Echo-Doppler evaluation of left ventricular diastolic function

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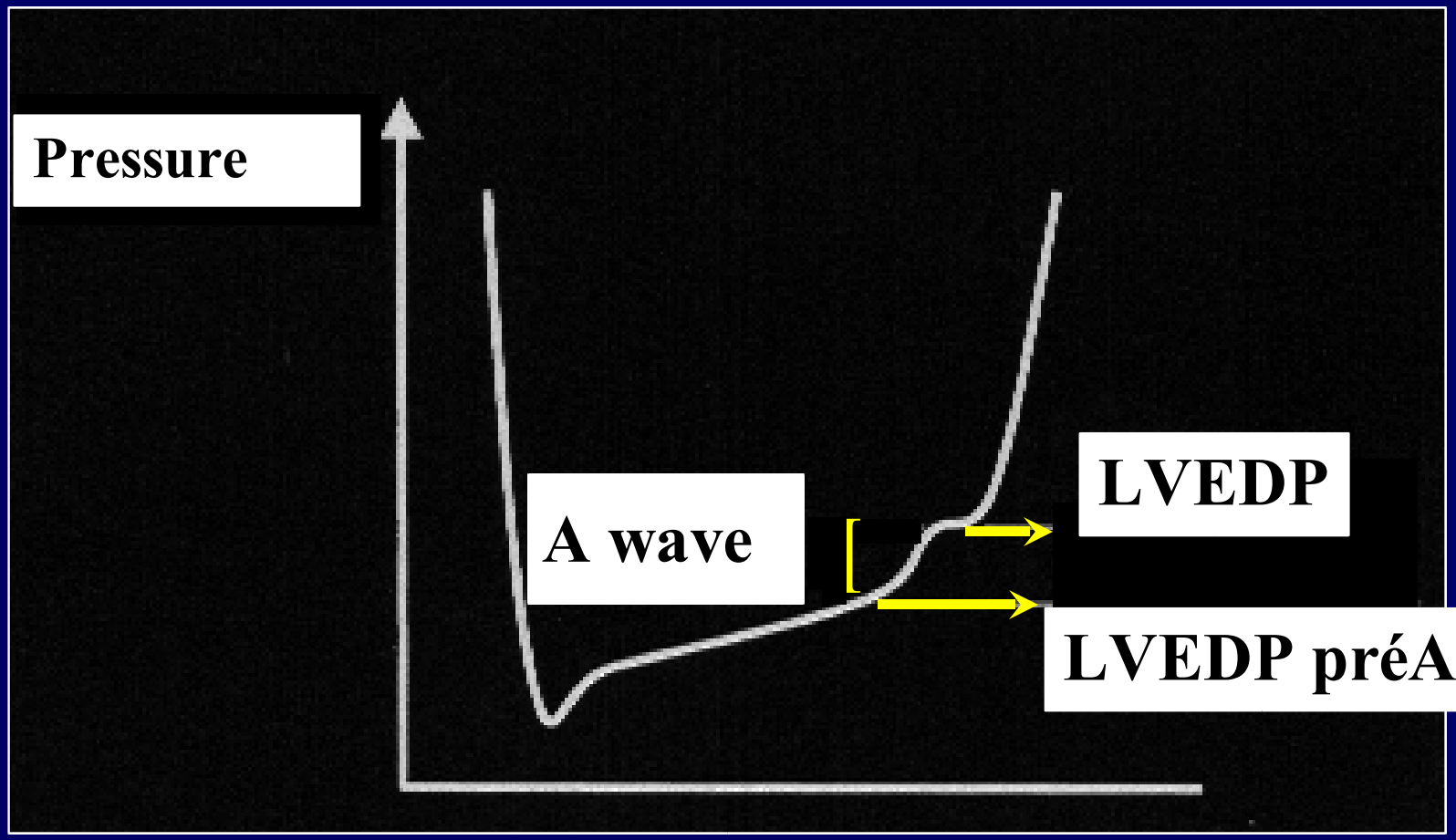
Amiens
France

Left ventricular pressure

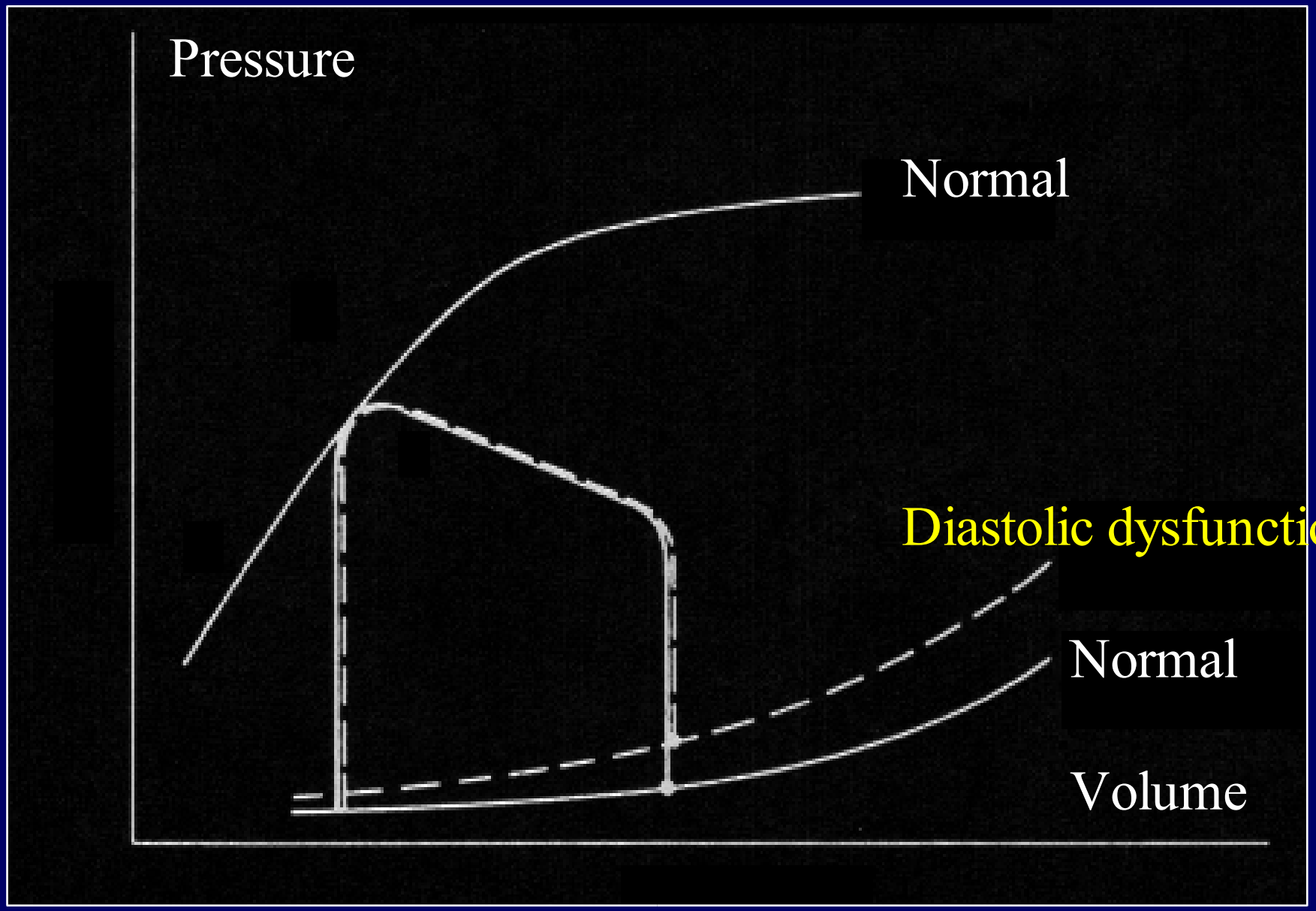


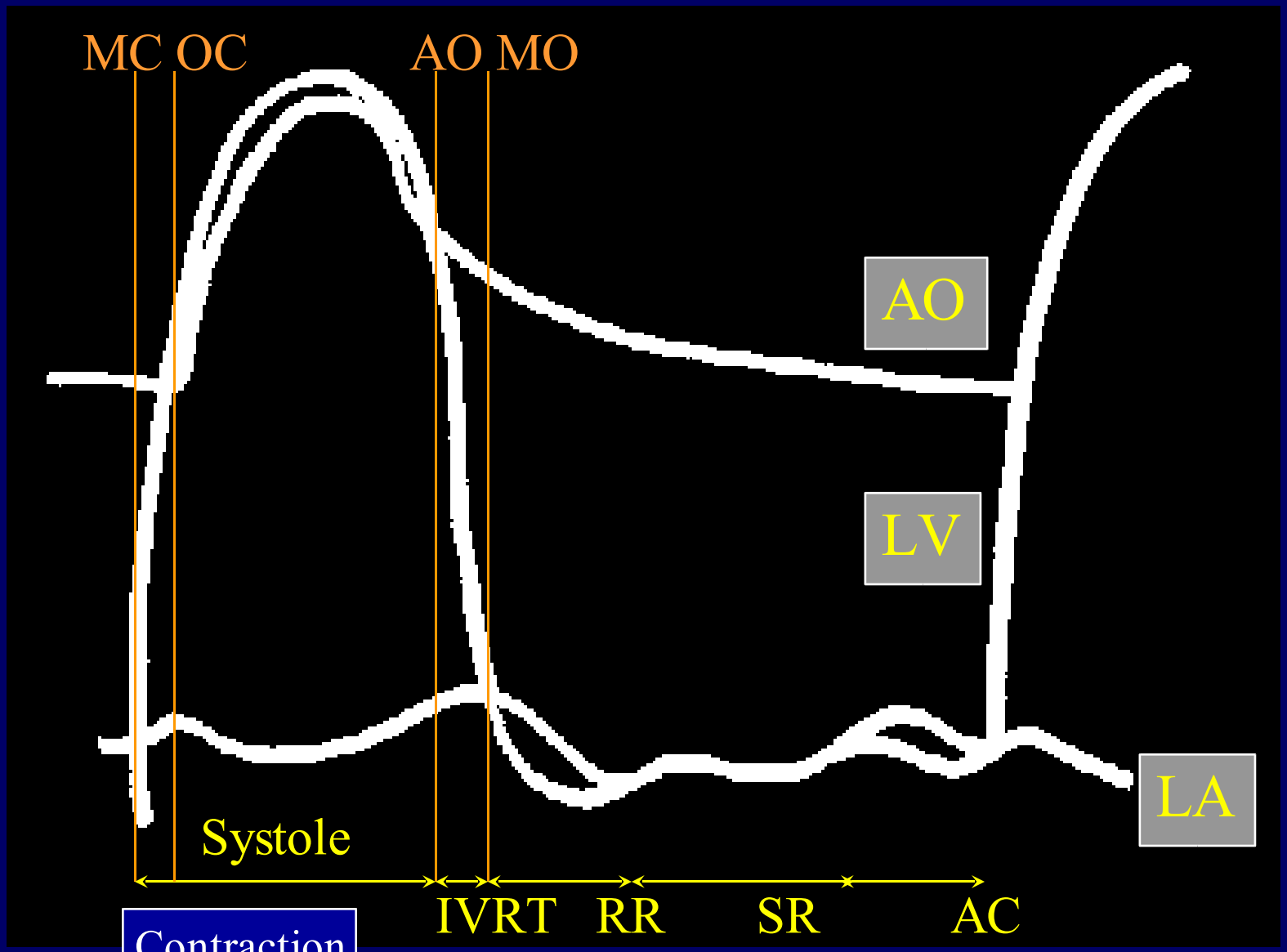
Congestive cardiac failure with preserved systolic function

- **50% of patients with congestive heart failure**

- Increased prevalence with
  - Age
  - Hypertension

Pathophysiology




MC
OC
AO
MO
AO
LV
LA
Systole
IVRT
RR
SR
AC
Contraction
Relaxation
Filling

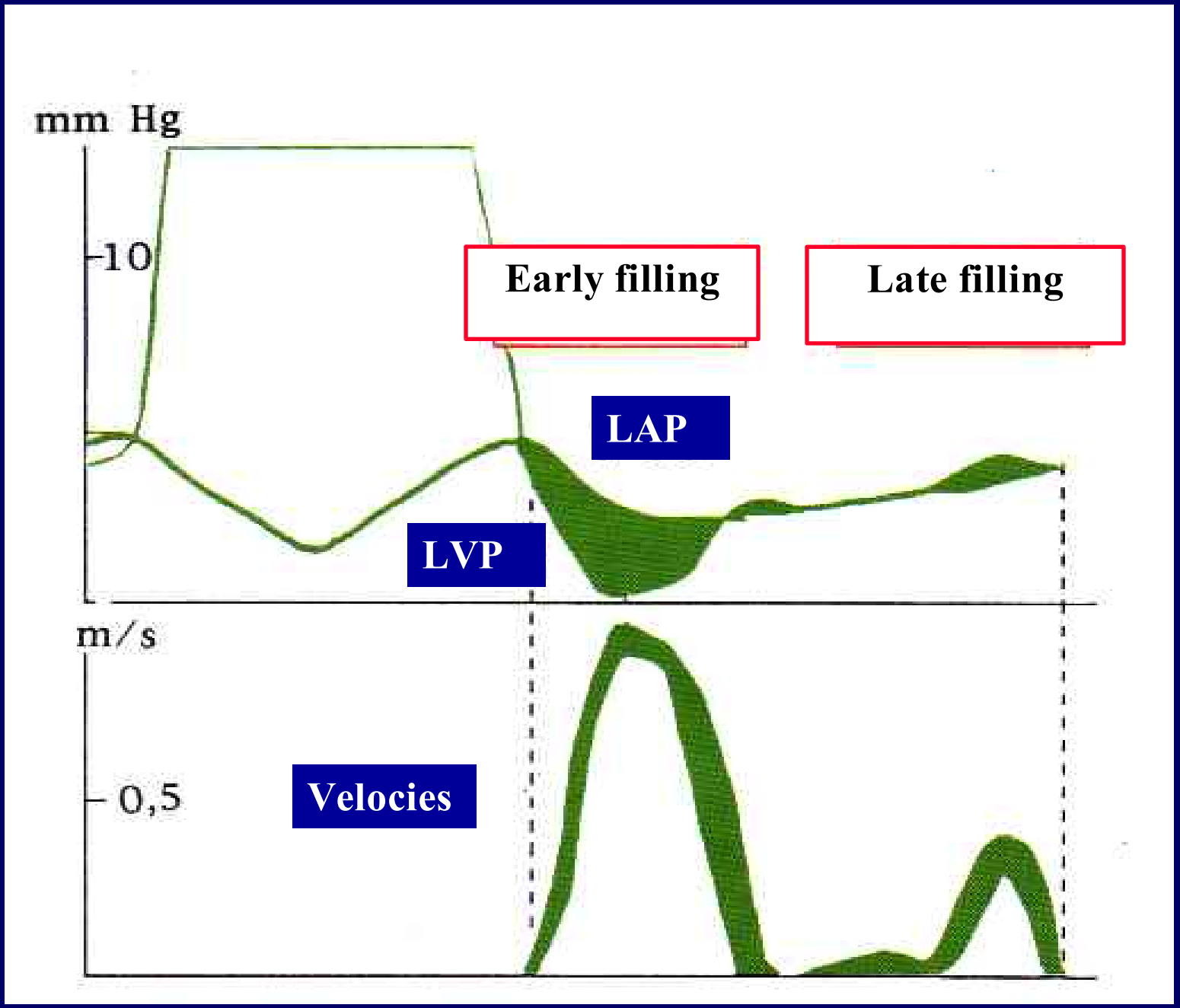
Diastolic cardiac dysfunction

- Impaired LV relaxation
- Impaired LV compliance
  - Hypertrophy
  - infiltration
  - Collagen

Tools

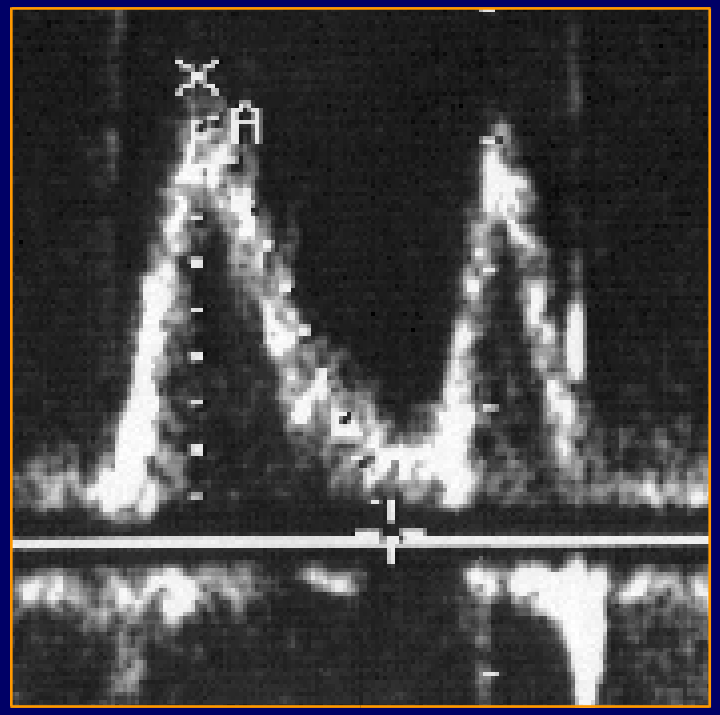
- Mitral flow
- Pulmonary venous flow
- Vp : left ventricular inflow propagation velocity using M-mode color Doppler imaging
- Ea : annulus displacement analysed using doppler tissue imaging (DTI)

I Mitral Flow

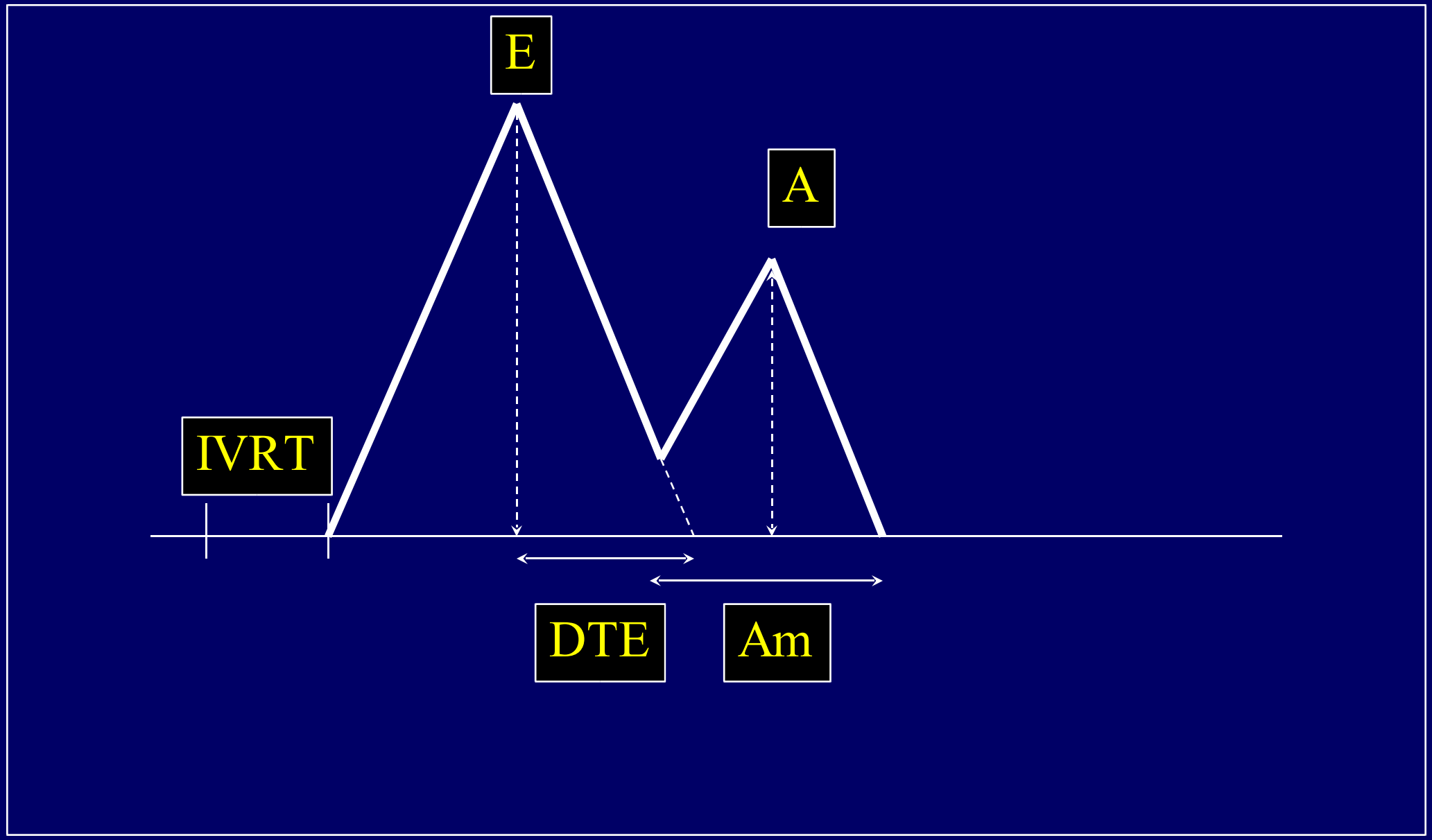

mm Hg
10
Early filling
Late filling
LAP
LVP
m/s
0,5
Velocies

Mitral flow : how to record ?

- Pulsed Doppler
- Correct Alignement
- Small window
- At the tip of mitral valve
- Visible opening sound
- Settings et filters
- 100 mm/s
- Average of 3 measurements



Mitral Flow : which measurement ?



Mitral Flow : normal values

(Appleton et al, J Am Coll Cardiol 1988 ; 12 : 426-40)

- **Isovolumic relaxation time**
  - **avant 40 ans : 69 ± 12ms**
  - **après 40 ans : 76 ± 13ms**

- **Maximal velocity of E : 86 ± 13 cm/s**
- **Maximal velocity of A : 56 ± 13 cm/s**
- **E/A : 1.6 ± 0.4**

- **Deceleration time of E : 199 ± 32 ms**

Normales:
- **E/A = 1 - 2**
- **TDE = 150-220 ms**
- **TRIV = 60 - 100 ms**

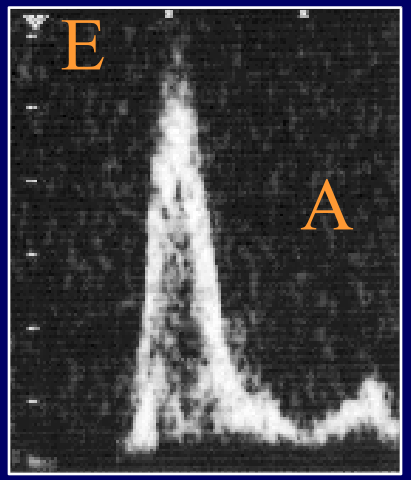
Factors influencing mitral flow

- Age
- Heart rate
- LV relaxation+++
- LV compliance+++
- Load conditions+++
- Mitral regurgitation or stenosis

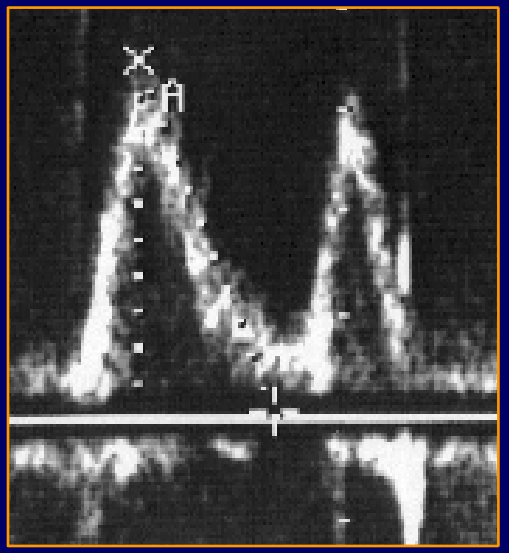
Mitral flow and age

- Young subject
  ↗ E, ↘ A, ↗ E/A
  ↘ TDE

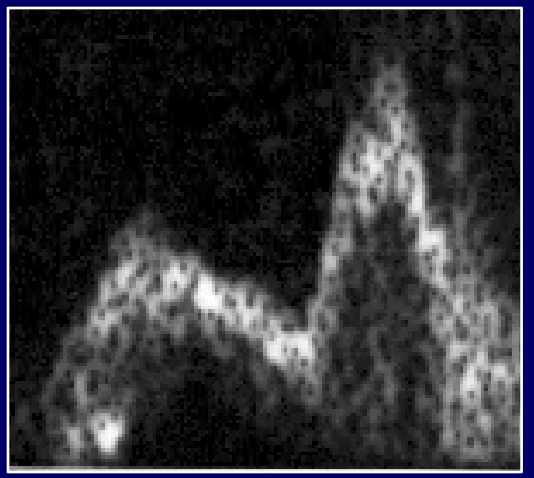
E/A < 1 in 85% of subjects > 70 ans
(Sagie et al. JASE 1993)



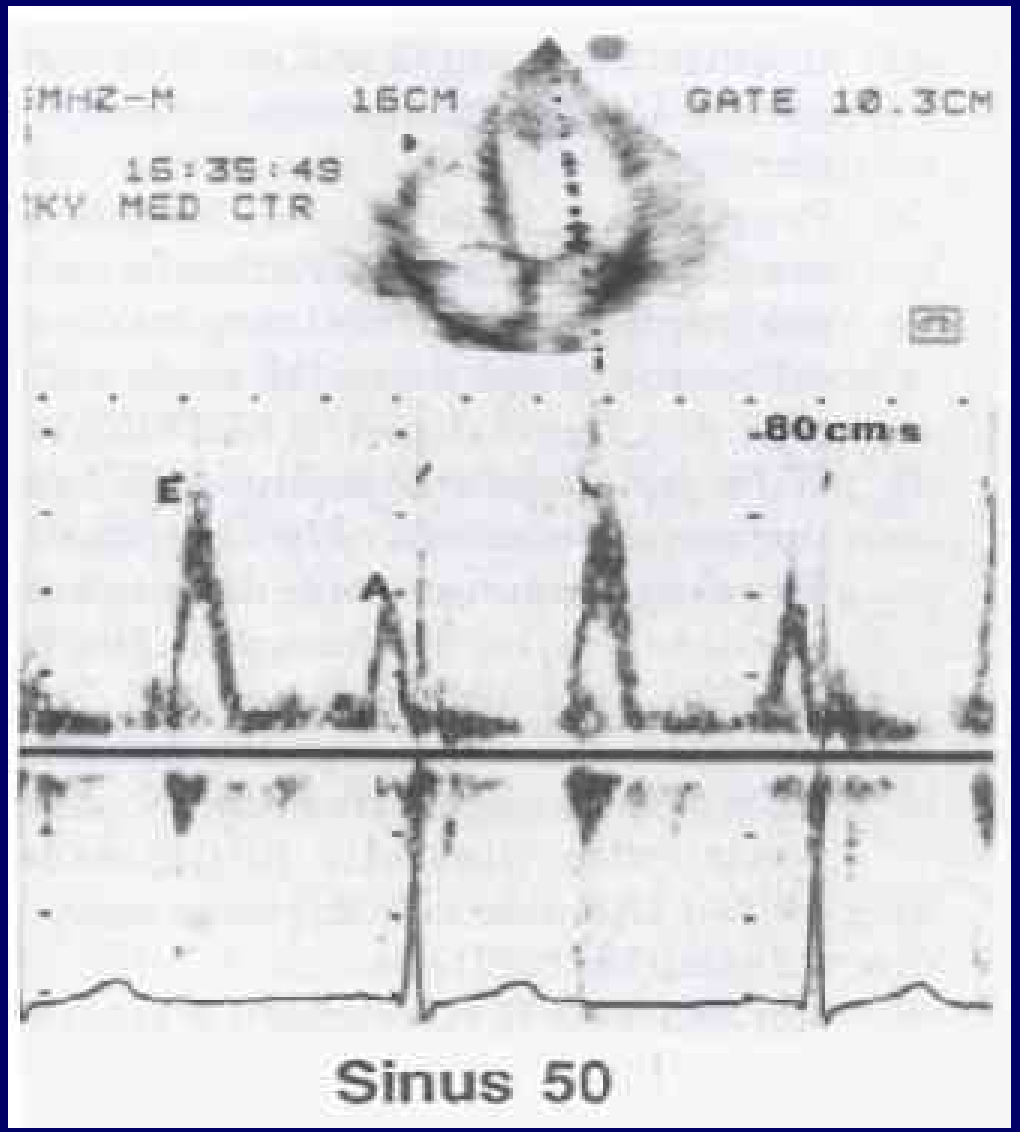
- Middle age subject



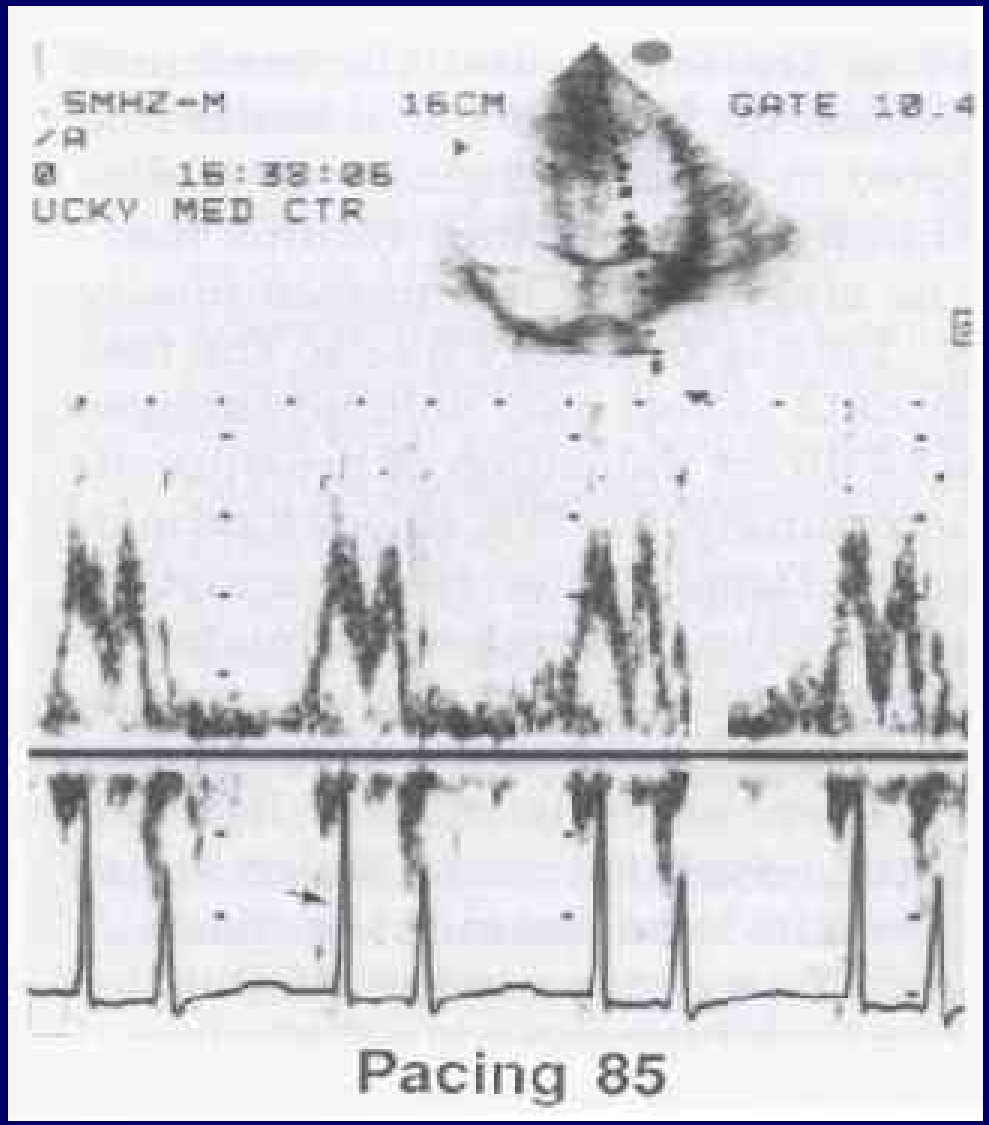
Aged subject



Heart Rate

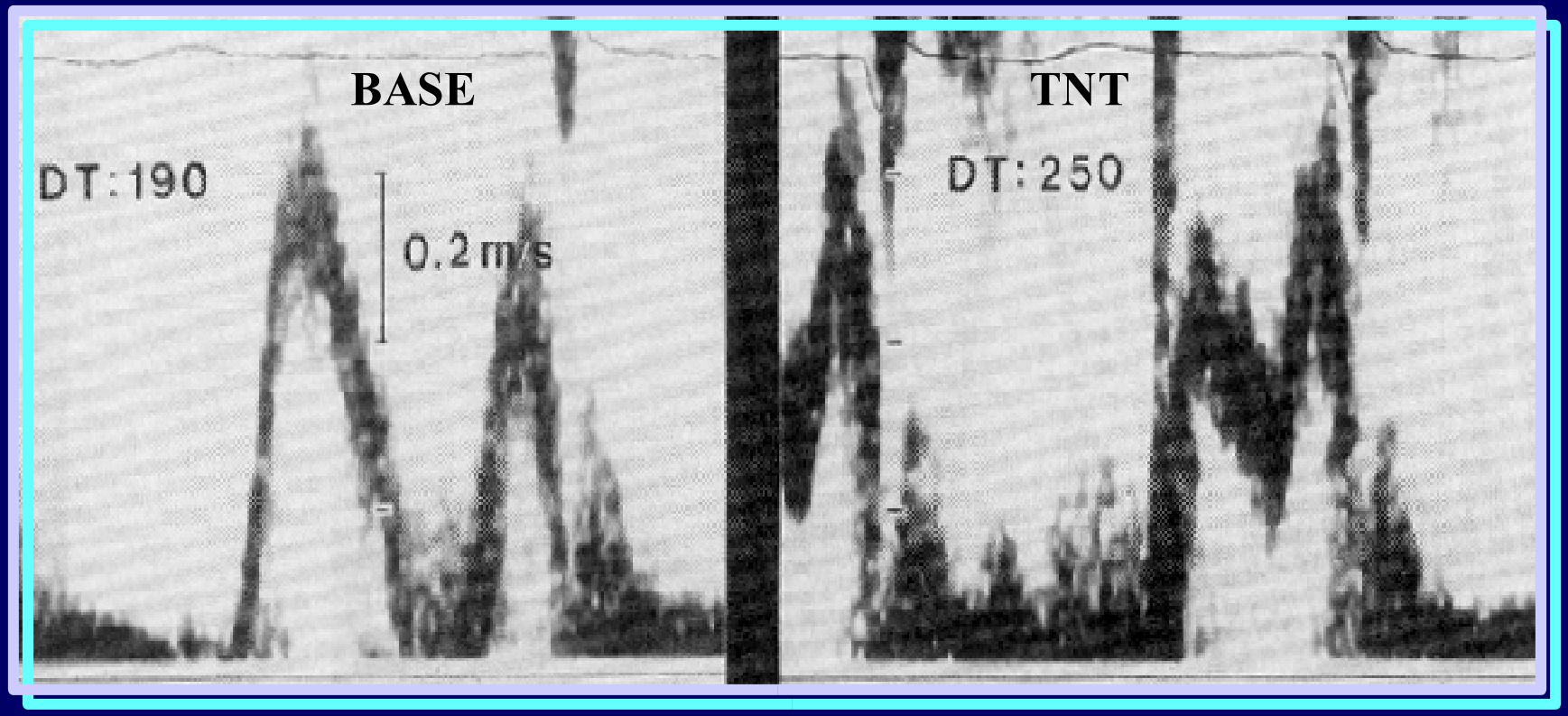


Sinus 50



Pacing 85

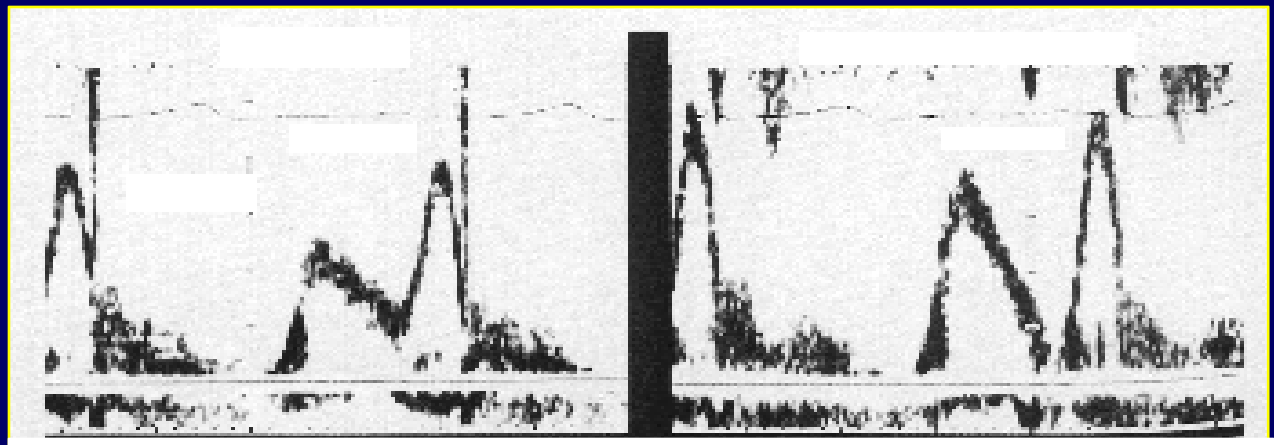
Decreased preload



SOHN, JACC 1997

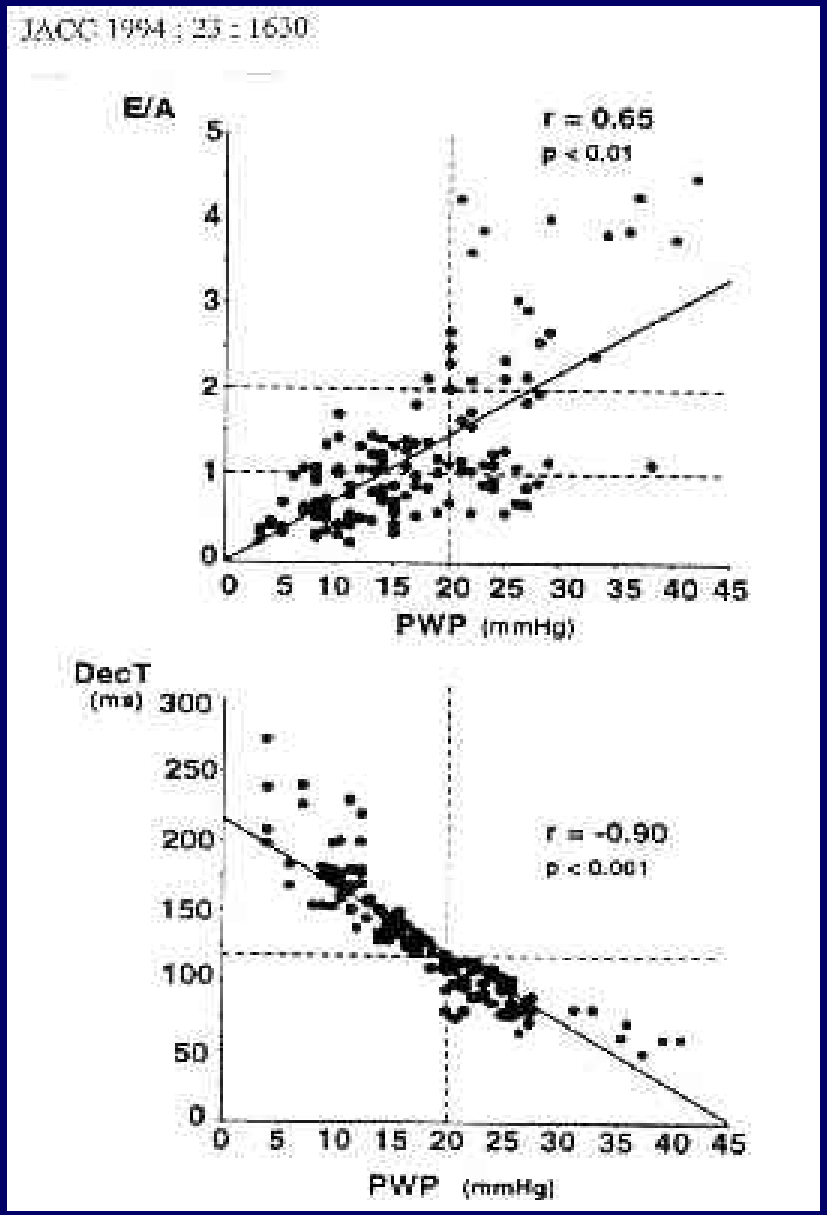
Mitral Flow
Effect of preload modification

Basal **Fluid challenge**



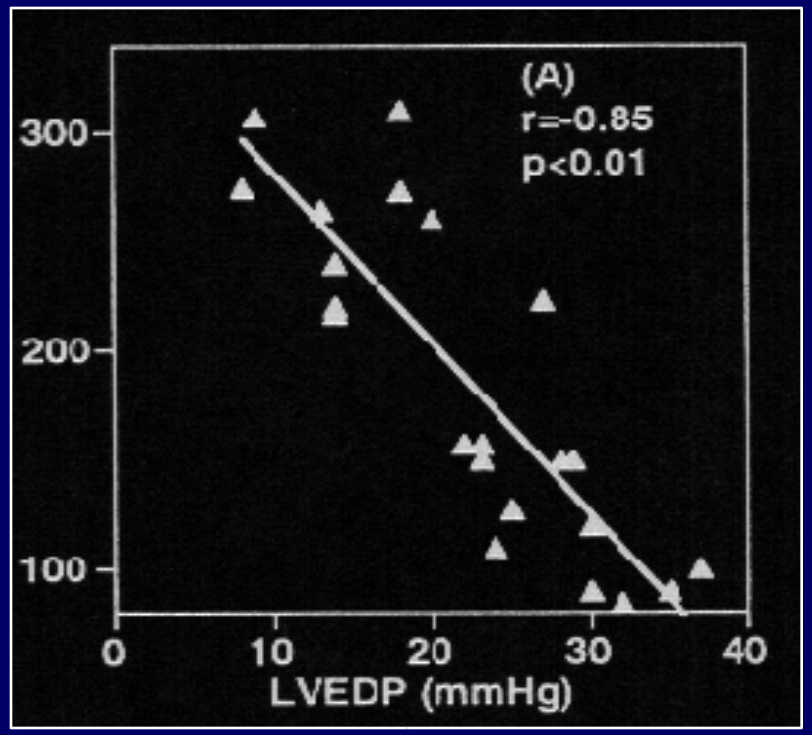
Mitral flow

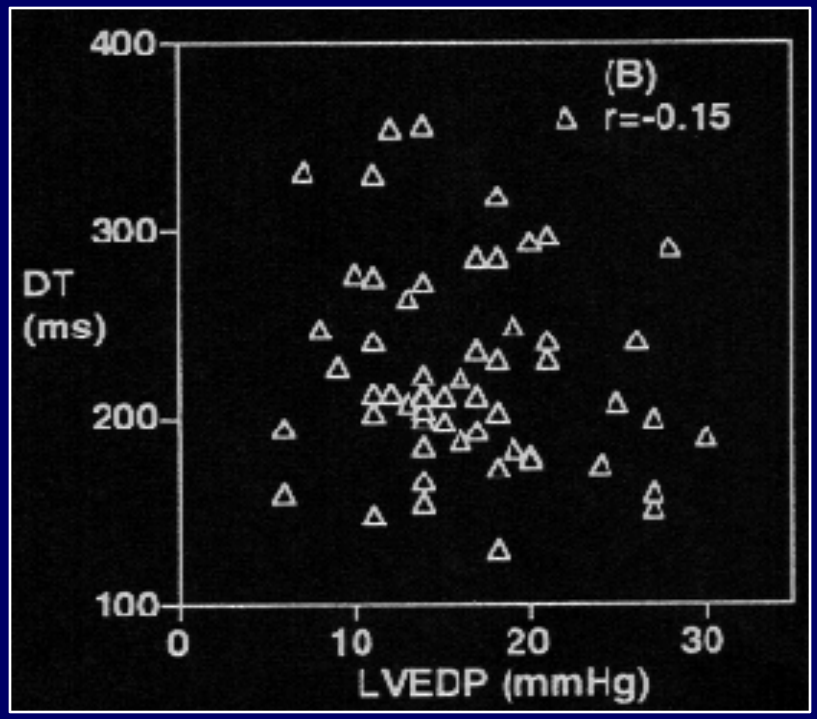
LVDP


JACC 1994 ; 23 : 1630
E/A
r = 0.65
p < 0.01
5
4
3
2
1
0
0 5 10 15 20 25 30 35 40 45
PWP (mmHg)
DecT
(ms) 300
250
200
150
100
50
0
r = -0.90
p < 0.001
0 5 10 15 20 25 30 35 40 45
PWP (mmHg)

Correlation DTE and LVEDP

(Yamamoto et al. JACC 1997;30:1819-26)





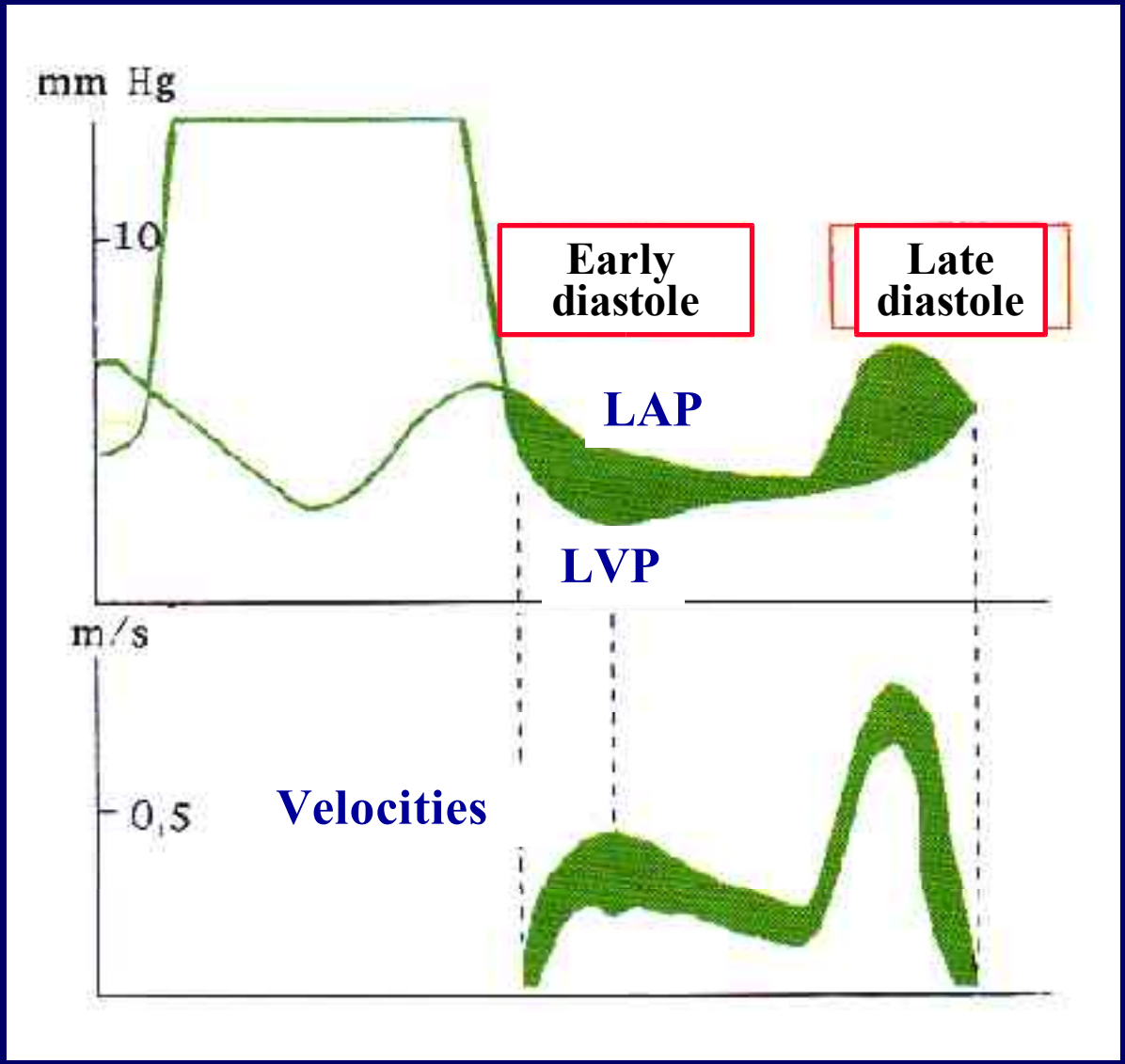
EF < 50% : r = - 0,85

EF > 50% : r = - 0,15

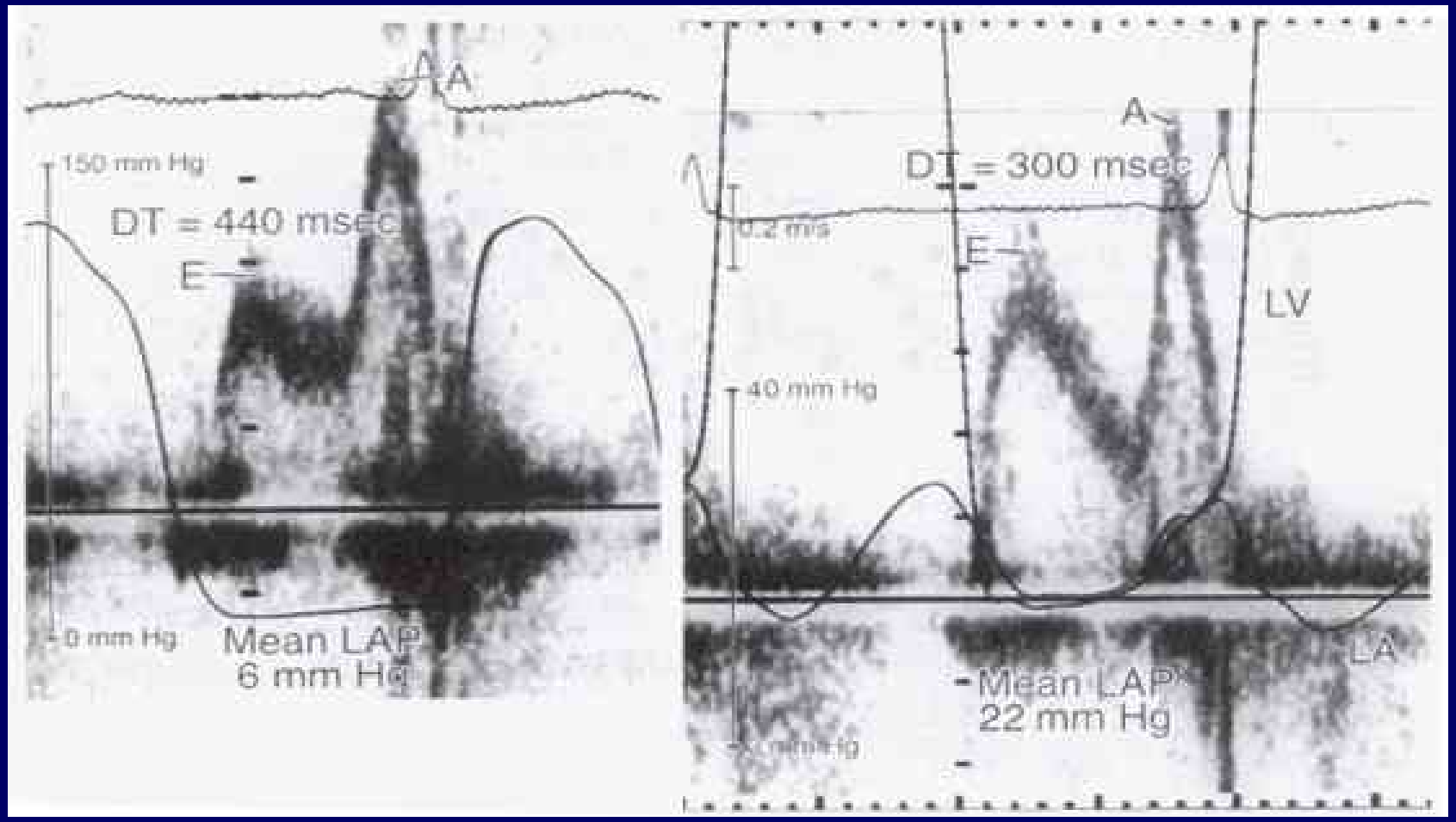
DTE ≤ 150 ms et LV dysfunction : PTDVG ≥ 15 - 20 mmHg

Type I of Appleton

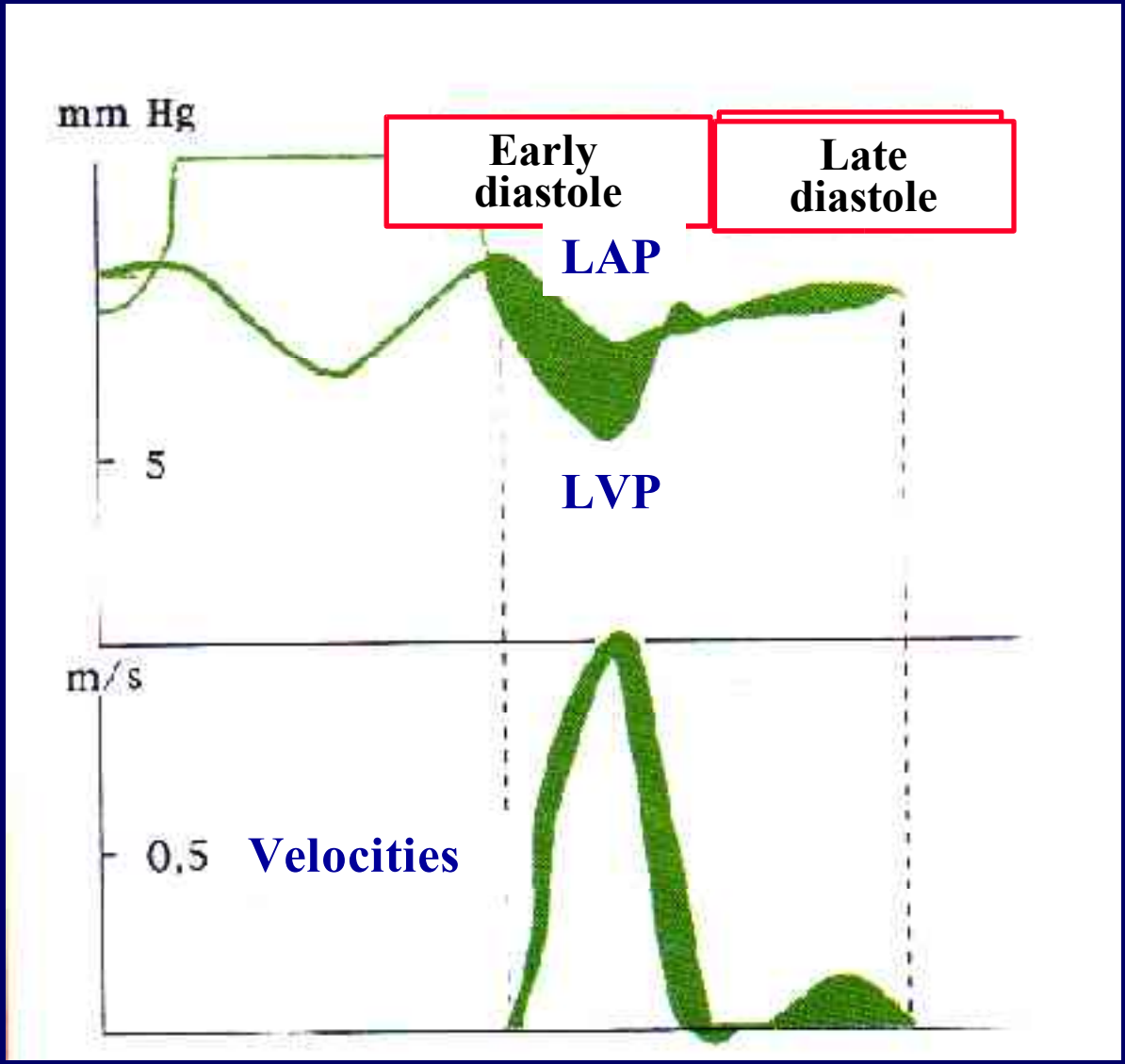
relaxation impairement



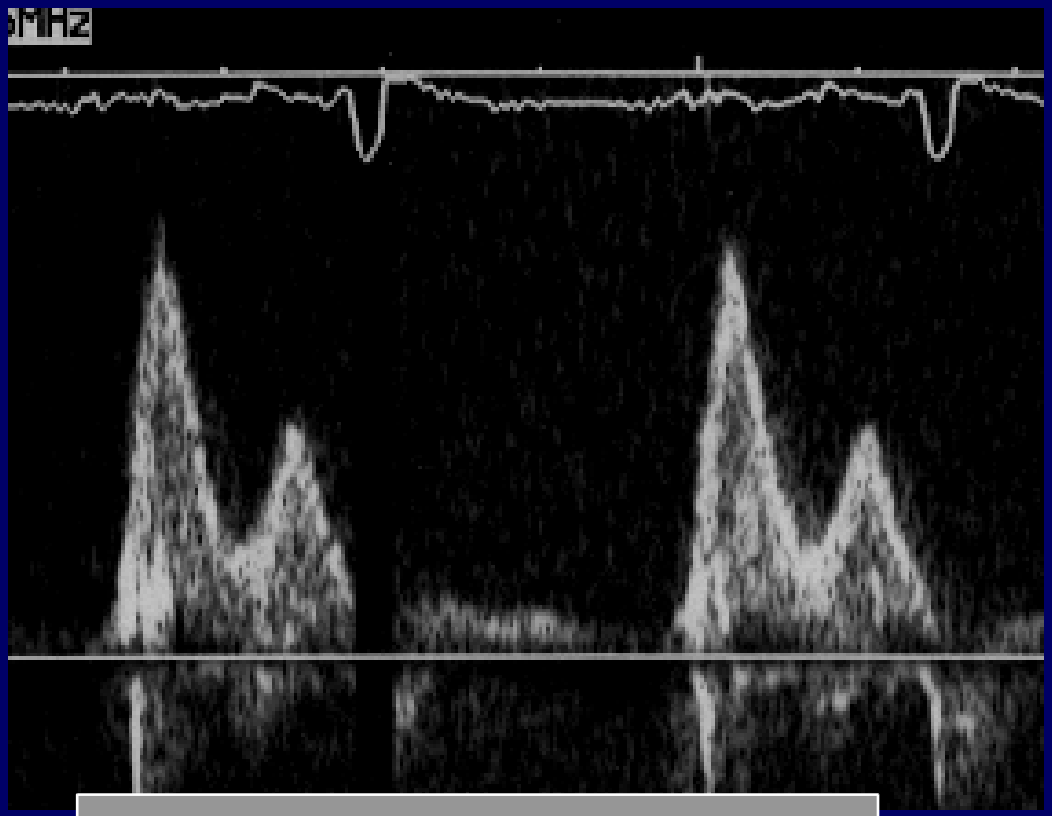
HCM with normal EF



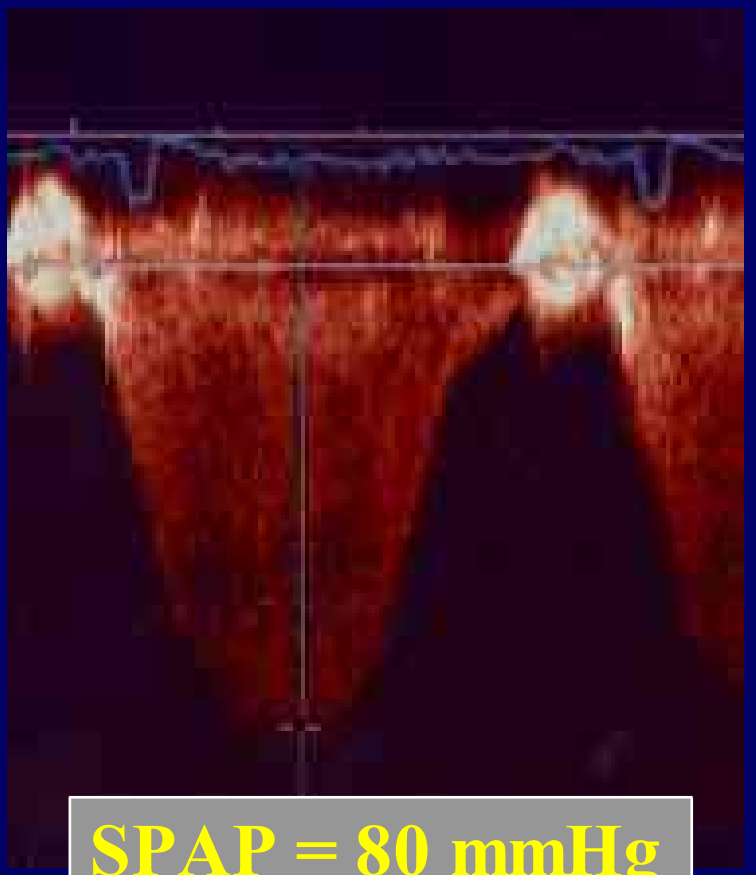
Flux Mitral Type II de Appleton



Compliance impairement (restrictive profile)
Anterior infarction - FE = 30%

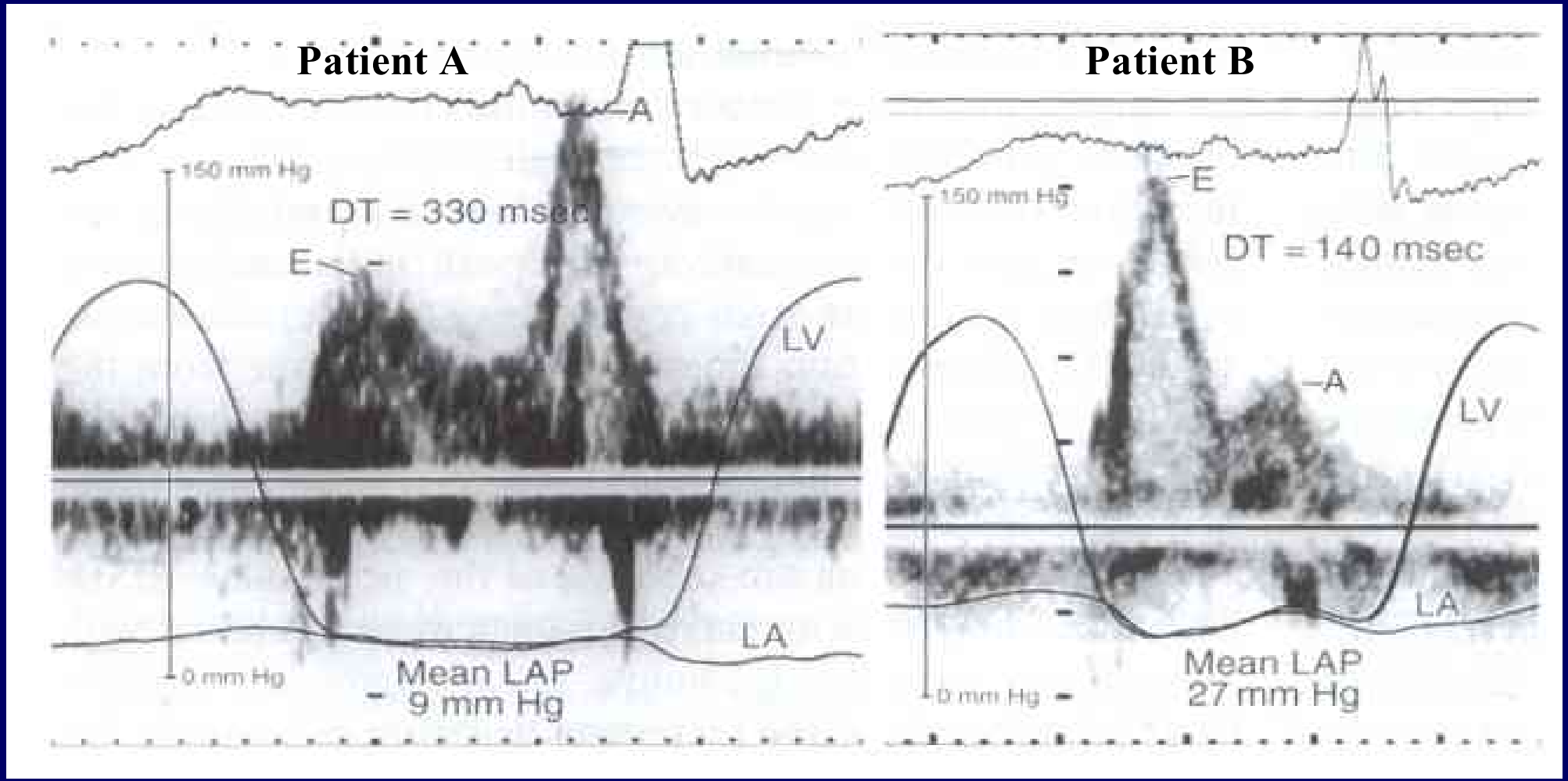


E/A = 2 ; DTE = 100 ms

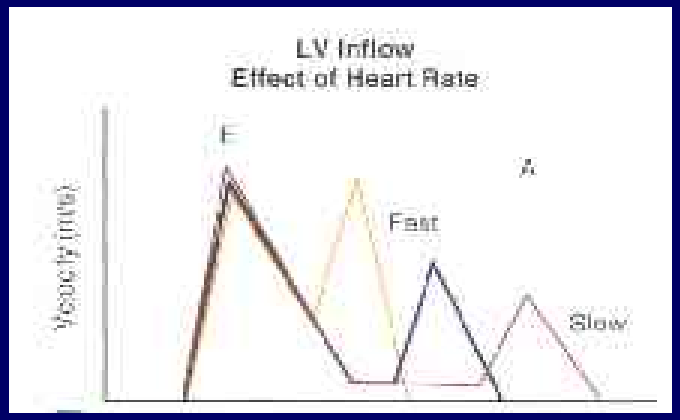


SPAP = 80 mmHg

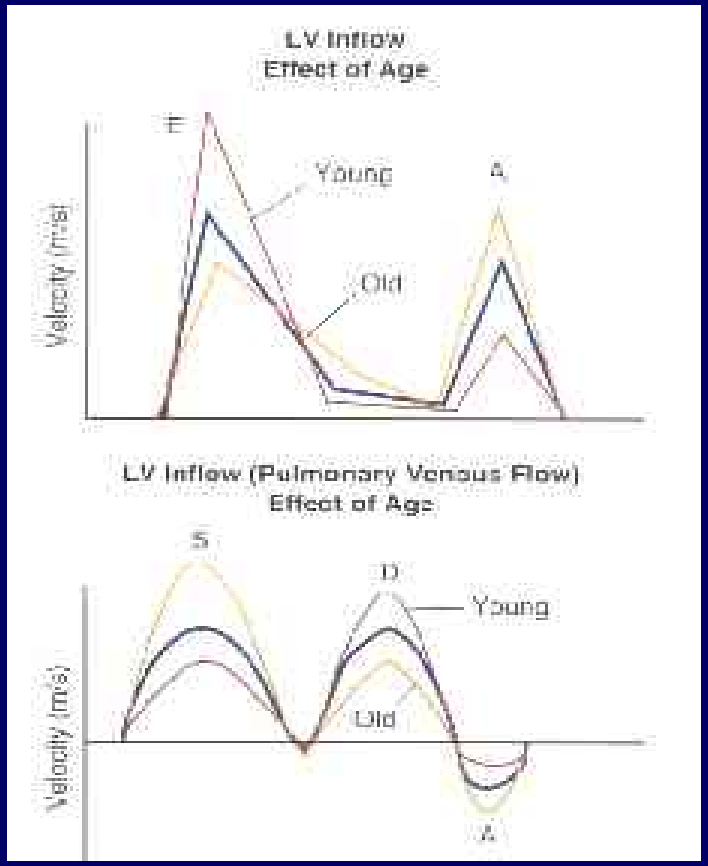
Ejection fraction = 30%



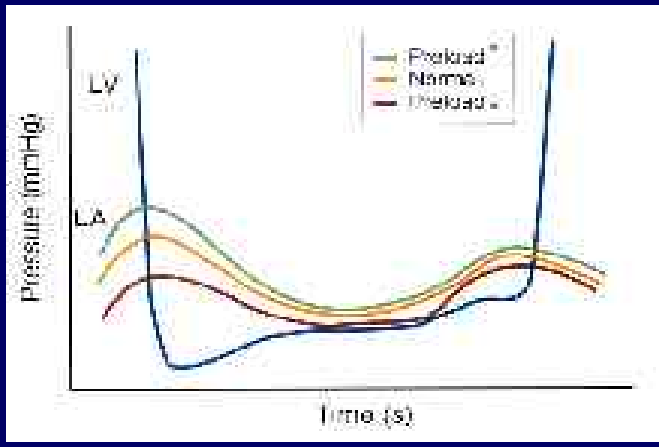
Heart Rate

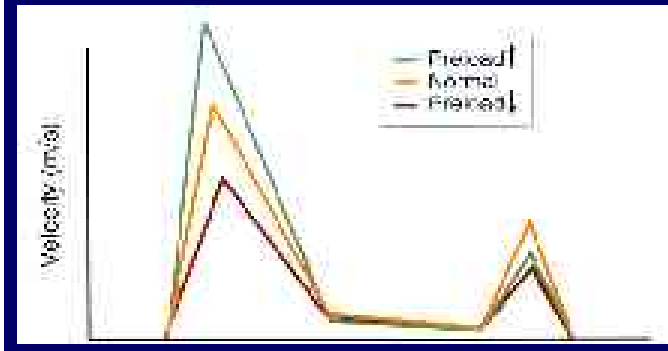


Age



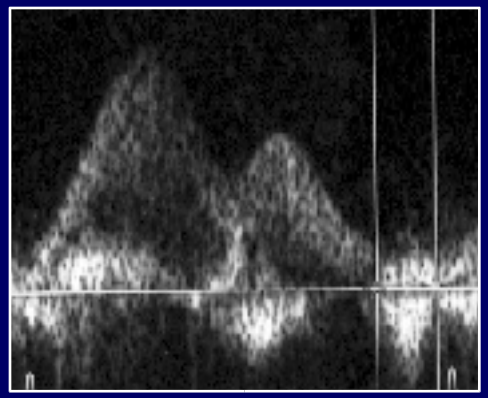
Preload





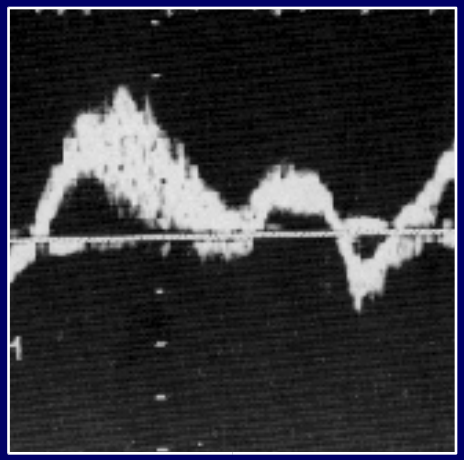
II Pulmonary venous flow

Pulmonary venous flow : how to record ?



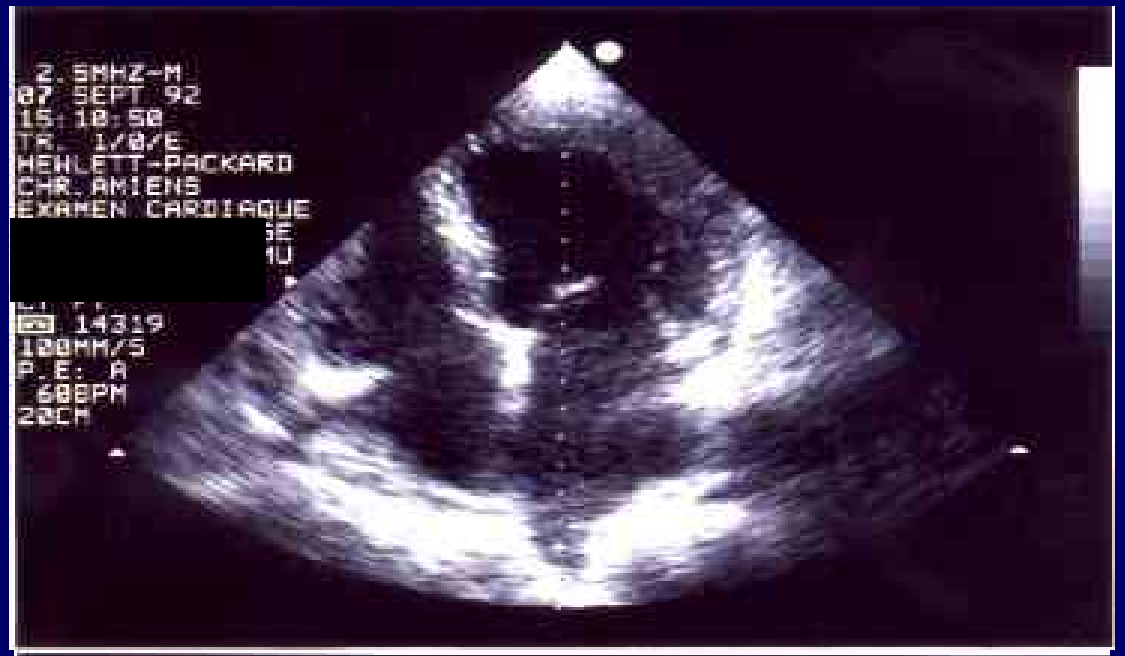
TTE: RSPV

- **4C apical view**
- **Small window**
- **1 - 2cm into PV**
- **minimum settings**
- **minimum filters**
- **100mm/s**
- **faisability by TTE:**
  - **S et D : 70 à 95%**
  - **Ap : 40 à 90%**
- **reproductibility Ap (Yamamoto 97)**
  10 ± 8ms (inter)



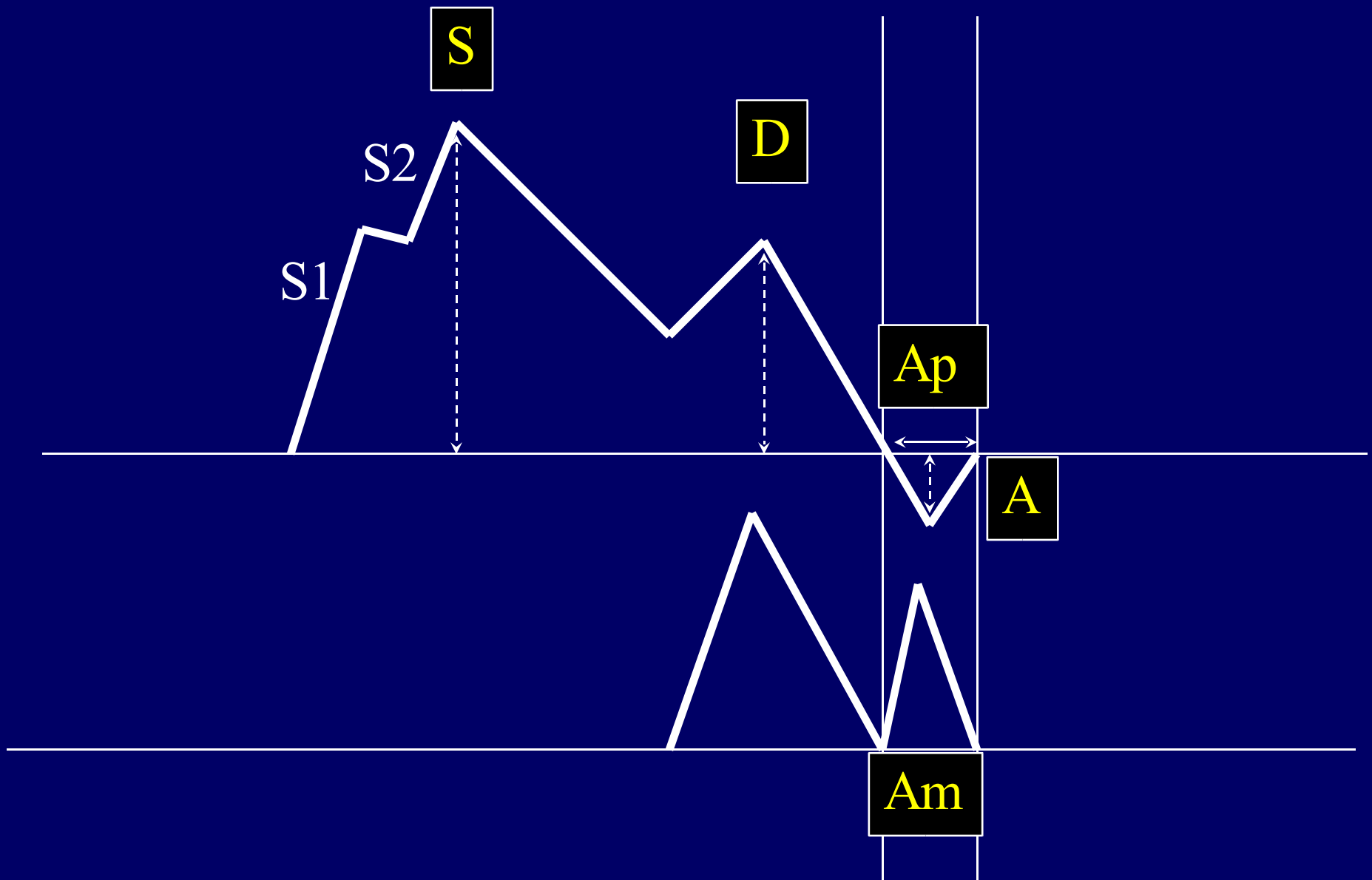
TEE: LSPV

Pulmonary venous flow : how to record ?


2.5MHZ-M
07 SEPT 92
15:10:50
TR. 1/0/E
HEWLETT-PACKARD
CHR.AMIENS
EXAMEN CARDIAQUE
14319
120MM/S
P.E: A
60BPM
20CM


2.5MHZ-M 100MM/S P.E:5
HEWLETT-PACKARD 20CM
CHR.AMIENS TR. 1/0/E/F/A
EXAMEN CARDIAQUE 49BPM
14319
27 SEPT 92
15:07:33
A V.MAX=29.8 CM/S
V.MOY=23.3 CM/S
INTEG=5.13 CM
B V.MAX=55.8 CM/S
V.MOY=38.4 CM/S
INTEG=14.2 CM
C V.MAX=51.9 CM/S
V.MOY=26.5 CM/S
INTEG=16.8 CM
FENETR:18.8CM
LONG:0.12CM
48.
CM/S
-48.
54
20

Pulmonary veinous flow : what to mesure ?



Normal values for pulmonary venous flow

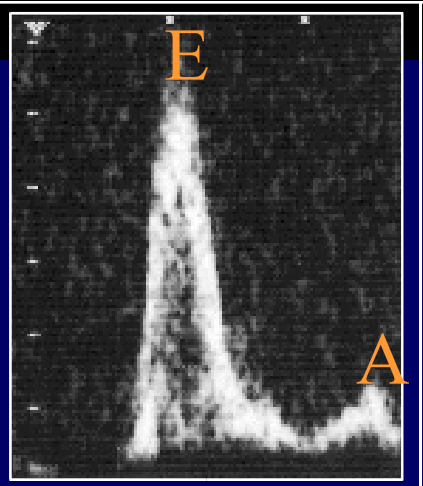
- S : 65 ± 15 cm/s
- D : 45 ± 14 cm/s
- A : -18 ± 7 cm/s

Normal values :
- **S/D > 1**
- **Ap < 35 cm/s**
- **durée Ap ≤ Am**
- **FS > 55%**

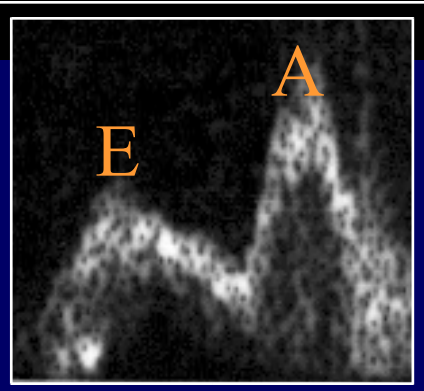
- Duration A : 140 ± 35 ms (60 à 230 ms) < duration A (mitral)
- Systolic fraction : $\frac{\text{VTIS}}{\text{VTI S + VTI D}} = 66 \pm 10\%$

Effect of age on pulmonary venous flow

Young :
- ↗E ↘A ↗E/A
- ↘DTE

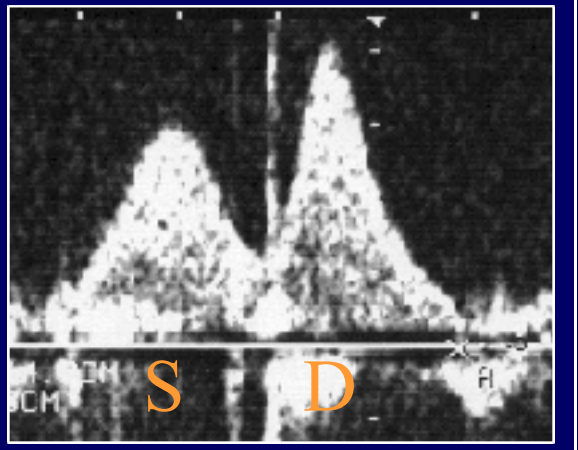


Aged :
- ↘E ↗A ↘E/A
- ↗DTE

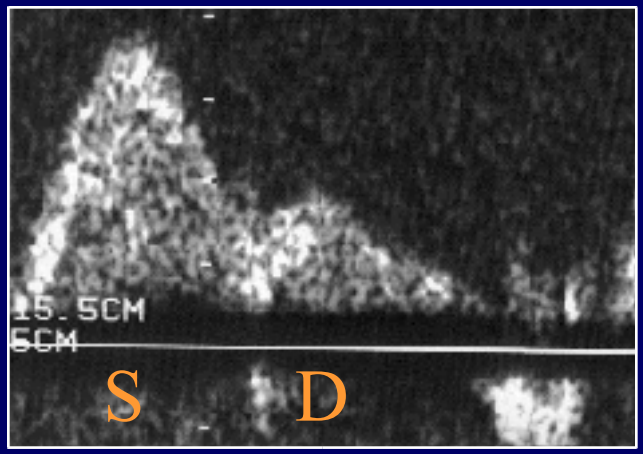


E/A < 1 in 85% of > 70 ans (Sagie et al. JASE 1993)

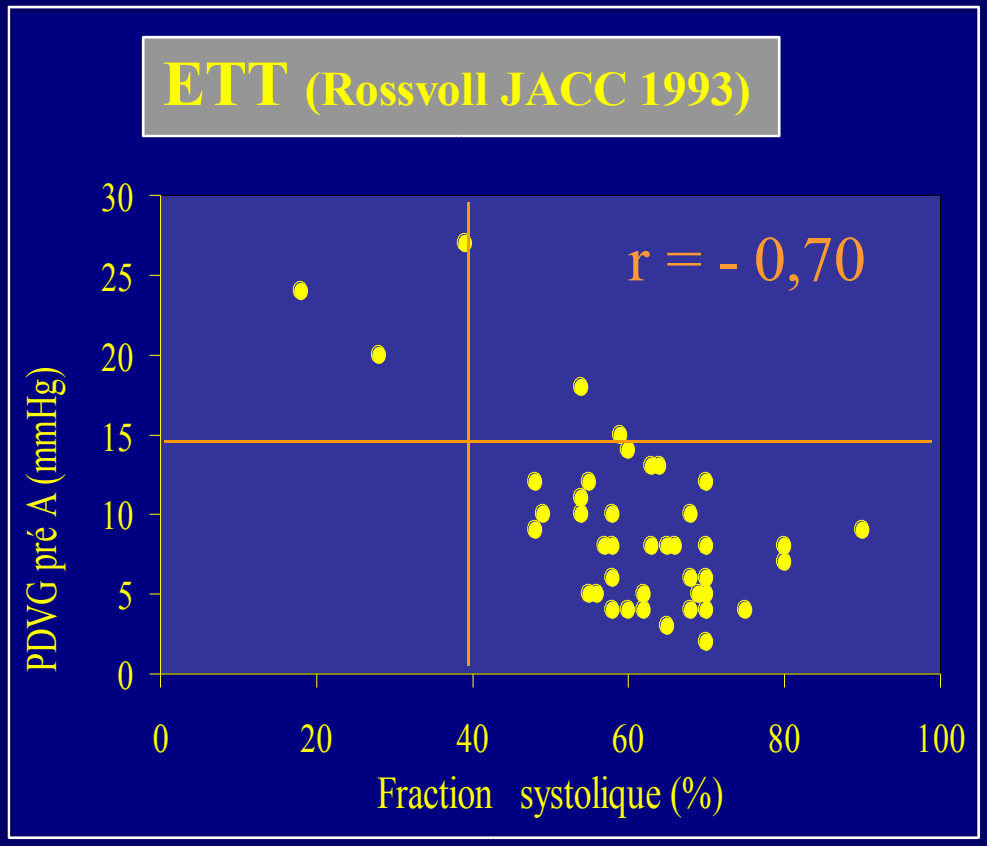
- S/D <1

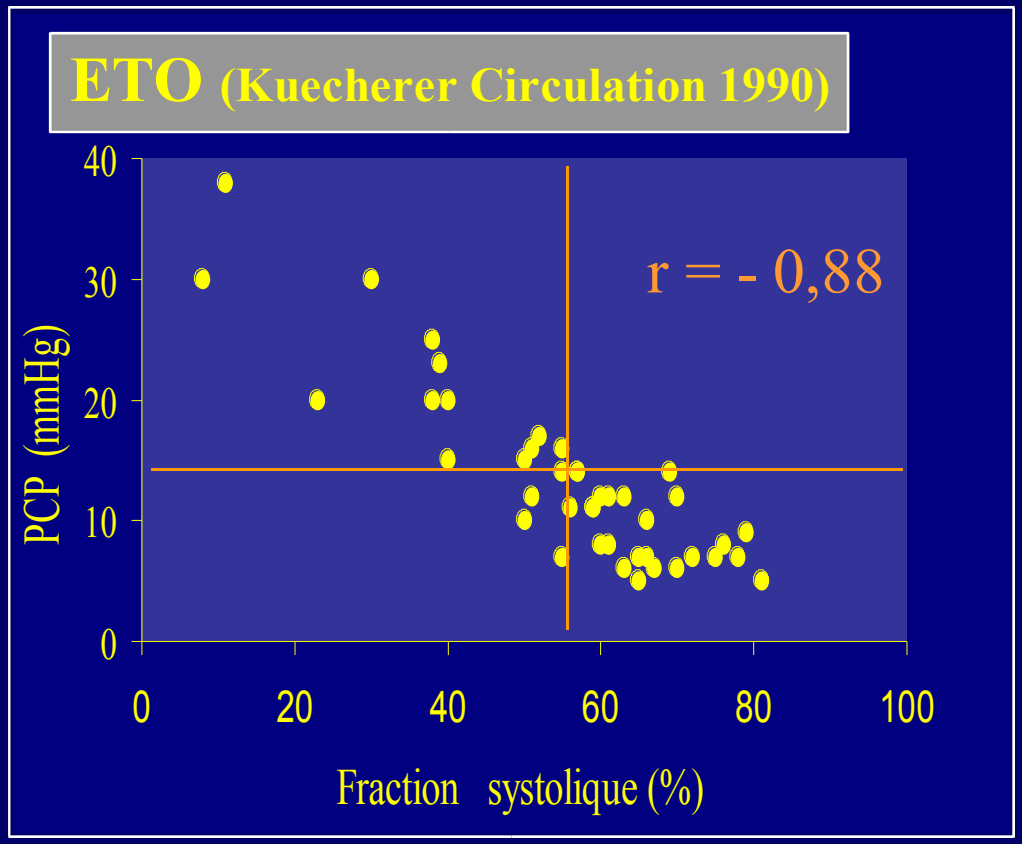


- S/D > 1



LV diastolic pressure and systolic fraction



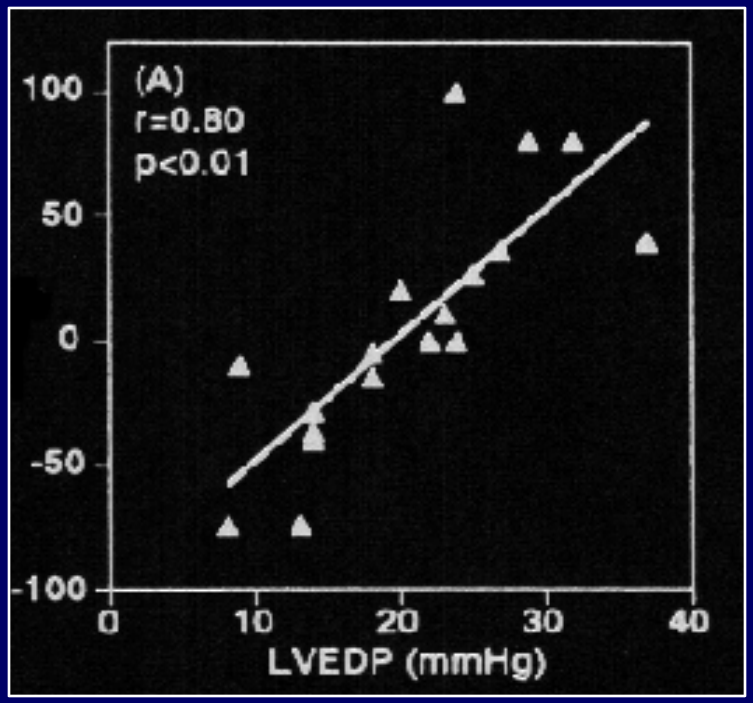


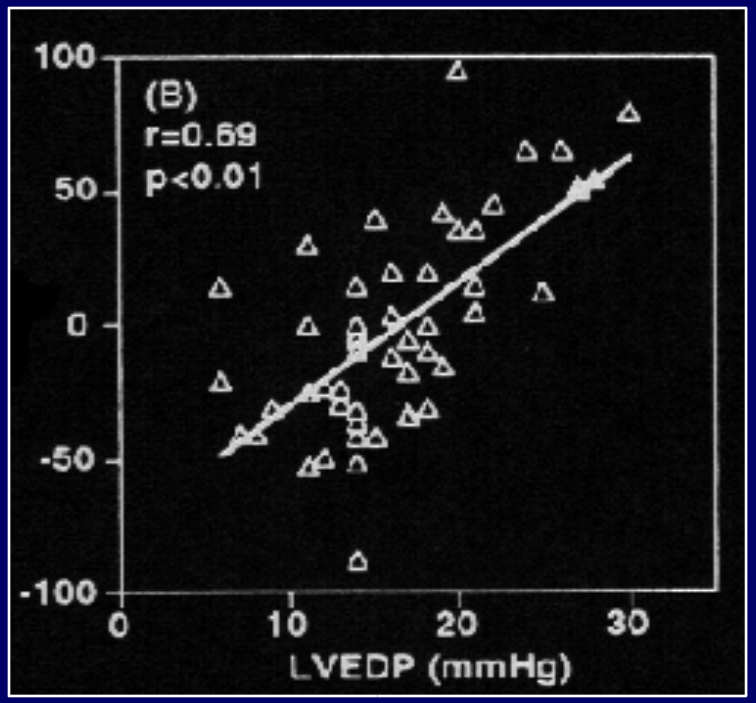
SF< 40% ⟶ LVDP préA> 15mmHg

SF < 55% ⟶ PWP ≥ 15 mmHg

Corrélation Ap - Am et LVEDP

(Yamamoto et al. JACC 1997;30:1819-26)





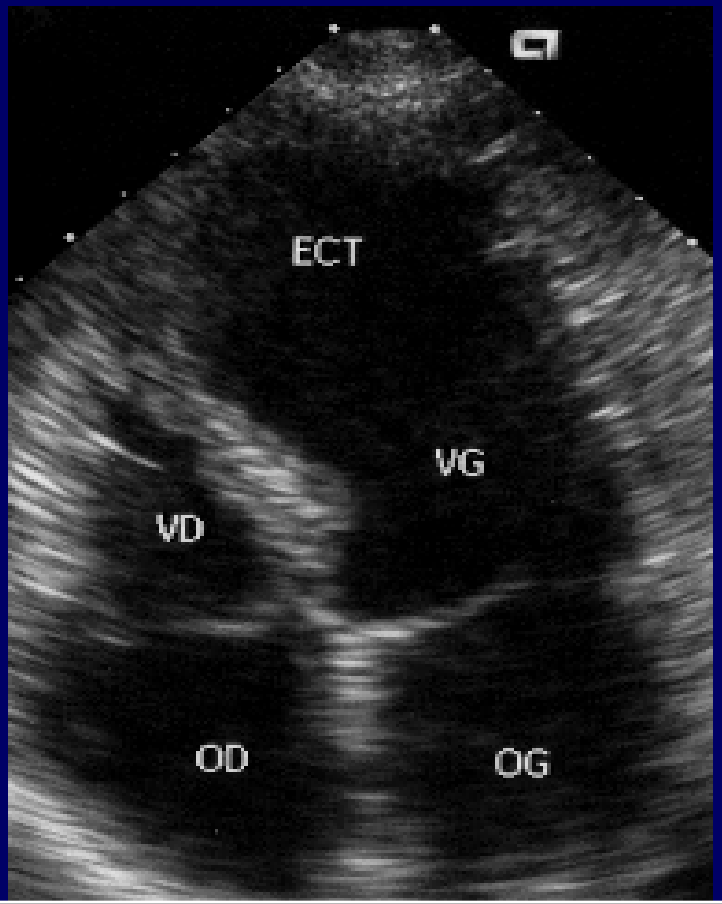
EF< 50% r=0,80

EF >50% r = 0,69

Ap > Am : LVEDP > 15mmHg (Se : 85%, Sp: 79%, Rossvoll)

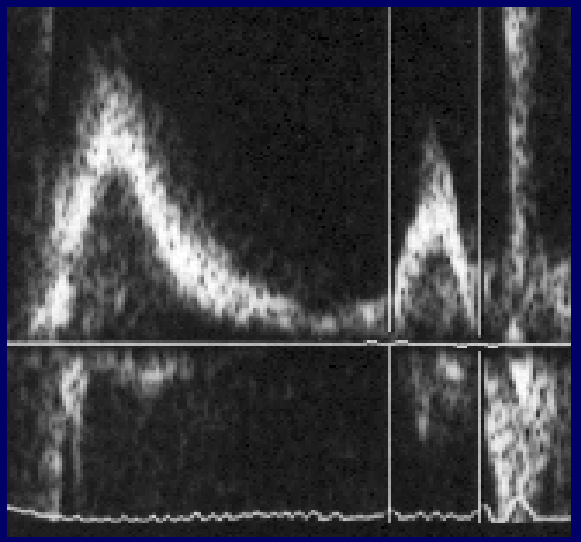
Ap - Am >20ms : LVEDP > 12mmHg (Se : 74%, Sp: 95%,Appleton)

Ap - Am

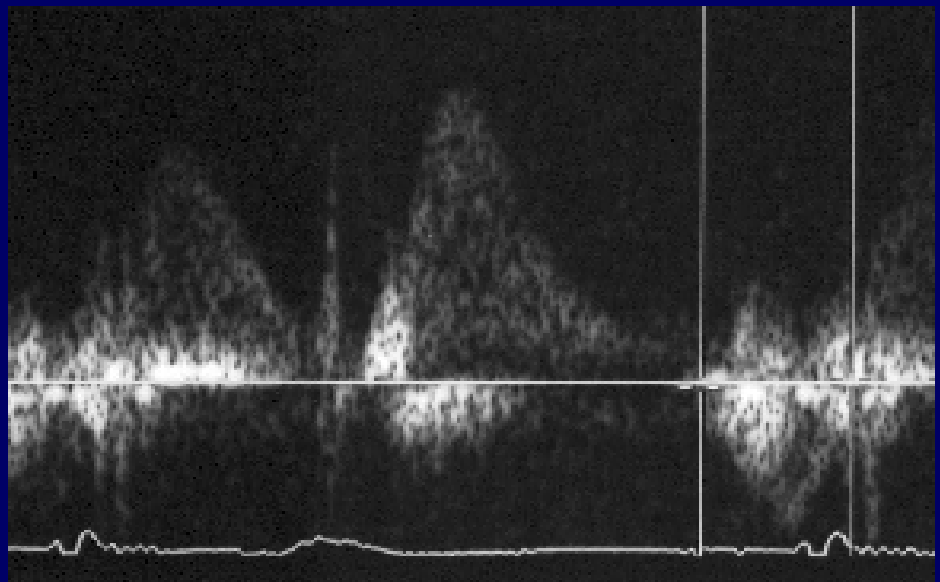


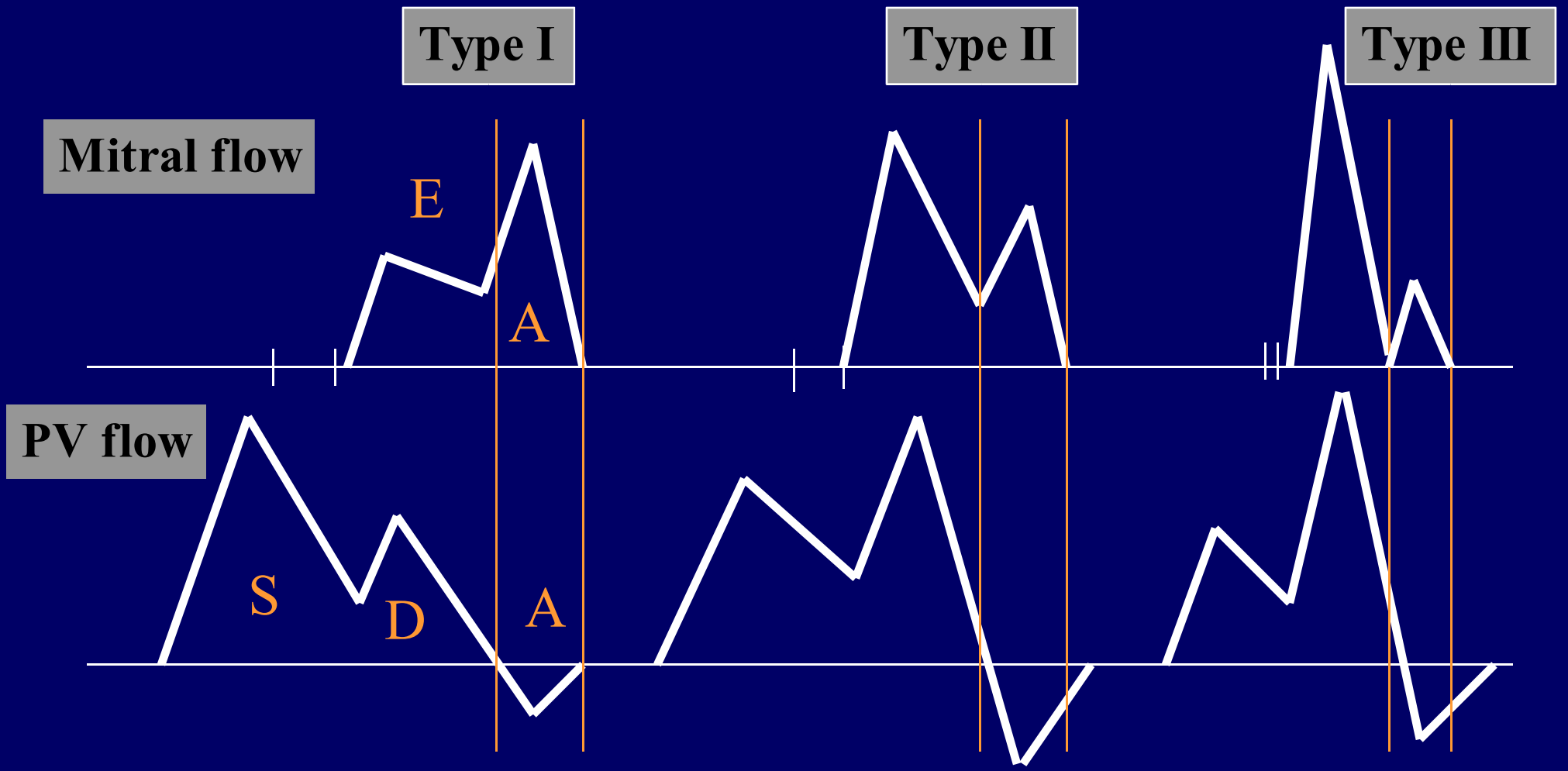
Anterior MI - EF 40%
LVEDP = 20mmHg

Am = 120 ms



SF=40%, Ap = 220 ms

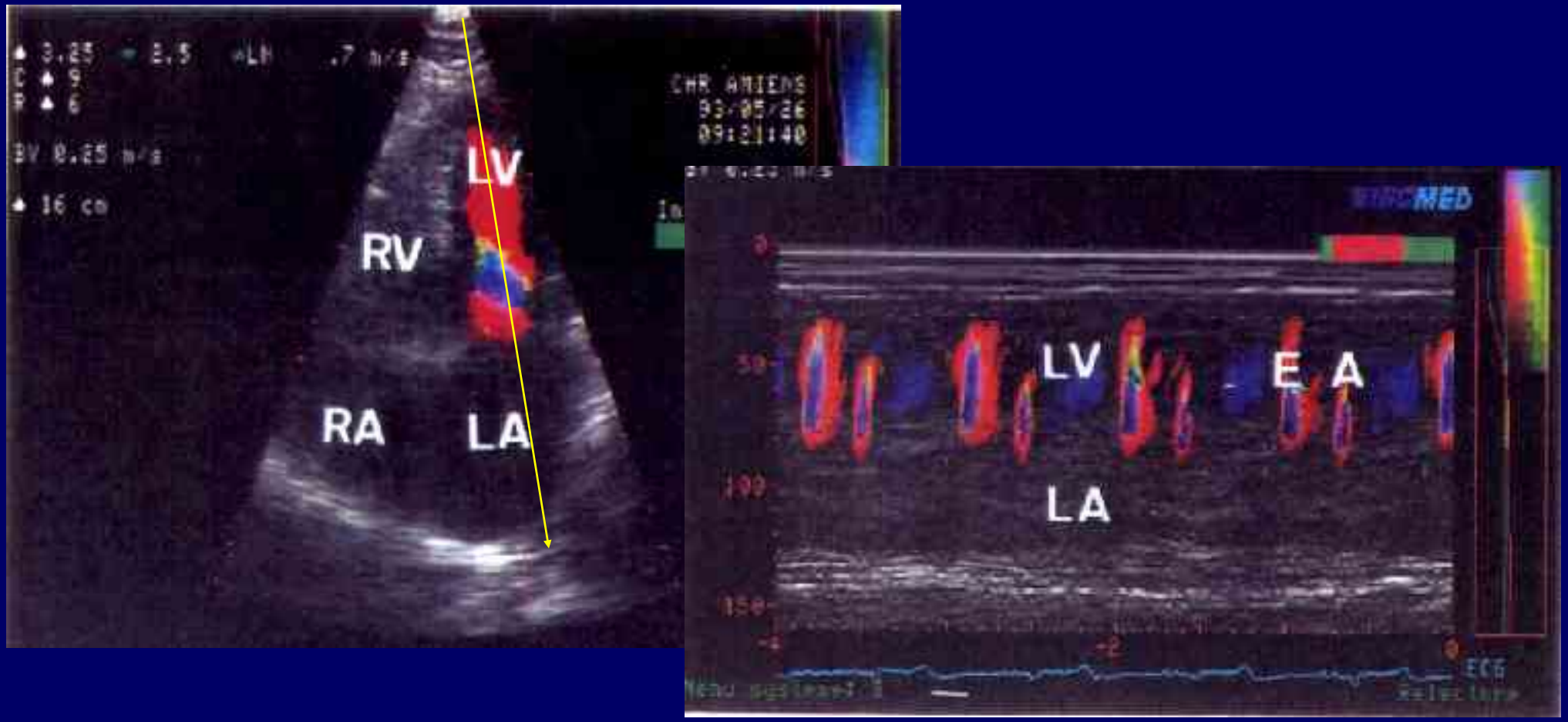




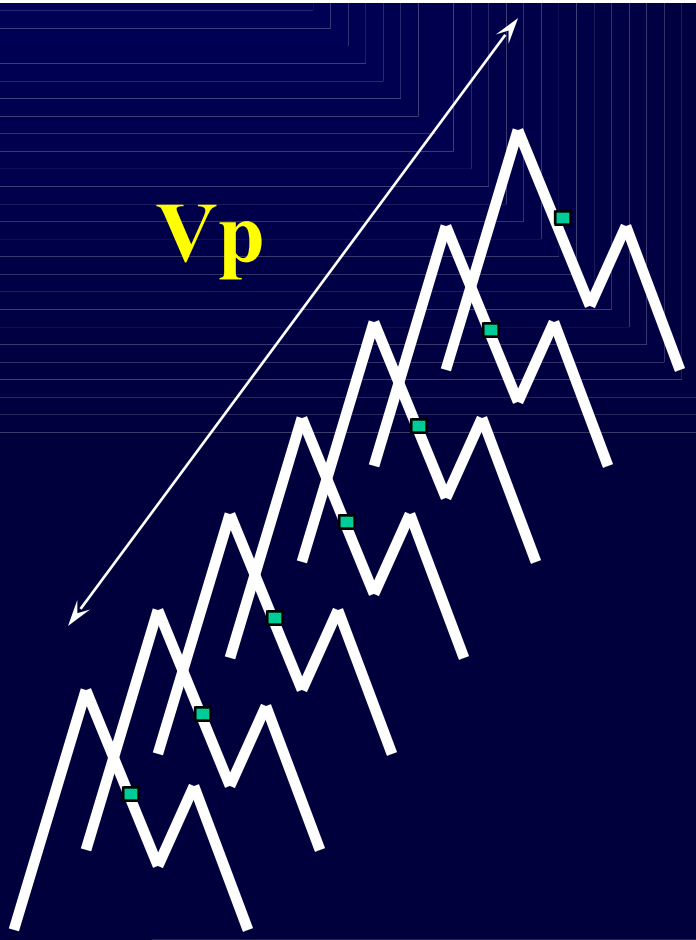
Appleton et al

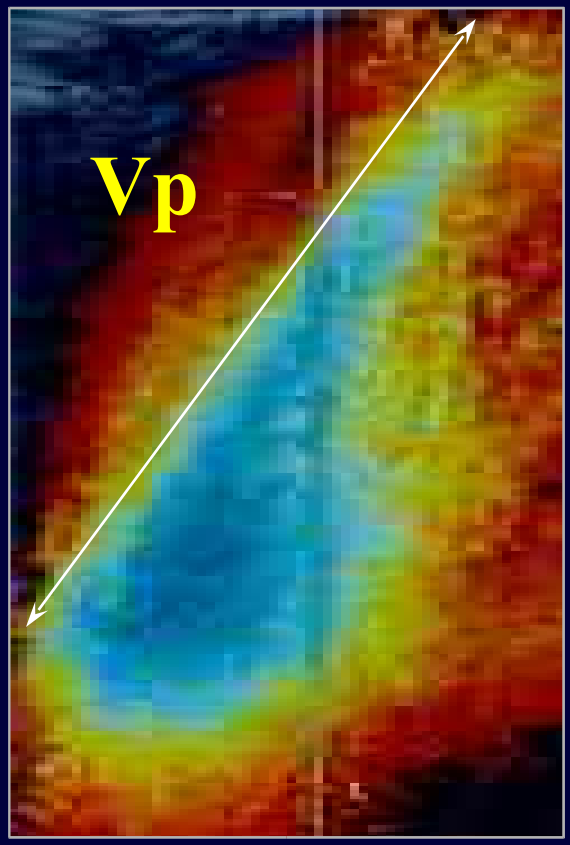
III Mitral flow propagation velocity (Color M-Mode)

Mitral flow propagation velocity (Vp) (Color M-Mode)



Mitral flow propagation velocity (Color M-Mode)

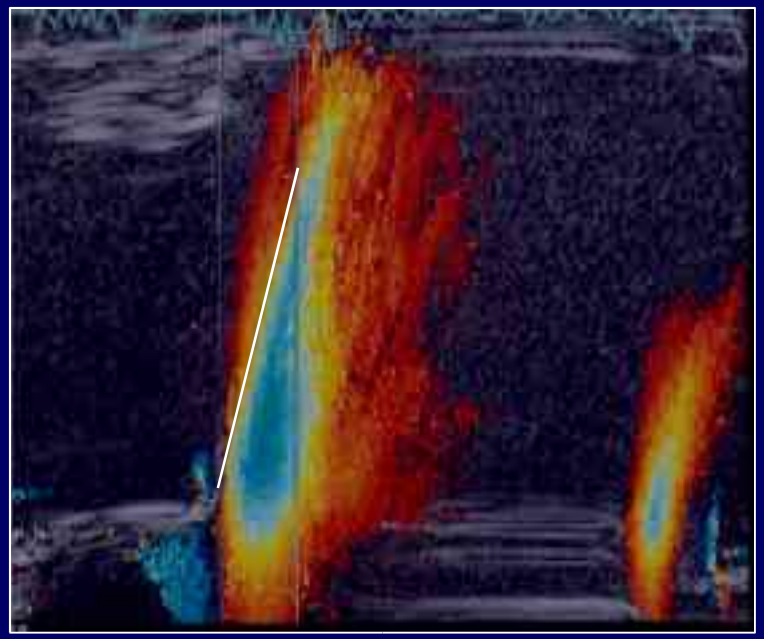




Vp = slope of isovelocities
= LV relaxation index

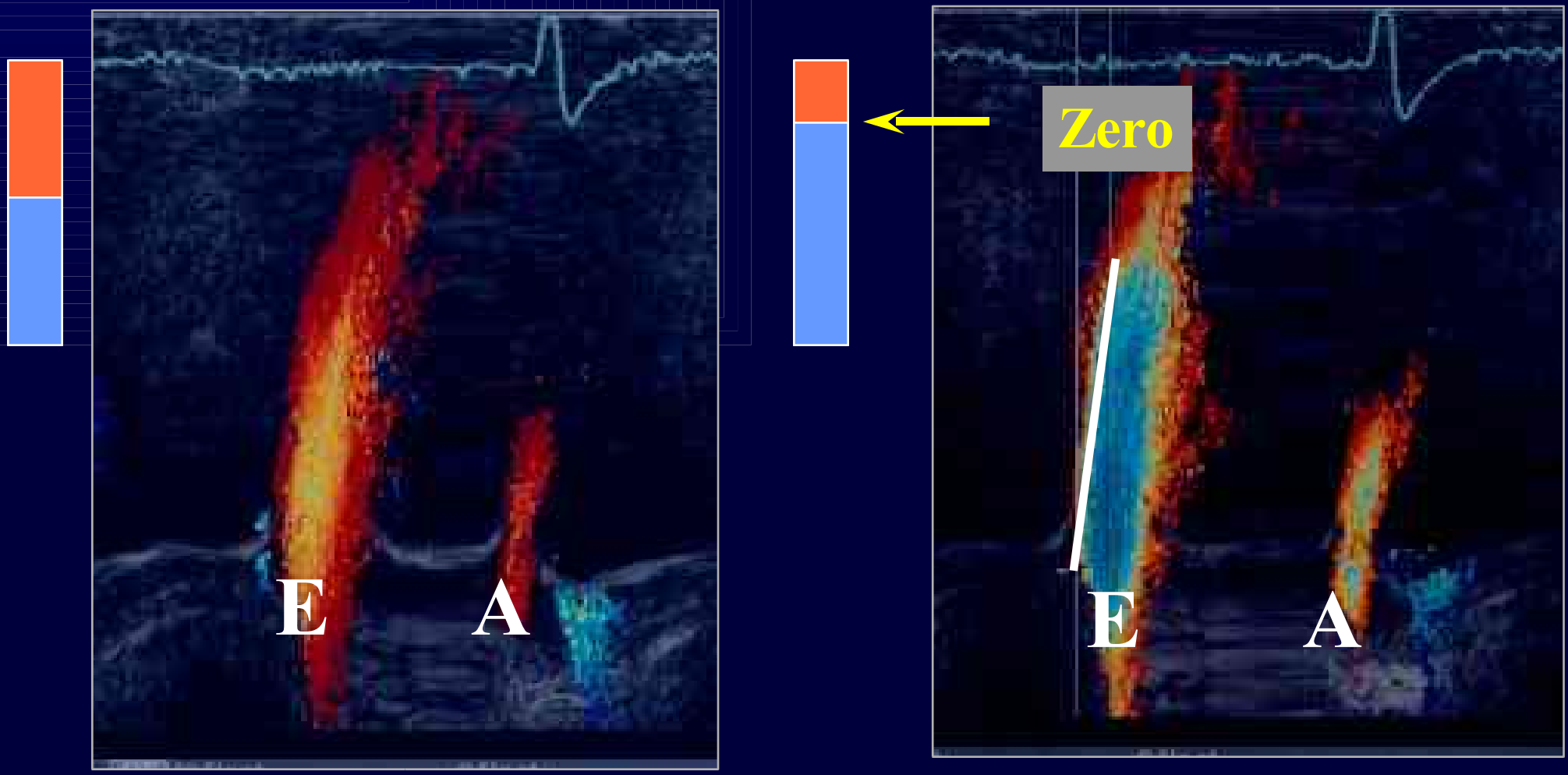
Mitral flow propagation velocity (Color M-Mode) : how to measure?

- 4C apical view
- Color Doppler
- M-mode
- 100 mm/s
- Aliasing limit : 50% to 75% E velocity
- Mesure of Vp :
  - Slope of isovelocity first aliasing (interface between orange and blue)
  - Mitral annulus to 4 cm into LV
  - Average of 3 measurements

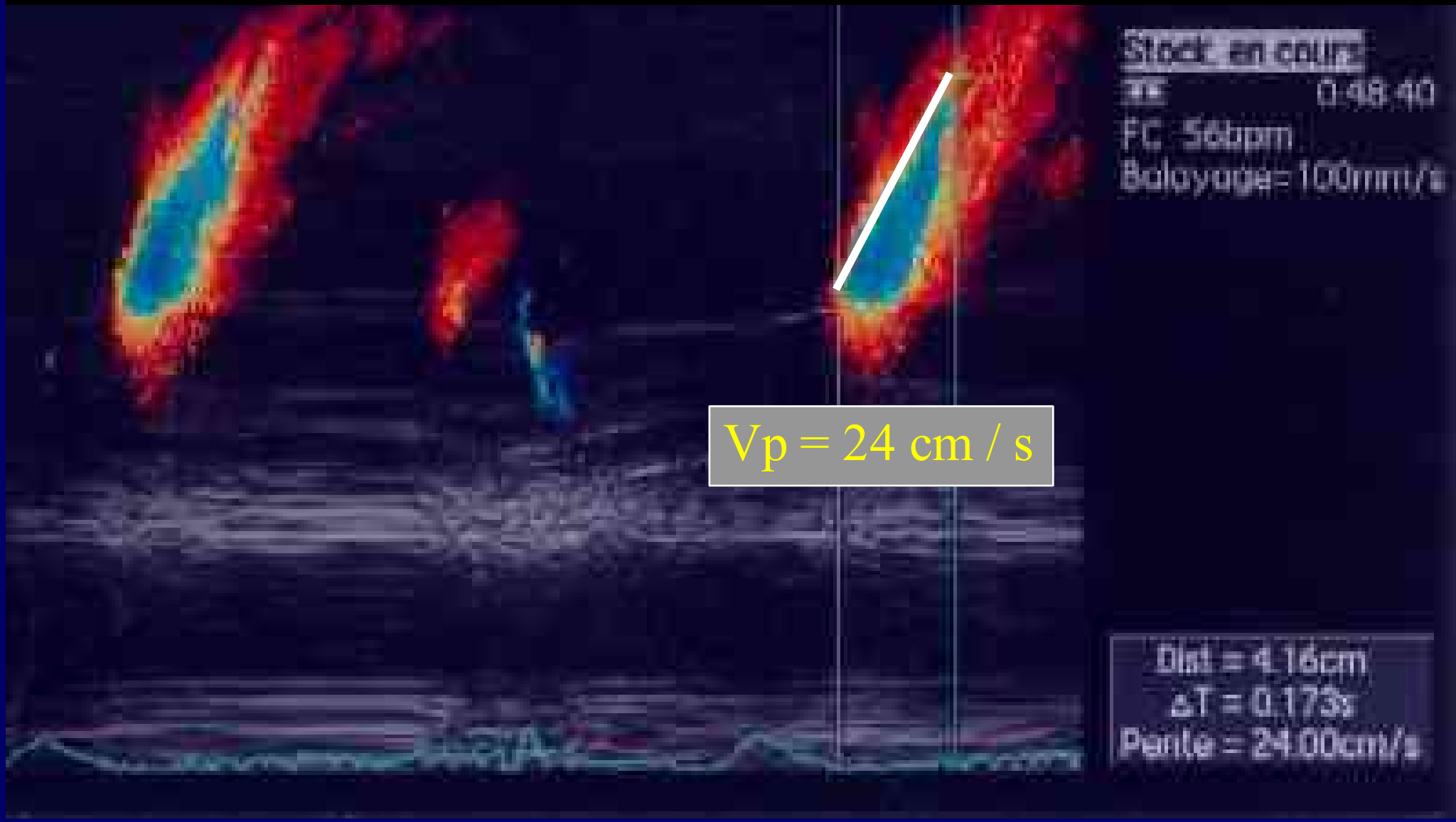


Vp > 45 cm/s

Vp : measurement



Anterior MI - EF = 40% - LVEDP = 20mmHg



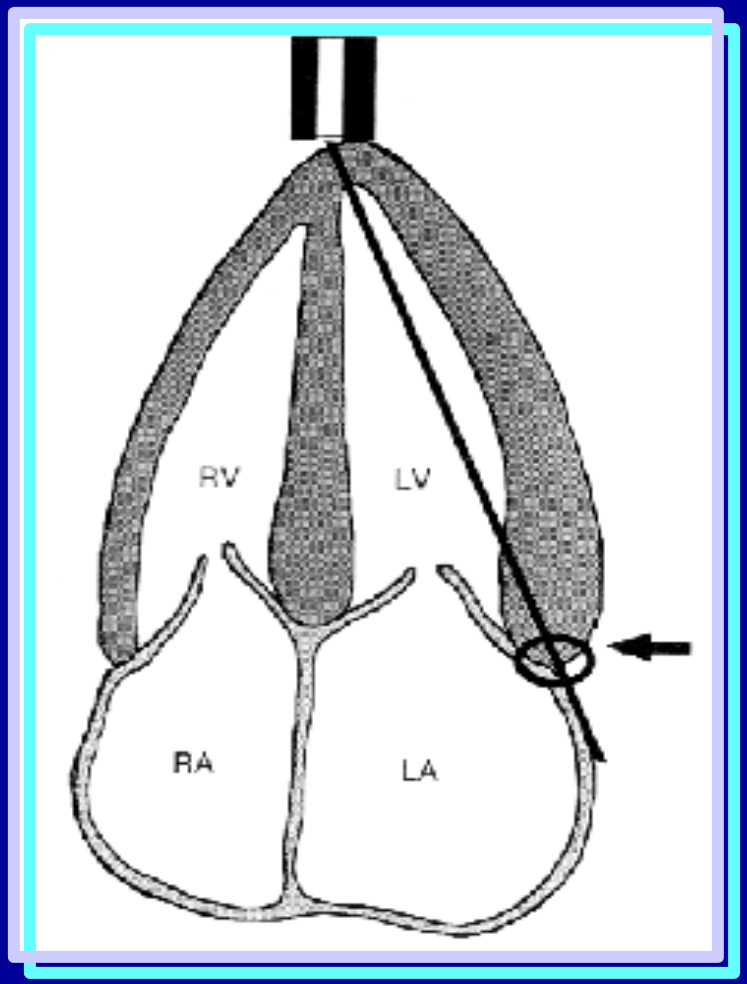
Mitral flow propagation velocity (Color M-Mode)

- Relaxation index
- Preload independant
- To distinguish normal and pseudo normal MF
- Recordable in 80% of patients
- Limits : influence of age

Vp : influence of age
Normal values(Mego et al. JASE 1998; 11: 20-5)

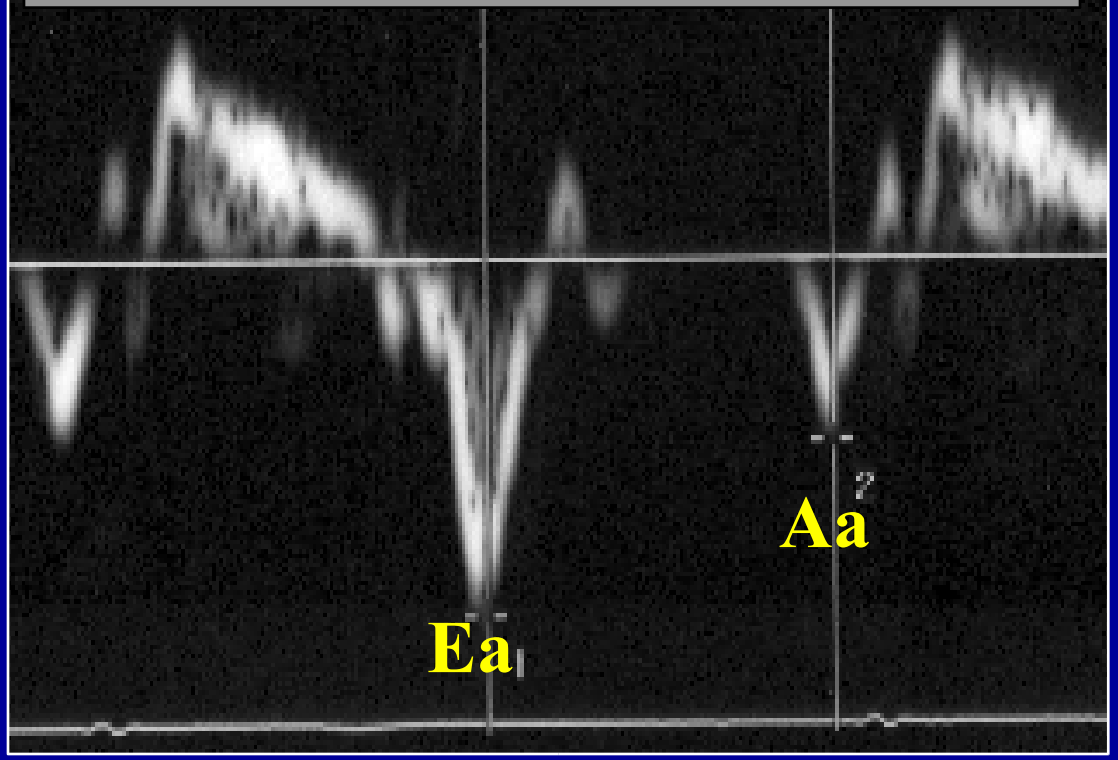
Age (years)	Vp (cm/s)
21-35	77 ± 25
36-50	70 ± 23
51-60	53 ± 15
> 65	43 ± 11

IV Mitral annulus movement (DTI)



Normal values

Ea > 8 cm/s et Ea / Aa > 1

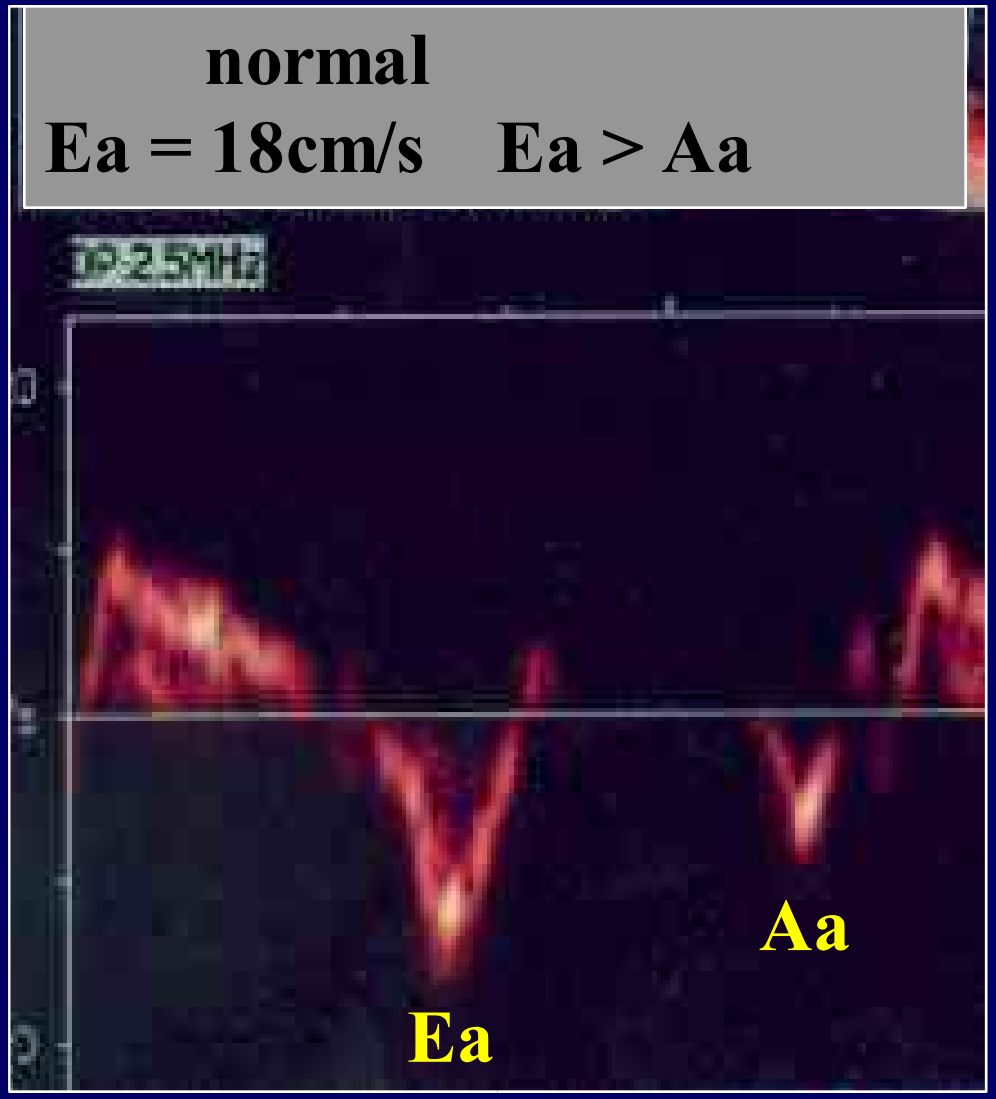


- **DTI**
- **Mitral annulus**
- **Minimum settings**

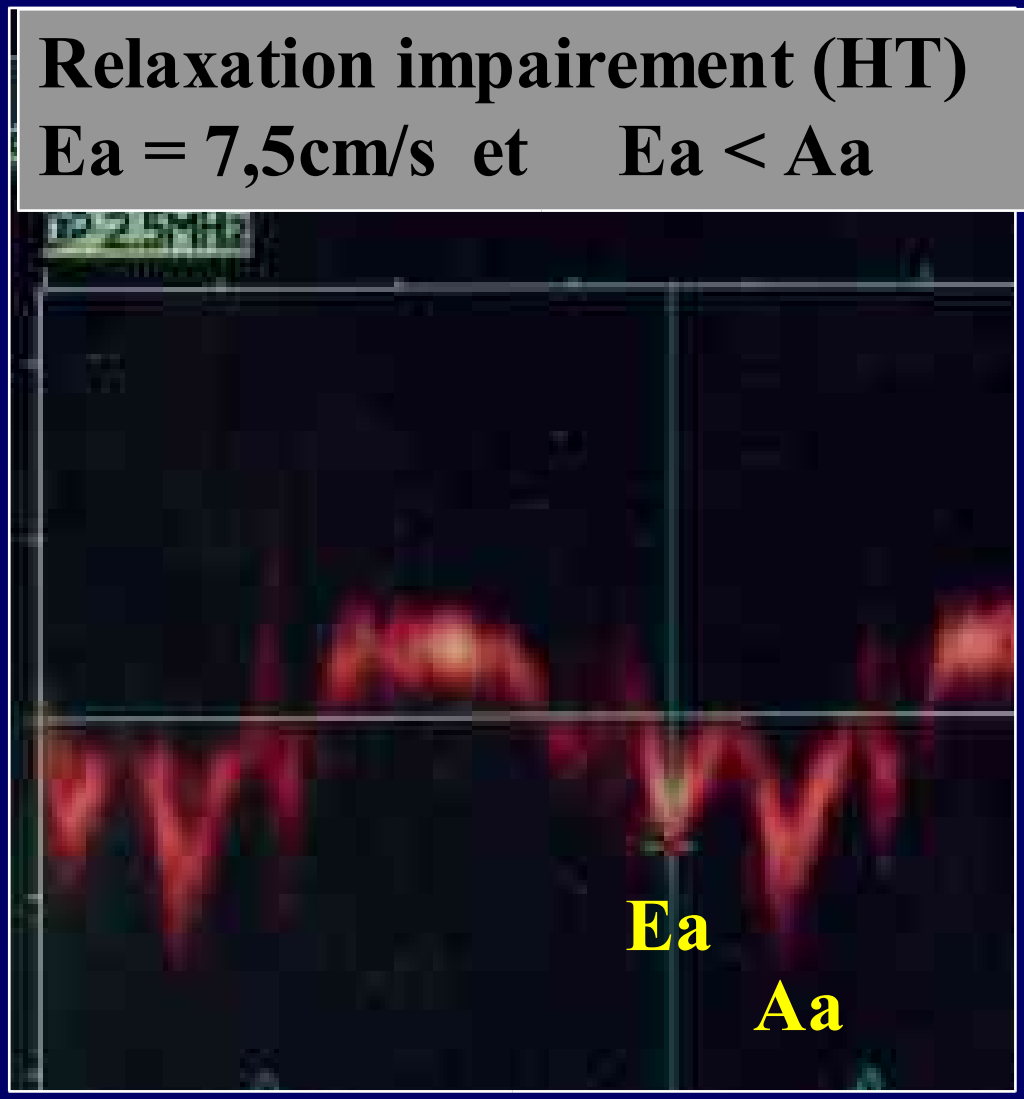
- **Ea = 15 ± 4 cm/s**
  Aa = 10 ± 3 cm/s

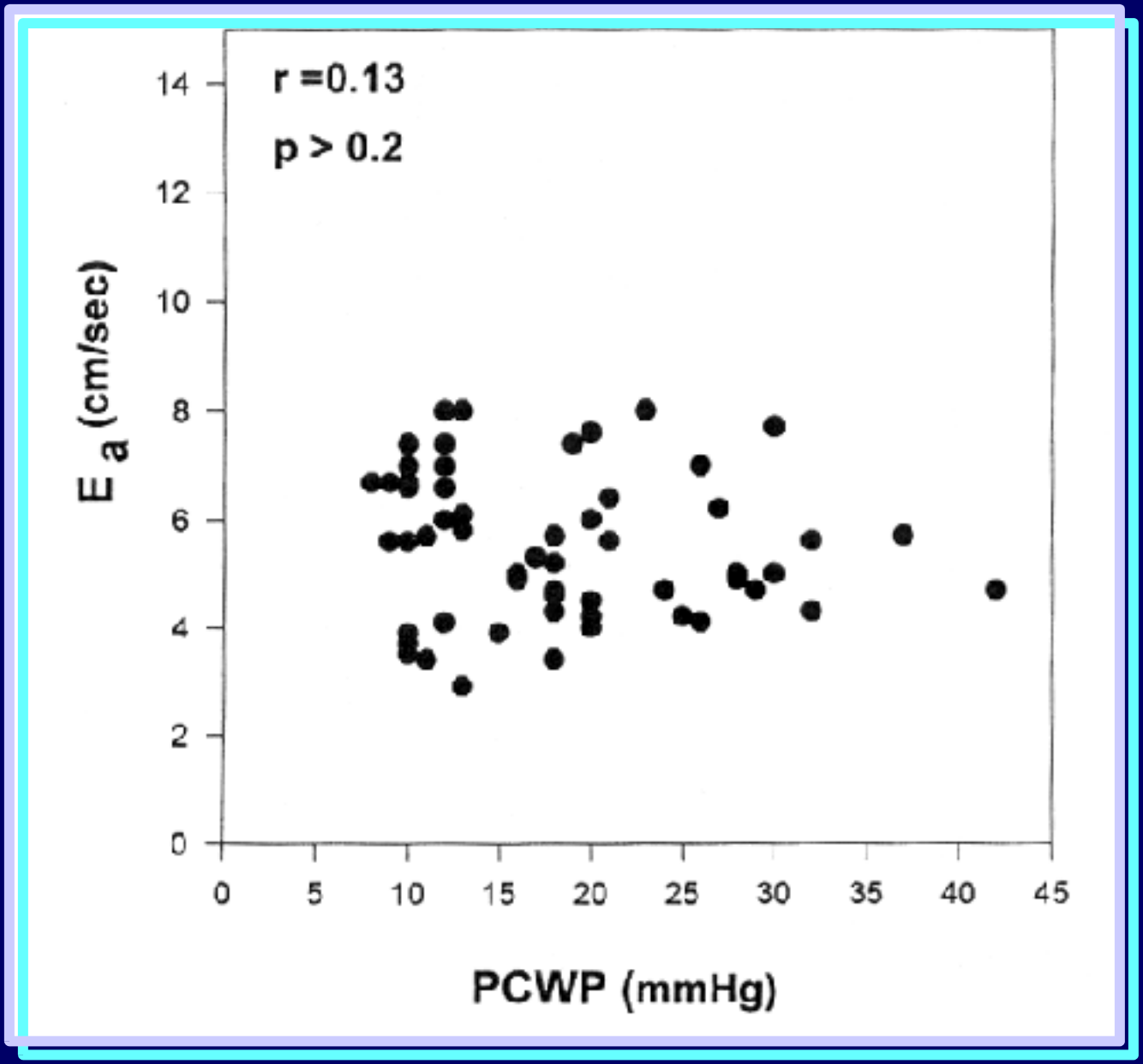
Mitral annulus movement

normal
Ea = 18cm/s Ea > Aa



Relaxation impairement (HT)
Ea = 7,5cm/s et Ea < Aa



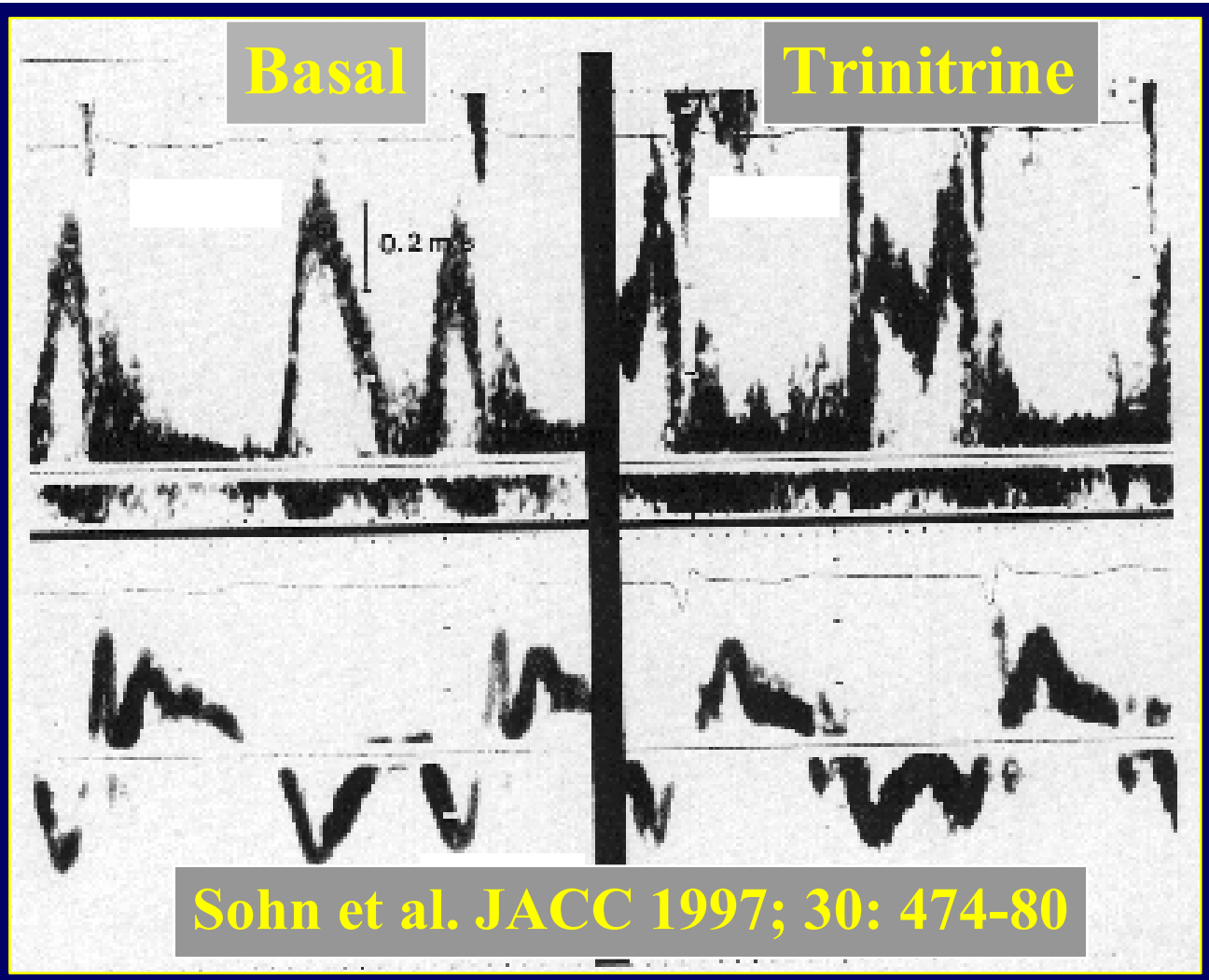


Nagueh, JACC 1997

Preload effect on mitral annulus DTI

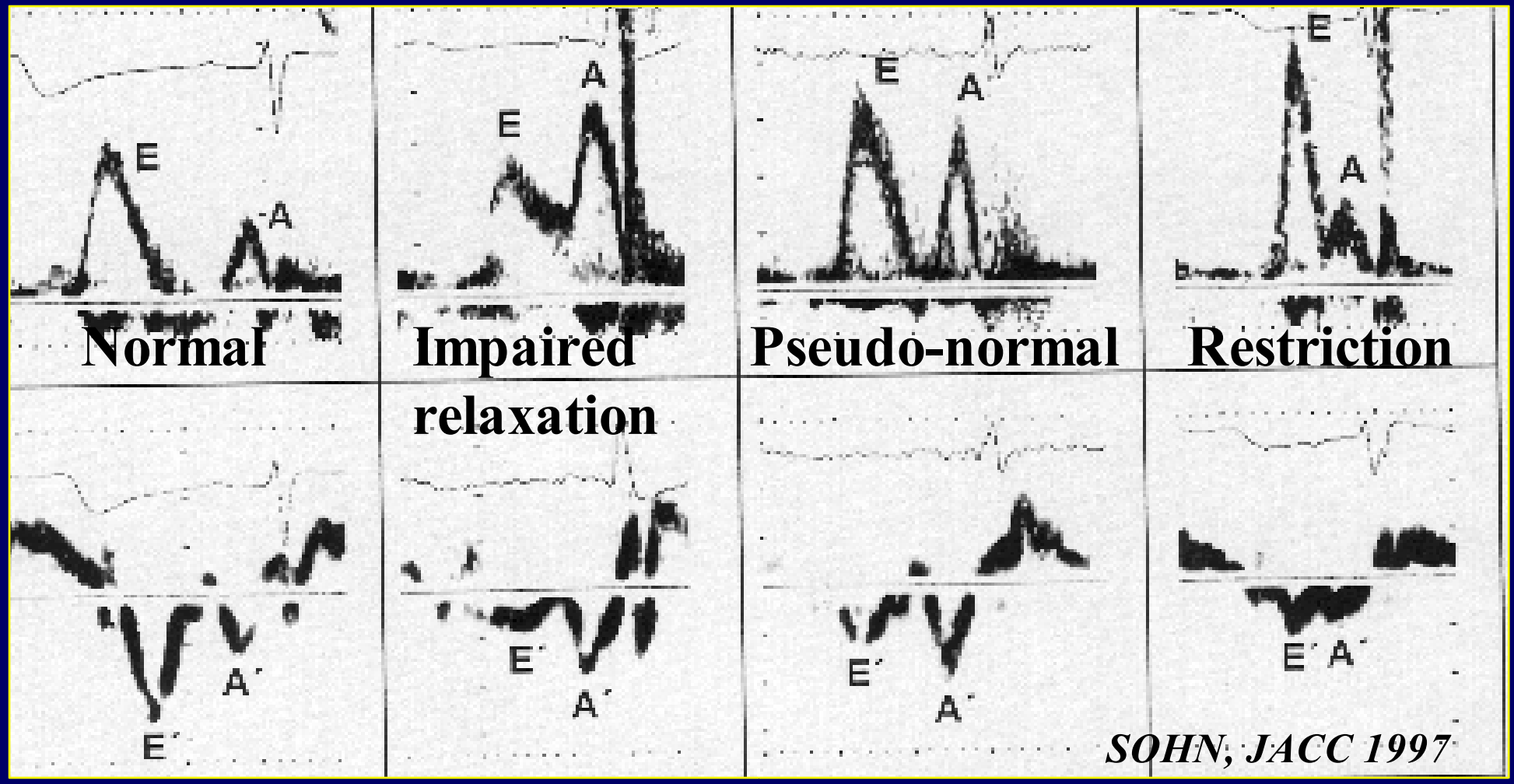
Mitral flow

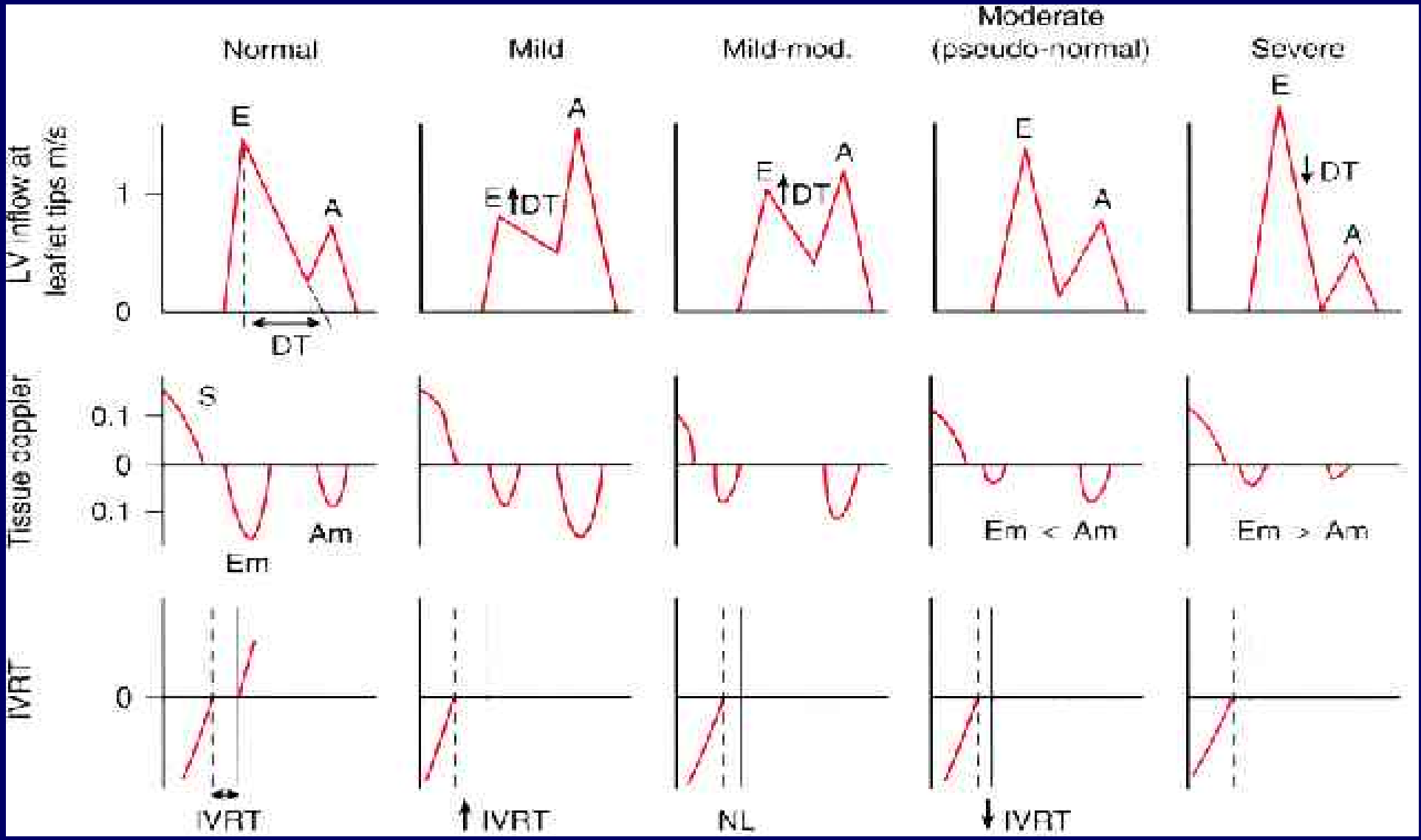
DTI



Sohn et al. JACC 1997; 30: 474-80

Mitral annulus movement (DTI)

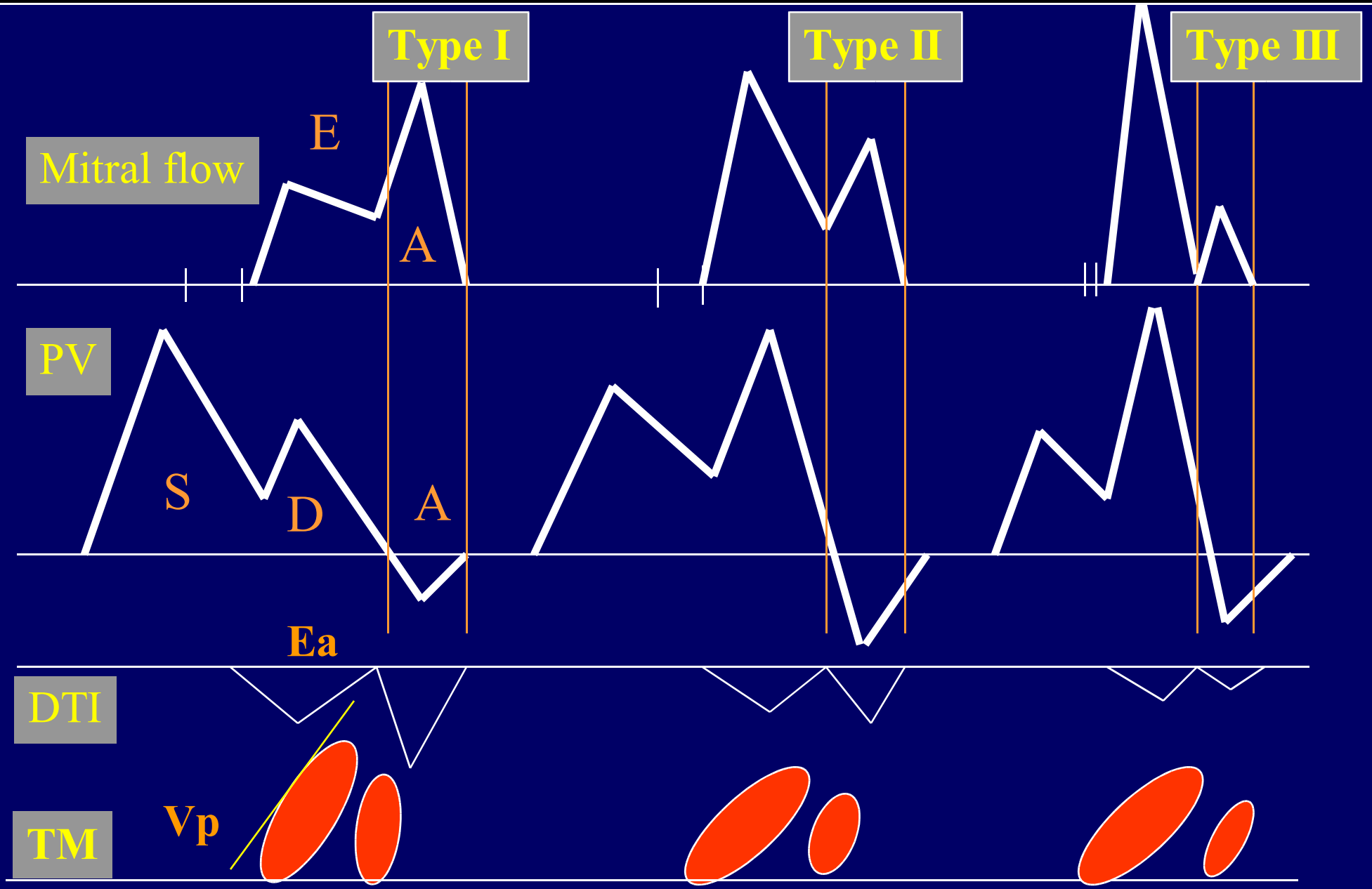



Normal
Mild
Mild-mod.
Moderate
(pseudo-normal)
Severe
LV inflow at leaflet tips m/s
E
A
DT
1
0
Tissue doppler
S
0.1
0
0.1
Em
Am
Em < Am
Em > Am
IVRT
IVRT
NL
IVRT

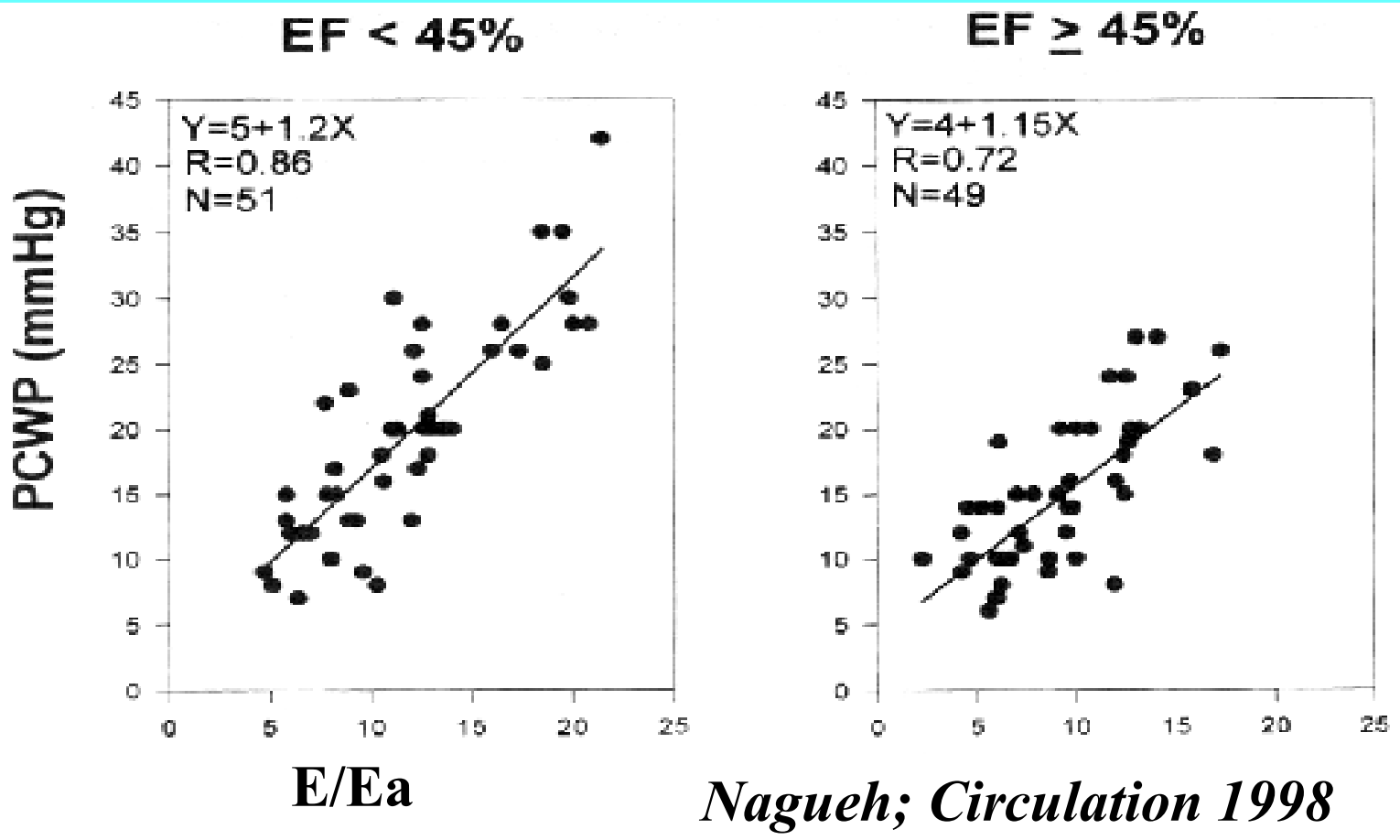
Conclusion

- In ICU many factors influence mitral flow and pulmonary venous flow (age, HR, LVDP, compliance, relaxation)
- These indice may not be used to assess LV diastolic function (compliance and relaxation)
- To assess relaxation : Vp and Ea/Aa

Diagnosis of LV diastolic dysfunction



Estimation LVDP pre A : E/Ea



Nagueh; Circulation 1998

E/Ea > 10 (Nagueh JACC 1997) ou E/Ea > 15 (Ommen Circulation 2000)

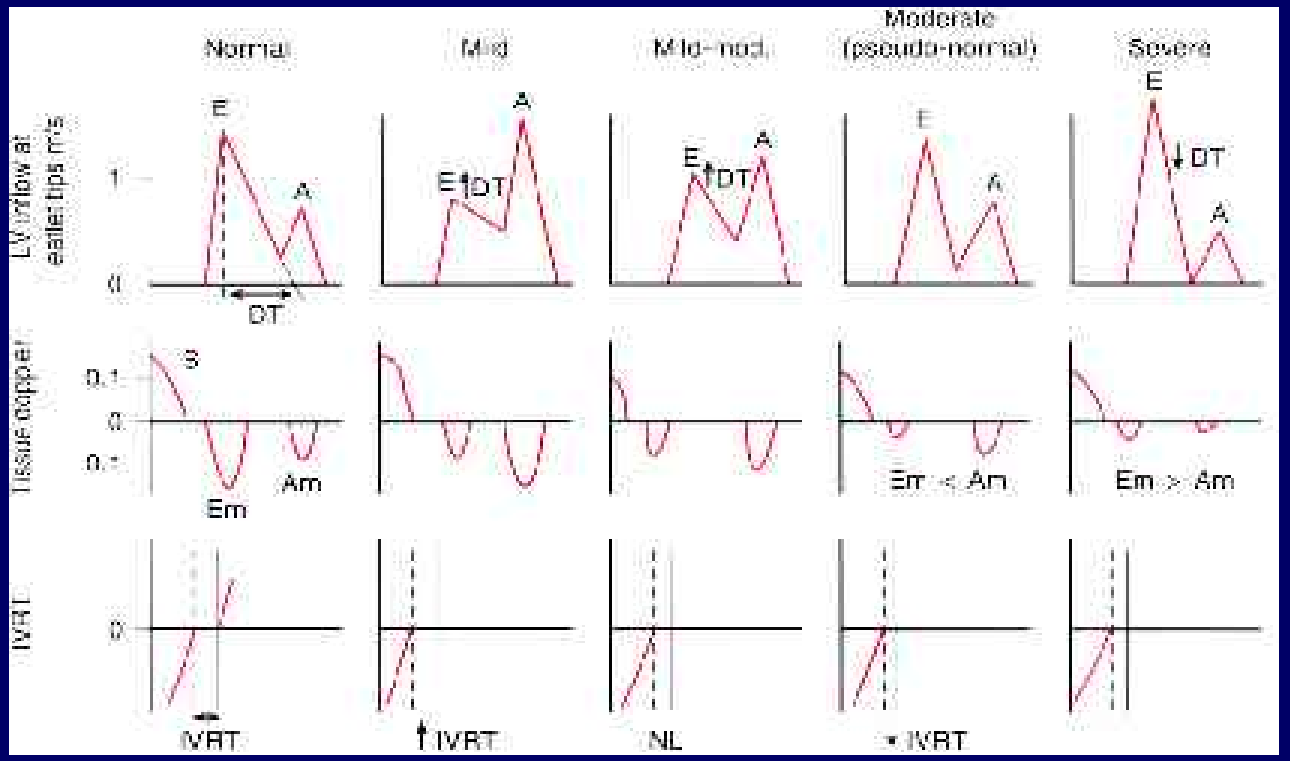


FIGURE 7-25. Diagram of the changes in diastolic parameters with diastolic function ranging from normal to severely impaired, corresponding to the classification in Table 7-6. Left ventricular inflow at the mitral leaflet tips (*top*), tissue Doppler velocities at the base of the septum adjacent to the mitral annulus (*middle*), and the isovolumetric relaxation time (IVRT) (*bottom*) are shown. Abbreviations as in other tables and figures.

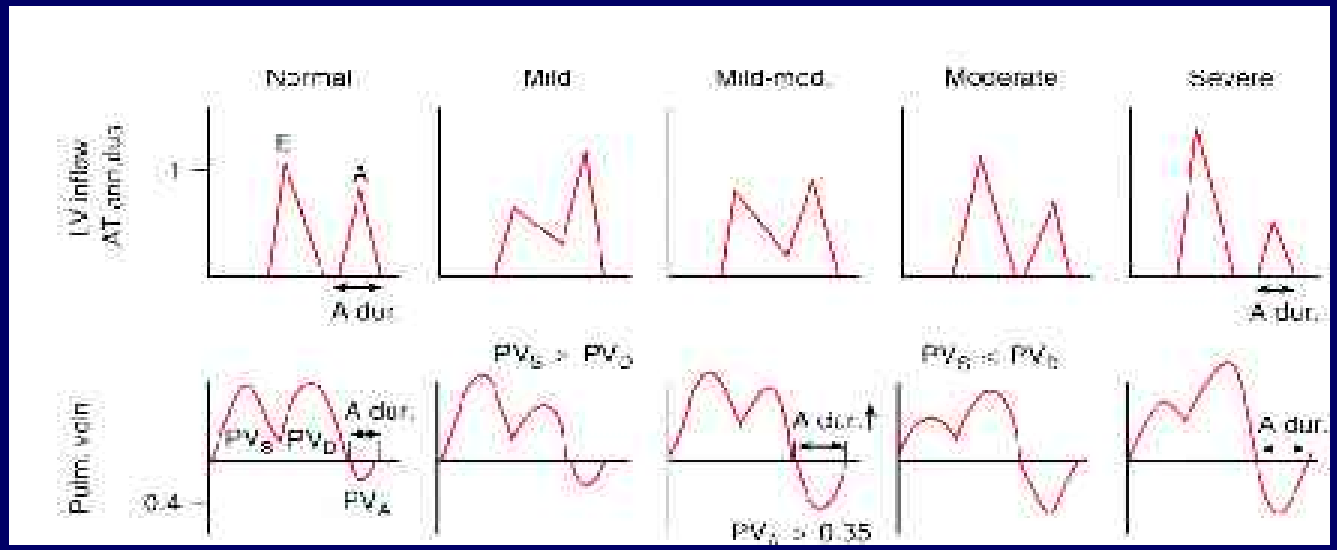


FIGURE 7–26. Evaluation of left atrial pressure is based on the pattern of left ventricular filling recorded at the mitral annulus (*left*) and pulmonary vein flow (*below*). With elevated left atrial pressures, the mitral deceleration time (DT) shortens and the velocity and duration of the atrial reversal in the pulmonary vein increase, with an $PV_A > 0.35$ m/s and at least 30 ms longer in duration than the transmitral A-duration indicating elevated filling pressures. With diastolic dysfunction, the diastolic phase of pulmonary venous flow exceeds the systolic phase of flow.

Arguments en faveur élévation des pressions de remplissage VG

- E/A >2
- TDE < 150 ms
- Fraction systolique FVP < 50%
- Durée Ap > durée Am*
- E/Vp* > 1.8 - 2
- E/Ea* > 10-15

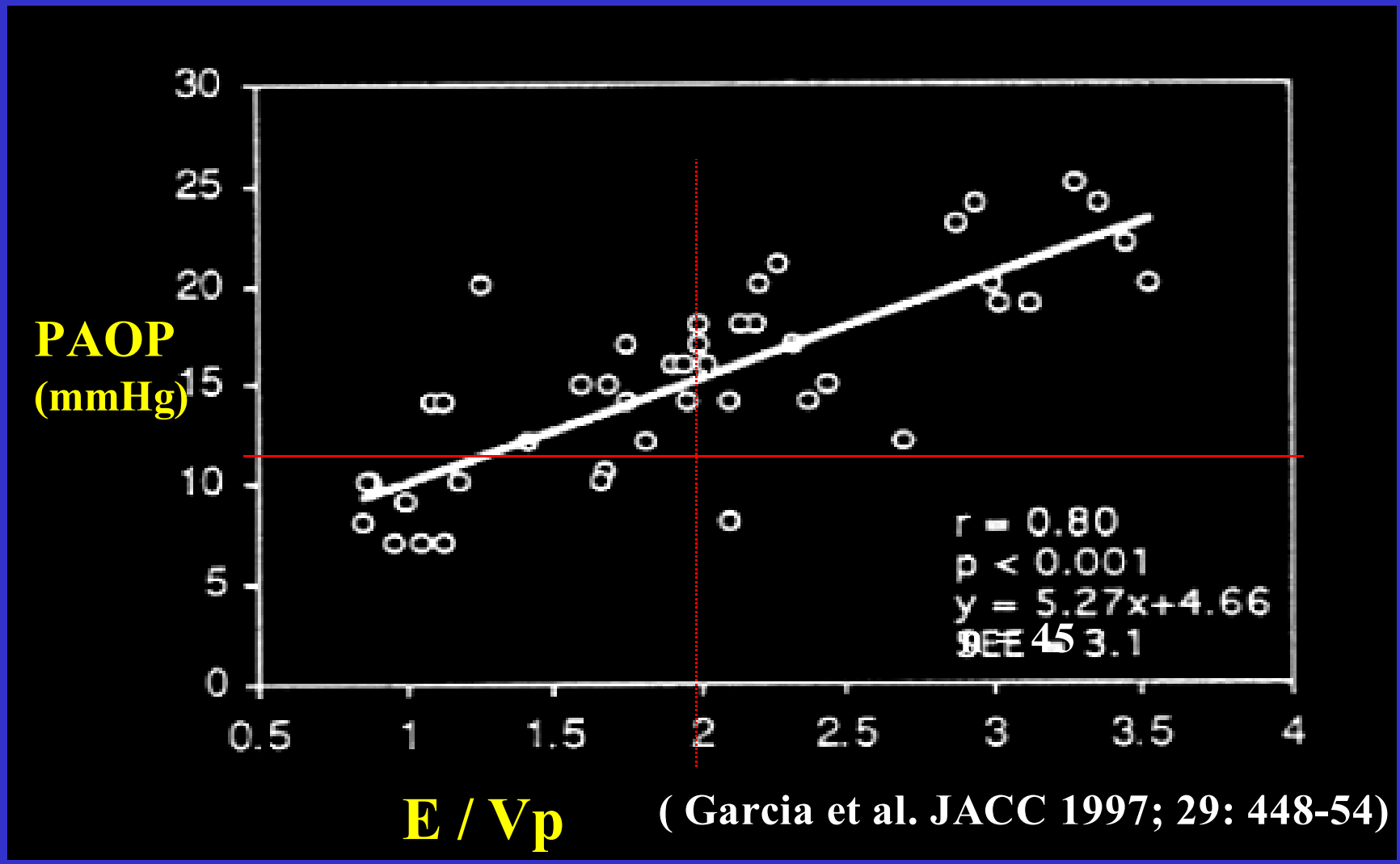
V Left ventricular diastolic filling

Etude du remplissage VG par écho Doppler

Les 3 « stades » d ’anomalie du remplissage VG

- Stade I : Réduction du remplissage protodiastolique
- Stade II : Flux « normalisé ou pseudonormal »
- Stade III a : Flux mitral restrictif « résolutif »
  Stade III b : Flux mitral restrictif « permanent »

PWP and E/Vp



Correlation between E/Vp and PAOP (r=0,65), E/Vp ³ 1,4; PAOP > 15mmHg (Se: 72% , Sp:100%) **Nagueh et al. Circulation 1996; 94: 2138-45**

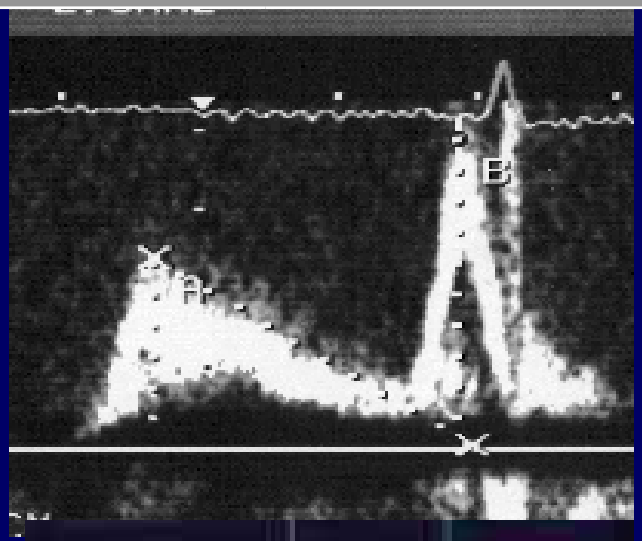
Etude du remplissage VG par écho Doppler

Stade I

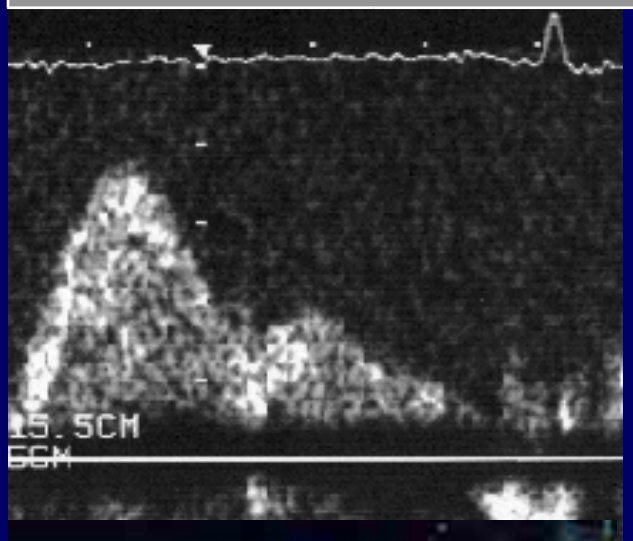
- Symptomes : asymptomatique ou dyspnée d ’effort modérée
- Oreillette gauche : taille normale ± hypercontractile
- Ventricule gauche : fraction d ’éjection normale ou ↓
- Doppler mitral : ↑ TRI, ↓ E, ↑ onde A, ↓ E/A, ↑ TDE
- Doppler flux VP : diminution vitesse flux diastolique (S>D)
- Physiopathologie : ralentissement relaxation VG (VP, Ea)
- Pressions de remplissage : normales ou peu augmentées si dysfonction systolique

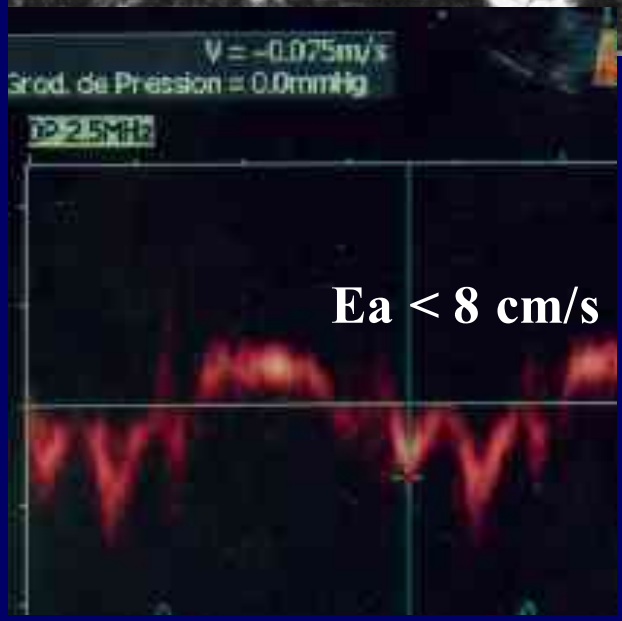
ANOMALIE DE RELAXATION (RAC)

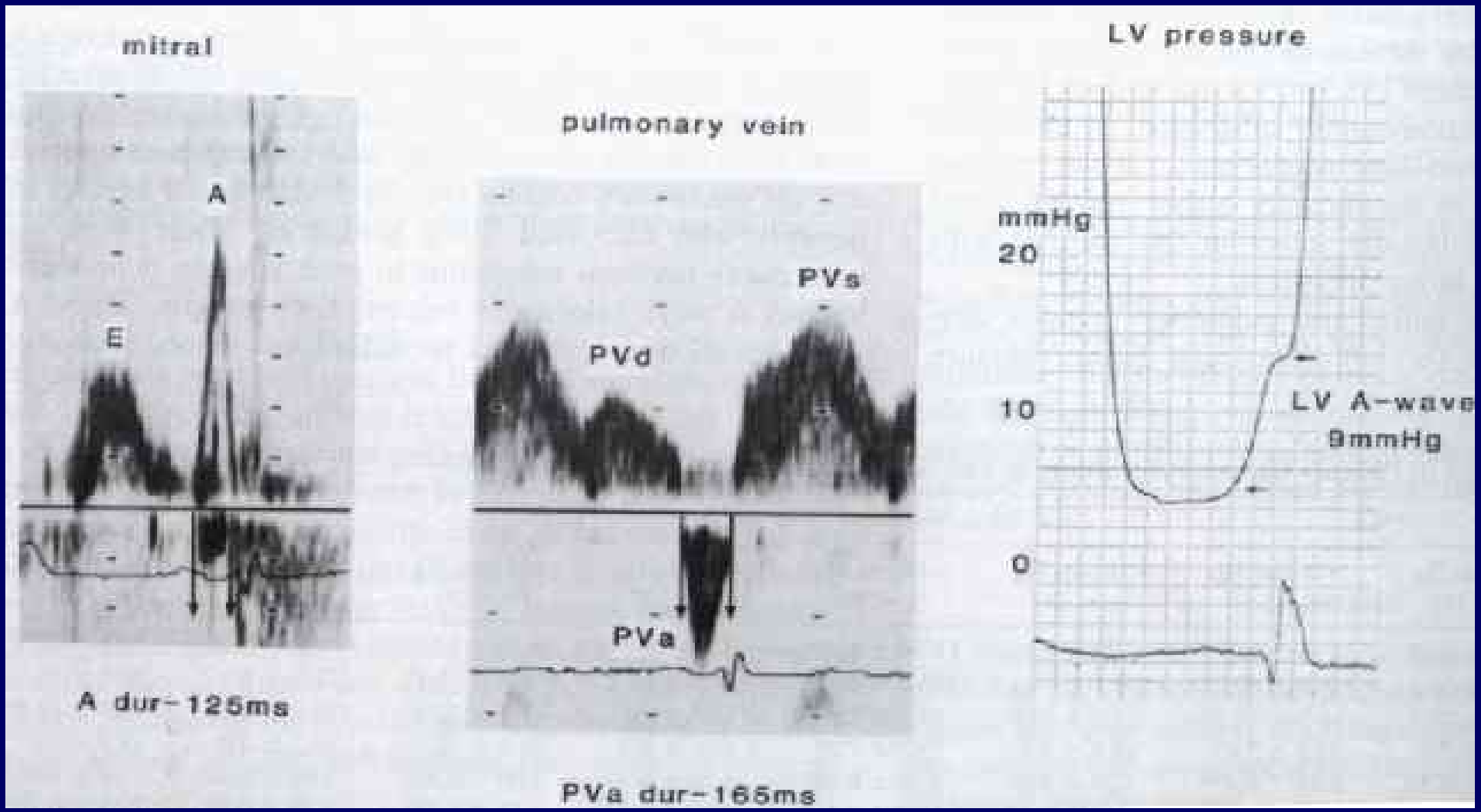
E/A < 1 TDE = 460 ms



Réduction D, S/D > 1






mitral
A
E
A dur-125ms
pulmonary vein
PVs
PVd
PVa
PVa dur-165ms
LV pressure
mmHg
20
10
0
LV A-wave
9mmHg

Flux mitral type I - cardiopathies

- HTA - cardiopathie hypertensive
- Cardiomyopathie hypertrophique primitive
- Rétrécissement aortique
- Cardiomyopathie dilatée ou restrictive
- Cardiopathie ischémique

……

Ce type traduit une anomalie de la relaxation VG avec pressions de remplissage normales ou relativement peu élevées, une anomalie de compliance VG est ici peu probable

Etude du remplissage VG par écho Doppler

Stade II

- symptomes : dyspnée d ’effort modérée à moyenne
- oreillette gauche : ↑ taille ± ↓ contractilité
- ventricule gauche : fraction éjection normale ou ↓
- pressions de remplissage VG : augmentées
- Flux mitral : normal

- Flux VP : ↑ durée flux rétrograde A + ↓ flux systolique S
- Physiopathologie : altération relaxation VG + aug. P remplissage (diminution compliance VG)

Flux mitral normalisé

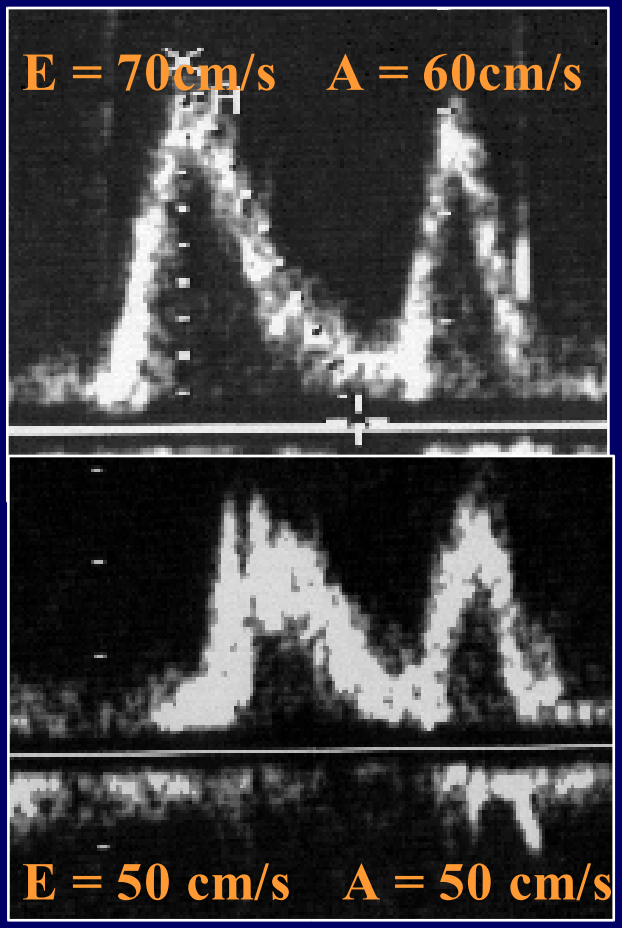
- HVG - altération fonction VG
- Manœuvre de Valsalva ou TNT sublinguale
- Comparaison ondes A mitrale et A pulmonaire, ↓S FVP
- TM couleur : Vitesse de propagation flux remplissage < 45 cm/s
- Doppler tissulaire Ea < 8 cm/s

FLUX MITRAL NORMAL ou NORMALISE
INTERET VALSALVA ET TNT

- Aspect normal :

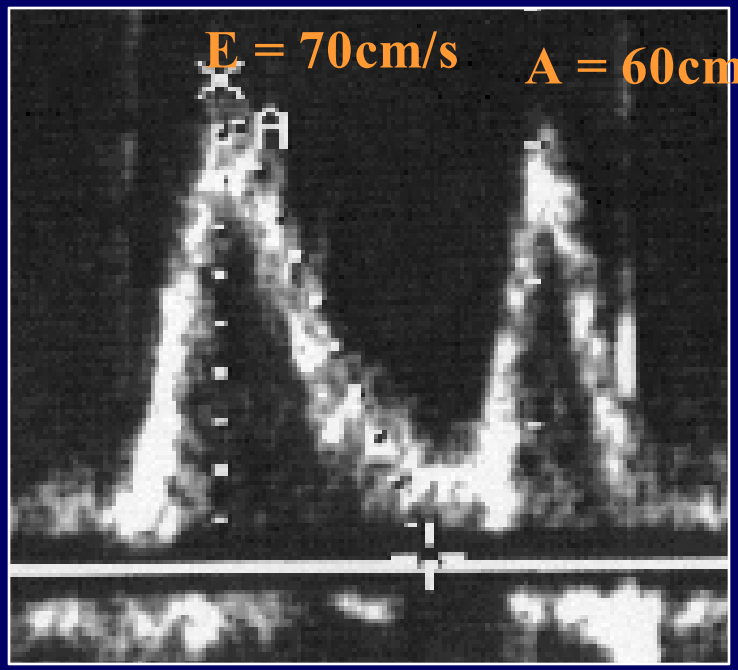
  Réduction de E et de A

  Absence de réduction de E / A

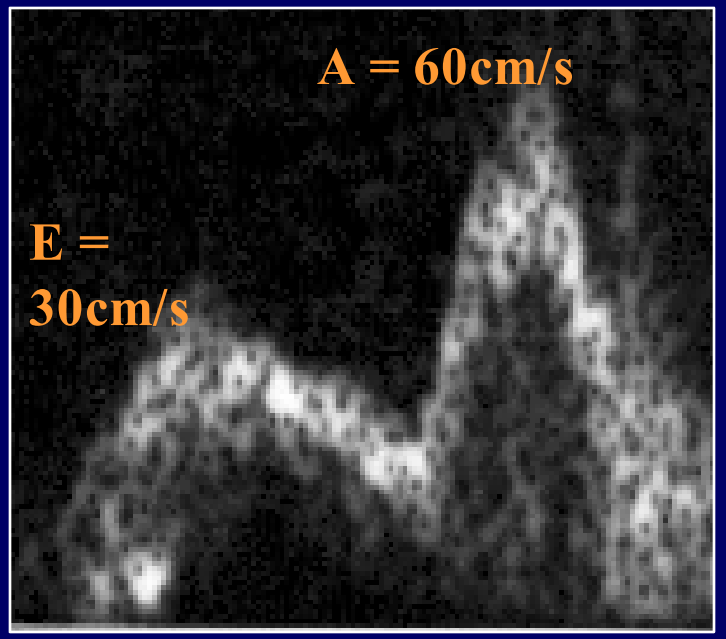


Valsalva : aspect normal

FLUX MITRAL NORMALISE
INTERET VALSALVA ET TNT



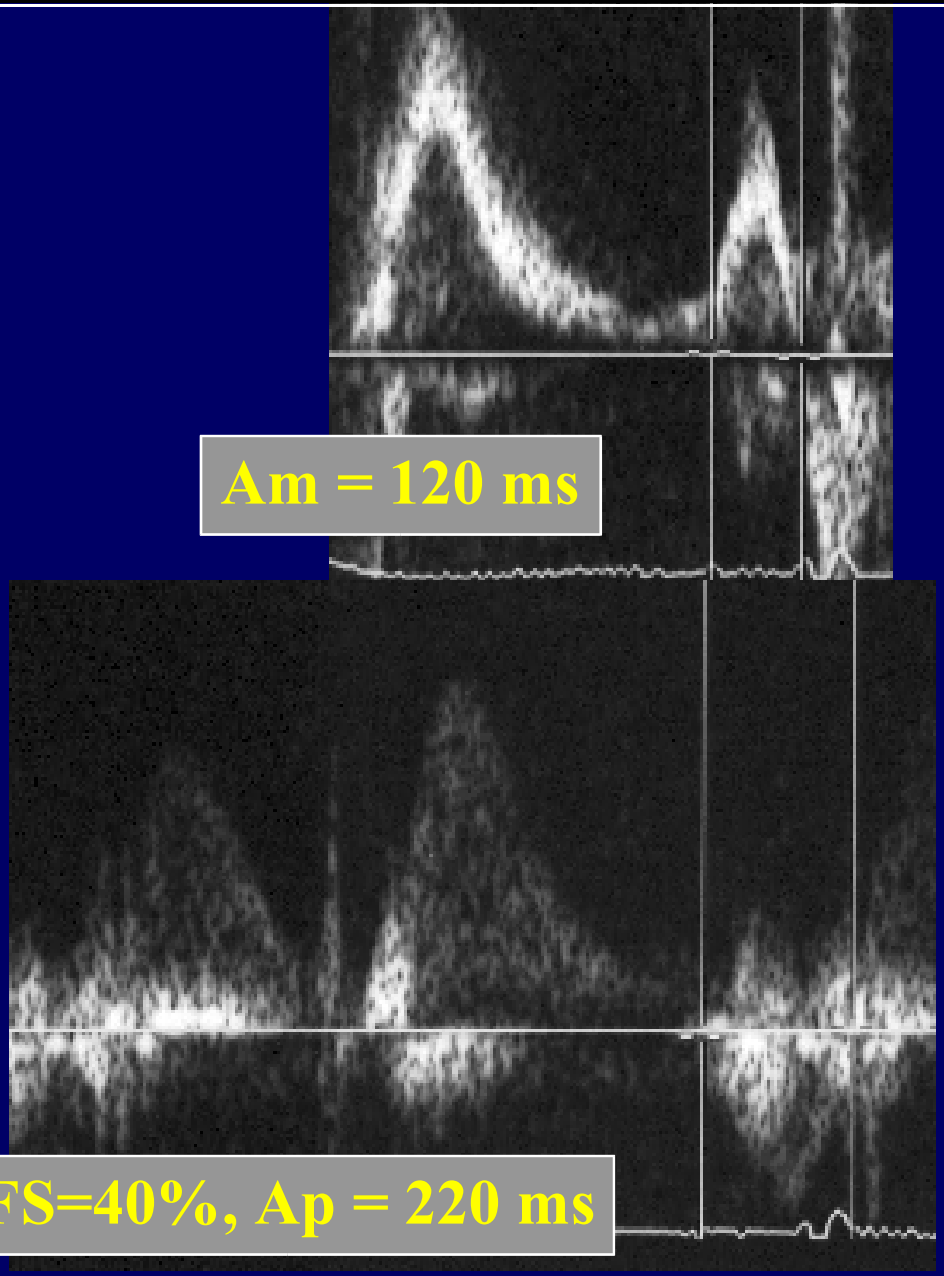
Valsalva
réponse anormale



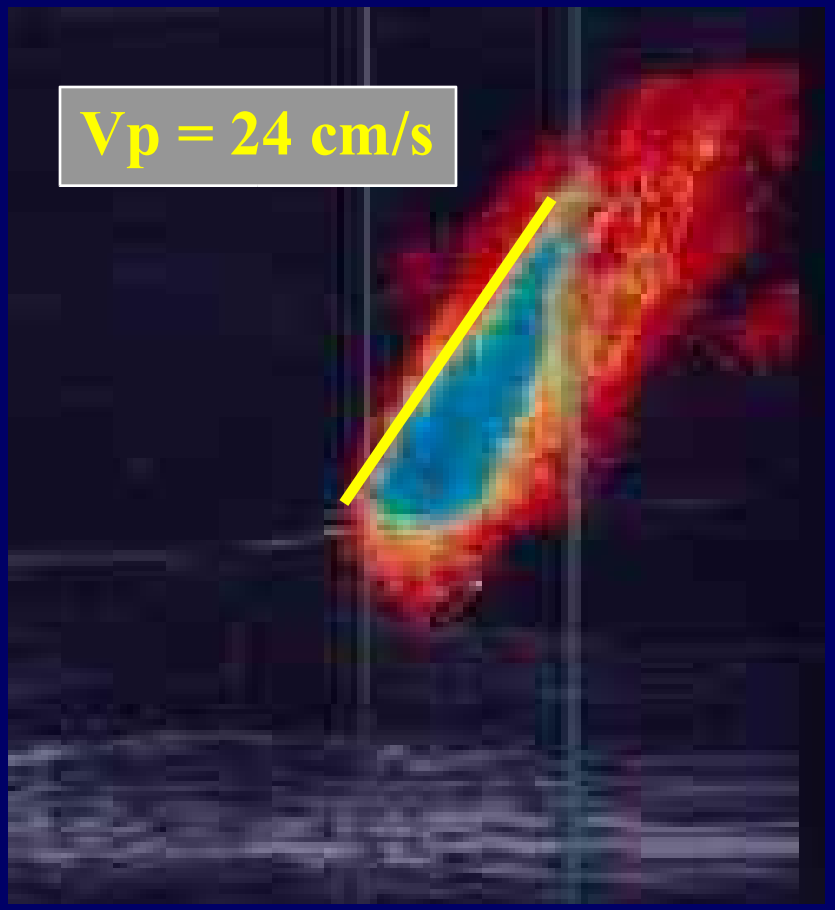
Réduction de E <u>sans réduction de A</u>

Réduction de E / A

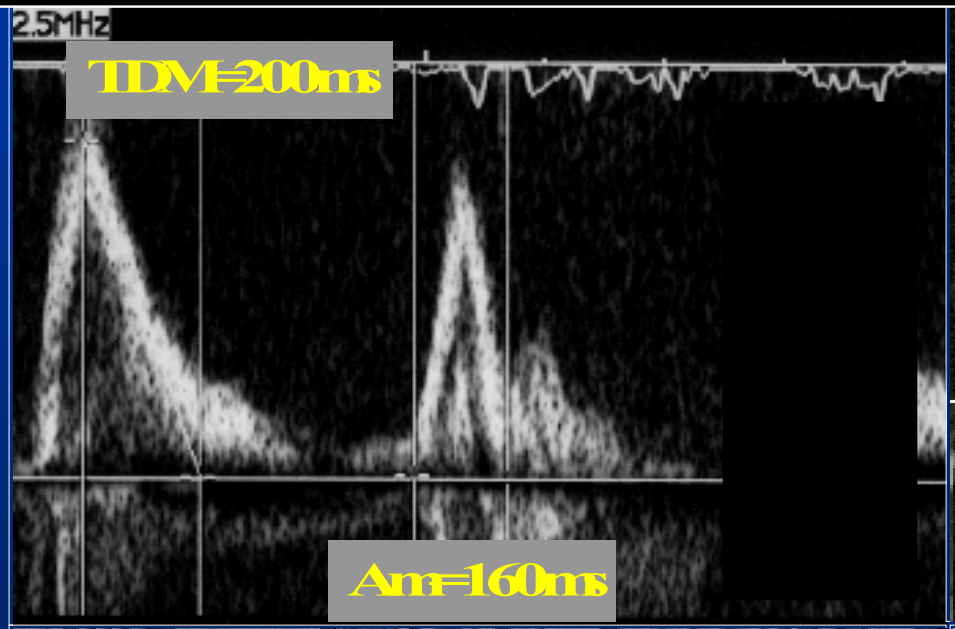
FLUX MITRAL NORMALISE ?

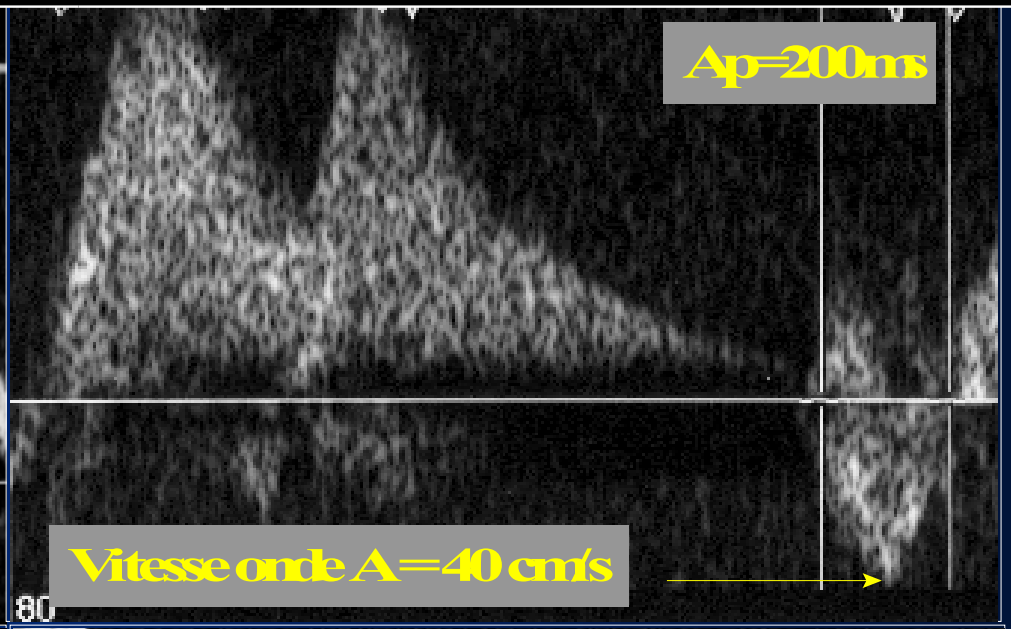


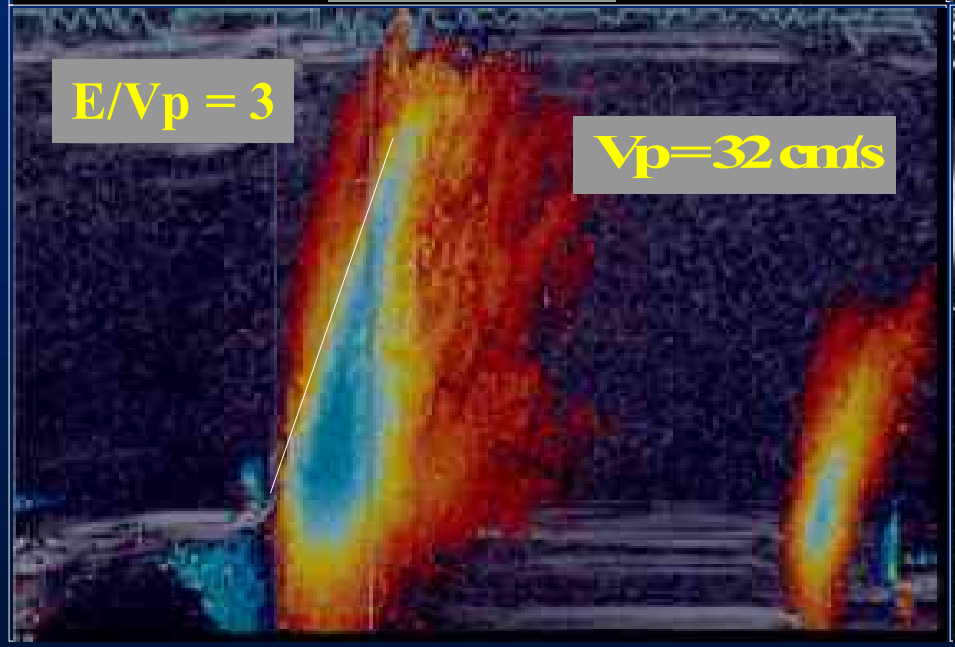
IDM antérieur - FE 40%
(PTDVG = 20mmHg)

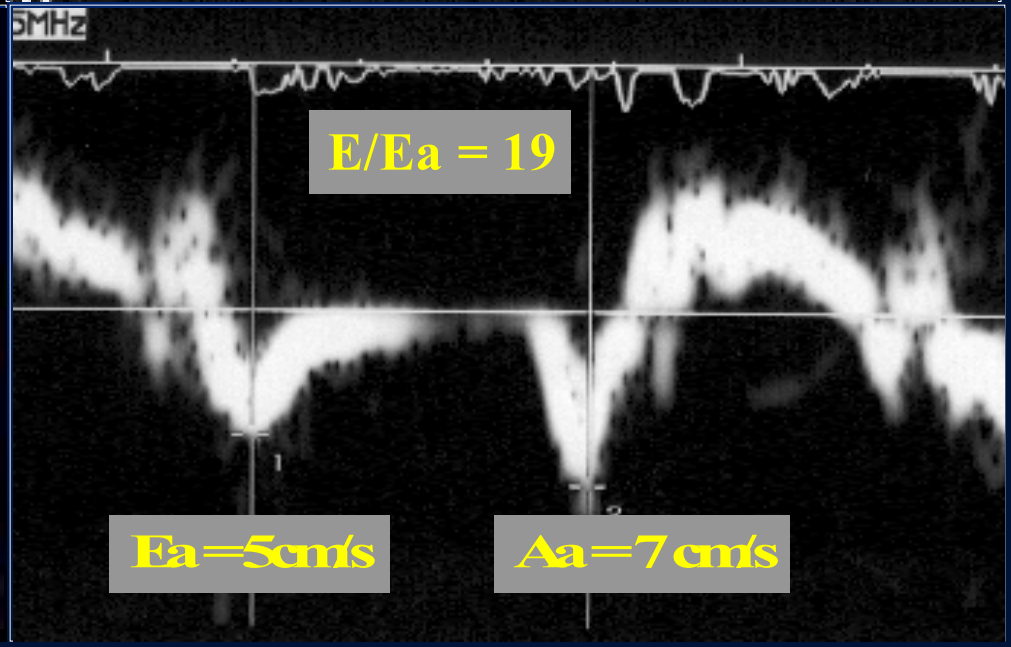


Flux mitral pseudo-normal









Etude du remplissage VG par écho Doppler

Stade III

- symptomes : dyspnée invalidante stade III - IV NYHA
- oreillette gauche : dilatation et ↓ contractilité
- ventricule gauche : - fraction d ’éjection ↓ ↓ ↓
  - fraction d ’éjection normale
- pressions de remplissage : très élevées

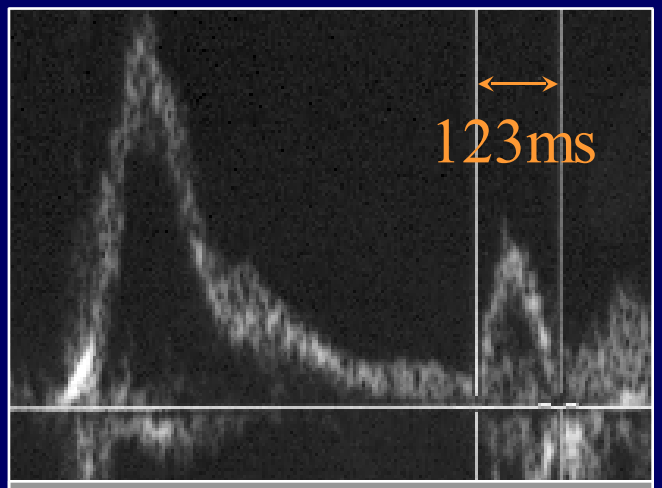
Etude du remplissage VG par écho Doppler
Flux mitral restrictif

- Doppler mitral
  - ↓ temps de relaxation isovolumique
  - ↑onde E, ↓ A, ↑↑ E/A
  - ↓ temps de décélération E
- Doppler FVP
  - ↓ vitesse flux systolique S
  - ↓ fraction systolique
  - durée A pulm. > durée A mitrale ± ↑ vitesse A

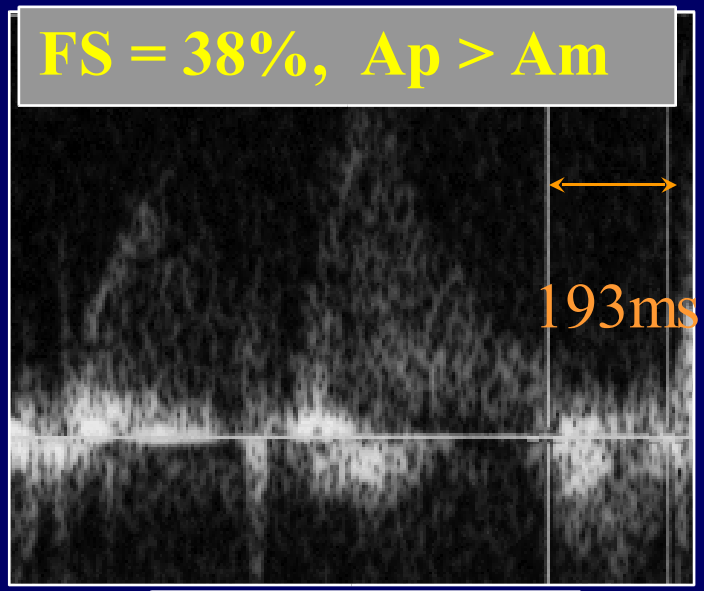
- Physiopathologie : altération sévère compliance VG
  ralentissement relaxation VG (↓ VP et Ea)

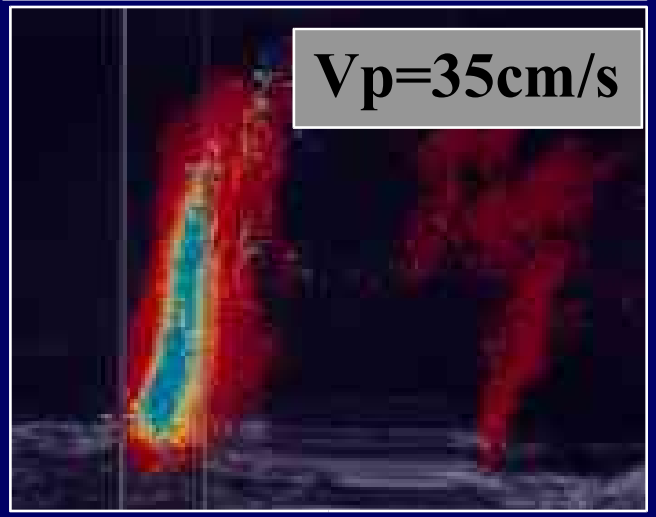
Flux mitral restrictif

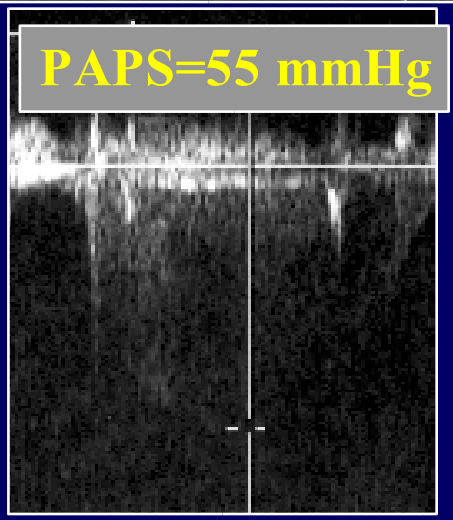
IDM antérieur avec dysfonction systolique (FE = 31%, PTDVG = 35mmHg)



E/A=3, TDM = 130ms

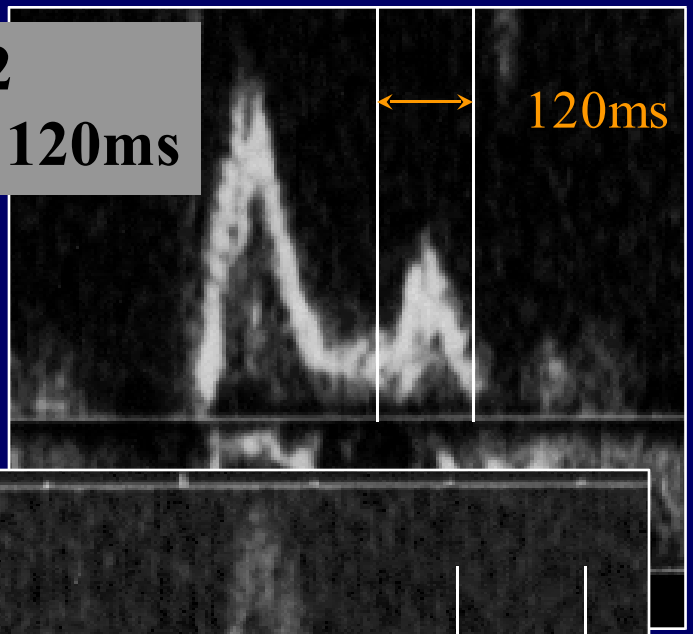


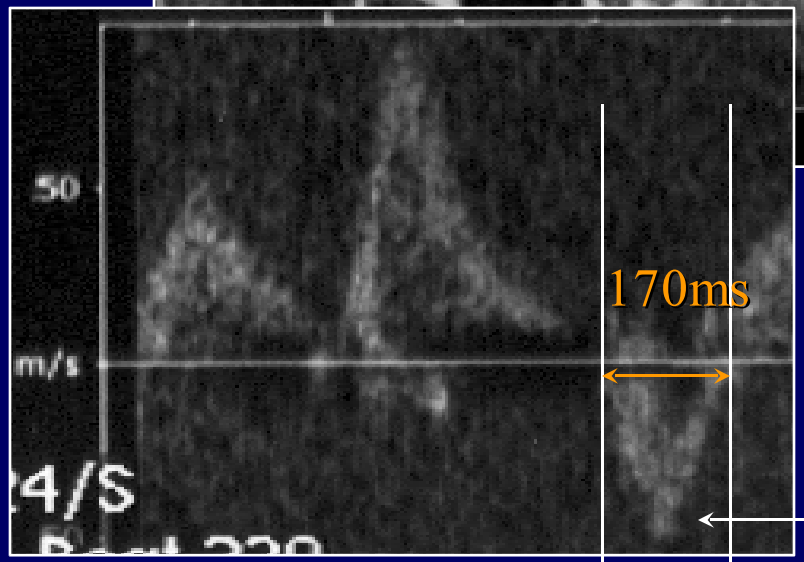




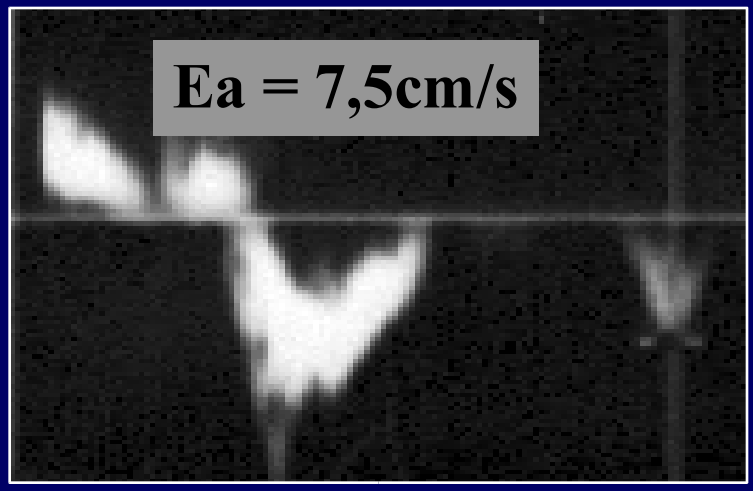
Flux mitral restrictif
Dysfonction systolique (FE = 30%)

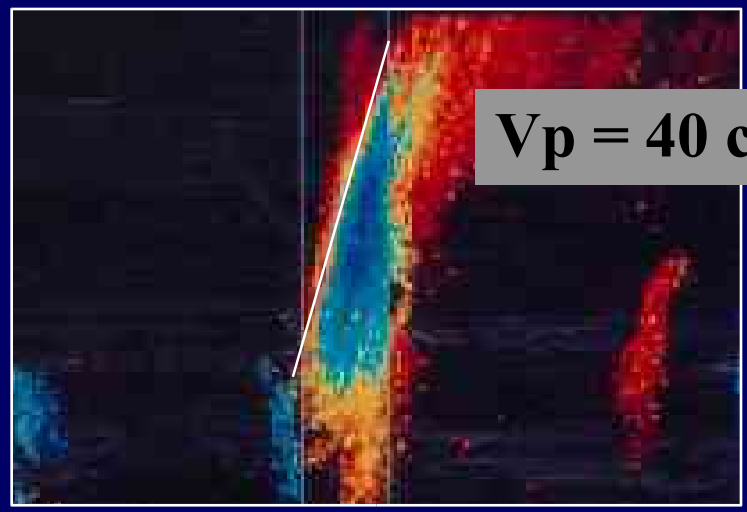
E/A = 2
TDE = 120ms





S/D < 1, FS = 37%, Ap>Am





Etude du remplissage VG par écho Doppler

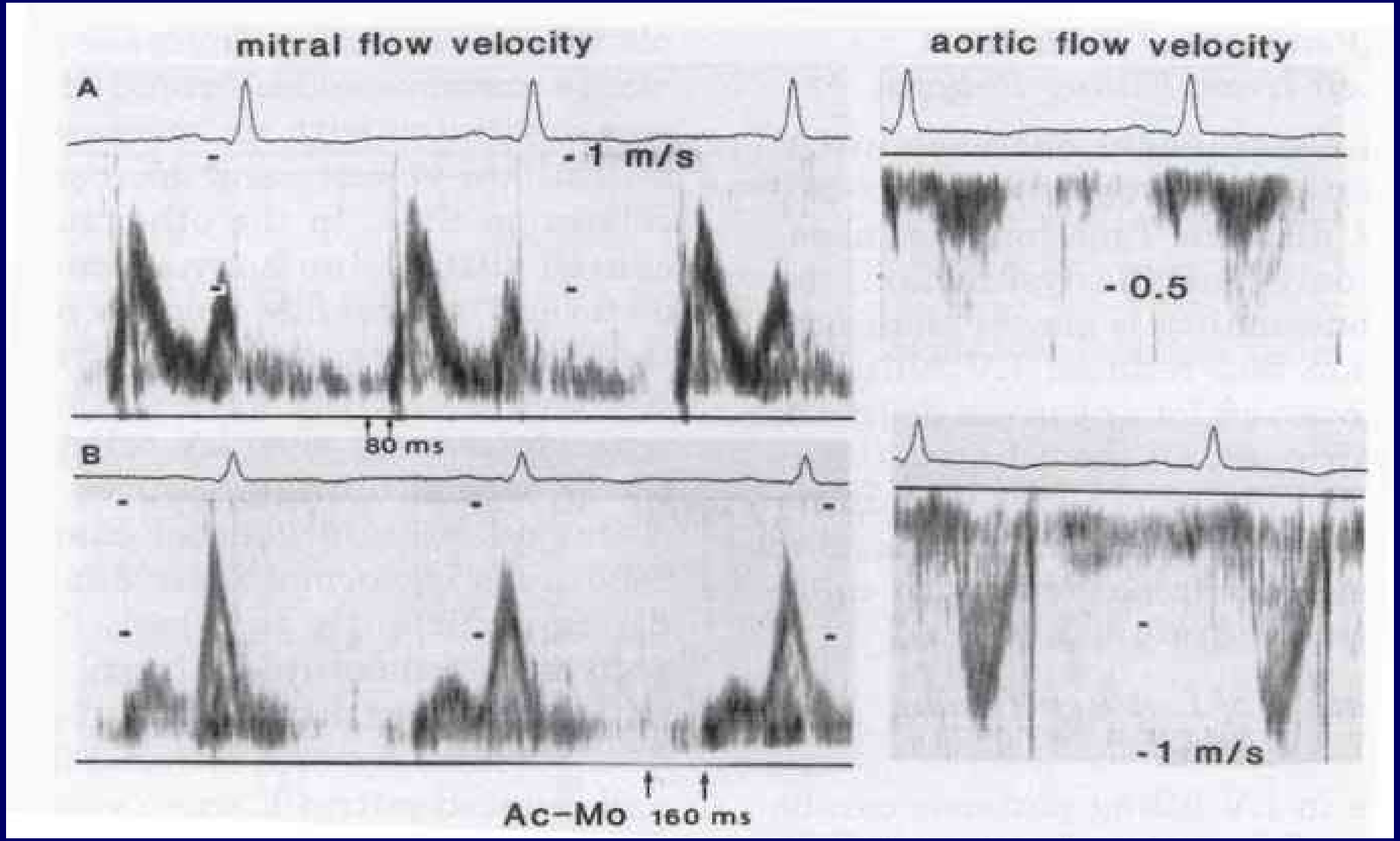
Flux mitral restrictif

- cardiopathie ischémique
- cardiopathie dilatée
- cardiopathie restrictive
- ……..
- (insuffisance mitrale)

Ce type est la traduction d ’une diminution+++ de la compliance VG associée à une probable altération de la relaxation, les pressions de remplissage étant franchement élevés.

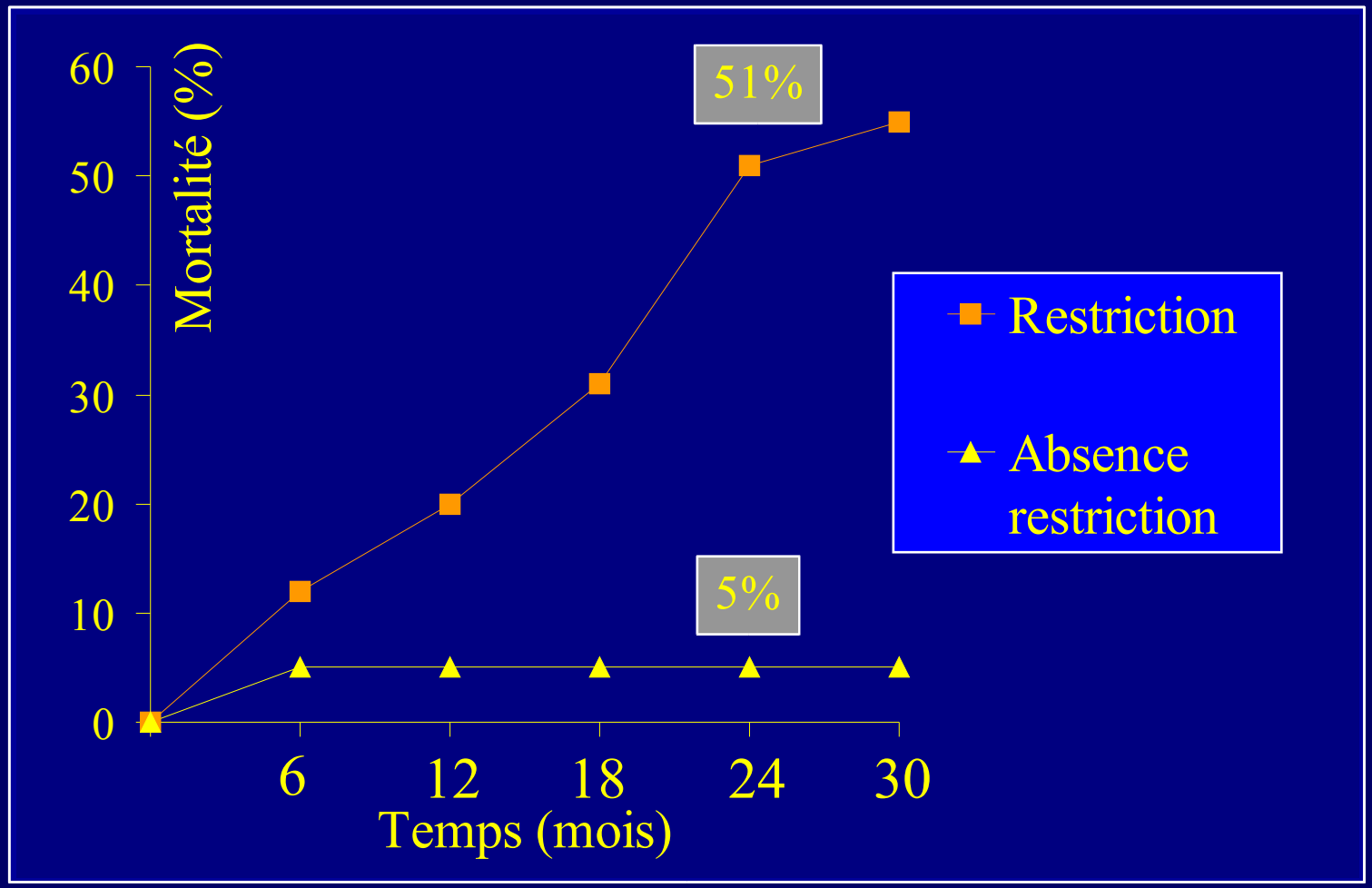
LES DIFFERENTS PROFILS

	normal jeune	normal adulte	anomalie relaxation (Ptdvg N)	anomalie relaxation (Ptdvg ↗)	pseudo normal	restrictif
E/A	> 1 (2)	1-2	< 1	< 1	1-2	> 2
TDM (ms)	<220 (150)	150-220	> 220	> 220	150-220	< 150
TRIV (ms)	<100 (60)	60-100	> 100	> 100	60-100	< 60
S/D	< 1	> 1	> 1	> 1	< 1	< 1
Ap-Am (ms)	< 0	< 0	< 0	> 0	> 0	> 0
Vp (cm/s)	> 55	> 45	< 45	< 45	< 45	< 45
Ea (cm/s)	> 10	> 8	< 8	< 8	< 8	< 8


mitral flow velocity
aortic flow velocity
A
- 1 m/s
- 0.5
80 ms
B
- 1 m/s
Ac-Mo
160 ms

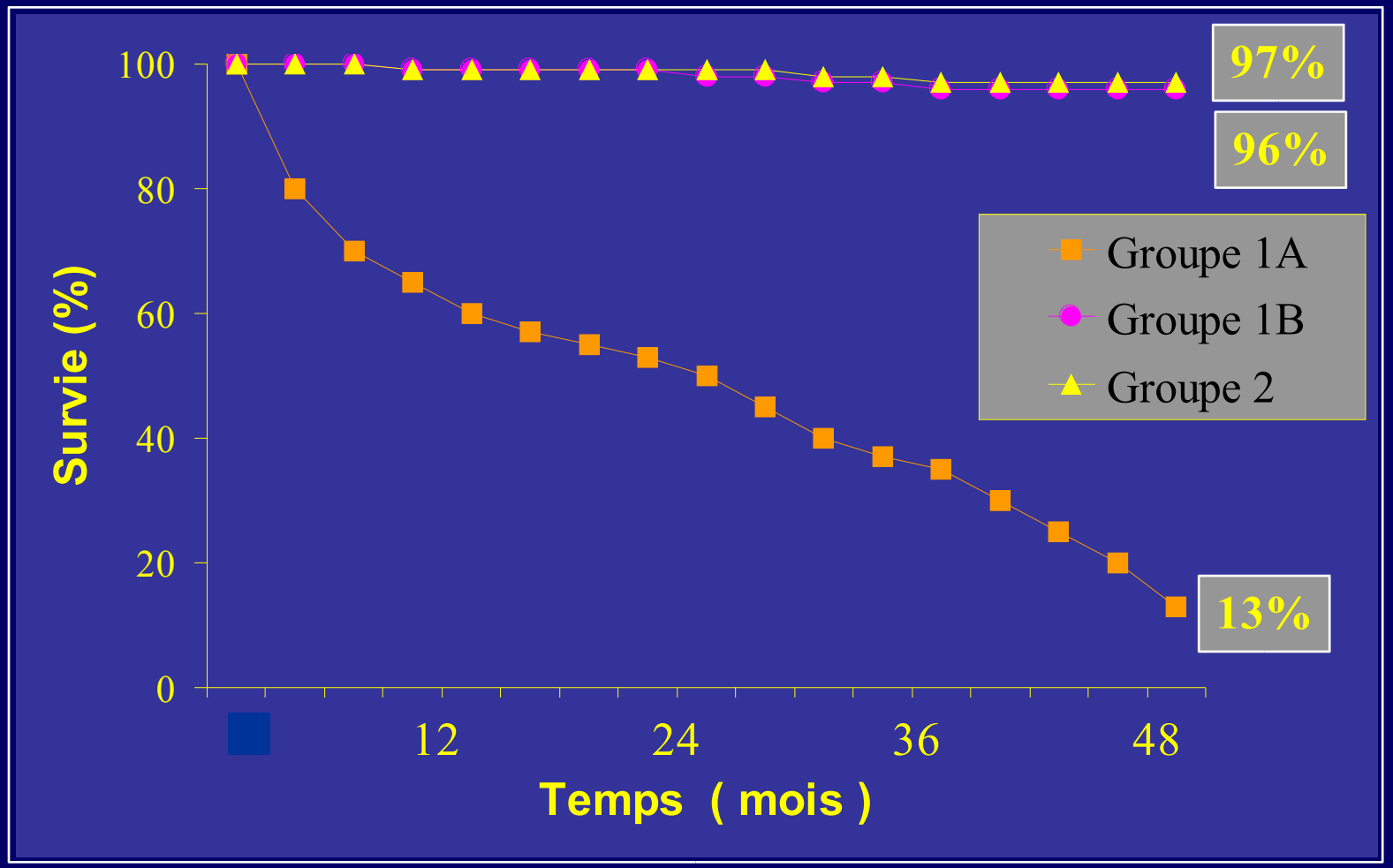
Dysfonction systolique VG : valeur pronostique du flux mitral

(Xie et al. JACC 1994; 24: 132-9)



Valeur pronostique de l'évolution du flux mitral en cas de cardiomyopathie dilatée

(Pinamonti et al. JACC 1997; 29: 604 - 12)



1A : restriction persistante à 3 mois

1B: restriction régressive à 3 mois

2: absence restriction

Distinction entre un flux mitral normal et normalisé

Flux mitral normalisé = anomalie relaxation + élévation P remplissage

✓ **Mise en évidence élévation pressions remplissage**

- S/D < 1 et FS < 55% (FVP)
- Durée Ap > Am* (FVP)
- Indices combinés* (E/Vp ≥ 2 ; E/Ea ≥ 10 - 15)

✓ **Mise en évidence anomalie relaxation**

- Réduction de Vp (< 45cm/s) et Ea (< 8cm/s)
- Flux mitral après Valsalva

Limites des paramètres de fonction diastolique

- Age : tous les indices dépendent de l ’âge
- Fonction systolique normale : **E/Ea, E/Vp, et Ap-Am**

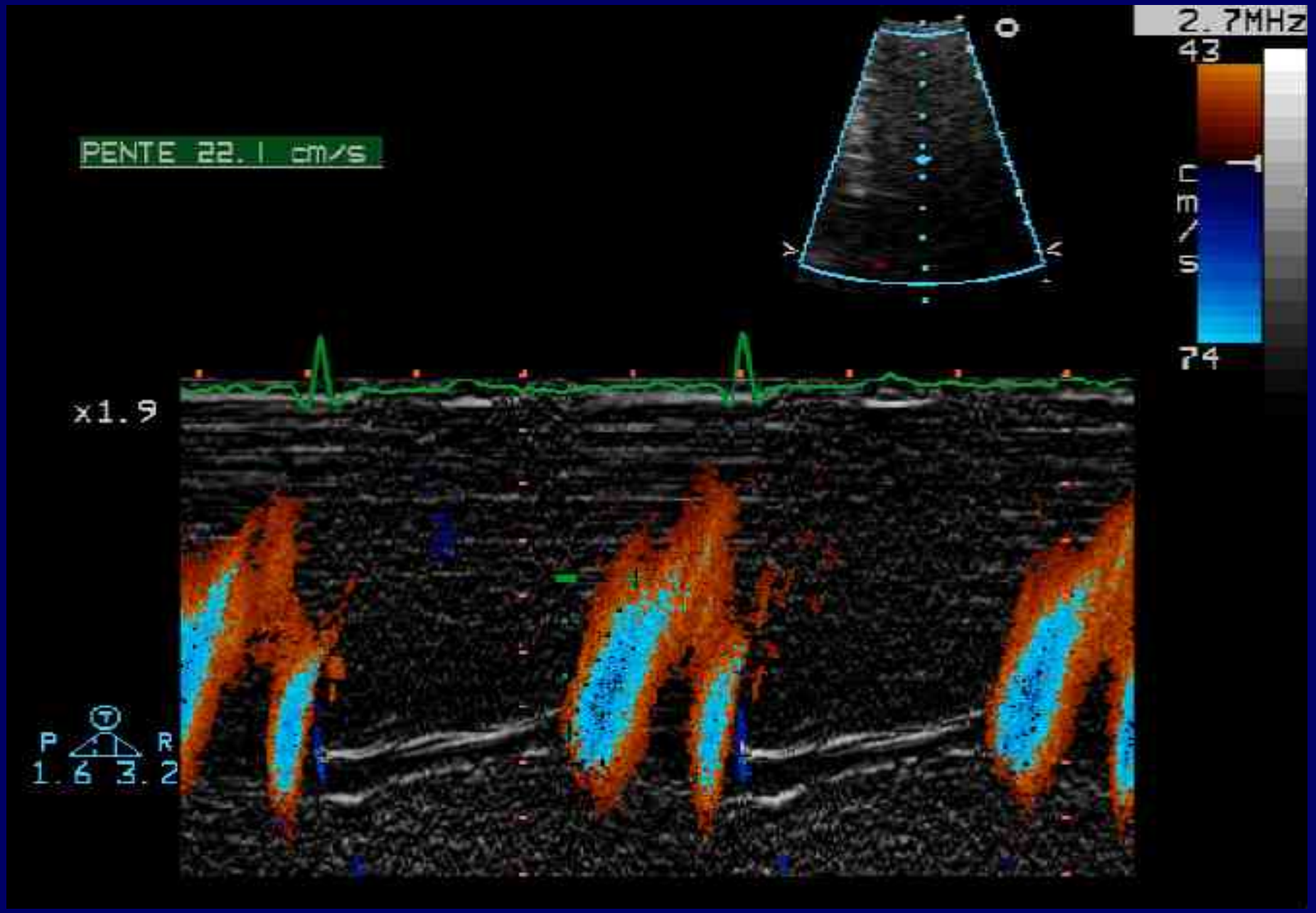
(E/A, TDE, FS mal corrélés aux pressions de remplissage)

- AC/FA : indices utilisables = **TDE**, **E/Ea et E/Vp**
- Tachycardie sinusale : intérêt du **massage sino-carotidien**
- Insuffisance mitrale

Etude du remplissage VG par écho Doppler

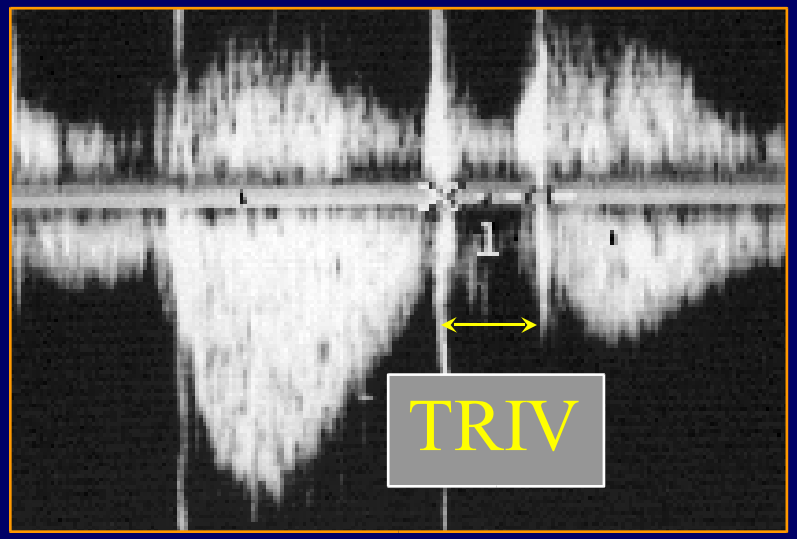
Flux mitral - flux veineux pulmonaire - VP - Ea

- Approche non invasive de la fonction diastolique VG
- Estimation du niveau des pressions de remplissage VG
- Flux mitral restrictif « permanent » : facteur de mauvais pronostic de l 'IC
- Renseigne sur l 'effet du traitement au cours du suivi


PENTE 22.1 cm/s
2.7MHz
43
cm/s
74
x1.9
P
R
1.6
3.2

TRIV : COMMENT MESURER ?

- Doppler continu



- Doppler pulsé
  (enregistrement clic aortique et flux mitral)
- 70 – 90 ms