

Nafisa Dajani, MD

Doppler Studies in Obstetrics

Ovid Search

- Term : Doppler studies and IUGR 11613 ref.
- Term : MCA and fetal anemia 126 ref.

Doppler studies

- A non invasive method of prognostic values in pregnancies complicated by IUGR, Hypertensive disorders complicated by IUGR, Fetal anemia, twin-twin transfusion syndrome

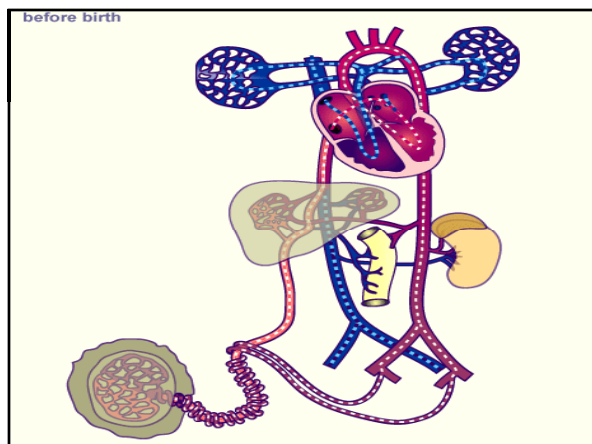
The Cardiovascular system

Reflect the cardiovascular system

Arterial : umbilical, Middle cerebral

Venous : Umbilical Vein, Ductus-venosus

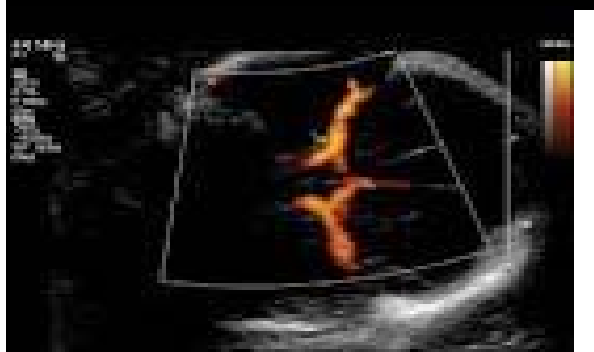
Other: uterine, inferior vena cave , descending aorta, TC, mitral



PRINCIPLE for Detection of Fetal Anemia

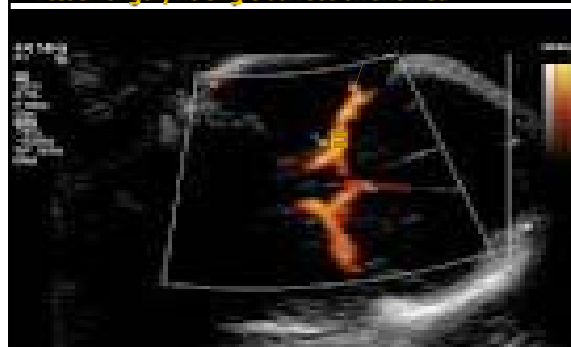
- Oxygen delivery to the brain is maintained by increased flow of low viscosity blood.
- Why the MCA? Accessible till term
Can obtain an insonation angle of zero to obtain the fastest speed of flow

MCA : Fetal anemia



MCA : Fetal anemia

Magnify image, 2mm from exit, zero angle and whole vessel length, no angle correction allowed



Angle of insonation zero, get the highest speed

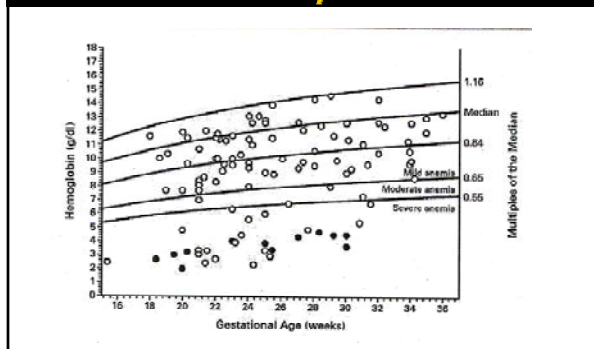


How good is the test

- The sensitivity in picking up moderate or severe fetal anemia is 88%- 100%, FPR 12% . NPV 98%, PPV 53%
- The optimal threshold for mild anemia is 1.29 MOM , for moderate anemia 1.5 MOM , and for severe 1.55 MOM

New England J Med, 2000, vol 342, Mari
BJOG, 2002,109(7):746, Mari, Zimmerman

HGB: 250 normal versus 110 with isoimmunization by cordocentesis



PSV and Anemia

TABLE 3. EXPECTED PEAK VELOCITY OF SYSTOLIC BLOOD FLOW IN THE MIDDLE CEREBRAL ARTERY AS A FUNCTION OF GESTATIONAL AGE.

WEEK OF GESTATION	MULTIPLES OF THE MEDIAN			
	1.00 (MEDIAN)	1.29	1.50	1.55
	cm/sec			
18	23.2	29.9	34.8	36.0
20	25.5	32.8	38.2	39.5
22	27.9	36.0	41.9	43.3
24	30.7	39.5	46.0	47.5
26	33.6	43.3	50.4	52.1
28	36.9	47.6	55.4	57.2
30	40.5	52.3	60.7	62.8
32	44.4	57.3	66.6	68.9
34	48.7	62.9	73.1	75.6
36	53.5	69.0	80.2	82.9
38	58.7	75.7	88.0	91.0
40	64.4	83.0	96.6	99.8

Indications

- Proven to be sensitive to anemia from alloantibody other than anti D
- Also for anemia due to fetal infections, Parvo
- Also works in fetuses with hydrops
- Also in TTTS where the donor may be anemic/IUGR

Comparison

- OD 450 has a sensitivity of 84% for severe anemia, and 74% for moderate anemia
- OD 450 not reliable for Kell isoimmunization

Pitfalls

- Measurement technique: needs training
- Fetus : not moving or breathing
- Gestational age: elevated MCA PSV after 35 weeks may not reflect anemia. If high values are obtained, perform amnio for FLM testing and OD450, if severe anemia then deliver, otherwise wait till 37-38 weeks

MCA, PSV in IUGR

- 2007, reported as a new parameter for IUGR
- IUGR fetuses have increased HGB rather than anemia
- Animal studies suggest that PO₂ and PCO₂ may increase brain blood flow

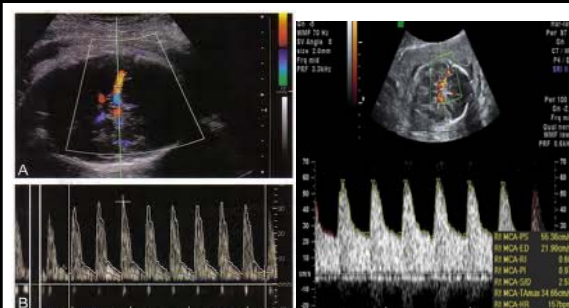
Variables that affect MCA/Hanif et al Am. J. Peri. 2007;24 (8)
MCA PSV a new Doppler parameter IUGR, u/s obst gyn 2007;29:310-316

MCA, PSV in IUGR

- Studies in fetuses (small number, c/section) suggest a relationship between blood flow and PCO₂ and PO₂ (cord gases) . Hypercapnea and hypoxemia increase blood flow)
- Two Indices : PI (measures variability of blood flow s-d/mean velocity in a cardiac cycle) or PSV

Variables that affect MCA/Hanif et al Am. J. Peri. 2007;24 (8)
MCA PSV a new Doppler parameter IUGR, u/s obst gyn 2007;29:310-316

Normal/Abnormal MCA Waveform



womenwomenshealthsection.com
section.com

Indices: PI, PSV, S/D, RI

- PI of the MCA has been shown to be related to PO₂ but not PCO₂
- PI changes before PSV
- IUGR: hypoxemia followed by hypercapnea (speculation), may explain why the PI stops changing or plateaus with progressive IUGR when the PSV is high

Peak Systolic Velocity

Table 2 Fetal centiles of peak systolic blood flow velocity in the fetal middle cerebral artery (MCA-PSV)

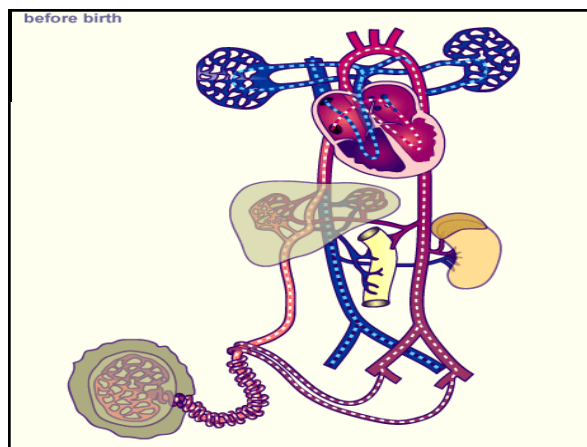
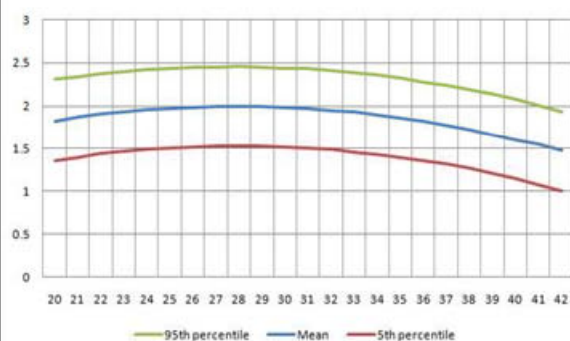
Week of gestation	MCA-PSV (cm/s)		
	5th	50th	95th
19	16.7	19.7	23.0
20	18.1	21.8	26.0
21	19.5	23.9	29.0
22	20.8	26.0	32.0
23	22.2	28.2	35.0
24	23.6	30.3	38.1
25	24.9	32.4	41.1
26	26.3	34.6	44.1
27	27.7	36.7	47.1
28	29.0	38.8	50.1
29	30.4	40.9	53.1
30	31.8	43.1	56.1
31	33.1	45.2	59.1
32	34.5	47.3	62.1
33	35.9	49.5	65.1
34	37.2	51.6	68.2
35	38.6	53.7	71.2
36	40.0	55.8	74.2
37	41.3	58.0	77.2
38	42.7	60.1	80.2
39	44.1	62.2	83.2
40	45.4	64.4	86.2

TABLE 3. EXPECTED PEAK VELOCITY OF SYSTOLIC BLOOD FLOW IN THE MIDDLE CEREAL ARTERY AS A FUNCTION OF GESTATIONAL AGE.

Week of Gestation	MULTIPLES OF THE MEAN			
	1.00 (MEAN)	1.39	1.60	1.85
	cm/sec			
18	23.2	29.9	34.8	36.0
20	25.5	32.8	38.2	39.5
22	27.9	36.0	41.9	43.3
24	30.7	39.5	46.0	47.5
26	33.6	43.3	50.4	52.1
28	36.9	47.6	55.4	57.2
30	40.5	52.2	60.7	62.8
32	44.4	57.3	66.6	68.9
34	48.7	62.9	73.1	75.6
36	53.5	69.0	80.2	82.9
38	58.7	75.7	88.0	91.0
40	64.4	83.0	96.6	99.8

Middle Cerebral Artery Pulsatility Index (PI)

Arduini et al. J Perinat Med 1990;18(3):165-172



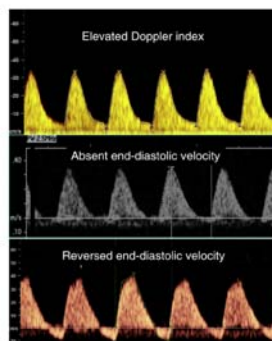
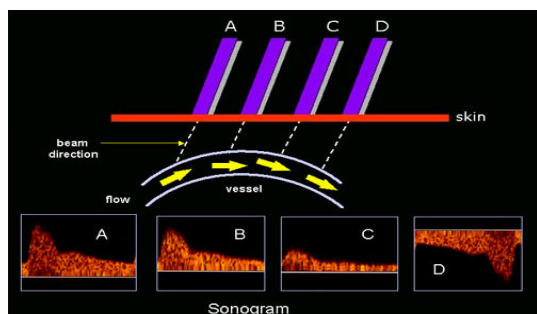
Umbilical Artery

- Measures placental Resistance
- Placental Resistance decreases with gestational age

Factors affecting the waveform

- Gestational age: the higher GA the lower the placental resistance, lower S/D and RI
- FHR: no changes within the 120-160b/min range, abnormal with HB
- Breathing: measure in apnea
- Fetal behavioral states: no changes for the umbilical, but measure during sleep in the MCA
- Technique: angle, filter, free loop

Angle Of Insonation



IUGR

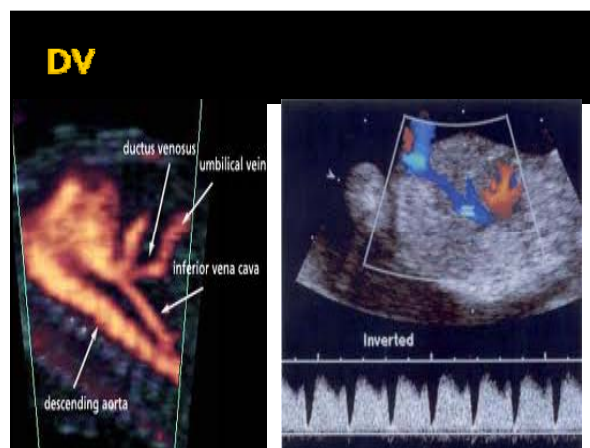
- In IUGR this transformation of the spiral arterioles does not occur and low flow high resistance persists, leading to placental bed infarction and further decrease in supply

Placental Resistance

- When more than 30% of the villi are abnormal the umbilical artery S/D are elevated
- When 60-70% of the villi are abnormal there is absent diastolic flow. High perinatal mortality.

Ductus venosus

- Abnormal DV dopplers are considered predictive of poor fetal outcome including mortality
- Narrow vessel, in the liver, that shunts the majority of oxygenated blood flow from the umbilical vein into the IVC, right atrium. FO, left heart, brain. (Venturi effect)
- Connects the left hepatic vein to the IVC. Closes after birth becomes the ligament venosum



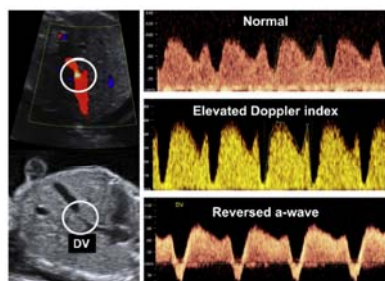
Abnormal Dopplers

- Redistribution of blood flow through the ductus venosus precedes the onset of decrease in liver blood flow and the decrease in AC
- Absent or reversed a wave in the DV is preterminal
- Neurodevelopmental delay at age 2 yrs correlates with GA at delivery, birth weight and reversed flow in the umbilical artery

GRIT

DV

- The a wave is the atrial contraction
- With increased resistance against the atrial contraction(placenta pathology) the 'a' wave is depressed and is reversed with right side heart failure.



DV

- The DV doppler may be abnormal in aneuploidy (80% with DS), CDH (Atresias: PS or PA), AV malformations (vein of Galen),TTTS

IUGR

- Timing of Delivery controversial.
- Could Doppler abnormalities help in timing of delivery?
- Most studies support a sequence of deterioration of the Doppler studies in most but not all fetuses. Different fetuses have differing CV profiles . The etiology of the IUGR and the gestational age of the matters.

- The sequence of changes in Doppler and biophysical parameters as severe fetal growth restriction worsens⁺

• A. A. Baschat^{1,2}, U. Gembruch³, C. R. Harman³
 Ultrasound in Obstetrics & Gynecology
 Volume 18, Issue 6, pages 571-577, December 2001

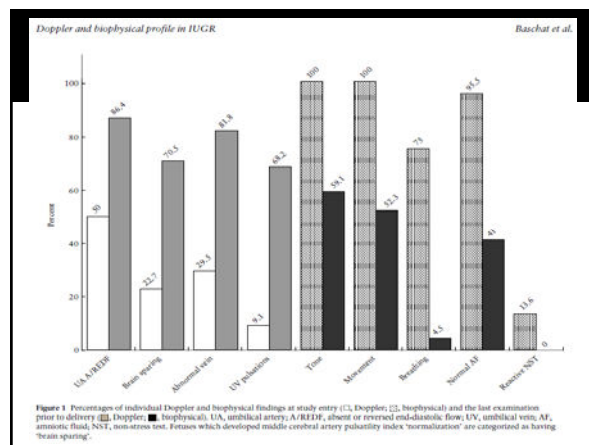
Sequence of Doppler and BPP

- 236 fetuses
- Criteria for entry: Elevated PI of the umbilical artery, AC <5%ile at entry, BW <10%ile, BPP at less than 6 before delivery, normal fetus, no immediate indication for delivery

- Average age at entry 25 weeks, Average age at delivery 29 6/7 weeks
- Median interval of performance of BPP and Doppler's 1.5 days, duration of testing from 6-69 days, average 21 days

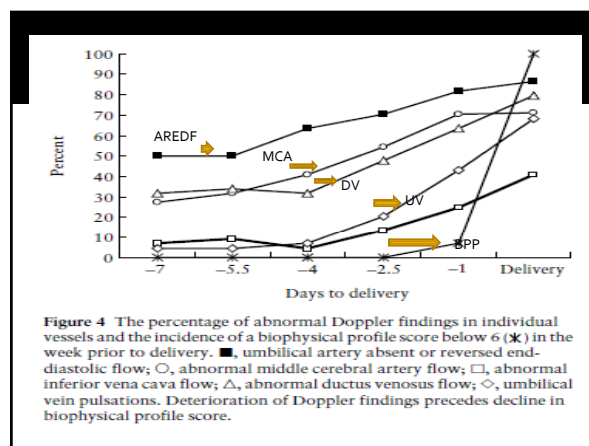
At Entry

- At entry 100% had an elevated umbilical artery PI (prerequisite for inclusion) 50% had absent or reversed flow, all fetuses had BPP above 6 at entry, with fluid, tone, movement maintained, breathing present in 75% and NST reactive in only 13%
- 22.7% already had MCA brain sparing, 30% had abnormal venous indices



First Observation

- Hemodynamic changes preceded deterioration of biophysical testing in most fetuses with IUGR



Sequence of behavioral deterioration

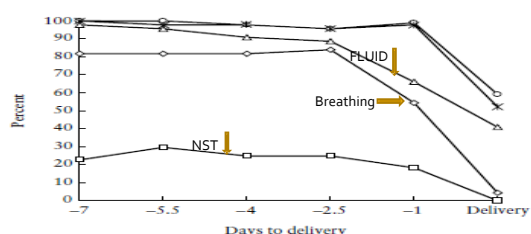


Figure 3 Presence of individual biophysical components during the last week prior to delivery: normal tone (○), normal movement (✱), breathing (◊), normal amniotic fluid (Δ) and reactive non-stress test (◻). All fetuses had a non-reactive non-stress test. Fetal breathing, amniotic fluid volume, tone and movement were sequentially lost prior to delivery.

Second Observation

- Sequential cardiovascular deterioration
Whereas the assumption is that there is a sequential deterioration of the umbilical, followed by brain sparing and then by venous deterioration this is not so in clinical practice

Conclusions

- Deterioration in all vascular beds occurred only in 70% by the time delivery occurred and deterioration in at least one parameter occurred in 90%
- Some fetuses "normalized" the brain sparing effect as clinical deterioration continued
- This sequence may not apply to fetuses above 32 weeks gestation

Ultrasound in Obstetrics & Gynecology
Volume 10, Issue 5, pages 571-577, December 2001

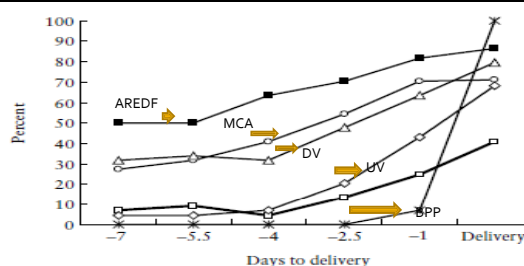


Figure 4 The percentage of abnormal Doppler findings in individual vessels and the incidence of a biophysical profile score below 6 (✱) in the week prior to delivery. ■, umbilical artery absent or reversed end-diastolic flow; ○, abnormal middle cerebral artery flow; Δ, abnormal inferior vena cava flow; ◊, abnormal ductus venosus flow; ◻, umbilical vein pulsations. Deterioration of Doppler findings precedes decline in biophysical profile score.

Conclusions

- Which system to use? Doppler or fetal surveillance?
- Doppler deterioration calls for increased surveillance and preparation for delivery
- When both systems deteriorate, delivery is indicated
- The most common earliest deterioration in fetal testing occurs with NST and breathing

Sequence of CV Deterioration

- Fetal cerebral blood flow redistribution in late gestation: identification of compromise in small fetuses with normal umbilical artery Doppler

R. HERSHKOVITZ, J.C.P. KINGDOM, M. GEARY and C.H. RODECK
Fetal Medicine Unit, Department of Obstetrics and Gynaecology, University College Hospital, London, UK
Ultrasound Obstet Gynecol 2000; 15: 209±212

Results

- 47 fetuses with IUGR > 35 weeks gestation
- Sixteen (34%) demonstrated middle cerebral artery deterioration of which nine (56%) had normal umbilical artery Doppler waveforms
- MCA blood flow redistribution was associated with an increased incidence of cesarean delivery and need for neonatal admission.

Fetal brain Doppler to predict cesarean delivery for nonreassuring fetal status in term small-for-gestational-age fetuses.

- 210 term small-for-gestational-age fetuses with normal umbilical artery Doppler and 210 control participants matched by gestational age.
- a significant higher incidence of cesarean delivery (37.6% compared with 19.5%)
- nonreassuring fetal status (29% compared with 4.8%, $P < .001$),
- neonatal acidosis (7.6% compared with 2.4%, $P = .03$)

Obstet Gynecol. 2011 Mar;117(3):618-26. Cruz-Martinez R, Figueras F, Hernandez-Andrade E, Oros D, Gratacos E.

Conclusion

- Normal umbilical artery S/D ratios may give false reassurance of fetal well being and have proven ineffective in preventing late gestation fetal death > 34 weeks

Obstet Gynecol. 2011 Mar;117(3):618-26. Cruz-Martinez R, Figueras F, Hernandez-Andrade E, Oros D, Gratacos E.

GRIT

- Randomized trial
- Compromised fetuses 24-36 weeks, n 588
- Two groups, immediate delivery (after 48 hrs of steroids), versus delayed
- Dopplers recorded
- Neurodevelopment delay at age 2 yrs correlates with GA at delivery, birth weight and reversed flow in the umbilical artery

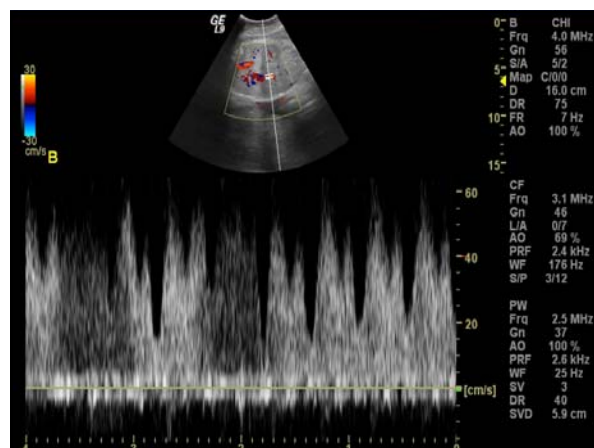
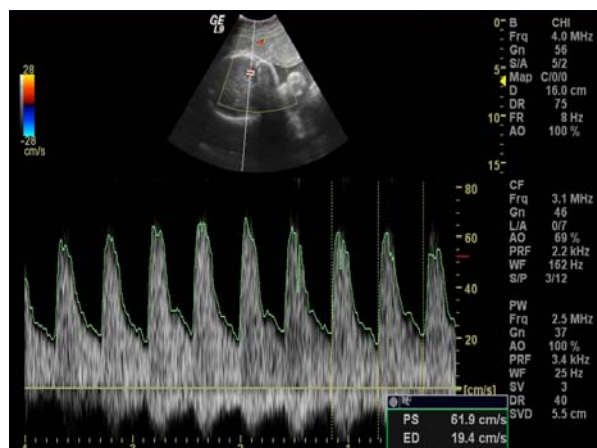
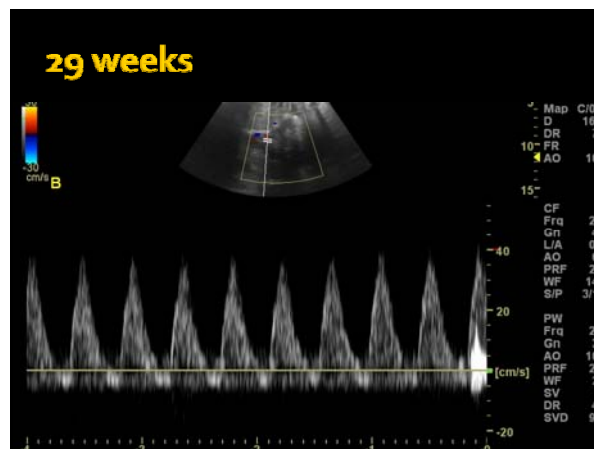
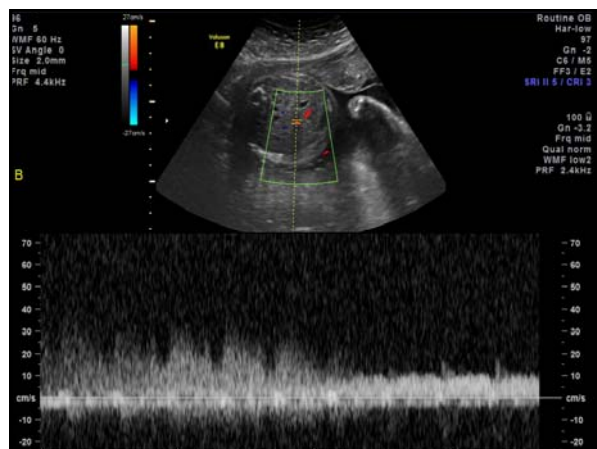
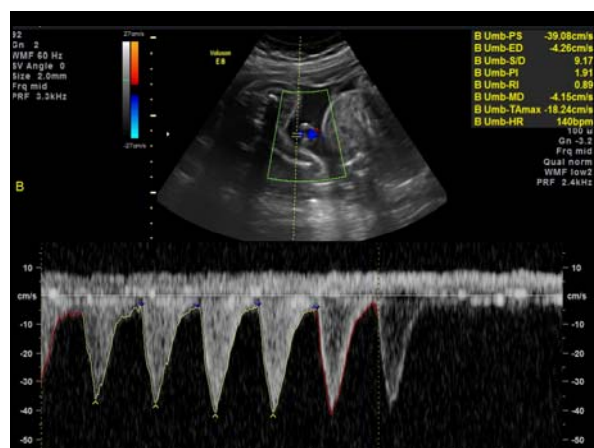
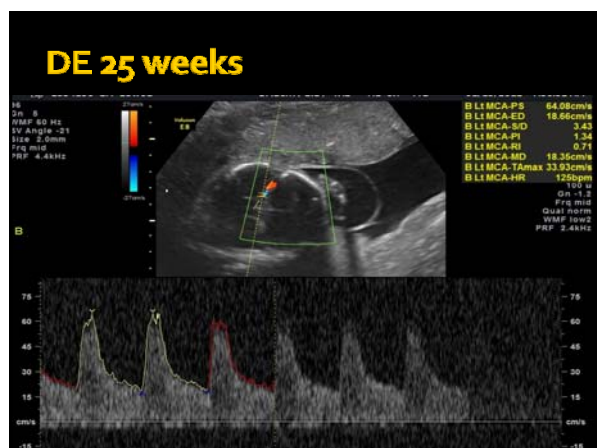
BJOG: an International Journal of Obstetrics and Gynaecology
January 2003, Vol. 110, pp. 27-32

Case 1

- 28 yr old primigravida, type 1 DM, di-di twin gestation with a 41% growth discordance detected at 20-25 weeks gestation started at 21 % at 21 weeks
- Abnormal dopplers of the IUGR twin (increased S/D ratios and centralization of flow)
- Admitted at 28 weeks due to progression of the abnormal dopplers to absent diastolic flow, steroids for FLM, mild preeclampsia diagnosed
- Delivered for severe preeclampsia 29 weeks with reversed diastolic flow

Case 1

- Twin A Apgar scores of 8 and 9, weight 1590 grams. Twin B Apgar scores of 8
- and 9, weight 930 grams.
- Placenta: Twin B two vessel cord only. No infarcts

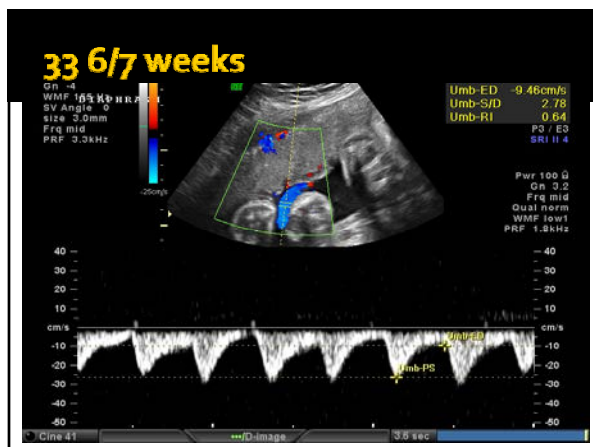


Case 2

- 21 yr old g2 po, pregnancy
- Previous pregnancy complicated by abruption at 17 weeks with IUFD, size 15-16 weeks
- Poor weight gain, lag in fundal height at 34 weeks, U/S with EFW 25%ile, AC <5%ile
- F/U at 36 weeks with EFW <10%ile, Abnormal MCA but normal UA dopplers
- Induced at 37 5/7 weeks, Apgars 8,9, 2435gr, hypoglycemia transient. D/C home DOL2

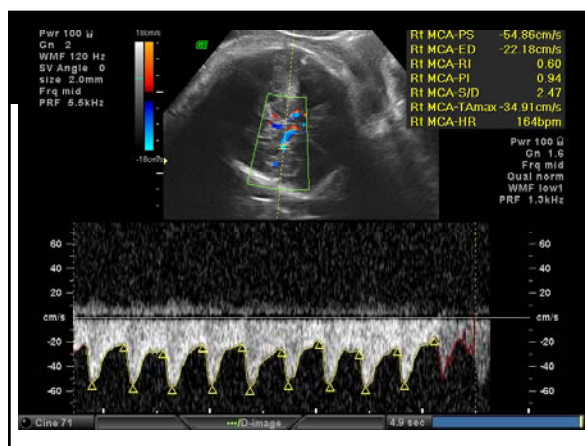
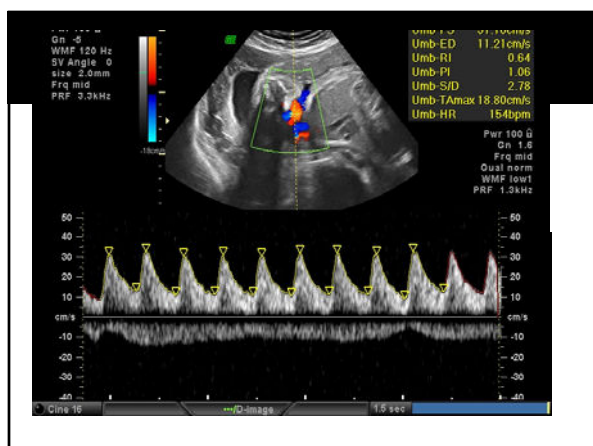
AS Case 2

Indication	Sex	Female	Sonogr.	RR
LMP	GA(EDD)	33w6d	EDD	04/11/2012
DOC	GA(AIA)	33w3d	EDD(AIA)	04/14/2012
EFW (Hadlock)	Value	Range	Age	Range
AC/BPD/FL/HC	1999g (4lb7oz)	+292g	32w2d	Williams 25.5%
2D Measurements	ALIA	Value	m1	m2
BPD (Hadlock)	✓	8.40 cm	8.24	8.49
OFD (HC)	✓	10.94 cm	10.81	10.96
HC (Hadlock)	✓	31.20 cm	30.57	31.31
AC (Hadlock)	✓	27.51 cm	27.04	27.57
FL (Hadlock)	✓	6.30 cm	6.10	6.52
2D Measurements	Value	m1	m2	m3
AFI				
O1	2.31 cm	2.31		
O2	2.06 cm	2.06		
O3	4.24 cm	4.24		



36-37 weeks

Indication	Sex	Female	Sonogr.	MG
LMP	GA(EDD)	36w2d	EDD	04/11/2012
DOC	GA(AIA)	34w1d	EDD(AIA)	04/26/2012
EFW (Hadlock)	Value	Range	Age	Range
AC/BPD/FL/HC	2196g (4lb13oz)	+321g	33w1d	Williams <10.0%
2D Measurements	ALIA	Value	m1	m2
BPD (Hadlock)	✓	8.74 cm	8.74	
OFD (HC)	✓	10.90 cm	10.90	
HC (Hadlock)	✓	31.31 cm	31.31	
AC (Hadlock)	✓	28.94 cm	28.94	
FL (Hadlock)	✓	6.43 cm	6.43	
2D Measurements	Value	m1	m2	m3
AFI				
O1	4.73 cm	4.73		
O2	2.35 cm	2.35		
O3	2.71 cm	2.71		



Newborn

- Placenta with calcifications
- Baby newborn weight 3-10%ile

Case 3

- 39 yr old G2Po, first seen at 21 weeks gestation, referred for renal pelviectasis. U/s with slight lag in FL and bilateral pelviectasis. MSS
- 30 weeks with bi;lateral pelviectasis EFW 23%ile and FL 19%ile but AC was 7%ile Doppler studies done intermittent absence of the a wave in the DV and normal UA and MCA
- 32 weeks EFW < 5%ile
- 37 weeks EFW 7%ile
- IUFD at 39 weeks

Case 3

- Placenta: fibrinoid necrosis, infarction calcifications, acute hemorrhage, acute and chronic inflammation, eccentrically attached umbilical cord
- Fetal microarray analysis and photographs sent for DR Shaeffer to evaluate. No results yet

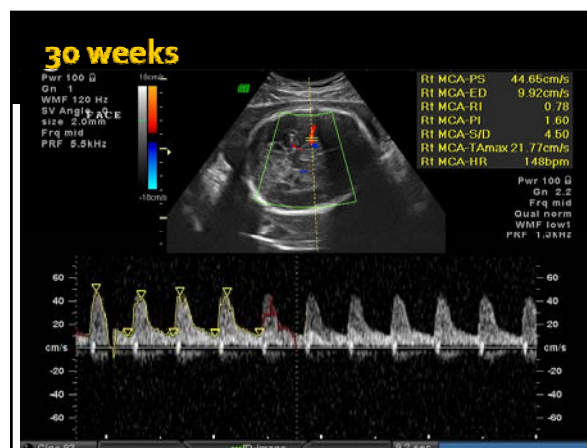
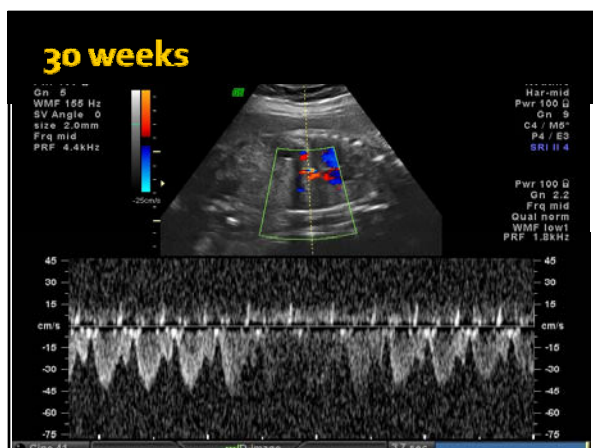
30 weeks

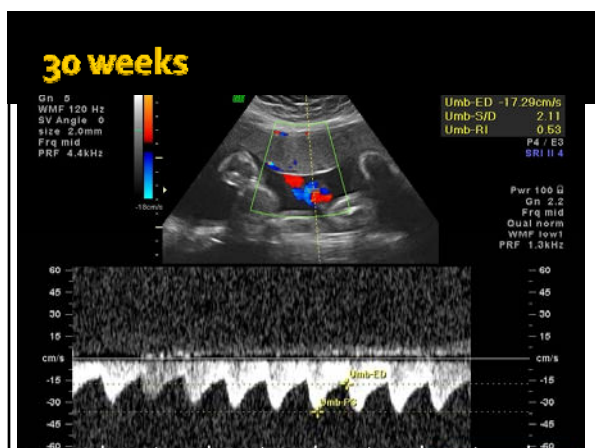
LMP	05/25/2011	GA(LMP)	30w1d	EDD(LMP)	02/29/2012	G	2	Ab
DOC		GA(AM)	29w6d	EDD(AM)	03/02/2012	P	1	Ec

EFW (Hadlock)	Value	Range	Age	Range	Growth
AC/BPD/FL/HC	1351g (3lb8oz)	+ 198g	29w6d		Williams 36.9%

2D Measurements	ALIA	Value	m1	m2	m3	Meth.	Age	Range	Dev.
BPD (Hadlock)	✓	7.68 cm	7.68			avg.	30w6d	29w14.3d-30w1d	59.3%
OFD (HC)		9.72 cm	9.72			avg.			
HC (Hadlock)	✓	27.98 cm	27.98			avg.	30w1d	29w14.3d-30w1d	25.4%
AC (Hadlock)	✓	24.31 cm	24.24	24.38		avg.	28w1d	27w34.29w5d	8.4%
FL (Hadlock)	✓	5.61 cm	5.61			avg.	29w1d	28w1d-30w6d	19.2%

3D Measurements	Value	m1	m2	m3	m4	m5	m6	Meth.
AFI								
Q1	1.95 cm	1.95						avg.
Q2	4.78 cm	4.78						avg.
Q3	1.48 cm	1.48						avg.





Ref. Phys. AHEC JONESBORO
Sonogr. KRISTEN

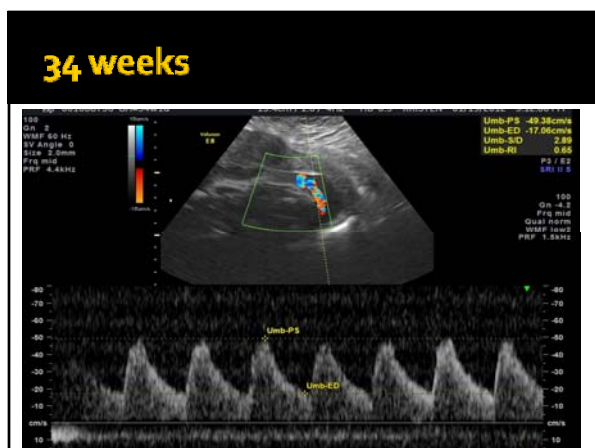
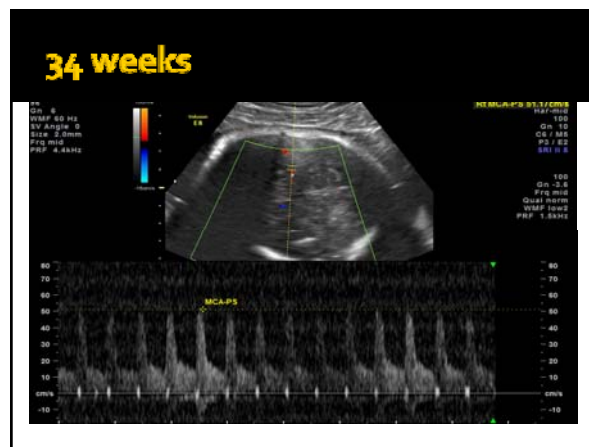
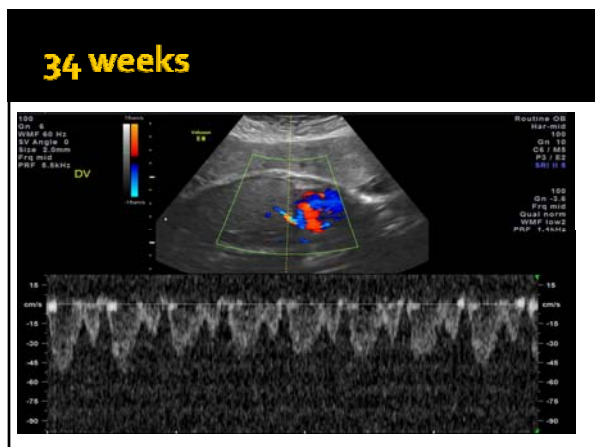
Indication: _____

LMP 05/25/2011 GA(LMP) 34w1d EDD(LMP) 02/29/2012 G 2 Ab
DOC _____ GA(AUA) 32w1d EDD(AUA) 03/14/2012 P 1 Ec

EFW (Hadlock)	Value	Range	Age	Range	GP	Hadlock
AC/BPD/FL/HC	1772g (3lb15oz)	± 259g				<3.0%

2D Measurements	AUA	Value	m1	m2	m3	Meth.	Age
BPD (Hadlock)	✓	7.95 cm	8.00	7.90		avg.	3.6% 31w6d
OFD (HC)		10.68 cm	10.58	10.79		avg.	
HC (Hadlock)	✓	29.82 cm	29.61	30.02		avg.	3.4% 33w0d
AC (Hadlock)	✓	25.31 cm	25.63	24.99		avg.	<2.3% 29w4d
FL (Hadlock)	✓	6.58 cm	6.64	6.52		avg.	33.8% 33w6d

2D Measurements	Value	m1	m2	m3	m4	m5	m6	Meth.
Uterus								
Cervix Length	4.04 cm	4.04						avg.
AFI								
Q1	4.86 cm	4.86						avg.



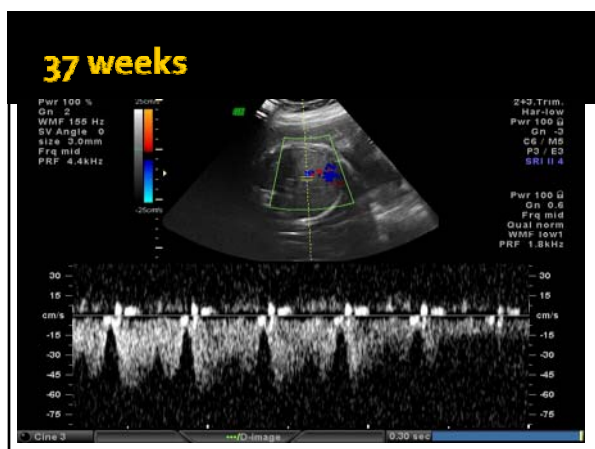
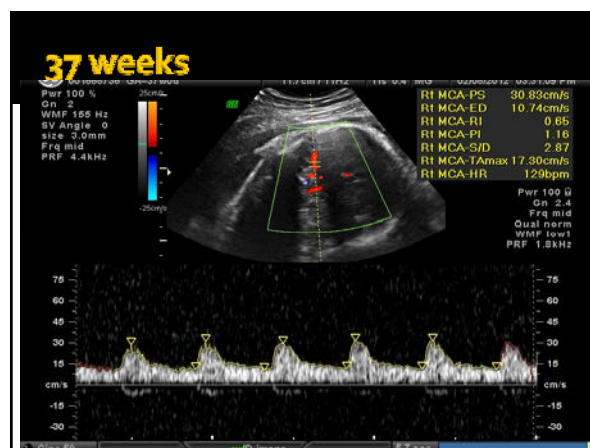
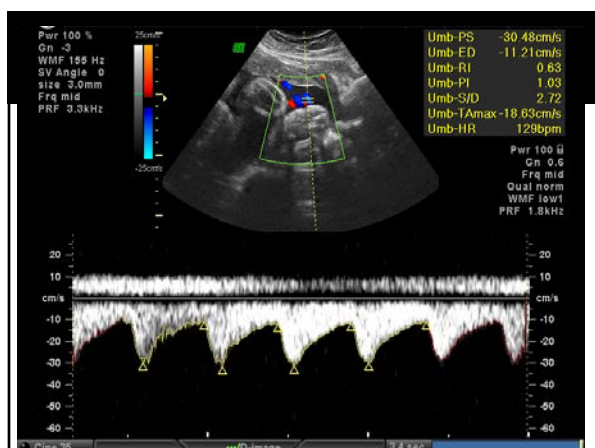
Indication: _____ Sex: Female Sonogr. MG

LMP 05/25/2011 GA(LMP) 34w1d EDD(LMP) 02/29/2012 G 2 Ab
DOC _____ GA(AUA) 35w1d EDD(AUA) 03/14/2012 P 0 Ec

EFW (Hadlock)	Value	Range	Age	Range	Growth
AC/BPD/FL/HC	2439g (5lb6oz)	± 356g	34w2d		Williams <10.8%

2D Measurements	AUA	Value	m1	m2	m3	Meth.	Age	Range	Dev.
BPD (Hadlock)	✓	8.82 cm	8.51		8.74	avg.	35w5d	34w3d-36w6d	28.8%
OFD (HC)		10.85 cm	*	10.50	11.21	avg.			
HC (Hadlock)	✓	31.87 cm	*	31.41	32.27	avg.	35w6d	32w6d-38w6d	7.2%
AC (Hadlock)	✓	29.76 cm	*	29.76		avg.	33w6d	32w6d-34w6d	<2.8%
FL (Hadlock)	✓	6.79 cm	*	6.79		avg.	34w6d	33w4d-36w2d	7.1%

2D Measurements	Value	m1	m2	m3	m4	m5	m6	Meth.
AFI								
O1	3.83 cm	3.83						avg.
O2	4.64 cm	4.64						avg.
O3	6.83 cm	6.83						avg.



Doppler Application: Patterns of Deterioration

- Perinatal risk prediction based on umbilical artery doppler alone is inadequate. Gestational age affects the U/A. Each fetus may have a different CV profile
- The Cardiovascular (doppler) and behavioral (BPP) manifestations of fetal deterioration can occur independent of each other resulting in discordant Doppler and BPP findings

Abnormal Dopplers

- Redistribution of blood flow through the ductus venosus precedes the onset of decrease in liver blood flow and the decrease in AC
- Absent EDF in the u/a is ominous and reversed diastolic flow is preterminal
- Absent or reversed a wave in the DV is preterminal
- Neurodevelopmental delay at ge 2 yrs correlates with GA at delivery, birth weight and reversed flow in the umbilical artery