Assessment of Fetal Cardiac Function & Cardiac Output

Matthew L Moehlmann, DO

Pediatric Cardiology, Ward Family Heart Center, Children's Mercy Kansas City

Cardiac High Acuity Monitoring Program (CHAMP)

Pediatric and Fetal Echocardiography

Cardiac Magnetic Resonance and Computed Tomography

Assistant Professor UMKC and KU

Disclosure

- I have no relevant disclosures

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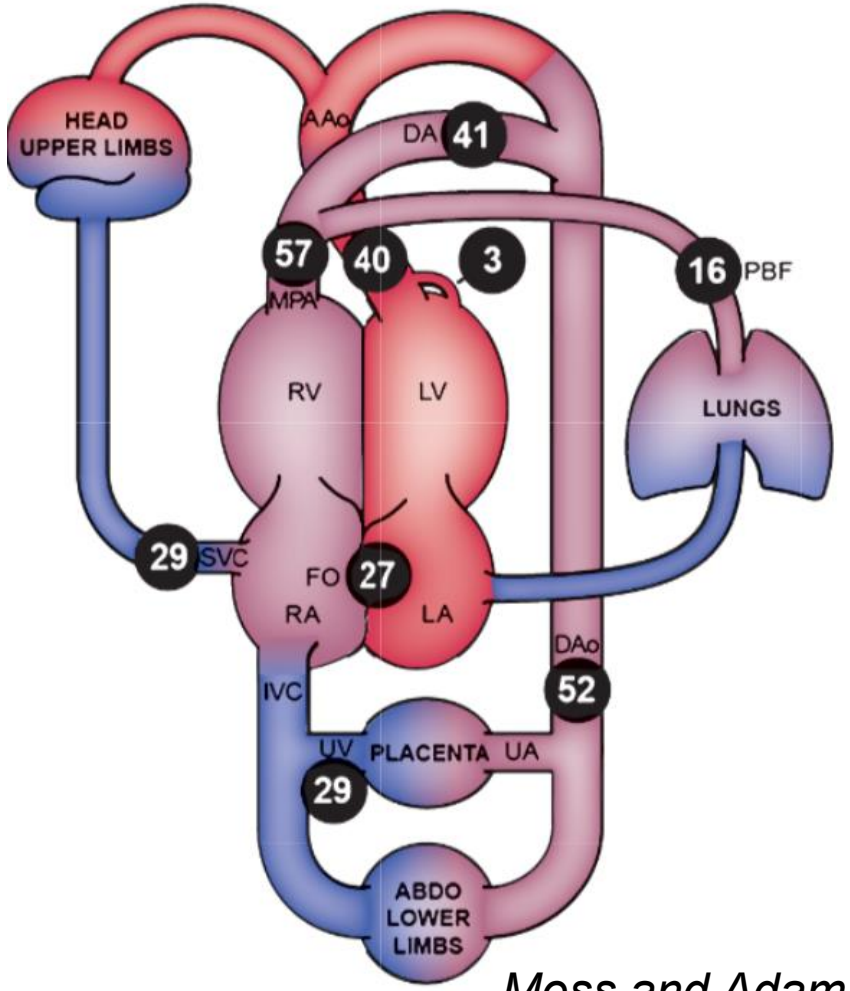
Objectives

- Why assessment of function is critical to the fetus and counseling
- How to measure myocardial function
- Cardiac Outputs

Why assessment of function is critical to the fetus and counseling

Fetal Physiology

- Parallel circulation
  - Combined cardiac output
- Fetal LV mostly responsible for head and upper body while the RV is responsible for the lower body and placenta
- Increased non-contractile elements
  - Reduced compliance compared to postnatal with unfavorable response to volume loading
- Sarcoplasmic reticulum accumulates calcium at a slower rate compared to adult myocardium
- The sole source of metabolic energy of the fetal myocardium is glucose



Moss and Adams' 9th ed

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Fetal Cardiomyopathy

- 55 Fetuses diagnosed with cardiomyopathy
  - 22 dilated cardiomyopathy
  - 33 hypertrophic cardiomyopathy
- Mortality
  - Dilated cardiomyopathy 82%
  - Hypertrophic cardiomyopathy 52%

- Risk factors of perinatal demise
  - Systolic dysfunction (SF <28%)
  - Atrioventricular valve regurgitation
  - Diastolic dysfunction
    - Associated with an 8-fold increased risk of mortality

Pedra et al. *Circulation* 2002

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Normal fetal Cardiac function

Systolic

Diastolic

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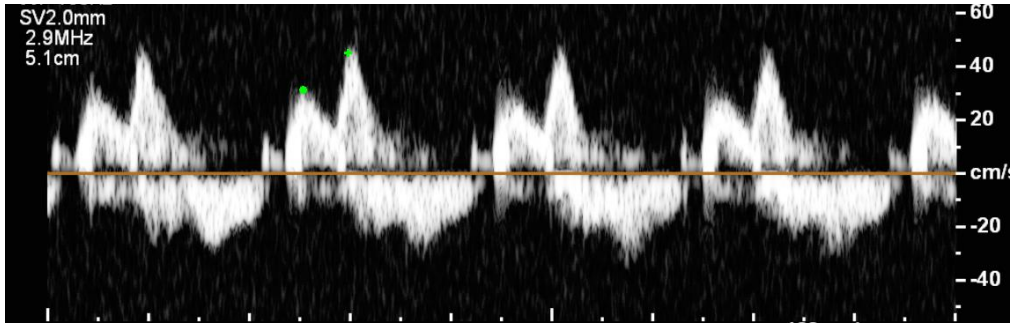
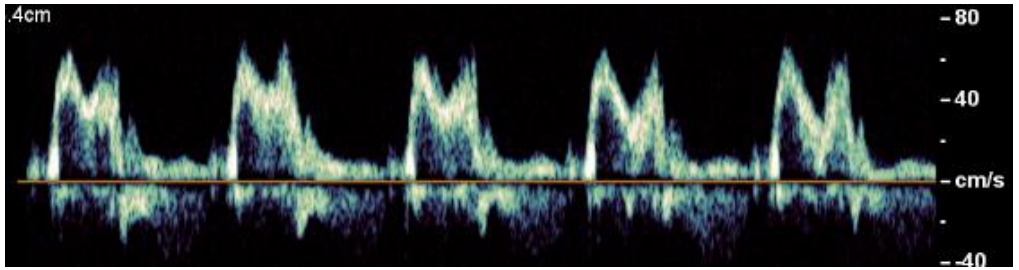
Normal fetal Cardiac function

Systolic

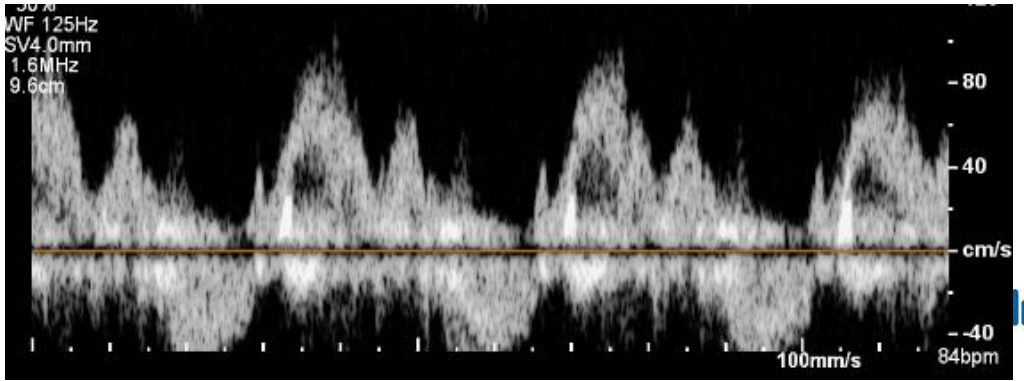
Diastolic



Fetal



Transition



"Adult"

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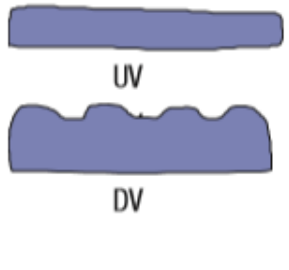
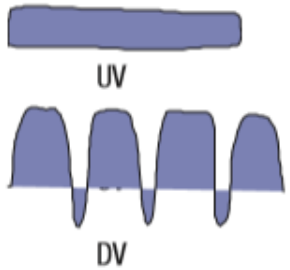
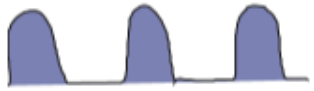
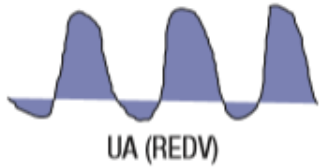
How to measure myocardial function

Cardiovascular Profile Score

	Normal, 2 Points	−1 Point	−2 Points
Hydrops	None	Ascites or pleural effusion or pericardial effusion	Skin edema
Venous Doppler (Umbilical vein and ductus venosus)			
Heart size (heart area/ chest area)	>0.20 and ≤0.35	0.35–0.50	>0.50 or <0.20
Cardiac function	Normal TV and MV RV/LV FS >0.28 Biphasic diastolic filling	Holosystolic TR or RV/LV FS <0.28	Holosystolic MR or TR dP/dt< 400 or monophasic filling
Arterial Doppler (umbilical artery)			

Donofrio et al. *Diagnosis and Treatment of Fetal Cardiac Disease: A Scientific Statement from the American Heart Association* 2014

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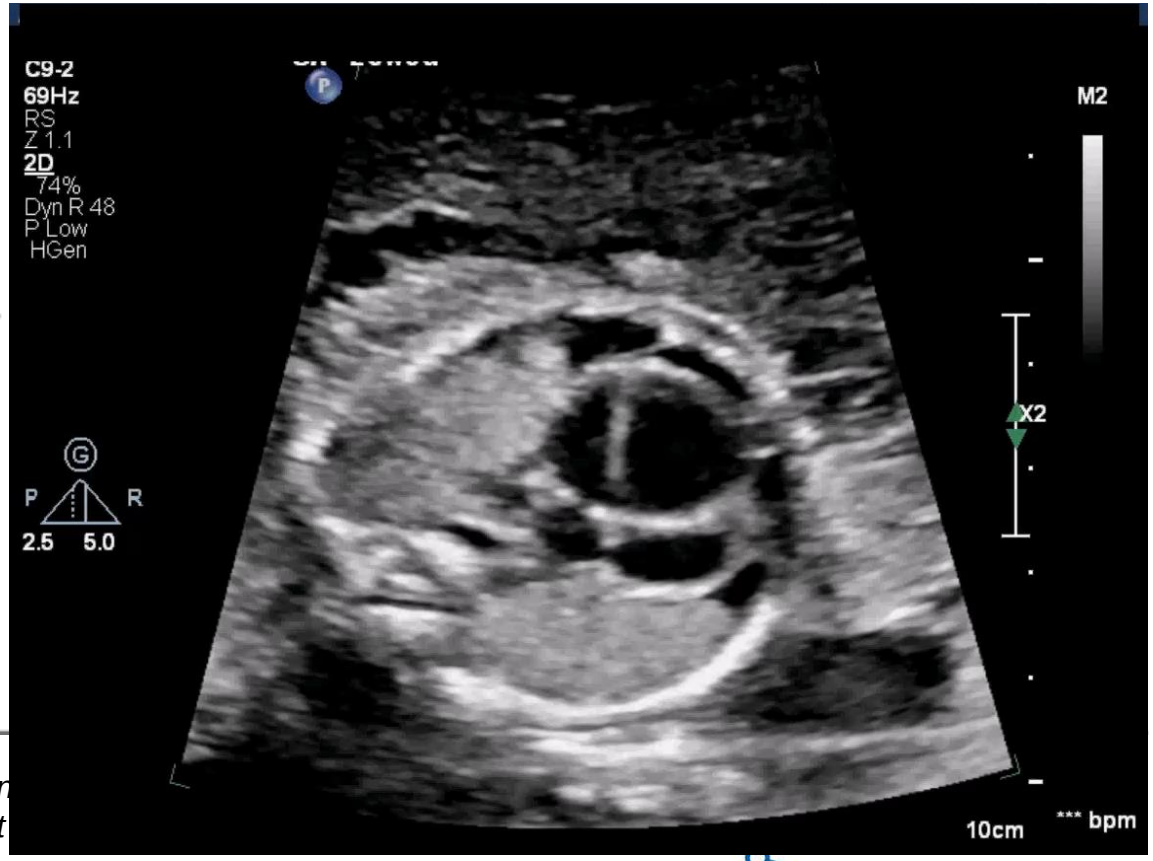

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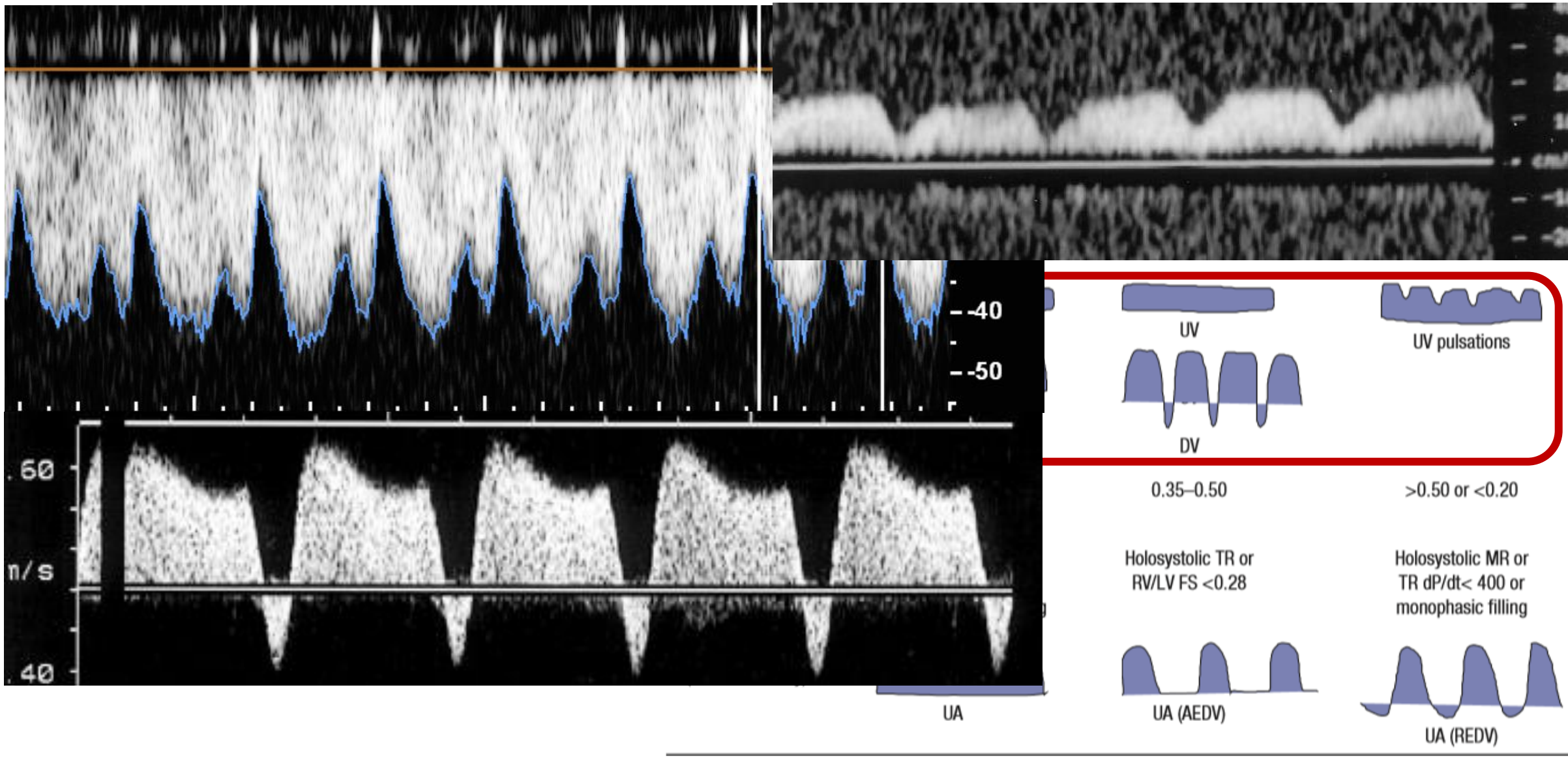

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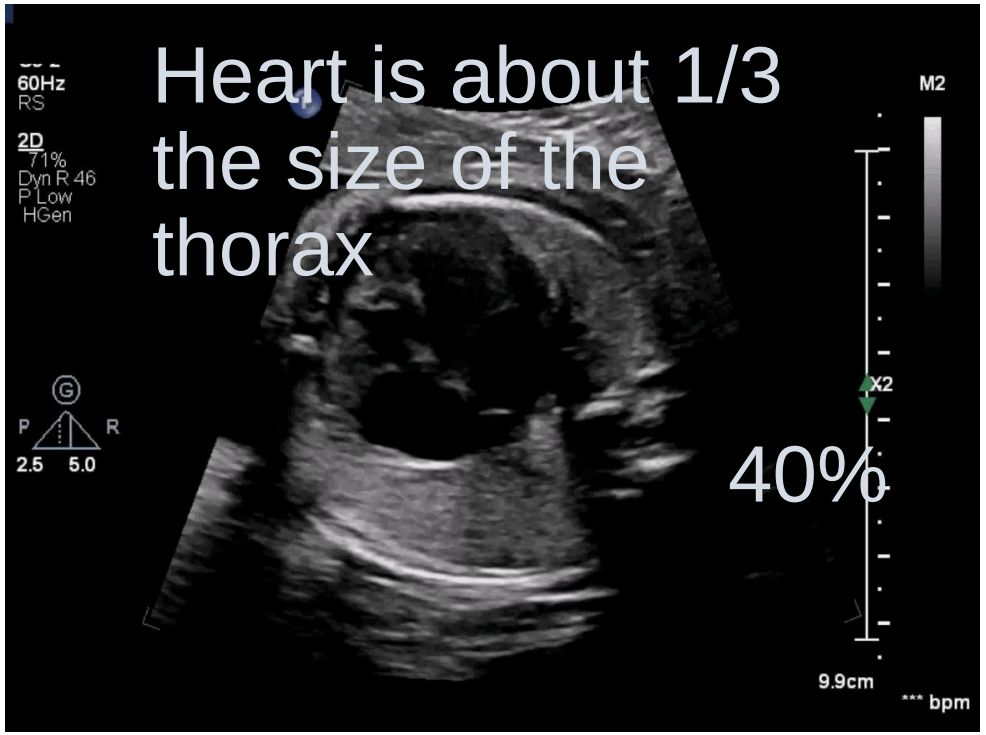

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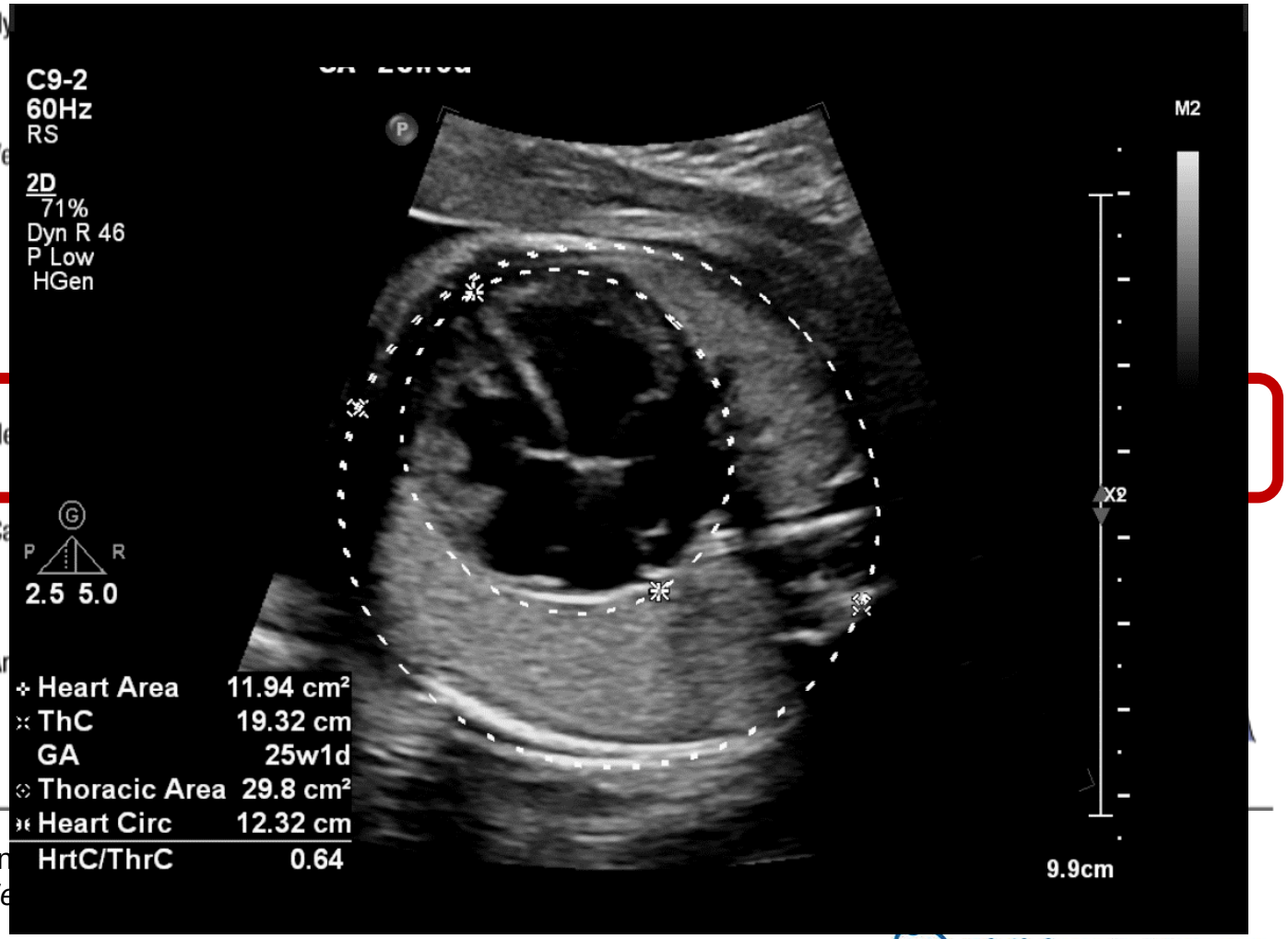

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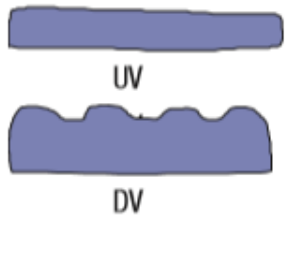
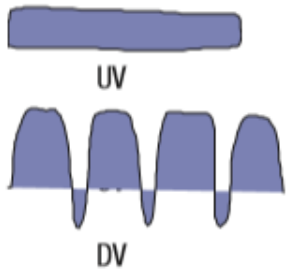
Venous Doppler (Umbilical vein and ductus venosus)			
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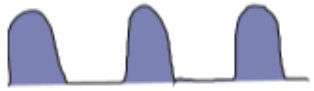
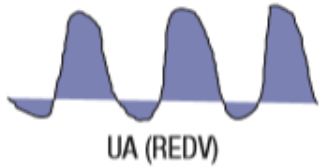
Arterial Doppler (umbilical artery)			

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Cardiovascular

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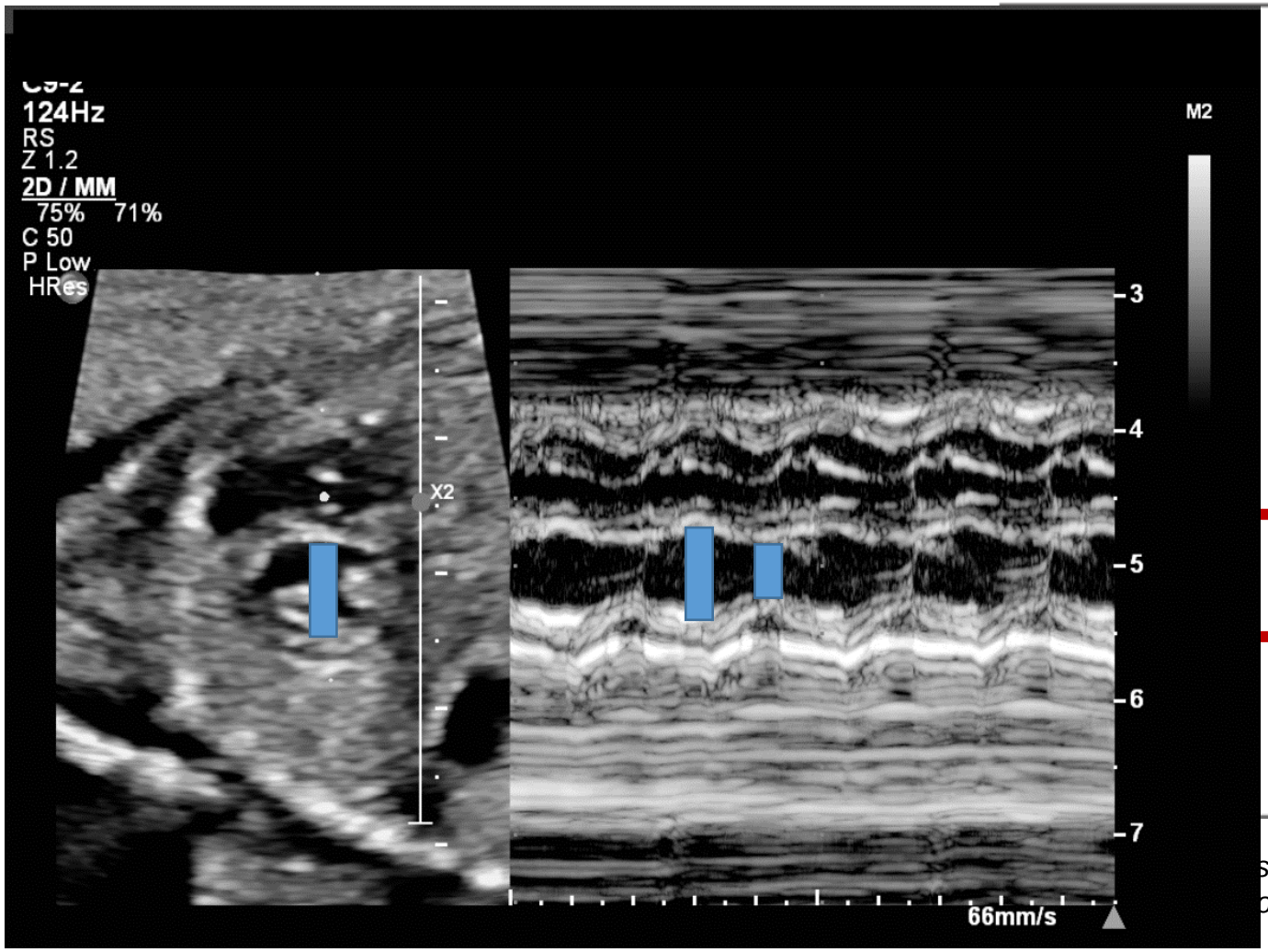

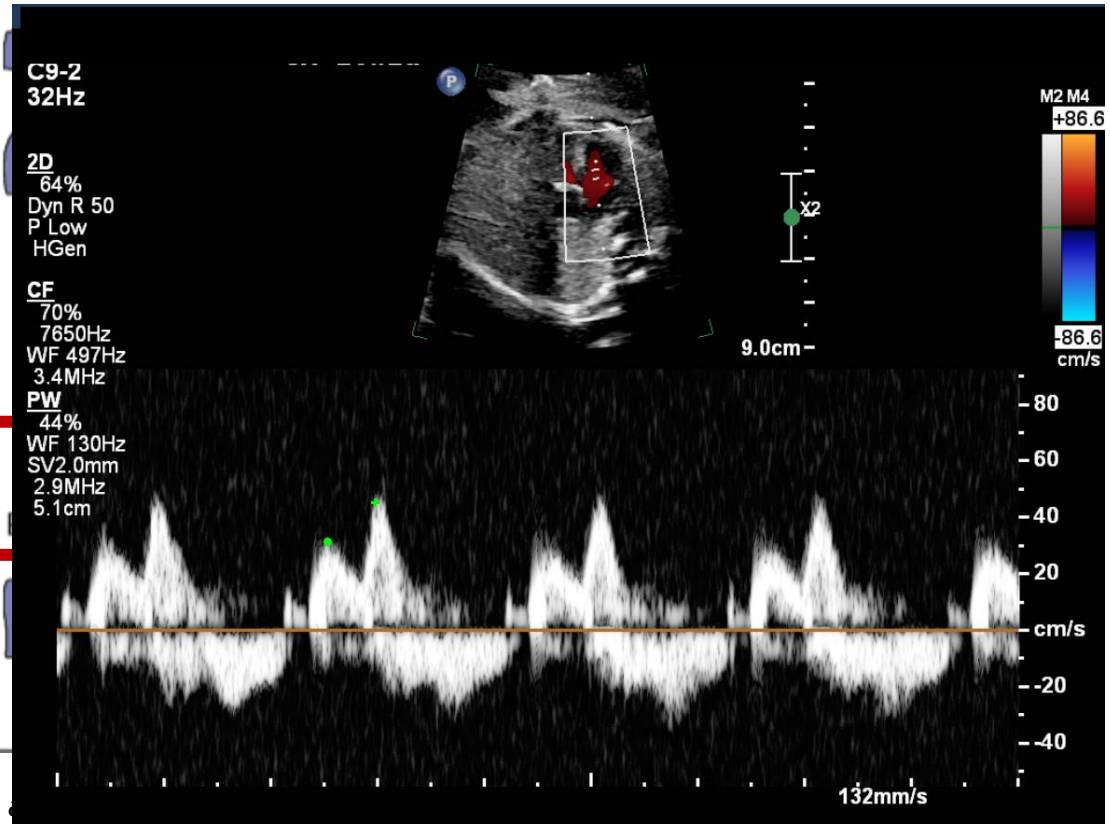

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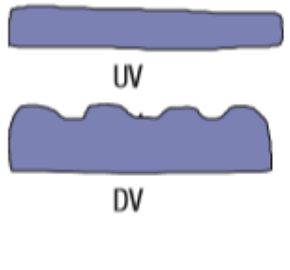
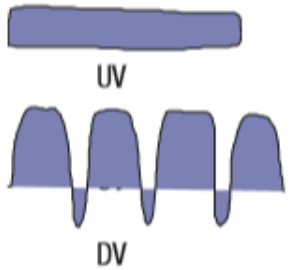
Venous Doppler (Umbilical vein and ductus venosus)	 UV DV	 UV DV	 UV pulsations
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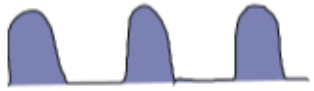
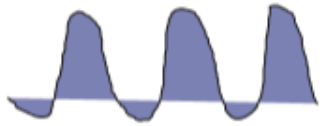
Arterial Doppler (umbilical artery)	 UA	 UA (AEDV)	 UA (REDV)

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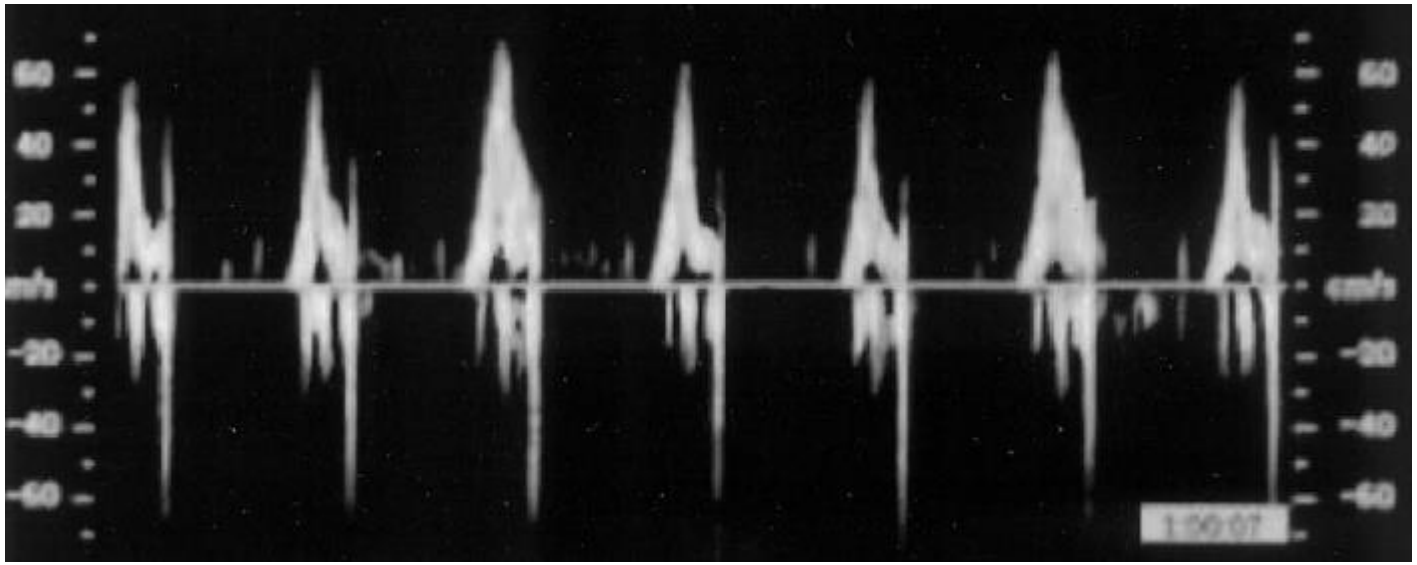

DV

Heart size (heart area/ chest area)	>0.20 and ≤0.35	0.35–0.50	>0.50 or <0.20
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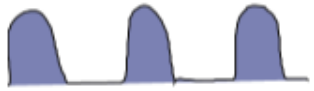
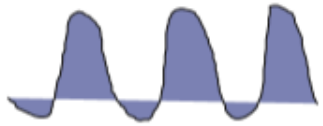
Arterial Doppler (umbilical artery)	 UA	 UA (AEDV)	 UA (REDV)

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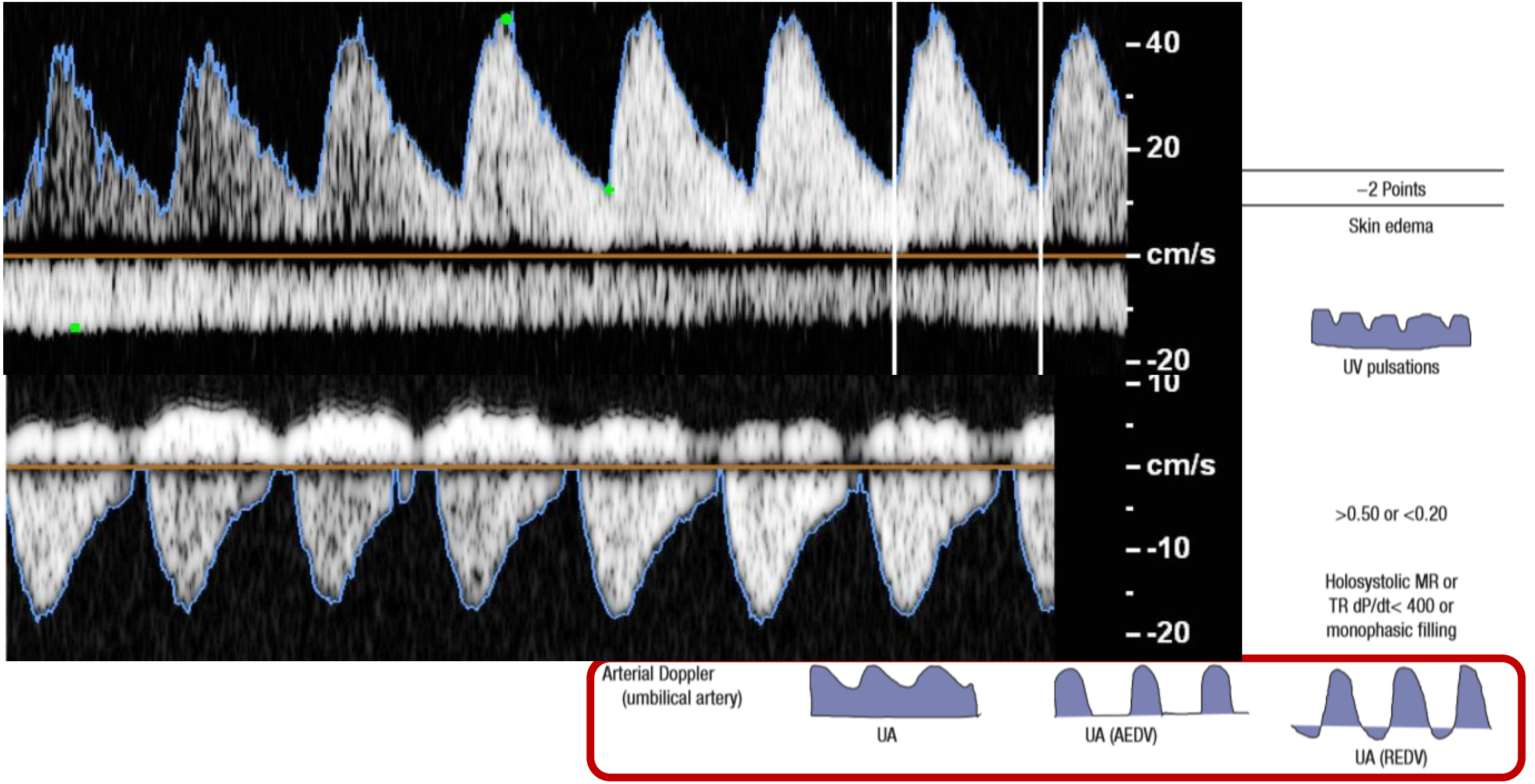

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Cardiovascular Profile Score (CVPS)

- 102 Hydropic fetuses of any cause
  - Median CVPS 6
  - ~1/3 perinatal death
- 40 had longitudinal CVPS data
  - Survival had mean/median increase in CVPS of 1
  - Non-survivors had mean/median decrease in CVPS of 1-2

Hofstaetter et al. *Journal Maternal-Fetal Medicine and Neonatal Medicine*. 2006

- 131 fetuses with CHD
- CVP ≤ 7 compared to those with score of ≥ 8 significantly more likely to suffer mortality
  - CVPS 6 100%
  - CVPS 7 67%
  - CVPS 8-10 12-17%

Wieczorek et al. *Ultrasound Obstet Gynecol*. 2008

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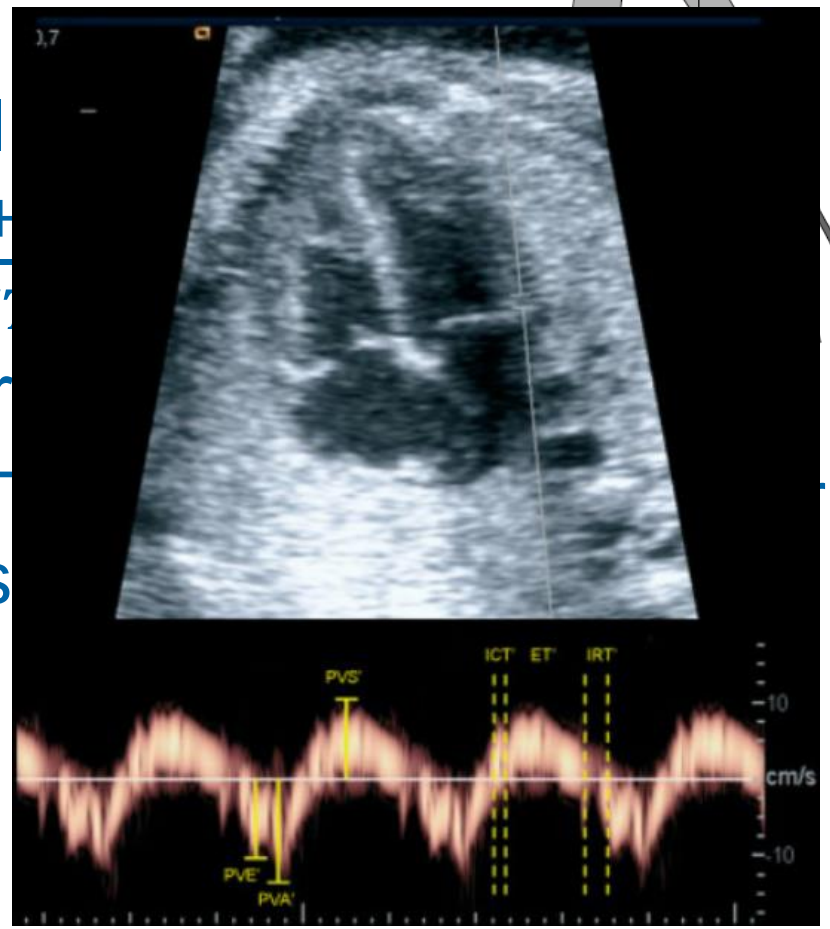
Additional measures of function

Myocardial F nce Index

- MPI
- $\frac{ICT+}{ET}$
- 'Nor
- IVR
  dias



Comas et al. *Ultrasound Obstet Gynecol* 2011

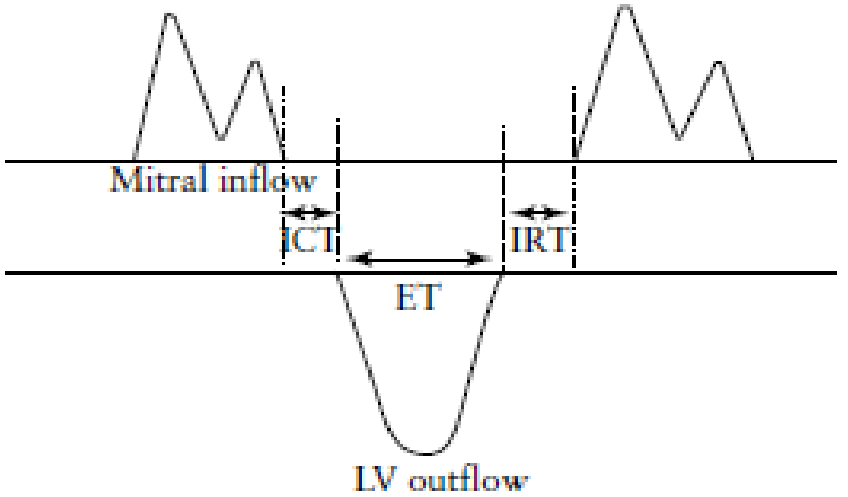


Table 1 Pulsed Doppler-derived time interval data obtained from 74 normal fetuses at 18–31 weeks' gestational age

Parameter	*Time interval data (mean ± SD)*
ICT	43 ± 14 ms
ET	173 ± 16 ms
IRT	48 ± 13 ms
TI	0.53 ± 0.13

ET, ejection time; ICT, isovolumic contraction time; IRT, isovolumic relaxation time; SD, standard deviation; TI, Tei Index (ICT + IRT/ET).

Friedman et al. *Ultrasound Obstet Gynecol* 2003

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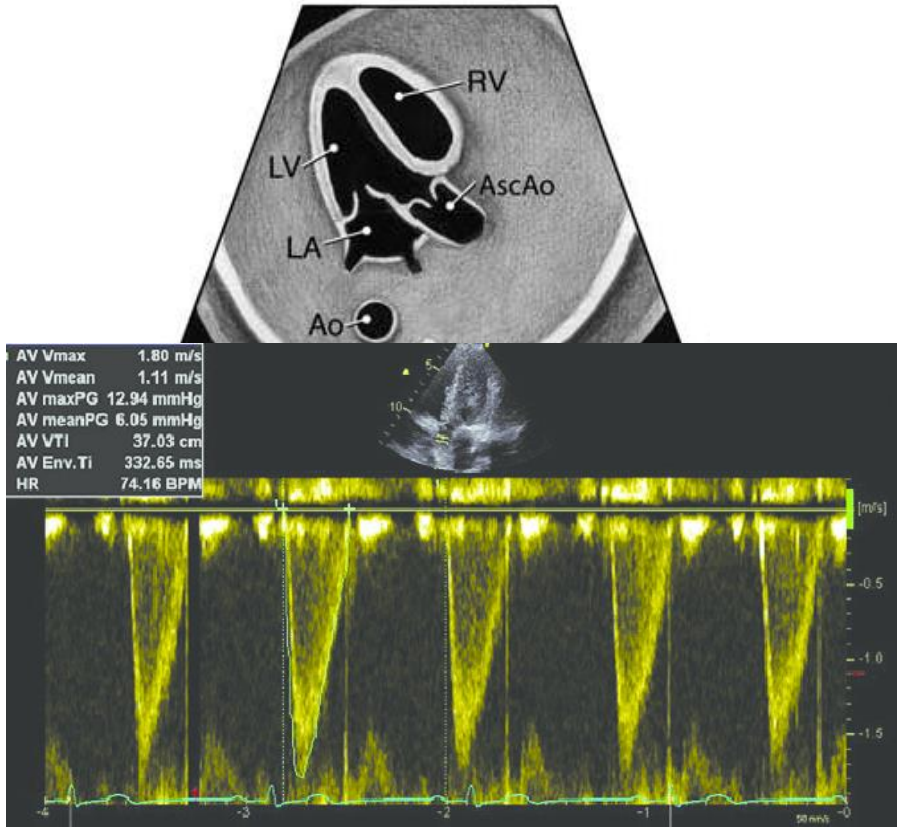
Spectral Doppler Derived Cardiac Output

- Combined cardiac output calculation
  - Measure fetal HR
  - Aortic and Pulmonary valve annulus diameter (area calculated from this)
  - Spectral Doppler tracing of aortic and pulmonary valve and measure the velocity-time integral
  - Output across that valve = HR*VTI*Valve area
    - CO = HR * SV
      - SV = VTI *valve area
  - Add aortic and pulmonary calculations together to obtain the combined cardiac output
    - Normal 420-450 ml/kg/min



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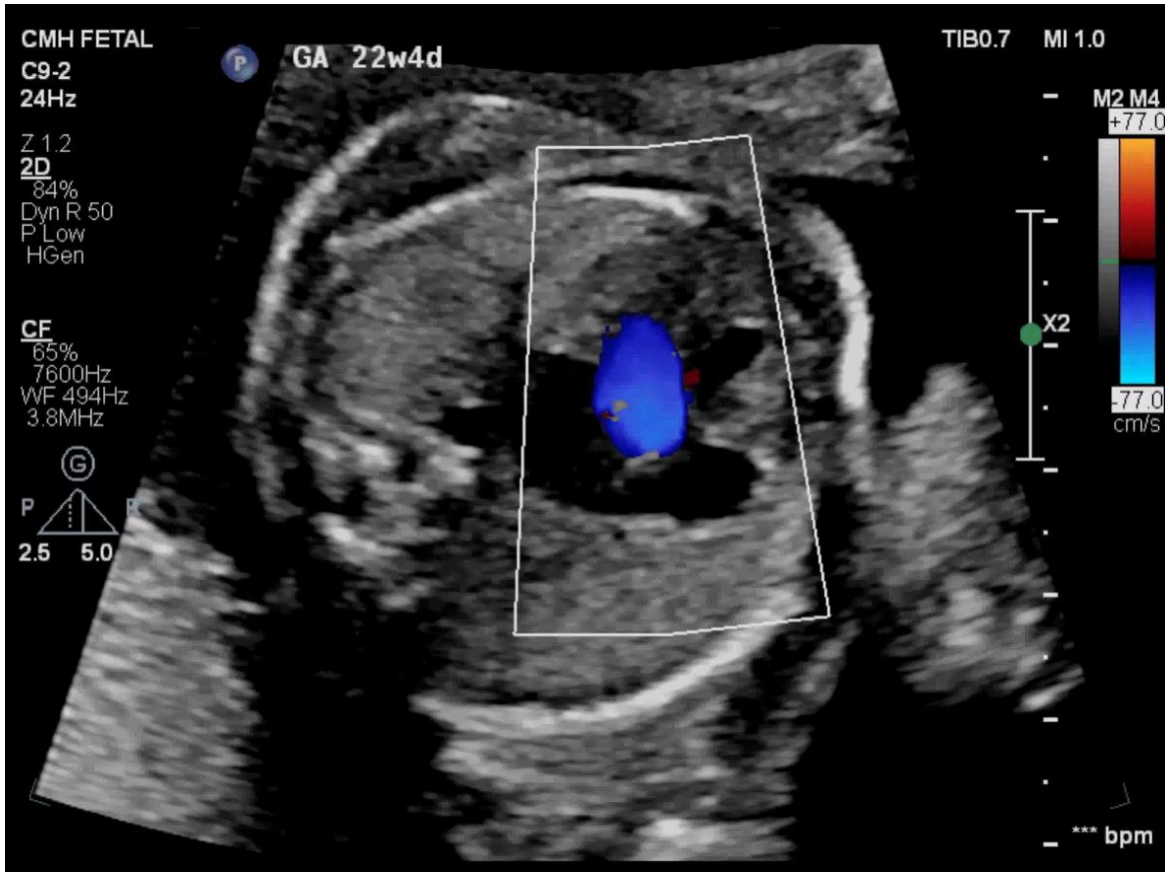
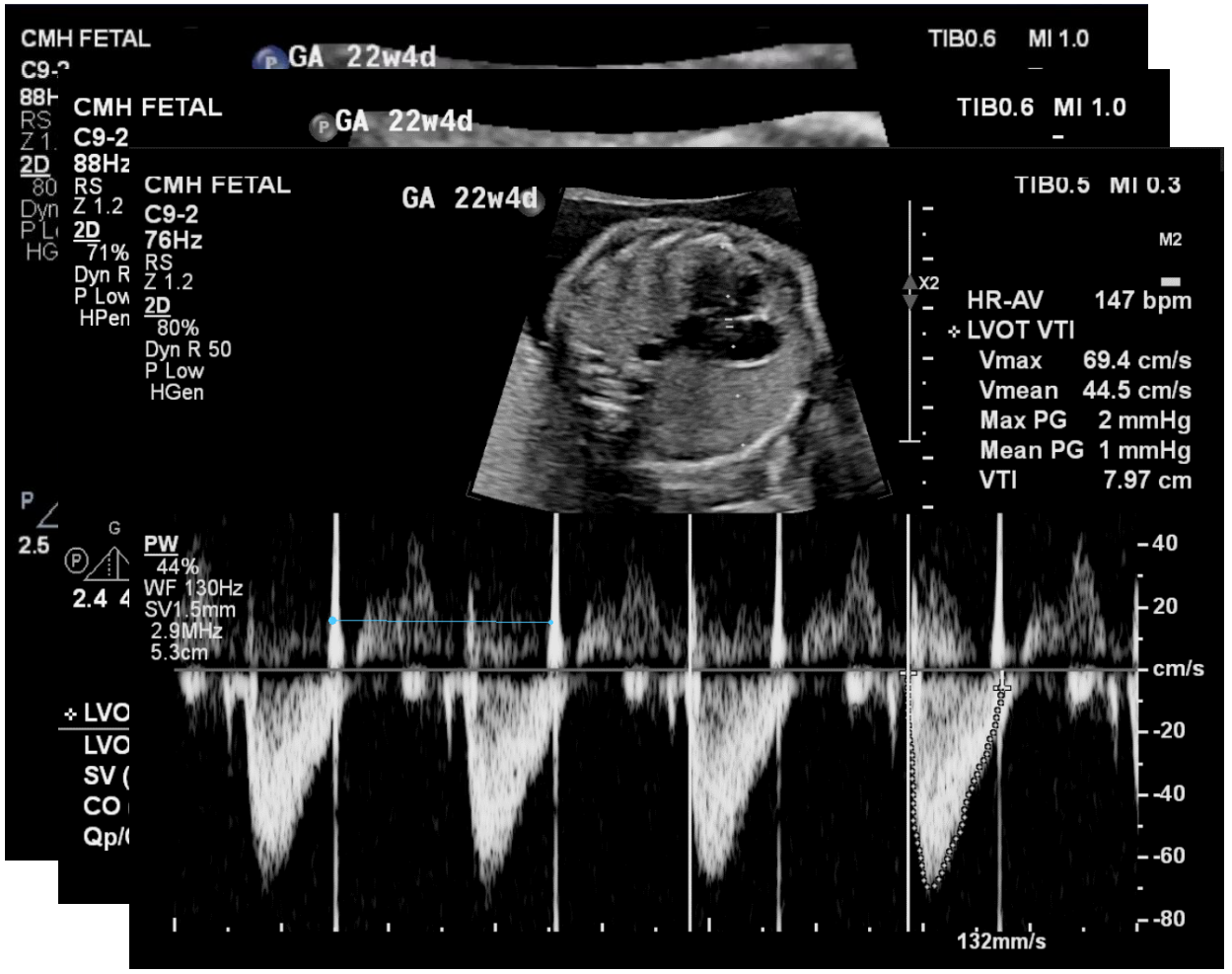
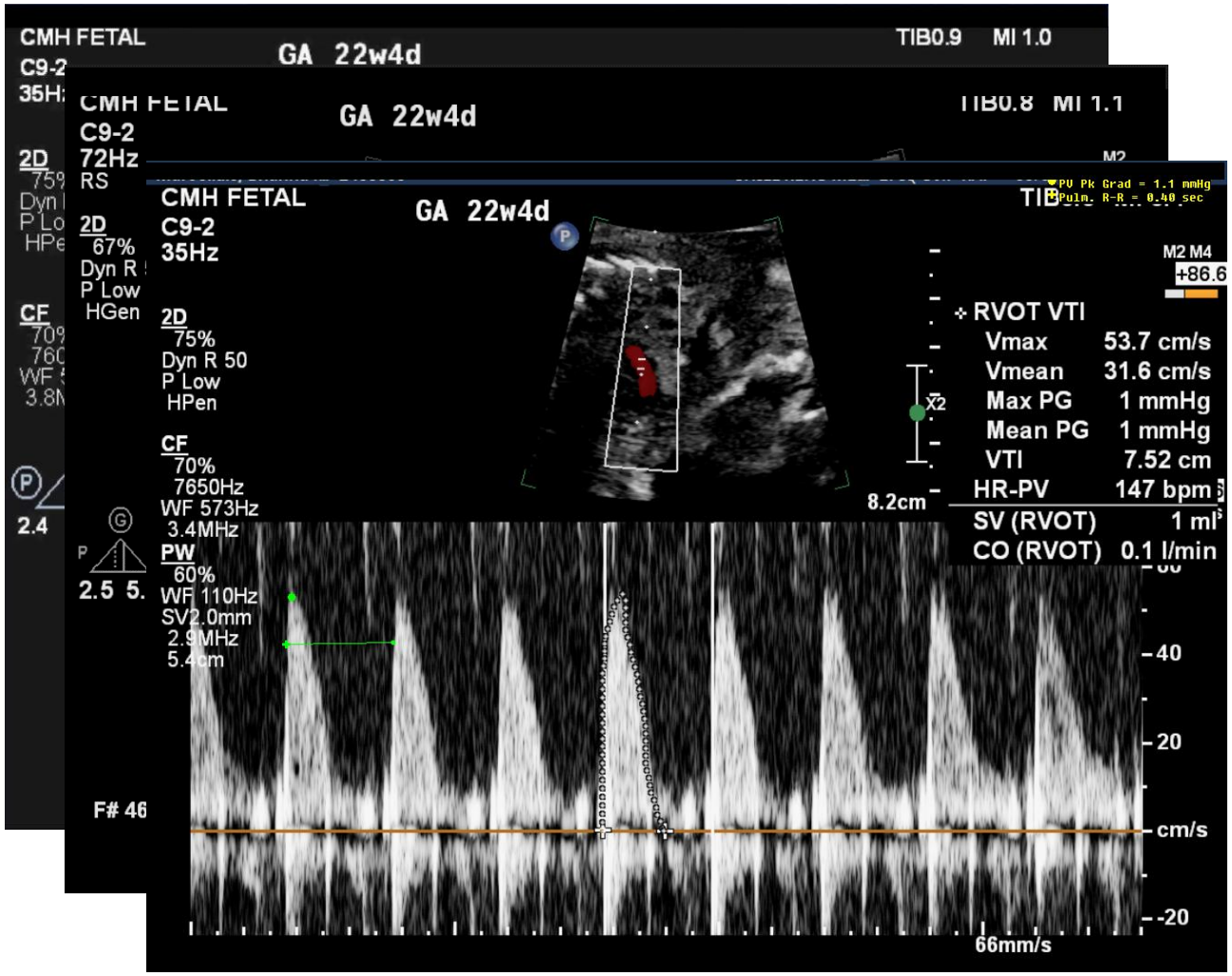
CMH FETAL
C9-2
76Hz
RS
Z 1.2
2D
80%
Dyn R 50
P Low
HGen
GA 22w4d
TIB0.5
MI 1.0
M2
X2
P
R
2.5
5.0
*** bpm


CMH FETAL
C9-2
24Hz
Z 1.2
2D
84%
Dyn R 50
P Low
HGen
CF
65%
7600Hz
WF 494Hz
3.8MHz
2.5 5.0
GA 22w4d
TIB0.7 MI 1.0
M2 M4
+77.0
-77.0
cm/s
X2
*** bpm

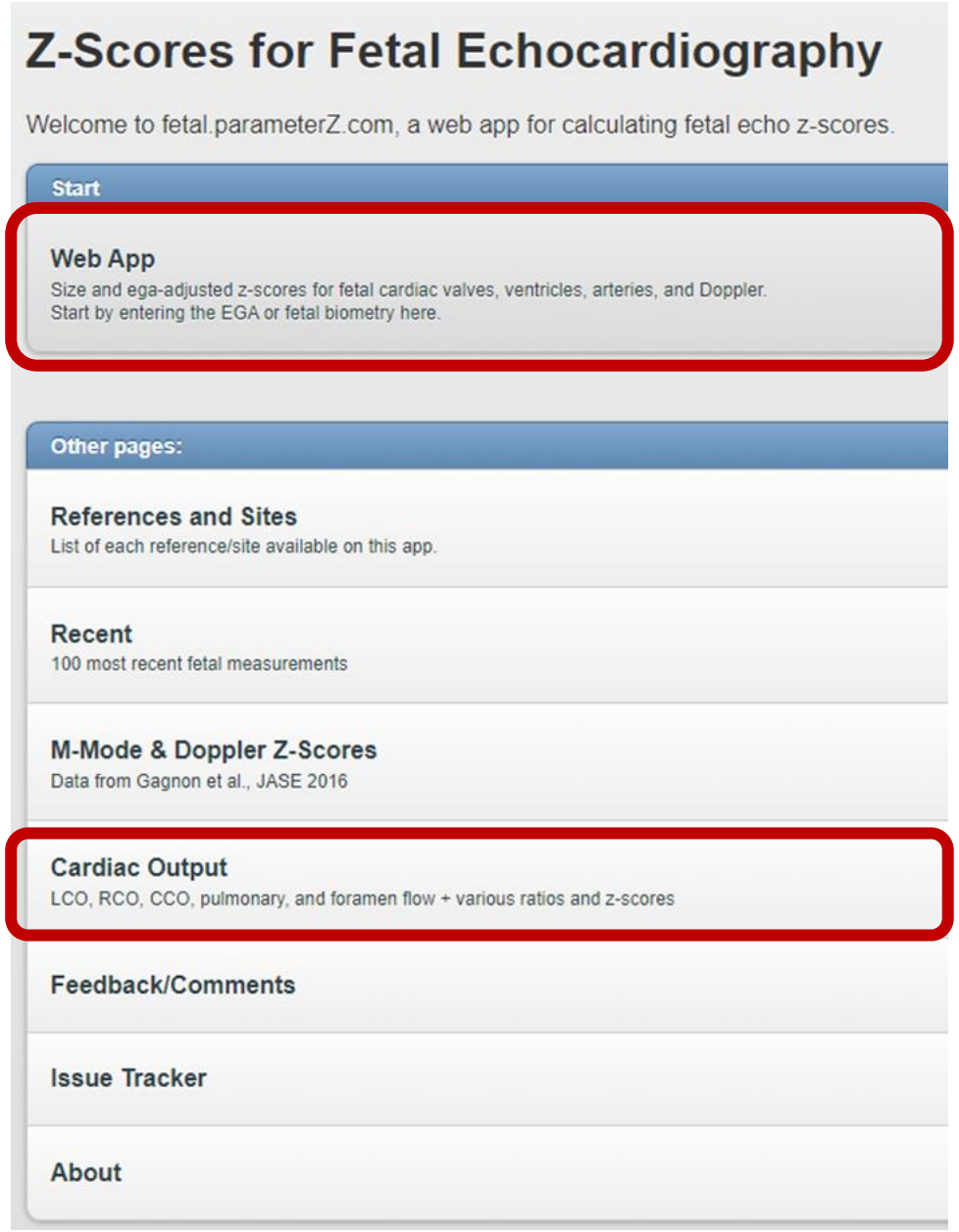

CMH FETAL
C9-2
88Hz
RS
Z 1.2
2D
71%
Dyn R
P Low
HPen
76Hz
80%
Dyn R 50
P Low
HGen
GA 22w4d
TIB0.6 MI 1.0
TIB0.5 MI 0.3
M2
X2
HR-AV 147 bpm
LVOT VTI
Vmax 69.4 cm/s
Vmean 44.5 cm/s
Max PG 2 mmHg
Mean PG 1 mmHg
VTI 7.97 cm
PW
44%
WF 130Hz
SV1.5mm
2.9MHz
5.3cm
2.4
2.5
40
20
cm/s
-20
-40
-60
-80
132mm/s


GA 22w4d
C9-2
73Hz
RS
2D
69%
Dyn R 50
P Low
HGen
M2
X2
11cm
2.5 5.0


CMH FETAL
GA 22w4d
C9-2
35Hz
2D
67%
Dyn R 50
P Low
HPen
CF
70%
7650Hz
WF 573Hz
3.4MHz
PW
60%
WF 110Hz
SV2.0mm
2.9MHz
5.4cm
M2 M4
RVOT VTI
Vmax 53.7 cm/s
Vmean 31.6 cm/s
Max PG 1 mmHg
Mean PG 1 mmHg
VTI 7.52 cm
HR-PV 147 bpm
SV (RVOT) 1 ml
CO (RVOT) 0.1 l/min
8.2cm
40
20
cm/s
-20
66mm/s

www.fetal.parameterz.com

- Helpful website for measurement z-scores and cardiac outputs



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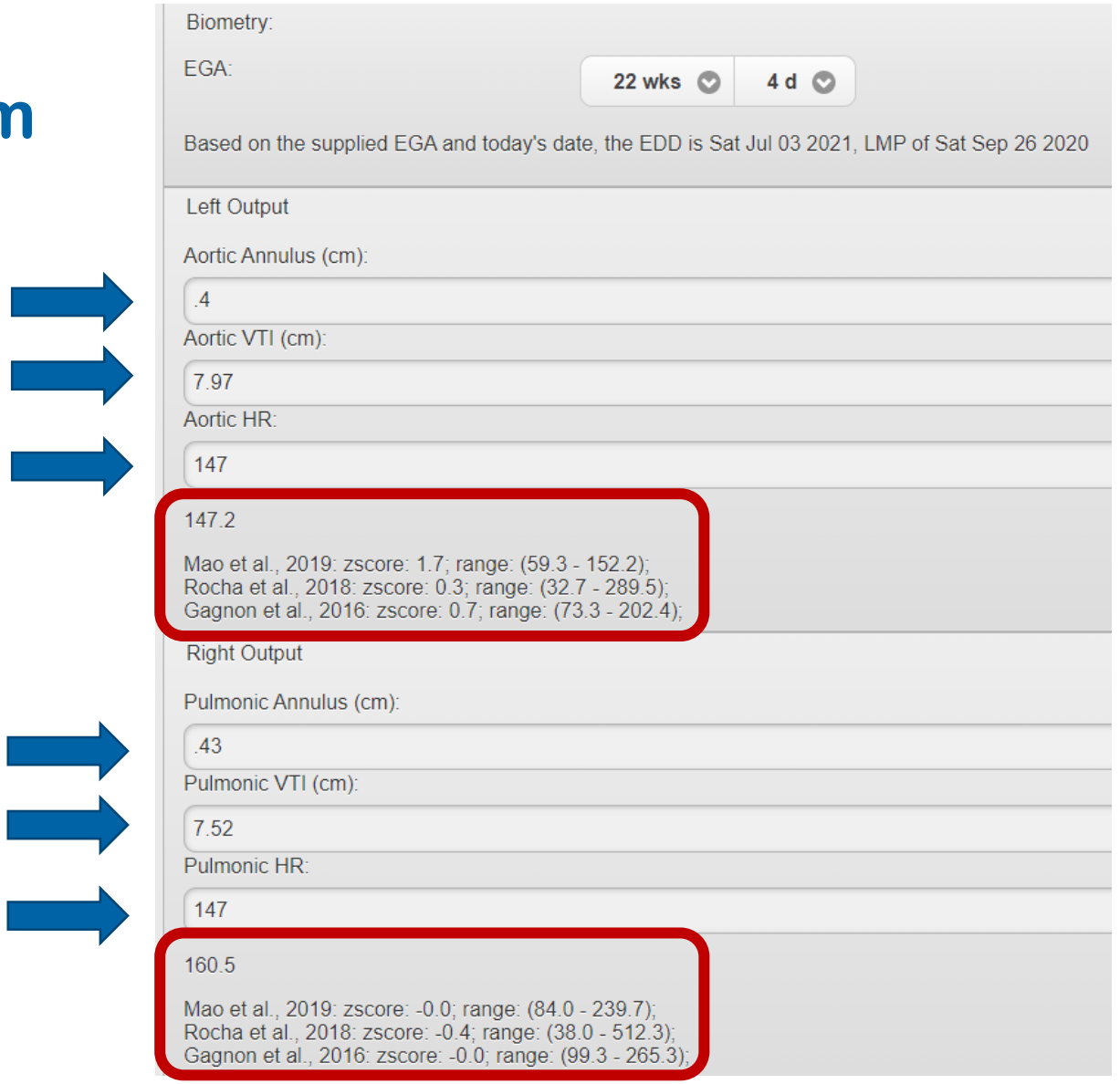
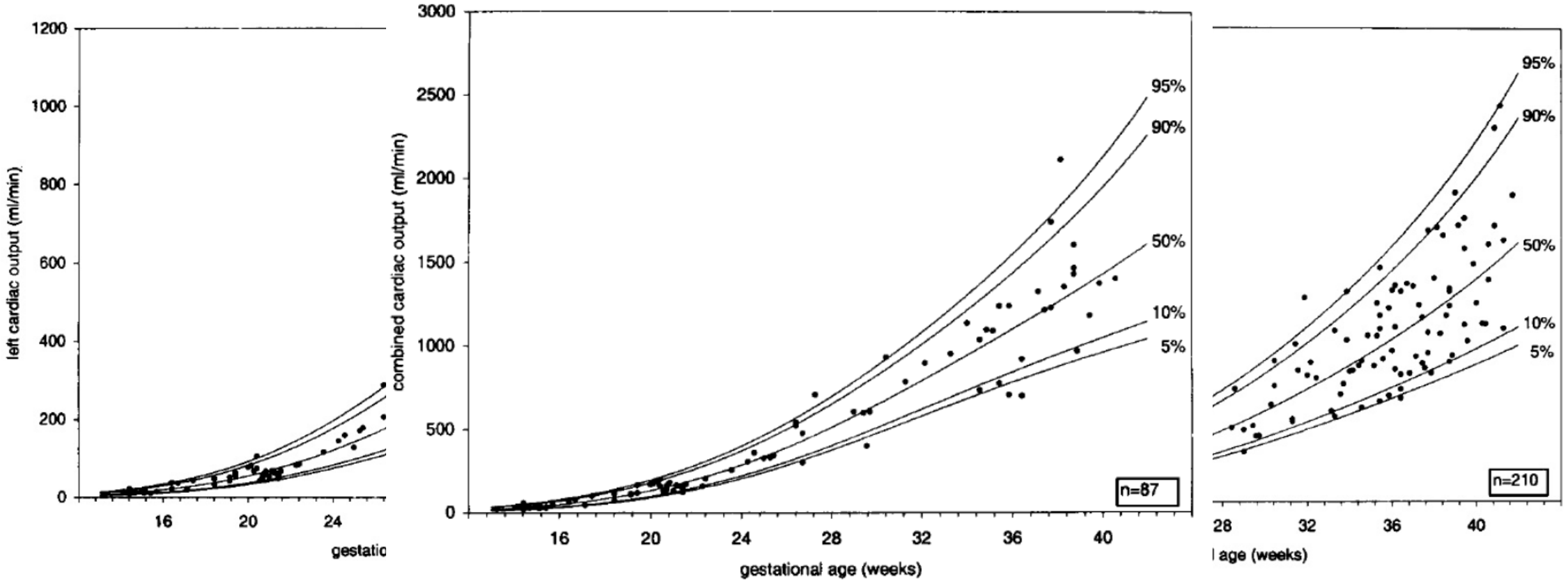
www.fetal.parameterz.com

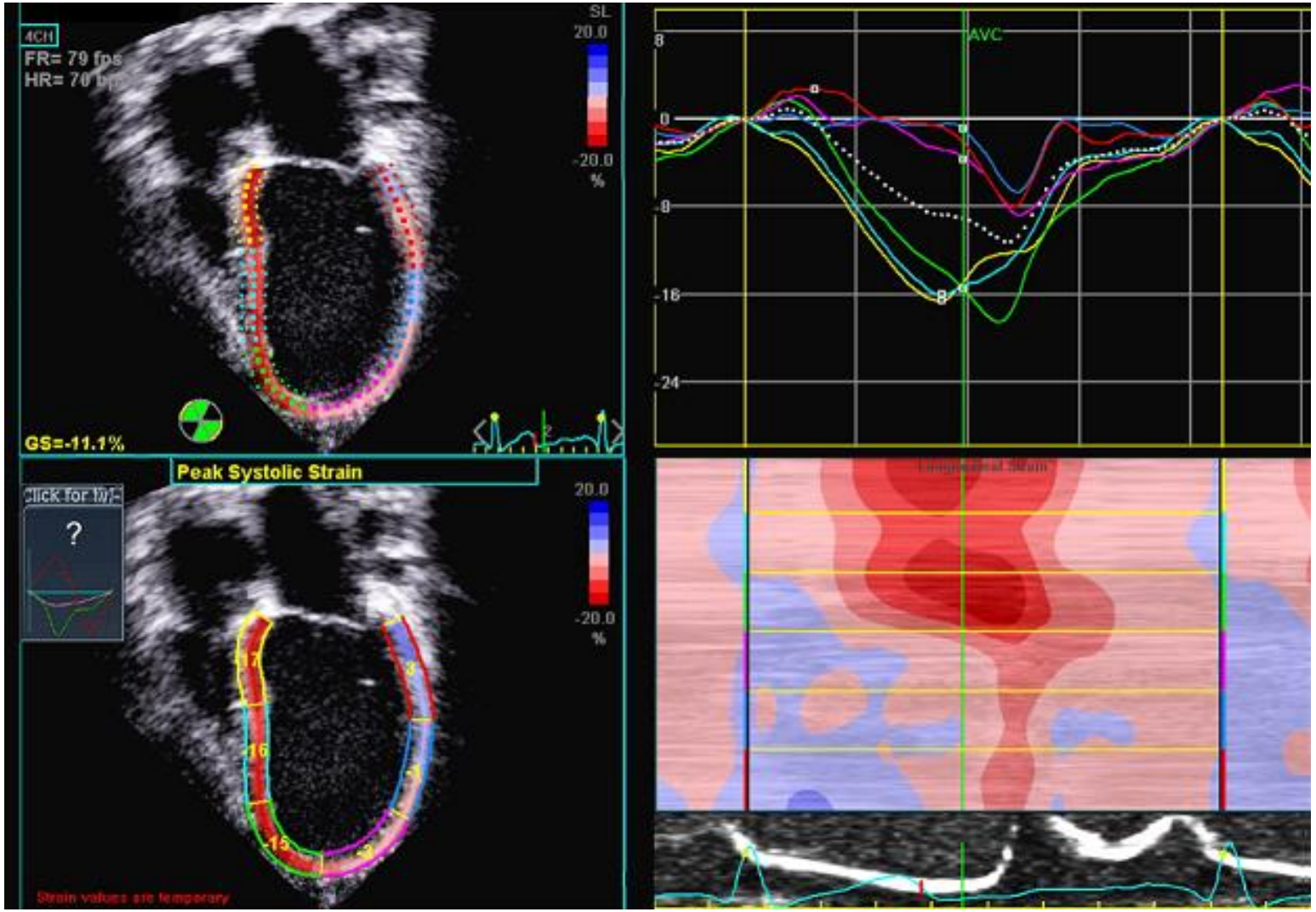
Our patient




left cardiac output (ml/min)
1200
1000
800
600
400
200
0
16
20
24
gestatic
combined cardiac output (ml/min)
3000
2500
2000
1500
1000
500
0
95%
90%
50%
10%
5%
n=87
16
20
24
28
32
36
40
gestational age (weeks)
95%
90%
50%
10%
5%
n=210
28
32
36
40
l age (weeks)

Strain

- $\varepsilon = \frac{\Delta L}{L_0}$
- Speckle tracking
- Feature tracking
- Advantages
  - Angle independent
  - Could identify otherwise unrecognizable systolic dysfunction
- Disadvantages
  - Small size
  - High heart rates
  - No ECG
  - Need high frame rate



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Summary

- Assessment of ventricular function is essential to fetal counseling
- Comprehensive cardiovascular functional assessment is relatively quick and feasible

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Thank you

Questions?

mlmoehlmann@cmh.edu

(847) 826-1882

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