LV diastolic function (II)

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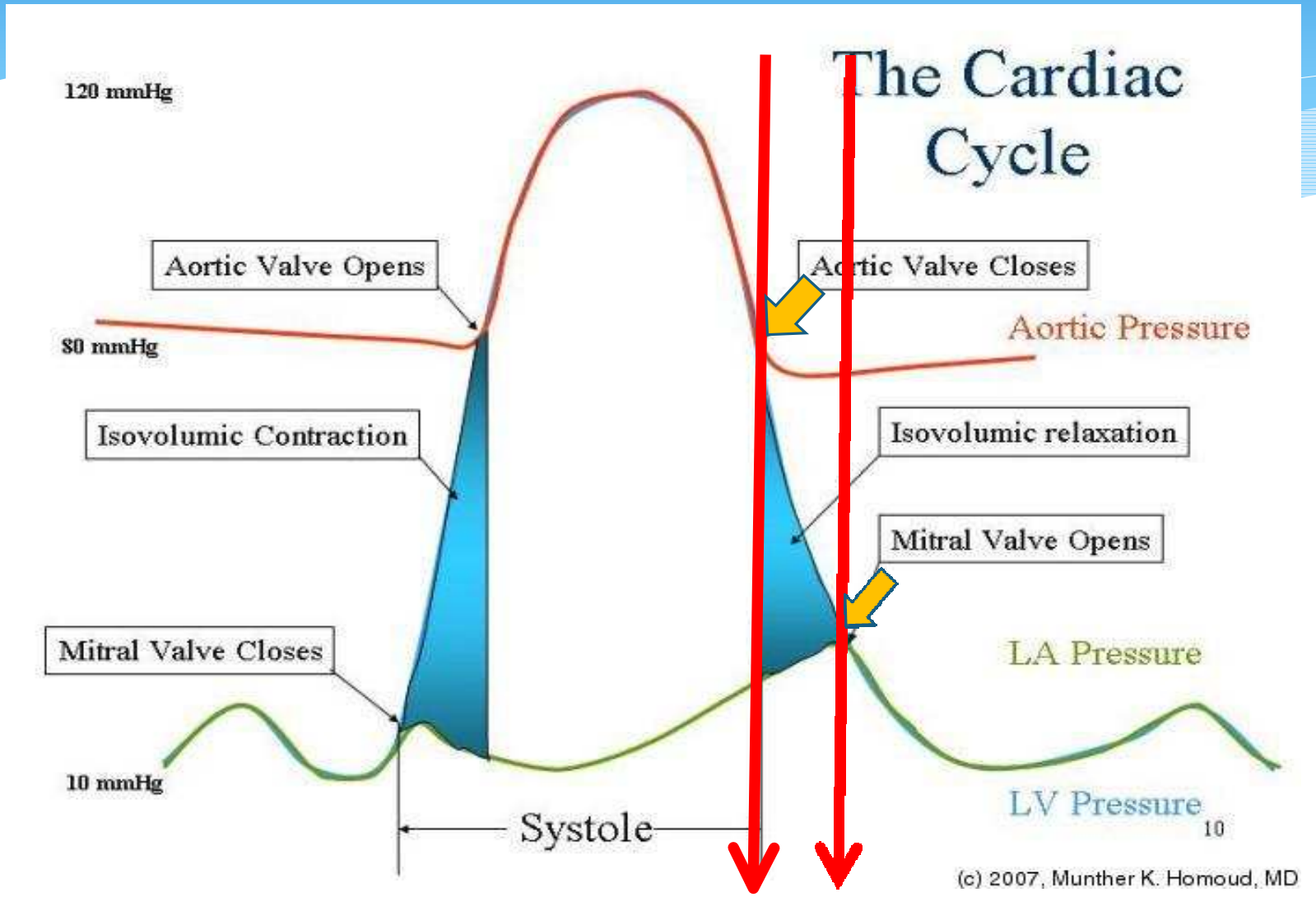
Deformation Measurements

* mitral E velocity/global myocardial strain rate ratio predicted LV filling pressure
* Doppler flow velocity and myocardial velocity imaging are the preferred initial echocardiographic methodologies for assessing LV diastolic function

Left Ventricular Untwisting

* when viewed from apex toward the base, the LV apex shows systolic counterclockwise rotation and the LV base shows a net clockwise rotation (isovolumetric relaxation period and is largely finished at the time of mitral valve opening)
* recoil rate
* LV twist appears to play an important role for normal systolic function, and diastolic untwisting contributes to LV filling through suction generation
* Diastolic dysfunction associated with normal aging, however, does not appear to be due to a reduction in diastolic untwist


The Cardiac Cycle
120 mmHg
80 mmHg
10 mmHg
Aortic Valve Opens
Aortic Valve Closes
Aortic Pressure
Isovolumic Contraction
Isovolumic relaxation
Mitral Valve Opens
Mitral Valve Closes
LA Pressure
LV Pressure
Systole
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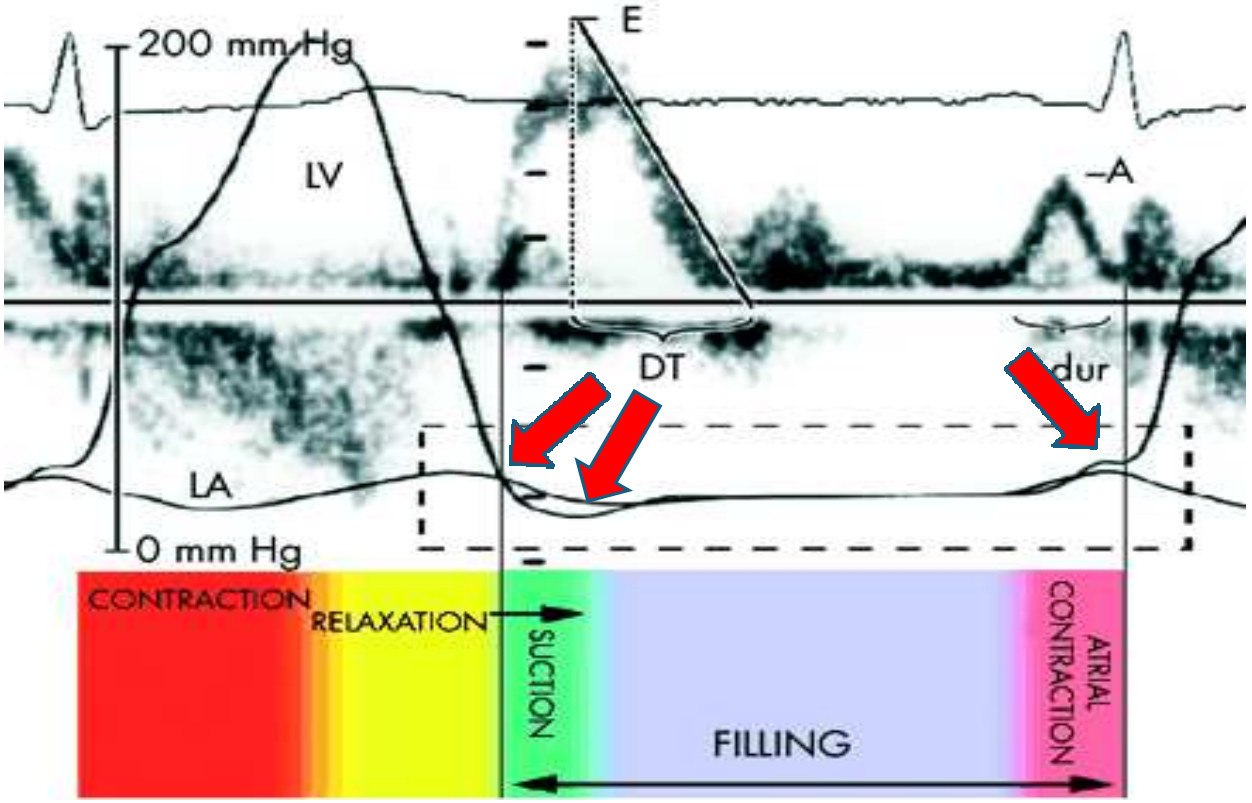
relaxation

stiffness

Filling pressure

Diastolic dysfunctio

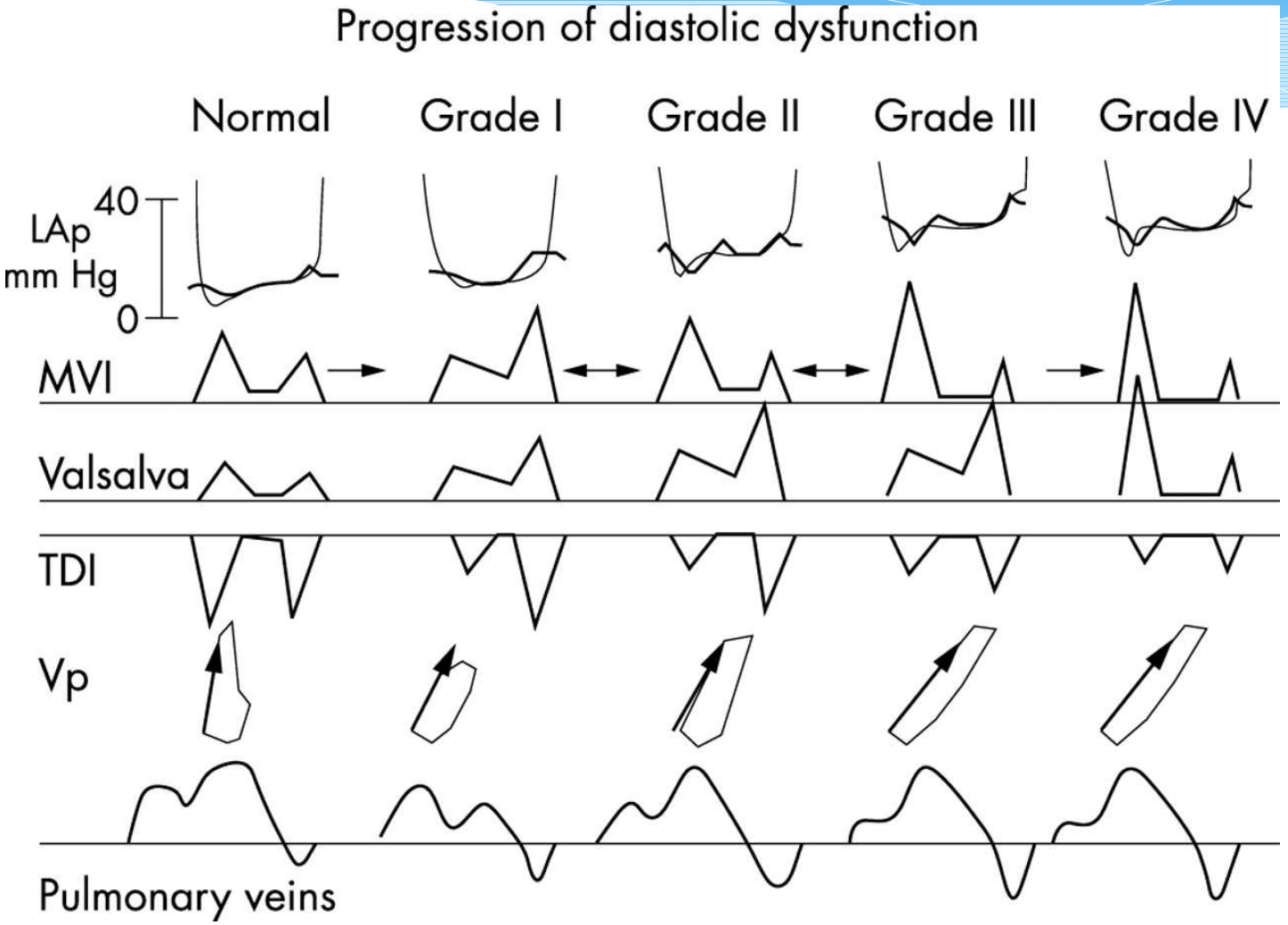
Cardiac cycle



relaxation, stiffness, filling pressures

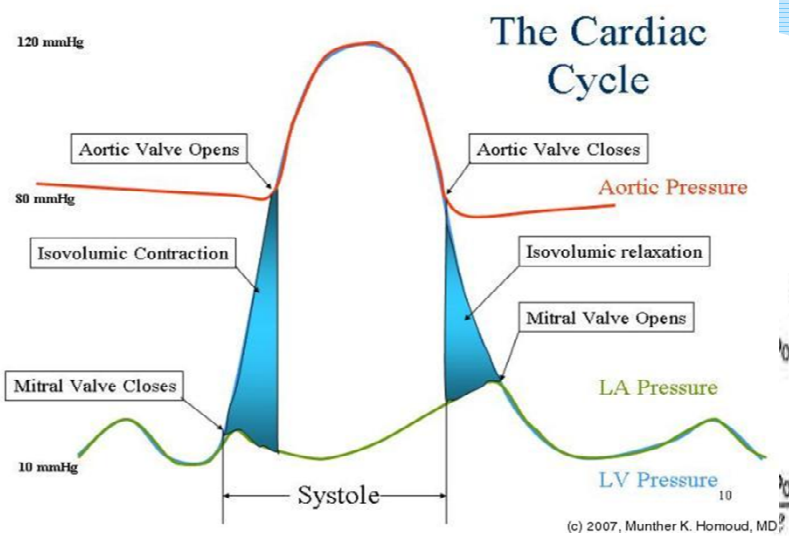
* **relaxation**: IVRT and isovolumetric or early diastolic annular motion or LV strain rate
* **compliance**: DT of mitral E velocity, A-wave transit time, the ratio of LVEDP to LV end-diastolic volume, increased LVEDP, mitral A-wave duration, reduced a', and prolonged Ar duration in pulmonary venous flow
* **early diastolic LV and LA pressures**: E/e' ratio, DT of mitral E velocity in patients with depressed EFs, and to some extent LA enlargement

The progression of left ventricular diastolic dysfunction can be readily assessed using a combination of Doppler echocardiographic variables.

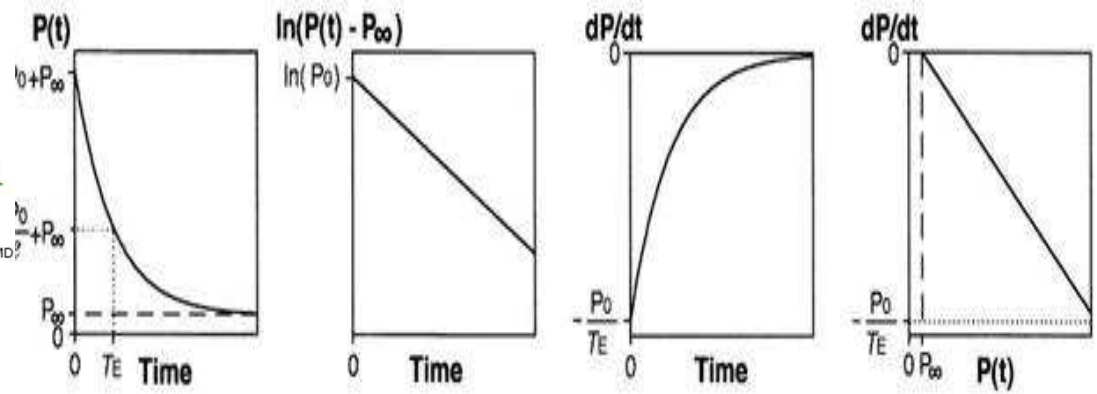


Ommen S R , Nishimura R A Heart 2003;89:iii18-iii23

Estimation of Left Ventricular Relaxation (1)



$$P_v = P_0 e^{-t/\tau} + b$$



* 1. Direct Estimation:
* IVRT
* Aortic regurgitation CW signal
* MR CW signal

Estimation of Left Ventricular Relaxation - IVRT

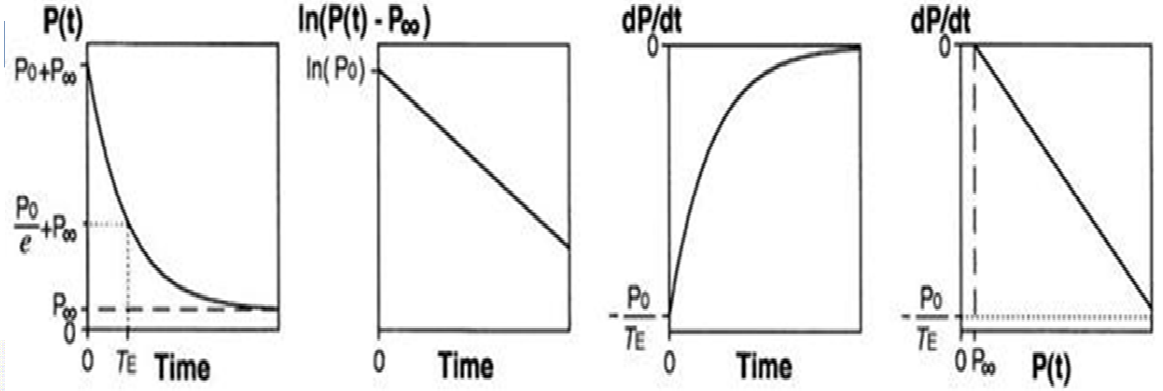
* LV impaired relaxation ➔LV pressure falls slowly during the isovolumic relaxation period ➔ IVRT ↑
* Limited: accuracy, preload
* (IVRT/[ln LV end-systolic pressure - ln LA pressure]) ➔ □

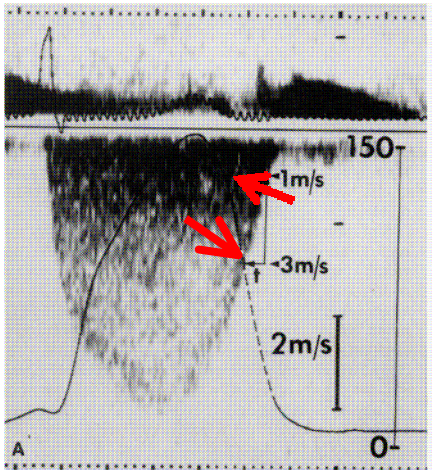
Aortic regurgitation CW signal

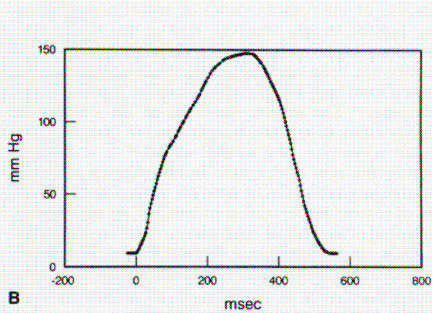
* dP/dtmin ($4V^2$*1,000/20)

MR CW signal

* -dP/dt $_{min}$ (mm Hg/s)=[4(VMR2)^2-4(VMR1)^2]*1,000/20
* τ =time interval between the point of -dP/dt $_{min}$ to the point at whic







Estimation of Left Ventricular Relaxation (2)

* 2. Surrogate Measurements
* Mitral inflow velocities
* Tissue Doppler annular signals
* Color M-Mode Vp

Estimation of Left Ventricular Relaxation - Mitral inflow velocity

E/A ratio <1 and DT>220 ms

* high specificity for abnormal LV relaxation
* But normal or increased filling pressures

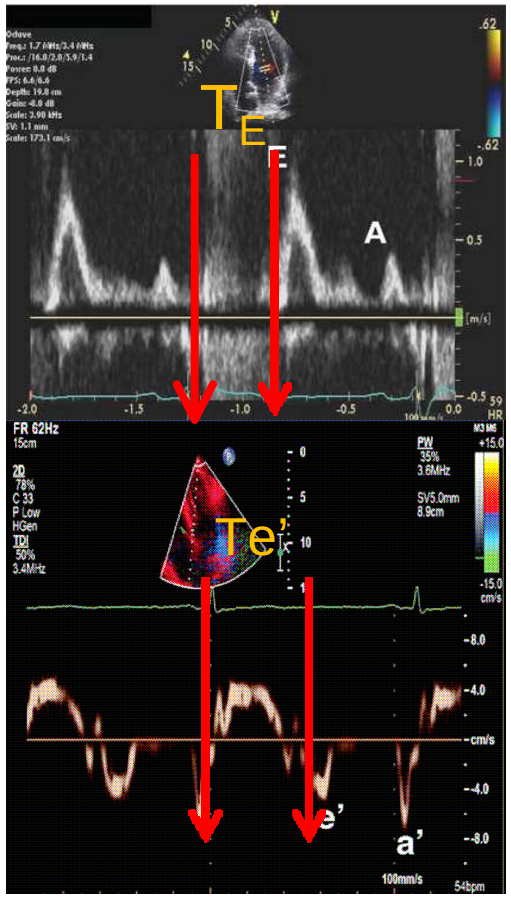
Estimation of Left Ventricular Relaxation –Tissue Doppler annular signal

- e' (lateral) <8.5 cm/s or e' (septal) <8 cm/s have impaired myocardial relaxation
- e´ is less than the mean minus 2 standard deviations of the age group to which the patient belongs

Table 1 Normal values for Doppler-derived diastolic measurements

Measurement	Age group (y)			
	16–20	21–40	41–60	>60
IVRT (ms)	50 ± 9(32–68)	67 ± 8(51–83)	74 ± 7(60–88)	87 ± 7(73–101)
E/A ratio	1.88 ± 0.45(0.98–2.78)	1.53 ± 0.40(0.73–2.33)	1.28 ± 0.25(0.78–1.78)	0.96 ± 0.18(0.6–1.32)
DT (ms)	142 ± 19(104–180)	166 ± 14(138–194)	181 ± 19(143–219)	200 ± 29(142–258)
A duration (ms)	113 ± 17(79–147)	127 ± 13(101–153)	133 ± 13(107–159)	138 ± 19(100–176)
PV S/D ratio	0.82 ± 0.18(0.46–1.18)	0.98 ± 0.32(0.34–1.62)	1.21 ± 0.2(0.81–1.61)	1.39 ± 0.47(0.45–2.33)
PV Ar (cm/s)	16 ± 10(1–36)	21 ± 8(5–37)	23 ± 3(17–29)	25 ± 9(11–39)
PV Ar duration (ms)	66 ± 39(1–144)	96 ± 33(30–162)	112 ± 15(82–142)	113 ± 30(53–173)
Septal é (cm/s)	14.9 ± 2.4(10.1–19.7)	15.5 ± 2.7(10.1–20.9)	12.2 ± 2.3(7.6–16.8)	10.4 ± 2.1(6.2–14.6)
Septal é/á ratio	2.4*	1.6 ± 0.5(0.6–2.6)	1.1 ± 0.3(0.5–1.7)	0.85 ± 0.2(0.45–1.25)
Lateral é (cm/s)	20.6 ± 3.8(13–28.2)	19.8 ± 2.9(14–25.6)	16.1 ± 2.3(11.5–20.7)	12.9 ± 3.5(5.9–19.9)
Lateral é/á ratio	3.1*	1.9 ± 0.6(0.7–3.1)	1.5 ± 0.5(0.5–2.5)	0.9 ± 0.4(0.1–1.7)

* time interval TE-e´ lengthens and correlates well with τ and LV minimal pressure



Estimation of Left Ventricular Relaxation -Color M-Mode Vp

* Normal Vp is ≥50 cm/s
* Vp is most reliable as an index of LV relaxation in patients with depressed EFs and dilated left ventricles

In the other patient groups, it is preferable to use other indices

Key points for LV relaxation

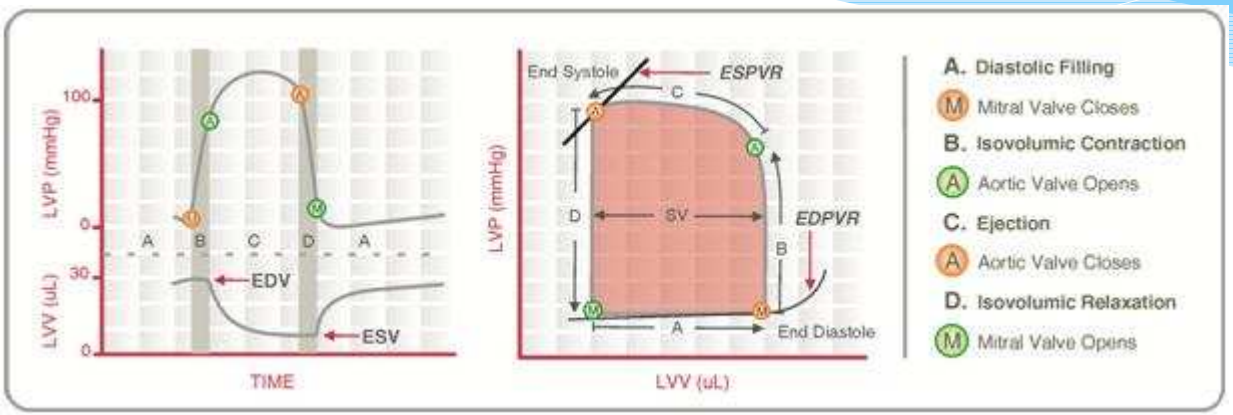
(1) IVRT by itself has limited accuracy, given the confounding influence of preload on it, which opposes the effect of impaired LV relaxation.

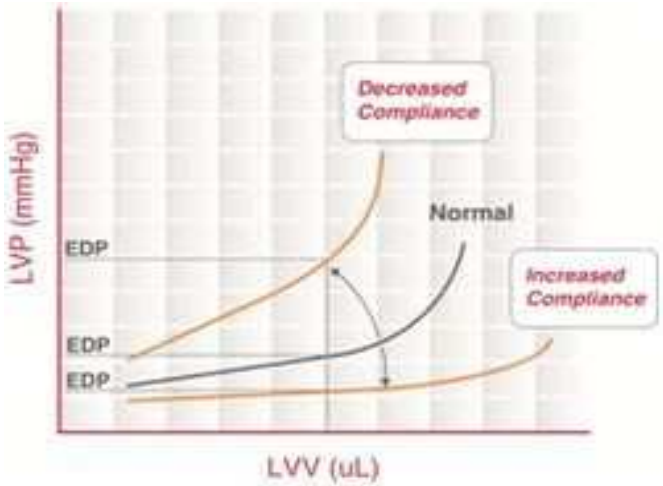
(2) Most patients with e´ (lateral)<8.5 cm/s or e´ (septal)<8 cm/s have impaired myocardial relaxation

(3) Vp is most reliable as an index of LV relaxation in patients with depressed EFs and dilated left ventricles

(4) For research purposes, mitral and aortic regurgitation signals by CW Doppler can be used to derive τ

Estimation of Left Ventricular Stiffness





stiffness =dP/dV
Compliance = 1/stiffness

Estimation of Left Ventricular Stiffness

* B. Surrogate Measurements
* 1. DT of mitral E velocity

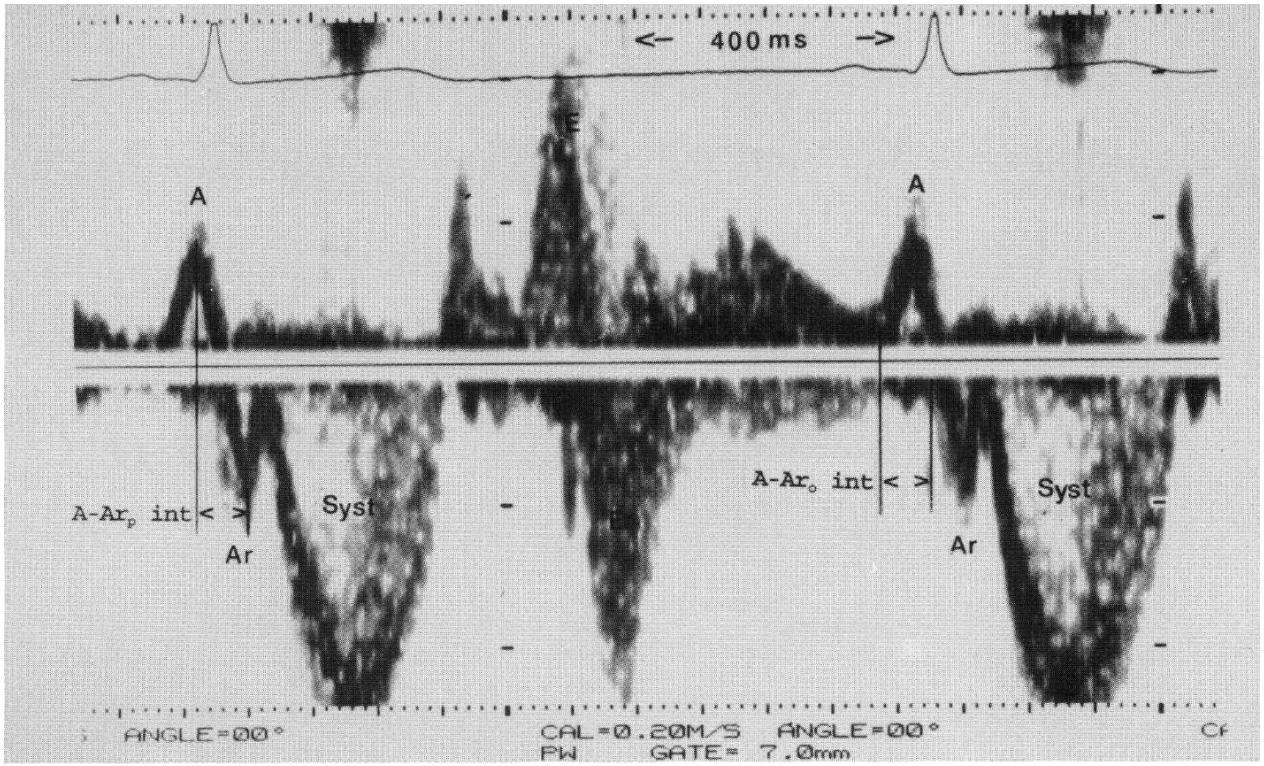
$$KLV=[70\ ms/(DT-20\ ms)]^2$$

=> viscoelasticity and LV relaxation is needed

mitral DT is an important parameter that should be considered in drawing conclusions about operative LV stiffness, particularly in patients without marked slowing of LV relaxation

Estimation of Left Ventricular Stiffness

* 2. A-Wave transit time



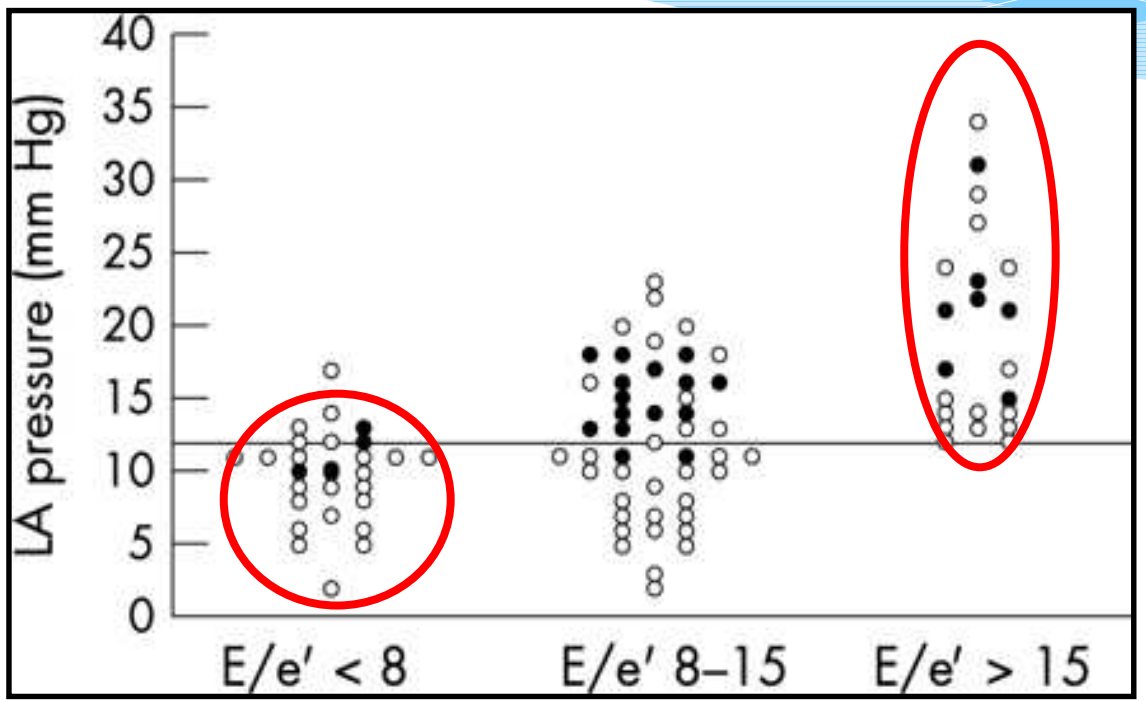
Diastolic Stress Test

* DOE => exercise/dobutamine stress test
* Impaired relaxation => E ↑ ↑, e' ↑ => E/e' ration

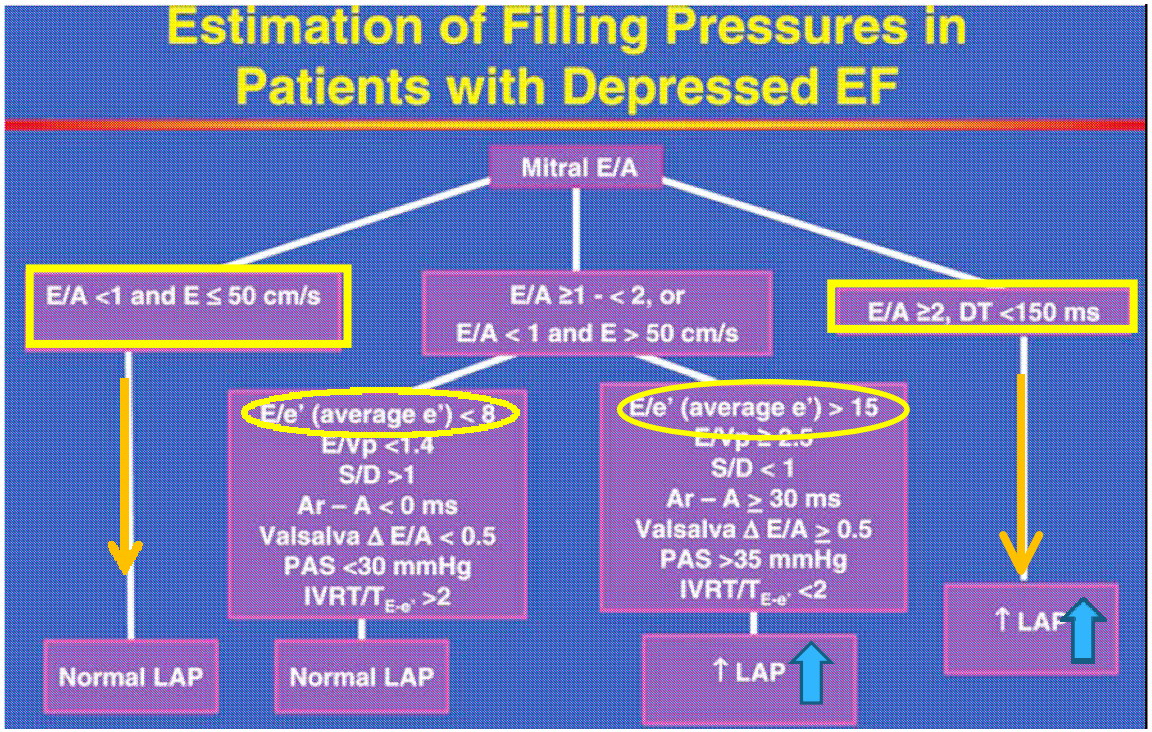
Table 2 Changes in mitral and tissue Doppler septal velocities with exercise in normal subjects (mean age, 59 ± 14 years)[145]

Variable	Baseline	Exercise
E (cm/s)	73 ± 19	↑ 90 ± 25
A (cm/s)	69 ± 17	↑ 87 ± 22
DT (ms)	192 ± 40	↓ 176 ± 42
é (cm/s)	12 ± 4	↑ 15 ± 5
E/é	6.7 ± 2.2	6.6 ± 2.5

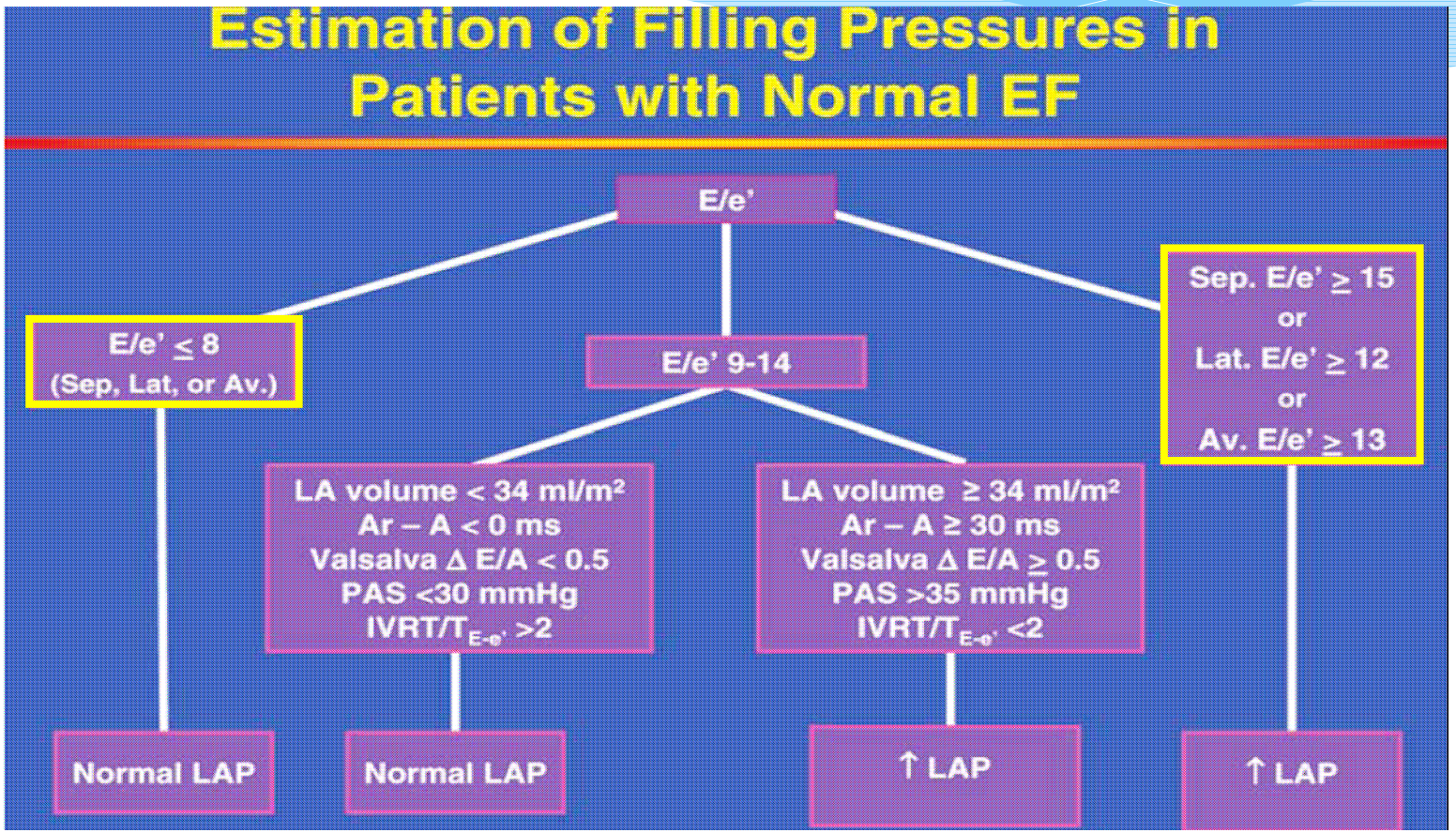
Estimation of LV Filling Pressures



Estimation of LV Filling Pressures in Patients With Depressed EFs



Estimation of LV Filling Pressures in Patients With Normal EFs



Practical Approach to Grade Diastolic Dysfunction