
بسم الله الرحمن الرحيم

Advanced echocardiographic parameters of volume status in CHF with renal failure

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Fellowship of echocardiography

SBMU

ESC
European Society of Cardiology

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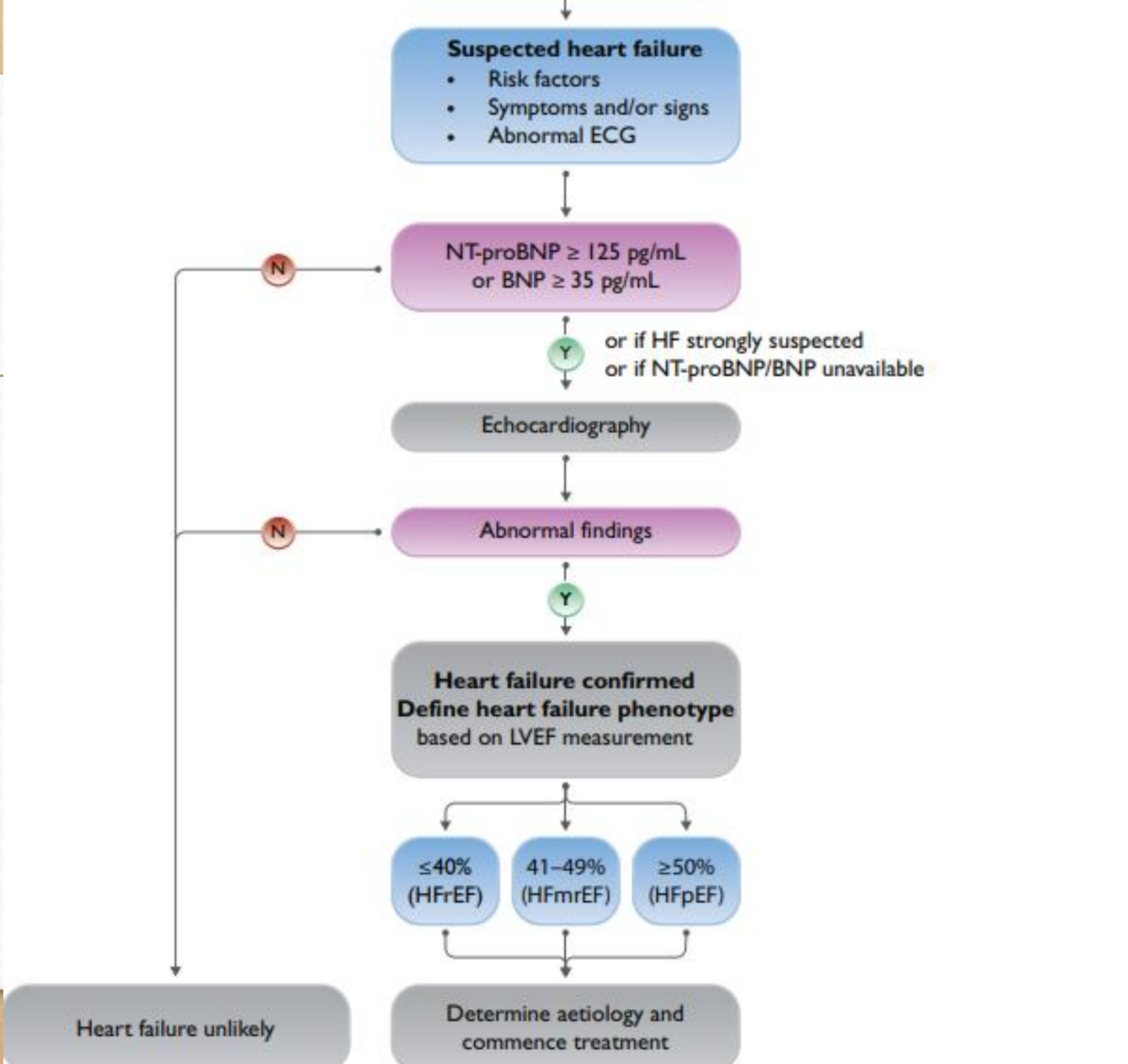
ESC GUIDELINES

2021 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure

Developed by the Task Force for the diagnosis and treatment of acute and chronic heart failure of the European Society of Cardiology (ESC)

With the special contribution of the Heart Failure Association (HFA) of the ESC


Suspected heart failure
Risk factors
Symptoms and/or signs
Abnormal ECG
NT-proBNP ≥ 125 pg/mL
or BNP ≥ 35 pg/mL
N
Y
or if HF strongly suspected
or if NT-proBNP/BNP unavailable
Echocardiography
Abnormal findings
N
Y
Heart failure confirmed
Define heart failure phenotype
based on LVEF measurement
≤40%
(HFrEF)
41–49%
(HFmrEF)
≥50%
(HFpEF)
Heart failure unlikely
Determine aetiology and
commence treatment

*Incidence of HF in known CKD: **17% to 21%***

Reduced eGFR ……..increased risk of all-cause mortality, cardiovascular mortality, and hospitalization in patients with HFpEF or HFrEF

HFrEF and HFpEF (55% of both groups) : CKD G3a or higher (eGFR < 60 ml/min per 1.73 m2)

44% of patients on hemodialysis have HF (HFpEF, or HFrEF,)

Optimizing volume status in CKD and heart failure

Kidney Disease Outcomes Quality Initiative ***(KDOQI) guidelines***

---

the maintenance of euvolemia is a major component of effective treatment.

Euvolemia

may be defined as a state ***of normal biventricular filling pressures*** (ie, *right* ***atrial*** **pressure and pulmonary capillary wedge pressure)**

Or

The lowest filling pressure that can be achieved :

without compromising cardiac output

without significant extravascular fluid accumulation

Most ***nephrologists define euvolemia:***

the absence of clinical evidence of volume overload or volume depletion

---

many patients (particularly those with HF) may be at the prescribed target weight

But, are not truly euvolemic.

We need a balance that minimizes risk of ***interdialytic hypervolemia and intradialytic hypovolemia***

- In attempting to achieve postdialysis euvolemia in patients with ventricular systolic and/or diastolic dysfunction, ***hypotension during dialysis*** is a common and challenging problem, especially ***when interdialytic fluid gain*** is large.

- ***The screening echocardiogram*** ***enables assessment of intravascular and intracardiac volumes, ventricular function, and any valve disease.***

- Imaging should be carried out when patients on dialysis are close to dry weight, and.

preferably on a nondialysis day for patients on hemodialysis

filling pressures evaluation in most clinical settings by

noninvasive methods

1- assessment of jugular venous pressure, peripheral edema, third heart sound, lung rales

2- echocardiographic findings such as inferior vena cava diameter and collapsibility, E/e' ratio)

when the volume status of a patient remains uncertain (eg, if the patient has persistent HF symptoms despite apparently optimized volume status)

referral to a cardiologist is suggested to evaluate the risks and benefits of

invasive hemodynamic assessment

ASE GUIDELINES AND STANDARDS

Guidelines for the Use of Echocardiography as a Monitor for Therapeutic Intervention in Adults: A Report from the American Society of Echocardiography

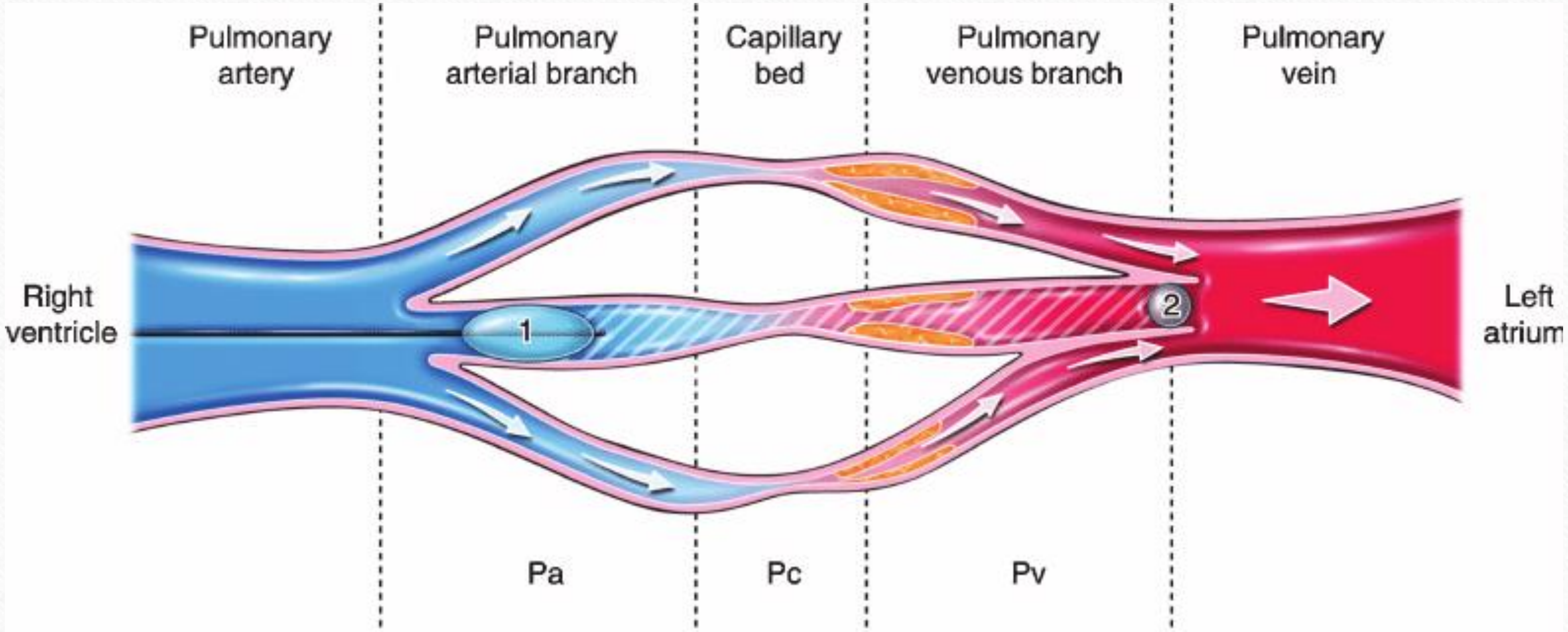
Thomas R. Porter, MD, FASE (Chair), Sasha K. Shillcutt, MD, FASE, Mark S. Adams, RDCS, FASE, Georges Desjardins, MD, FASE, Kathryn E. Glas, MD, MBA, FASE, Joan J. Olson, BS, RDCS, RVT, FASE, and Richard W. Troughton, MD, PhD, *Omaha, Nebraska; Boston, Massachusetts; Salt Lake City, Utah; Atlanta, Georgia; Christchurch, New Zealand*

(J Am Soc Echocardiogr 2015;28:40-56.)

Keywords: Echocardiography, Monitoring, Therapy, Doppler

LV filling pressure

The normal pulmonary capillary wedge pressure
4 to 12 mmHg



What is LV filling pressure?

Mean LA.

Mean PCWPpr

LV.Pr - LA.Pr

Mean LV diastolic pressure

LVEDpr

In early stage of diastolic dysfunction,LVEDpr is elevated,but mean PCWP and LAP is normal

HFrEF(Heart failure with reduced EF):

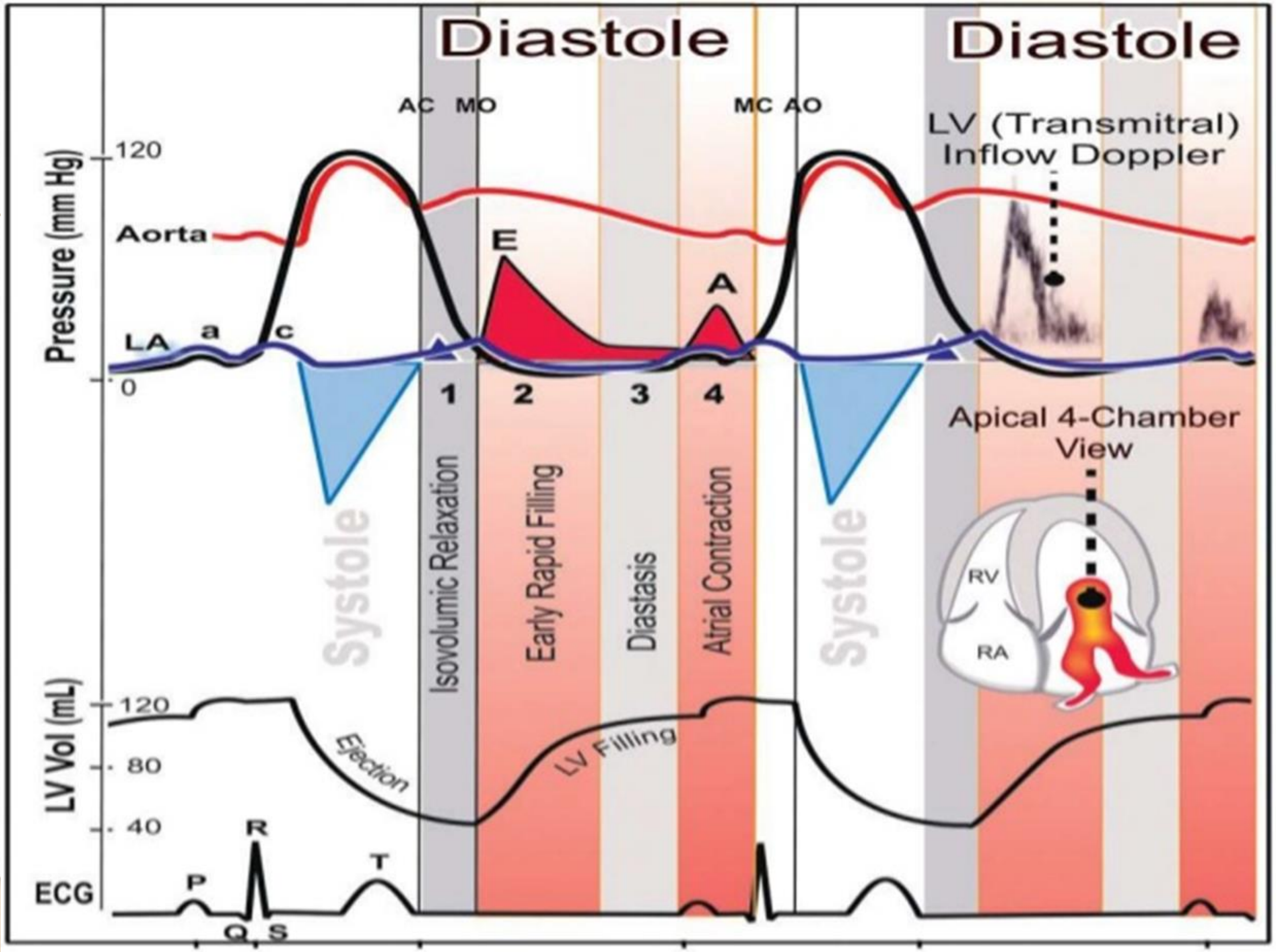
Increased PCWP

Normal PCWP

HFprEF(Heart failure with preserved EF):

Increased PCWP

Diastology


Diastole
Diastole
AC MO
MC AO
LV (Transmitral)
Inflow Doppler
Pressure (mm Hg)
120
0
Aorta
LA
a
c
E
A
1
2
3
4
Systole
Isovolumic Relaxation
Early Rapid Filling
Diastasis
Atrial Contraction
Systole
Apical 4-Chamber
View
RV
RA
LV Vol (mL)
120
80
40
Ejection
LV Filling
ECG
P
R
Q
S
T

Early rapid filling phase (E wave)

-LA pressure & LA-LV pressure gradient

-myocardial relaxation (is an active, energy-dependent) and LV elastic recoil

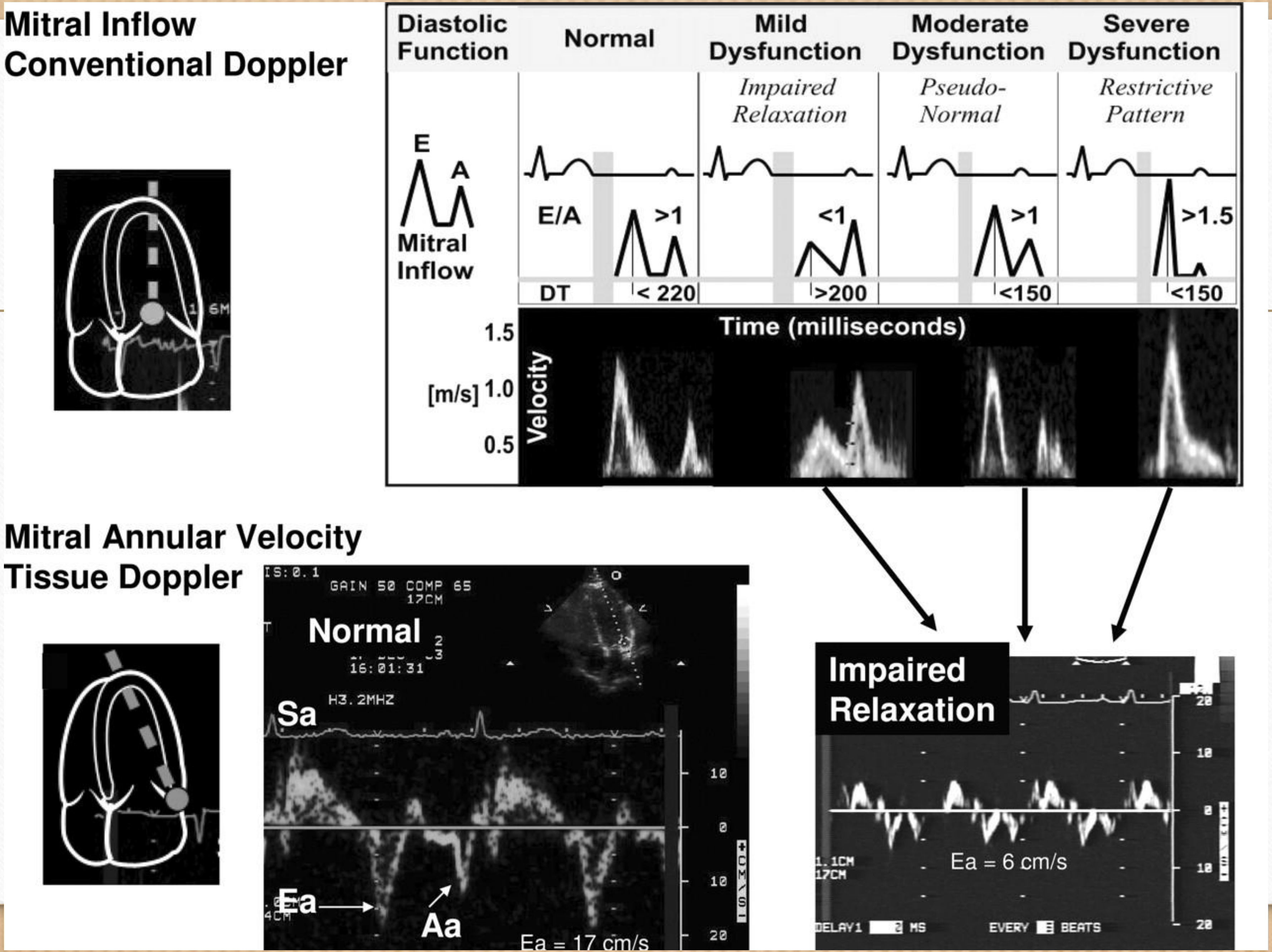
blood is effectively "pulled" into the left ventricle)

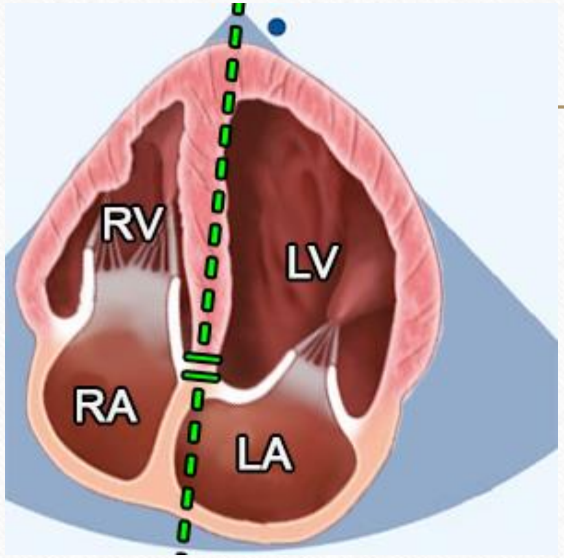
-LV diastolic stiffness

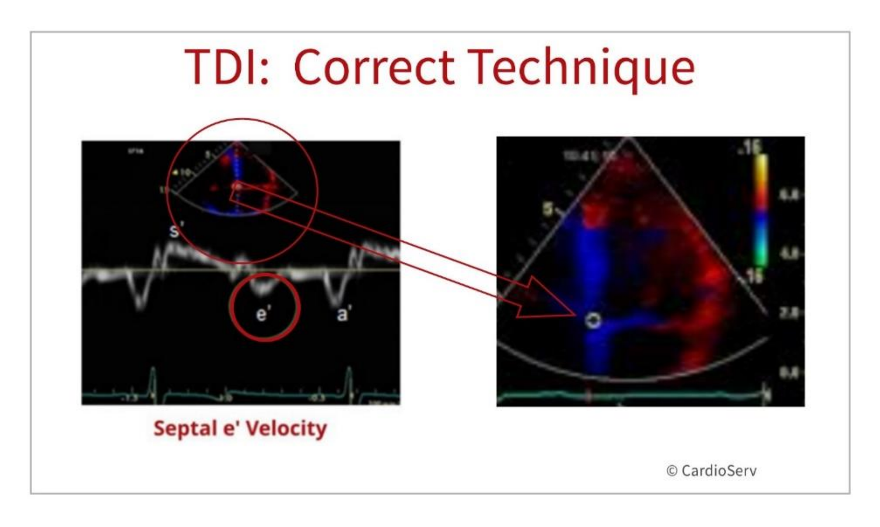
-ventricular interaction, Pericardium, PVs and mitral orifice area

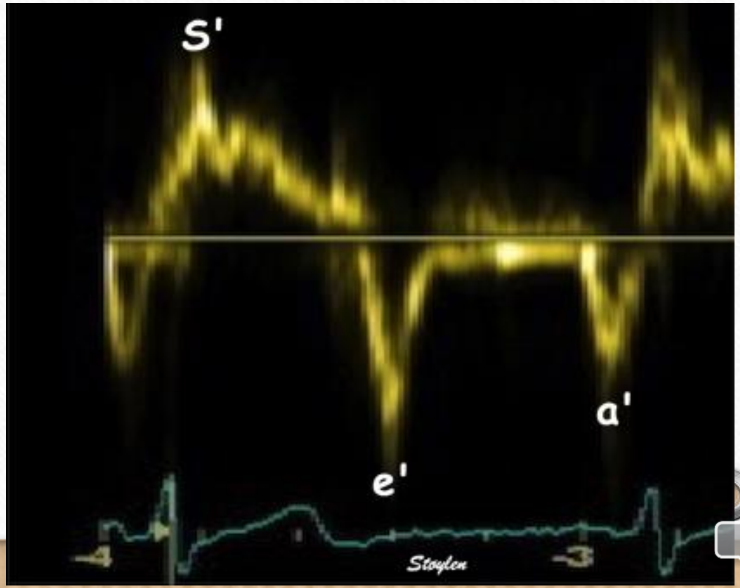
In HFpEF , Relaxation and recoil are abnormal and filling can be maintained only by increased LA pressure

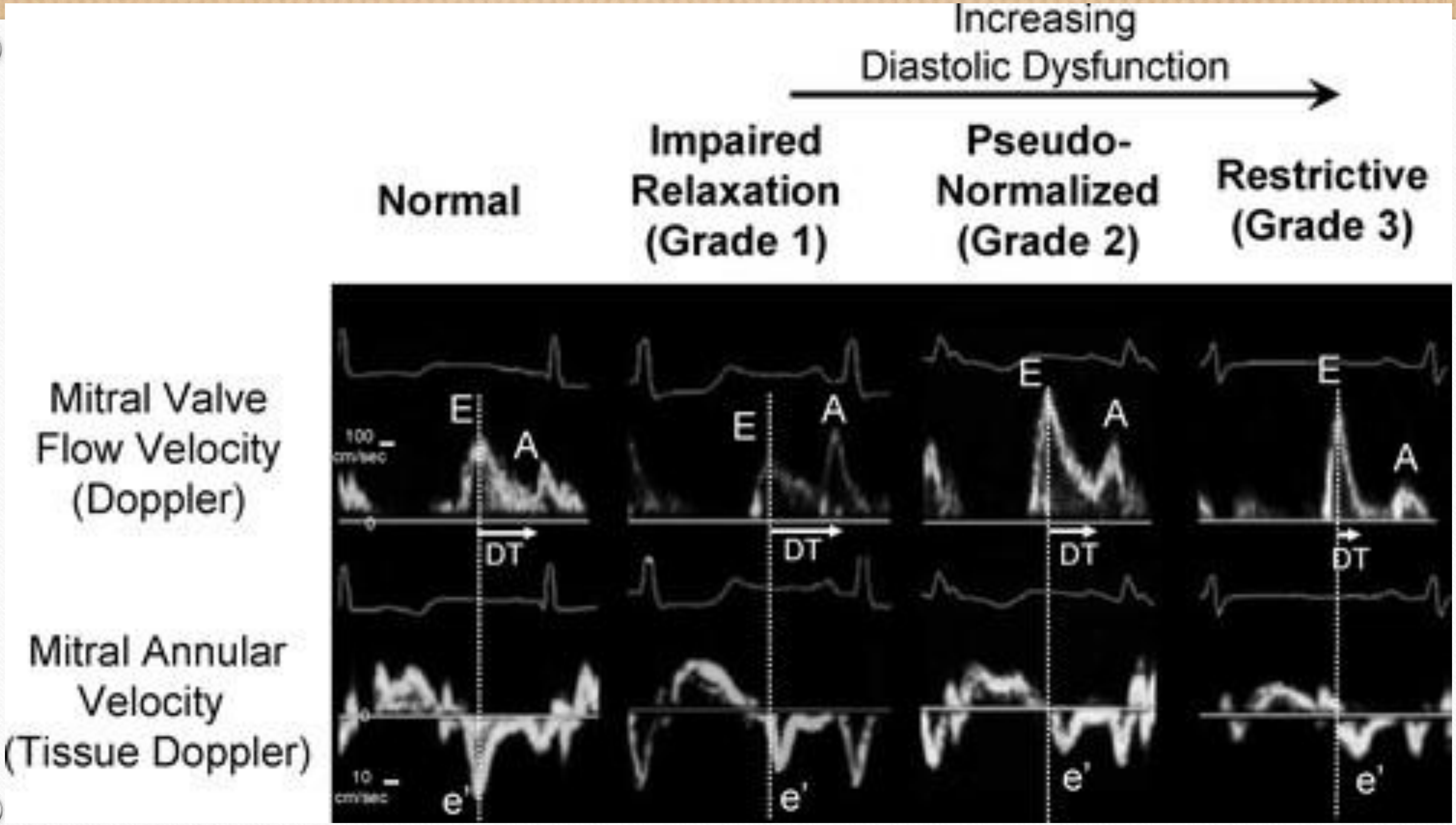
blood must be "pushed" into the left ventricle


Mitral Inflow
Conventional Doppler
Diastolic Function
Normal
Mild Dysfunction
Moderate Dysfunction
Severe Dysfunction
Impaired Relaxation
Pseudo-Normal
Restrictive Pattern
E
A
Mitral Inflow
E/A
>1
<1
>1
>1.5
DT
< 220
>200
<150
<150
Time (milliseconds)
1.5
[m/s] 1.0
0.5
Velocity
Mitral Annular Velocity
Tissue Doppler
GAIN 50 COMP 65
17CM
Normal
16:01:31
H3.2MHZ
Sa
Ea
Aa
Ea = 17 cm/s
10
0
10
20
Impaired
Relaxation
Ea = 6 cm/s
20
10
0
10
20
DELAY1
MS
EVERY
BEATS


RV
LV
RA
LA


TDI: Correct Technique
e'
a'
Septal e' Velocity
© CardioServ


s'
e'
a'
Stoylen



Increasing
Diastolic Dysfunction
Normal
Impaired Relaxation (Grade 1)
Pseudo-Normalized (Grade 2)
Restrictive (Grade 3)
Mitral Valve Flow Velocity (Doppler)
Mitral Annular Velocity (Tissue Doppler)
E
A
DT
e'
100 cm/sec
10 cm/sec
0

both E and e′ normally increase in response to increased volume load and exercise , but not in heart failure(Increased E and decreased e’)

Average E/e’ <8 normal LV filling pressure

E/e’ >14 high specificity for increased LV filling

PCWP: 1.25(E/e’) + 1.9

E: 0.9 m/s

e’: 5cm/s

E/e’: 18

PCWP: 24 mmHg

The four variable for diastolic evaluation

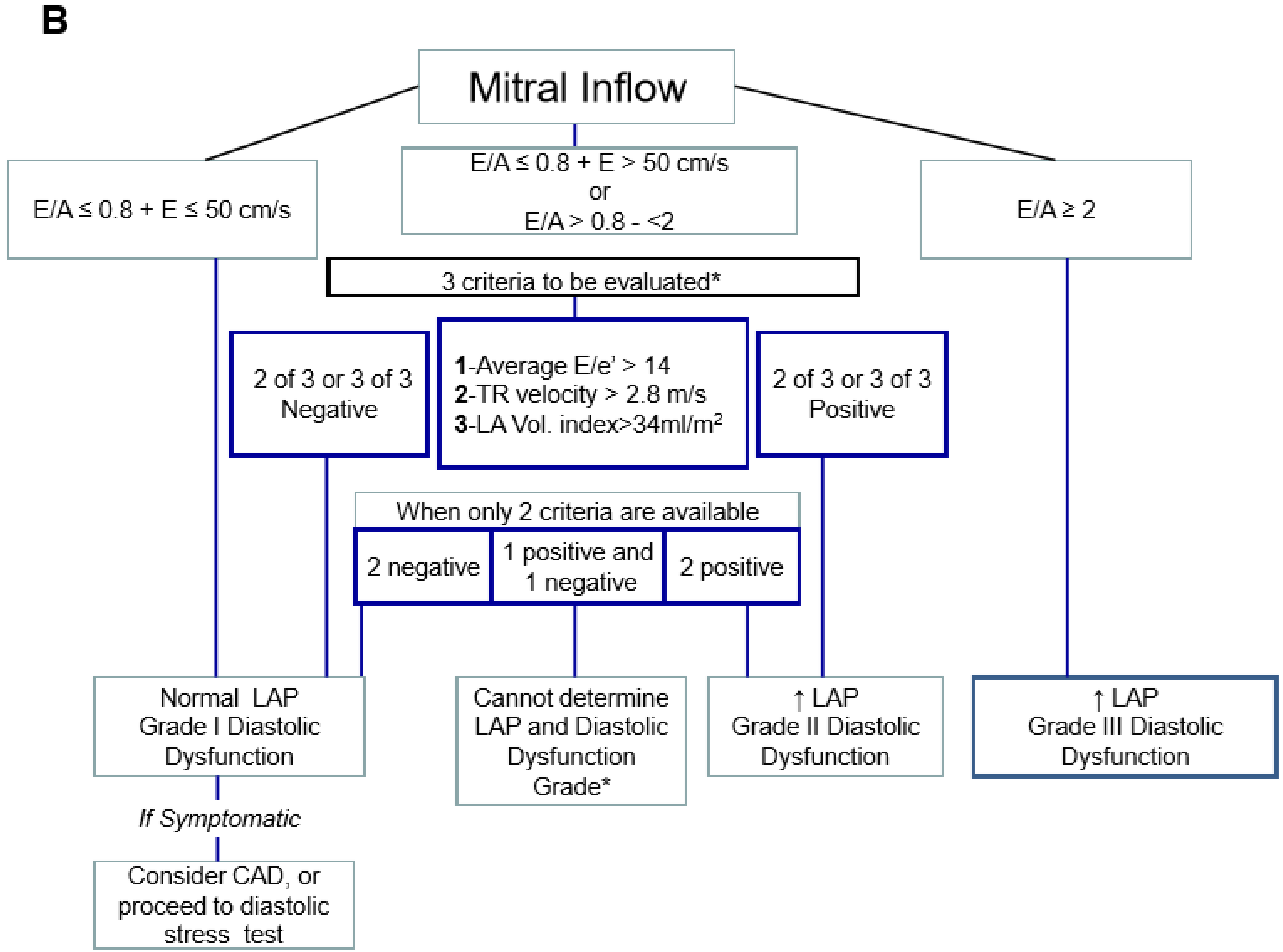
*Septal e'<7cm/s,Lateral<10cm/s

*E/e'>14(Septal>13,Lat>15cm/s)

*LAV.Index>34cc/m2 (>90%)

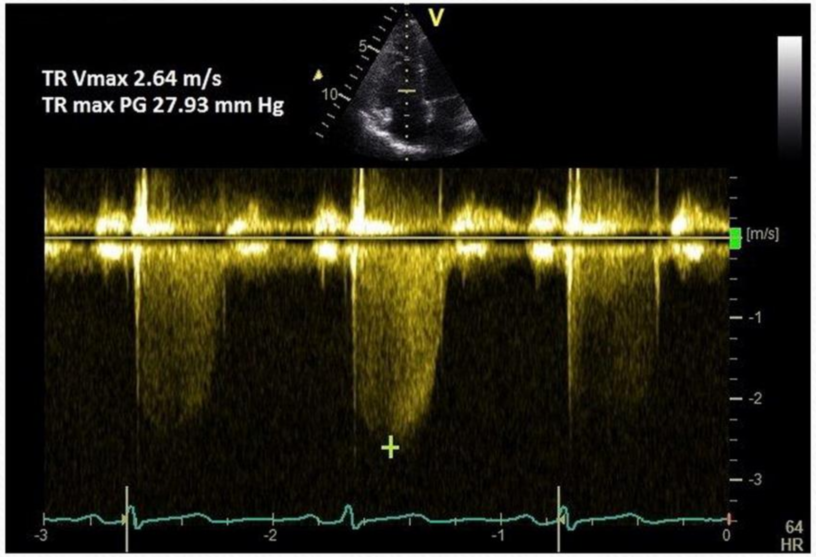
(Sensitive,but nt specific)

*TR velocity>2.8m/s


B
Mitral Inflow
E/A ≤ 0.8 + E ≤ 50 cm/s
E/A ≤ 0.8 + E > 50 cm/s
or
E/A > 0.8 - <2
E/A ≥ 2
3 criteria to be evaluated*
2 of 3 or 3 of 3
Negative
1-Average E/e' > 14
2-TR velocity > 2.8 m/s
3-LA Vol. index>34ml/m²
2 of 3 or 3 of 3
Positive
When only 2 criteria are available
2 negative
1 positive and
1 negative
2 positive
Normal LAP
Grade I Diastolic
Dysfunction
Cannot determine
LAP and Diastolic
Dysfunction
Grade*
↑ LAP
Grade II Diastolic
Dysfunction
↑ LAP
Grade III Diastolic
Dysfunction
If Symptomatic
Consider CAD, or
proceed to diastolic
stress test

PH

SPAP=4x(TR velocity)2+ RA pressure



*TR velocity >2.8m/s

ePLAR

(Echo pulmonary to LA ratio)

TR velocity/E/e’=0.3

Postcapillary<0.25

Precapillary>0.4

RV filling pressure

IVC size

- *the lost prestige and reduced popularity of CVP, measurement of IVC size to evaluate the volume status of critical patients* ***are increasingly in intensive care units.***

IVC

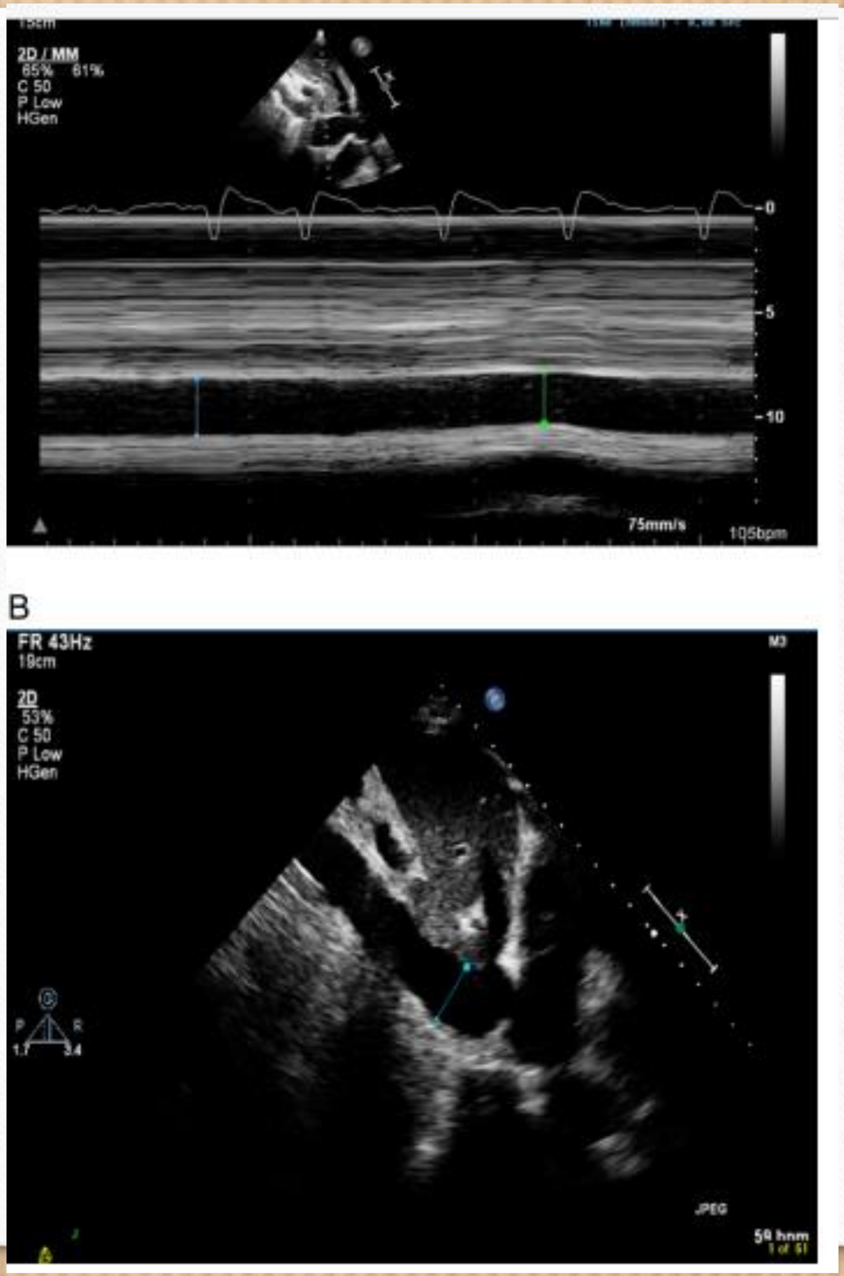
measured just *distal to the hepatic vein*

-in spontaneously breathing patients

correlates with RAP

In ventilated patients a *low correlation* between IVC size and RAP

(***RAP of less than 10 mmHg can be assumed if the IVC is less than 12 mm)***



ASE guidlines

IVC size /collapsibility, for RAP Rudski *et al.*[31], Brennan *et al.*[32]	2D harmonic	Visualization throughout the respiratory cycle	Size ≤ 2.1 cm; collapses >50% during sniff = RAP 0–5 mm Hg Size > 2.1 cm; collapses >50% during sniff = 5–10 mm Hg Size > 2.1; collapses <50% during sniff = 10–20 mm Hg

- A small IVC(< 10mm) suggests that fluid is tolerated

ventilated patients often have a dilated IVC because of increased intrathoracic pressure rather than as a reflection of their intravascular volume status.

- ***An exaggerated response in IVC collapse (>50%)*** occurs in patients in the hypovolemic state during *inspiration*

The 2010 echocardiography guideline

in patients who are unable to adequately perform ***a sniff****, an IVC that collapses* ***20% with quiet inspiration*** *suggests elevated mean* RAP.

The ability ***to remove 0.5 L to 2 L of ultrafiltrate during dialysis*** could best be predicted using an IVC collapsibility cutoff of 23% to 18.5% (approximately ***20%),*** are consistent with this.

Underestimation of intravascular volume may occur *with intra-abdominal hypertension.*

Distended IVC in this circumstance likely indicates intravascular ***hypervolemia***

IVC collapsibility index

- in spontaneously breathing patients:

[maximum diameter on expiration – (minimum diameter on inspiration/maximum diameter on expiration)]

- An IVC collapsibility index of *greater than 50%* is associated with *reduced right atrial pressure* and *severe dehydration*, and indicates that the patient *needs fluid therapy.*

the IVC distensibility index

- In mechanically ventilated patients
  - IVC distensibility index = [(maximum diameter on inspiration–minimum diameter on expiration)/minimum diameter on expiration]

- on mechanically ventilated adult patients in septic shock demonstrated that the IVC distensibility index values of *greater than 18%* were in favor of ***fluid deficit***

- *In both spontaneously breathing and ventilated patients*, a *small IVC that varies in size* with respiration with:

- non-dilated right heart chambers
- a non-displaced interventricular septum
- absence of right and left ventricular systolic failure
- and absence of markers of raised LVEDP

all suggest

fluid administration will not cause acute harm.

Simple Two-Dimensional Echocardiographic Scoring System for the Estimation of Left Ventricular Filling Pressure

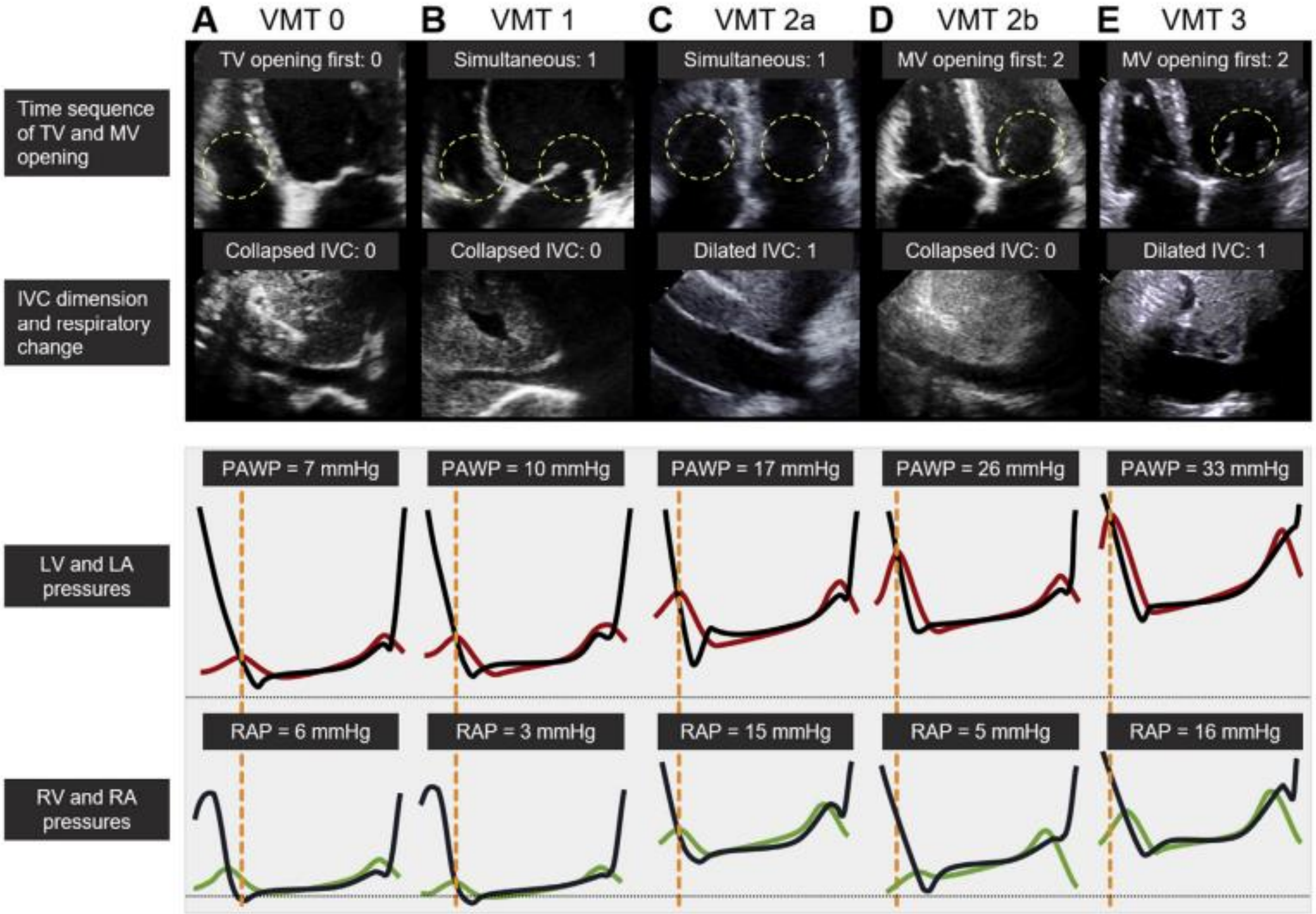
Michito Murayama, MS, Hiroyuki Iwano, MD, PhD, Hisao Nishino, AS, Shingo Tsujinaga, MD, PhD, Masahiro Nakabachi, MS, Shinobu Yokoyama, AS, Miho Aiba, MS, Kazunori Okada, PhD, Sanae Kaga, PhD, Miwa Sarashina, MD, PhD, Yasuyuki Chiba, MD, Suguru Ishizaka, MD, Ko Motoi, MD, Mutsumi Nishida, PhD, Hitoshi Shibuya, AS, Kiwamu Kamiya, MD, PhD, Toshiyuki Nagai, MD, PhD, and Toshihisa Anzai, MD, PhD, *Sapporo, Japan*

Background: When left ventricular filling pressure (LVFP) increases, the mitral valve opens early and precedes tricuspid valve opening in early diastole. The authors hypothesized that a visually assessed time sequence of atrioventricular valve opening could become a new marker of elevated LVFP. The aim of this study was to test the diagnostic ability of a novel echocardiographic scoring system, the visually assessed time difference between mitral valve and tricuspid valve opening (VMT) score, in patients with heart failure.

Methods: One hundred nineteen consecutive patients who underwent cardiac catheterization within 24 hours of echocardiographic examination were retrospectively analyzed as a derivation cohort. In addition, a prospective study was conducted to validate the diagnostic ability of the VMT score in 50 patients. Elevated LVFP was defined as mean pulmonary artery wedge pressure (PAWP) $\geq$ 15 mm Hg. The time sequence of atrioventricular valve opening was visually assessed and scored (0 = tricuspid valve first, 1 = simultaneous, 2 = mitral valve first). When the inferior vena cava was dilated, 1 point was added, and VMT score was ultimately graded as 0 to 3. Cardiac events were recorded for 1 year after echocardiography.

Results: In the derivation cohort, PAWP was elevated with higher VMT scores (score 0, 10 $\pm$ 5; score 1, 12 $\pm$ 4; score 2, 22 $\pm$ 8; score 3, 28 $\pm$ 4 mm Hg; $P < .001$, analysis of variance). VMT score $\geq$ 2 predicted elevated PAWP with accuracy of 86% and showed incremental predictive value over clinical variables and guideline-recommended diastolic function grading. These observations were confirmed in the prospective validation cohort. Importantly, VMT score $\geq$ 2 discriminated elevated PAWP with accuracy of 82% in 33 patients with monophasic left ventricular inflow in the derivation cohort. Kaplan-Meier analysis demonstrated that patients with VMT scores $\geq$ 2 were at higher risk for cardiac events than those with VMT scores $\leq$ 1 ($P < .001$).

Conclusions: VMT scoring could be a novel additive marker of elevated LVFP and might also be associated with adverse outcomes in patients with heart failure. (J Am Soc Echocardiogr 2021;■:■-■.)


A VMT 0
B VMT 1
C VMT 2a
D VMT 2b
E VMT 3
Time sequence of TV and MV opening
TV opening first: 0
Simultaneous: 1
Simultaneous: 1
MV opening first: 2
MV opening first: 2
IVC dimension and respiratory change
Collapsed IVC: 0
Collapsed IVC: 0
Dilated IVC: 1
Collapsed IVC: 0
Dilated IVC: 1
LV and LA pressures
PAWP = 7 mmHg
PAWP = 10 mmHg
PAWP = 17 mmHg
PAWP = 26 mmHg
PAWP = 33 mmHg
RV and RA pressures
RAP = 6 mmHg
RAP = 3 mmHg
RAP = 15 mmHg
RAP = 5 mmHg
RAP = 16 mmHg

VMT score >= 2 *predicted elevated PAWP with* ***accuracy of 86%*** *and showed incremental predictive value over clinical variables and guideline recommended diastolic function grading.*

- Echocardiography is ideally suited to guide *fluid resuscitation* in critically ill patients.

to assess fluid responsiveness by looking at:

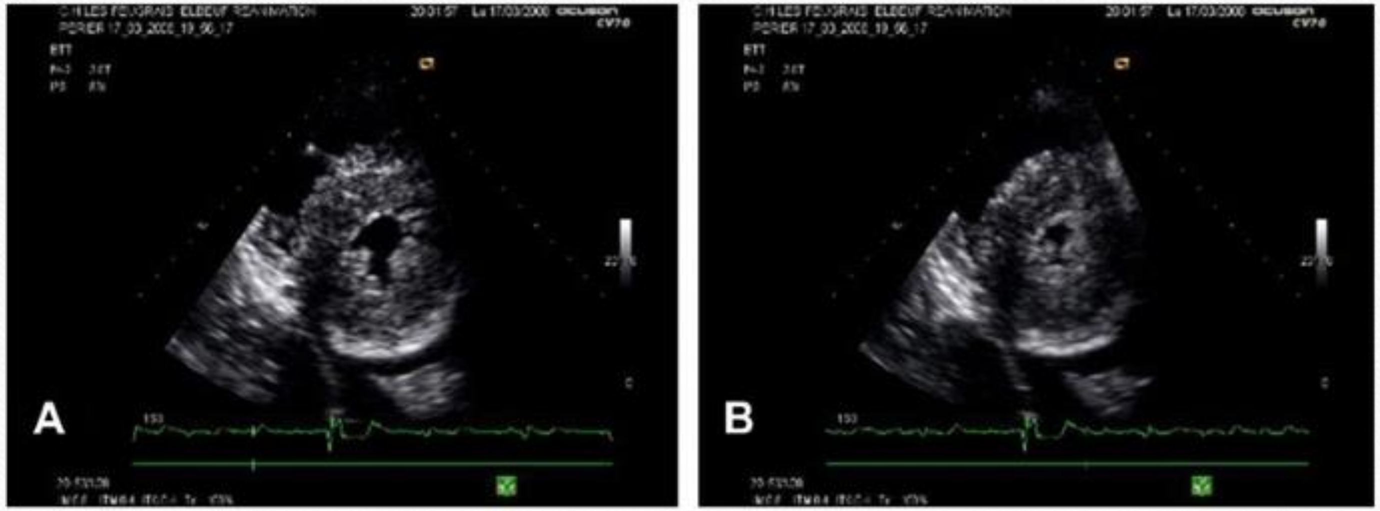
left ventricle

Aortic outflow

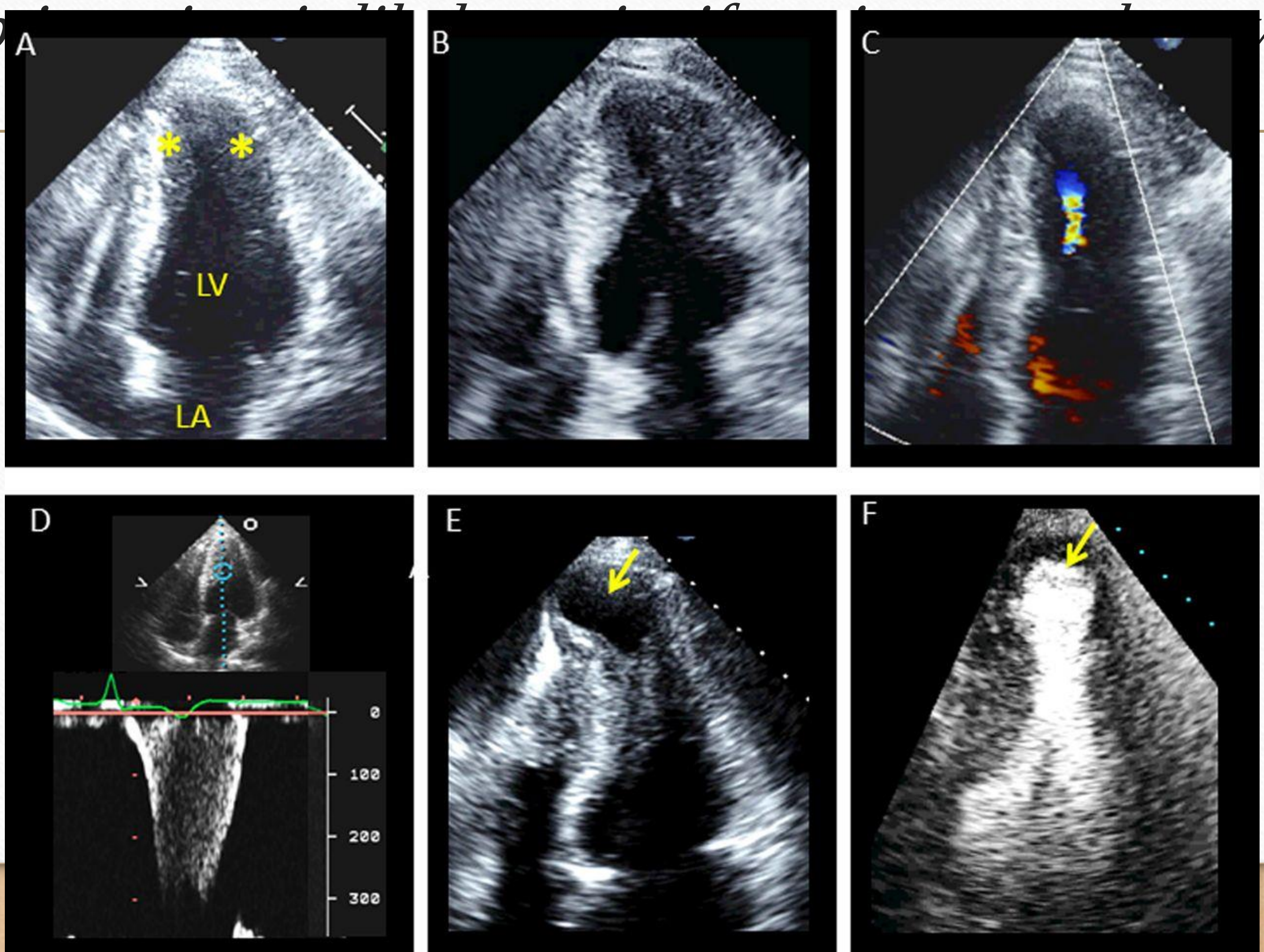
Inferior vena cava

Right ventricle

Hyperdynamic LV with an end-diastolic area in the PSAX view of ***less than 10 cm2*** *or papillary apposition* ***(kissing ventricles)*** *is strongly indicative of* ***hypovolaemia***



Presence of an IVG(Intra ventricular gradient) in a hypotensive sep [illegible] *volemia*



LV

Hypovolemia is best monitored using ***end-diastolic measurements***, because a low ***LV systolic diameter*** could also depict:

- 1-decreased systemic vascular resistance (SVR)
- 2- increased inotropic state
- 3- Decreased ventricular filling
-
- ***In hypovolemia, both LVIDD and LVIDS are decreased***, while in the setting of decreased SVR, LVIDD is normal and LVIDS is decreased

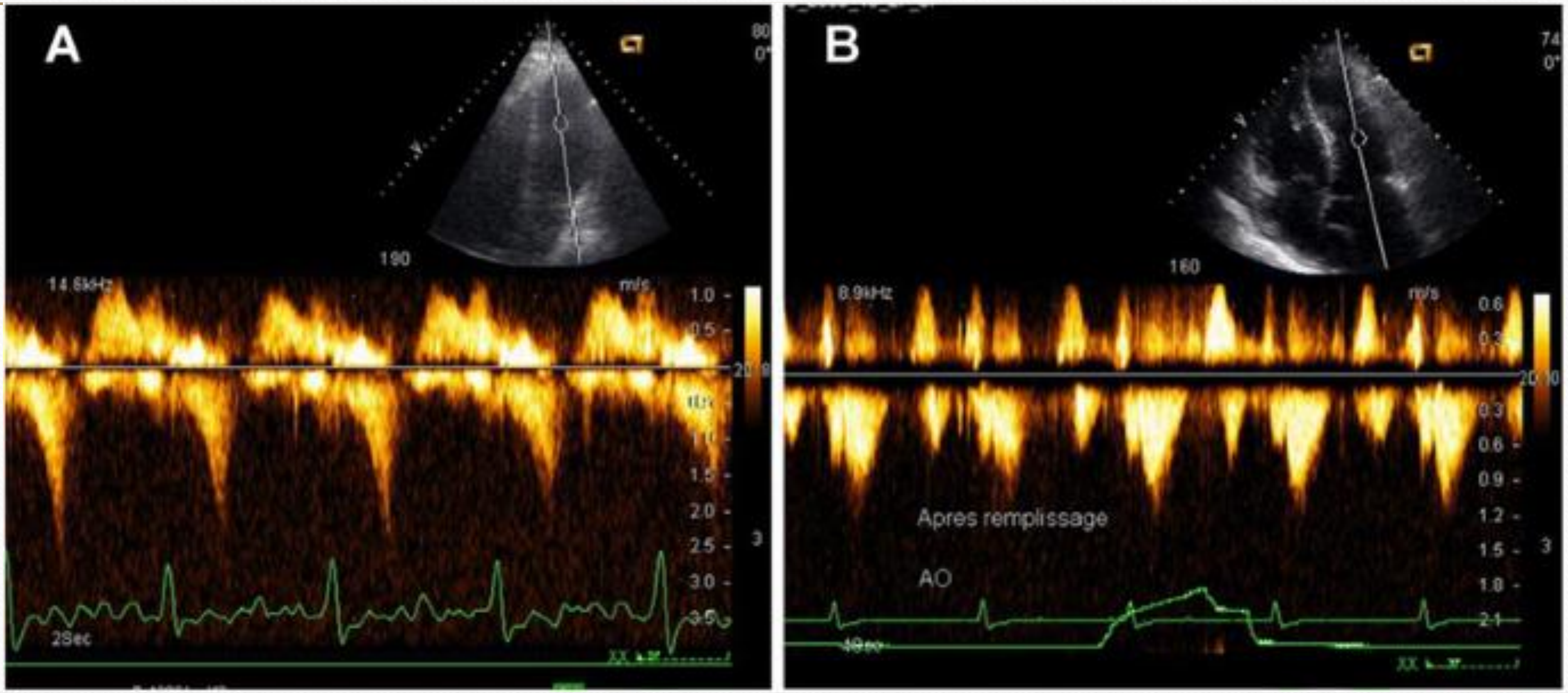
TTE:

parasternal short-axis (SAX) or long-axis (LAX) view using either 2D linear measurements or M-mode imaging at the LV minor axis, 1 cm distal to the mitral valve (MV) annulus ***at the MV valve leaflet tips.***

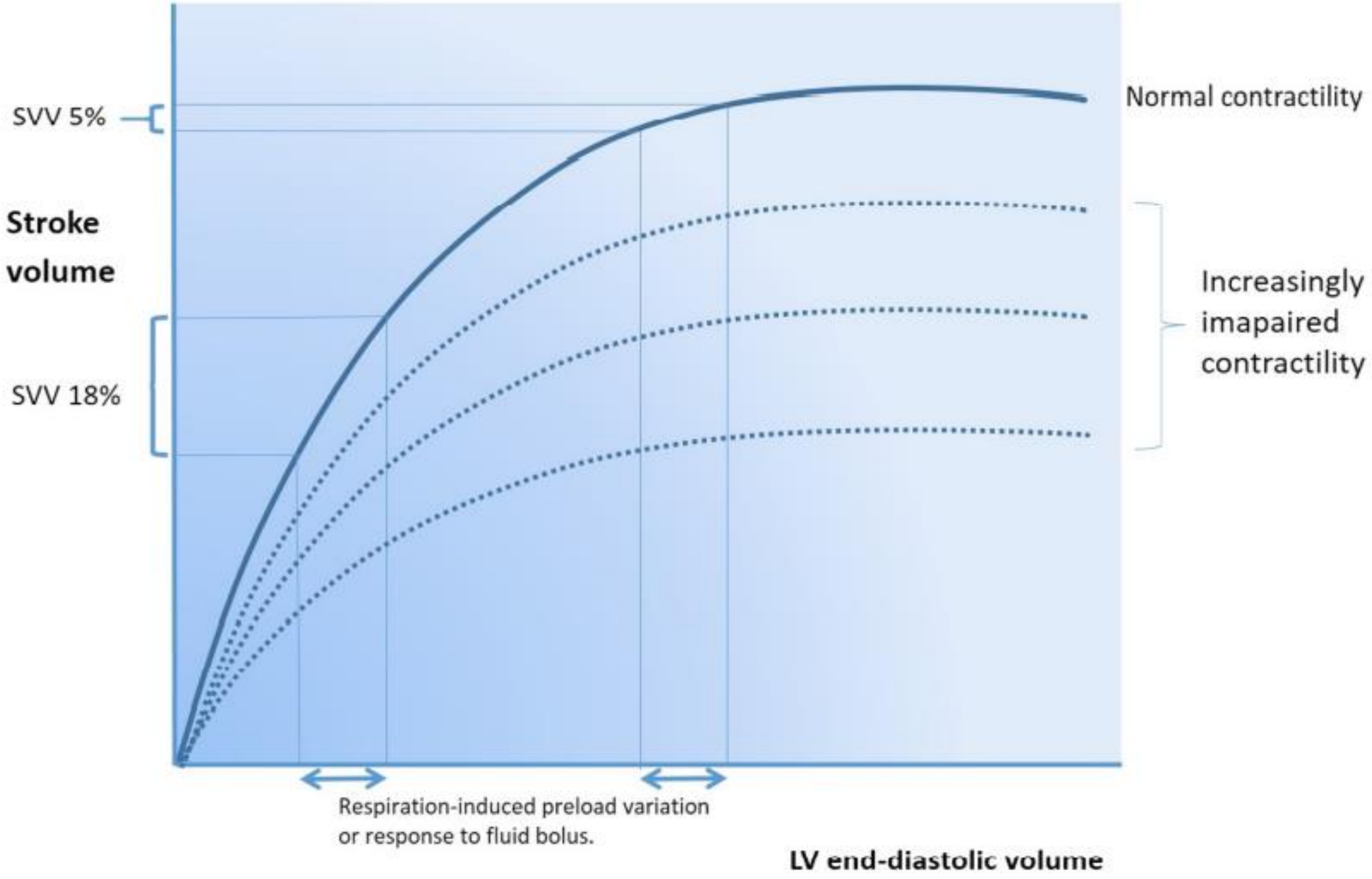
TEE :

-***Midesophageal (ME) two-chamber view*** at the ***MV leaflet tips***

- M-mode imaging in ***the transgastric LV SAX*** view at the midpapillary level.


A
B
Apres remplissage
AO

Fluid rsponsiveness (FR) in critically ill patients



SVV 5%
Stroke volume
SVV 18%
Normal contractility
Increasingly imapaired contractility
Respiration-induced preload variation or response to fluid bolus.
LV end-diastolic volume

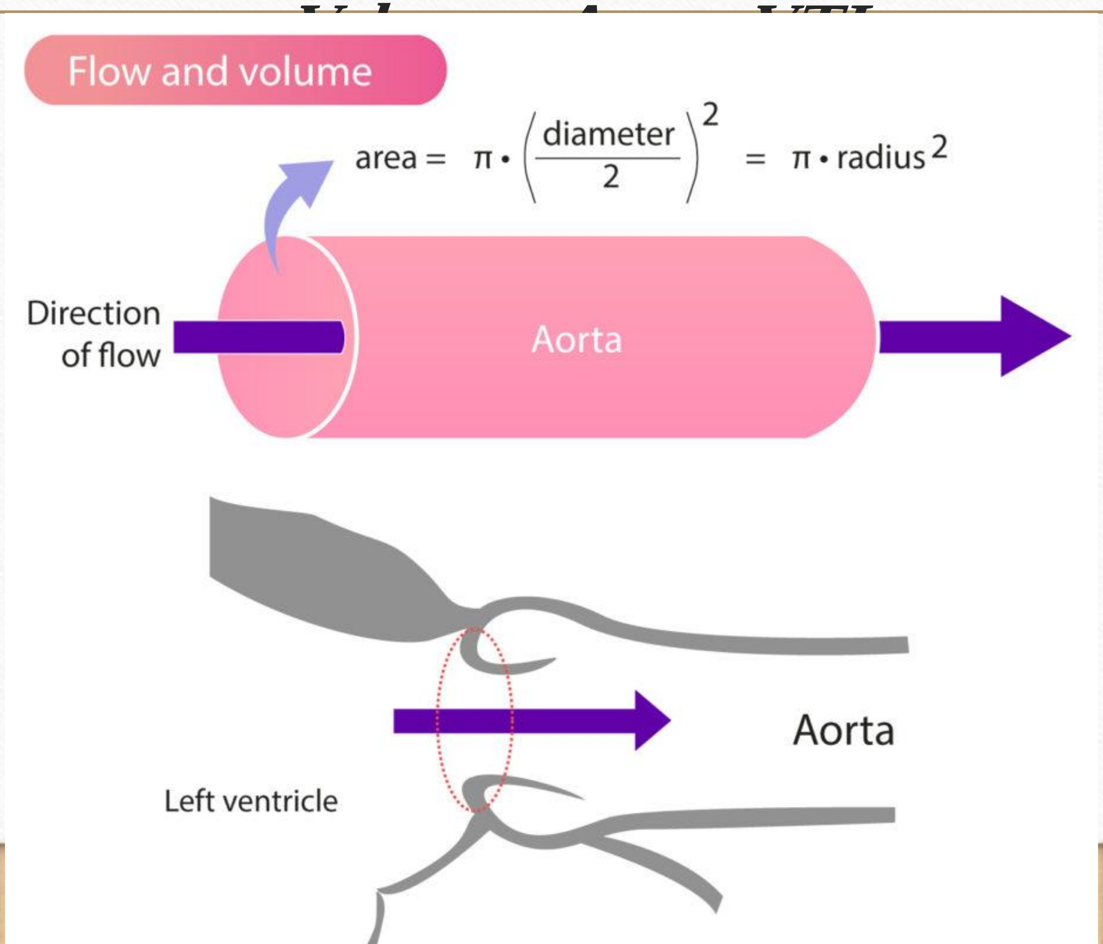
Fluid rsponsiveness

- increases their ***stroke volume by >15%*** after ***a 500mL*** fluid challenge
- An increment of SV (VTI) about ***10-12%*** *after* Passive leg raising ***suggests FR***
- Stroke volume variation in sinus rhythm of ***more than 12-14%***

Q(flow):area x velocity

Volume: Q(flow) x time   (when flow is constant,but not about heart)

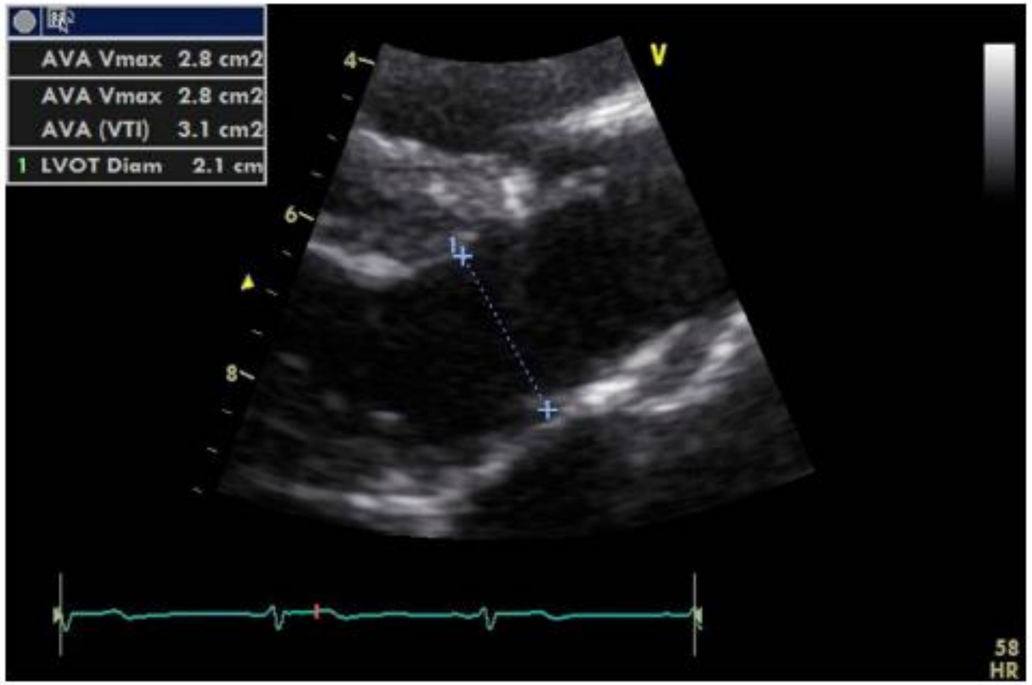
Volume: area x velocity x time

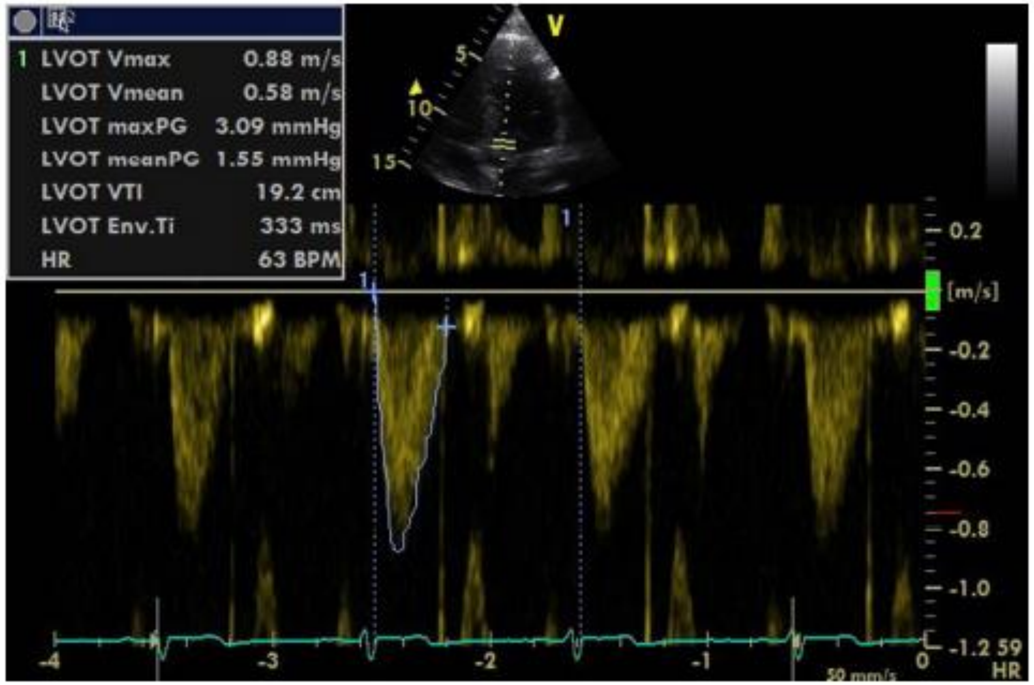


Volume: area x velocity x time

VTI: How far blood travels during flow period (Stroke distance in centimetres)

CSA= $2\pi r^2$ SV: (0.785 x D2) x VTI

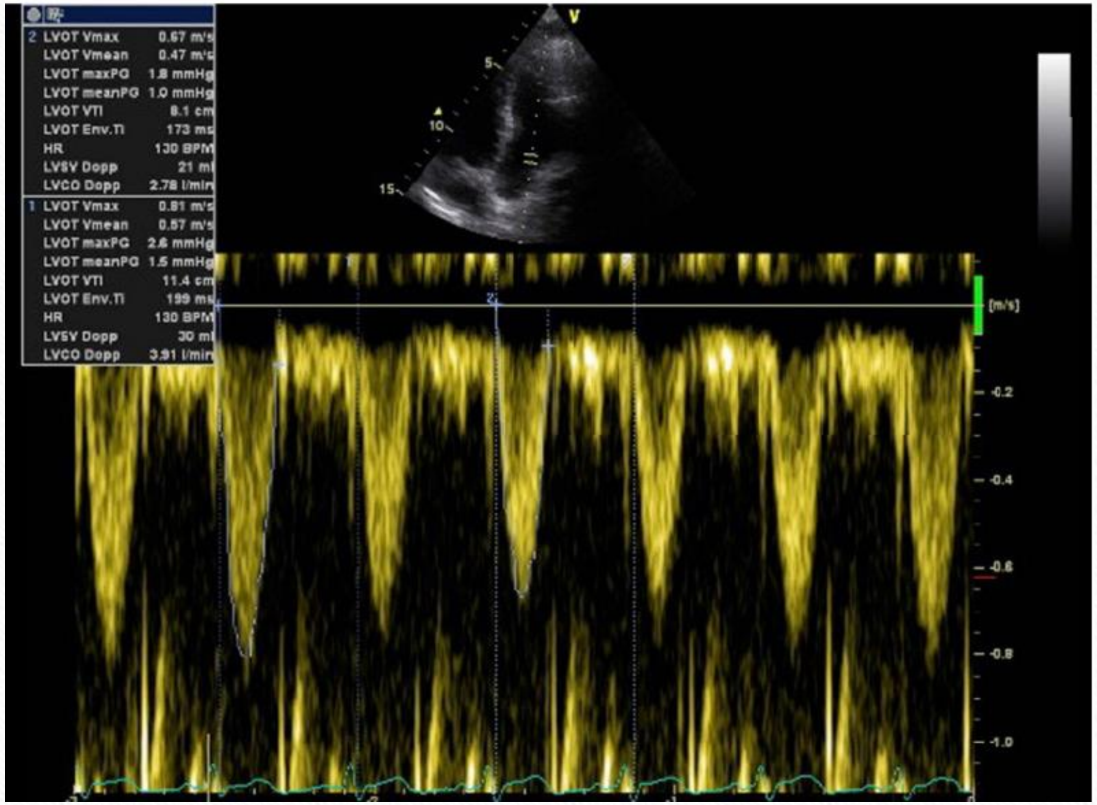




Stroke volume variation in sinus rhythm of *more than 12-14%*

accurately predicts fluid response

less than 10% a high negative predictive value



Fluid challenge

1-Rapid administration of 250–500 mm of intravenous fluid

2-measure LVOT VTI rather than adding in an LVOT measurement to get SV.

3-immediately before and after a fluid challenge

4--ideally be end expiratory or averaged over several consecutive beats.

a fluid responder is generally defined as someone who increases their ***stroke volume by >15%*** after ***a 500mL*** fluid challenge

Passive leg raising

A simple method of predicting fluid responsiveness.

Tilting a patient from a 45-degree semi-recumbent head up position to a 45-degree leg up position, which transfers up to *300 mL* of blood into the central circulation.

Tipping **the whole bed** and not lifting the legs avoids compression of the femoral veins.

Stroke volume or simply VTI across either outflow tract is **measured before and 1 min** after the PLR.

An increment of ***10% suggests FR***

Signs of overt hypovolaemia:

LV small (LVED area PSAX <10cm2)

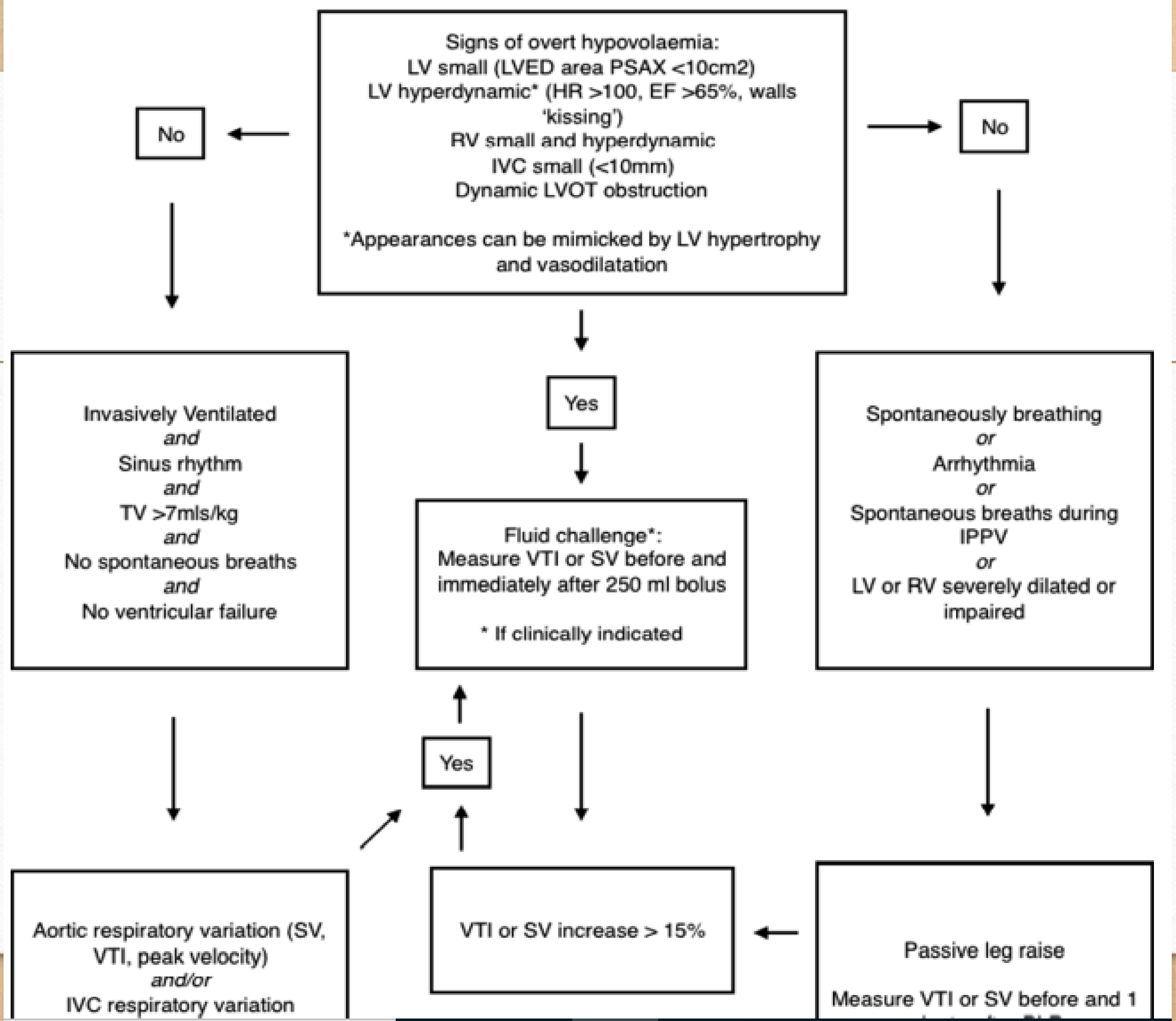
LV hyperdynamic* (HR >100, EF >65%, walls 'kissing')

RV small and hyperdynamic

IVC small (<10mm)

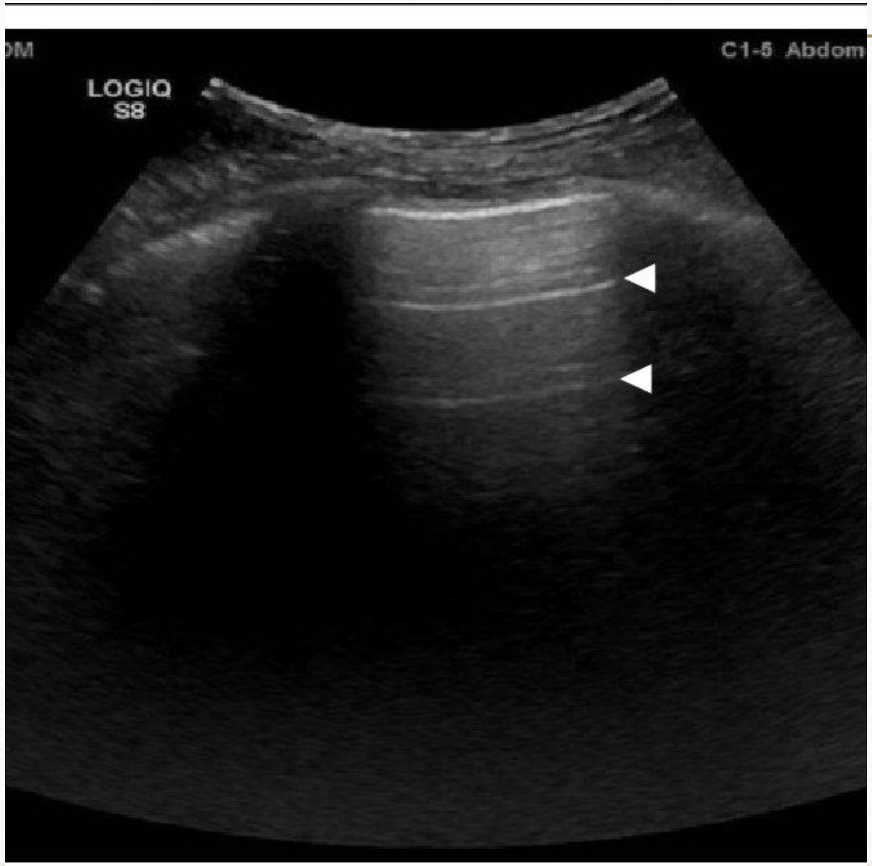
Dynamic LVOT obstruction

*Appearances can be mimicked by LV hypertrophy and vasodilatation


Signs of overt hypovolaemia:
LV small (LVED area PSAX <10cm2)
LV hyperdynamic* (HR >100, EF >65%, walls 'kissing')
RV small and hyperdynamic
IVC small (<10mm)
Dynamic LVOT obstruction
*Appearances can be mimicked by LV hypertrophy and vasodilatation
No
No
Yes
Invasively Ventilated
and
Sinus rhythm
and
TV >7mls/kg
and
No spontaneous breaths
and
No ventricular failure
Fluid challenge*:
Measure VTI or SV before and immediately after 250 ml bolus
* If clinically indicated
Spontaneously breathing
or
Arrhythmia
or
Spontaneous breaths during IPPV
or
LV or RV severely dilated or impaired
Yes
Aortic respiratory variation (SV, VTI, peak velocity)
and/or
IVC respiratory variation
VTI or SV increase > 15%
Passive leg raise
Measure VTI or SV before and 1

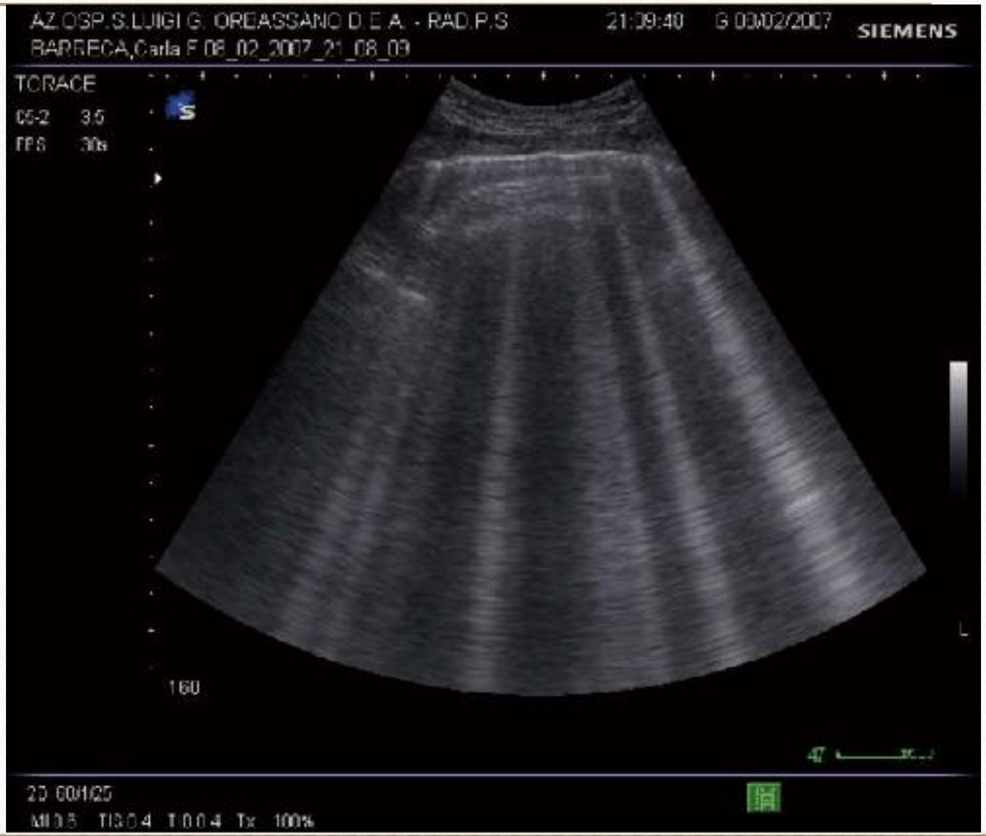
Ultrasonic

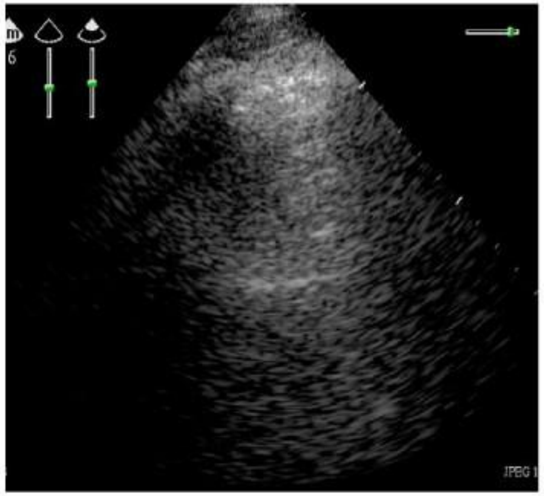
A-line artifacts



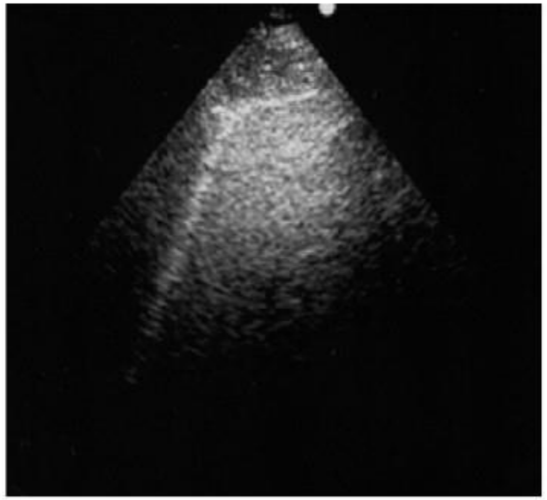
Ultrasonic comet tail sign (B-line)

discrete, *laser-like, vertical, hyperechoic image, that arises from the pleural line, extends to the bottom of the screen*

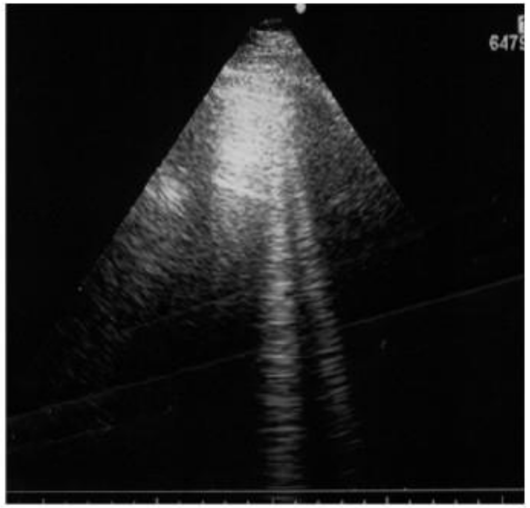




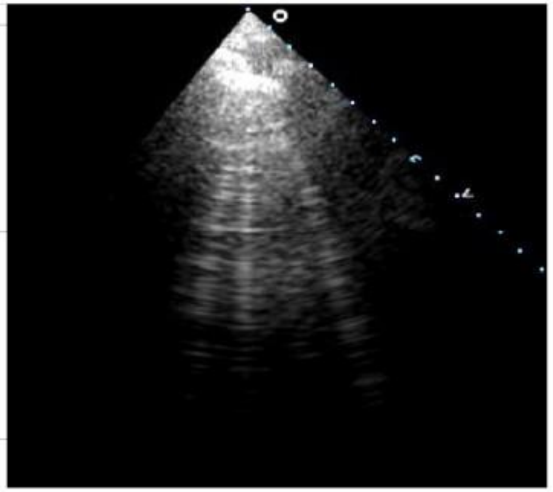
No B-lines



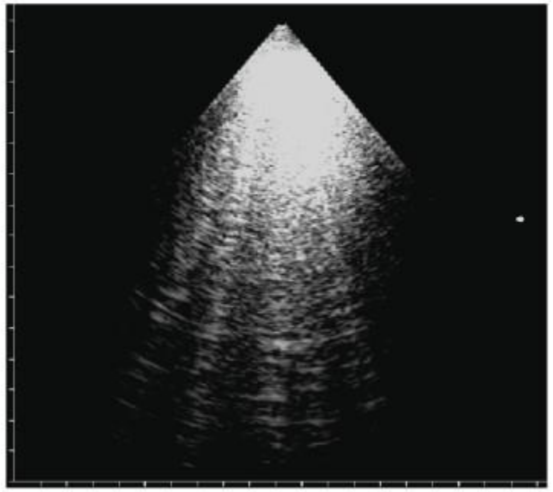
One B-line



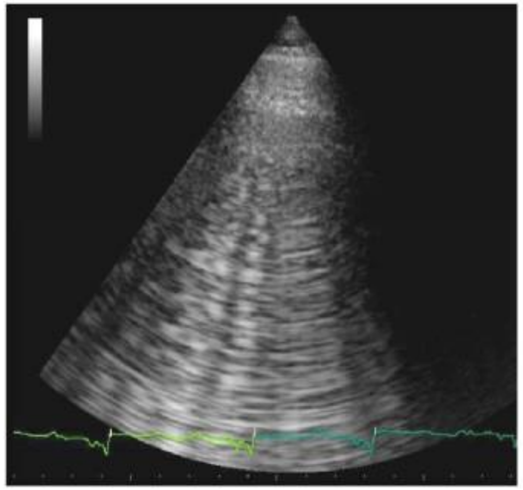
Two B-lines



Three B-lines



Five B-lines



Full white screen = 10 B-lines

Scoring

right side

Mid-axillary	Anterior axillary	Mid-clavicular	Para-sternal	Inter-costal space	Para-sternal	Mid-clavicular	Anterior axillary	Mid-axillary
				II				
				III				
				IV				
				V				

left side

Management

- B.Blockers and ACE.I and ARB in asymptomatic patients
- IN symptomatic patients:
- Self assessment
- Control of hypertention
- Treatment of CAD
- Treatments of arrhythmia(AF)
- Anemia
- High output state
- Management of renal failure (Optimizing the duration or frequency of dialysis)


The End