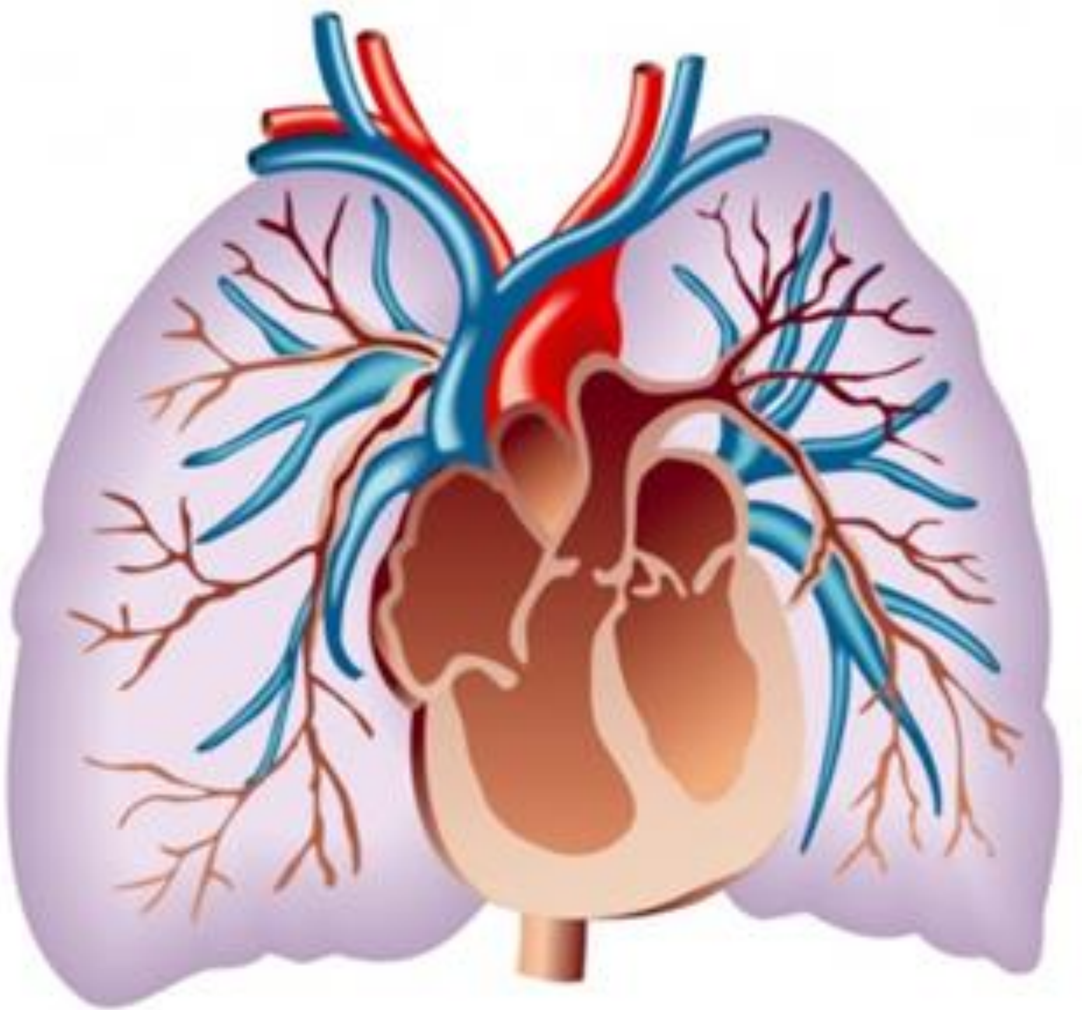


Echocardiography & Pediatric Pulmonary Hypertension

Presented by:
Kurt Scheeler RDCS (PE, AE)

Children's Hospital Colorado
Here, it's different.

6th Pediatric Echocardiography Symposium

Echocardiography & Pediatric Pulmonary Hypertension

Disclosures

- I have no relevant financial relationships with commercial interests

Echocardiography & Pediatric Pulmonary Hypertension

Echo Goals: Determine the presence and severity of Pulmonary hypertension (PHTN)

Normal cardiac pressures in children tend to increase with age, as such, a fractional relationship of pulmonary systolic pressures related to systemic systolic blood pressure creates a more accurate representation of pulmonary hypertension.

Pulmonary Hypertension Severity	
Normal	≤ 20 mmHg or ≤1/3 of systemic BP
Mild	1/3 - 2/3 of systemic BP
Moderate	2/3 - 1 of systemic BP
Severe	> 1 of systemic BP (supra-systemic)

**PHTN in pediatric patients includes any patient with a mean pulmonary arterial pressure (mPAP) > 20 mmHg at rest by heart catheterization.

Echocardiography & Pediatric Pulmonary Hypertension

Timing

It should be noted that in utero and shortly after birth pulmonary pressures are significantly higher due to normal developmental processes.

These pressures tend to drop rapidly over the first 24 hours of life, then gradually diminish over the next 1-3 months.

By example, what may appear to be mild to moderate hypertrophy in an adult may be considered normal in an infant for 2-3 months

Echocardiography & Pediatric Pulmonary Hypertension

Echo Evidence of Pulmonary Hypertension

Severity of Pulmonary Hypertension based on Echo Indices			
	Measurement	**Mild to Moderate PHTN**	**Severe PHTN**
Tricuspid regurgitation Jet	RSVP	2.8 – 4 m/s	> 4 m/s
Shunts (PDA & VSD)	sPAP / RSVP	Left to Right	Right to Left (Supra-systemic)
Pulmonary valve regurgitation	mPAP	2 - 3 m/s	> 3 m/s
Septal flattening (IVS)	EI	Normal or mildly flattened in systole	Flattened or leftward bulging
RV hypertrophy	Visual	Mild to Moderate	Moderate to Severe
RV dilation	Visual	Mild to Moderate	Moderate to Severe
RV function	FAC	Normal-Mild dysfunction	Moderate to Severe dysfunction

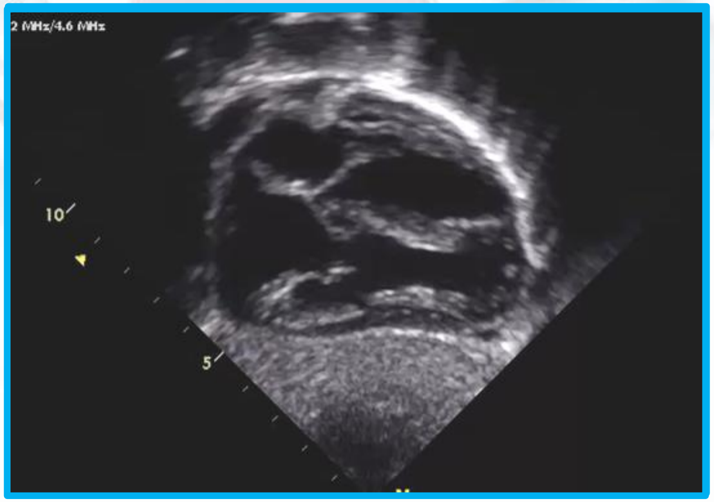
Varghese N et al. *Ped All Imm Pulm.* 2019;32(4): 140-8

Imaging

Echocardiography & Pediatric Pulmonary Hypertension

“The 1st Four”: A quick overview of patients’ PHTN status

Subcostal: coronal view (ant tilt)



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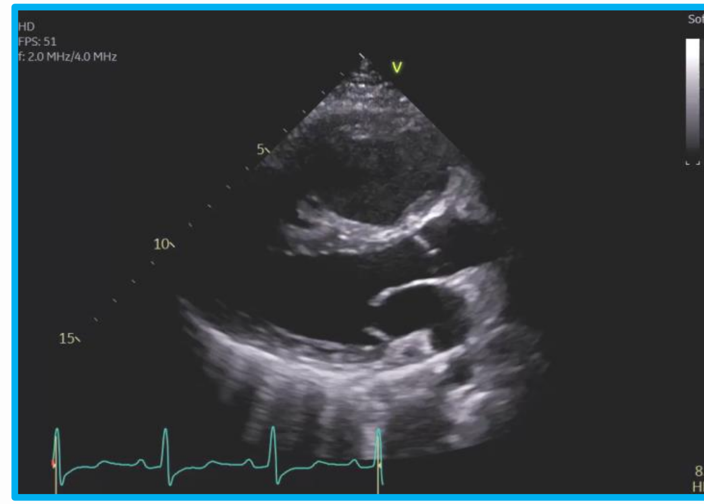
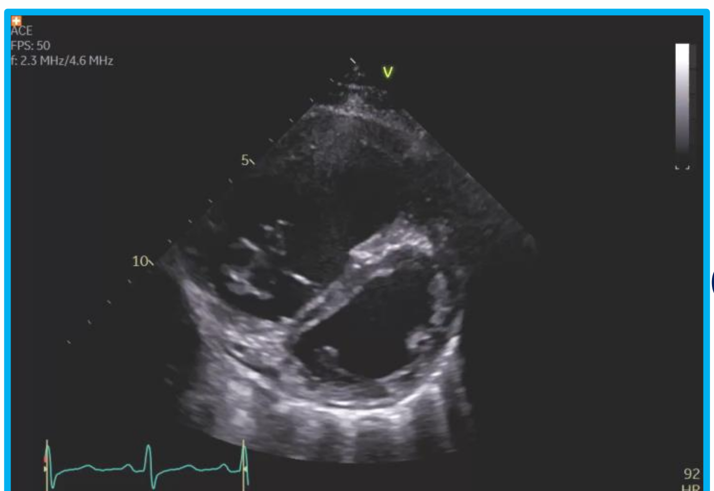
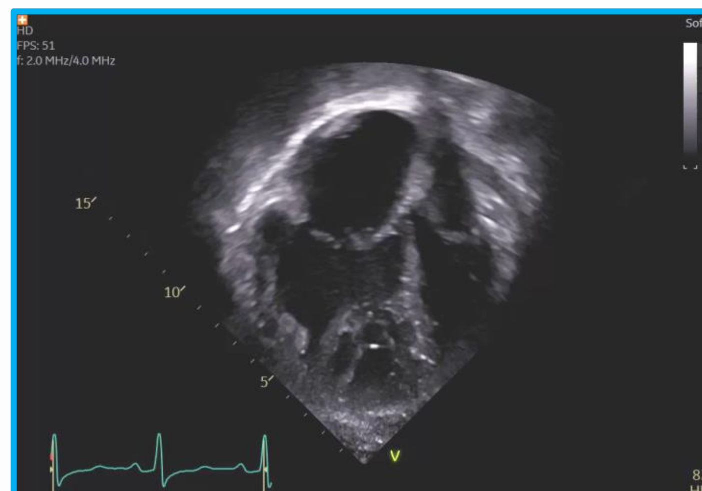


PSAX



A4C (RV Focused)



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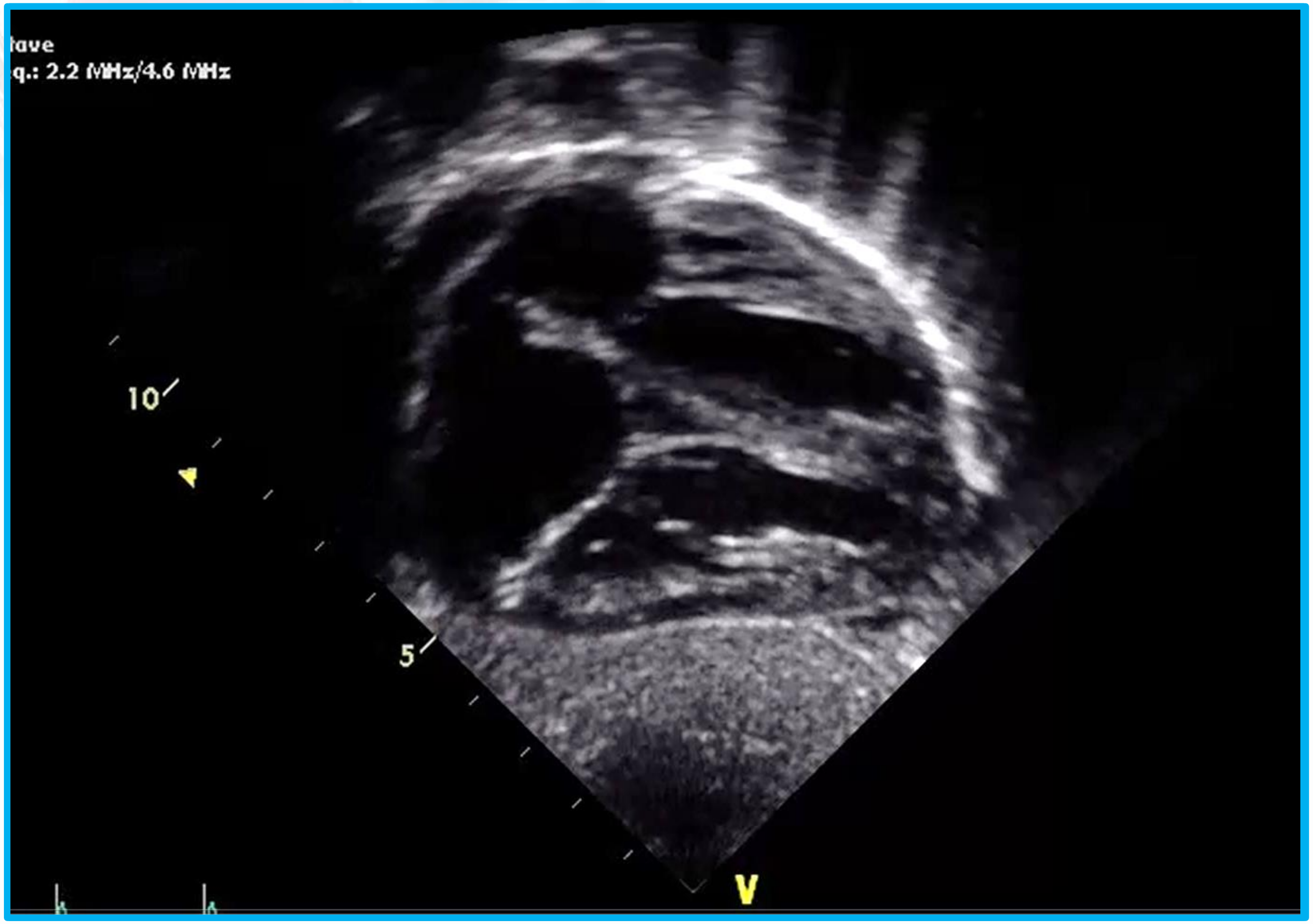
"The 1st Four": A quick overview of patients PHTN status



Subcostal: coronal view (anterior tilt)

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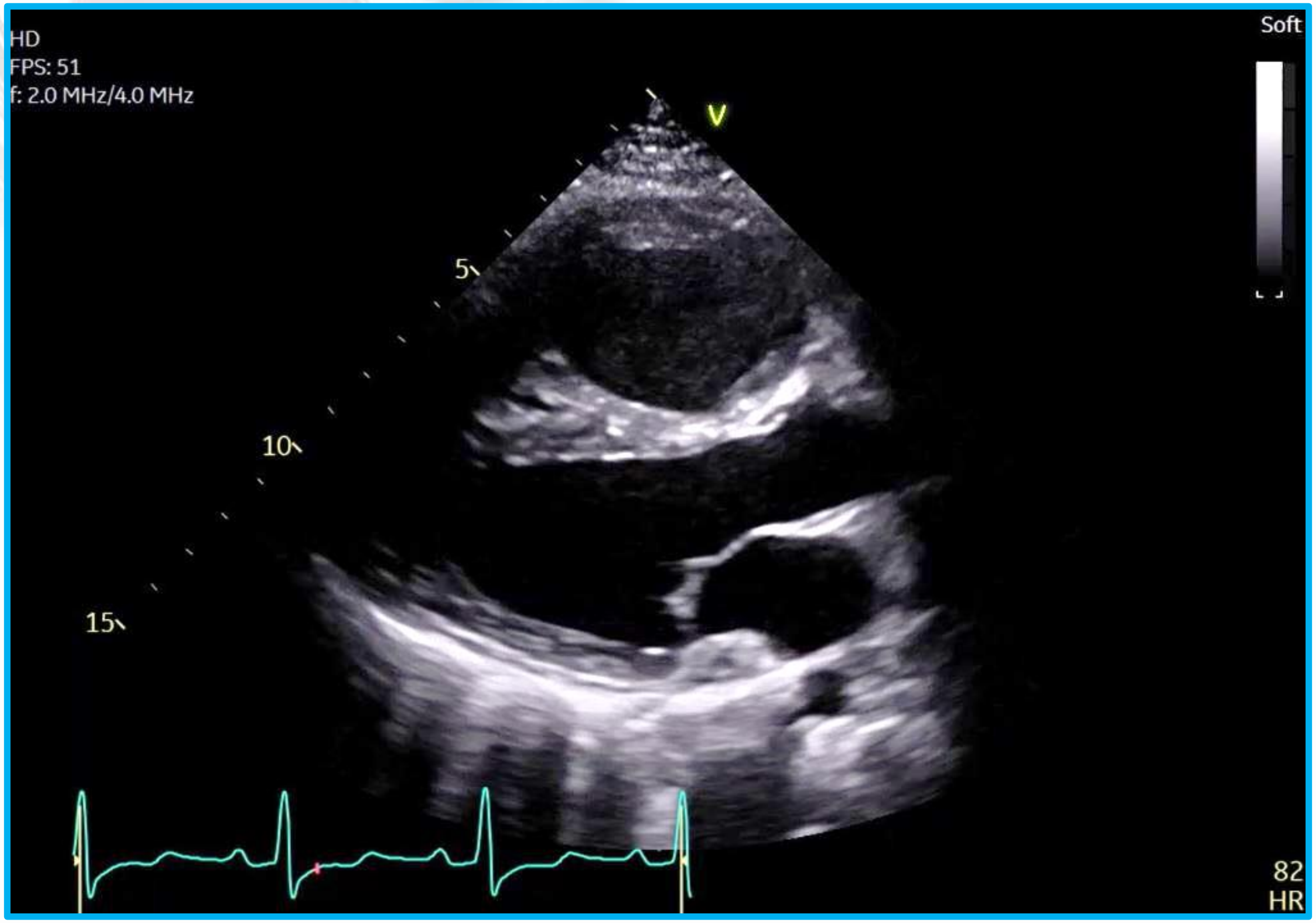
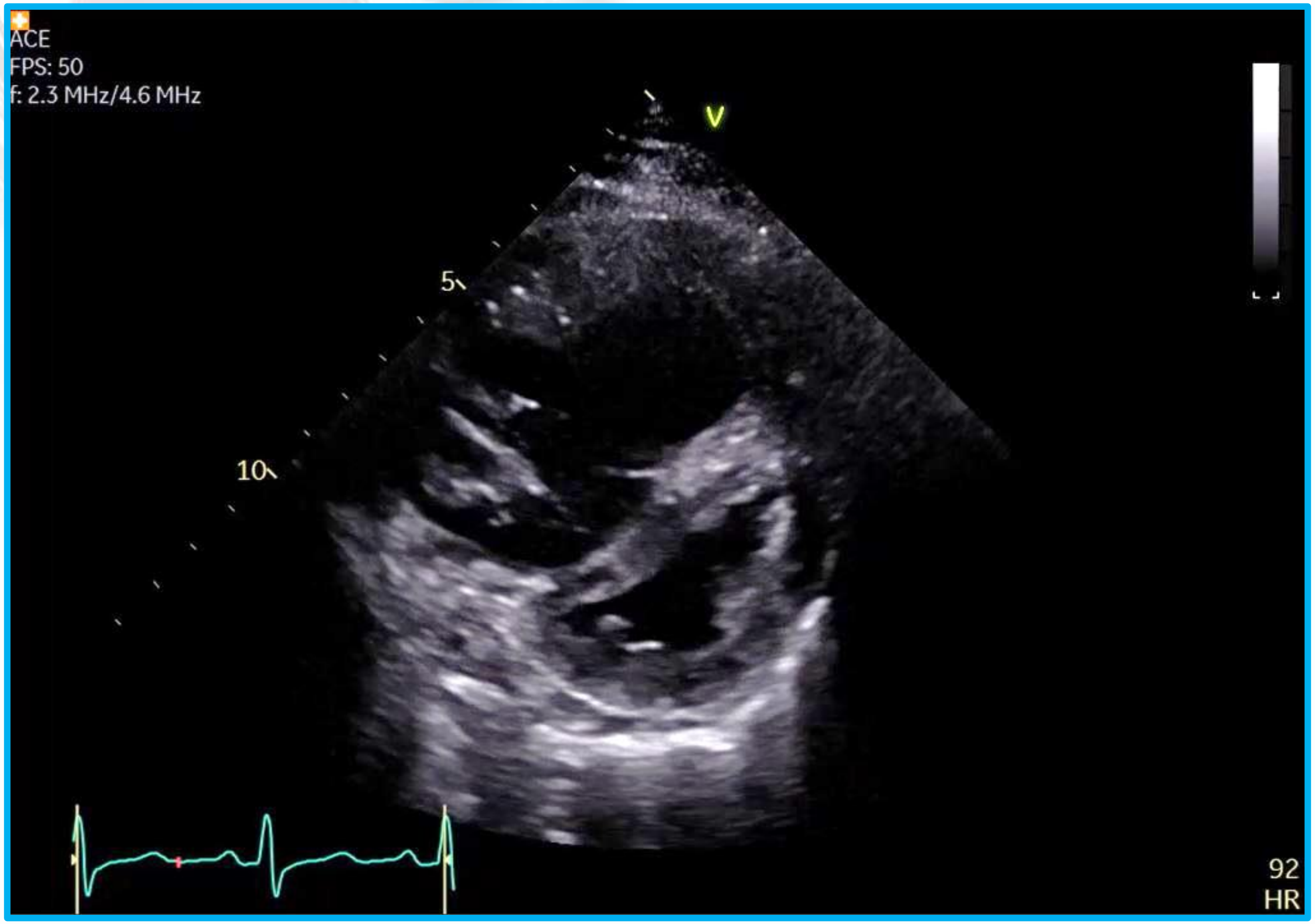
“The 1st Four”: A quick overview of patients PHTN status



PLAX

Echocardiography & Pediatric Pulmonary Hypertension

"The 1st Four": A quick overview of patients PHTN status



PSAX (papillary level)

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"The 1st Four": A quick overview of patients PHTN status

A4C (RV Focused)

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Order of preference for determining severity of PHTN

- PDA (sPAP)
- VSD (RVSP)
- Pulmonary insufficiency (mPAP)
- Tricuspid Regurgitation jet (RVSP)
- Septal Flattening (Eccentricity Index)

Estimating Right Heart Pressures (RSVP) using the Simplified Bernoulli Equation

- Uses velocity (V) to calculate pressure gradient (delta) between two structures

DeltaP = $4V^2$

Daniel Bernoulli
"Formula guy"

Echocardiography & Pediatric Pulmonary Hypertension

Tricuspid Regurgitation:

- Use TR peak systolic Doppler velocity to determine RVSP (right ventricular systolic pressure)
- RVSP is equivalent to sPAP (systolic pulmonary artery pressure) in normal anatomy. E.g. no pulmonary stenosis

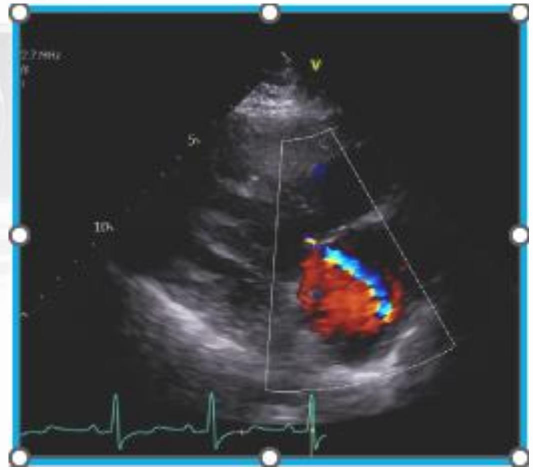
Formula: $RVSP = 4(V)^2 + RAP$

A4C (RV Focused)

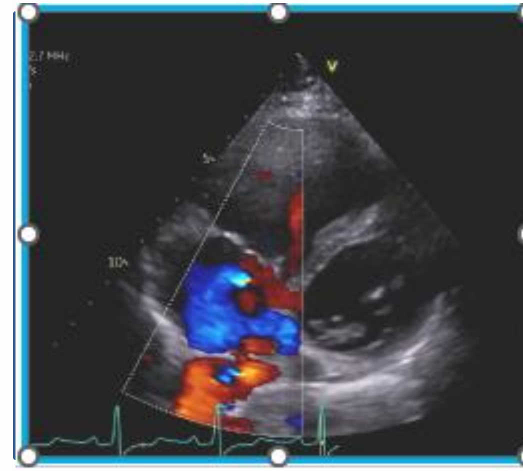
Echocardiography & Pediatric Pulmonary Hypertension

Scanning TR

- Many views incl. A4C, RVIT, PSAX, & Apical RAO
- Use mini color sweeps to find highest velocities
- Keep Doppler as parallel as possible with flow
- Capture fullest CW Doppler envelope
- Use lower frequency probe for better Doppler envelope
- Use highest velocity for calculation

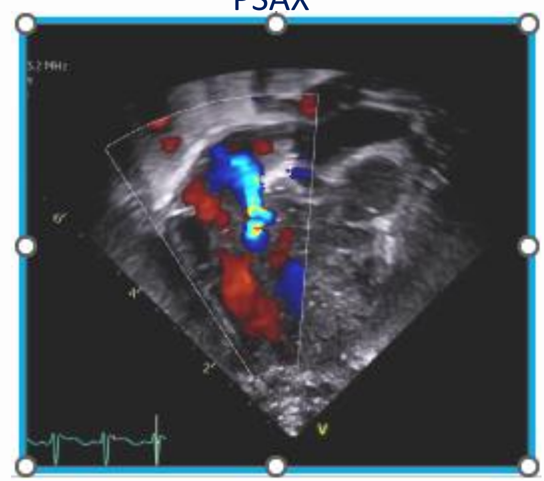


RVIT



PSAX

A4C



Apical RAO

Echocardiography & Pediatric Pulmonary Hypertension

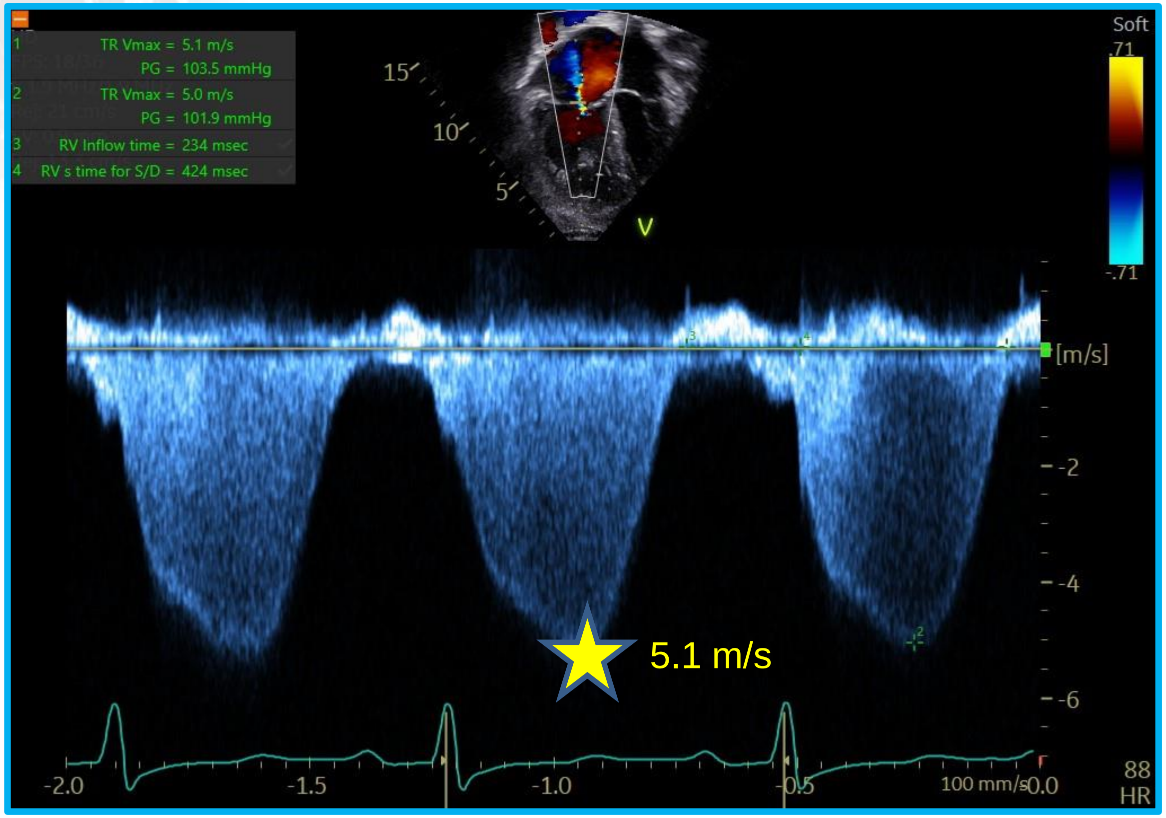
TR: Doppler Velocities

- Full TR Jet using CW
- TR = 5.1 m/s

Formula: RVSP = $4(V)^2$ + RAP

$4(5.1 m/s)^2$ + 2 mmHg =

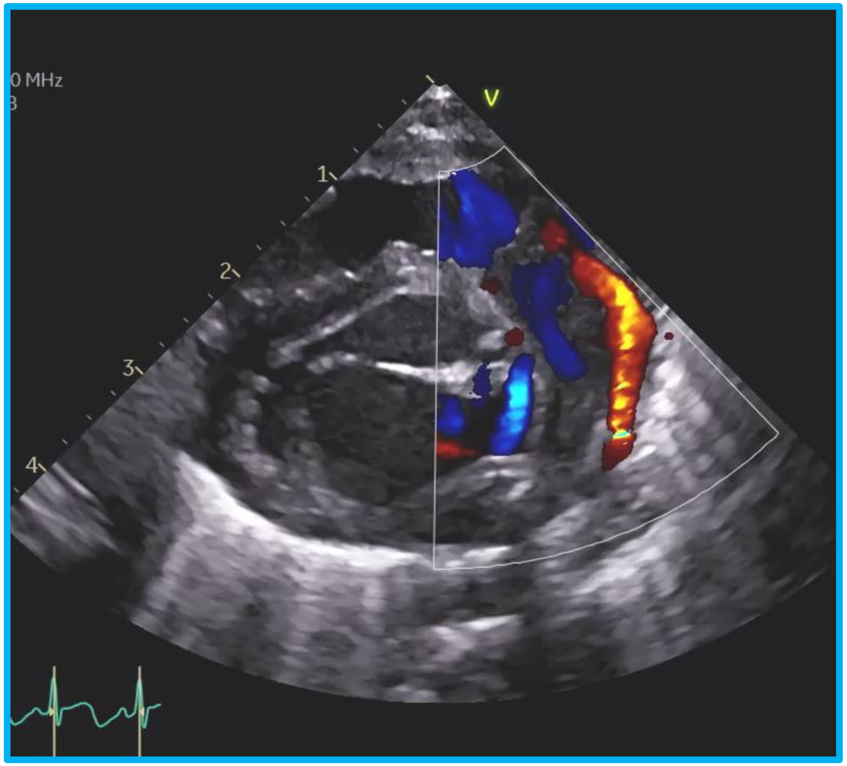
RVSP = 106 mmHg !!



Echocardiography & Pediatric Pulmonary Hypertension

PDA: Patent ductus arteriosus

- Use PDA peak systolic Doppler velocity to determine sPAP (systolic pulmonary arterial pressure)
- sPAP is equivalent to RVSP in normal anatomy. E.g. no pulmonary stenosis
- Large PDAs may equalize pulmonary and systemic pressures making Doppler measurements unreliable



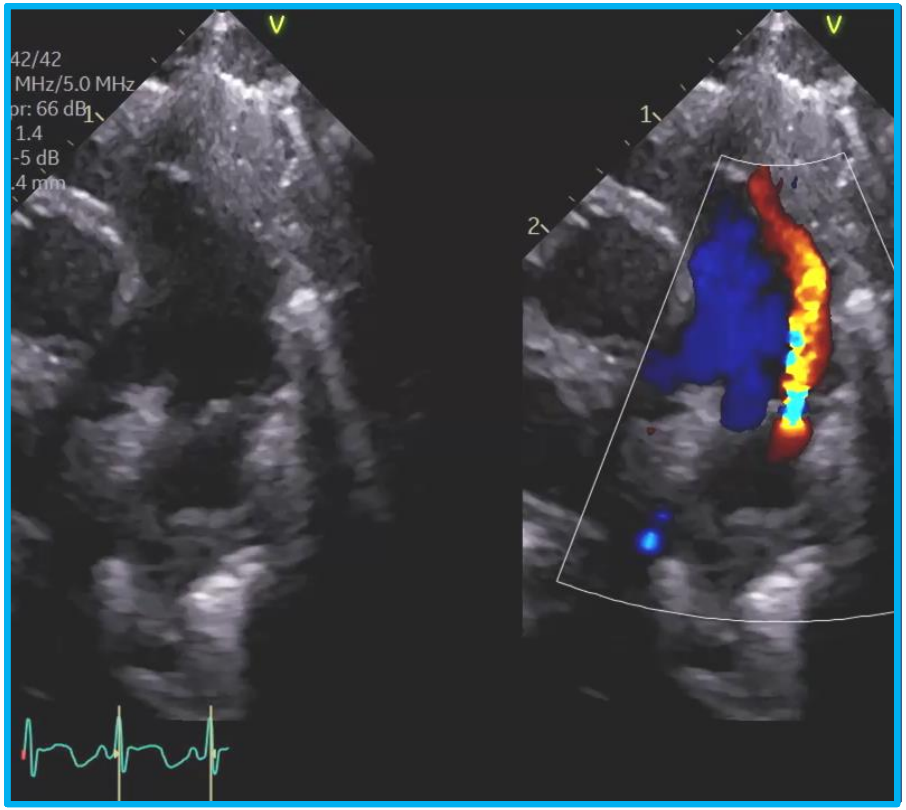
Formulas:

Equation for LEFT to RIGHT shunting PDA: sPAP = Systolic BP – $[4(V)^2]$

Equation for RIGHT to LEFT shunting PDA: =sPAP = Systolic BP + $[4(V)^2]$

Scanning PDAs: Parasternal Short Axis (PSAX)

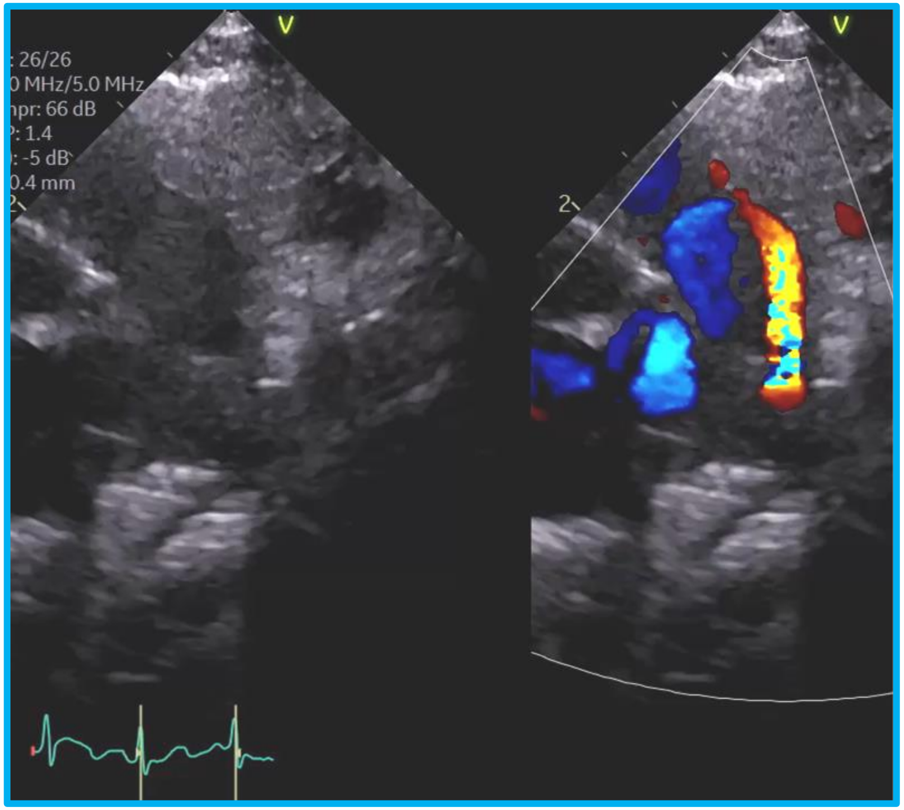
1. Obtain normal PSAX base view with indicator at 1-2 o'clock
2. For ductal or 3-finger view, move superiorly toward 1st intercostal space
3. Use small sweeps and rotation to find widest diameter of the PDA by 2D and highest velocity by color Doppler
4. Adjust Nyquist accordingly
5. Perform full sweep from before aorta to past Pulmonary arteries
6. Capture 2D and color clips of PDA



PSAX (PDA Focused)

Scanning PDAs: Suprasternal notch (SSN)

1. Probe placed in SSN, with indicator at 1 o'clock, move toward 1st left intercostal space
2. Use small sweeps and rotation to find widest diameter of the PDA by 2D and highest velocity by color Doppler
3. Adjust Nyquist accordingly
4. Perform full sweep from before aorta to past Pulmonary arteries
5. Capture 2D and color clips of PDA



SSN (PDA Focused)

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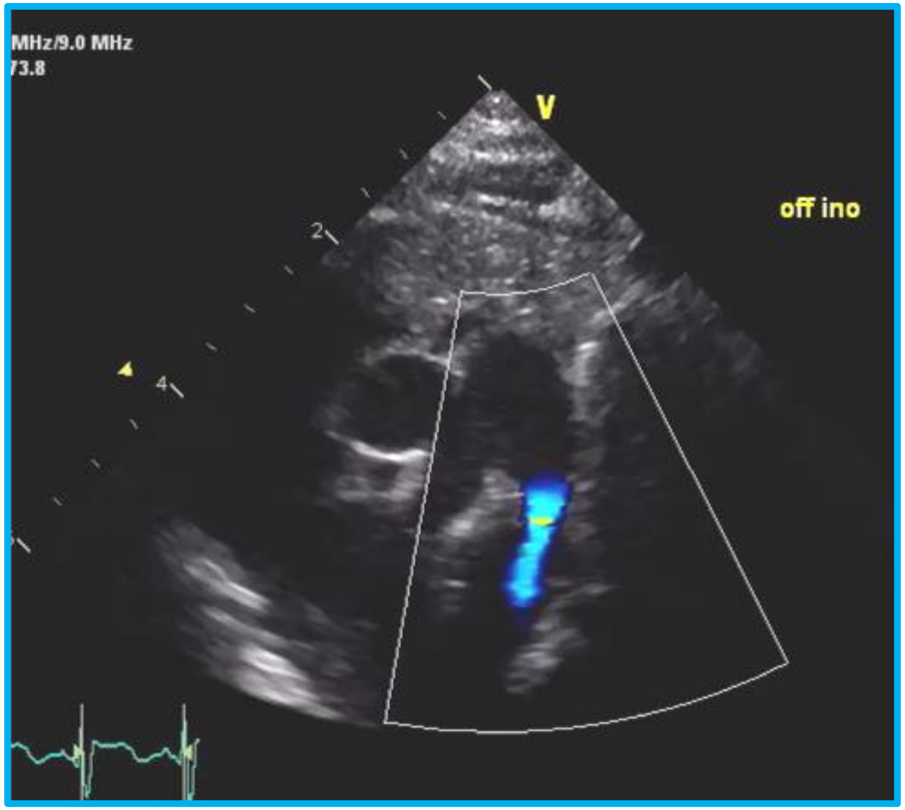
PDA: Shunt direction

- Left to right shunting indicates systemic pressures are higher than pulmonary pressures
  (PDA seen as Red flow from Aorta to MPA)

- Right to Left shunting indicates pulmonary pressures are higher than systemic pressures
  (PDA seen as Blue flow from MPA to Aorta)

Blue PDA flow can often be confused for LPA flow

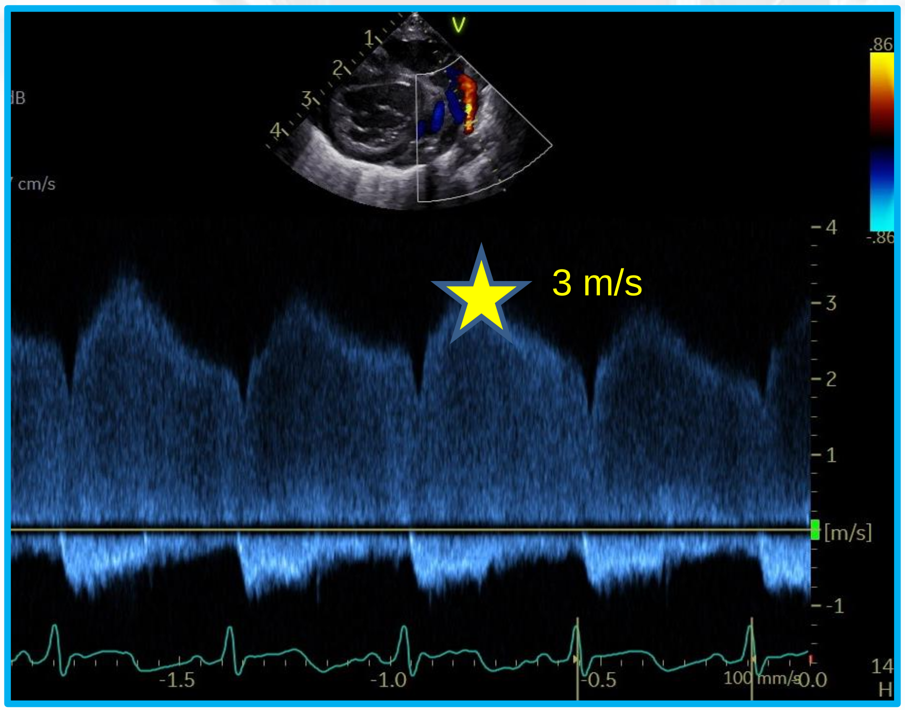


SSN (PDA Focused)

Echocardiography & Pediatric Pulmonary Hypertension

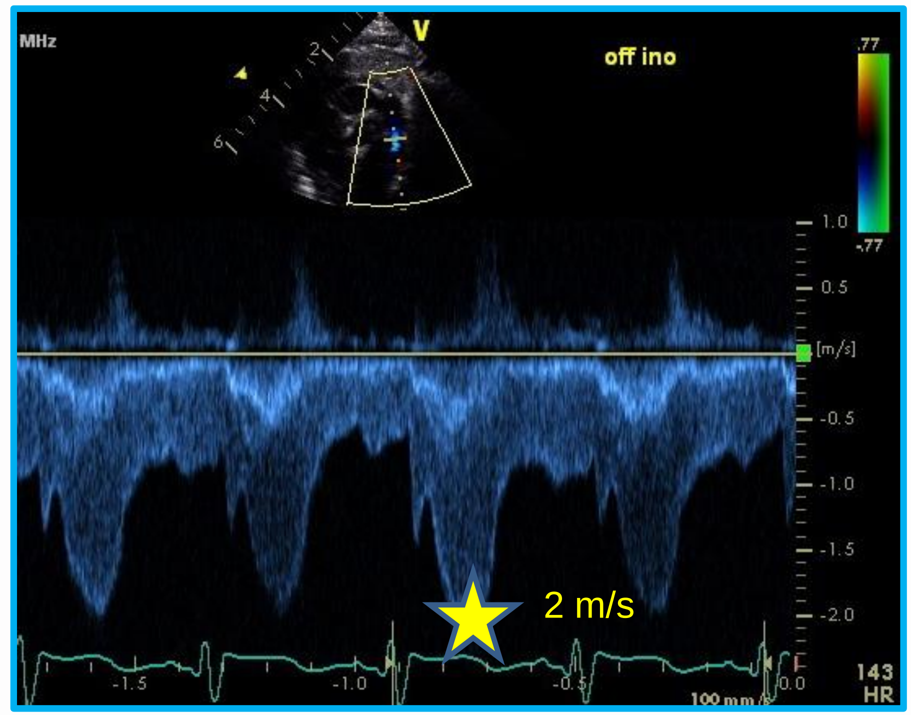
PDA: Doppler Velocities

PDA with continuous Left to Right shunting in systole



120 BP – [4(3 m/s)^2] =
120 BP – 36 = 84 mmHg sPAP

PDA with continuous Right to Left shunting in systole

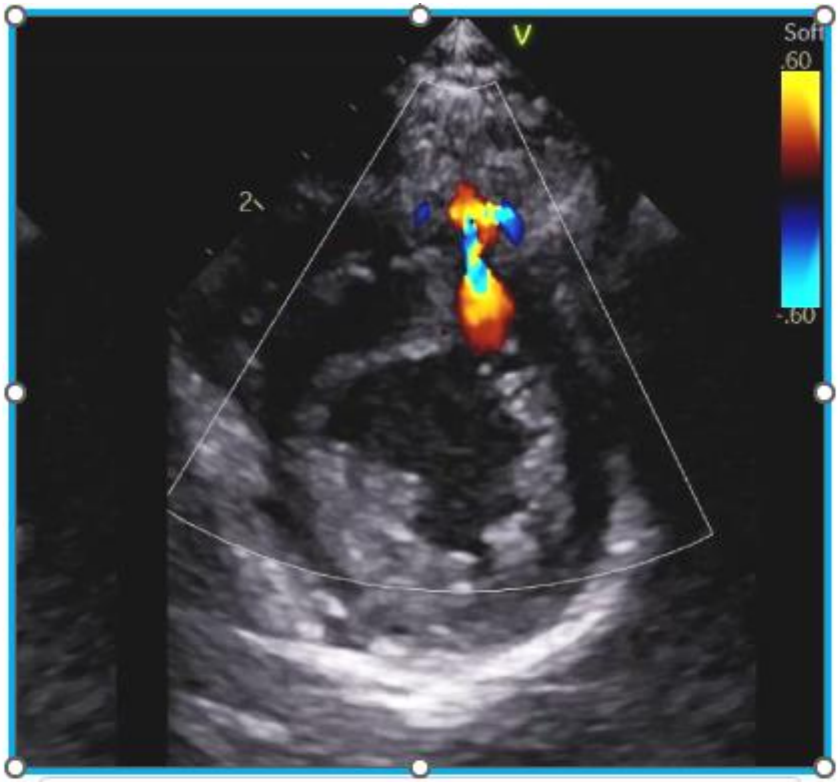


120 BP – [4(2 m/s)^2] =
120 BP + 16 = 136 mmHg sPAP
(Supra-systemic – Zoinks!)

Echocardiography & Pediatric Pulmonary Hypertension

VSD: Ventricular septal defect

- Use highest VSD Doppler velocity to determine RVSP
- Large VSDs may equalize RV and LV pressures making Doppler measurements unreliable



PSAX

Formulas: (similar to PDA formula)

Equation for LEFT to RIGHT shunting VSD: RVSP = Systolic BP – $[4(V)^2]$

Equation for RIGHT to LEFT shunting VSD: RVSP = Systolic BP + $[4(V)^2]$

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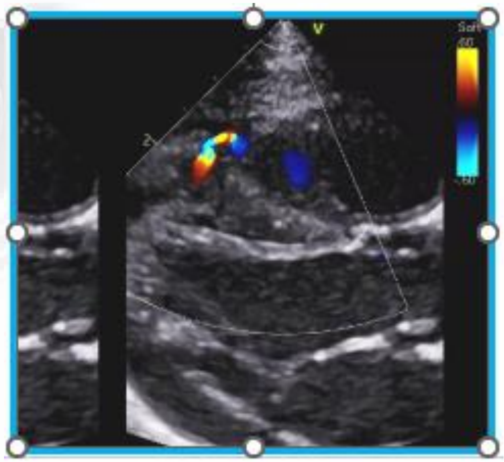
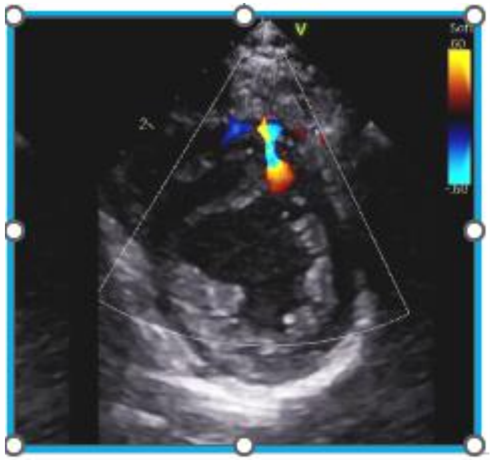
Scanning VSDs

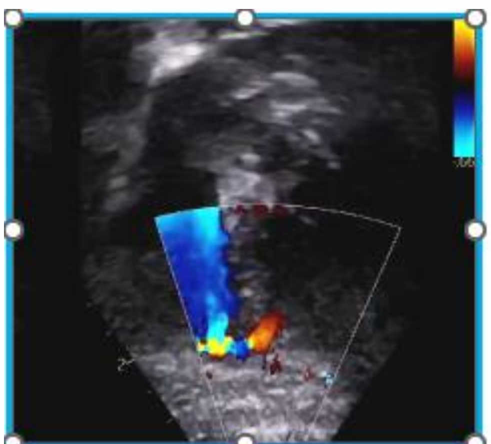
1. Best views for VSD include PLAX, PSAX, Apicals & Subcostal coronal view
2. Use long sweeps find widest diameter of the VSD by 2D and highest velocity by color Doppler
3. Adjust Nyquist accordingly
4. Capture Color Compare clip
5. PW for directionality
6. CW often needed to capture highest velocities
7. Use highest velocity to calculate RVSP



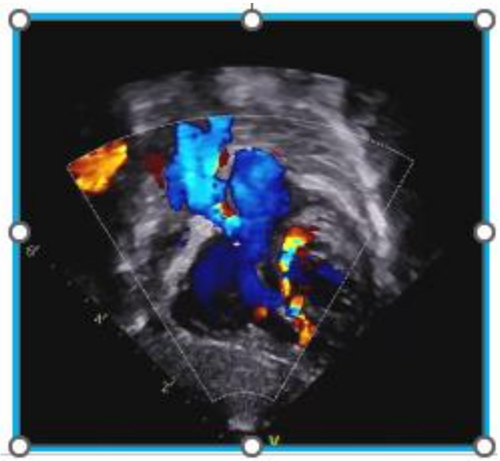
PLAX



PSAX



A4C

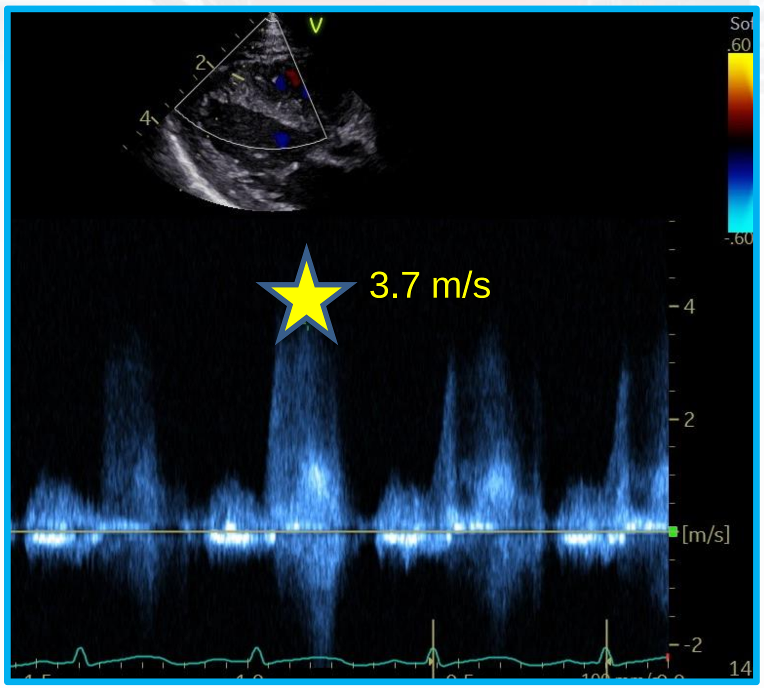


Subcostal coronal (ant tilt)

Echocardiography & Pediatric Pulmonary Hypertension

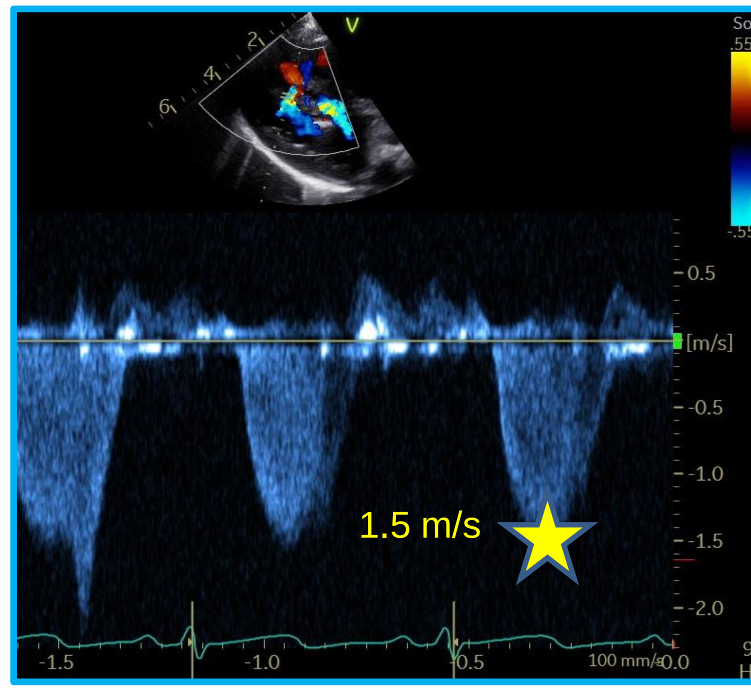
VSD: Doppler Velocities

VSD with Left to Right Shunting in systole



120 BP – $[4(3.7\ m/s)^2]$ =
120 BP – 55 = 65 mmHg RVSP

VSD with Right to Left Shunting in systole



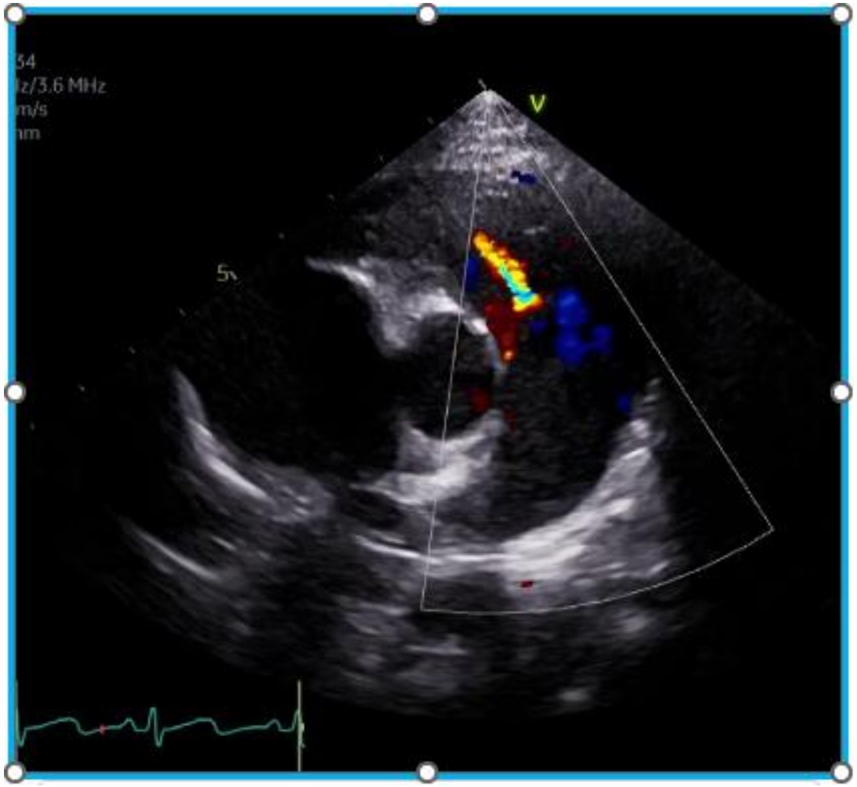
120 BP – $[4(1.5\ m/s)^2]$ =
120 BP + 9 = 129 mmHg RVSP
(Supra-systemic – Zoinks!)

Echocardiography & Pediatric Pulmonary Hypertension

Pulmonary insufficiency

- Pulmonary insufficiency provides best correlation to mPAP measured by heart catheterization
- Use highest PI Doppler velocity at beginning diastole to determine mPAP

Formula:
$mPAP = 4(PRV_{BD})^2 + RAP$



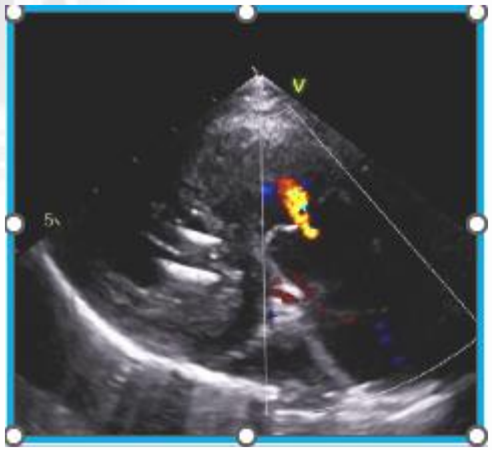
PSAX

Echocardiography & Pediatric Pulmonary Hypertension

Scanning PI

1. Best views for PI include RVOT, & PSAX.
2. Alternative views include Apical RAO and Subcostal coronal (anterior)
3. Use small color compare sweeps to find highest velocities
4. Capture full PI jet clip
5. Use CW Doppler to capture highest PI velocity at beginning of diastole

RVOT



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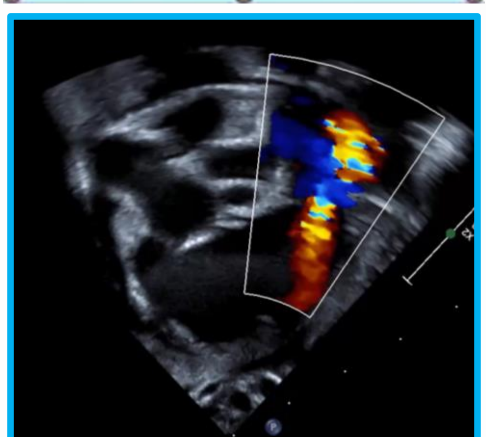
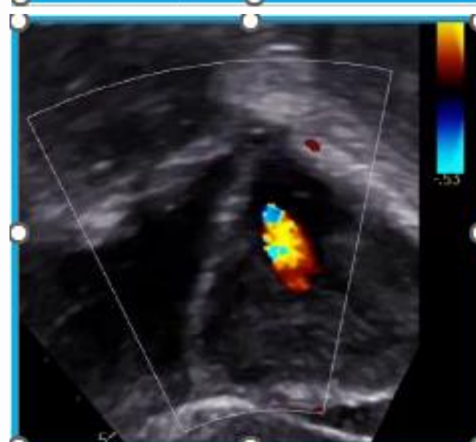


Apical RAO



Subcostal coronal (ant tilt)

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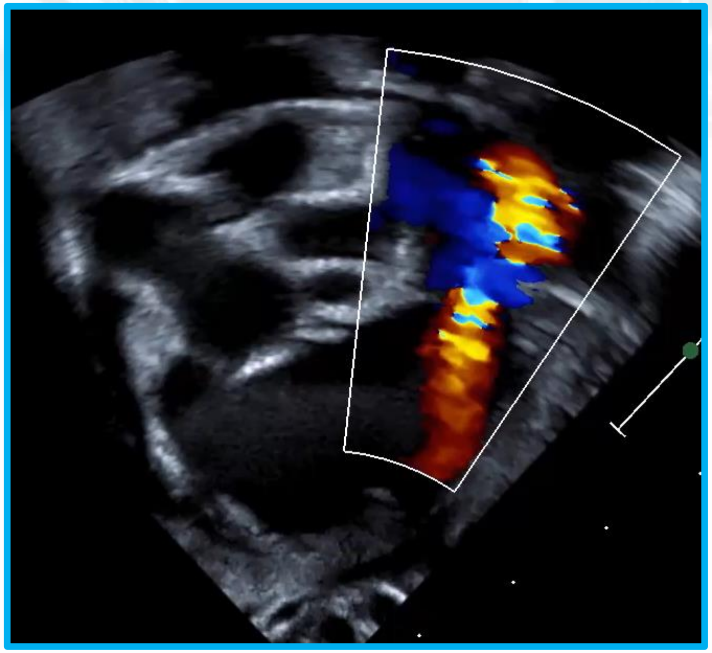
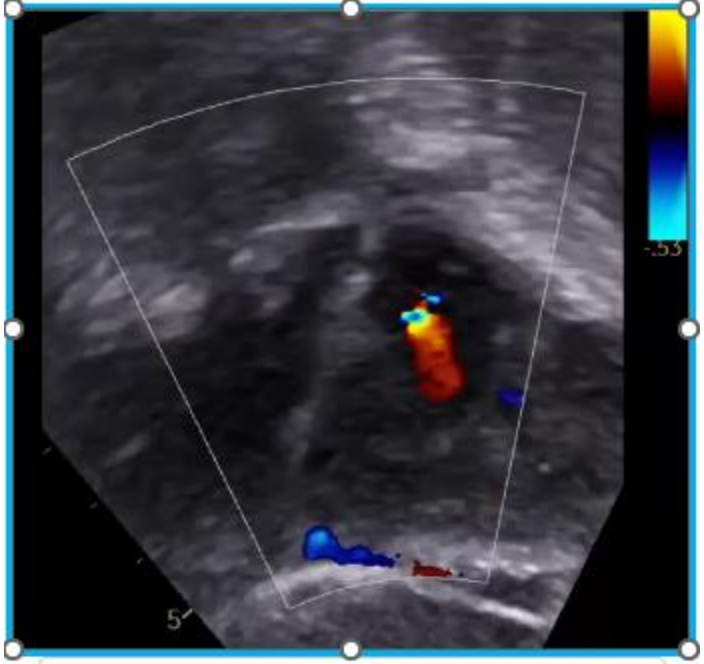
PI: Alternative views

Apical RAO



- From A4C, rotate to approx. 1 o’clock.
- May need to slide more medial
- Pan to bring in both inflow and outflow

Subcostal coronal (ant tilt)



- From subcostal coronal view (4 chamber) pan anterior until you see pulmonary artery

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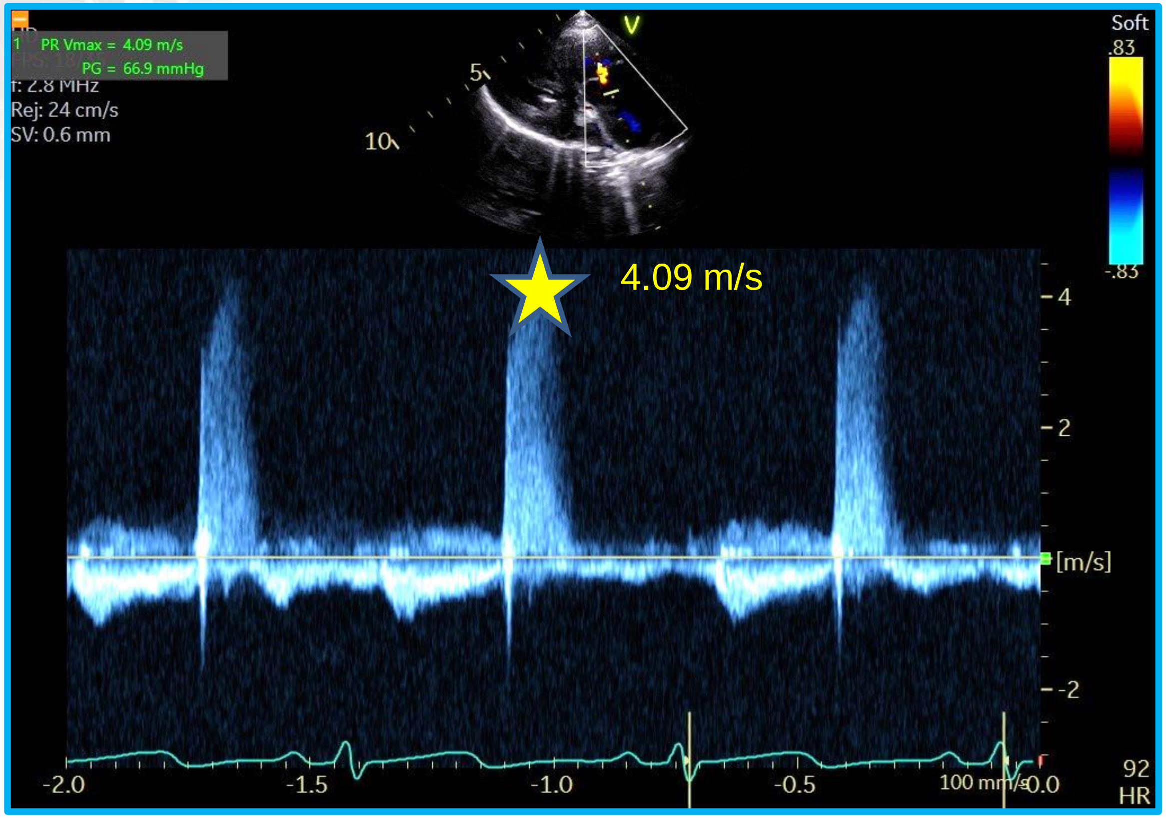
PI: Doppler Velocities

- PI Jet using CW
- PI = 4.09 m/s

Formula:
Mean PAP = $4(PRV_{BD})^2$ + RAP

$4(4.09 m/s)^2$ + 2 mmHg =

mPAP = 67 mmHg



Incomplete envelope, but early diastole is measurable

Septal flattening & Eccentricity Index (EIs & EImax)

- EI Used to quantify septal flattening
- Unitless measurement
- Septal flattening w/o EI measurements can be used for a quick visual assessment of PHTN

PSAX

Scanning Septal Flattening: Don't over rotate

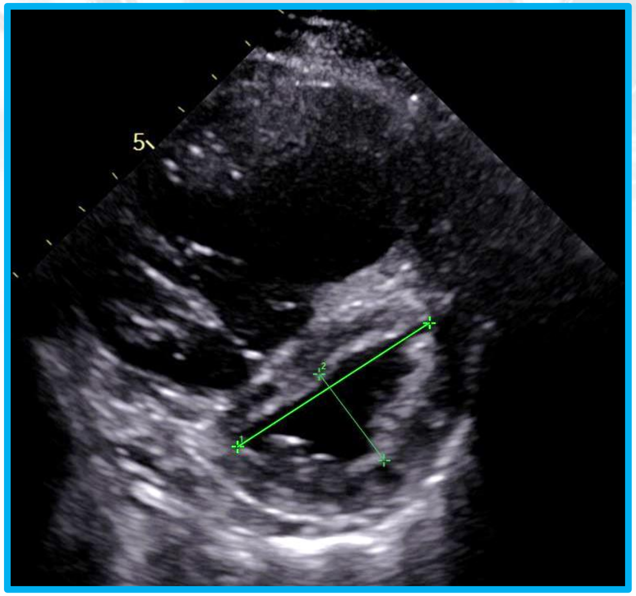
- PSAX view with focus on LV at papillary level
- Goal is to capture LV at its roundest in end systole
- Move higher on chest and rotate probe to achieve
- Low probe location & over rotation and can make SF appear more severe than it is

Mild septal flattening

Mild septal flattening (low on chest & over rotated)

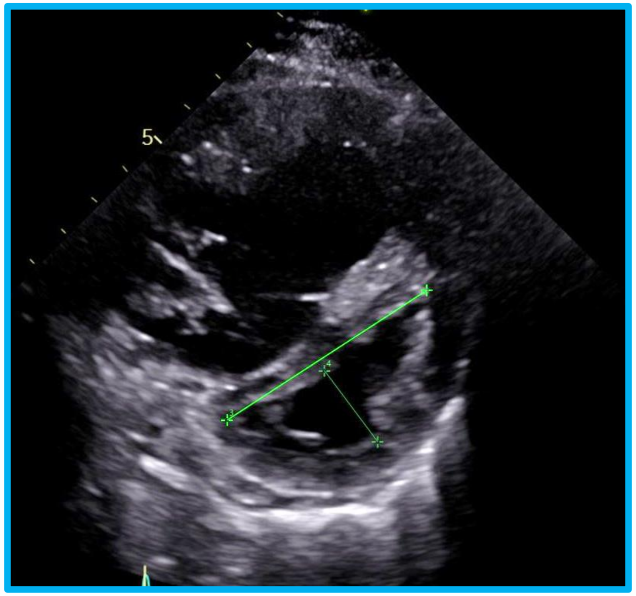
Measuring Septal Flattening with EIs & EImax

EIs



1. Scroll to end systole, (one frame before hinge-points begin to move outward)
2. Measure from compact myocardium to compact myocardium (not trabeculations)
3. EIs D1 is measure horizontally, parallel to the septum
4. EIs D2 is measured perpendicular to D1

EImax



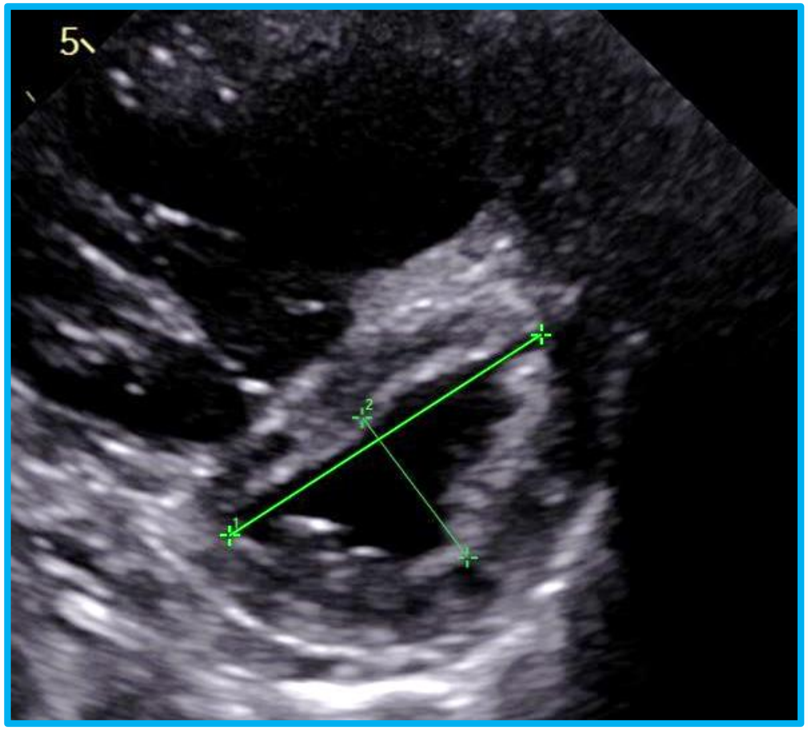
1. From EIs scroll to one frame before posterior (one frame before inferior wall relaxes
2. Measure from compact myocardium to compact myocardium (not trabeculations)
3. EImax D1 is measure horizontally, from hinge-point to hinge-point
4. EImax D2 is measured perpendicular to D1

Echocardiography & Pediatric Pulmonary Hypertension

Calculating Septal Flattening with EIs (not EImax) & assessing visually

Formula: D1 / D2 = EIs

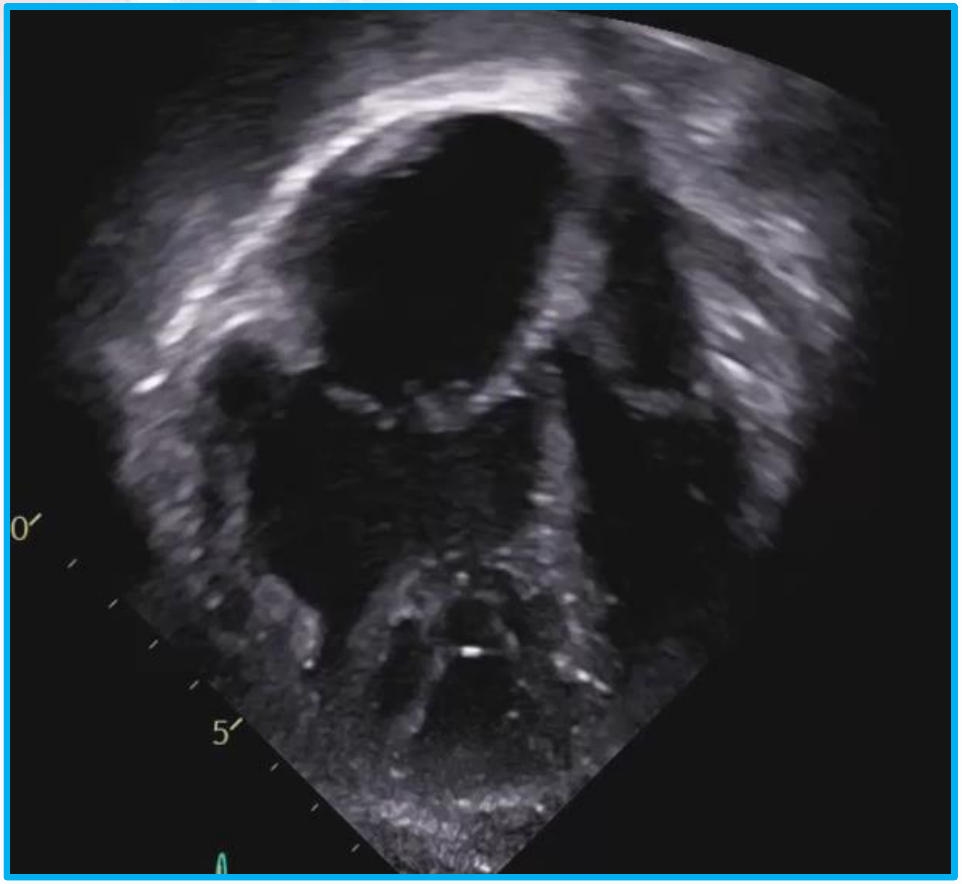
Eccentricity Index scale (EIs)		Septal position
Normal	1.0	Round
Mild	1.2 - 1.5	Slight flattening toward LV
Moderate	1.5 - 2	Flattening parallel
Severe	> 2	Bows into LV



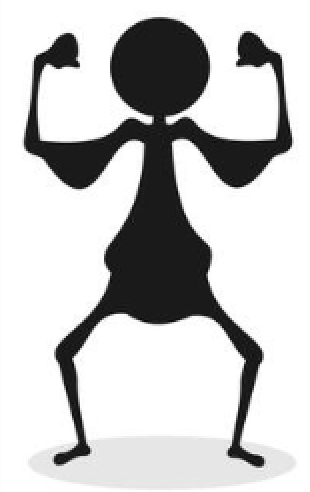
Example:
D1 / D2 = EIs
4.8cm / 2.3 cm = 2.1
Severe Septal Flattening !! Zoinks!

Echocardiography & Pediatric Pulmonary Hypertension

Right ventricle: Assessing in the setting of PHTN



A4C (RV Focused)



Right ventricle: Assessing in the setting of PHTN

- Increased resistance in lungs creates increased afterload, requiring the right ventricle to work harder to move blood.
- Increased afterload can result in hypertrophy, dilation, and reduced RV function
- This can lead to right heart failure

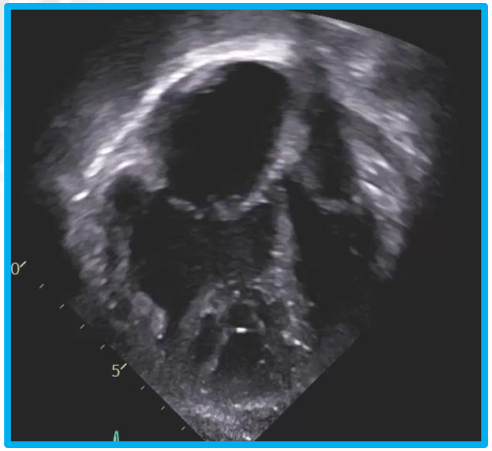
RV indices of PHTN		
	Mild-Moderate PH	**Severe PH**
RV hypertrophy	Mild to Moderate	Moderate – Severe
RV dilation	Mild to Moderate	Moderate – Severe
RV dysfunction	Normal – Mild	Moderate – Severe

Echocardiography & Pediatric Pulmonary Hypertension

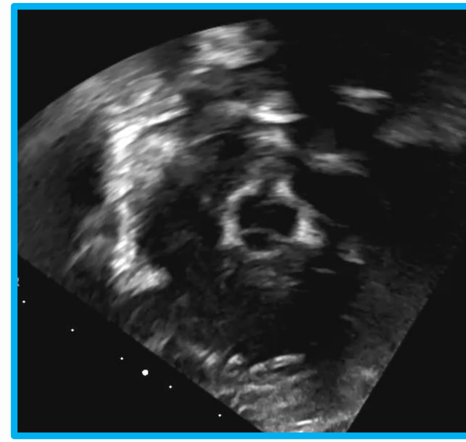
Scanning the right ventricle

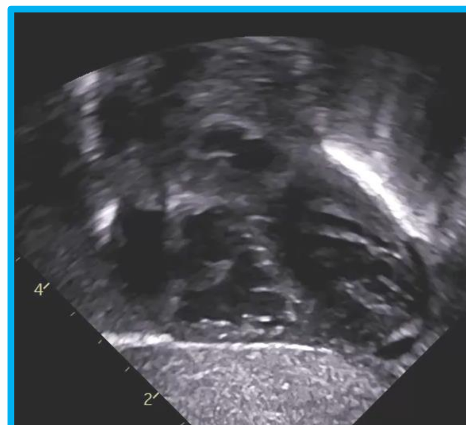
- Best views include A4C, Apical RAO and Subcostal coronal (anterior)
- A4C tip: RV focus by sliding more medial to bring RV free wall
- A4C sweep for full a more complete view of RV
- Apical RAO: sliding medial, indicator at ~1 o'clock, show inflow, RV and outflow

A4C (RV focused)



Apical RAO





Subcostal coronal (ant tilt)

Echocardiography & Pediatric Pulmonary Hypertension

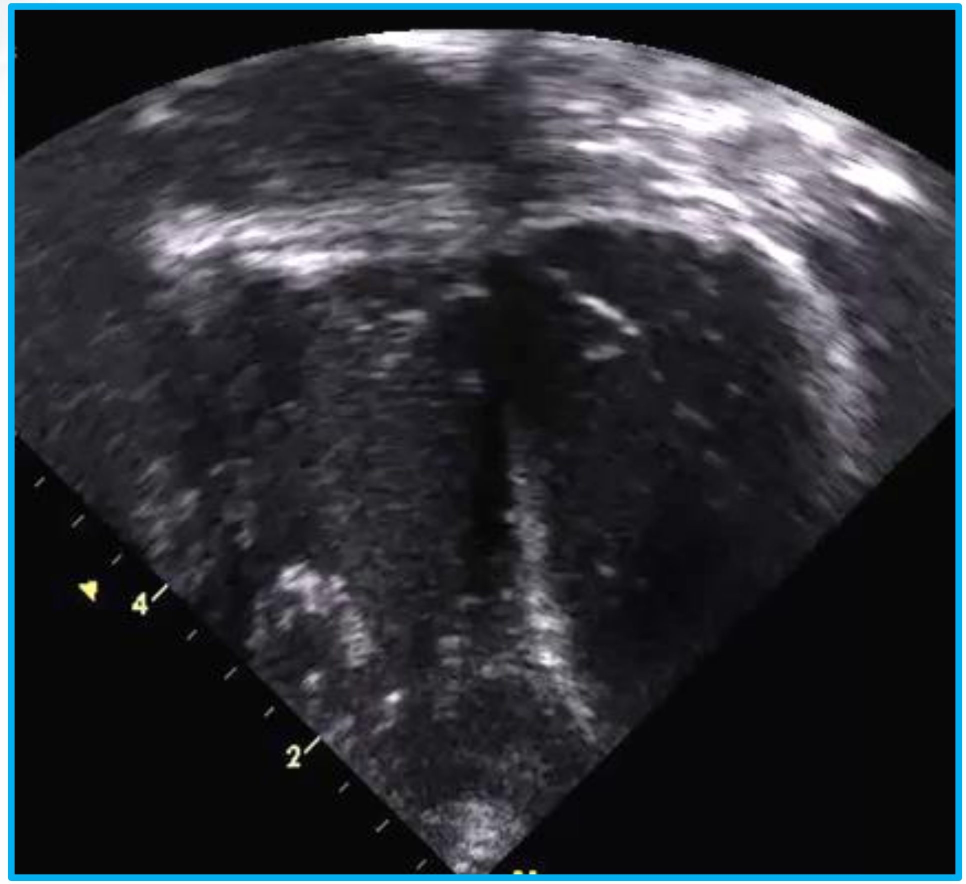
Right Ventricle: Hypertrophy

- Increased global RV wall hypertrophy associated with increased afterload
- Heart is adapting to maintain stroke volume against afterload
- Best assessed in diastole

Subcostal coronal (ant tilt)

Moderate Hypertrophy

A4C (RV focused)



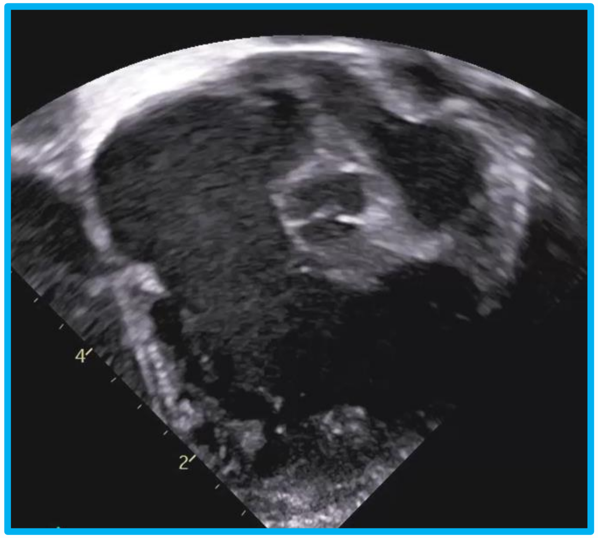
Echocardiography & Pediatric Pulmonary Hypertension

Right Ventricle: Dilation

- Dilation occurs after adapting via hypertrophy fails
- Heart is attempting to maintain stroke volume by increasing diastolic volume

A4C (RV focused)

Moderate Dilation



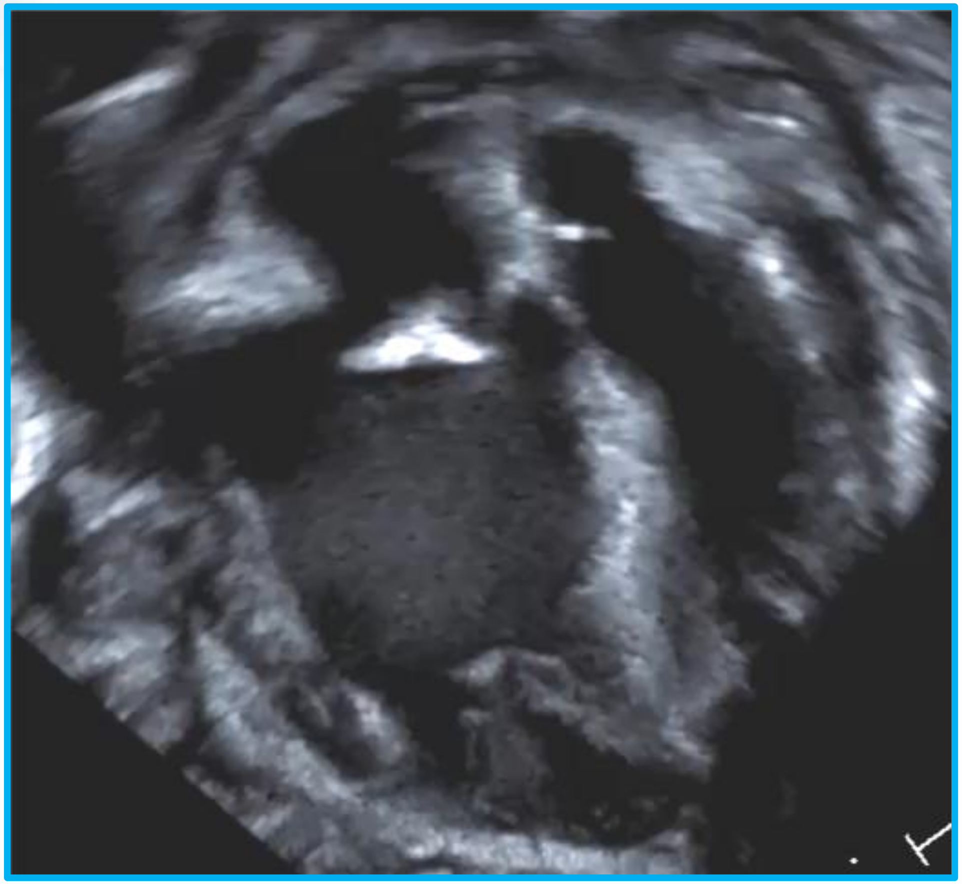
Apical RAO (~1 o'clock)

Echocardiography & Pediatric Pulmonary Hypertension

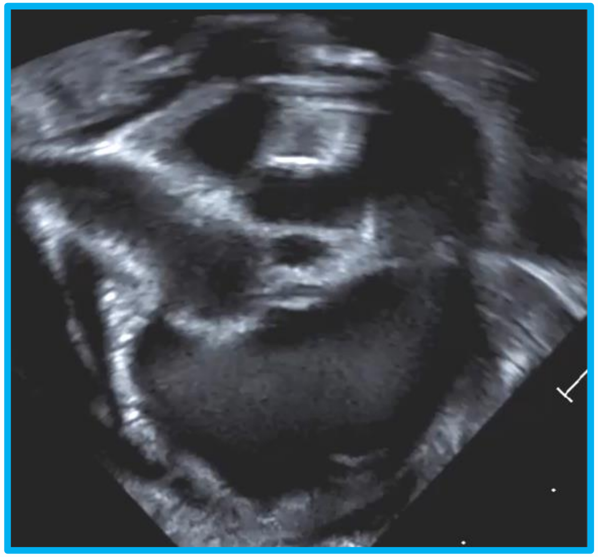
Right Ventricle: Reduced Function

- In the setting of increased afterload from PHTN the RV's myocardium will begin to fail
- This results in reduced RV function and cardiac output

A4C (RV focused)



Severe RV dysfunction



Apical RAO (~1 o'clock)

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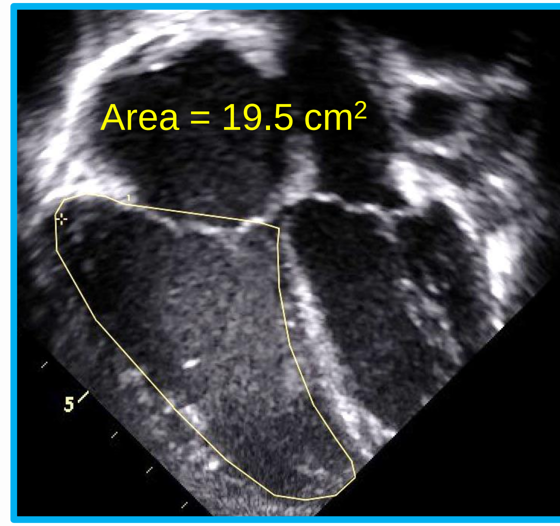
Right Ventricular function: Fractional Area change (FAC)

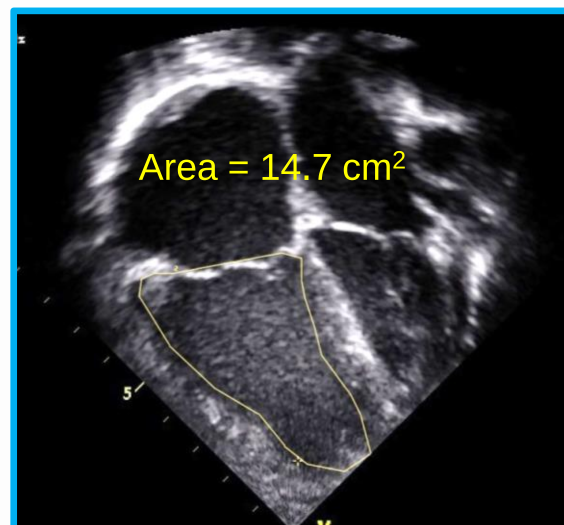
- Similar to a Simpson's single plane measurement
- Takes into account both longitudinal and radial function (TAPSE & Squeeze)
- Measured in A4C (RV focused)
- Measure end diastolic area (EDA)
- Measure end systolic area (ESA)
- Do not include trabeculations

FAC	
Normal RV function	> 35% FAC
Mildly diminished	28-35%
Moderately diminished	21-28%
Severely diminished	<21%

Formula: FAC % = (EDA-ESA) / EDA

E.g. 19.5cm^2-14.7cm^2 / 19.5cm^2 = 24.6% FAC, Moderately reduced





A4C (RV focused)

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Immediately contact an attending when you see…

- Tricuspid regurgitation > 4 m/s
- PDA with right to left shunting in systole
- Pulmonary insufficiency > 3 m/s in beginning diastole
- Severe septal flattening
- RV function reduced from prior echo

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References:

Images & graphics:

Lung and Heart: https://byjus.com/biology/pulmonary-hypertension/

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Thank you for attending!

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