Cardiac Measurements

- Cardiac Chamber Quantification
- Hemodynamics

ALPINION
MEDICAL SYSTEMS

Clinical Specialist Team

Echocardiography

- Method: transthoracic, transesophageal, intra-cardiac
- Type: 2D, M-mode, Dolor Doppler, Tissue Doppler, 3D
- Structure; Chamber size, valves, neoplasm, pericardium great vessels, IVC, SVC
- Function ; Systole, Diastole

  Hemodynamics

Transducer for Echocardiography

MP 1-5X

Single Crystal Phased Array
Application : Adult Echo, TCD,
Pediatric Echo

SP 1-5/SP1-5

Single Crystal Phased Array
Application : Adult Echo, TCD,
Pediatric Echo

P 1-5CT
SP1-5T

Phased Array
Application : Adult Echo, TCD,
Pediatric Echo,

CW2.0

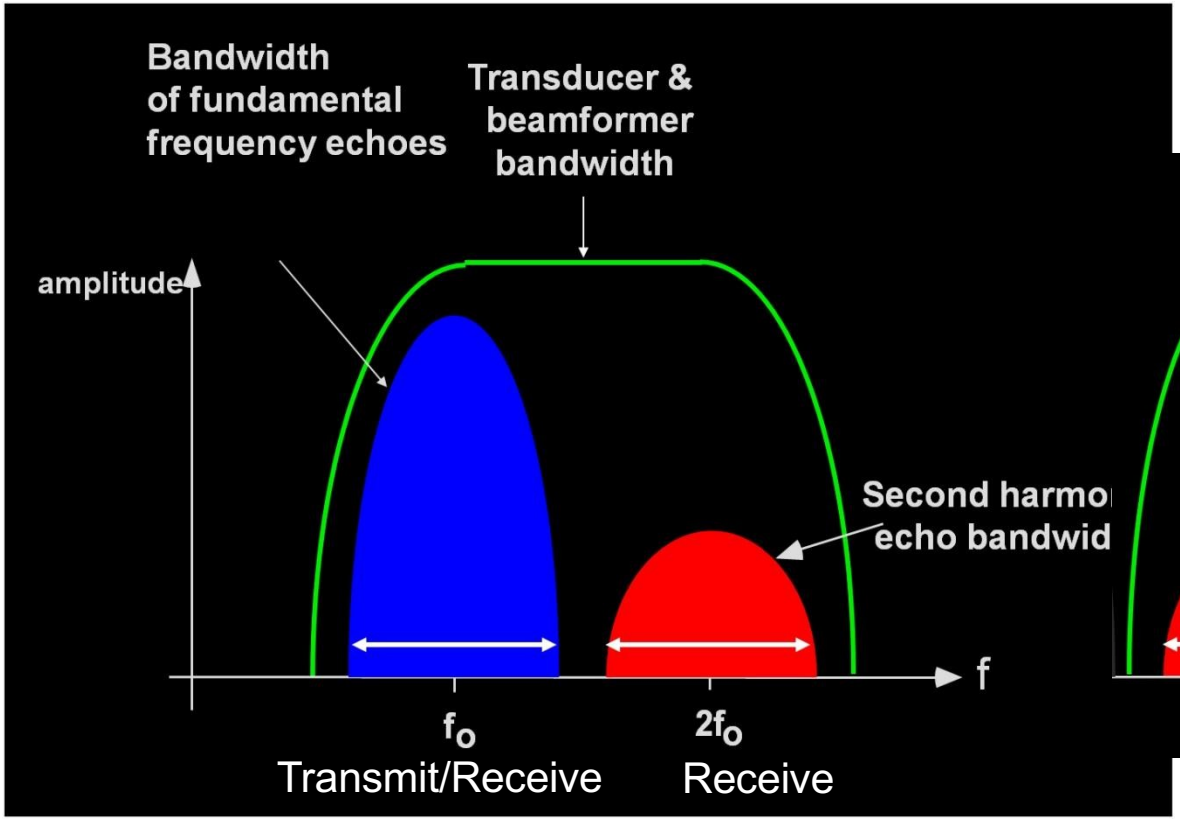
Pencil Type probe
Application : Vascular, valvular Dopp
ler study, Doppler spectrum only

CW5.0

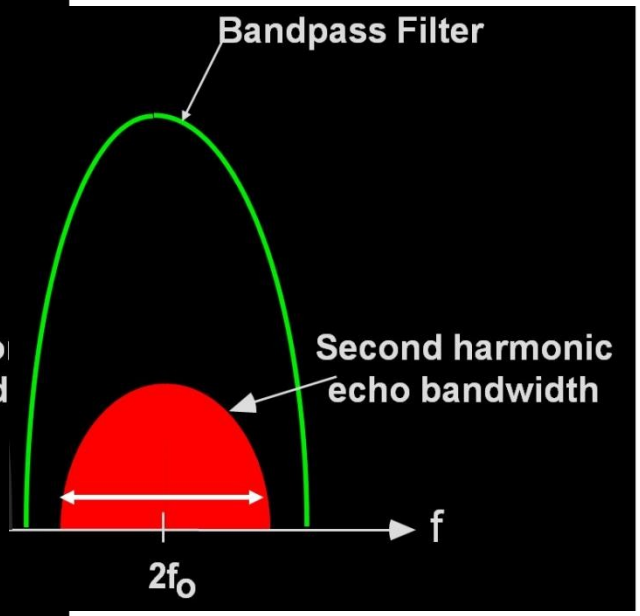
Pencil Type probe
Application : Vascular,
Doppler spectrum only

Features: Harmonic Imaging Technology

- Filtered Tissue Harmonic Imaging



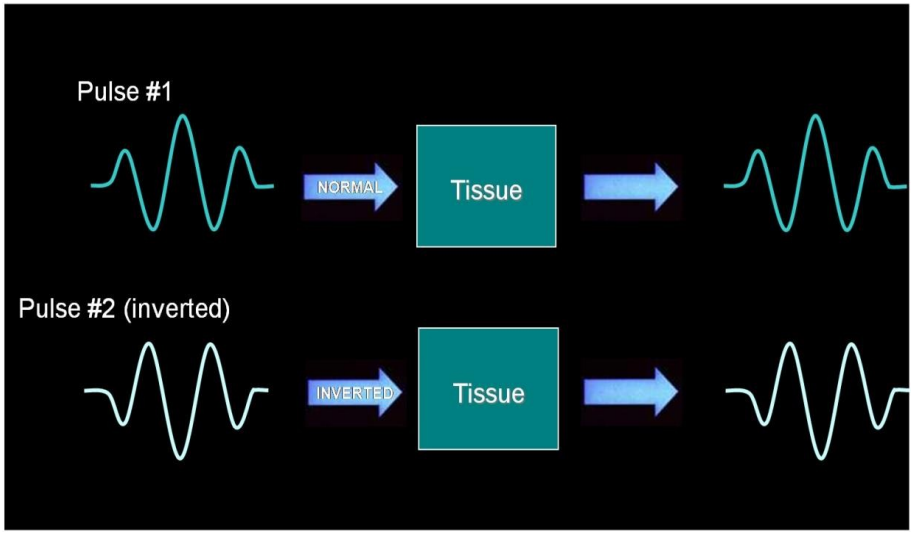
- transmit : f_o
  - low frequency
  - good penetration
- receive : f_o & $2f_o$

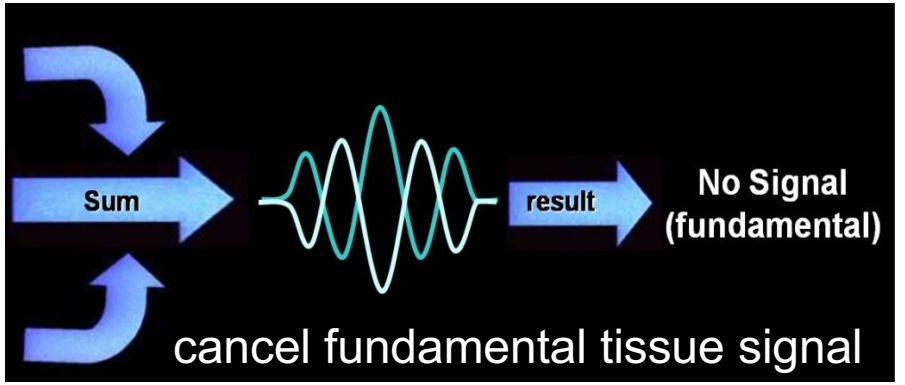


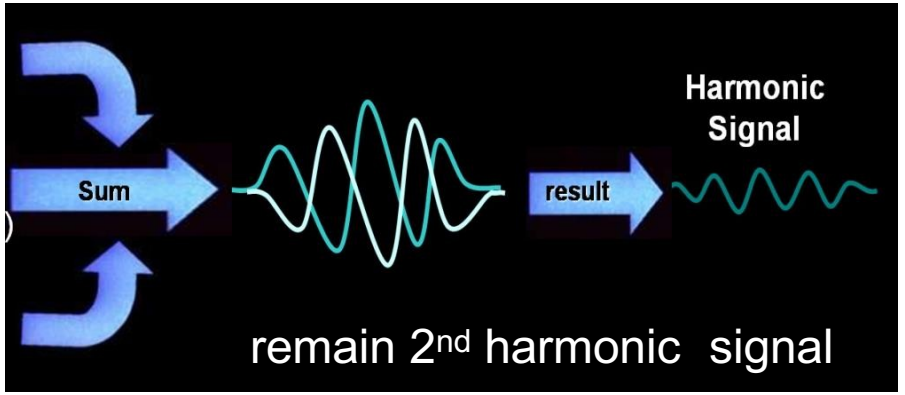
- Receive &Cut off : f_o
- Use: 2 f_o
  -week penetration but clear

Features: Harmonic Imaging Technology

- Pulse Inversion Harmonic Imaging
  - Eliminate fundamental signal by summation
  - Frame rate becomes half of its original frame rate



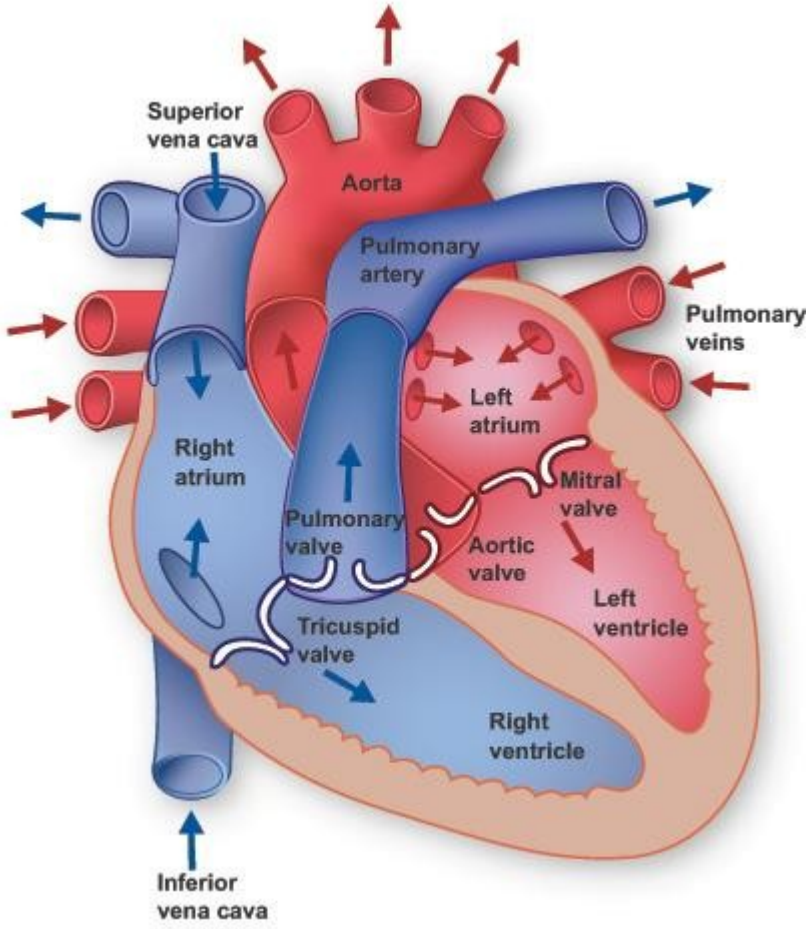


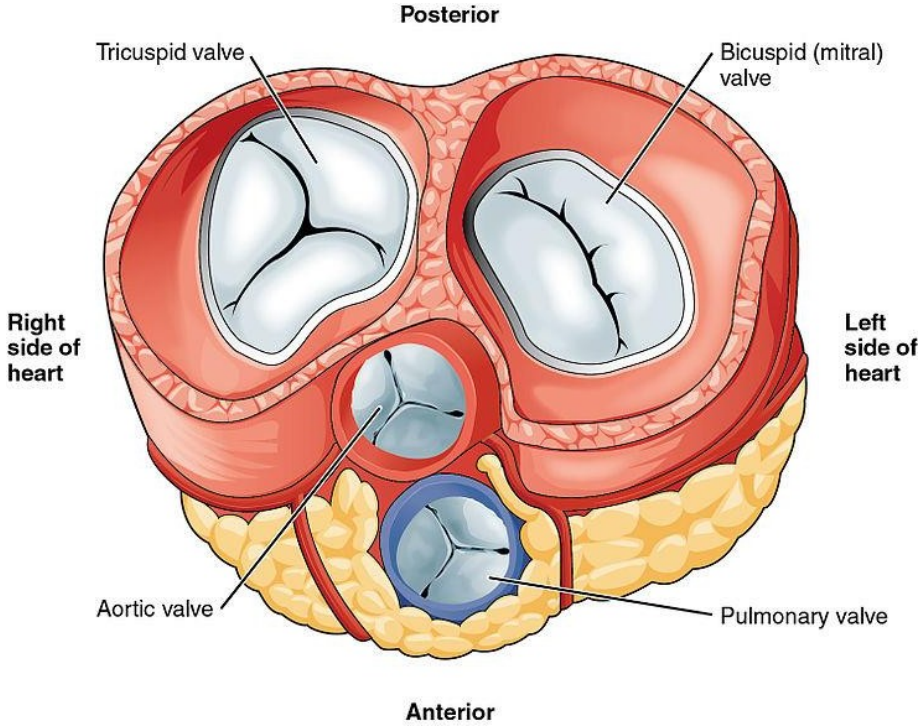


Basic views & parameters

ALPINION Medical Systems , Clinical Specialist Team

Anatomy and blood Circulation of the heart

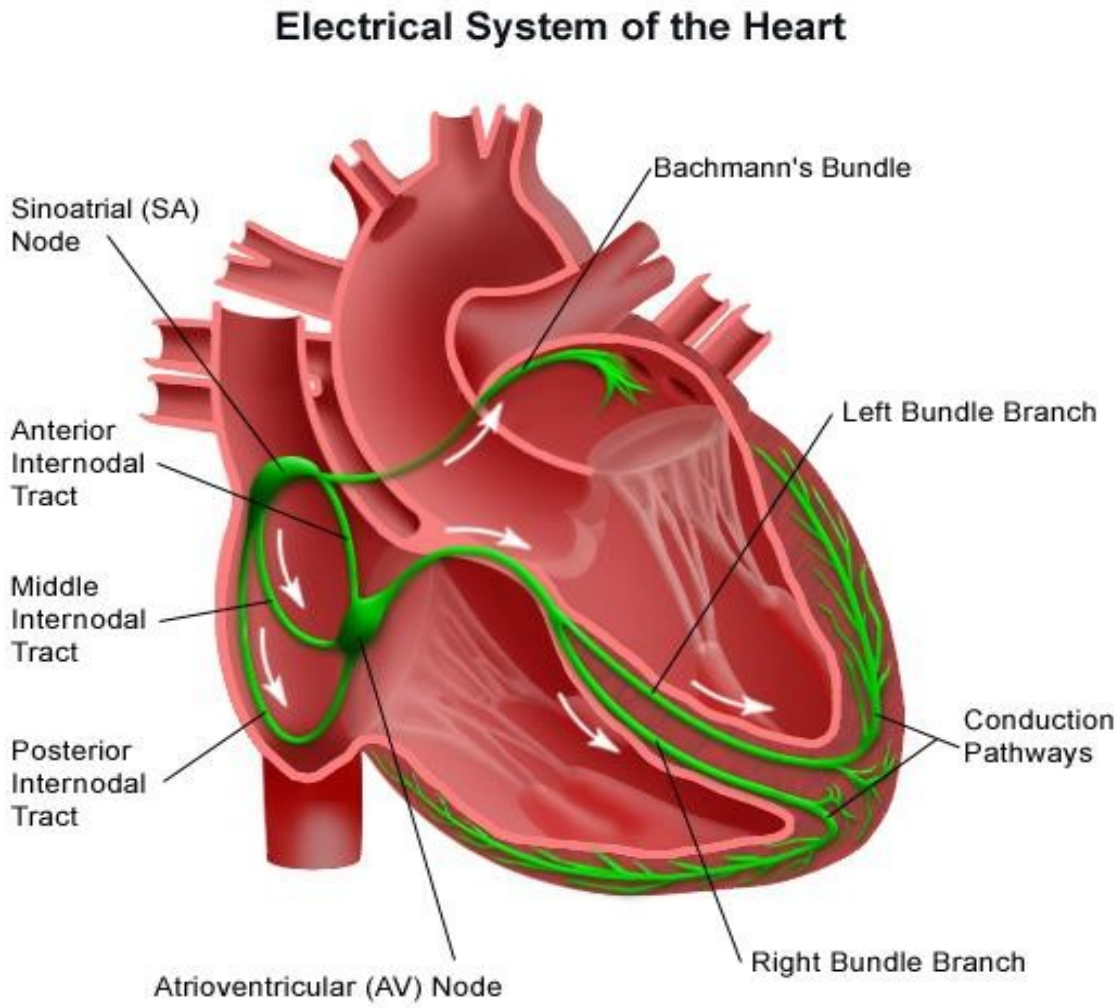




The Conduction System of the heart

a group of specialized cardiac muscle cells send signals to the heart muscle, cause to contract ;

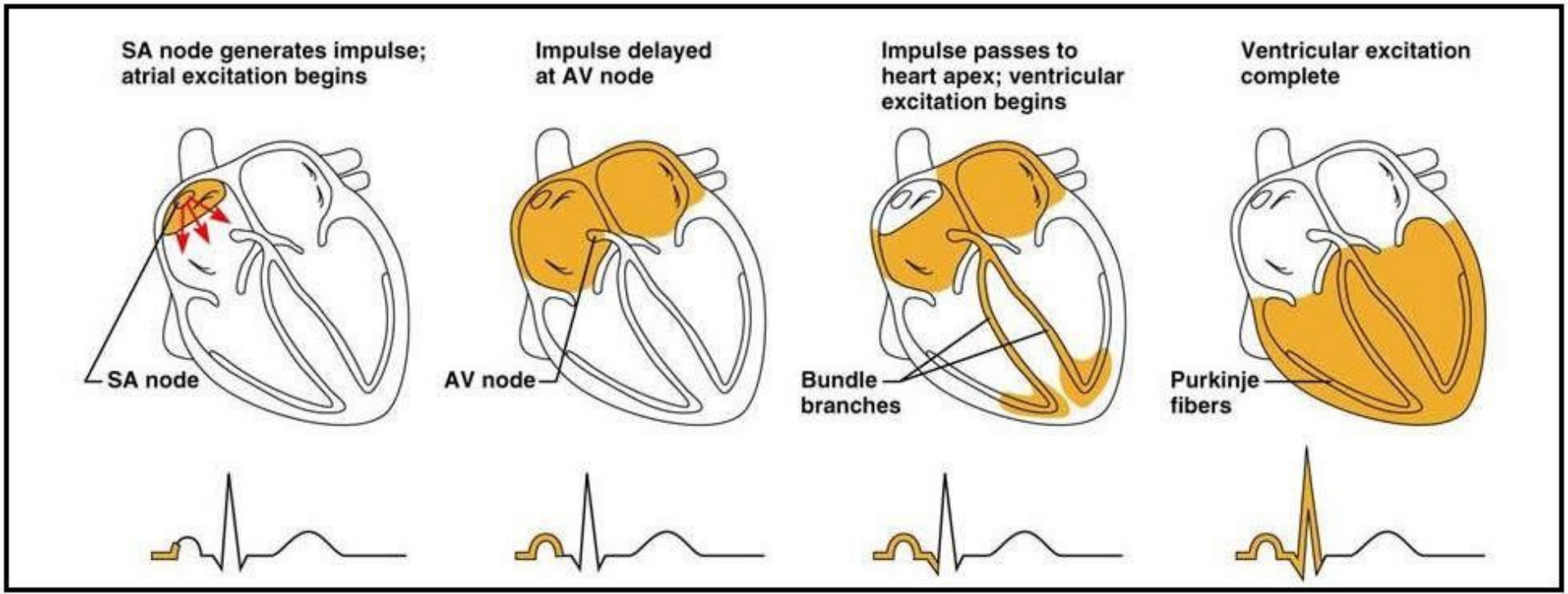
SA node
-> AV node
-> Bundle of His
-> bundle branches
-> Purkinje fibers



The Conduction System of the heart & ECG

Intracardiac tracings show the normal intervals between

- P: atrial depolarization
- PQ segment: SA node to AV node
- QRS complex: ventricular depolarization
- ST segment : ventricular depolarization
- T : ventricular repolarization



Parameters for 2D

- Image “Depth”: 15-16 cm for Parasternal Long Axis view, 17-18cm for Apical View
- Frequency : Harmonic 3.6MHz/Harmonic 3.2Mhz/2Mhz
- Focus : LV posterior wall
- Dynamic Range: 60 - 72dB

Parameter	Effect	Parameter	Effect
Frequency	The higher frequency, the finer image	**Harmonic**	Enhance the contrast resolution with fine tissue differentiation
Dynamic Range	Between the highest and the lowest signal value in system. Use optimizing tissue texture	**Rejection**	Suppress below a certain level of echo information
Focus	Enhance the resolution around focus range	**SRI**	Unnecessary speckle noise reduction imaging
Persist	Provides smoothing effect by frame averaging, no affect frame rate	**Full SRI**	Option further steps of SRI
Line Density	the more line density, the more spatial resolution . Trade off Frame rate	**Gray Map**	Display intensity to variable brightness

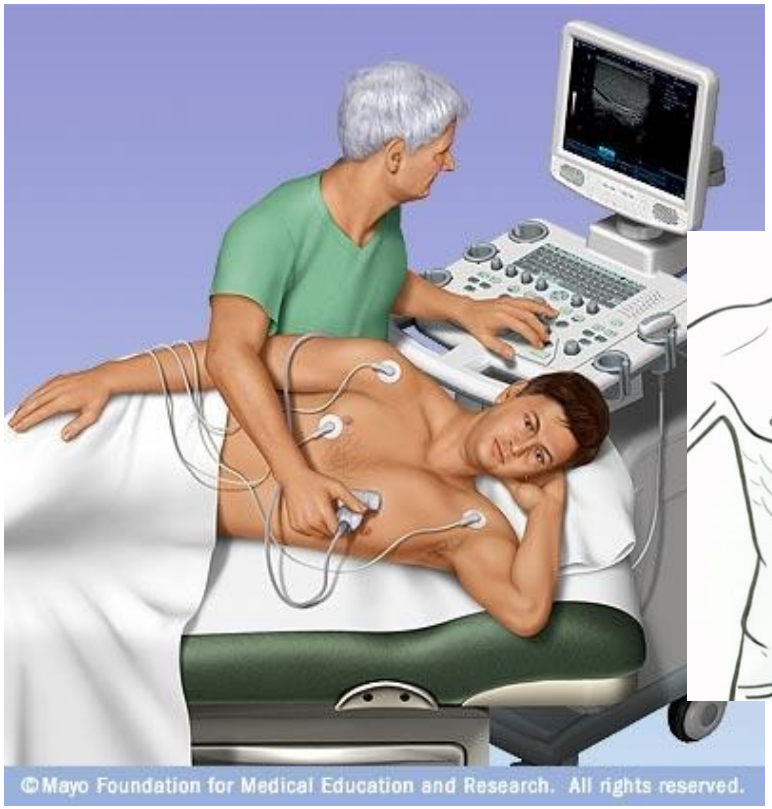
Parameters for the color

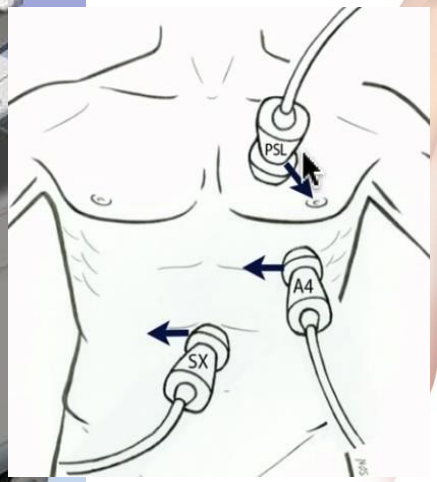
parameter		Increase
Frequency	Determine maximum velocity range, low frequency is available to process higher velocity	the pixel size becomes fine and small
PRF	Determine color scale (velocity)	Send more PRF,
Wall filter	Filter our clutter signals caused from vessel movement	For high dynamic organ needs, such as heart
Persist	Provides smoothing effect by frame averaging, not affect frame rate	Remaining image
Threshold	threshold assigns the color information to stop at which gray scale	Display color on bright B-mode
Type	Velocity, velocity variance (directional power doppler), Power doppler (intensity).	VV & PD for low velocity detection or renal flow
Ensemble	packet size , 8-10 for cardiac, 14 for vein, 12 for renal	Reduce frame rate
Smooth	The higher, the finer margine	
Angle steer	Align to the flow direction -20^{o}/ 0^{o}/ 20^{o}, -9/0/+9	Perpendicular flow to transducer's insonation
Line density	Same as 2D –mode. .	The more the detail resolution

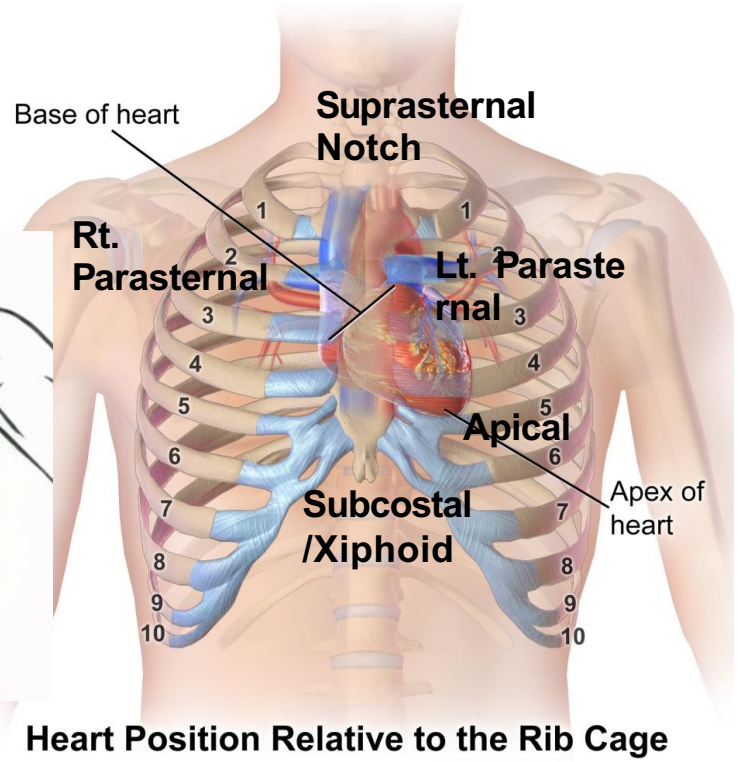
Characteristics of Doppler

Color	Power Doppler	Pulsed wave	Continuous wave
direction	flow detection, directional flow	sample volume (gate) , velocity range	unknown gate, detect high velocity (regurgitation, stenosis)
Mean velocity	Intensity	Target velocity	Max velocity

Scanning Tips : Positions

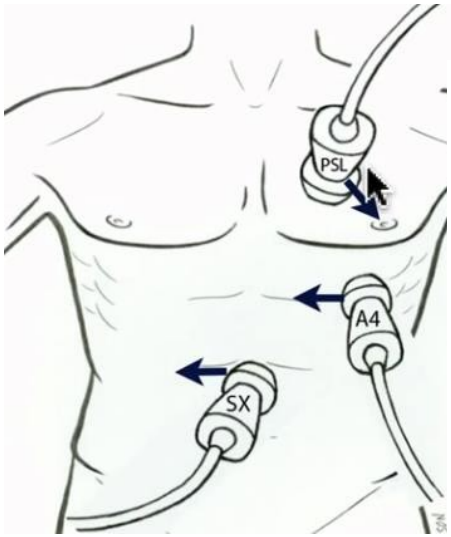


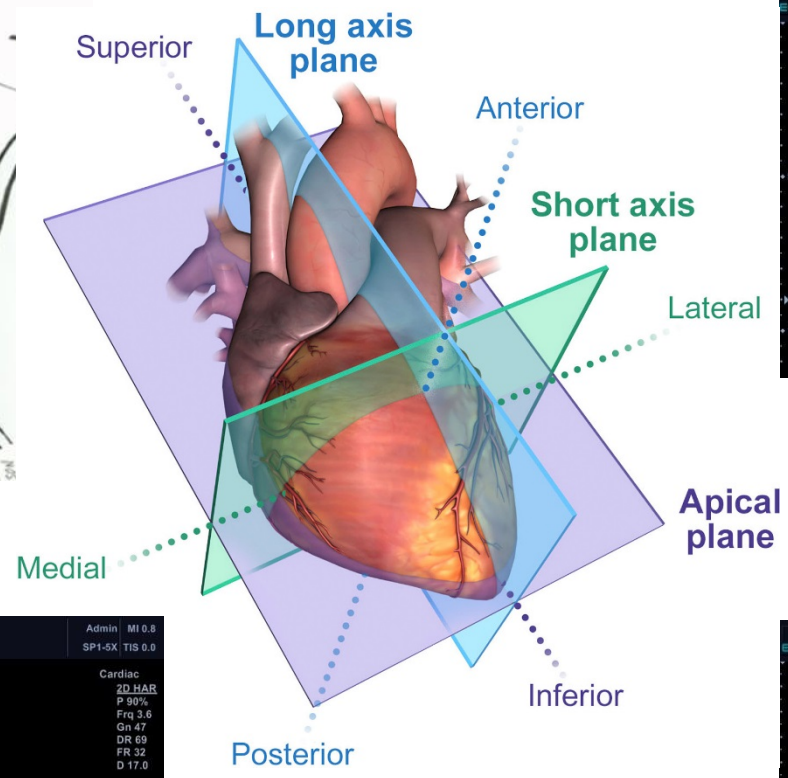




Heart Position Relative to the Rib Cage

Basic Echocardiographic Views

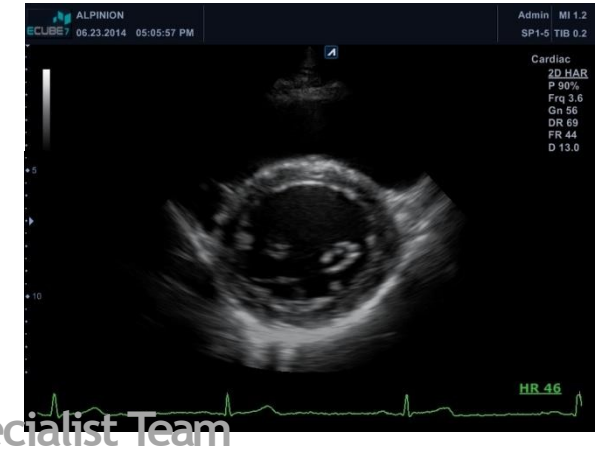




1. PLAX view

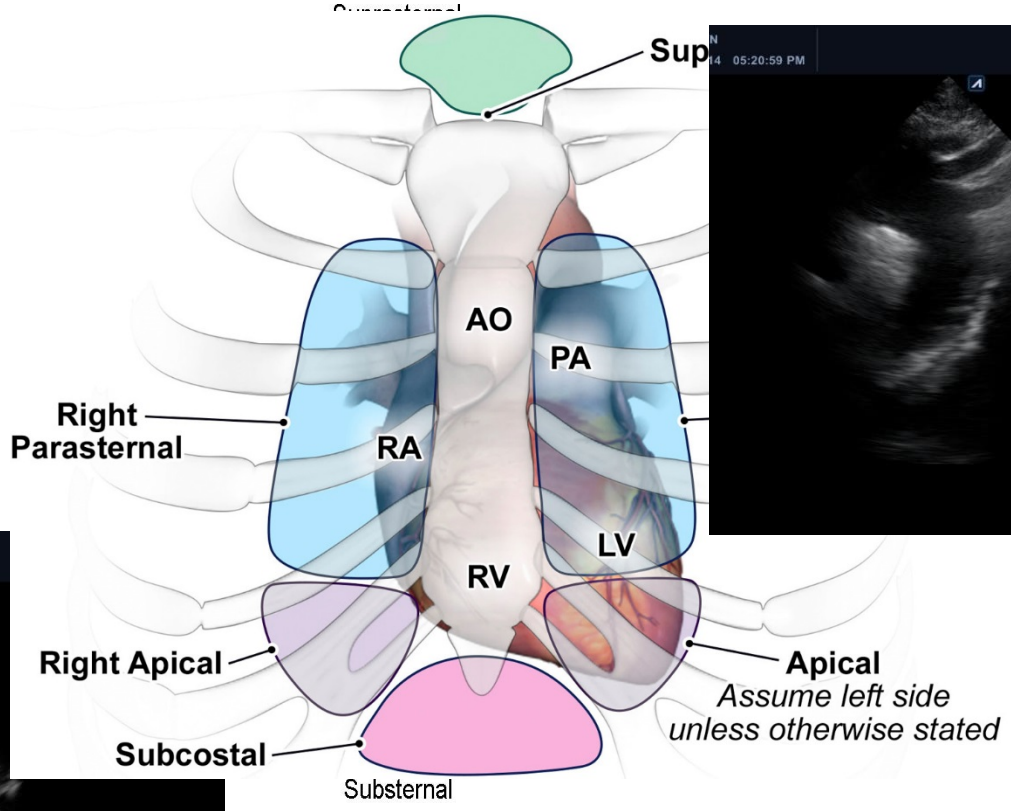
2. PSAX view

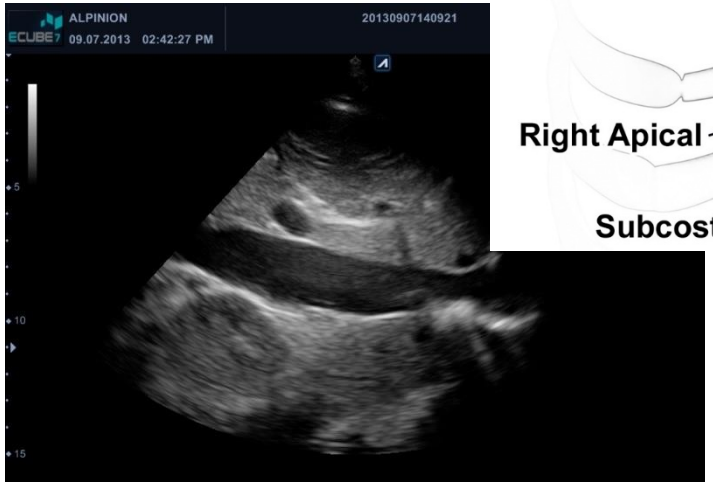
3. Apical view



Basic Echocardiographic Views

5. Suprasternal view

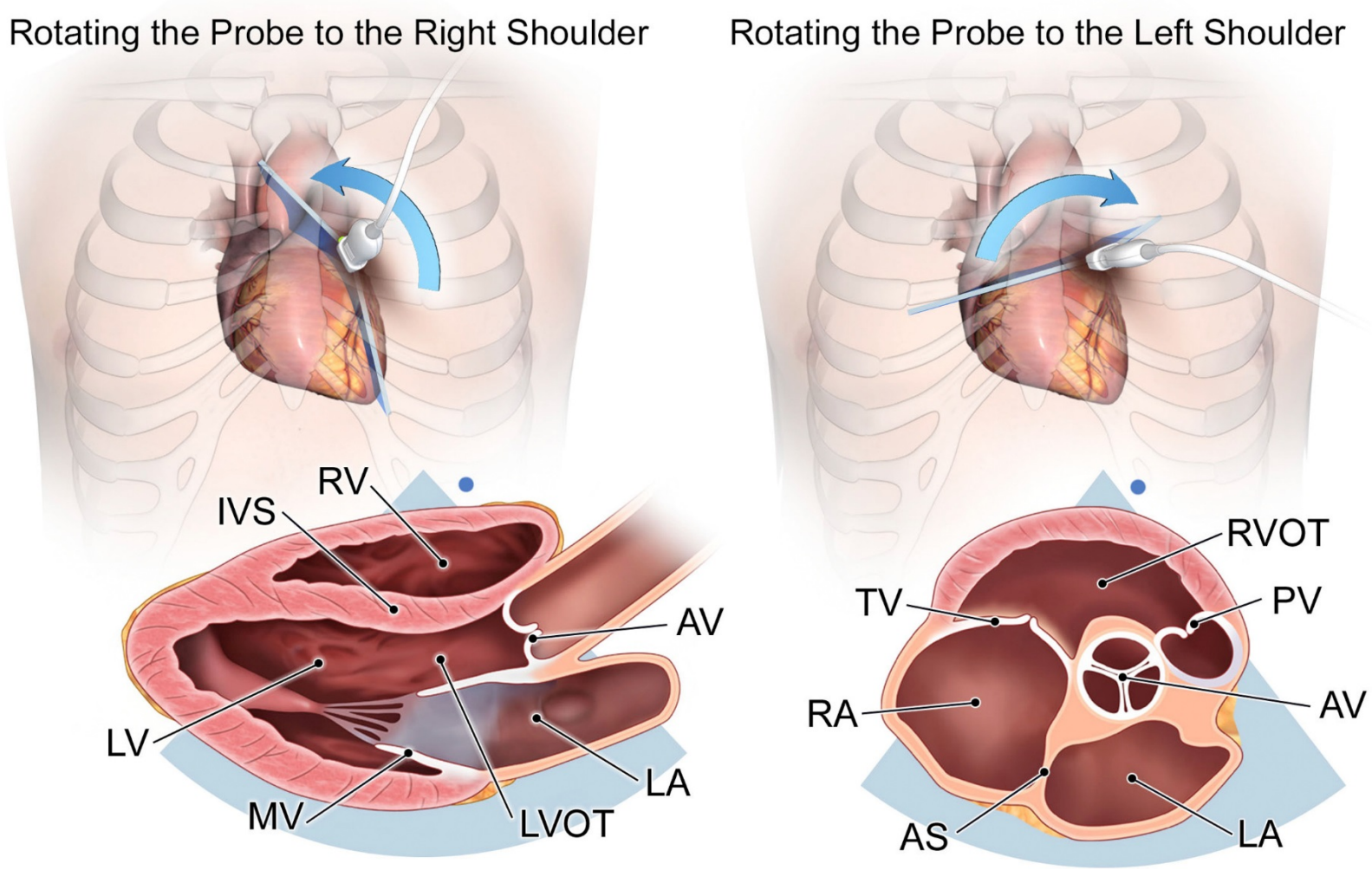




4. Subxiphoid view

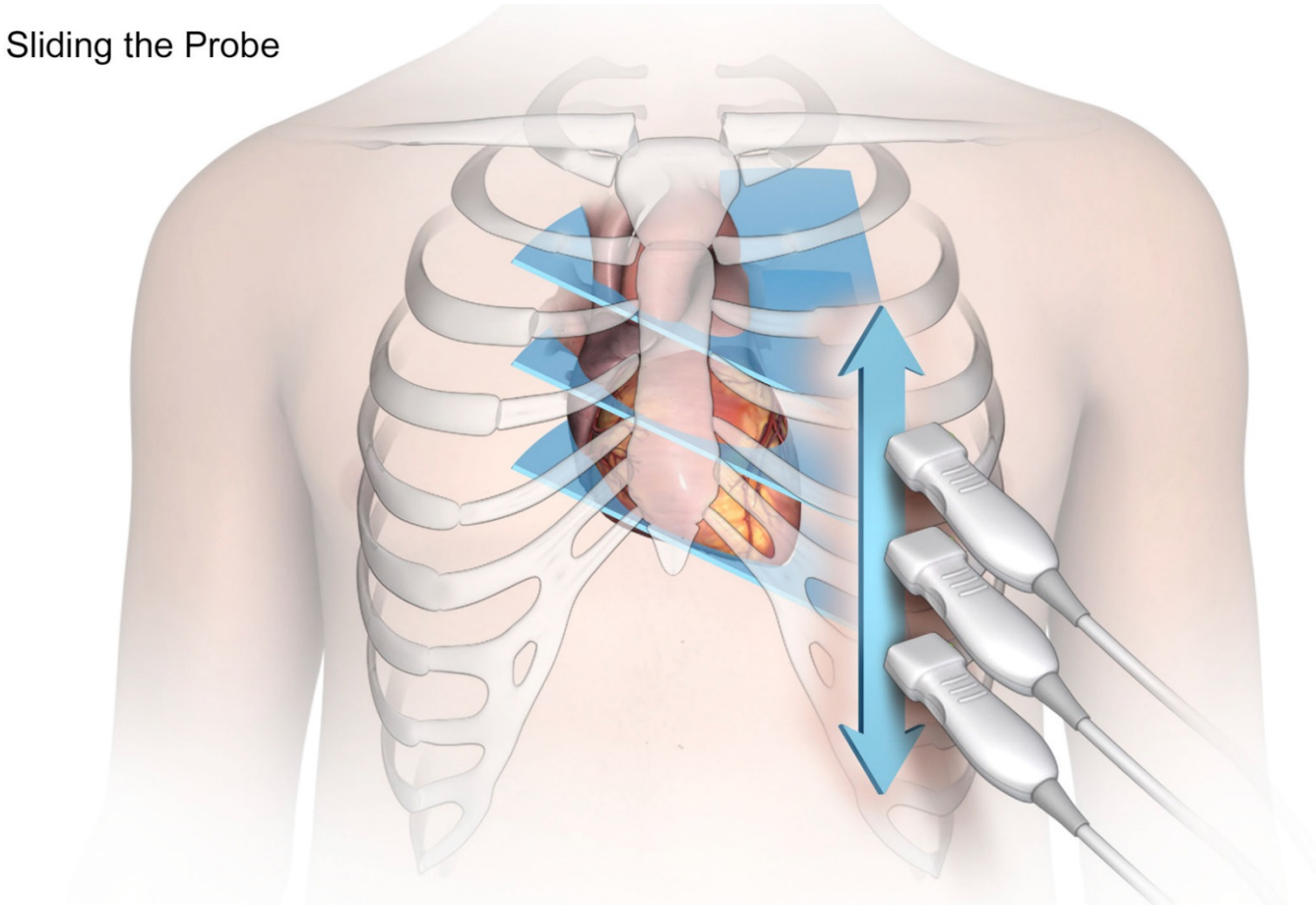
Basic Echocardiographic Views

Rotation probe



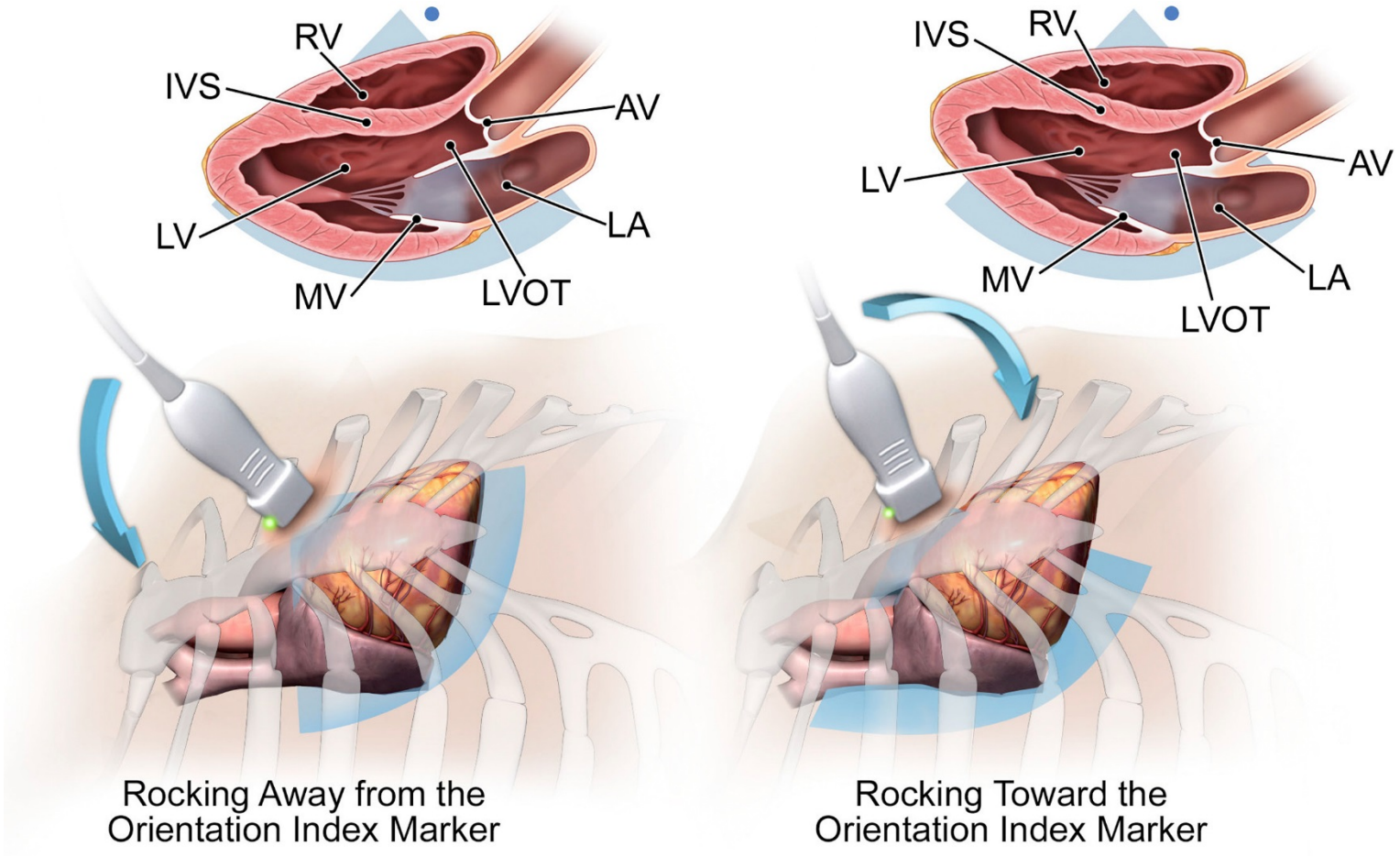
Basic Echocardiographic Views

Sliding probe



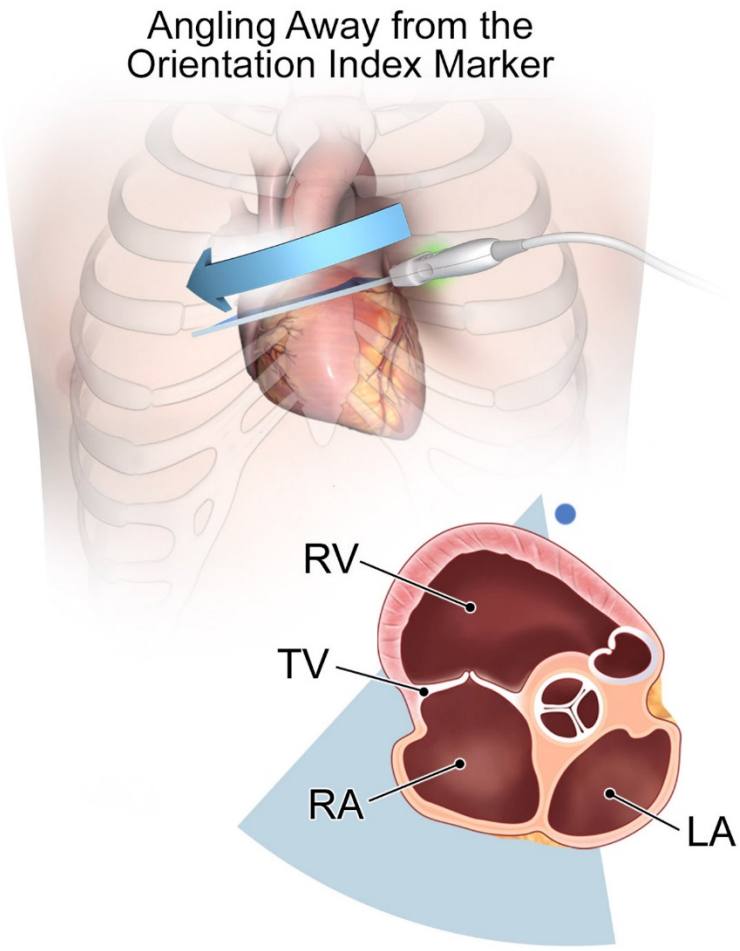
Basic Echocardiographic Views

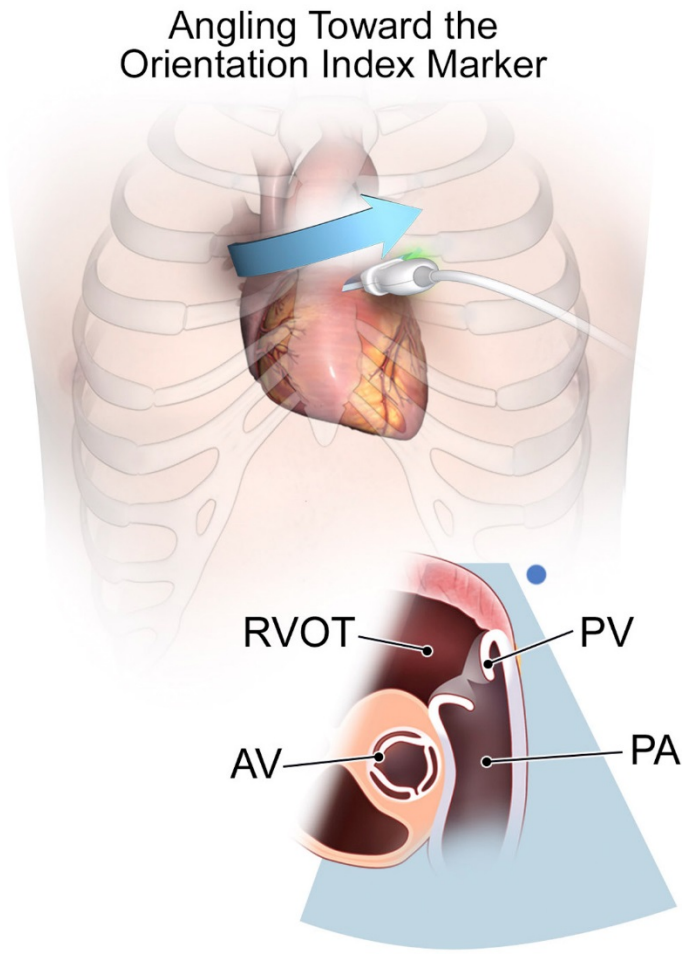
Rocking manuever



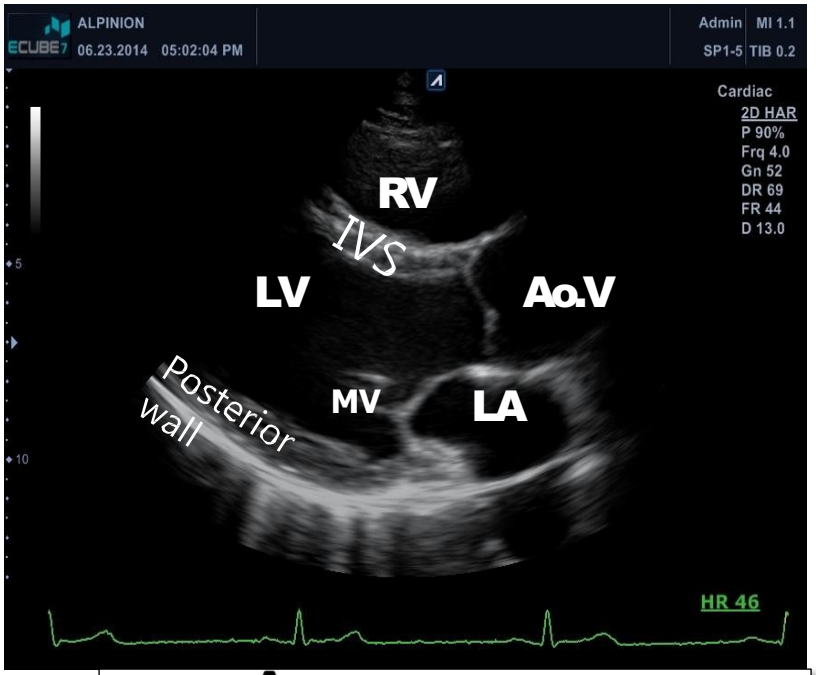
Basic Echocardiographic Views

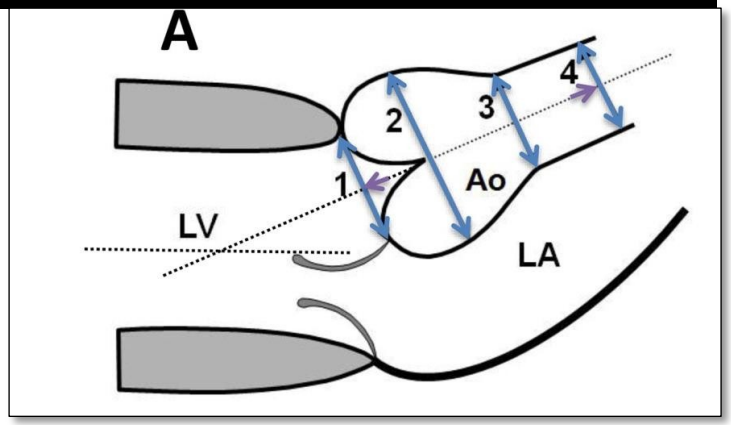
Angling probe





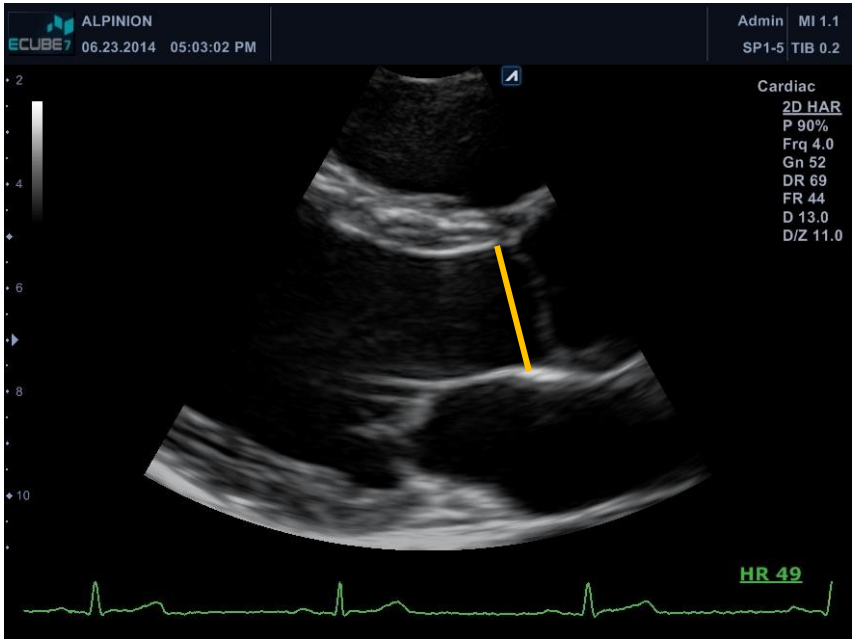
Parasternal Long Axis view





- Transducer position: left sternal intercostal spce 2-5th
- horizontally to keep the interventricular septum and the Aortic wall
- Size and thickness of the septum and posterior wall
- Motility of the LA, LV
- Changes of the Aortic Valve
- Measure ascending aorta at each point
- Pericardial effusion

Parasternal Long Axis view



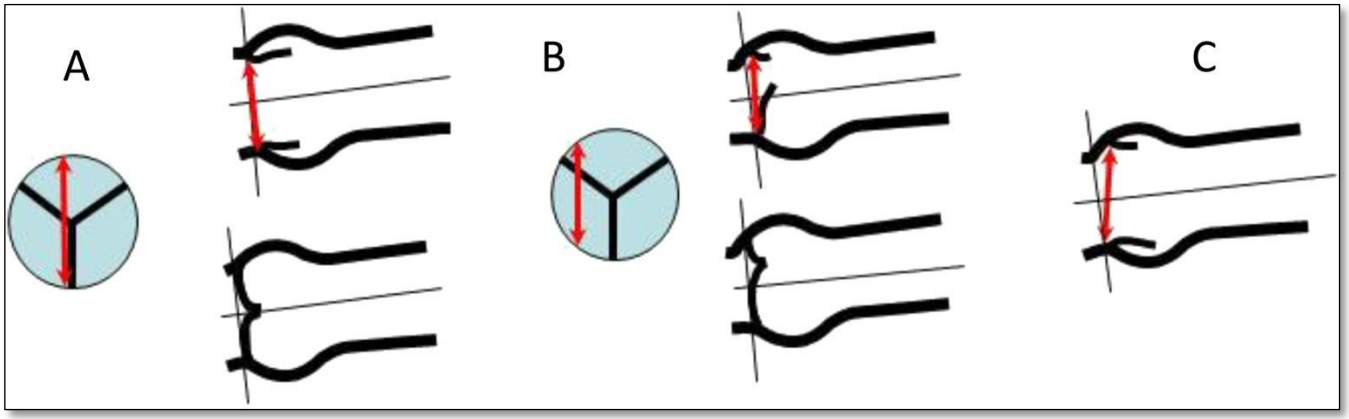
Zoom : contain the aortic valve and the mitral valve

- Measure LVOT diameter for LVOT stroke volume

  $= 0.785 * D^2 * LVOT_{TVI}$

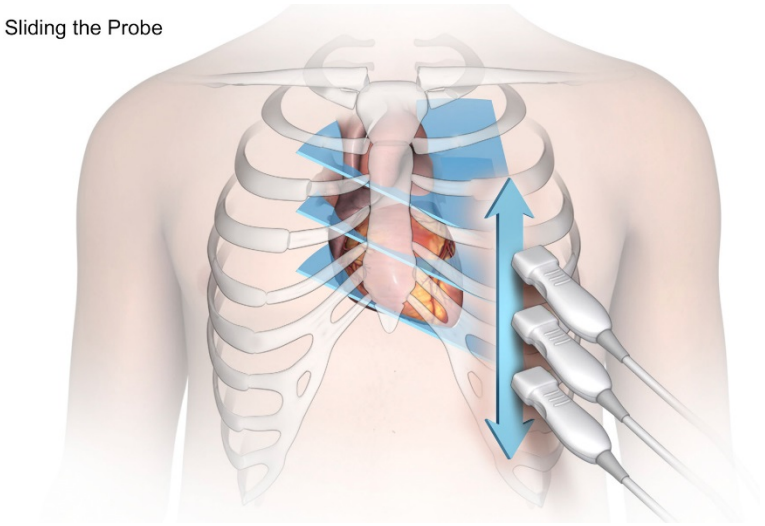
- Cine save for the mitral valve and its apparatus` morphology

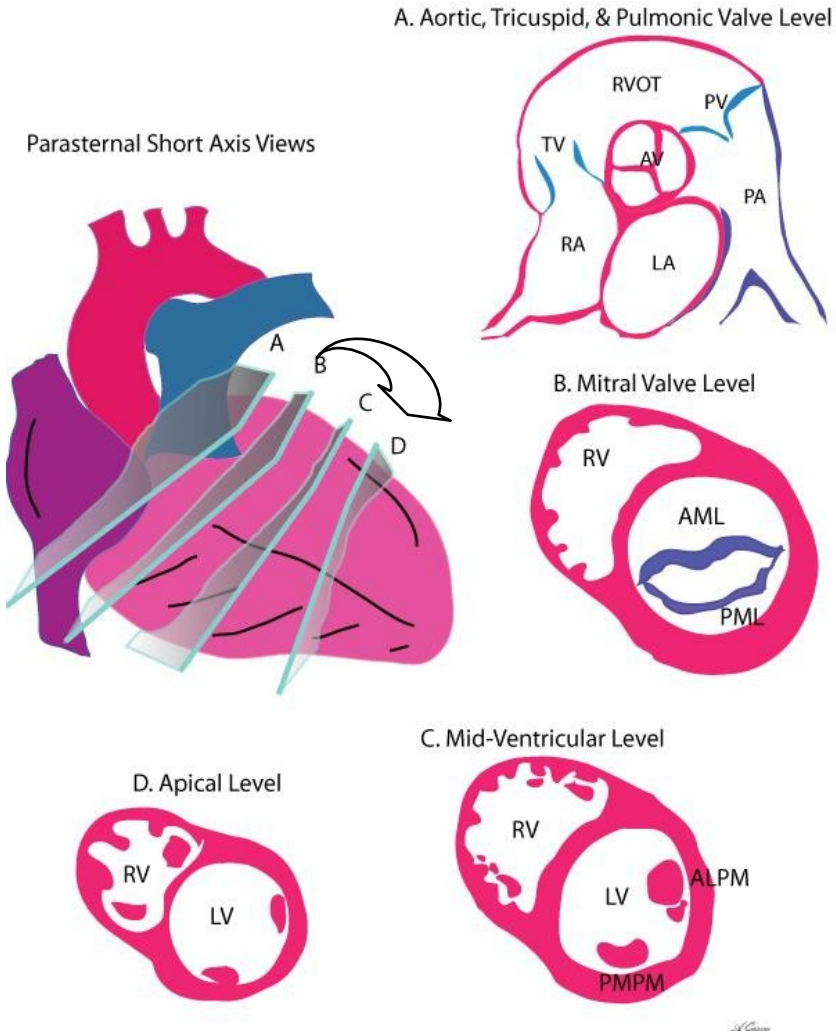
2015 ASE GUIDELINES and STANDARDS



Parasternal Short Axis view

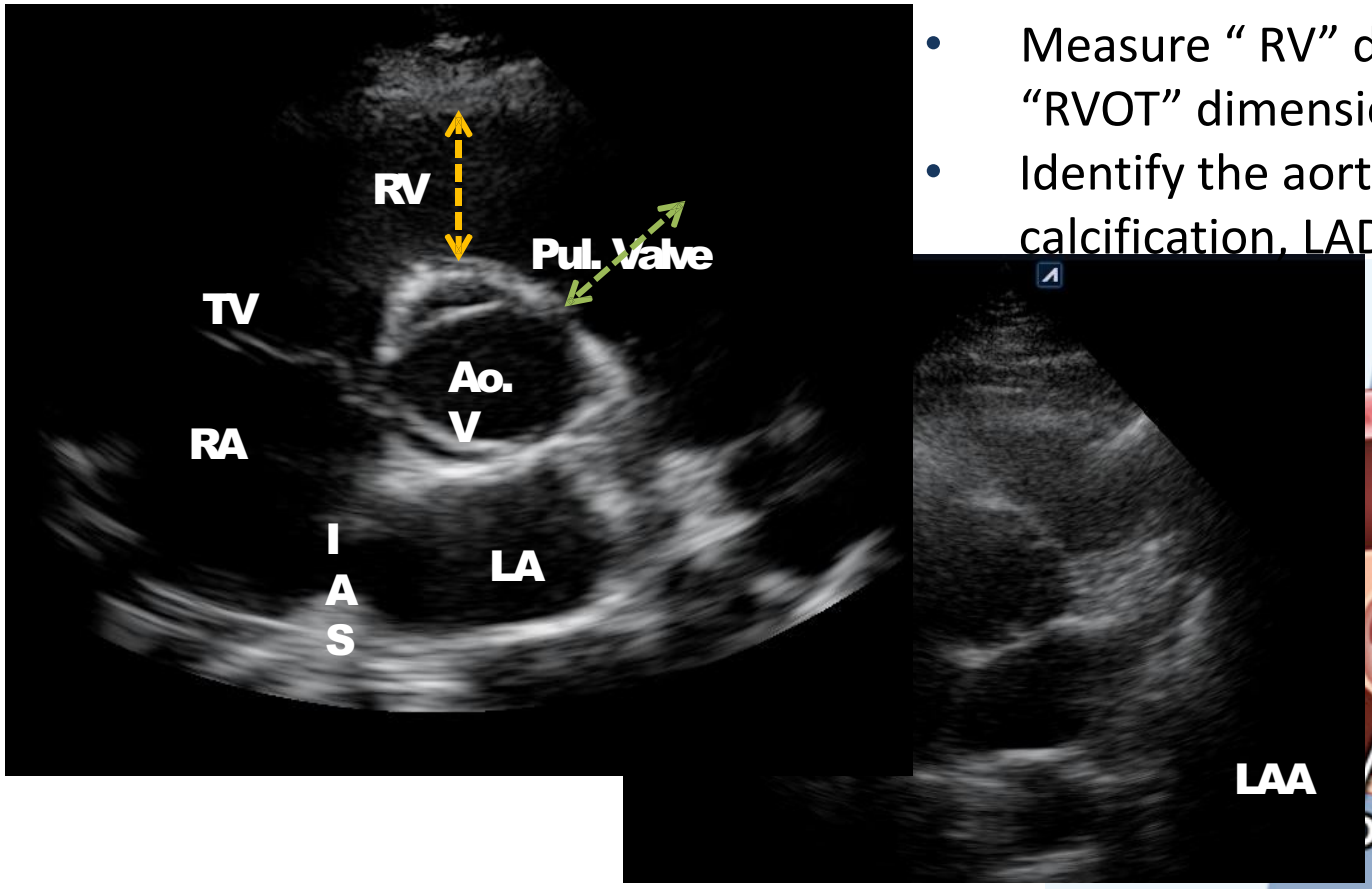
- Turn a transducer to clockwise around 90 ^{o} from PLAX
- Aortic valve level
- Mitral valve level
- Papillary muscle level
- Apex level



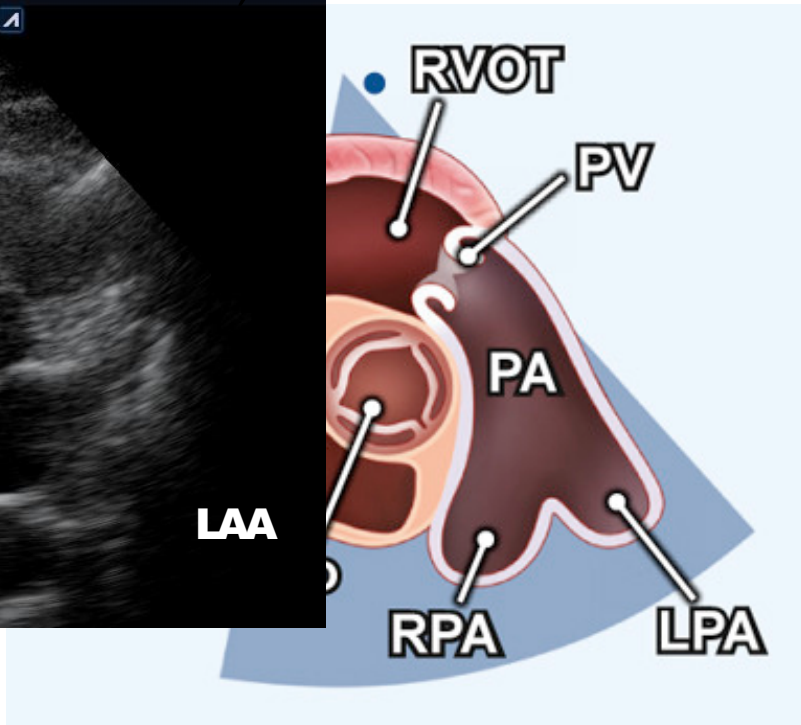


Parasternal Short Axis view

Aortic Valve level



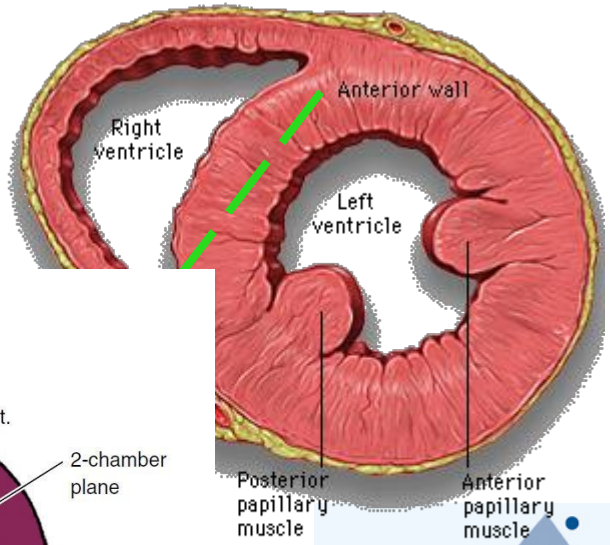
- Measure " RV" dimension and "RVOT" dimension
- Identify the aortic valves; 3 cusps, calcification, LAD os



Parasternal Short Axis view

Mitral Valve, Papillary muscle level

- Wall motion, wall thicknes s degenerative changes
- If there were pressure overload, LV looks " D" shape



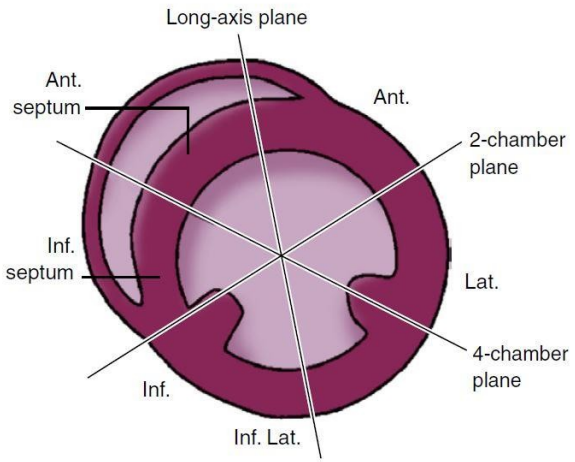
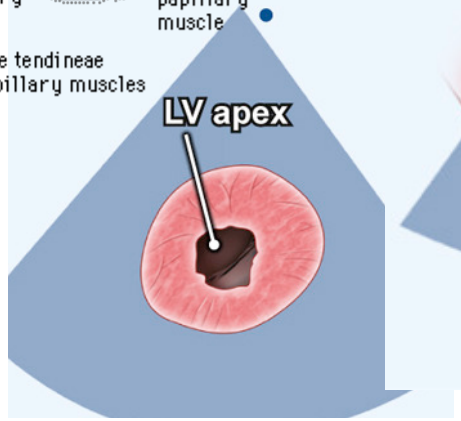
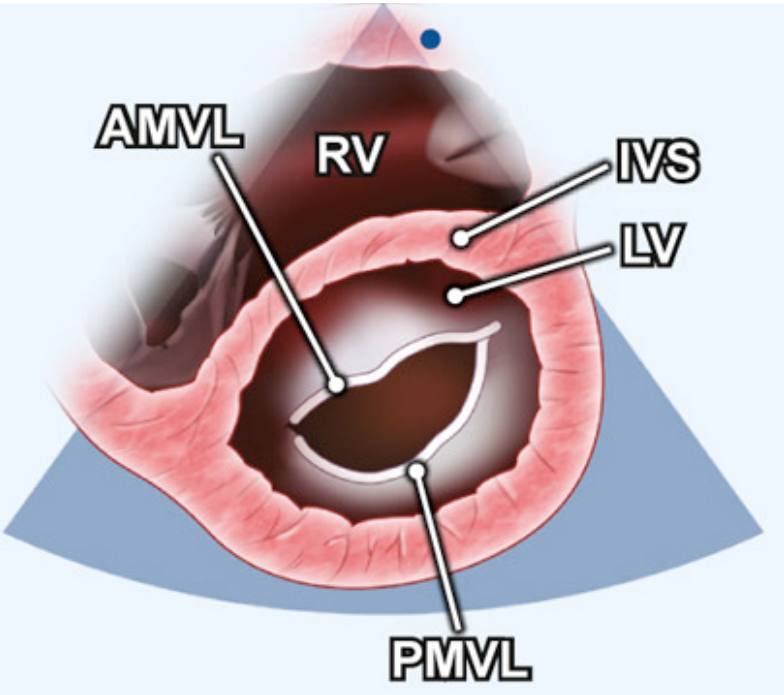


Figure 2–14 **Apical image planes.** The apical image planes are perpen-

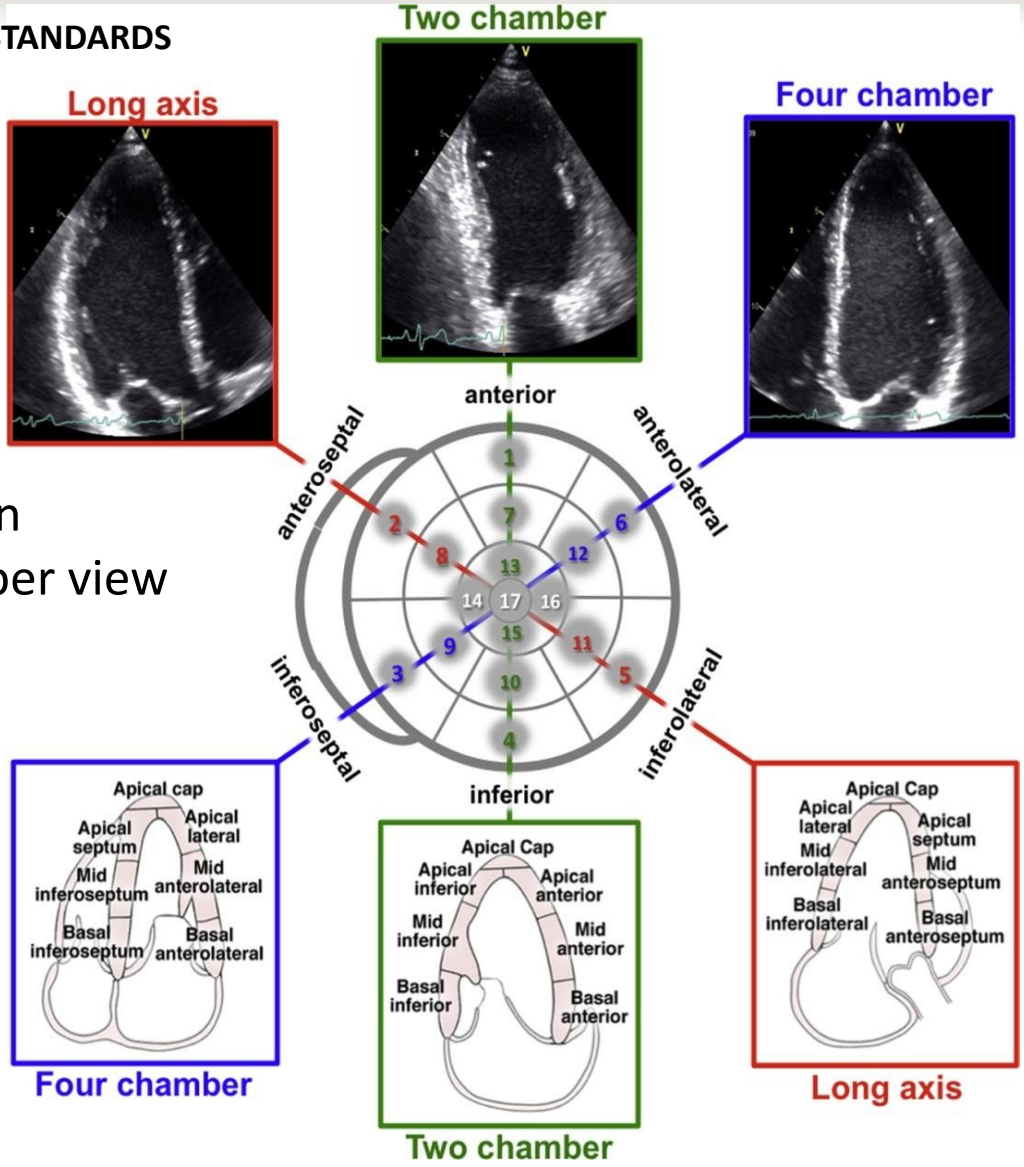




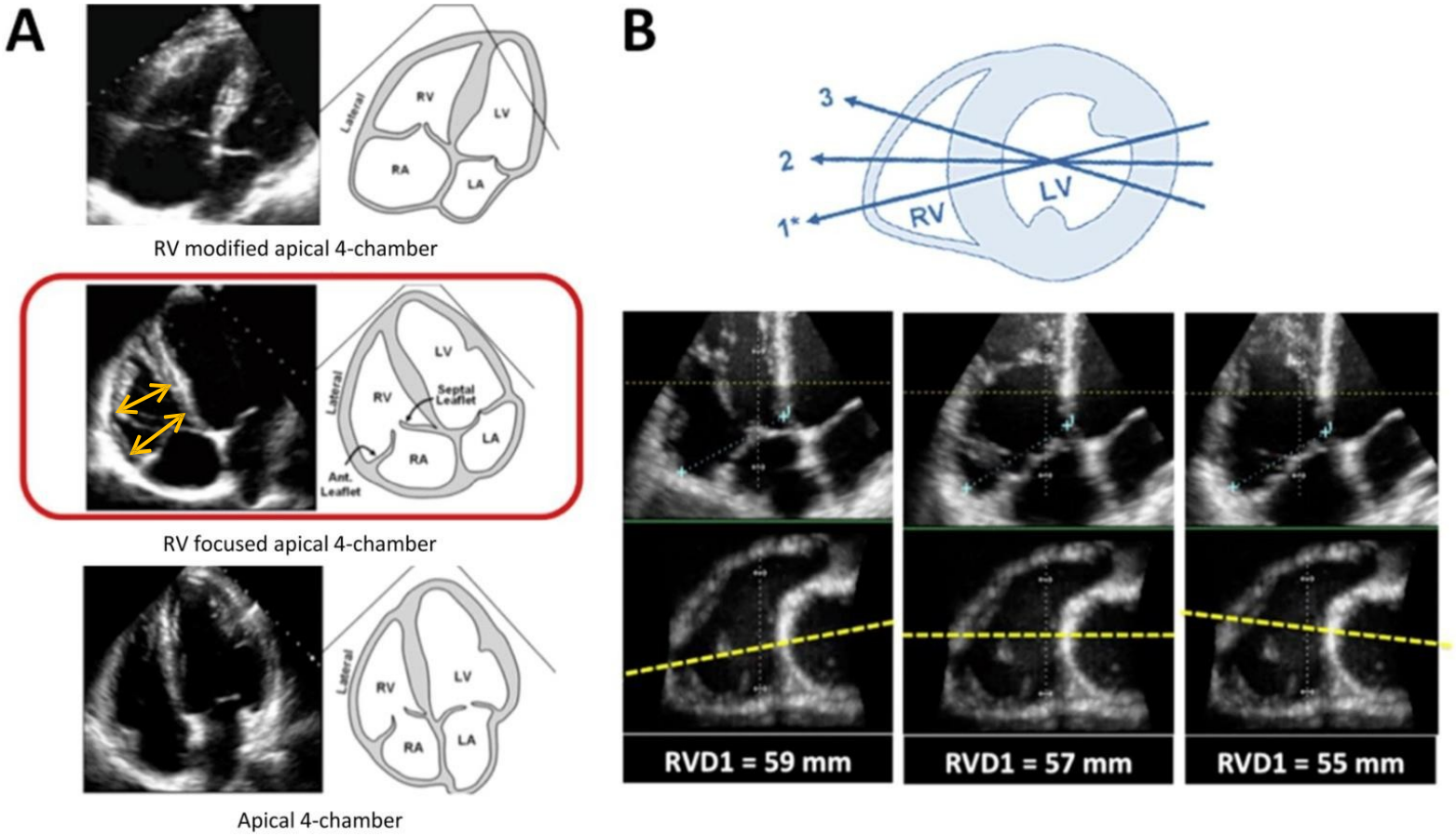
Apical view - the left ventricle

2015 ASE GUIDELINES and STANDARDS

- Measure Ejection Fraction at 4chamber and 2chamber view
- Measure RV size

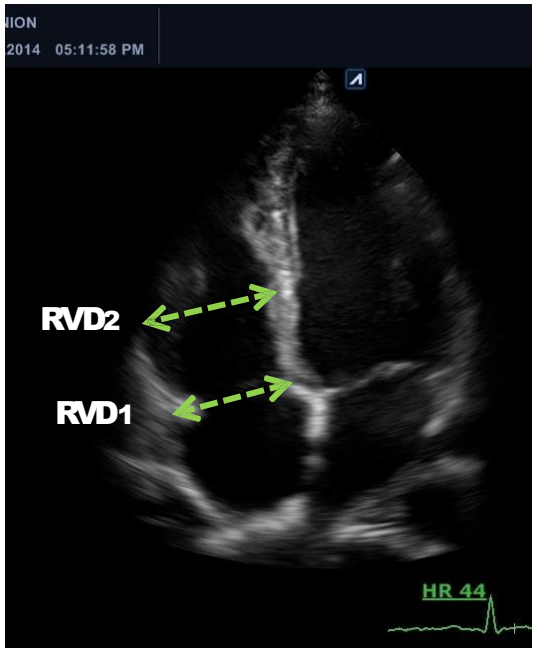


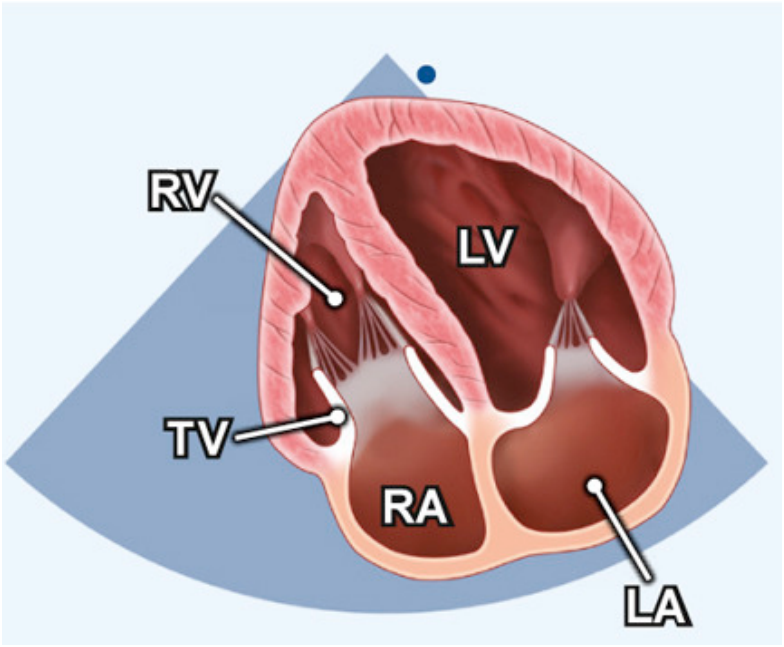
Apical view – the right ventricle



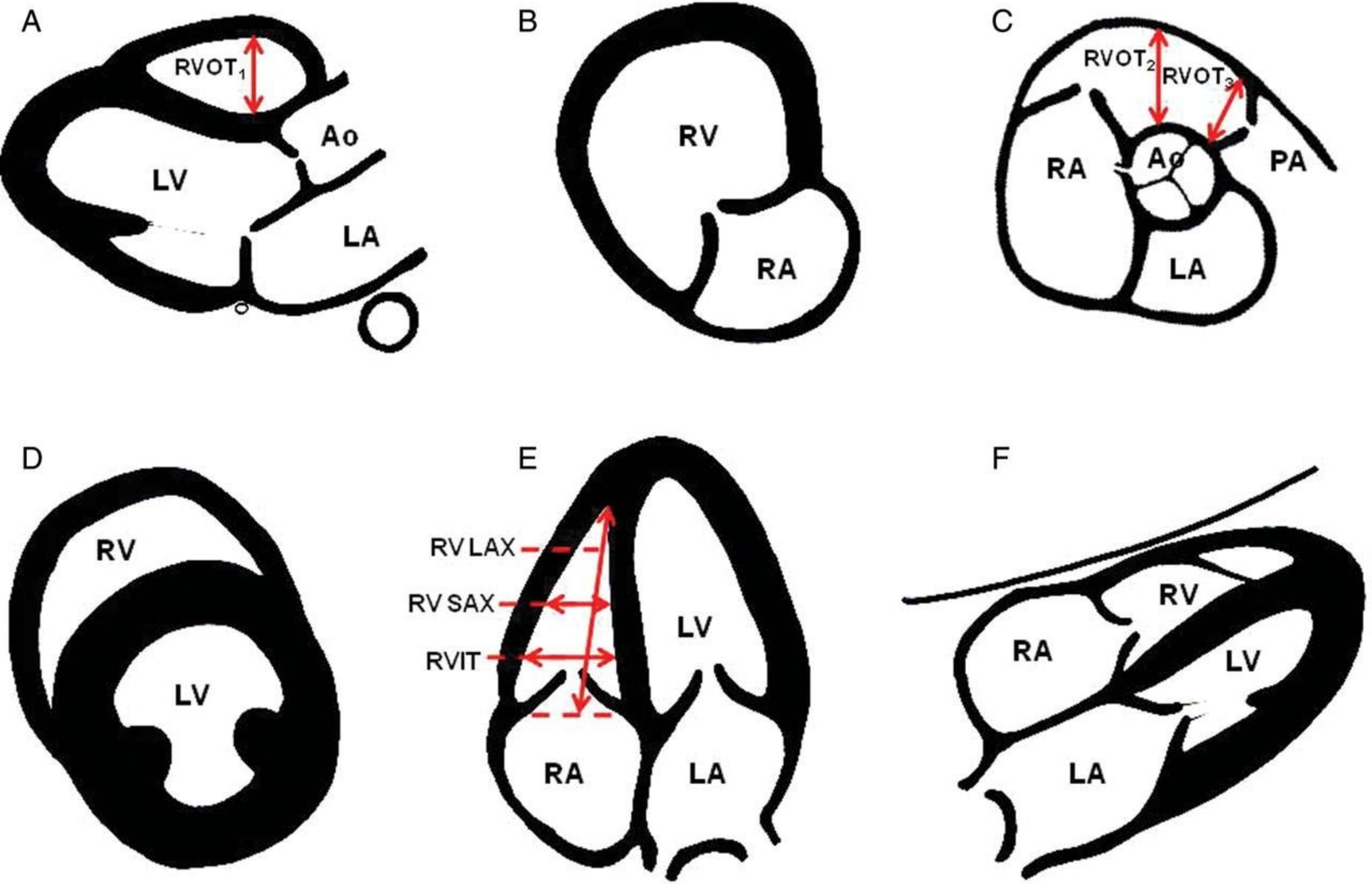
- Measure RV dimensions at
- modified 4chamber
- Measure RIMP with doppler , TAPSE with M-mode

The Right Ventricle : Dimensions



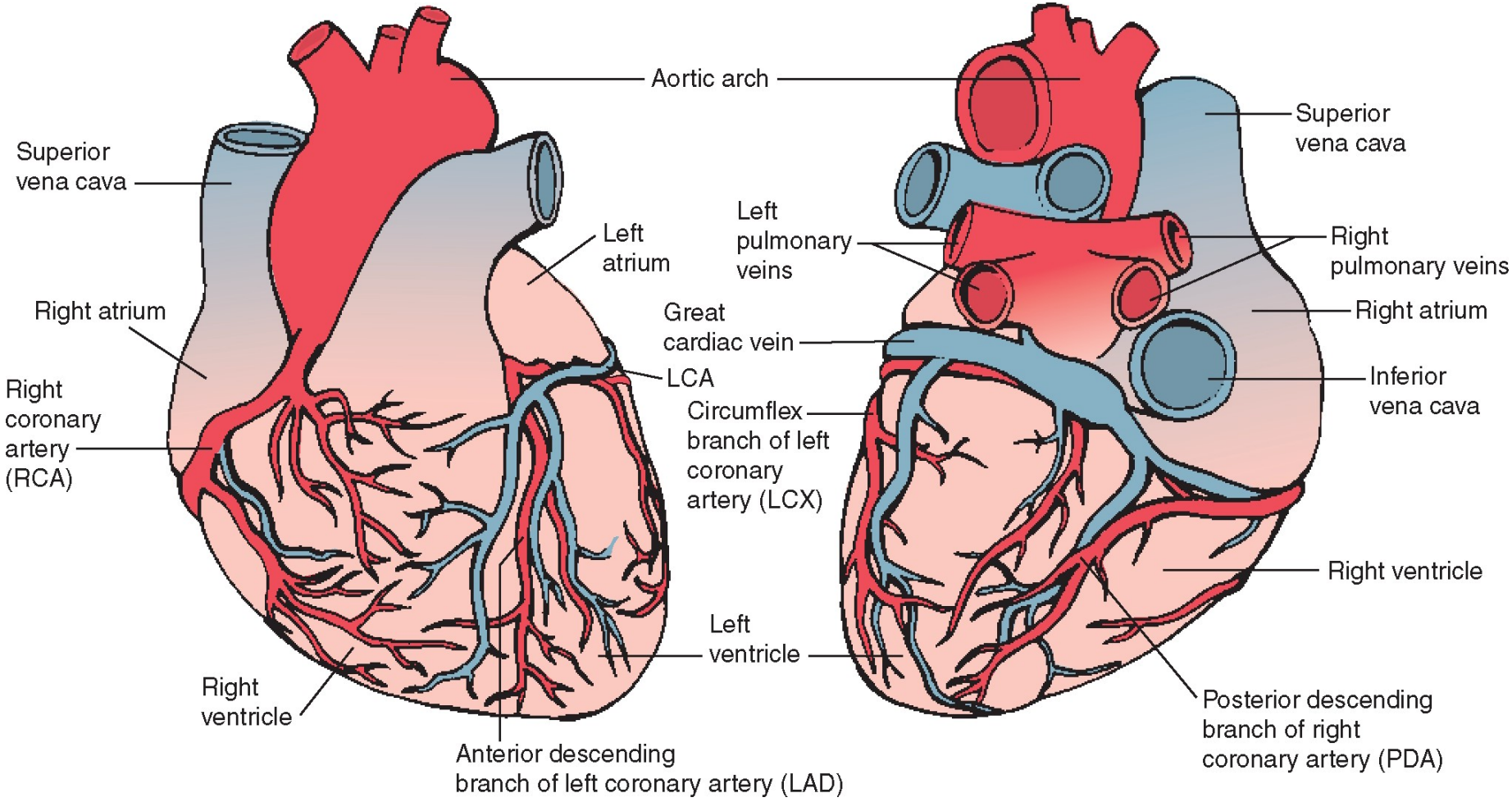


- RVD1 : maximal transverse dimension in the basal 1/3 of RV inflow in RV focused view (slightly off-axis 4 Chamber view)
- RVD2 : transverse RV diameter in the middle third of RV inflow


A
RVOT1
Ao
LV
LA
B
RV
RA
C
RVOT2
RVOT3
RA
Ao
PA
LA
D
RV
LV
E
RV LAX
RV SAX
RVIT
LV
RA
LA
F
RV
RA
LV
LA

The Coronary circulation

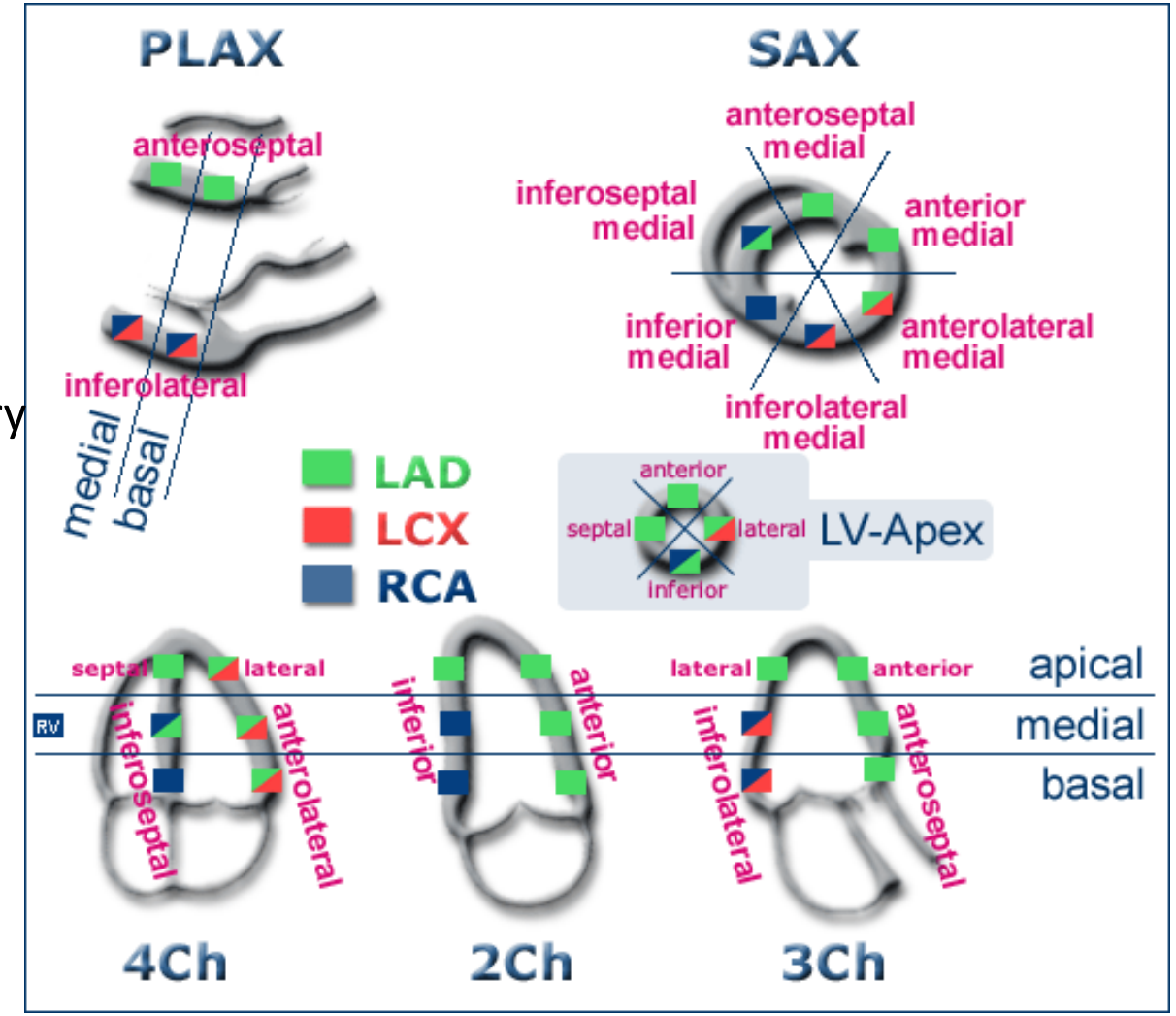
- the circulation of blood in the blood vessels of the heart muscle



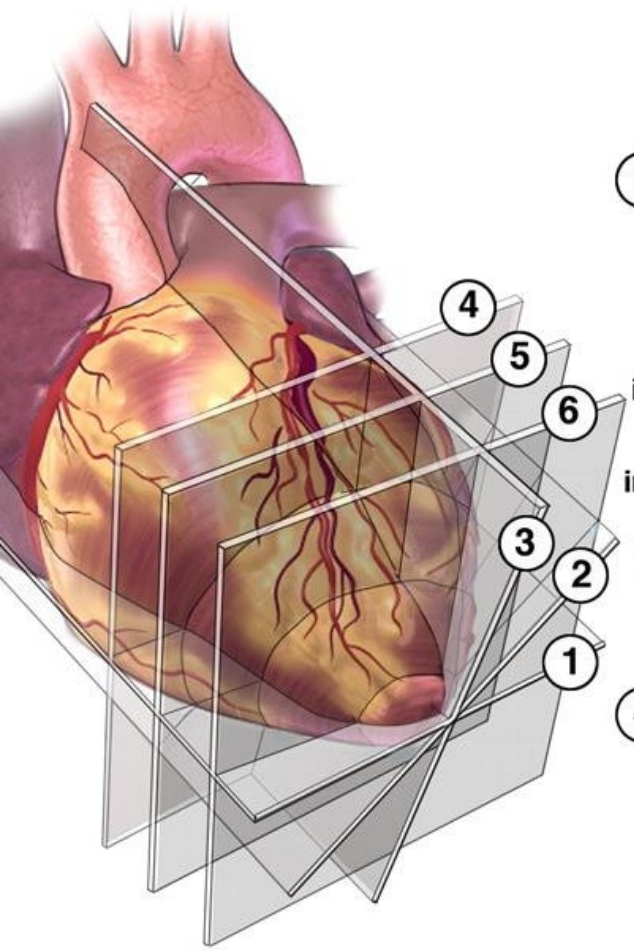
Coronary territory and wall motion

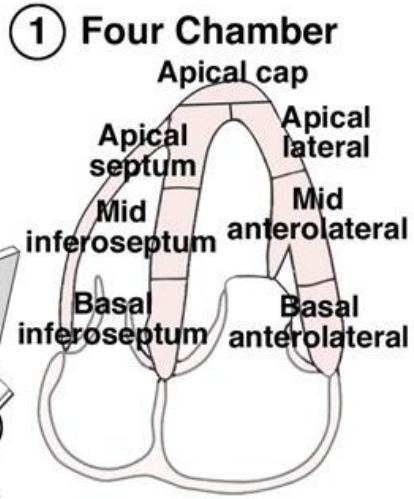
Typical distribution

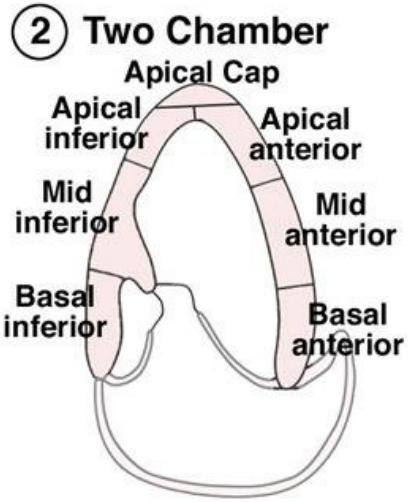
- LAD, The left anterior descending coronary artery
- The circumflex
- The right coronary artery

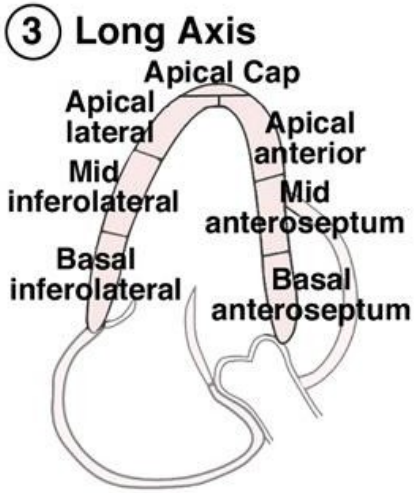


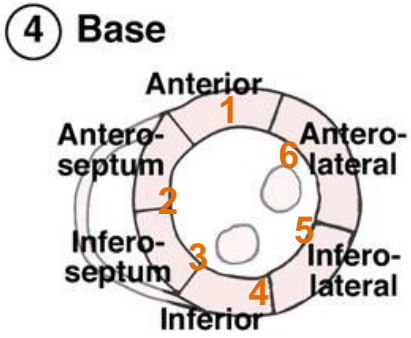
Coronary territory and wall motion

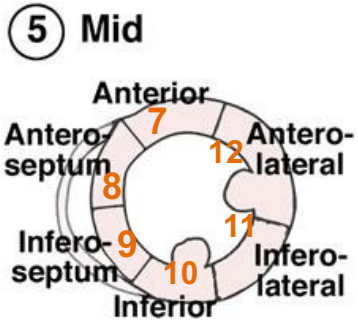


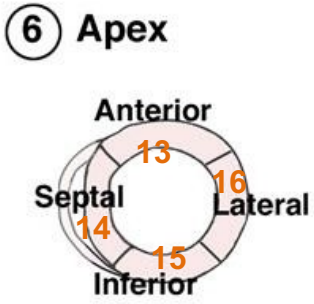




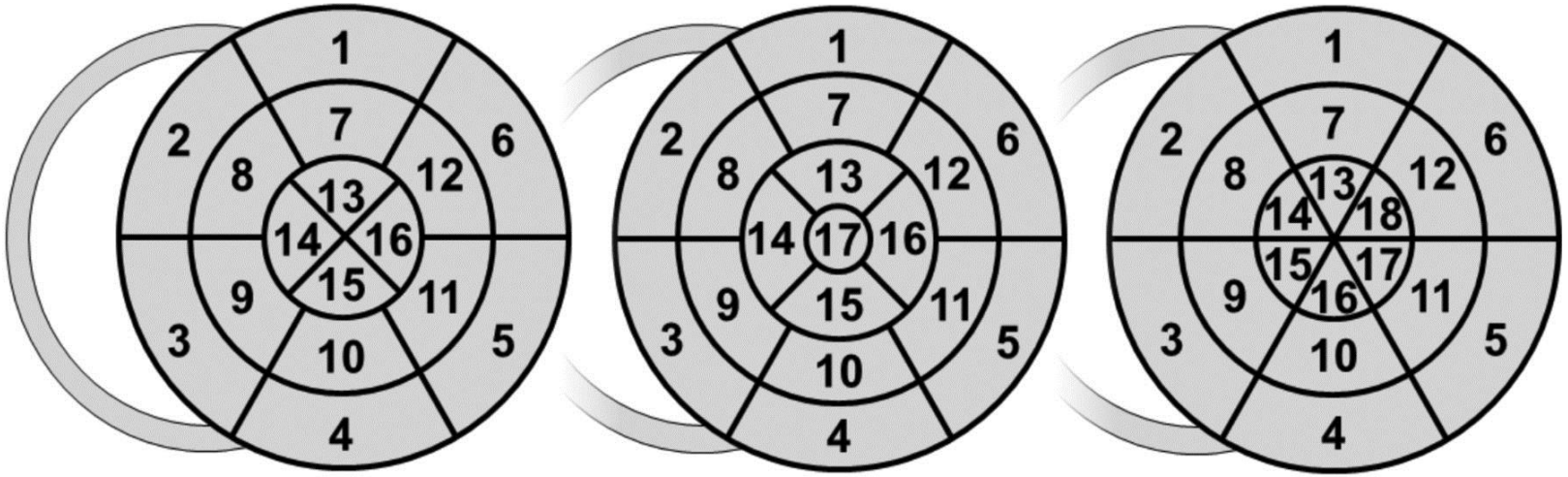








Coronary territory and wall motion



all models

1. basal anterior
2. basal anteroseptal
3. basal inferoseptal
4. basal inferior
5. basal inferolateral
6. basal anterolateral
7. mid anterior
8. mid anteroseptal
9. mid inferoseptal
10. mid inferior
11. mid inferolateral
12. mid anterolateral

16 and 17 segment model

13. apical anterior
14. apical septal
15. apical inferior
16. apical lateral

17 segment model only

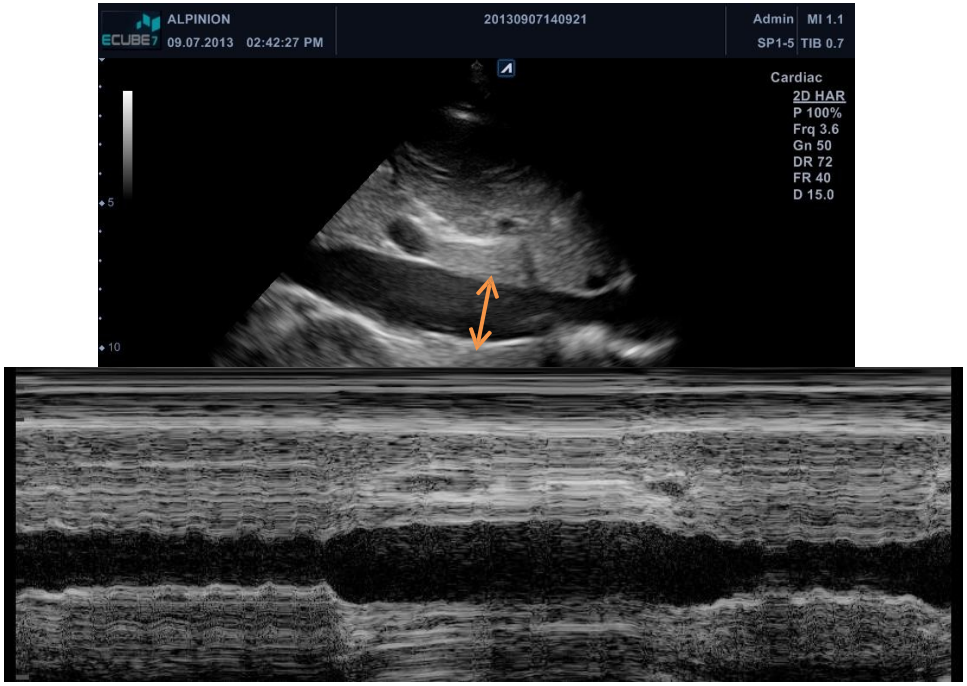
17. apex

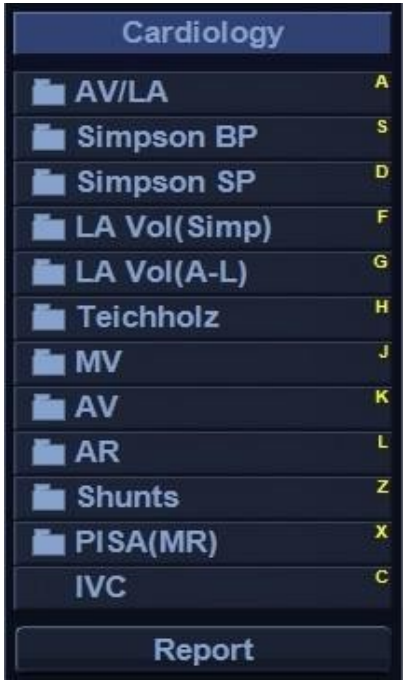
18 segment model only

13. apical anterior
14. apical anteroseptal
15. apical inferoseptal
16. apical inferior
17. apical inferolateral
18. apical anterolateral

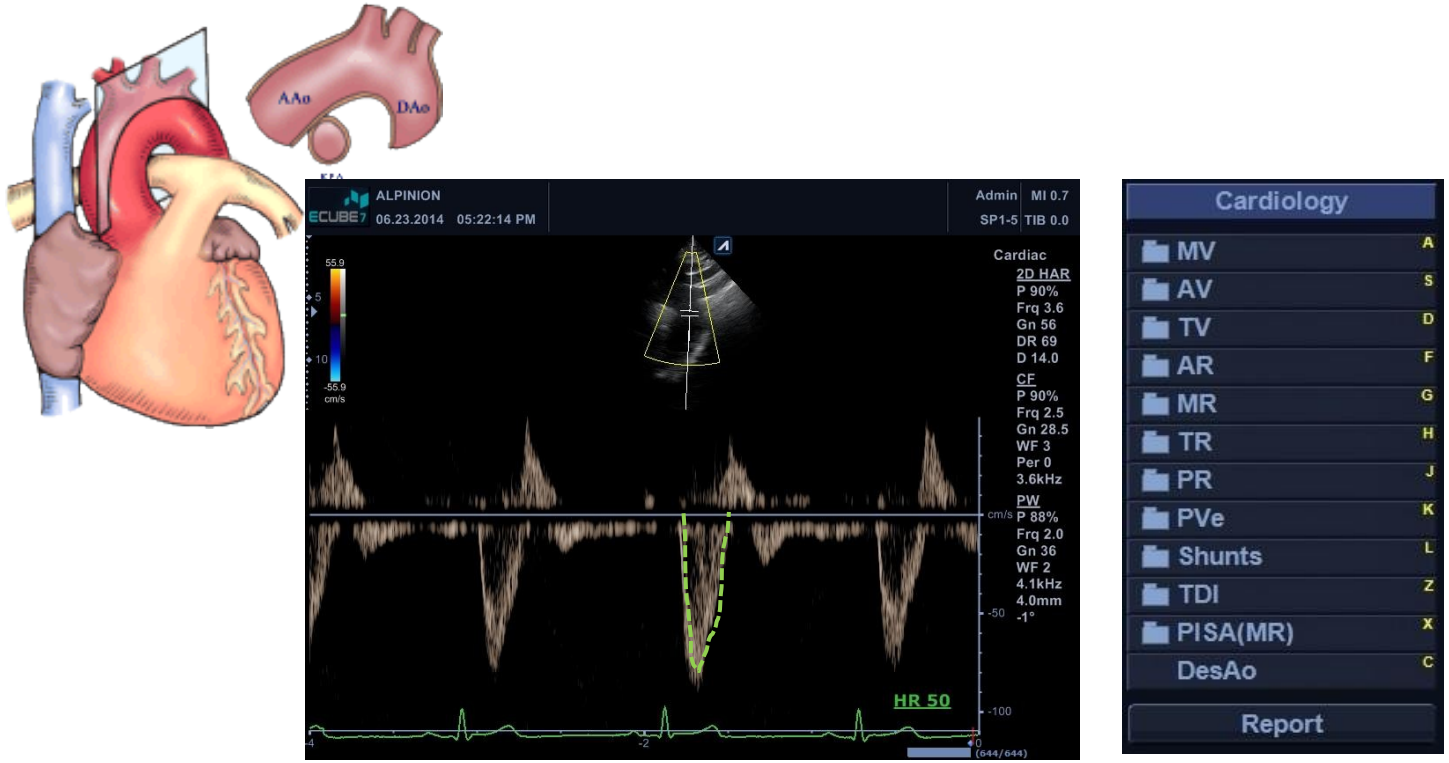
Subcostal view- M-mode

- Measure a diameter of the IVC
- Record diameter changes during inspiration and expiration
- Make a “New Measurement” under name of “IVC”





Suprasternal view Doppler



- In case of Aortic regurgitation, to measure velocity of the Descending Aorta

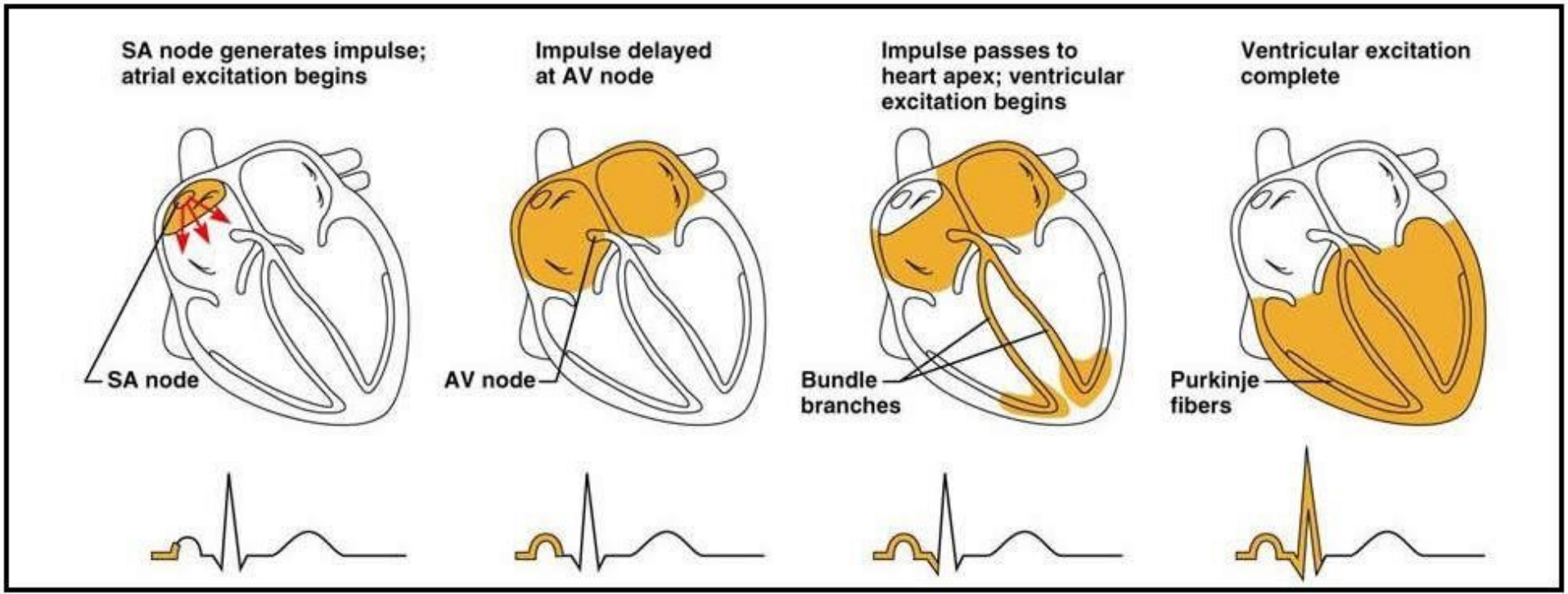
Measurements & Calculation

ALPINION Medical Systems, Clinical Specialist Team

The Conduction System of the heart & ECG

Intracardiac tracings show the normal intervals between

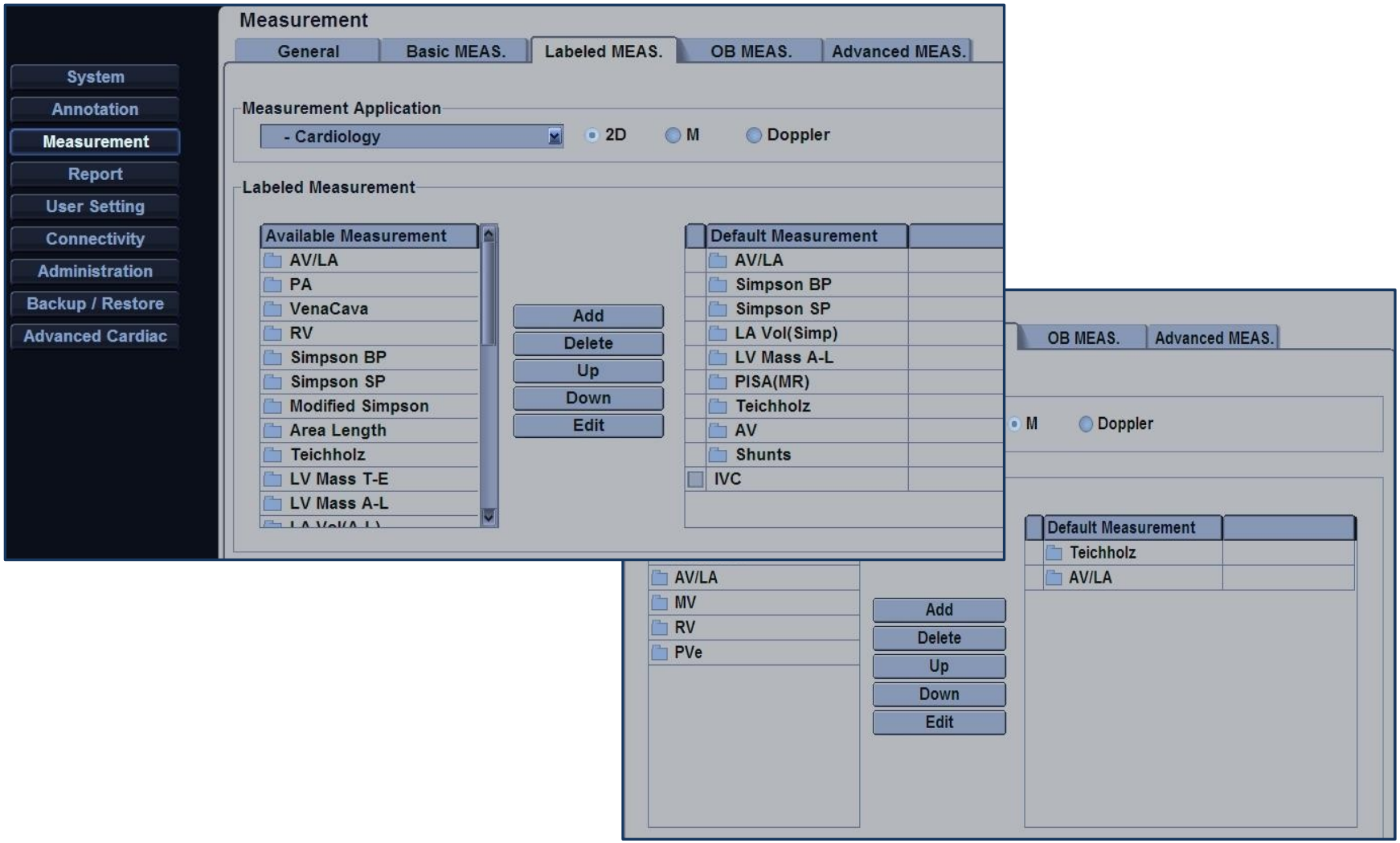
- P: atrial depolarization
- PQ segment: SA node to AV node
- QRS complex: ventricular depolarization
- ST segment : ventricular depolarization
- T : ventricular repolarization



Chamber Quantification & Great Vessel

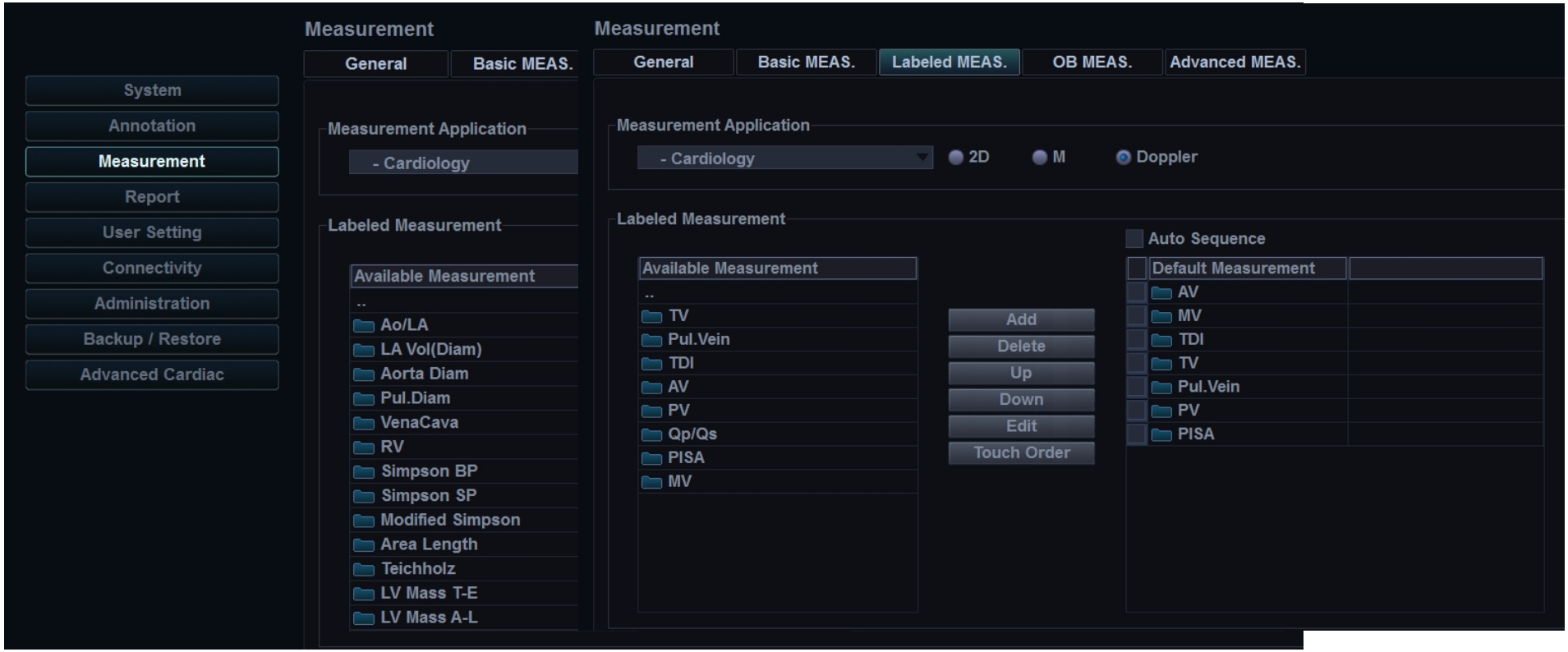
- The Left Ventricle size and thickness
- The LV Global Systolic Function
- LV Regional Function LV Mass
- The Right Ventricle
- RV Systolic Function
- The Left and Right Atria
- The Aortic Annulus and Aortic Root

Set Up : 2D Measurement



Set Up : Doppler Measurement

- Different from system to system



Cardiac Function – Systolic function

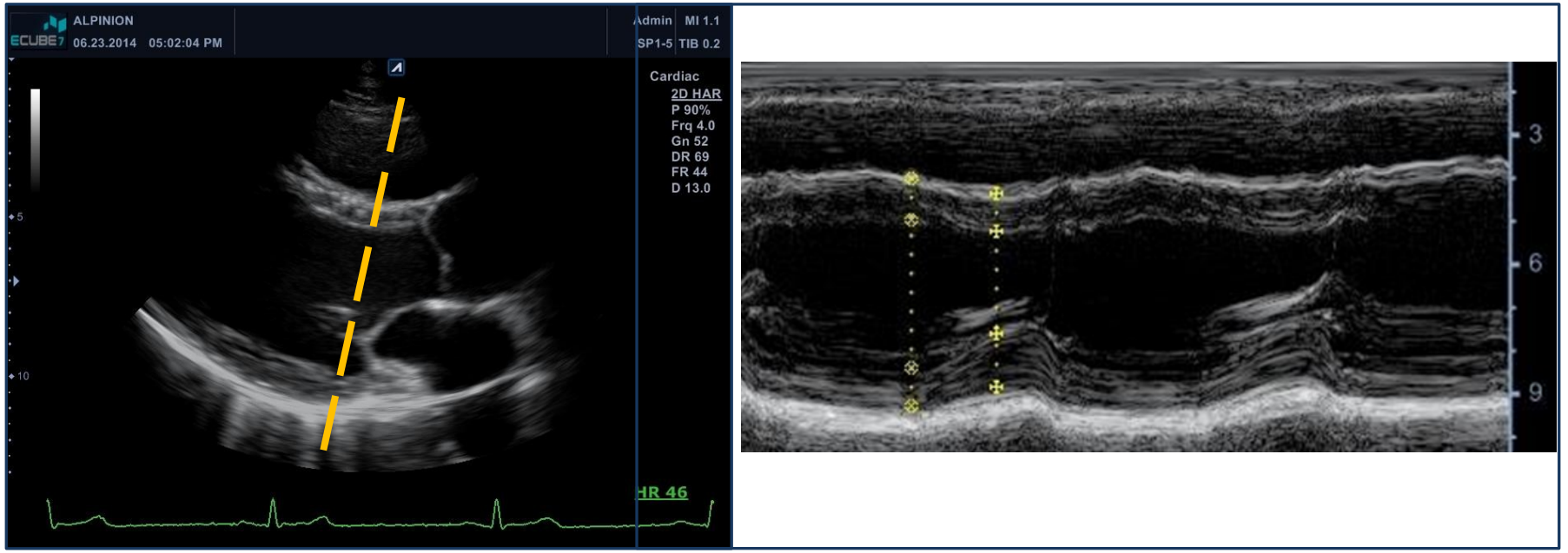
- Left Ventricular function
  - Systolic function
    - Fractional shortening, Ejection Fraction
    - Tissue Doppler Imaging
    - Myocardial Performance Index
    - dp/dt using mitral regurgitation
    - Newer techniques
      - ✓ Strain imaging
  - Diastolic function
- Right Ventricular function
  - Systolic function
    - Annular velocity, FAC, RIMP, TAPSE

Systolic function: LV volume

- Systolic Function ≈ Ejection Fraction
- Evaluated by Simpson's Method
- Assessment of left ventricle systolic function is an important clinical variable with respect to diagnosis, prognosis and treatment

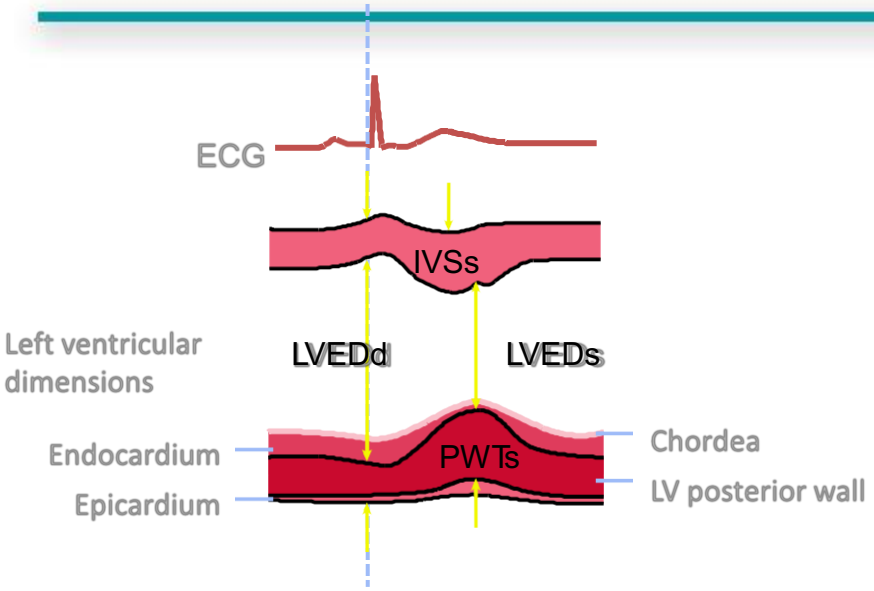
$$\frac{EDV - ESV}{EDV} \times 100 \Rightarrow EF$$

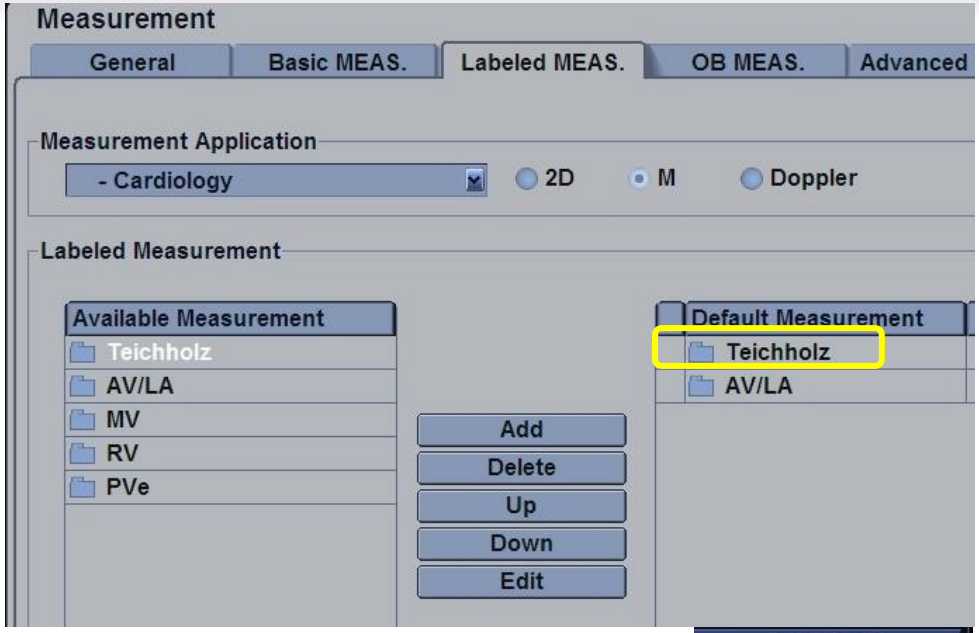
Systolic function : Internal linear dimension



- Left Ventricle M - mode
  - Place (M-line) over the mitral valve leaflet tip, perpendicular 90 ^{o} to the LV axis
  - Perform M-mode by pressing “M” knob

Systolic function : Internal linear dimension

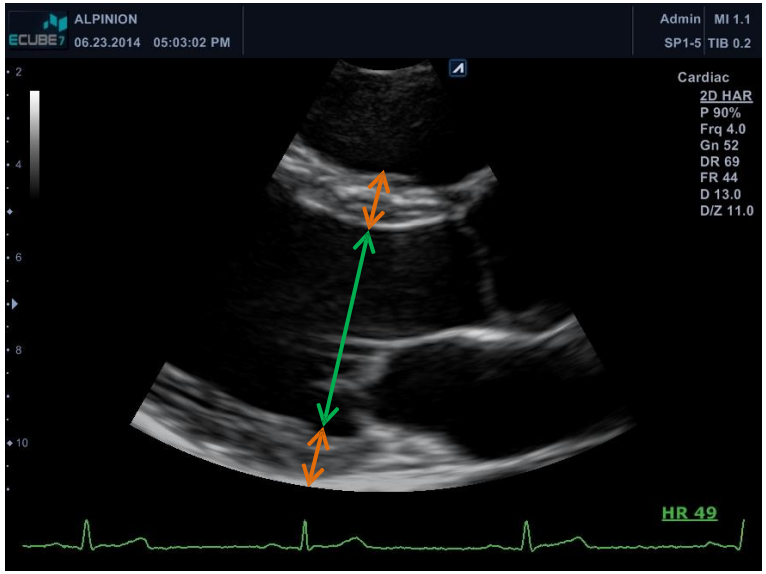


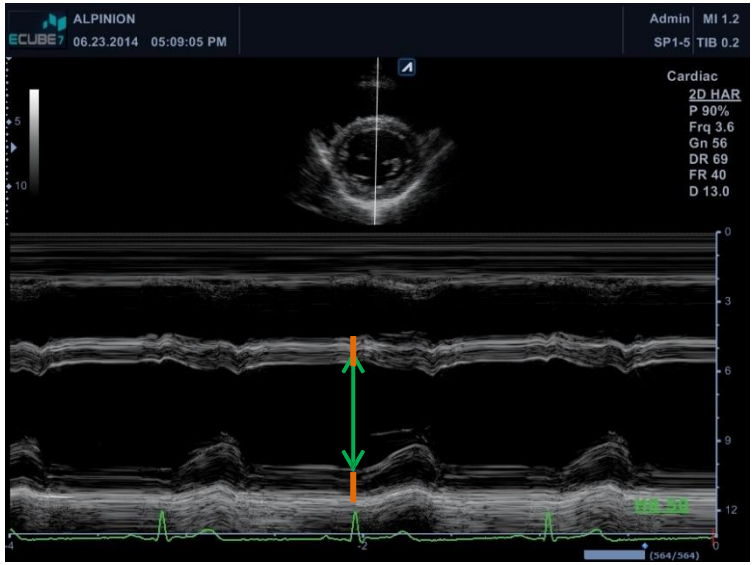


- Measurement -> Teichholz
- set cursor at “R” point on ECG for diastole measure
- Start from “RVID”, or select “Diastole” measure from “ IVSd”
- Place a cursor from IVS upper end -> “Set” drag another cursor to the lower end of IVS -> “Set”, drag a cursor to LVID-> “Set”, drag a cursor to LVPW->”Set”
- press “Systole” and repeat from IVSs through LVPWs

***Turn On/Off each measurement item on “System Preset”
-> “ Measurement” -> “Labeled Measure”

Systolic function: LV fractional shortening





Truly perpendicular to the long axis of the left ventricle

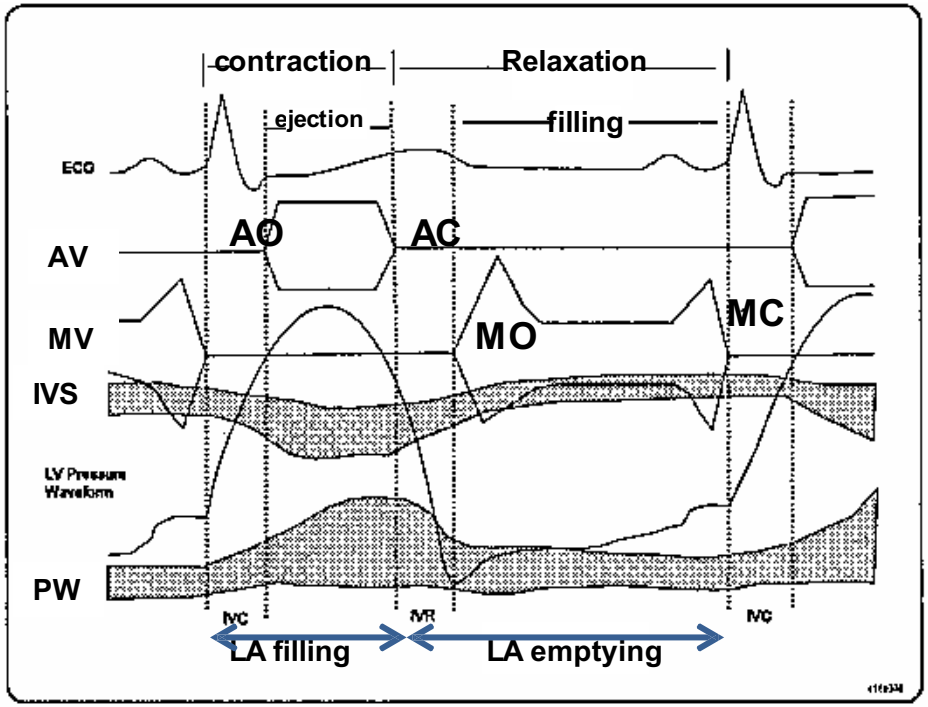
- Fractional Shortening of LV : (LVIDd – LVIDs) / LVIDs *100
- Calculation of relative wall thickness with the formula

(2 x posterior wall thickness)/ (LVIDd at end –diastole)

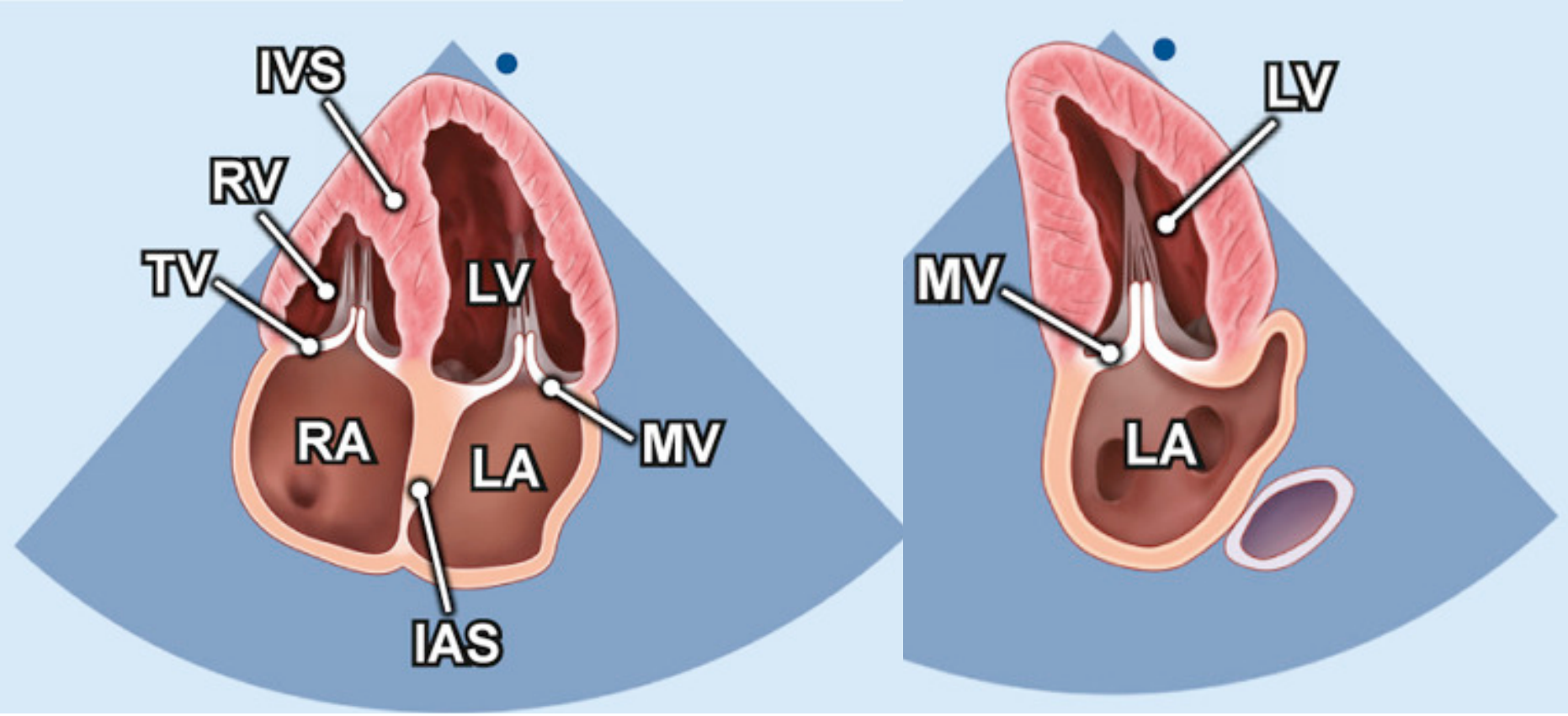
	Female	Male
Relative wall thickness (cm)	**0.22-0.42**	**0.24-0.42**
Septal thickness (cm)	**0.6-0.9**	**0.6-1.0**
Posterior wall thickness (cm)	**0.6-0.9**	**0.6-1.0**

Systolic function: LV dimension, volume

- EF by M-mode
  - Teichholz or Quinones method
  - Not recommended by 2015 ASE

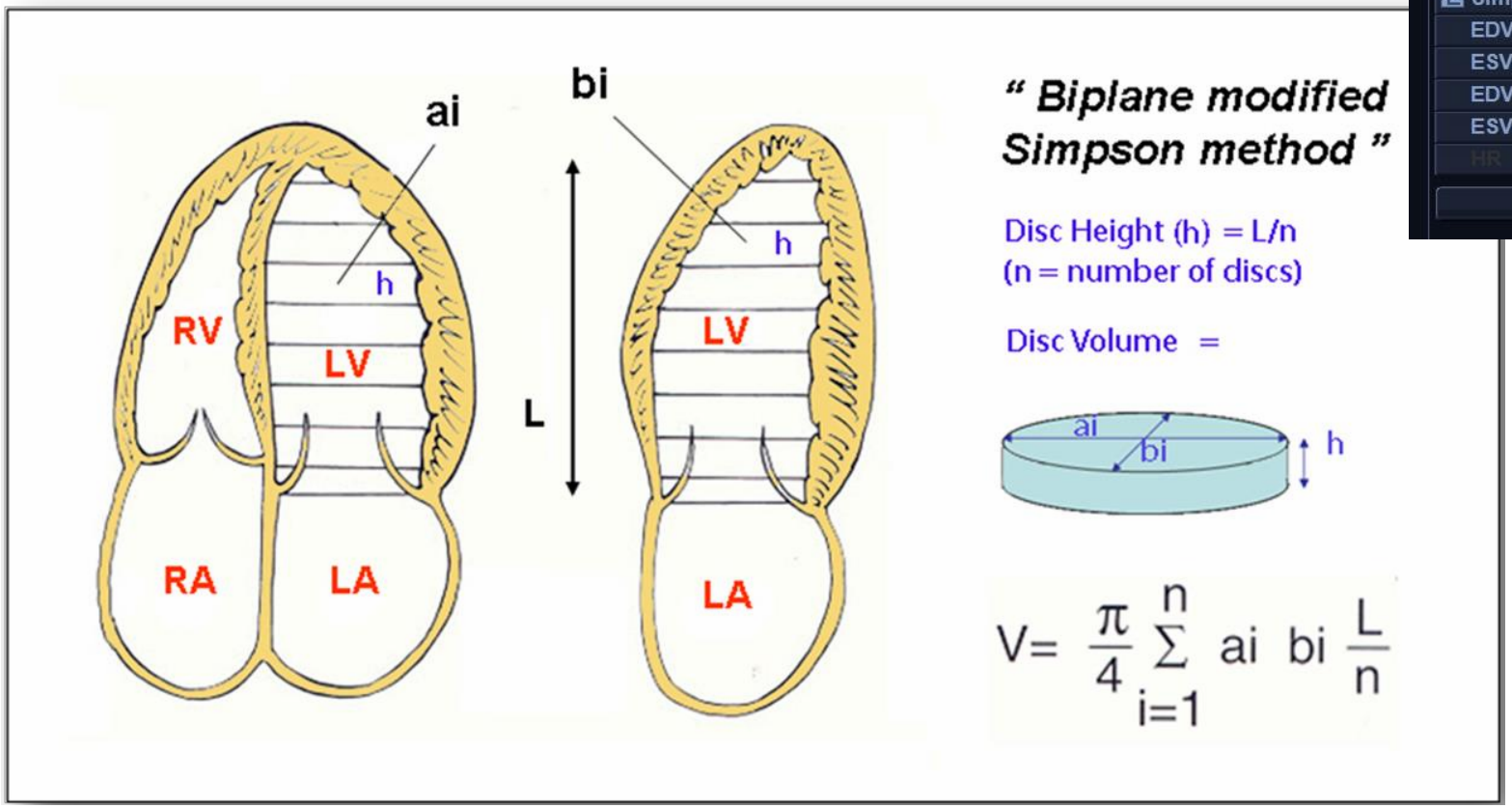


Systolic function: LV volume



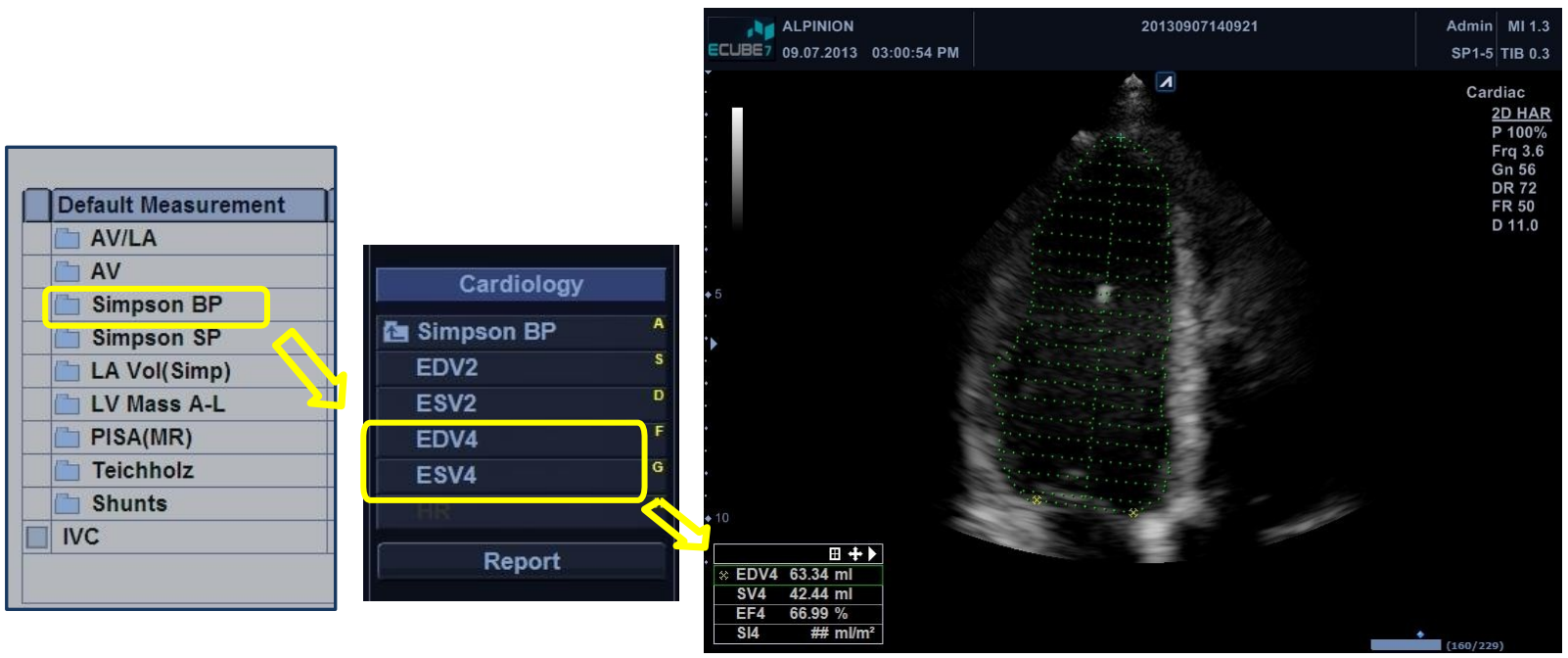
Systolic function: LV volume

- Biplane Simpson's method (Modified Simpson's method)
  - LV volumes is measured form annulus to annulus tracing along the endocardial border of the LV



Systolic function: LV Ejection Fraction

- Biplane Simpson's method (Modified Simpson's method)
  - LV length is defined as the distance between the center of the mitral ann ular ring and the apex
  - Once "EDV4" is done ->"Priority" for change phase -> Trackball to search end-systole -> "Measure " -> select "ESV4" -> repeat trace



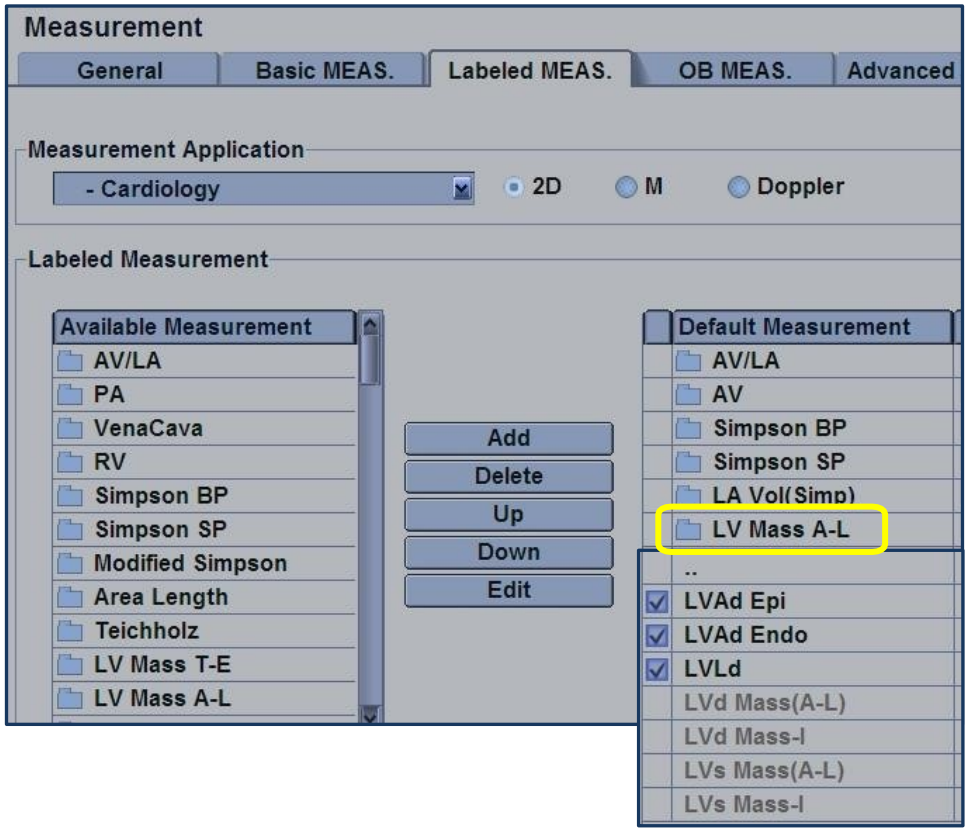
Systolic function: LV volume

- LV Volume
  - Calculated from the dimension and area
  - Apical 4 chamber and 2 chamber views
  - Modified Simpson's method or disk summations method

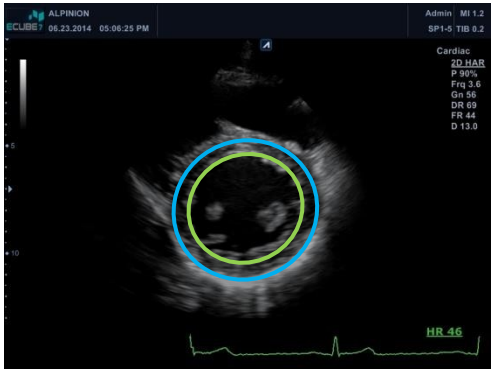
Normal values for 2D echocardiographic parameters of LV size and function according to gender, 2015 ASE

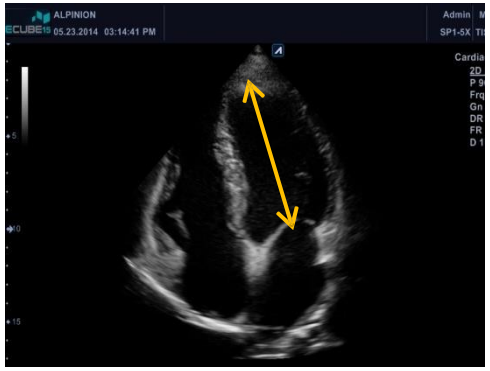
Parameter	Male		Female	
	Mean ± SD	2-SD range	Mean ± SD	2-SD range
LV internal dimension				
Diastolic dimension (mm)	50.2 ± 4.1	42.0 -58.4	45.0 ± 3.6	37.8 – 52.2
Systolic dimension (mm)	32.4 ± 3.7	25.0 -39.8	28.2 ± 3.3	21.6 – 34.8
LV volume (biplane)				
LV EDV (mL)	106 ± 22	62 -150	76 ± 15	46 -106
LV ESV (mL)	41 ± 10	21 -61	28 ± 7	14 - 42
LV volume nomalized by BSA				
LV EDV (mL/m²)	54 ± 10	34 -74	45 ± 8	29 -61
LV ESV (mL/m²)	21 ± 5	11- 31	16 ± 4	8 - 24
LV EF (biplane)	62 ± 5	52 -72	64 ± 5	54 - 74

Systolic function: LV mass



Systolic function: LV mass





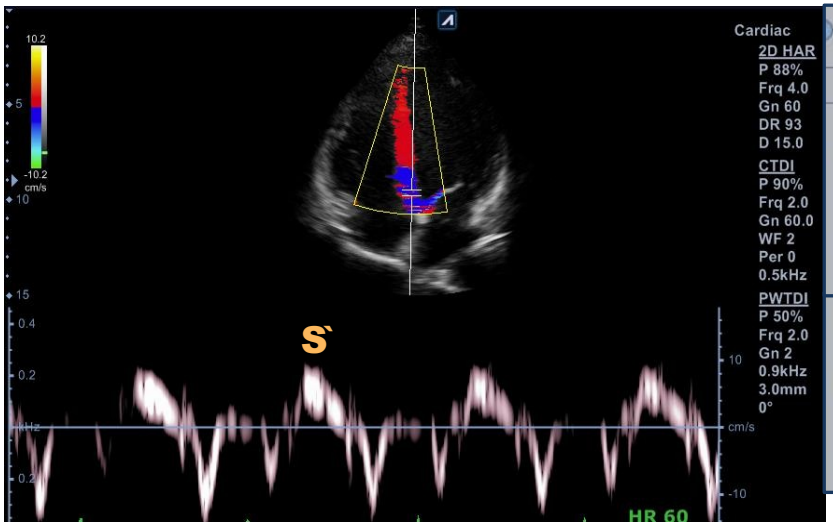
Normal ranges for LV Mass indices

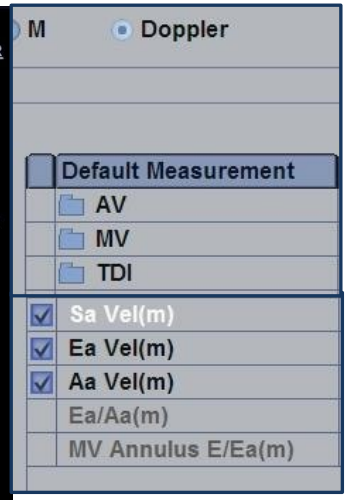
	Female	Male
LV mass(g)	66-150	96-200
LV mass/BSA(g/m²)	44-88	50-102

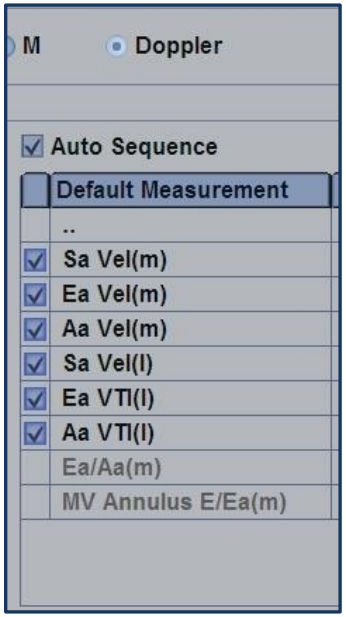
- Parasternal short axis view
- Select “ T-E method ” or “Area-Length method”
- Measure outer circle for “A1” exclude papillary muscle , inner circle for “A2”
- Go to apical 4 chamber view
- Measure “LV dimension” from apex to mid annular point
- Use BSA index

Systolic function: Annular tissue doppler

- Activate color TDI and apply to myocardial septal wall
- Press PW with sample volume by 4mm at junction of mitral annulus to septum

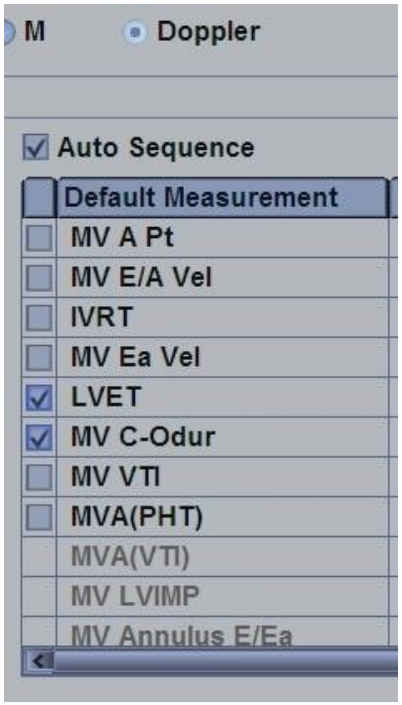


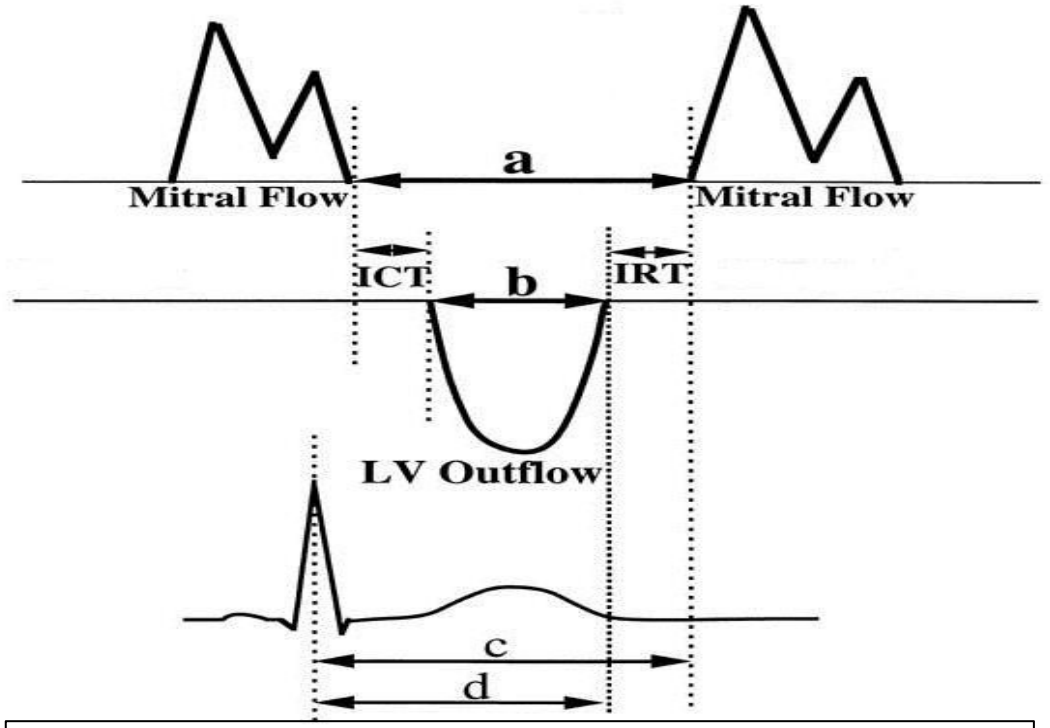




Systolic function: Myocardial Performance Index

- LV MPI : normal value 0.35 ± 0.05
  - place PW gate between the mitral and the aortic valve
  - measure the time at mitral closing point to next opening
  - measure the LV ejection time

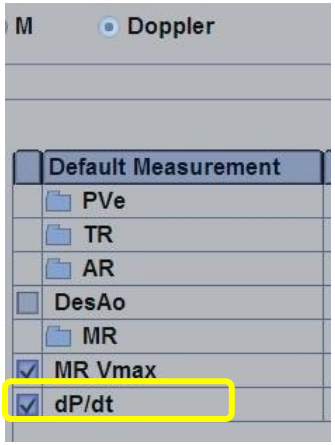


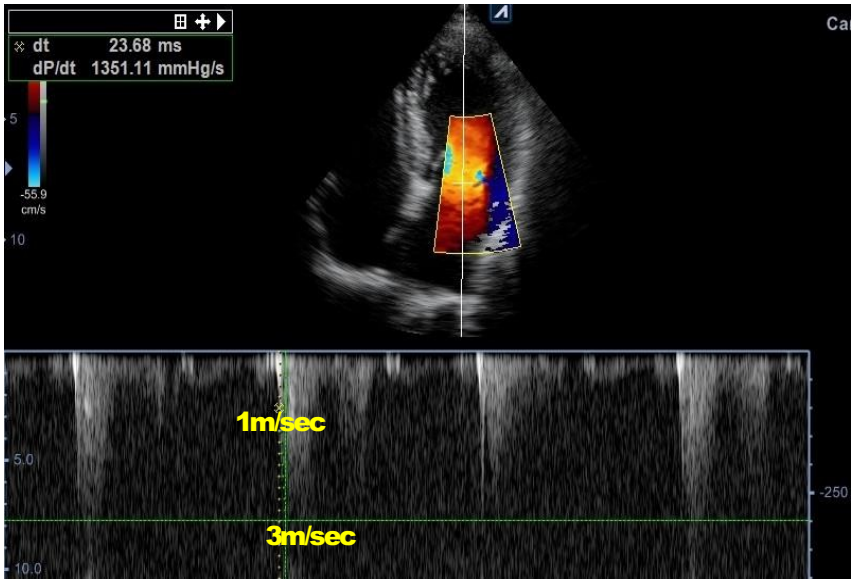


MPI = (a –b) / b = (IVCT +IVRT) / ET

Systolic function: MR dp/dt

- dP/dt in Mitral Regurgitation flow
  - Obtain CW spectral from the mitral regurgitation jet
  - open an measurement item “ MR dp/dt” from MR
  - bring a cursor at 1 m/sec point on the MR CW spectrum
  - Then, place another cursor at 3m/sec on the same MR CW





LV Systolic function :

Normal ranges and severity partition cutoff values for 2DE-derived LV EF and LA volume, 2015 ASE

Parameter	Male			
	Normal	Mildly abnormal	Moderately abnormal	Severely abnormal
LV EF (%)	52-72	41-51	30-40	<30
LA volume/BSA (mL/m²)	16-34	35-41	42-48	>48

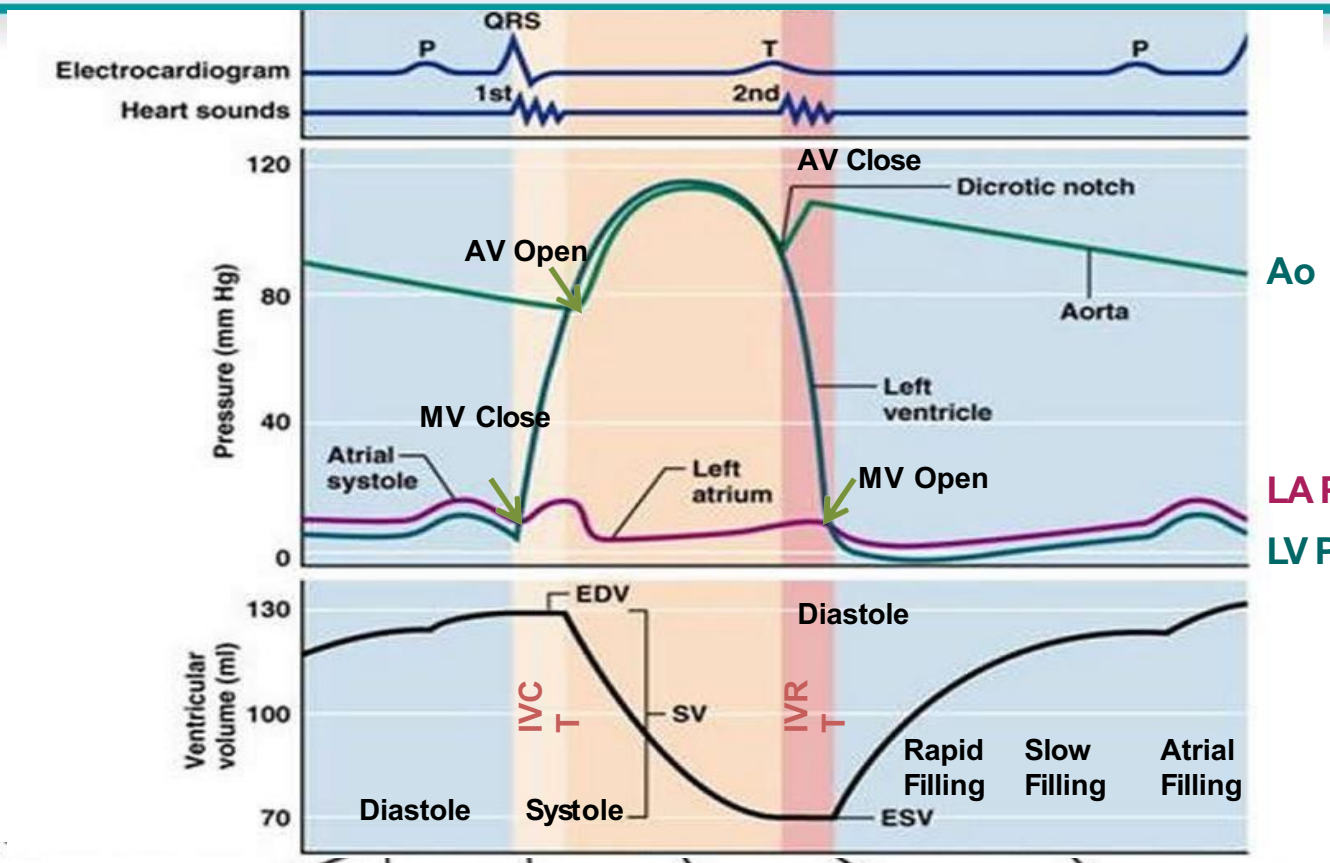
Parameter	Feale			
	Normal	Mildly abnormal	Moderately abnormal	Severely abnormal
LV EF (%)	54-74	41-53	30-40	<30
LA volume/BSA (mL/m²)	16-34	35-41	42-48	>48

- Strain (%) = (L t - L0)/ L0
  - GLS measurements should be made in the 3 standard apical long axis, 4 chamber, and 2 chamber views and averaged
  - A peak GLS in the range of -20%
  - The lower the absolute value of strain, the more likely abnormal

Echocardiograph for Diastolic function

- Left Ventricular function
  - Diastolic function
    - adequate filling of the ventricle during rest and exercise without abnormal increase in diastolic pressure

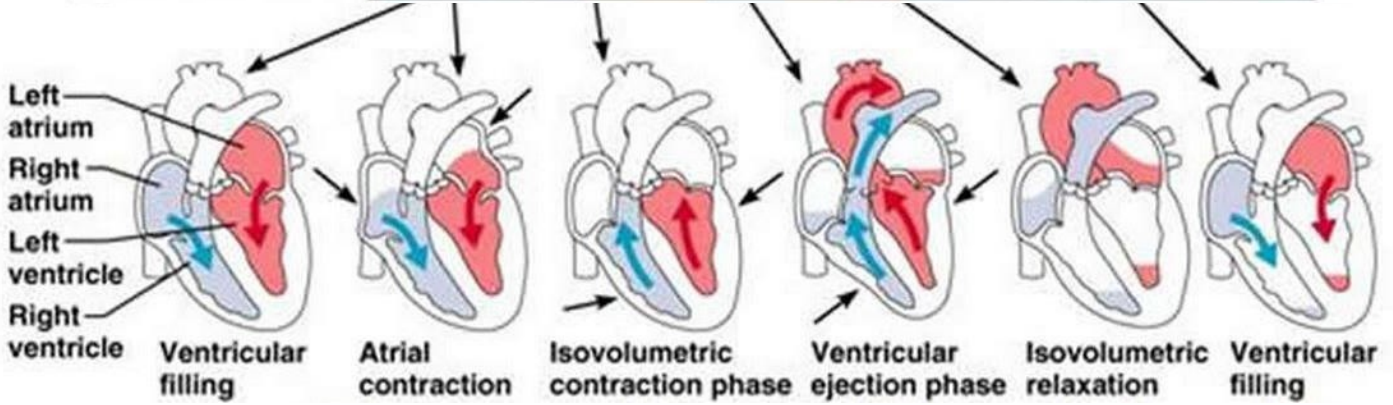
Diastole in Cardiac Cycle



Ao Pressure

LA Pressure

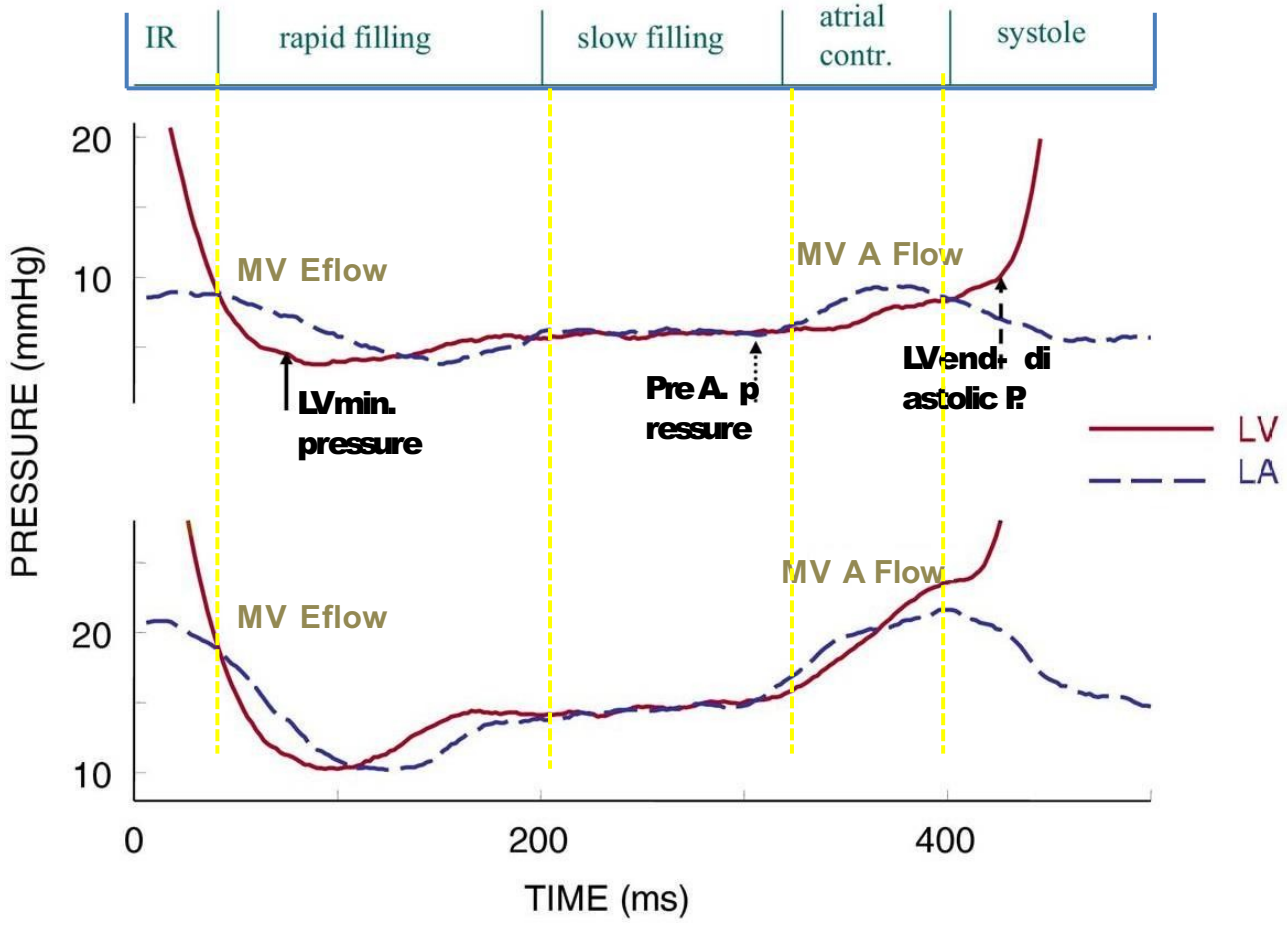
LV Pressure



Echocardiograph for Diastolic function

- Determinants of LV filling
  - active myocardial relaxation
  - LV compliance
  - LA function
  - heart rate
  - pericardium

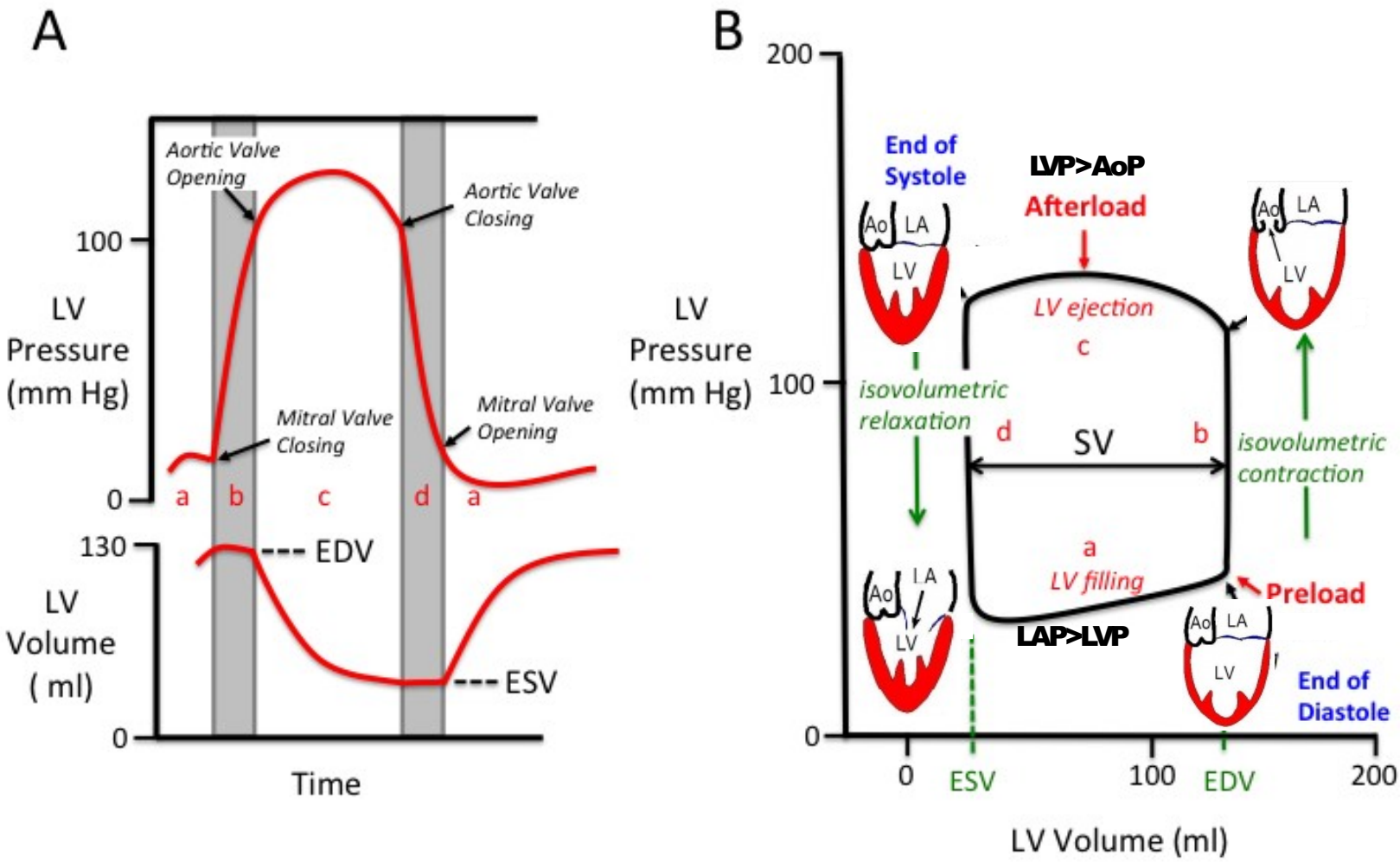
Pressure gradient during diastole phases



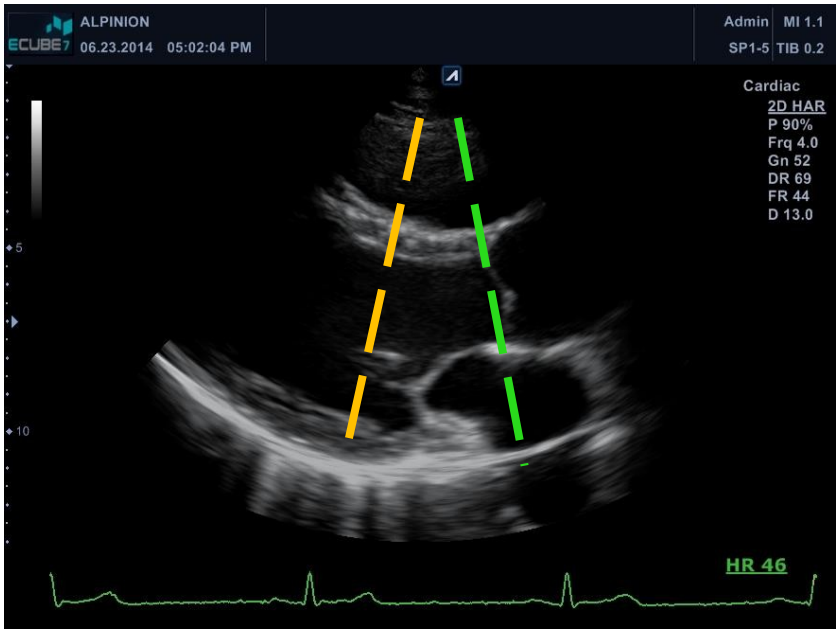
Echocardiography for Diastolic function

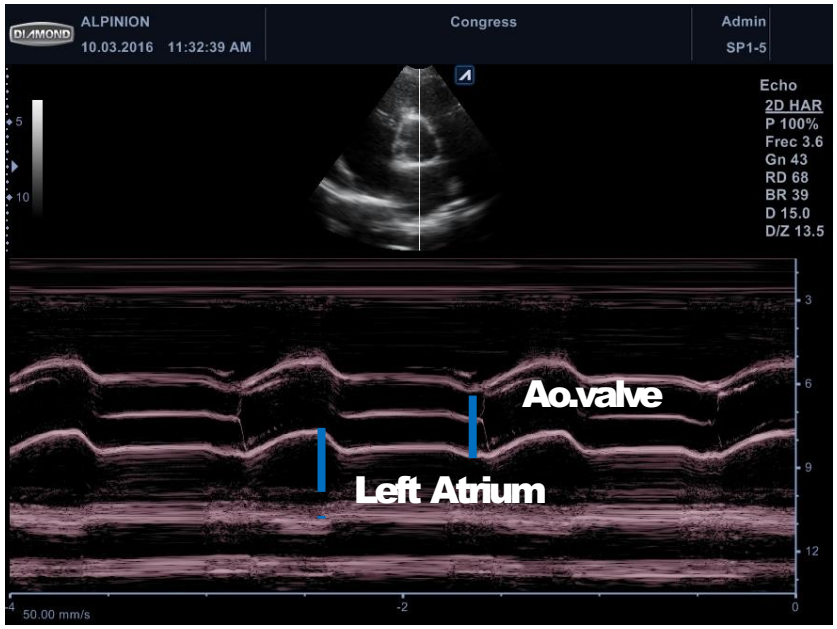
- LA Volume
- Isovolumic Relaxation Time
- Mitral inflow
    - initial low pressure filling : E wave
    - active atrial contraction : A wave
- Pulmonary vein flow
- Tissue Doppler : E`

Pressure - Volume curve in Cardiac Cycle



Diastolic function: LA volume



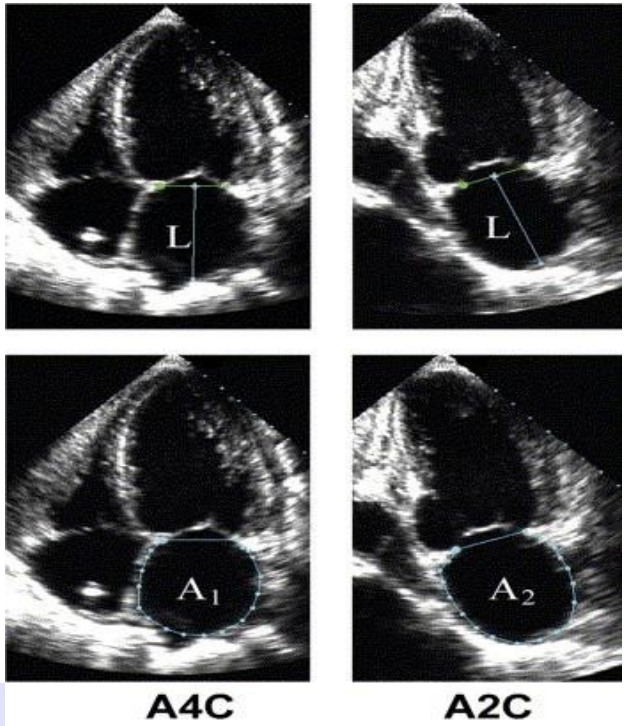


- Measure the Aortic valve and the Left atrium
  - Keep M-line 90 ^{o} to Aorta/Left Atrium wall
  - “ Measure ” -> Ao/ LA folder
  - Put a cursor edge to edge

Diastolic function: LA volume

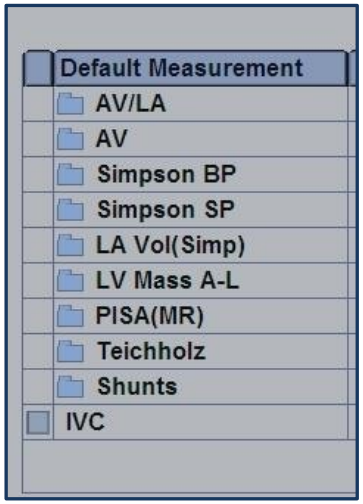
- Select 1 of “LA Vol(Simp)” measurements

  - place a cursor on mitral annulus-septal wall -> trace to opposite site



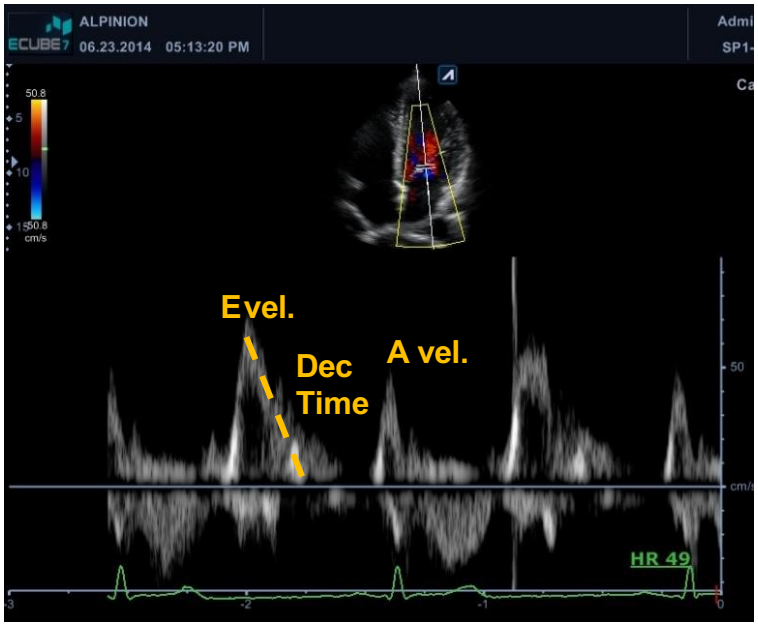
	Normal range	Mildly abnormal	Moderately abnormal	Severely abnormal
Male	16-34	35-41	42-48	48>
Female	16-34	35-41	42-48	48>

LA volume/BSA (ml/m²)

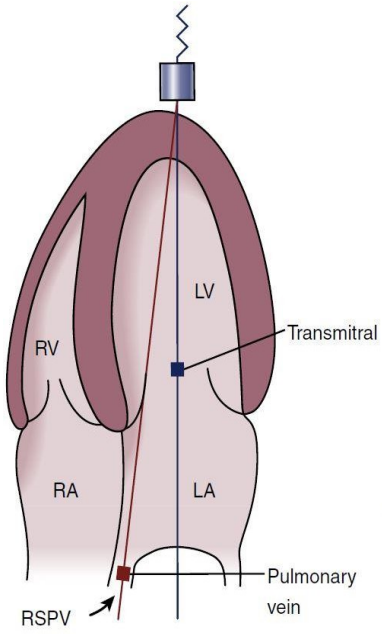


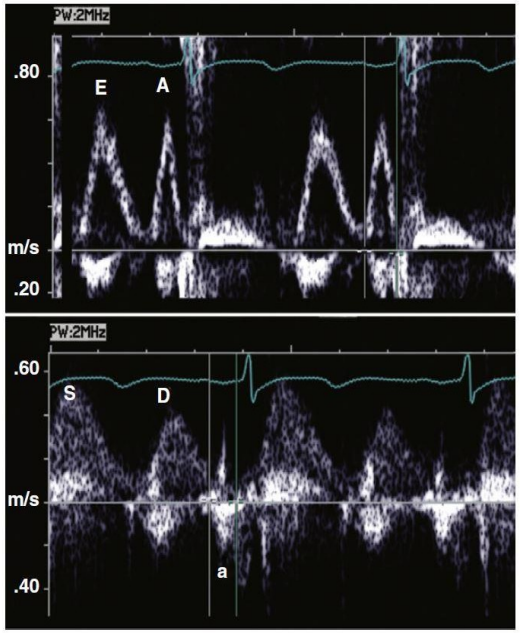
Diastolic function: Mitral flow

- Mitral Inflow ; Peak E vel., Deceleration Time, Peak A vel., IVRT
- Sample volume; 2-3mm, locates at between 2 leaplets ` tip



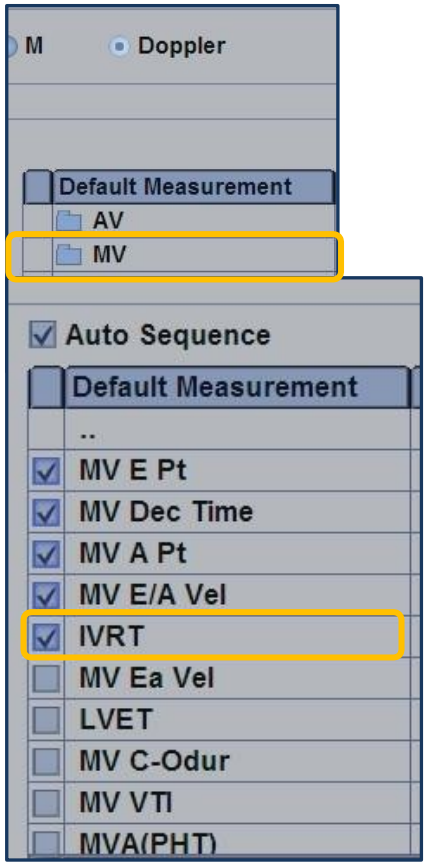
Otto. Text book of Clinical Echocardiography, 5th

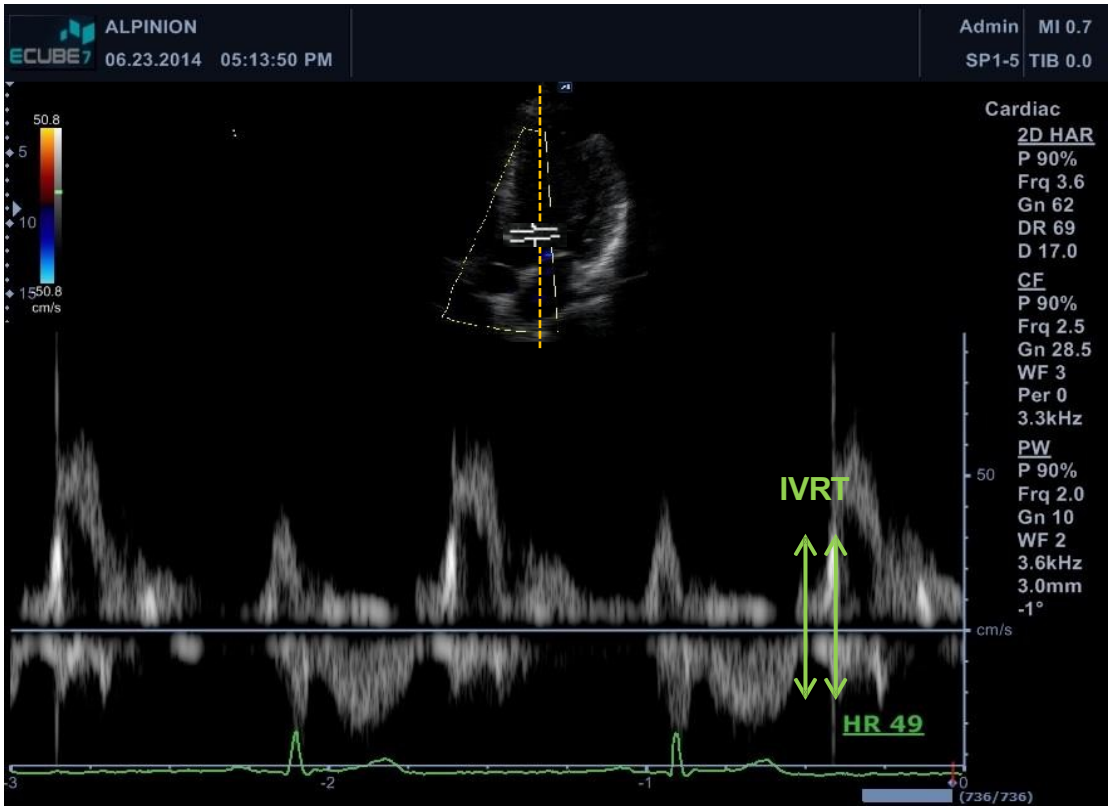




Diastolic function: Mitral flow

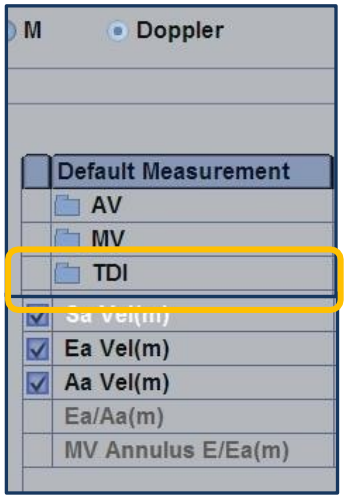
- Mitral Inflow ; Peak E vel., Deceleration Time, Peak A vel., IVRT
- Sample volume; locates SV between LV outflow and MV inflow

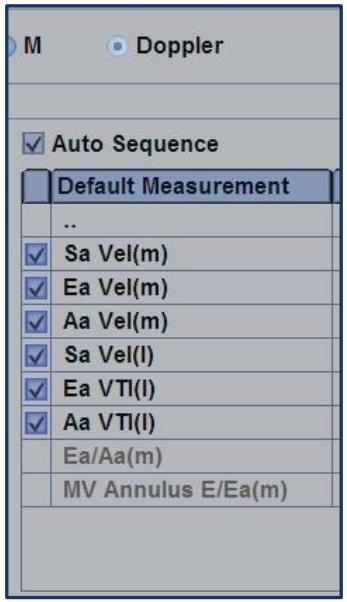


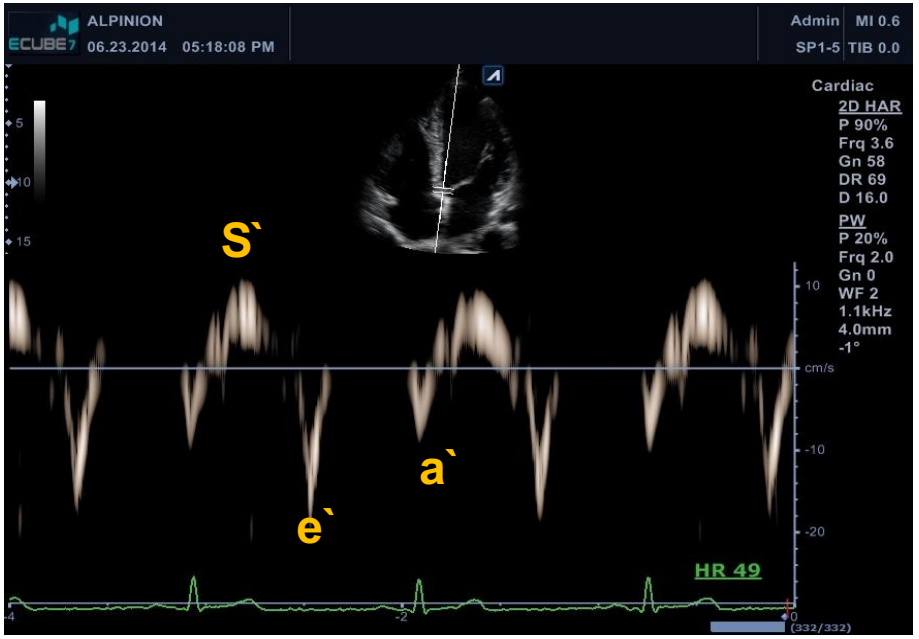


Diastolic function: Tissue velocity at mitral annulus

- TDI : Ea Vel or MV Ea Vel.
  E/E' value : 8 normal 15> abnormal
- E` < 8.5Cm/sec, E`/A` <1
- usually lateral TDI shows higher velocities than septal



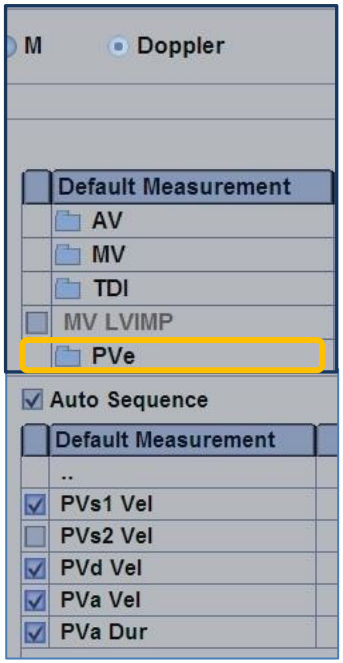


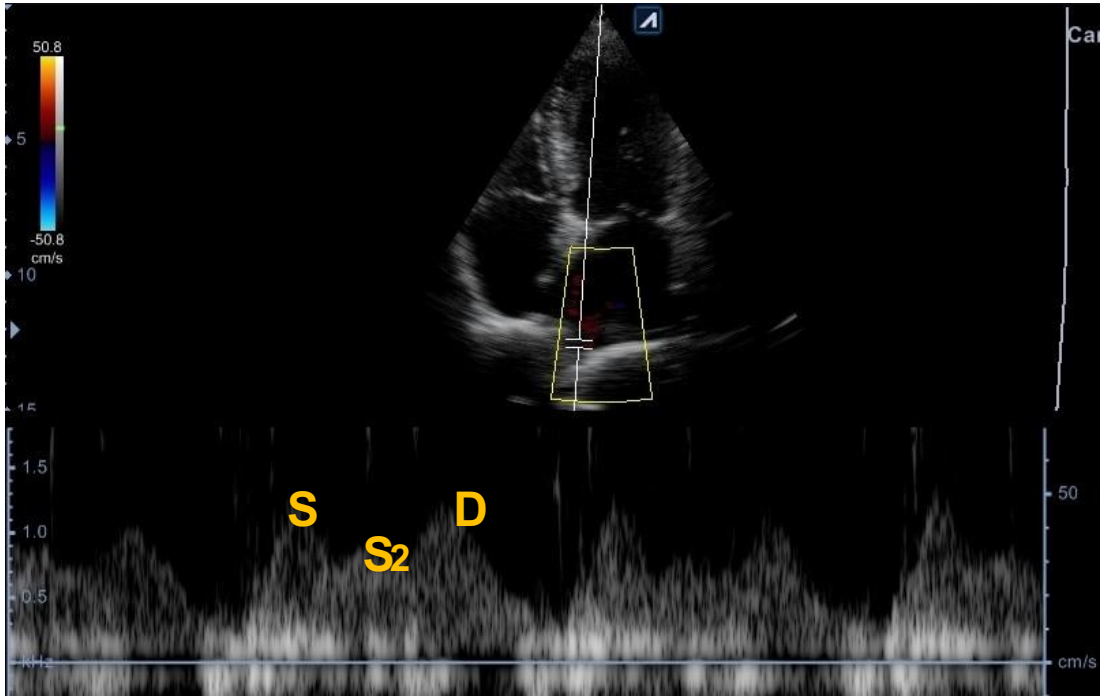


Tissue Doppler Imaging

Diastolic function: Pulmonary vein flow

- Pulmonary vein flow ; systolic Vel., diastolic Vel., A vel. & duration
- Measure item under “ PVe”
- Sample volume ; 2-3mm, below into pulmonary vein 0.5cm

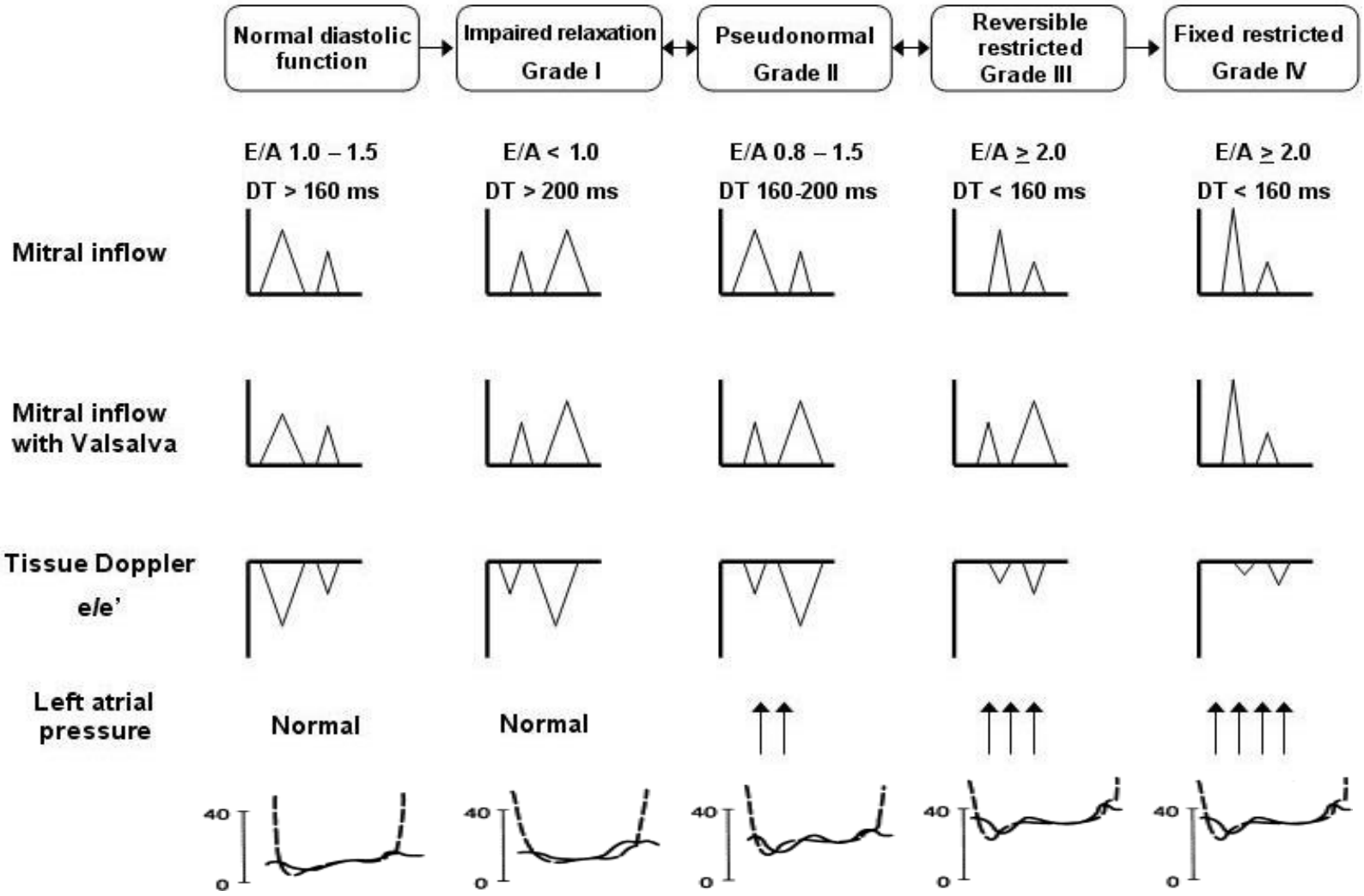


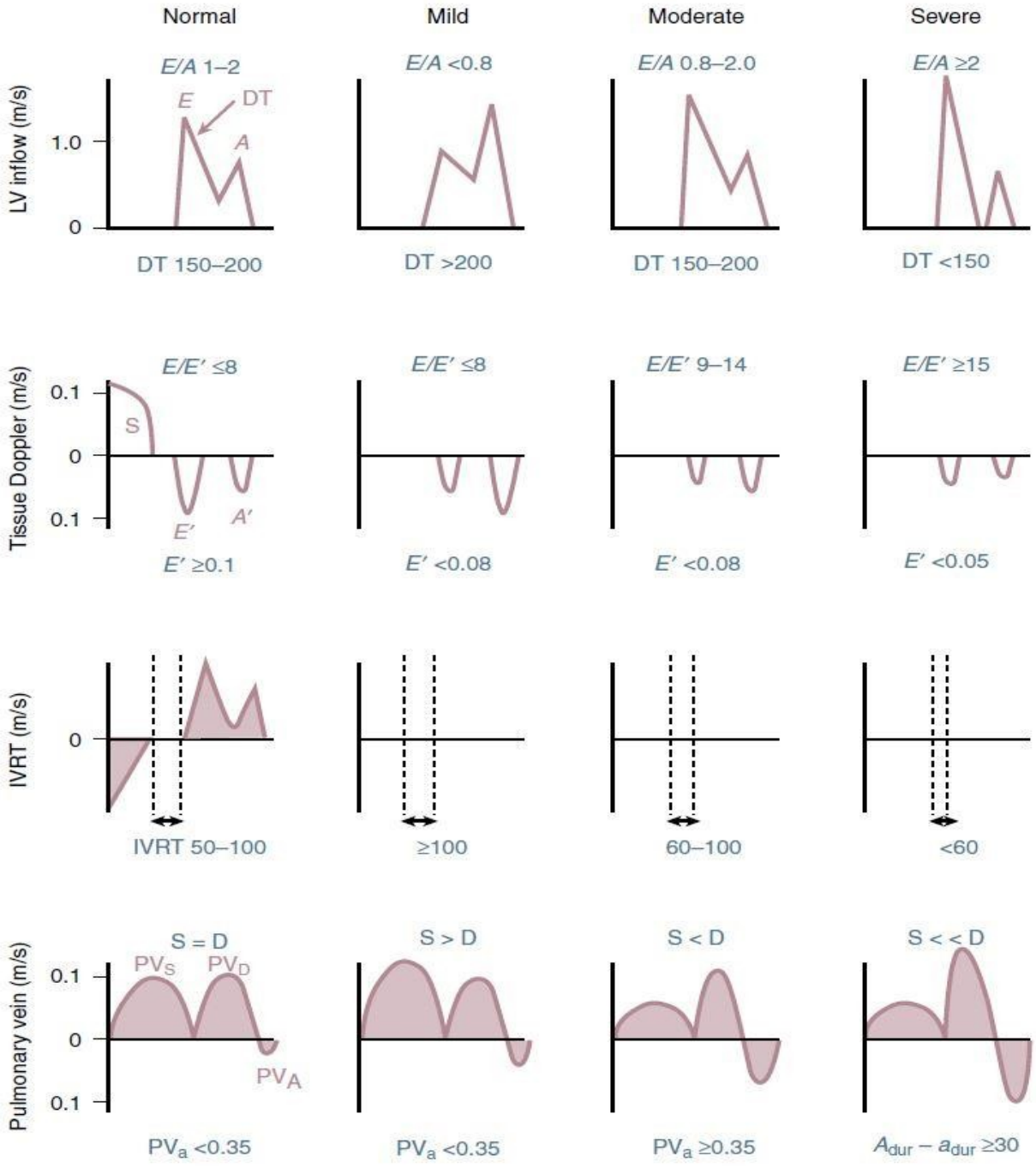


Normal Values for Doppler- derived diastolic m

Measurement	Age Group			
	16-20	21-40	41-60	>60
IVRT(ms)	50 ±9 (32-68)	67± 8(51-83)	74 ±7(60-88)	87 ±7(73-101)
E/A ratio	1.88±0.45 (0.98-2.78)	1.53±0.4 (0.73-2.33)	1.28±0.25 (0.78-1.78)	0.96±0.18 (0.6-1.32)
DT(ms)	142±19(104-180)	166±14(138-194)	181±19(143-219)	200±29(142-258)
A duration (ms)	113±17(79-147)	127±13101-153)	133±13(107-159)	138±19(100-176)
PV S/D ration	0.82±0.18 (0.36-1.18)	0.98±0.32 (0.34-1.62)	1.21±0.2 (0.81-1.61)	1.39±0.47 (0.45-2.33)
PV Ar (cm/sec)	16±10(1-36)	21±8(5-37)	23±3(17-29)	25±9(11-39)
PV Ar duration(ms)	66±39(1-144)	96±33(30-162)	112±15(82-142)	113±30(53-173)
Septal e` (cm/sec)	14.9±2.4 (10.1-19.7)	15.5±2.7 (10.1-20.9)	12.2±2.3 (0.5-1.7)	10.4±2.2 (6.2-14.6)
Septal e`/a` ratio	2.4	1.6±0.5(0.6-2.6)	1.1±0.3(0.5-1.7)	0.85±0.2 (0.45-1.25)
Lateral e`(cm/sec)	20.6±3.8(13-28.2)	19.8±2.9 (14-25.6)	16.1±2.3(11.5-20.7)	12.9±3.5 (5.9-19.9)
Latera; e`/a` ration	3.1	1.9±0.6(0.7-3.1)	1.5±0.5(0.5-2.5)	0.9±0.4(0.1-1.7)

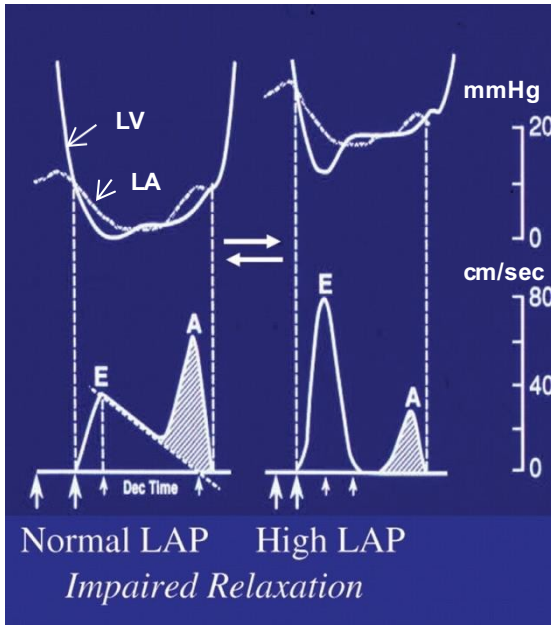
Echocardiographic classification of diastolic dysfunction

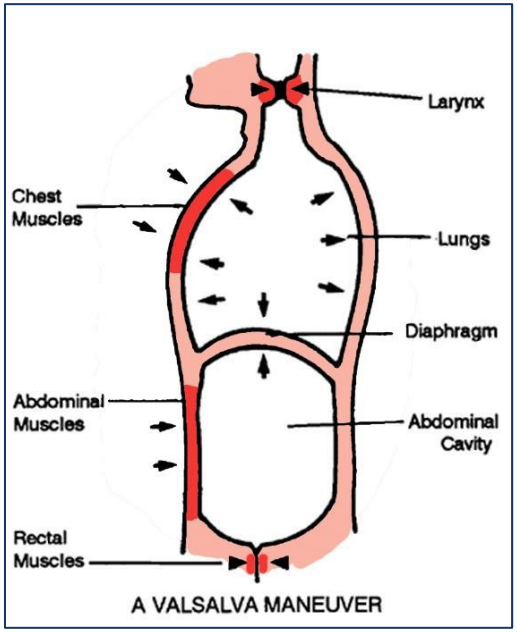


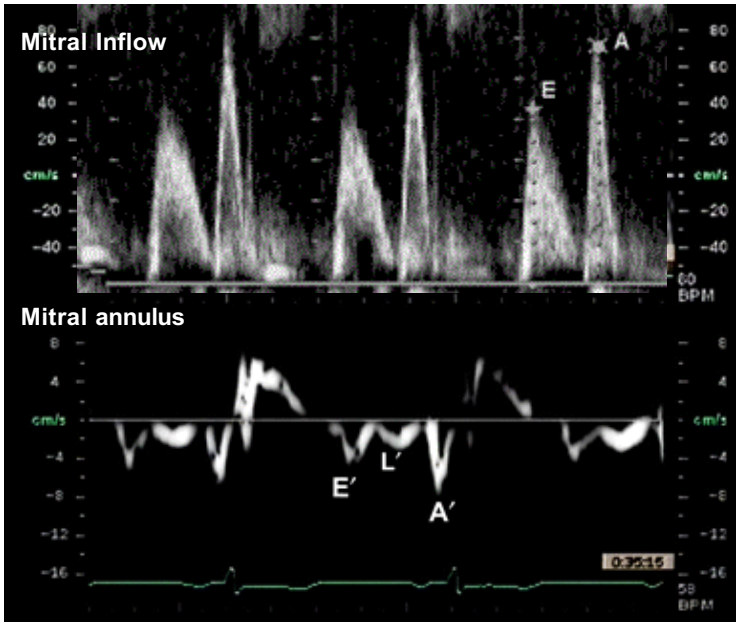

Normal
Mild
Moderate
Severe
E/A 1–2
E/A <0.8
E/A 0.8–2.0
E/A ≥2
LV inflow (m/s)
1.0
0
E
DT
A
DT 150–200
DT >200
DT 150–200
DT <150
E/E′ ≤8
E/E′ ≤8
E/E′ 9–14
E/E′ ≥15
Tissue Doppler (m/s)
0.1
0
0.1
S
E′
A′
E′ ≥0.1
E′ <0.08
E′ <0.08
E′ <0.05
IVRT (m/s)
0
IVRT 50–100
≥100
60–100
<60
S = D
S > D
S < D
S < < D
Pulmonary vein (m/s)
0.1
0
0.1
PVS
PVD
PVA
PVa <0.35
PVa <0.35
PVa ≥0.35
Adur – adur ≥30

Diastolic Function – Valsalva maneuver

- Valsalva maneuver decrease preload during strain phase
- Peudonormal mitral inflow changes to a pattern of impaired relaxation
- The E/e’ ratio was markedly increased, using e’ from either side of the annulus





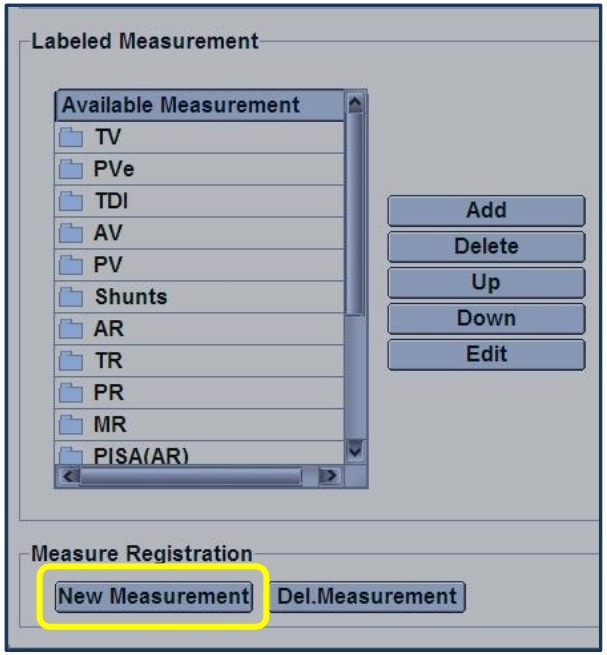


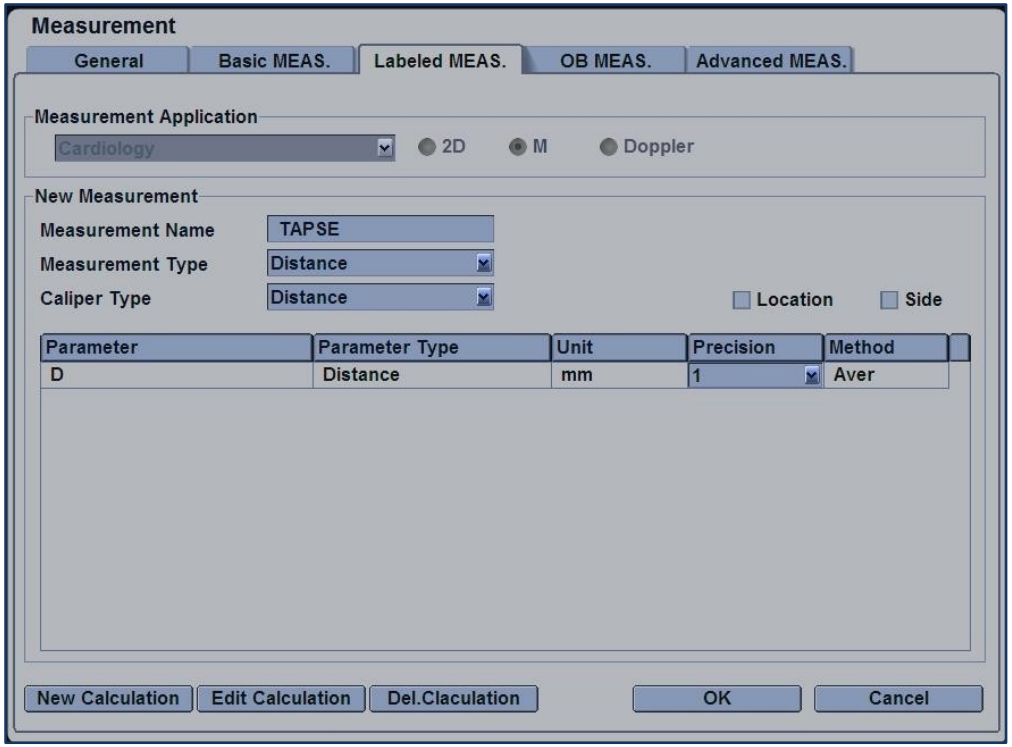
Diastolic function : Mitral Inflow

- Key Points

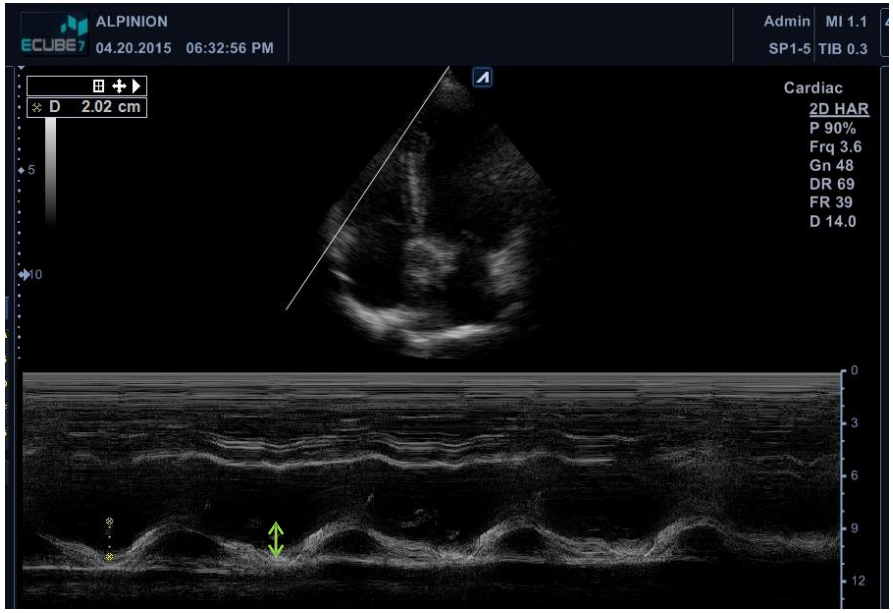
1. PW Doppler is performed in the apical 4-chamber view to obtain mitral inflow velocities to assess LV filling.
2. a 1-mm to 3-mm sample volume is placed between the mitral leaflet tips during diastole to record a crisp velocity profile.
3. Primary measurements include peak E and A velocities, E/A ratio, DT, and IVRT
4. Mitral inflow patterns include normal, impaired LV relaxation, Pseudonormal flow, and restrictive LV filling.
5. In patients with dilated cardiomyopathies, filling patterns correlate better with filling pressures, functional class, and prognosis than LV EF.
6. In patients with coronary artery disease and those with hypertrophic cardio myopathy in whom the LV EFs are 50%, mitral velocities correlate poorly wi th hemodynamics.

Create New measurement





Tricuspid Annular Plane Systolic Excursion:TAPSE



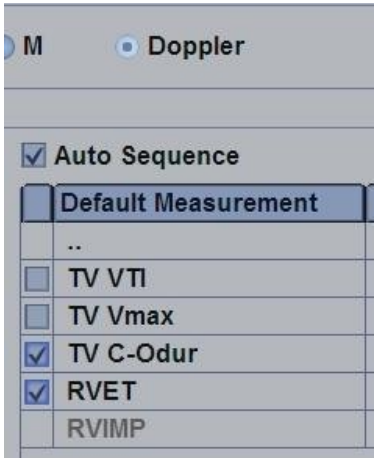
- RV dimensions at modified 4chamber
  - M-mode aligned along the direction of tricuspid lateral annulus
  - good correlations with parameters estimating RV global systolic function
  - TAPSE <17mm is highly suggestive of RV systolic dysfunction

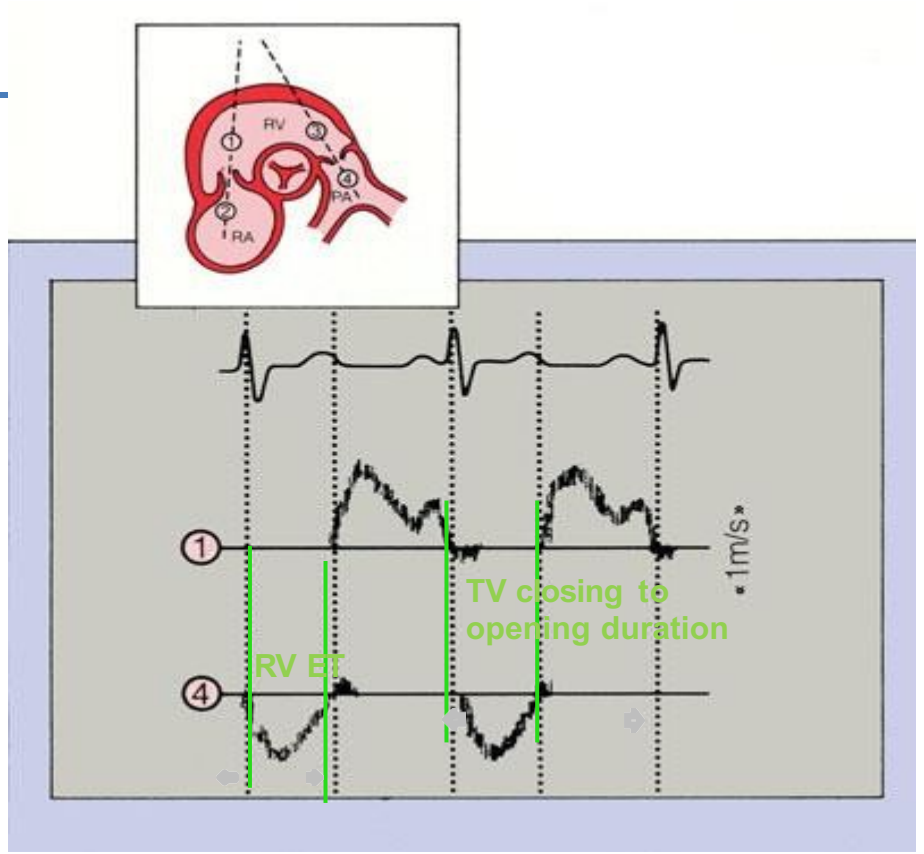
Systolic function - Right Ventricle

RV Systolic function ;RIMP by TDI or Tricuspid & pulmonary outflow

- Measure at 4chamber and short axis view
- Measure
- RIMP>0.43 by PW, >054 by TDI indicate RV dysfunction

$$RIMP = \frac{TCO - RVET}{RVET}$$





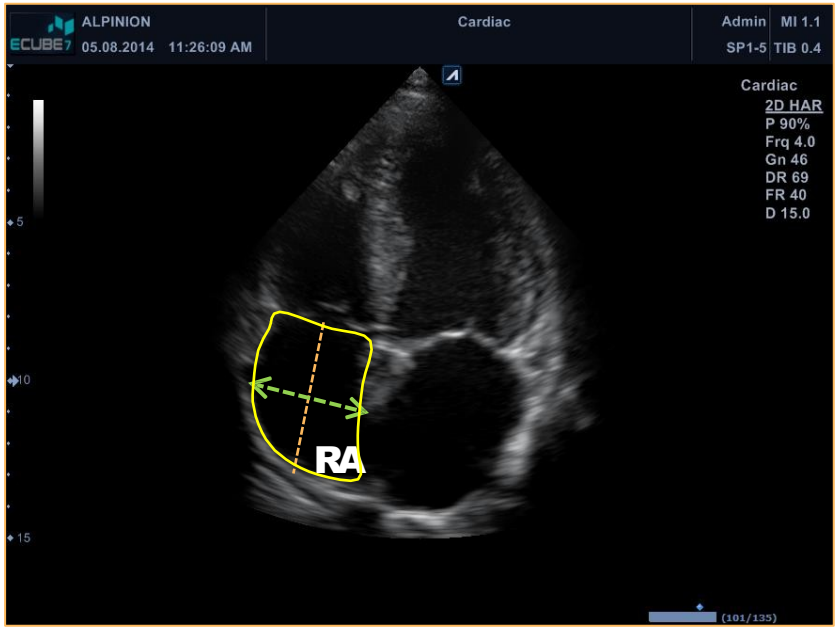
The Right Atrium

- Measure the Right Atrial volume

  - Linear dimension ; minor axis is measuredbetween the lateral RA wall and interatrial septum at the mid atrial level
  - Area ; by tracing the RA blood-tissue interface
  - Volume; single plane area-length method

- Normal ranges

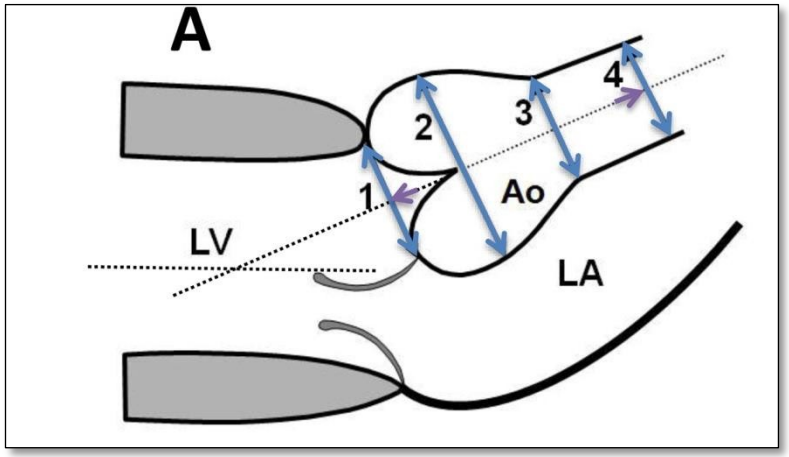
	Women	Men
RA minor axis, d (cm/m²)	1.9±0.3	1.9±0.3
RA major axis, d (cm/m²)	2.5±0.3	2.4±0.3
2D RA volume (mL/m²)	21±6	25±6

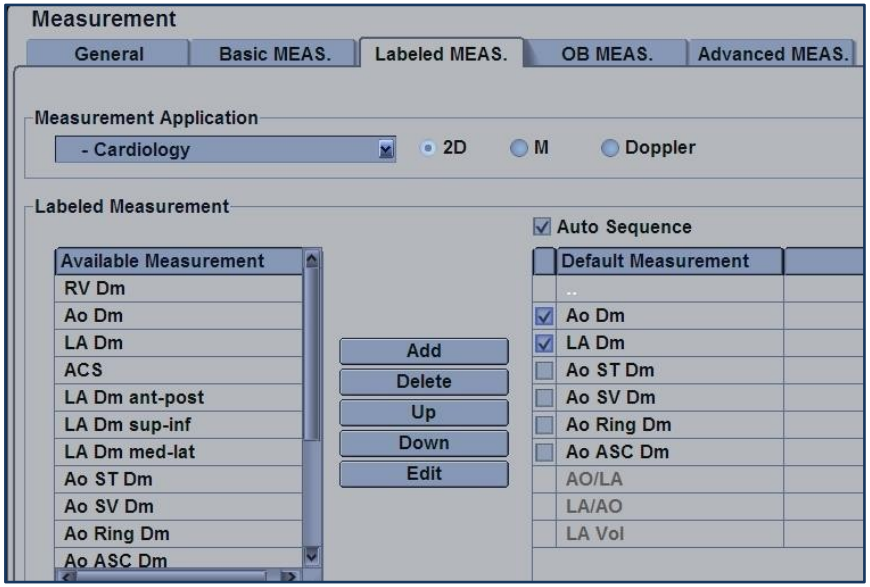


Aortic annulus & Aortic Root diameter

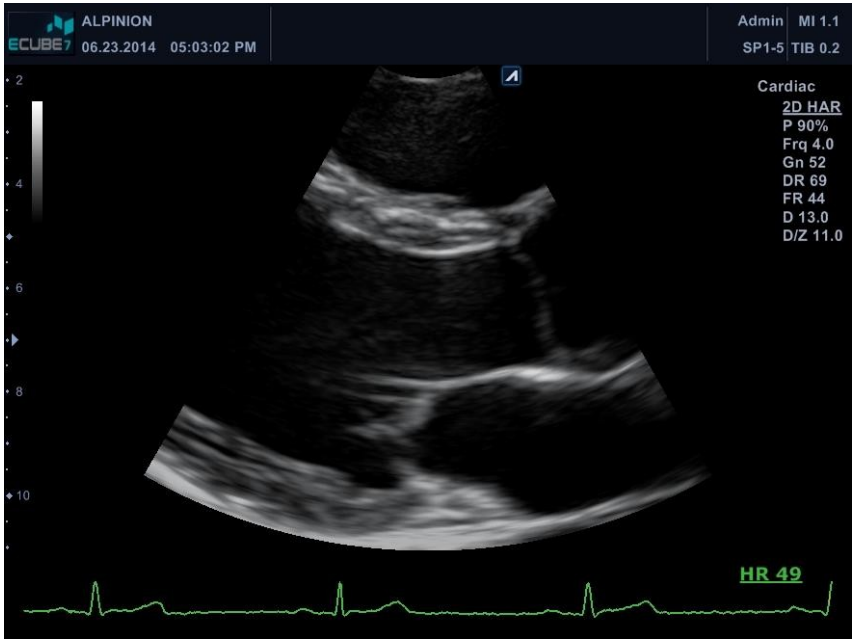
horizontally to keep the interventricular septum and the Aortic wall

- Measure ascending aorta at each point
- LVOT, Aortic Sinus, Sinotubular junction, Ascending Aorta
- Pericardial effusion





Left Ventricular Outflow Tract- diameter



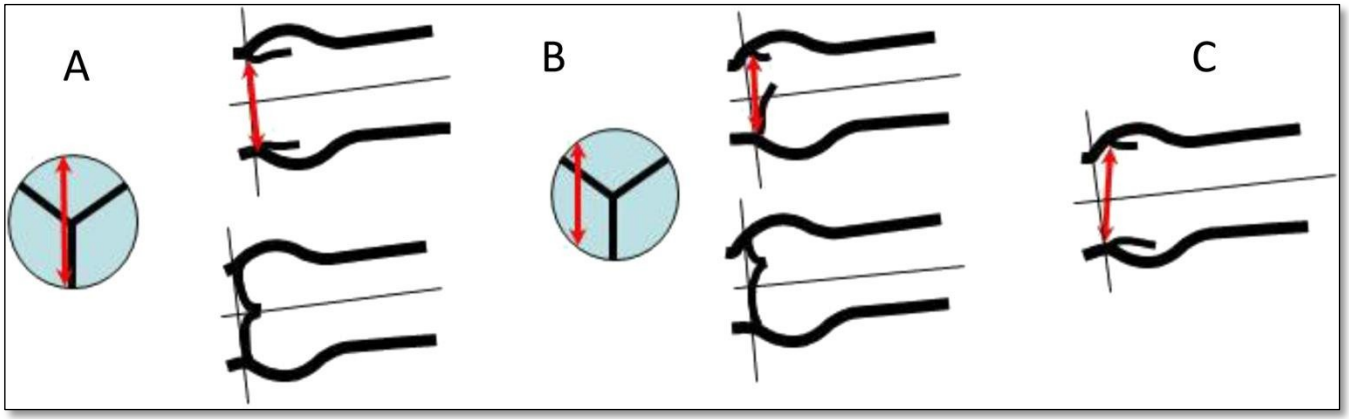
Zoom : Including the aortic valve and the mitral valve

- Measure LVOT diameter for LVOT stroke volume

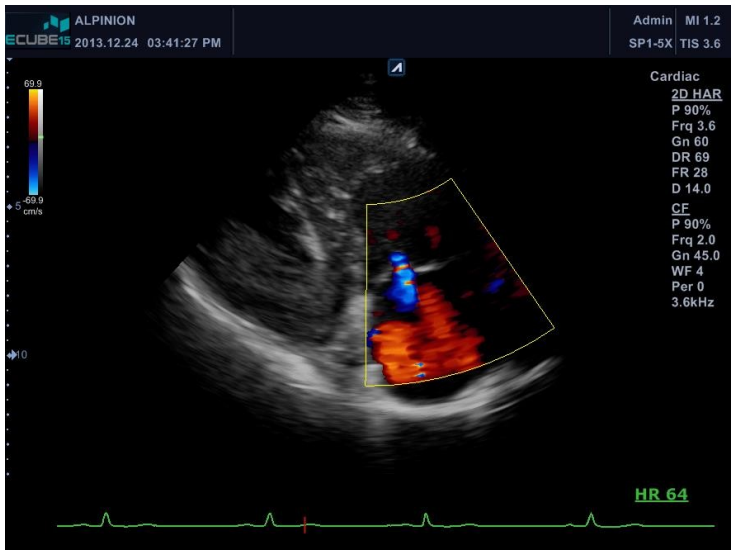
  $= 0.785 * D^2 * LVOT_{TVI}$

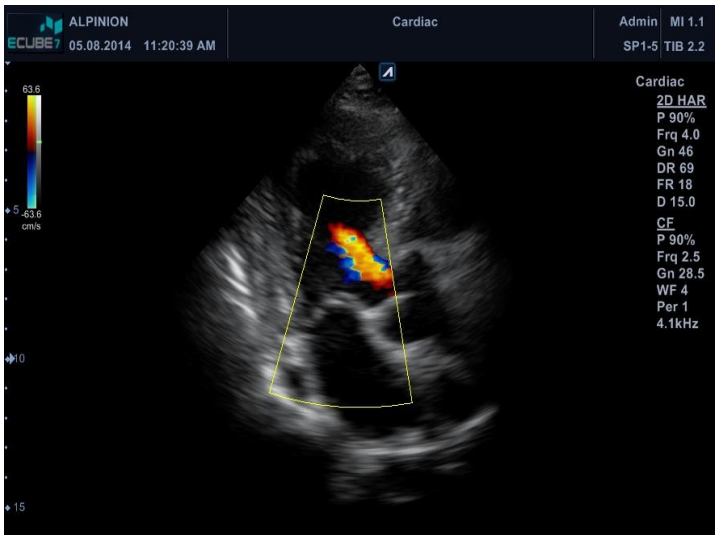
- Cine save for the mitral valve and its apparatus` morphology

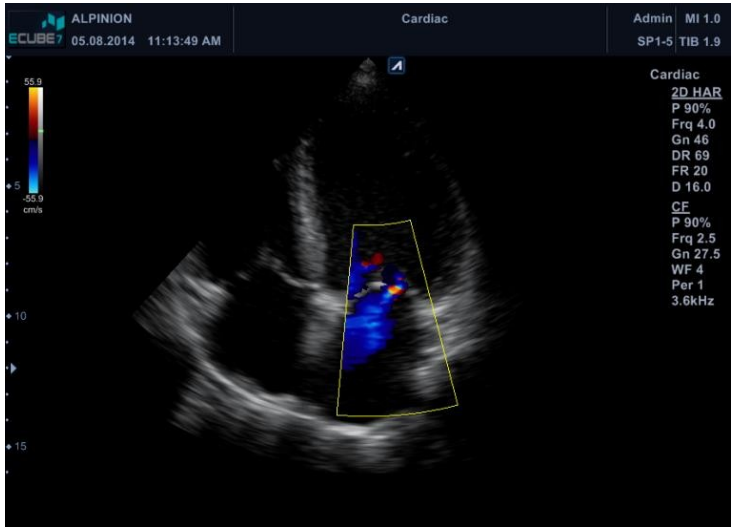
2015 ASE GUIDELINES and STANDARDS

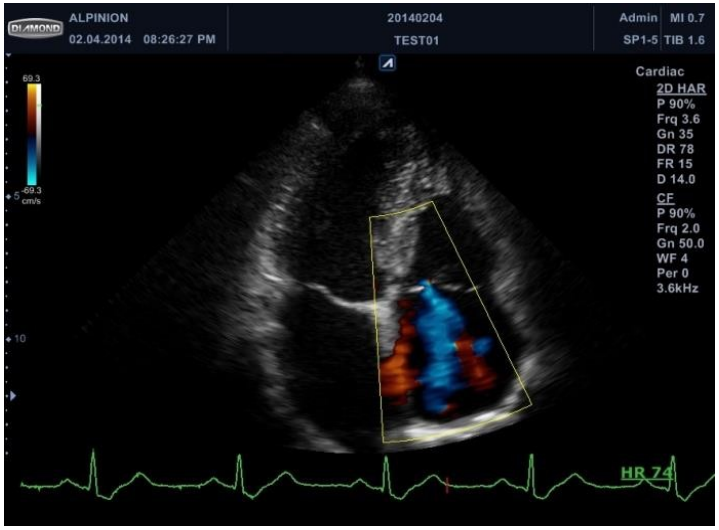


Color image - low PLAX and Apical window









Hemodynamic Measurements

ALPINION Medical Systems, Clinical Specialist Team

Echocardiographic evaluation

- Echocardiographic evaluation of cardiac adaptation to the **volume overload** offers, along with careful assessment of symptoms, and ideal tool for manag ement of valvular regurgitation and **timing of surgery**

- **2D** echocardiography provides an assessment of **valvular structure, mechanism** of regurgitation and adaptation to the volume overload state

- **Doppler** has become the first line approach to the evaluation and management of **valvular heart disease**

- Doppler allows a comprehensive evaluation of **the severity of regurgitation** using qualitative and quantitative methods from Color flow and spectral Do ppler

Derived Doppler Equation

Basic measurement

-. Bernoulli equation

Pressure Gradient= $4V^2$

Doppler Equation

$$\pm\Delta f = f_r - f_0$$

$$\Delta f = \frac{2\ f_0\ V\cos\theta}{C}$$

$$V = \frac{C\Delta f}{2\ f_0\cos\theta}$$

Derived Doppler Equation

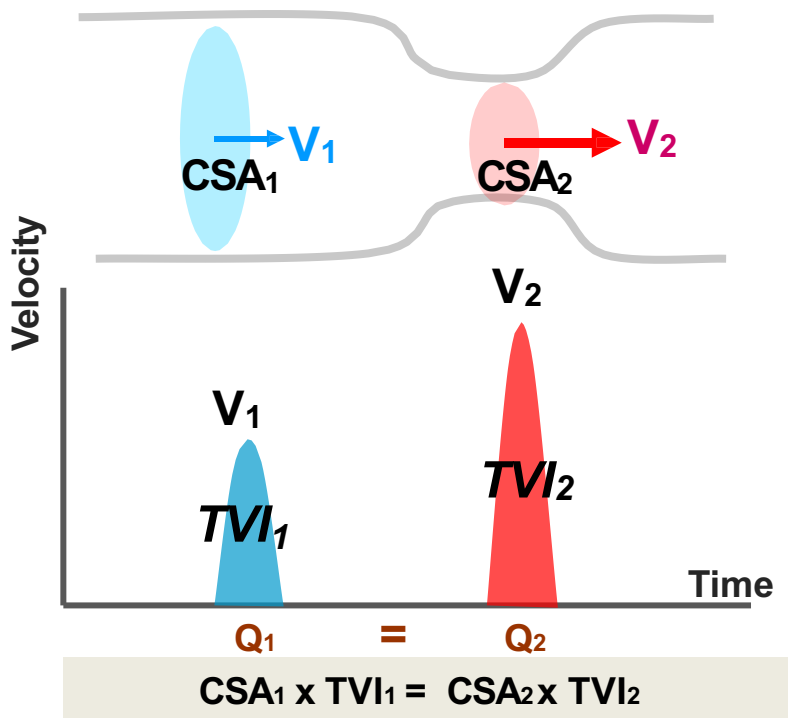
Advanced Measurements

-. Continuity Equation

-. Valve area, Shunt Study

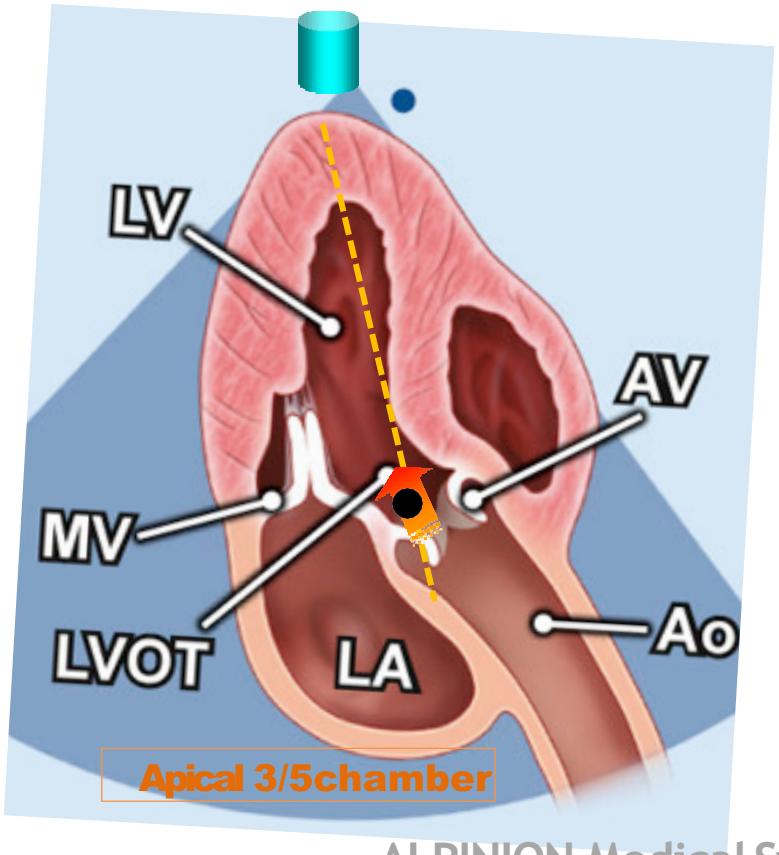
-. PISA method

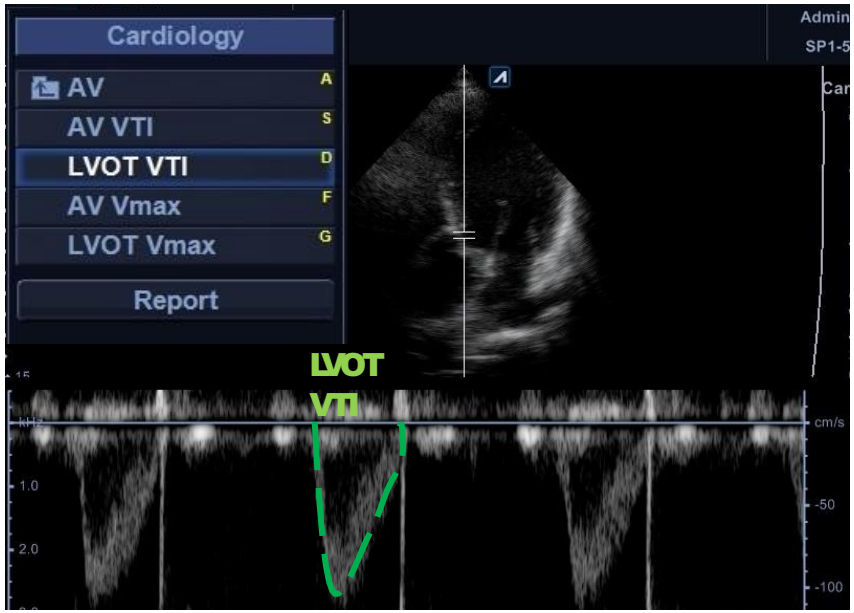
Doppler Equation



Calculation : LV stroke volume

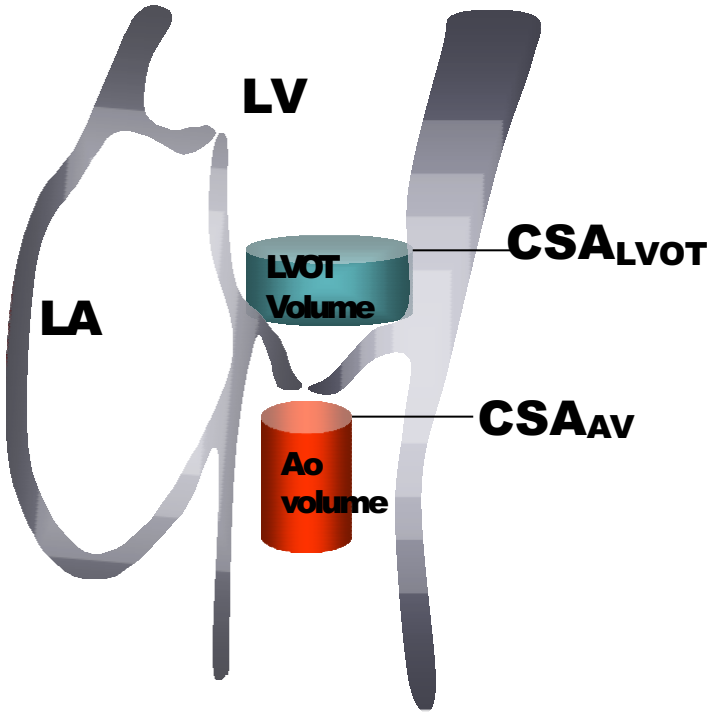
- measure stroke volume of the Left heart
  - put a pw gate on LVOT at apical 3 or 5 chamber view
  - Trace from open to close of LVOT spectrum





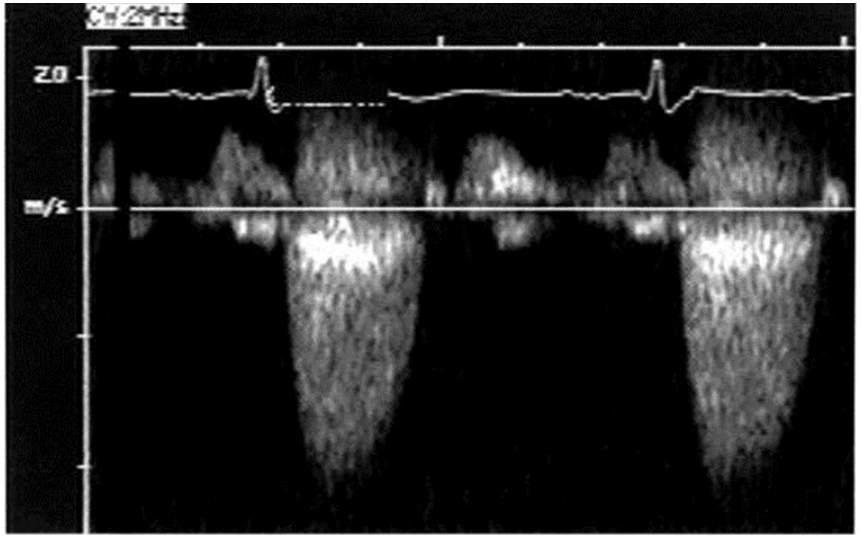
Calculation : Aortic Valve Area

- Continuity Equation
  - measure “2D” at LVOT Diameter in PLAX
  - measure VTI at LVOT(PW) in apical 5 chamber
  - measure VTI at Aortic Valve (CW) in apical 5 chamber

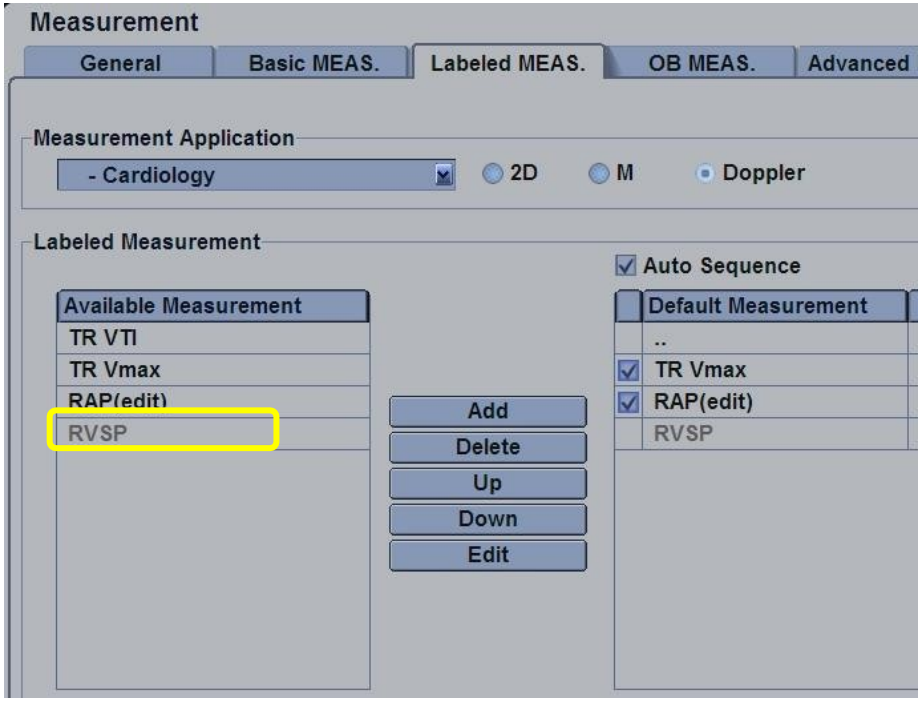


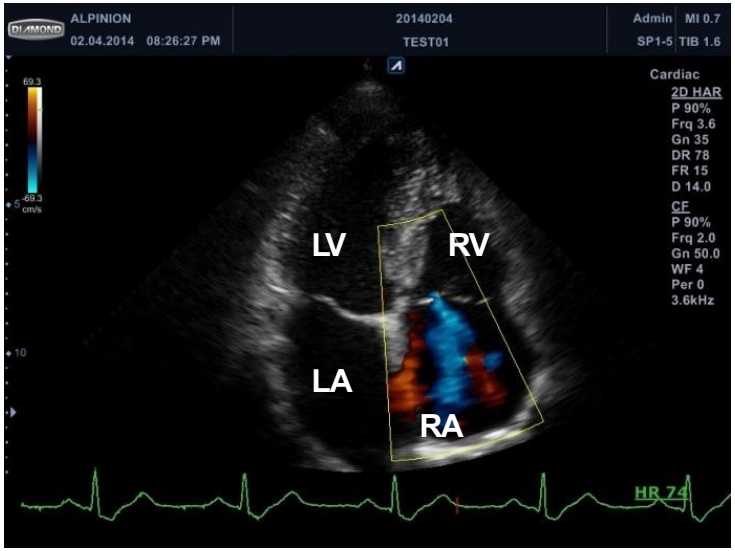
$$AV\,flow = LVOT\,flow$$

$$CSA_{AV} \times TVI_{AV} = CSA_{LVOT} \times TVI_{LVOT}$$



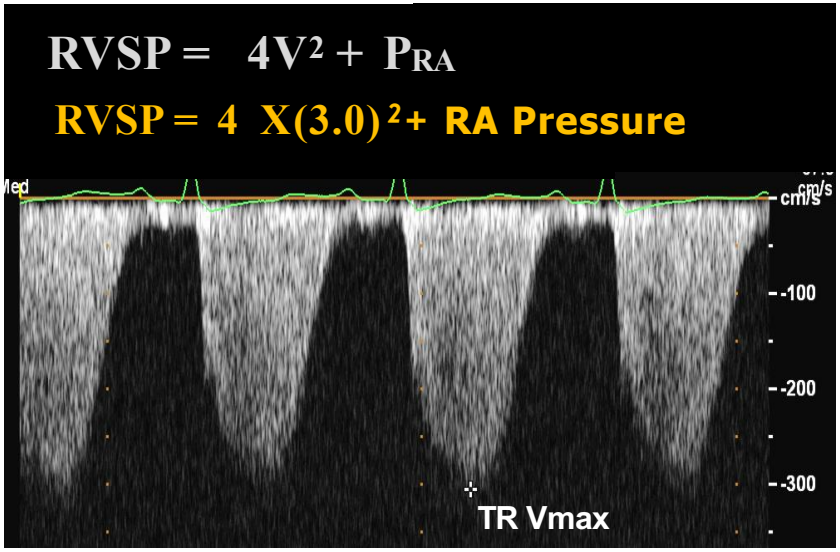
RV Systolic Pressure - Tricuspid Regurgitation





RVSP - Tricuspid Regurgitation

- Right Ventricle Systolic Pressure
  - when Tricuspid regurgitation displayed on color mode
- Place the cursor of CW doppler on the vena contracta -> press CW
- Calculate : Right Ventricle Systolic Pressure
  - “Measurement” -> ‘RVSP” -> measure “TR V max .”
  - select 1 of 5 , 10, 15, 20mmHg for “RAP”
- Pulmonary hypertension > 35~40mmHg

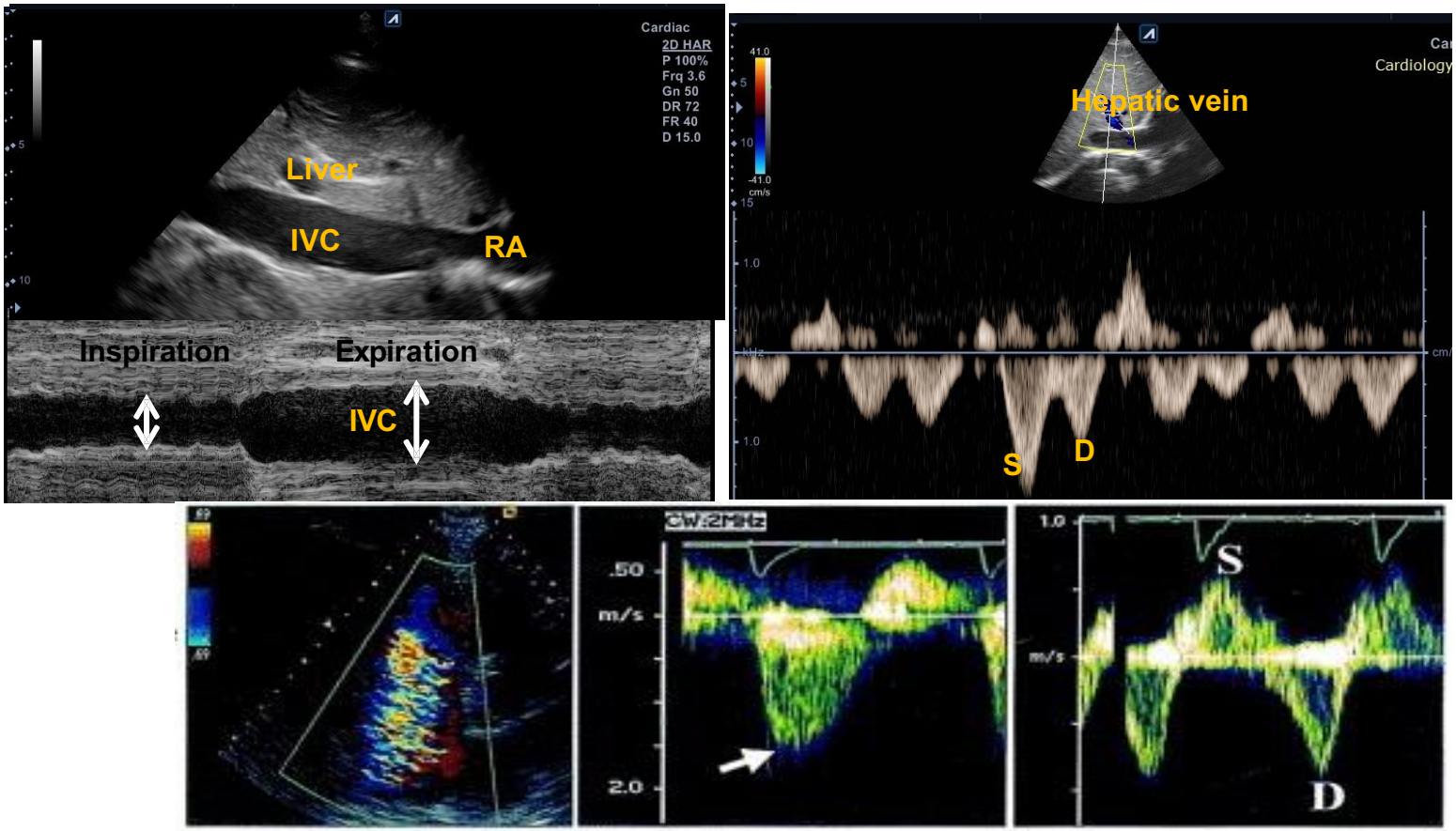


Grading tricuspid regurgitation severity

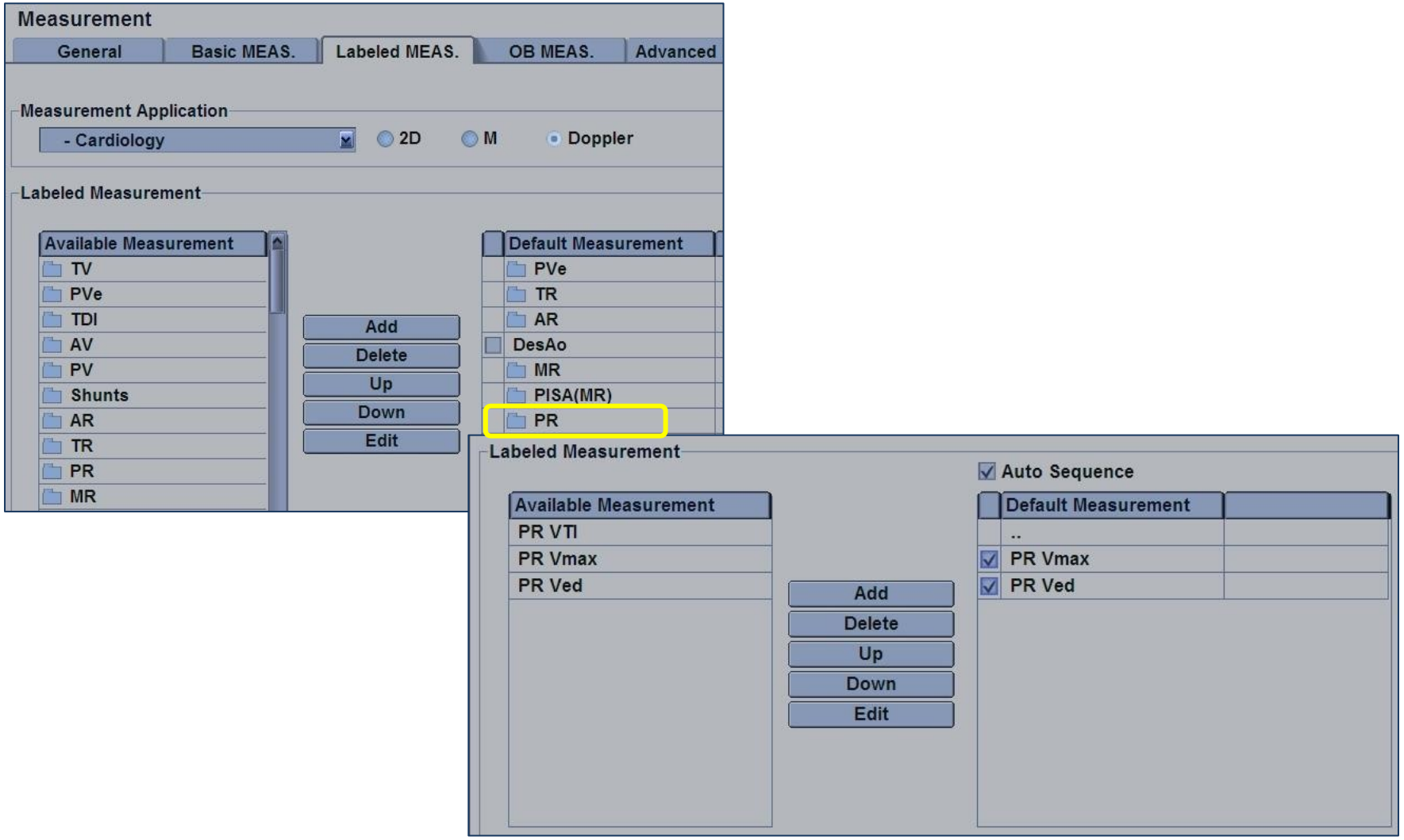
Parameters	Mild	Moderate	Severe
Tricuspid valve	Usually normal	Normal or abnormal	Abnormal/Flail leaflet/ poor coaptation
RV/RA/IVC size	Normal	Normal or dilated	Usually dilated
Jet area-central jets (cm^2)	< 5	5-10	>10
VC width	Not defined	Not defined, but < 0.7	>0.7
PISA radius (cm)	≤ 0.5	0.6~0.9	>0.9
Jet density and contour-CW	Soft and parabolic	Dense, variable contour	Dense, triangular with early peaking
Hepatic vein flow↑	Systolic dominance	Systolic blunting	Systolic reversal

RVSP – RA pressure

- IVC
  - IVC diameter<2.5cm, change according to respiration -> normal RA Pressure
  - Hepatic vein flow in severe TR, hepatic venous flow reversal in systole (S)

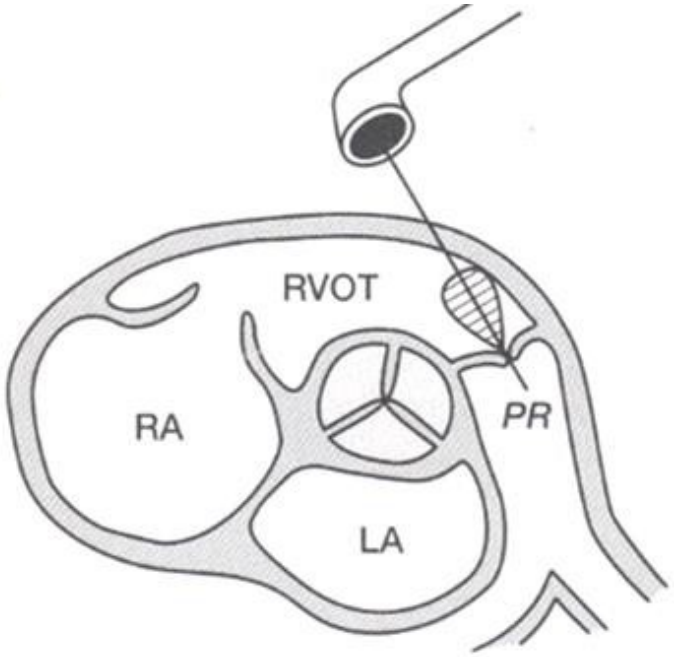


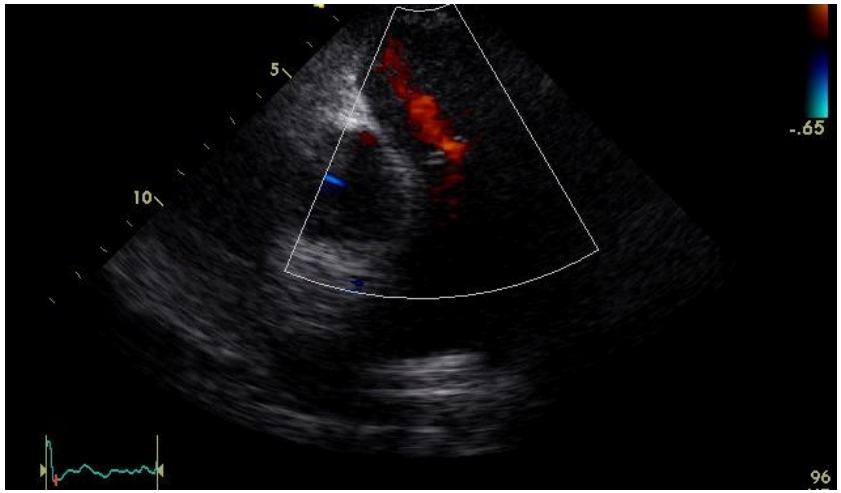
Pulmonary Artery Pressure

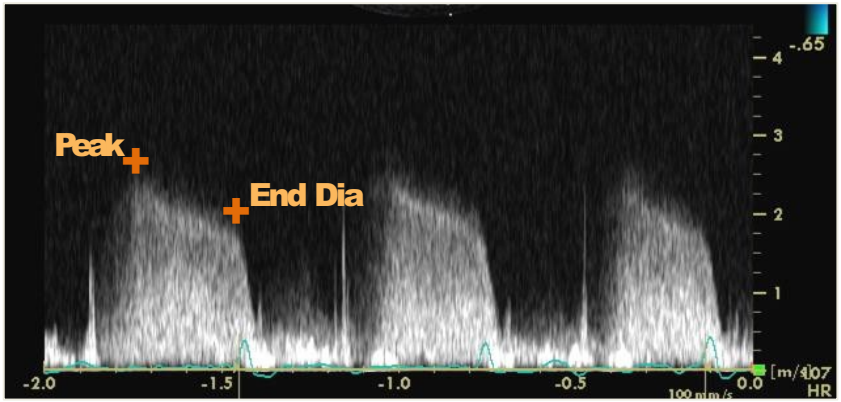


Calculation: Pulmonary Artery Pressure

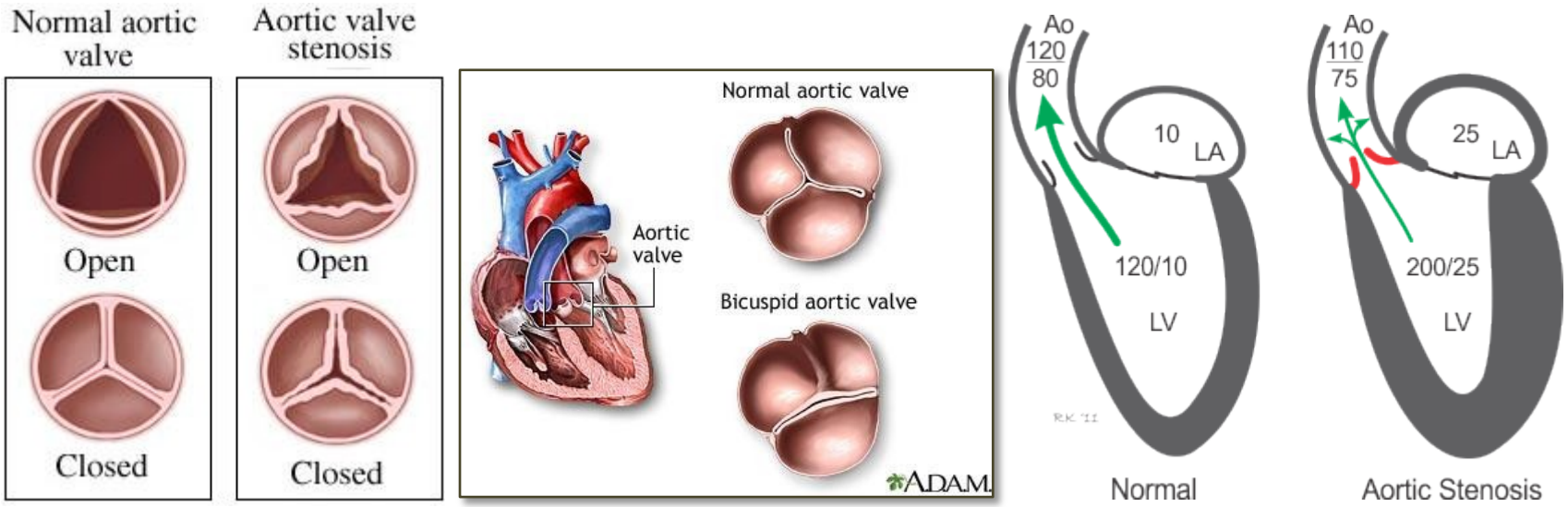
- **Mean PA pr= 4 $(V_{peak})^2$**
- **PA end-diastolic pressure**
  = 4 $(V_{ED})^2$ + RVEDP
  = 4 $(V_{ED})^2$ + RA pressure



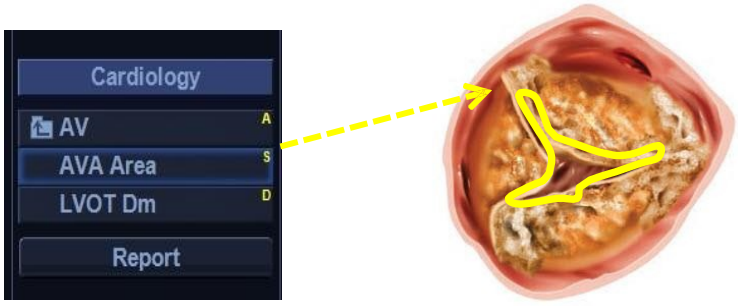




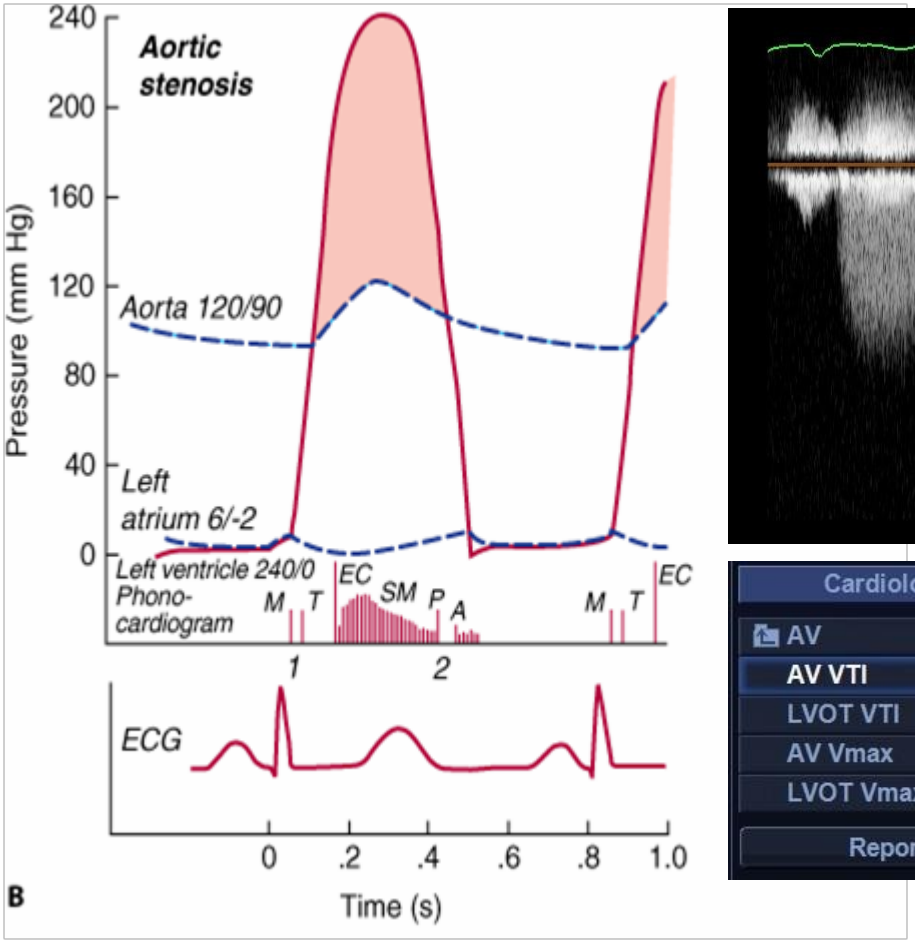
Aortic Stenosis

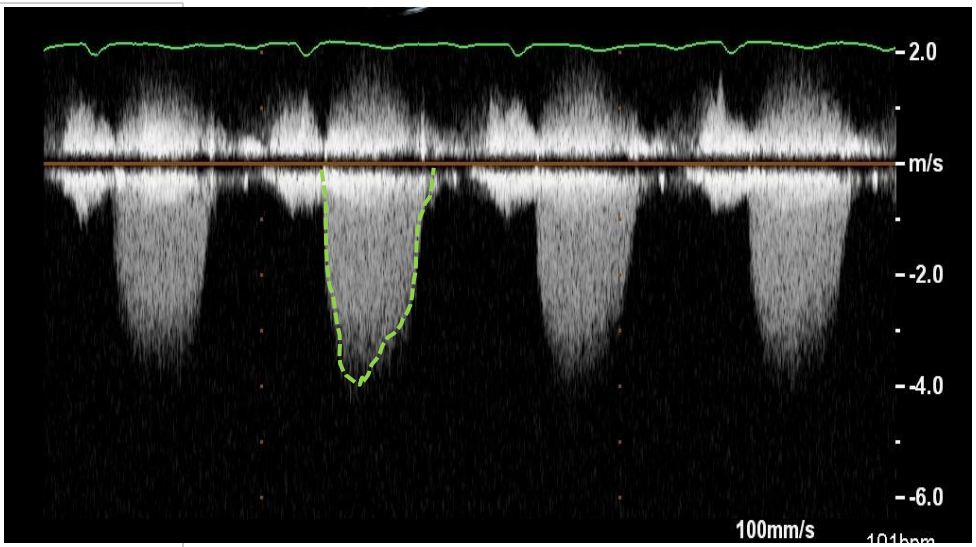


- Incase of Aortic Valve Stenosis, planimetry method is used at 2D
  - Draw along the open edge of the aortic valve



Aortic Stenosis – mean pressure gradient



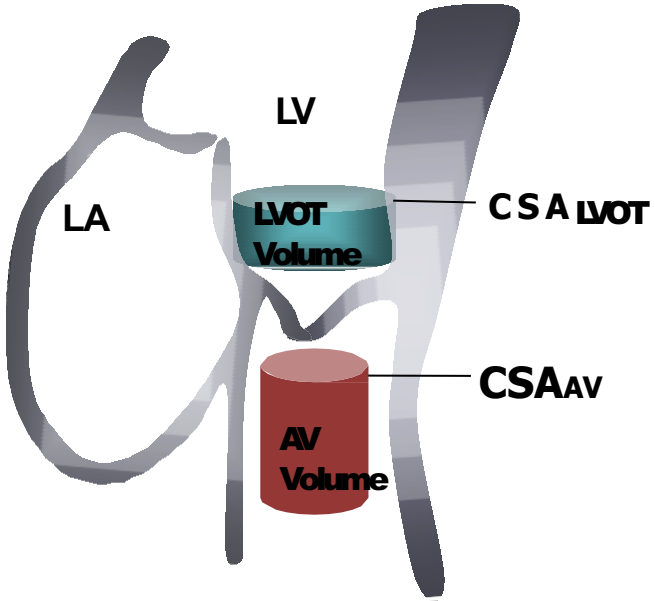


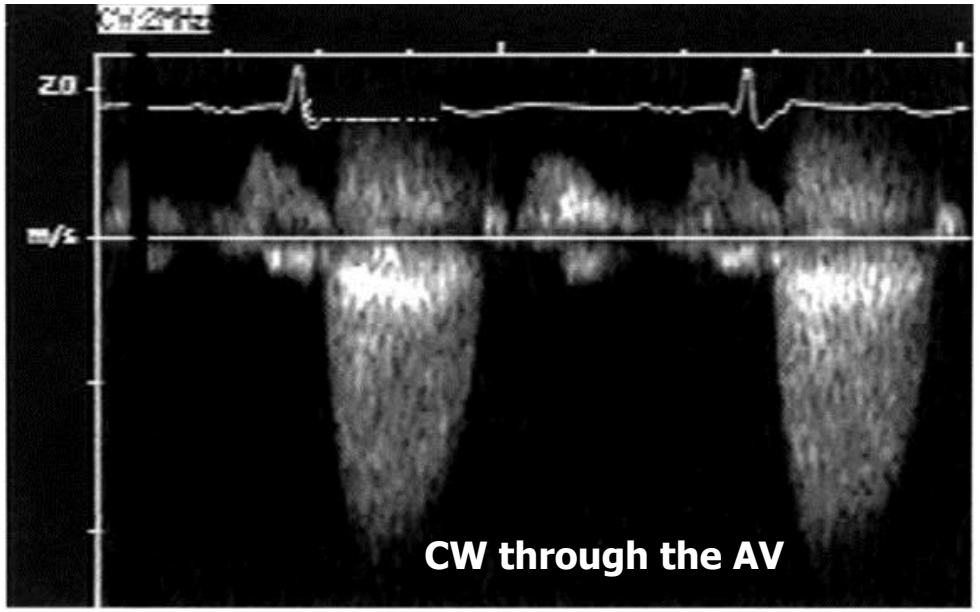
	Hemodynamics	AVA
mild	Mean <20	>1.5cm²
Mod.	20-40mmHg	1.0-1.5
severe	Mean > 40	<1.0

- Trace the aortic valve VTI, after acquisition a doppler image by CW

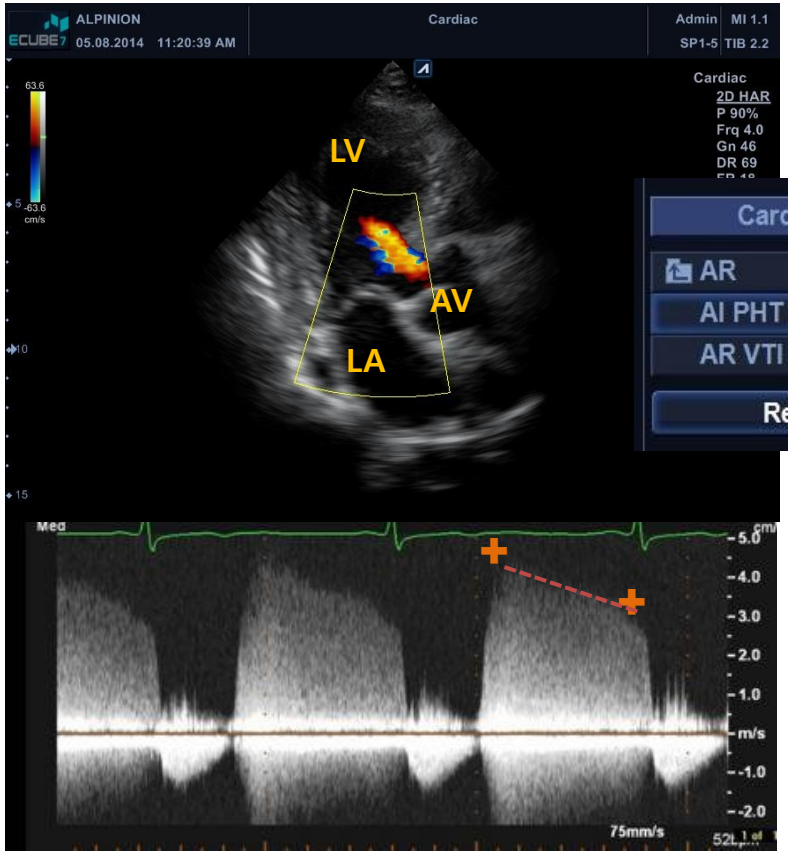
Aortic Valve Area : Doppler

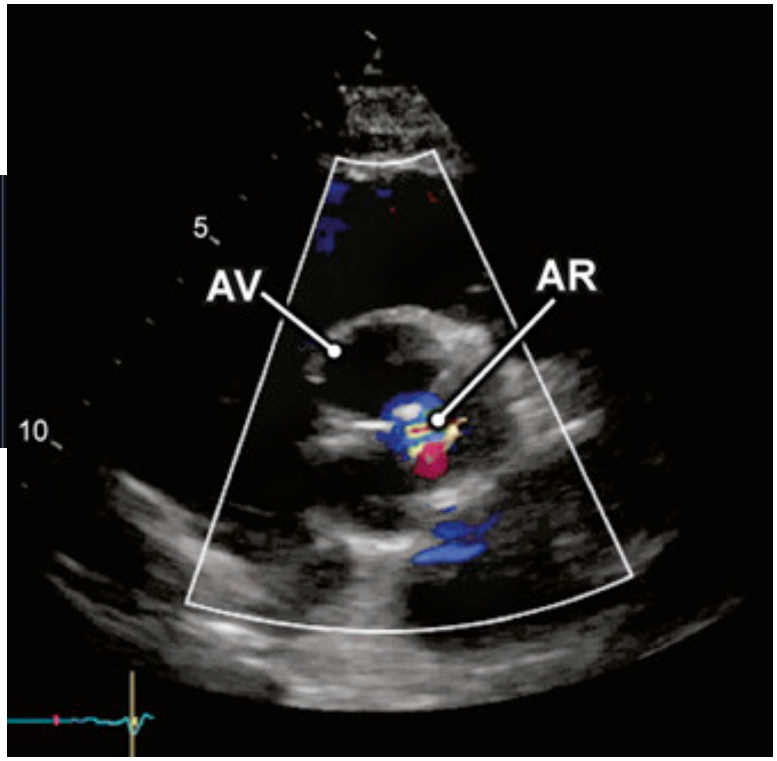
- Continuity Equation
  - measure “2D” at LVOT Diameter in PLAX
  - measure “VTI at LVOT(PW”) in apical 5 chamber
  - measure “VTI at Aortic Valve (CW)” in apical 5 chamber





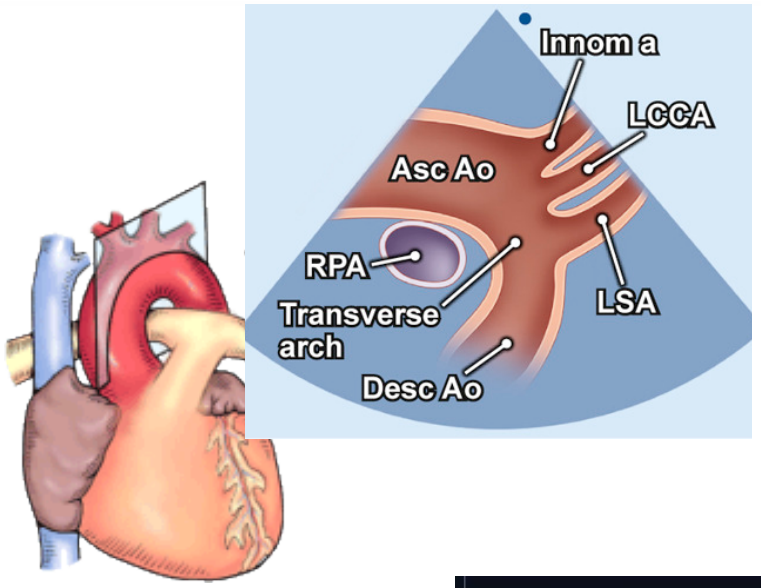
Aortic Regurgitation – Pressure Half Time

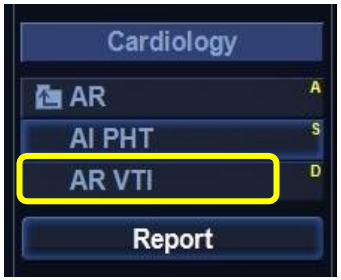


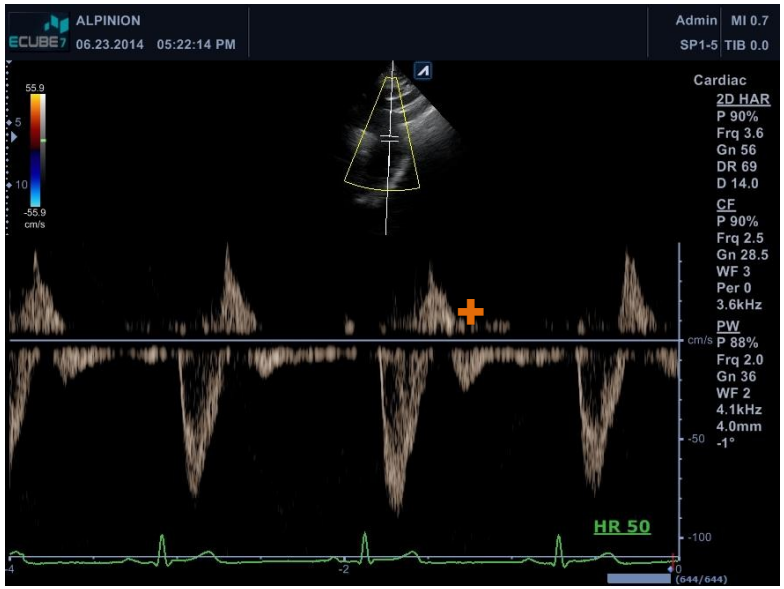


- measure " AI Pressure Half Time"
- steep deceleration rate of the AR velocity by CW Doppler, and a holo- diastolic flow reversal in the descending (desc.) aorta in severe AR

Aortic Regurgitation : Severity by Doppler





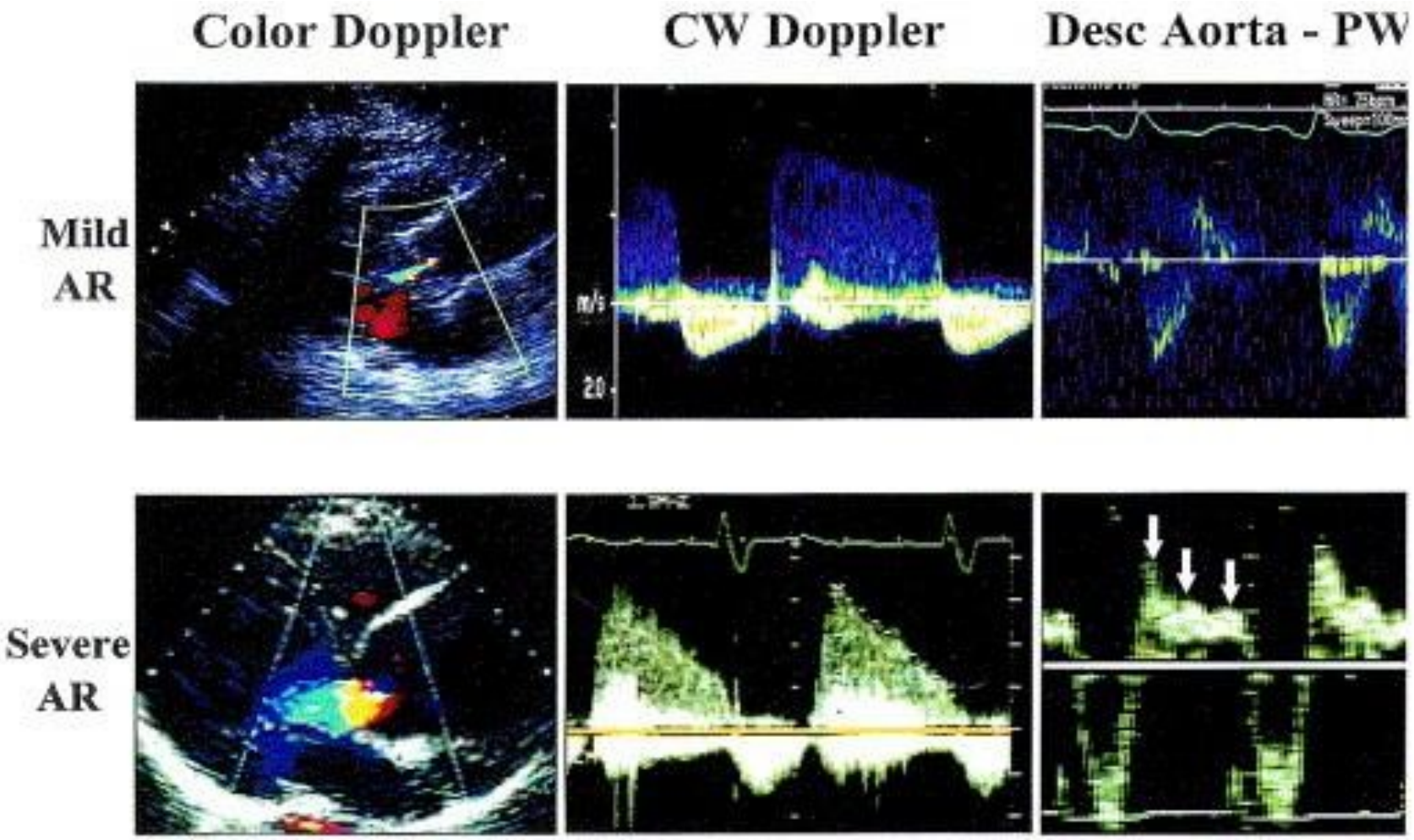


- In severe Aortic regurgitation, measure the VTI of reverse flow at the Descending Aorta

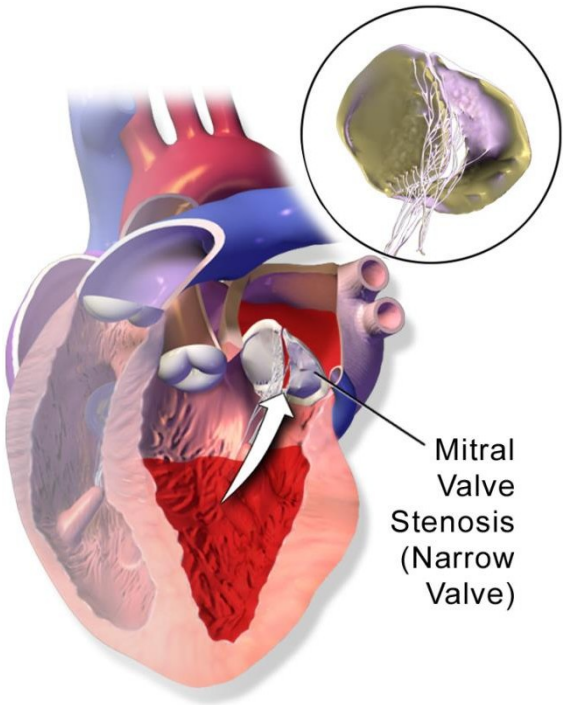
Grading of aortic regurgitation severity

	Mild	Moderate	Severe
Structural parameters			
LA size	Normal	Normal or dilated	Usually dilated
Aortic leaflets	Normal or abnormal	Normal or abnormal	Abnormal / flail, or wide coaptation defect
Doppler Parameters			
Jet width in LVOT-color flow	Small in central jets	intermediate	Large in central jets; variable in eccentric jets
Jet density -	Incomplete or faint	Dense	Dense
CW (PHT, ms)	Slow > 500	Medium 500-200	Steep < 200
Diastolic flow reversal in descending aorta -PW	Brief, early diastoic reversal	Intermediate	Prominent holodiastolic reversal
Quantitative parameters			
Vena contracta width, cm	< 0.3	0.3-0.60	> 0.6
Jet width/LVOT width, %	< 25	25-45 46-64	≥ 65
Jet CSA/LVOT CSA, %	< 5	5-20 21-59	≥60
Reg. Volume, ml/beat	< 30	30-44 45-59	≥ 60
Regurtant Fraction, %	< 30	30-39 40-49	≥ 50
EROA, cm^2	< 0.10	0.10-0.19 0.20- 0.29	≥ 0.30

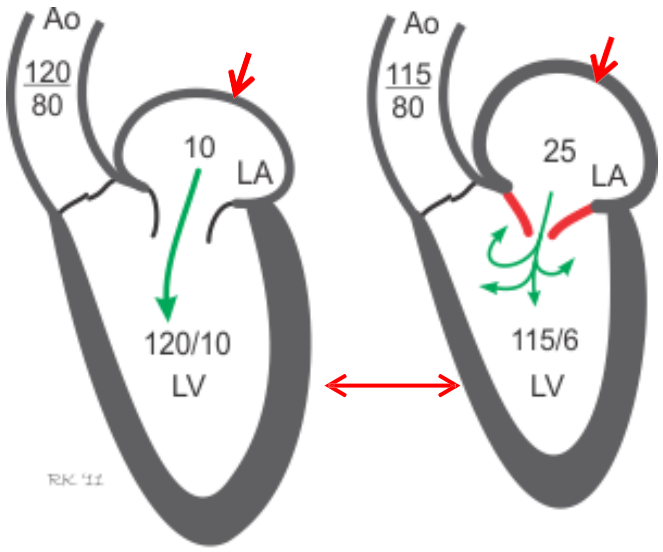
Grading of aortic regurgitation severity



Mitral Stenosis

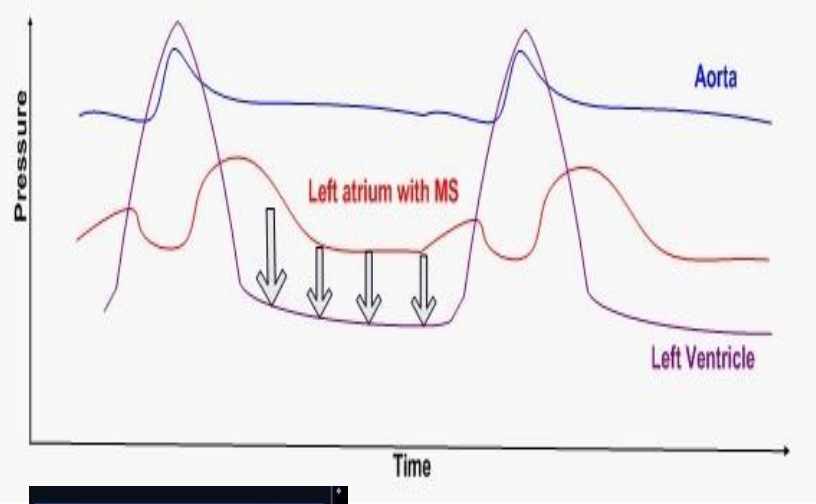


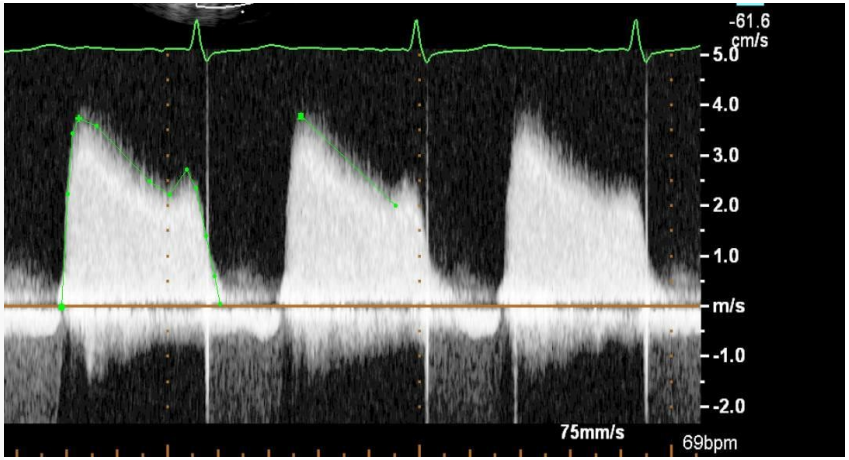
Mitral Valve Stenosis



- Incase of Mitral Valve Stenosis, planimetry method is used at 2D
- Also measure the left atrium size

Mitral Stenosis – mean VTI, Mitral valve Area





- Incase of Mitral Valve Stenosis, trace the mitral valve inflow
- Also measure the pressure half time for mitral valve area

Regurgitation Volume by PISA

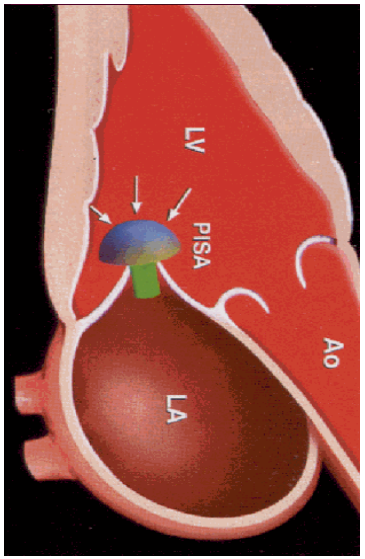
Continuity Equation

Mitral Regurgitation Volume by Proximal Isovolumetric Surface Area

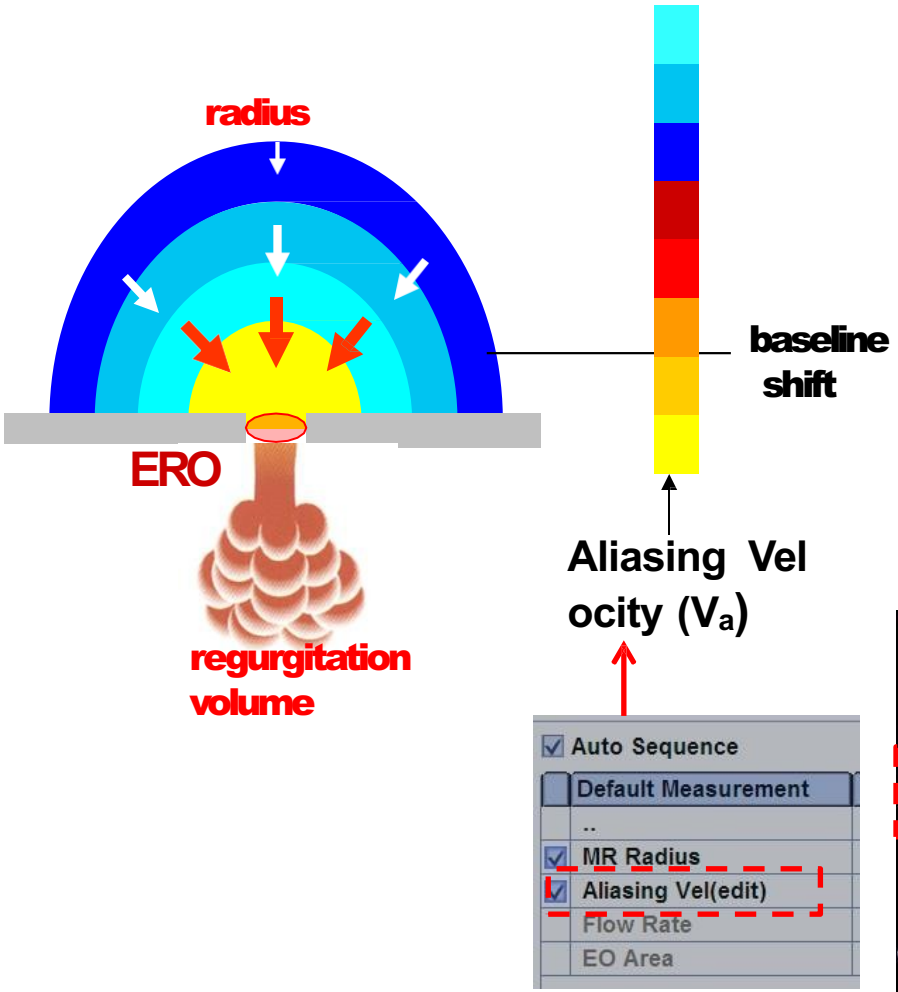
- **MR flow = PISA flow**
- ERO (Effective Regurgitant Orifice) E

RO x MR Vel. = 2 x π x R^2 x Alias Vel.

$$ERO = \frac{2 \times \pi \times R^2 \times \text{Alias Vel.}}{\text{MR max Vel.}}$$

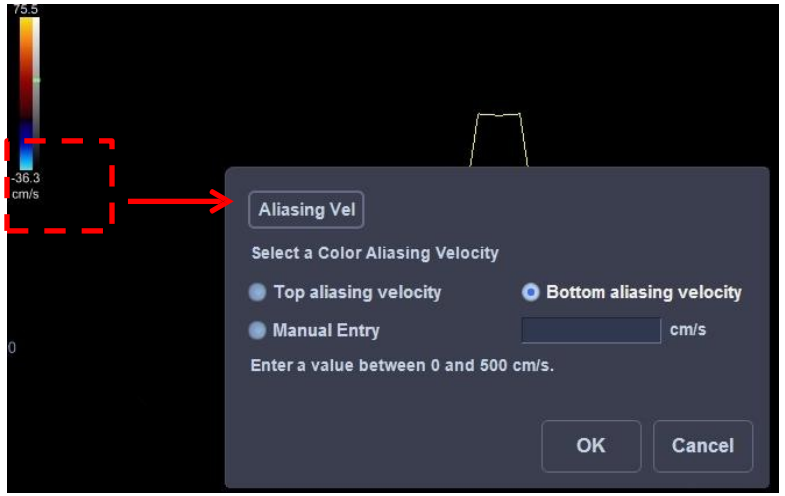


Regurgitation Volume by PISA



PISA method

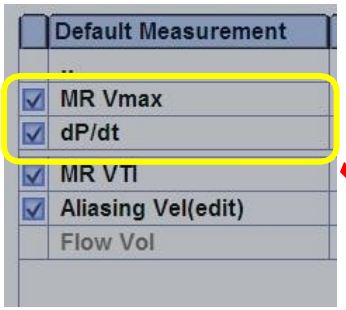
- Optimize regurgitant flow→ Zoom up
- baseline shift of color hue to describe the aliasing velocity up to 30~40cm/s
- Measure PISA radius & select 'PISA(MR)- aliasing Vel'

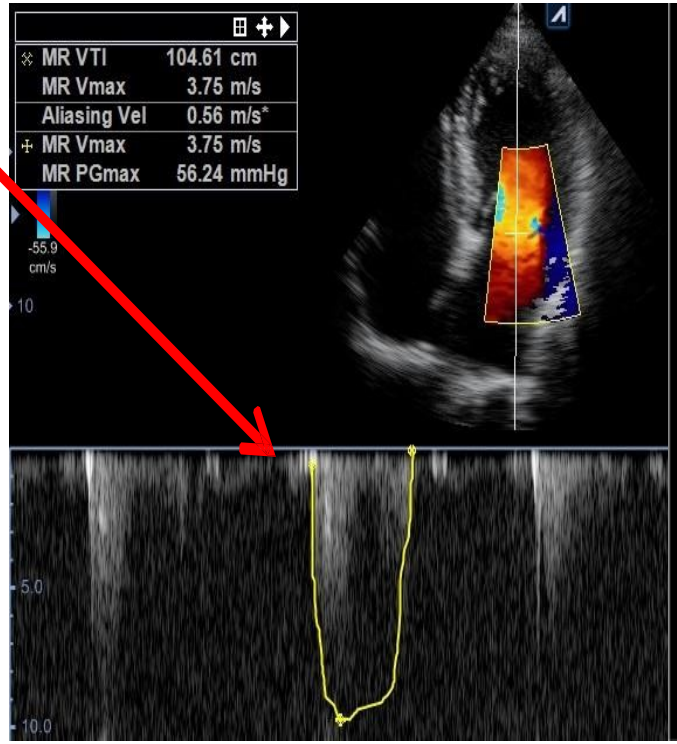


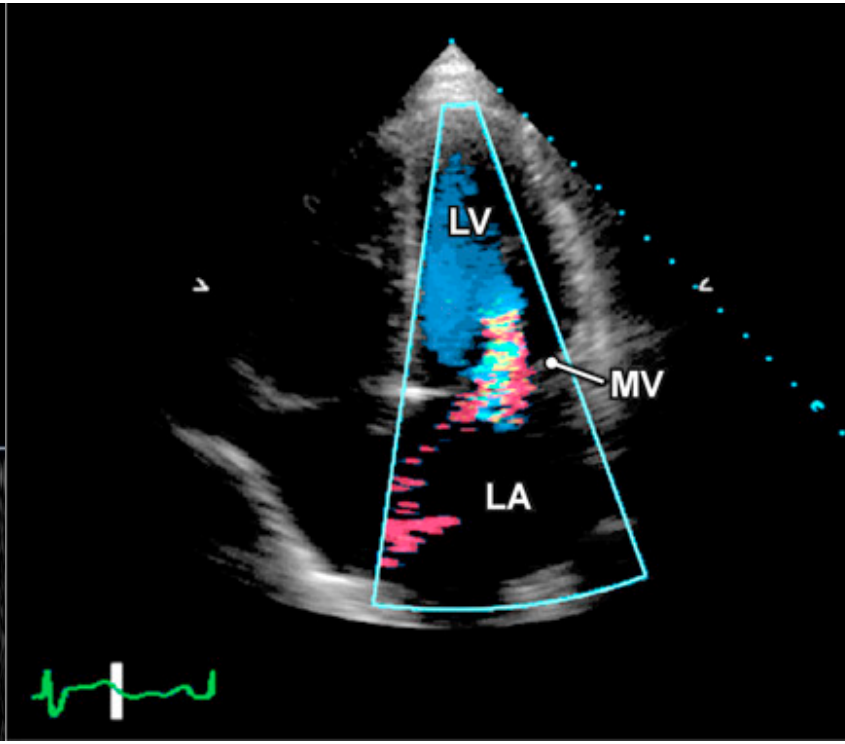
Regurgitation Volume by PISA

- Trace “ MR VTI” and “ Vmax” by CW Doppler

  - place a cursor at the vena contracta, perform CW, and trace along borderline







Grading of mitral regurgitation severity

	Mild	Moderate	Severe
Structural parameters			
LA size	Normal	Usually dilated**	Usually dilated**
LV size	Normal	Usually dilated**	Usually dilated**
Mitral leaflets or support apparatus	Normal or abnormal	Normal or abnormal	Abnormal/ Flail leaflet/ Ruptured papillary muscle
Doppler parameters			
Color flow jet area	Small, central jet (usually < 4cm² or <20% of LA area)	variable	Large central jet (usually >10cm² or > 40% of LA Area or variable size wll-Impinging jet weirling in LA
Mitral inflow	A wave dominant	Variable	E wave dominant (E usually 1,2 m/s)
Pulmonary vein flow	Systolic dominance	Systolic blunting	Systolic flow reversal
Quantitative parameters			
VC width (cm)	<0.3	0.3-0.69	≥0.7
R Vol (ml/beat)	<30	33-44 45-59	≥60
RF (%)	<30	30-39 40-49	≥50
EROA (cm²)	<0.20	1.20-1.29. 0.30-0.39	≥0.40

Grading of mitral regurgitation severity

	Mild	Moderate	Severe
Specific signs of severity	• Small central jet < 4cm² or <20% of LA size • Vena contracta width <0.3cm • No or minimal flow convergence	Signs of MR >mild present, but no criteria for severe MR	• Vena contracta width ≥ 0.7cm with large central MR jet (area >40% of LA) or with a wall-impinging jet of any size, swirling in LA • Large flow convergence • Systolic reversal in pulmonary veins • Prominent flail NV leaflet or ruptured papillary muscle
Supportive signs	• Systolic dominant flow in pulmonary veins • A-wave dominant mitral inflow • Soft density, parabolic CW Doppler MR signal • Normal LV size	Intermediate signs/ findings	• Dense, triangular CW Doppler MR jet • W-wave dominant mitral inflow (E>1.2m/s) enlarged LV and LA size (particulary when normal LV function is present).