Doppler Tissue Imaging (DTI)

Diastolic Function / LV Filling Pressures

Anthony Ryan
Chief Cardiac Physiologist.
Sligo University Hospital

- Diastolic dysfunction
- is defined as functional abnormalities that exist during LV relaxation and filling. When such abnormalities cause or contribute to the clinical syndrome of heart failure with a normal LV ejection fraction, it is appropriate to describe the condition as diastolic heart failure.

Mitral annular TDI

- Doppler Tissue Imaging (TDI) has been proven to be useful in estimating LV diastolic filling pressures and has clinical use in adult cardiology.
- potential role of TDI in the assessment of diastolic function combined with standard mitral Doppler recordings.

Limitations of standard Doppler velocities

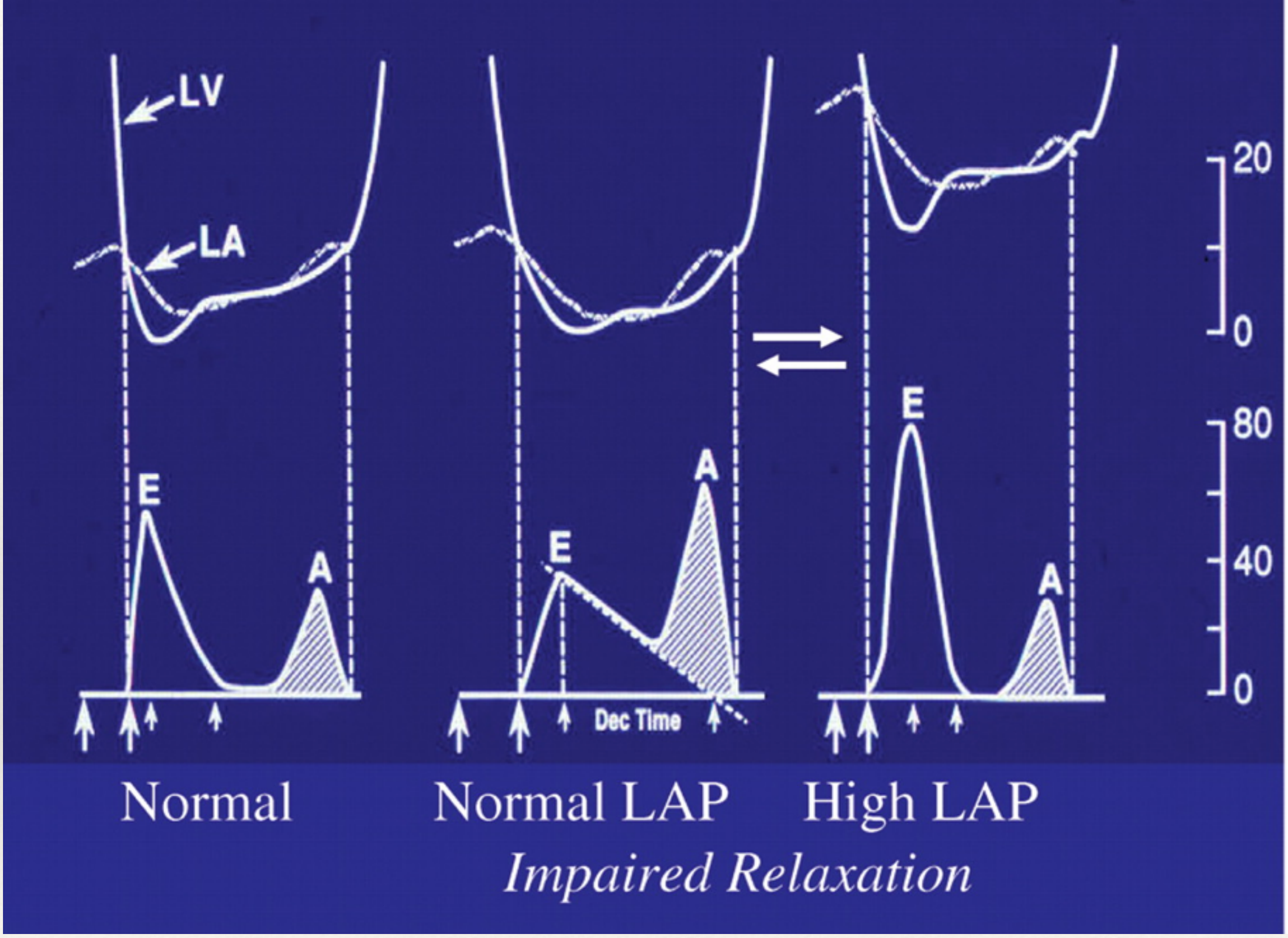
- assessment of LV filling pressures such as LA pressure and its surrogate PCWP, is of importance to the clinician.
- *If filling pressures are high,* this may be an indication that dyspnoea may be caused in part by *pulmonary congestion.*
- *If filling pressures are low,* this may help explain symptoms of low cardiac output or, in extremes cases *syncope.*
- a non-invasive technique may be useful in tailoring therapy.

Limitations of standard Doppler velocities

- In patients with reduced LVEF it has been well established that transmittal Doppler variables can be used to accurately predict PCWP.
- however, the transmittal flow variables predict filling pressures less reliably in patients with normal EF >53%
- This group comprise approx half of all patients with heart failure. Given these limitations, additional echo data is often needed.

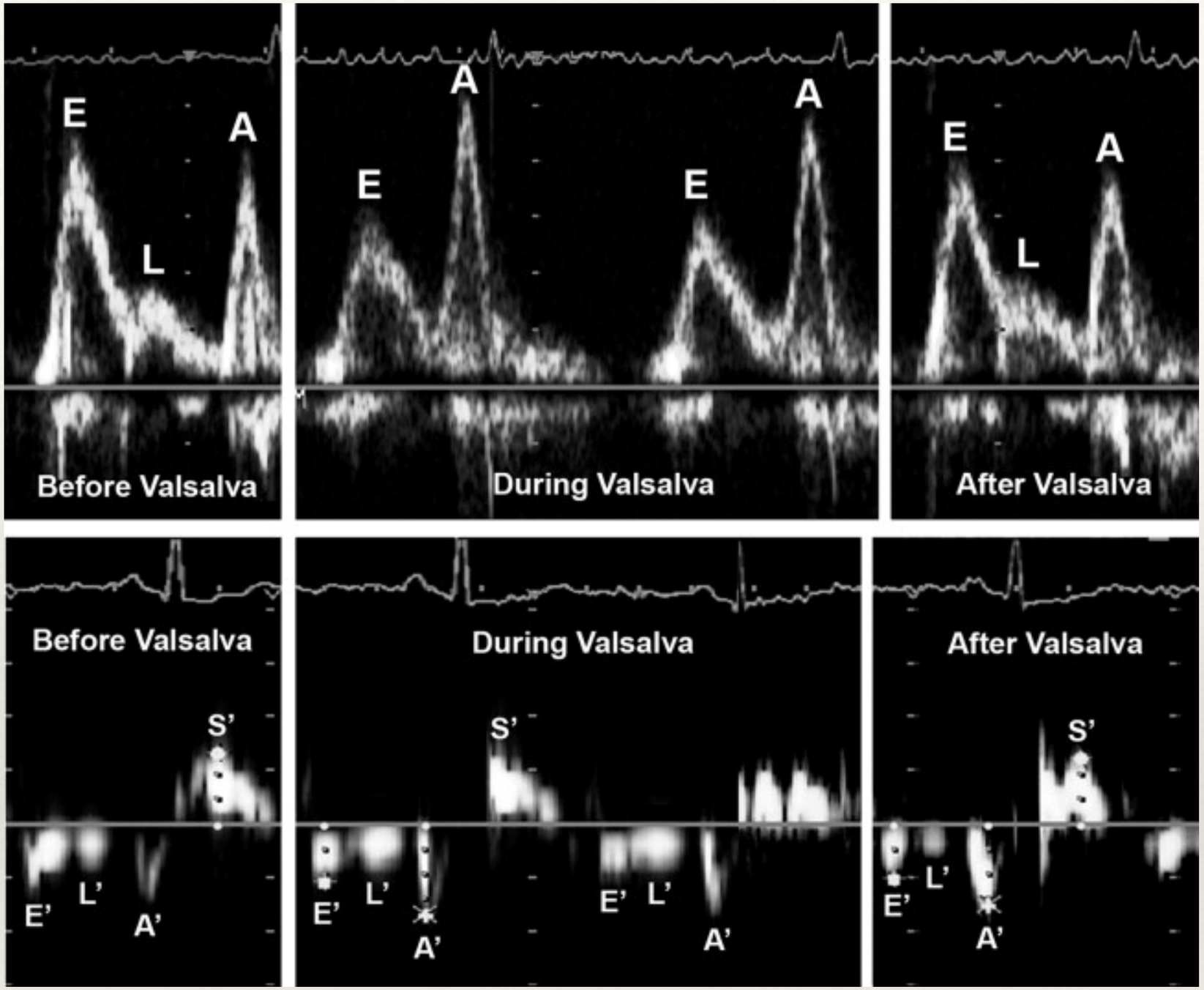
Principles of transmittal velocity curves

- In NSR diastolic flow from the LA to the LV across the MV, it has two components
- E wave reflects *early diastolic filling*
- A wave in *late diastole* which is related to flow caused by atrial contraction.
- these transmittal velocities are determined by the transmittal pressure gradient, which in turn is influenced by both the rate of early LV diastolic relaxation and the level of LAP


LV
LA
E
A
E
A
Dec Time
E
A
20
0
80
40
0
mm
cm/
Normal
Normal LAP
High LAP
Impaired Relaxation

MV inflow Doppler E/A

- the transmitral E wave velocity reflects the early diastolic pressure gradient between the LA and LV, which may be increased by elevated LAP, vigorous diastolic suction in normal LV filling or both.
- alterations in the pattern of these inflow variables allows understanding of ventricular diastolic function and prediction of prognosis.


E
A
L
Before Valsalva
A
E
E
A
During Valsalva
E
A
L
After Valsalva
S'
E'
L'
A'
Before Valsalva
S'
E'
L'
A'
E'
L'
A'
During Valsalva
S'
E'
L'
A'
After Valsalva

TDI

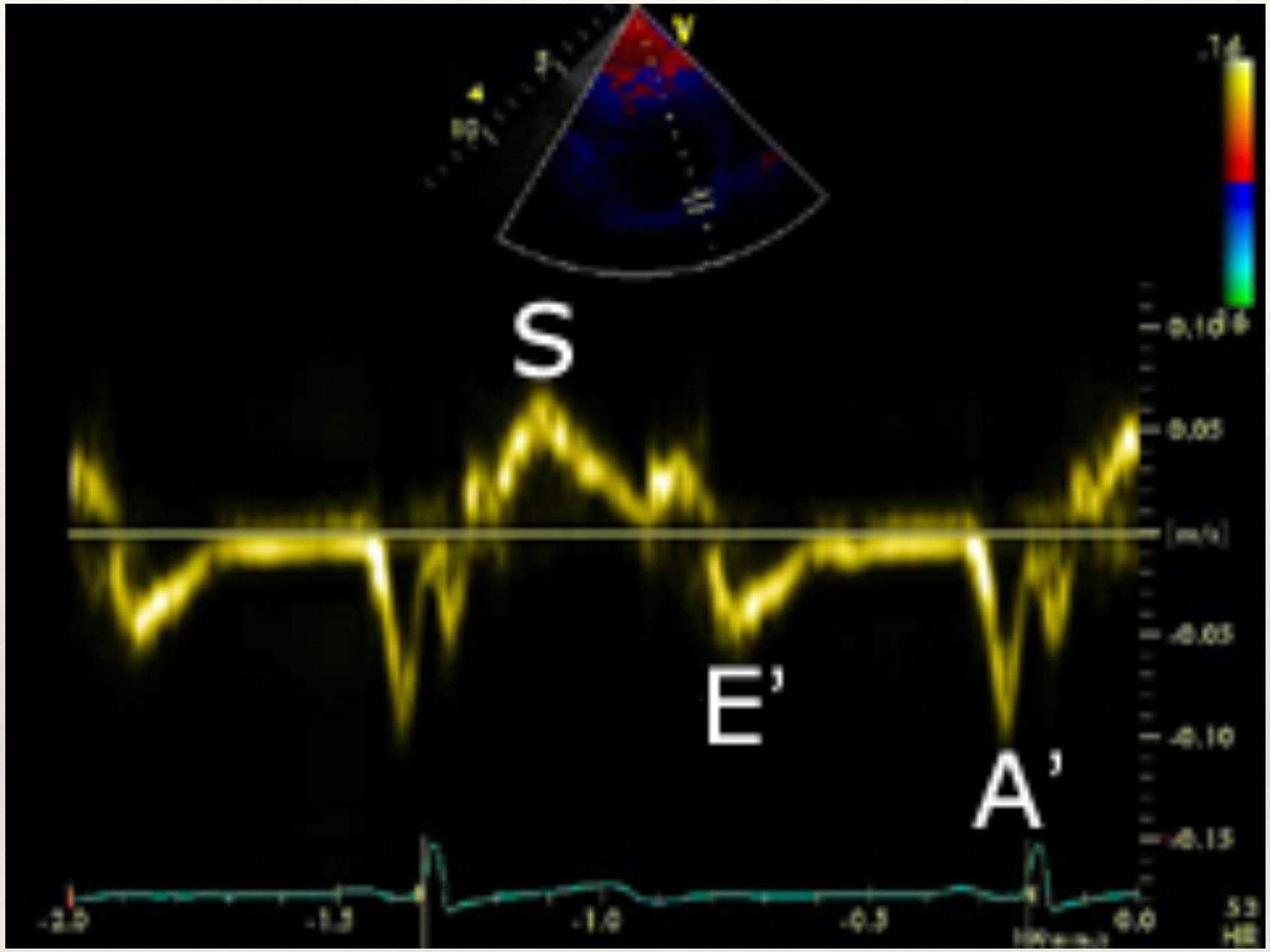
- annular TDI is easy to perform as it is not dependent on image quality or timely processing of the spectral Doppler signal.

TDI waveforms

- annular TDI waveforms obtained from the AP4ch view display direction and velocity of the annulus as it travels throughout the cardiac cycle.
- during systole, the annulus moves toward the apex resulting in a positive waveform on the Doppler display. There is one major systolic velocity (S').
- during diastole, the annulus is displaced first towards the base by the effects of ventricular relaxation, and again by atrial systole.

NSR

- the diastolic TDI waveform has two major components
- the early velocity (E’)
- the late velocity (A’)


S
E’
A’

Validation studies E’ ,E/E’ ratio

- Isaac et al 1989 first reported the use of TDI by quantitating high amplitude, low velocities of the posterior wall. But TDI did not come into widespread clinical use until 1990’s.
- The E/E’ ratio has been validated as a reliable index for the estimation of PCWP

E/E’

- The annular Doppler tissue E’ wave reflects the velocity of ventricular lengthening in early diastole and is related to time constant of relaxation and elastic recoil.
- Therefore a LV with a *slower relaxation will have a lower E’ velocity.*
- In this way the E’ velocity can correct the mitral E wave velocity for the influence of ventricular relaxation.

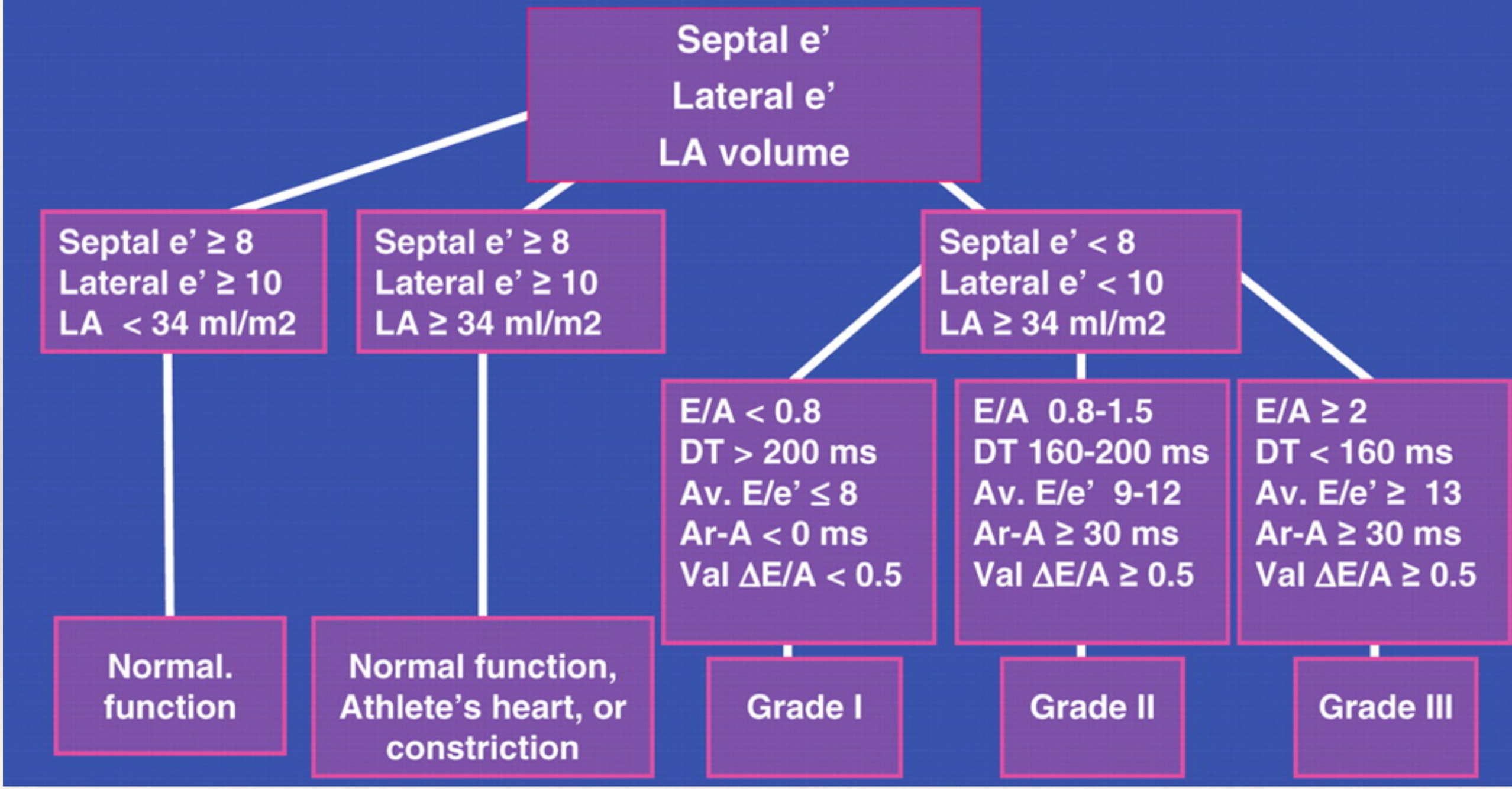
HTN

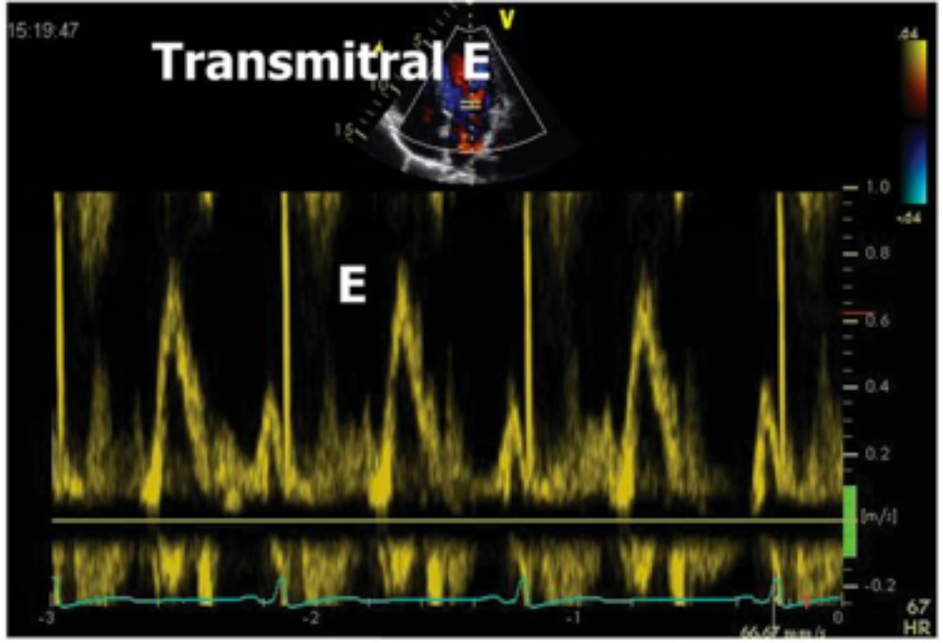
- a 65 yr old patient with HTN and Dyspnoea may have a normal appearance to mitral E wave velocity and E/A ratio.
- annular TDI average of Medial and Lateral annulus of MV can be very helpful in this case by calculating the E/E' ratio.

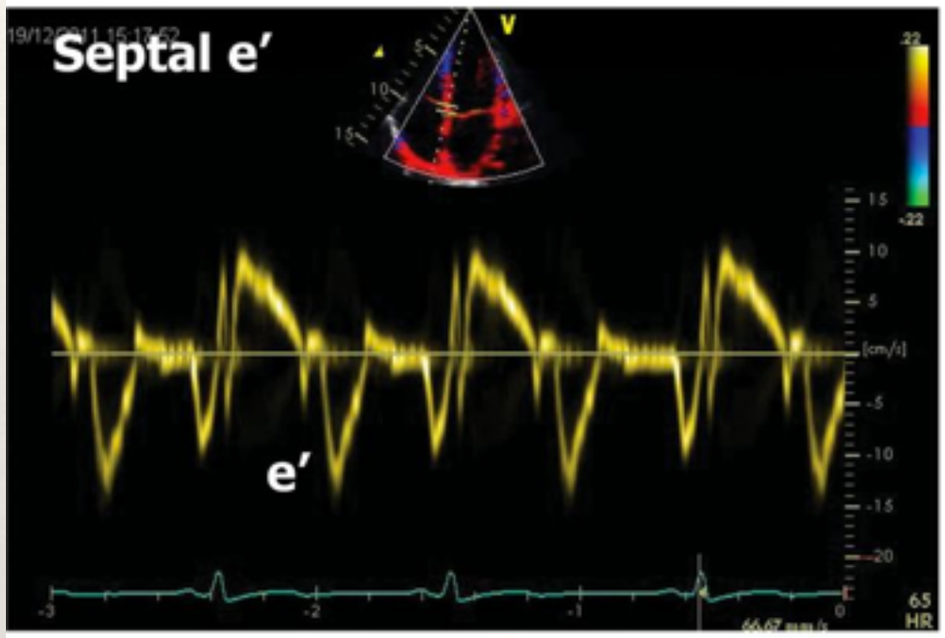
E/E' ratio

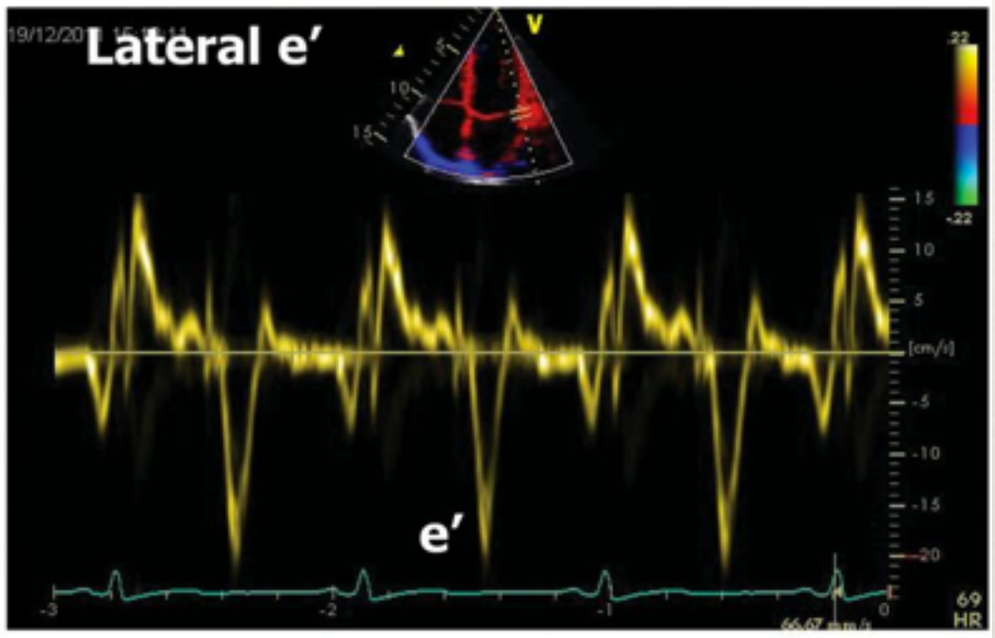
- a low E/E' ratio (<8) usually indicates normal LAP (<10mmHg)
- conversely, a high E/E' ratio (>15) usually indicates elevated LAP (>15mmHg).
- E/E' ratios between 8 and 15 need additional echo data including, Valsalva manoeuvre , pulm vein S/D ratio, pulm vein atrial reversal velocity and mitral A wave duration / pulmonary vein A duration ratio attempting to demonstrate elevated filling pressures.

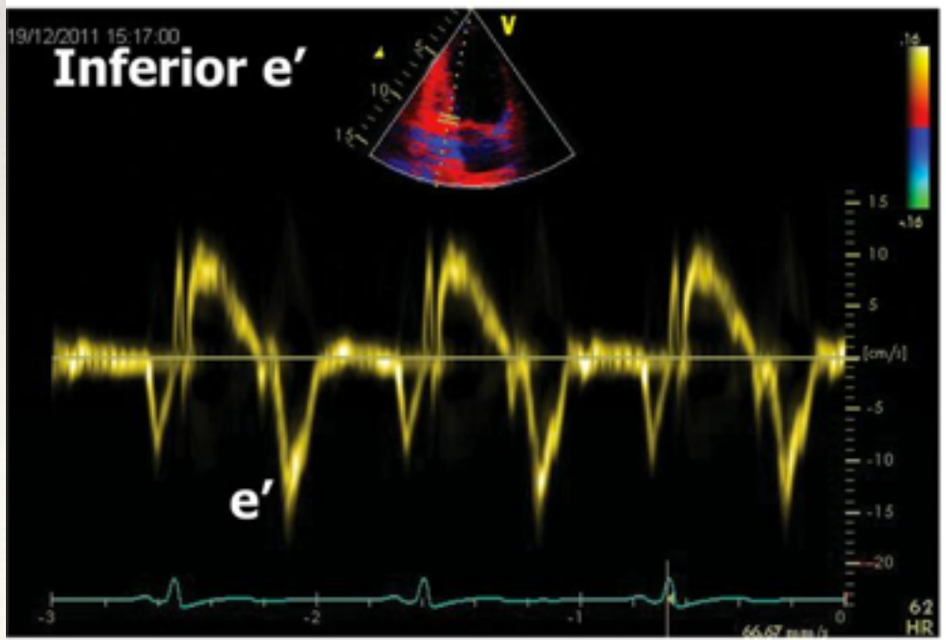
Practical Approach to Grade Diastolic Dysfunction

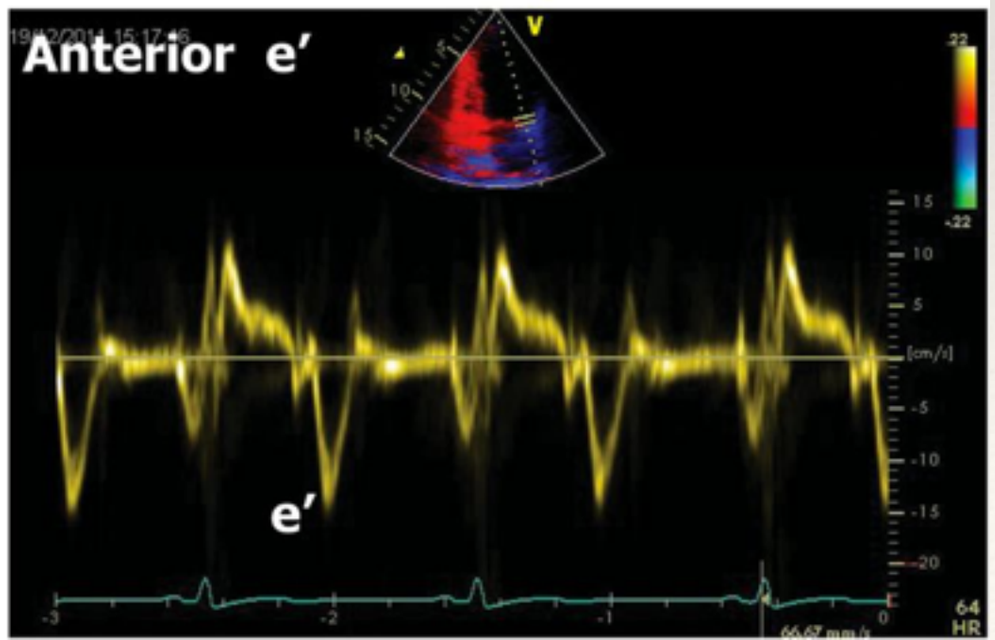


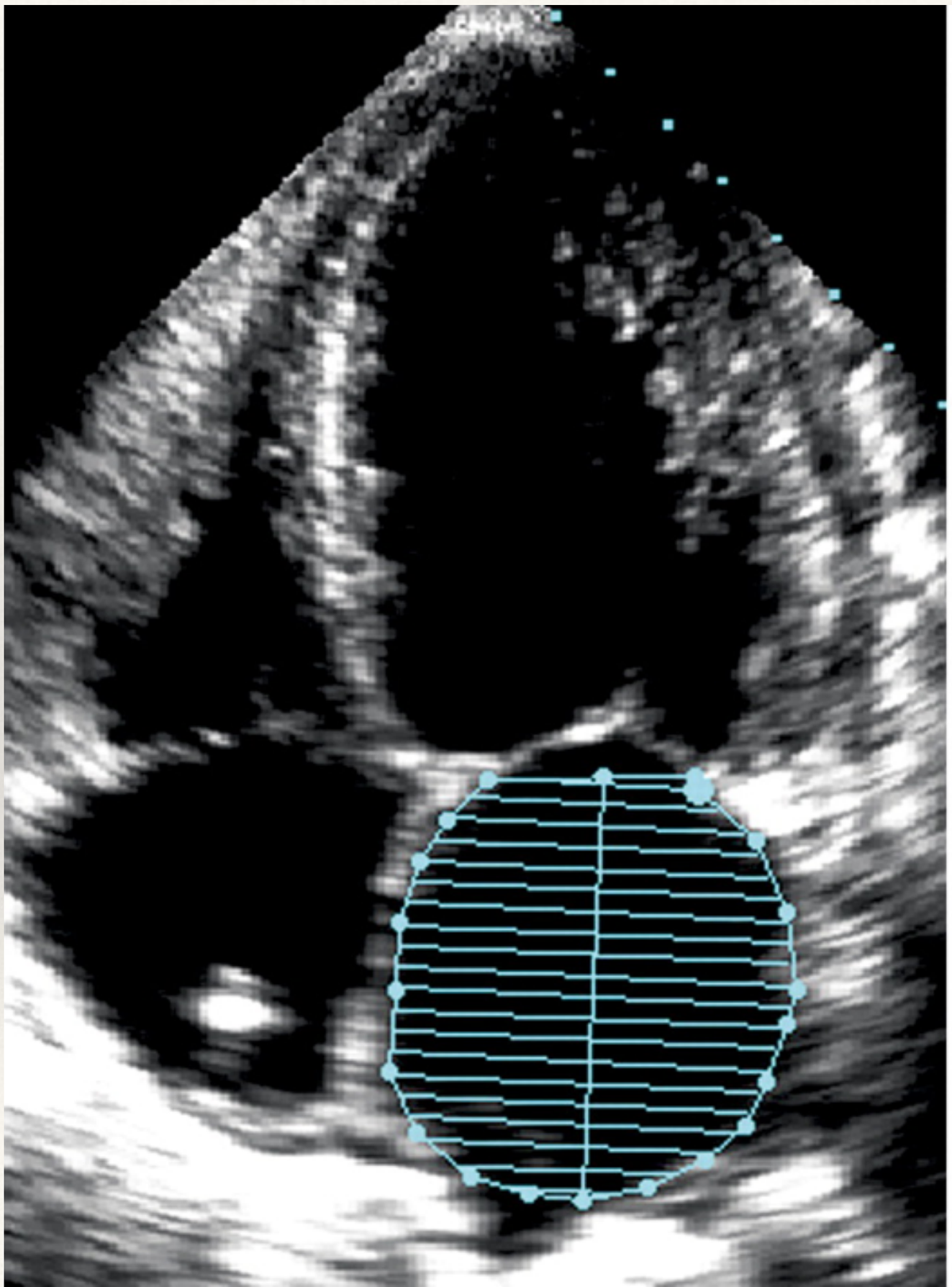

Transmitral E
E

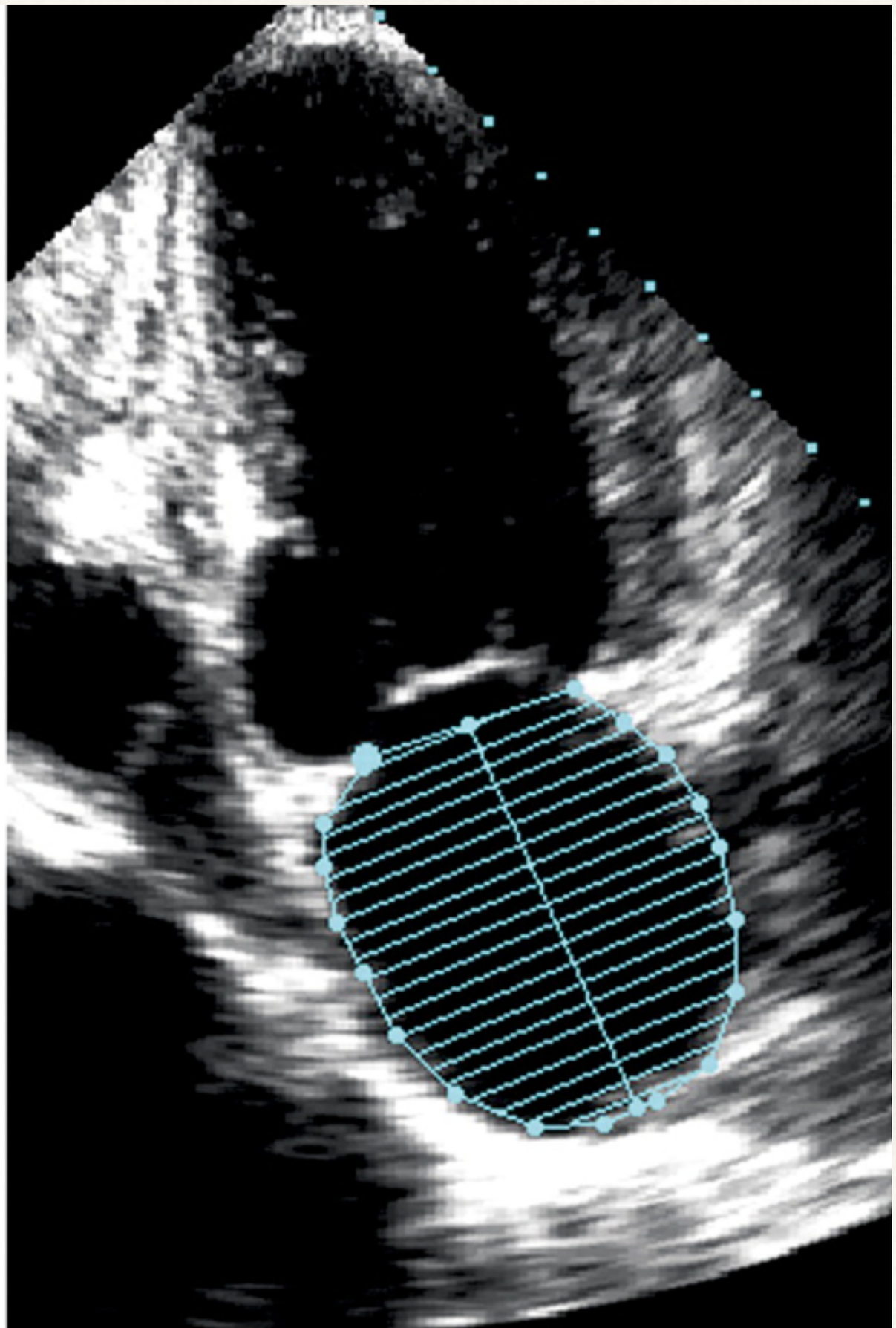

Septal e'
e'

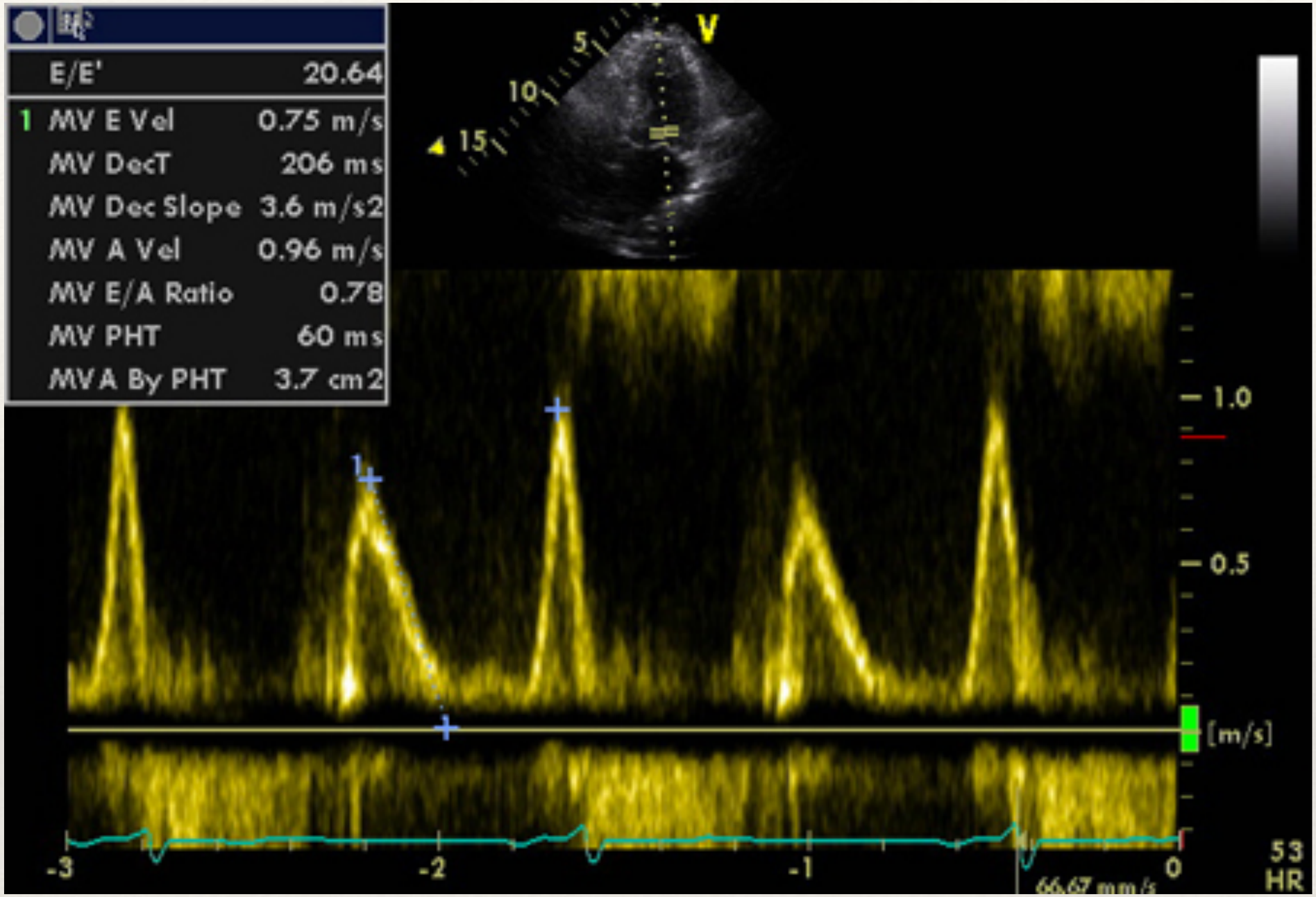

Lateral e'
e'

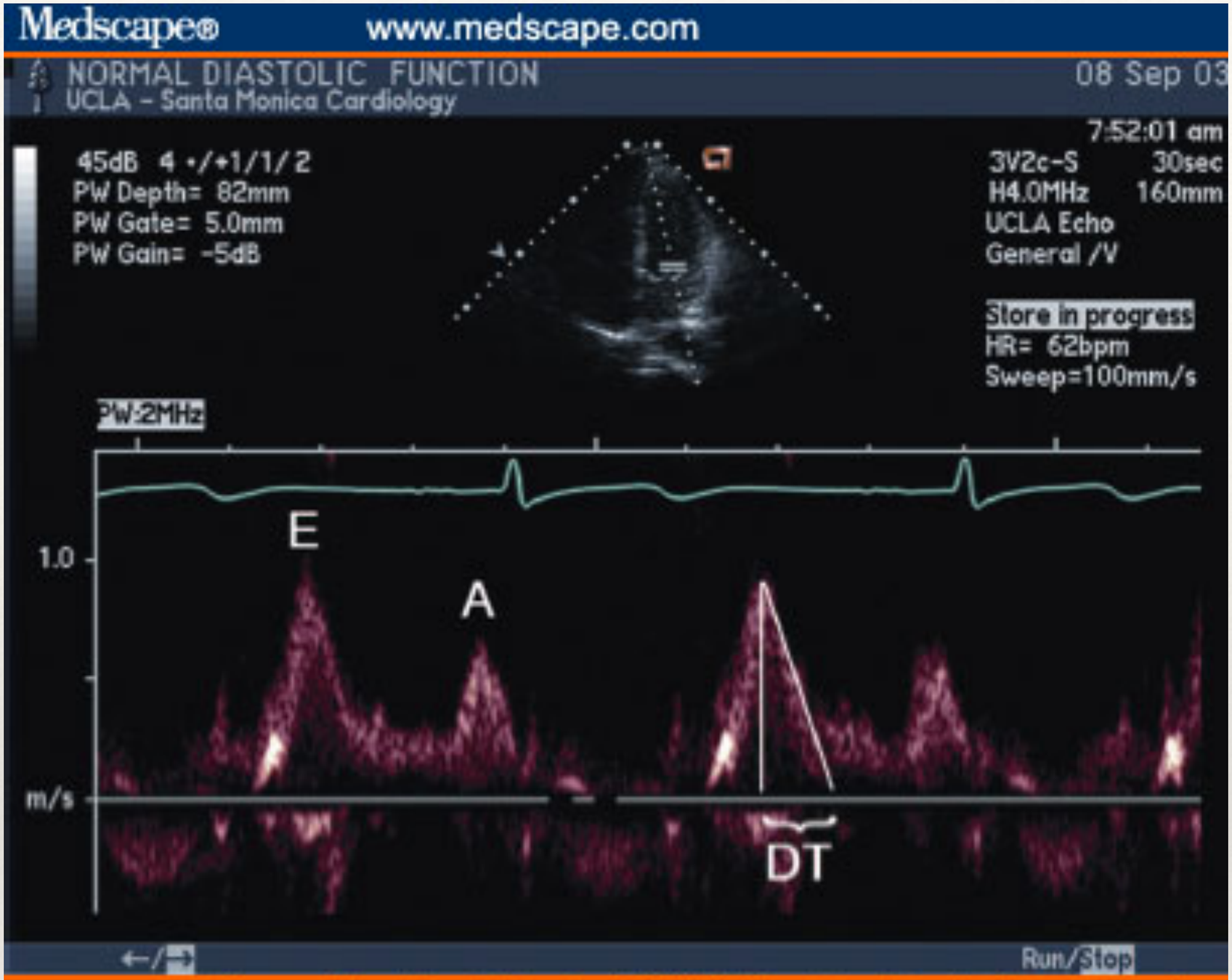

Inferior e'
e'

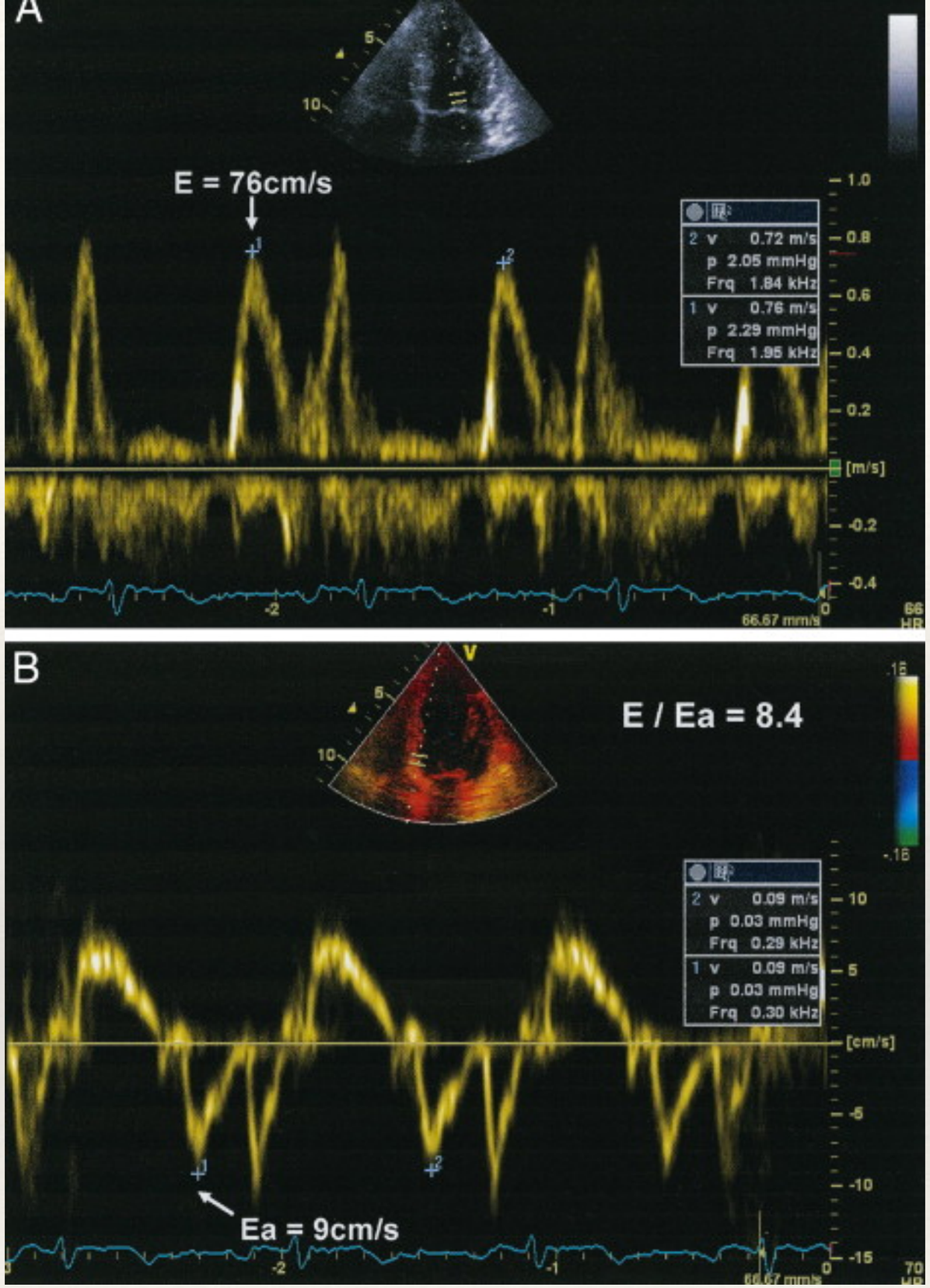

Anterior e'
e'

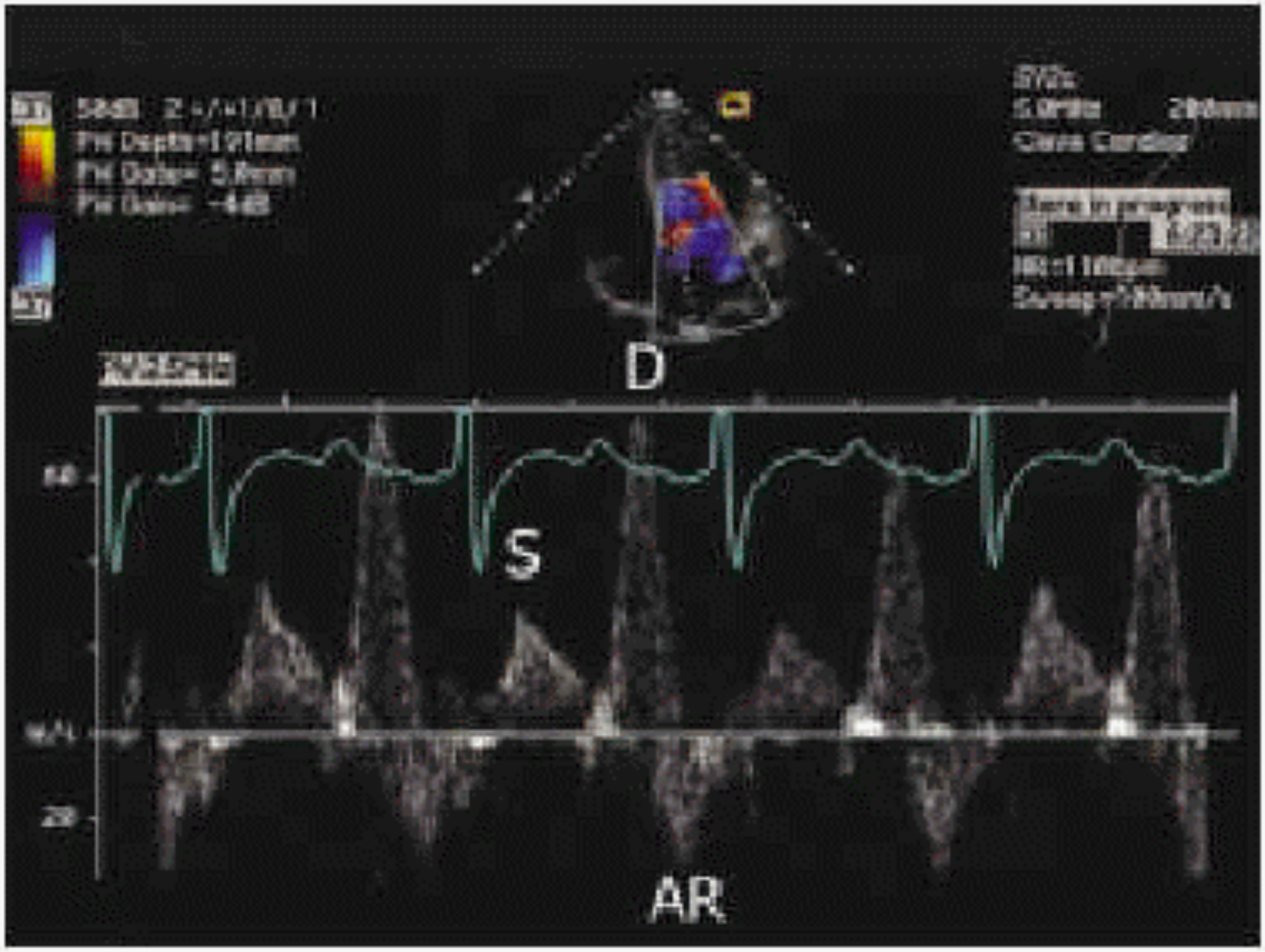


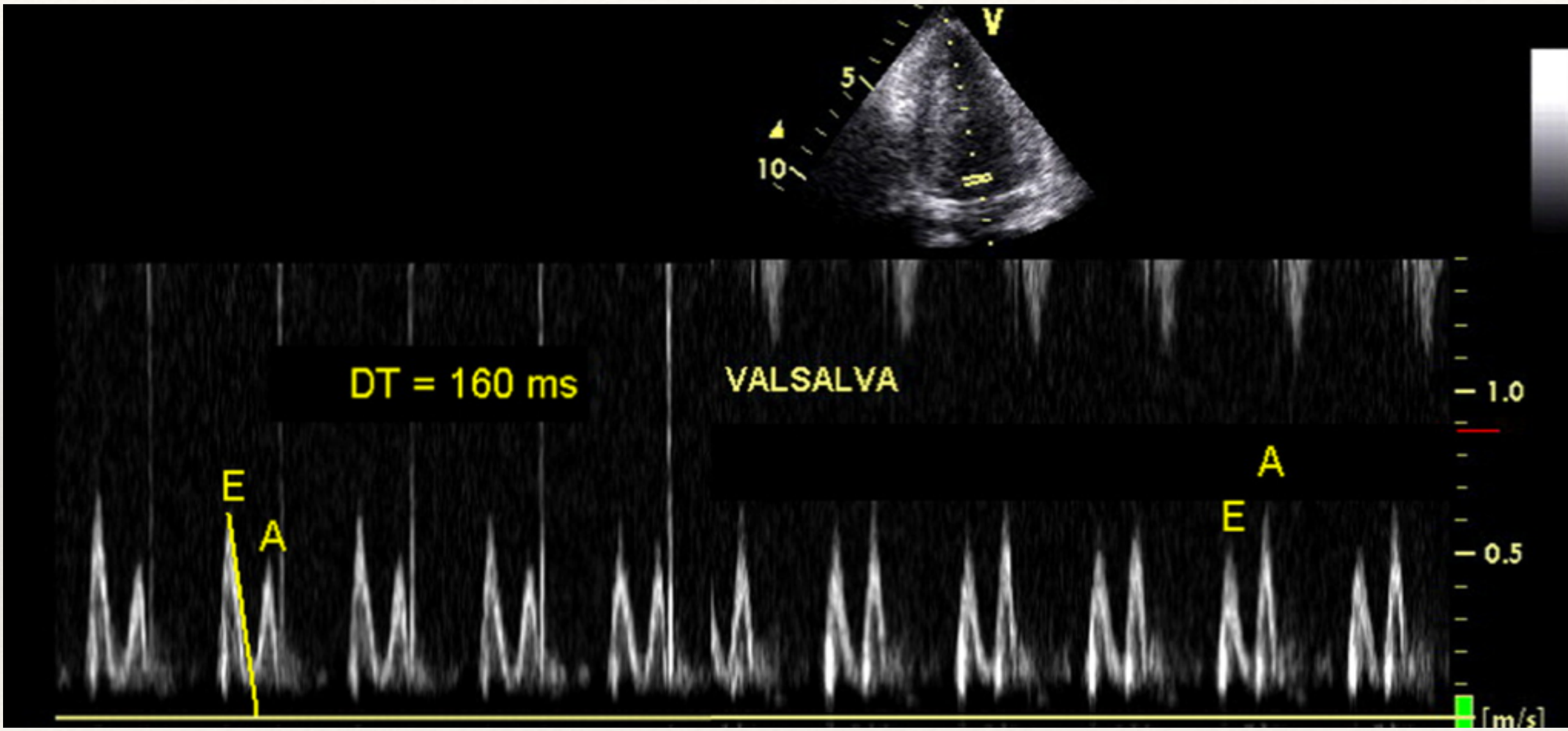



E/E' 20.64
1 MV E Vel 0.75 m/s
MV DecT 206 ms
MV Dec Slope 3.6 m/s2
MV A Vel 0.96 m/s
MV E/A Ratio 0.78
MV PHT 60 ms
MVA By PHT 3.7 cm2
5
10
15
V
1.0
0.5
[m/s]
-3
-2
-1
0
53
HR




A
E = 76cm/s
2 v 0.72 m/s
p 2.05 mmHg
Frq 1.84 kHz
1 v 0.76 m/s
p 2.29 mmHg
Frq 1.95 kHz
[m/s]
66.67 mm/s
B
E / Ea = 8.4
2 v 0.09 m/s
p 0.03 mmHg
Frq 0.29 kHz
1 v 0.09 m/s
p 0.03 mmHg
Frq 0.30 kHz
[cm/s]
Ea = 9cm/s


D
S
AR


V
5
10
DT = 160 ms
VALSALVA
E
A
E
A
1.0
0.5
[m/s]

Classification: diastolic dysfunction

Grade 1 (mild dysfunction) :

impaired relaxation with normal filling pressure

Grade 1a :

impaired relaxation with increased filling pressure

Grade 2 (moderate dysfunction):

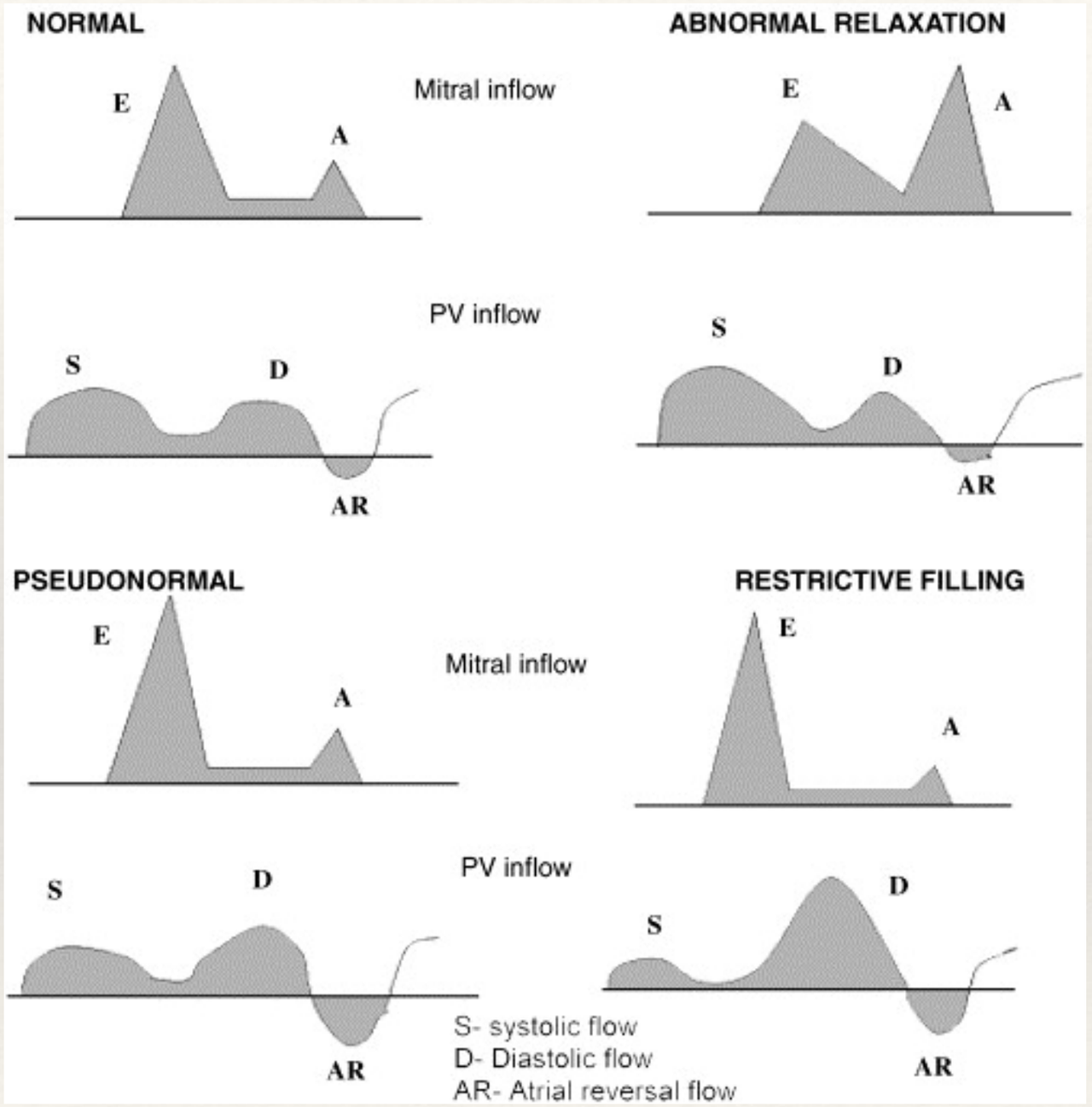
pseudonormalized mitral inflow pattern

Grade 3 (severe reversible dysfunction):

reversible restrictive (high filling pressure)

Grade 4 (severe irreversible dysfunction):

irreversible restrictive (high filling pressure)


NORMAL
E
A
Mitral inflow
ABNORMAL RELAXATION
E
A
PV inflow
S
D
AR
S
D
AR
PSEUDONORMAL
E
A
Mitral inflow
RESTRICTIVE FILLING
E
A
PV inflow
S
D
AR
S
D
AR
S- systolic flow
D- Diastolic flow
AR- Atrial reversal flow

- A recent study demonstrated that mitral annular A' velocity < 5cm/sec was the most powerful predictor of cardiac death or hospitalisation for worsening heart failure compared with clinical, haemodynamic and other echo variables. Yamamoto J Am Soc Echo 2003.
- A modest correlation between the peak mitral annular A' velocity and both LA systolic fractional area change and fractional volume change has been shown.
- DTI is a valuable tool for quantitating atrial function.