GENERAL UNIVERSITY HOSPITAL IN PRAGUE

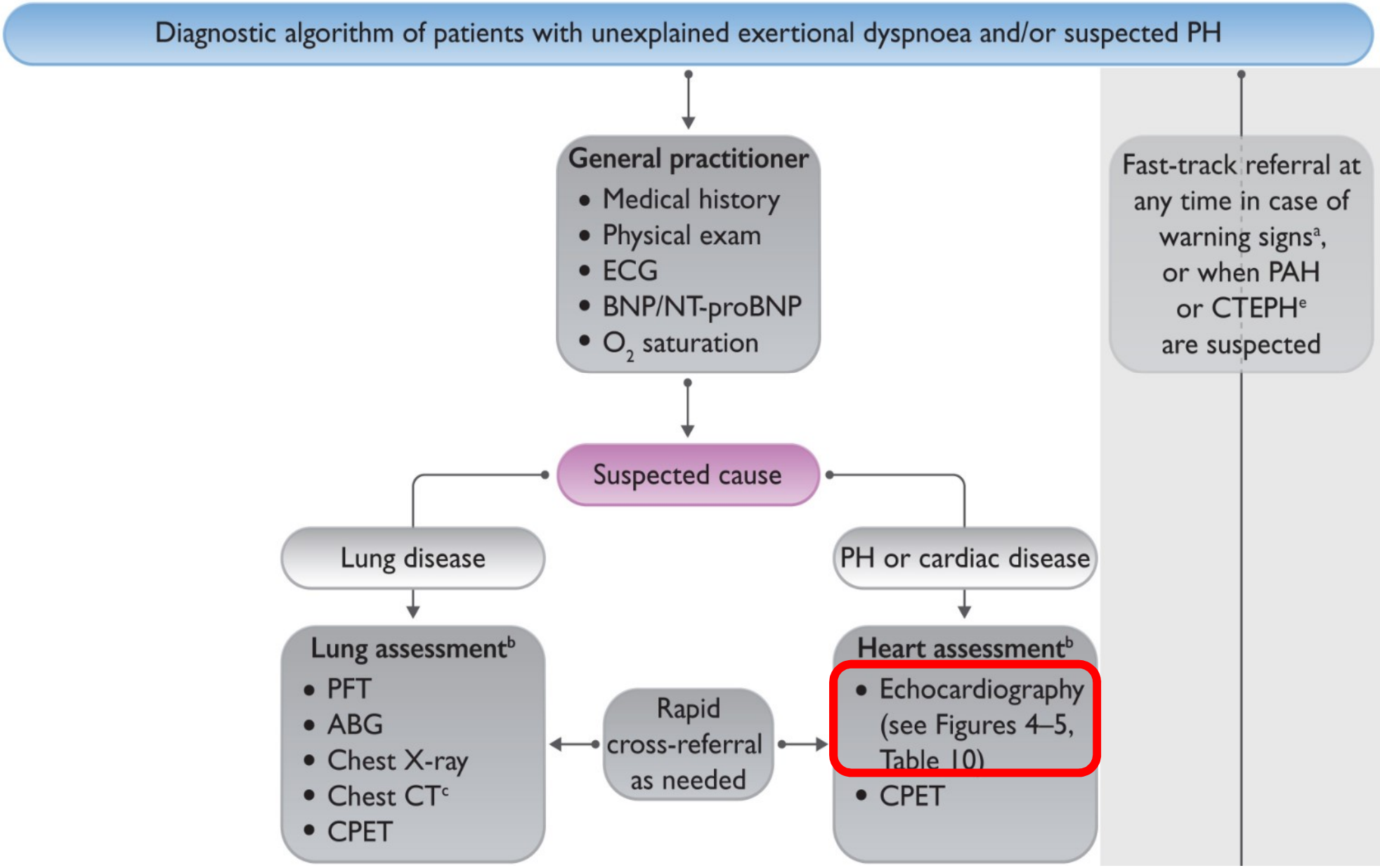
FIRST FACULTY OF MEDICINE
Charles University

Echocardiography in pulmonary hypertension

Aleš Linhart

Complex
CARDIO
VASCULAR
Center
GUH Prague

Diagnostic algorithm in dyspnea



Classification of PH

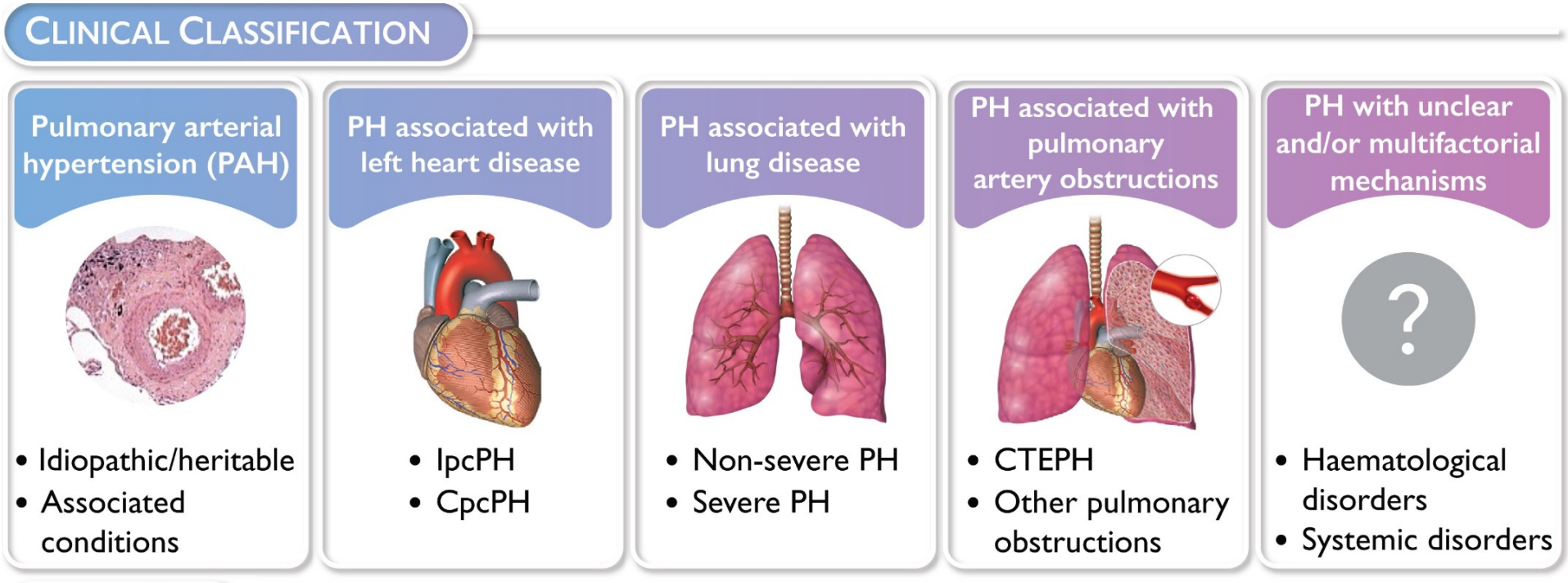
GROUP 1 Pulmonary arterial hypertension (PAH)

GROUP 2 PH associated with left heart disease

GROUP 3 PH associated with lung diseases and/or hypoxia

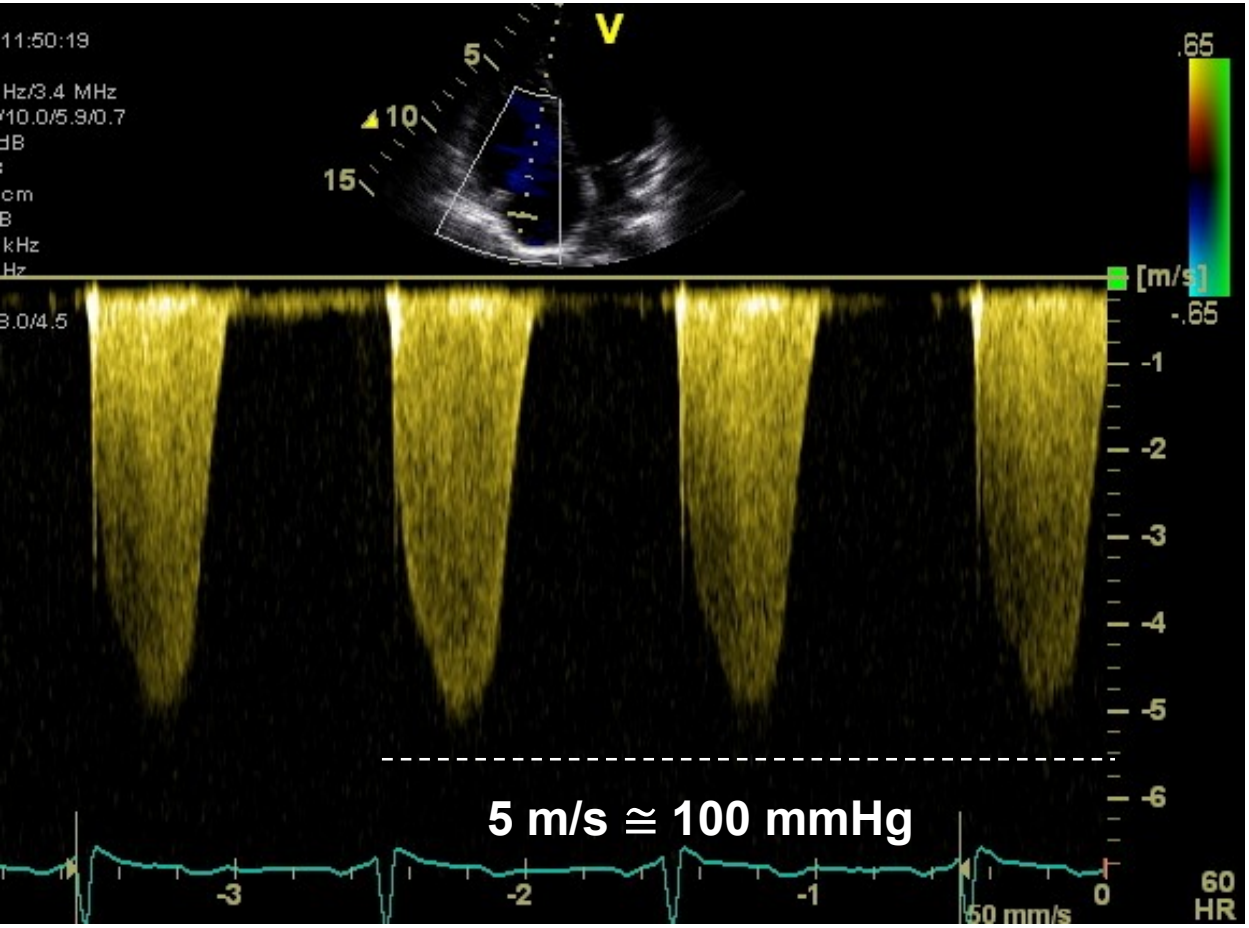
GROUP 4 PH associated with pulmonary artery obstructions

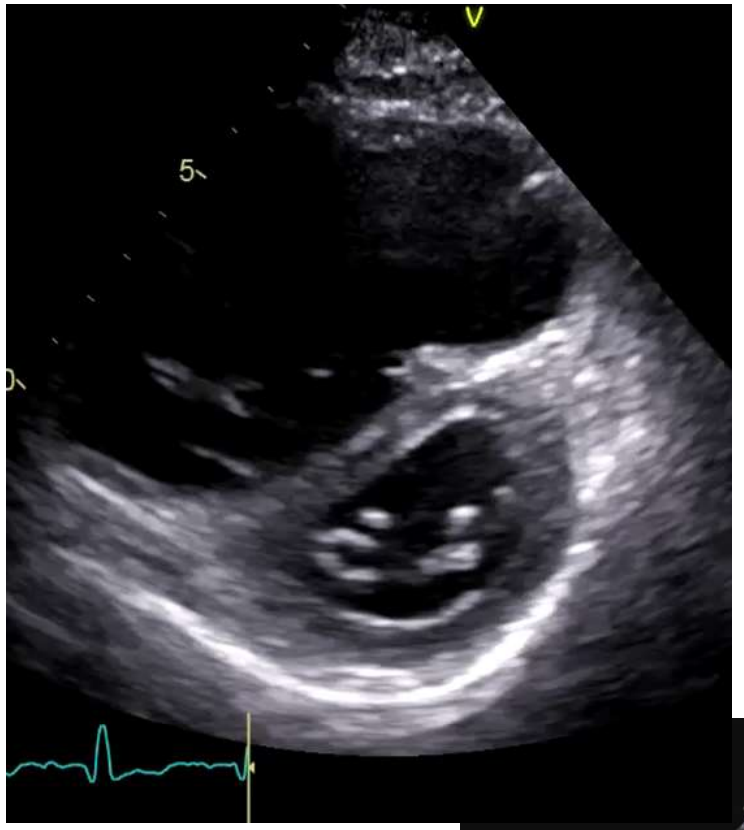
GROUP 5 PH with unclear and/or multifactorial mechanisms

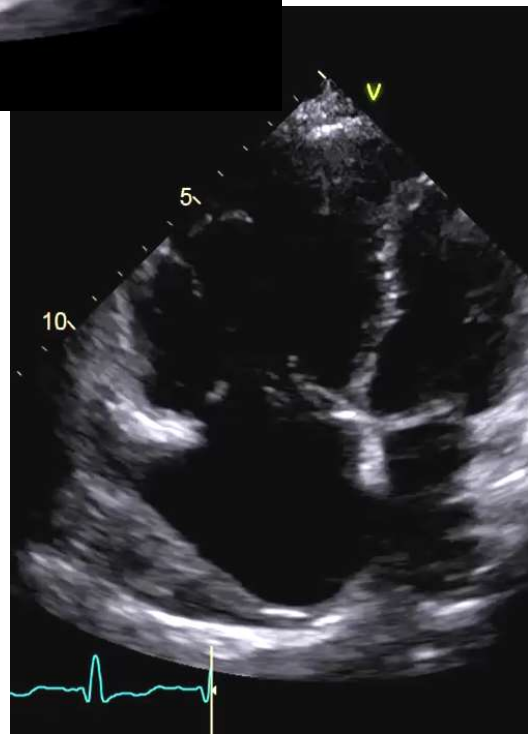


Humbert M. et al. *European Heart Journal*, 2022;43:3618–

Pulmonary arterial hypertension?







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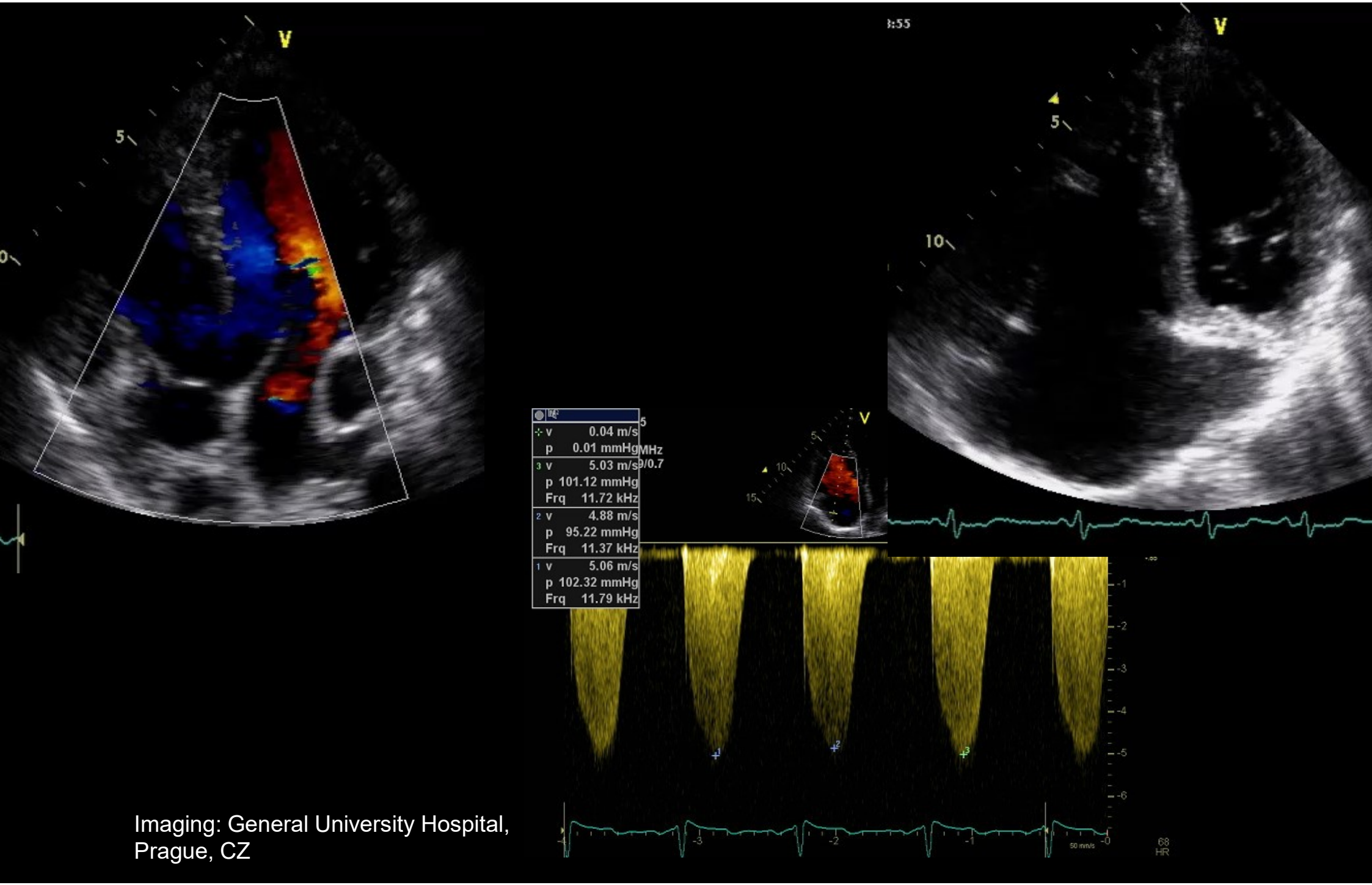

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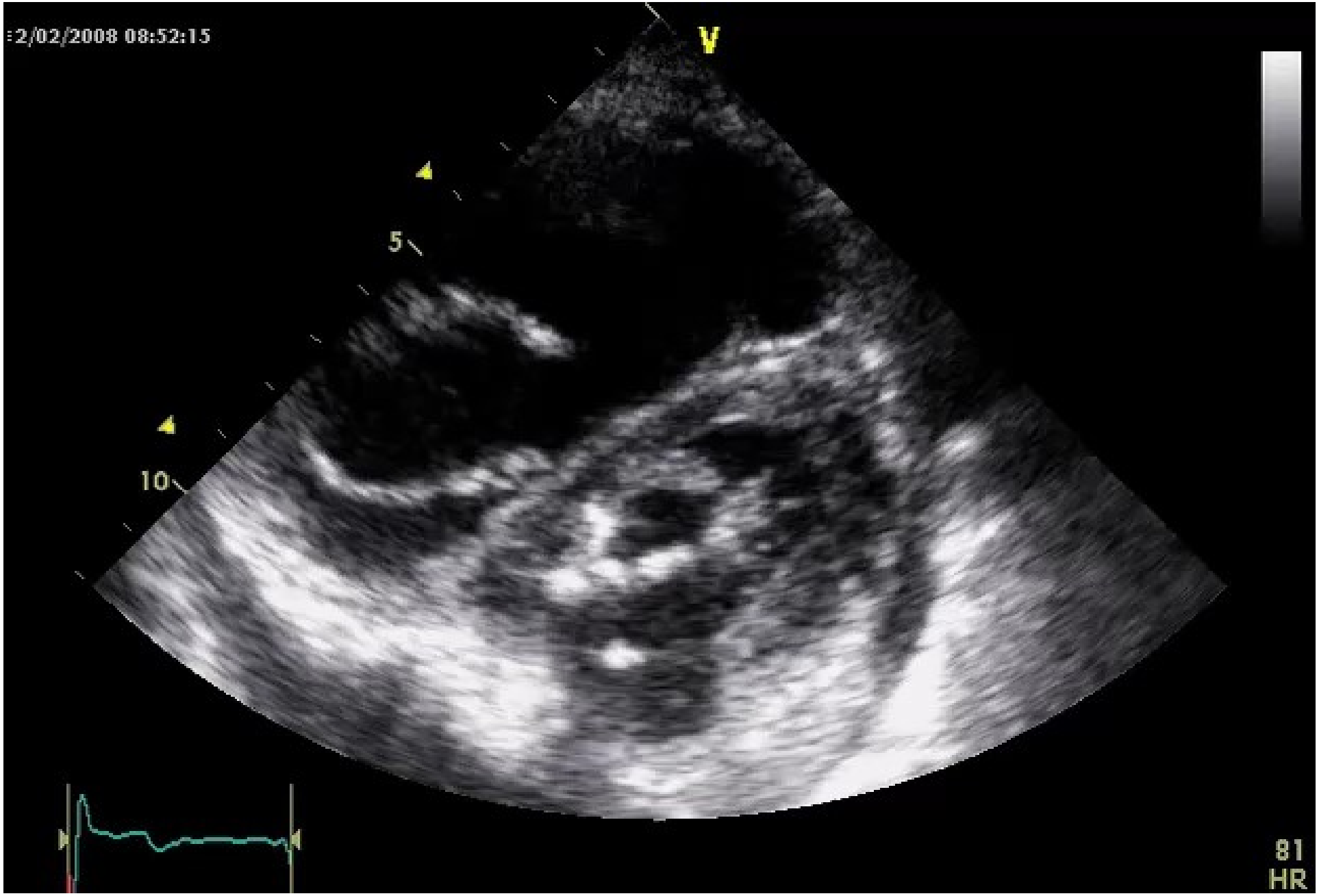

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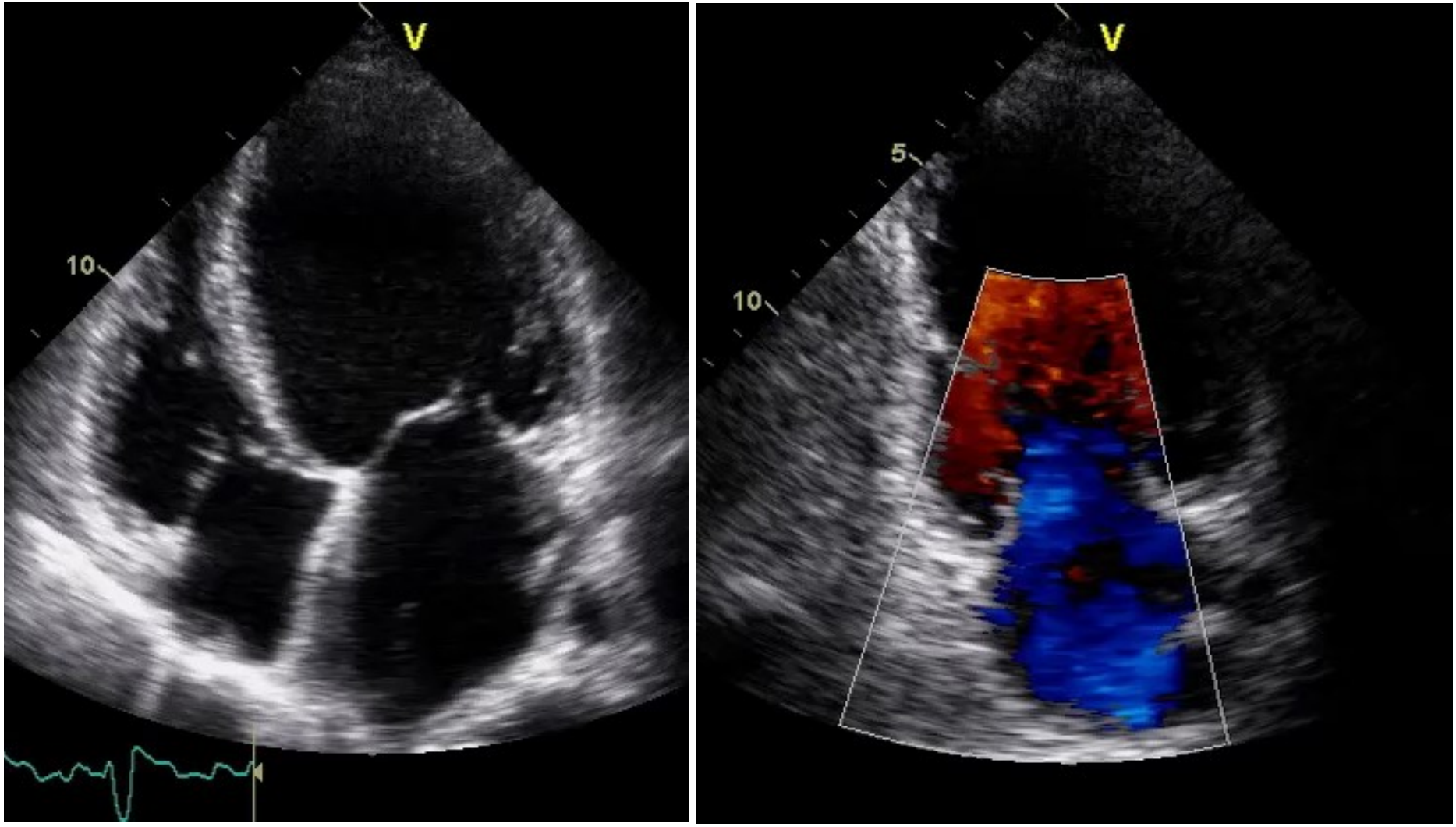
Left heart phenotype



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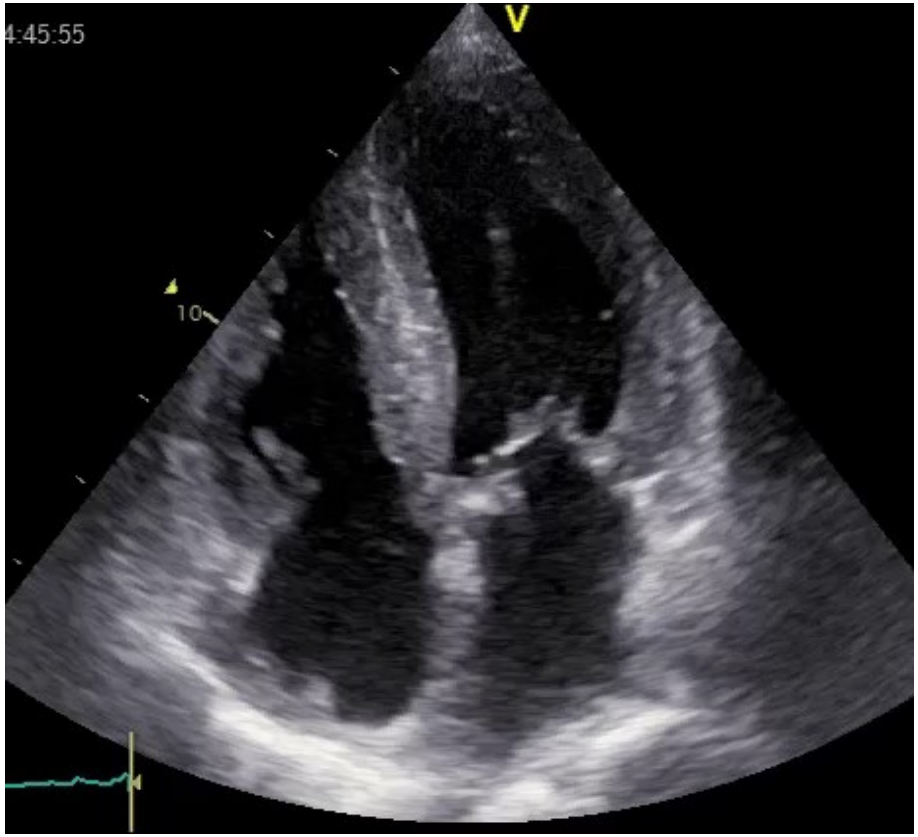
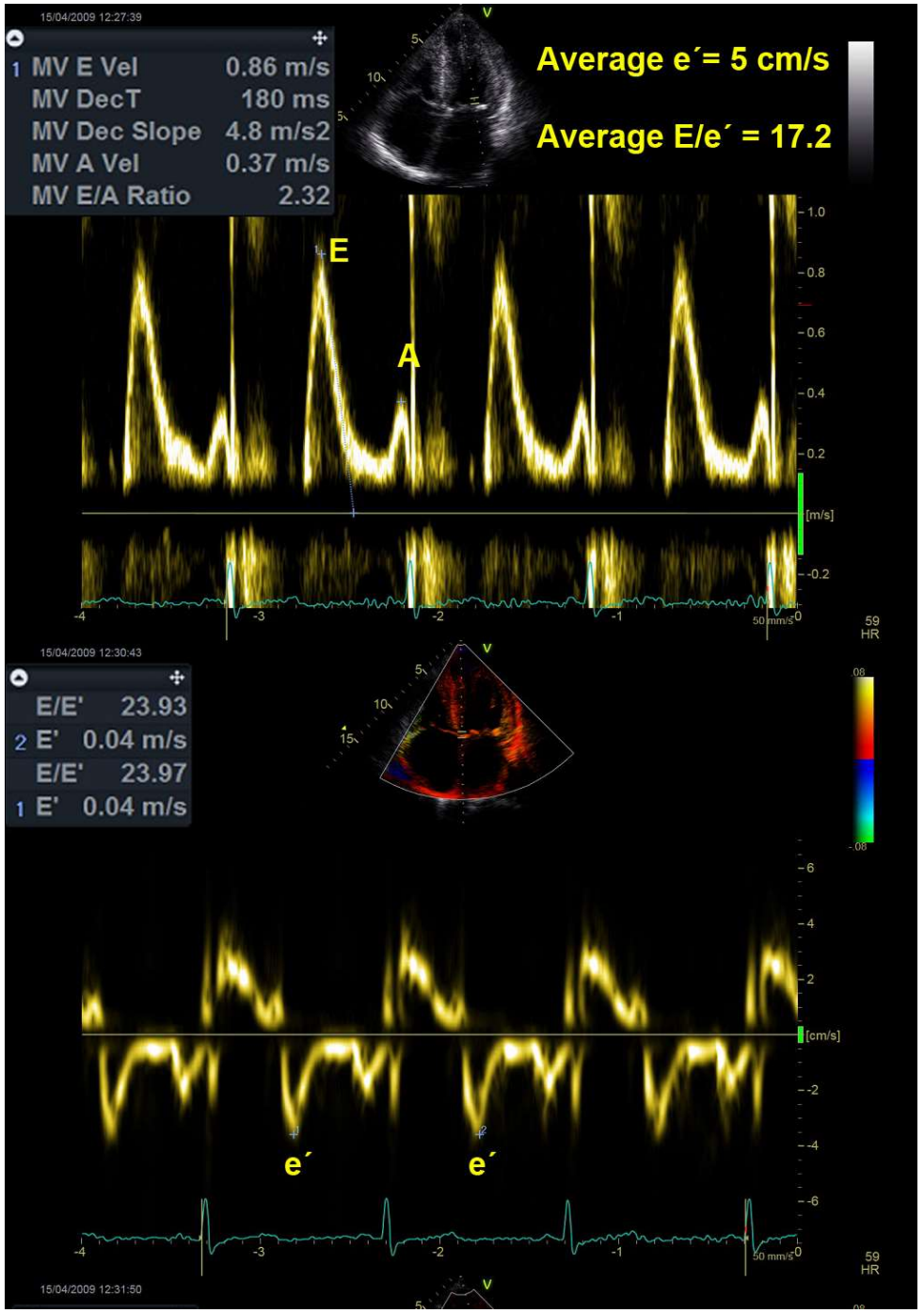
Restrictive cardiomyopathy





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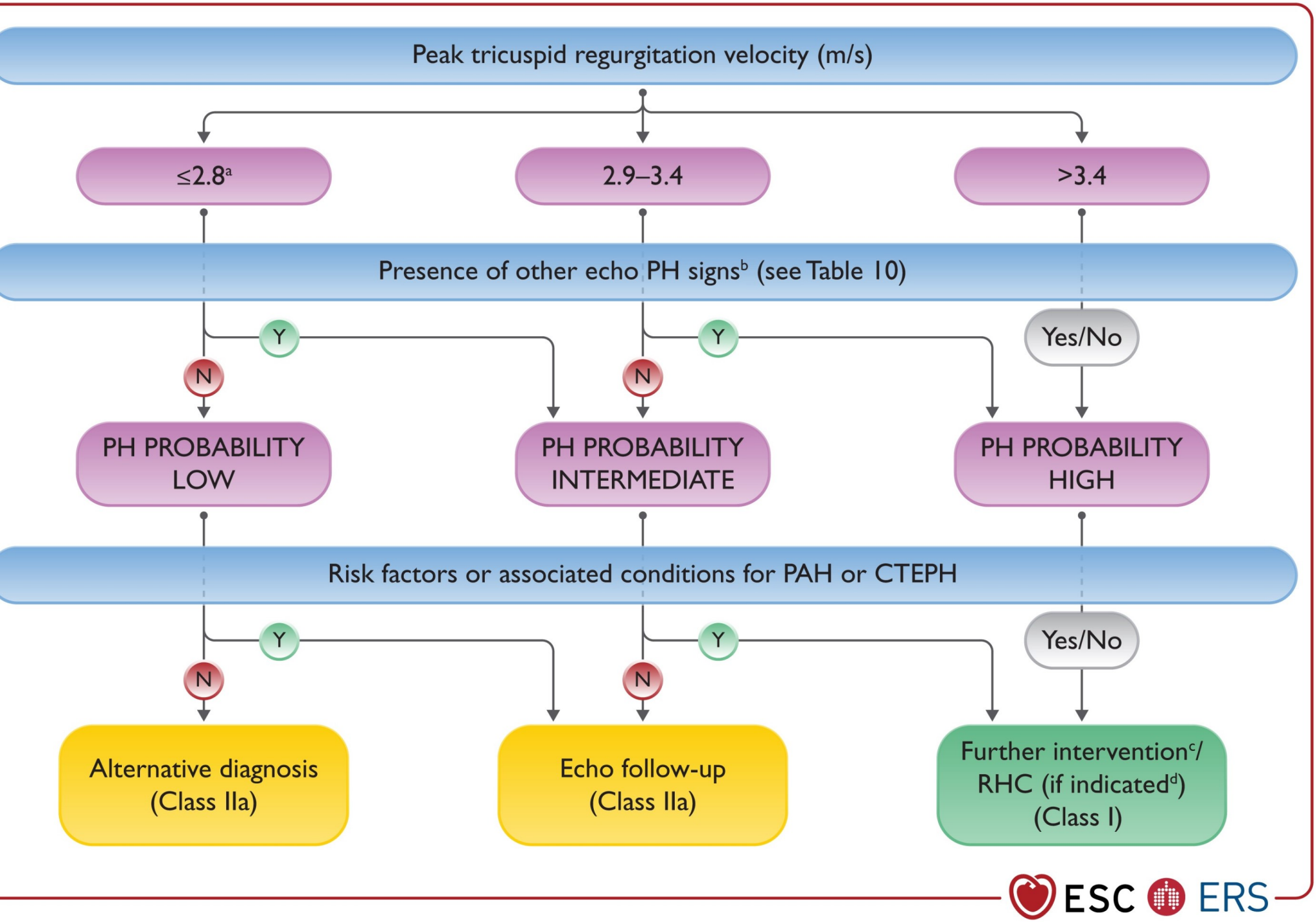
DIRECT ASSESSMENT OF PULMONARY PRESSURE


Peak tricuspid regurgitation velocity (m/s)
≤2.8[a]
2.9–3.4
>3.4
Presence of other echo PH signs[b] (see Table 10)
Y
N
Y
N
Yes/No
PH PROBABILITY LOW
PH PROBABILITY INTERMEDIATE
PH PROBABILITY HIGH
Risk factors or associated conditions for PAH or CTEPH
Y
N
Y
N
Yes/No
Alternative diagnosis (Class IIa)
Echo follow-up (Class IIa)
Further intervention[c]/ RHC (if indicated[d]) (Class I)
ESC
ERS

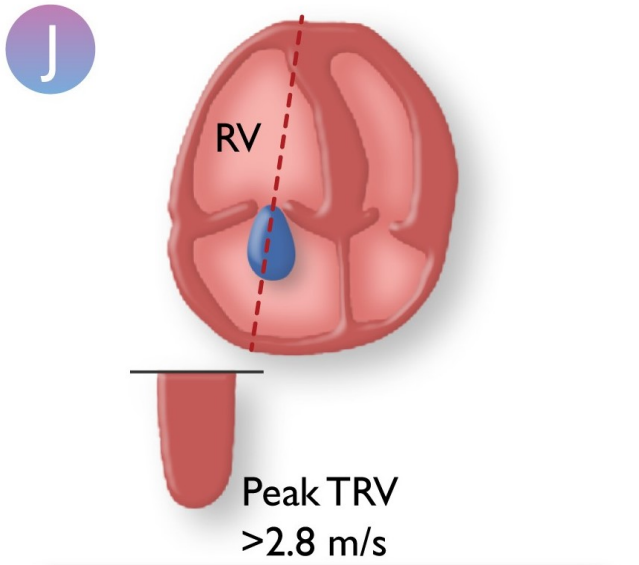
2.8 m/
=
31 mm

PASP vs. TRV

Considering the **inaccuracies in estimating RAP** and the amplification of measurement errors by using derived variables, the guidelines **recommend using the peak TRV (and not the estimat sPAP)** as the key variable for assigning the echocardiographic probability of PH.

A peak TRV >2.8 m/s may suggest PH; however, the presence or absence of PH cannot be reliably determined by TRV alone.

Lowering the TRV threshold in view of the revised haemodynamic definition of PH is not supported by available da

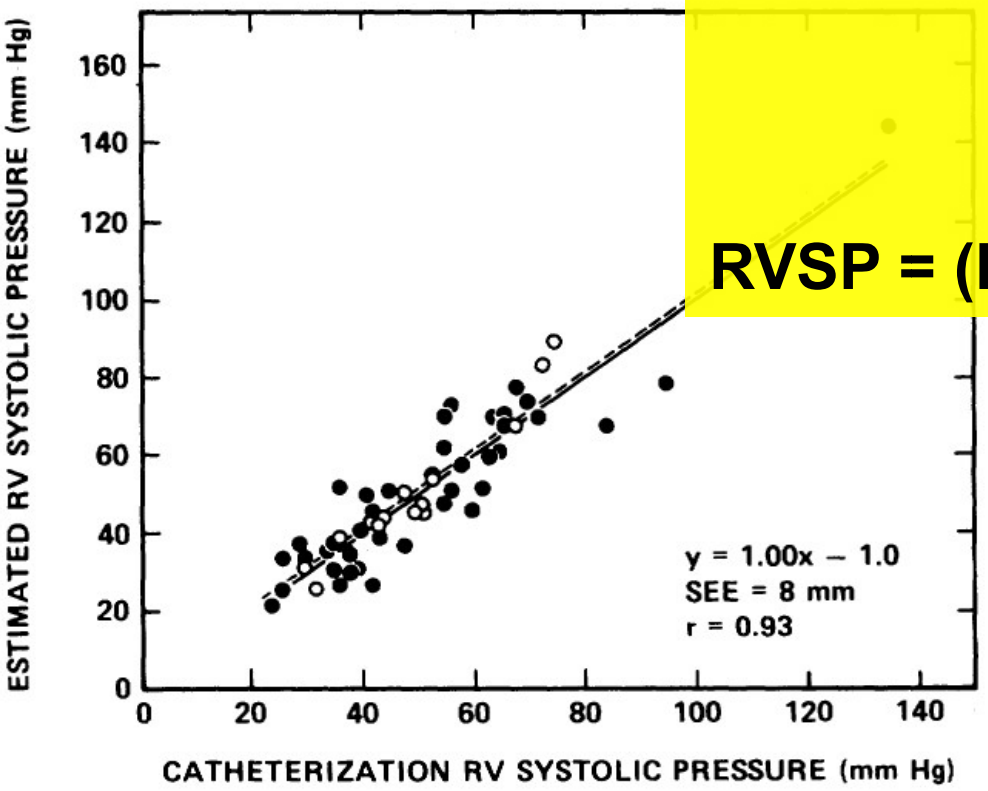


Increased systolic peak tricuspid regurgitation velocity (peak TRV); measured with continuous wave Doppler

ESTIMATES OF PULMONARY PRESSURES FROM TRICUSPID REGURGITANT JET

Noninvasive estimation of right ventricular systolic pressure by Doppler ultrasound in patients with tricuspid regurgitation

62 pts explored by RHC, echo and RHC within 24 hours



In the absence of pulmonary stenosis:

RVSP = PASP

RVSP = (RV-RA max-gradient) + RAP

RAP ~ (JVP + 5cm)/1.3 (mmHg)

Yock P., et al, Circulation 1984,70:

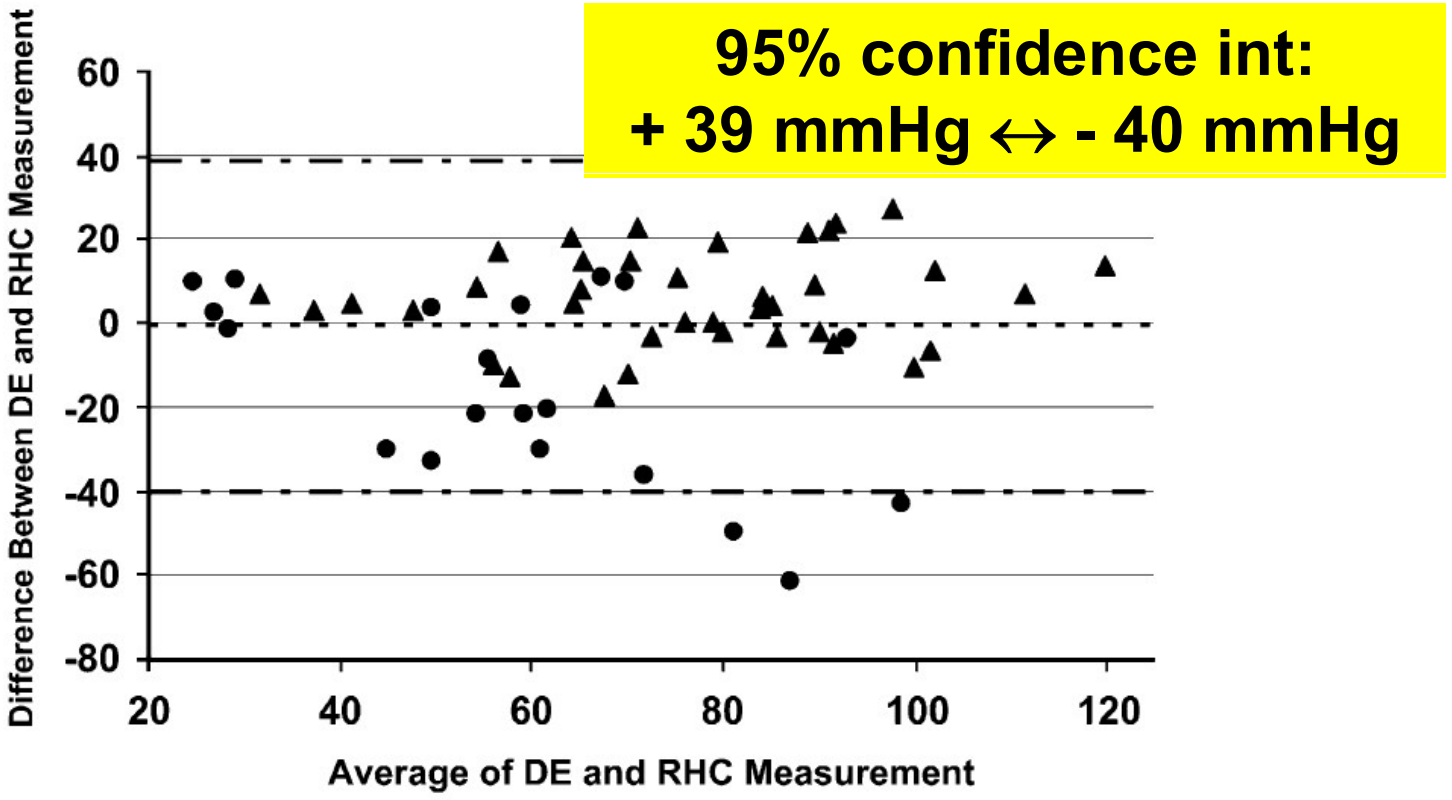
Accuracy of Doppler Echo in the Hemodynamic Assessment of PH

65 pts with different PAH types, PAMP 41 ± 15 mmHg,

Echo and Cath within 1 hour

(Johns Hopkins University, Baltimore, Maryland)

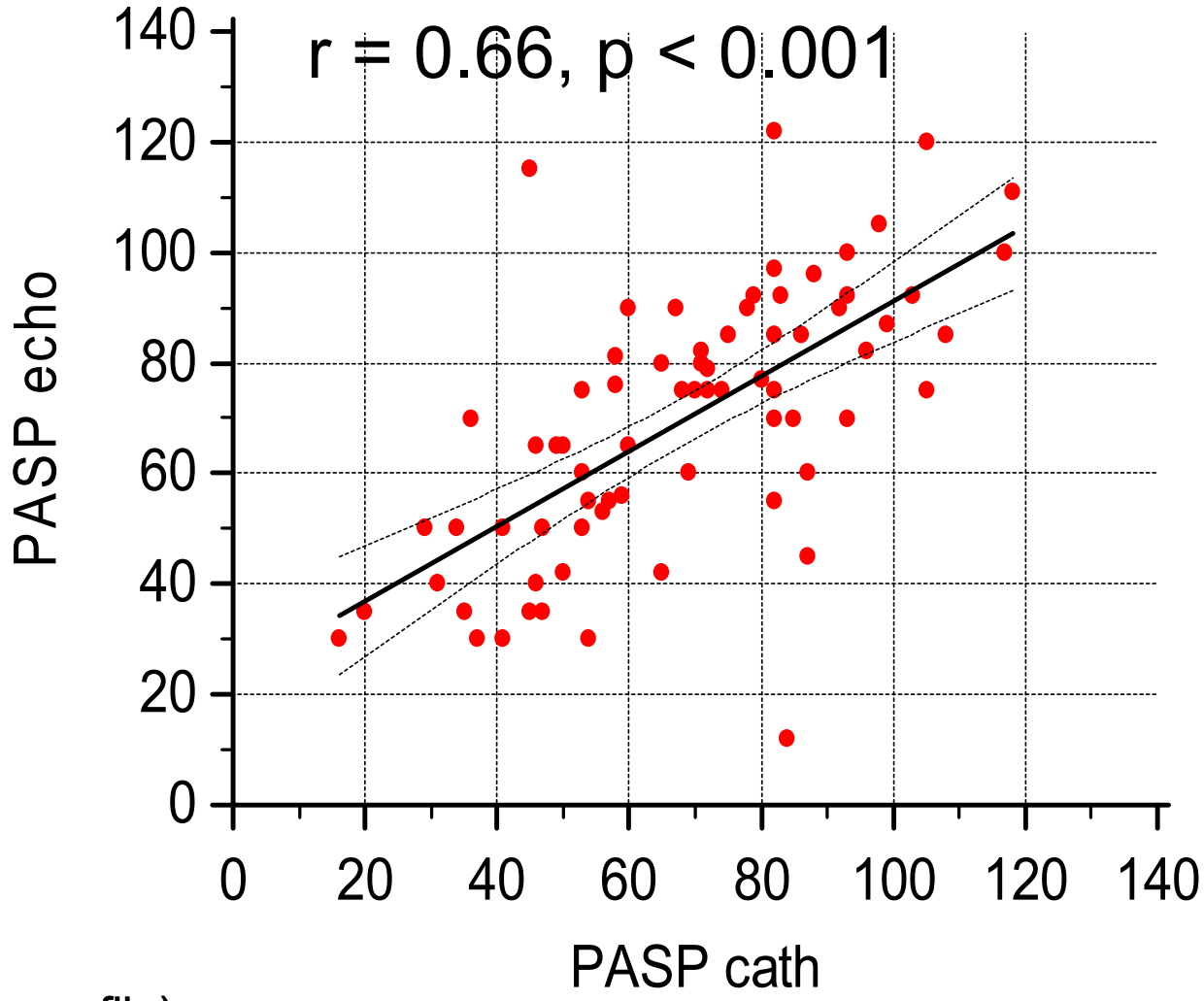
r = 0.66



Fisher MC., et al, Am J Resp Crit Care Med 2009,179: 6

Cath vs Echo data

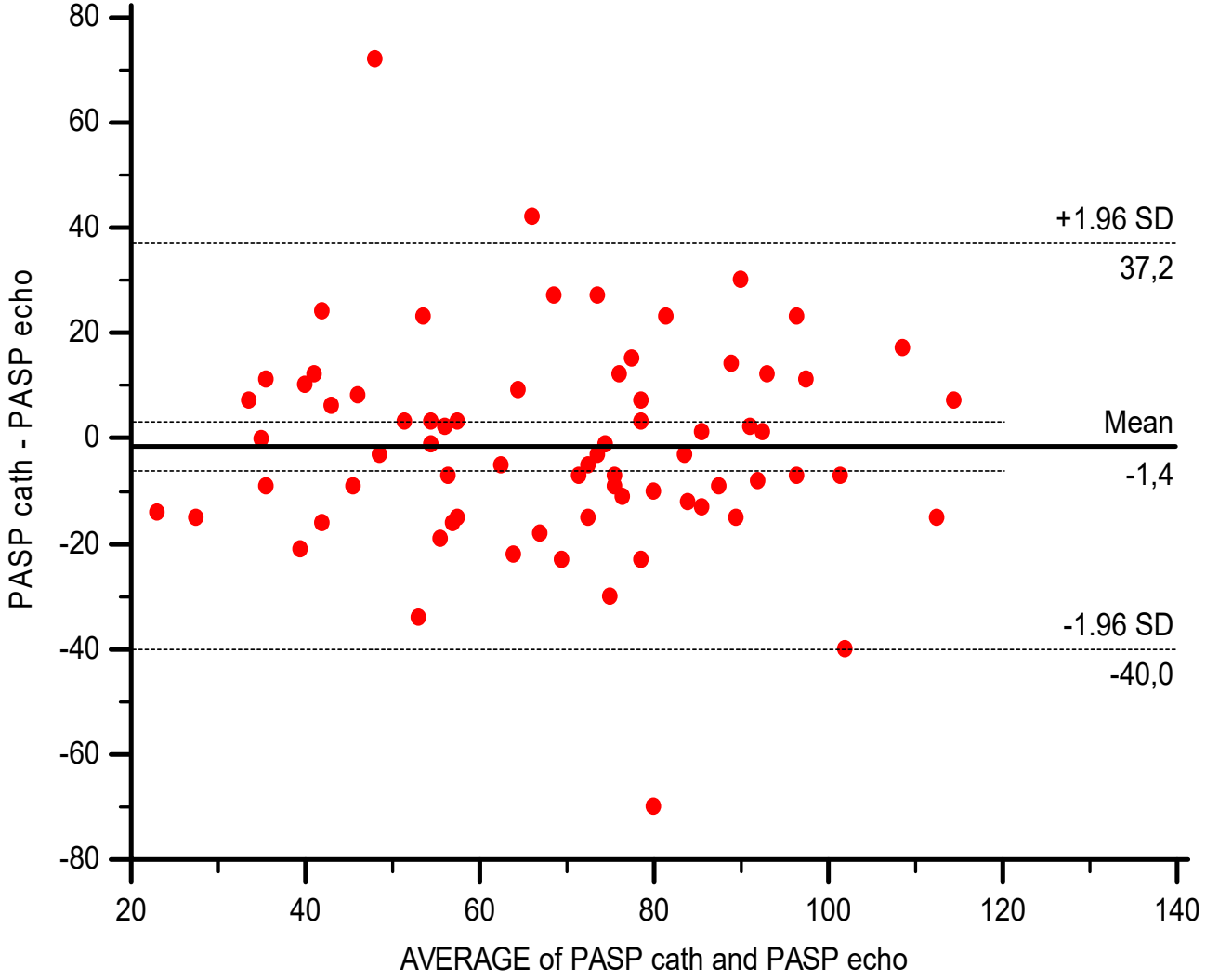
n= 72, RHC – ECHO < 7 days



láček, P. Jansa – data on file)

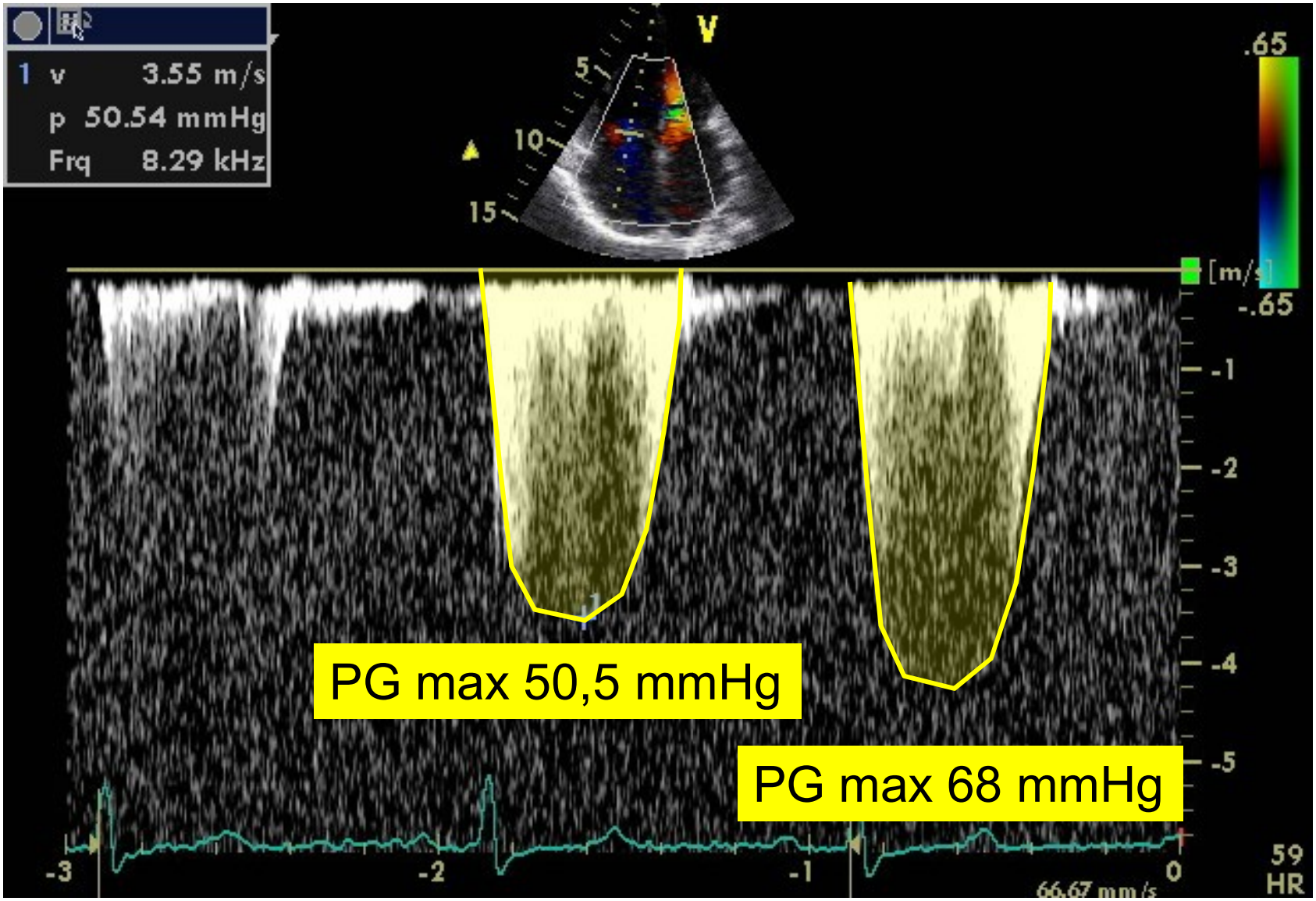
Cath vs Echo data

n= 72, RHC – ECHO < 7 days



oláček, P. Jansa – data on file)

Poor delineation of TR



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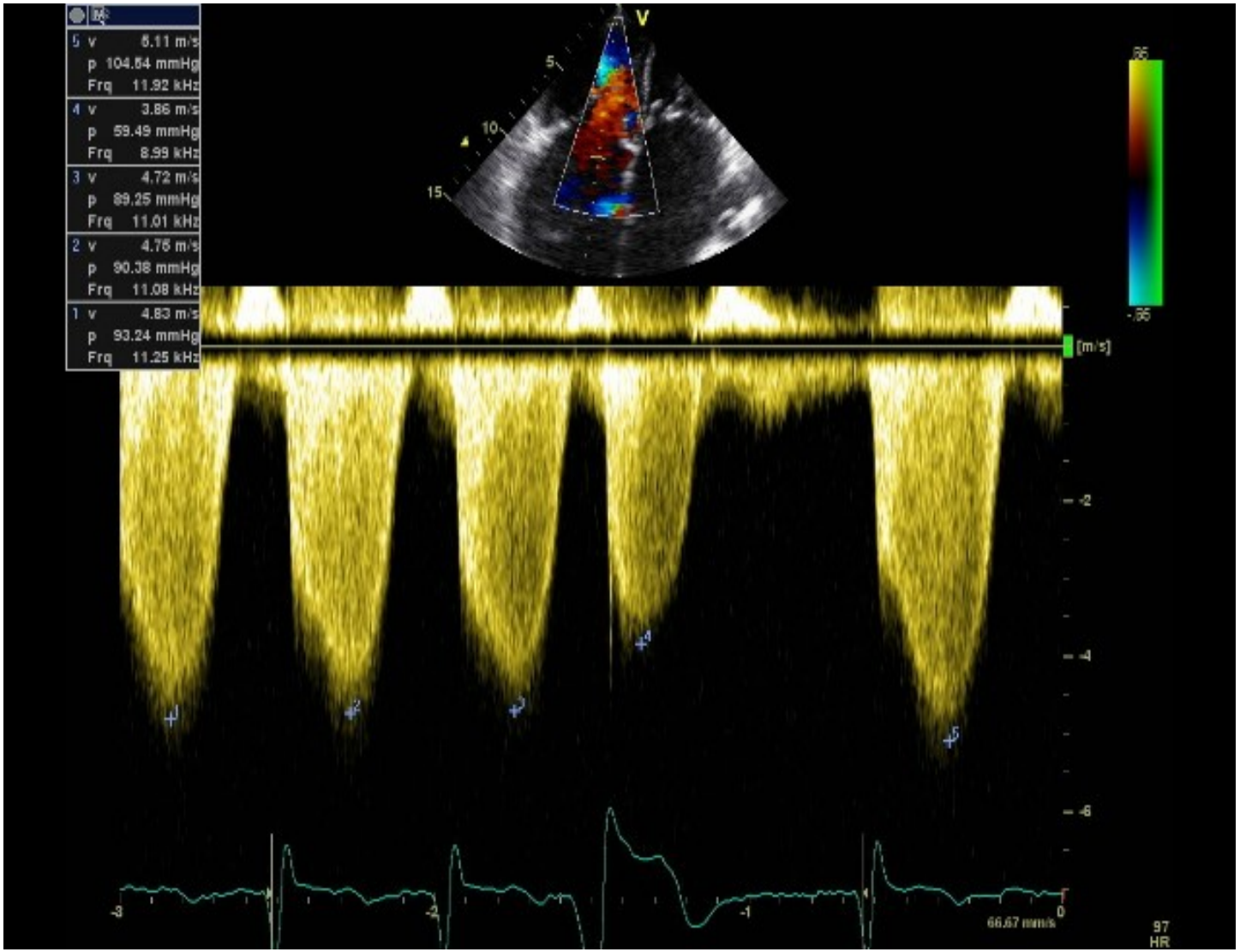
Postextrasystolic contractions



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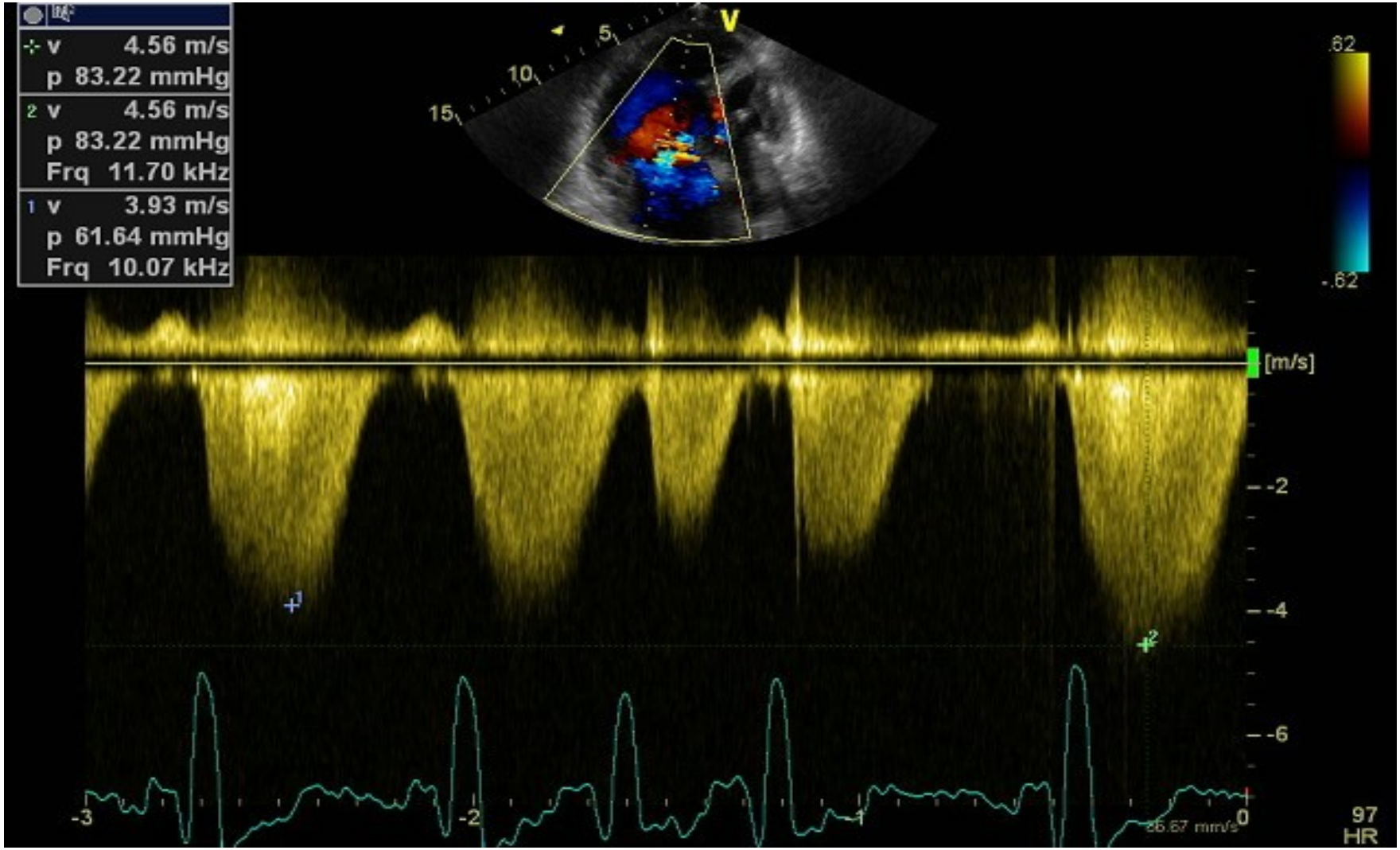
Potential pitfalls – postextrasystolic contractions



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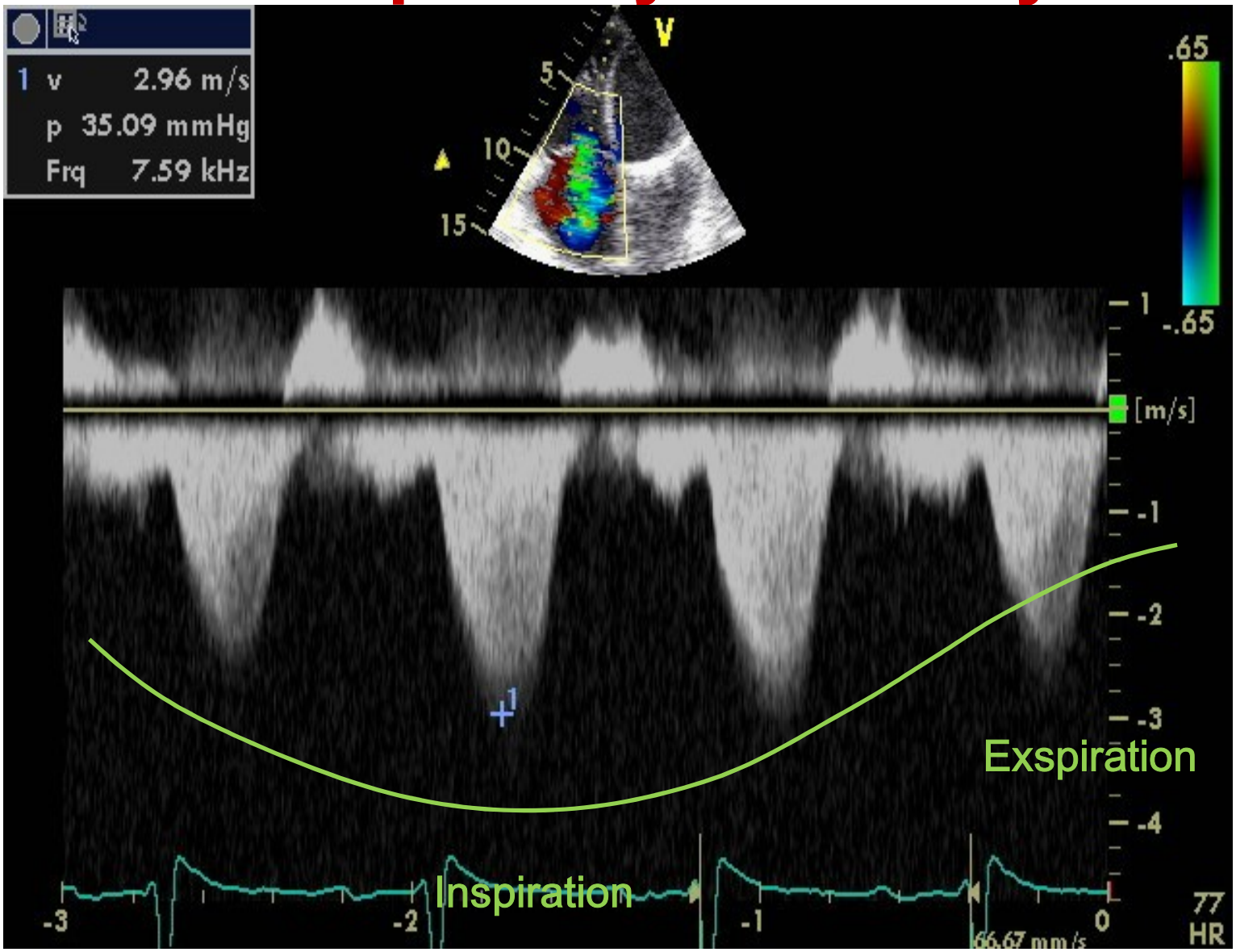
Respiratory variability



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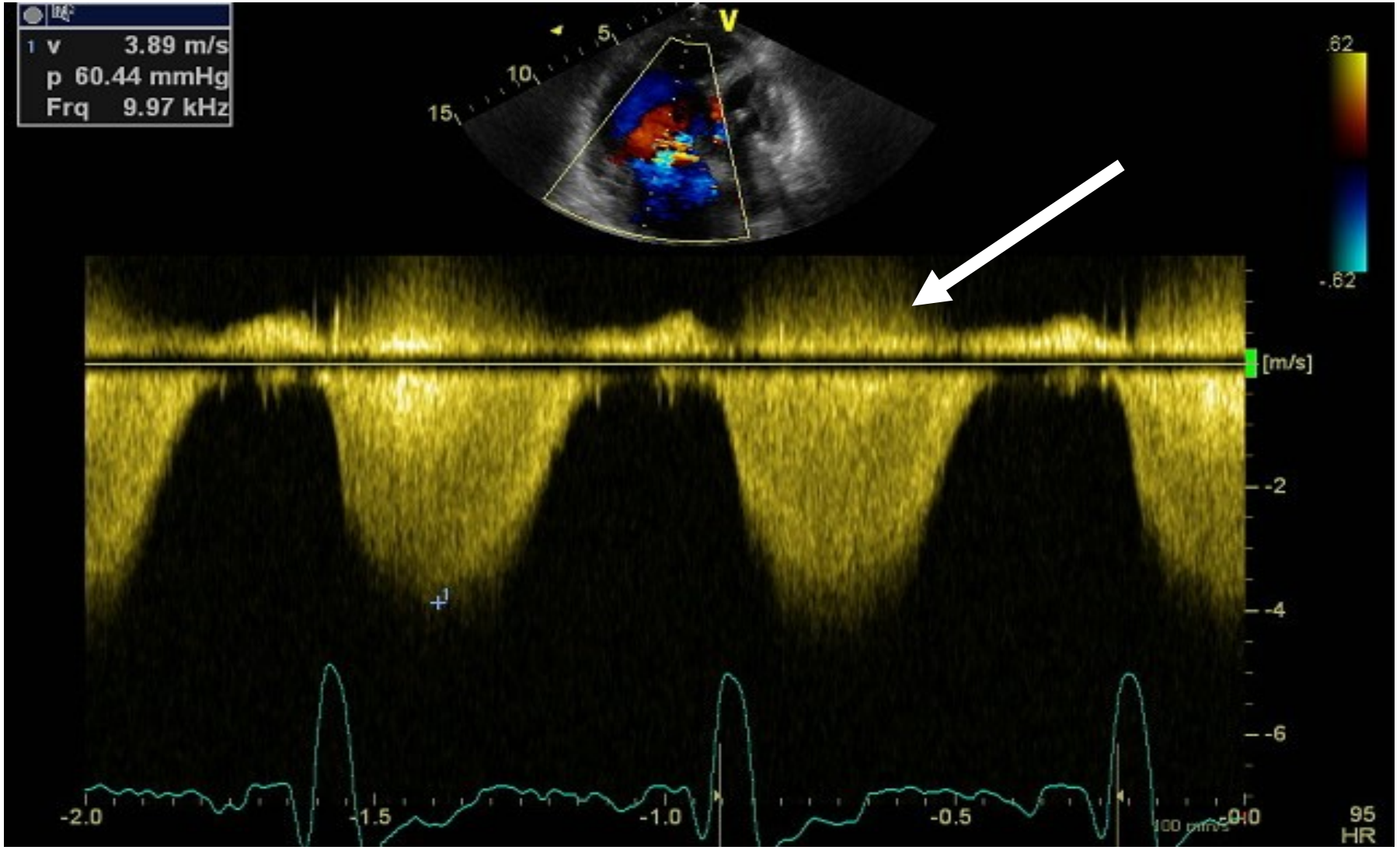
Spatial orientation of the RT jet



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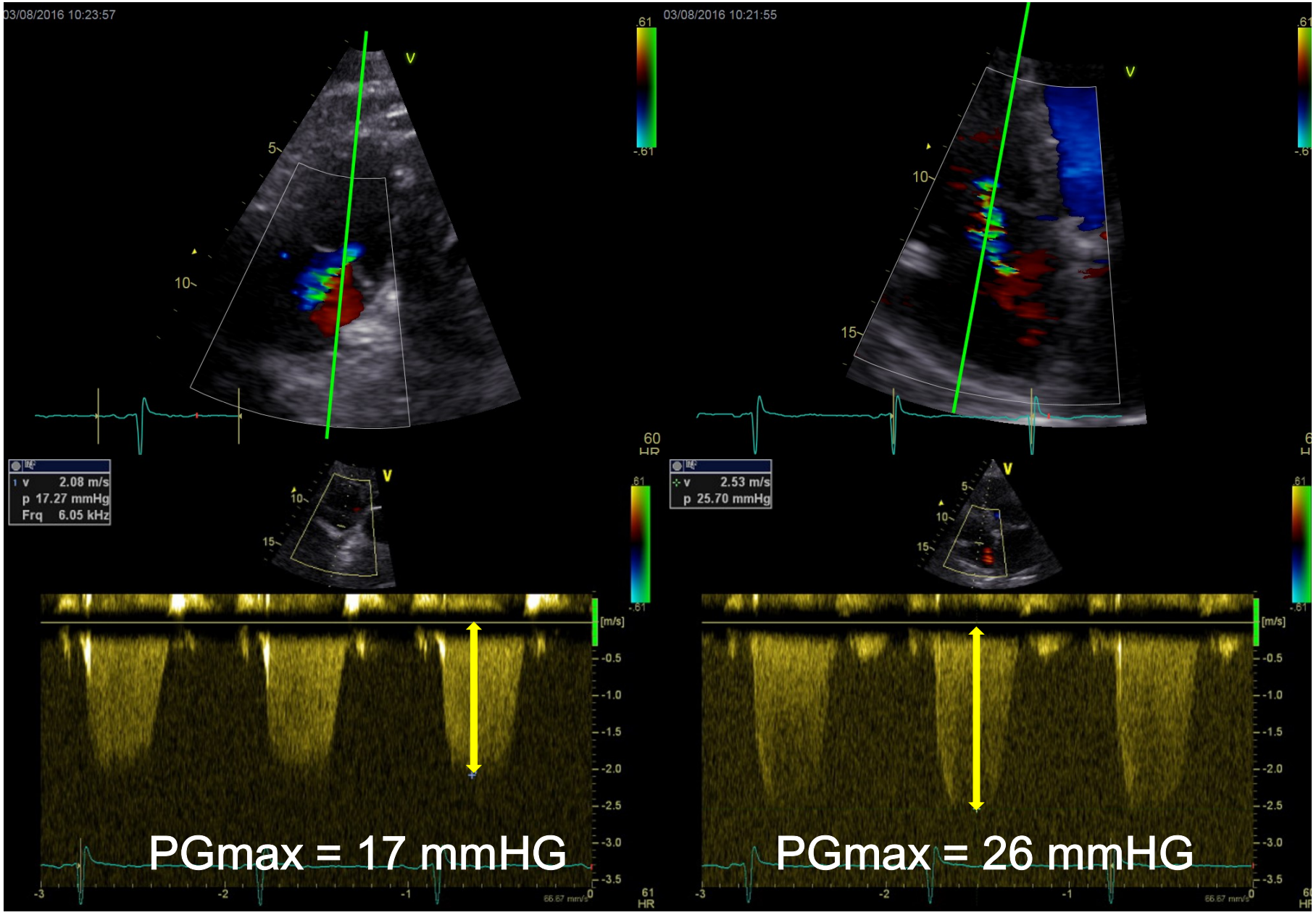
Angle dependence



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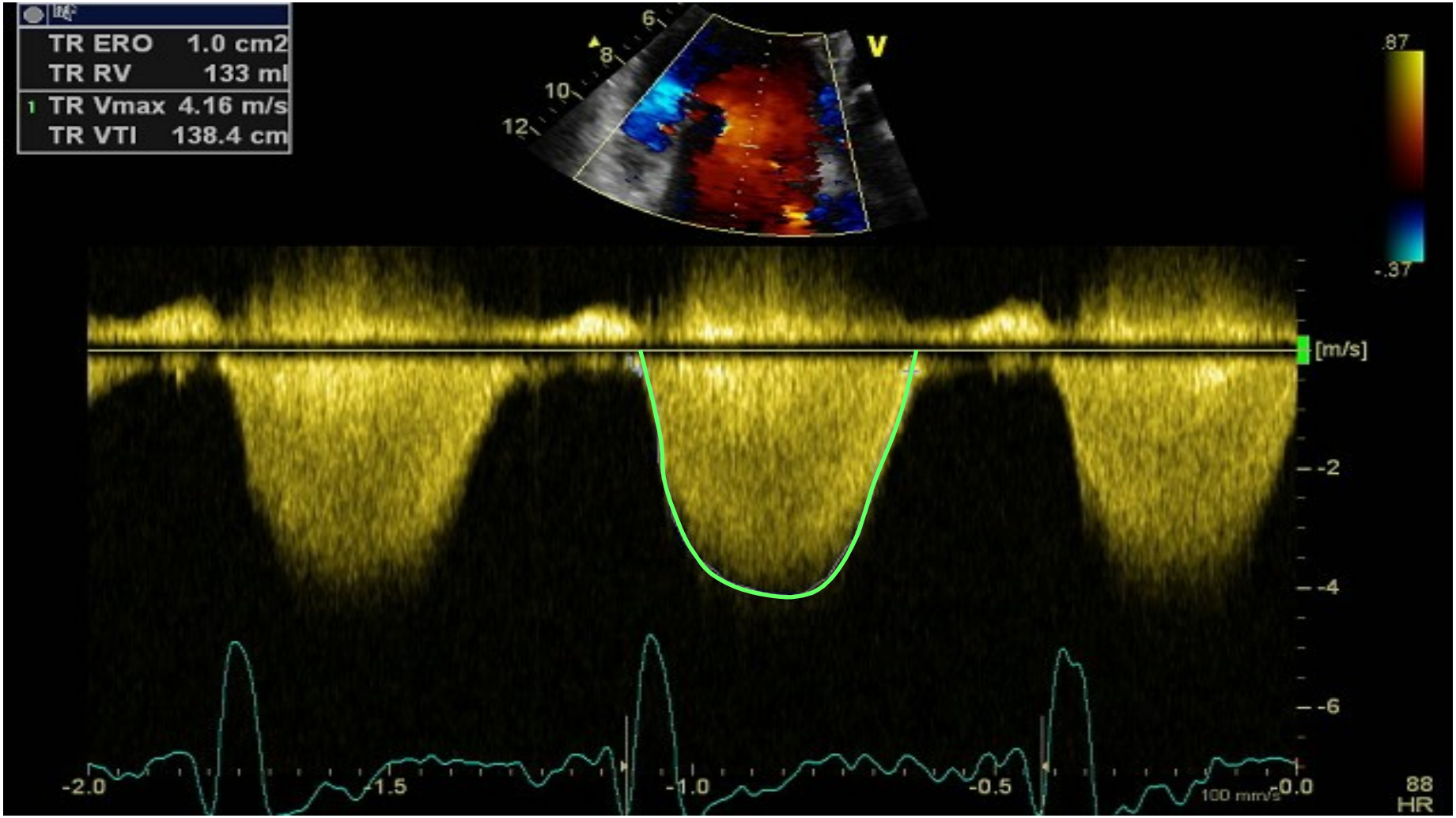
, Prague, CZ

Mean PAP estimation



$$MPAP = PG_{mean} + RAP_{estimate}$$

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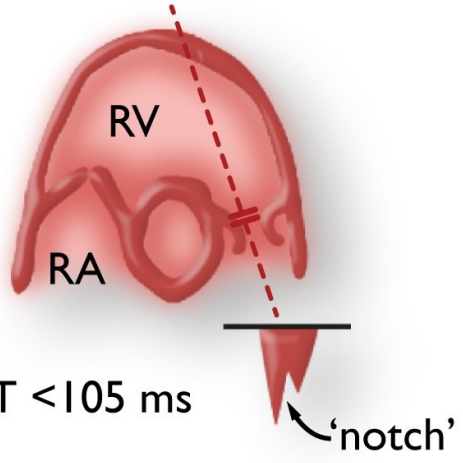
SECONDARY METHODS FOR DETECTION OF PULMONARY HYPERTENSION

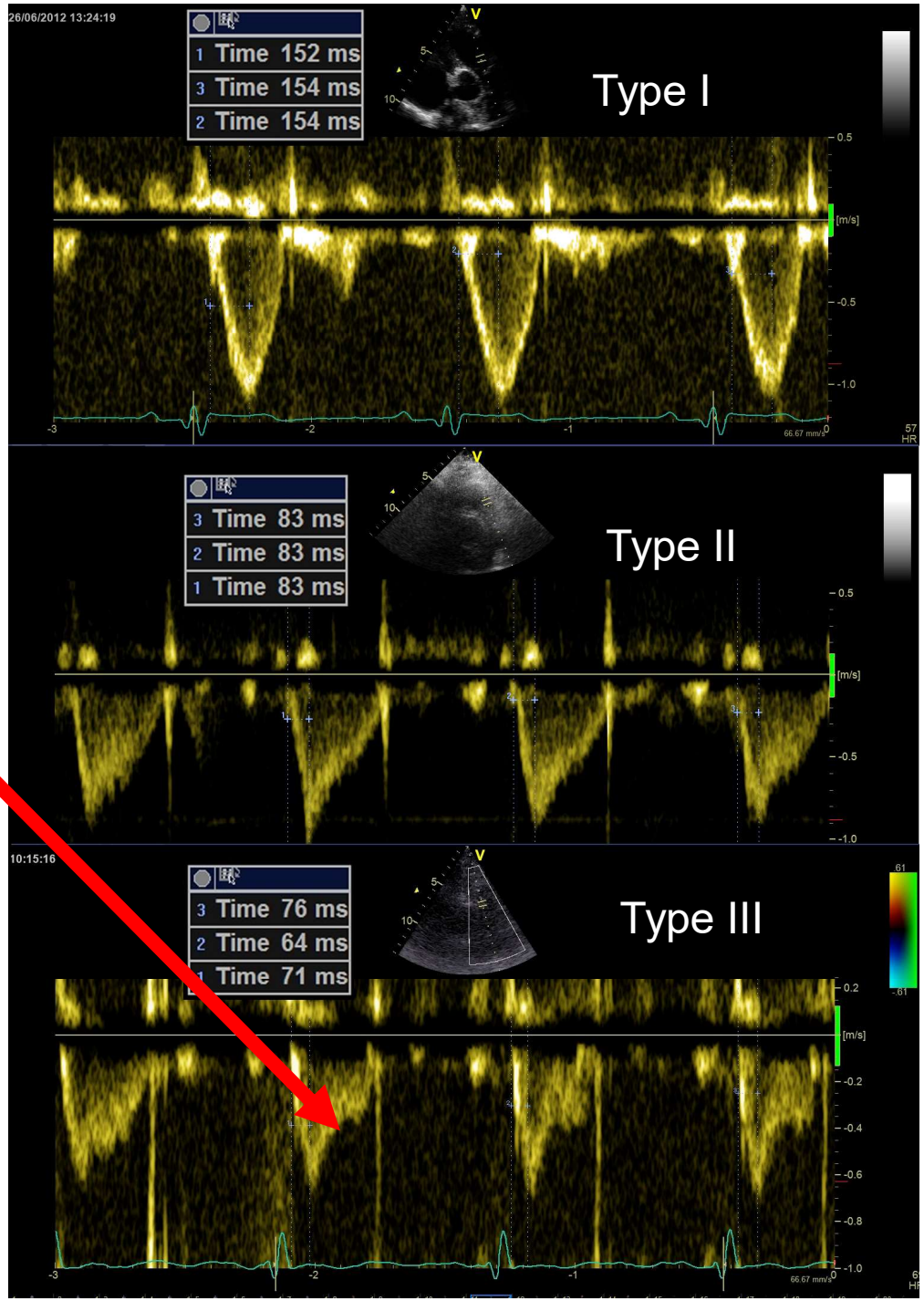
ypical characteristics of RV phenotype

hort acceleration time with notching



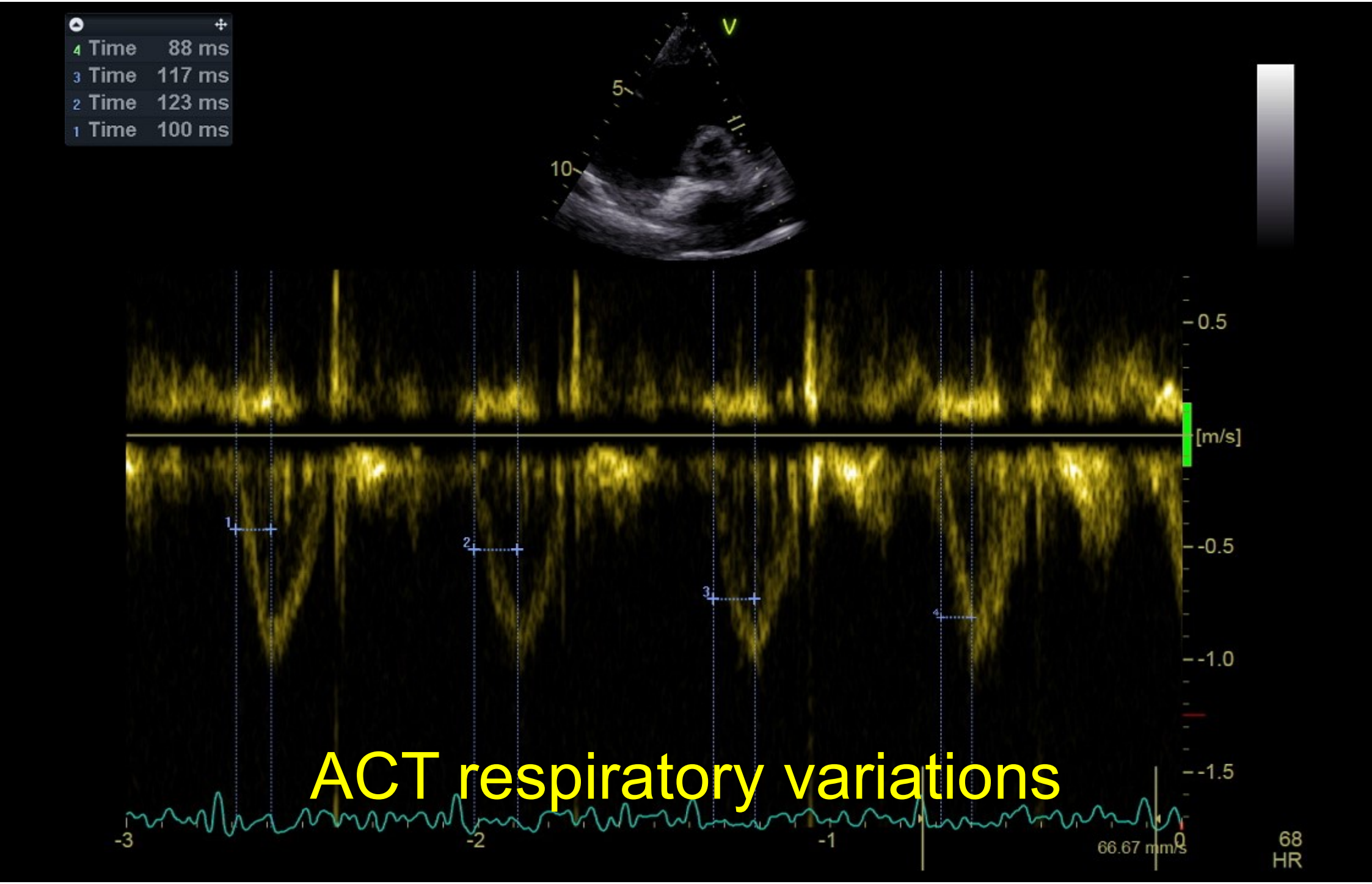
OT AT <105 ms

OT acceleration time of
monary ejection <105 ms
l-systolic 'notch' indicative of
-capillary PH



mbert M. et al. Eur Heart J. 2022;43:3618–3731

aging: General University Hospital, Prague, CZ


4 Time 88 ms
3 Time 117 ms
2 Time 123 ms
1 Time 100 ms
V
5
10
0.5
[m/s]
-0.5
-1.0
-1.5
1
2
3
4
-3
-2
-1
0
66.67 mm/s
68
HR
ACT respiratory variations

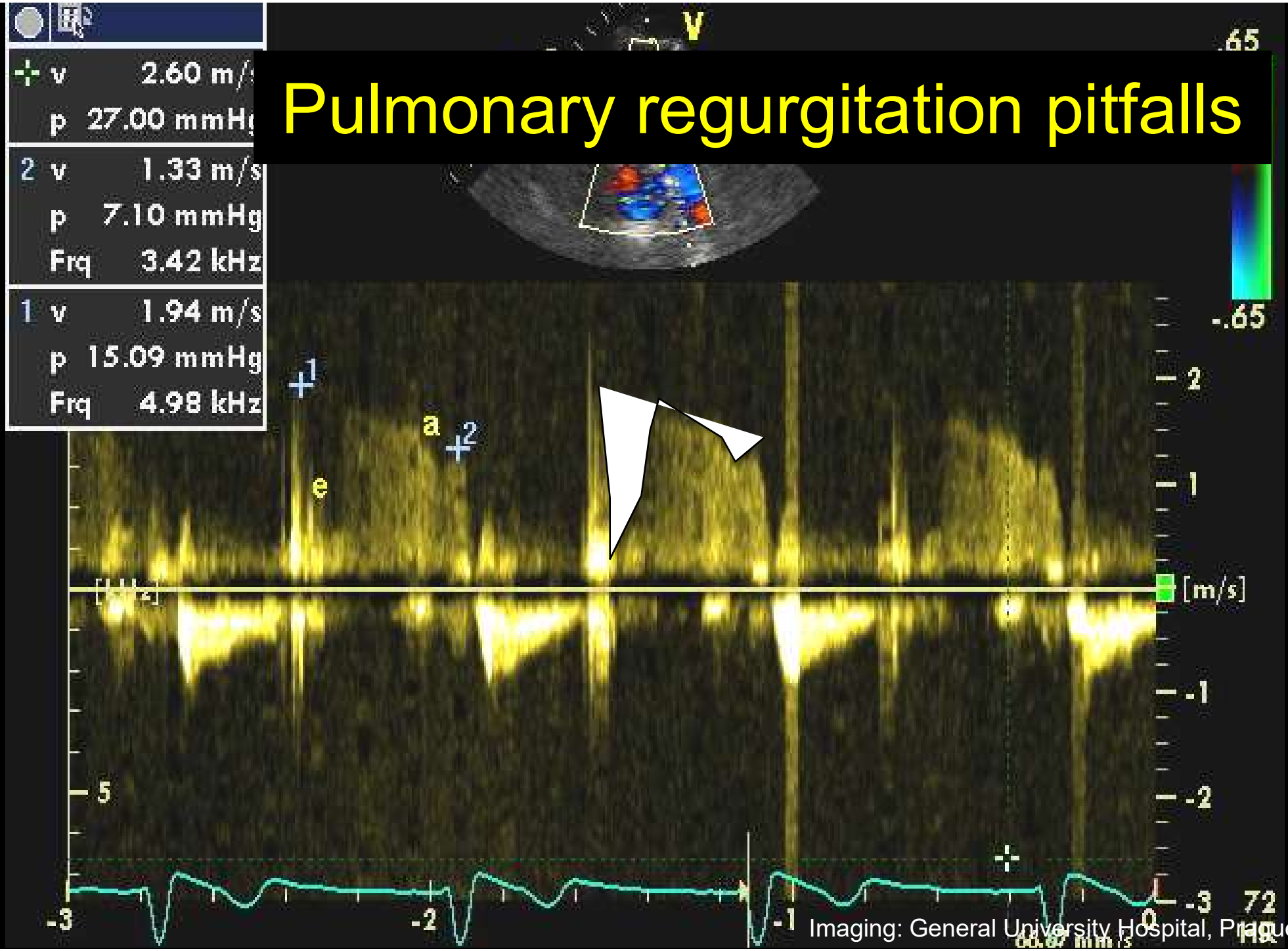
PAP estimates from pulmonary regurgitation

Early diastolic
pulmonary
regurgitation
velocity
>2.2 m/s*
(20 mmHg)

Humbert M. et al. Eur Heart J. 2022;43:3618–3731

Imaging: General University Hospital, Prague, CZ

Pulmonary regurgitation pitfalls



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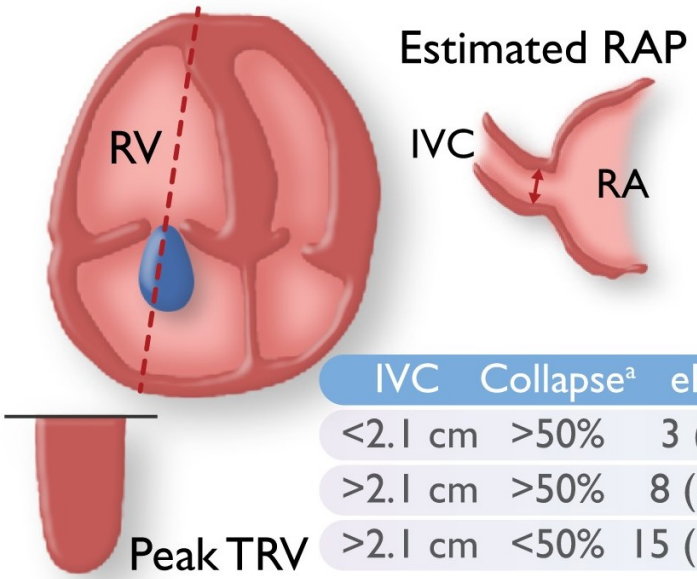


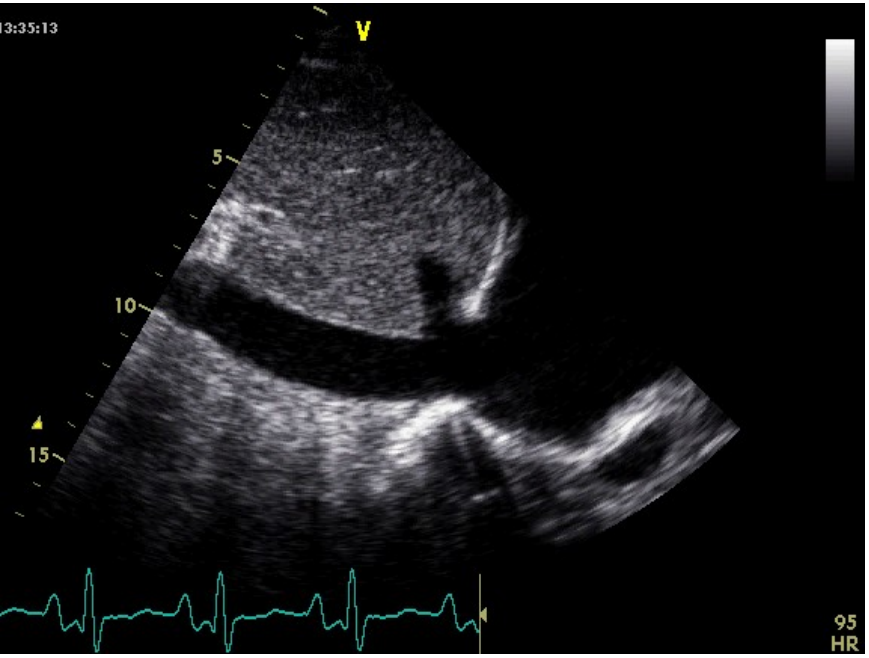
IVC	Collapse[a]	eRAP
<2.1 cm	>50%	3 (0-5)
>2.1 cm	>50%	8 (5-10)
>2.1 cm	<50%	15 (10-20)

Estimation of systolic pulmonary artery pressure (sPAP);
sPAP = TR pressure gradient + estimated RAP

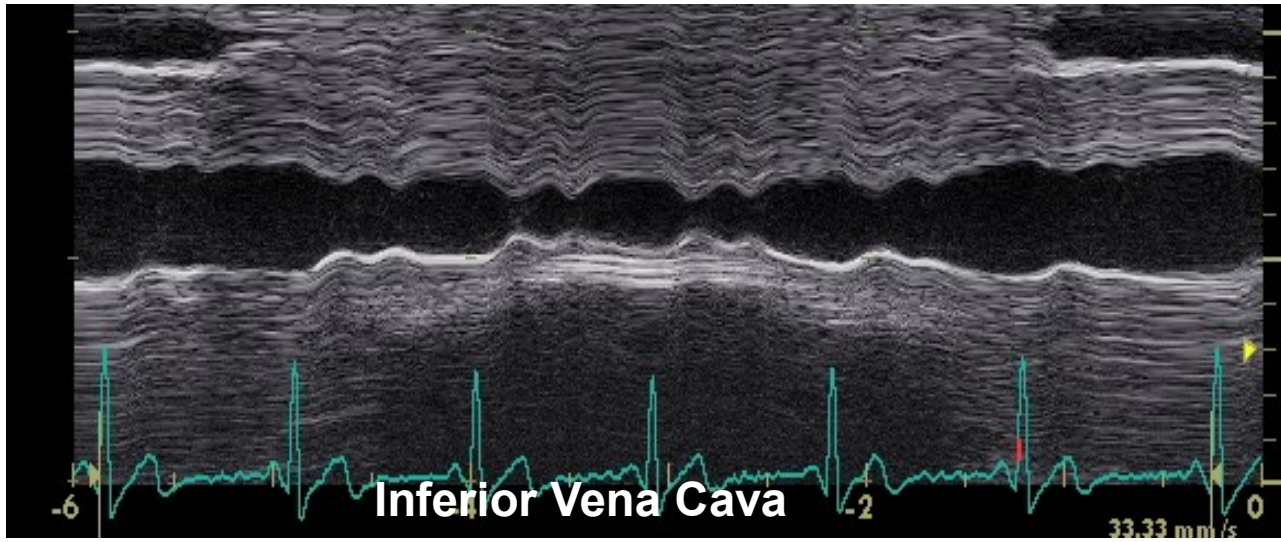
RIGHT ATRIAL PRESSURE

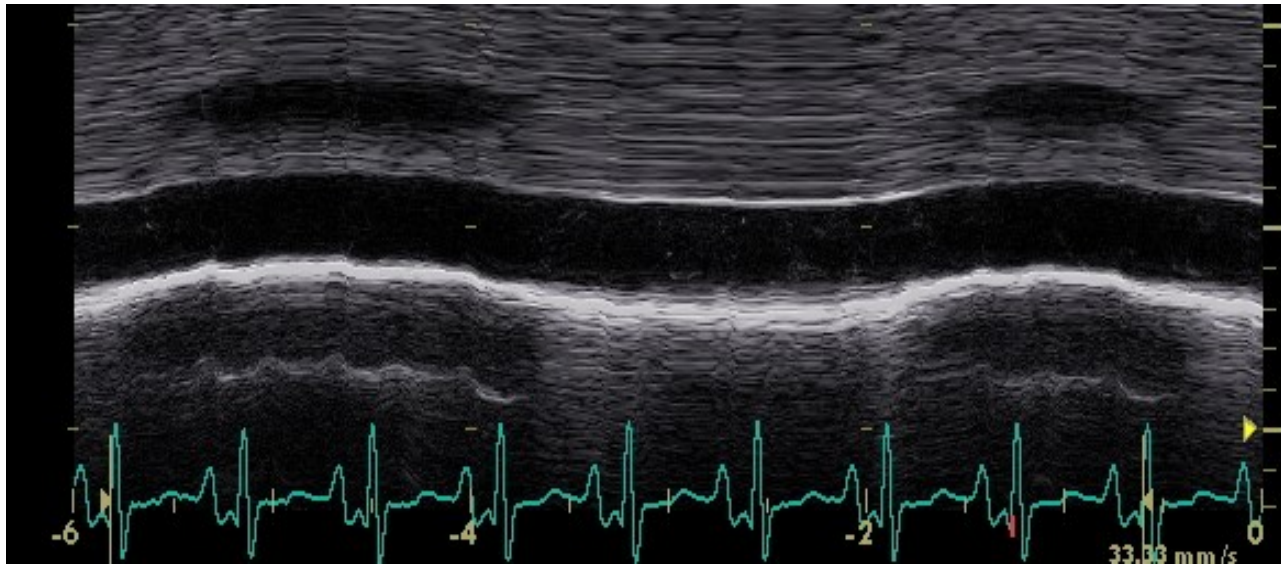
Vena cava diameter and collapsibility

Normal RAP



Elevated RAP





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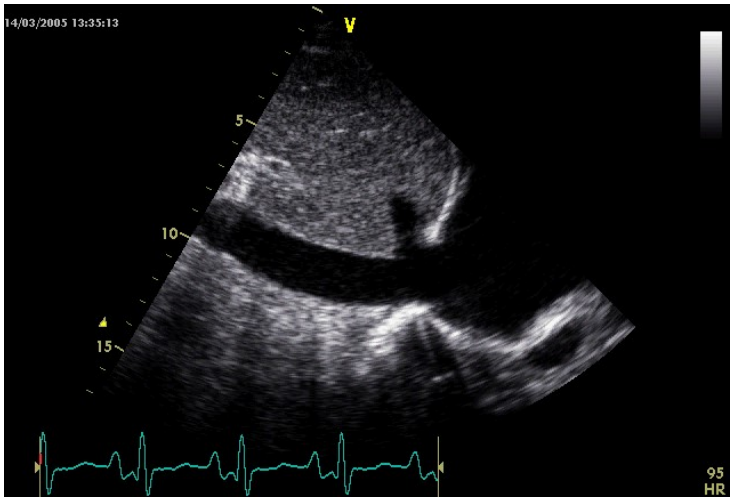
ASE/EAE 2010
RV filling pressures based on VCI assessments

RA pressure

	3 (0-5) **mmHg**	**8 mmHg**	**15** (10-20) **mmHg**
VCI diam.	≤ **21**	≤ 21 >	**> 21**
Collapse	**> 50%**	< 50% ≥	≤ **50 %**

Secondary parameters

- RV restrictive filling
- E/Et > 6
- D wave dominance in HV



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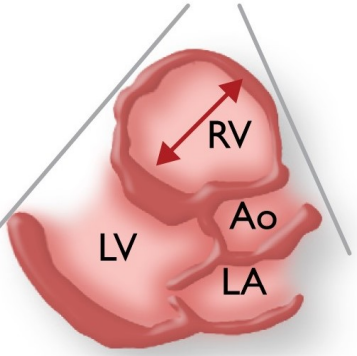
INDIRECT SIGNS OF PULMONARY HYPERTENSION

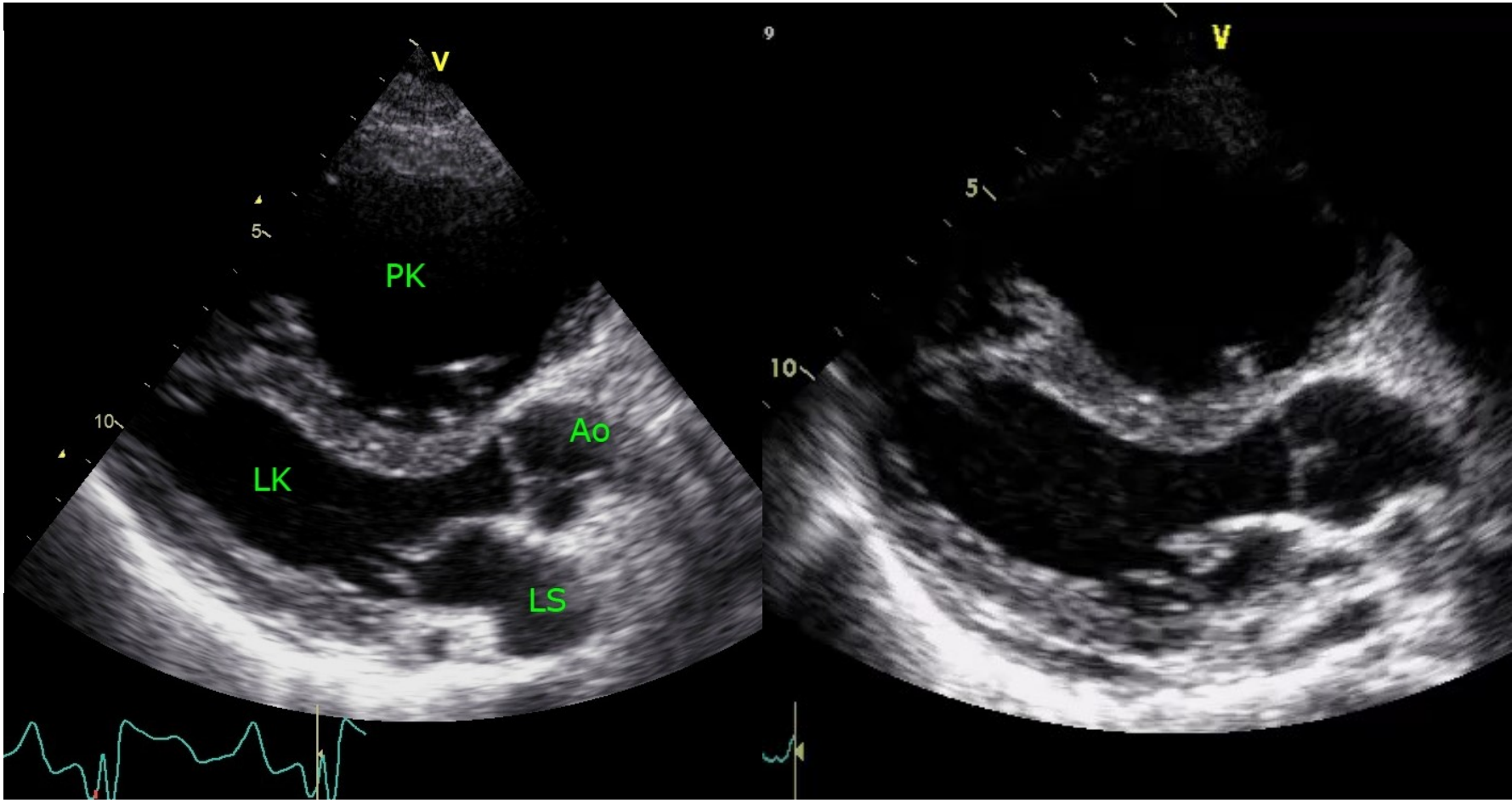
STRUCTURAL CHANGES

Typical characteristics of RV phenotype

Large RV, compressed IVS, smaller left atrial size



arged right ventricle;
asternal long-axis view



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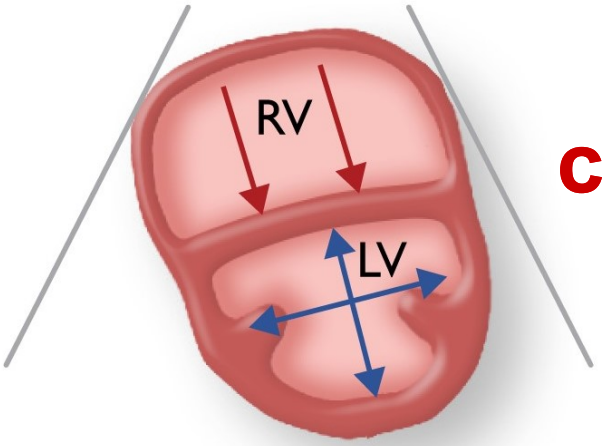

Typical characteristics of RV phenotype

D-shape

ttened interventricular septum
rows) leading to 'D-shaped' LV;
creased LV eccentricity index;
rasternal short-axis view

Flattening of the
nterventricular septum
(LVEI >1.1 in systole
and/or diastole)

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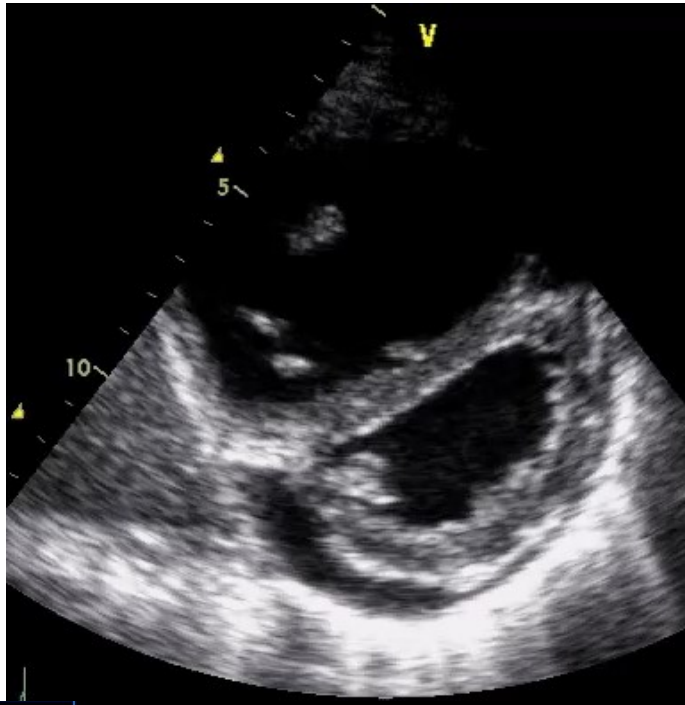

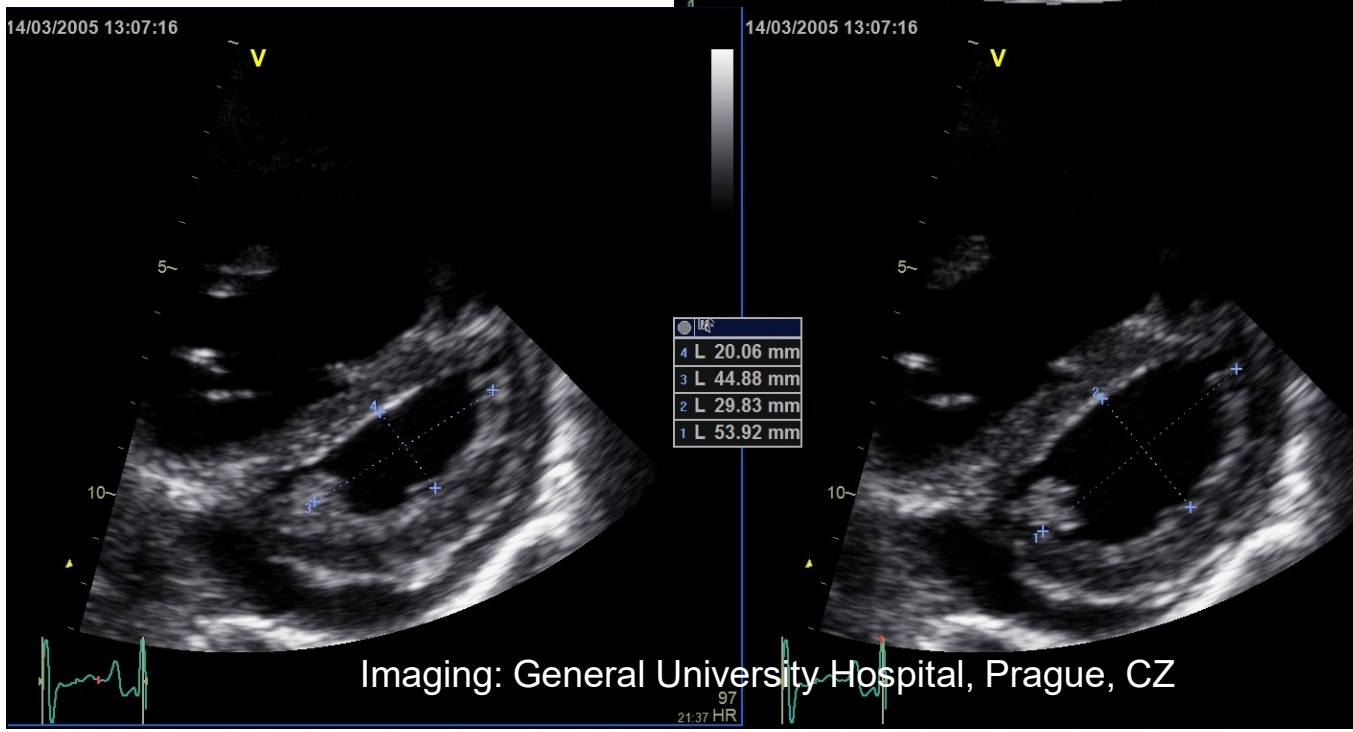

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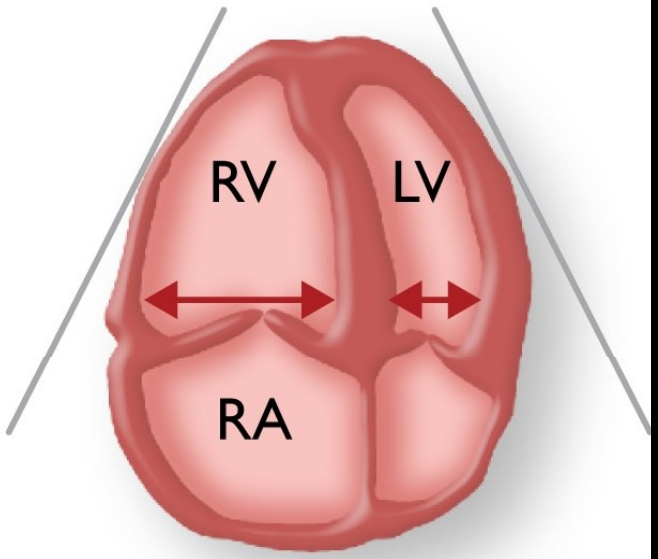
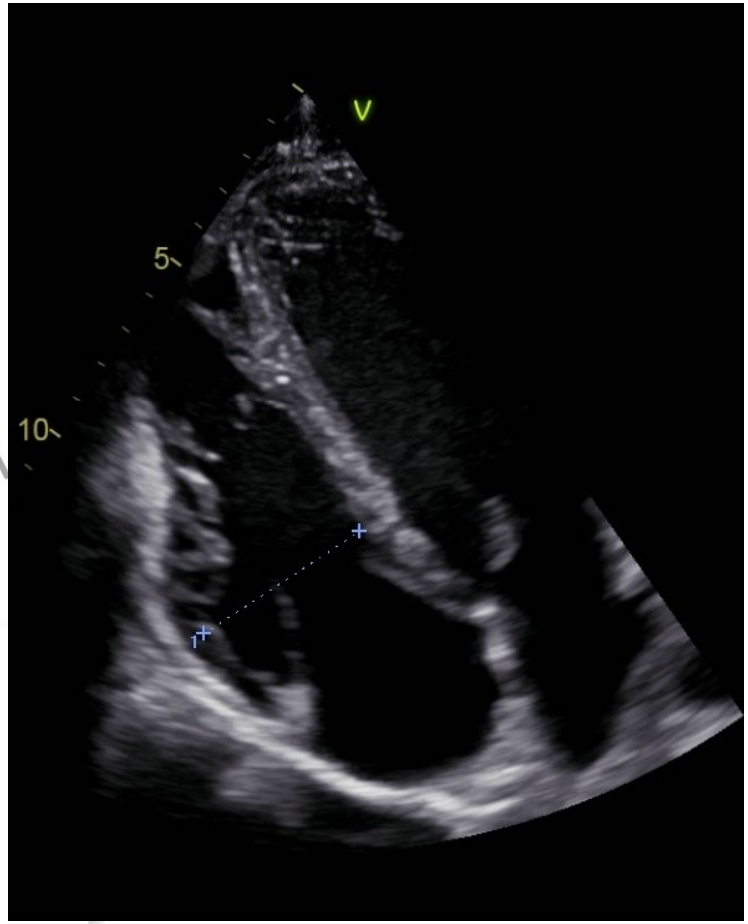
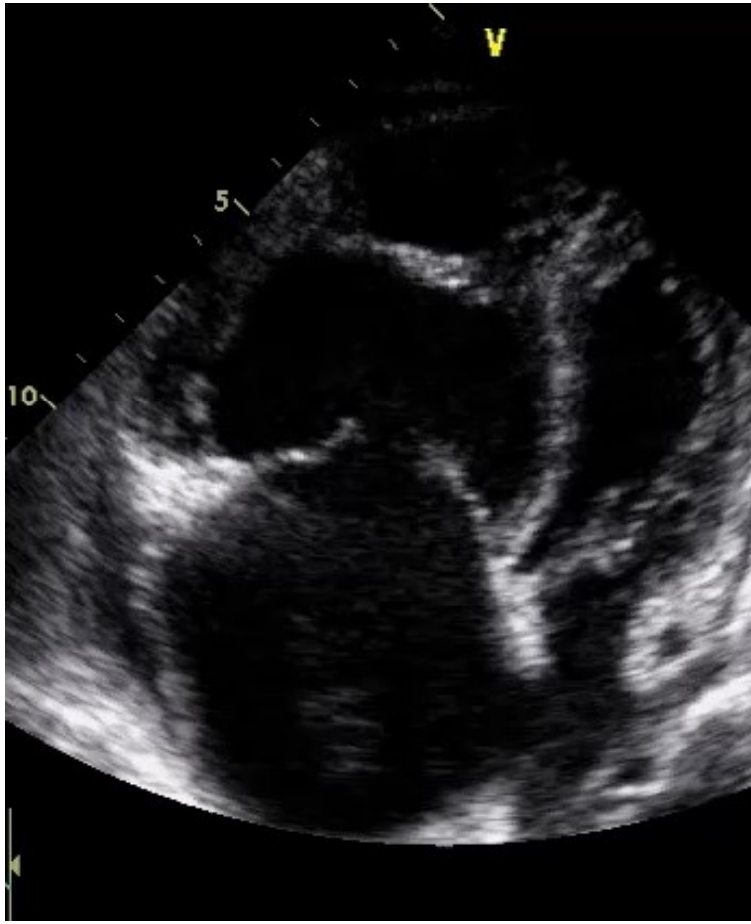
Typical characteristics of RV phenotype

RV > LV, apex formed by RV



Dilated RV with basal RV/LV
ratio >1.0;
four-chamber view





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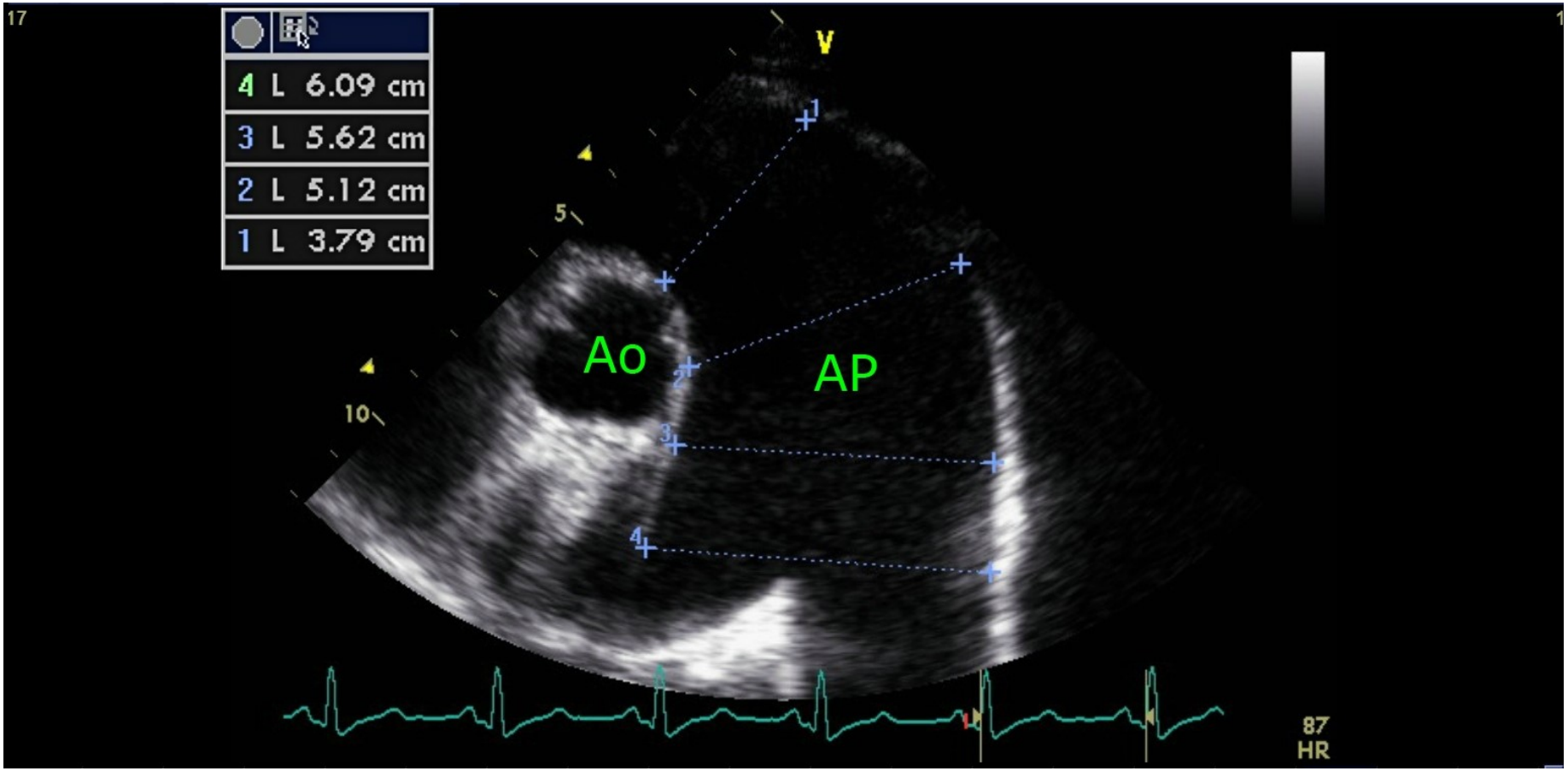
Pulmonary artery dilatation

PA diameter >AR diameter*

PA diameter >25 mm*



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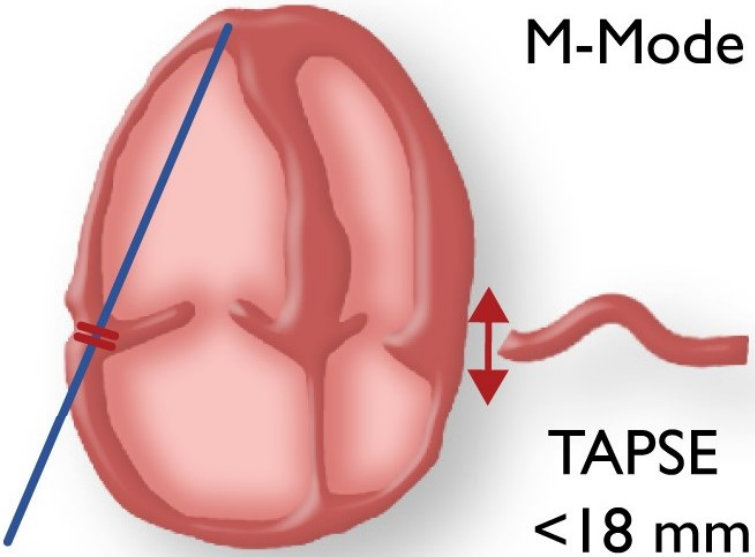
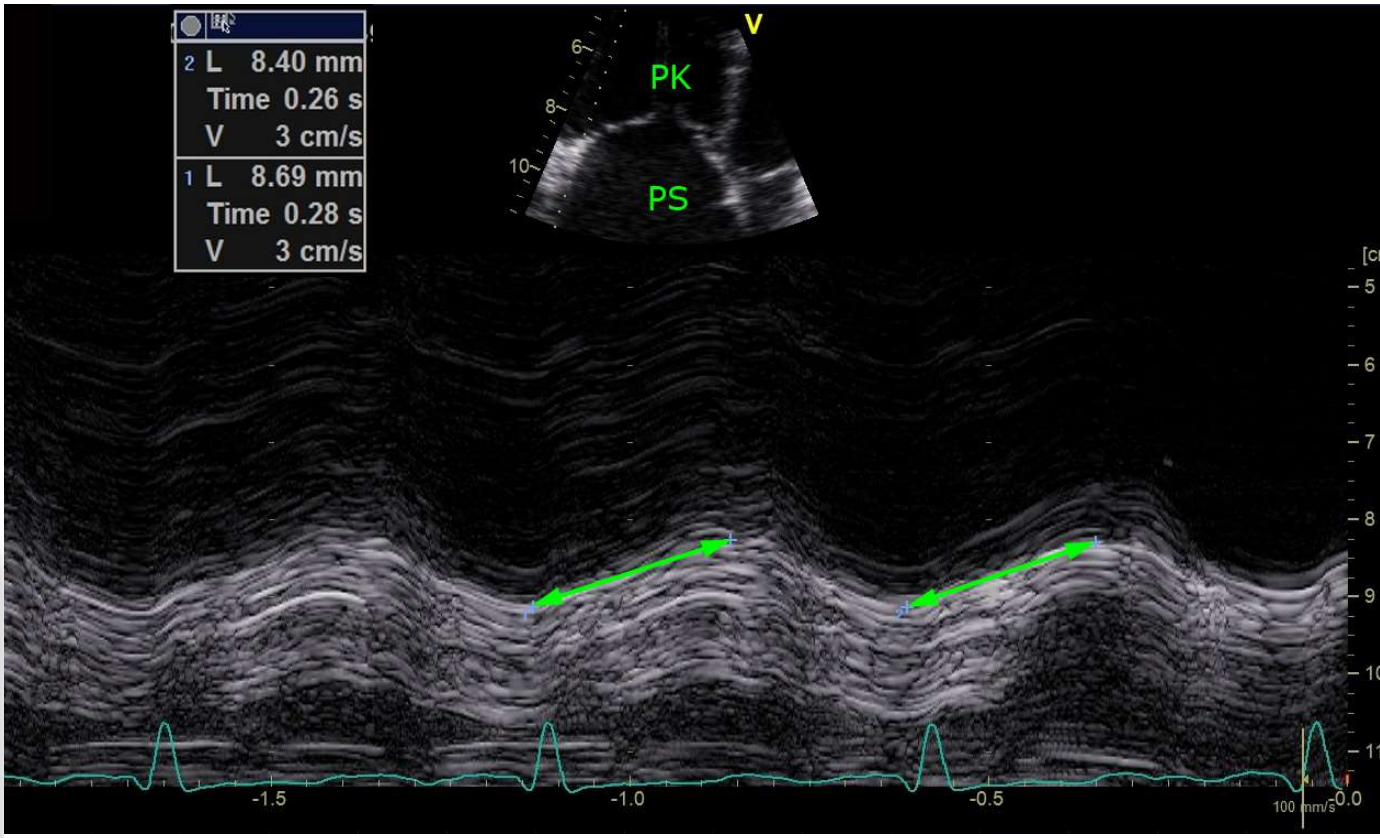
FUNCTIONAL CHANGES

Typical characteristics of RV phenotype

RV more often dysfunctional

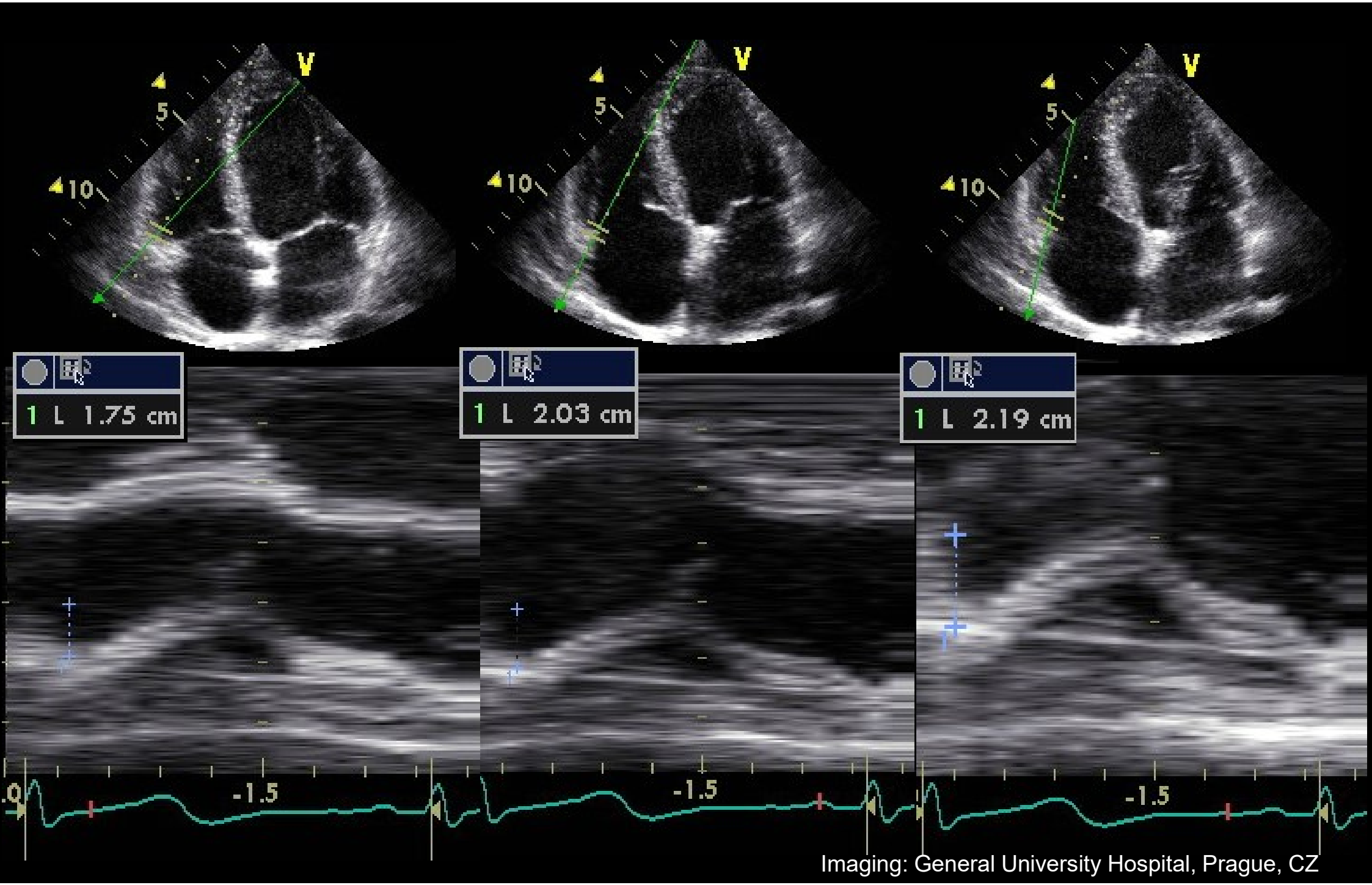


creased tricuspid annular
ne systolic excursion (TAPSE)
asured with M-Mode (<18 mm)

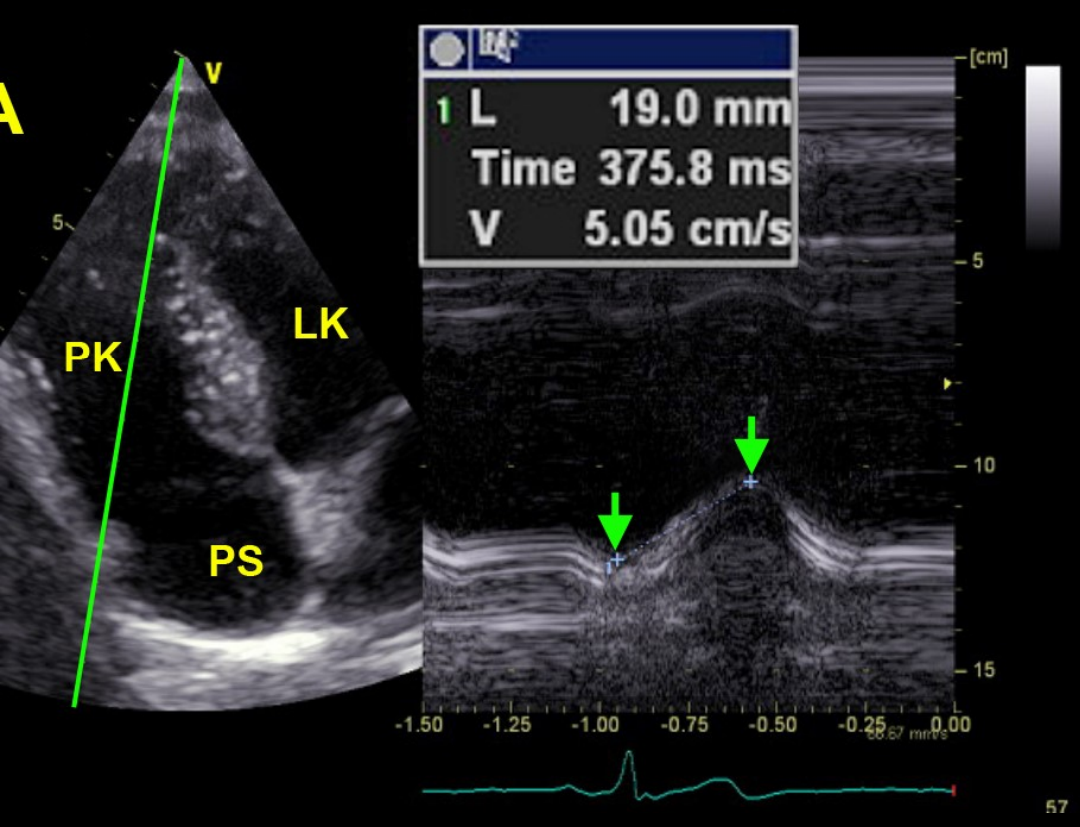


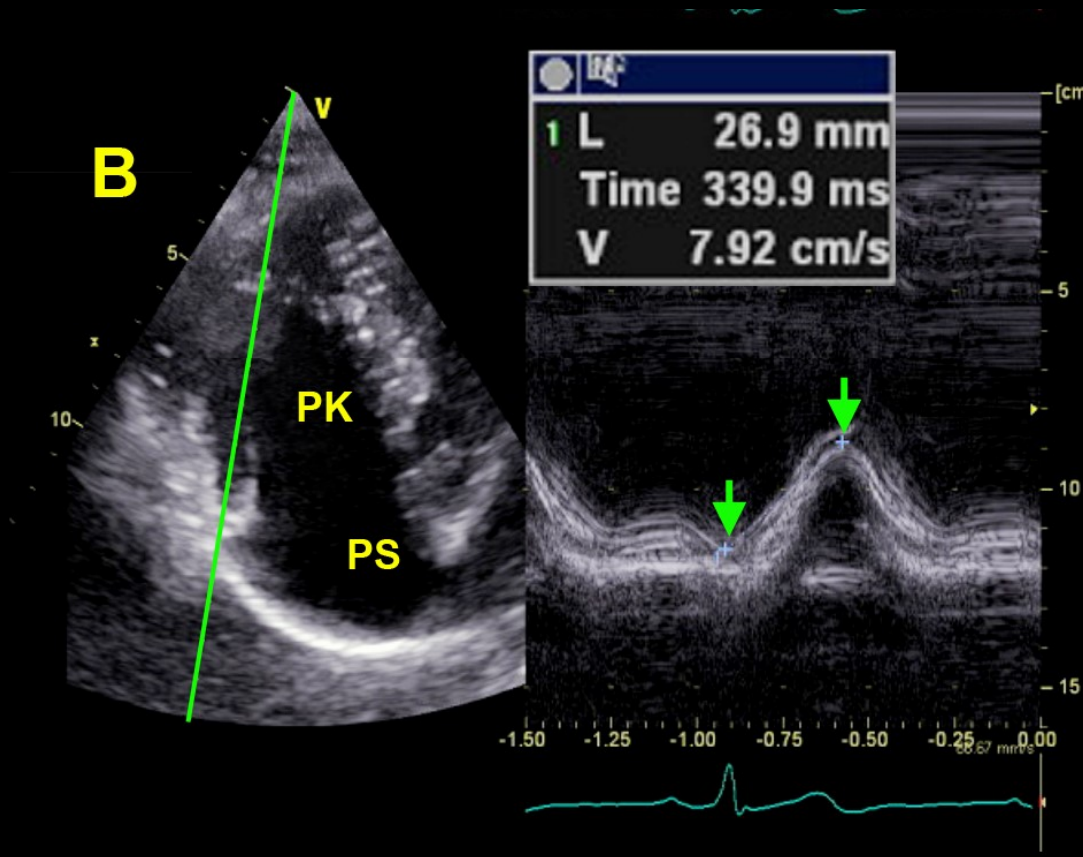
mbert M. et al. Eur Heart J. 2022;43:3618–3731

Imaging: General University Hospital, Prague, CZ


V
5
10
1 L 1.75 cm
1 L 2.03 cm
1 L 2.19 cm
-1.5
-1.5
-1.5
Imaging: General University Hospital, Prague, CZ

Angle dependence of TAPSE





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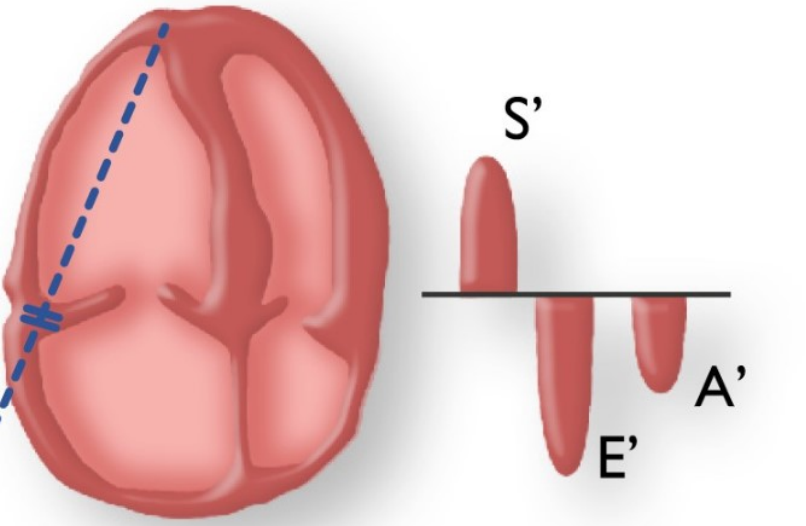
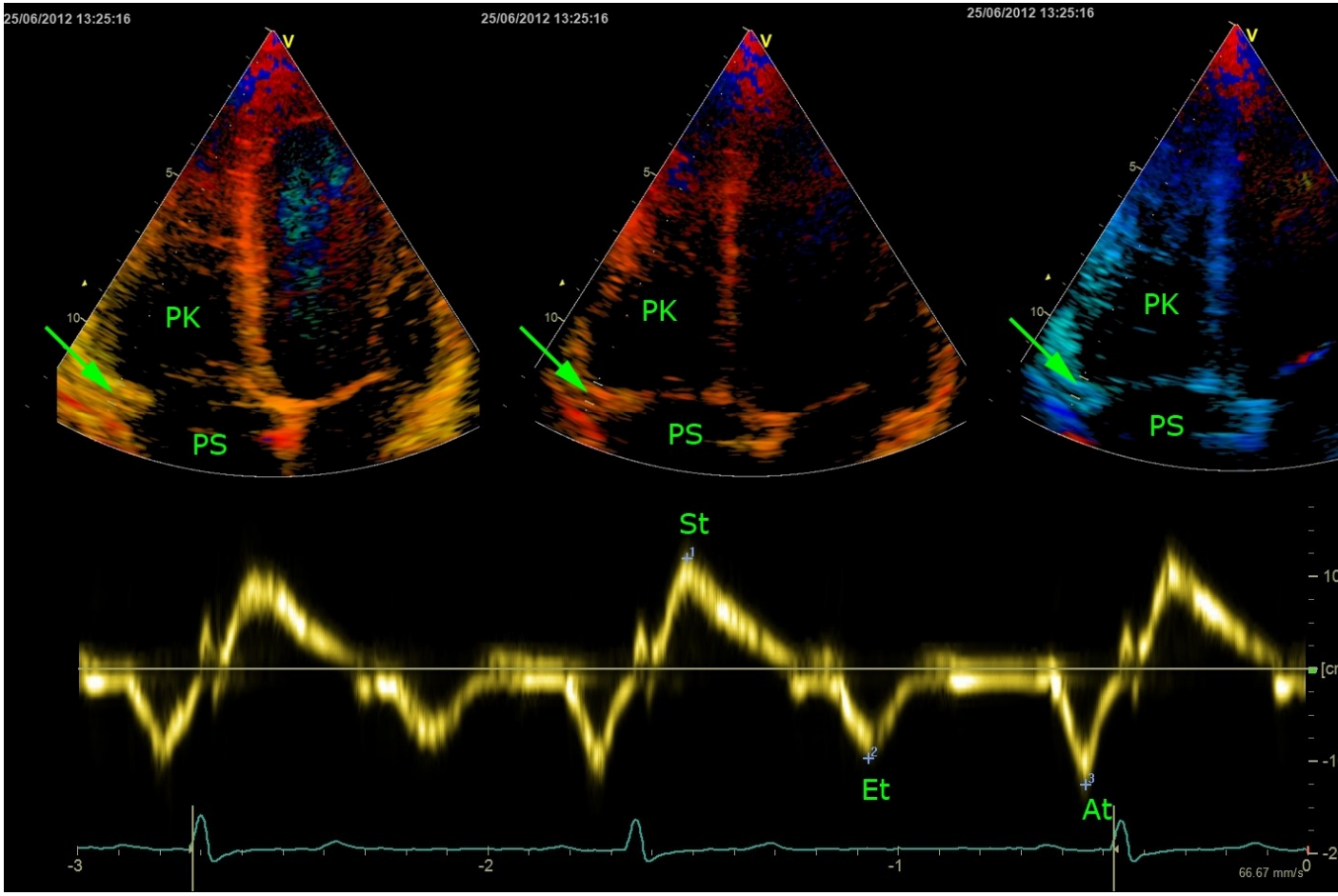
TDI – systolic velocity of TR annulus



S' <9.5 cm/s

Decreased peak systolic (S') velocity of tricuspid annulus (<9.5 cm/s) measured with tissue Doppler



mbert M. et al. Eur Heart J. 2022;43:3618–3731

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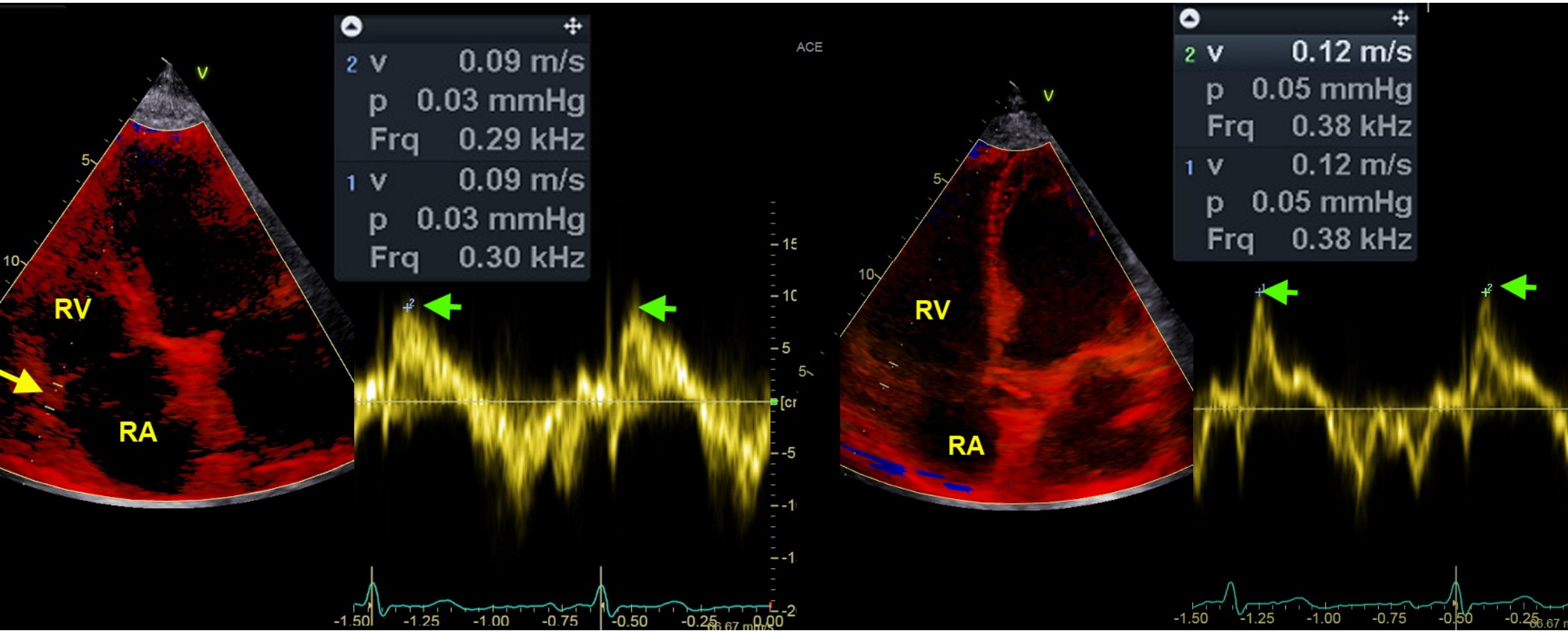
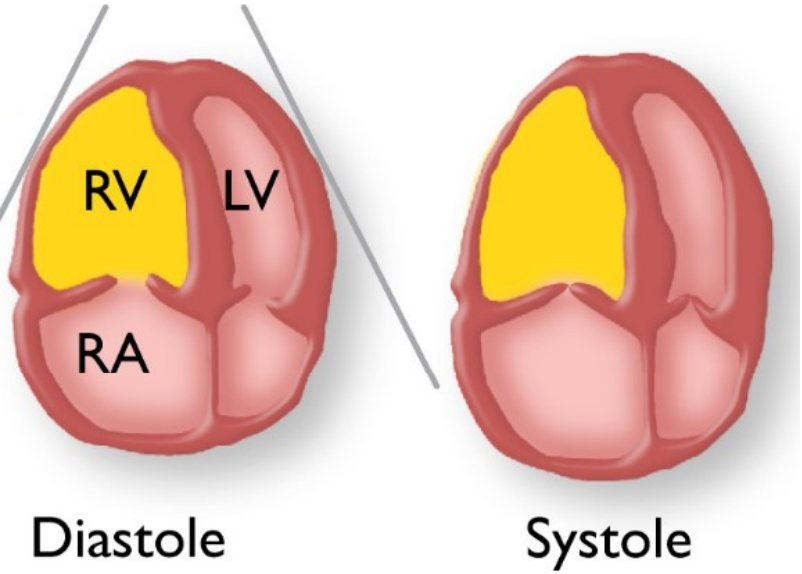
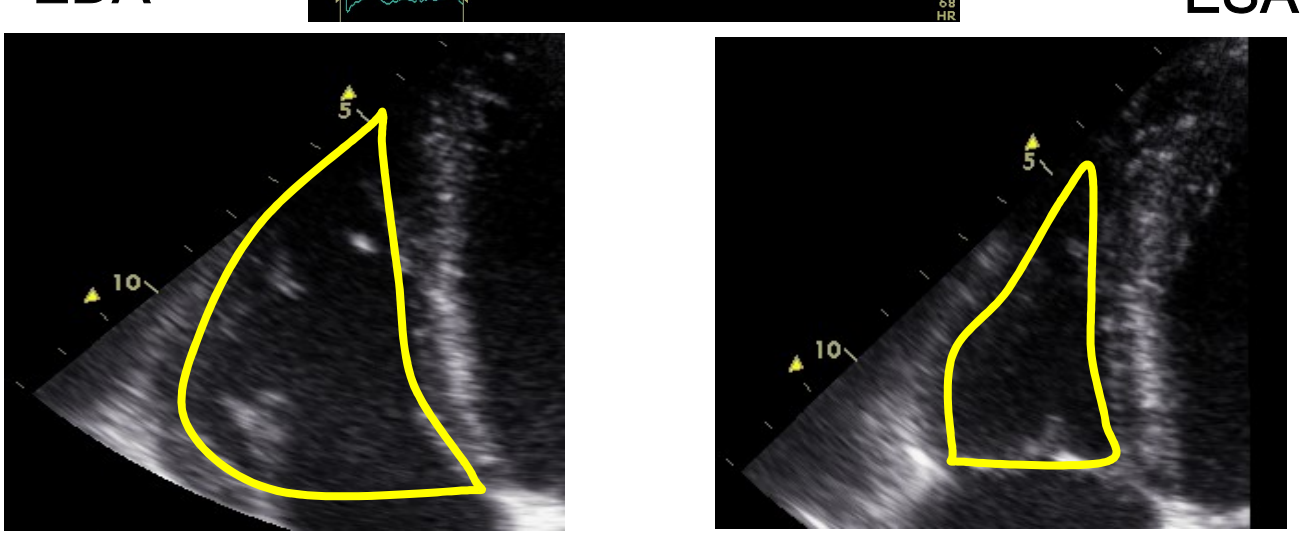
Angle-dependence of annular motion velocities



RV Systolic Function
Fractional Area Change



educed right ventricular
actional area change (<35%);
ur-chamber view



FAC = (EDA-ESA)/EDA x 100

FAC ≥ 35%

mbert M. et al. Eur Heart J. 2022;43:3618–3731

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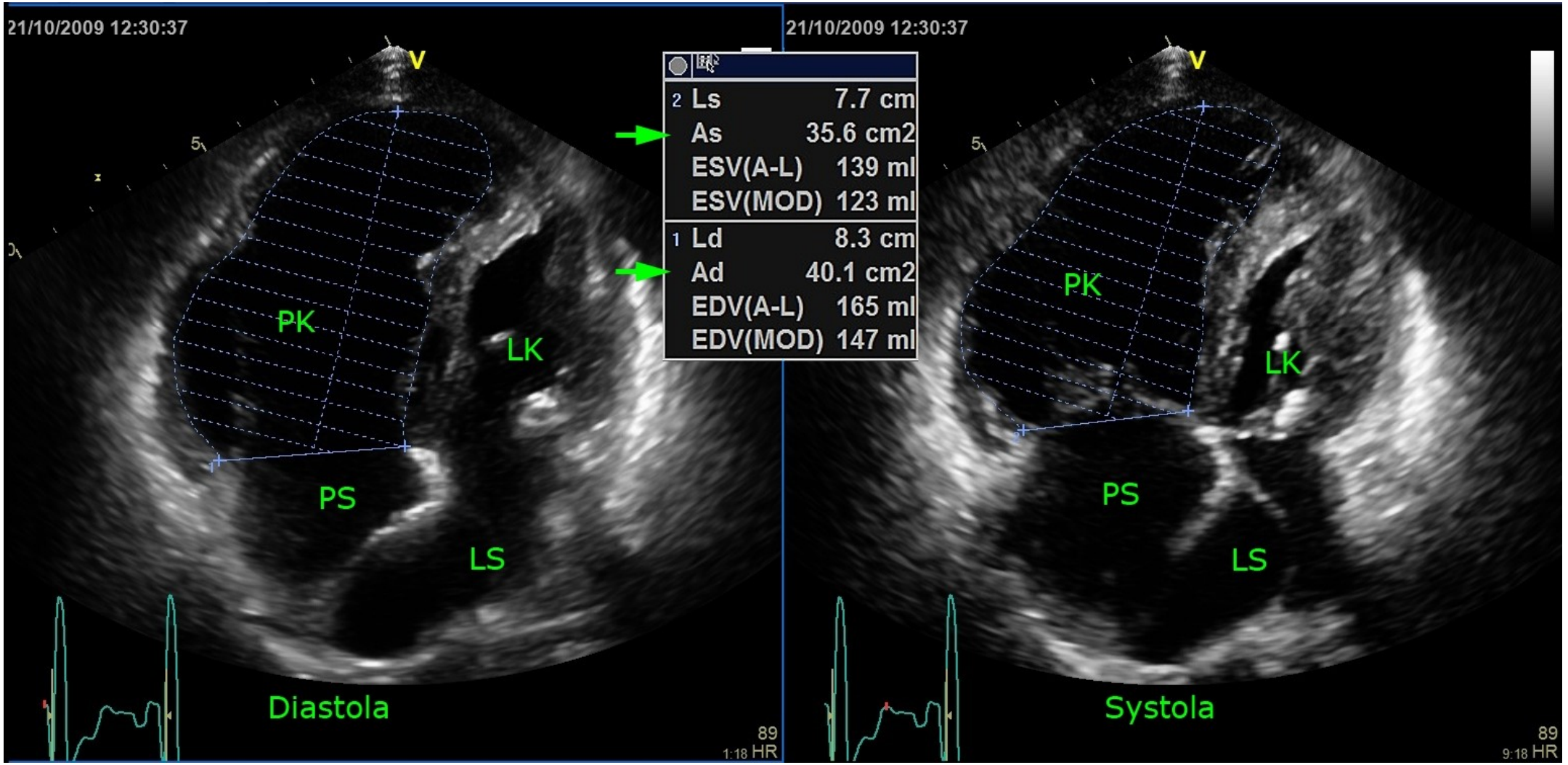
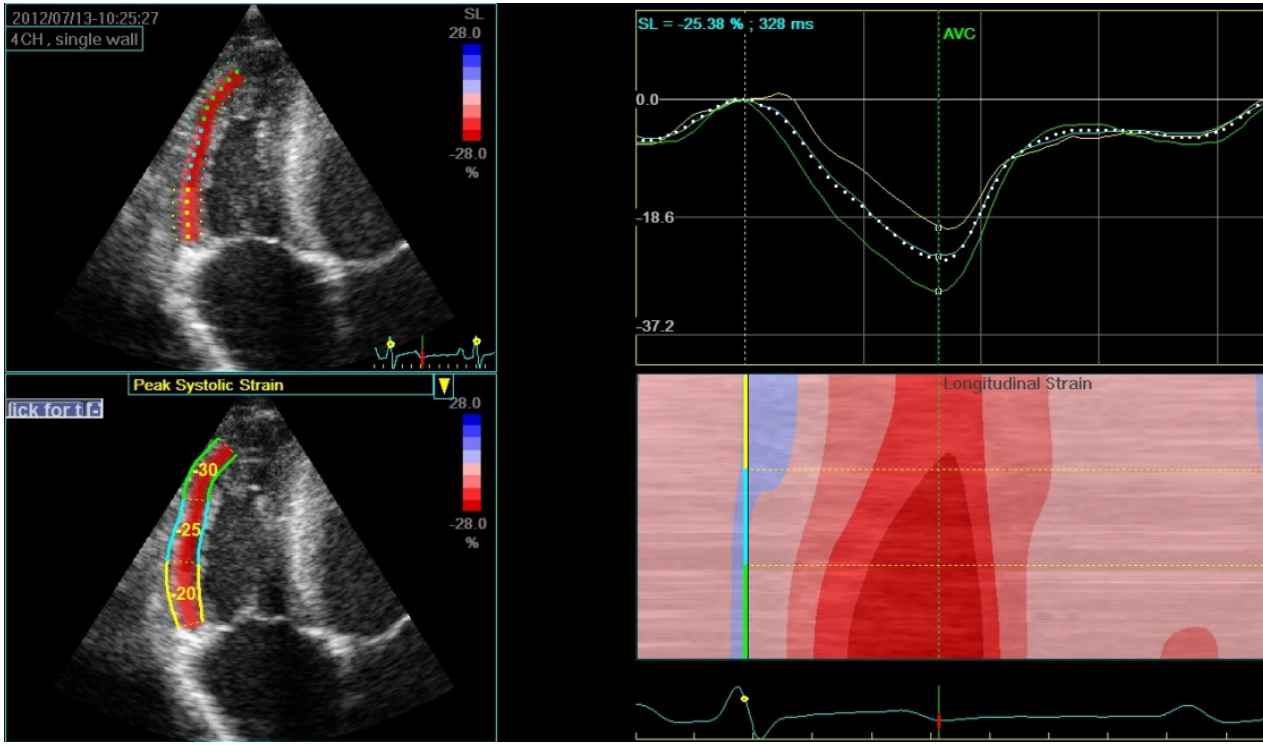
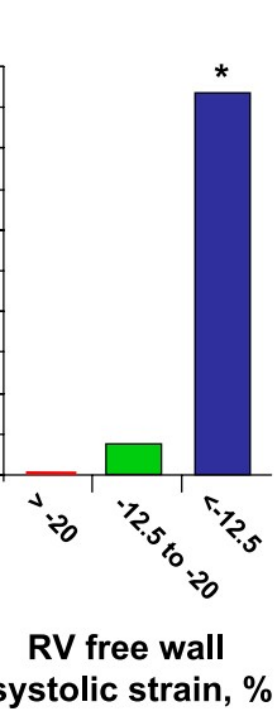
Fractional area change

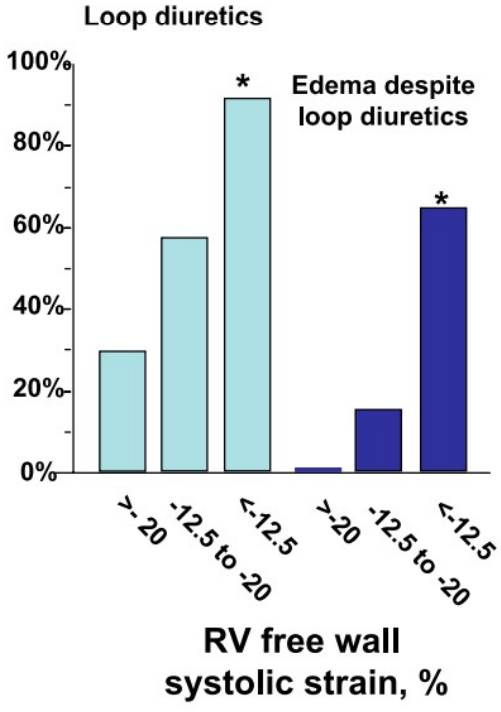


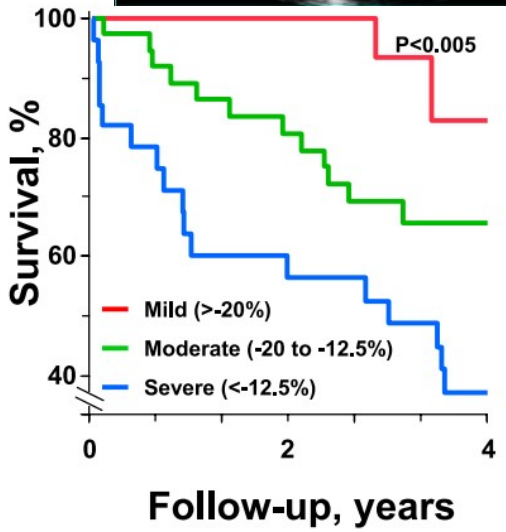
Imaging: General University Hospital, Prague, CZ

Right ventricular strain





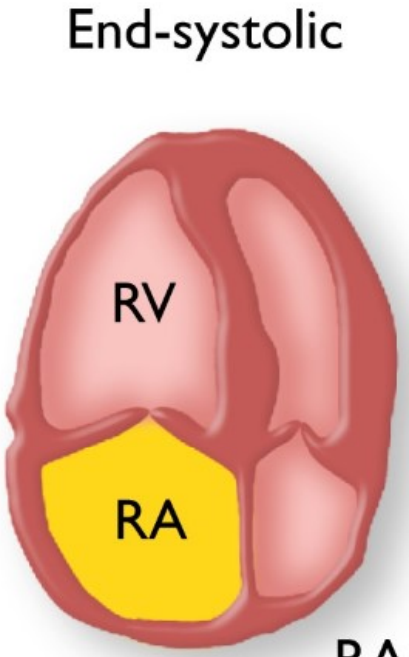




Sachdev A et al. Chest. 2011 Jun;139(6):1299

Imaging: General University Hospital, Prague

Right atrial dilatation



Ventricular end-systole
(the greatest RA volume)

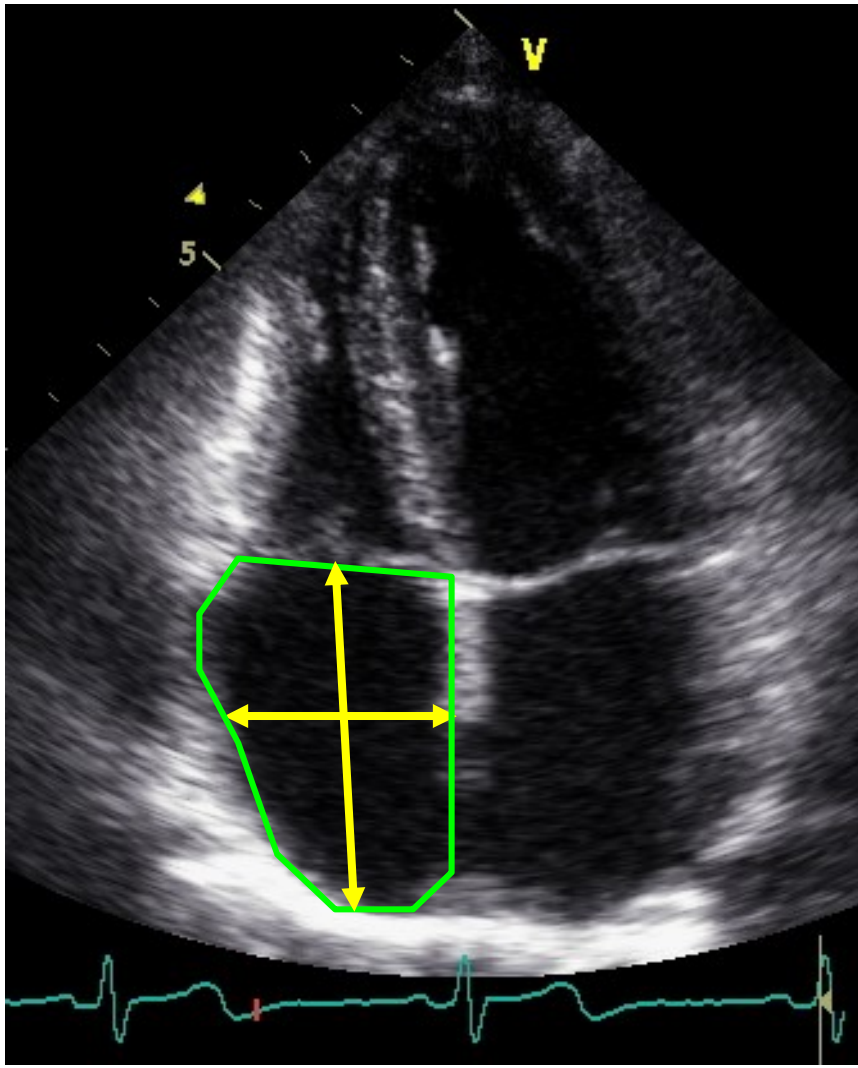
Right atrial dilatation:

area > 18 cm^2

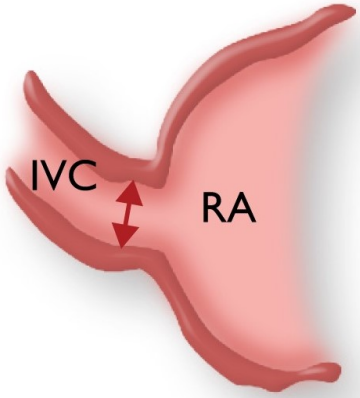
transverse diameter > 44 mm

long diameter > 53 mm

nlarged right atrial area
>18 cm^2);
our-chamber view

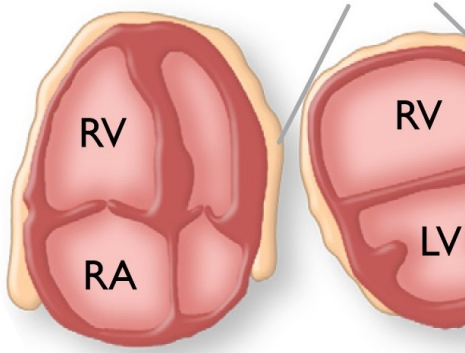


mbert M. et al. Eur Heart J. 2022;43:3618–3731



Typical characteristics of RV phenotype

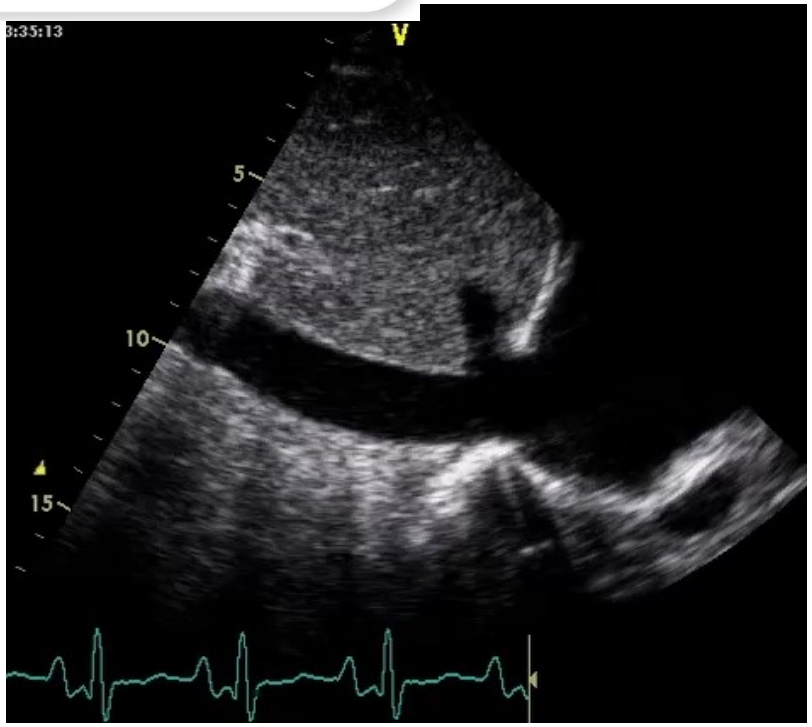
Impaired RV filling and pericardial effusion

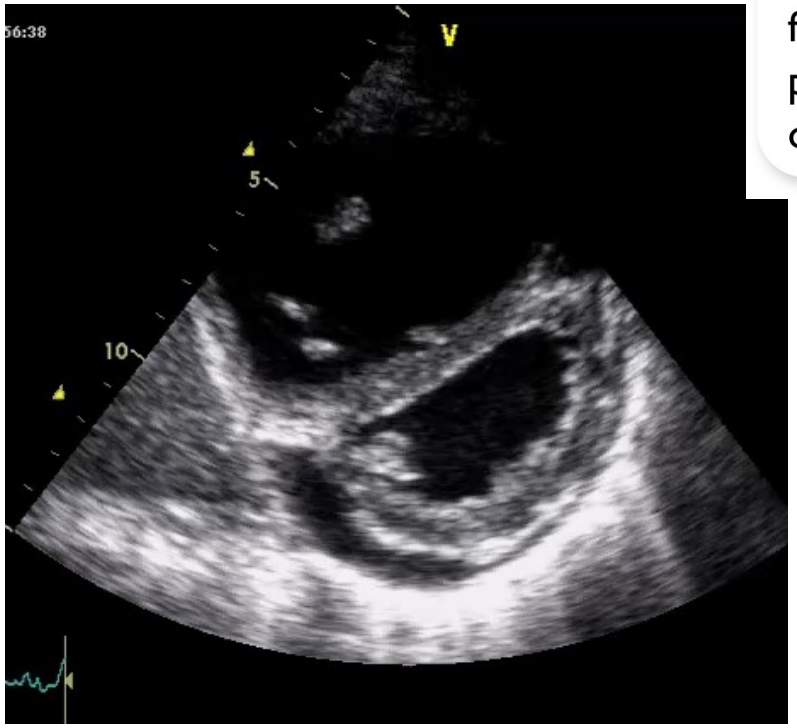


stended inferior vena cava
th diminished inspiratory
lapsibility; subcostal view

Humbert M. et al. Eur Heart J. 2022;43:3618–3731

Presence of pericardial effus
four-chamber view;
parasternal short-axis view;
other views (e.g. subcostal v

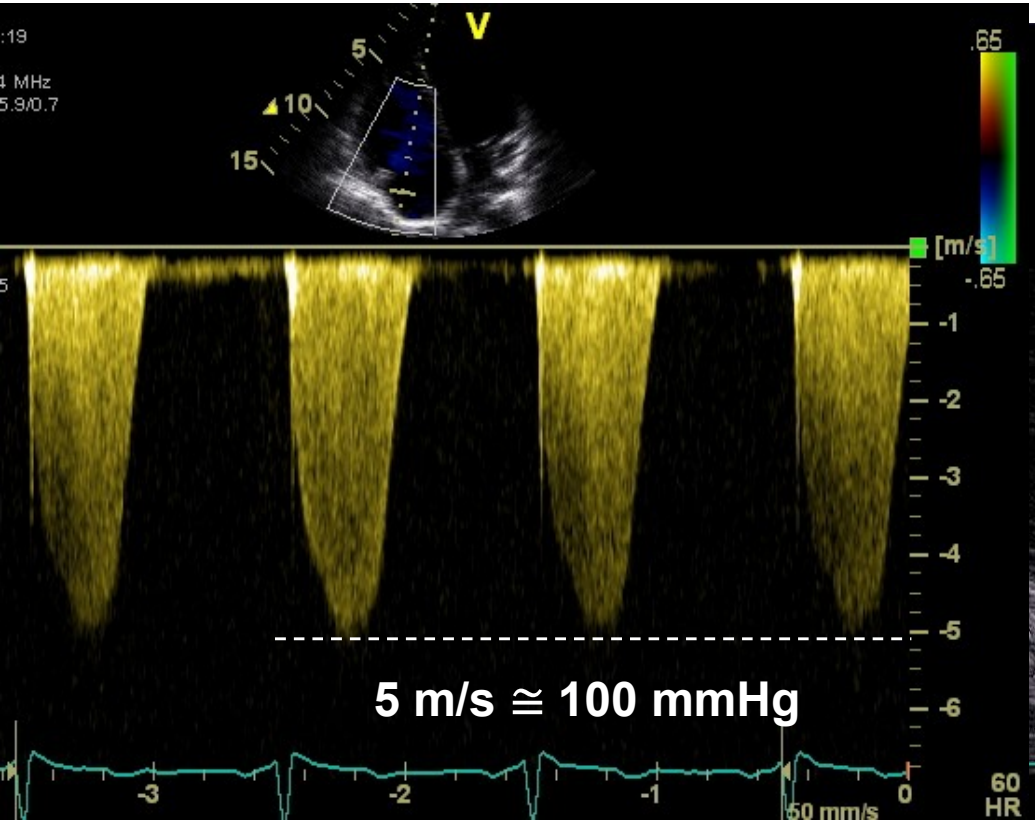


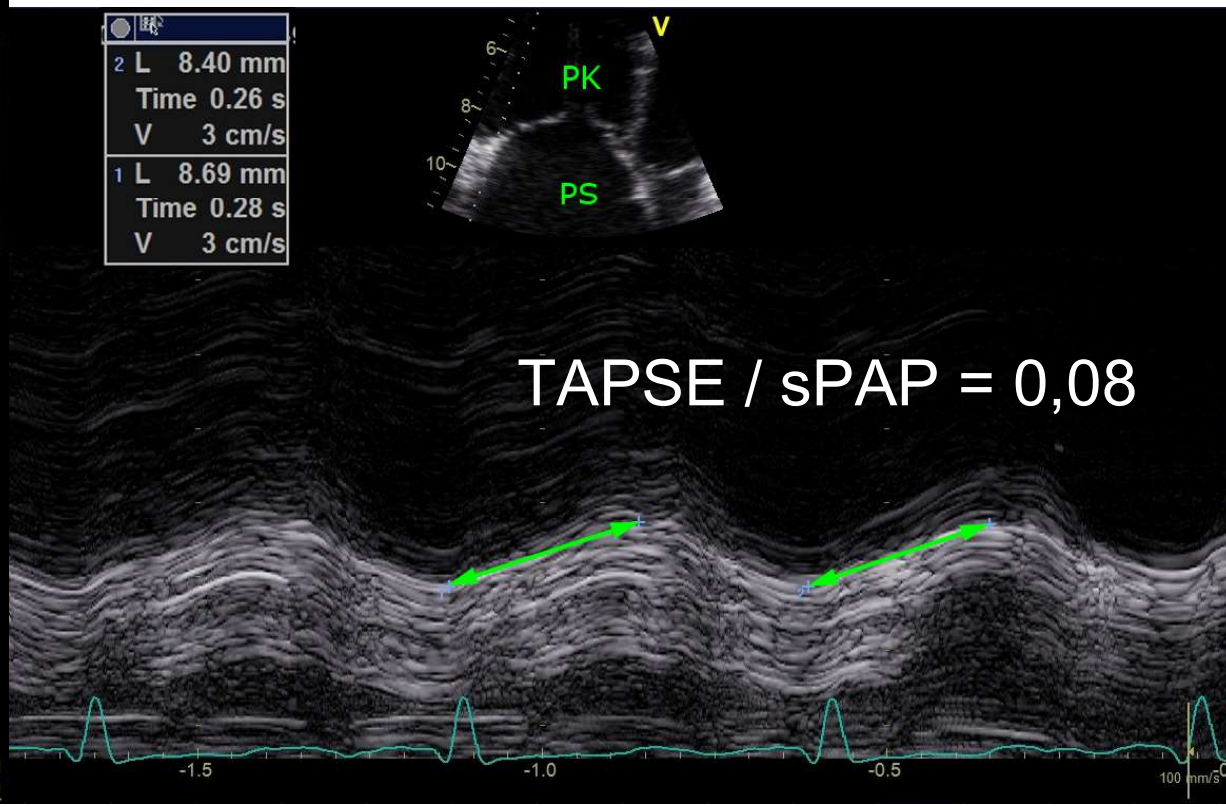


Imaging:
General
University
Hospital,
Prague, C

New mantra?

TAPSE/sPAP ratio <0.55 mm/mmHg*





mbert M. et al. Eur Heart J. 2022;43:3618–3731

Imaging: General University Hospital, Prague, CZ

TAPSE/sPAP as a surrogate of RV/PA coupling

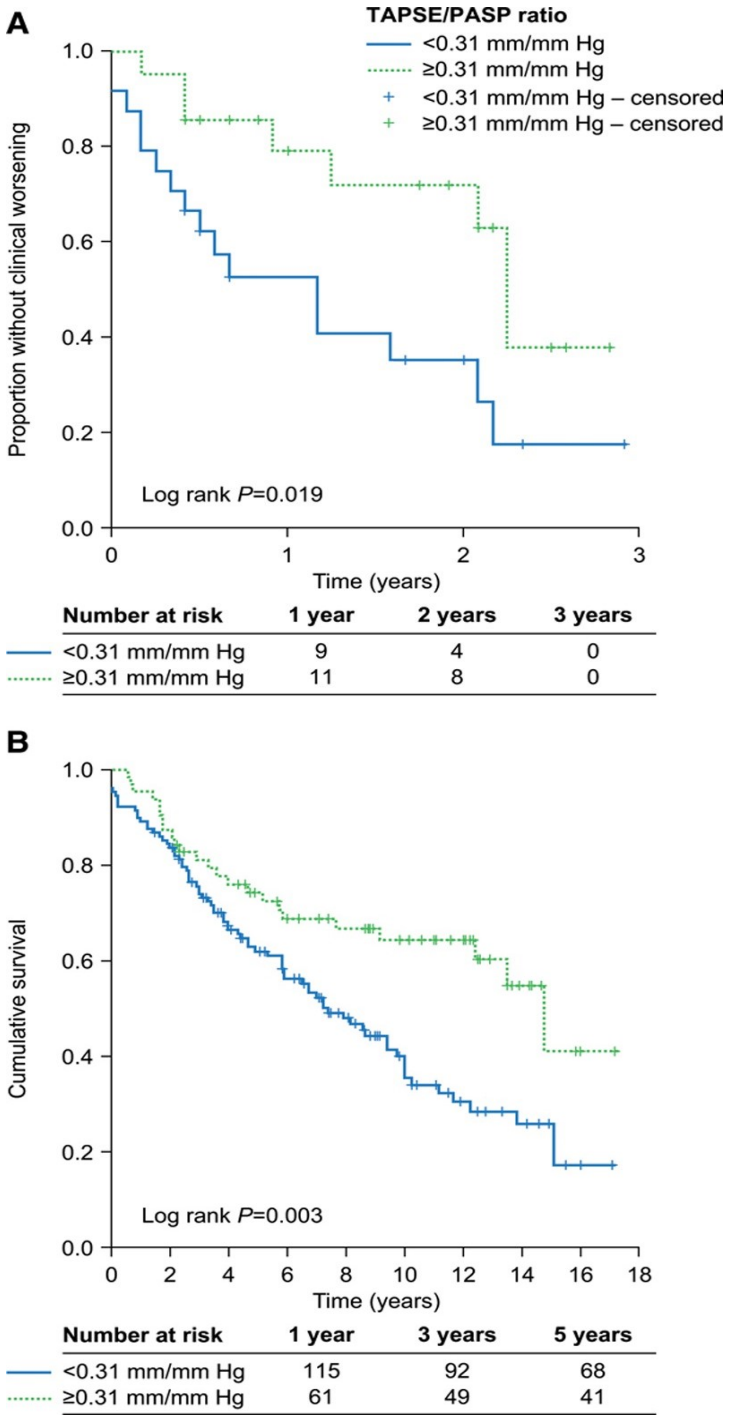
2 patients with PAH or CTEPH

ingle-beat RV P/V loops – measuring Ees/Ea

APSE/PASP - independent predictor of Ees/Ea multivariate OR: 18.6; 95% CI, 0.8-96.1; P=0.08).

APSE/PASP cutoff of 0.31 mm/mm Hg sensitivity: 87.5% and specificity: 75.9%) iscriminated RV-arterial uncoupling (Ees/Ea 0.805).

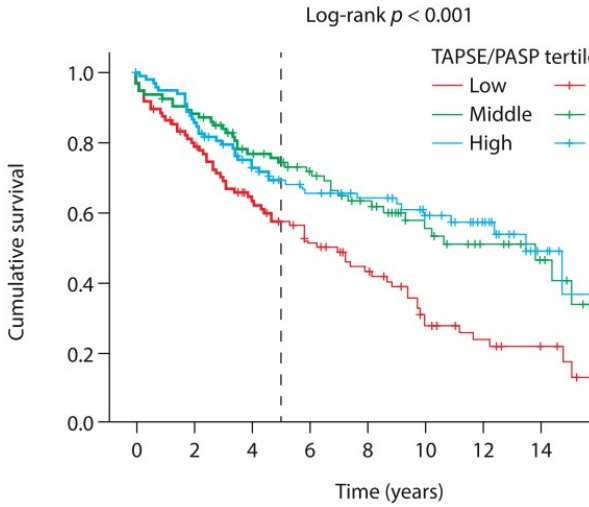
Patients with **TAPSE/PASP <0.31 mm/mm Hg ad a significantly worse prognosis than those with higher TAPSE/PASP.**



o K e tal. Circ Cardiovasc Imaging. 2019 Sep;12(9):e009047
o K et al. Int J Cardiol. 2018 Sep 1;266:229-235.

Prognostic stratification based on echo

minants of prognosis nated 1-year lity)	Low risk (<5%)	Intermediate risk (5–20%)	High risk (>20%)
ardiography	RA area <18 cm^2 TAPSE/sPAP >0.32 mm/mmHg No pericardial effusion	RA area 18–26 cm^2 TAPSE/sPAP 0.19–0.32 mm/mmHg Minimal pericardial effusion	RA area >26 cm^2 TAPSE/sPAP <0.19 mm/mmHg Moderate or large pericardial effusion



Number at risk	1 year	3 years	5
Low tertile	83	64	
Middle tertile	93	81	
High tertile	85	66	

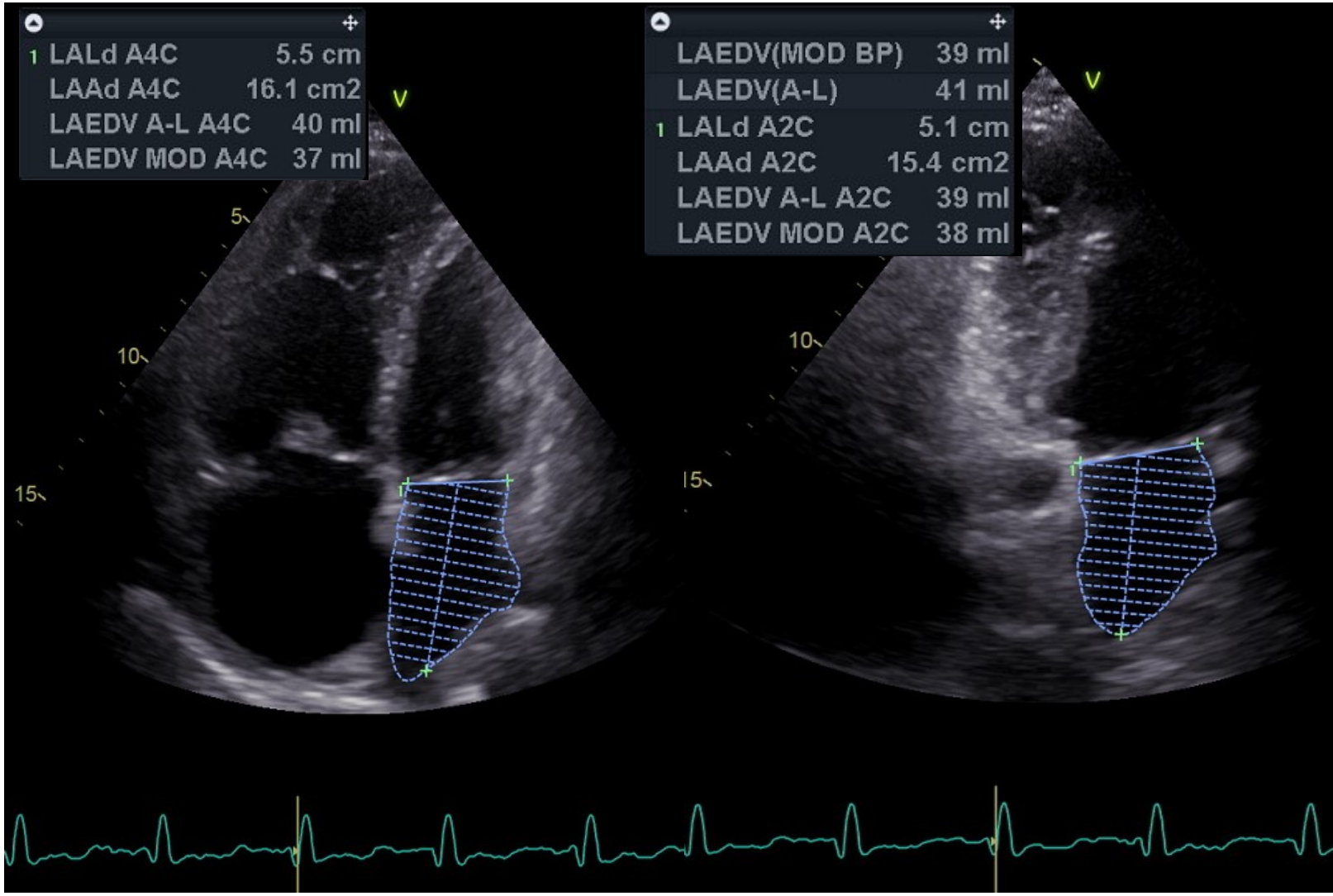
ert M. et al. Eur Heart J. 2022;43:3618–3731
K et al. Int J Cardiol. 2018 Sep 1;266:229-235.

WHAT SHOULD WE CONSIDER OUTSIDE OF THE RIGHT HEART?

Typical characteristics of RV phenotype

Smaller left atrial size

separate between
oup 2 PH and
er forms of PH,
d to assess the
elihood of left
ntricle (LV)
stolic dysfunction,
size and signs of
hypertrophy
ould always be
asured*



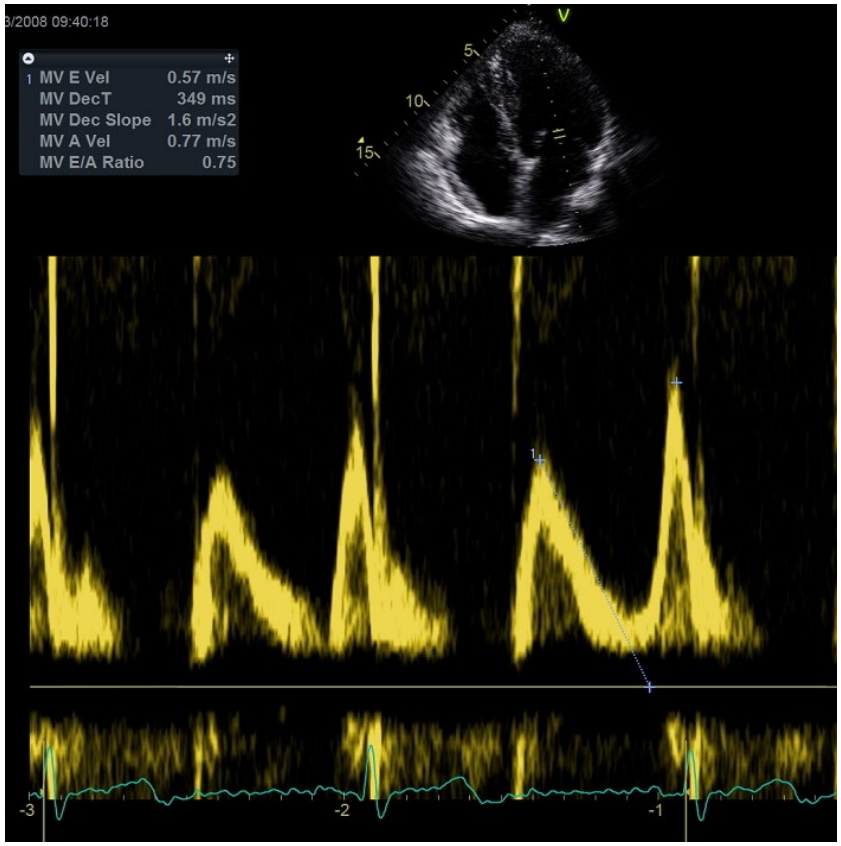
umbert M. et al. Eur Heart J. 2022;43:3618–3731

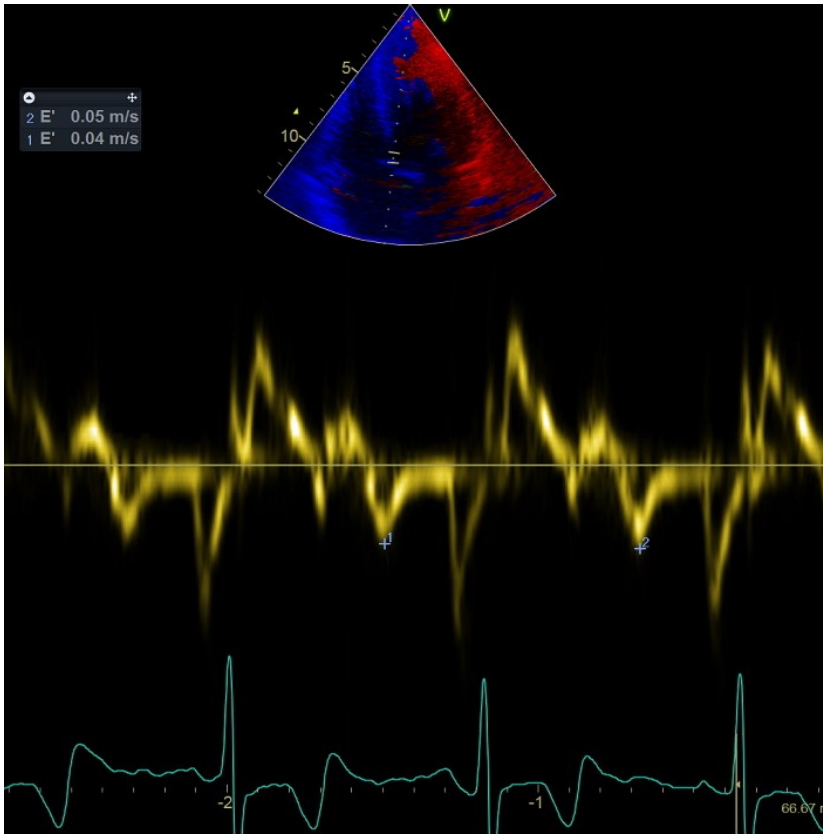
Imaging: General University Hospital, Prague, CZ

Typical characteristics of RV phenotype

Filling pattern of impaired relaxation

d Doppler
hocardiographic
gns (e.g. E/A
io, E/E') should
assessed*





*Humbert M. et al. Eur Heart J. 2022;43:3618–3731

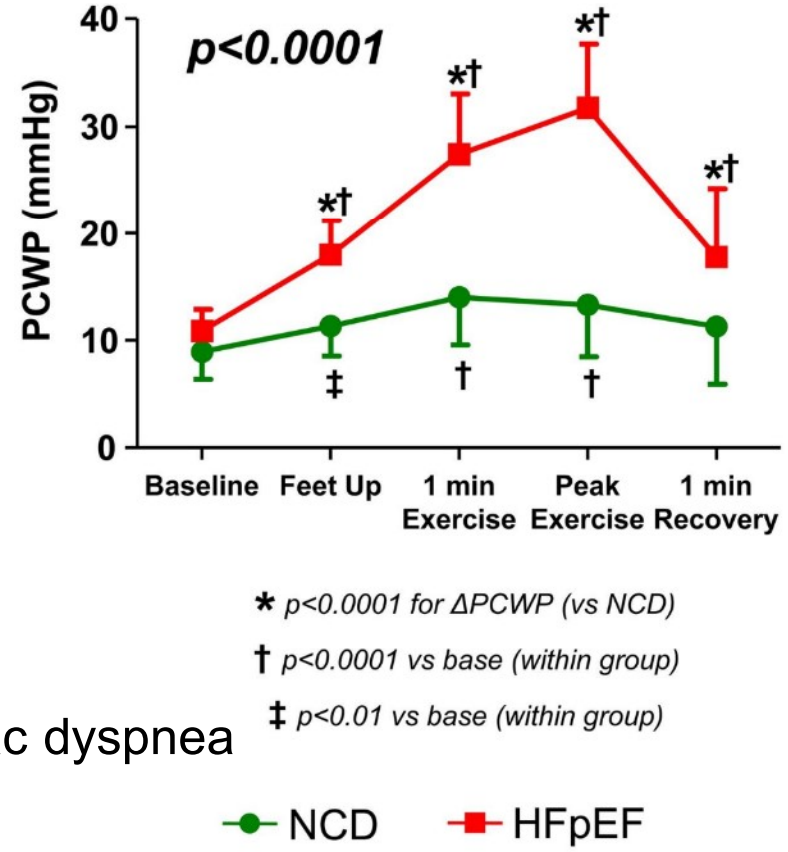
Imaging: General University Hospital, Prague, CZ

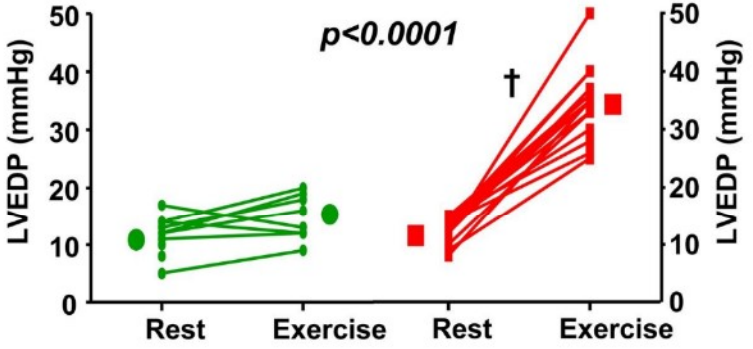
STRESS ECHOCARDIOGRAPHY

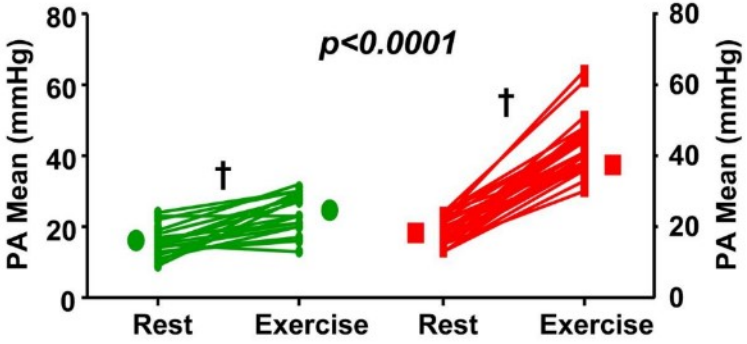
Stress RHC – PAWP ≥ 25 mmHg

55 subjects with exercise-induced dyspnea,
PAPM < 25 mmHg and PAWP < 15 mmHg at rest, normal BNP

Exercise rise in PAWP > 25 mmHg = HF-pEF







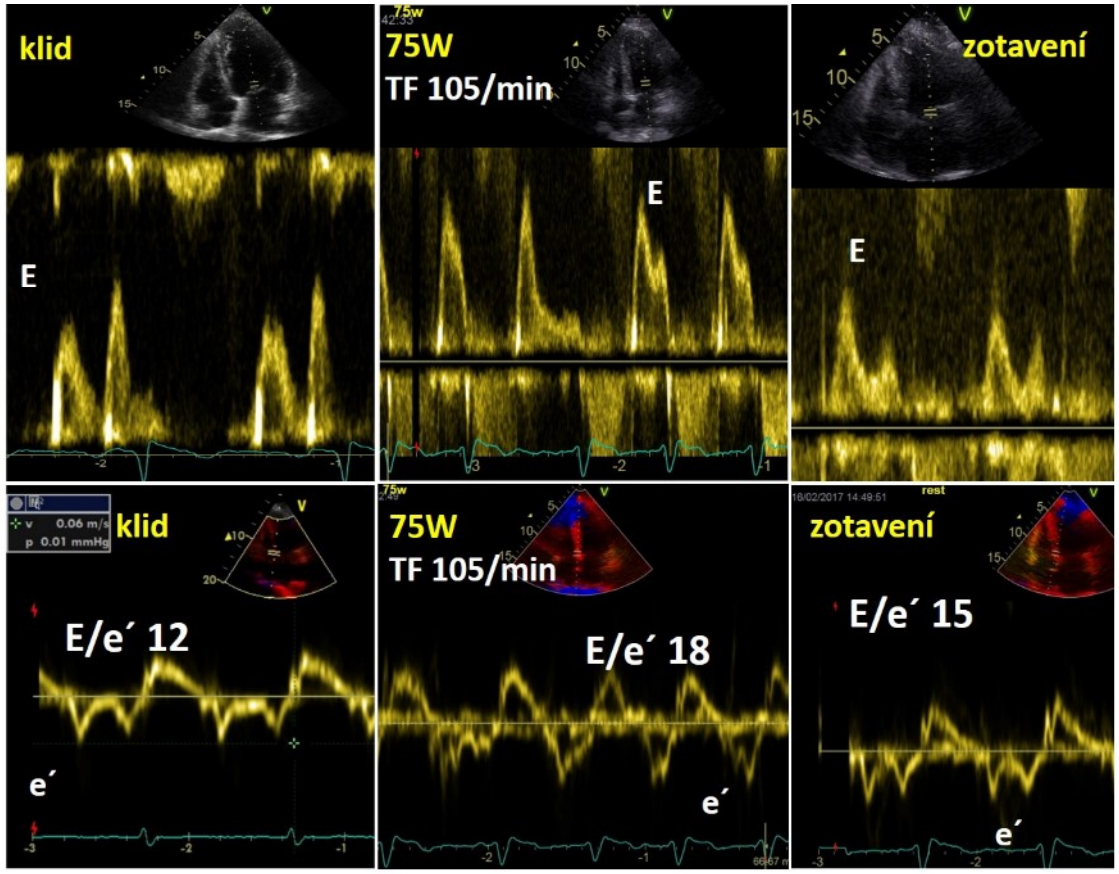
D= non-cardiac dyspnea

Borlaug BA et al. Circulation: Heart Failure. 2010;3:588-5

Stress echocardiography

E/e´ ratio at peak stress ≥15

tricuspid regurgitation (TR) velocity at peak stress >3.4 m/s



McDonagh T, Metra M, et al. Eur Heart J 2021; Hlubocká, Marek, Zátěžová echokardiografie, v Linhart et al. Vyšetřovací metody v kardiologii, Maxdorf 2021

WHEN RHC SHOULD BE CONSIDERED

Probability of PH due to left heart disease (LHD)

ure	PH-LHD unlikely	Intermediate probability	PH-LHD likely
	<60 years	60–70 years	>70 years
ity, hypertension, idaemia, glucose rance/diabetes	No factors	1–2 factors	>2 factors
ence of known LHD	No	Yes	Yes
ous cardiac intervention	No	No	Yes
fibrillation	No	Paroxysmal	Permanent/persistent
tural LHD	No	No	Present
	Normal or signs of RV strain	Mild LVH	LBBB or LVH
cardiography	No LA dilation E/e′ <13	No LA dilation Grade <2 mitral flow	LA dilation (LAVI >34 mL/m^2) LVH Grade >2 mitral flow
T	High VE/VCO_2 slope No EOV	Elevated VE/VCO_2 slope EOV	Mildly elevated VE/VCO_2 slo EOV
	No left heart abnormalities		LVH LA dilation (strain or LA/RA >

se oscillatory ventilation (EOV)
ntricular hypertrophy (LVH)

Humbert M. et al. *European Heart Journal*, 2022;43:3618–37

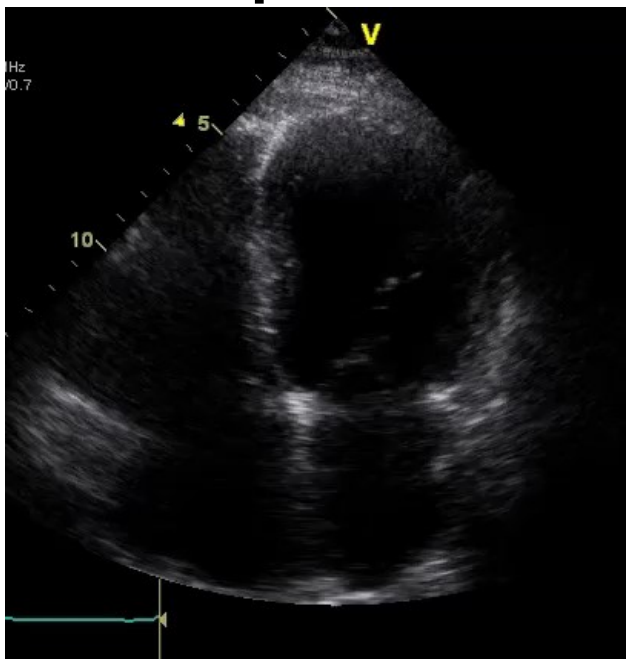
Who may benefit from RHC

PAH
CTEPH

Precapillary

Yes – to confirm the diagnosis + lead the Rx

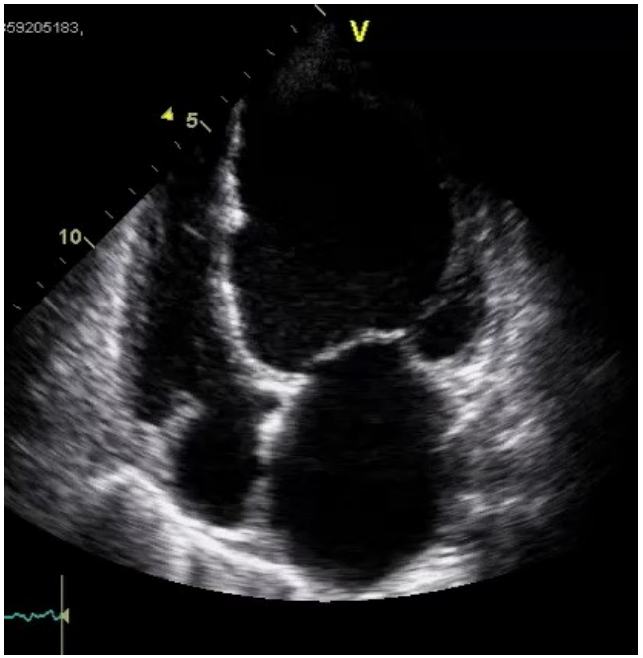
PAH / CTEPH?
PH in lung disease?
HF-pEF ?



Postcapillary ?
Combined?
Precapillary ?

Yes – if in doubt - to confirm the diagnosis

HF-rEF



Postcapillary

Yes – if HTx is considered

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Conclusions

- In most cases echocardiography is able to accurately identify patients with PH
- The degree of PH may be over or underestimated due to technical pitfalls
- New Guidelines do not change the position of echocardiography
- TRV is the preferred measurement
- TAPSE/sPAP – stressed out as an important prognostic measure (? thresholds, validation, error in the table)