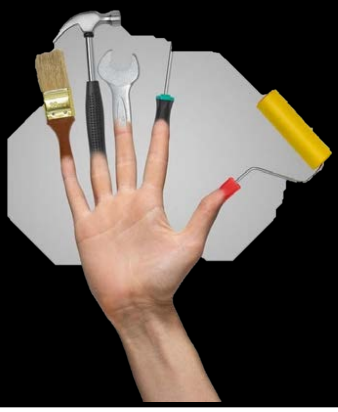
Practical Diastology… Tool Time!

Karen G. Zimmerman, BS, ACS, RDCS, RVT, FASE
HENRY FORD HEALTH SYSTEM
***DETROIT**, MI*



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2020

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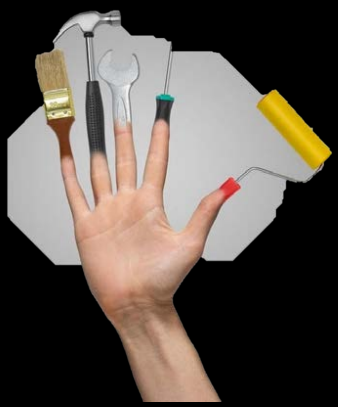
Disclosures: None



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Practical Diastology by Doppler

I. **Introduction**
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    A. Relax
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    D. Tissue Doppler Imaging
V. **Summary**

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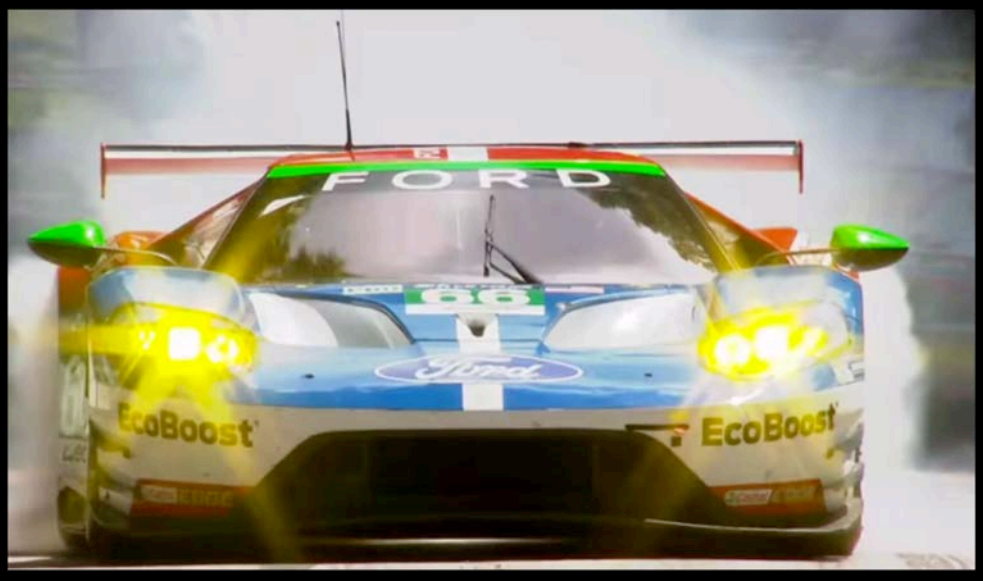
Tools for one of the finest machine around!



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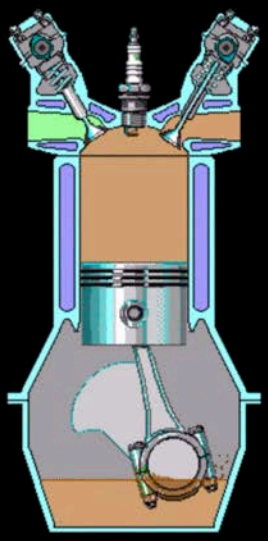
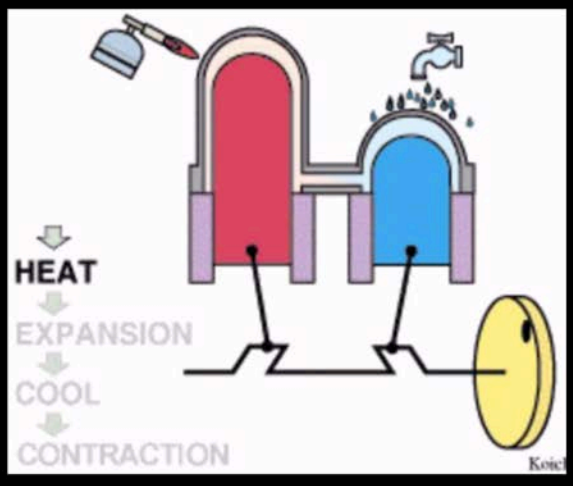
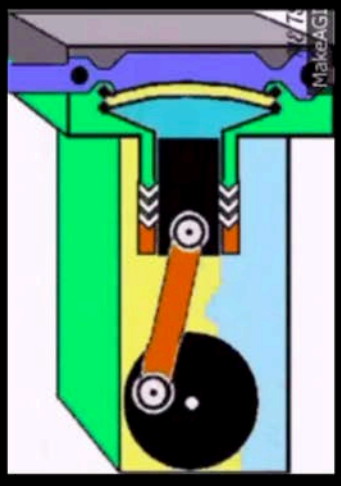
Let's start by looking under the hood

5

A pump must have good pistons!







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Diastole is about filling the ventricle

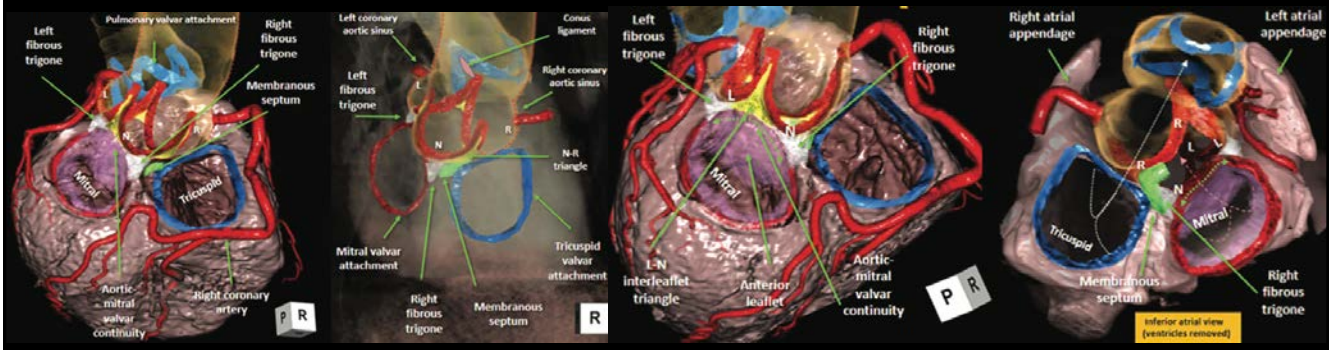
8

Must be relaxed to fill

9

10

Fibrous continuity and the atrioventricular plane



Saremi et al. RadioGraphics 2017;37:1330-1351

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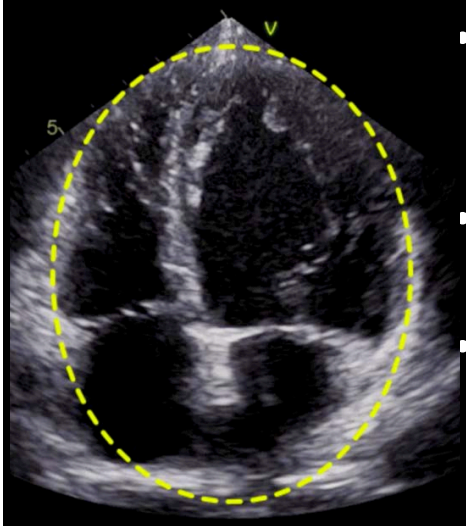
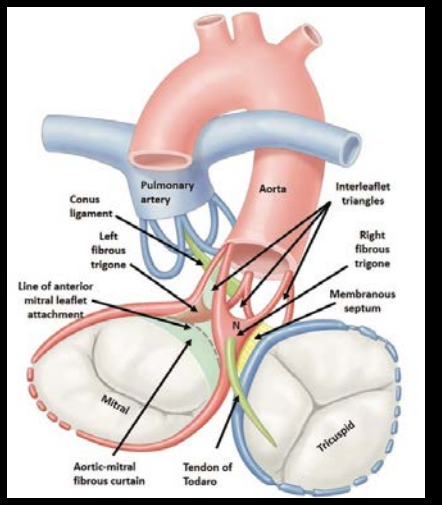
Filling left ventricular volume



- Outer contour relatively constant
- Apex is stationary
- Atria are attached to the large veins



http://folk.ntnu.no/stoylen/strainrate

Saremi et al. RadioGraphics 2017;37:1330-1351

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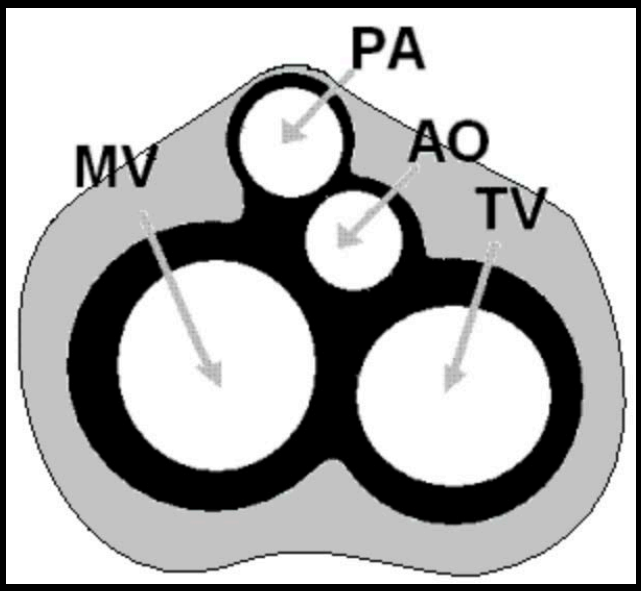
Atrioventricular plane (mitral annular relationship)



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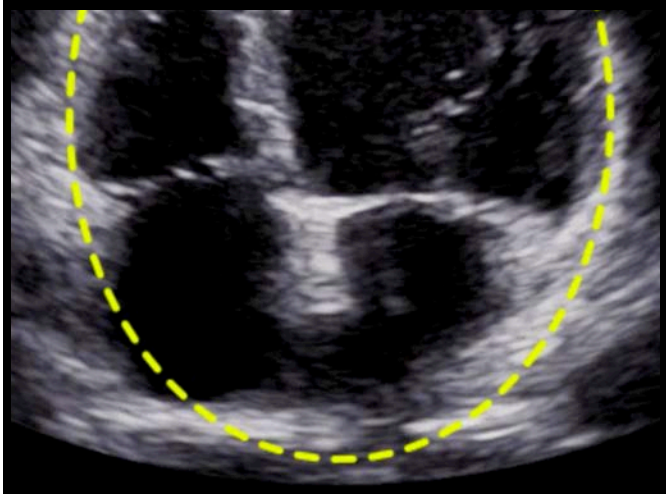
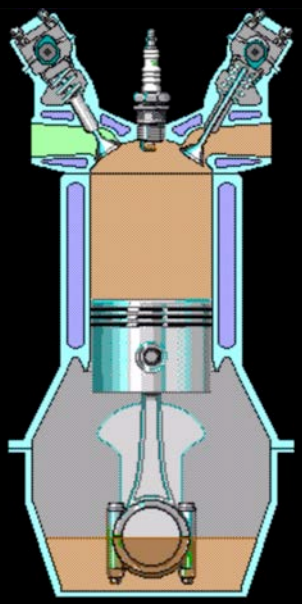
Atrioventricular plane is the piston of the pump



LA expands while LV shortens



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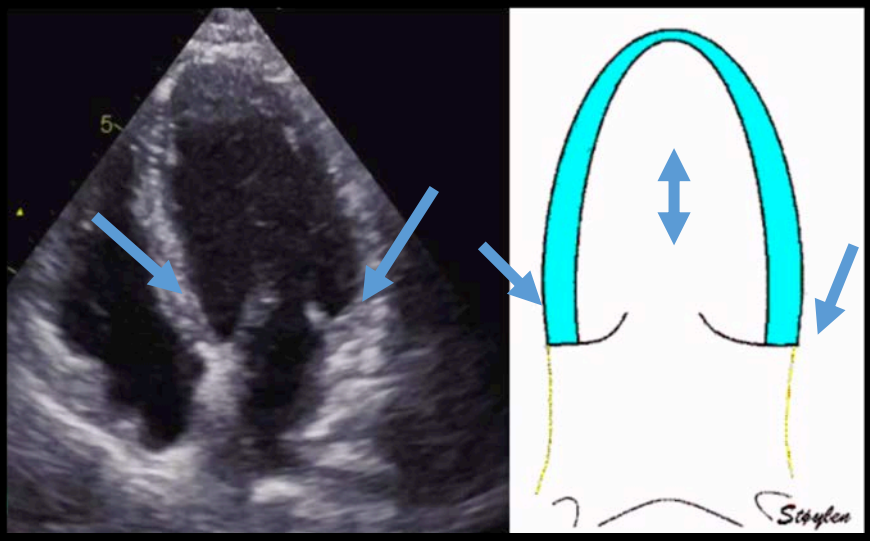
Chamber deformation reflects motion of atrioventricular plane (LA bigger- LV smaller)



http://folk.ntnu.no/stoylen/strainrate

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Ventricular compliance (flexibility) a measure of distensibility

Size, shape

Pericardium, RV, pleural effusion

Tissue characteristics (thick, speckled, infiltrated)

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What does this have to do with the Left Atrium?

LAE and elevated LAP

LAE and normal LAP

No LAE and normal LAP

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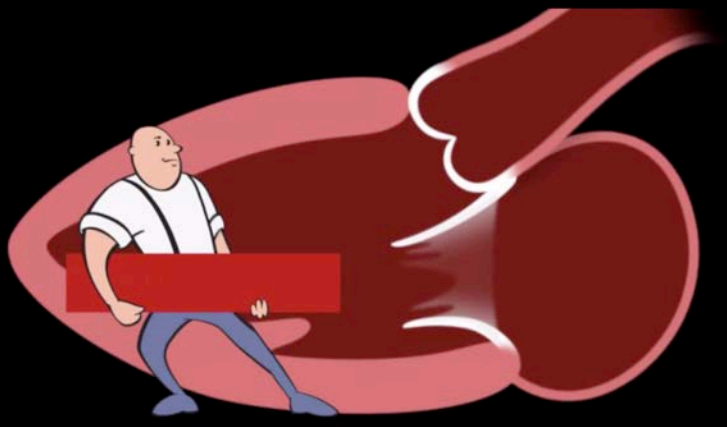
Blood is “pulled” into the LV from the LA



Oh, Jae et al. Circulation: Cardiovascular Imaging. 4(4):444-455, July 2011.

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Does the left ventricle relax and expand to fill?

What is happening in left atrium ?

Is there evidence of diastolic dysfunction?

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Diastolic dysfunction (DD) = impaired relaxation and increased chamber stiffness.

Non-compliance leads to increased left atrial filling pressures (LAP)

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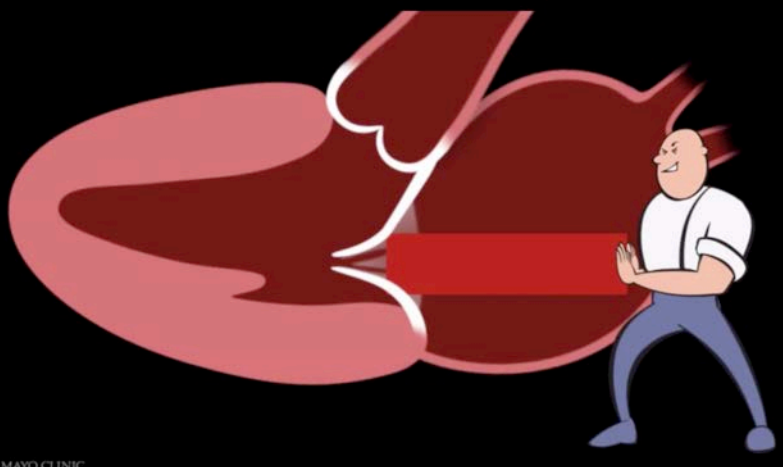
Blood is "pushed" into ventricle by way of increased left atrial pressure (LAP)



Oh, Jae et al. Circulation: Cardiovascular Imaging. 4(4):444-455, July 2011.

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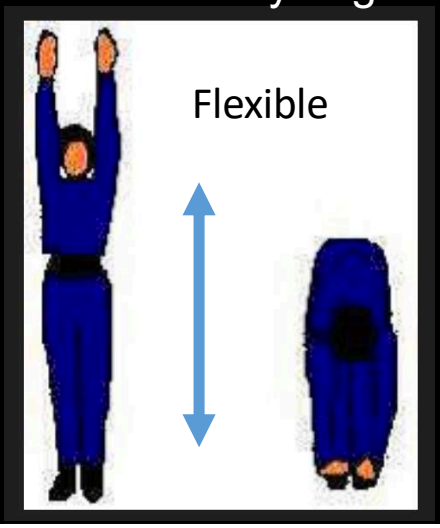
This is Bad

23

Stiffness is bad! Flexibility is good!

This difference in stretch is very small
Not flexible

This difference in stretch is very large



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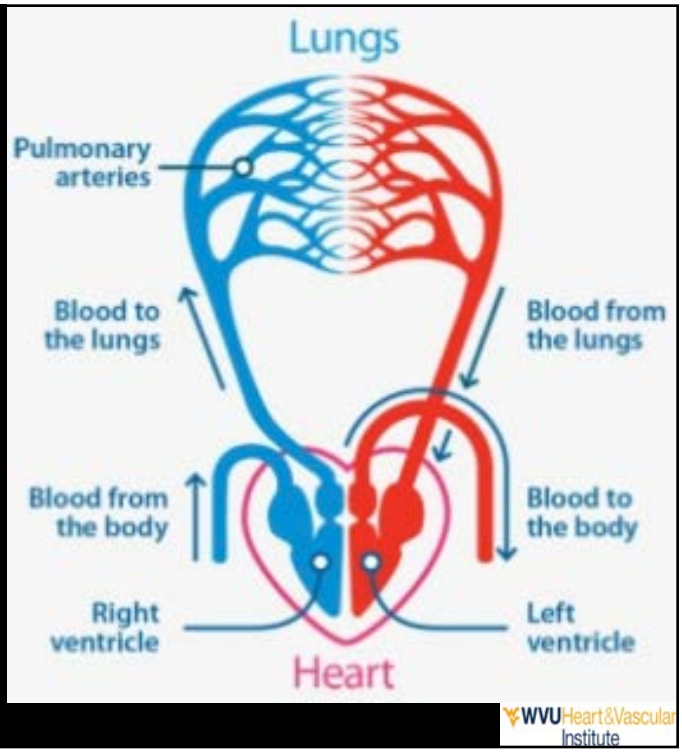
Heart Failure is a consequence of poor LV filling

Diastolic Dysfunction



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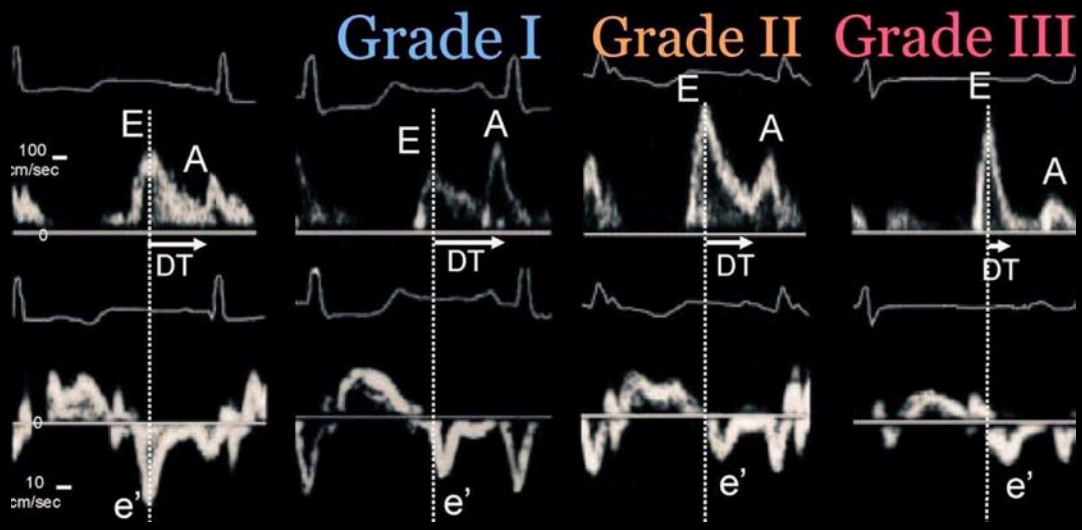
Grades of Diastolic Dysfunction Detected by Doppler Imaging



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Echocardiography #1 Tool for Diastolic Dysfunction and Heart Failure

- Cardiac anatomy
- Valve structure
- Wall thickness
- Chamber sizes
- Filling pressures

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Sonographer holds all the tools for diastolic assessment

- Fundamental to <u>every</u> single study
- Cursor placement and understanding is essential to guide therapy

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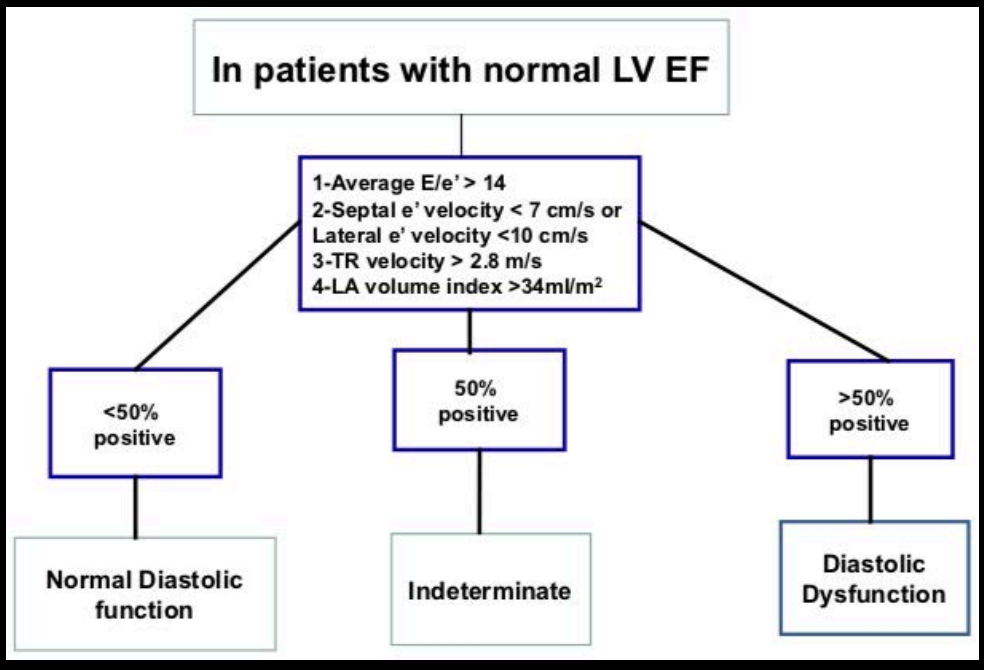

Nagueh, S F et al. J Am Soc Echocardiogr 2016:29:277-314

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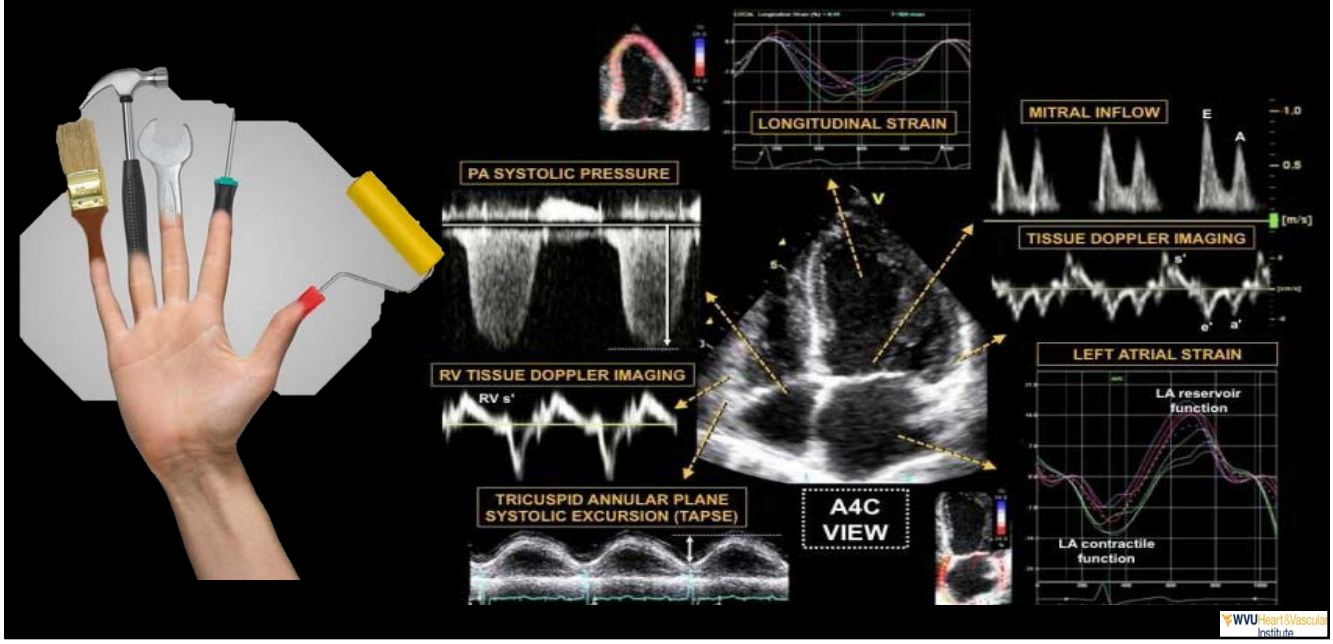
There are a number of ways to assess



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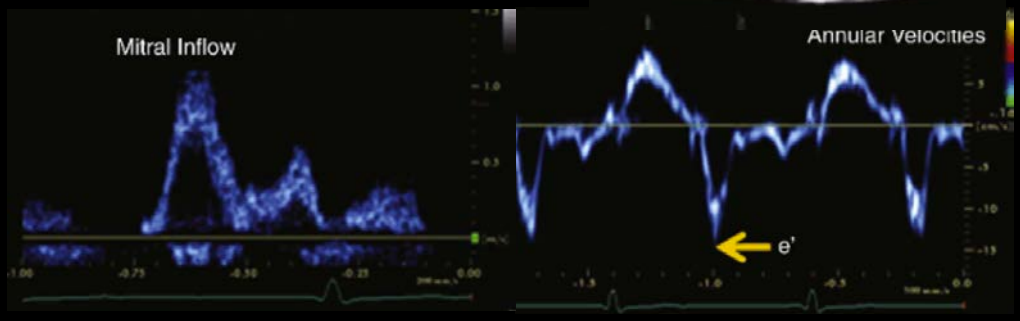
3 key measurements in every exam

- LA Volume
- Mitral Inflow
- Mitral Annular Velocities



Otto CM, ed. *The Practice of Clinical Echocardiography, 5th edition.* Elsevier Saunders, Philadelphia, Pennsylvania 2016

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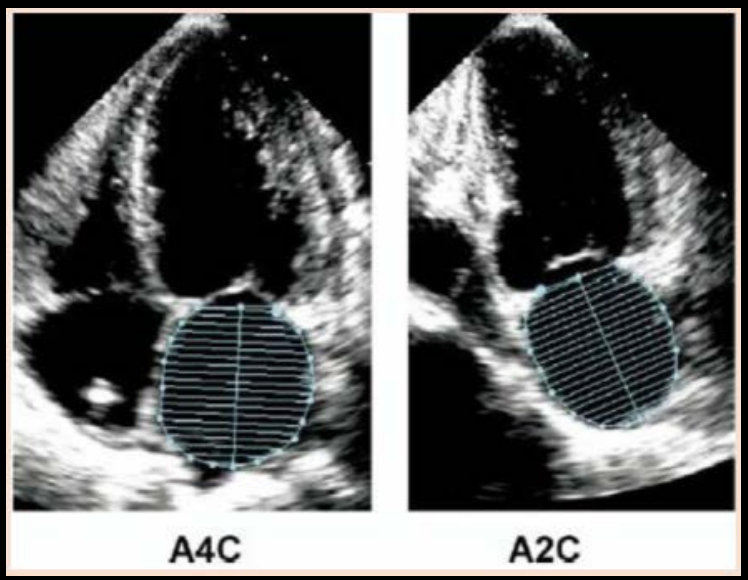
LA Volume Index

Good ≤ 34 mL/m²



Lang et al. Journal of the American Society of Echocardiography 2015 28, 1-39.e14DOI: (10.1016/j.echo.2014.10.003)

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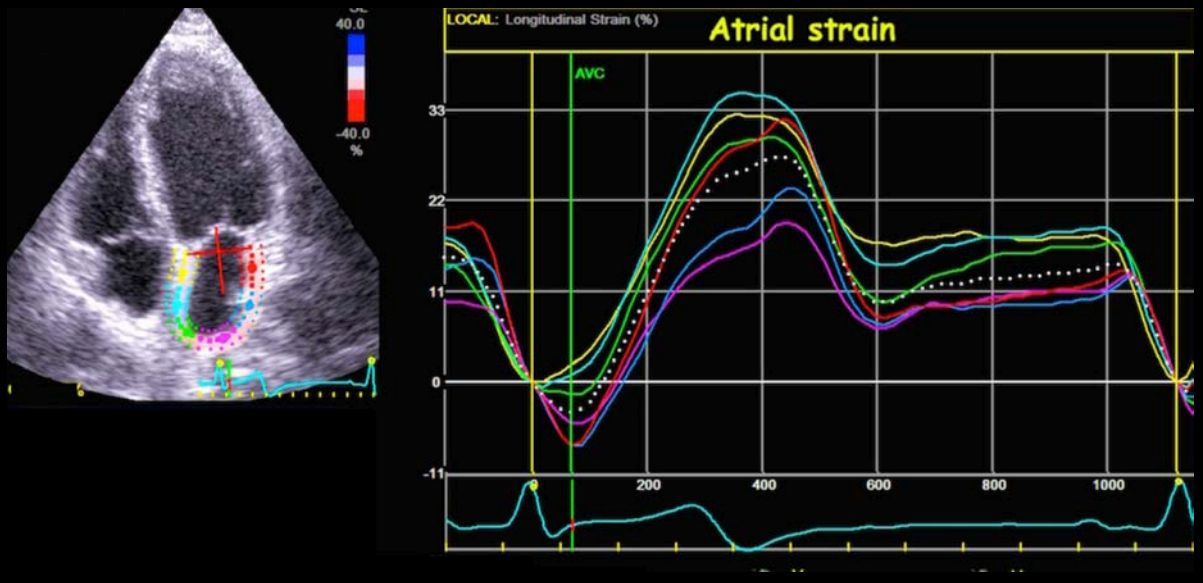
Left Atrial Strain



http://folk.ntnu.no/stoylen/strainrate

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How does the Left Atrium respond?

LAE and elevated LAP

LAE and normal LAP

No LAE and normal LAP

WVU Heart & Vascular Institute

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The real keys lie in Doppler imaging!

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Pulsed-wave Doppler imaging: Mitral Inflow and Stroke Volume

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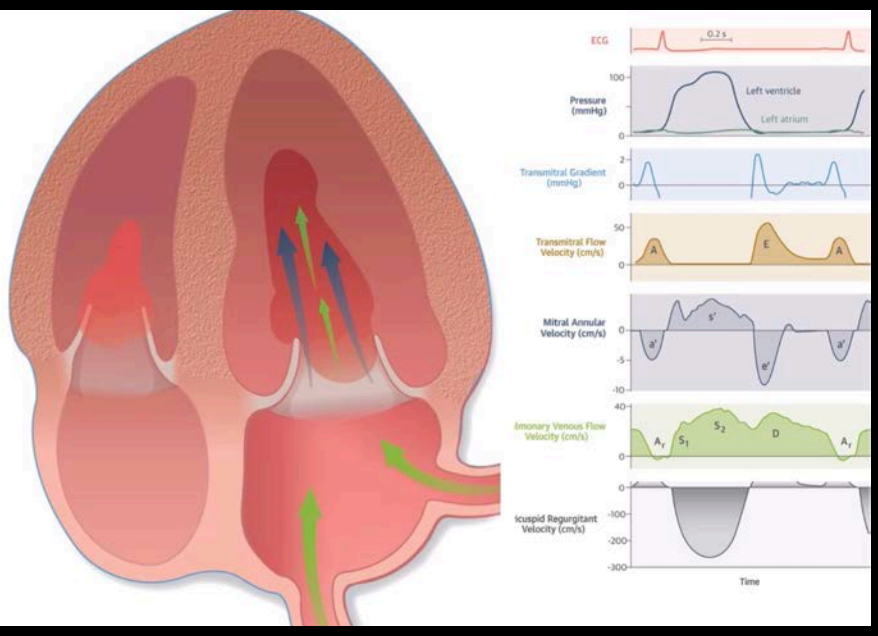
Doppler flow measured at the mitral valve tips reflect the maximal pressure differences between the left atrium and the left ventricle



Flachskampf, F.A. et al. J Am Coll Cardiol Img. 2015;8(9):1071-93

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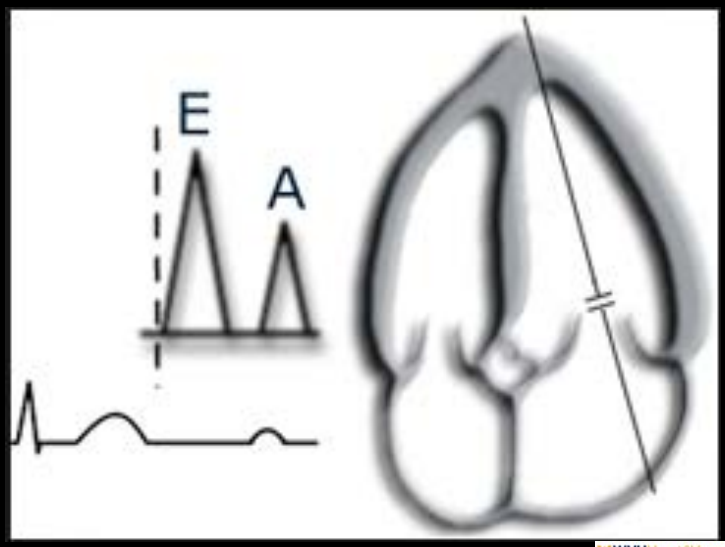
Mitral Inflow

- Early Rapid Filling E-wave
- Atrial kick A-wave, late filling is more about LV compliance



WVU Heart & Vascular Institute

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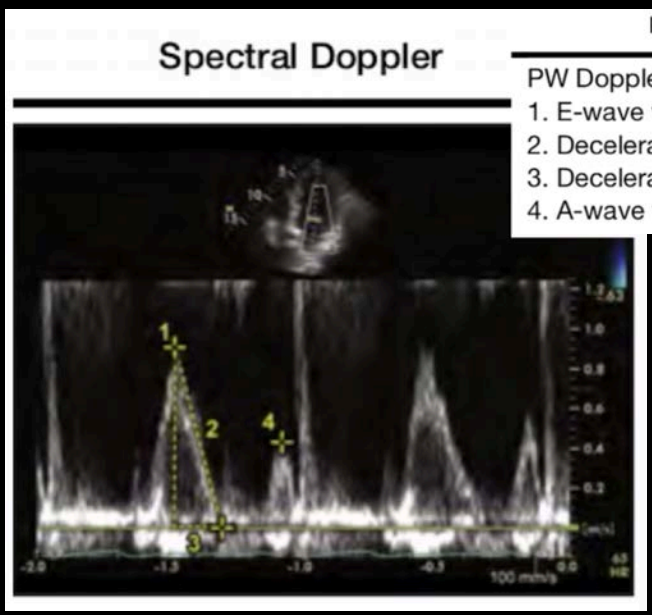
Location, Location, Location!



Mitchell et al. Journal of the American Society of Echocardiography DOI:(10.1016/j.echo.2018.06.004)

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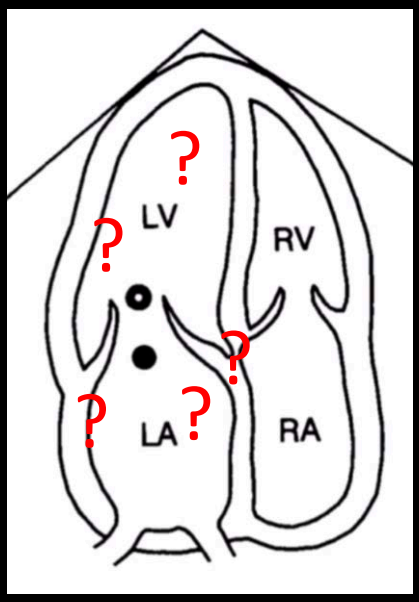
and often misplaced!



Ding et al J Am Soc Echocardiogr 1991;4:451-6

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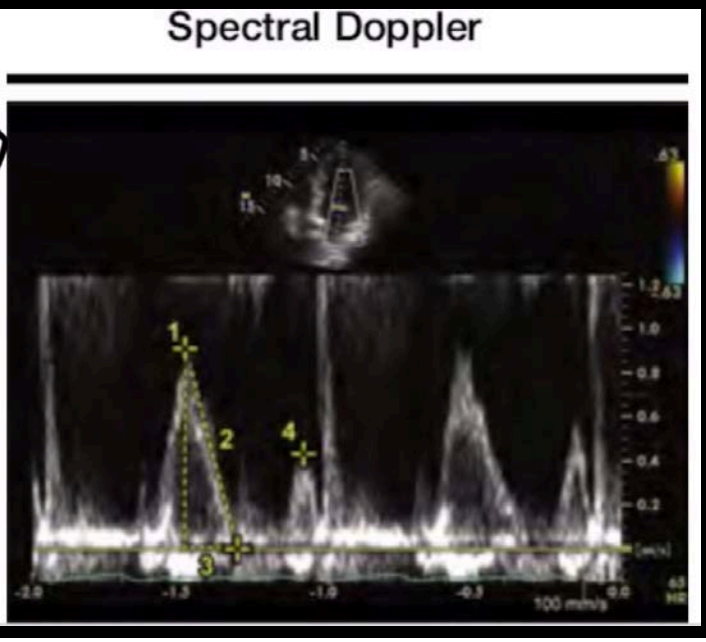
So, EXACTLY WHERE is the right location?



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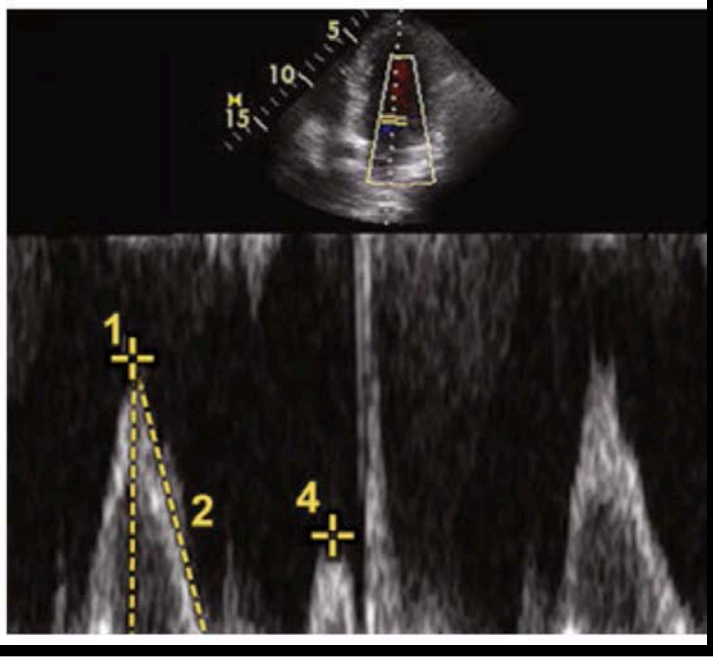
Even when extremely zoomed in, hard to tell..
Where exactly is this?

Does it really matter?



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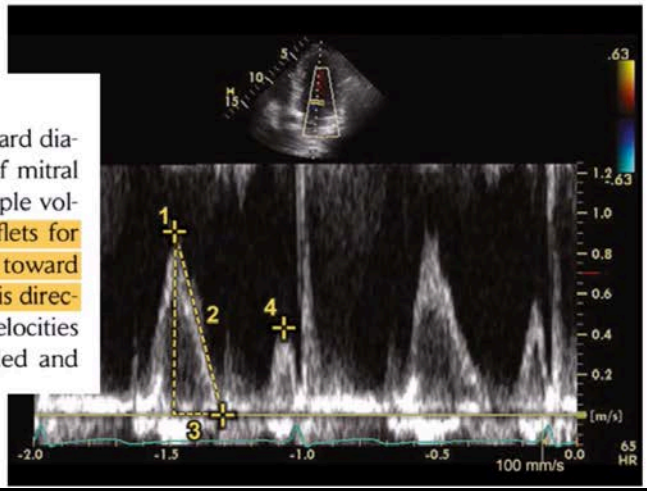
Guidelines say at the tips toward lateral wall... lateral wall?

C. MV

Spectral Doppler is used to characterize the patterns of forward diastolic flow across the MV and to measure several indices of mitral regurgitation, if present. In the A4C view, a 1- to 3-mm sample volume should be positioned at the tips of the open MV leaflets for PW Doppler recording. The sample volume should be placed toward the lateral wall, as blood normally flows across the valve in this direction. The peak E (early diastolic) and A (atrial contraction) velocities and MV early diastolic deceleration time should be recorded and



Mitchell et al. Journal of the American Society of Echocardiography DOI:(10.1016/j.echo.2018.06.004)

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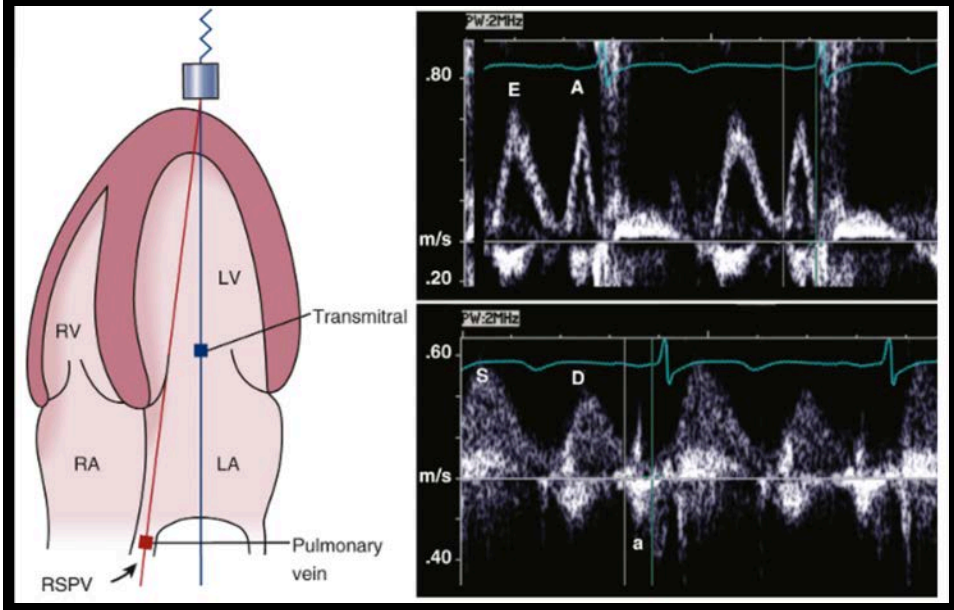
Apical 4C view, PW mitral leaflet tips



- **Low filter and gain settings**
- **Measure peak at leading edge of spectral waveform**

Otto CM, ed. *The Practice of Clinical Echocardiography, 5th edition.* Elsevier Saunders, Philadelphia, Pennsylvania 2016

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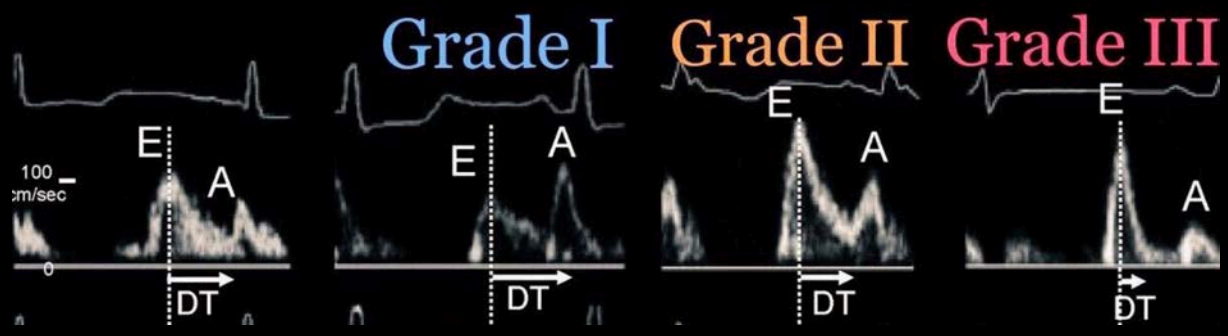
Grades of Diastolic Dysfunction detected by Doppler imaging



Normal | Mild | Pseudonormal | Severe Restrictive

@HeartToProve/Twitter

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Different strokes for different folks

- **Sample volume located at mitral annulus gives stroke volume:**
  - calculation for mitral regurgitation
  - assessment of diastolic filling fractions

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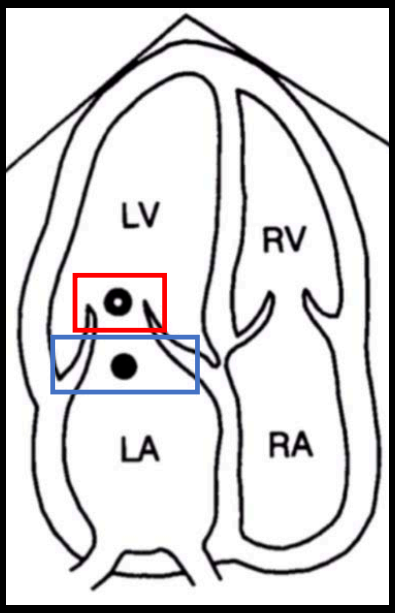
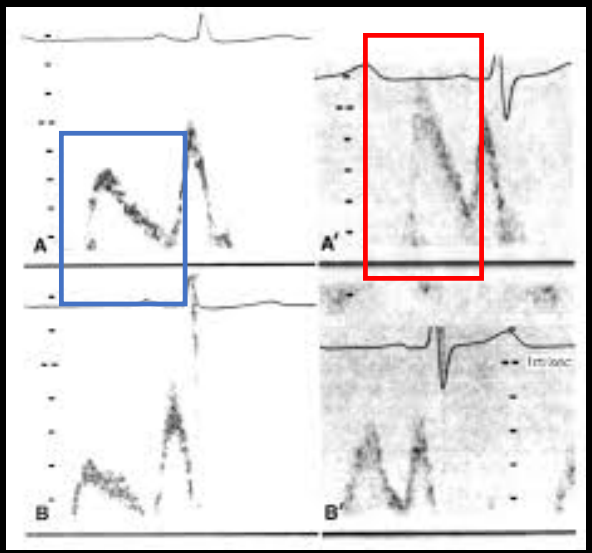
Placement matters!



Ding et al J Am Soc Echocardiogr 1991;4:451-6



SV annulus **SV leaflet tips**

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- Tips for inflow pressure gradients

Ding et al J Am Soc Echocardiogr 1991;4:451-6

Velocities are *significantly* higher at leaflet tips, (smaller area)

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Stroke Volume

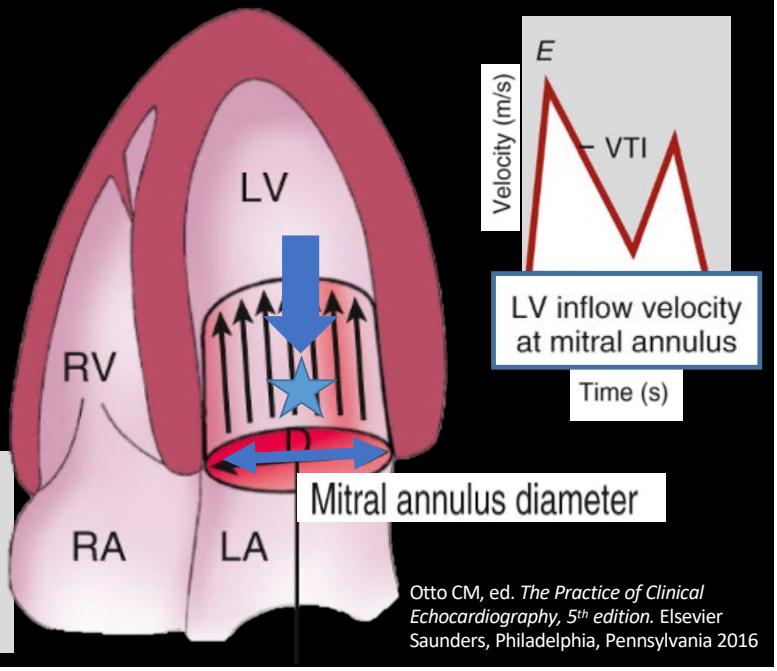
Calculate across mitral annulus:

- **Tracing the VTI**
- **Cross-sectional diameter at same location**

$$CSA = \pi(D/2)^2$$

Transmittal SV = CSA x VTI

Peak filling rate = *E* velocity x CSA



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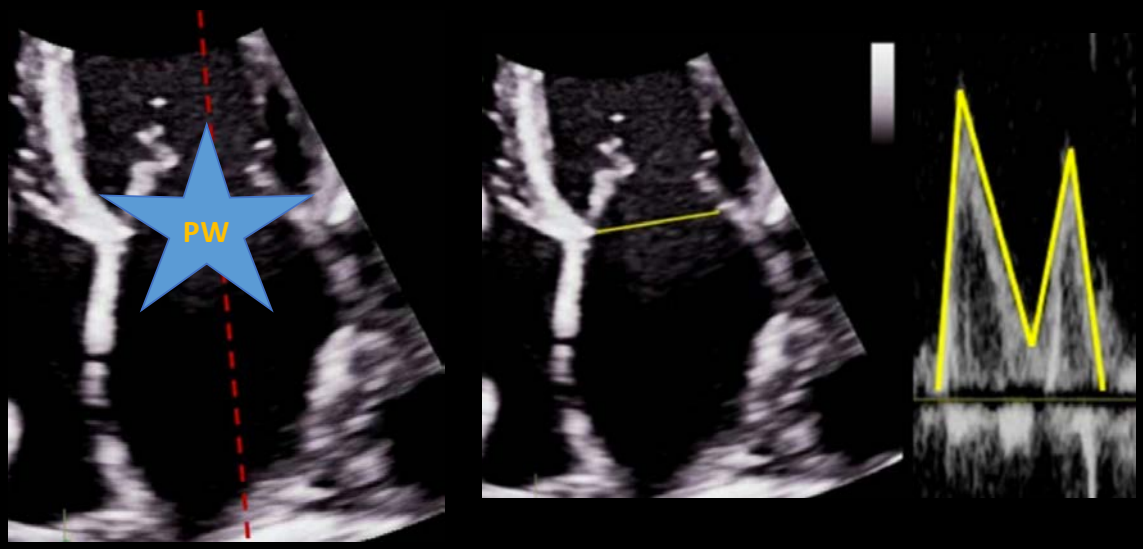
Stroke Volume PW cursor placement must be taken at same location as annular diameter!



@CardioServ

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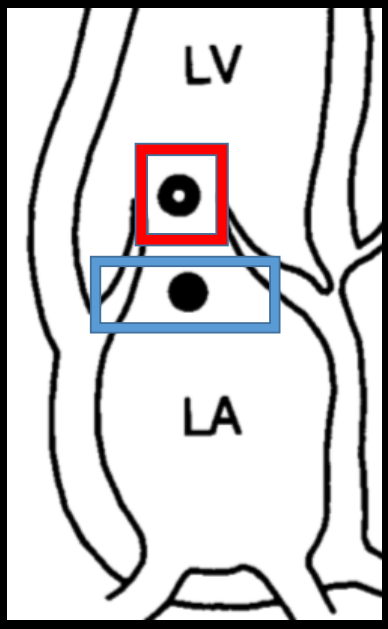

Higher velocity through smaller area

Ding et al J Am Soc Echocardiogr 1991;4:451-6

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***For <u>Diastolic</u>* assessment, Pulsed-Wave Doppler mitral inflow velocities…**

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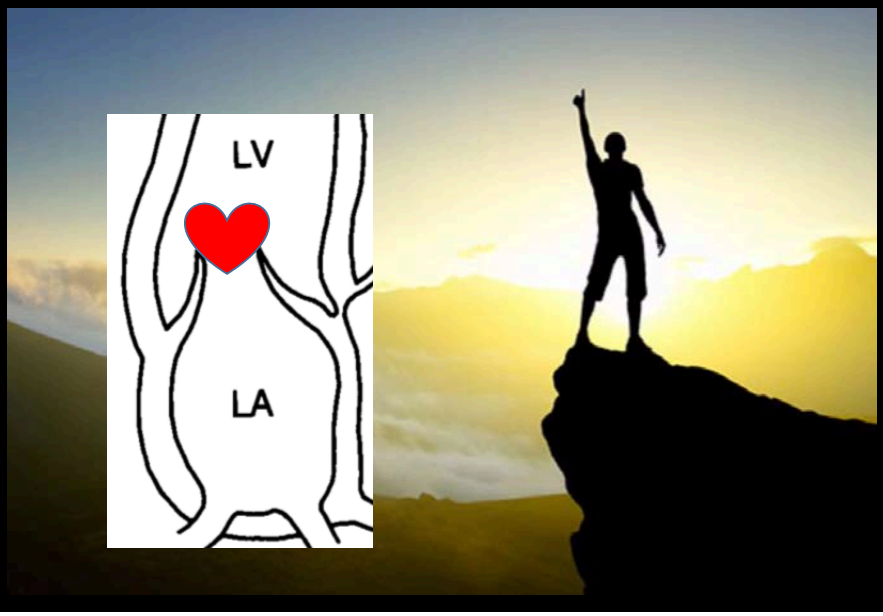
….take it *to the TOP!*



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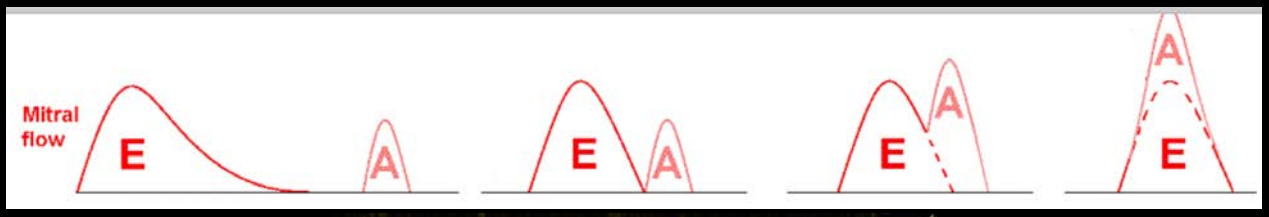
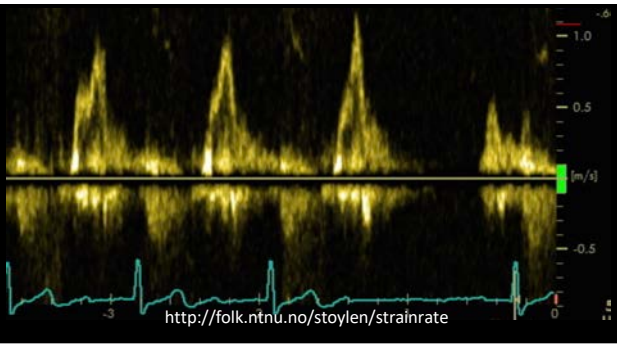
Short comings of mitral inflow

High heart rate = E at A fusion (>20 cm/sec)





http://folk.ntnu.no/stoylen/strainrate

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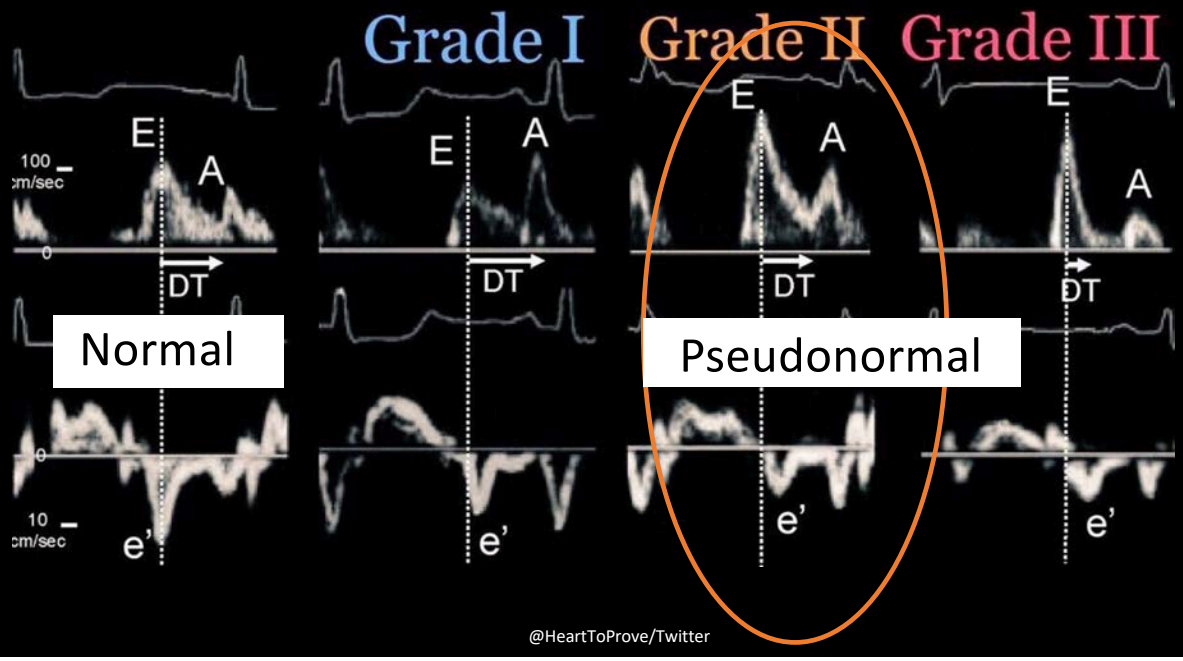
Pseudonormal pattern



@HeartToProve/Twitter

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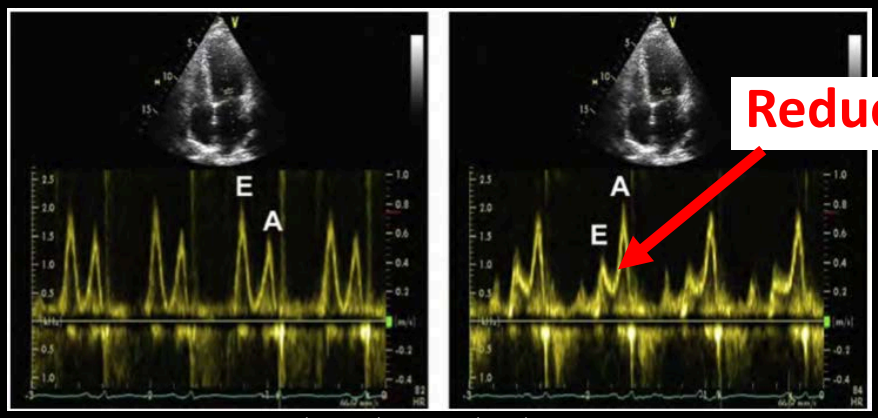
Short comings of mitral inflow

- **Pseudonormal pattern**
  - Valsalva reduces LA pressure
  - E and A will reverse with impaired filling



Nagueh, S F et al. J Am Soc Echocardiogr 2016:29:277-314

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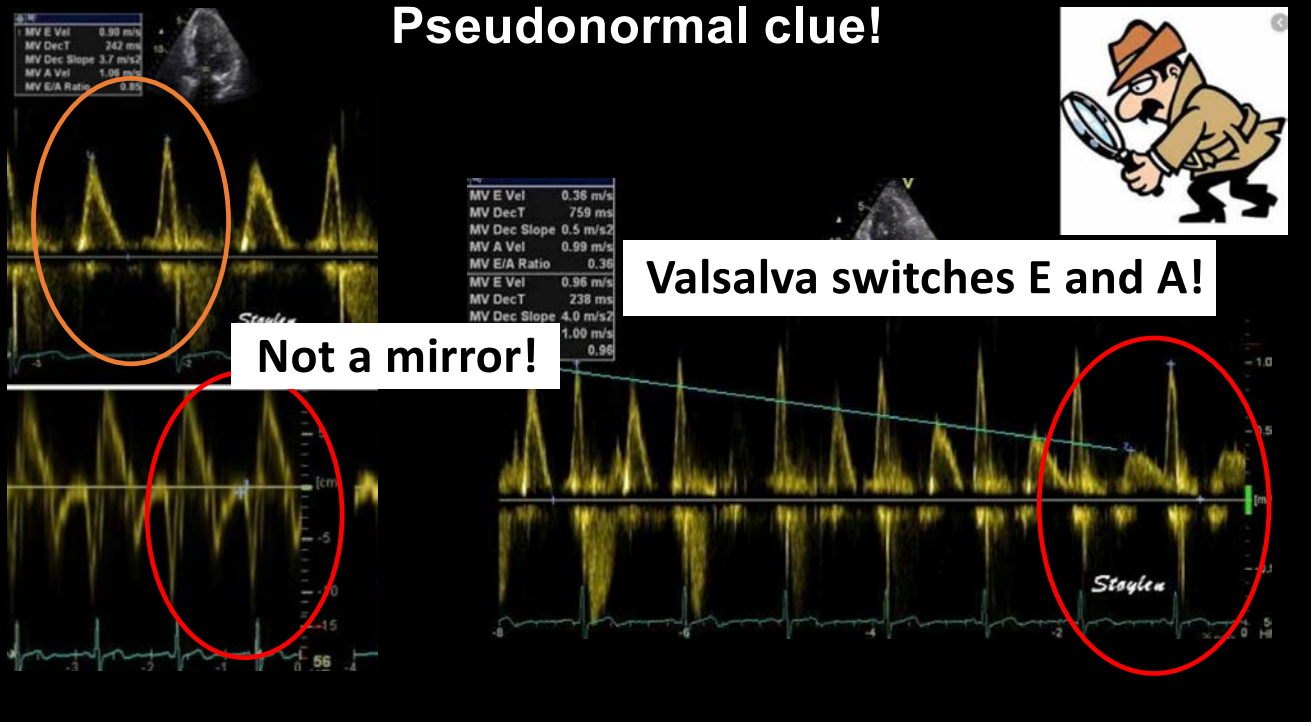
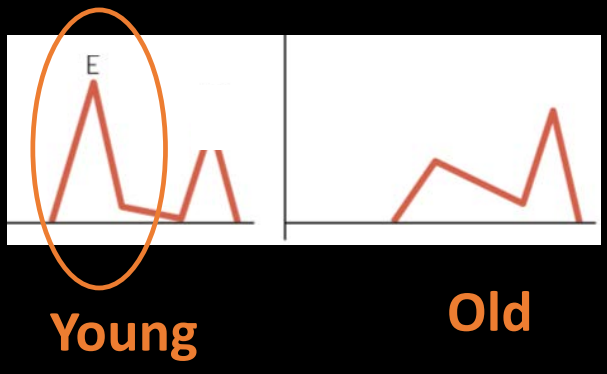
Pseudonormal clue!

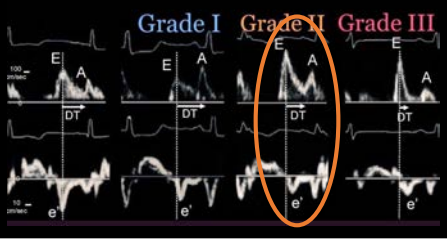


60

Short comings of mitral inflow

Young age (healthy hearts) often display Pseudonormal or restrictive pattern with high E/A ratios





Sidebotham DA, ed. *Practical Perioperative Transesophageal Echocardiography, 3rd edition*. Oxford University Press, Oxford, England 2018

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Short comings of mitral inflow

- Mitral Regurgitation = ↑ Volume LA and LV
- ↑ Peak Velocity (E-wave) of Early Diastolic Filling
- ↑ End-Diastolic Dimension (LVEDD)
- ↓ End-Systolic Dimension, with a Supranormal EF.
- The extra volume also increases LAP (not necessarily LV dysfunction)

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Continuous-wave Doppler Imaging: Mitral Regurgitation

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MR CW in Systole

- Signal intensity relative to antegrade flow
- Antegrade flow velocity
- Time course (shape) of velocity curve

Otto CM, ed. *Textbook of Clinical Echocardiography, 5th edition.* Elsevier Saunders, Philadelphia, Pennsylvania 2016

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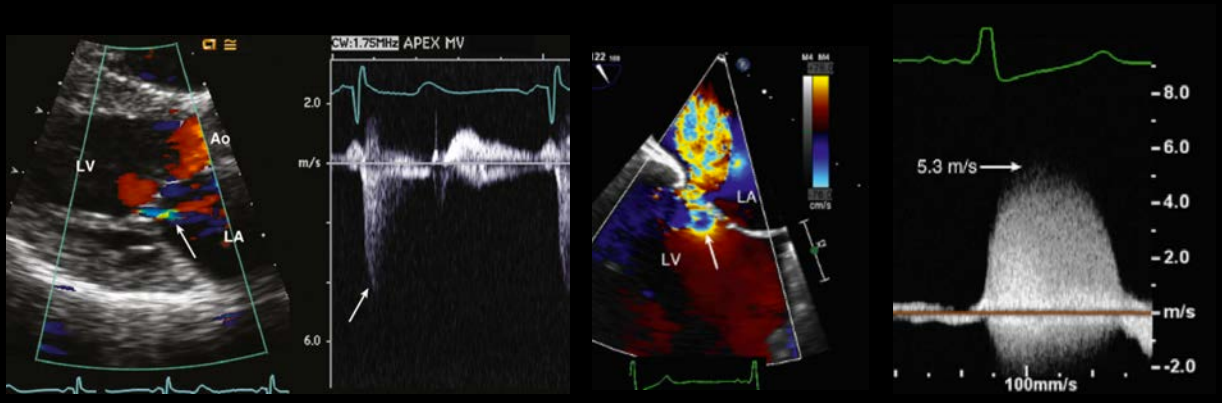
Signal intensity relative to antegrade flow

- Proportional to number of blood cells contributing to regurgitant signal
- Very helpful to compare intensity of signal



Otto CM, ed. *Textbook of Clinical Echocardiography, 5th edition.* Elsevier Saunders, Philadelphia, Pennsylvania 2016

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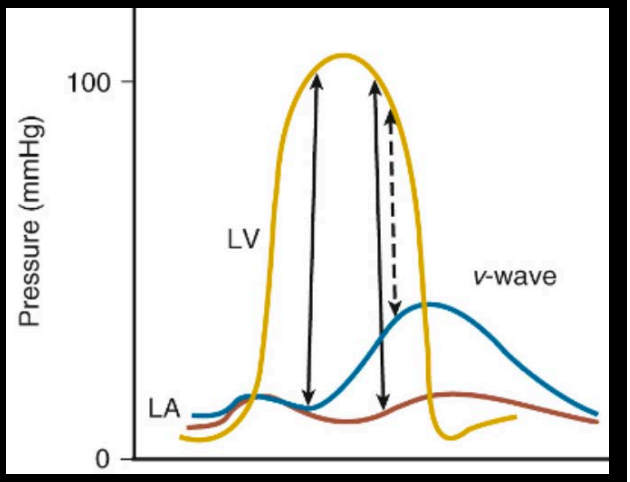
Antegrade flow velocity

- Increased antegrade volume flow rate across valve, results in increased velocity across valve
- Peak regurgitant velocity determined by LV-LA pressure gradient



Otto CM, ed. *Textbook of Clinical Echocardiography, 5th edition.* Elsevier Saunders, Philadelphia, Pennsylvania 2016

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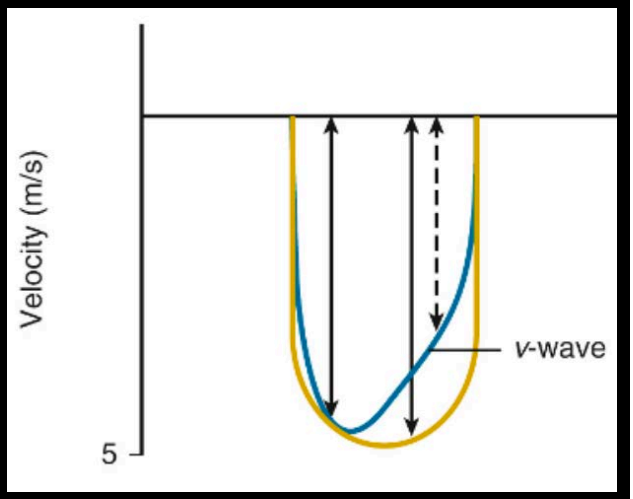
Antegrade flow velocity

- Typically 5-6 m/s
- CW velocity specific for increased LAP (early peaking)
- Greater the severity of MR, higher antegrade velocity



Otto CM, ed. *Textbook of Clinical Echocardiography, 5th edition.* Elsevier Saunders, Philadelphia, Pennsylvania 2016

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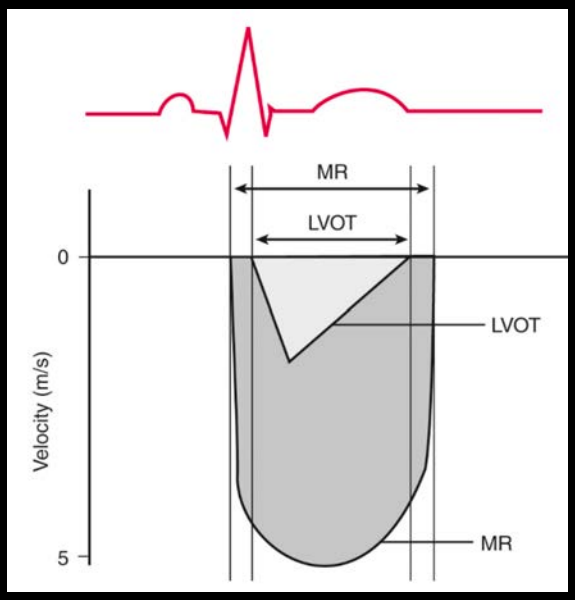
Time course (shape) of velocity curve

- Depends on time-varying pressure gradient
- Related to instantaneous pressure across valve (Bernoulli)



Otto CM, ed. *Textbook of Clinical Echocardiography, 5th edition.* Elsevier Saunders, Philadelphia, Pennsylvania 2016

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Bottom Line : MR = Extra Volume

- Increase LV Stroke Volume
- Increase LAP
- Increase LA Size
- Shape, timing and intensity determine severity

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Tissue Doppler Imaging (TDI) Annular Velocities

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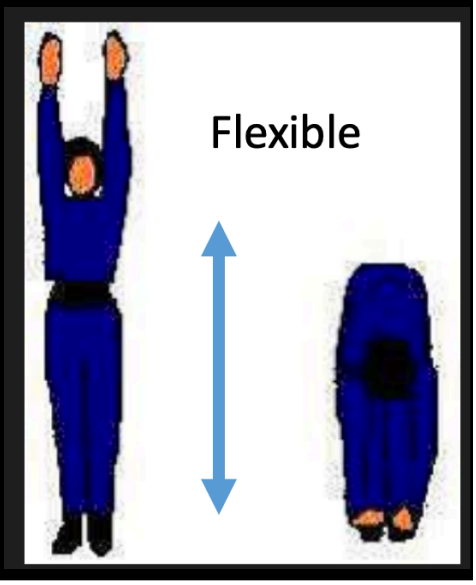
Measures <u>One</u> Direction of Stretch

- Quick, easy and reliable
- Less preload dependent
- <u>Very angle dependent</u>



Gorcsan J MSE 2017

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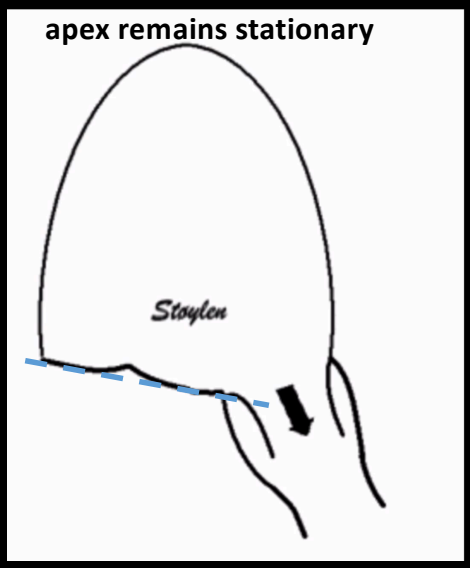
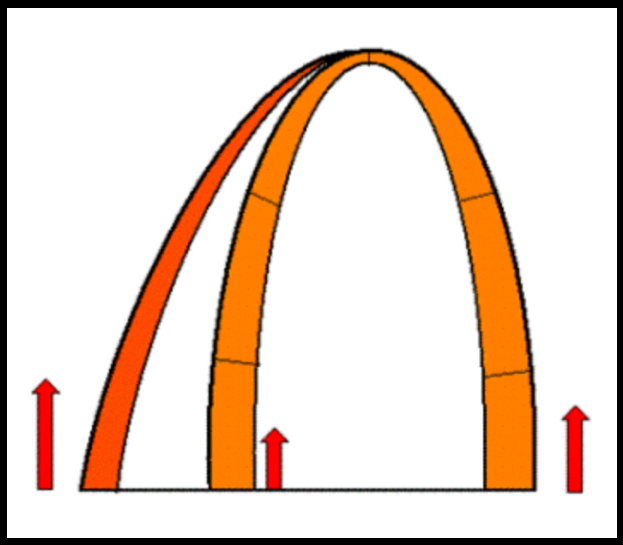
Cycle of atrioventricular plane





http://folk.ntnu.no/stoylen/strainrate

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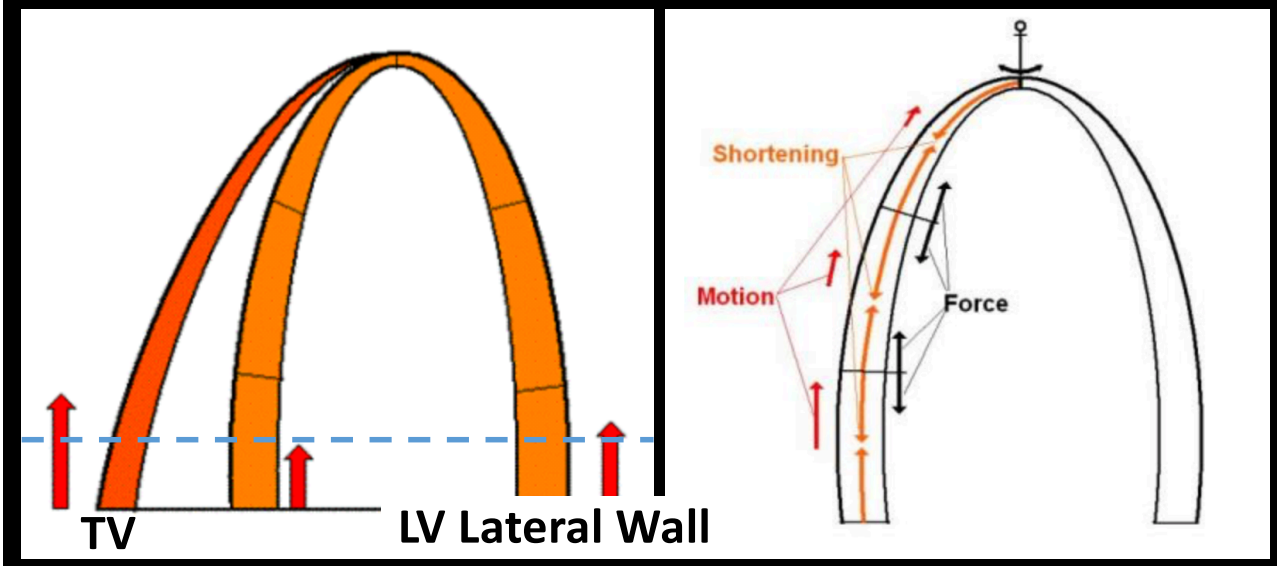
Atrioventricular plane (mitral annular motion)



http://folk.ntnu.no/stoylen/strainrate

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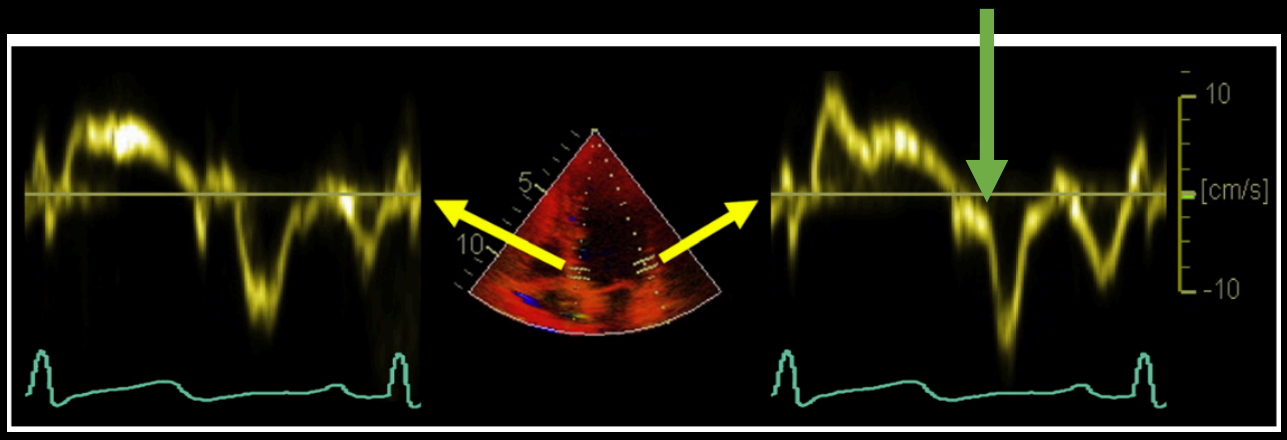
Normal Tissue Doppler Imaging cursor placement



Mor-Avi et al J Am Soc Echocardiogr 2011;24:277-313

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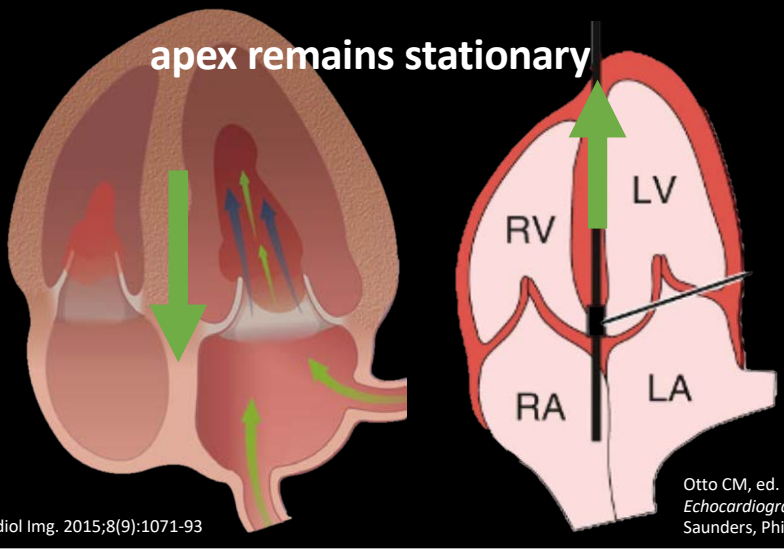
Movement of the Mitral Annulus

Go with the Flow!

apex remains stationary



Flachskampf, F.A. et al. J Am Coll Cardiol Img. 2015;8(9):1071-93

Otto CM, ed. *Textbook of Clinical Echocardiography, 5th edition.* Elsevier Saunders, Philadelphia, Pennsylvania 2016

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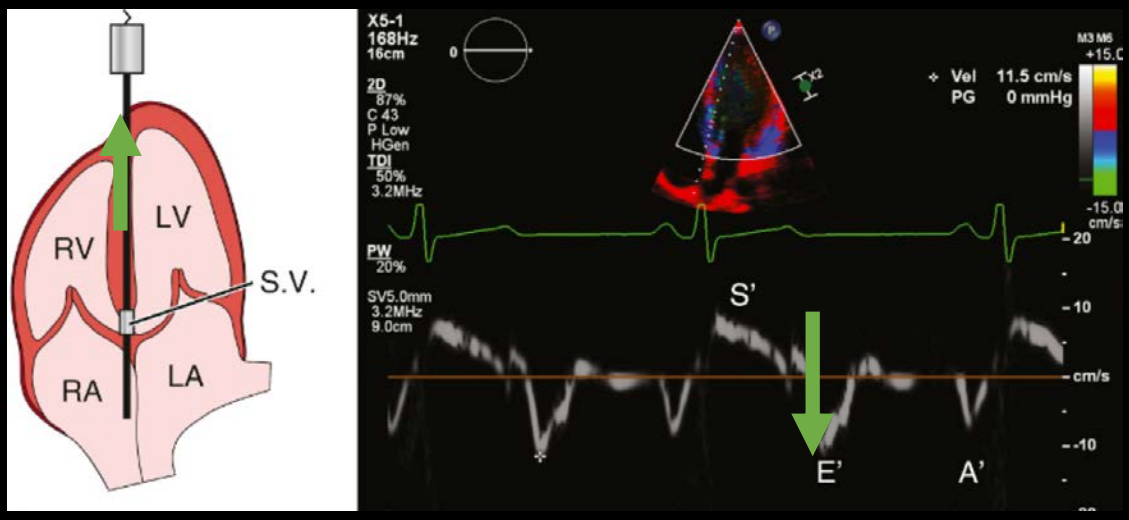
Tissue at the mitral annulus, On LV Side (where annulus moves, pulling valve open during ventricular filling)



Otto CM, ed. *Textbook of Clinical Echocardiography, 5th edition.* Elsevier Saunders, Philadelphia, Pennsylvania 2016

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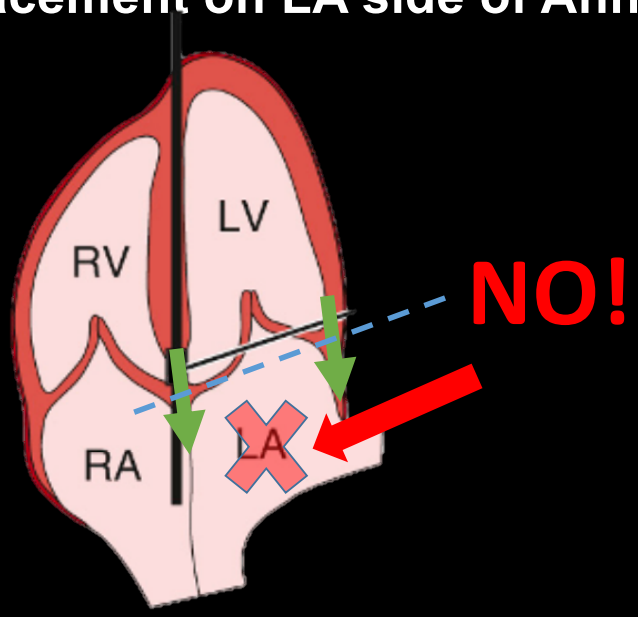
#1 Error is Placement on LA side of Annulus!



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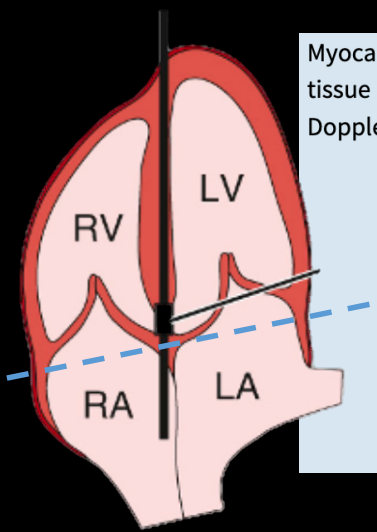
Basal segment of septal wall
Don't forget which side of fence contains LV!



Myocardial tissue Doppler	Pulsed Doppler	A4C with 2–4-mm sample volume placed within basal segment of septal wall	High TEE 4-chamber view with 2–3-mm sample volume placed within basal segment of septal wall	Very low gain settings, low wall filters	*E'* = early diastolic filling velocity (m/s) *A'* = filling velocity after atrial contraction (m/s) *E/E'* = ratio of LV inflow *E* velocity to tissue Doppler

Otto CM, ed. *Textbook of Clinical Echocardiography, 5th edition.* Elsevier Saunders, Philadelphia, Pennsylvania 2016

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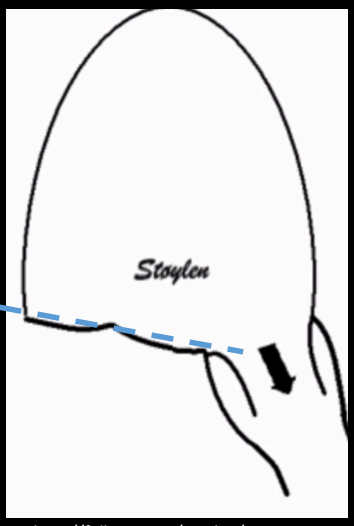
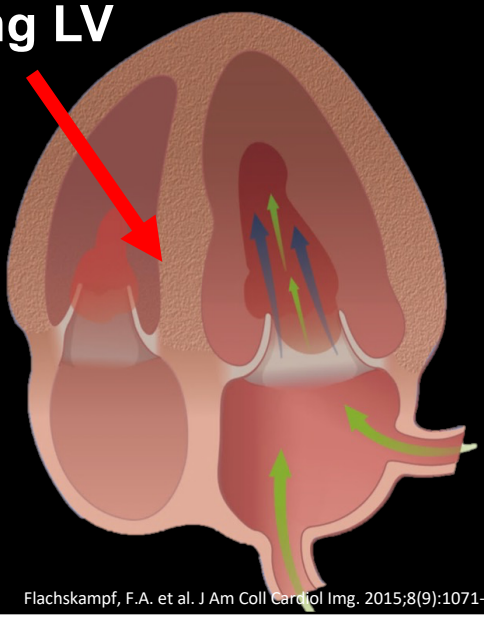
Tissue (red arrow) adjacent to fibrous mitral annulus pulls away from apex (Diastole) - opening mitral leaflets widening and filling LV



http://folk.ntnu.no/stoylen/strainrate



Flachskampf, F.A. et al. J Am Coll Cardiol Img. 2015;8(9):1071-93

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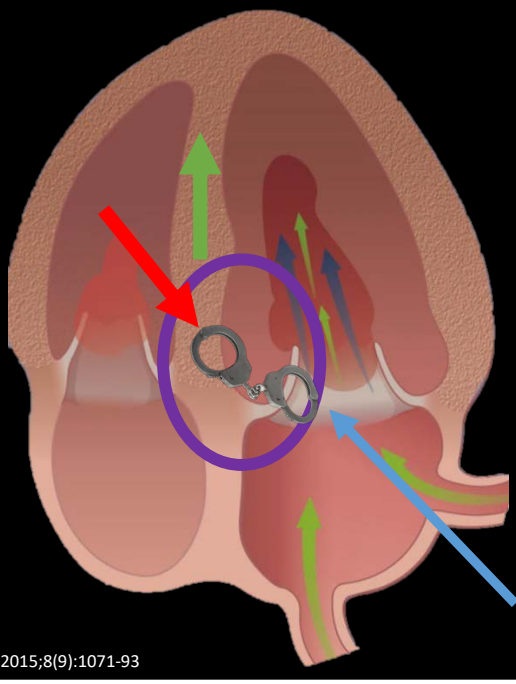
Movement of mitral annulus controls how much doors (valve leaflets) open and how well chamber can fill



Flachskampf, F.A. et al. J Am Coll Cardiol Img. 2015;8(9):1071-93

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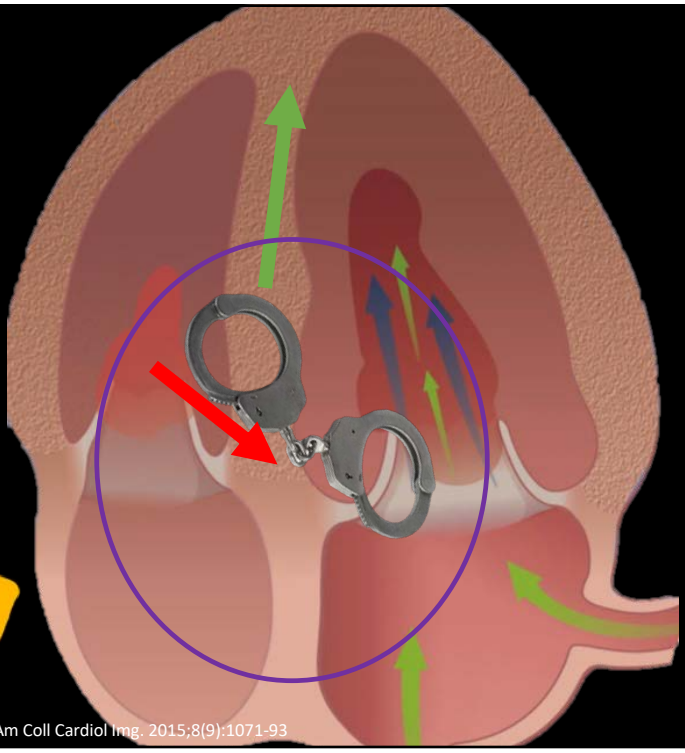
Fibrous areas and connected leaflets are controlled by movement of tissue pulling them along



Flachskampf, F.A. et al. J Am Coll Cardiol Img. 2015;8(9):1071-93

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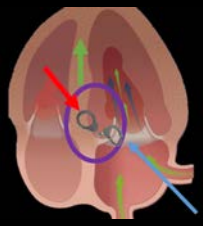
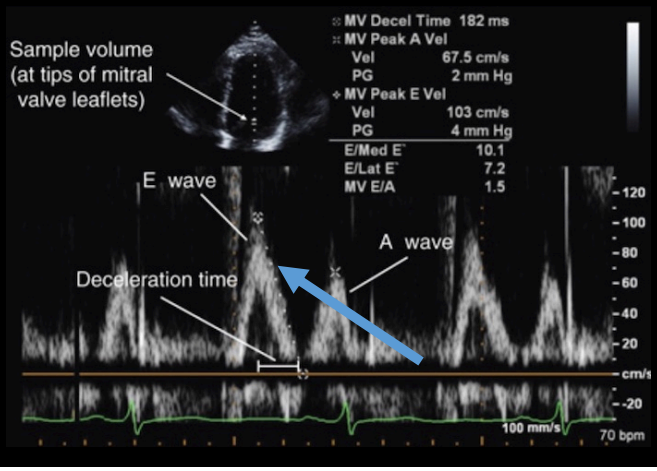
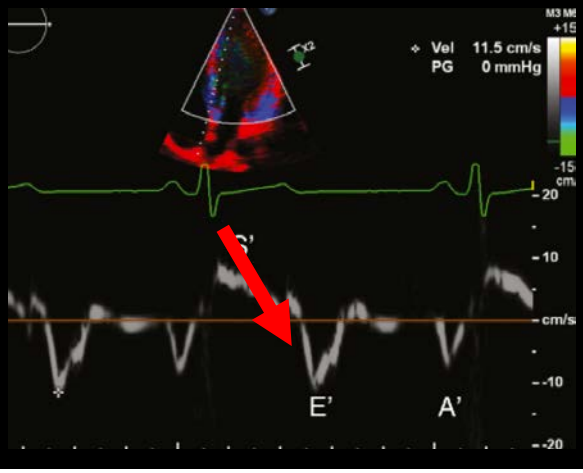
Ability to stretch and pull the annulus can be seen with Doppler







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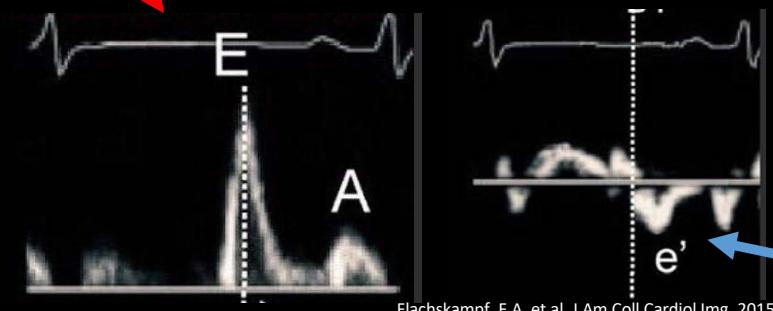
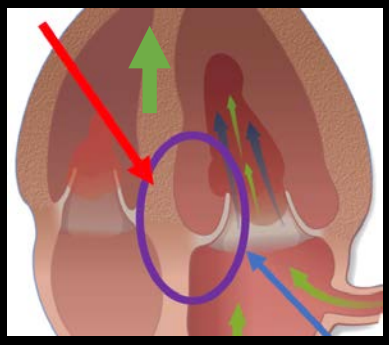
If tissue is not flexible or strong enough to hold filling door open, door will slam shut!

Slope is steep because it has no help to keep it open, there is a problem detected in tissue!





e' is small because it can't stretch to hold door open

Flachskampf, F.A. et al. J Am Coll Cardiol Img. 2015;8(9):1071-93

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Teamwork, tools and timing are everything!

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Conclusion

- Attention to detail
- Understanding direction of movement of myocardial structures and correlation with cursor placement with diastolic assessment is critical
- Improper cursor placement leads to completely inaccurate algorithms

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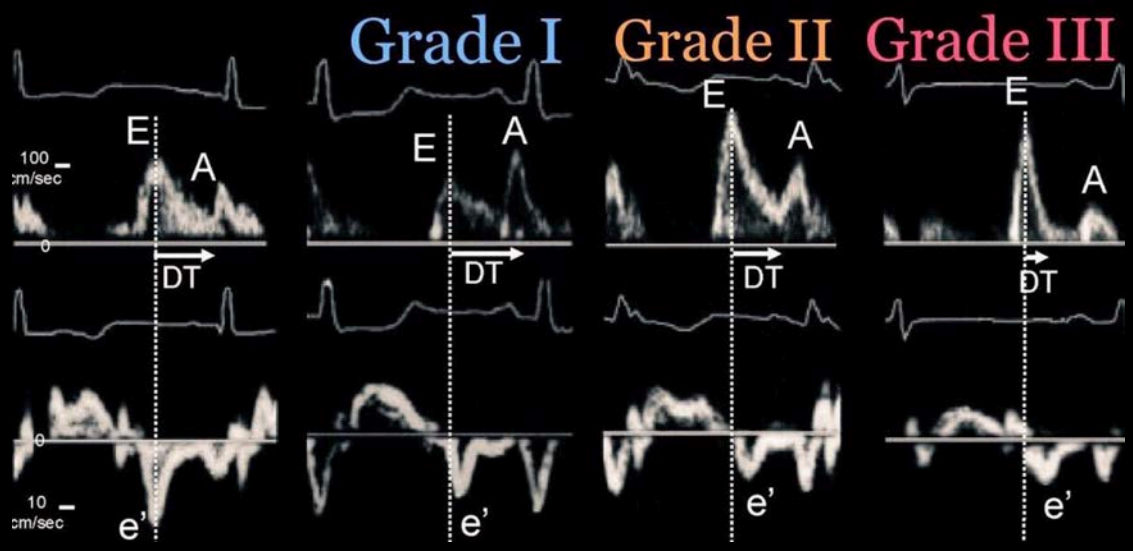
Grades of Diastolic Dysfunction detected by Doppler and TDI



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Thank you!

From Detroit

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Practical Diastology…
Tool Time!

Karen G. Zimmerman, BS, ACS, RDCS, RVT, FASE
HENRY FORD HEALTH SYSTEM
***DETROIT**, MI*

ASE

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2020

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