

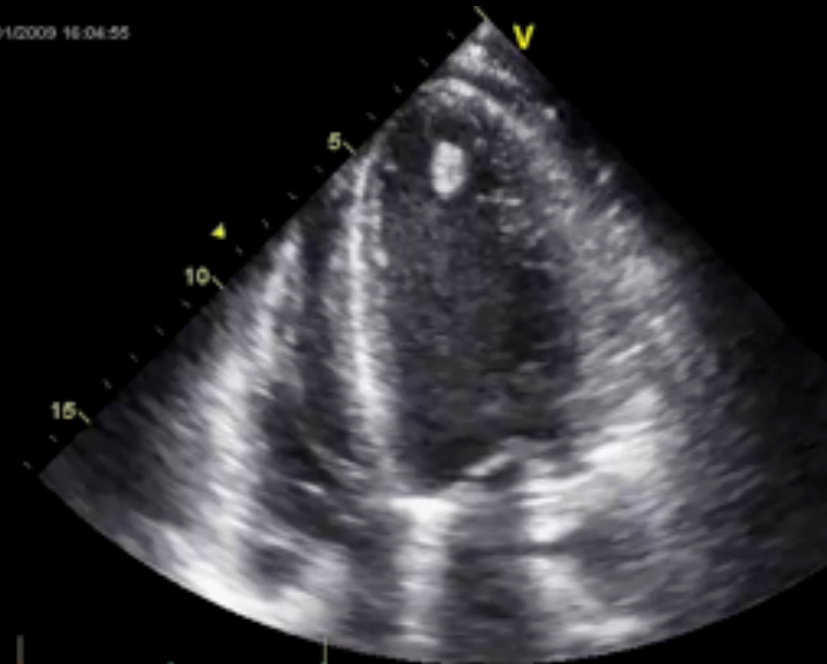
A night-time photograph of a canal bridge in Amsterdam, with buildings and lights reflected in the water. The bridge is illuminated with warm lights, and the buildings on either side are lit up, creating a vibrant scene. The water in the canal is calm, reflecting the lights from the bridge and buildings.

# Diastolische LV functie

R.K. Riezebos  
Cursus AMC 2019

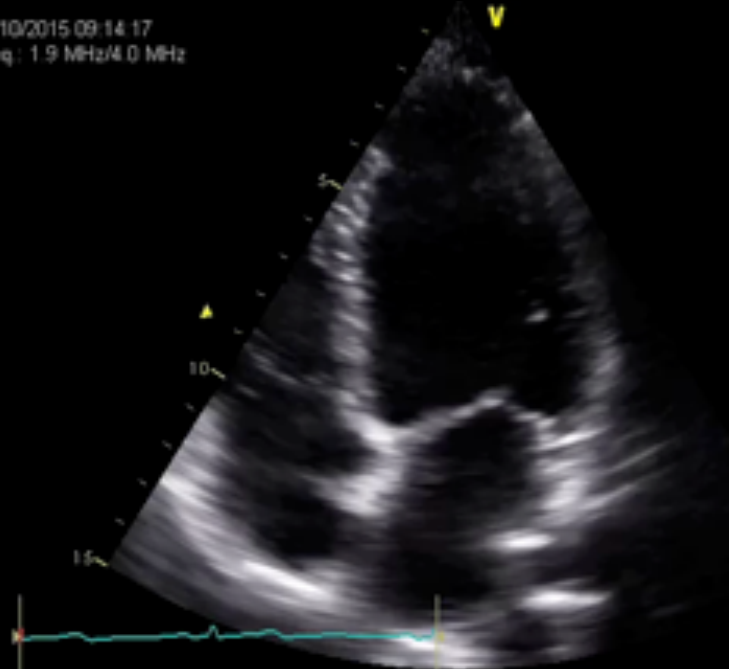
# Systolische versus diastolische functie

19/10/2009 16:04:55



Eye balling

01/10/2015 09:14:17  
Freq: 1.9 MHz/4.0 MHz



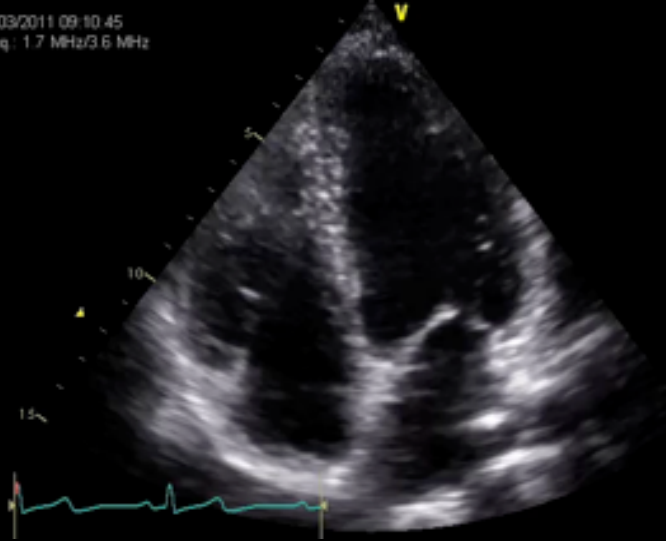
Metingen noodzakelijk

# Casus

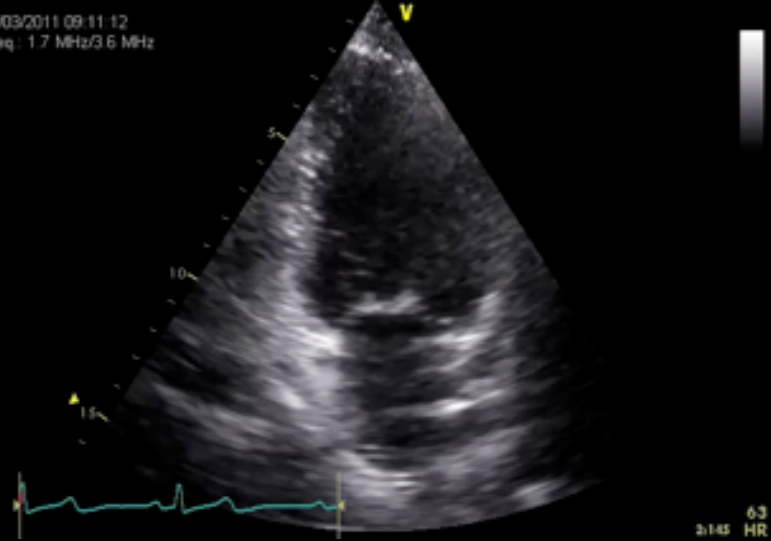
Vrouw 30 jaar komt met dyspnoe.

Obesitas (BMI 30).

24/03/2011 09:10:45  
Freq: 1.7 MHz/3.6 MHz

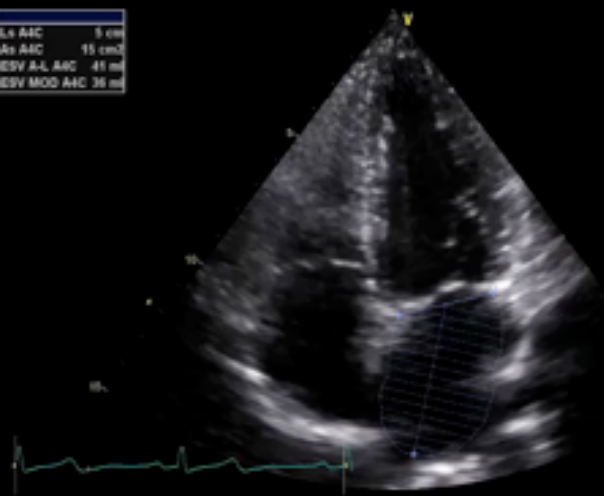


24/03/2011 09:11:12  
Freq: 1.7 MHz/3.6 MHz

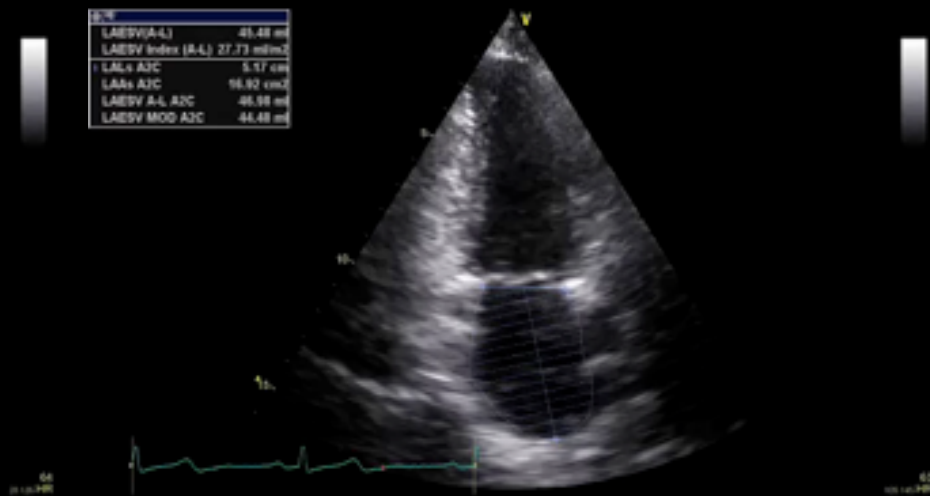


# LAVI 2011

LVS	
LALs AAC	9 cm
LAAs AAC	15 cm <sup>2</sup>
LAESV A-L AAC	41 ml
LAESV MOD AAC	36 ml

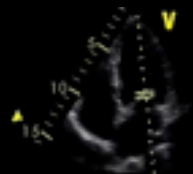


LVS	
LAESV(A-L)	41.48 ml
LAESV Index (A-L)	27.73 ml/m <sup>2</sup>
LALs A3C	5.57 cm
LAAs A3C	96.92 cm <sup>2</sup>
LAESV A-L A3C	46.98 ml
LAESV MOD A3C	44.48 ml

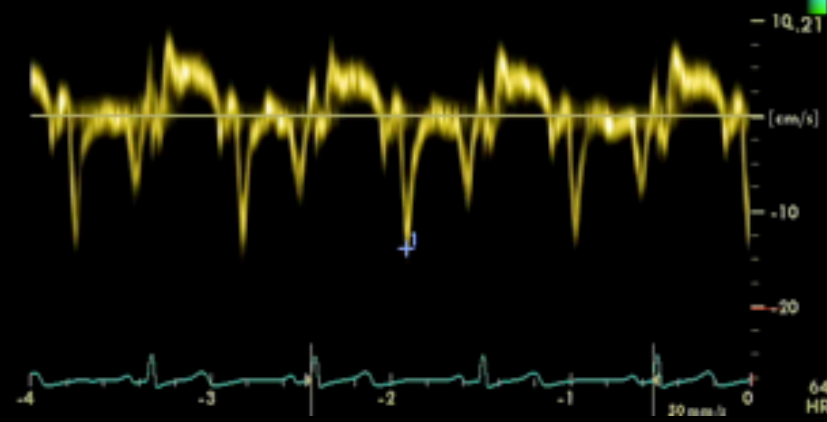
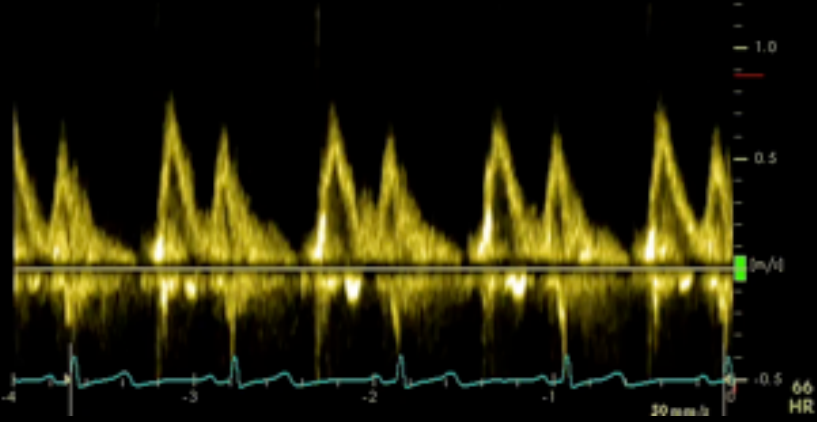
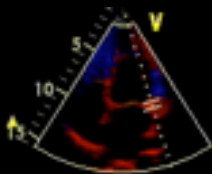


# Diastologie 2011

24/03/2011 09:12:57  
Freq: 1.7 MHz/3.6 MHz



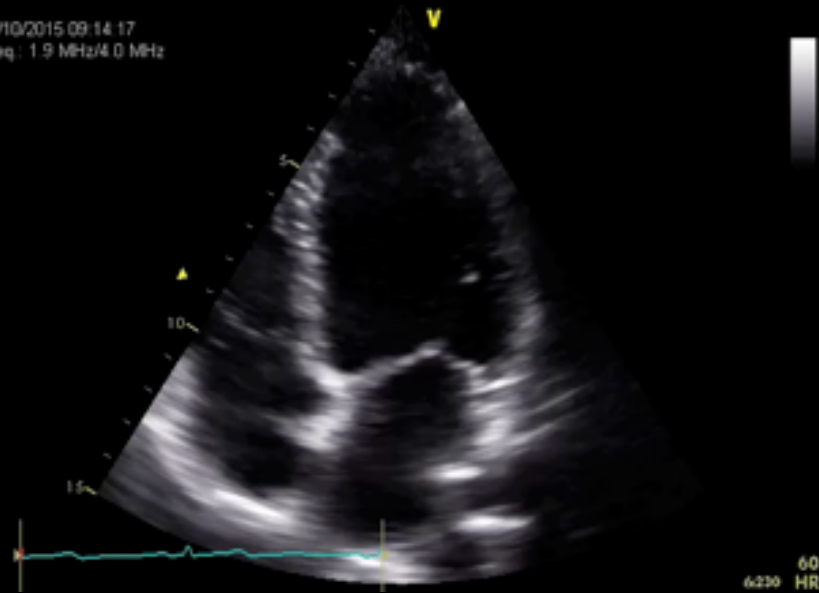
1 E' 0.14 m/s



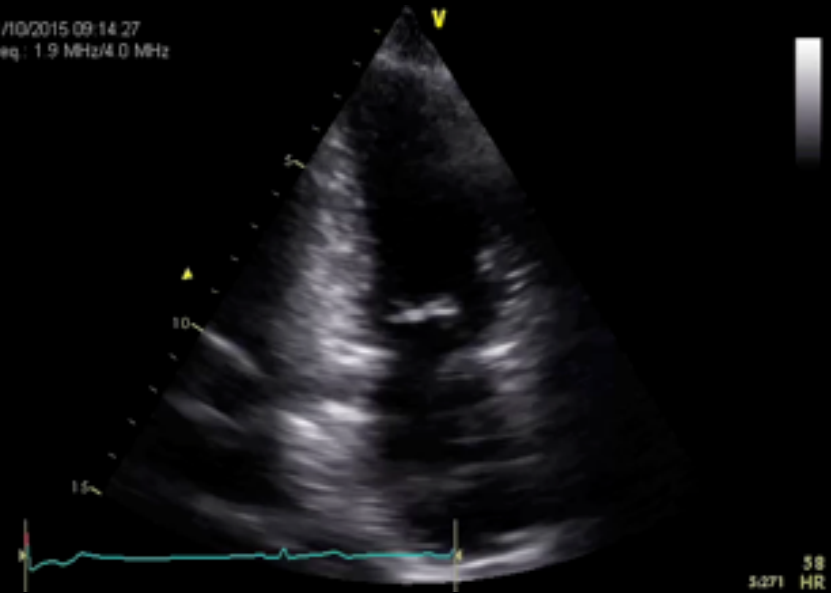
# Casus 4 jaar later

Progressieve dyspnoe, nu BMI 35, ook DM2 en HT

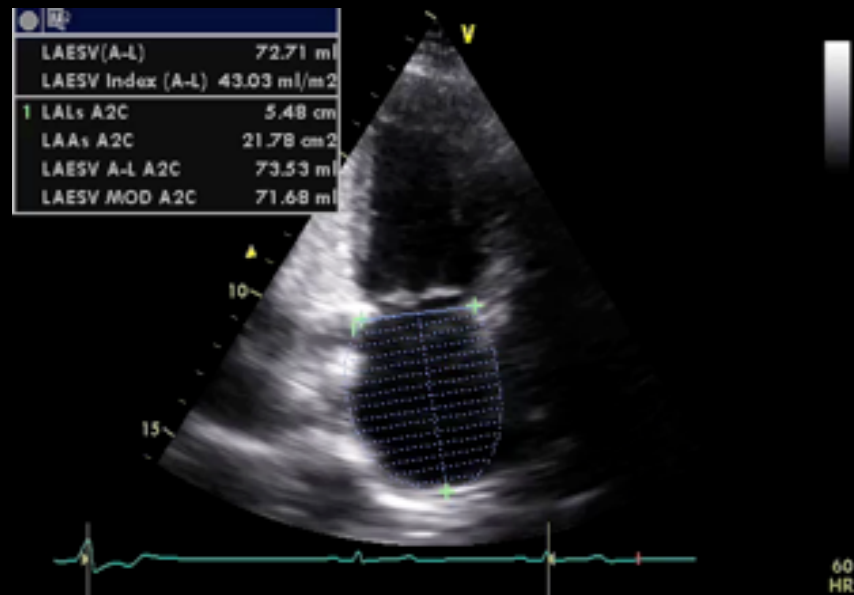
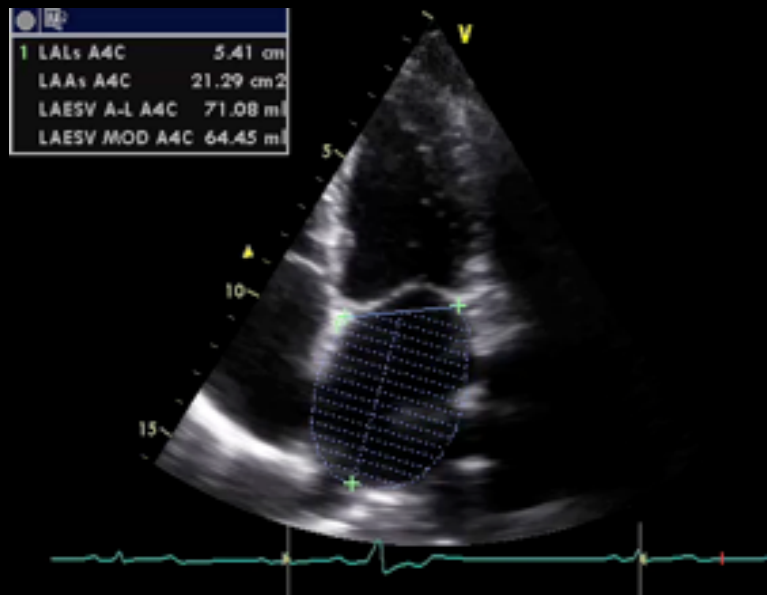
01/10/2015 09:14:17  
Freq: 1.9 MHz/4.0 MHz



01/10/2015 09:14:27  
Freq: 1.9 MHz/4.0 MHz

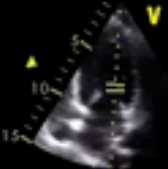


# LAVI 2015

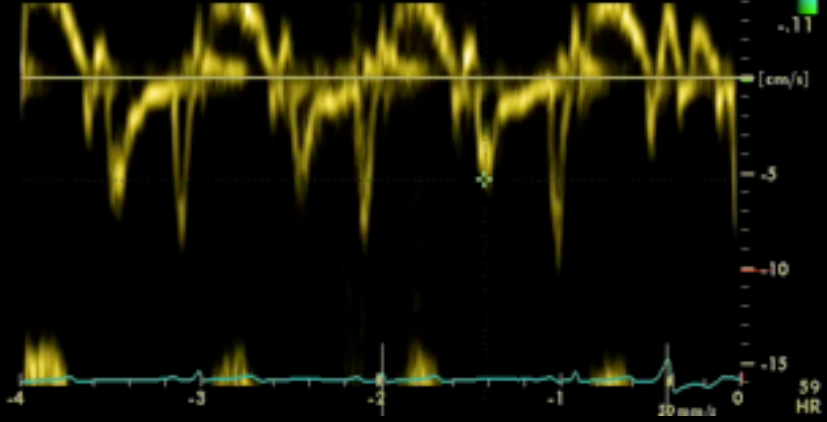
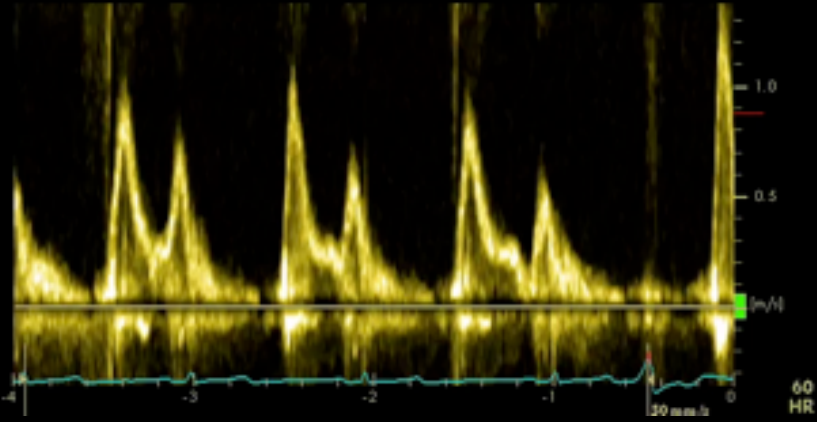
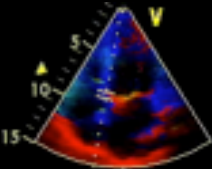


# Diastologie 2015

01/10/2015 09:16:33  
Freq: 1.9 MHz/4.0 MHz



0.05 m/s  
0.01 mmHg





# Wat is er gebeurd...

2011

## MV Doppler

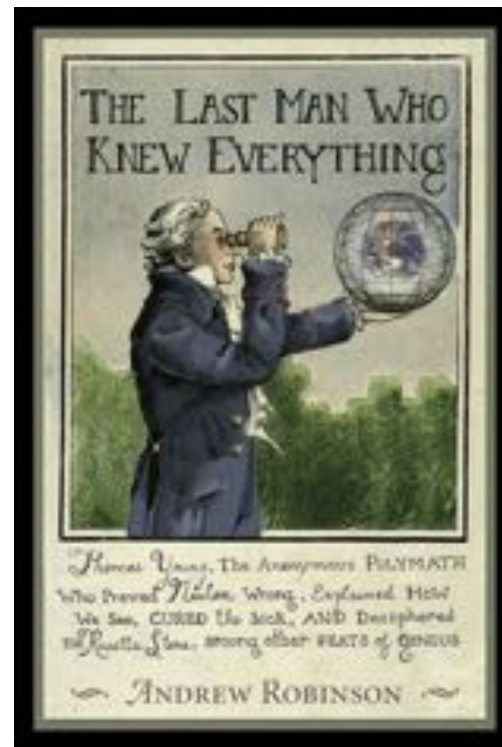
MV E Vel	0.6 m/s
MV DecT	173 m s
MV A Vel	0.5 m/s
MV E/A Ratio	1.2
E/E'	4.57
MV DecT	187 m s
E'	14.01 cm/s

2015

## MV Doppler

MV E Vel	1.0 m/s
MV DecT	137 m s
MV A Vel	0.7 m/s
MV E/A Ratio	1.6
E/E'	14.36
MV A Dur	137 m s
E'	7.31 cm/s

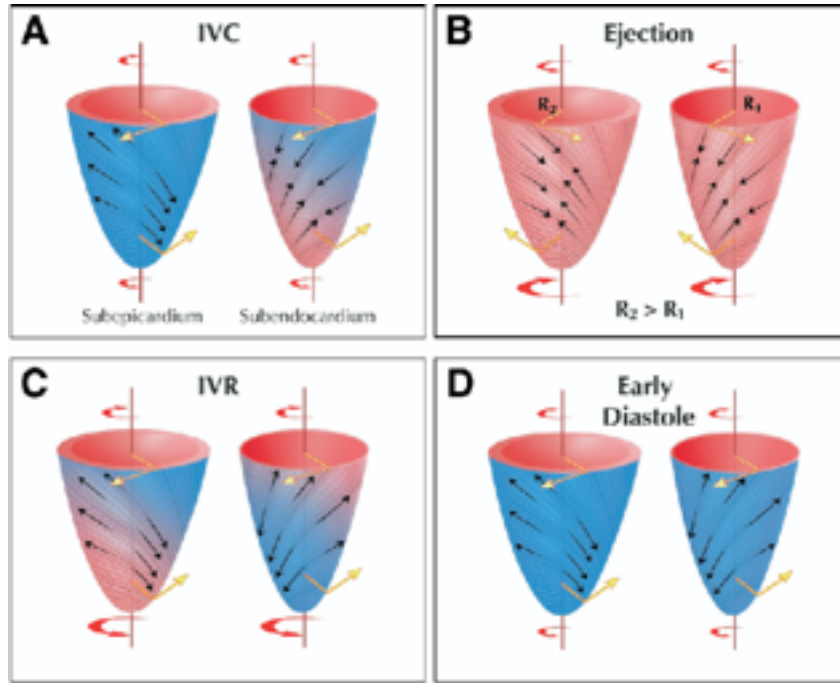
# Diastology – The Rosetta Stone of Cardiology



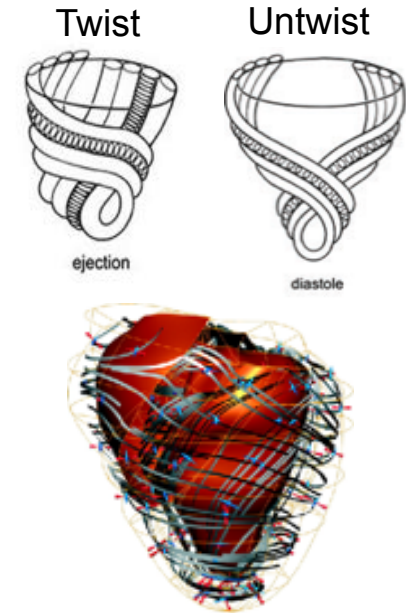
# De 4 klassieke fasen van de diastole

1. Isovolumetrische relaxatie fase: sluiting Ao klep tot opening MV
2. Snelle vullingsfase: transvalvulair druk gradiënt
3. Diastase: langzame vullingsfase: low flow
4. Atriale contractiefase: atrial kick

# Myocardiale *twist* en *untwist*

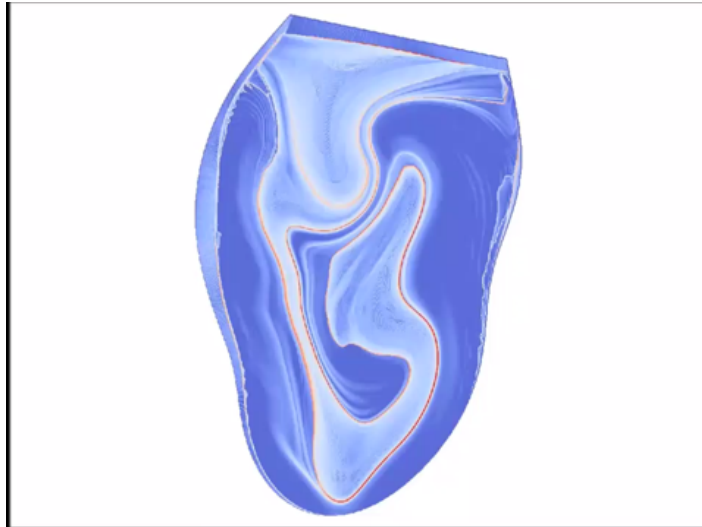


Generatie van de negatieve LV druk vindt plaats gedurende IVRT en wordt gerealiseerd door de *untwist*

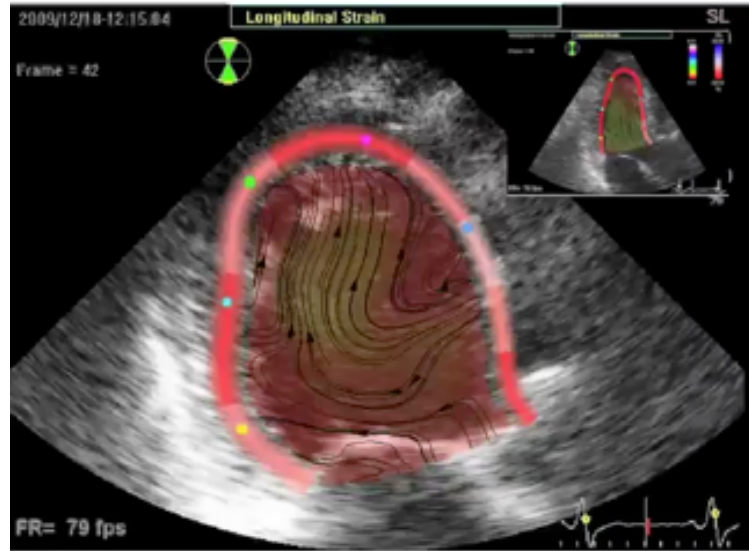


# Vloeistof dynamica: intraventriculaire vortices

Behoud kinetische energie



Normale vortices

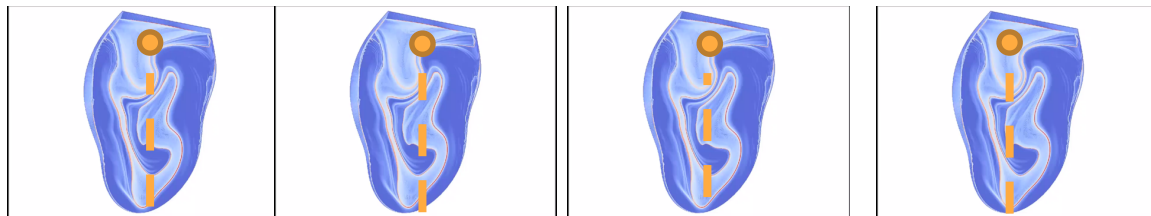
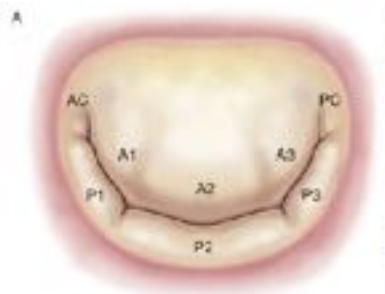


2D time-resolved flow mapping

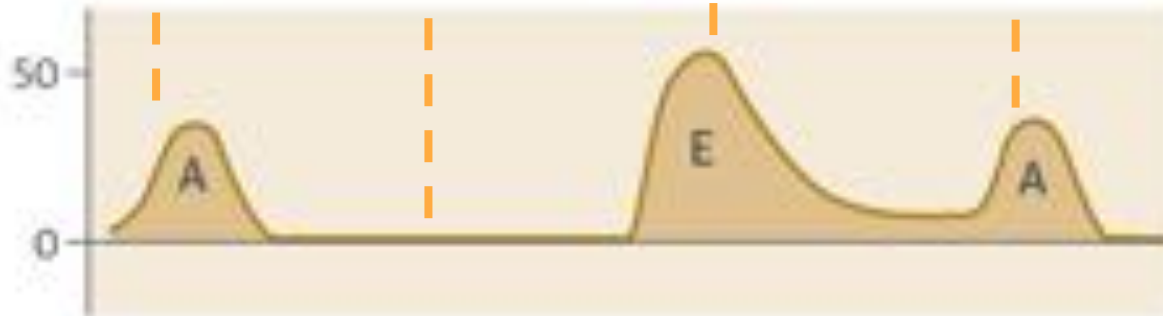
Gestoorde vortices

# Vertaling van vloeistof dynamica naar echo doppler

ECG



Transmitral Flow Velocity (cm/s)

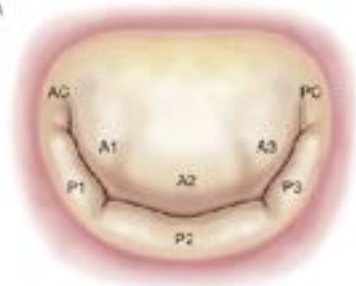


# Vertaling van vloeistof dynamica naar echo doppler

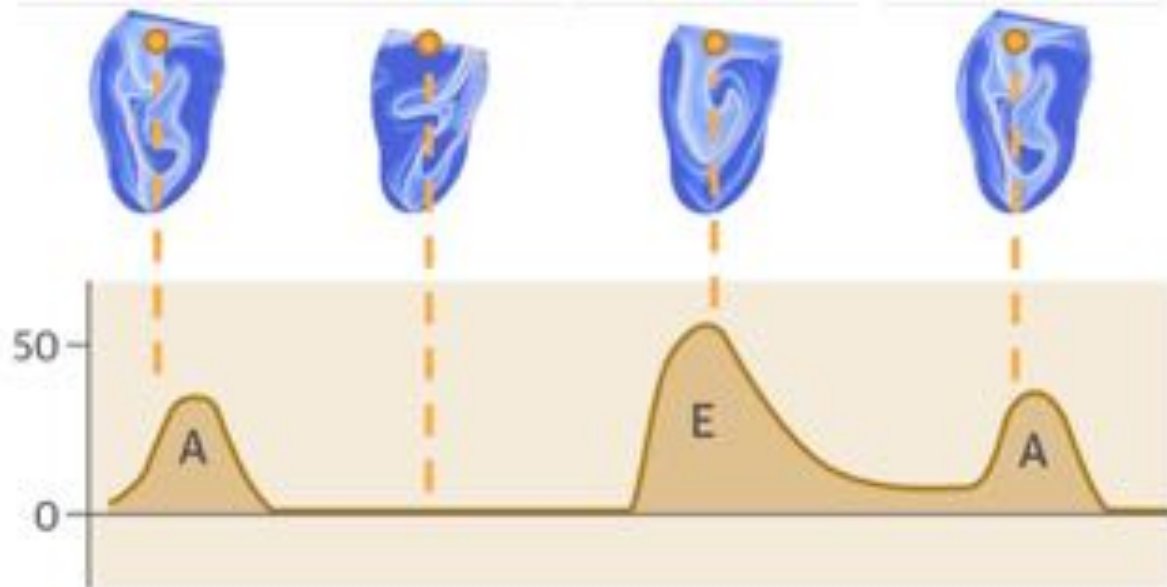
ECG



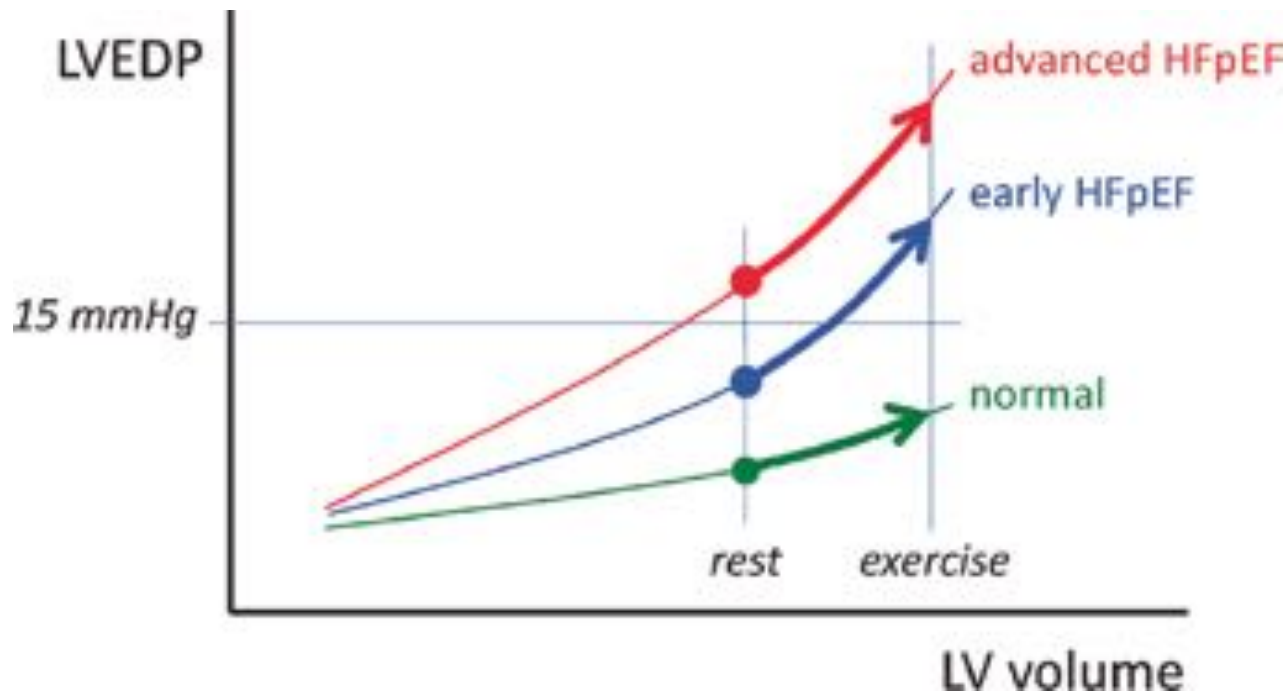
A



Transmitral Flow Velocity (cm/s)



# Diastologie: volume druk curves: het stijve hart



Identificatie van niet cardiale dyspnoe vs vroege vs gevorderd HFpEF



# Epidemiologie

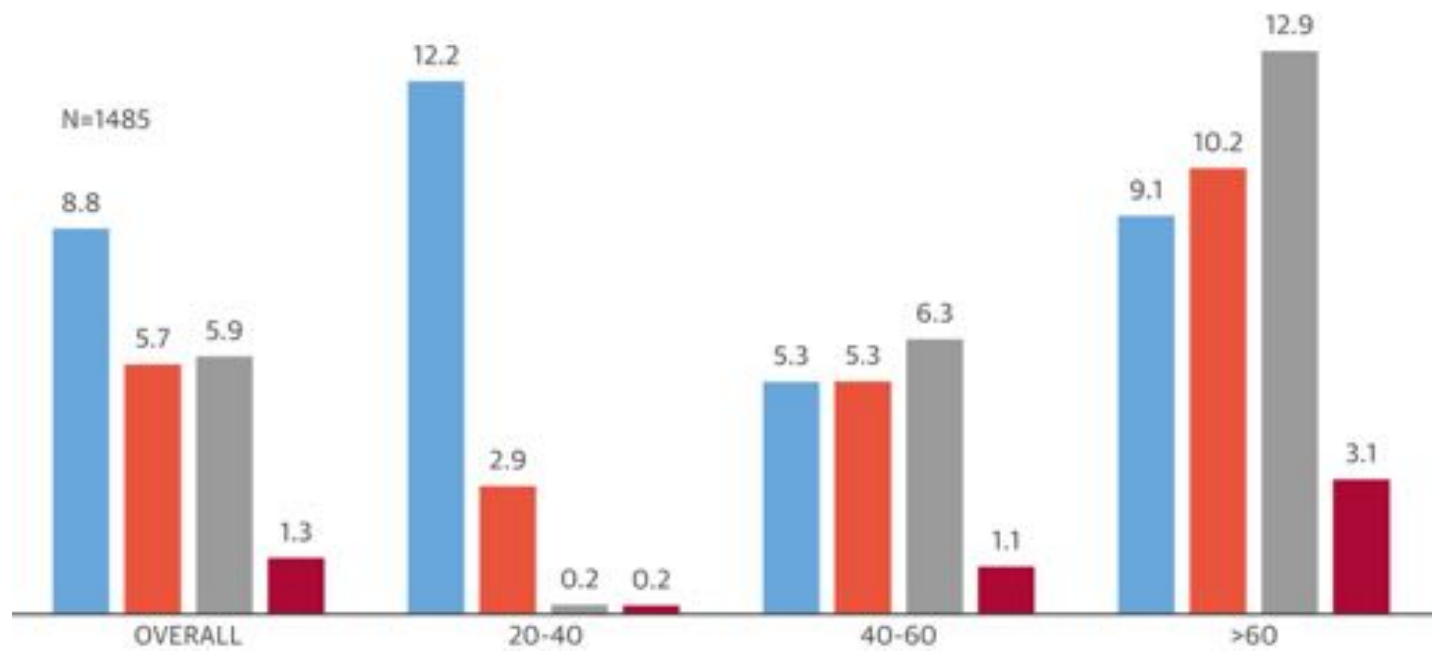
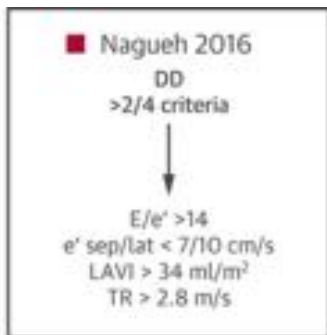
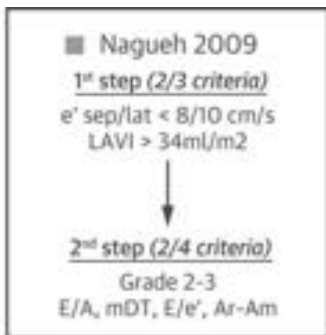
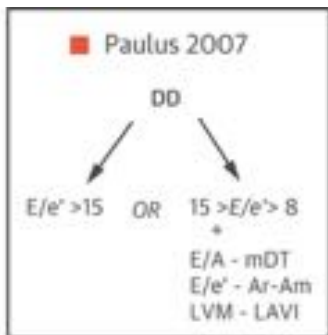
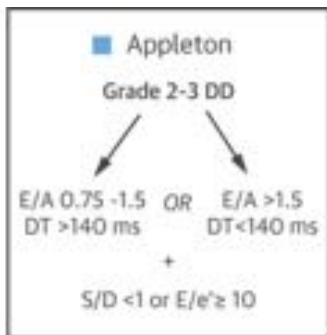
Prevalentie van diast dysfunctie: 28.1%

Cross-sectional survey of 2042 randomly selected residents of Olmsted County, ≥ 45 yrs from '97-'00

**Table 1. Prevalence of Systolic and Diastolic Dysfunction According to Age and Sex\***

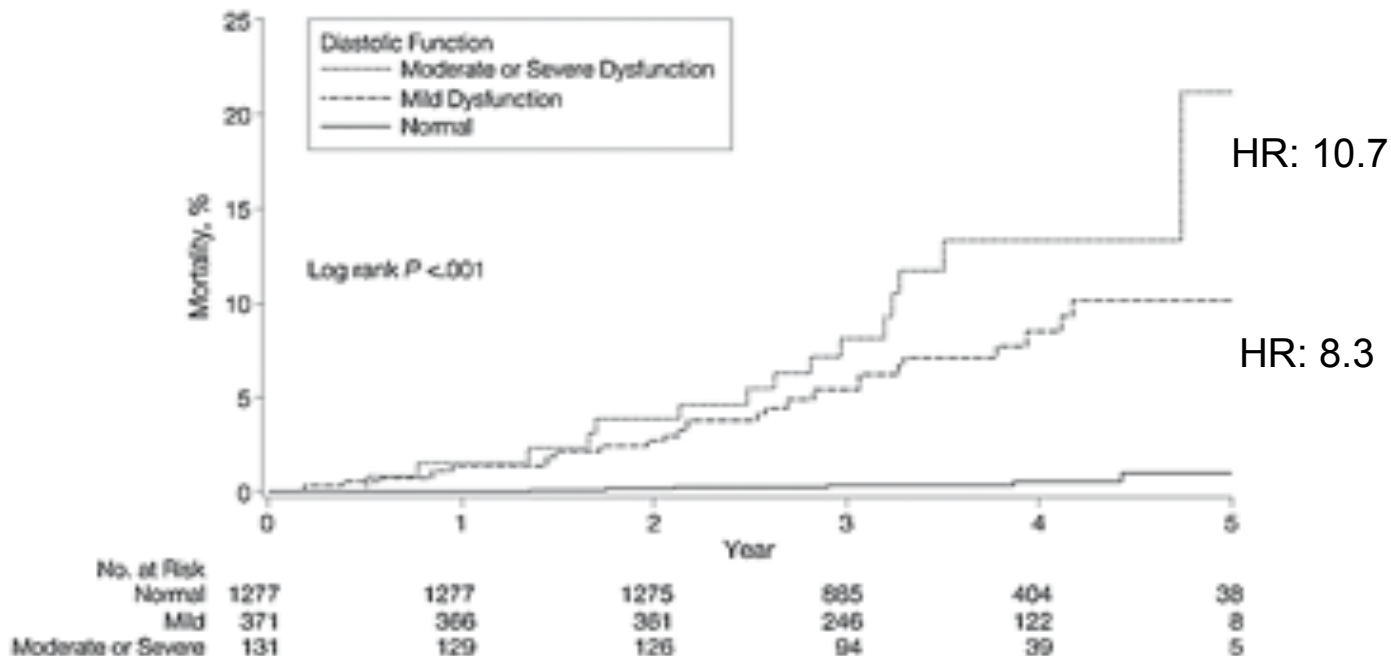
Variables	No. (%) of Patients Affected				Overall
	Age Group, y				
	45-54	55-64	65-74	≥75	
<b>Diastolic Dysfunction</b>					
<i>Mild</i>					
All	27 (4.8)	72 (13.2)	149 (34.2)	123 (52.8)	371 (20.8)
Men	20 (7.2)	43 (16.0)	78 (27.2)	49 (57.0)	188 (22.2)
Women	7 (2.4)	29 (10.4)	73 (21.6)	74 (50.3)	183 (19.4)
<i>Moderate</i>					
All	8 (1.4)	33 (6.0)	43 (9.9)	34 (14.6)	118 (6.6)
Men	5 (1.8)	19 (7.1)	17 (8.3)	15 (17.4)	56 (6.7)
Women	3 (1.0)	14 (5.0)	26 (11.3)	19 (12.9)	62 (6.6)
<i>Severe</i>					
All	0 (0)	2 (0.4)	3 (0.7)	8 (3.4)	13 (0.7)
Men	0 (0)	0 (0)	2 (1.0)	3 (3.5)	5 (3.6)
Women	0 (0)	2 (0.7)	1 (0.4)	5 (3.4)	8 (8.8)
<b>Systolic Dysfunction</b>					
<i>Any, ejection fraction &lt;=50%</i>					
All	18 (3.0)	30 (4.8)	37 (7.1)	38 (12.9)	123 (6.0)
Men	15 (5.1)	23 (7.4)	27 (10.6)	26 (22.8)	91 (10.2)
Women	3 (1.0)	7 (2.2)	10 (3.8)	12 (6.8)	32 (3.8)
<i>Moderate to severe, ejection fraction &lt;=40%</i>					
All	5 (0.8)	8 (1.3)	14 (2.7)	13 (4.4)	40 (2.0)
Men	5 (1.7)	5 (1.9)	12 (4.7)	9 (7.9)	31 (3.6)
Women	0 (0.0)	2 (0.6)	2 (0.8)	4 (2.2)	8 (1.0)

\*A total of 1790 participants were classified as having normal diastolic function or as having mild, moderate, or severe diastolic dysfunction with 243 classified as indeterminate. Ejection fraction was assessed in 2000 participants.



# Diastolische dysfunctie voorspeller van mortaliteit

Mayo clinic Olmsted County data: 2042 randomly selected residents >45 yrs.



# Aanbevelingen 2016

## ASE/EACVI GUIDELINES AND STANDARDS

### Recommendations for the Evaluation of Left Ventricular Diastolic Function by Echocardiography: An Update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging

Sherif F. Nagueh, Chair, MD, FASE,<sup>1</sup> Otto A. Smiseth, Co-Chair, MD, PhD,<sup>2</sup> Christopher P. Appleton, MD,<sup>3</sup> Benjamin F. Bredt III, MD, FASE,<sup>4</sup> Hristina Drazinich, MD, FASE,<sup>5</sup> Thor Edvardsen, MD, PhD,<sup>6</sup> Frank A. Flachskampf, MD, PhD, FESC,<sup>7</sup> Thierry C. Gillebert, MD, PhD, FESC,<sup>2</sup> Allan L. Klein, MD, FASE,<sup>8</sup> Patrizio Lancellotti, MD, PhD, FESC,<sup>9</sup> Paolo Marino, MD, FESC,<sup>2</sup> Joo K. Oh, MD,<sup>1</sup> Bogdan Alexandra Popescu, MD, PhD, FESC, FASE,<sup>2</sup> and Alan D. Waggoner, MHS, RDCS<sup>1</sup>, Houston, Texas; Oulu, Norway; Phoenix, Arizona; Nashville, Tennessee; Hamilton, Ontario, Canada; Uppsala, Sweden; Ghent and Liège, Belgium; Cleveland, Ohio, Newark, Italy; Rochester, Minnesota; Bucharest, Romania; and St. Louis, Missouri

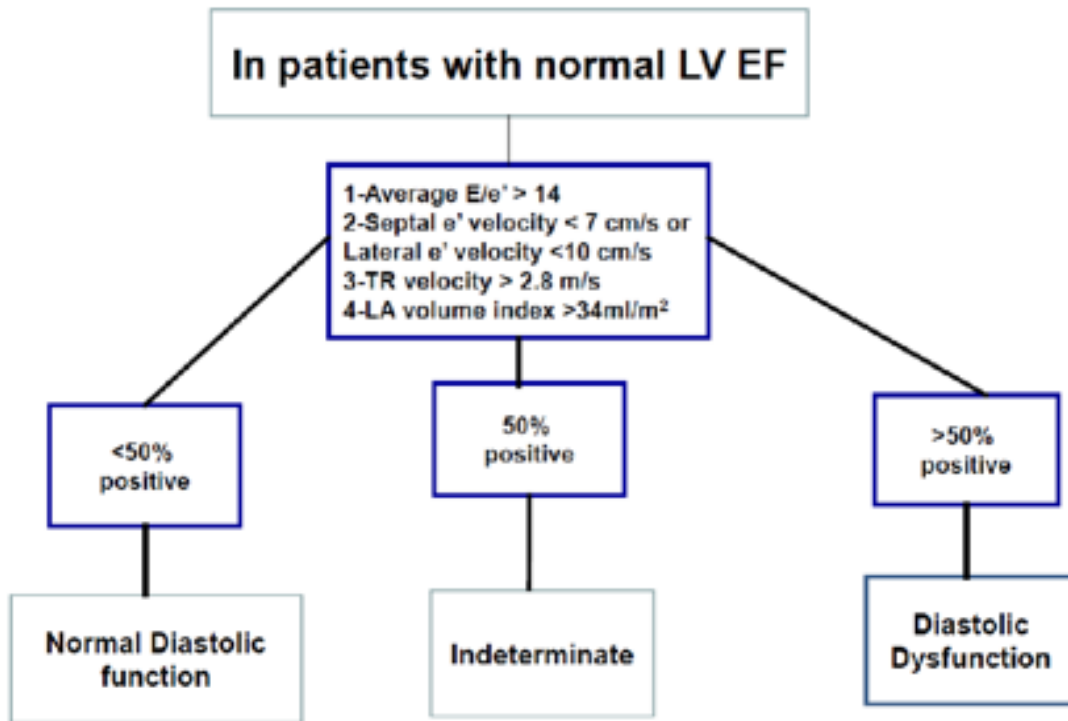
(J Am Soc Echocardiogr 2016;29:277-314.)

**Keywords:** Diastole, Echocardiography, Doppler, Heart failure

## Achtergrond:

- Diastologie is te complex.
- Wordt niet goed geïnterpreteerd.
- Onvoldoende gebruikt.
- Dus: makkelijker maken

# Vereenvoudigd algoritme bij normale LVEF



# Echo doppler metingen

**Directe** drukmetingen zijn met imaging niet mogelijk: Wel volumes, bloed- en weefsel snelheden

## *Structuur en volume*

- LVH, LAVI

*Doppler metingen zijn essentieel:*

## **Mitralisinstroom doppler**

- Piek E en A, ratio
- E deceleratie tijd

## **Pulmonaal veneuze instroom doppler**

- Piek S en D, ratio
- Verschil duur AR en A

## **SPAP**

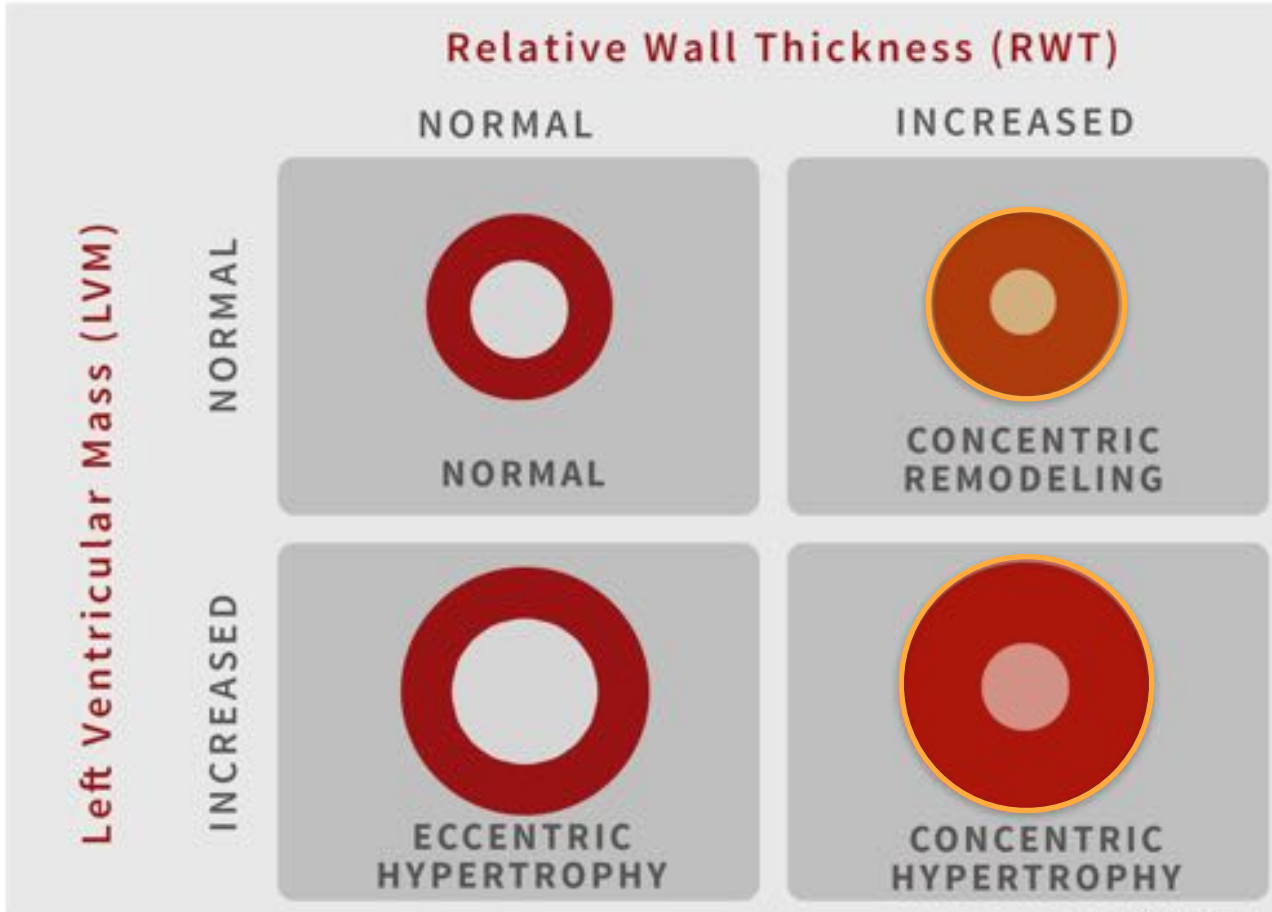
- TVRmax

## **DTI MA**

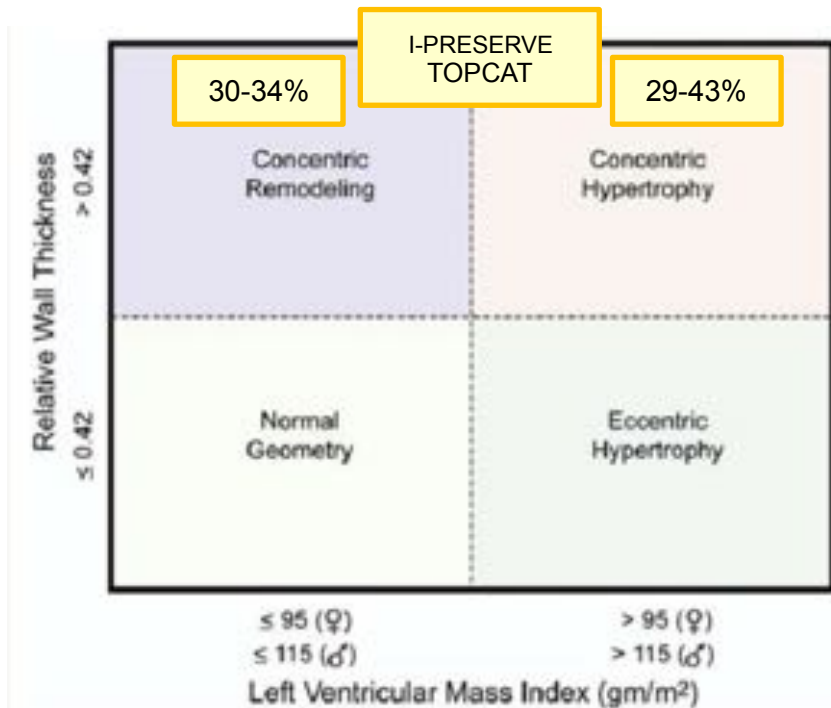
- Laterale annulus, septaal

## **Eventueel IVRT, color M flow (Vp)**

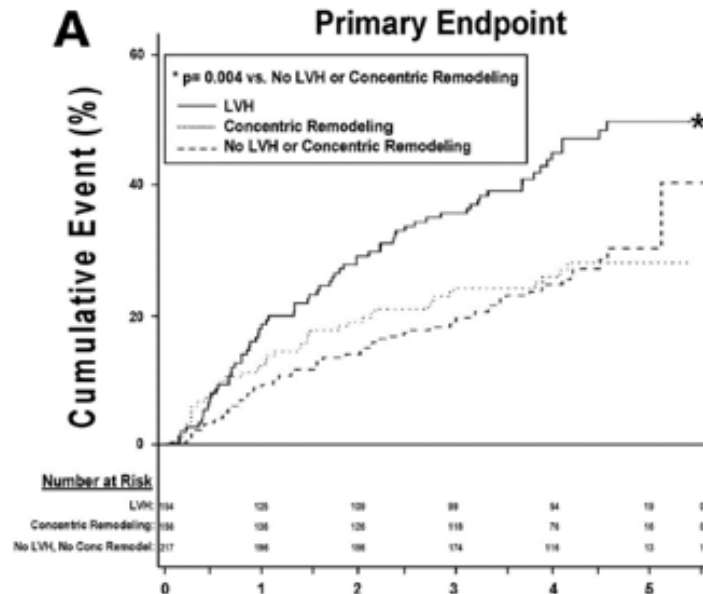
R



# Anatomie & Volumes: Structural LV remodeling



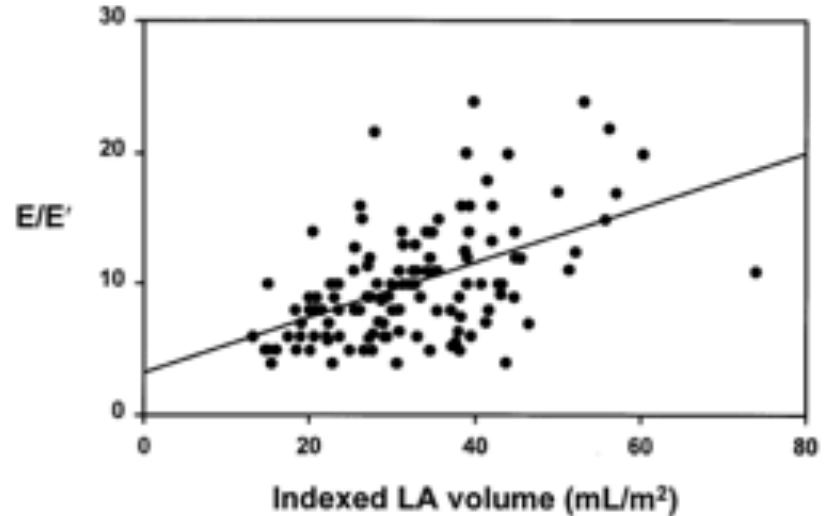
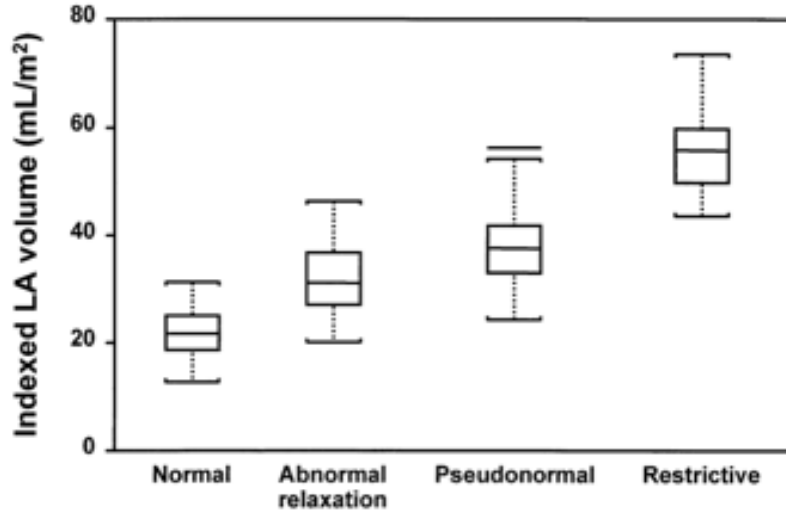
I-PRESERVE





# LAVI indicator van diastolisch functie

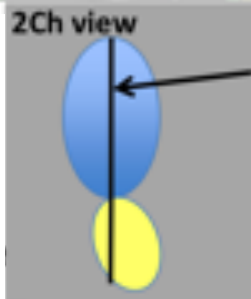
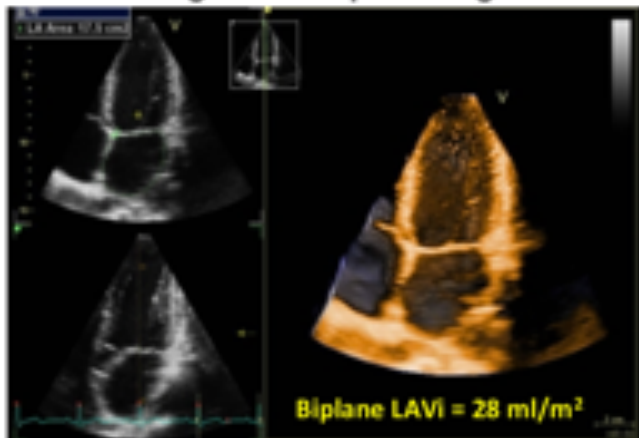
Left Atrial Volume Index (LAVI) in TOPCAT and I-preserve



*LAVI: the HbA1c of diastology: association with severity and duration of diastolic LV dysfunction*

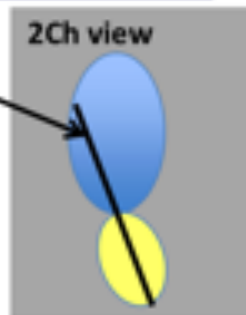
# Invloed van techniek van 2D beeld selectie op LAVI

Data set aligned for optimizing LV

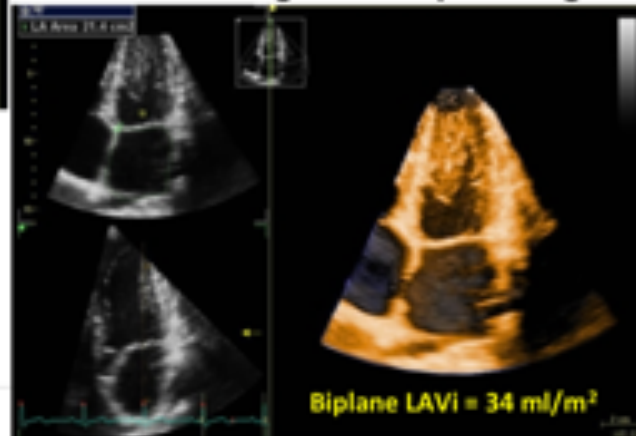


4Ch plane optimized for LV

4Ch plane optimized for LA



Data set aligned for optimizing LA



# LAVI en de relatie met prognose (15 jaar fup)

All cause mortality- age adjusted Cox Proportional Hazard Models for

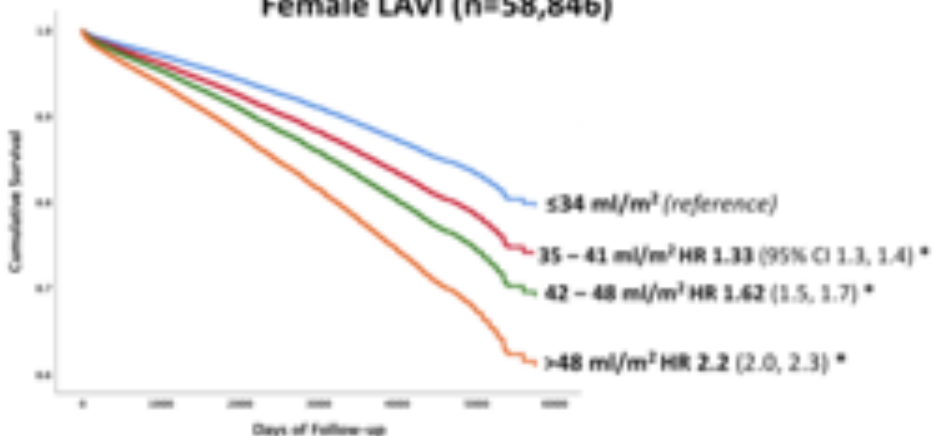
## LAVI CLINICAL SEVERITY

as per 2015 ASE and ESC Guidelines:

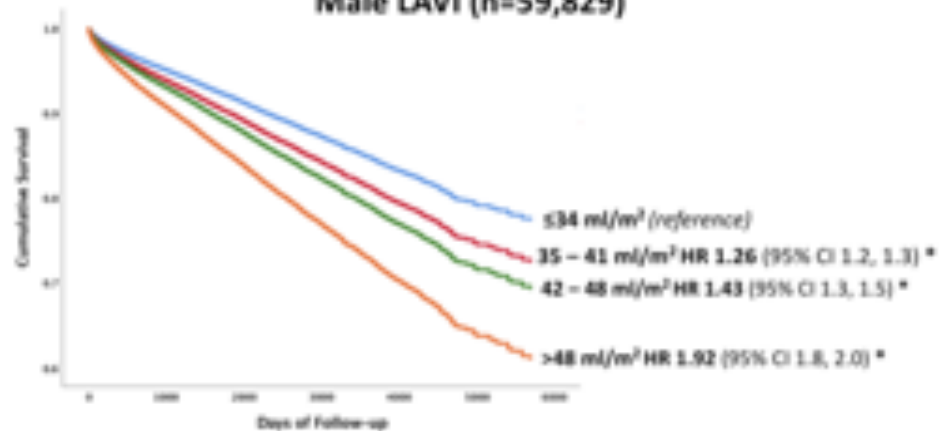
Upper Limit of NORMAL 34ml/m<sup>2</sup>

MILD enlargement 35-41ml/m<sup>2</sup>, MODERATE enlargement 42-48ml/m<sup>2</sup>, SEVERE enlargement >48ml/m<sup>2</sup>

Female LAVI (n=58,846)

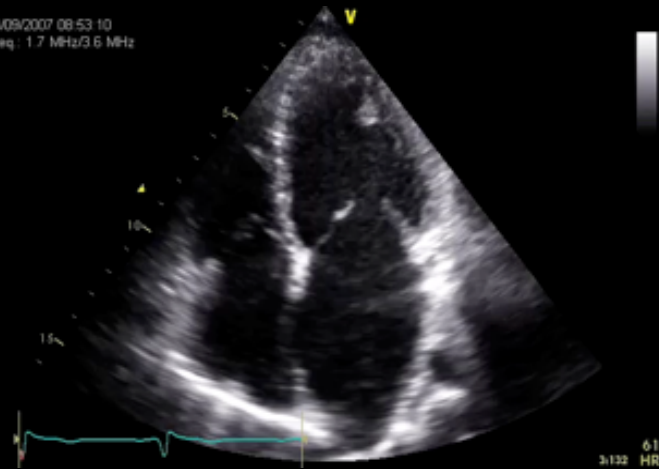


Male LAVI (n=59,829)



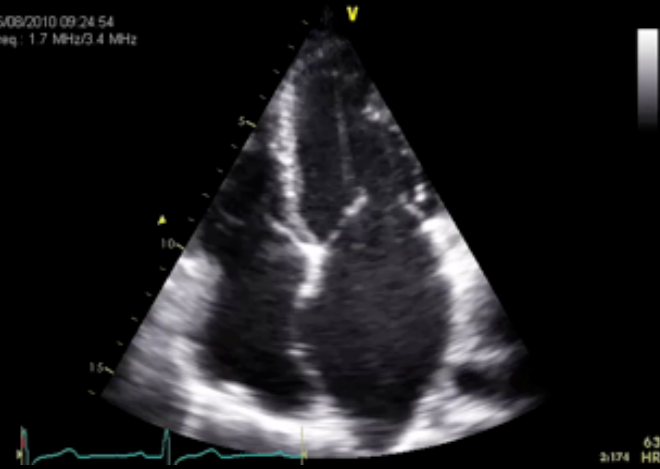
# Follow up restrictieve CMP

04/09/2007 09:53:10  
Freq: 1.7 MHz/3.6 MHz

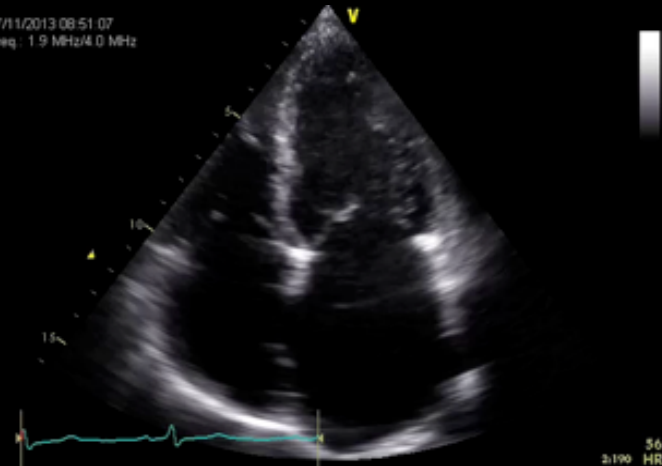


2007 LAVI 60 ml/m<sup>2</sup>  
2010 LAVI 70 ml/m<sup>2</sup>  
2013 LAVI 80 ml/m<sup>2</sup>  
2015 CVA en PAF

26/09/2010 09:24:54  
Freq: 1.7 MHz/3.4 MHz



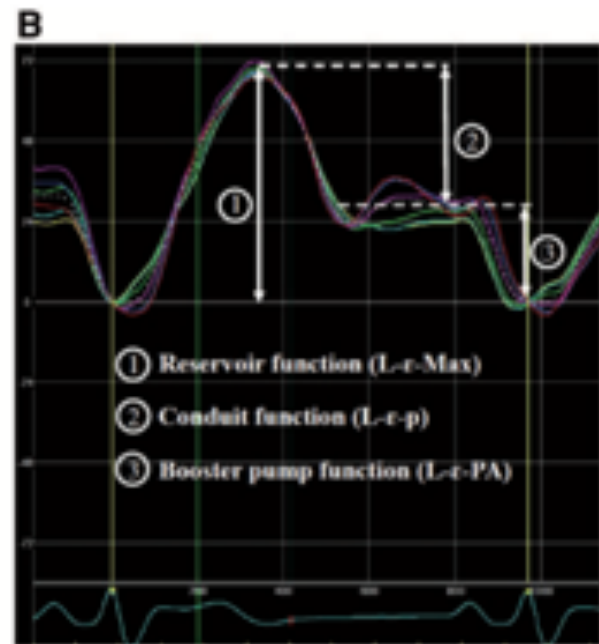
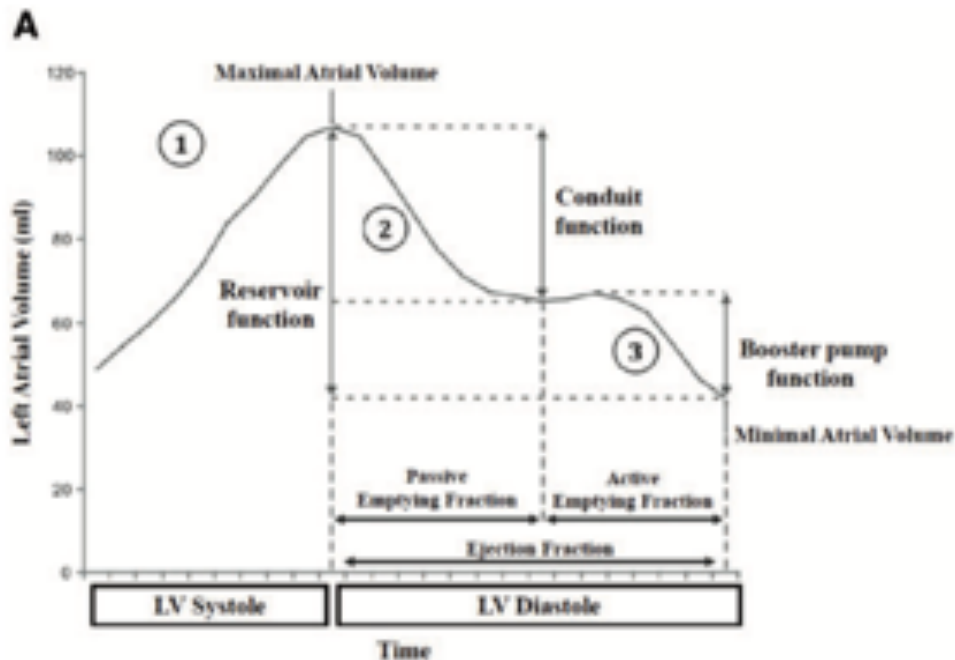
07/11/2013 09:51:07  
Freq: 1.9 MHz/4.0 MHz



# Atriale functie parameters - Volumes en deformatie

Volume

Strain

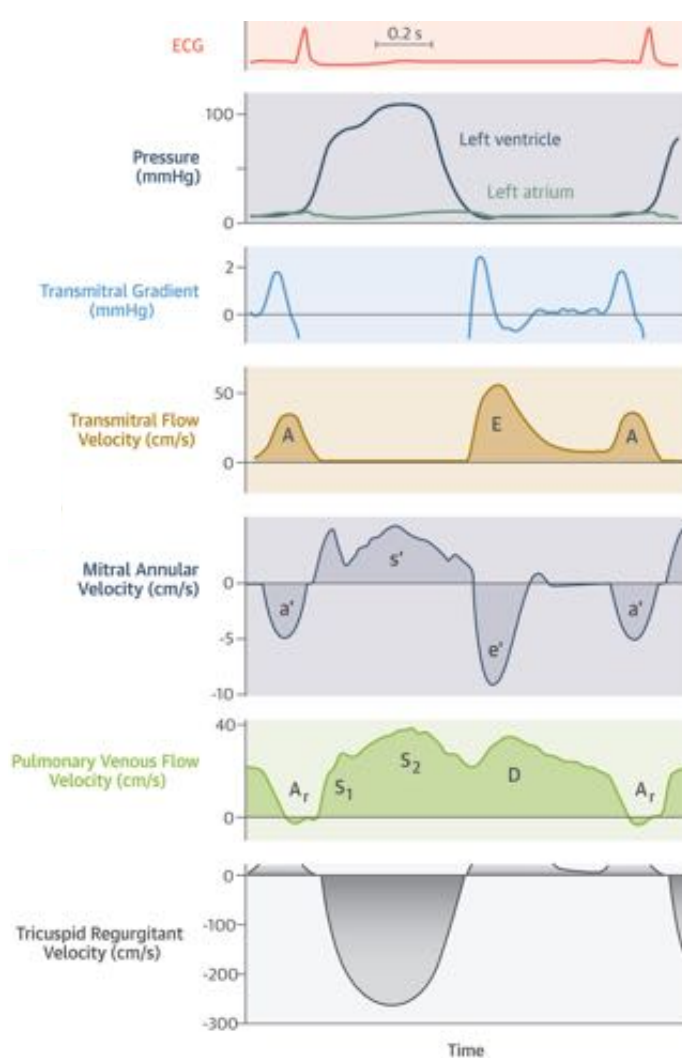
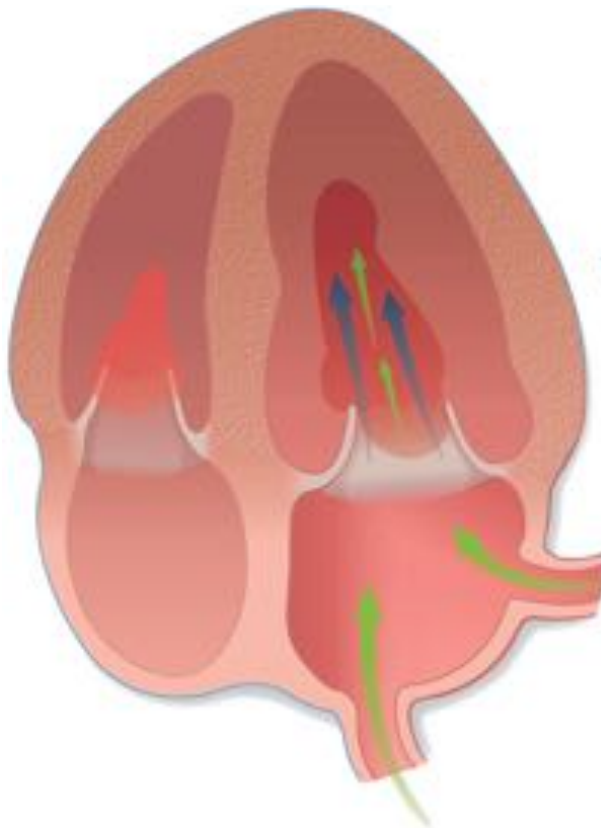


# Relatie LAVI, diastologie en events

	normaal	benigne	mild risico	matig risico	ernstig risico
LAVI (ml/m <sup>2</sup> )	16-34	> 34 vergroot	35-41 licht vergroot	42-48 vergroot	≥ 48 sterk vergroot
TD e' (cm/s)	≥ 10 normaal	≥ 10 normaal	< 10 abnormaal	< 8 abnormaal	< 5 sterk abnormaal

*Dilation of atria can be a physiological remodelling; decrease of function is always abnormal*

# Indirecte bepaling van diastolische drukken en druk-volume relaties



# PW doppler bepaling van de mitralisflow snelheid

Mitralisflow snelheid reflecteert het transmitrale druk gradiënt

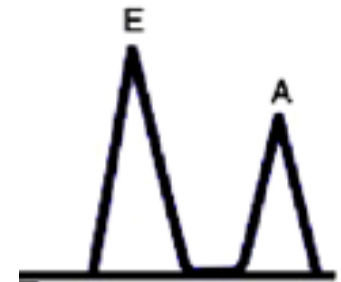
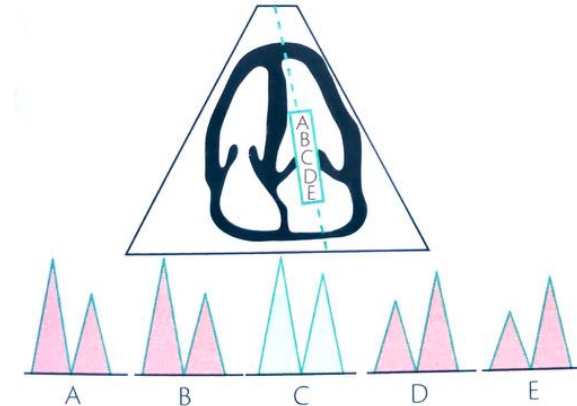
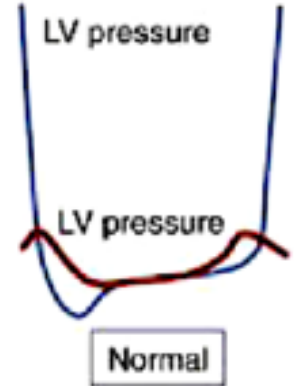
=bloed verplaatsingsnelheid door de tips van de MV in de vroege diastole

Wordt beïnvloed door de relaxatiesnelheid

De passieve recoil van de LV

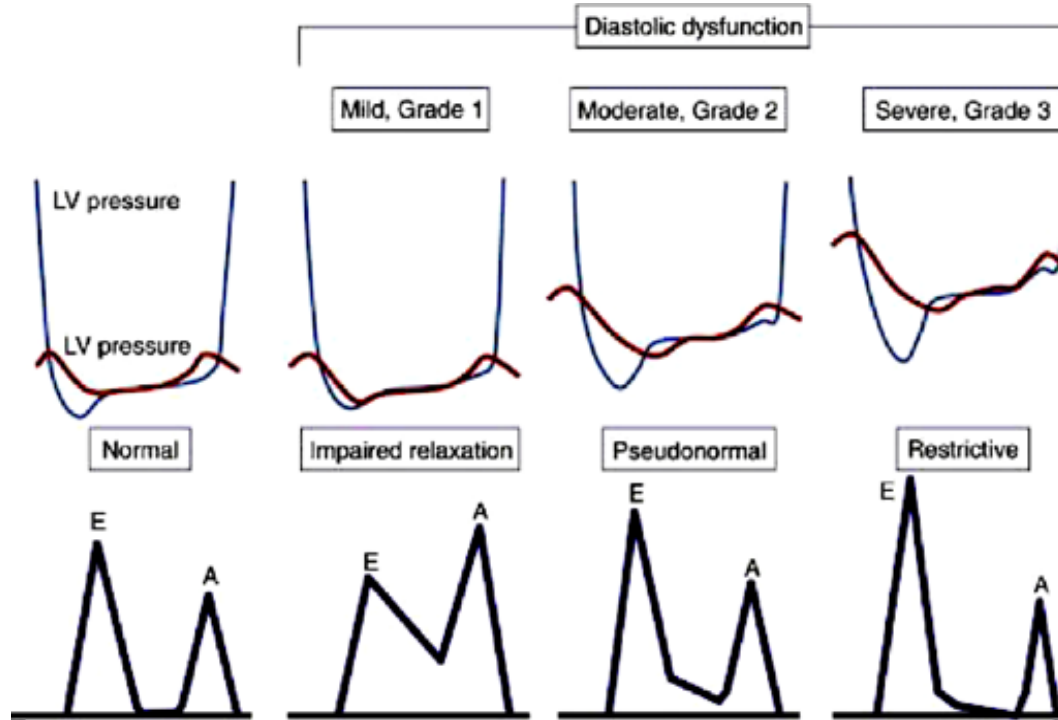
Compliantie van de LV

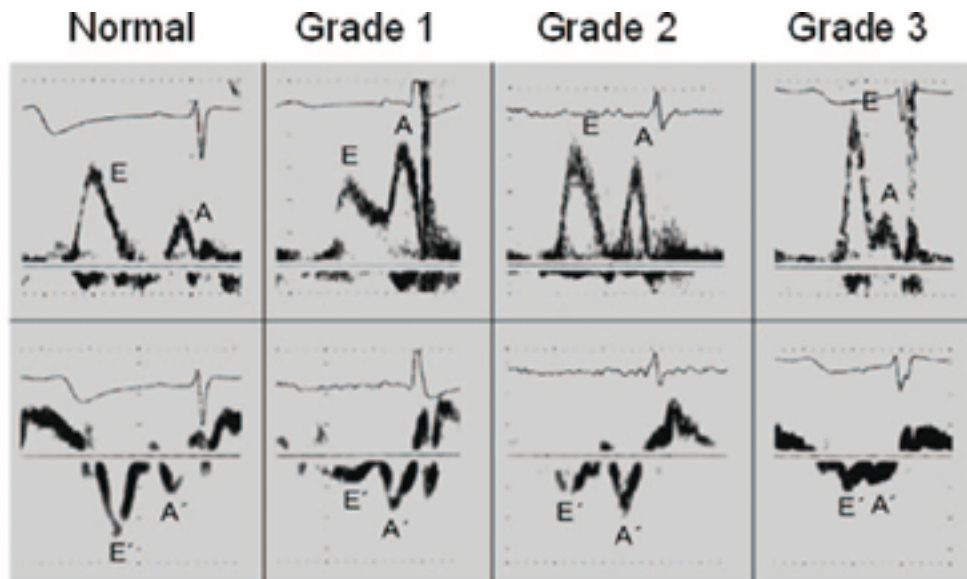
Diastolische drukken in LA en LV





# Doppler patronen en druk gradiënten

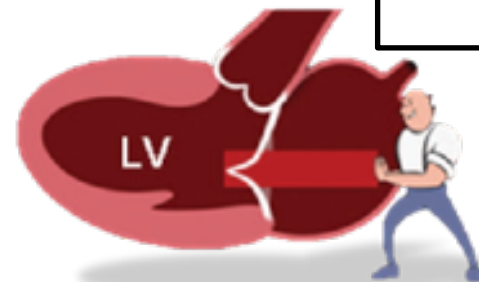




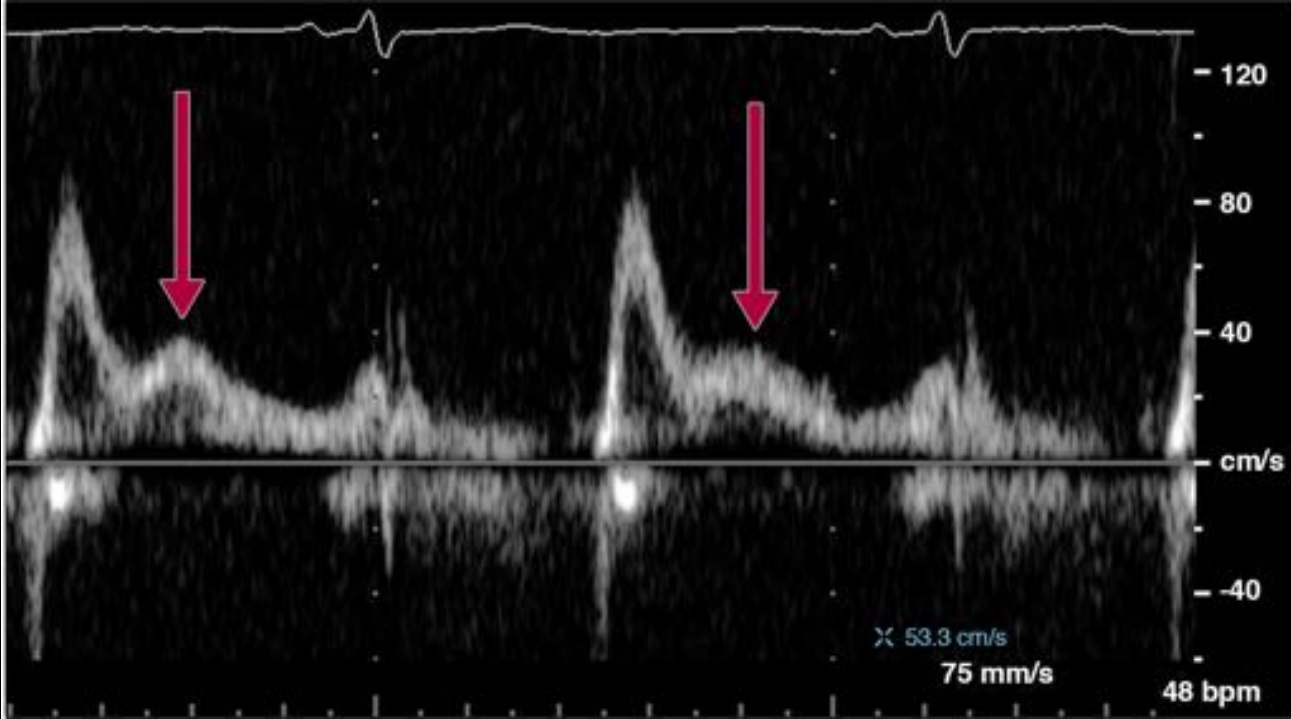
Negative LV pressure driven  
"suction"



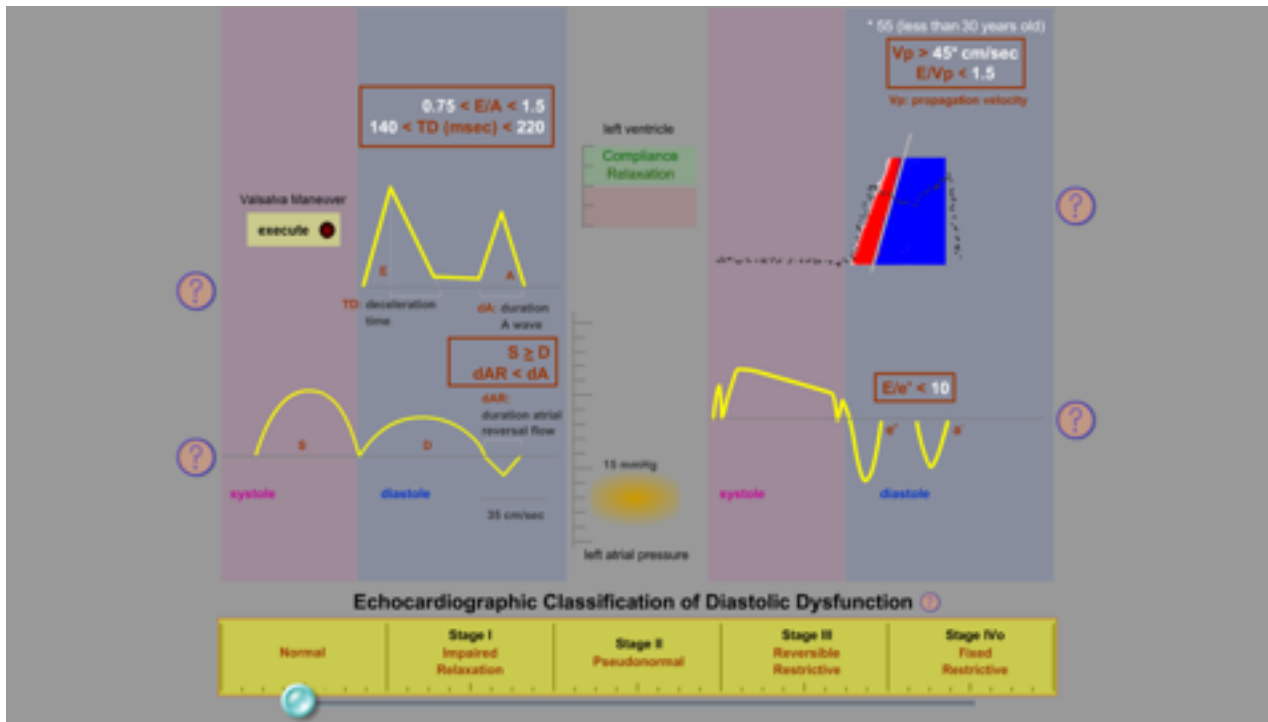
Positive LA pressure driven  
"pushing"



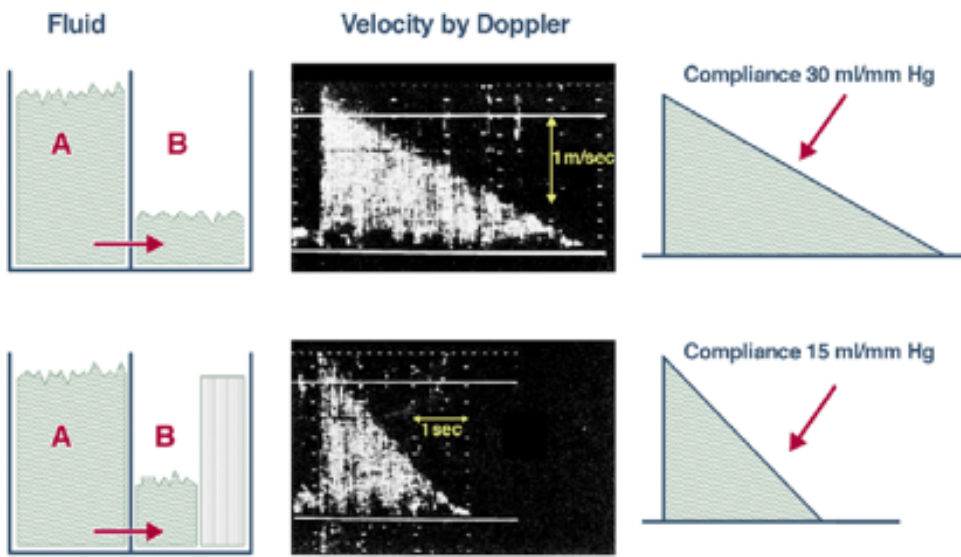
# Unmasking pseunormaal - L wave



# Dynamische doppler patronen - herkenning



# Mitralis inflow deceleratie tijd: maat voor LV compliantie

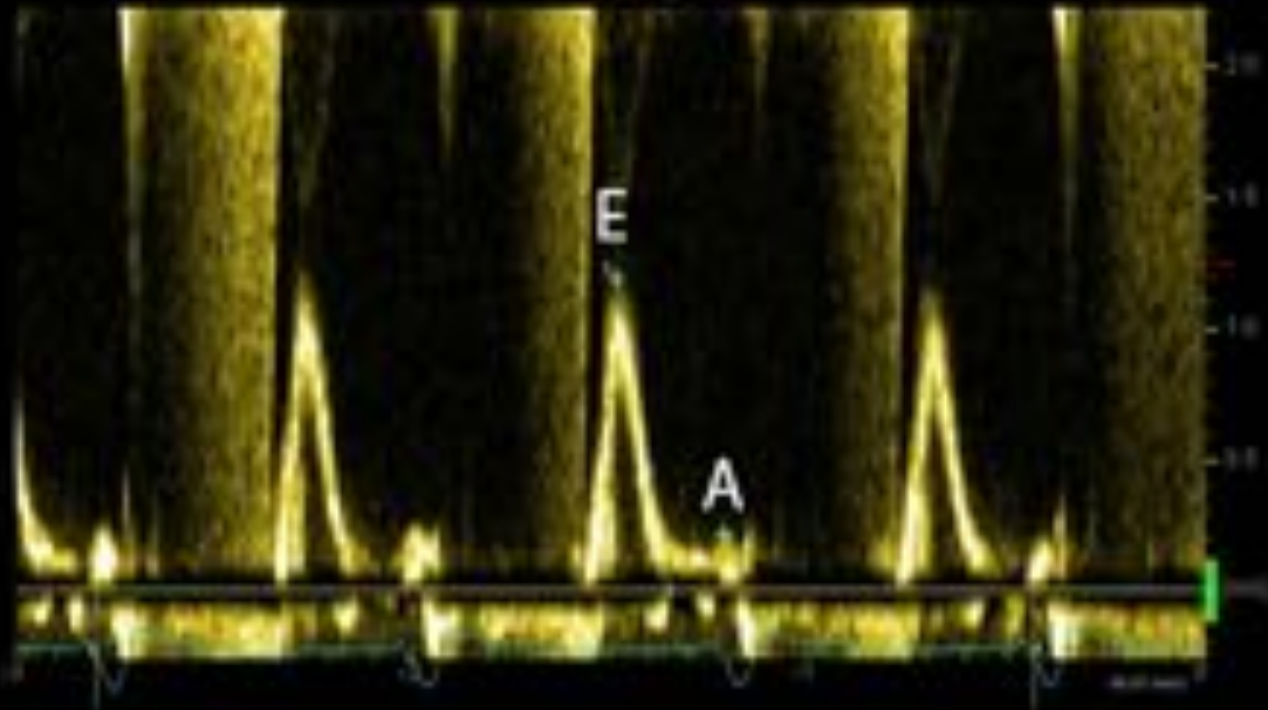


Compliantie: mate van rekbaarheid

DC < 150 ms (pas op bij gezonde jongeren)

(elasticiteit = mate van terugveerbaarheid)

14.01	
MV E Vel	1.18 m/s
MV Dec T	121.4 ms
MV Dec Slope	8.8 m/s <sup>2</sup>
MV A Vel	0.21 m/s
MV E/A Ratio	5.6



# TDI bepaling van de e'

Pulsed TDI gemeten e' snelheid van septale en laterale mitralis annulus

=LV verlengingssnelheid in de vroege diastole

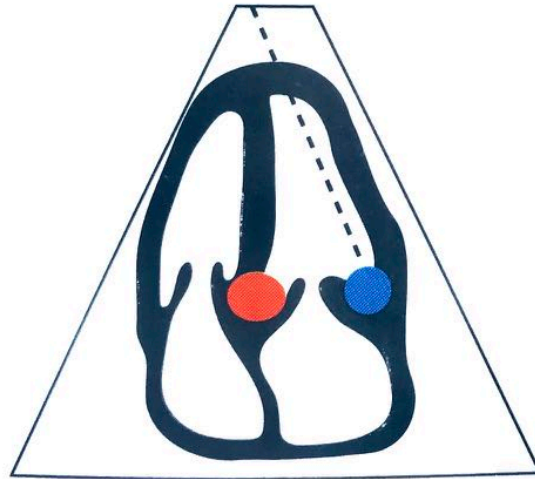
Middel lat + sept. waardes tenzij...

Afhankelijk van

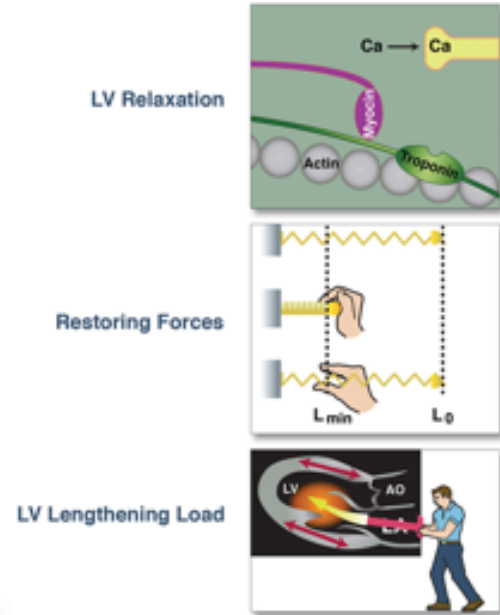
Actieve relaxatie component

Passieve relaxatie component

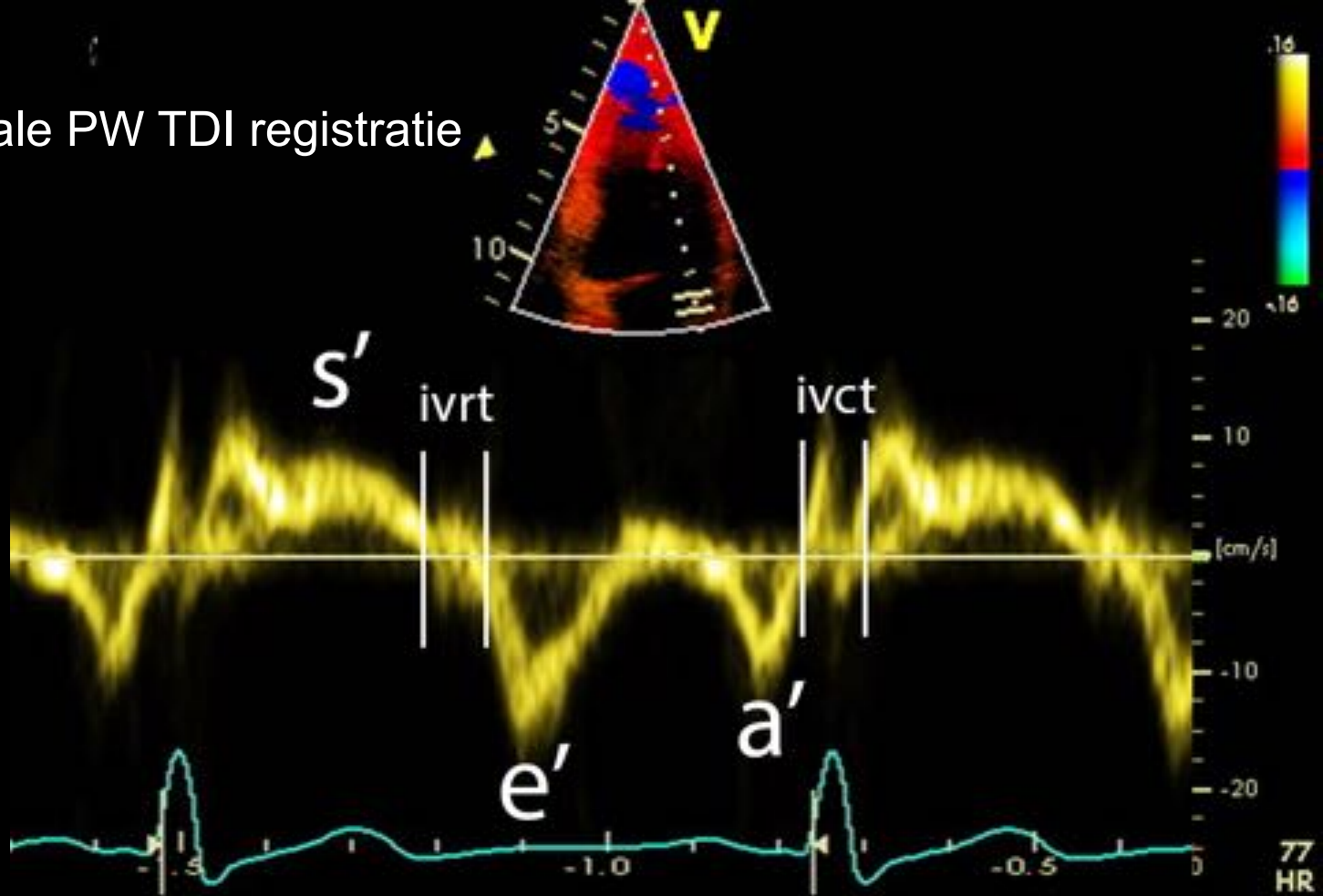
Ook wel druk verschillen



Septaal < lateraal, ULN is >8cm/s

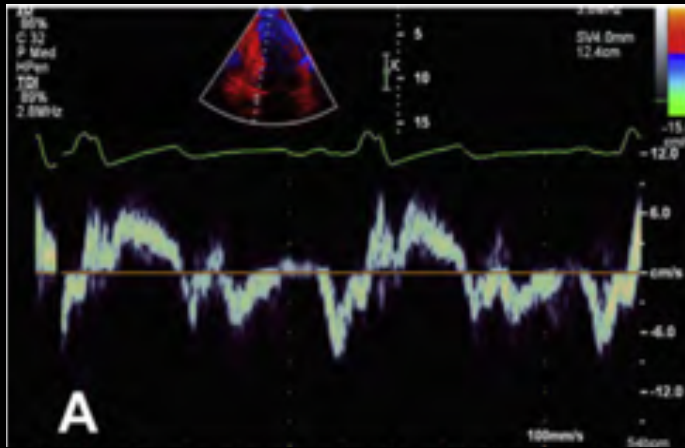


# Normale PW TDI registratie

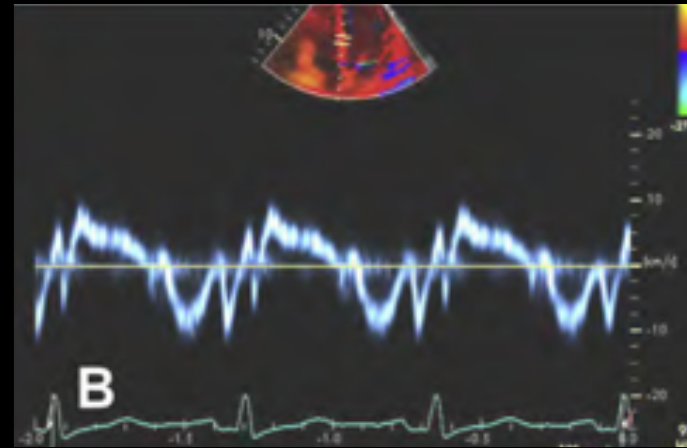




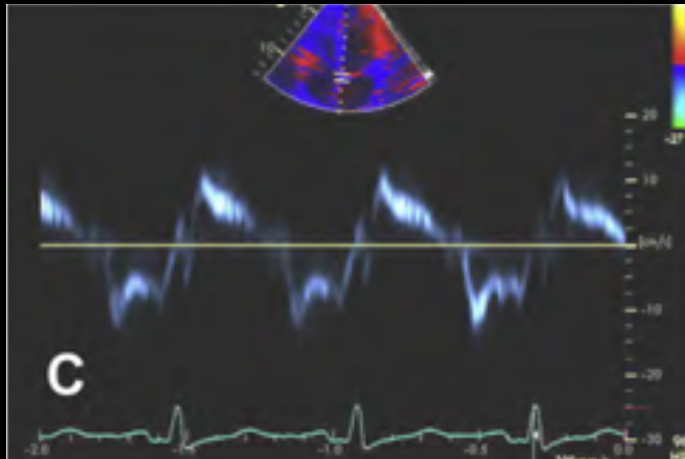
Juist



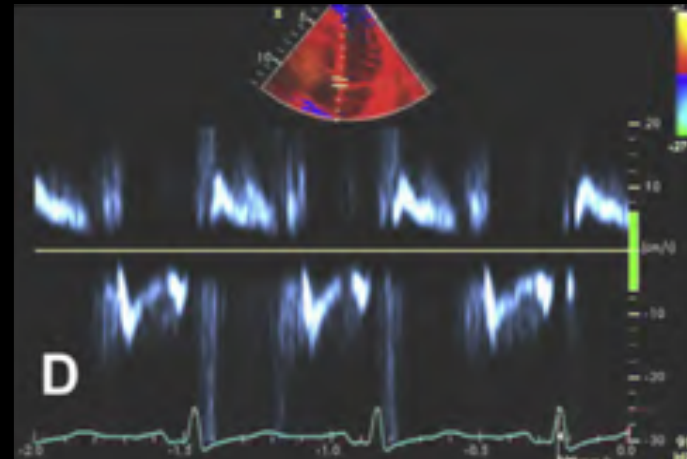
Sample  
positie



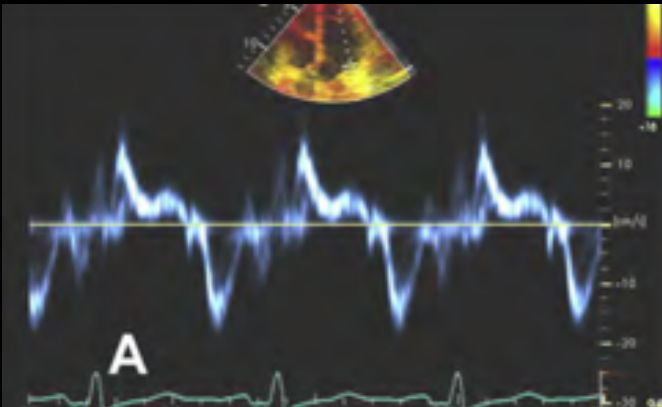
Gain



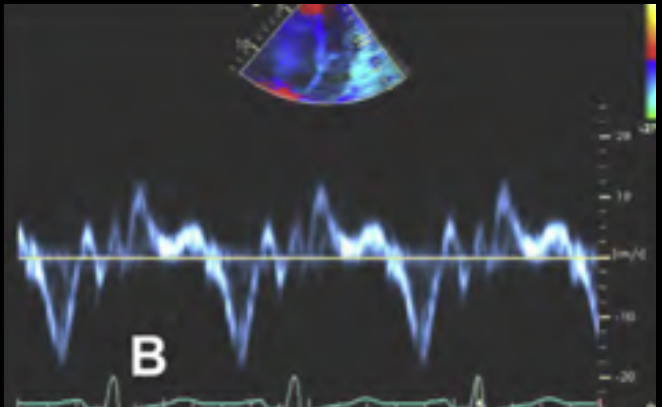
Band  
filter



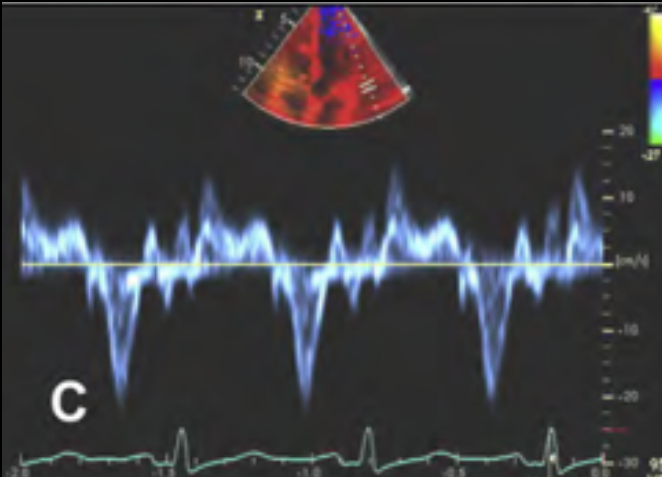
In LV holte



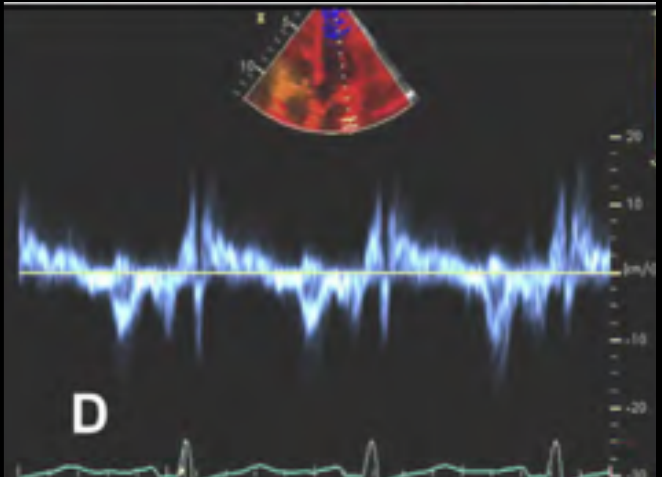
Lat wand



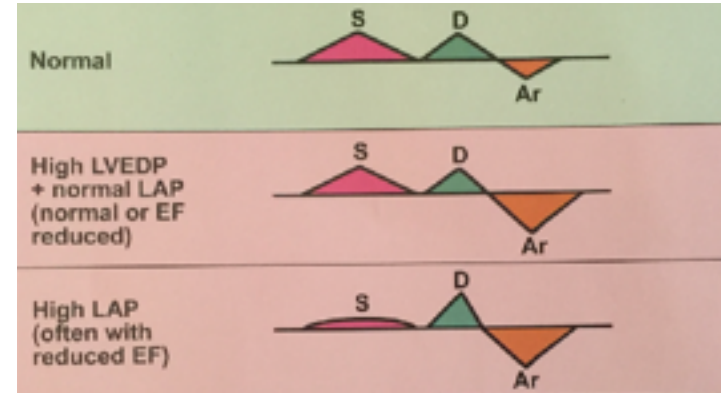
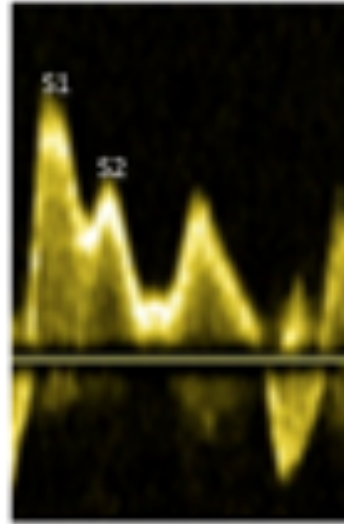
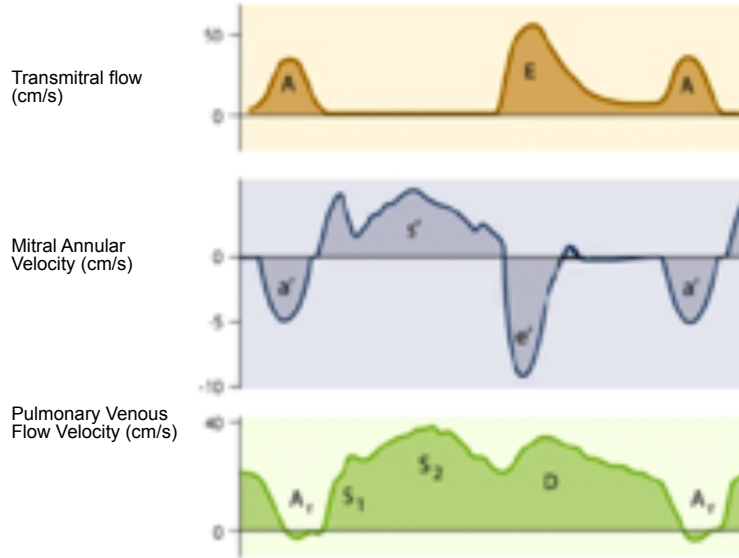
Buiten het hart



In LA



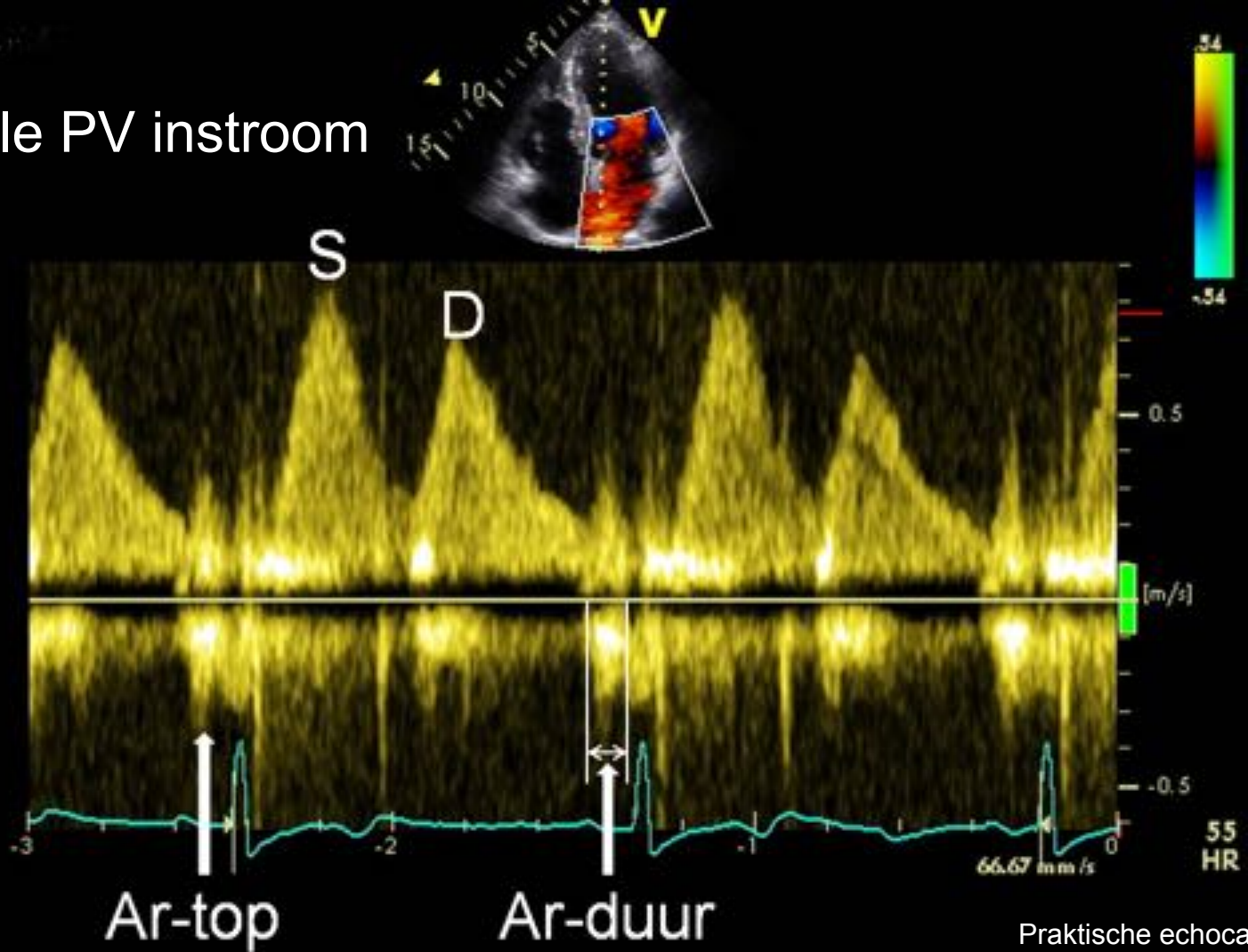
# Longvene flow



S1: relaxatie van het LA

S2: RV/LV ejectie en *mitral annular descent*

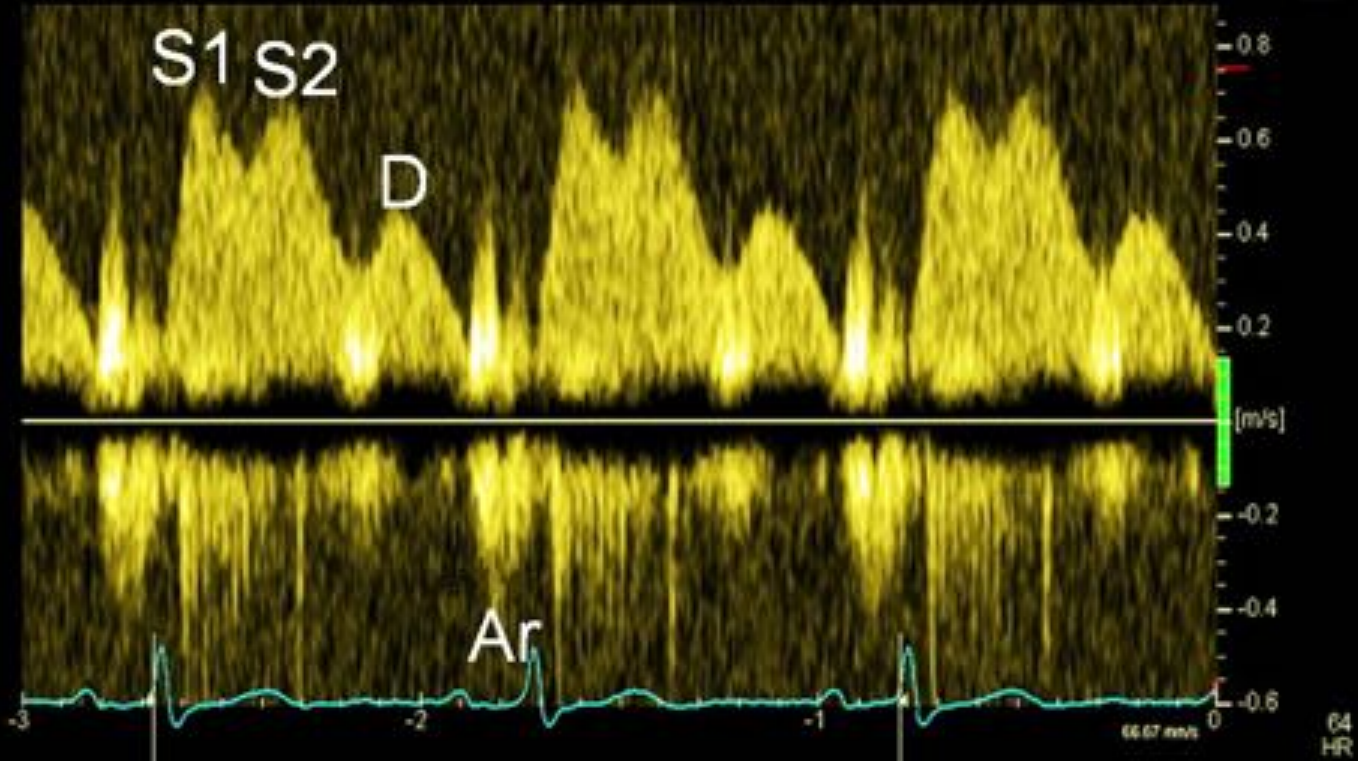
# Normale PV instroom



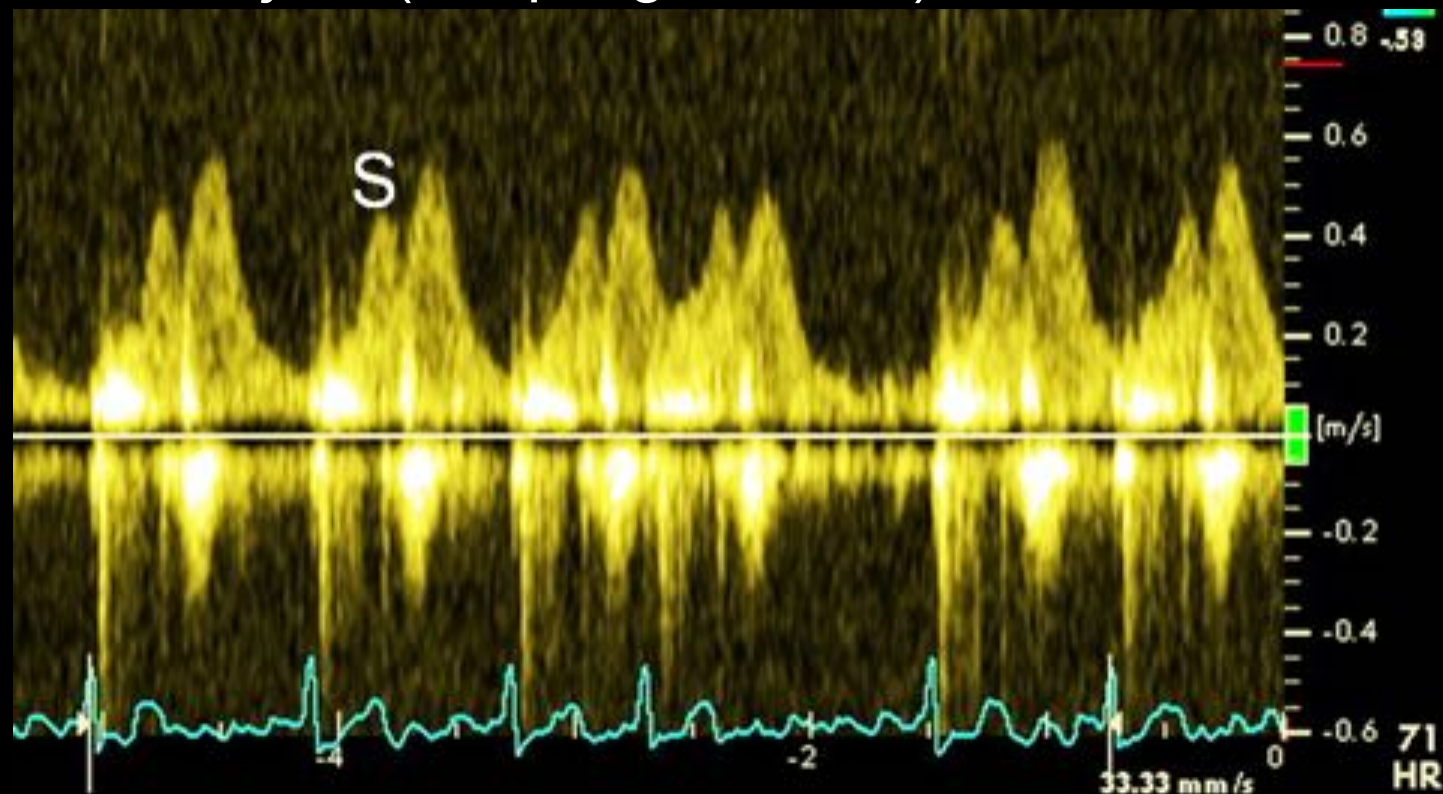
# PV instroom met S2



S1 Atriale relaxatie  
S2 verplaatsing MV annulus  
S2 = diastolische instroom meting



# PV instroom bij AF (S top lager dan D)



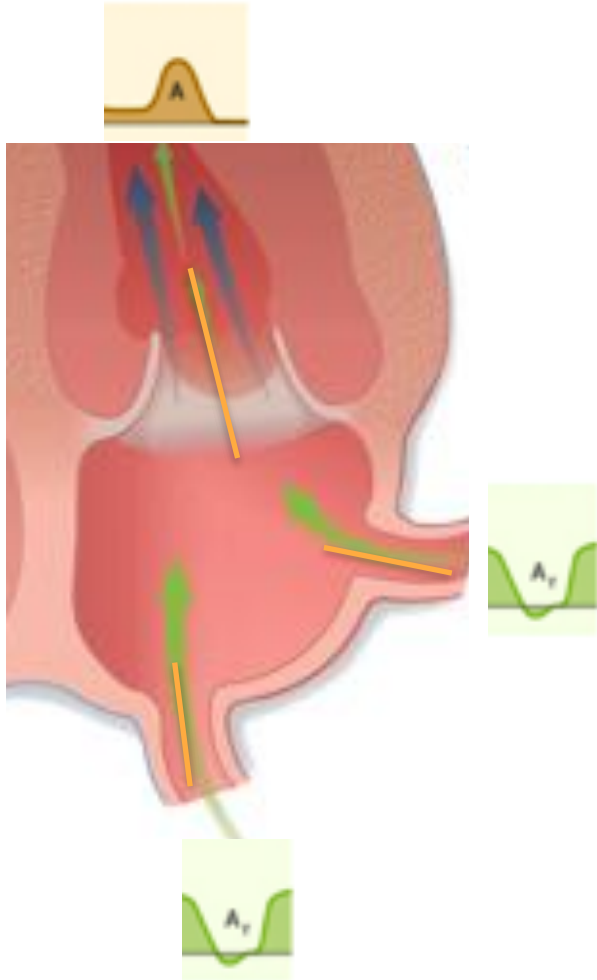
# Verhoogde LVEDD

Verminderde LV compliantie

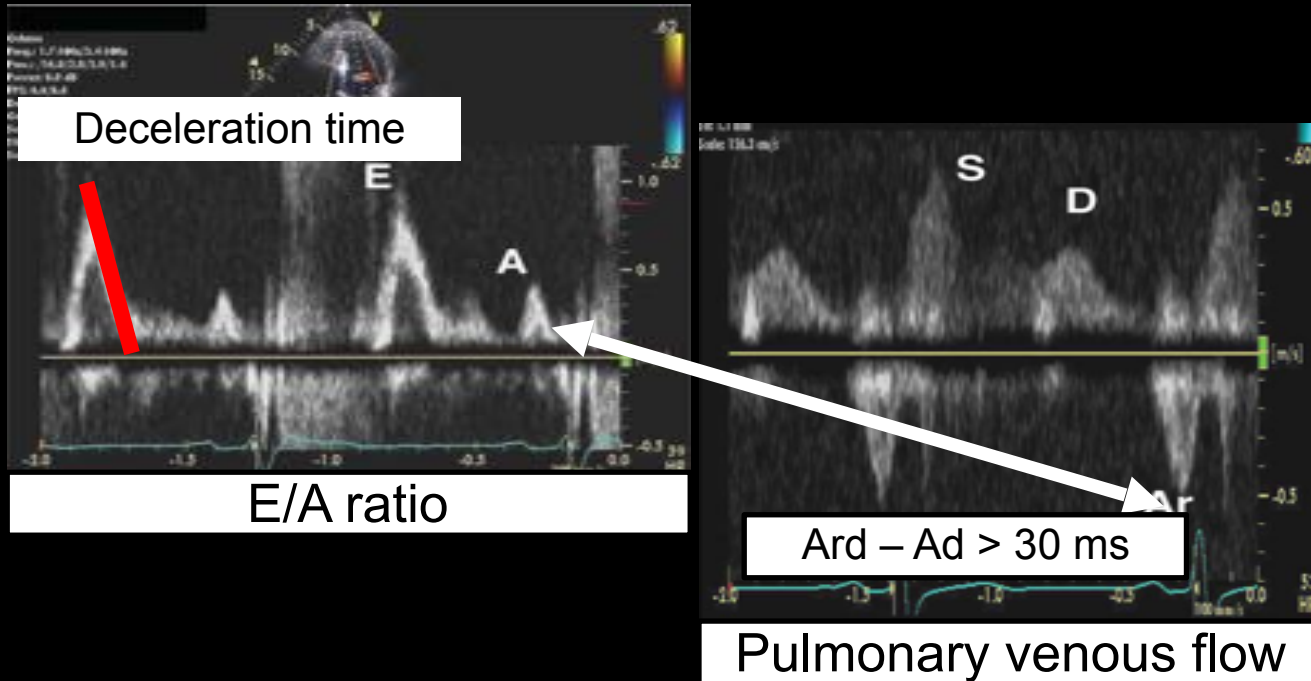
Atriale *push back* naar longvenen

Amplitude:  $AR > 40 \text{ cm/sec}$

Duur:  $ARd - Ad > 30 \text{ ms}$

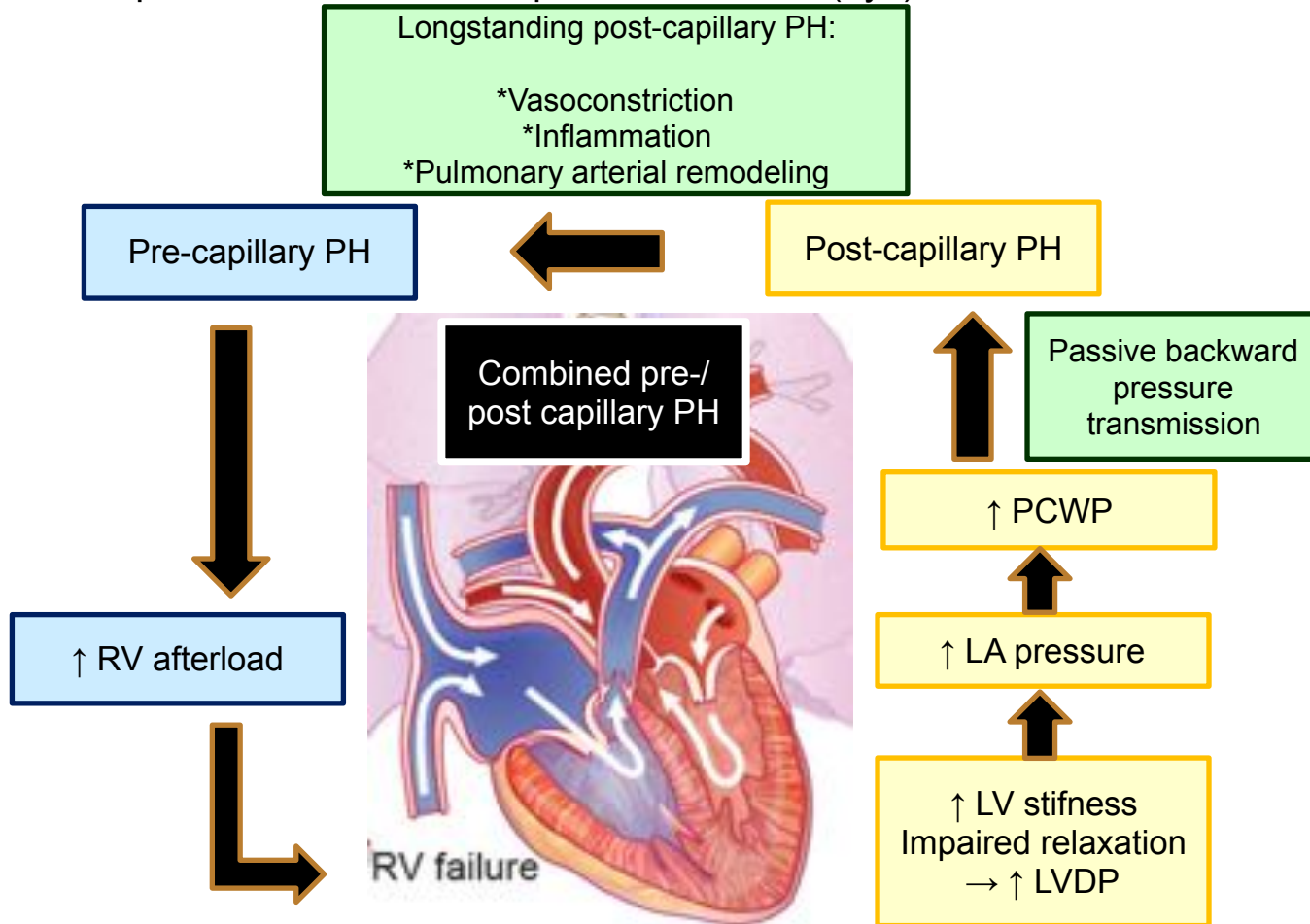


# Relatie transmitrale flow en PV flow





# HFpEF: The link between pulm HT and RV (dys)function





**Left Heart**

- ↑ LV filling pressure
- ↑ Chronic RV afterload
- ↑ Ventricular interaction

**Comorbidities**

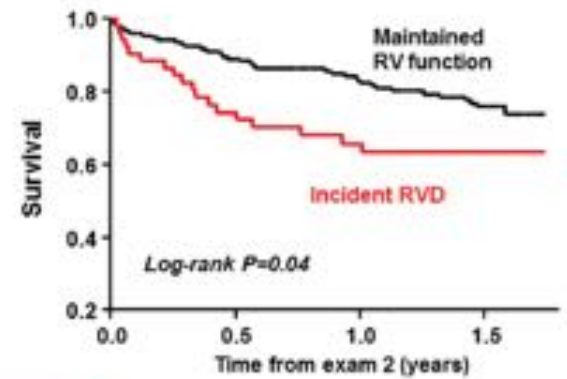
- Atrial fibrillation
- Coronary disease
- Obesity



**Right Heart**

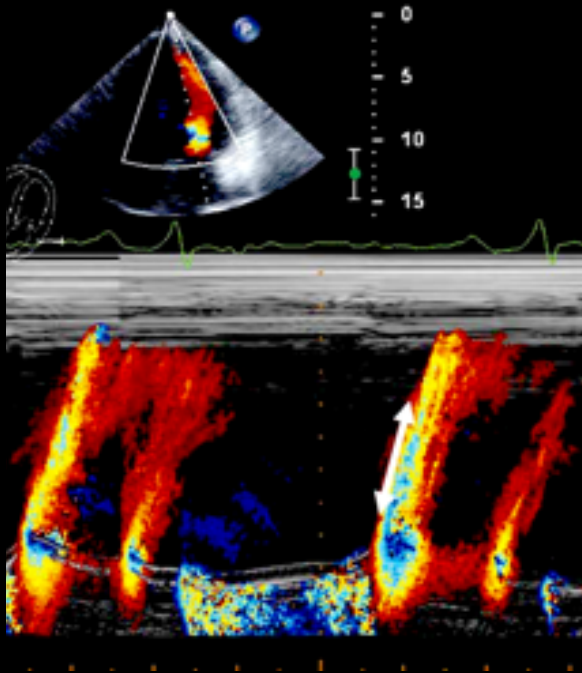
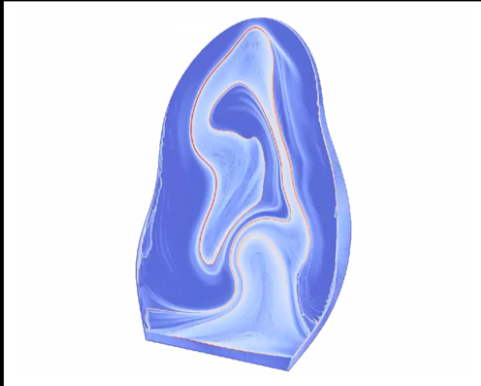
- ↓ FAC
- ↑ RV remodeling
- ↑ Atrial fibrillation
- ↑ TR
- ↑ RA dilation

**Vicious Cycle**

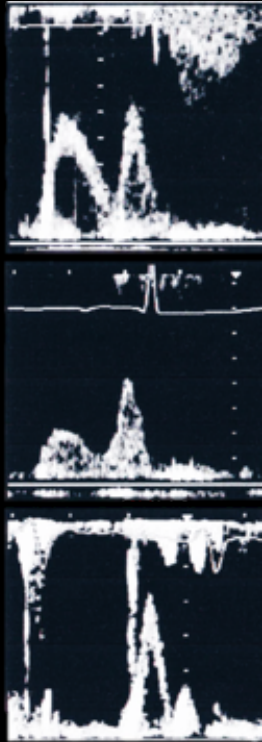
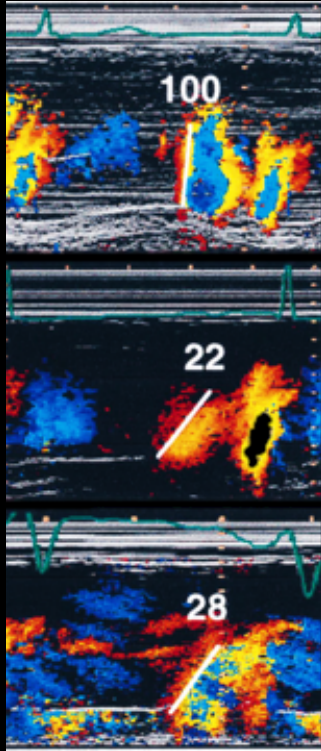


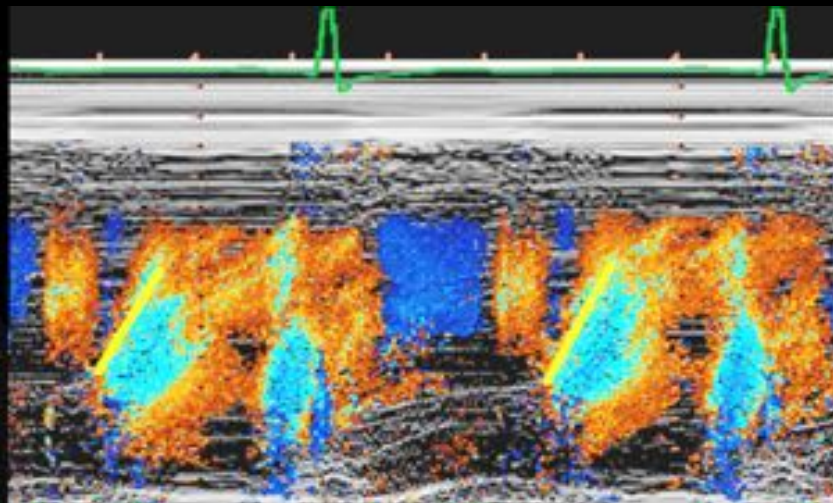
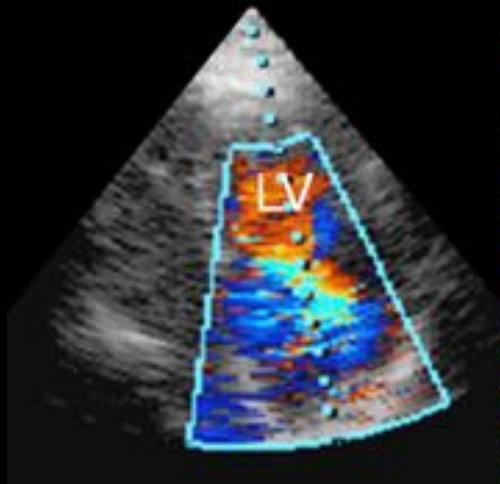
Time (Years)

# Propagation velocity: snelheid "E" vortex richting apex

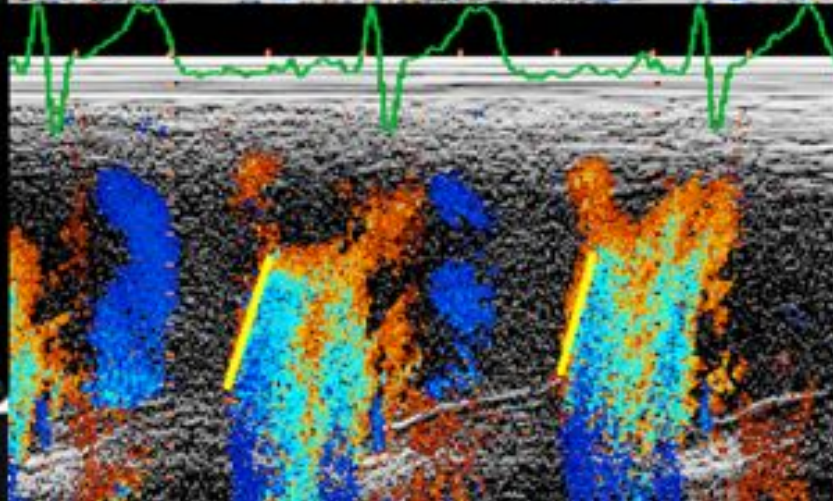
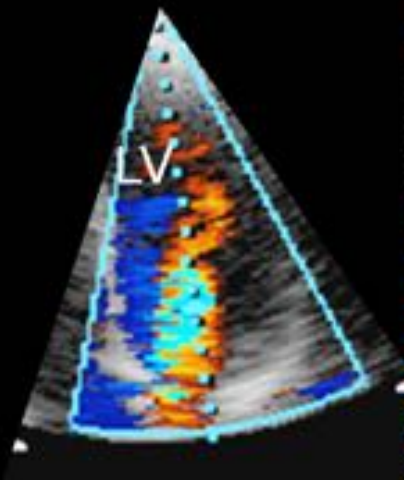


Normaal  $V_p > 45$  cm/sec



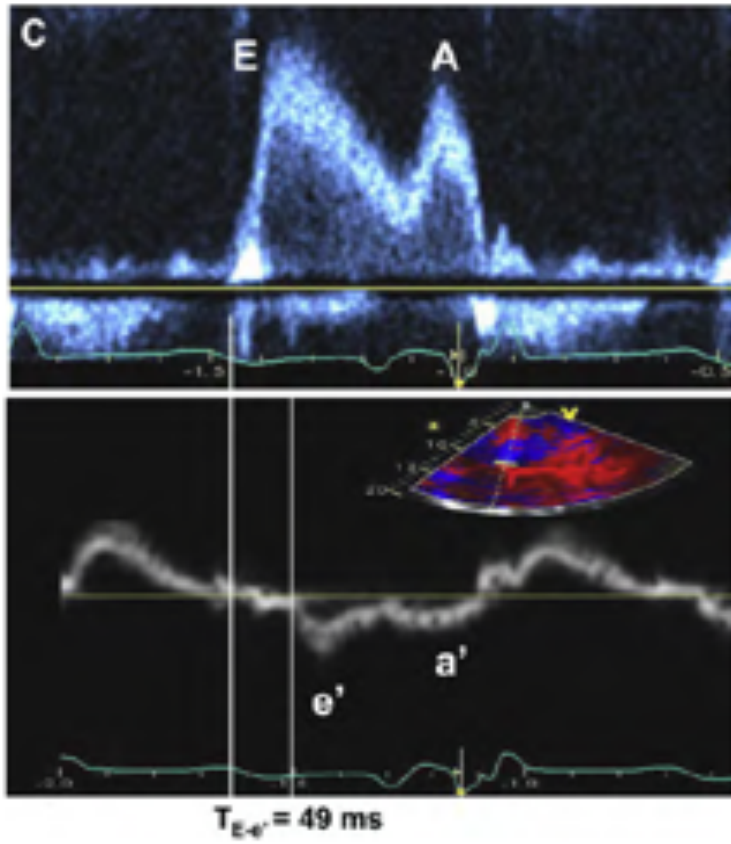


Scheef gemeten  
38cm/sec



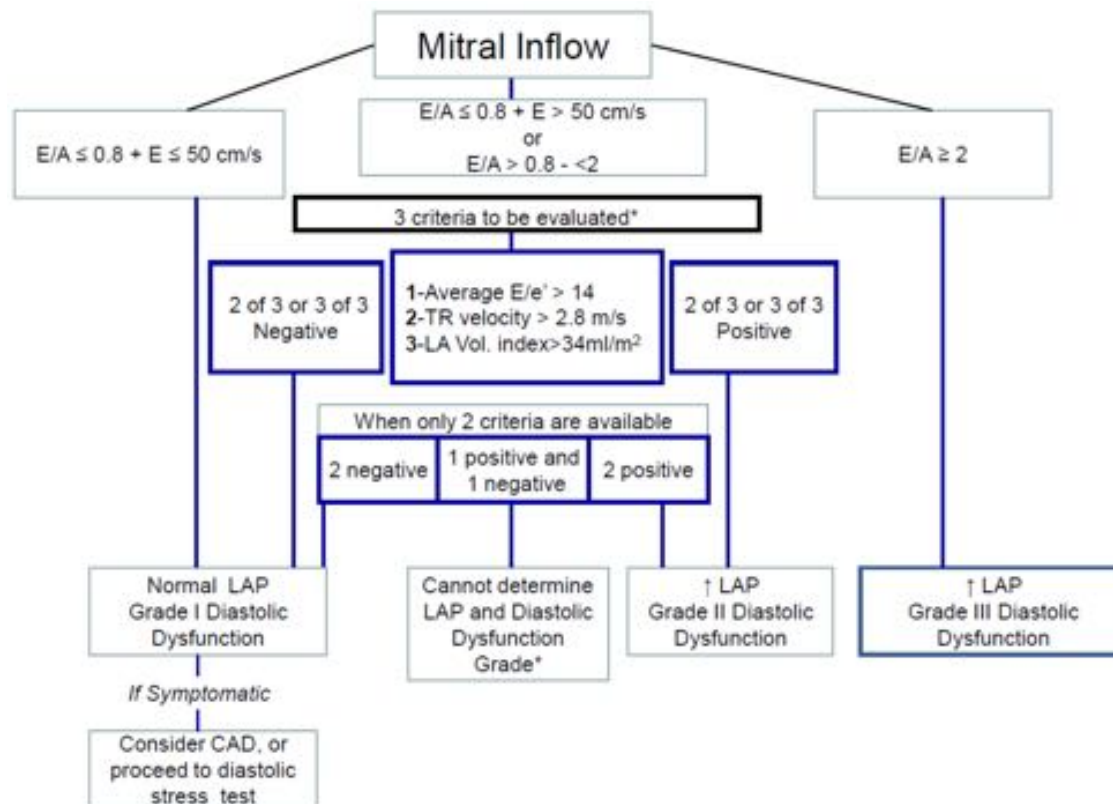
Correct gemeten  
58cm/sec

$T_{E-e'}$



Verhoogde LA vullingsdruk bij  $TE-e' > 50 \text{ ms}$

# Algoritme bij afwijkingen en/of verminderde LVEF



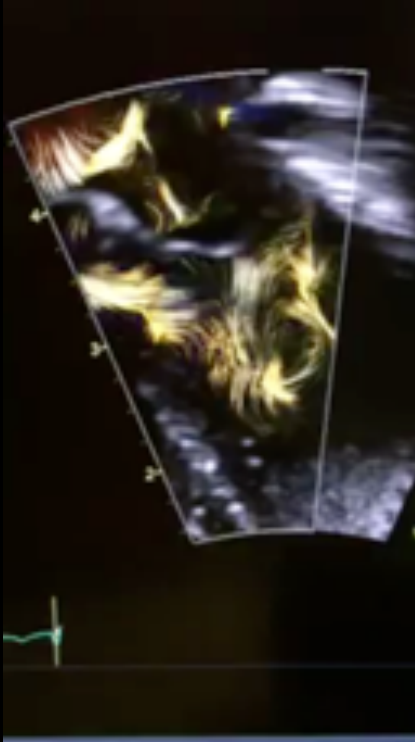
# Bepaling diastologie in speciale situaties

**Table 6** Assessment of LV filling pressures in special populations

Disease	Echocardiographic measurements and cutoff values
AF <sup>103,104,105</sup>	Peak acceleration rate of mitral E velocity ( $\geq 1,900$ cm/sec <sup>2</sup> ) IVRT ( $\leq 65$ msec) DT of pulmonary venous diastolic velocity ( $\leq 220$ msec) E/Vp ratio ( $\geq 1.4$ ) Septal E/e' ratio ( $\geq 11$ )
Sinus tachycardia <sup>41,44</sup>	Mitral inflow pattern with predominant early LV filling in patients with EFs $< 50\%$ IVRT $\leq 70$ msec is specific (79%) Pulmonary vein systolic filling fraction $\leq 40\%$ is specific (88%) Average E/e' $> 14$ (this cutoff has highest specificity but low sensitivity) When E and A velocities are partially or completely fused, the presence of a compensatory period after premature beats often leads to separation of E and A velocities which can be used for assessment of diastolic function
HCM <sup>100-108</sup>	Average E/e' ( $> 14$ ) Ar-A ( $\geq 30$ msec) TR peak velocity ( $> 2.8$ m/sec) LA volume ( $> 34$ mL/m <sup>2</sup> )
Restrictive cardiomyopathy <sup>13,107-109</sup>	DT ( $< 140$ msec) Mitral E/A ( $> 2.5$ ) IVRT ( $< 50$ msec has high specificity) Average E/e' ( $> 14$ )
Noncardiac pulmonary hypertension <sup>33</sup>	Lateral E/e' can be applied to determine whether a cardiac etiology is the underlying reason for the increased pulmonary artery pressures When cardiac etiology is present, lateral E/e' is $> 13$ , whereas in patients with pulmonary hypertension due to a noncardiac etiology, lateral E/e' is $< 8$
Mitral stenosis <sup>110</sup>	IVRT ( $< 60$ msec has high specificity) IVRT/T <sub>E-w</sub> ( $< 4.2$ ) Mitral A velocity ( $> 1.5$ m/sec)
MR <sup>110-112</sup>	Ar-A ( $\geq 30$ msec) IVRT ( $< 60$ msec has high specificity) IVRT/T <sub>E-w</sub> ( $< 5.6$ ) may be applied for the prediction of LV filling pressures in patients with MR and normal EFs Average E/e' ( $> 14$ ) may be considered only in patients with depressed EFs

A comprehensive approach is recommended in all of the above settings, which includes estimation of PASP using peak velocity of TR jet ( $> 2.8$  m/sec) and LA maximum volume index ( $> 34$  mL/m<sup>2</sup>). Conclusions should not be based on single measurements. Specificity comments refer to predicting filling pressures  $> 15$  mm Hg. Note that the role of LA maximum volume index to draw inferences on LAP is limited in athletes, patients with AF, and/or those with mitral valve disease.

# Nieuwe ontwikkelingen: Blood speckle imaging



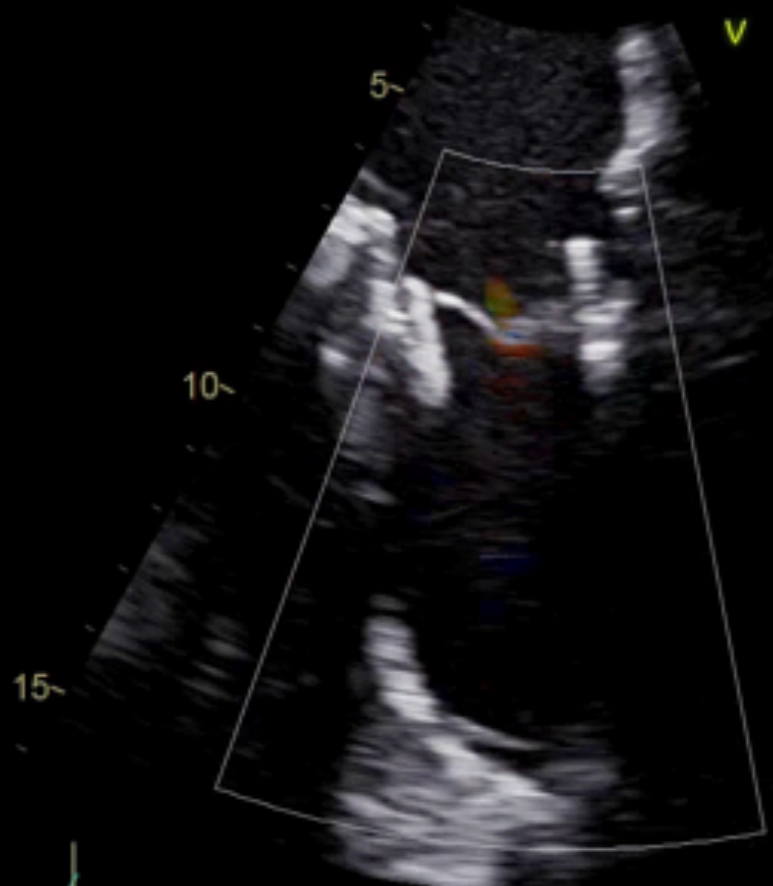
Non doppler

Post processing on high frame rates: 700fps

Advanced speckle tracking



Slowness: 1.1 %



80  
HR

# Conclusie

Diastolische dysfunctie komt veel voor en is een belangrijke marker voor ziekte en prognose.

TTE is van onschatbare waarde bij het niet-invasief schatten van de LV druk

Begrijp de onderlinge verhoudingen van de verschillende doppler parameters

Probeer druk/doppler patronen te herkennen.

Je hebt altijd meerdere parameters nodig, gebruik ze hiërarchisch.

De meest robuuste parameters zijn  $e'$ ,  $E/e'$ , LAVI en TR  $v_{max}$

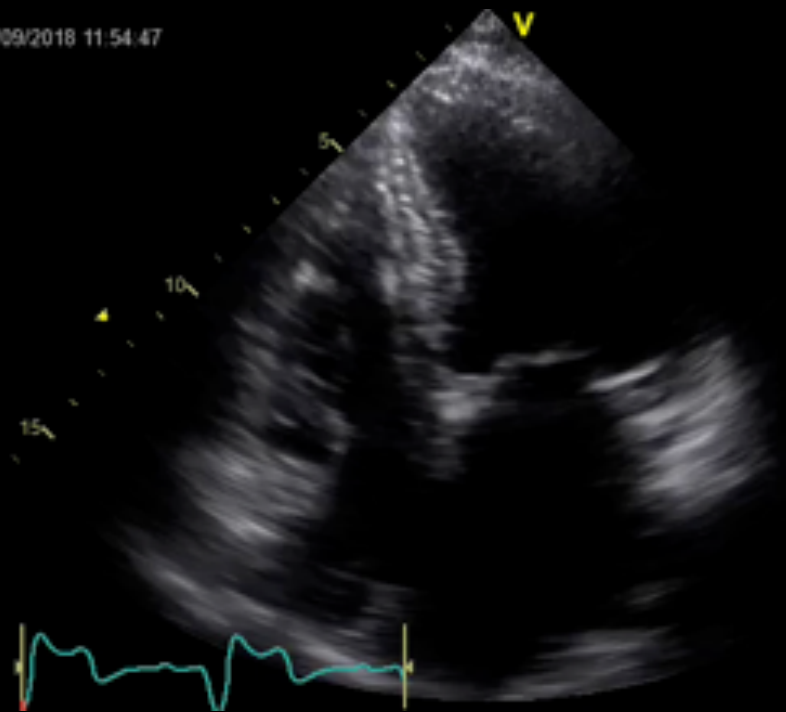
**Klinische, anatomische (volume/structuur) en functionele (doppler) parameters moeten congruent zijn**



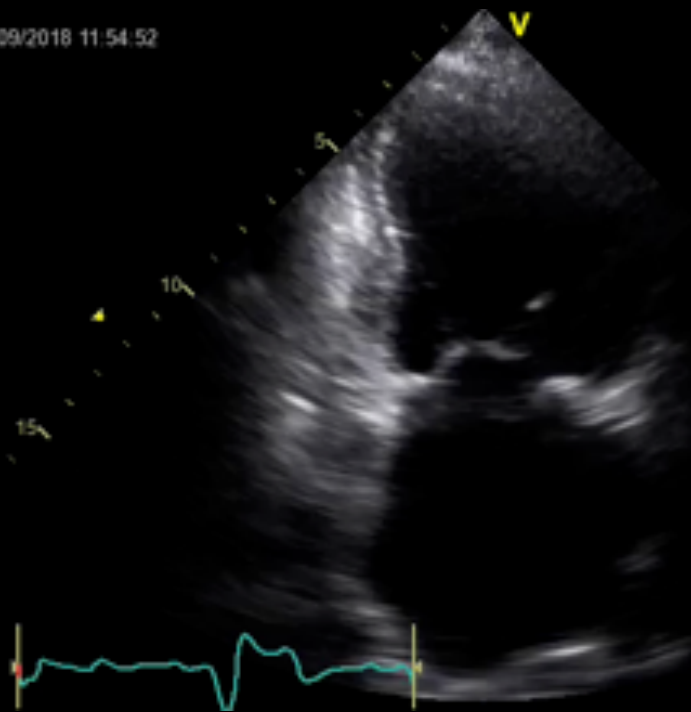
*Diastologie: je gaat het pas zien als je het doorhebt*

# Casus: man 75jr, dyspnoe d'effort

08/09/2018 11:54:47

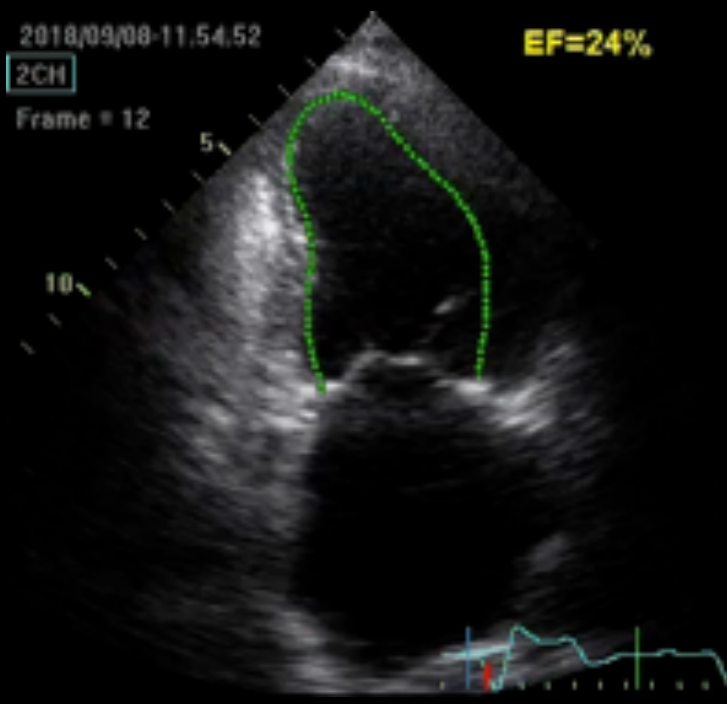
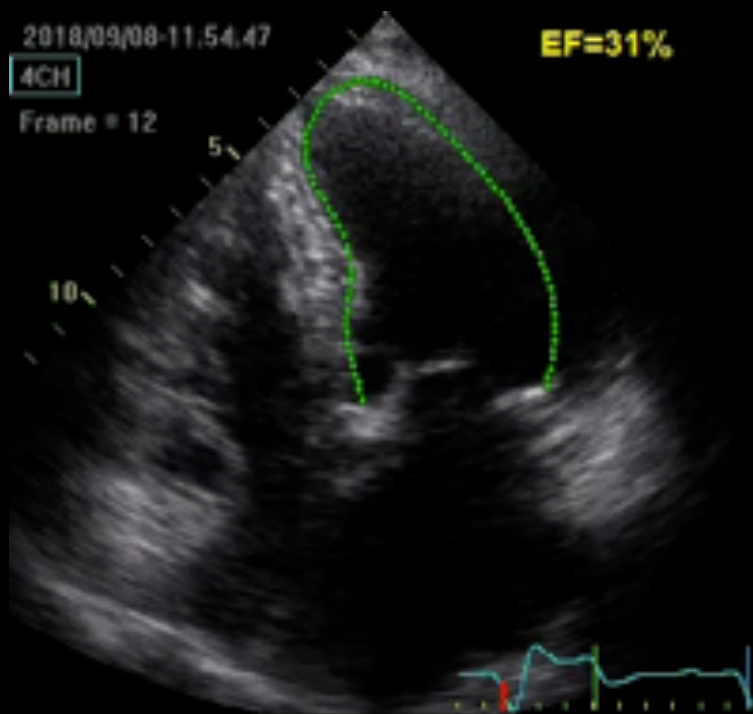


08/09/2018 11:54:52



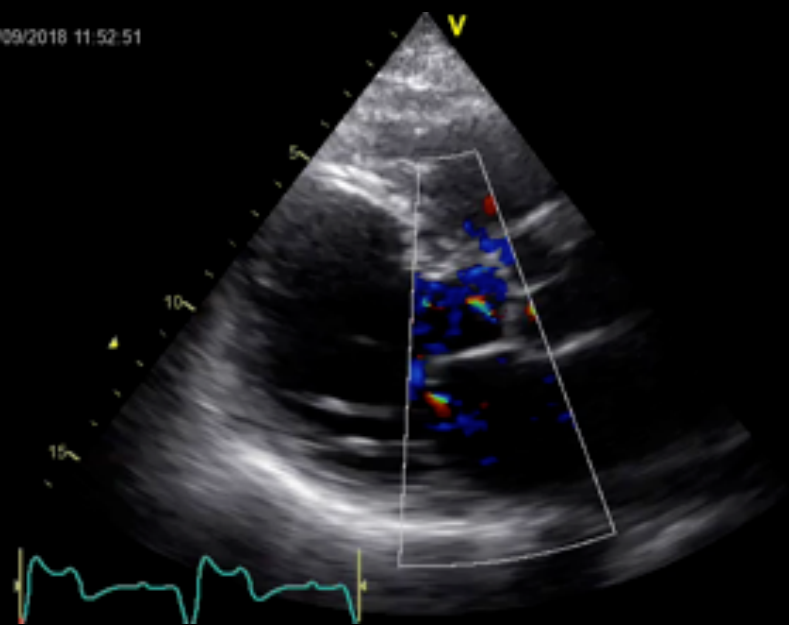
2:131 61 HR

# Casus: man 75jr, dyspnoe d'effort

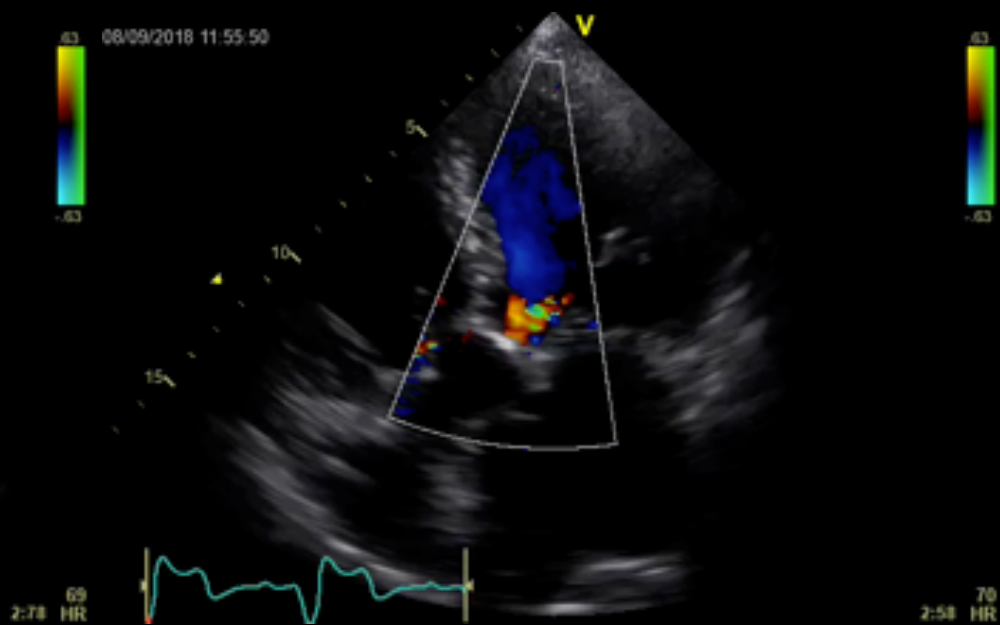


# AoI

08/09/2018 11:52:51

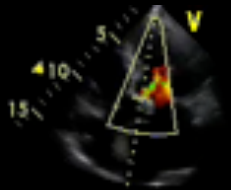


08/09/2018 11:55:50

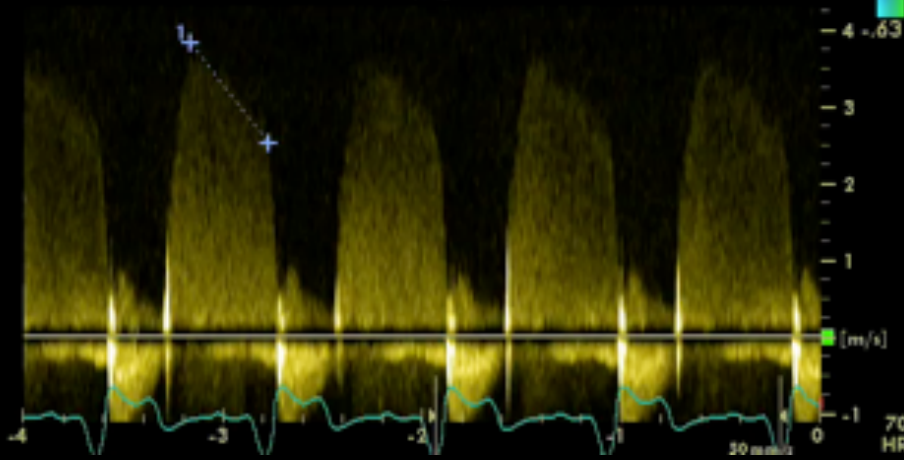
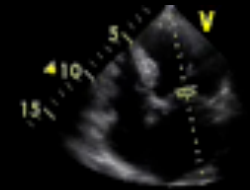


70 HR  
2:58

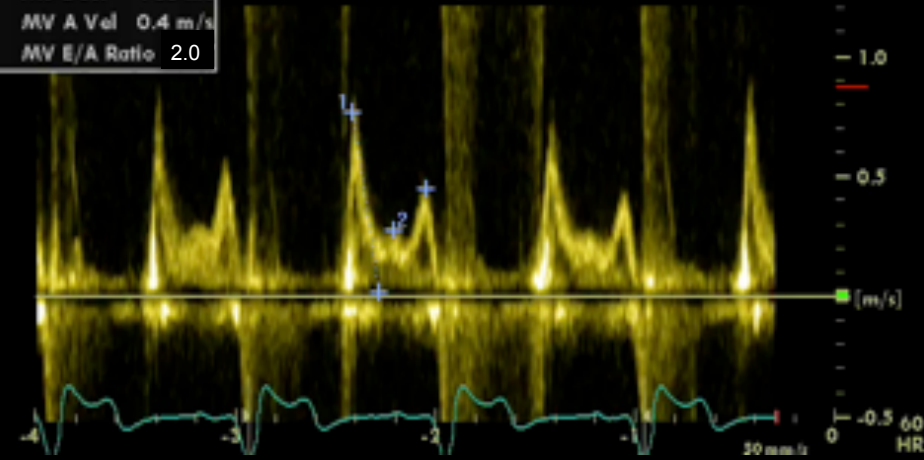
1 AR Vmax	3.8 m/s
AR maxPG	59 mmHg
AR PHT	300 m/s
AR DecTime	1145 ms



2 v	0.3 m/s
P	0 mmHg
Frq	0.70 kHz
1 MV E Vel	0.8 m/s
MV DecT	136 ms
MV A Vel	0.4 m/s
MV E/A Ratio	2.0



PHT 300ms



E/A 2.0

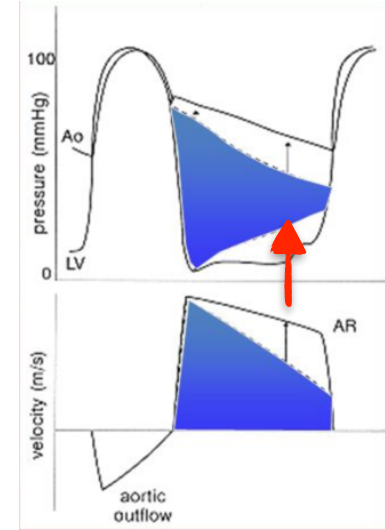
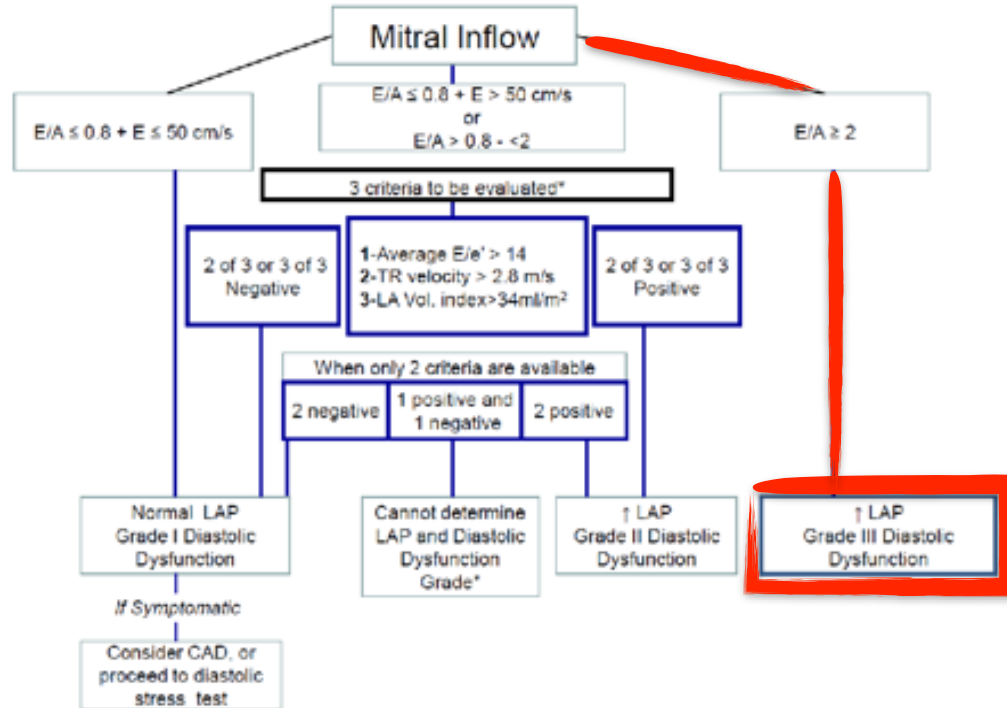
# Vraag

Er is bij deze patient sprake van

1. Milde aorta insufficiëntie en normale diastologie
2. Matige aorta insufficiëntie en normale diastologie
3. Milde aorta insufficiëntie en ernstige diastolisch dysfunctie
4. Ernstige aorta insufficiëntie en milde diastolisch dysfunctie



# Algoritme ter differentiëring bij sLVF



Ernstige diastolische dysfunctie geeft snelle verhoging van de LVED  
 Dit resulteert in een snellere Ao-LV druk equilibratie  
 Dit geeft een kortere PHT