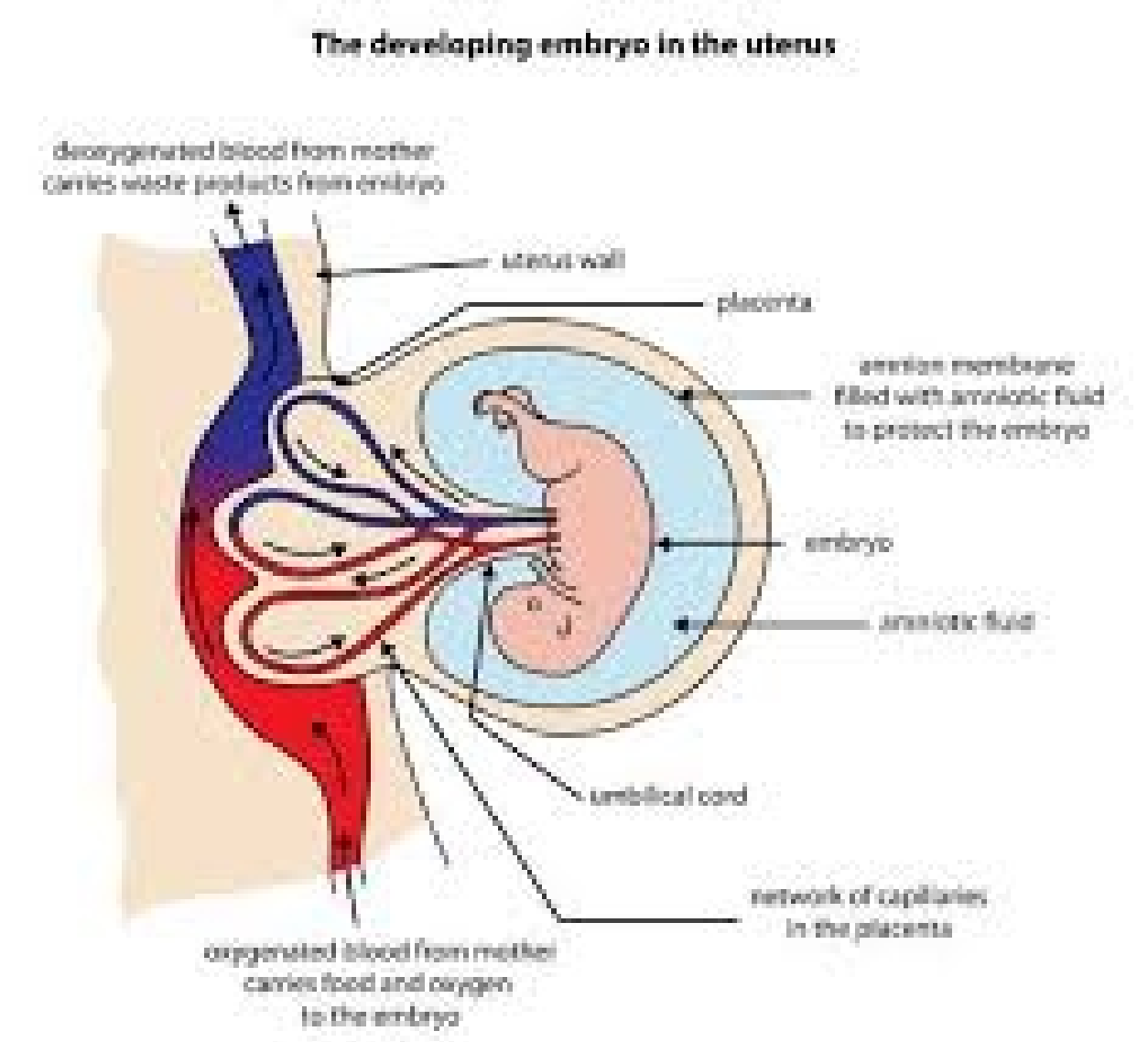
Doppler Evaluations: Outside of the Heart

Emanuel J Vlastos, MD

9 February 2021

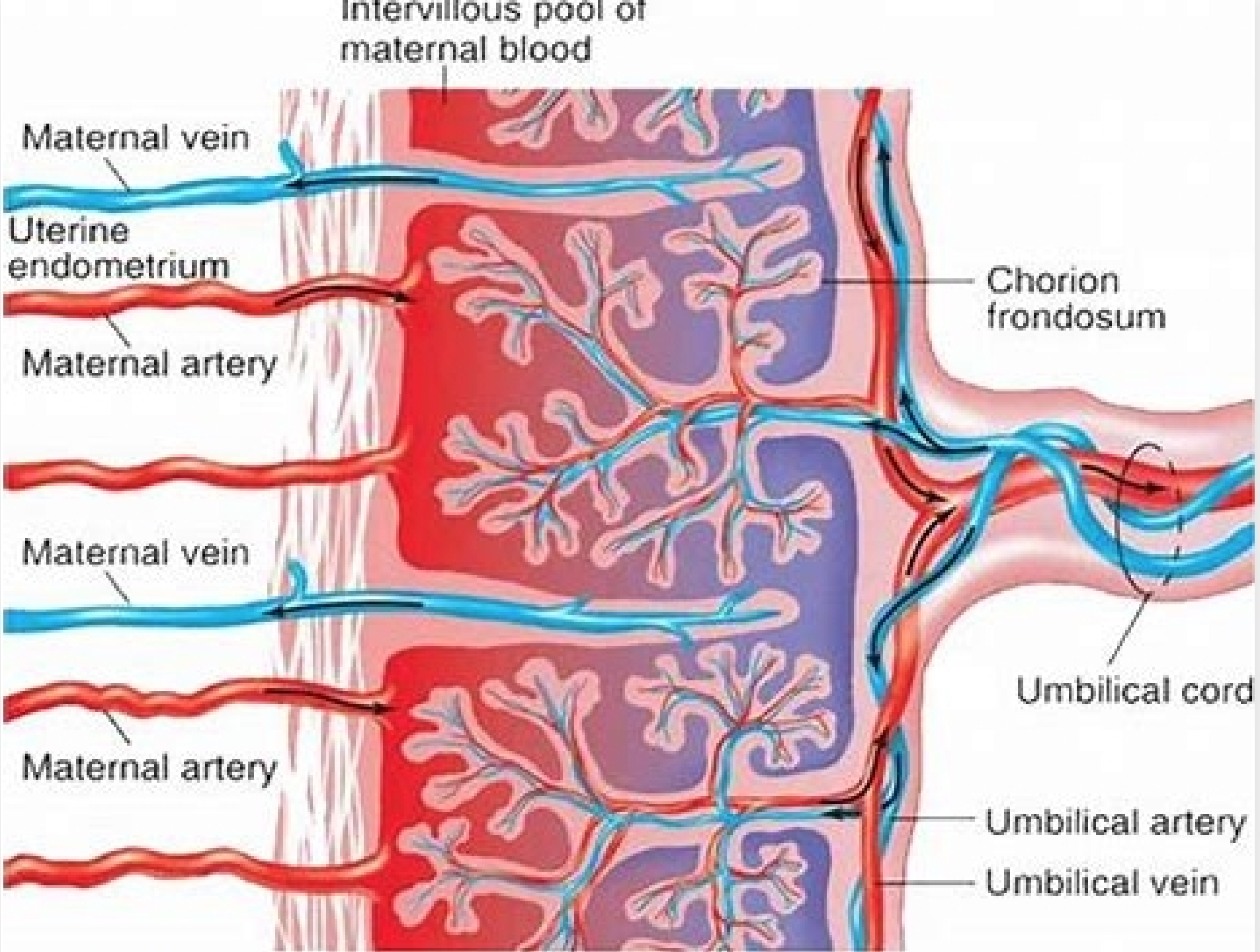
Nidation: Hemochorial

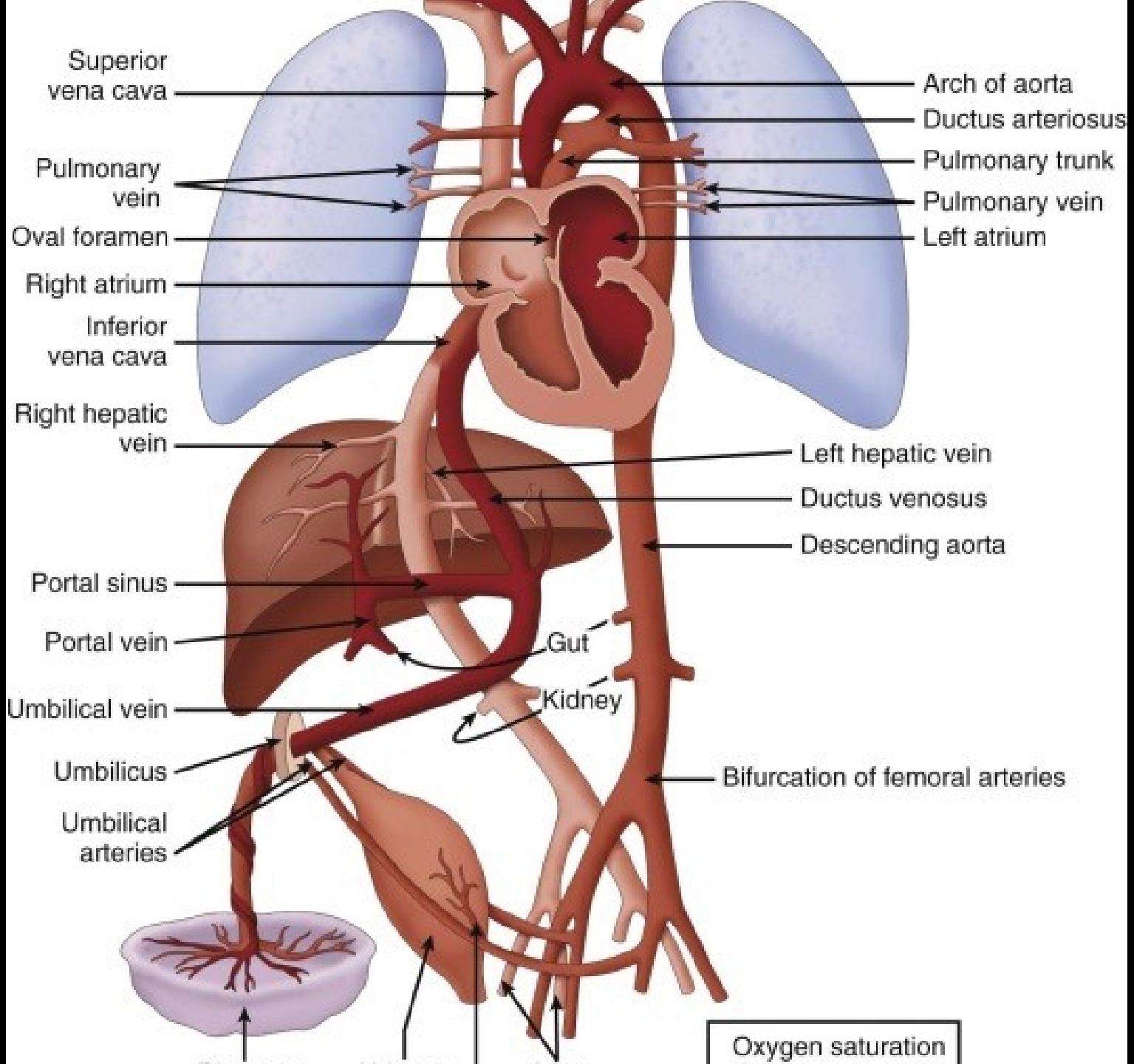


Placentation

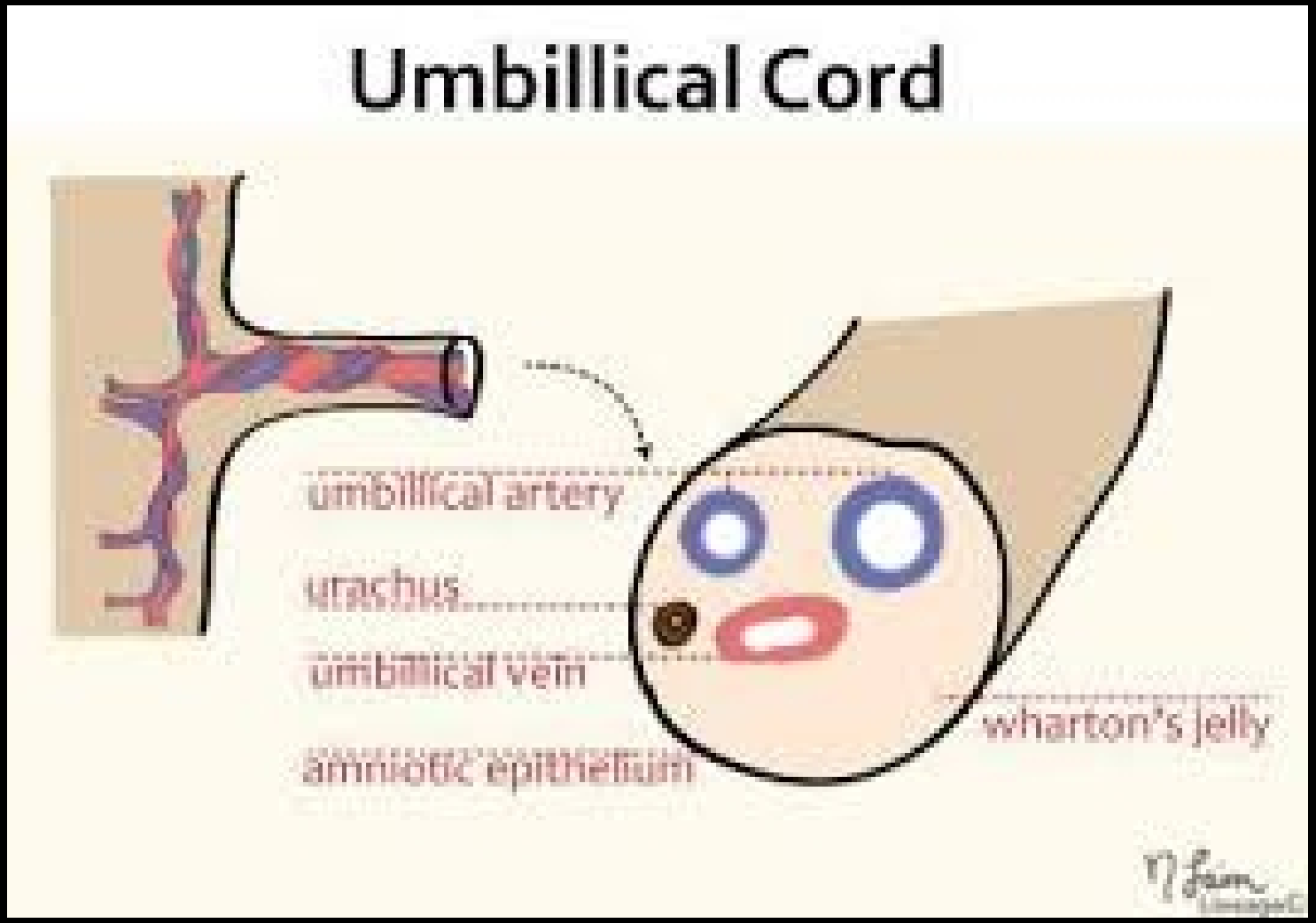
- Sperm + ovum = zygote
- Zygote to morula
- Morula to blastocyst
- Blastocyst to endometrial subsurface implantation
- Placentation via concomitant embryonic and maternal circulatory changes

Root ball = plant + dirt


Intervillous pool of maternal blood
Maternal vein
Uterine endometrium
Maternal artery
Chorion frondosum
Maternal vein
Umbilical cord
Maternal artery
Umbilical artery
Umbilical vein


Superior vena cava
Arch of aorta
Ductus arteriosus
Pulmonary trunk
Pulmonary vein
Pulmonary vein
Oval foramen
Left atrium
Right atrium
Inferior vena cava
Right hepatic vein
Left hepatic vein
Ductus venosus
Descending aorta
Portal sinus
Portal vein
Gut
Kidney
Umbilical vein
Umbilicus
Bifurcation of femoral arteries
Umbilical arteries
Oxygen saturation

The Cord

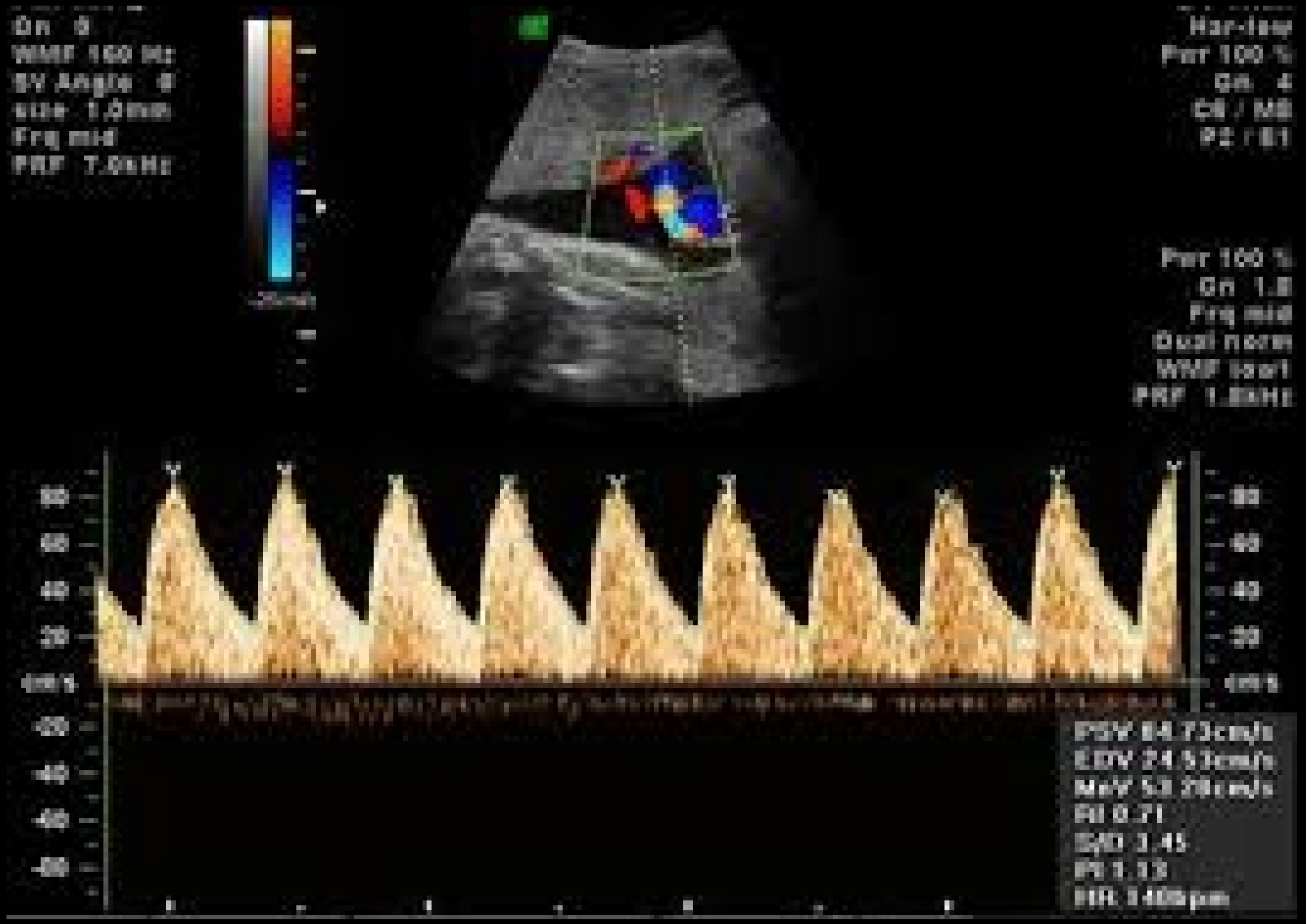

Umbillical Cord
umbillical artery
urachus
umbillical vein
amniotic epithelium
wharton's jelly

Umbilical Vessels

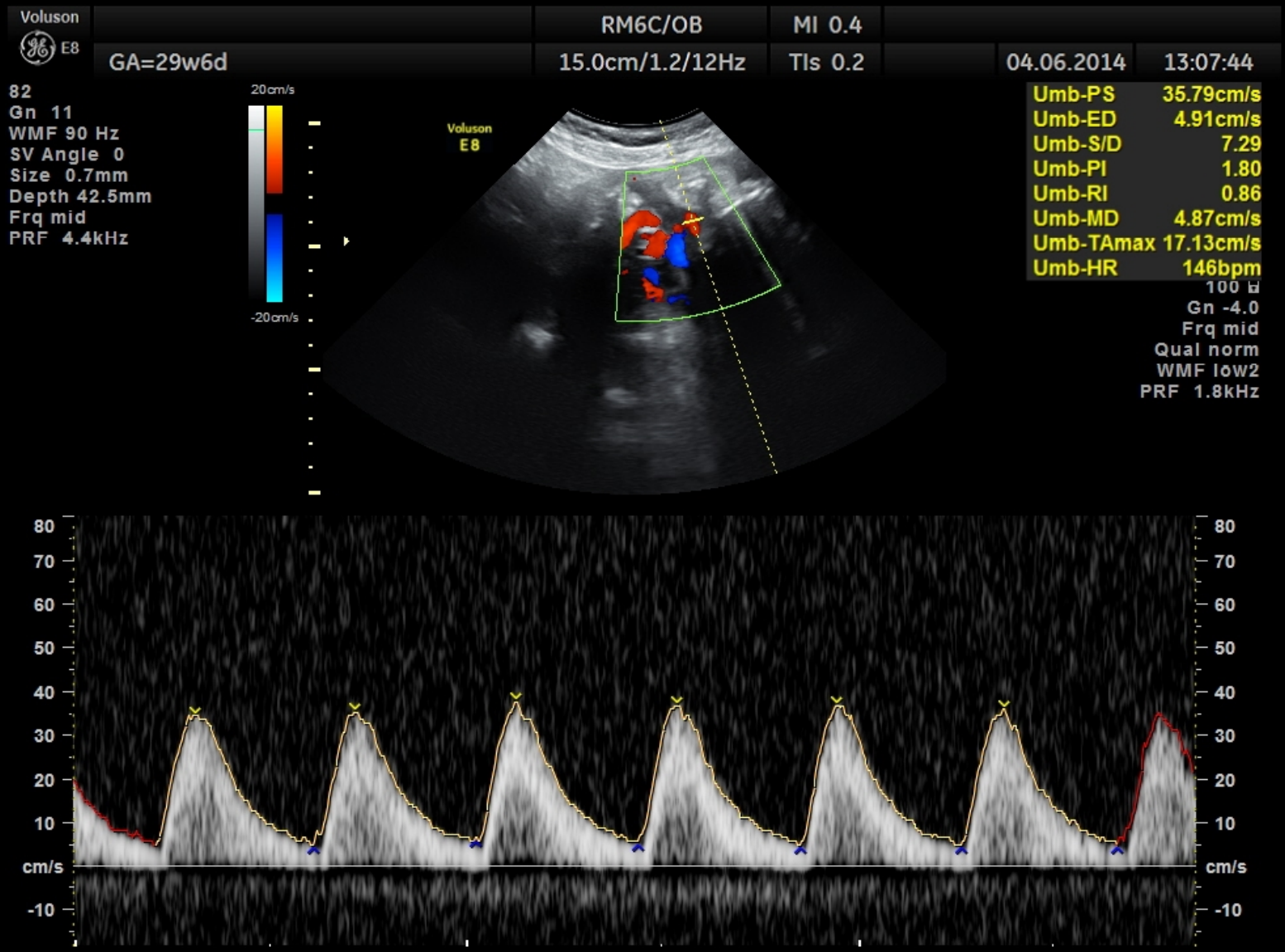
- Four: 2 arteries and 2 veins – 2 veins include the persistence of the right umbilical vein (usually becomes atretic in weeks 6-7)
- Three: 2 arteries and 1 vein - usual
- Two: 1 artery and 1 vein
  - Most often a benign finding: 1 – 2% of fetuses
  - May be due to **Hyrtl anastomoses** as noted in a 2 and 3 vessel cord in same fetus!
  - Has been described in aneuploidy fetuses (ie, T21)

Umbilical Artery

Typical

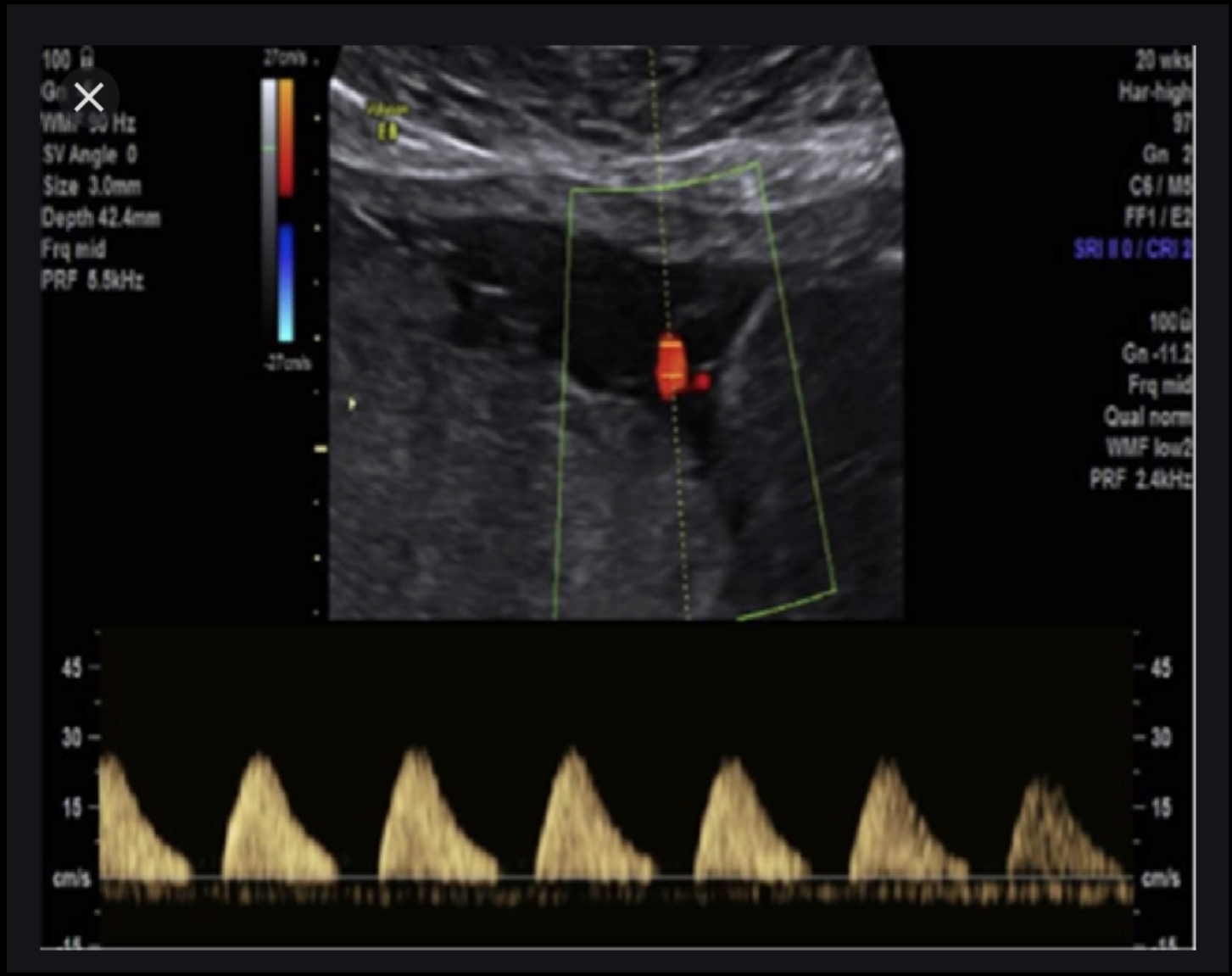

PSV 84.73cm/s
EDV 24.53cm/s
MnV 53.28cm/s
PI 0.71
S/D 3.45
RI 1.13
HR 140bpm

Less Common

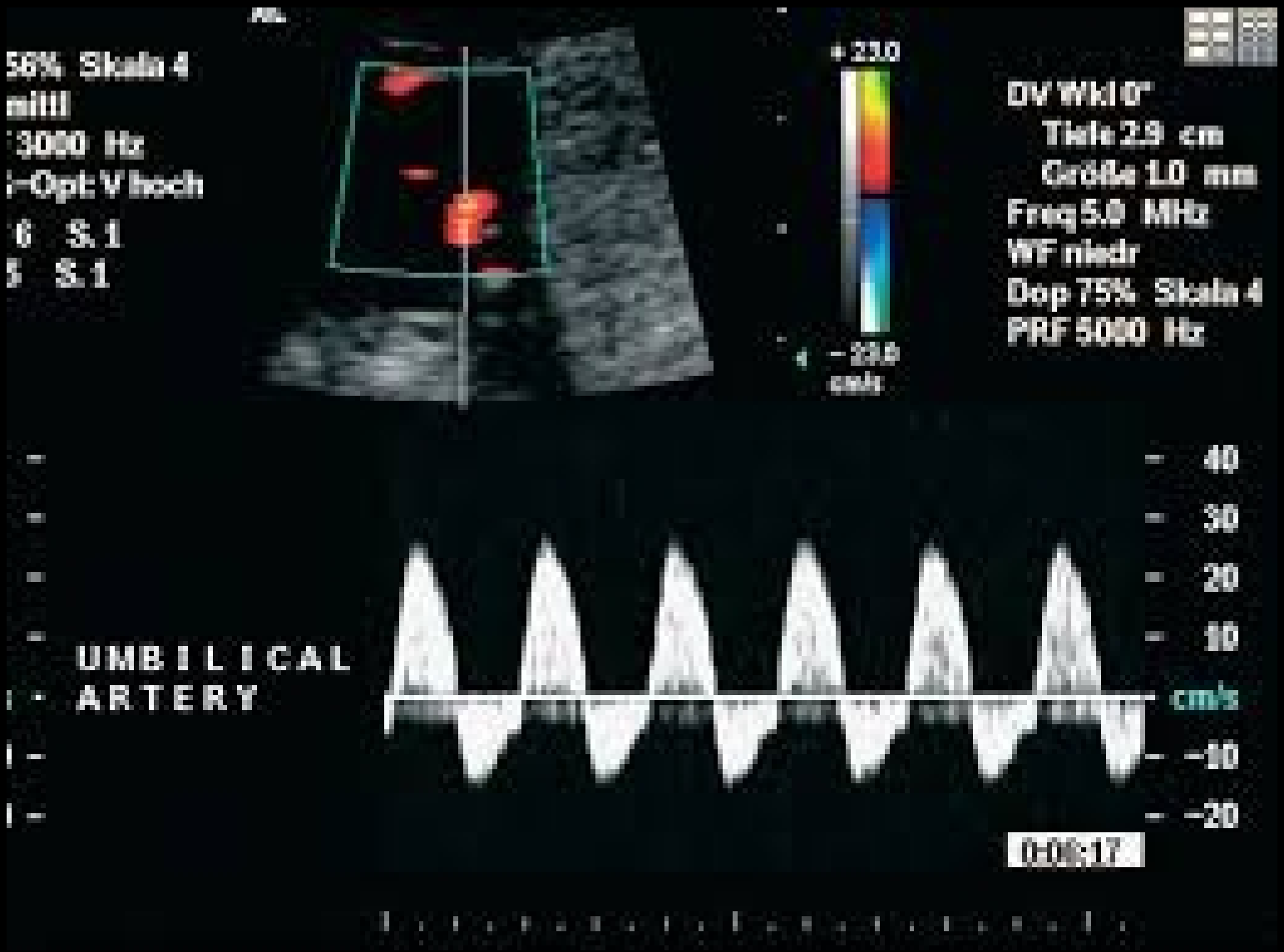

Voluson
E8
GA=29w6d
RM6C/OB
15.0cm/1.2/12Hz
MI 0.4
TIs 0.2
04.06.2014
13:07:44
82
Gn 11
WMF 90 Hz
SV Angle 0
Size 0.7mm
Depth 42.5mm
Frq mid
PRF 4.4kHz
20cm/s
-20cm/s
Umb-PS 35.79cm/s
Umb-ED 4.91cm/s
Umb-S/D 7.29
Umb-PI 1.80
Umb-RI 0.86
Umb-MD 4.87cm/s
Umb-TAmax 17.13cm/s
Umb-HR 146bpm
100
Gn -4.0
Frq mid
Qual norm
WMF low2
PRF 1.8kHz
80
70
60
50
40
30
20
10
cm/s
-10

Even Less Common

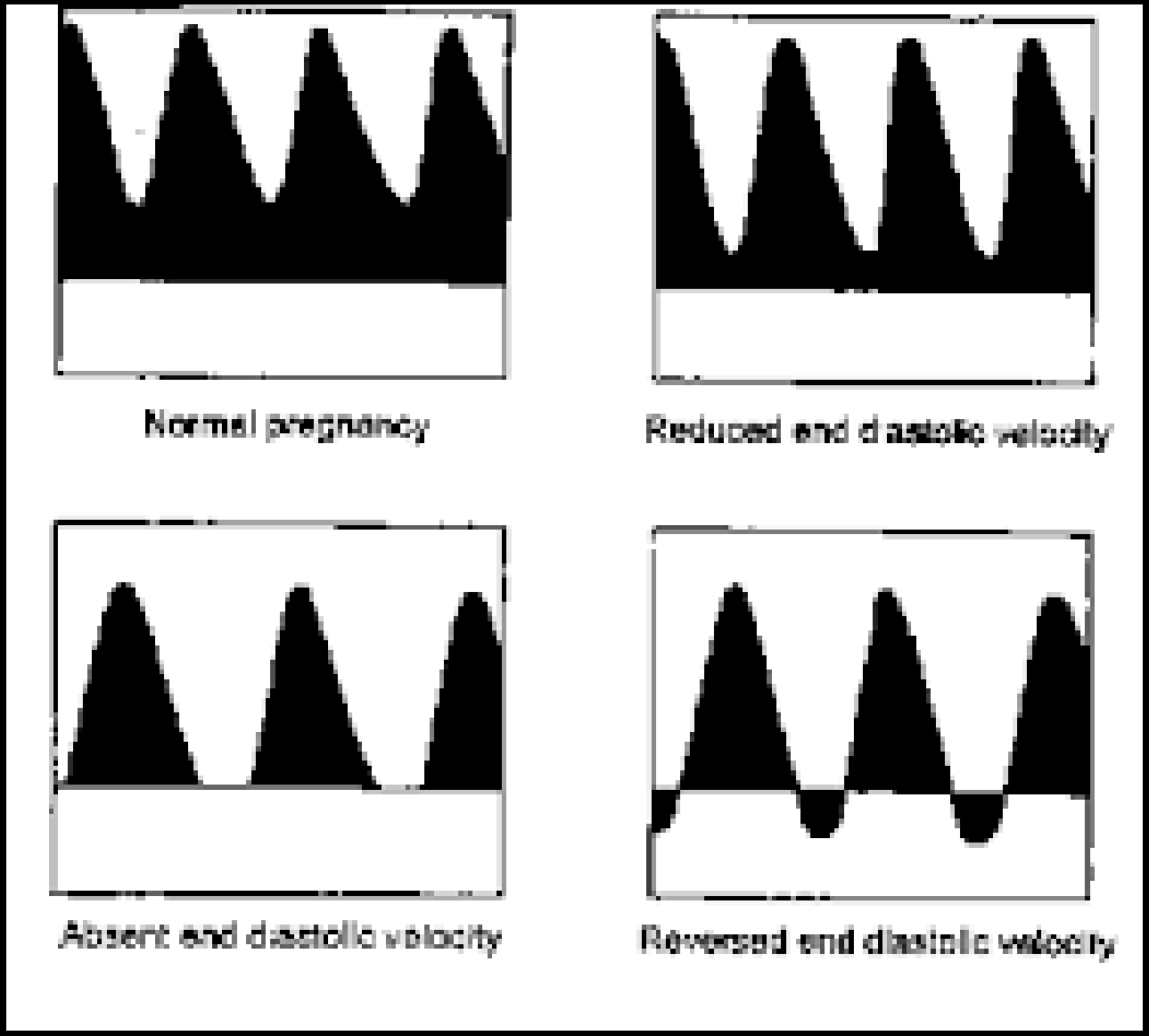
Even Less Common



Uncommon


56% Skala 4
3000 Hz
Opt: V hoch
+ 23.0
− 23.0
cm/s
DV Wkl 0°
Tiefe 2.9 cm
Größe 1.0 mm
Freq 5.0 MHz
WF niedr
Dop 75% Skala 4
PRF 5000 Hz
UMBILICAL ARTERY
40
30
20
10
cm/s
−10
−20

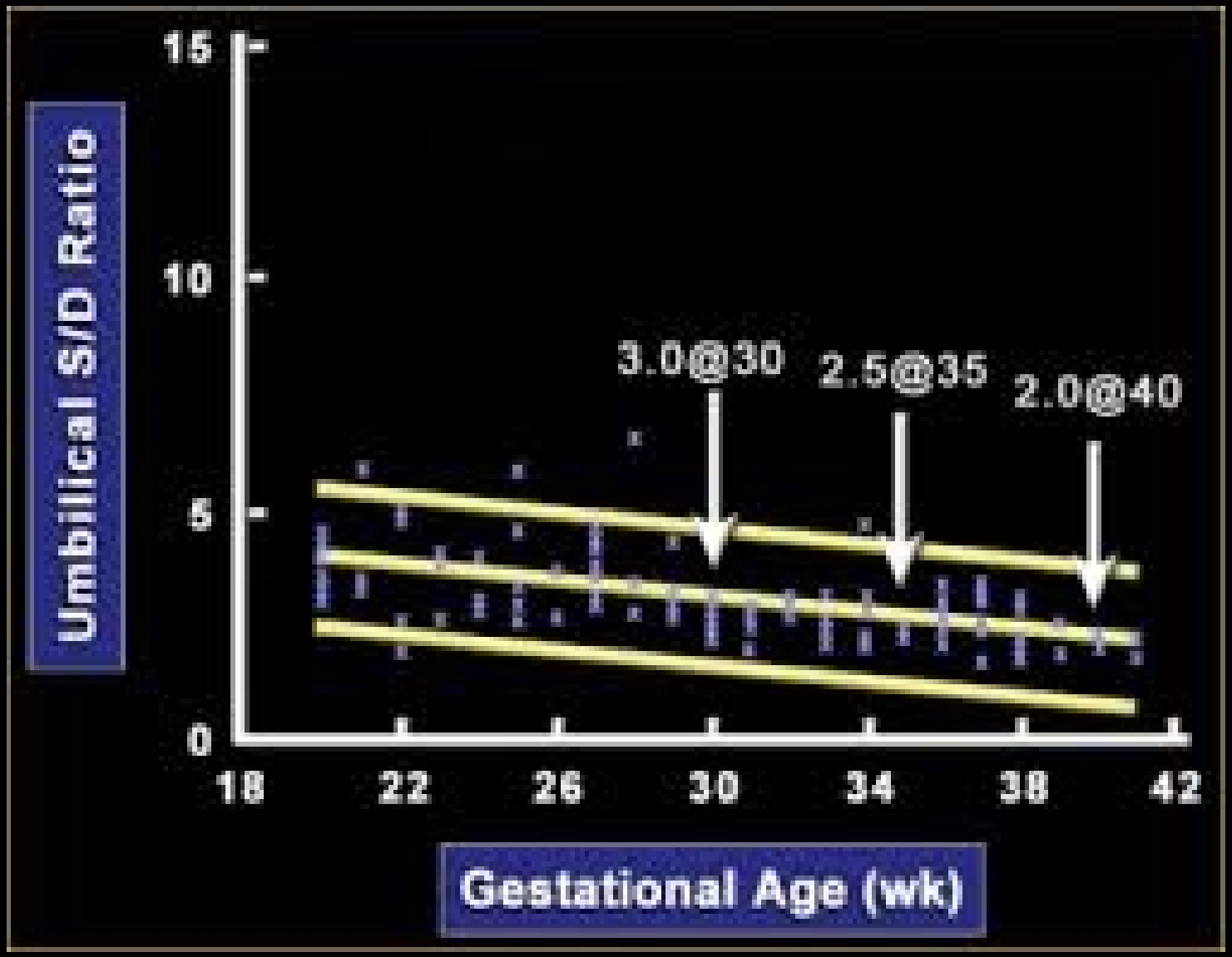
In toto


Normal pregnancy
Reduced end diastolic velocity
Absent end diastolic velocity
Reversed end diastolic velocity

Umbilical Artery

- There is, in general, a decrease in the Doppler peak and increase in the diastolic nadir throughout gestation, ie decreased resistance
- Hence, the systolic/diastolic decreases
- Generally (eyeball it rule), the S/D is 3 at 30 weeks and decreases with time

Umbilical Artery S/D



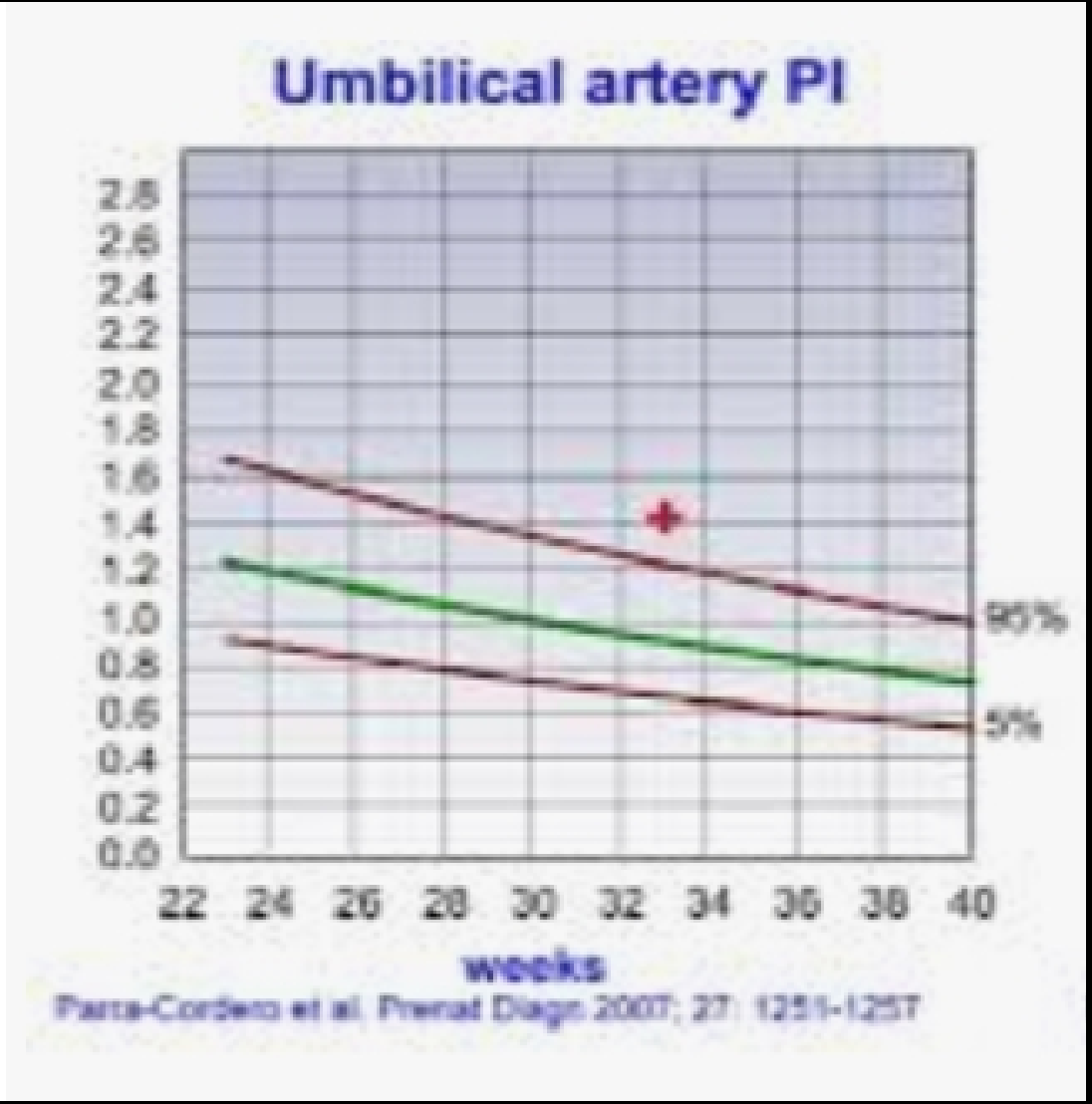
Umbilical Artery

- Additionally, there are 2 more measures of the umbilical artery Doppler waveform

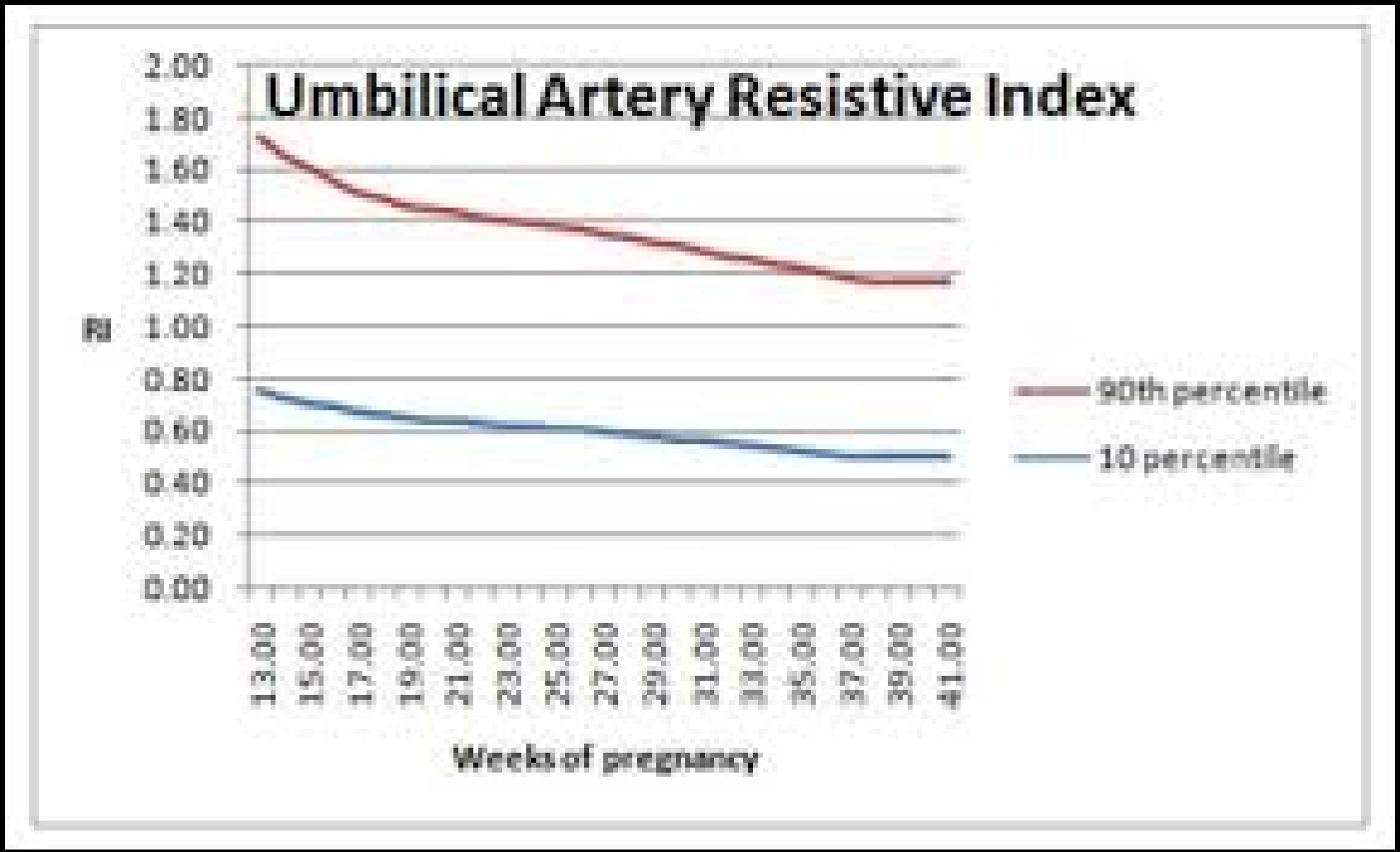
- Pulsatility Index: SV – DV/TAV
  - systolic, diastolic, time-average velocities
  - Cannot use with absent end diastolic flow

- Resistance Index: SV - DV/SV
  - Systolic, diastolic, systolic velocities

Umbilical Artery PI



Umbilical Artery RI



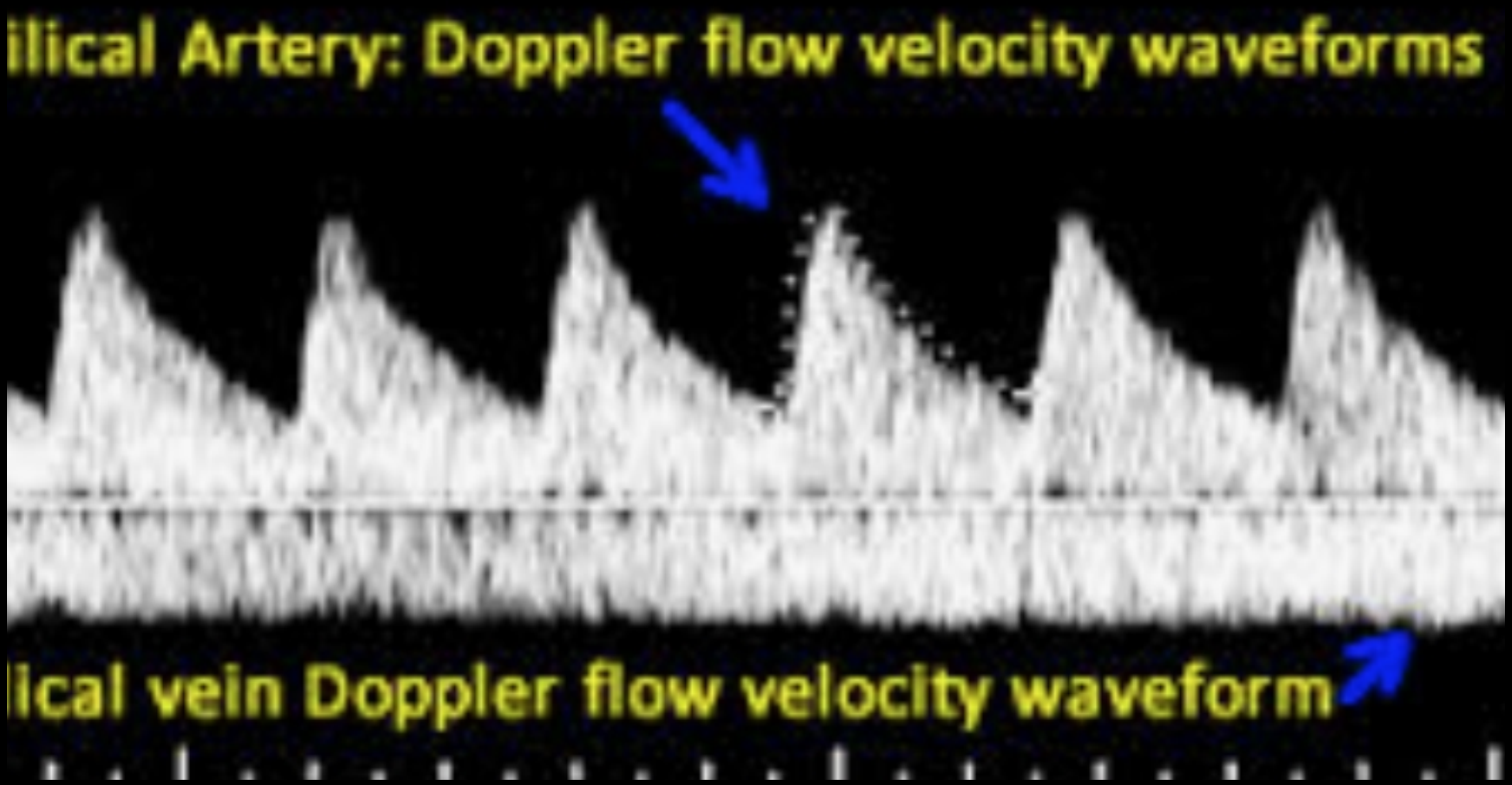
Umbilical Artery Doppler: So What?

- The UA flow patterns are representative of the combined resistances of the fetal circulation and placental circulation
- Hence, the diseases of the fetal cardiac/vasculature may influence the UA pattern
- In kind, placental resistance may influence the UA pattern
- Lastly, both fetal and placental pathologies may be at play, ie hypoplastic left heart with placental insufficiency.

Umbilical Vein

- Almost always, the only vein of the umbilical cord
- Derives from the left side (right umbilical vein almost always becomes atretic)
- Represents the fetal vessel with the highest oxygen concentration (pKa 4.7 = 80-85% saturation)
- Flow dynamics are continuous

Umbilical Vein Doppler Flow Pattern

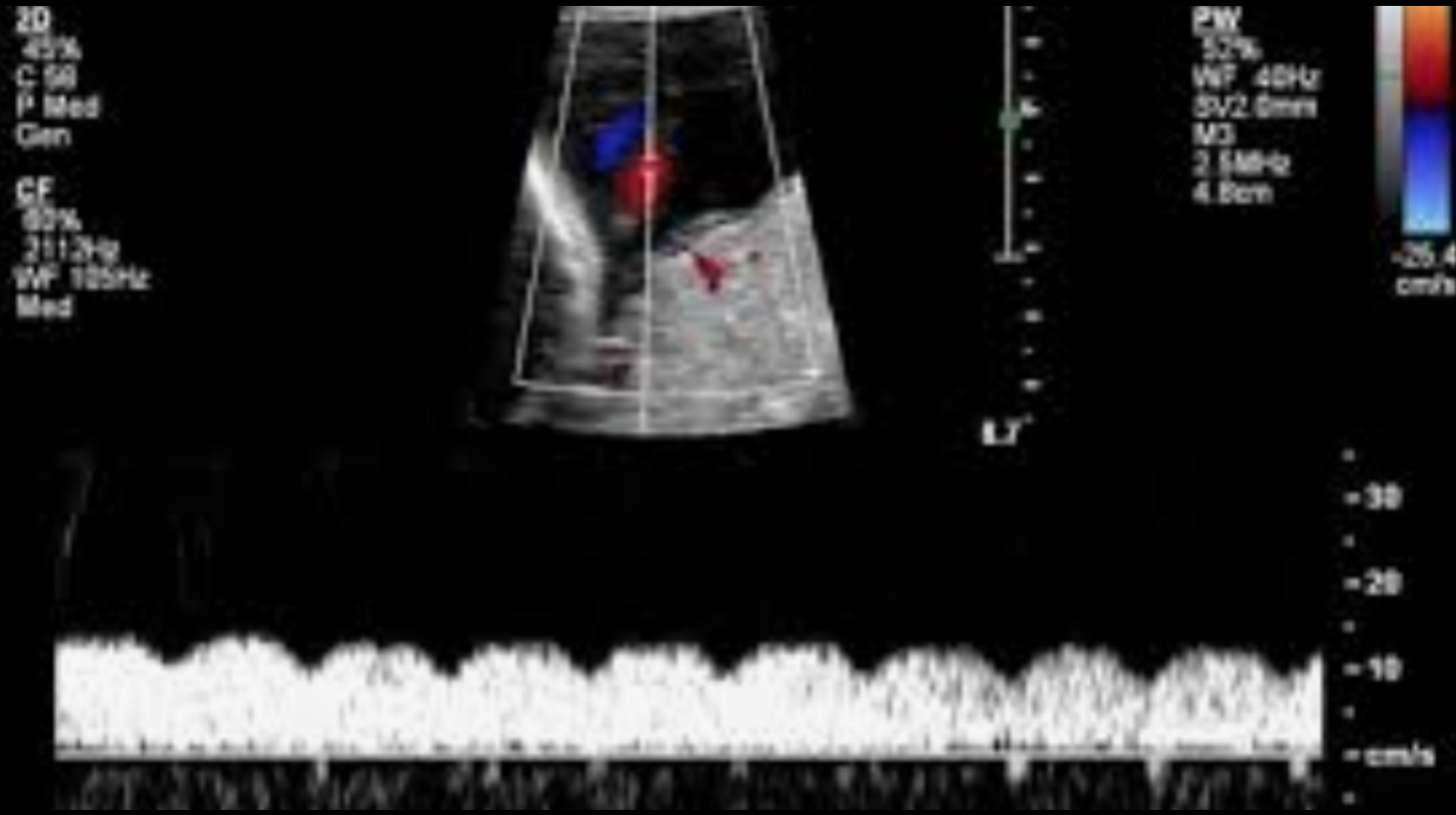


Umbilical Vein Doppler Flow Patterns

- Typical (prior slide)
- Breathing: oscillatory pattern spanning more than 1.5 – 2.5 cardiac cycles
- Hiccups: abrupt, intermittent breaks in pattern
- Single: pulsation with cardiac cycle
- Double: similar to DV pattern, reflecting the right heart ventricular systolic and diastolic rhythm

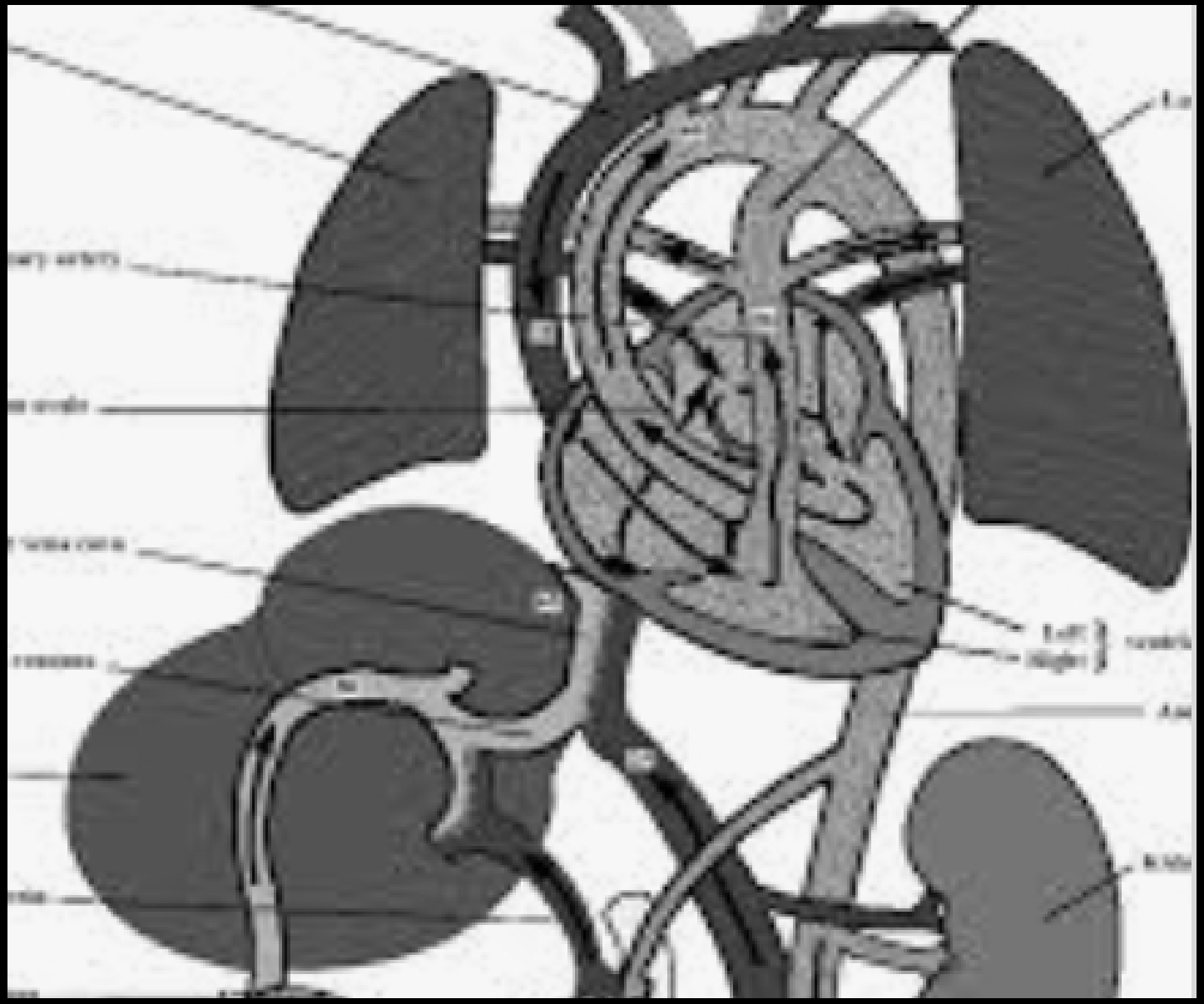
UV: Breathing

UV: 1:1 with arterial pulsation



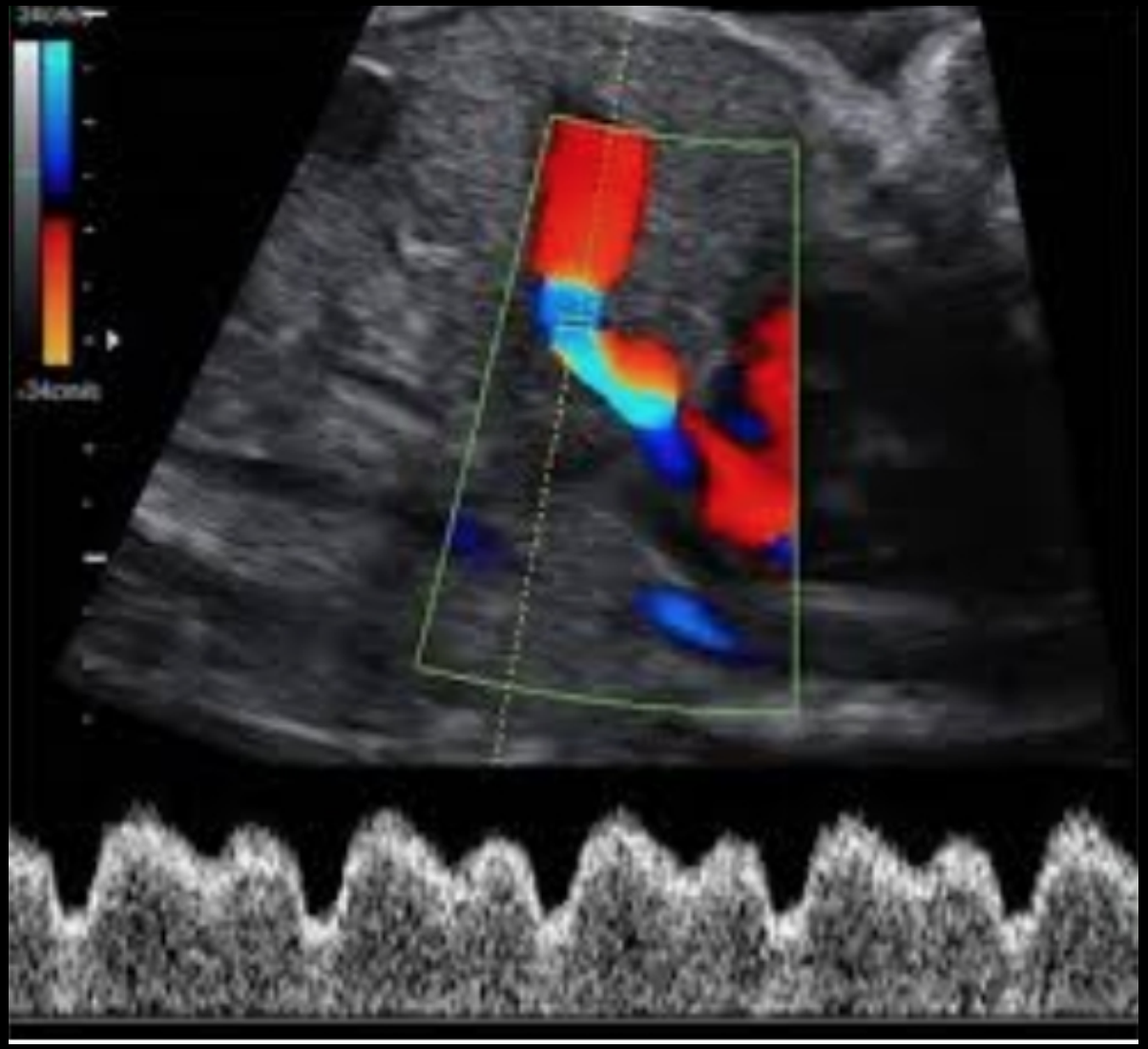
UV: mimicking DV

Ductus Venosus

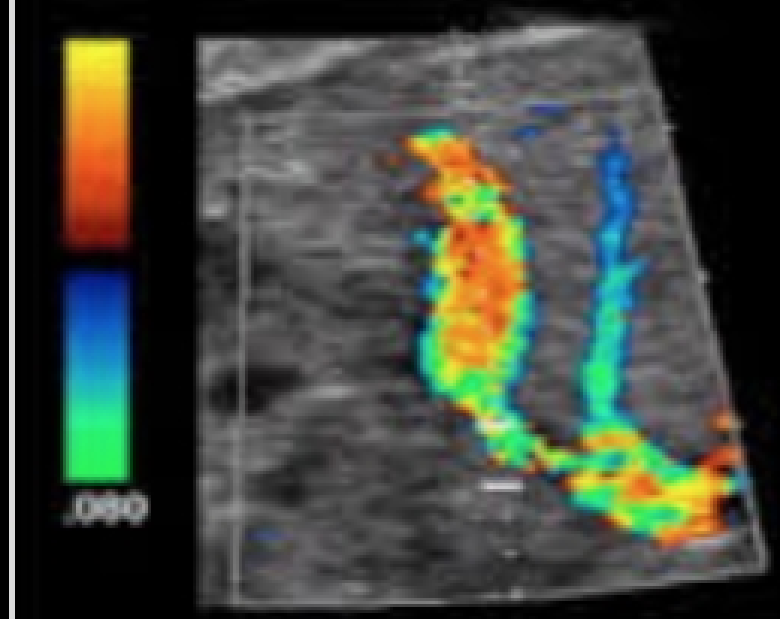


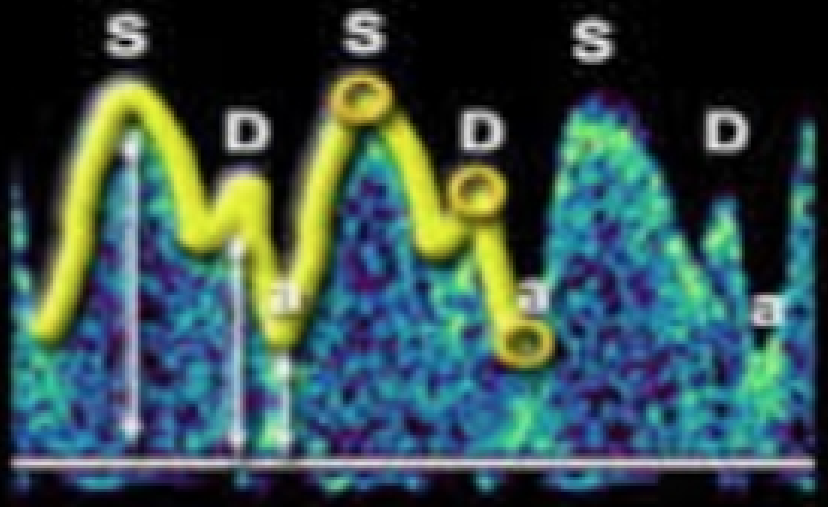
Ductus Venosus: 1st Trimester

Ductus Venosus: 2nd Trimester



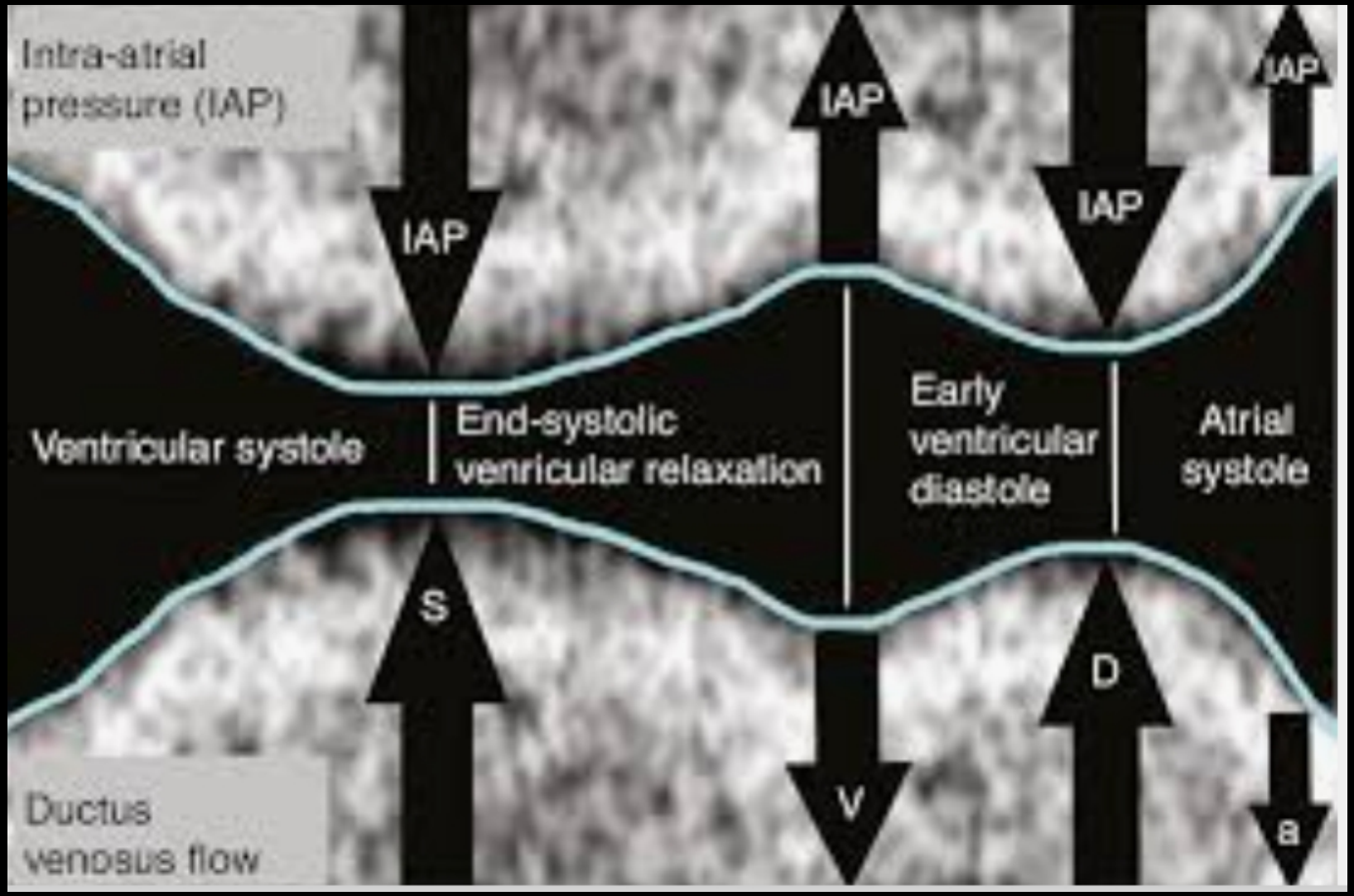
Ductus Venosus Doppler



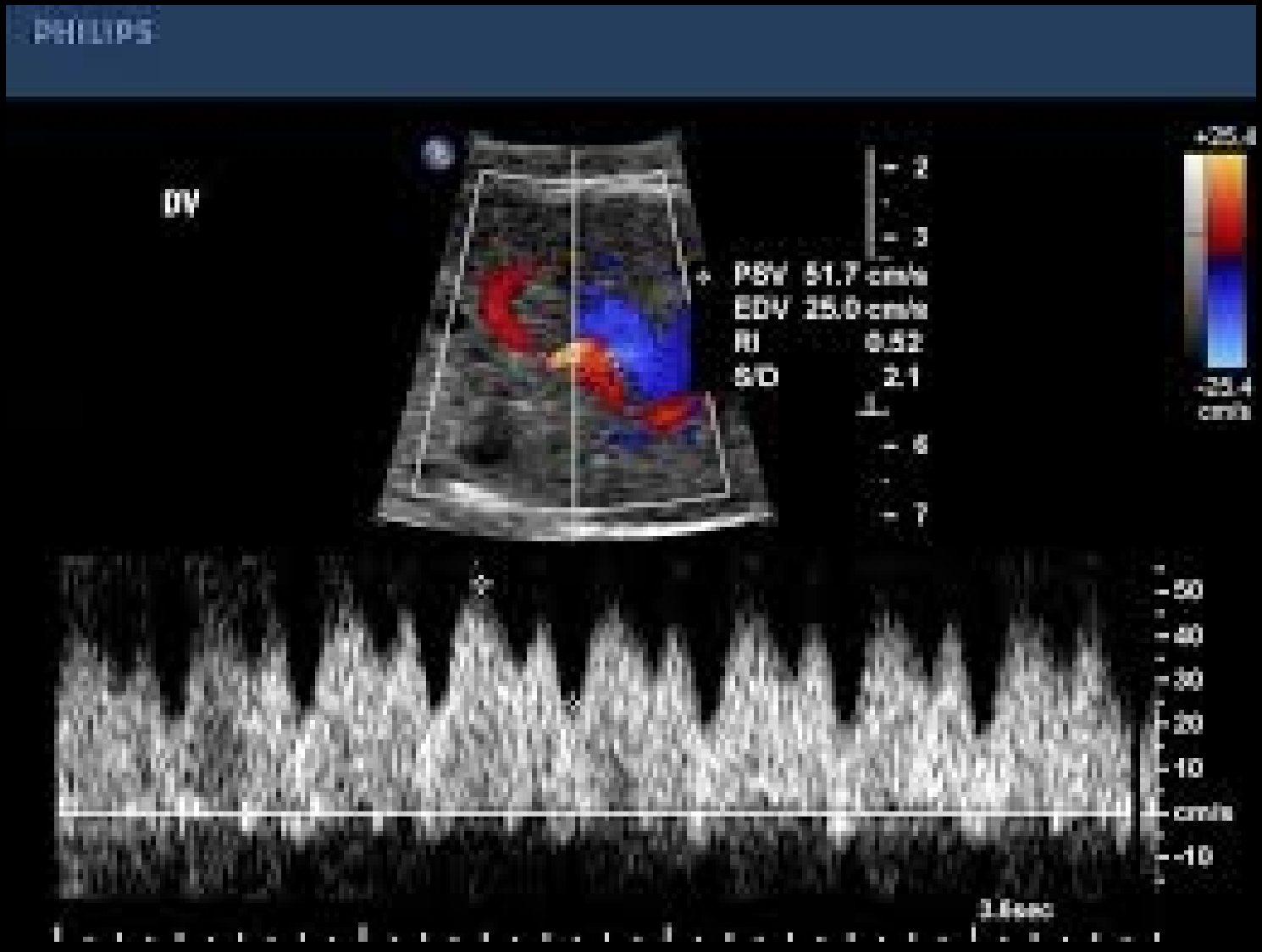


S = Ventricular systole
D = early diastole
a = atrial contraction

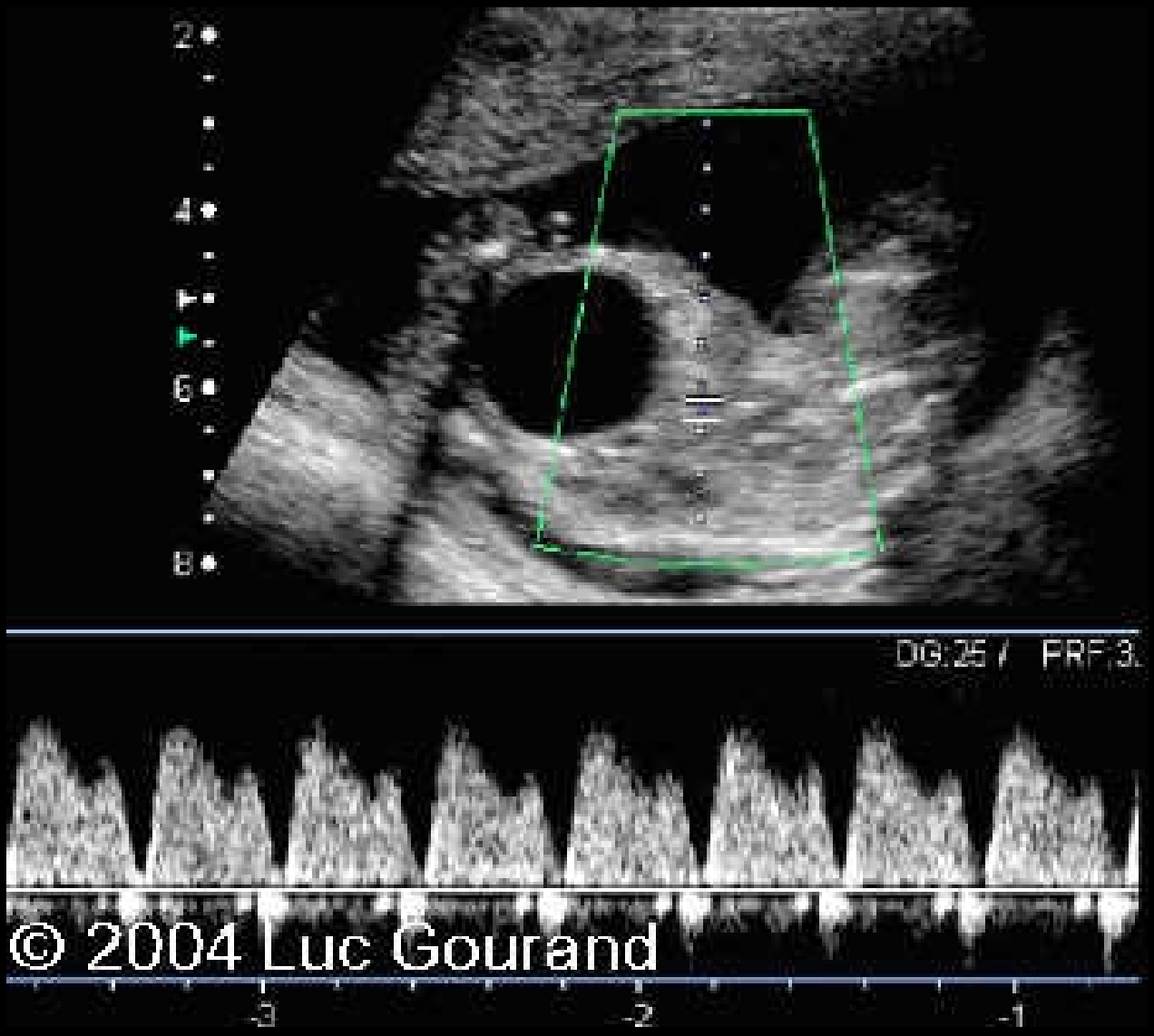
Ductus Venosus Doppler Pattern



DV: Common

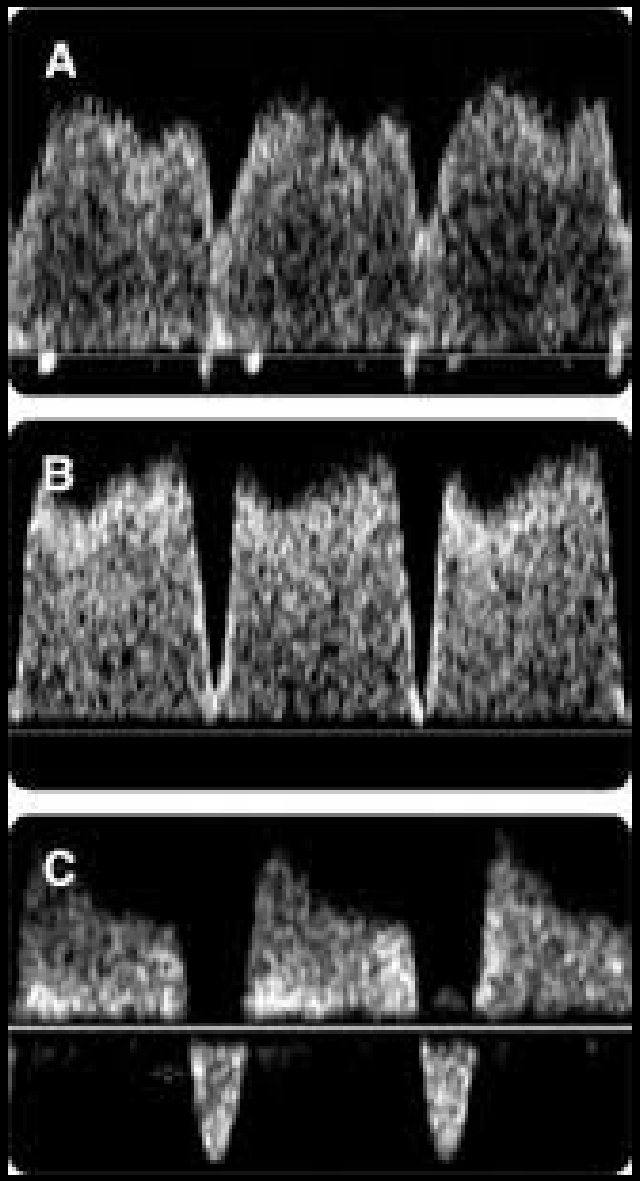


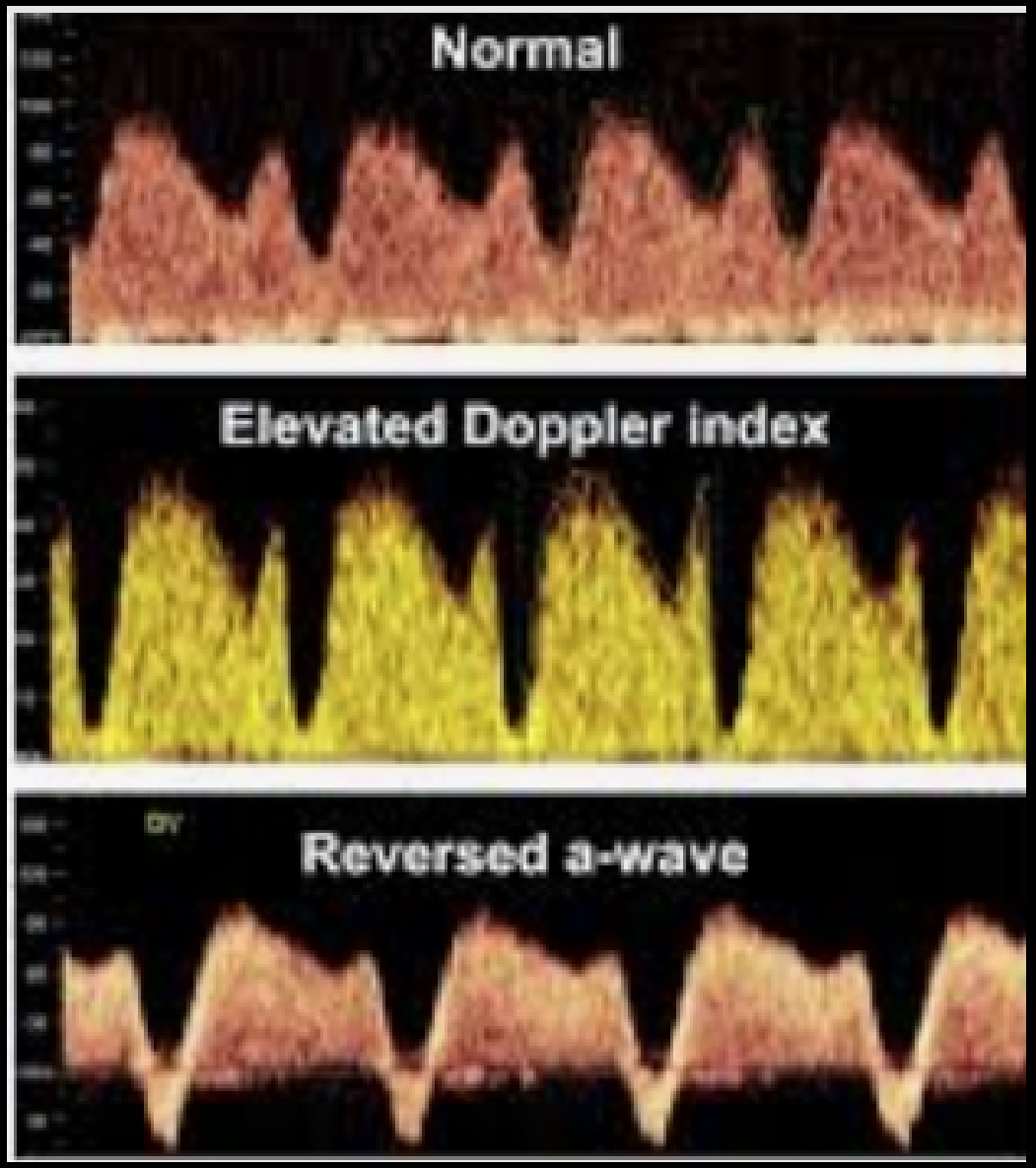
DV: Less Common



DV: Least Common

DV: In toto





Ductus Venosus: So What?

- PVIV – Peak velocity index of veins
  - Defined: (S-a)/D = Ventricular systole – atrial systole/ventricular diastole
- In conditions such as pregestational diabetes mellitus, fetal anemia, fetal growth restriction, fetal acidemia, twin twin transfusion syndrome, congenital heart disease and fetal myocardial hypertrophy the DV-PVIV is elevated
- Normative values have been generated for the second and third trimesters (Baschat, UOB 2003)

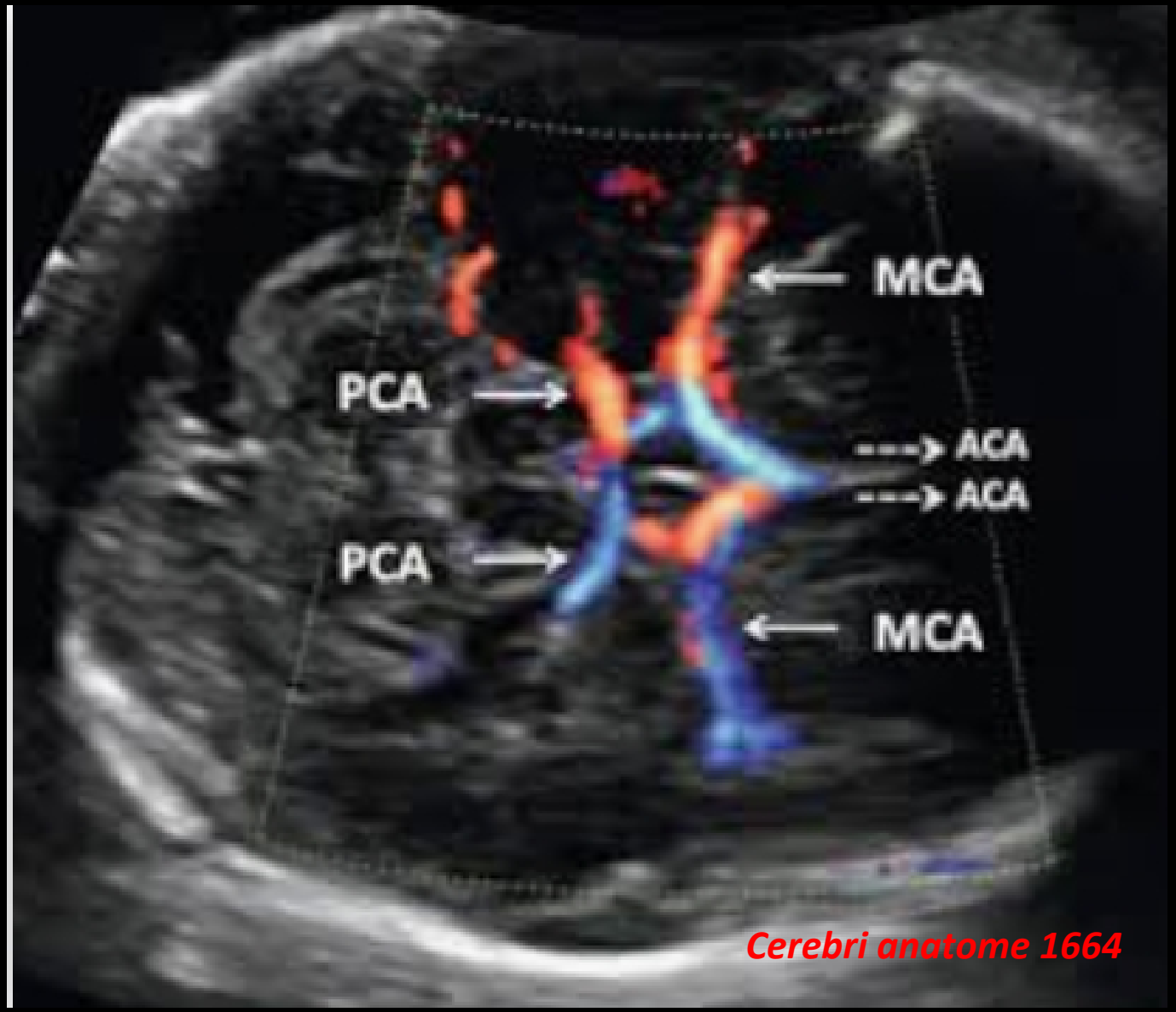
Ductus Venosus

- The DV is one measure of cardiac preload
- In a myriad of fetal growth abnormalities, placental pathologies and cardiac malformations, the DV flow patterns will change from derived norms
- The challenge and frustration is found in the combined understanding of venous and arterial indices applied in a clinical presentation, ie the maternal-fetal dyad

Middle Cerebral Artery (MCA)

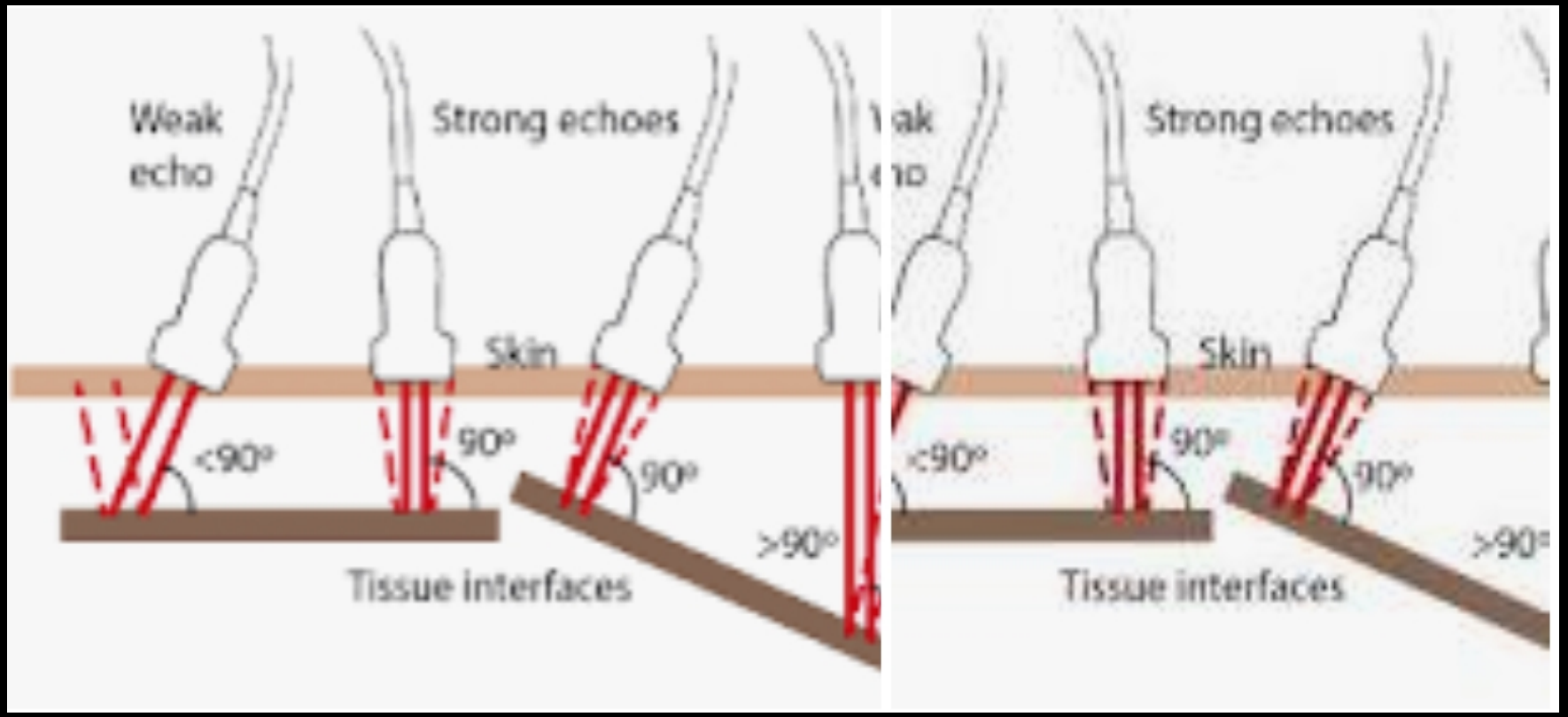
- The fetal central nervous system circulation possesses a number of vessels which are amendable to Doppler interrogation
- The MCA is one of several which fulfills the criteria of size, integrity of anatomic position and access for reliable measurements
- As such, the MCA has and continues to be described in numerous clinical scenarios

Willis Circle: MCA



MCA Doppler Acquisition

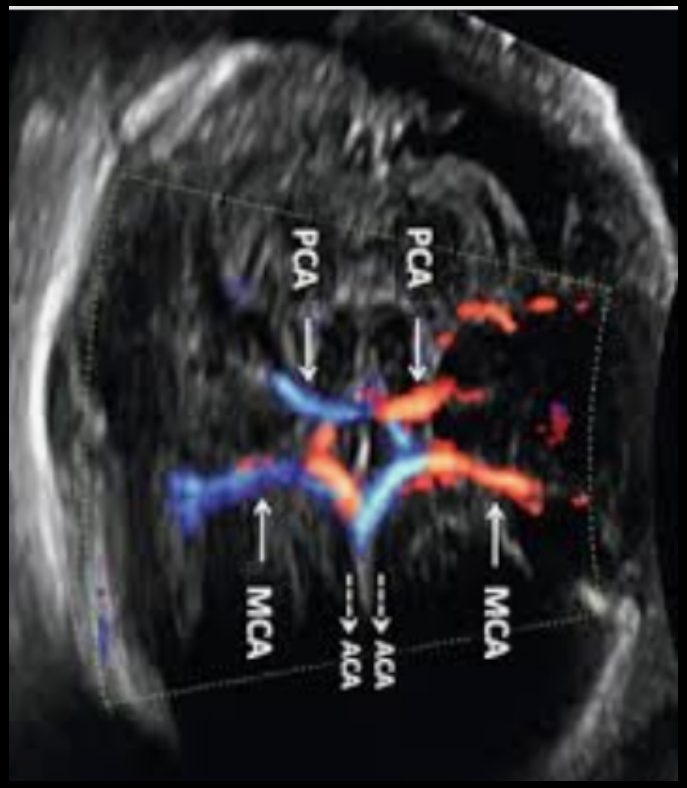
- The angle of insonation is, well, the KEY



MCA Acquisition

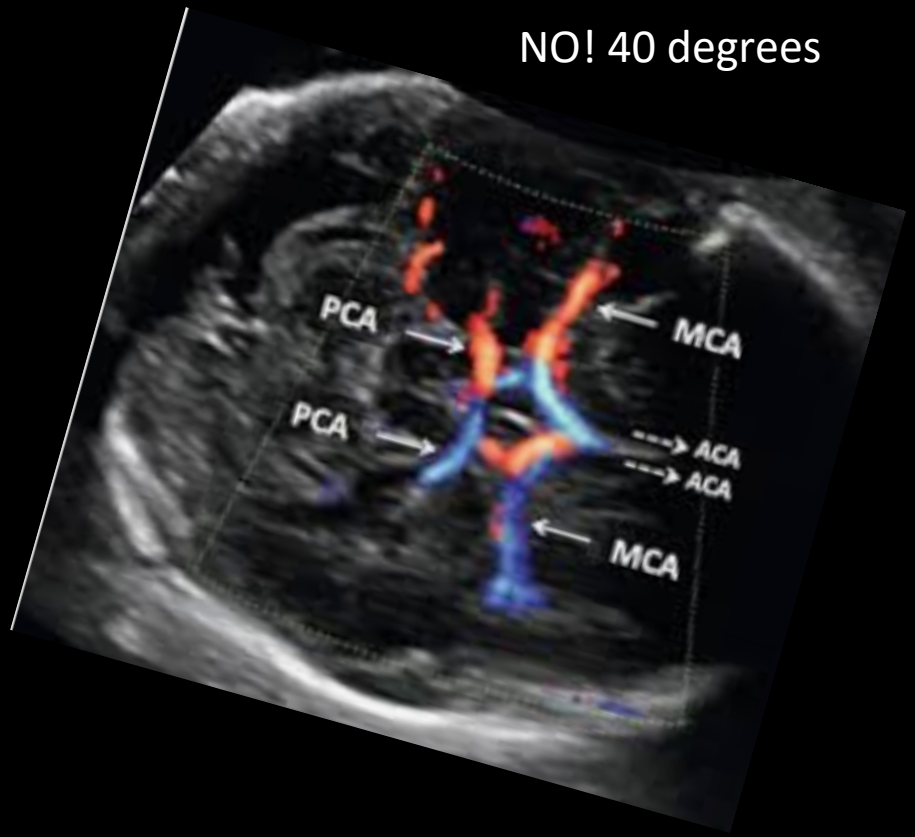
- Fetal quiescence
- Angle of insonation at 6 degrees or less
- Doppler gate to equal vessel size
- Preferable MCA on near side; however, far side may be used
- **NB: Increased angle of insonation will increase the peak velocity**
- MCA ratio measurements are unaffected

MCA: Angle of insonance



NO! 100 degrees

NO! 40 degrees

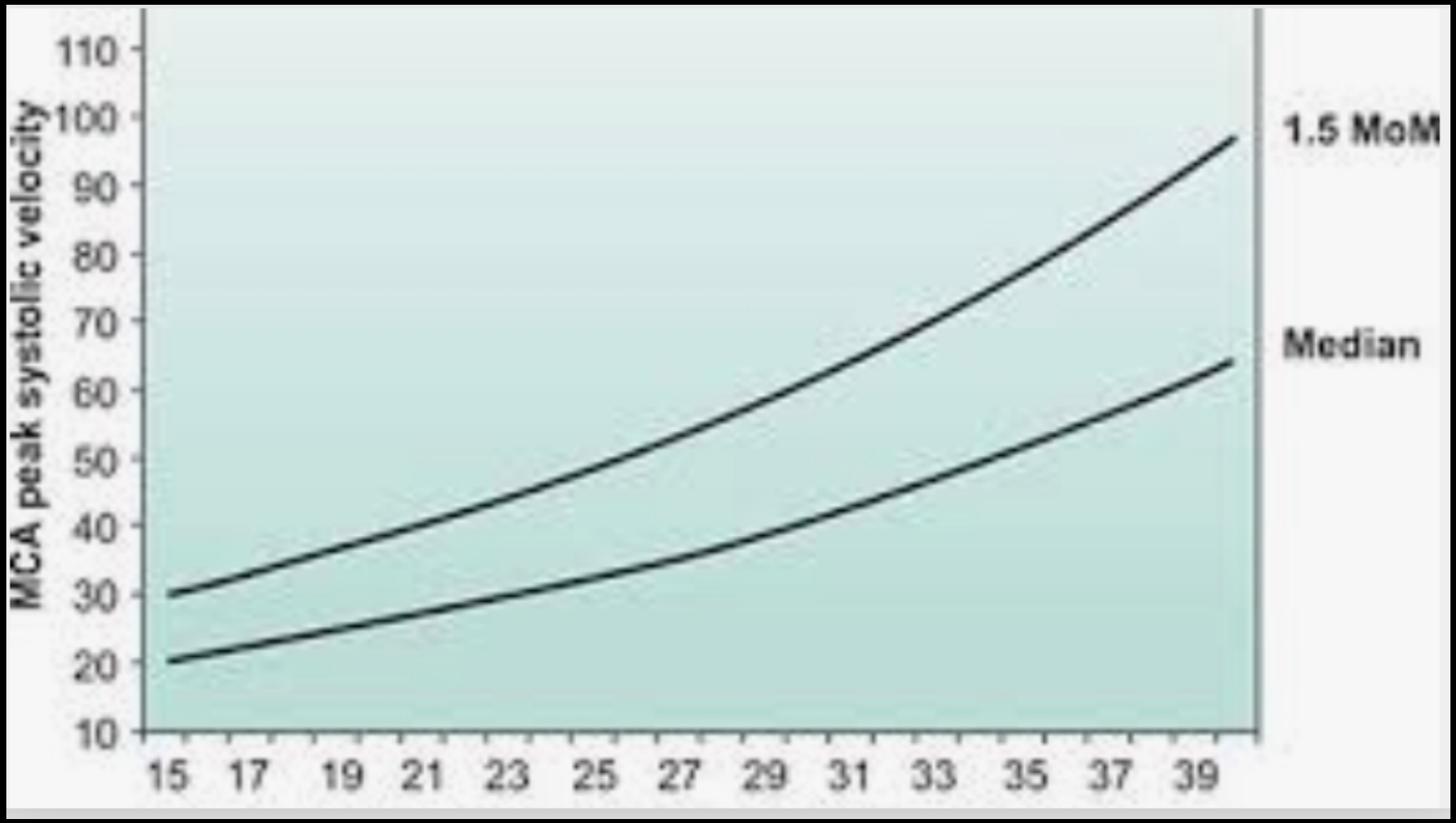


YES! Far side at 0 degrees!!!

MCA Peak Systolic Velocity

- Common evaluation of the fetal MCA
- Mari, NEJM 2000, described the positive correlation of PSV MCA with fetal anemia
- In particular instance of concern for fetal anemia (isoimmunization, suspected fetal-maternal hemorrhage from trauma), a multiple of the medium of 1.5 normal is consistent with significance risk of anemia.

MCA PSV: risk of anemia



Other Doppler Studies

- IVC – has relative stability despite many pathologic states. A last vessel to degrade in flow velocities
- Renal artery and vein – preliminary studies in known/suspected fetal renal diseases: MCDK, AR/DPKD, bladder outlet obstruction syndromes
- Superior mesenteric artery in gut disorders: gastroschisis, diaphragmatic hernia, etc.

Application

Clinical Vignette

- 42 year old G6 P3104 at 28 weeks gestation
- Seen for completion of the anatomical survey and growth evaluation

28 weeks: Biometrics

Fetal Evaluation

Number Of Fetuses:	1	Presentation:	Cephalic
Preg. Location:	Intrauterine	Placenta:	Anterior
Fetal Heart Rate(bpm):	148	P. Cord Insertion:	Normal
Cardiac Activity:	Observed		

Amniotic Fluid

Amniotic F.V.:	Polyhydramnios						
RUQ:	12.03	cm	RLQ: 6.97	cm	LUQ: 11.13	cm	LLQ: 7.54	cm
AFI Sum:	37.67	cm	> 97 %Tile:		Largest Pocket:	12.03	cm

Biophysical Evaluation

Amniotic F.V:	Polyhydramnios	F. Tone:	Observed
F. Movement:	Observed	N.S.T:	Nonreactive
F. Breathing:	Not Observed	Score:	6/10

Biometry

BPD:	70.2	mm	G. Age: 28w 1d	30 %tile	CI (BPD/OFD):	79.3	%	70 - 86
OFD:	88.5	mm			FL/HC:	20.6	%	18.8 - 20.6
HC:	252.1	mm	G. Age: 27w 3d	13 %tile	HC/AC:	1.07		1.05 - 1.21
AC:	235.6	mm	G. Age: 27w 6d	41 %tile	FL/BPD:	73.9	%	71 - 87
FL:	51.9	mm	G. Age: 27w 5d	33 %tile	FL/AC:	22.0	%	20 - 24
HUM:	47.9	mm	G. Age: 28w 0d	49 %tile				
CER:	32	mm	G. Age: 28w 0d	50 %tile				
LV:	4.42	mm						
CM:	2.26	mm						

28 weeks: Biometrics

Biometry - Continued

IOD:	11.9 mm	G. Age:	18w 2d	< 5 %tile
OOD:	38.9 mm	G. Age:	22w 5d	< 5 %tile
HUM:	47.9 mm	G. Age:	28w 0d	49 %tile
FL:	51.9 mm	G. Age:	27w 5d	33 %tile
ULN:	42.8 mm	G. Age:	27w 4d	25 %tile
TIB:	44 mm	G. Age:	27w 1d	28 %tile
RAD:	38.1 mm	G. Age:	26w 4d	38 %tile
FIB:	44 mm	G. Age:	27w 0d	61 %tile
Estimated FW:	**1127 gm. 2 lb 8 oz**			**47 %Tile**

Gestational Age

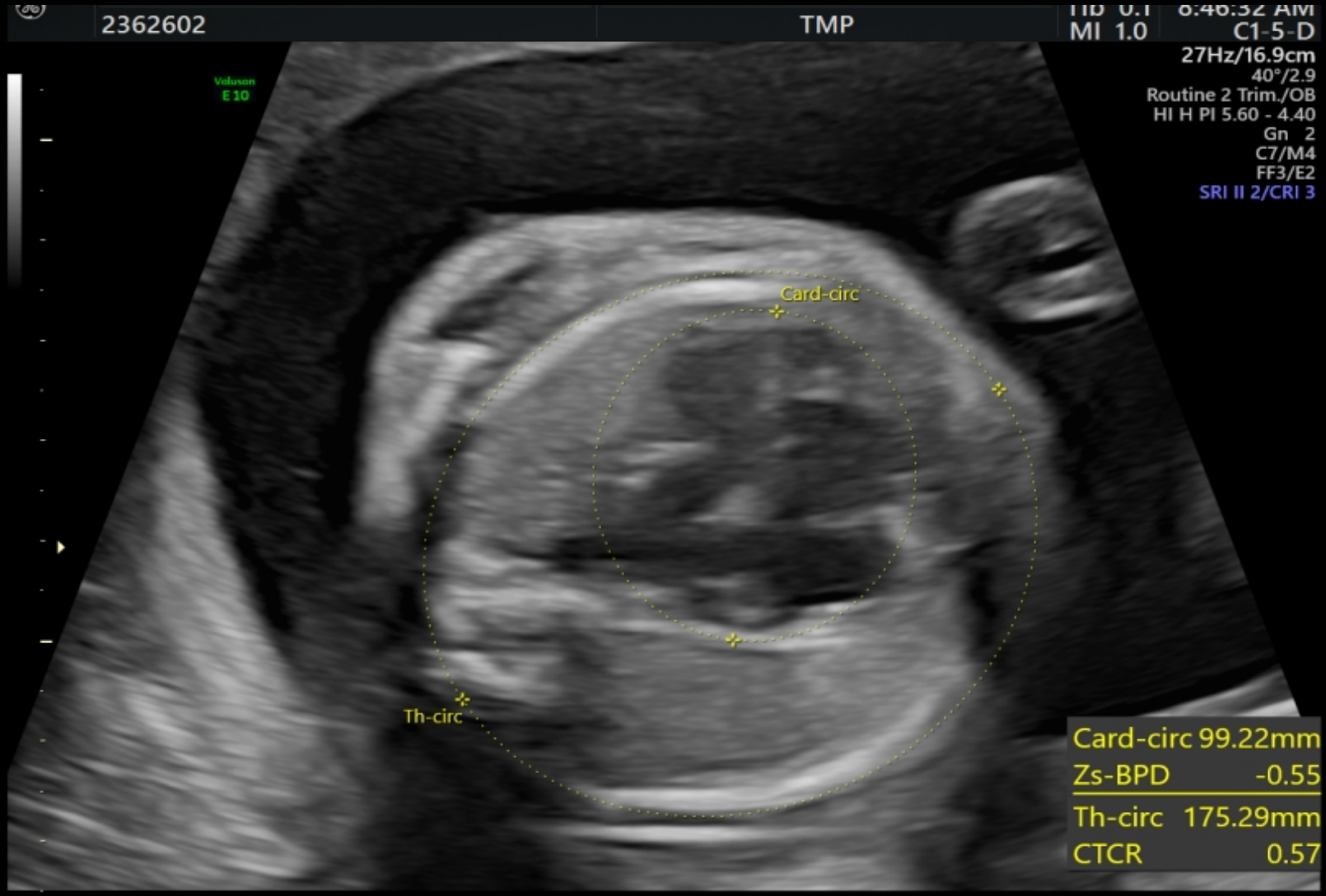
LMP:	28w 0d	Date:	5/28/2020	EDD:	03/04/21
U/S Today:	27w 6d			EDD:	03/05/21
Best:	28w 0d	**Determined By:**	LMP (05/28/20)	**EDD:**	03/04/21

Doppler - Fetal Vessels

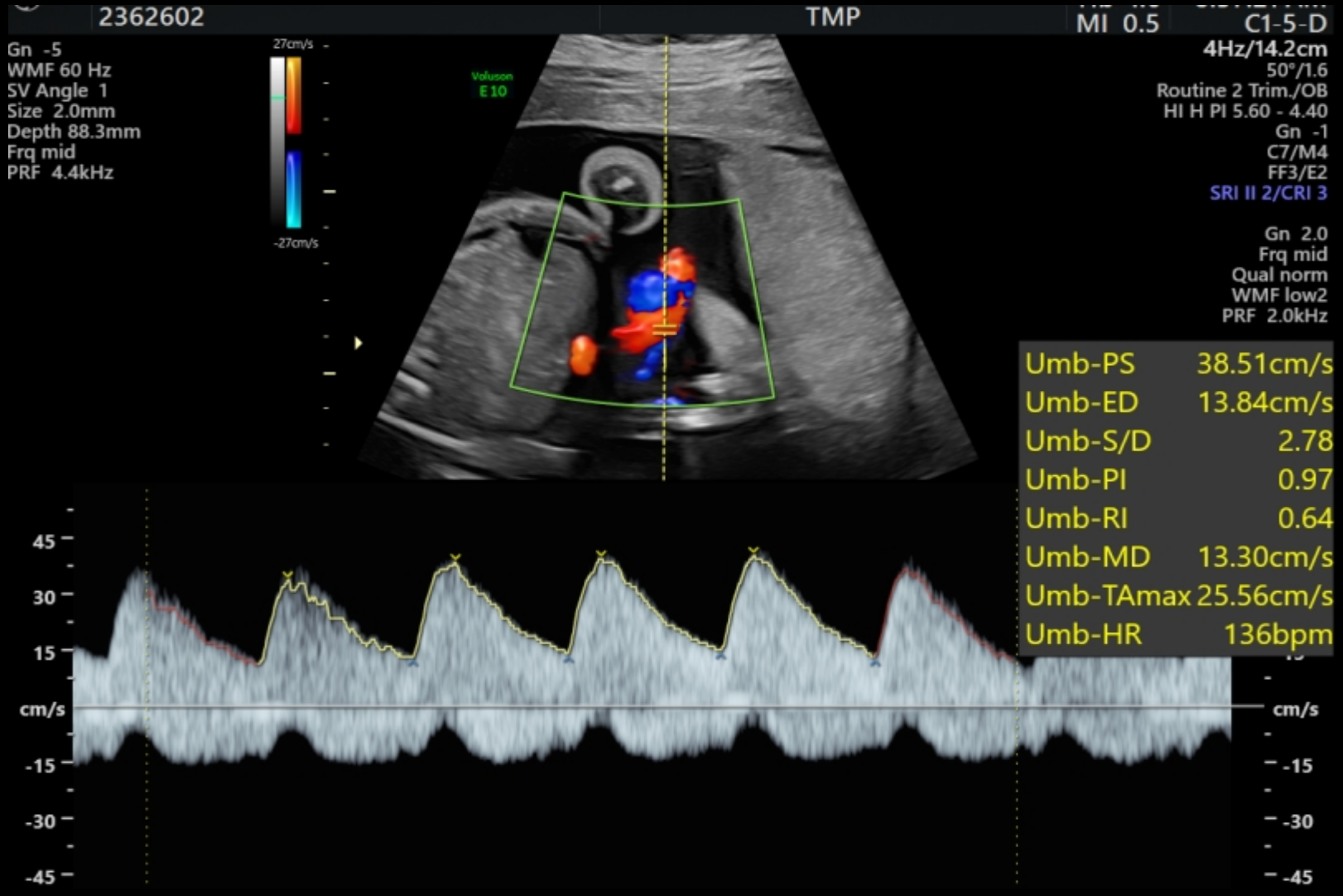
	S/D	%tile	RI	%tile	PI	%tile	PSV (cm/s)			ADFV	RDFV
Umbilical Artery:	2.92	45	0.66	50	1.02	53	38.51			No	No
Middle Cerebral Artery:	5.28		0.81		1.79	18	72	1.95	MoM		

MCA PI / UA PI	%tile

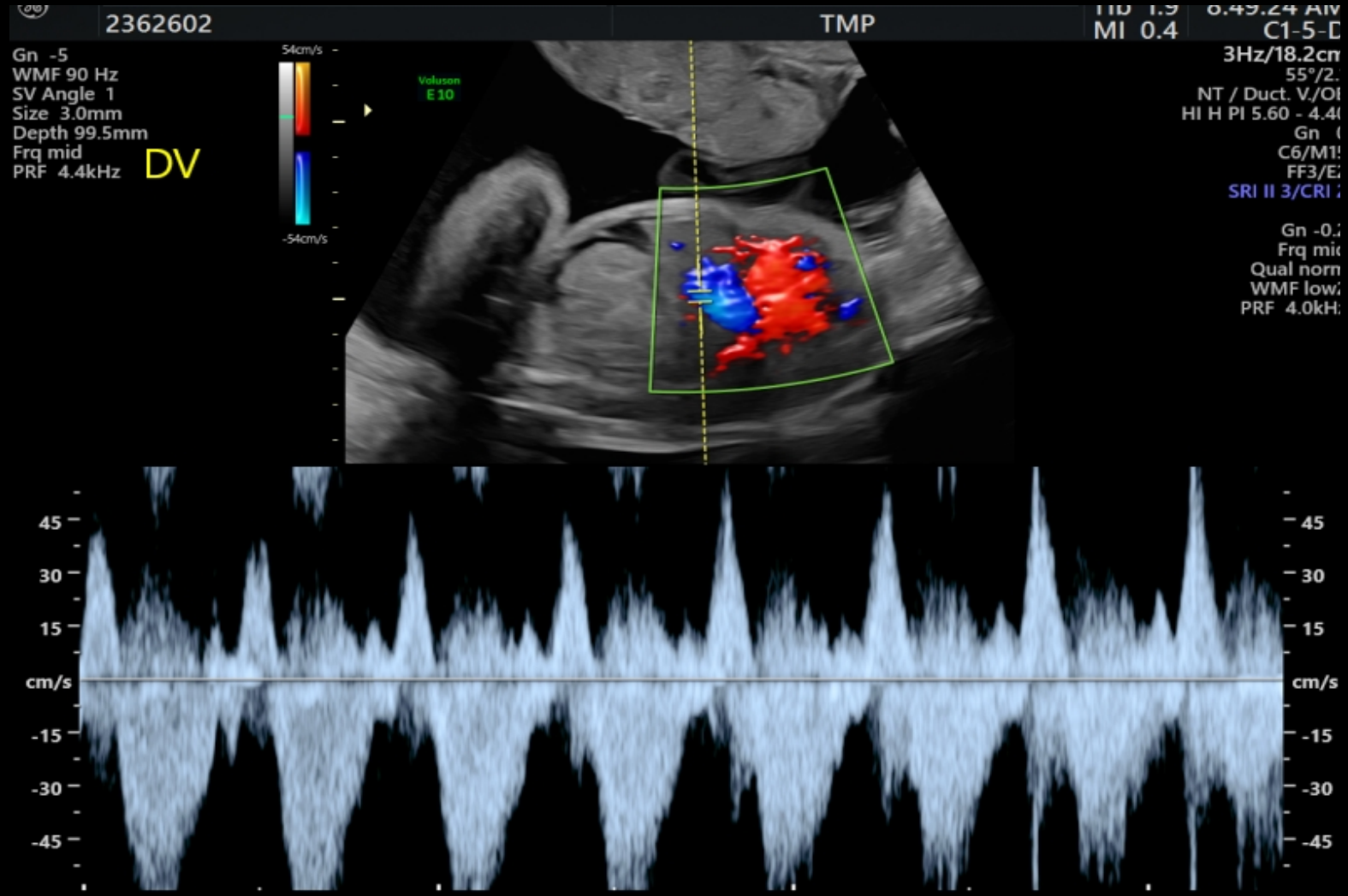
28 weeks


2362602
TMP
MI 1.0
C1-5-D
27Hz/16.9cm
40°/2.9
Routine 2 Trim./OB
HI H PI 5.60 - 4.40
Gn 2
C7/M4
FF3/E2
SRI II 2/CRI 3
Card-circ
Th-circ
Card-circ 99.22mm
Zs-BPD -0.55
Th-circ 175.29mm
CTCR 0.57

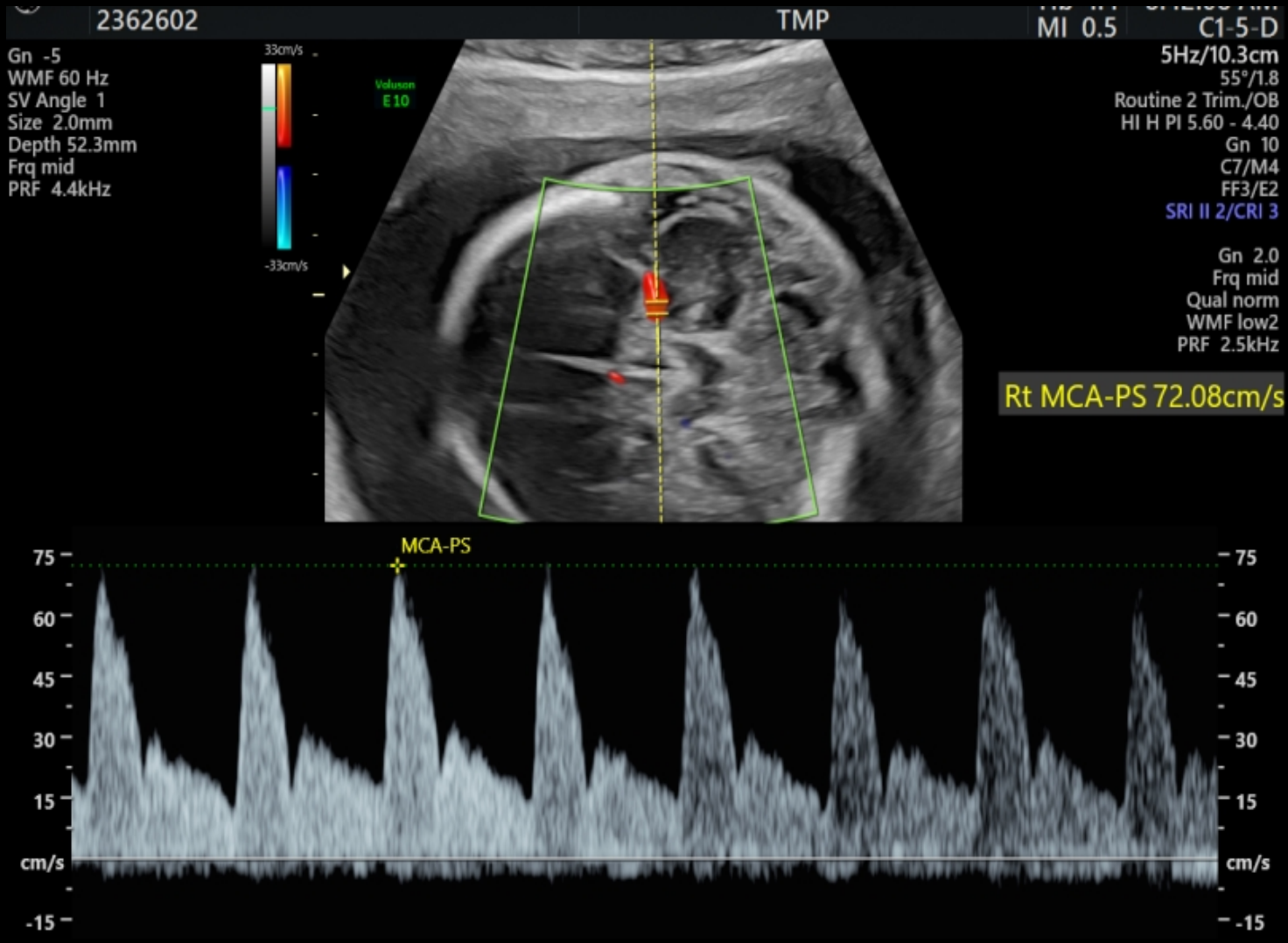
28 weeks: UA and UV



28 weeks: Ductus Venosus



28 weeks


2362602
TMP
MI 0.5
C1-5-D
Gn -5
WMF 60 Hz
SV Angle 1
Size 2.0mm
Depth 52.3mm
Frq mid
PRF 4.4kHz
33cm/s
-33cm/s
Voluson
E10
5Hz/10.3cm
55°/1.8
Routine 2 Trim./OB
HI H PI 5.60 - 4.40
Gn 10
C7/M4
FF3/E2
SRI II 2/CRI 3
Gn 2.0
Frq mid
Qual norm
WMF low2
PRF 2.5kHz
Rt MCA-PS 72.08cm/s
MCA-PS
75
60
45
30
15
cm/s
-15

Clinical Vignette: 28 weeks

- Heart: AV canal v DORV
- UA = wnl
- UV = 1:1 pulsatility (CHF +/- CHD)
- DV = reversed a-wave, increased PVIV
- MCA PSV > 1.95 MoM (>1.5 consistent with anemia)
- Hydrops fetalis

28 weeks

- Next day to OR
- PUBS with IT
  - H/H 9.8/27 Plts 68k
  - Transfused PRBC and platelets
- No complications
- Amnioreduction due to polyhydramnios
- Micro array analysis performed

30 weeks

- Hydrops resolved
- UA = wnl
- UA pulsations resolved
- DV persistent a-wave reversal and decreased PVIV
- MCA PSV was < 1.5 MoM
- Micro array resulted = trisomy 18

34 weeks

- Return of hydrops
- Patient counseling
- Desire live birth and therapy
- Repeat PUBS with IT: PRBC + platelets
  - H/H 9.9/29 platelets 74K
- Hydrops resolved within ten days
- 02.11.2021 37w0d scheduled MIL at CMH