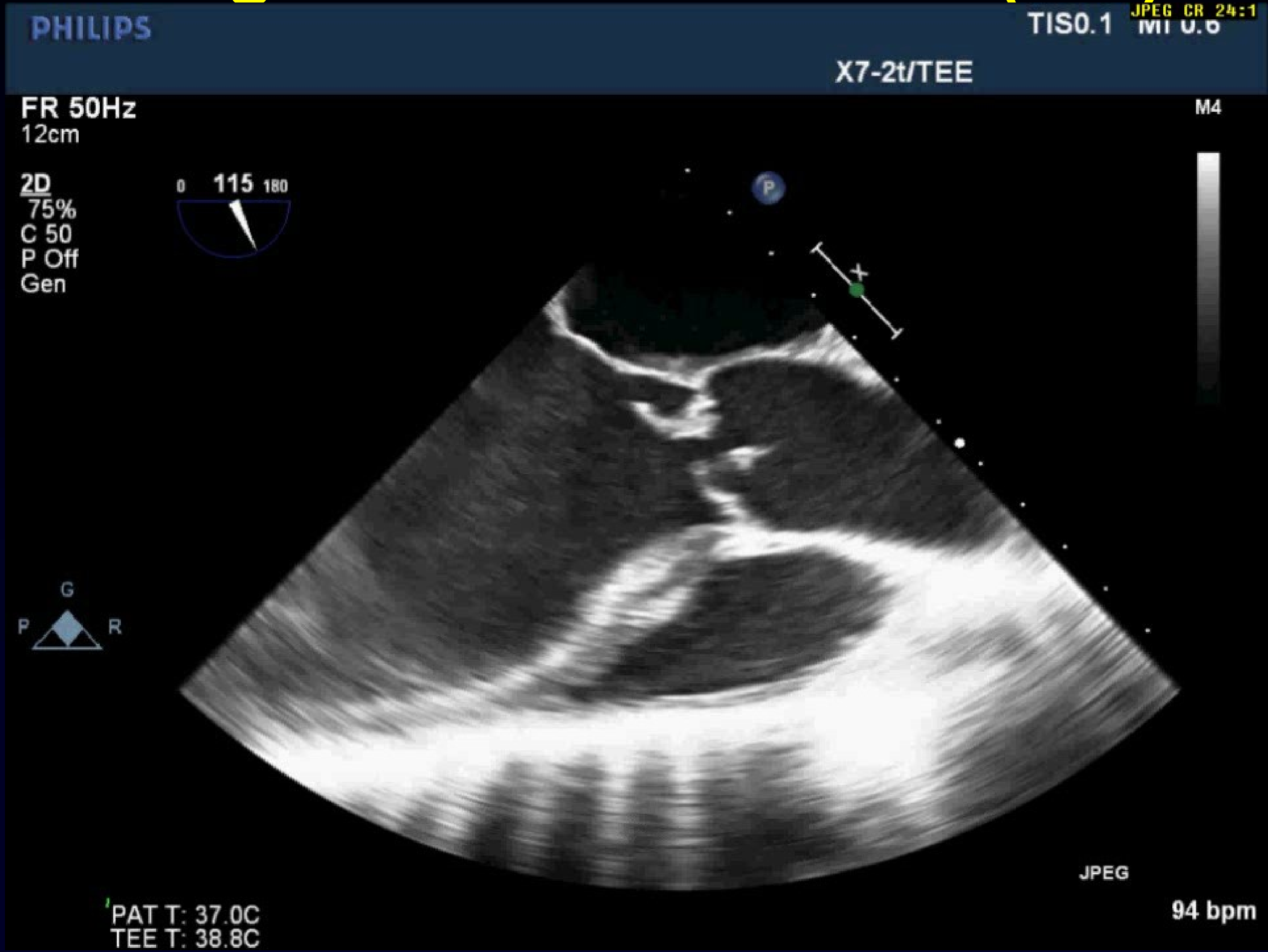
Critical care echocardiography

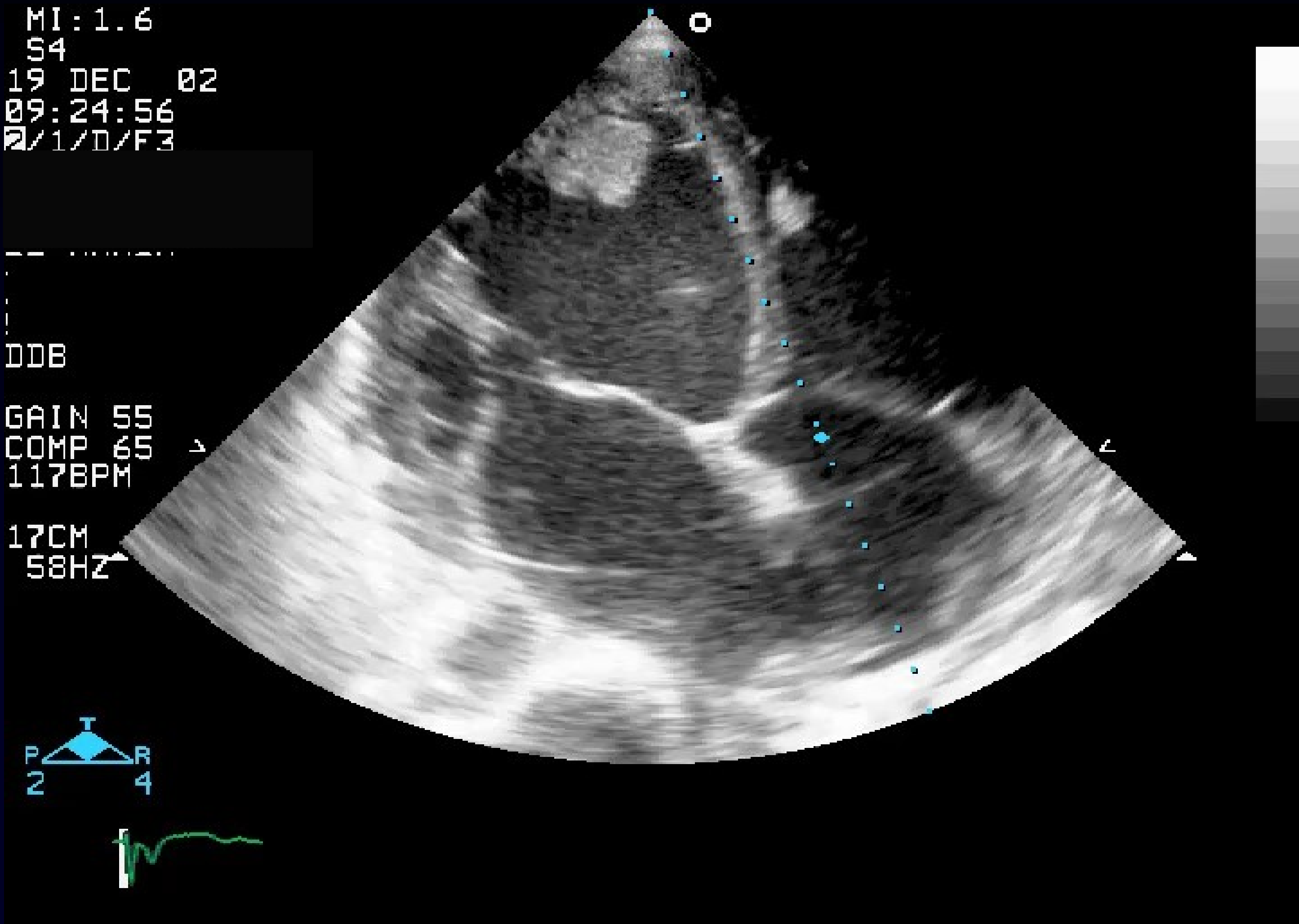
1- Focused evaluation

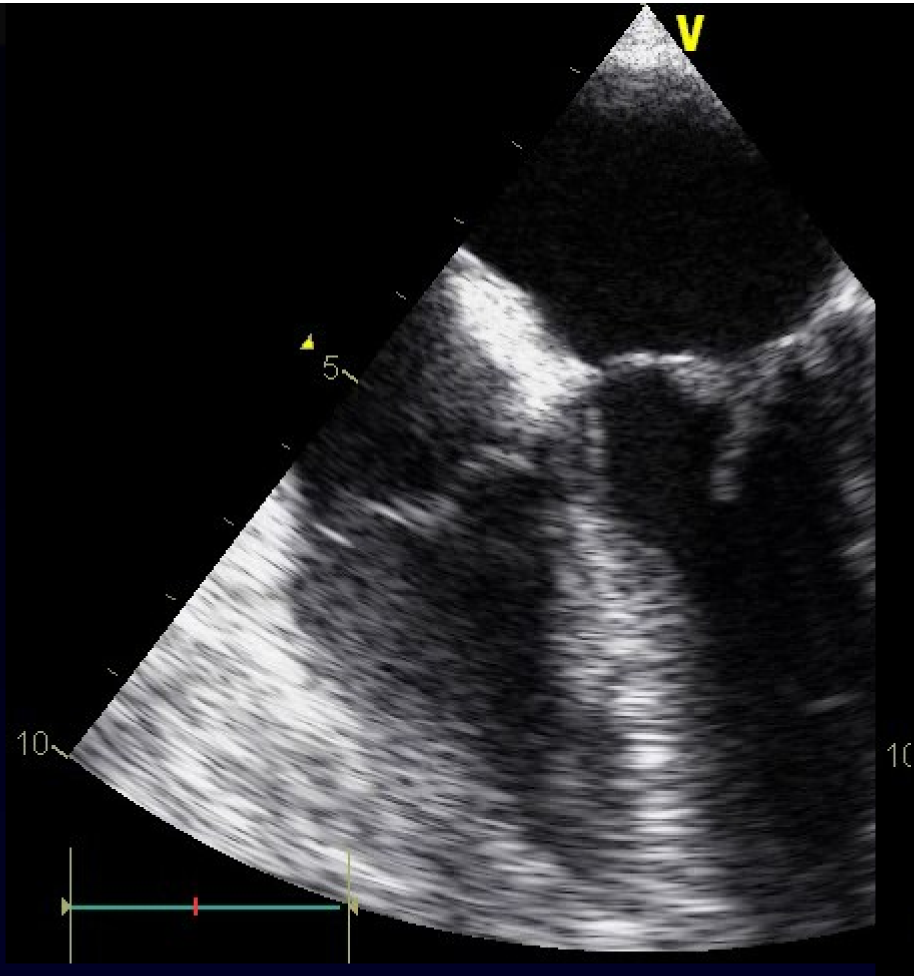
2- Full hemodynamic evaluation

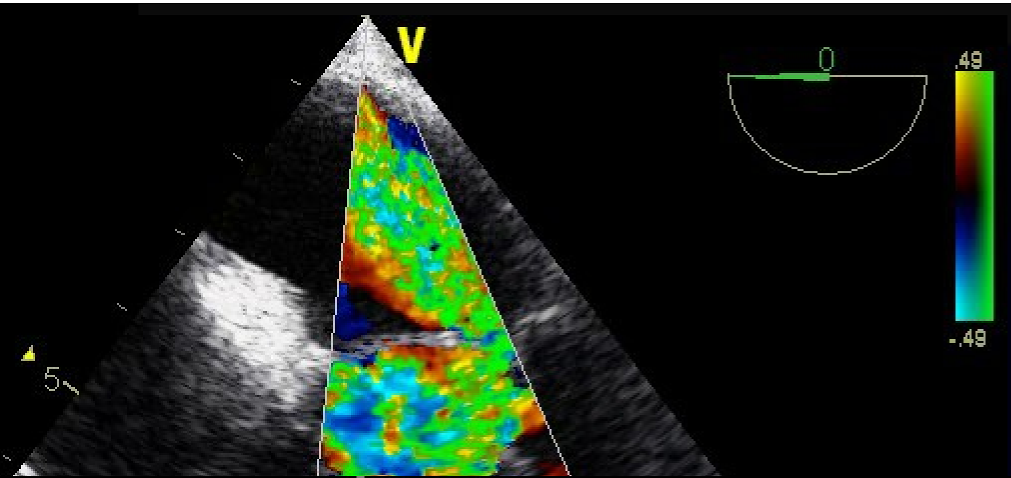
3- Specific patterns

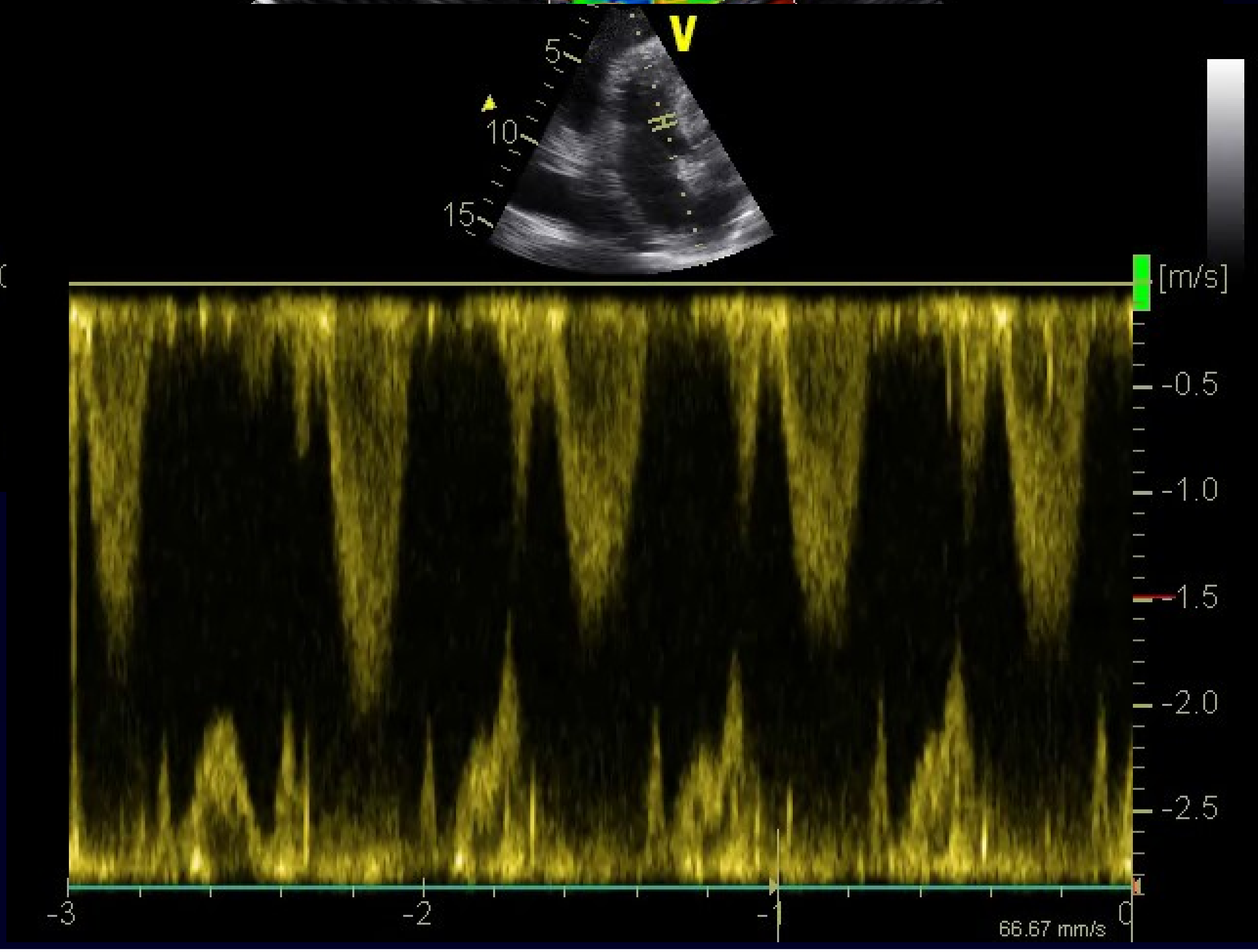
Long axis view LV 120° (ME)




MI:1.6
S4
19 DEC 02
09:24:56
2/1/D/F3
[redacted]
DDB
GAIN 55
COMP 65
117BPM
17CM
58HZ
P R
2 4







T FORGET TO IDENTIFY
ECIFIC PATTERNS !

/hat should be measured / estimated ?

Beginners

- Pericardial effusion
- RV/LV size
- LV function
- Preload responsiveness (Ao flow or SVC or IVC)

- VTIao
- PAPs (tricuspid regurgitation)
- PA flow
- E/A and E/Ea

- Aorta
- Morphology (regional hypokinesia, valve disease, PFO)


Thank you
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