Pravostranné selhání v intenzivní péči

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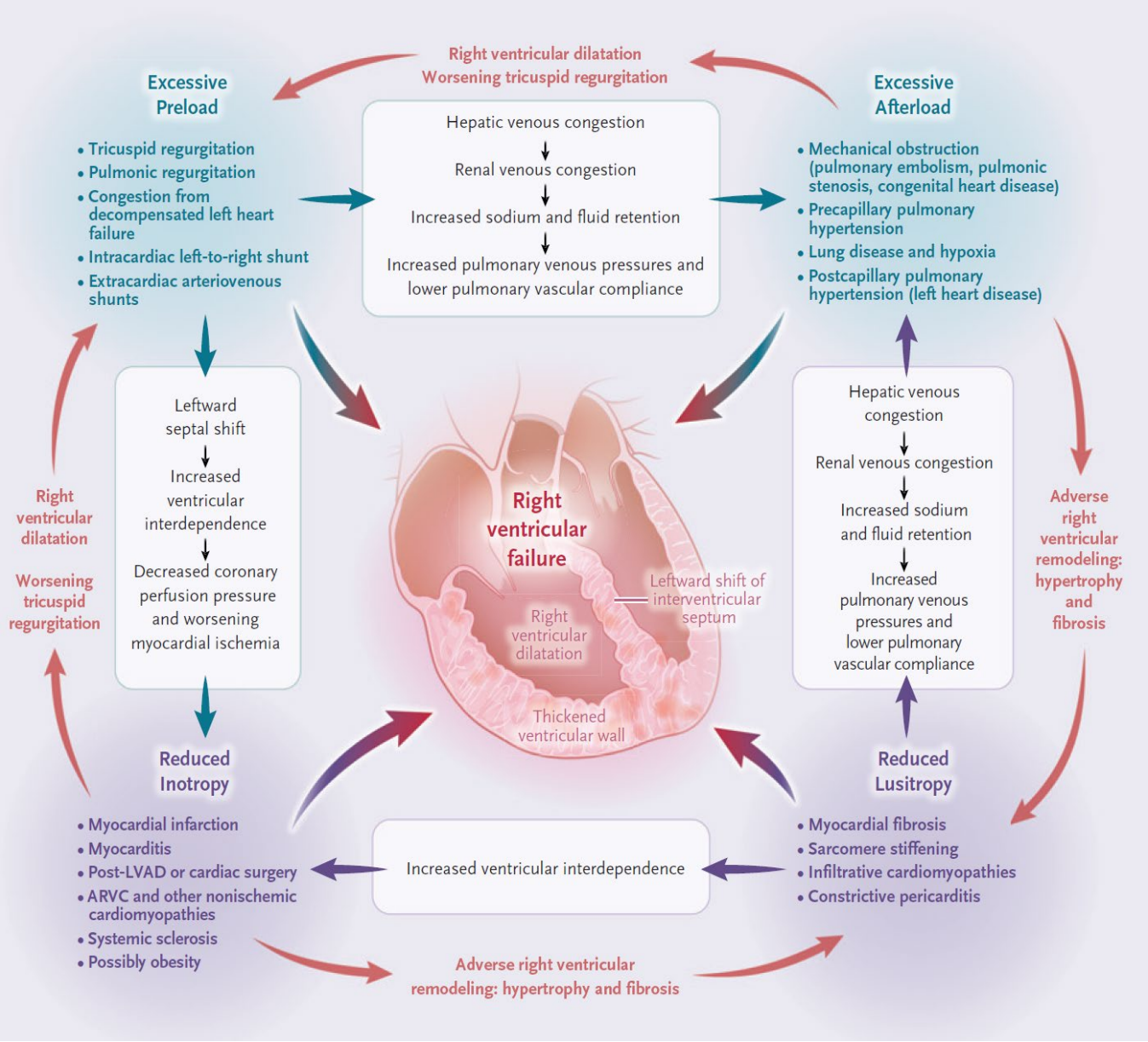
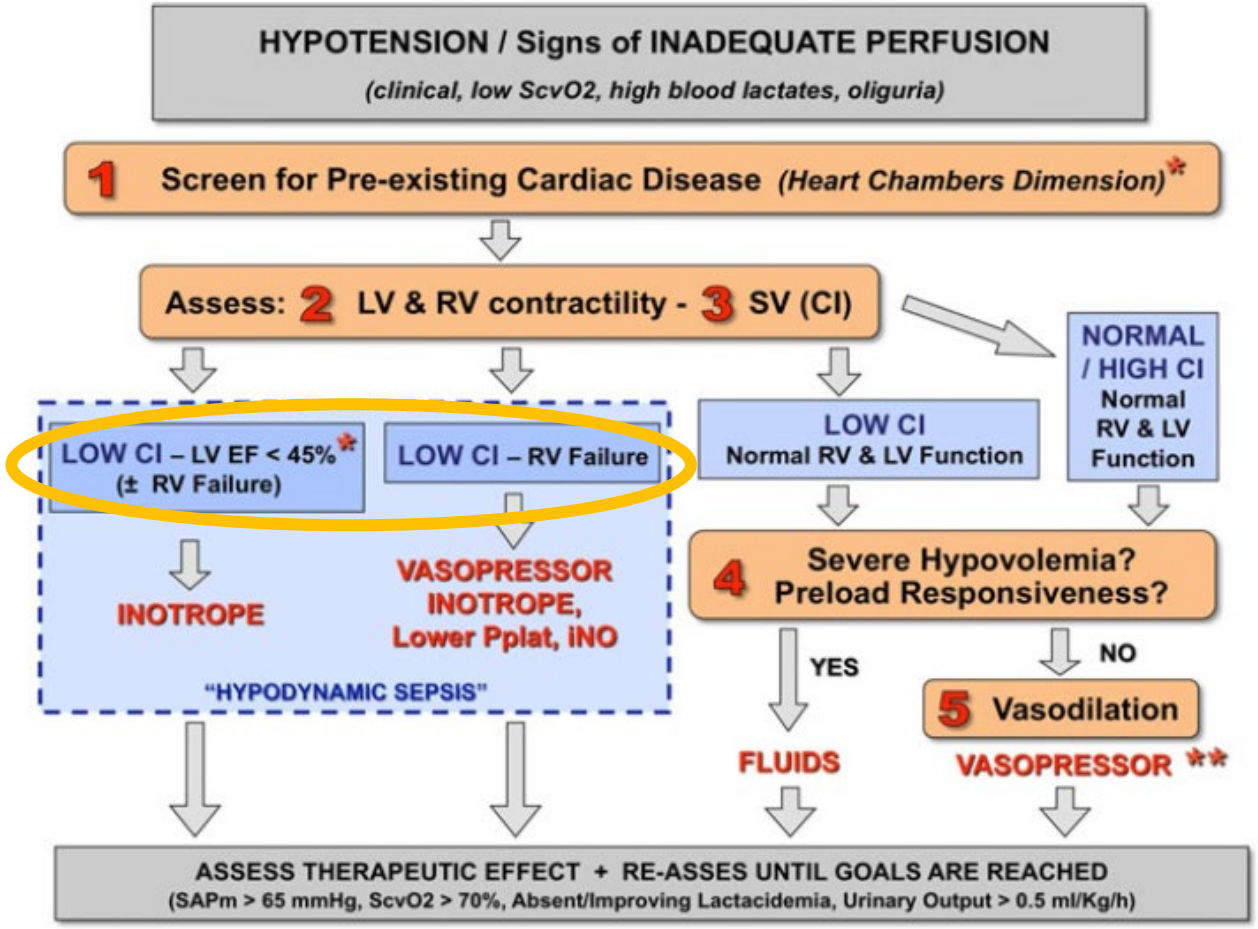
RV physiology



- Lower O_2 requirement than the LV - less myocardial mass
- Perfusion via 2/3 RCA, 1/3 LCA
- RV perfused in both systolic and diastolic phases (unlike LV)
- Wraps around LV
- 25% of contraction generated by LV

N Engl J Med 2023;388:1111-25.
DOI: 10.1056/NEJMra2207410

RV is sensitive to preload changes over time



- Manifests during haemodynamic instability due to other causes (IPPV, sepsis…)
- Risk of haemodynamic collapse during <u>rapid</u> volume expansion in preexisting RV dysfunction on IPPV
- SSC 30 ml/kg over 3h……?!

(Via G, Price S: Ultrasound J, 2011)

Importance of CVP (and pressure curve)

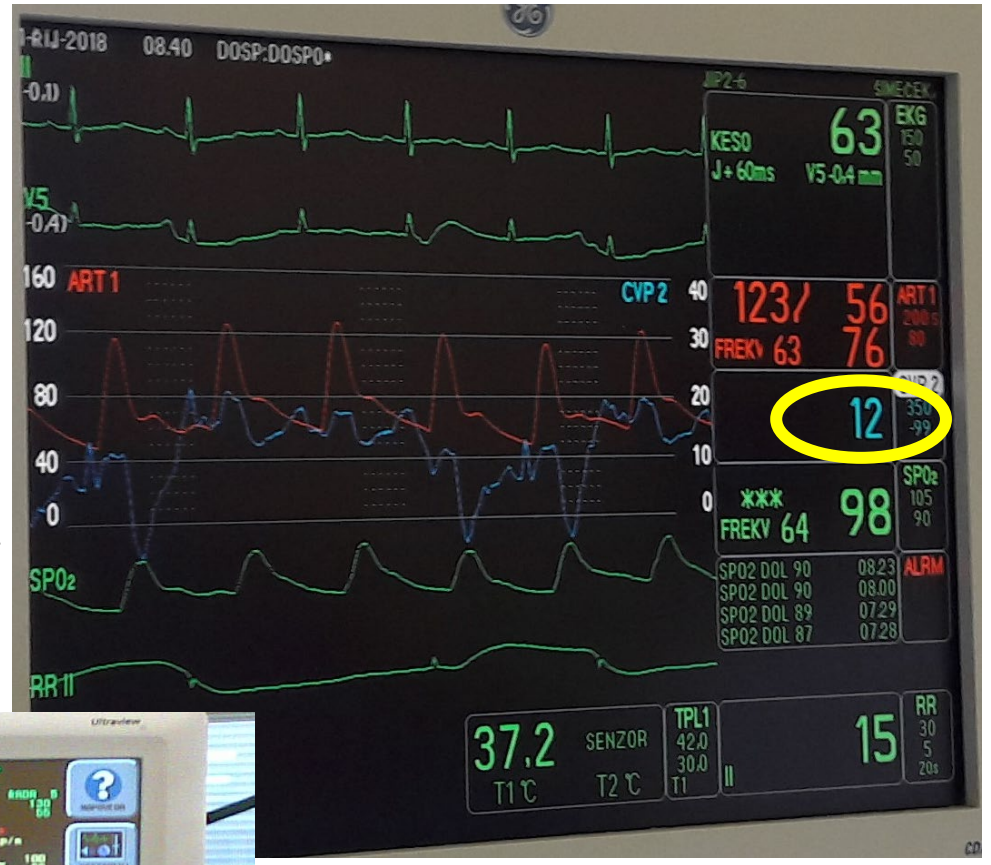
1.) Diagnosis of obstructive shock

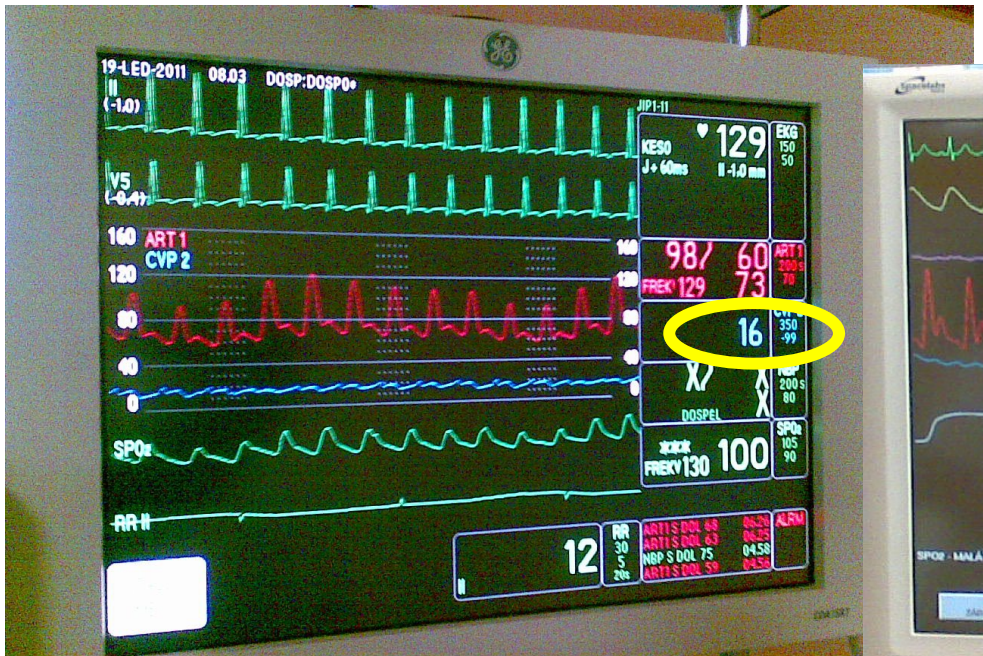
2.) **Right heart:**

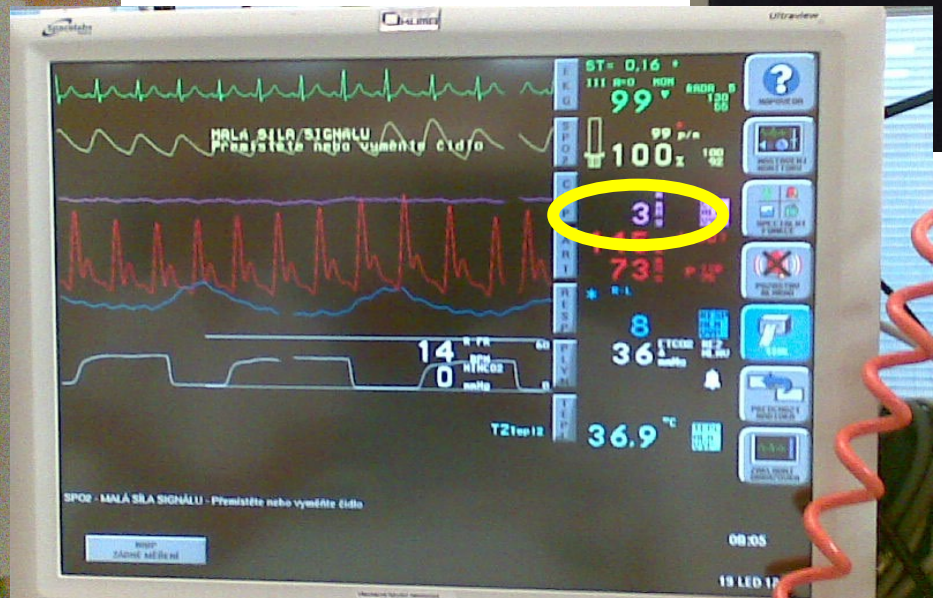
- **Significant TR**
- **RV function and response to fluids**

3.) Dynamic monitoring of fluid challenge

4.) $ScvO_2$, $cvpO_2$ ($cvpO_2$ correlates better with $cvpO_2$ than $ScvO_2$ and SvO_2 (Kazda A et al, 1998)







IVC diameter: RV and preload

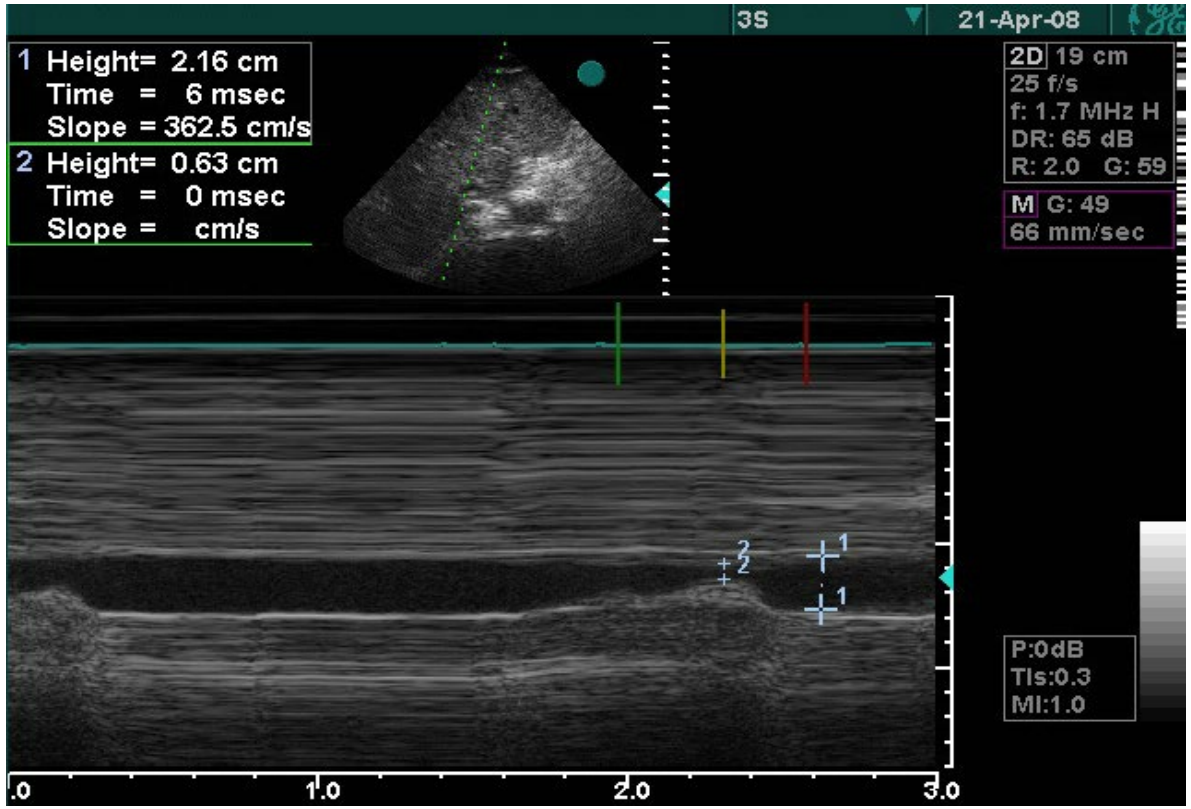


TABLE 33–3. Right Atrial Pressure Estimation from Inferior Vena Caval Diameter

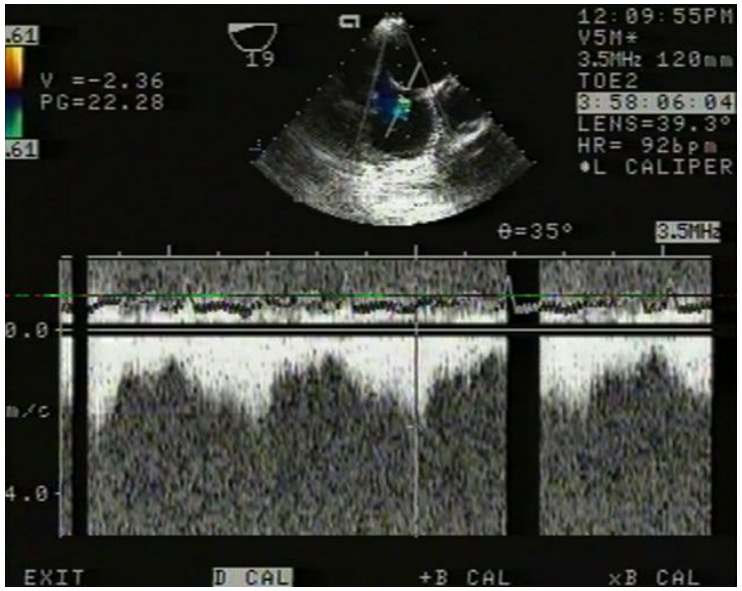
Inferior Vena Caval Diameter	Diameter Change with Inspiration	Right Atrial Pressure Estimate, mm Hg
Small (<1.5 cm)	Collapse	0–5
Normal (1.5 to 2.5 cm)	>50% decrease	5–10
Dilated (>2.5 cm)	<50% decrease	10–15
Dilated inferior vena cava and hepatic veins	No change	>20

Otto C: Practice of Clinical Echocardiography, 2012

IVC collapse of at least -13% in inspirium (mandatory IPPV)
predicts **PAvti response to volumexpansion** with 94% specificity
(Barbier C: Intensive Care Med 2004; 30: 1740-1746)

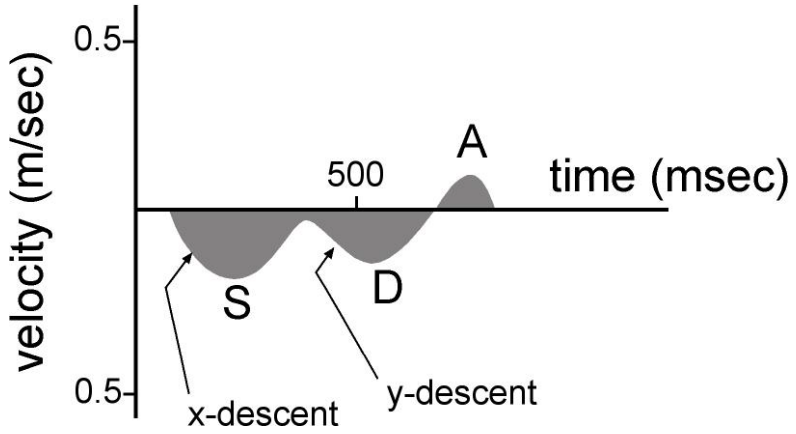
RV inflow: 2D

- **RA filling:** IVC and hepatic veins
  - dilatation – not dependent on ventilation modality
- **RA Pressure:** 2D a M mode IVC
- **RA size:** Up to 38 mm (28-53mm), RA area: <20cm^2
- **IA septum:** medial-RA, mid-systolic shift to LA, impact of respiratory cycle (IPPV)
  - Permanent bowing into RA implicates LAP>15 mmHg (Royse C, 1994 and 2014)
- **IA septal aneurysms/defects**
  - LA-RA
  - RV overload, PH, RVF

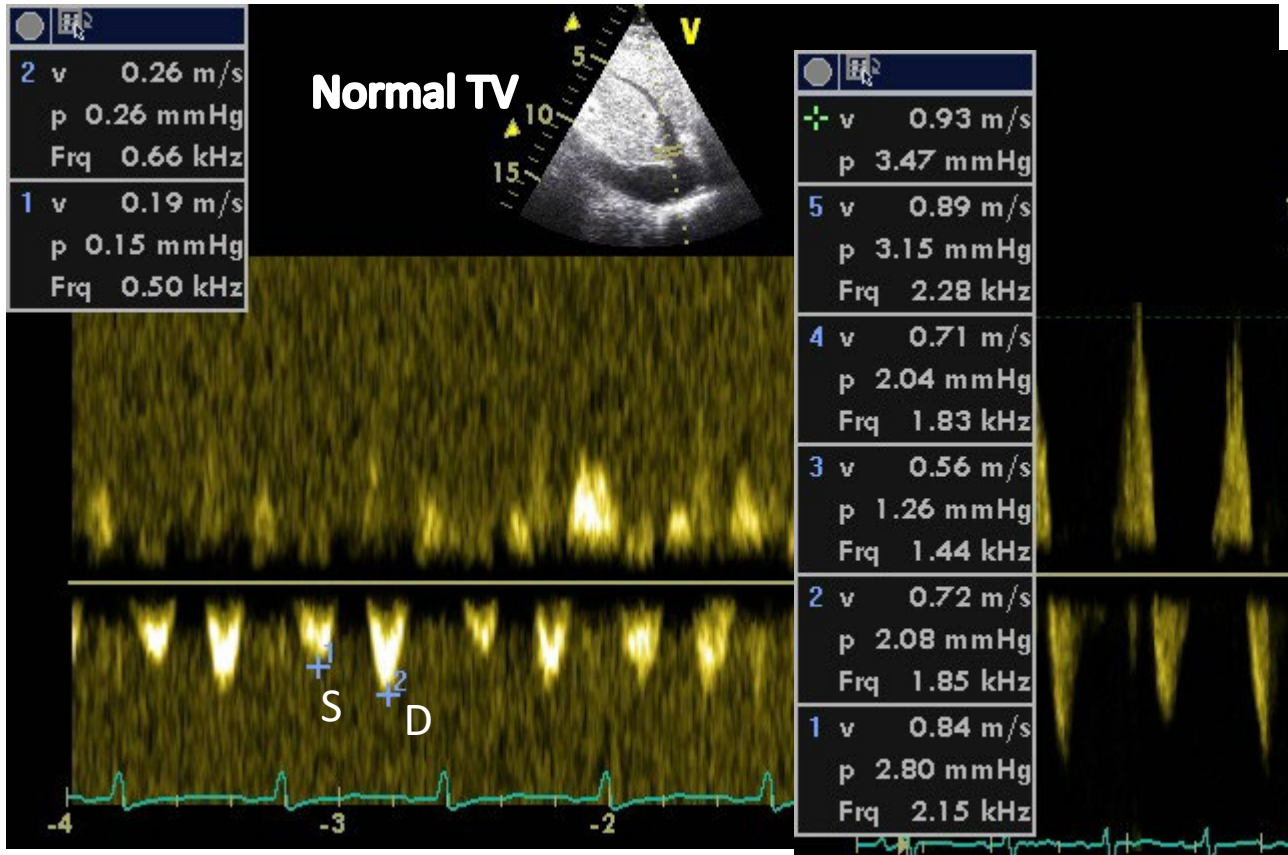


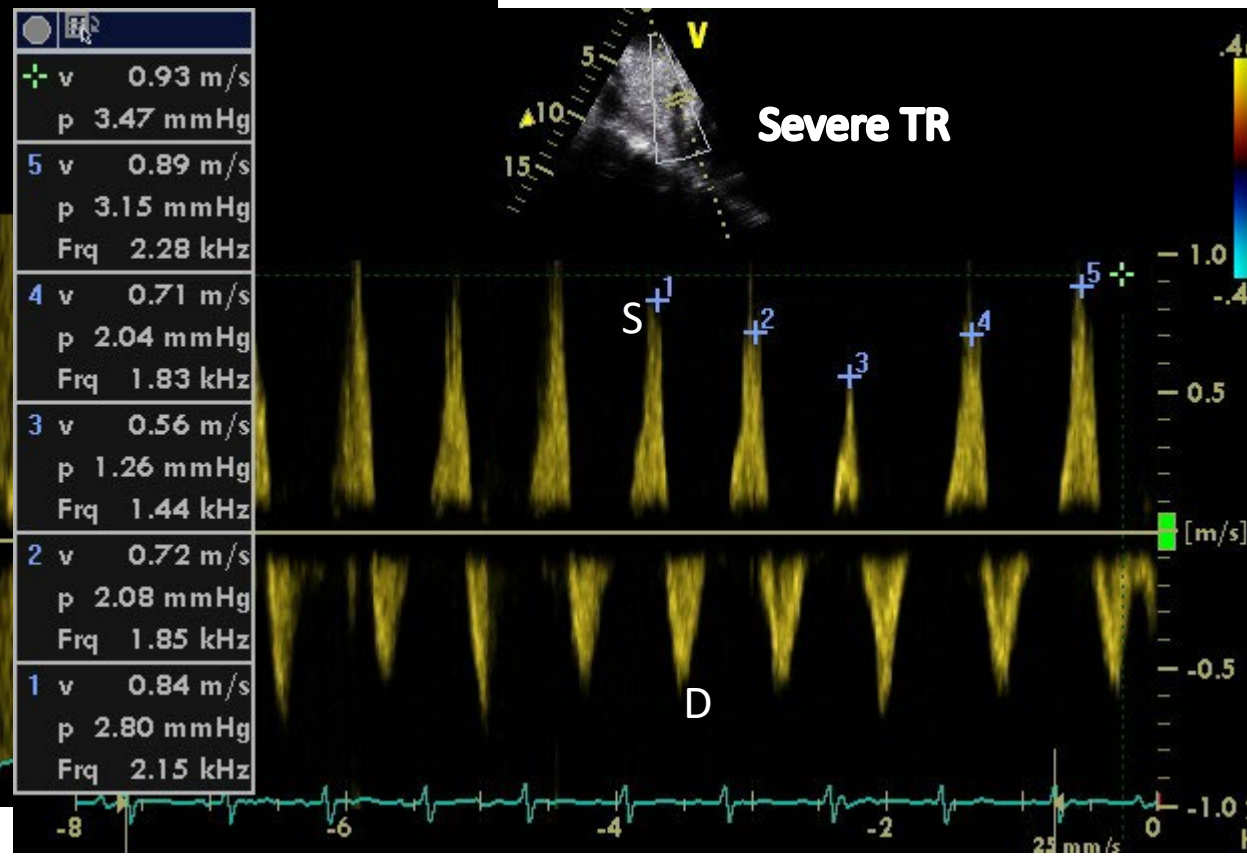
RV inflow: TR

- **Hepatic veins**
- S wave, D wave
- small reversal between them (TV annular recoil)
- A wave as systolic reversal in atrial systole (IV phase of diastole)

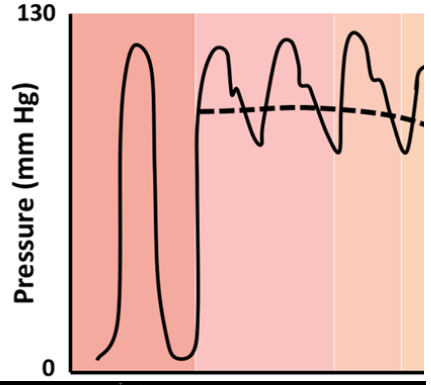


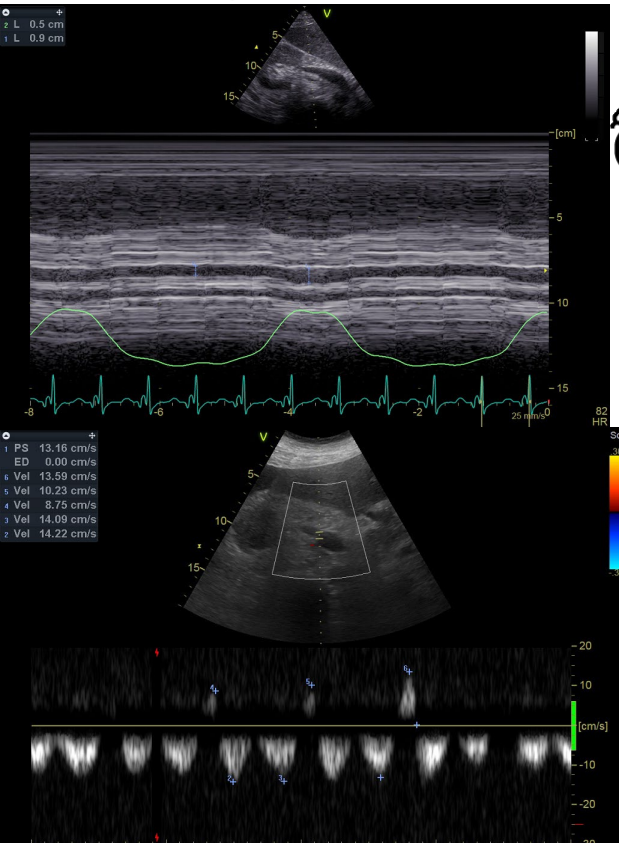
- Flattening or reversal of S wave
- Sig. reversal > 0.3-0.4 m/s
- In relation to severity of TR



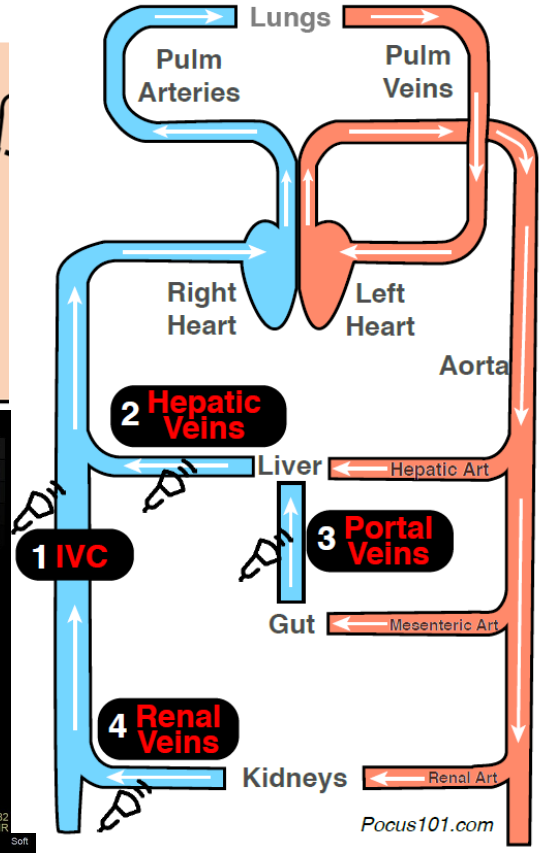


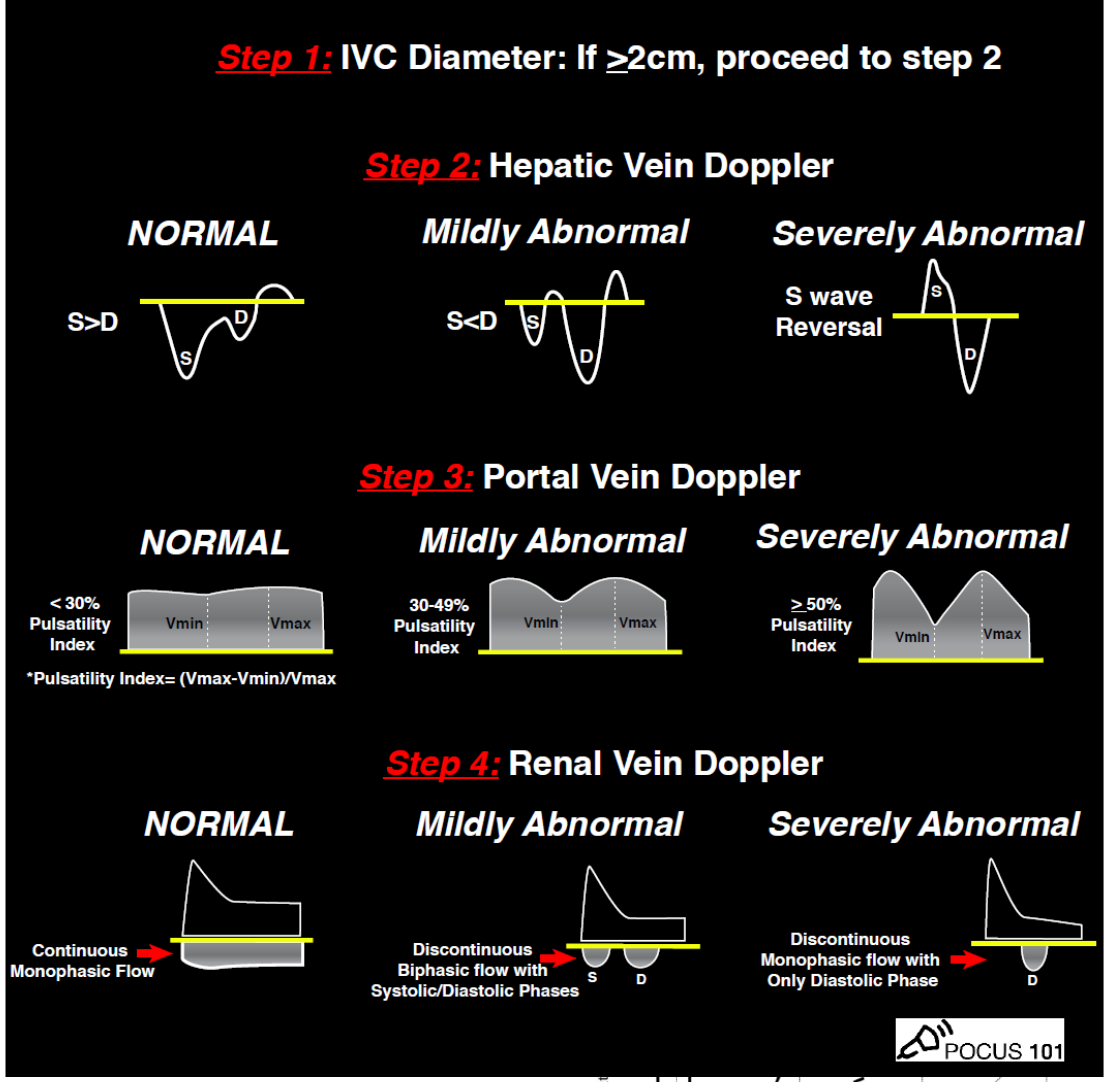
RV inflow: Ve





Venous Excess Ultrasound VExUS





Interpretation

Grade 0
(no congestion)
IVC < 2cm

Grade 1
(Mild congestion)
IVC ≥2cm and any combo of Normal or Mildly Abnl Patterns

Grade 2
(Moderate congestion)
IVC ≥2cm and ONE Severely Abnl Pattern

Grade 3
(Severe congestion)
IVC ≥2cm and ≥ 2 Severely Abnl Patterns

ic DO_2/VO_2

l

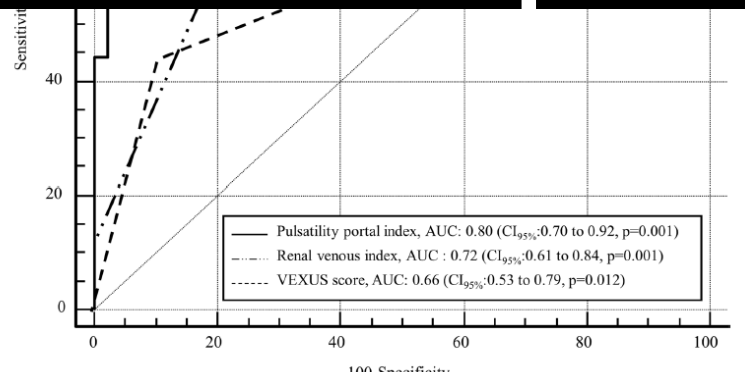
and PK/PD

Guinot et al. Critical Care (2022) 26:305
https://doi.org/10.1186/s13054-022-04180-0

Critical Care

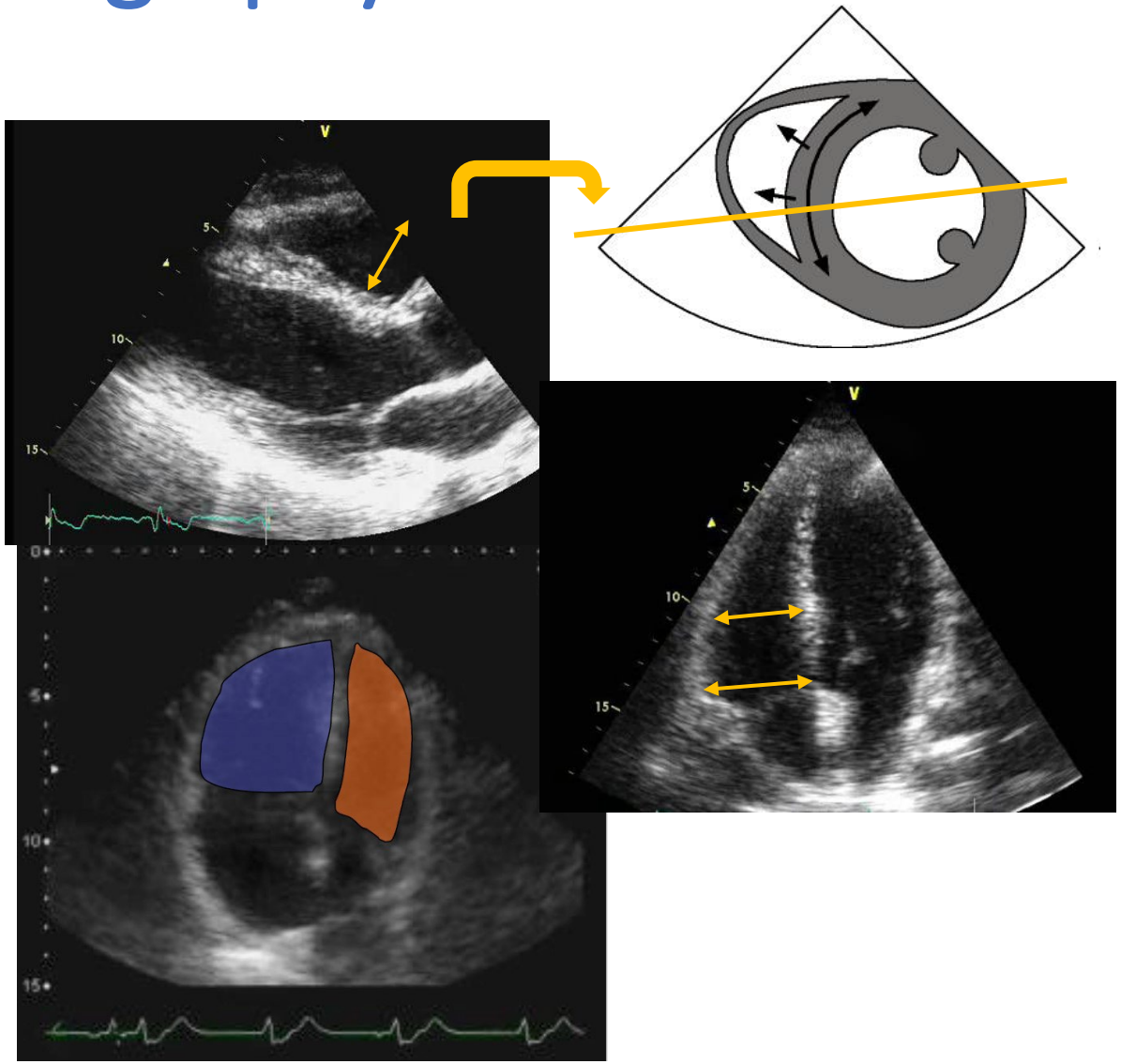
RESEARCH Open Access

Doppler study of portal vein and renal venous velocity predict the appropriate fluid response to diuretic in ICU: a prospective observational echocardiographic evaluation



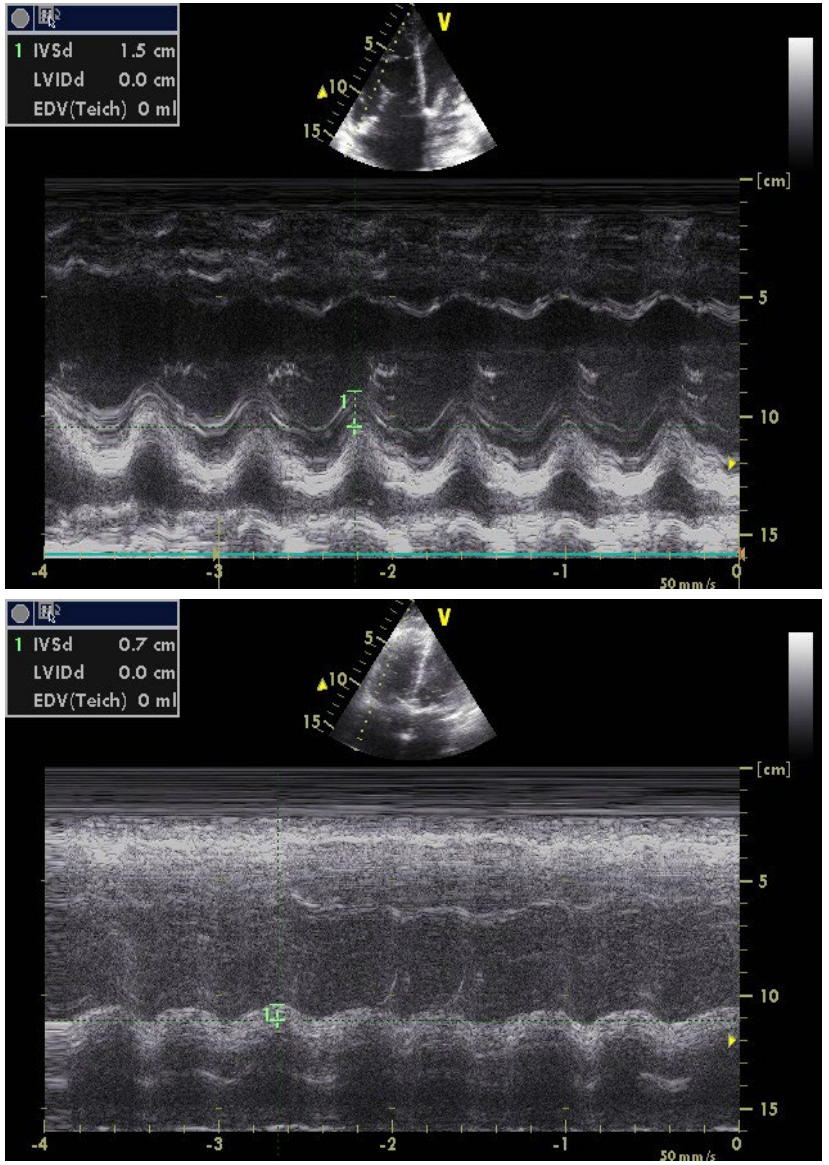
RV assessment by echocardiography

- Basal (tricuspid) and midventricular taken in A4C
- Parasternal RV inflow underestimates – foreshortening
- RV EDA / LV EDA < 0.6
- Moderate dilatation 0.6-1.0
- Severe > 1.0
- TV anulus closer to apex than mitral
- Contractility essentials
  - Apical kinetics (LV !)
  - Free wall contractility
  - Longitudinal contractility



RV outflow: contractility

- RV_EF: linear relationship to survival on IPPV
- RV_EF: impact on outcome in CHF with CAD
- RV function - prognosis in CHF on LVAD and HTx
- RV function - prognosis in chronic pulmonary disease (e.g. COPD in ICU care)
- RV function predicts exercise capacity (6min WT) and survival in PH
- RV contractile reserve - 1-year outcome in dilated cardiomyopathy



Circulation, 2008, EHJ 2005, Nature Reviews, Cardiology 2010

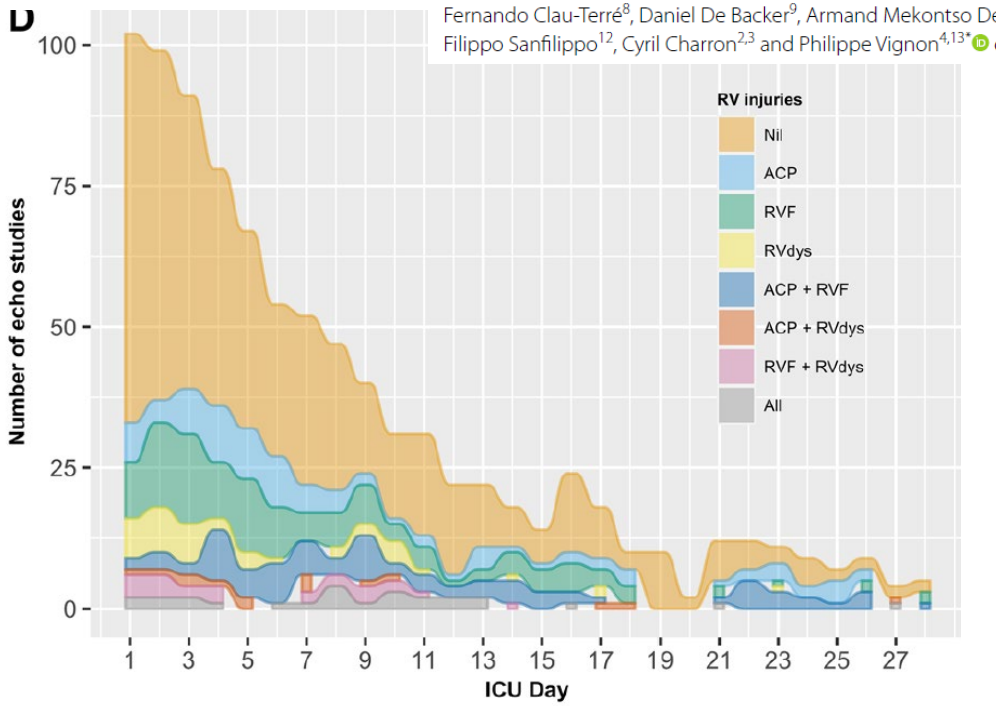
RV on IPPV and prognosis

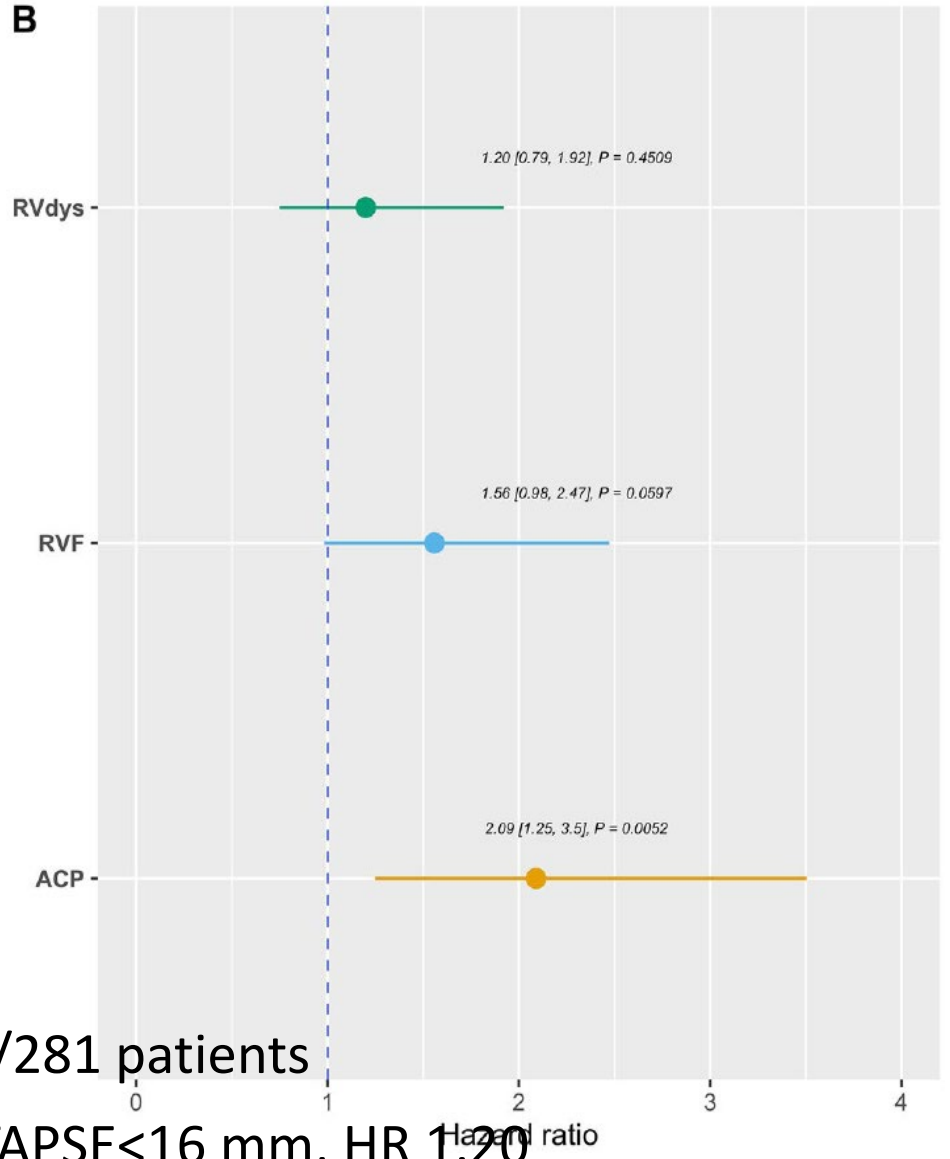
Intensive Care Med (2023) 49:946–956
https://doi.org/10.1007/s00134-023-07147-z

ORIGINAL

Echocardiography phenotypes of right ventricular involvement in COVID-19 ARDS patients and ICU mortality: post-hoc (exploratory) analysis of repeated data from the ECHO-COVID study

Stephen Huang[1], Antoine Vieillard-Baron[2,3], Bruno Evrard[4], Gwenaël Prat[5], Michelle S. Chew[6], Martin Balik[7], Fernando Clau-Terré[8], Daniel De Backer[9], Armand Mekontso Dessap[10], Sam Orde[1], Andrea Morelli[11], Filippo Sanfilippo[12], Cyril Charron[2,3] and Philippe Vignon[4,13*] on behalf of the ECHO-COVID study group

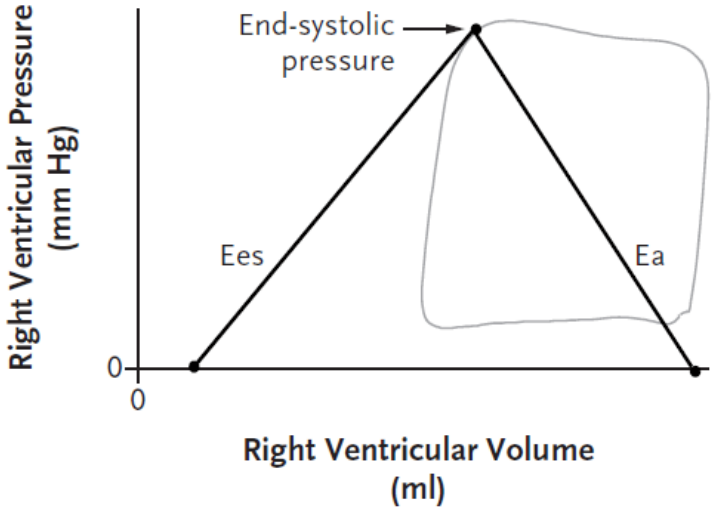




- 948 echo reports/281 patients
- RD dysfunction: TAPSE<16 mm, HR 1.20
- RVF: RV dilatation + CVP>8 mmHg/IVC dilated, HR 1.56
- ACP: LVEDA/RVEDA>0.6, PSM, HR 2.09

RV contractility and sensitivity to afterload

- RV cycle with limited isovolumic stage…. x LV
- PA functional reserve: -30-50%
- PAP up to 40 mmHg tolerated without previous adaptation: dilated RV, prolonged isovolumic contraction
- Increase of RV afterload, tendency for ischaemia:
  - Diastolic perfusion only
  - Increased myocardial mass (chronic)



D'Alto *et al. Crit Care* (2020) 24:670
https://doi.org/10.1186/s13054-020-03385-5

Critical Care

RESEARCH Open Access

Right ventricular-arterial uncoupling independently predicts survival in COVID-19 ARDS

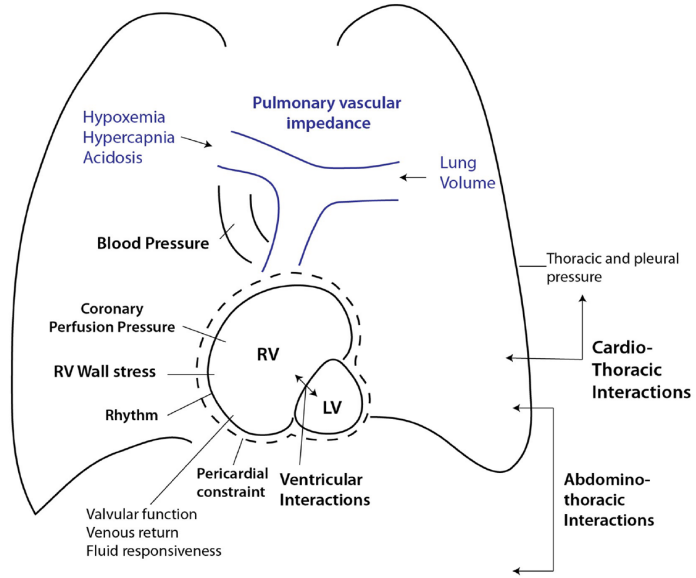
Michele D'Alto[1*†], Alberto M. Marra[2†], Sergio Severino[3], Andrea Salzano[4], Emanuele Romeo[1],

ESC HEART FAILURE
ESC Heart Failure (2023)
Published online in Wiley Online Library (wileyonlinelibrary.com) **DOI:** 10.1002/ehf2.14289

ORIGINAL ARTICLE

Prognostic implication of a novel right ventricular injury score in septic patients

Hongmin Zhang[1*], Dingding Zhang[2], Xiaoting Wang[1*], Ye Liu[3], Hui Lian[4], Qing Zhang[1], Hua Zhao[1],



- Ees /Ea RV between 1.5-2 (x LV 0.9-1), RV-PA coupling: TAPSE/PAPs > 0.63- 0.47 mm/mmHg
- RV-PA uncoupling Ees/Ea ……..TAPSE/PAPs …… ≤0.4 mm/mmHg

Intensive Care Med (2018) 44:774–790
https://doi.org/10.1007/s00134-018-5172-2

IPPV: dynamic and static power delivered to the cardiorespiratory system

$$\text{Power}_{rs} = RR \cdot \left\{ \Delta V^2 \cdot \left[\frac{1}{2} \cdot EL_{rs} + RR \cdot \frac{(1 + I:E)}{60 \cdot I:E} \cdot R_{aw} \right] + \Delta V \cdot PEEP \right\},$$

IPPV = mechanical power

- Vt (exponential^2)
- ΔPaw (Pplat-PEEP) (exponential^2)
- Flow (exponential^2)
- PEEP (exponential$^{1.4}$)
- RR (linear)

….mechanical damage to lung

- Lung size (small with lower threshold..)
- Edema, inflammation
- Inhomogenity (main factor for VILI !)
- Perfusion
- pH, pCO_2, pO_2

Extremes of IPPV: Are worshippers of LRM chasing a right physiology model ?

Baby lung

- Animal model of surfactant removal (lavage with a detergent)
- Dominant collapse of the distal bronch. tree – in contrast to inflammation and edema
- Weight not increased, size reduced….
- Responds to LRM

Steinberg J, Schiller HJ, Halter JM, Gatto LA, Dasilva M, Amato M, McCann UG, Nieman GF: **Tidal volume increases do not affect alveolar mechanics in normal lung but cause alveolar overdistension and exacerbate alveolar instability after surfactant deactivation.** *Crit Care Med* 2002, **30:**2675-2683.

Spragg RG, Smith RM, Harris K, Lewis J, Hafner D, Germann P: **Effect of recombinant SP-C surfactant in a porcine lavage model of acute lung injury.** *J Appl Physiol* 2000, **88:**674-681.

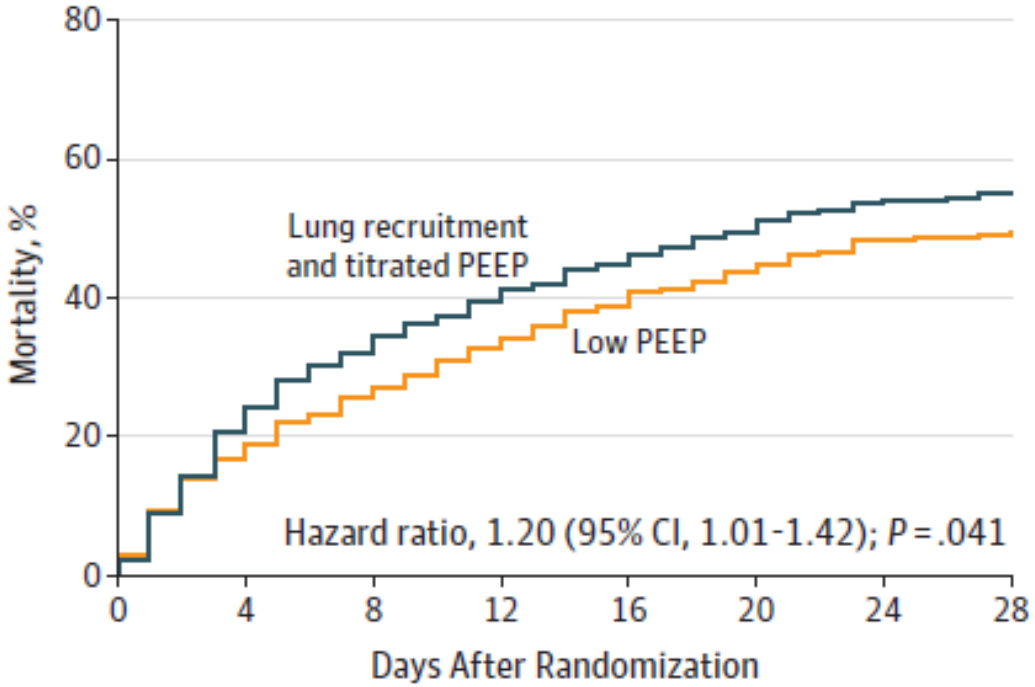
Inflammatory ARDS

- ARDS induced by oleic acid
- Inflammation of lung parenchyma – distension rather then a collapse
- distal bronch tree filled with hemorh. fluid
- Weight increased
- No response to LRM
- LRM blows up the less affected lung regions, Vd increases
- Dramatic impact on pulmonary perfusion and RV afterload

DiRocco JD, Pavone LA, Carney DE, Lutz CJ, Gatto LA, Landas SK, Nieman GF: **Dynamic alveolar mechanics in four models of lung injury.** *Intensive Care Med* 2006, **32:**140-148.

RV, pulmonary circulation and splanchnic perfusion were NOT an endpoint in any lung recruitment study (!)

- AlVEOLI
- LOVS
- ExPress
- Pharlap
- EPVEnt 2
- ART



Mild ALI (n=62)[a]	ARDS (n=401)
60 (96.8)	382 (95.3)
24 (38.7)	222 (55.4)
28 (45.2)	142 (35.4)
41 (66.1)	300 (74.8)
7 (11.3)	67 (16.7)
5 (8.1)	75 (18.7)
6 (9.7)	91 (22.7)
7.40 (0.10)	7.34 (0.14)
39.7 (9.5)	44.9 (12.7)
239 (30)	119 (43)
34 (24–45)	41 (32–52)
4.9 (2.5)	7.1 (3.5)

- Brun-Buisson C, et al. ALIVE Study. INT CARE MED 2003

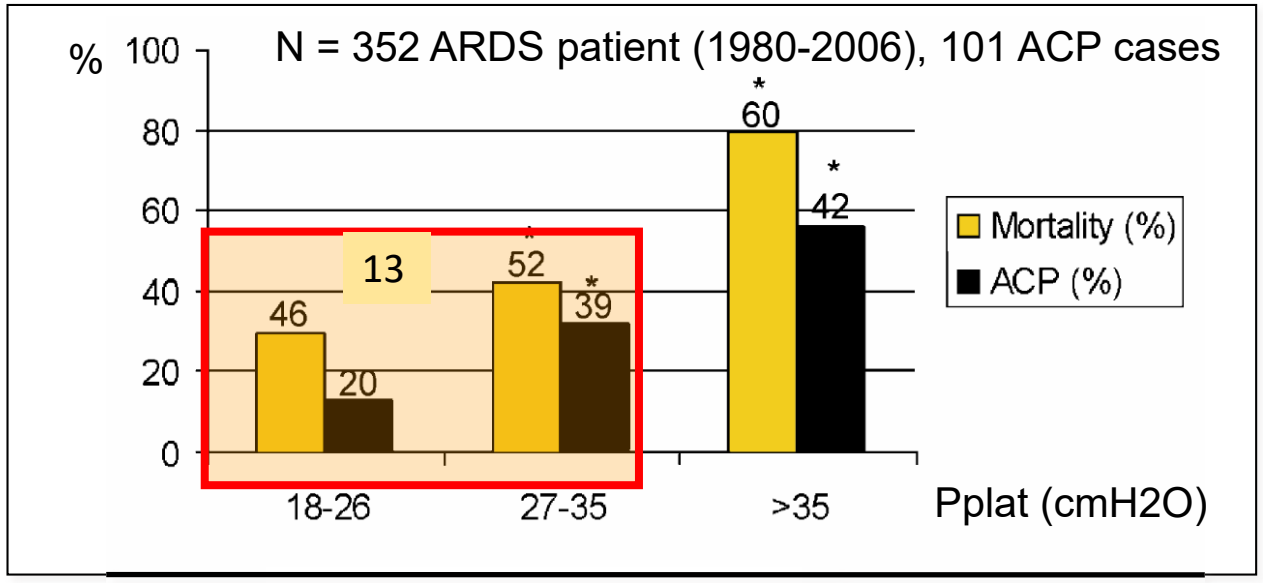
JAMA | Original Investigation | CARING FOR THE CRITICALLY ILL PATIENT

Effect of Lung Recruitment and Titrated Positive End-Expiratory Pressure (PEEP) vs Low PEEP on Mortality in Patients With Acute Respiratory Distress Syndrome
A Randomized Clinical Trial

Outcome	Lung Recruitment Maneuver With PEEP Titration Group (n = 501)	Low-PEEP Group (n = 509)	Type of Effect Estimate	Effect Estimate (95% CI)	P Value
Primary Outcome					
Death ≤28 d, No. of events/total No. (%)	277/501 (55.3)	251/509 (49.3)	HR	1.20 (1.01 to 1.42)	.041
Within 6 mo[a]	327/501 (65.3)	305/509 (59.9)	HR	1.18 (1.01 to 1.38)	.04

Aggresive IPPV in ARDS: risk of RV failure - typically in predisposed patients

- ACP up to 33% (Jardin F, Intensive Care Med 2007)
- Pplat < 27 mbar only 13%
- ACP 22% (ΔPaw 18±5 vs 16±5 mbar) (Mekontso-Dessap, Intensive Care Med 2016)
- Survival on IPPV linearly related to EF_RV (Steltzer H: Anaesthesia 1994)
- ACP and RVF as an indication to VA-ECMO….



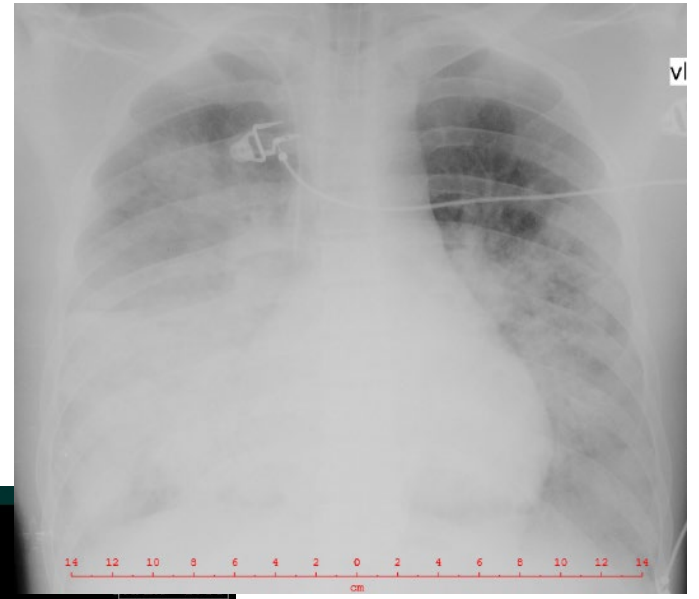
Jardin F, Vieillard-Baron A. INT CARE MED 2007

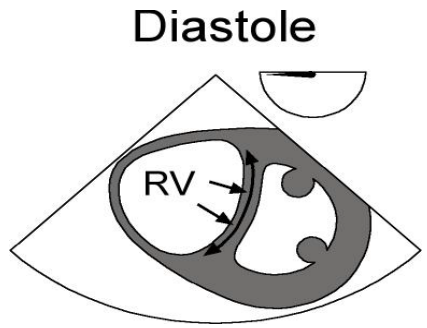
Intensive Care Med (2016) 42:862–870
DOI 10.1007/s00134-015-4141-2

SEVEN-DAY PROFILE PUBLICATION

Armand Mekontso Dessap
Florence Boissier
Cyril Charron
Emmanuelle Bégot
Xavier Repessé
Annick Legras
Christian Brun-Buisson
Philippe Vignon
Antoine Vieillard-Baron

Acute cor pulmonale during protective ventilation for acute respiratory distress syndrome: prevalence, predictors, and clinical impact

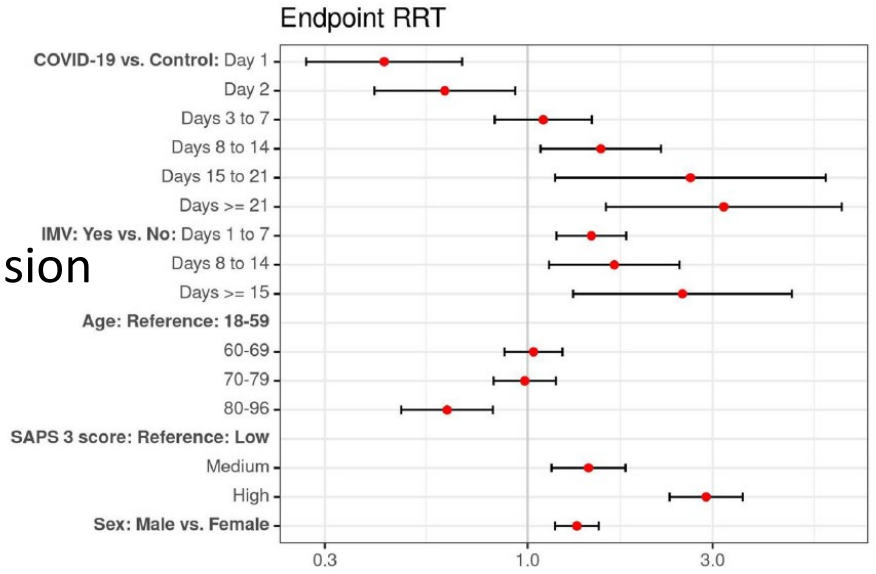


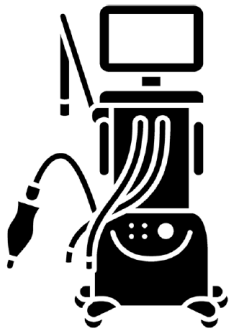


IPPV, RV and kidney function

- Days of IPPV bound to ARF/RRT and outcome in Covid-19
- PEEP+volume expansion+neurohumoral effects
- Role of CVP and Echocardiography+CUS in IPPV setting
- VV-ECMO may alleviate aggressive IPPV and PEEP – splanchnic perfusion

Perschinka *et al. Annals of Intensive Care* (2025) 15:17
https://doi.org/10.1186/s13613-025-01424-4

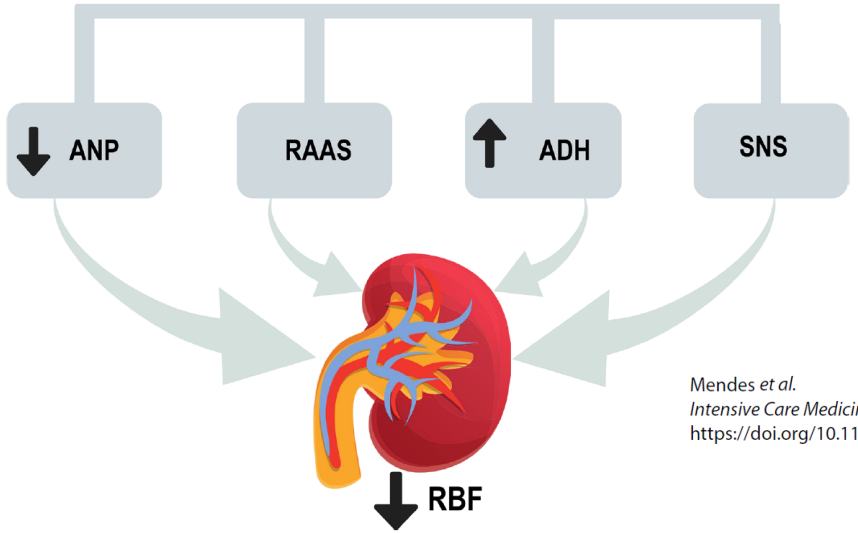




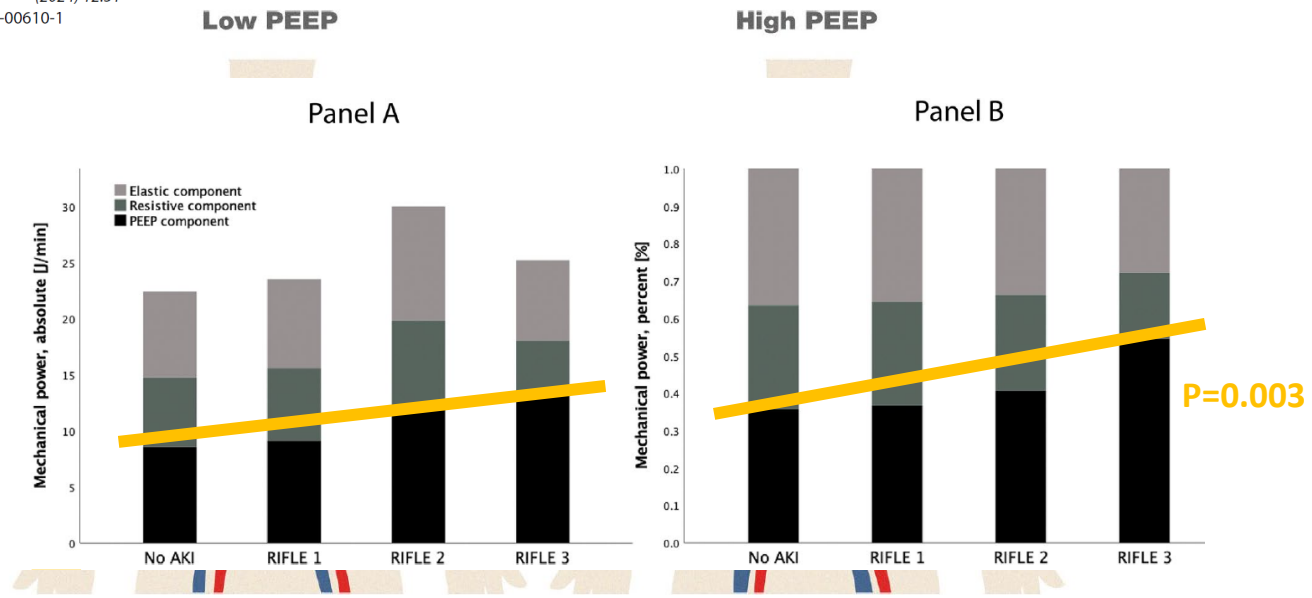
Mechanical ventilation

Benites *et al. Critical Care* (2025) 29:130
https://doi.org/10.1186/s13054-025-05343-5

Gattarello *et al.*
Intensive Care Medicine Experimental (2024) 12:31
https://doi.org/10.1186/s40635-024-00610-1

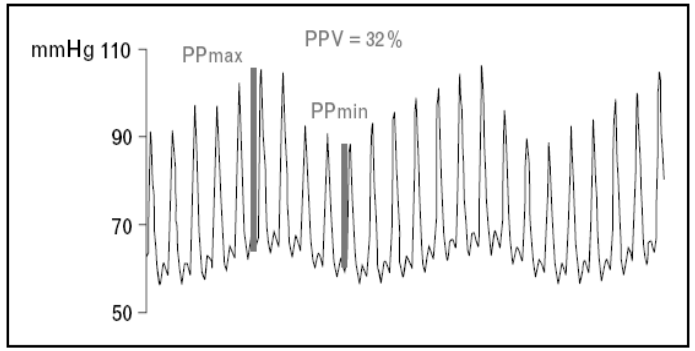


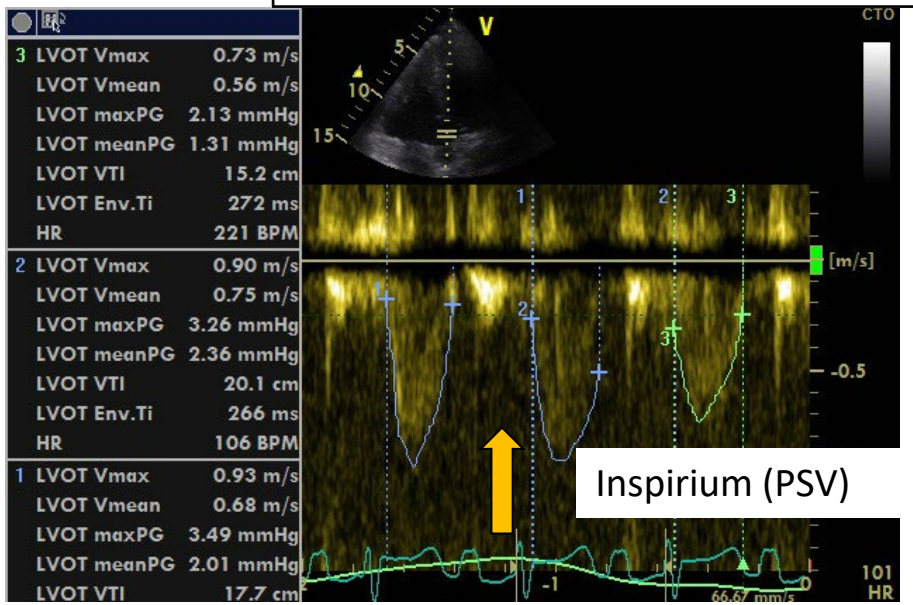
Mendes *et al.*
Intensive Care Medicine Experimental (2024) 12:81
https://doi.org/10.1186/s40635-024-00672-1



PPV interpretation in severe RV dysfunction…..

- 1.) decrease of **RVEF** and increase of **RVEDV** with **RV dilatation**
- 2.) Permanent increase of PVR leads to acute cor pulmonale:
  - a.) RV dilatation (RVEDA/LVEDA>0.6)
  - b.) paradoxic septal motion
- 3.) increase of CVP
- 5.) decrease of SV and CO
  - pulsus paradoxus
  - **dDown Effect (Pp, BPs variation)**

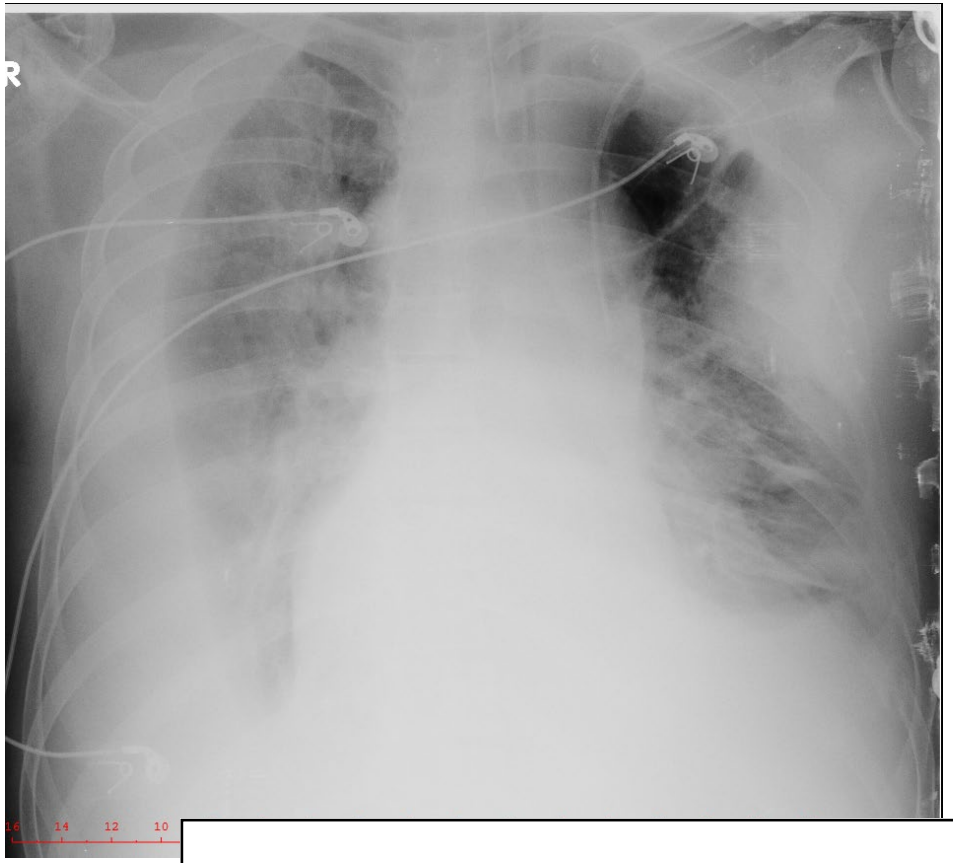




Inspirium (PSV)

48y male drinker, intubated for hypoxia

- Pneumococcus
- SIMV, Pplat 32, PEEP 14, f 24/min, I/E 1/1.5, FiO_2 0.80
- Bilateral CDs: drainage 12F L 450 ml and 20F R 950 ml
- Septic shock, NAD 0.45 ug/kg.min, lactate 2.8 mmol/l
- Persisting requirement for high FiO_2
- LRM 44 mbar/PEEP 20 mbar/40 min..18 mbar/3h
- Remaining on Pplat 36, PEEP 16, f 20/min, I/E 1/1.2, FiO_2 0.50….NAD 0.75 ug/kg.min, lactate 6.2

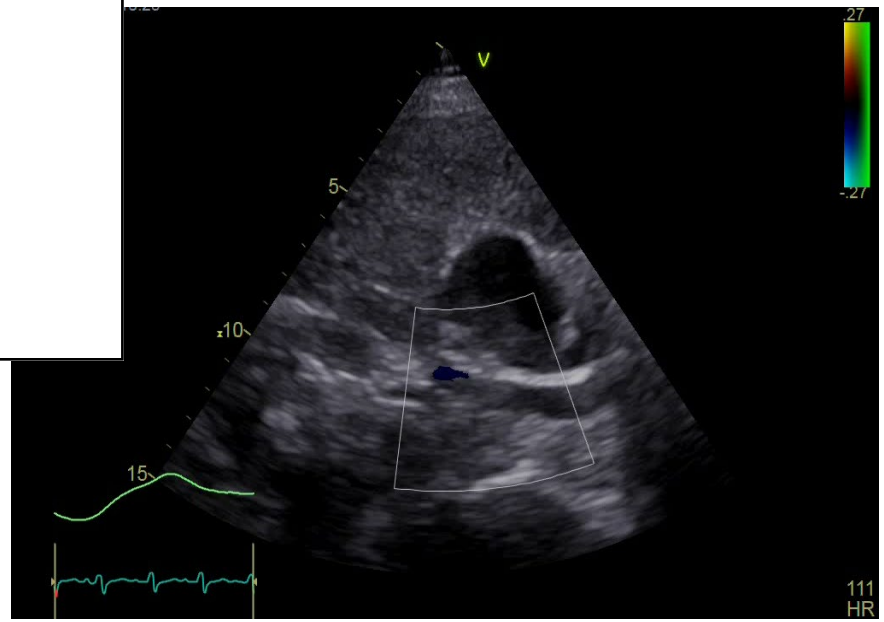


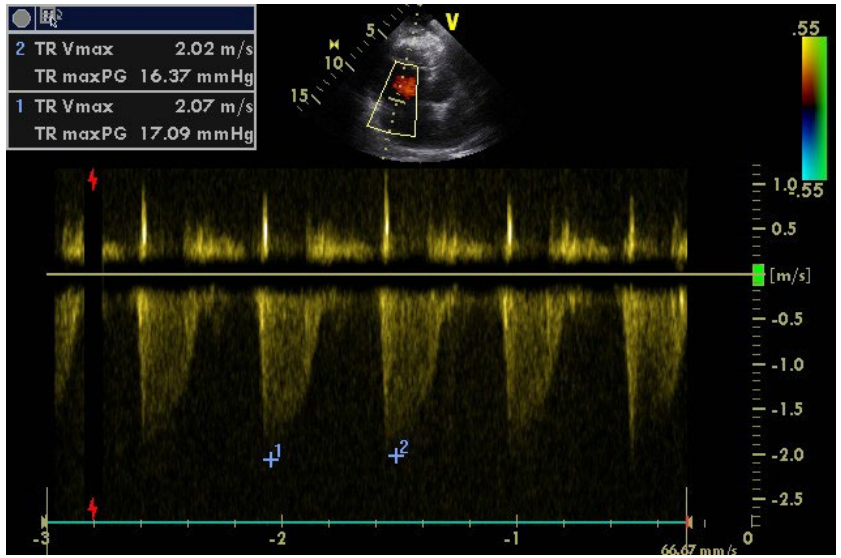
- FiO_2 0.45, improved gases and X-ray……
- Sinus 120/min, NAD 0.85 ug/kg.min, lactate 6.8 mmol/l, CO 6.4 l/min
- Hypoglycaemia, bilirubin 65 umol/l, AST 20.5, ALT 18.5 ukat/l….
- ARF, start CRRT

LRM induced RV failure and ARF (+16h)

- Pressure/volume overload of the RV
- Signs of ACP, no PH (CVP 18 mmHg + 17 mmHg TRcw)
- RV/PA uncoupling: TAPSE/PAPs 5/17 = 0.29 mm/mmHg
- Liver congestion in primary steatofibrosis
- Ventilator induced cardiorenal syndrome, CRRT + RCA….

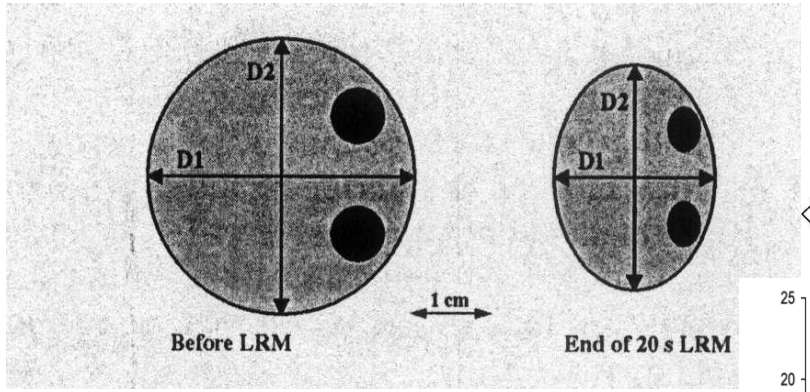
- VExUS without echocardiography ?



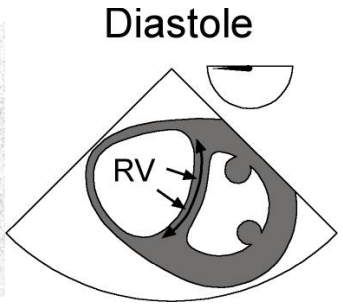


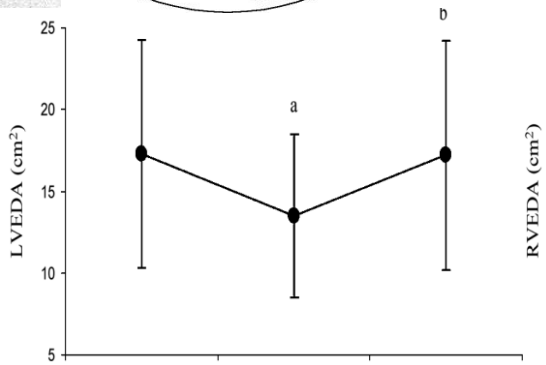
Lung recruitment maneuver - if ever, then always with echo !

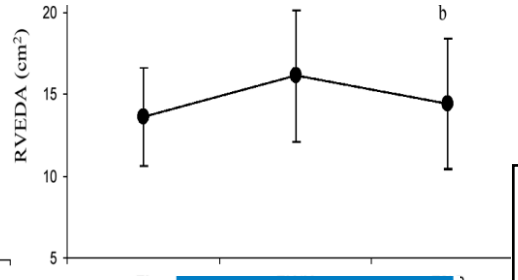
- Decreased EI (D2/D1)= RV pressure overload, risk of ACP, diastolic LV failure
- Decrease of SV_{RV} and LV preload reduces SV and CO by 50%, MAP by 20% (Nielsen J: Intensive Care Med 2005)



Critical Care 2009, **13**:R59 (doi:10.1186/cc7786)







- +16h:…BIPAP, Pinsp 24, PEEP 8, f 18/min, IT 1.3s, FiO_2 0.65, PSV 12 mbar, Vt 570 ml
- Weaned via PSV, extubated day 5.
- Off CRRT on day 6., regained renal functions
- Discharged day 7.

Research

Respiratory and haemodynamic changes during decremental open lung positive end-expiratory pressure titration in patients with acute respiratory distress syndrome

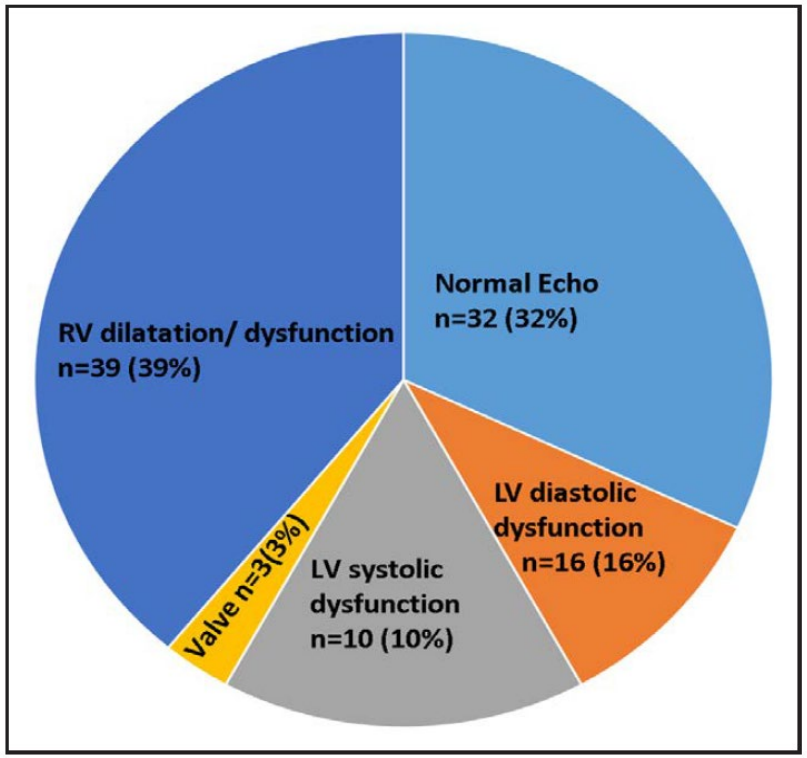
Christian Gernoth[1], Gerhard Wagner[2], Paolo Pelosi[3] and Thomas Luecke[1]

Open Access

ORIGINAL RESEARCH ARTICLE

Spectrum of Cardiac Manifestations in COVID-19

A Systematic Echocardiographic Study



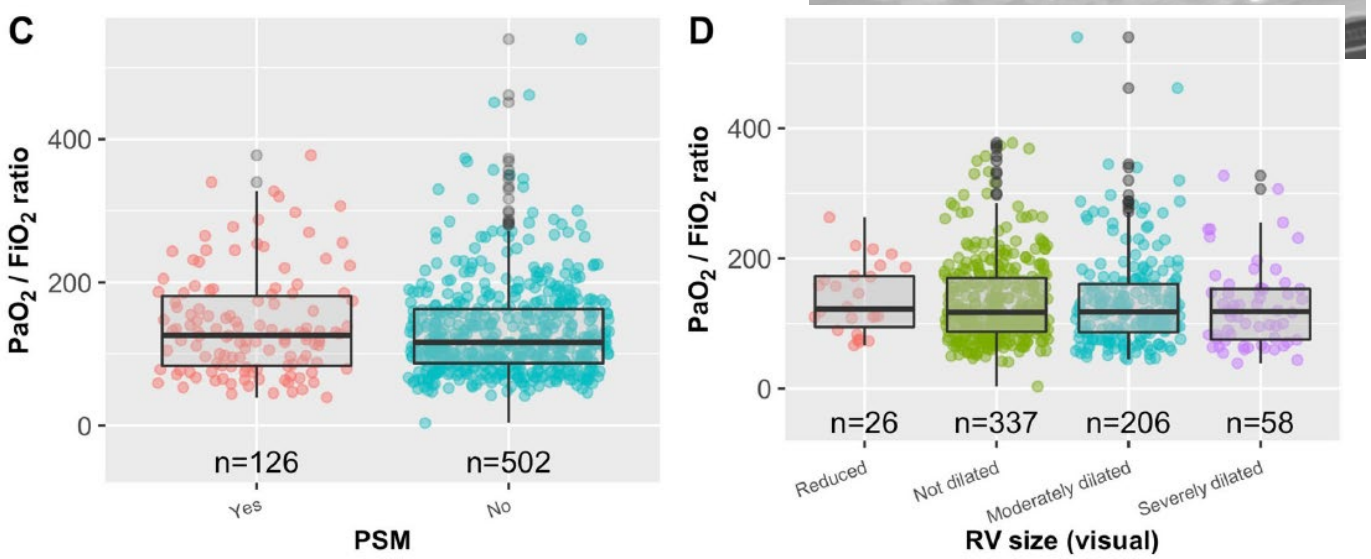
- Dilated RV and PH in 31-39%
- Related to mortality, OR 4.5, p=0.005
  - (Argulian E, JACC 2020, 13:2459-60)
- SV arrhythmias in 44% ICU patients

RV echocardiography parameters as an indication to earlier VV-ECMO instead of later VA ?

ORIGINAL

Echocardiography findings in COVID-19 patients admitted to intensive care units: a multi-national observational study (the ECHO-COVID study)

Stephen Huang[1], Philippe Vignon[2], Armand Mekontso-Dessap[3], Ségolène Tran[4], Gwenael Prat[5], Michelle Chew[6], Martin Balik[7], Filippo Sanfilippo[8], Gisele Banauch[9], Fernando Clau-Terre[10], Andrea Morelli[11], Daniel De Backer[12], Bernard Cholley[13], Michel Slama[14], Cyril Charron[4], Marine Goudelin[2], Francois Bagate[3], Pierre Bailly[5], Patrick-Johansson Blixt[6], Paul Masi[3], Bruno Evrard[2], Sam Orde[1], Paul Mayo[15], Anthony S. McLean[1] and Antoine Vieillard-Baron[4,16*] on behalf of the ECHO-COVID research group



Petit *et al. Crit Care* (2021) 25:220
https://doi.org/10.1186/s13054-021-03646-x

Critical Care

- No relation between right heart echoparameters and ELSO oxygenation/ ventilation criteria for VV-ECMO
- Progression of ACP towards a need for VA-ECMO not desirable in ARDS with higher BMI

RESEARCH LETTER Open Access

Evaluation of right ventricular function and driving pressure with blood gas analysis could better select patients eligible for VV ECMO in severe ARDS

Matthieu Petit[1,2*], Armand Mekontso-Dessap[3,4,5], Paul Masi[3,4], Annick Legras[7], Philippe Vignon[6] and Antoine Vieillard-Baron[1,2]

Thank you for your attention !

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