

Fetal Imaging of Multiple Gestations

Beth M. Kline-Fath, MD
Chief of Fetal Imaging
Associate Professor of Radiology
Cincinnati Children's Hospital Medical Center
University of Cincinnati



Fetal Care Center of Cincinnati

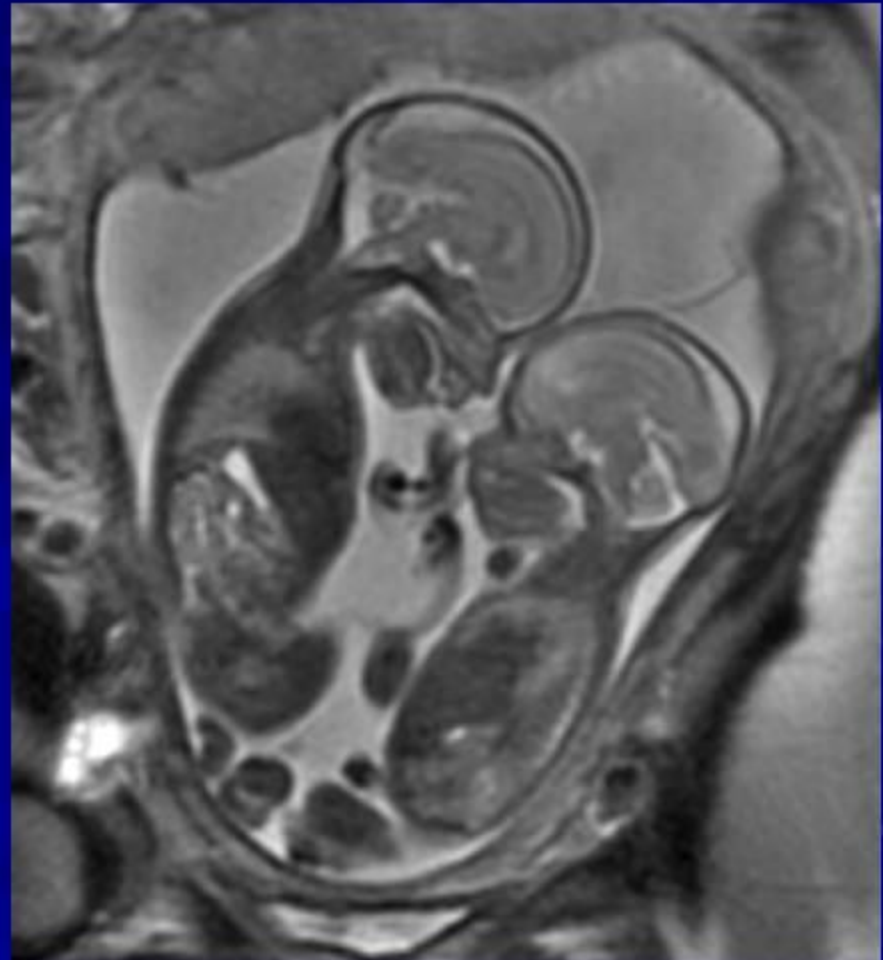
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**Cincinnati
Children's**
Hospital Medical Center

Multiple gestations

- 1-2% all births
- Steeply increased past 20 years
 - Assisted reproductive techniques
 - US 62% increase since 1980
- 10-14% perinatal mortality
 - 1/3 stillbirth
 - 2/3 neonatal
 - *Premature*



Multiple Gestation Data

Morbidity and mortality in multiple gestation

Characteristic	Twins
Average birth weight	2347 g
Average gestational age	35.3 wk
Percentage with growth restriction	14-25
Percentage requiring admission to neonatal intensive care unit	25
Percentage with major handicap	-
Risk of cerebral palsy	4 times more than singletons
Risk of death by age 1 year	7 times higher than singletons

Complicated twin, triplet, and high-order multifetal pregnancy. *Obstet Gynecol* 2004; 104:869

Zygotic Terminology

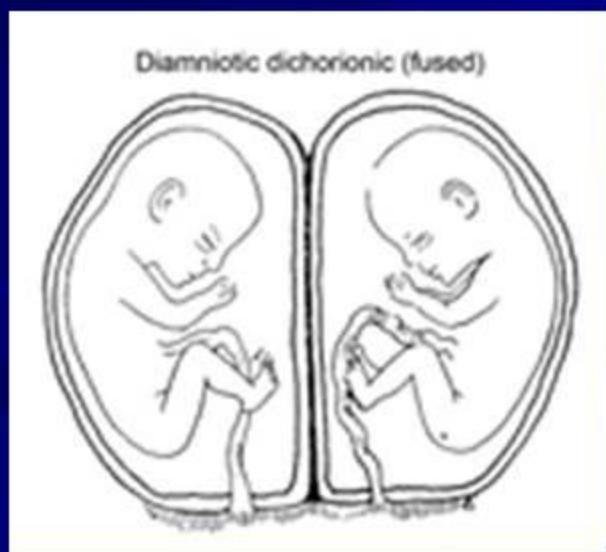
- Dizygotic (2/3 cases)
 - Fertilization of two or more oocytes
 - Fraternal
 - Variable
 - Family history (prior twin pregnancy)
 - Age (older age)
 - Race
- Monozygotic (1/3 cases)
 - Early embryonic splitting of single ovum
 - Identical
 - Constant
 - Independent of age, race, parity or heredity



Zygotic Nomenclature



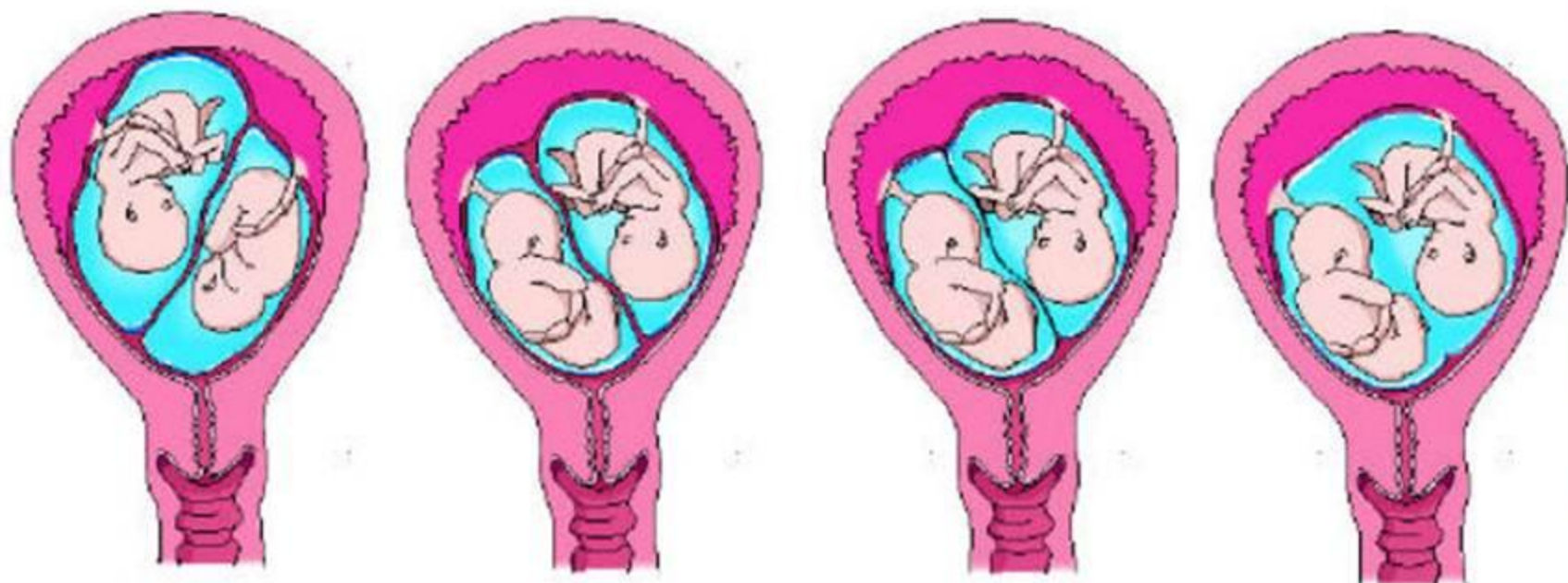
3-8 d



0-3 d



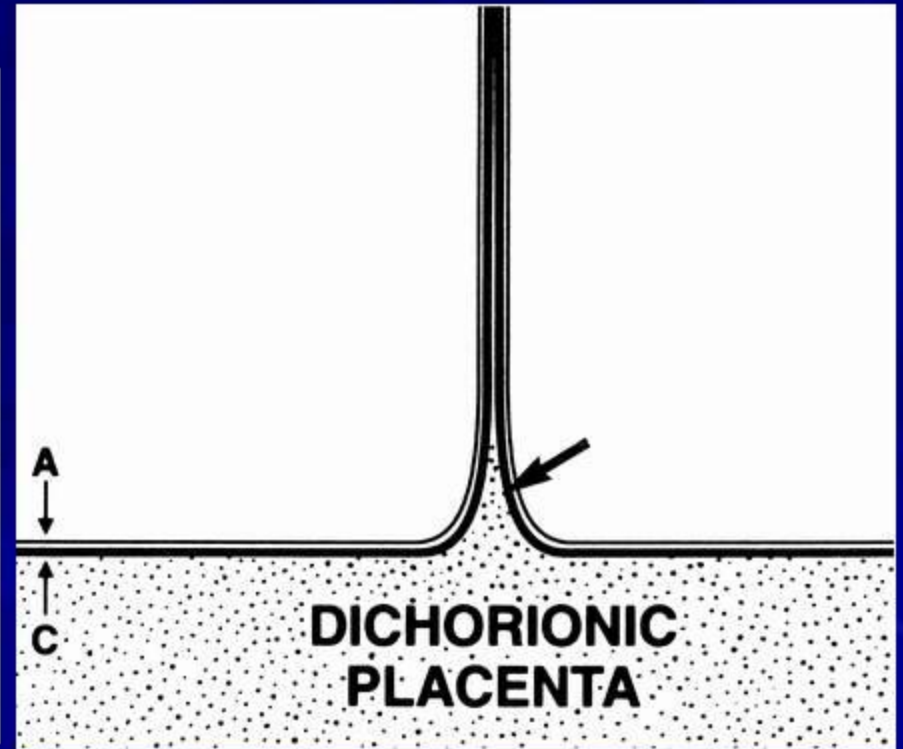
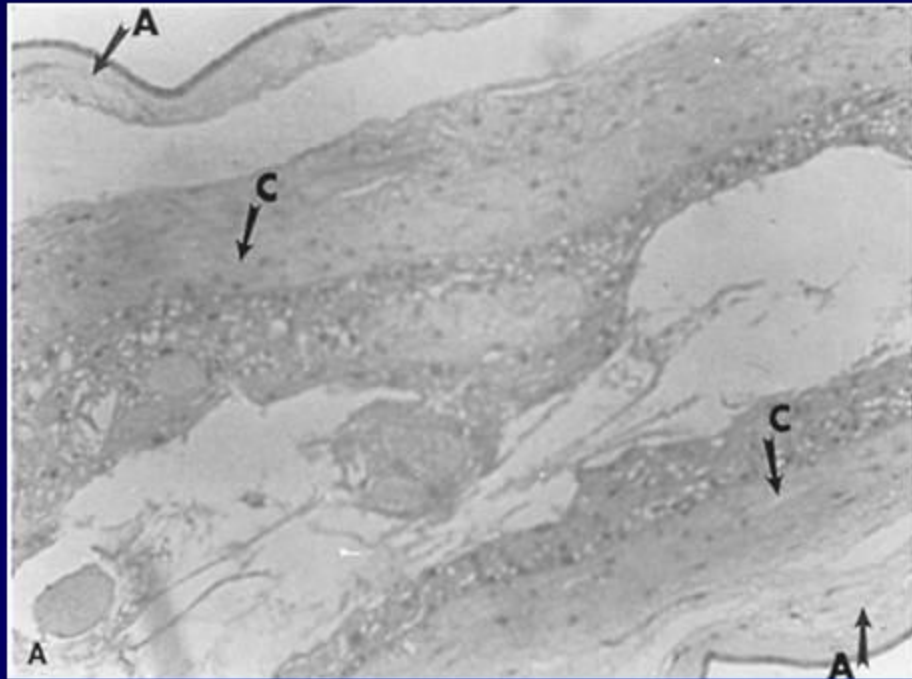
8-13 d



DiAmniotic DiChorionic Separate placentae	DiAmniotic DiChorionic Fused placentae	DiAmniotic MonoChorionic Single placenta	MonoAmniotic MonoChorionic Single placenta
Frequency: 35%	27%	36%	2%
Mortality: 13%	11%	32%	44%

Jeanty, P et al. Sonography of Multiple Gestations. The Fetus. Net 2000

Dichorionic

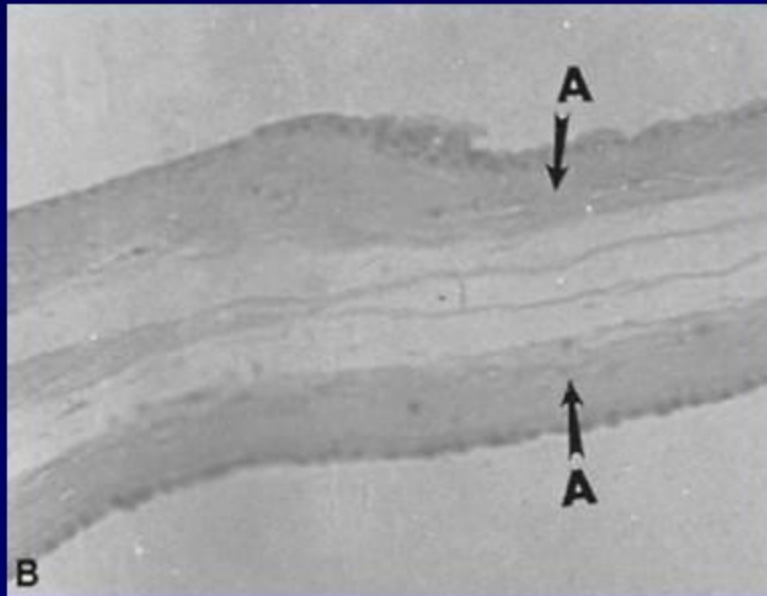


A= Amnion

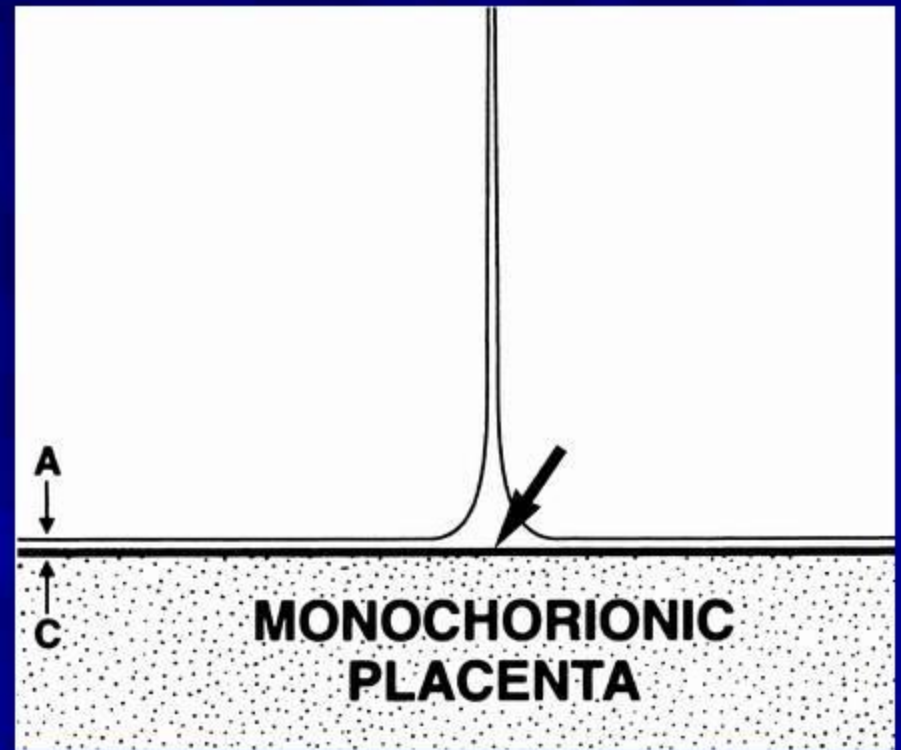
C=Chorion

Twin peak or Lambda
Thick intertwin membrane
Separate placentas

Monochorionic



A= Amnion
C=Chorion



T sign
Thin wispy membrane
One placenta

Determining Chorionicity

- Different sex
- Two separate placentas
 - Difficult later in gestation
- Appearance of the membrane
 - 5 weeks transvaginal
 - <14 weeks gestation



Outline of Monochorionic Pathology

73% twin intrauterine deaths

- *Congenital malformations*
- *Unequal sharing- placental insufficiency*
- *Vascular anastomosis*
 - Twin twin transfusion syndrome (TTTS)
 - Twin embolization syndrome (TES)
 - Twin reversed arterial perfusion syndrome (TRAP)
- *Monoamniotic*
 - Cord entanglement
 - Conjoined

CCHMC Monochorionic Imaging

- Ultrasound and Doppler
 - Umbilical artery (UA)
 - Umbilical vein (UV)
 - Ductus venosus (DV)
 - Middle cerebral artery (MCA)
- Fetal MRI
- Echocardiogram

Fetal MR Imaging

- >16 weeks GA
- Adjunct
 - Ultrasound
 - Suboptimal US
 - Fetal anatomy
 - Fetal anomalies/cranial
- Useful prior to fetal surgery
 - Pregnancy anatomy

Congenital Malformations

5% CCHMC

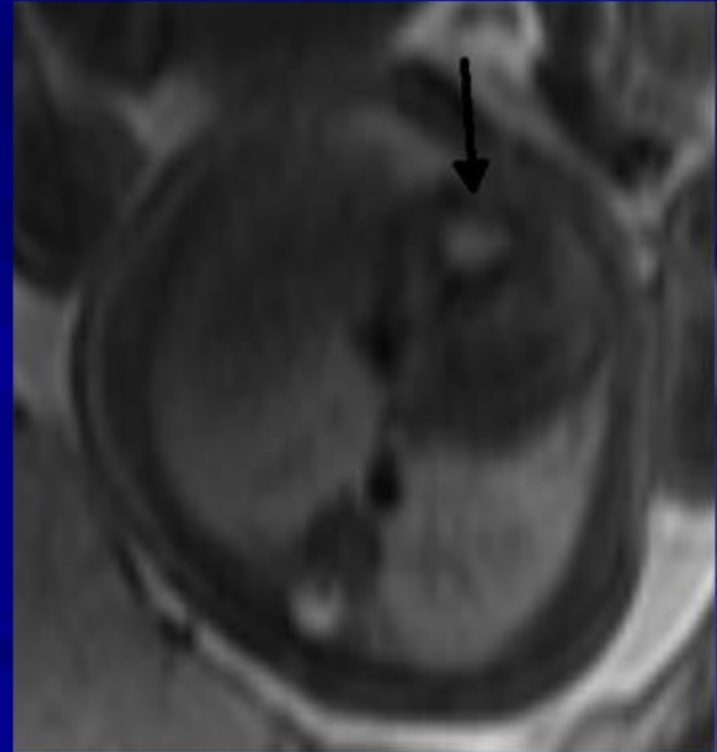
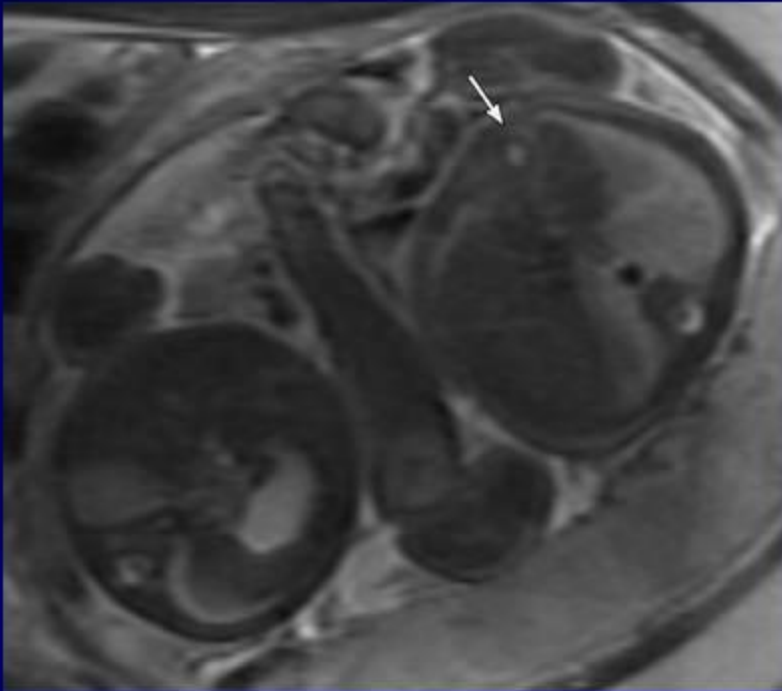
■ Chromosomal

- 15-20% (>singleton)
- Smaller twin
- Discordant major
- Concordant minor

■ Congenital anomalies

- Etiology
 - Crowding
 - Defect embryo splitting
 - Vascular compromise
- Twins 2.1% (singleton 1.2%)
- Monozygotic > dizygotic
 - 16.7% minor/major
 - Concordance 10-20%

Congenital Malformations



Placental Insufficiency

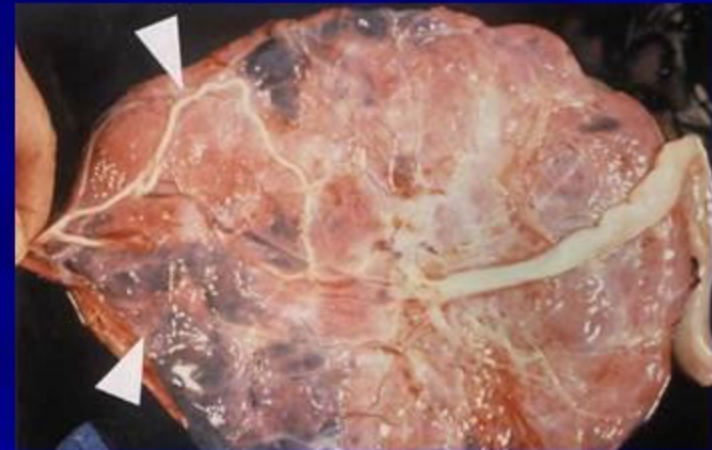
14% CCHMC

- Failure of the placenta to supply nutrients to fetus and remove toxic wastes
- 25% twin gestations
- Differential
 - Chromosomal/congenital anomalies
 - Infection (TORCH)

Placental Insufficiency

■ Causes

- Unequal placental sharing
- Velamentous cord insertion
 - 6-7 times > singleton
- Single UA
 - 3-4 times > singleton
- Inadequate uteroplacental interface
- Preeclampsia
 - 5-6 times > singleton



www.tttsfoundation.org/fig4

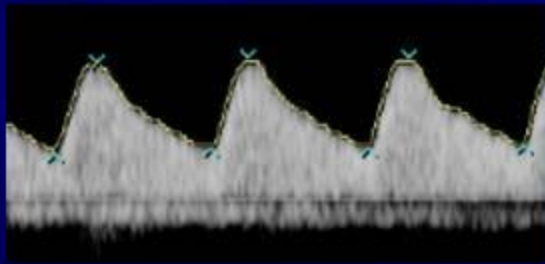
US Twin Placental Insufficiency

- Serial growth assessment
- >20% weight discordance
- abdominal circumference diverging >20mm
- Difference BPD > 6mm with smaller BPD < 2SD mean
- HC diverging > 5%
- Low amniotic fluid IUGR twin

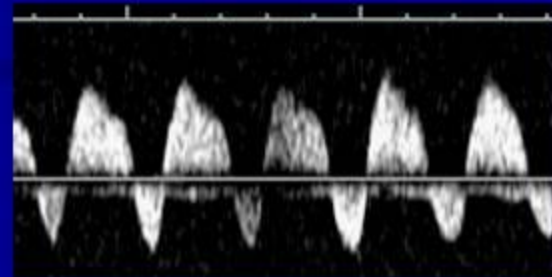
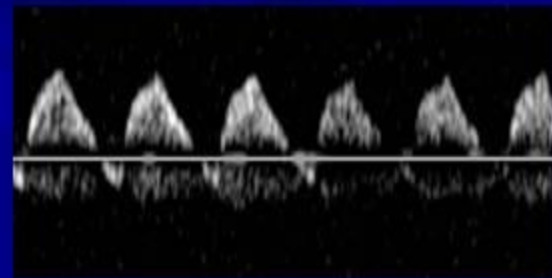
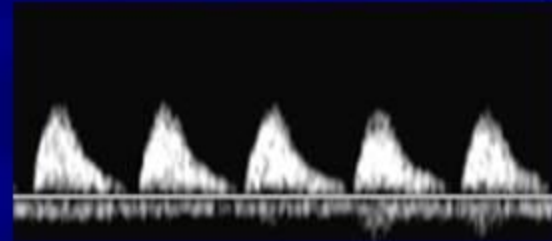
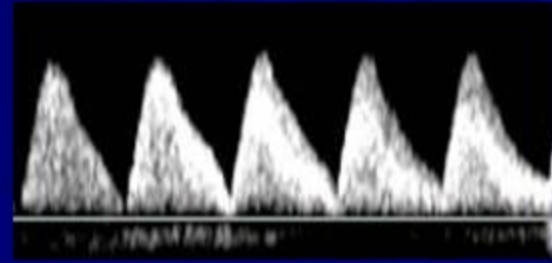
Placental Insufficiency Doppler

- Deteriorating placental circulation/ UA
 - Loss diastolic flow
 - UA S/D ratios discordant >15%
 - Elevated S/D ratio
- Deliberate redistribution of blood flow (brain sparing)/ MCA
- Cardiac compromise
 - DV –loss or reversal A wave
 - UV – pulsatile or reversed flow

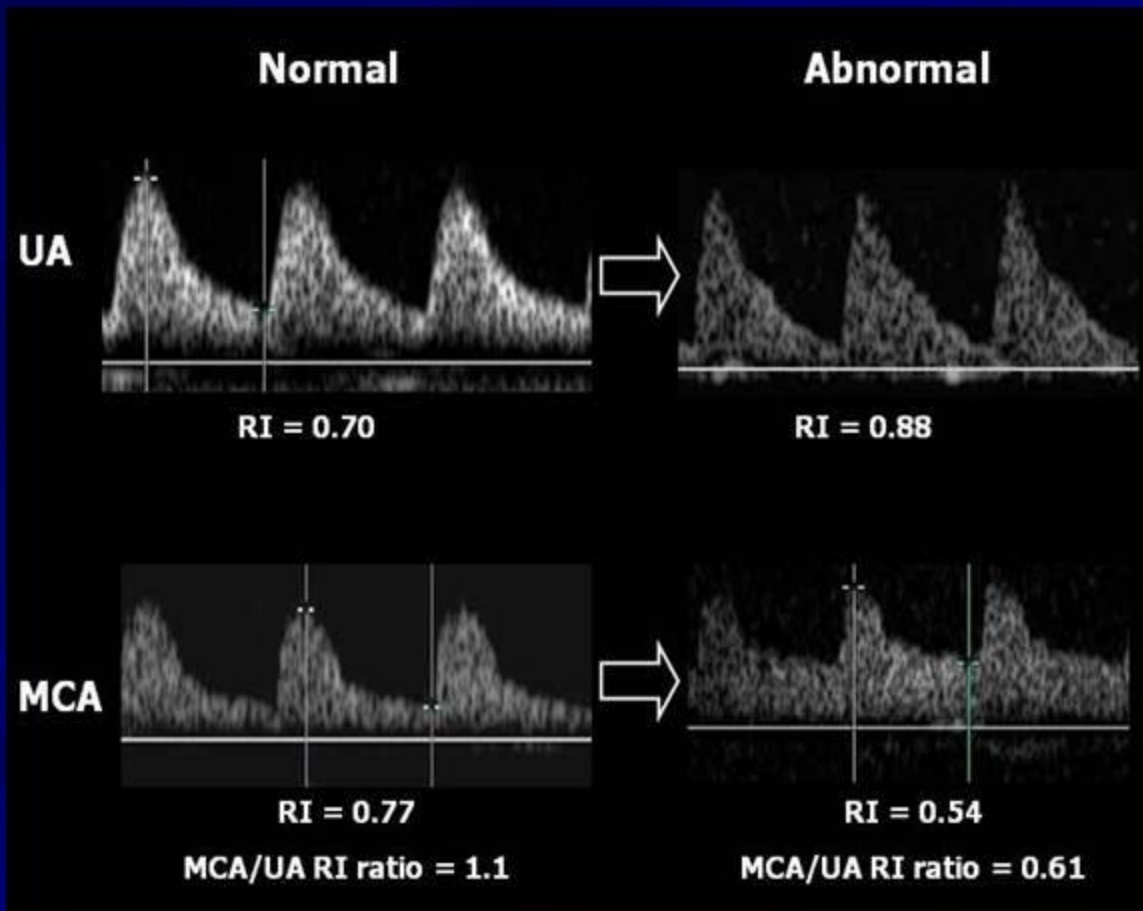
Umbilical Artery Doppler



Normal



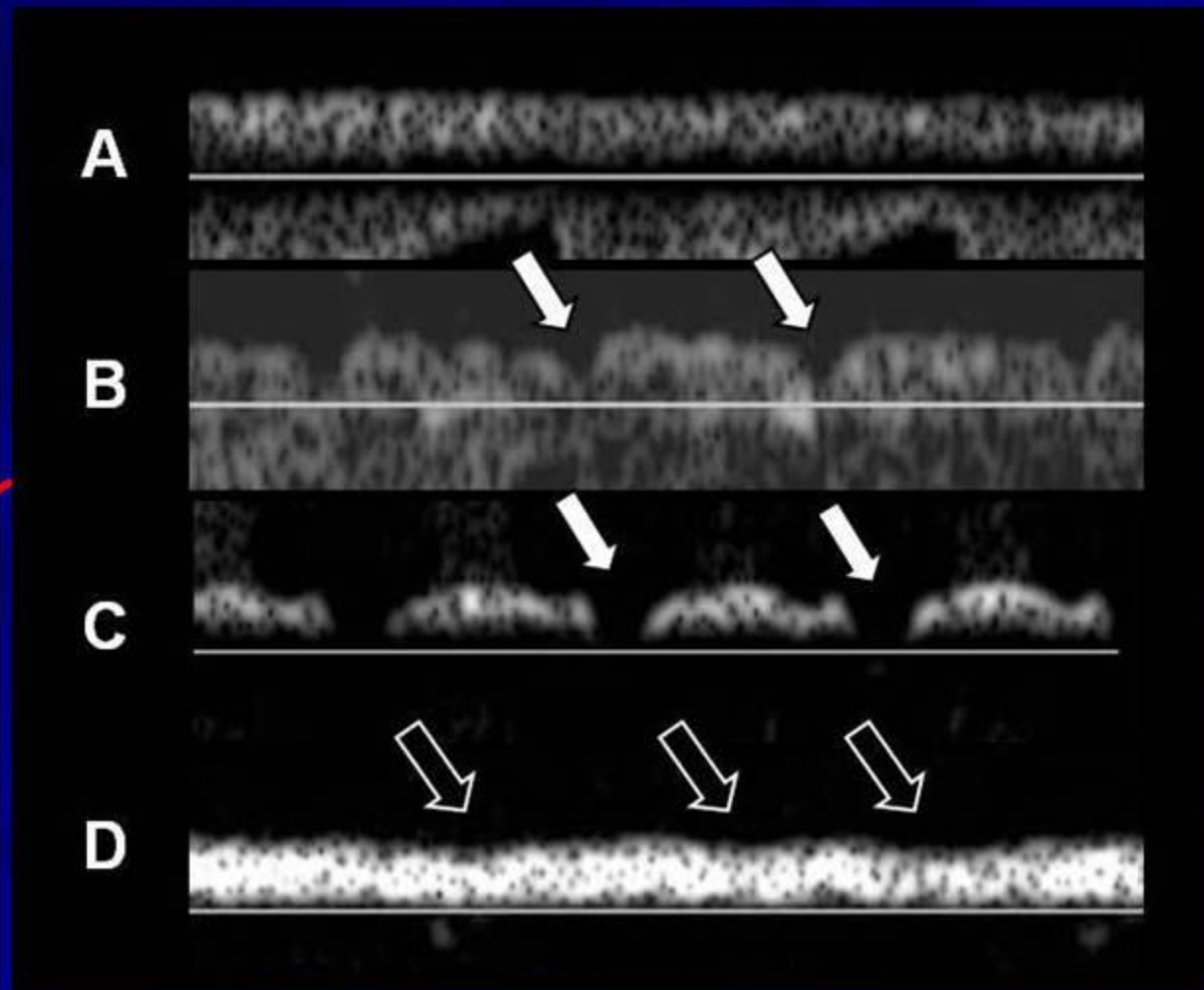
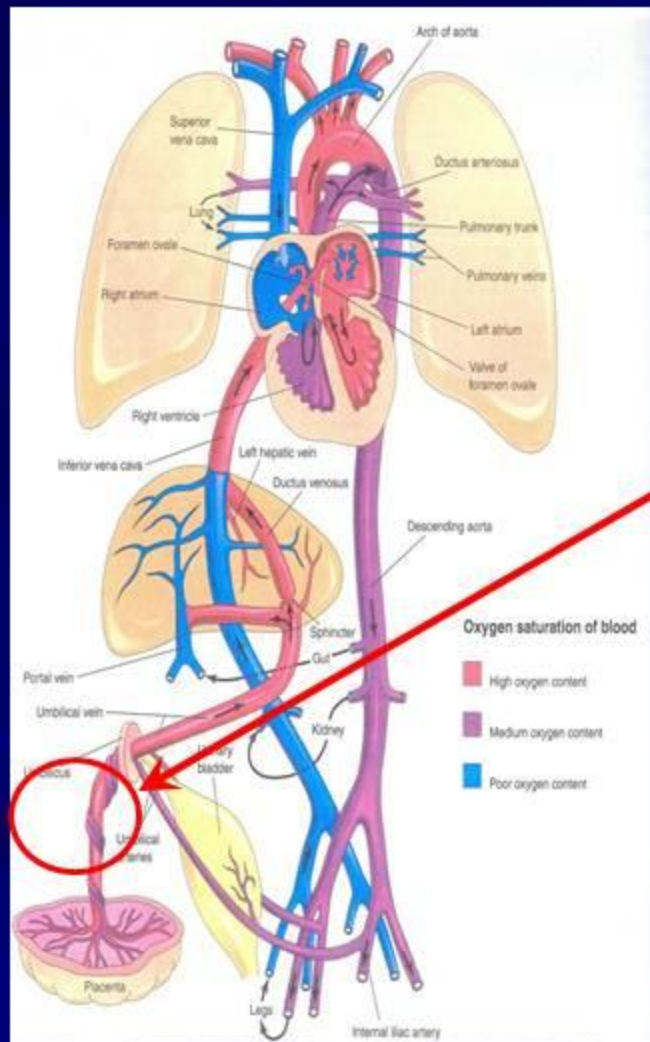
Redistribution of Cardiac Output



- IUGR
- CHD
- TTTs

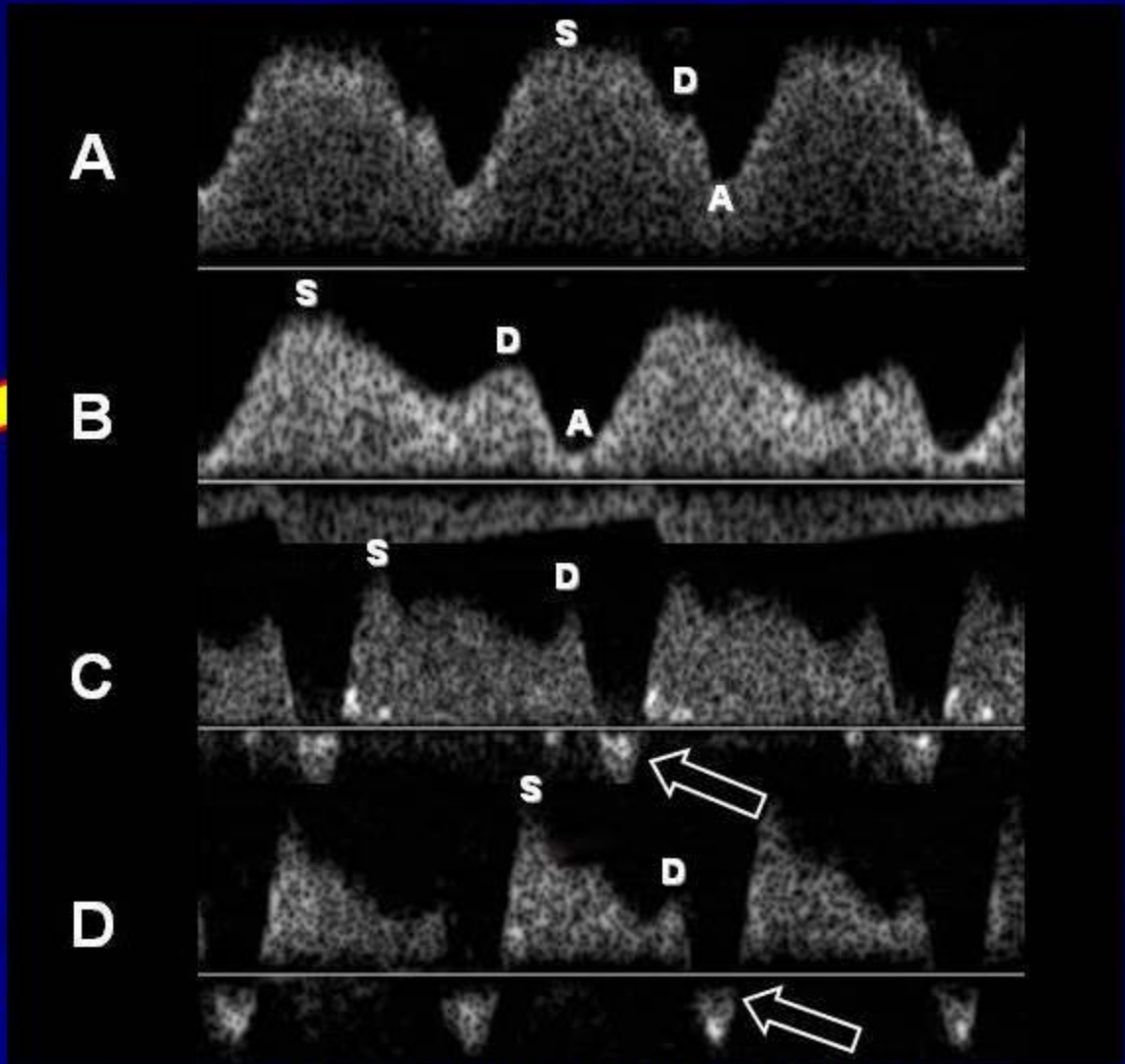
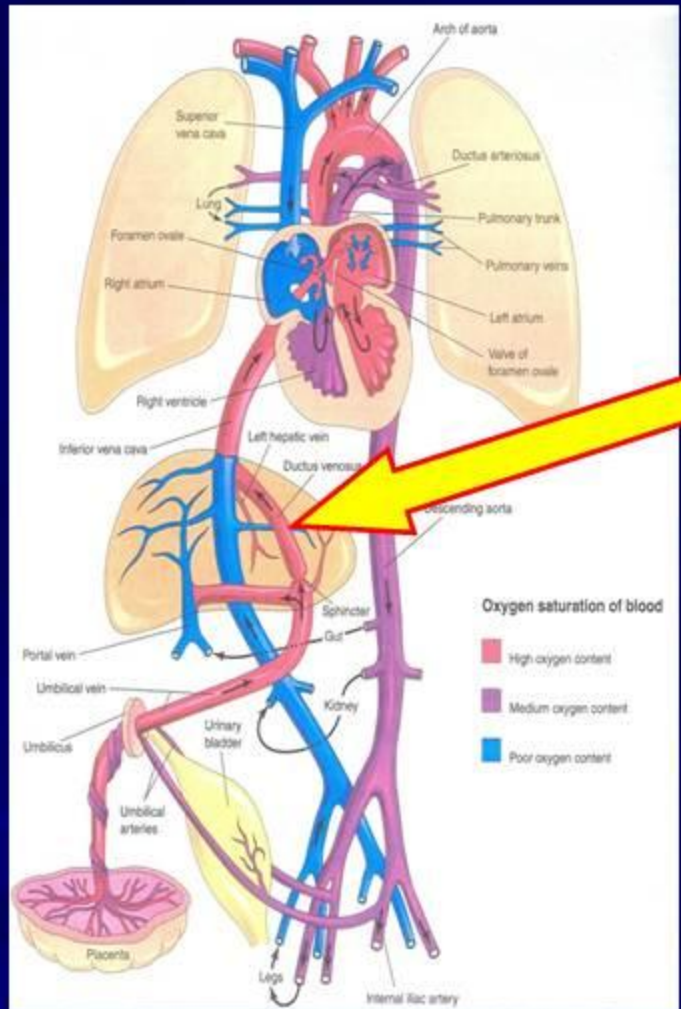
Courtesy Rick Michelfelder, MD

Umbilical Venous Doppler



Courtesy Rick Michelfelder, MD

Ductus Venosus Doppler



Courtesy Rick Michelfelder, MD

Placental Insufficiency

- Increased morbidity/mortality
 - Reduced physical/mental development
- Abnormal UA
 - Abdominal problems
- Abnormal UA and MCA
 - High risk
 - IVH
 - Long ICU admission
- Abnormal DV and UV
 - Stillbirth
 - High perinatal mortality

Fetus: A/2

LMP GA(EDD) 24w2d EDD 01/19/2008 G 1 Ab
 DOC GA(AUA) 24w5d EDD(AUA) 01/16/2008 P Ec

EFW (Hadlock)	Value	Range	Age	Range	Growth
AC/BPD/FL/HC	755g (1lb11oz)	+ 110g	24w5d		Williams 58.1%

2D Measurements	AUA	Value	m1	m2	m3	Meth.	Age	Range	Dev.
BPD (Hadlock)	<input checked="" type="checkbox"/>	6.07 cm	6.07			avg.	24w5d	22w4d-26w6d	58.6%
OFD (HC)		7.45 cm	7.45			avg.			
HC (Hadlock)	<input checked="" type="checkbox"/>	21.93 cm	21.93			avg.	24w0d	22w3d-25w3d	20.3%
HC* (Hadlock)	<input type="checkbox"/>	21.30 cm	21.30				23w3d	21w6d-24w6d	7.2%
AC (Hadlock)	<input checked="" type="checkbox"/>	20.68 cm	20.68			avg.	25w2d	23w0d-27w3d	71.6%
FL (Hadlock)	<input checked="" type="checkbox"/>	4.51 cm	4.51			avg.	24w6d	22w6d-27w0d	57.2%
HL (Jeanty)	<input checked="" type="checkbox"/>	4.00 cm	4.00			avg.	24w2d	21w4d-27w1d	40.0%
Cereb (Hill)	<input checked="" type="checkbox"/>	2.83 cm	2.83			avg.	24w0d	22w0d-26w0d	88.8%

2D Calculations

CI (BPD/OFD) 81% (70 - 86%) FL/BPD
 FL/HC (Hadlock) 21% (19 - 21%) FL/AC
 HC/AC (Campbell) 1.06 (1.05 - 1.21)

Fetus: B/2

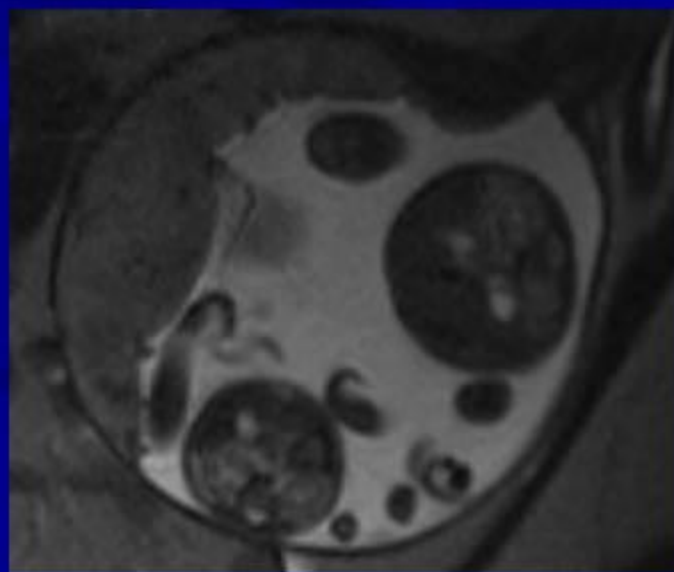
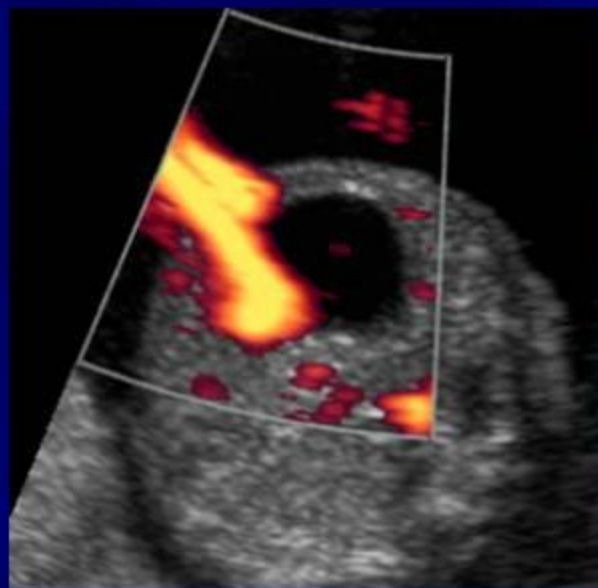
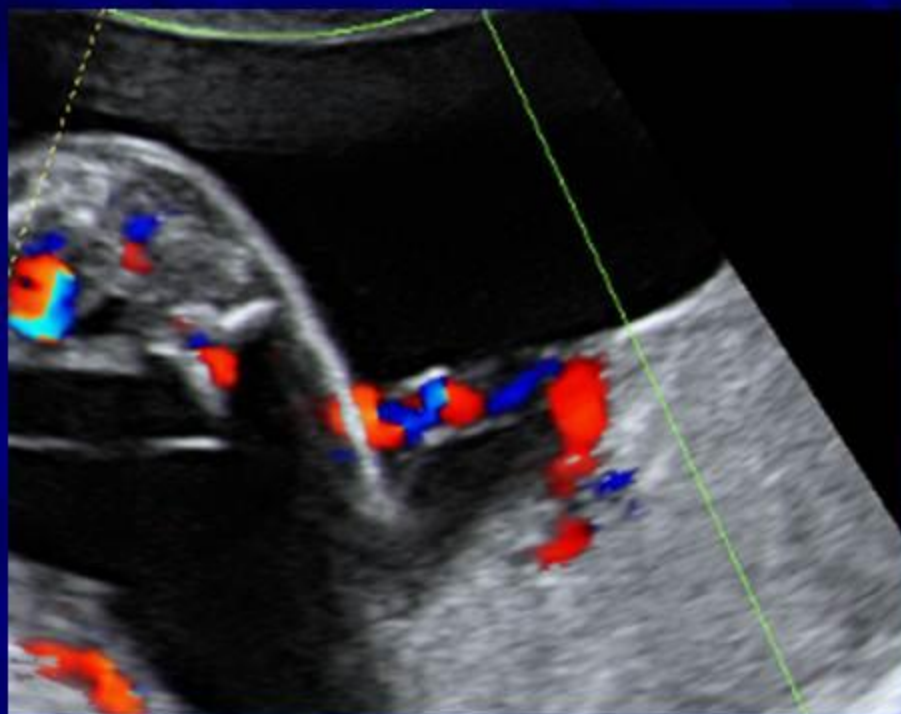
LMP GA(EDD) 24w2d EDD 01/19/2008 G 1 Ab
 DOC GA(AUA) 21w5d EDD(AUA) 02/06/2008 P Ec

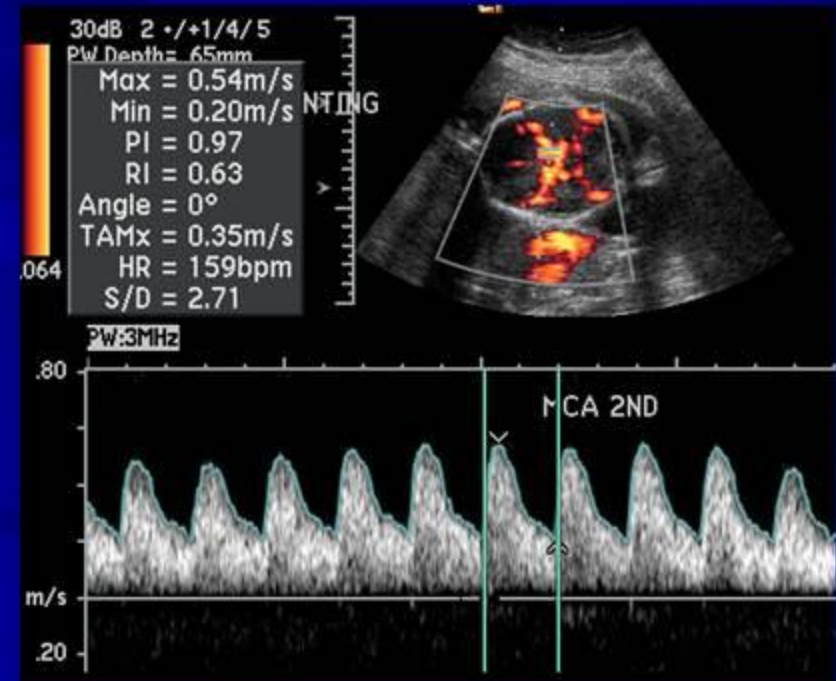
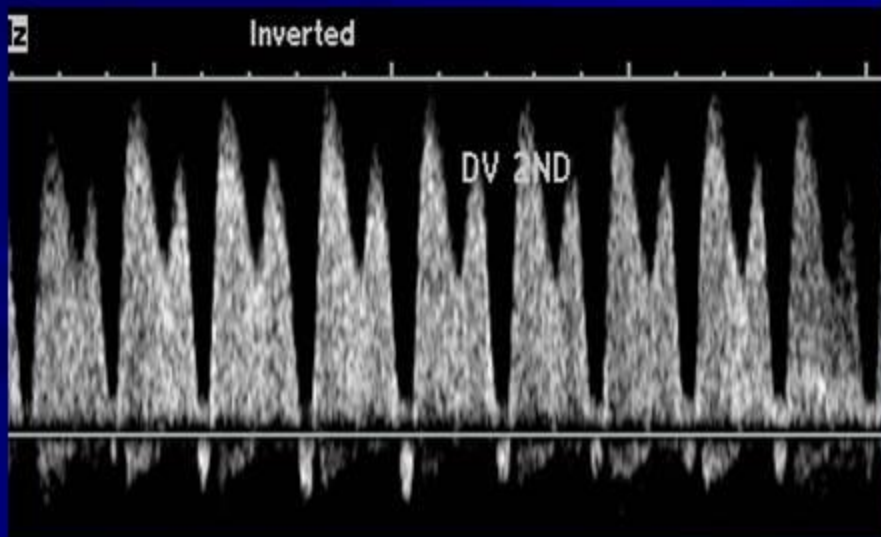
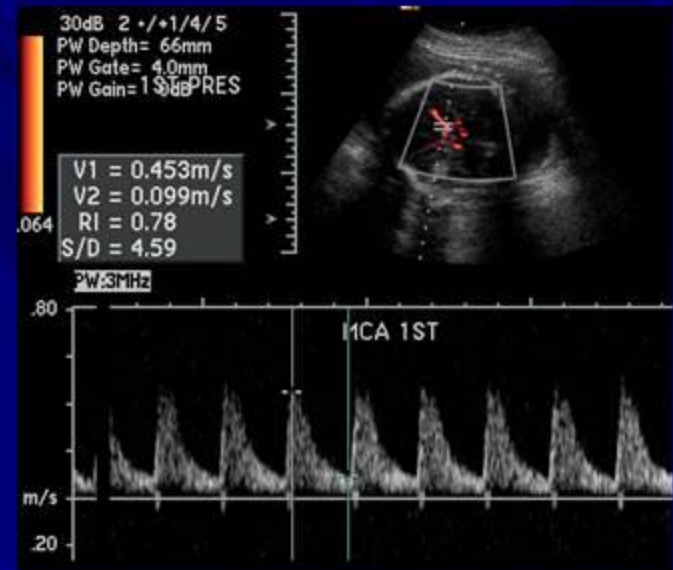
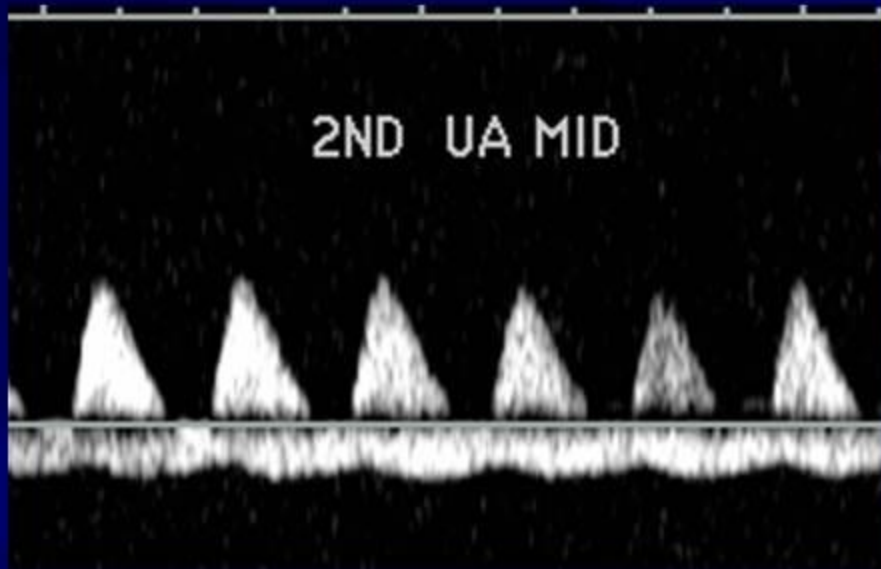
EFW (Hadlock)	Value	Range	Age	Range	Growth
AC/BPD/FL/HC	401g (14oz)	+ 59g	21w0d		Williams <10.0%

2D Measurements	AUA	Value	m1	m2	m3	Meth.	Age	Range	Dev.
BPD (Hadlock)	<input checked="" type="checkbox"/>	5.39 cm	5.39			avg.	22w3d	20w5d-24w d	<2.0%
OFD (HC)		6.89 cm	6.89			avg.			
HC (Hadlock)	<input checked="" type="checkbox"/>	19.75 cm	19.75			avg.	22w0d	20w3d-23w3d	<2.0%
HC* (Hadlock)	<input type="checkbox"/>	19.36 cm	19.36				21w4d	20w1d-23w1d	<2.0%
AC (Hadlock)	<input checked="" type="checkbox"/>	16.18 cm	16.18			avg.	21w2d	19w1d-23w2d	<2.0%
FL (Hadlock)	<input checked="" type="checkbox"/>	3.39 cm	3.39			avg.	20w4d	18w6d-22w3d	<2.0%
HL (Jeanty)	<input checked="" type="checkbox"/>	3.11 cm	3.11			avg.	20w2d	17w4d-23w0d	<5.0%
Cereb (Hill)	<input checked="" type="checkbox"/>	2.24 cm	2.01	2.31	2.41	avg.	21w0d	20w0d-21w6d	<2.0%
IOD		1.58 cm	1.58			avg.			
BOD (Jeanty)	<input checked="" type="checkbox"/>	3.92 cm	3.92			avg.	24w6d	21w4d-28w d	32.1%

2D Calculations

FL/HC (Hadlock) 17% (19 - 21%) FL/AC 21% (20 - 24%)
 HC/AC (Campbell) 1.22 (1.05 - 1.21)





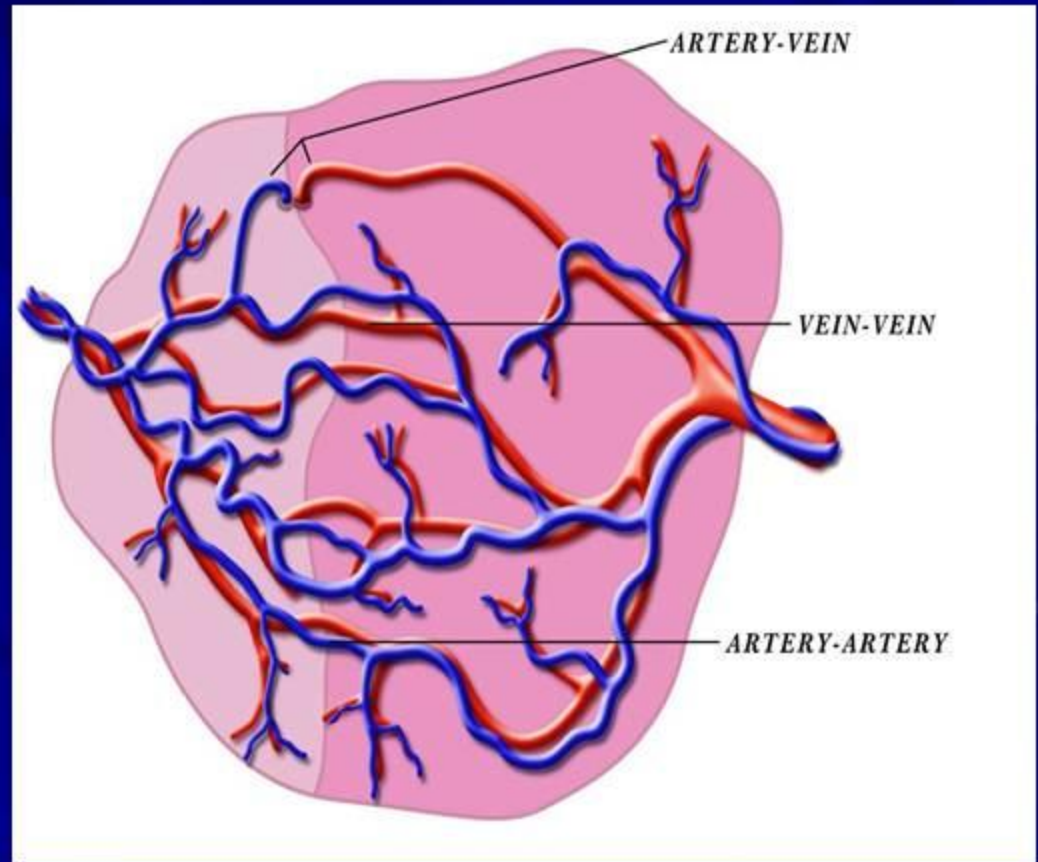
Twin Twin Transfusion Syndrome

65% CCHMC

- Untreated 80-100% mortality
 - Preterm labor
 - TES
 - Neurologic deficits (18-26%)
- 10-20% monochorionic
 - Diamniotic
- Second trimester
 - 16-26 weeks
 - Early gestation more severe

TTTS Pathology

- Vascular placental communications between twins
- Unbalanced flow
 - Artery to vein
 - Protective
 - Vein to vein
 - Artery to artery



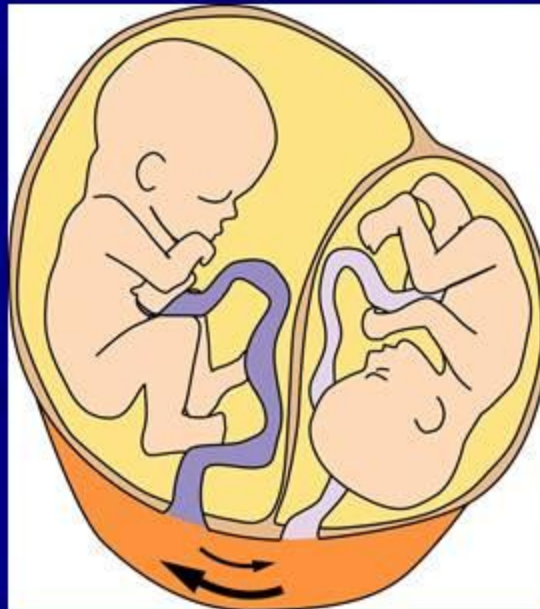
TTTS

■ Recipient

- Hypervolemic
- Polyuria
- Polyhydramnios
- Cardiac dysfunction

■ Donor

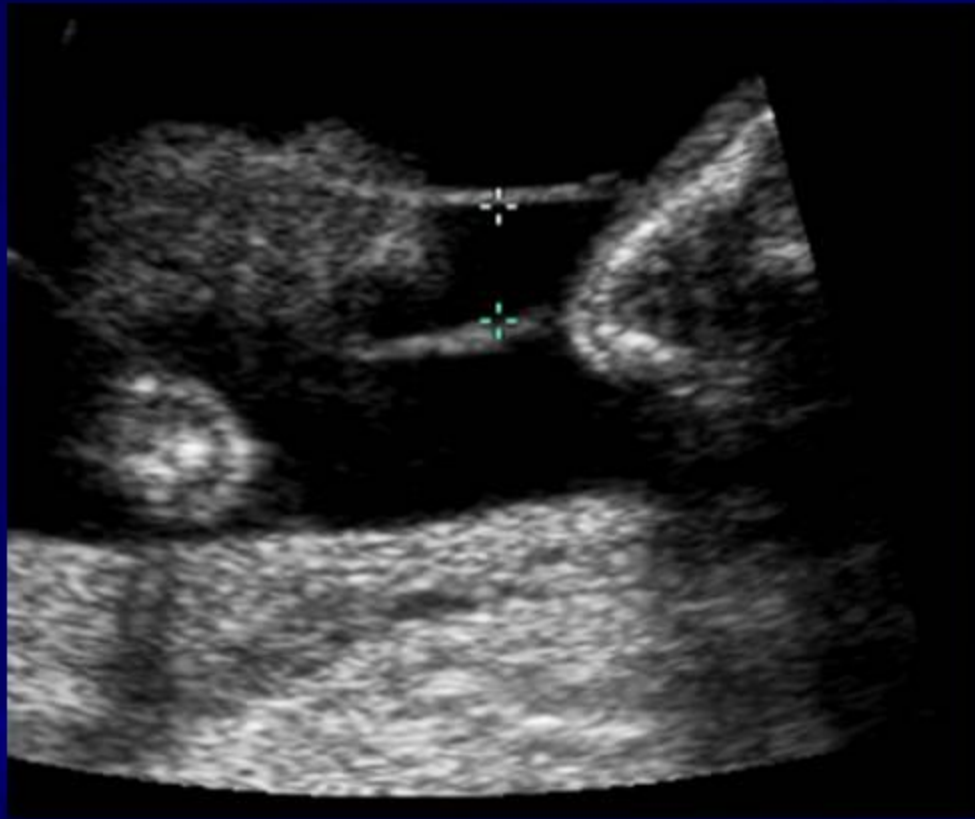
- Hypovolemic
- Oliguria
- Oligohydramnios
- Growth restriction



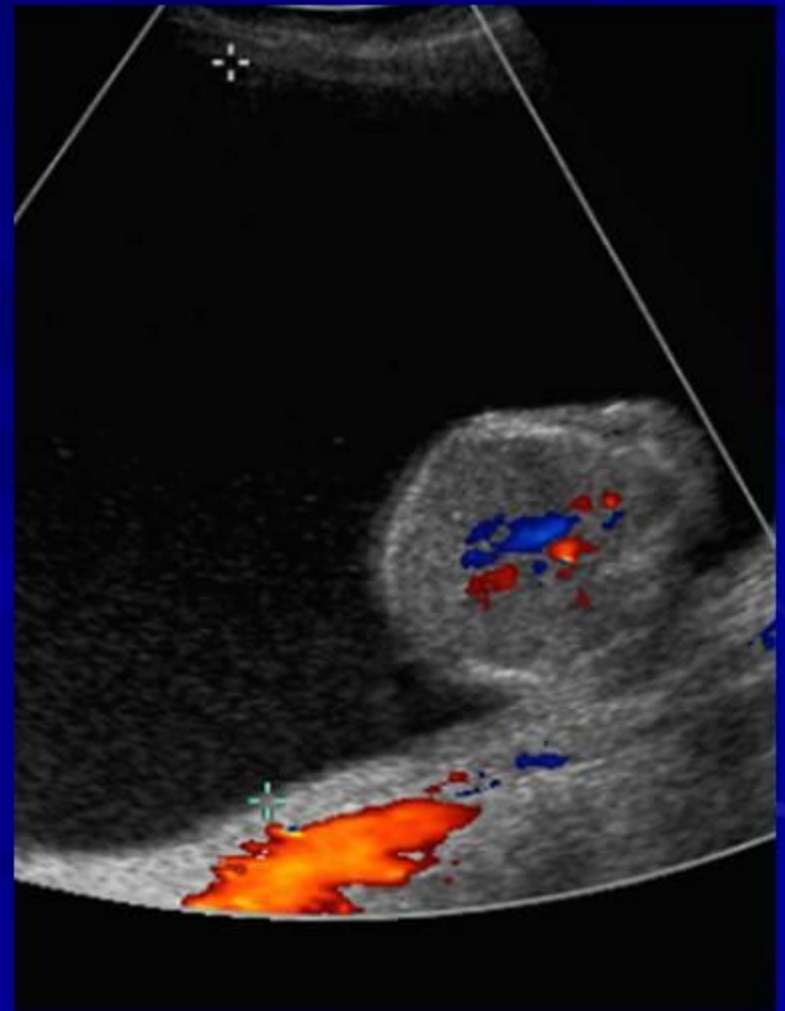
TTTS Diagnosis

- Disparate amniotic fluid volumes
- Lack of bladder in donor
- Cardiac dysfunction recipient
- Abnormal Doppler
 - Recipient-abnormal ductus venosus/umbilical vein
 - Donor-abnormal umbilical artery
- Significant growth discordance >20%
- Hydrops

US Disparate Amniotic Fluid

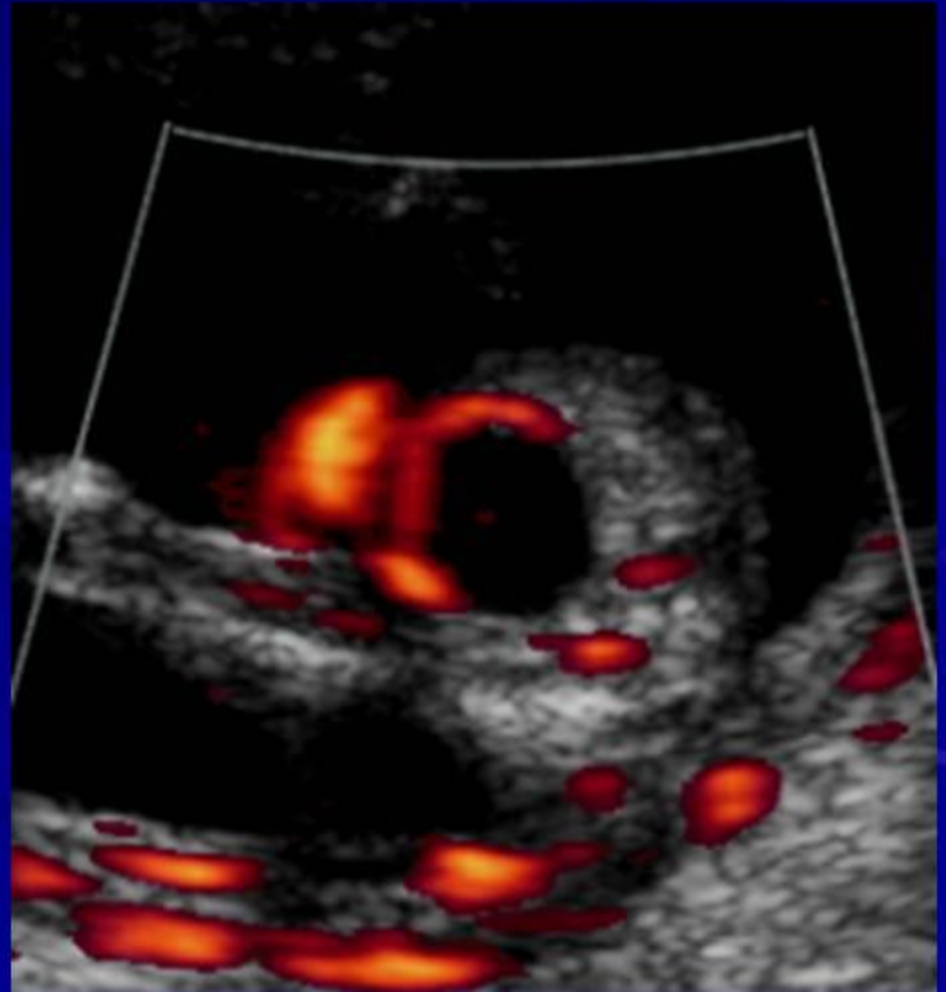
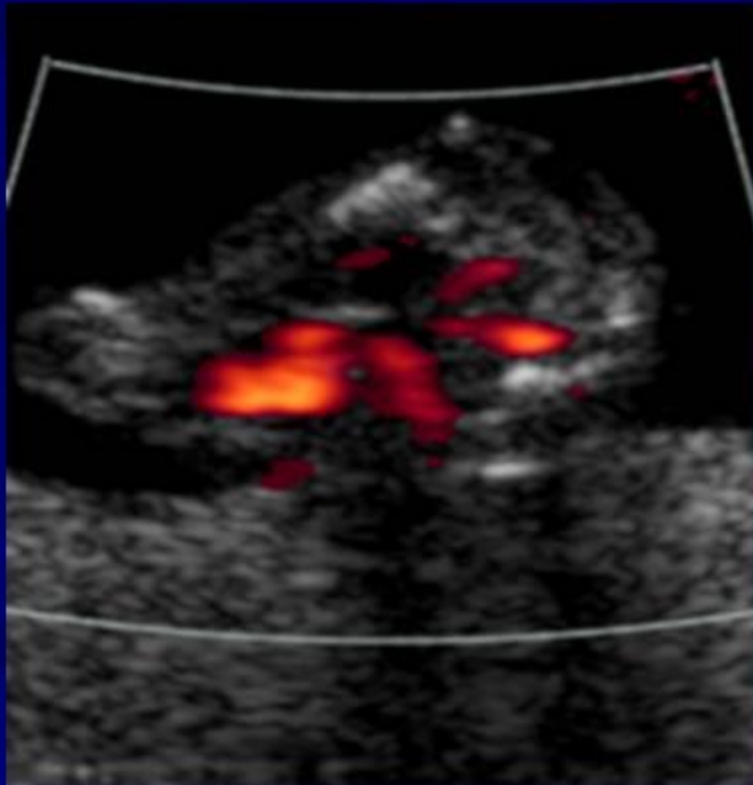


Deepest vertical pocket
1.3 cm versus 11cm

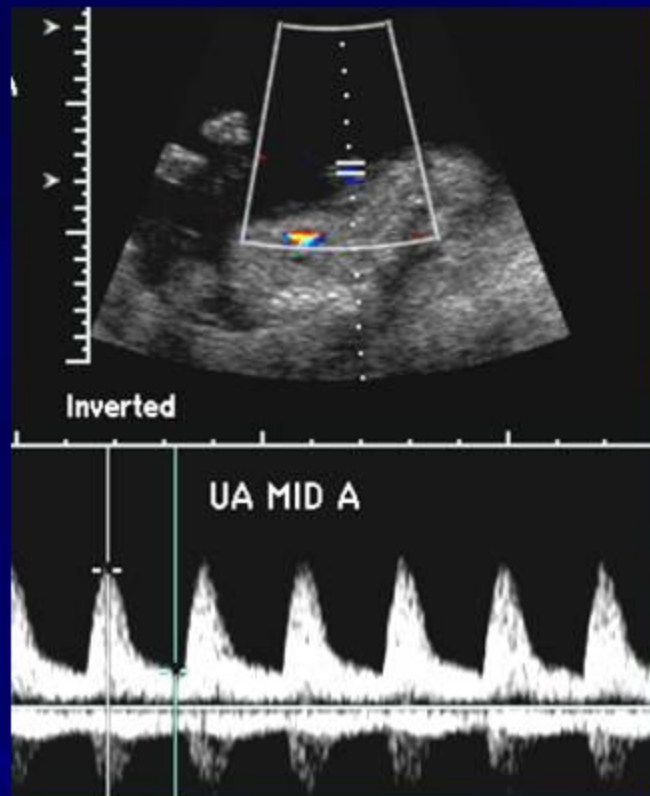


US Disparate Growth and Bladder

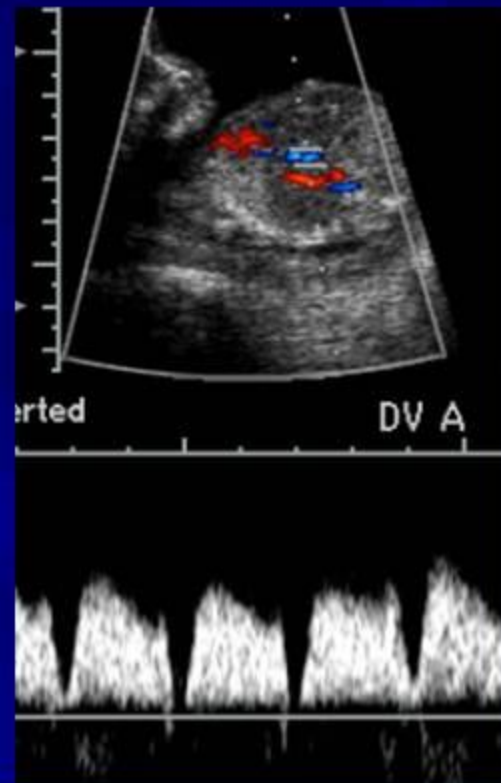
Donor



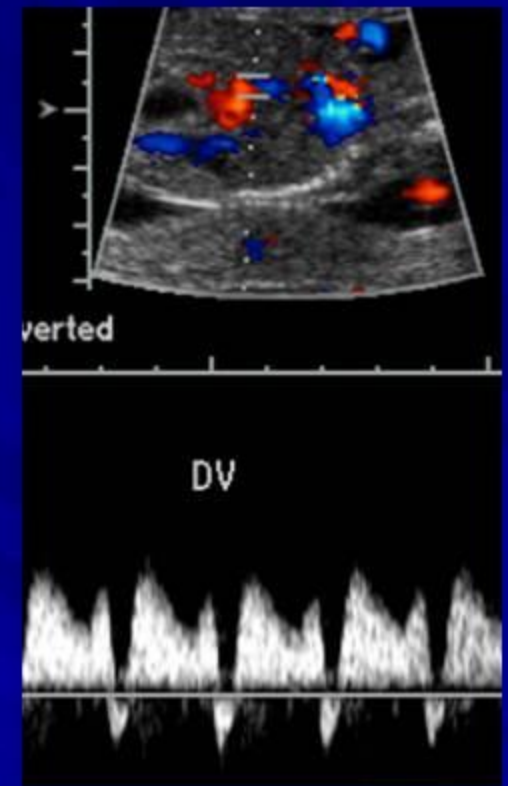
Venous Doppler Recipient



Pulsatile UV

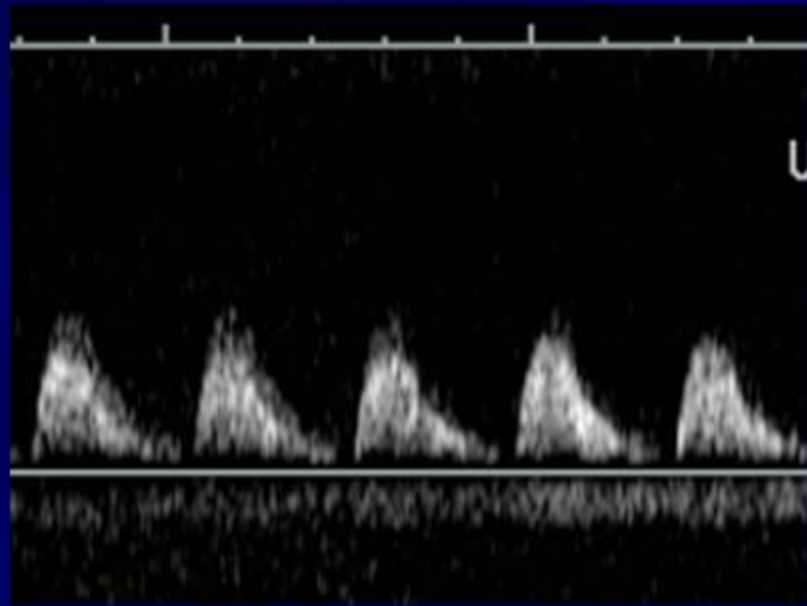


Loss of a wave

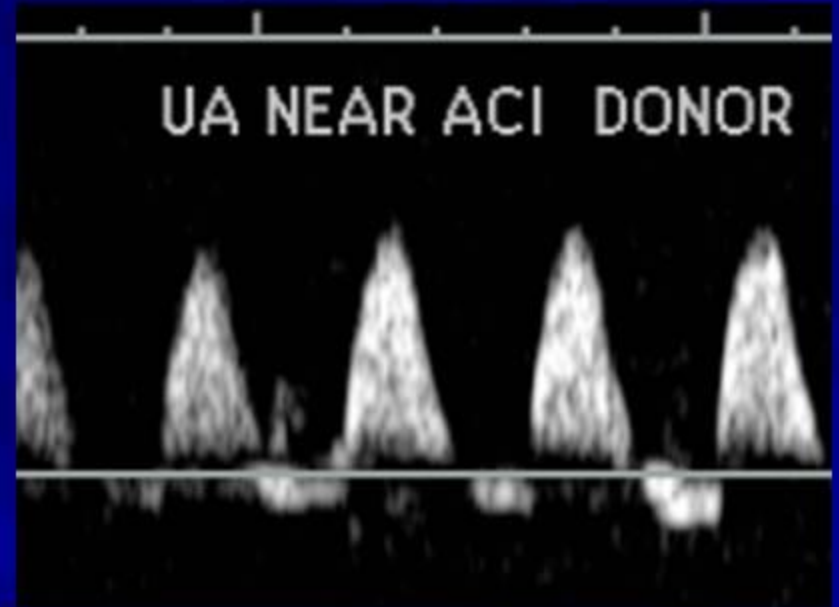


Reversal

UA Doppler Donor



Diastolic drop off



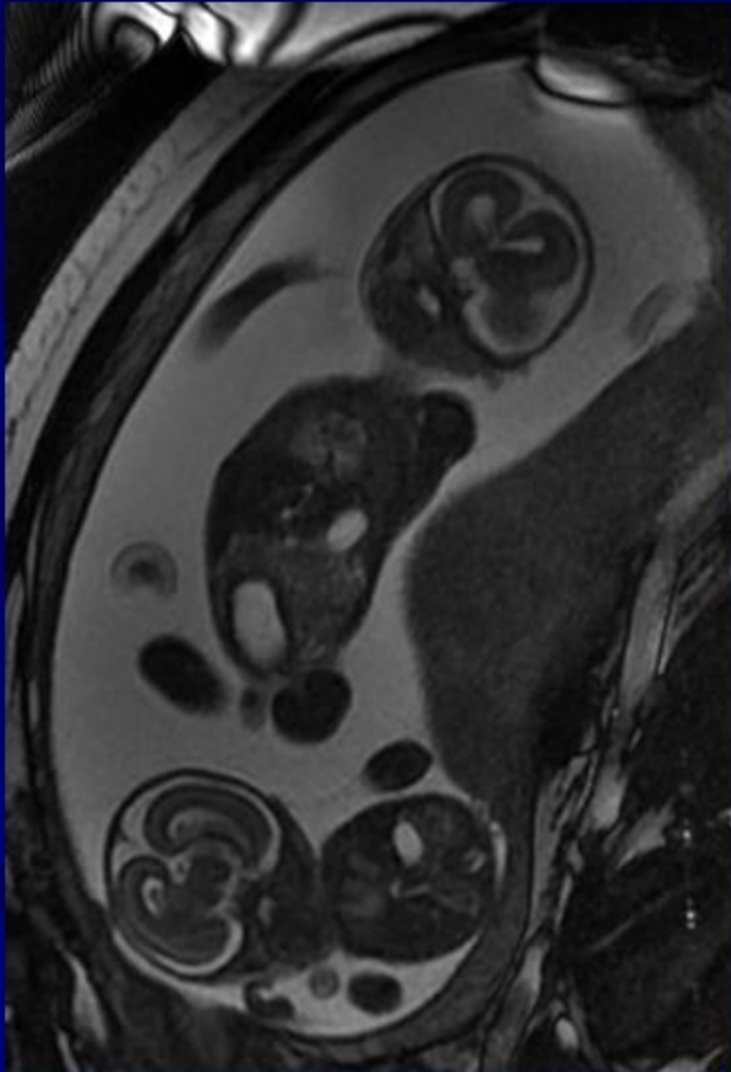
Diastolic reversal

Fetal MR Findings

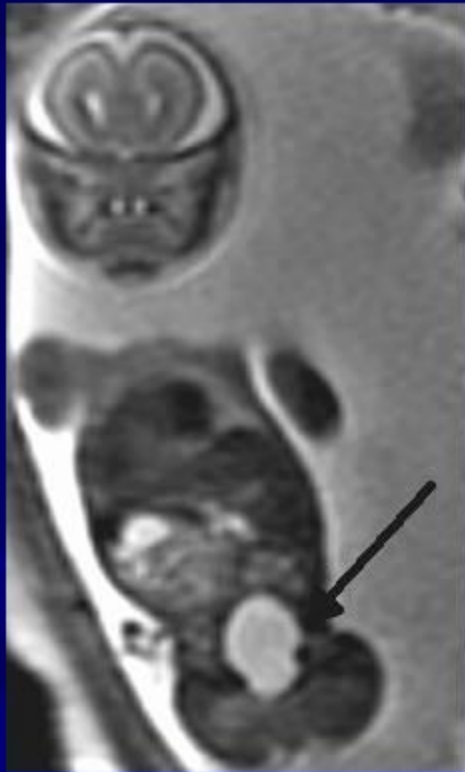
	Donor	Recipient
Amniotic Fluid Status	<u>Oligohydramnios</u> 24/24 (100%) "Stuck" configuration 10/24 (42%)	<u>Polyhydramnios</u> 24/24 (100%)
Urinary	No or small bladder 23/24 (96%)	Bladder distention 24/24 (100%) <u>Pelvocalyceal distention</u> 15/24 (63%)
Cardiac		<u>Cardiomegaly</u> 15/24 (63%)
Cerebral	Cerebral malformation 2/24 (8%) <u>Cerebral venous sinus enlargement</u> 2/24 (8%)	IVH/ischemia 2/24 (8%) <u>Cerebral venous sinus enlargement</u> 2/24 (8%)
Other	Growth restriction 15/24 (63%) <u>Hydrops</u> 2/24 (8%)	Lung lesion 1/24 (4%) <u>Hydrops</u> 2/24 (8%)
Outcome	Demise 1/25 (4%)	Demise 1/25 (4%)

Kline-Fath B, Calvo-Garcia MA, O'Hara SM, Crombleholme TM, Racadio JM. Twin-twin transfusion syndrome: cerebral ischemia is not the only fetal MR imaging finding. *Pediatric Radiology* 2007; 37:47-56

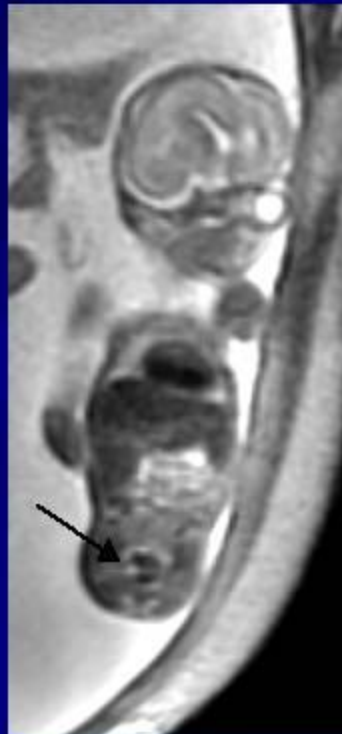
MRI Disparate Amniotic Fluid



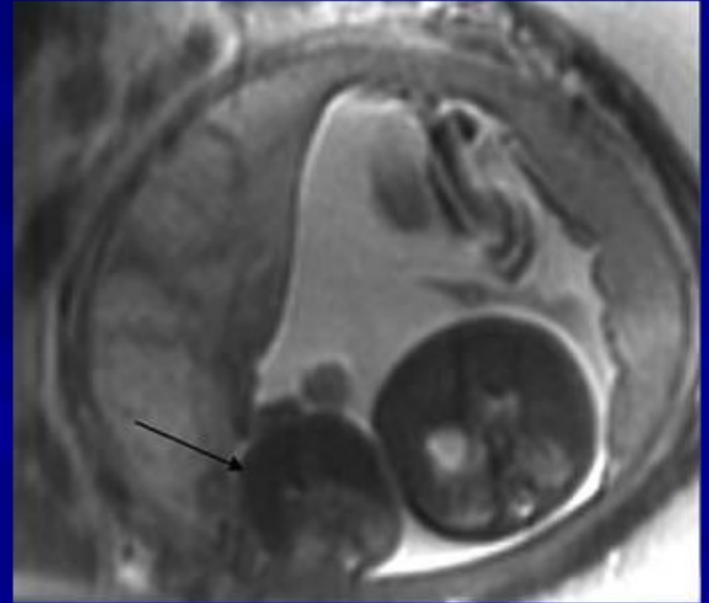
MRI Disparate Bladders and Growth



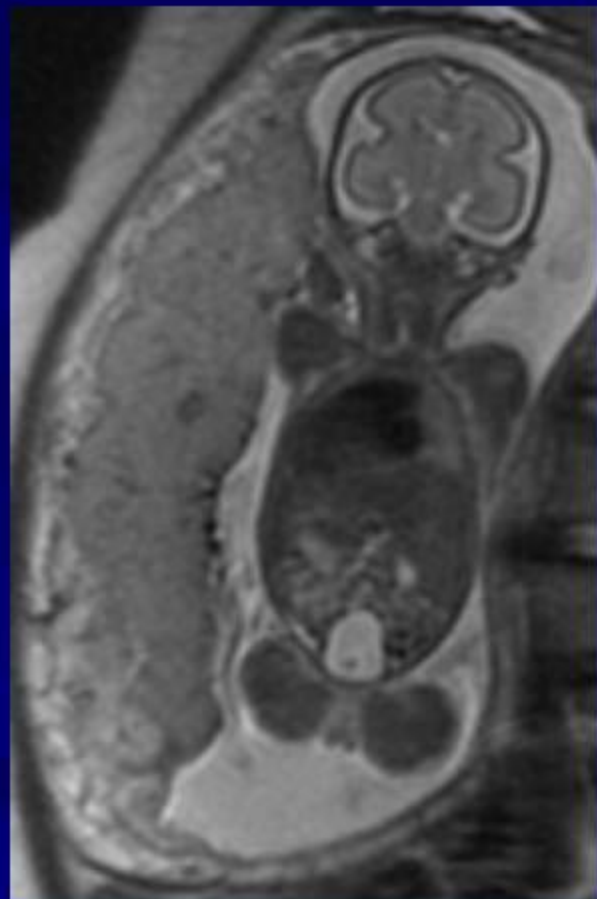
Recipient



Donor



MRI Recipient Cardiac

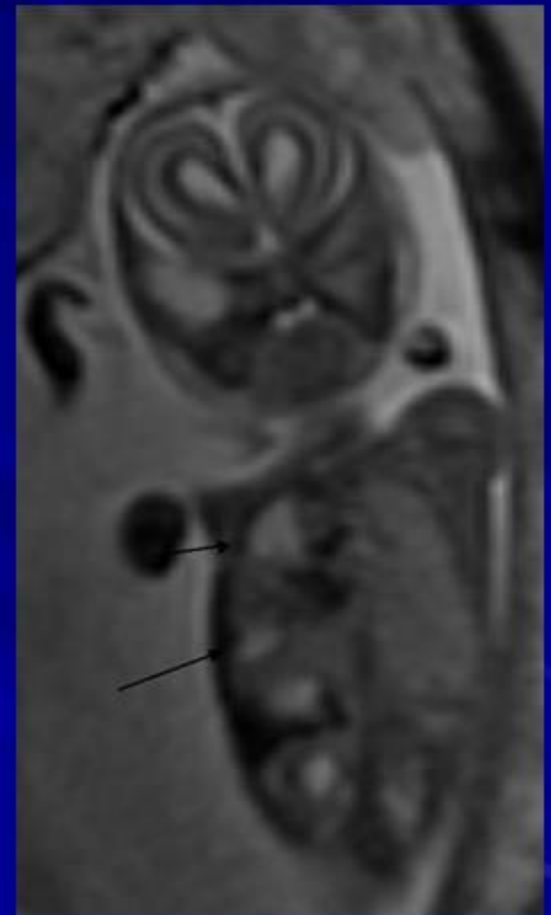
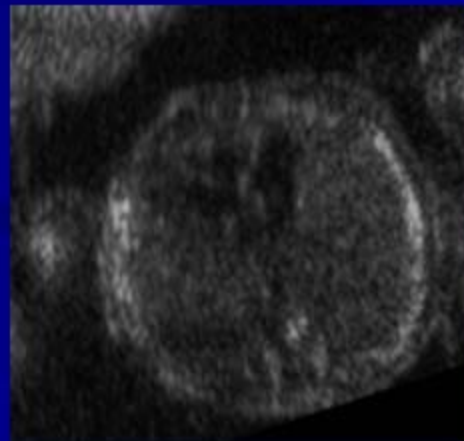


MRI Hydrops



MRI Recipient Lung Lesion (4-5%)

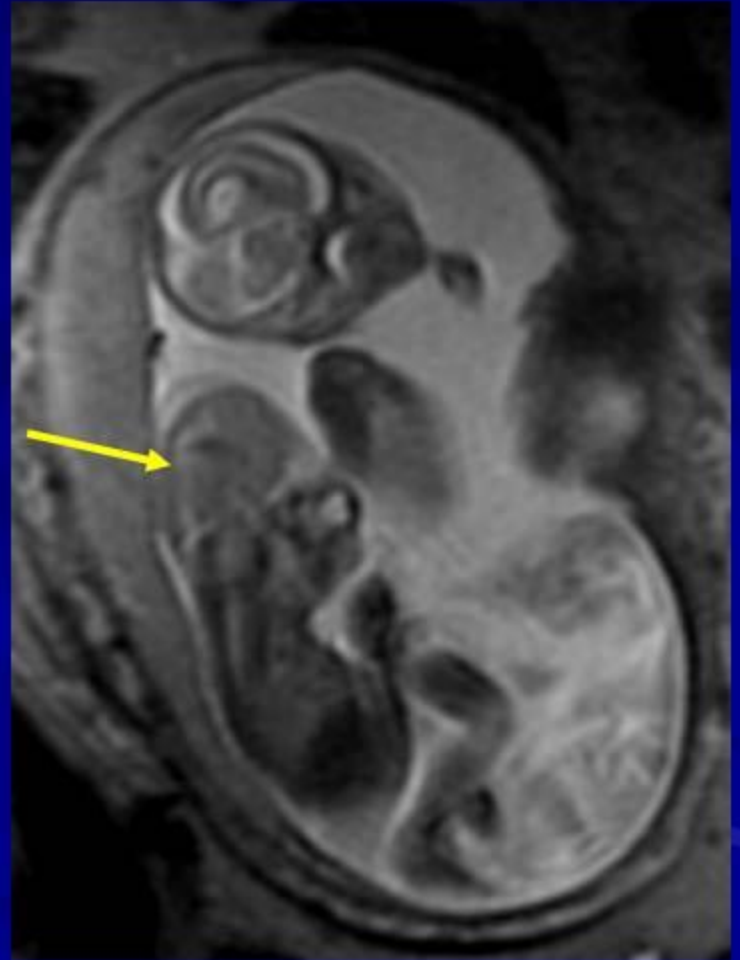
- Speculated CPAM
- Increased cell proliferation/decreased apoptosis
- Vasoactive mediators in TSTS



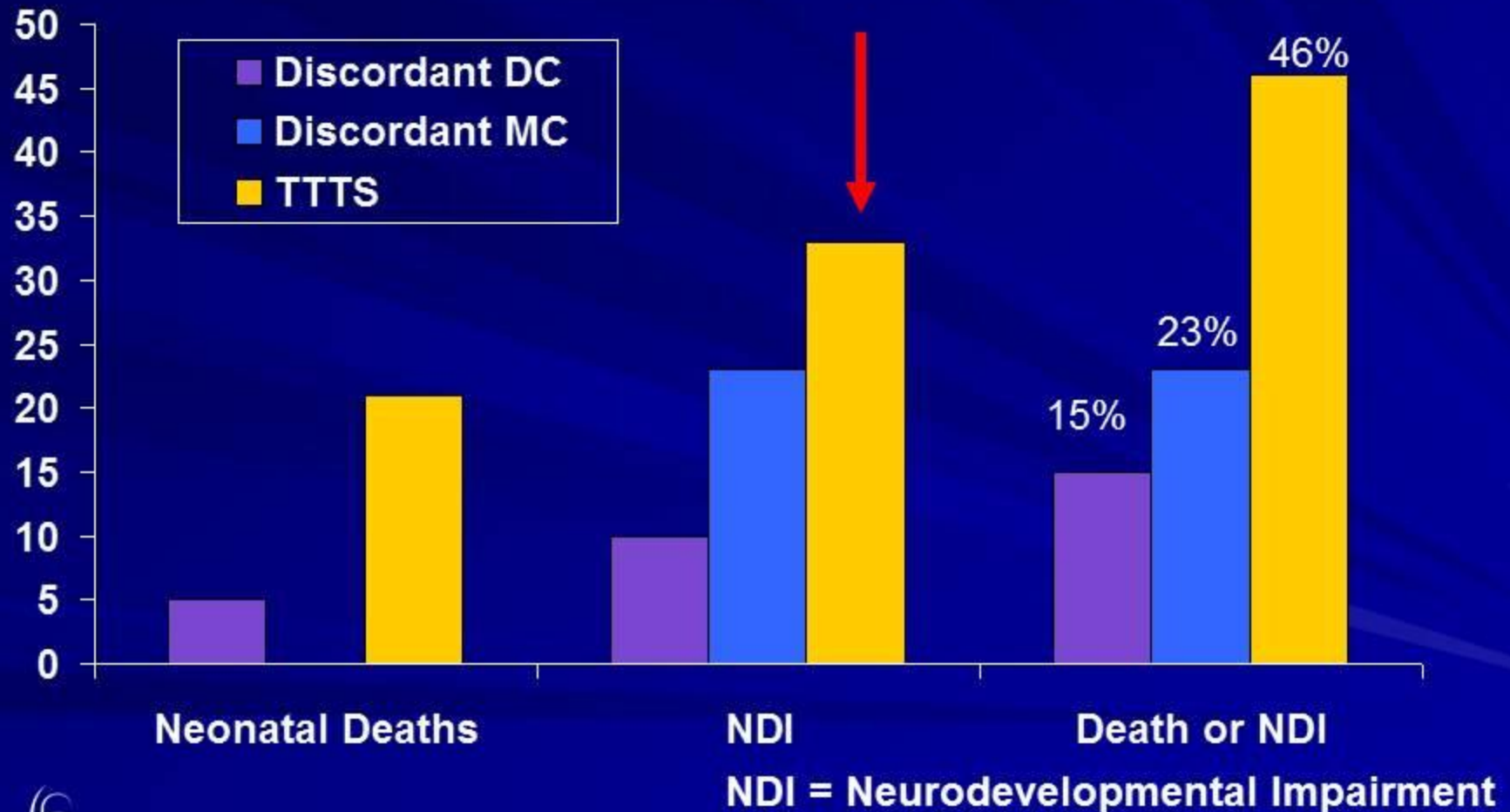
Donor Brain Malformation(5%)

- Higher risk of malformations than singletons
- Monozygotic pregnancy malformation risk has been suggested to be 2 to 3 times the background
- Donor-consequence of the diminished cerebral blood flow early in gestation

Donor Brain Malformation

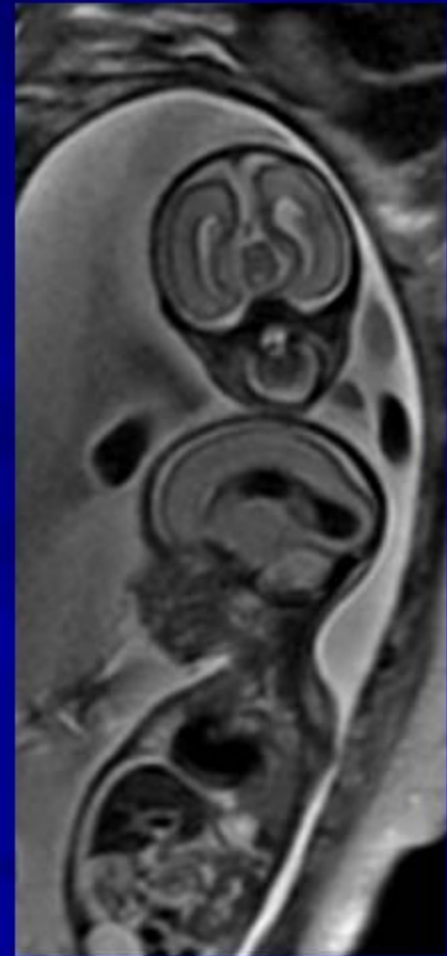


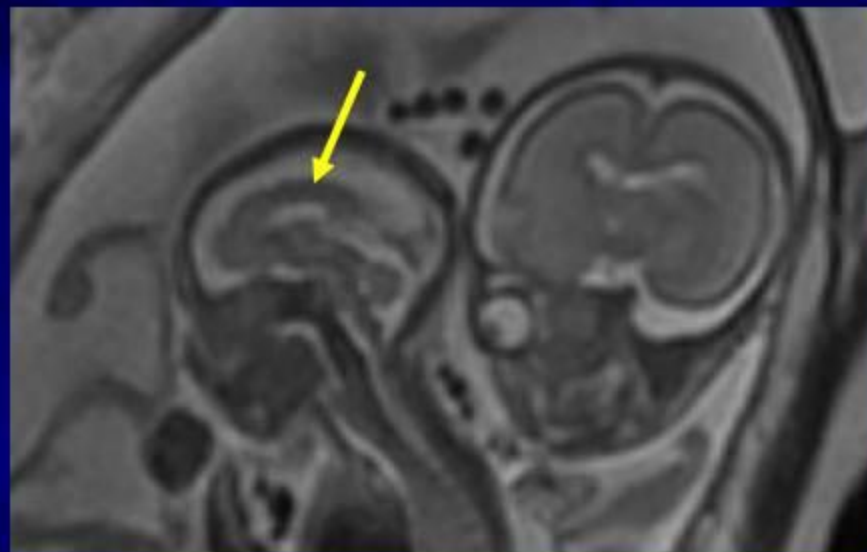
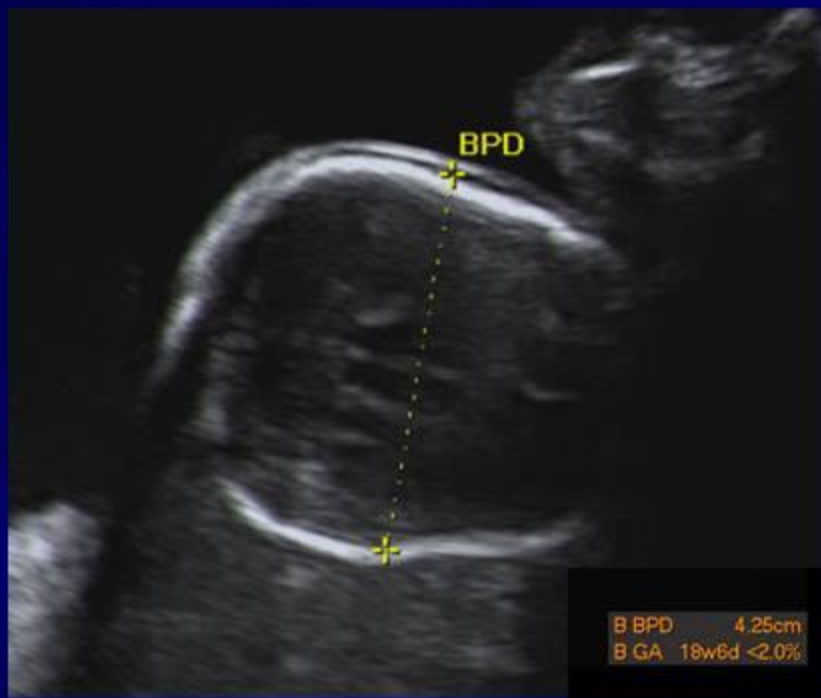
Morbidities and Mortalities associated with being Discordant or TTTS



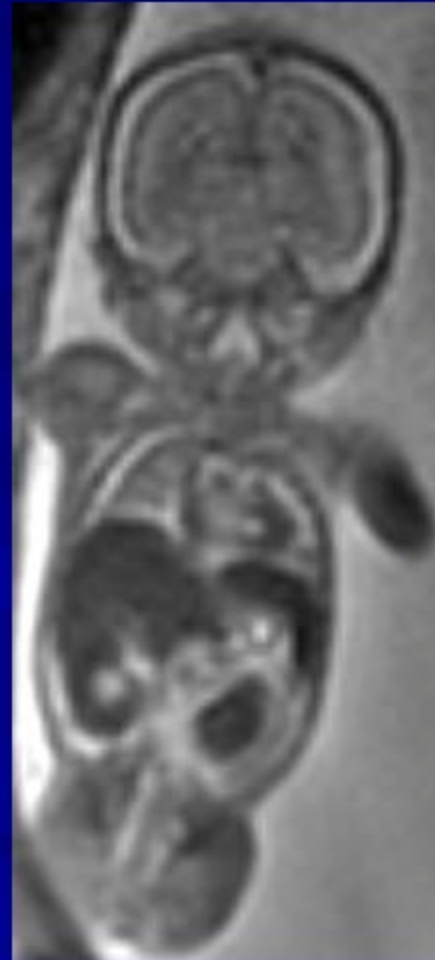
MRI Cerebral Ischemia/Hemorrhage (5-8%)

- Acute stage not visualized with ultrasound
- Chronic stage
 - Normal head ultrasound
 - Enlarged ventricles

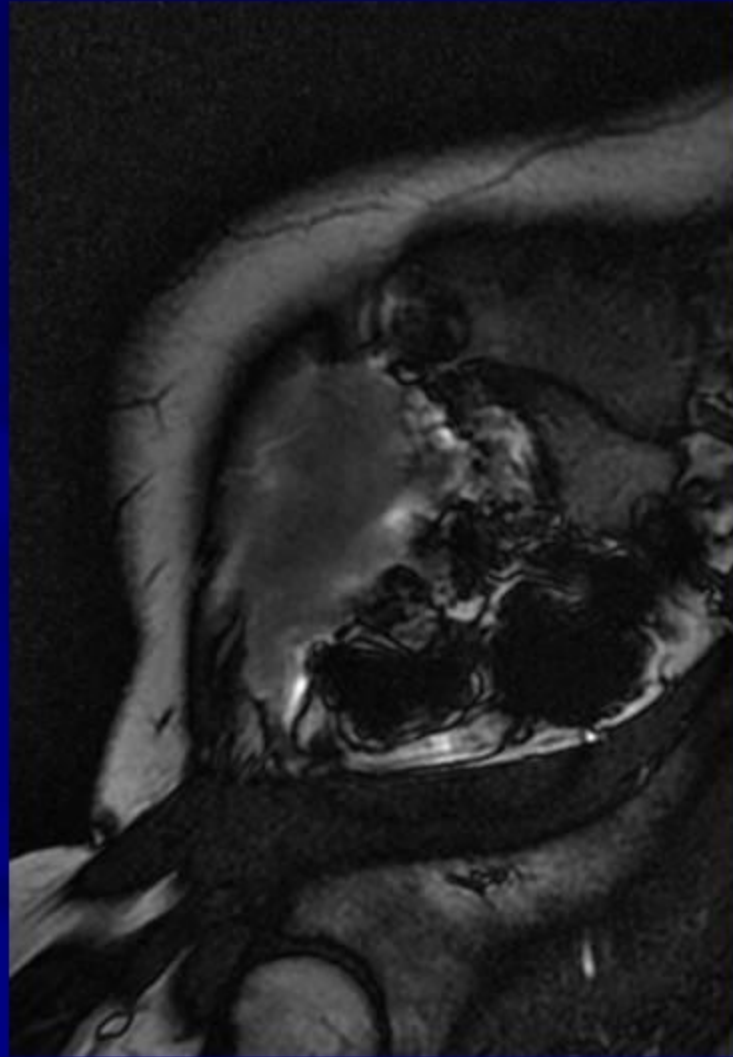




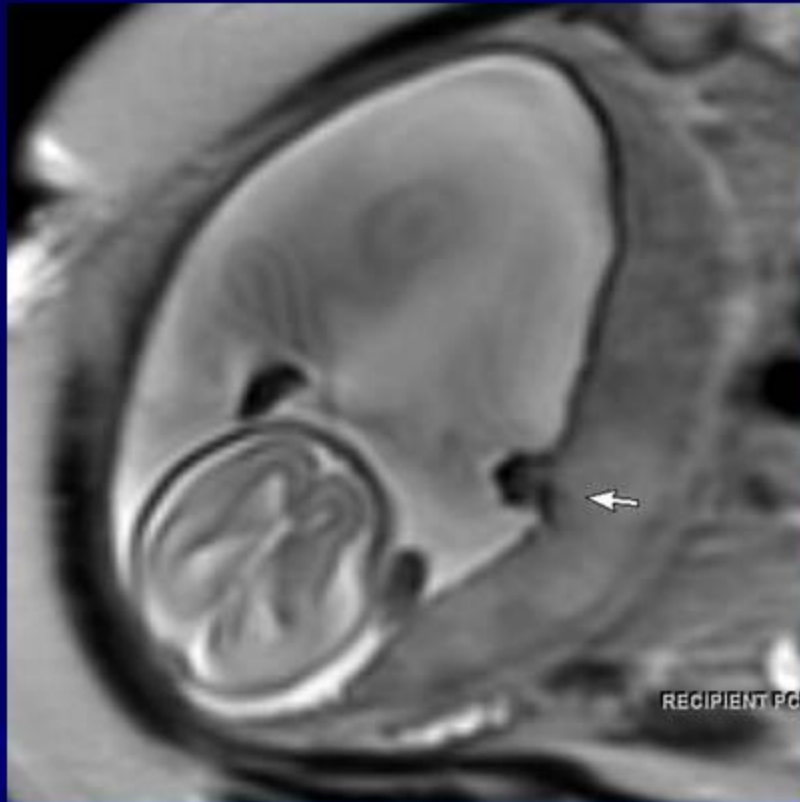
MRI Demise



Anatomy of the Placenta



Cord Insertions

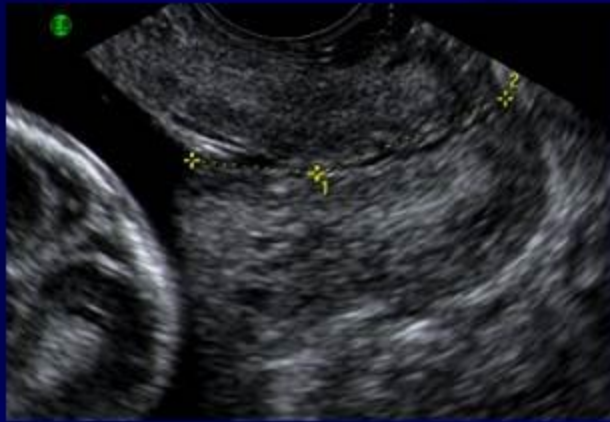


Central



Membranous

Cervix



TTTS Quintero Staging

- Stage I: polyhydramnios > 8 cm
oligohydramnios < 2 cm
bladder visible in Donor
- Stage II: bladder not visible in Donor
no critically abnormal Doppler's
- Stage III: critically abnormal Doppler's
absent end-diastolic velocity UA (Donor)
reverse flow DV (Recipient)
pulsatile UV flow (associated with TR)
- Stage IV: hydrops
- Stage V: demise one/both

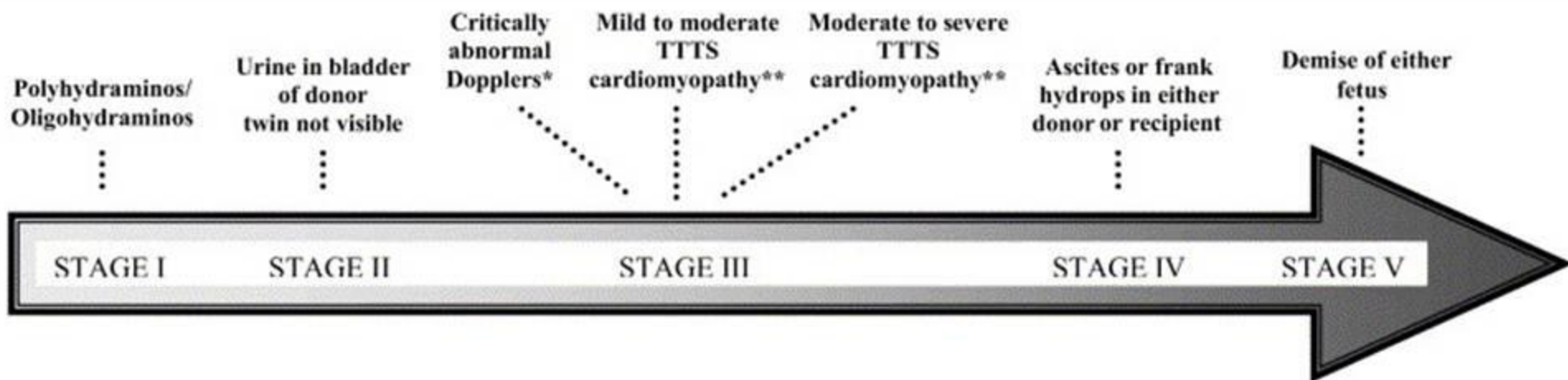
Ventricular Hypertrophy in TTTS: Recipient Twin



Dimension	Z-value
RV end-diastolic dimension	- 0.9 ± 0.7
LV end-diastolic dimension	- 0.5 ± 0.6
RV free wall thickness	2.8 ± 1.8
IVS thickness	2.4 ± 1.5
LV free wall thickness	2.8 ± 1.8

Courtesy Rick Michelfelder, MD

Cincinnati Grading

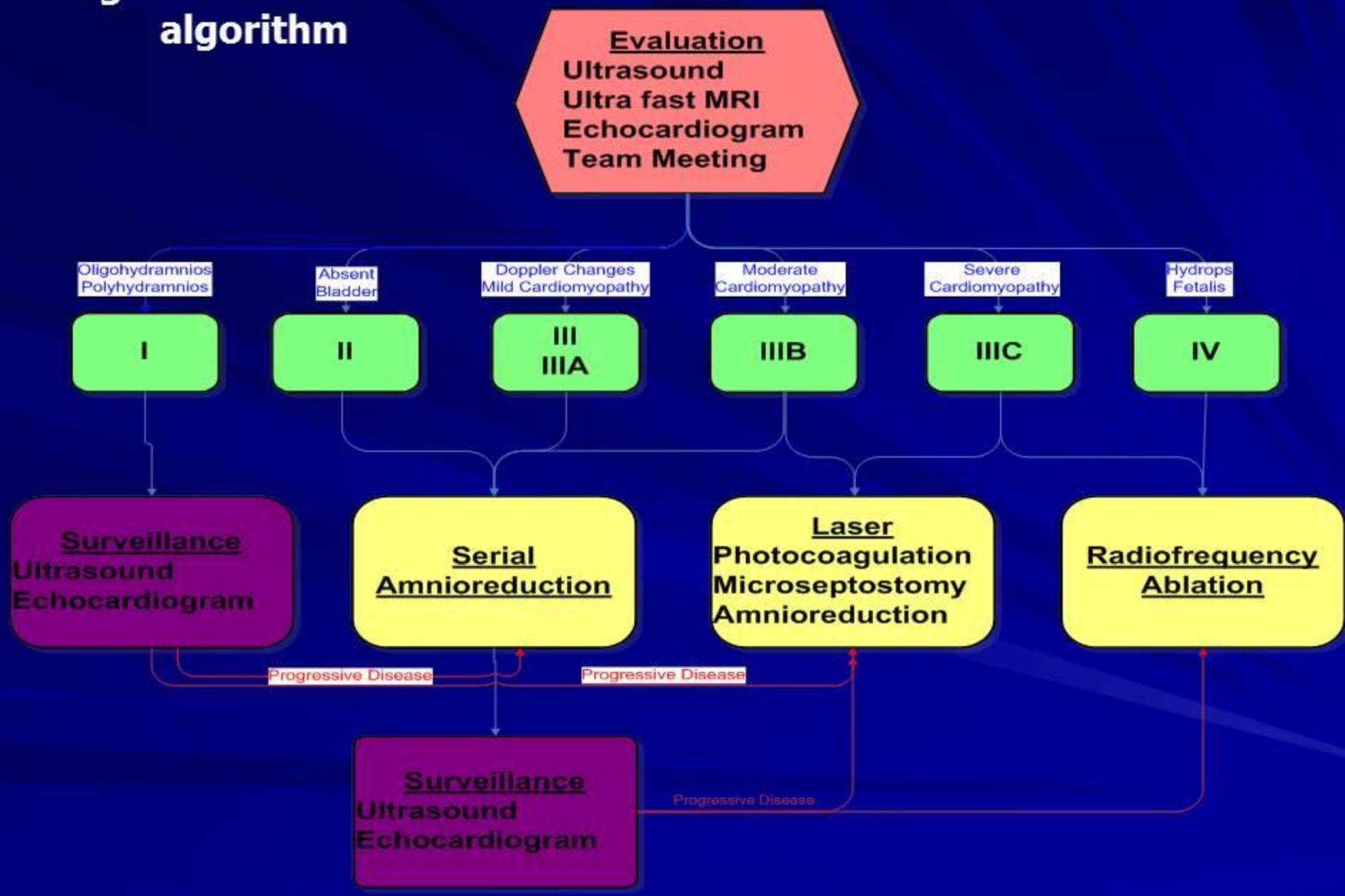


* Critically abnormal Dopplers defined as at least one of absent or reverse end diastolic flow in the umbilical artery, reverse flow in the ductus venosus or pulsatile umbilical venous flow

** TTTS cardiomyopathy assessed by atrioventricular valvular incompetence, ventricular wall thickness and ventricular function

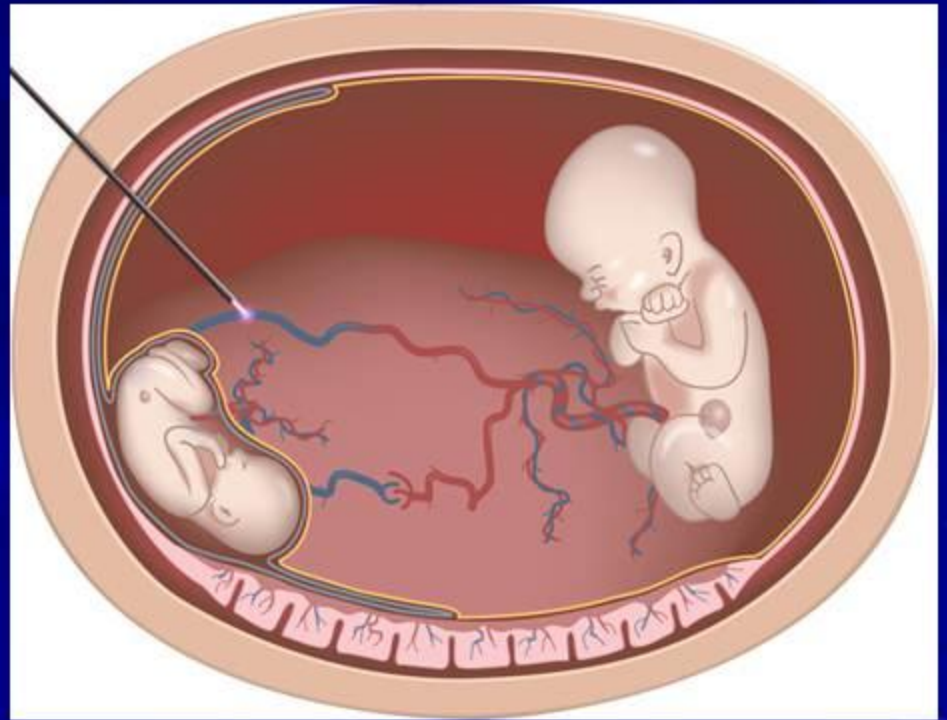
Harkness UF, Crombleholme TM. Twin-Twin Transfusion Syndrome: Where Do We Go From Here? Seminars in Perinatology 2005 29:296-304

Stage based treatment algorithm



TTTS Intervention

- Fetoscopic laser photocoagulation
 - Improved survival rates and neurological outcomes



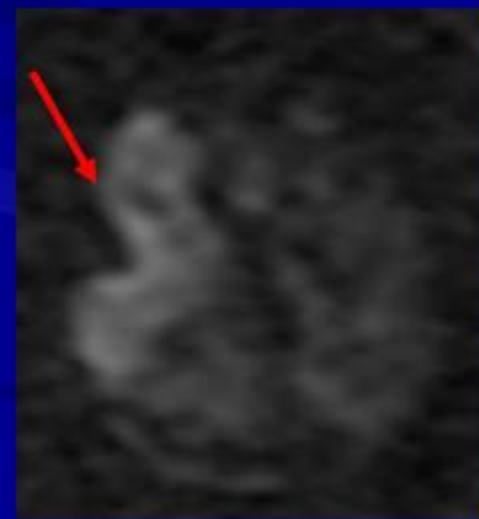
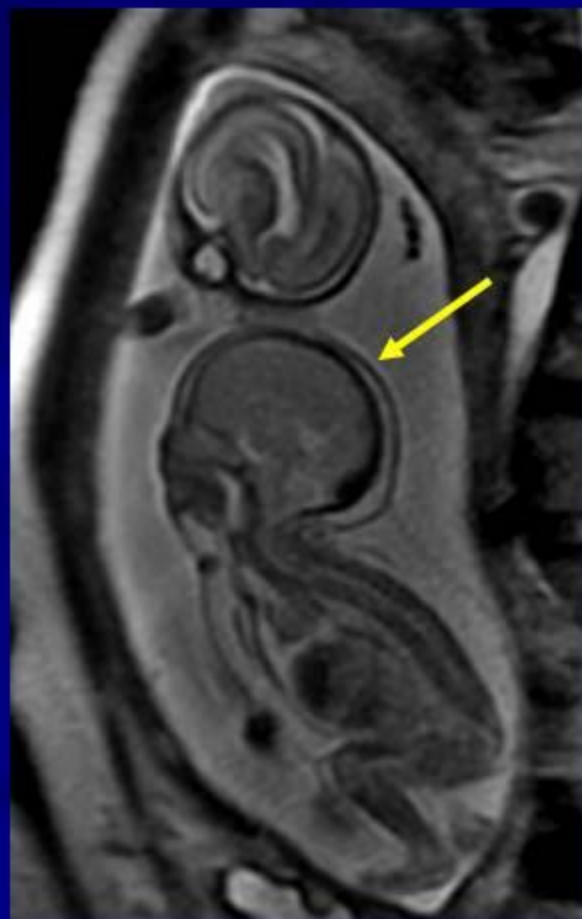
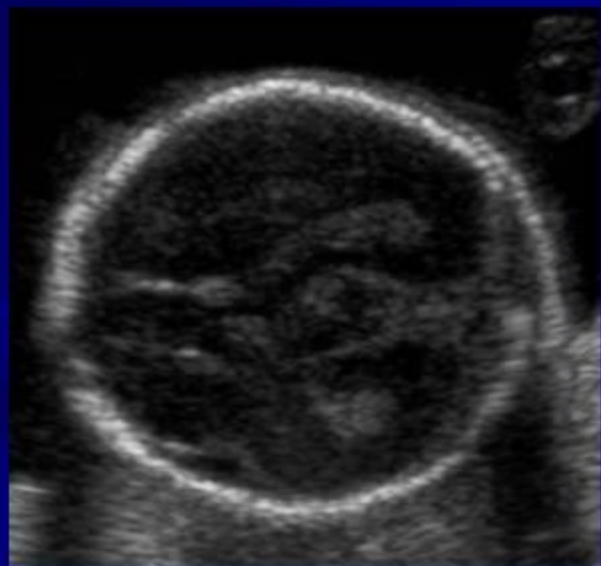
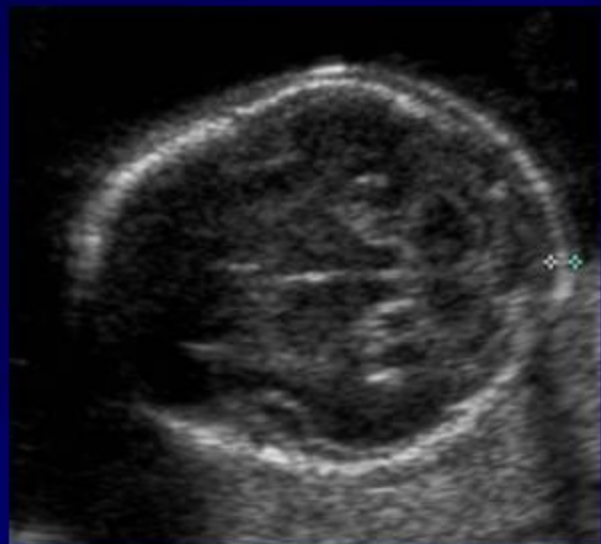
<http://www.mombaby.org/UserFiles/File/TTTS.html>

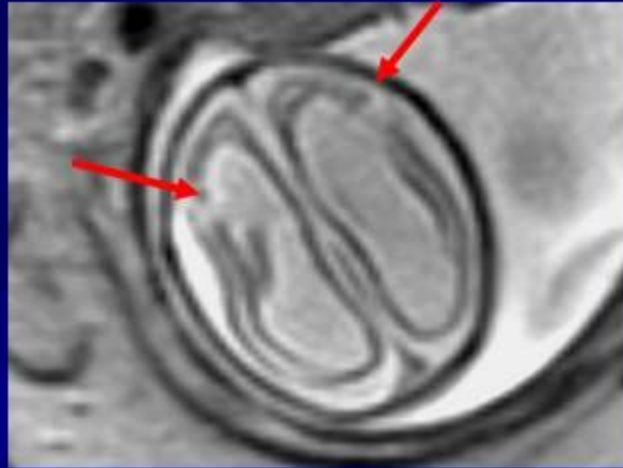
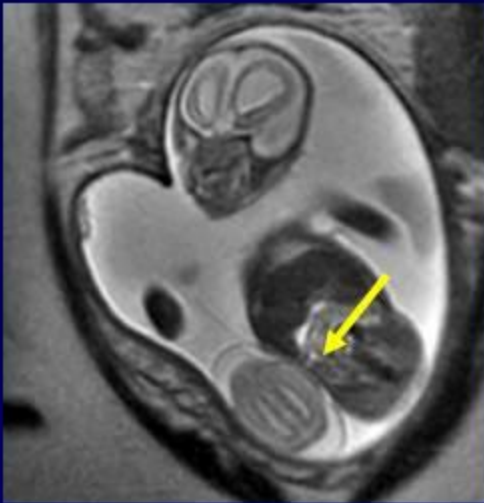
Differential Diagnosis

- Twin embolization syndrome
- Placental Insufficiency
- Discordant twins due to genetic abnormality
- Twin reversed arterial transfusion syndrome

Twin Embolization Syndrome (TES)

- *In utero* demise of one twin
 - Acute hemodynamic shifts
 - Reverse blood flow live to dead
- Tissue necrosis/death of living twin
 - Brain
 - Kidneys
- Placental Insufficiency
 - 20-30% morbidity/mortality co-twin



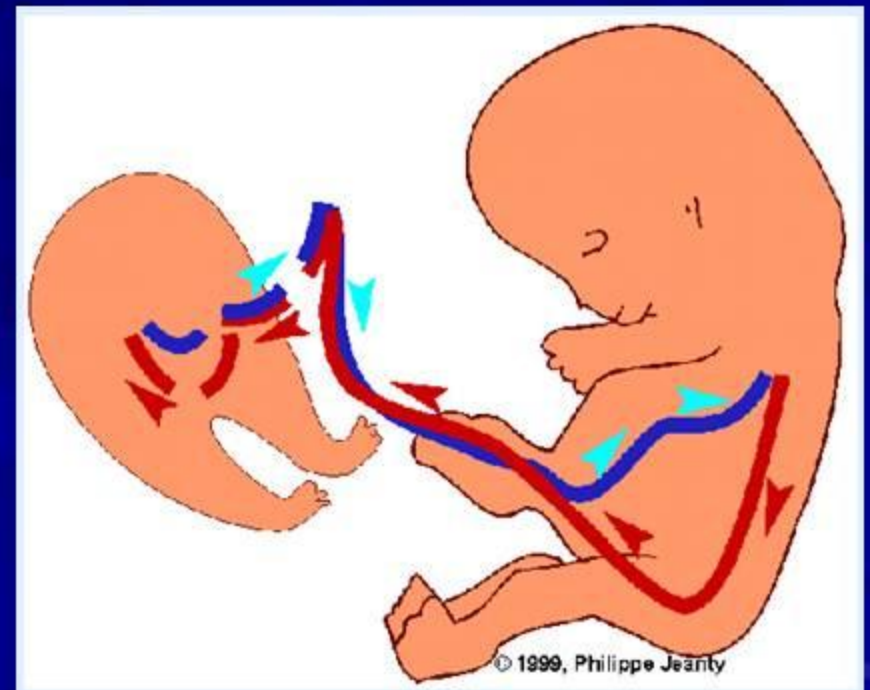


22 Weeks gestation

Twin Reversed Arterial Perfusion

11% CCHMC

- Most extreme form of TTTS
- 1% Monochorionic
- Umbilical arterial to arterial vascular connection



TRAP

■ Acardius

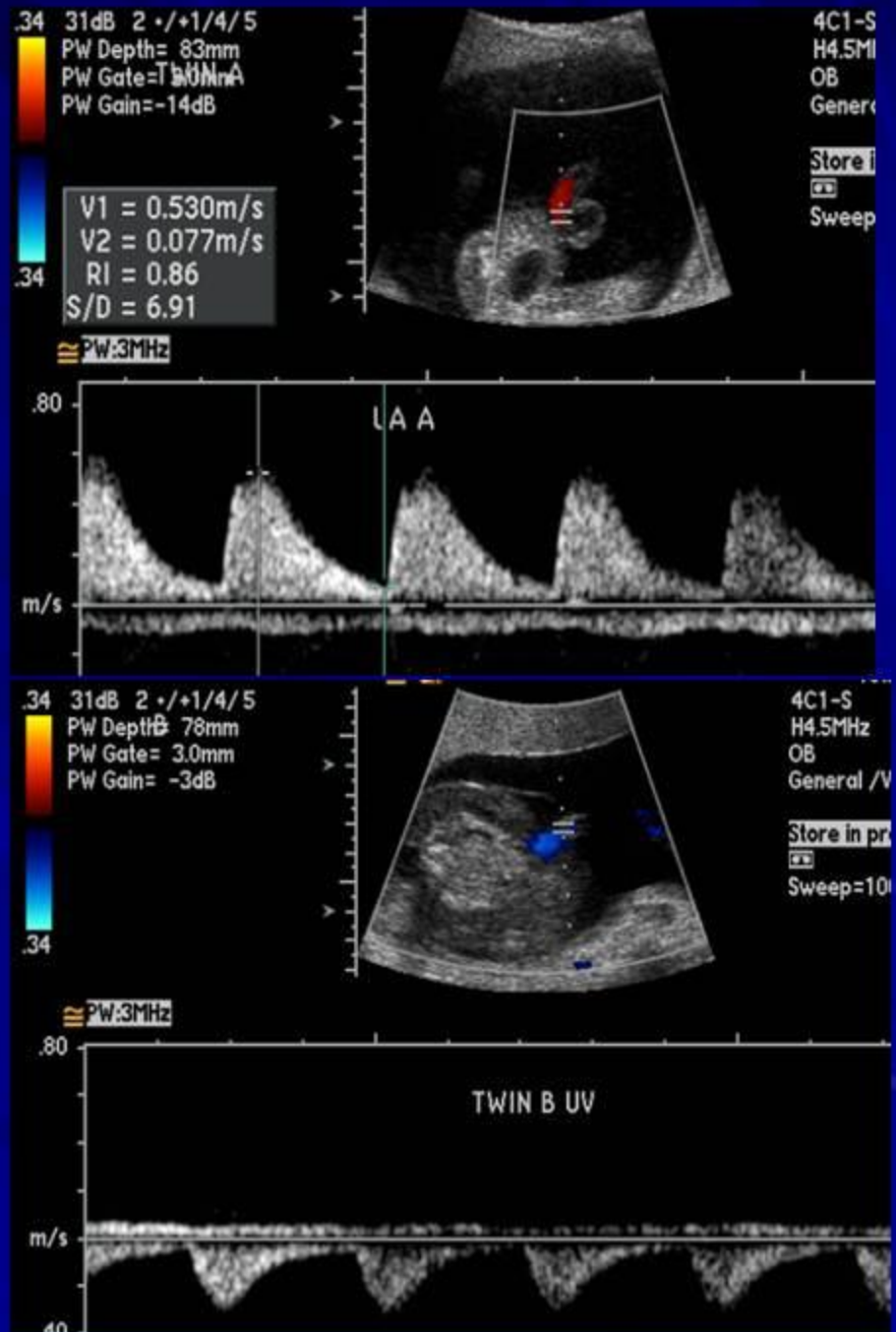
- Unoxygenated blood
- Abnormally developed
 - Head
 - Heart
 - Upper extremities
 - Cervical spine
- Cystic hygroma

■ 100% mortality

■ Pump

- Arterial donor
- 9% chromosomal anomaly
- Congestive heart failure
 - Polyhydramnios
 - Hydrops
- 50% mortality

■ Umbilical artery
Doppler waveforms
confirm diagnosis



TRAP Prognosis

- Cardiac disease in pump
- Volume of acardius
- Cord entanglement
- Polyhydramnios
 - Prematurity

- Acardiac to Pump Twin Ratio:

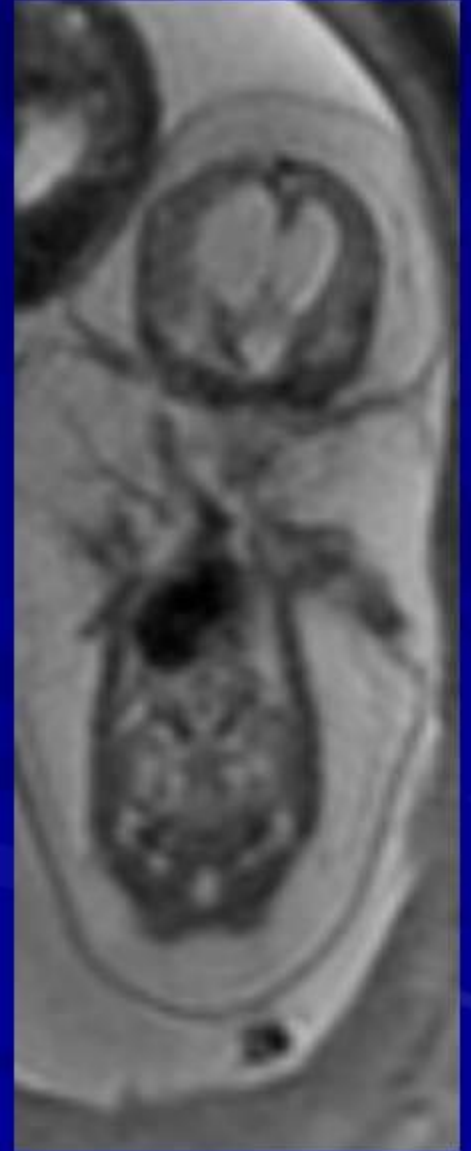
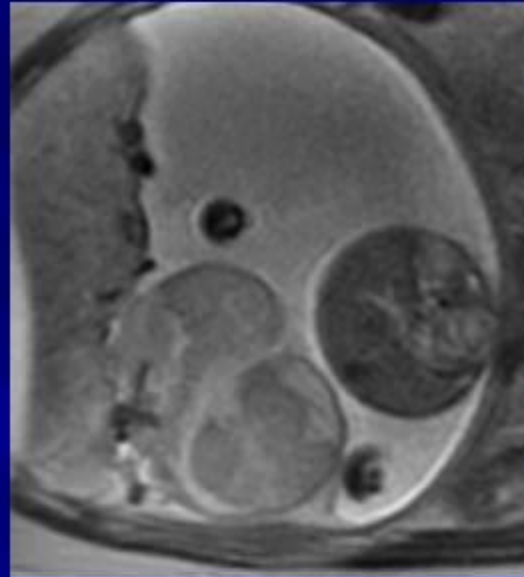
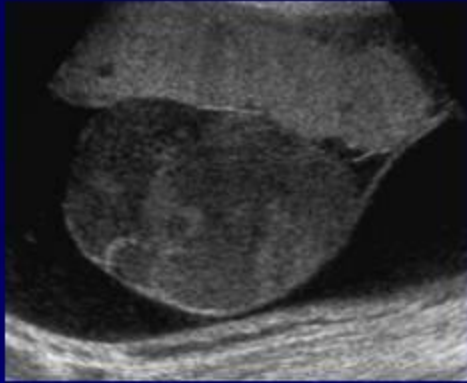
*Total volume of trunk +
extremities ÷ EFW Pump*

Pump death 64% > .5

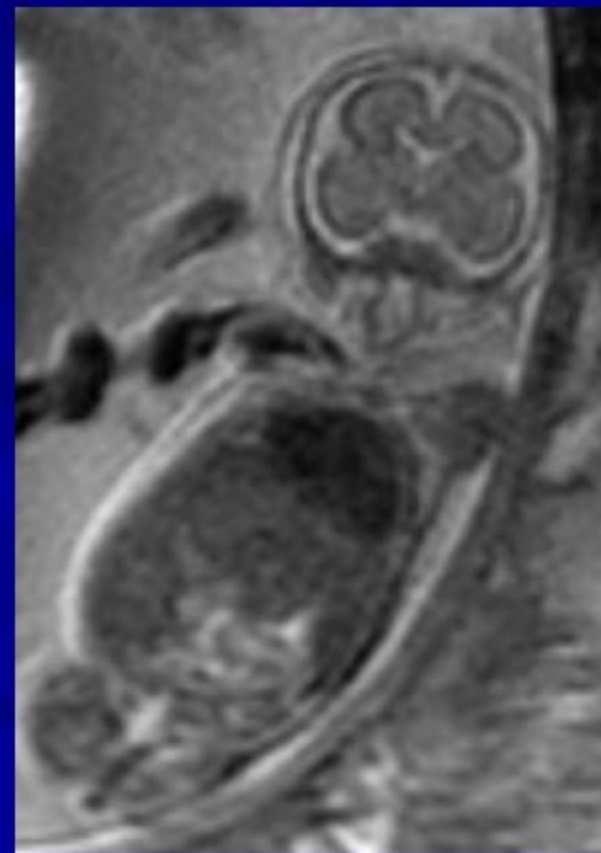
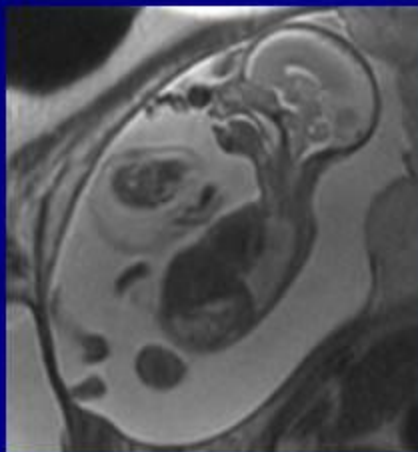
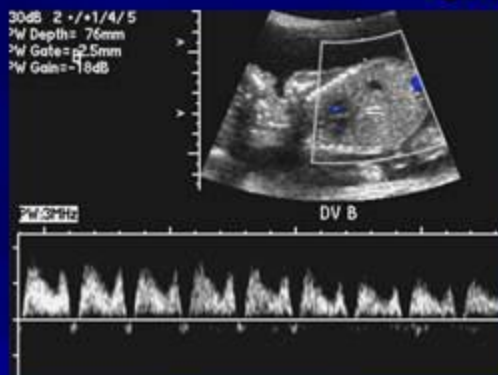
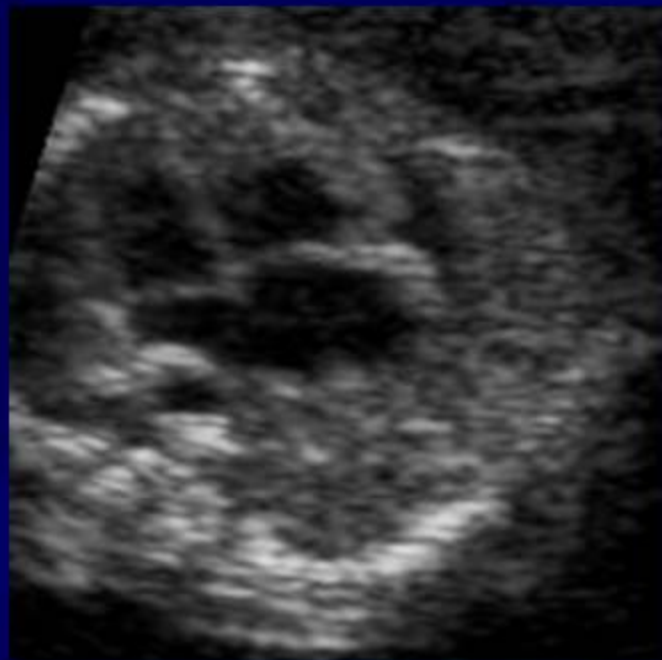
90% > .7



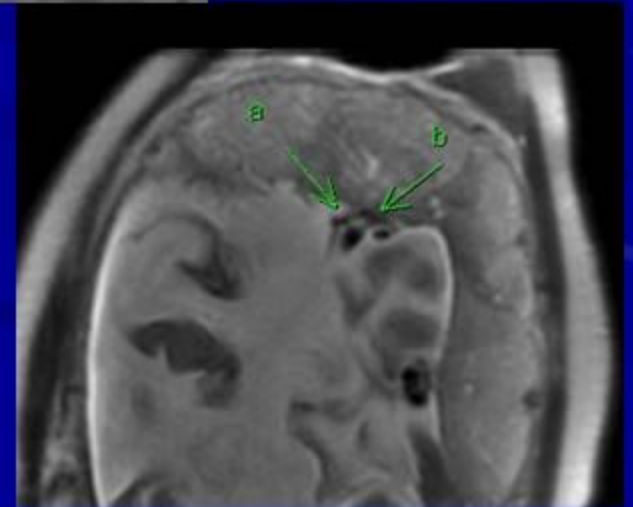
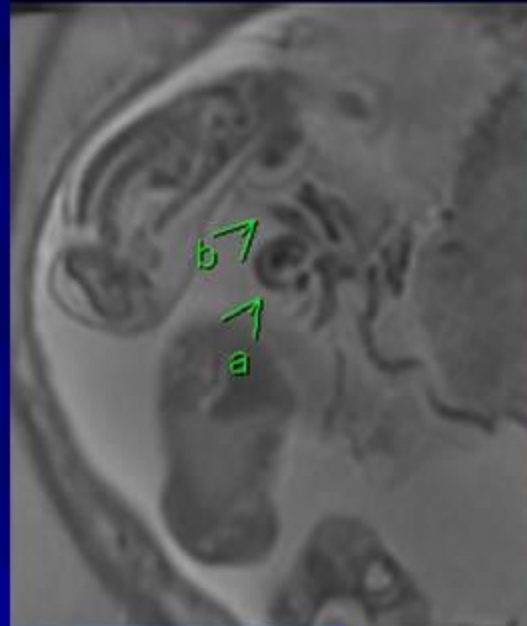
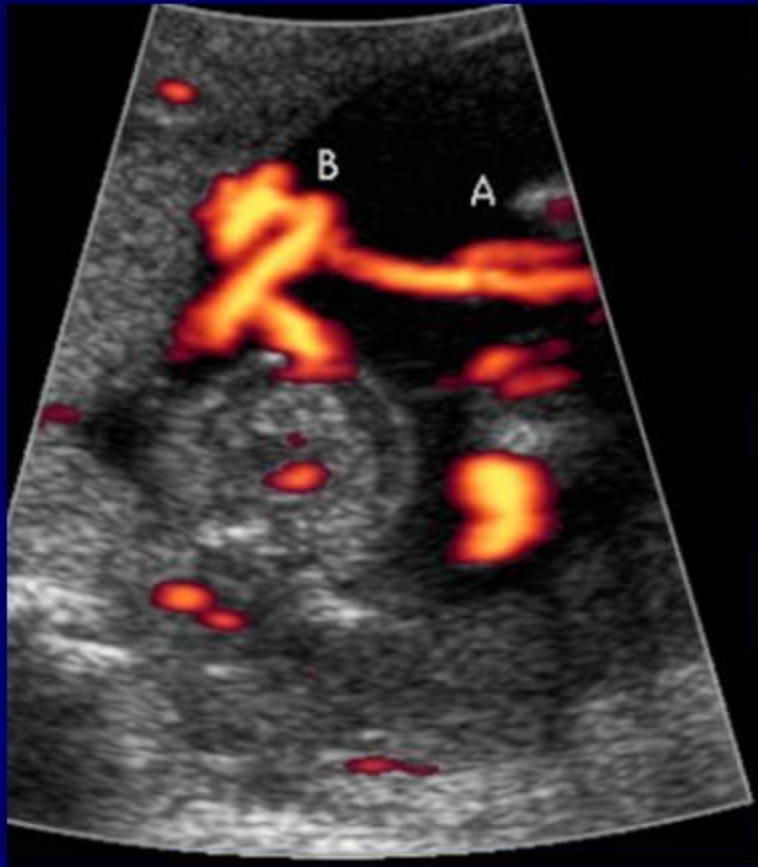
Ultrasound



Pump twin-cardiac disease

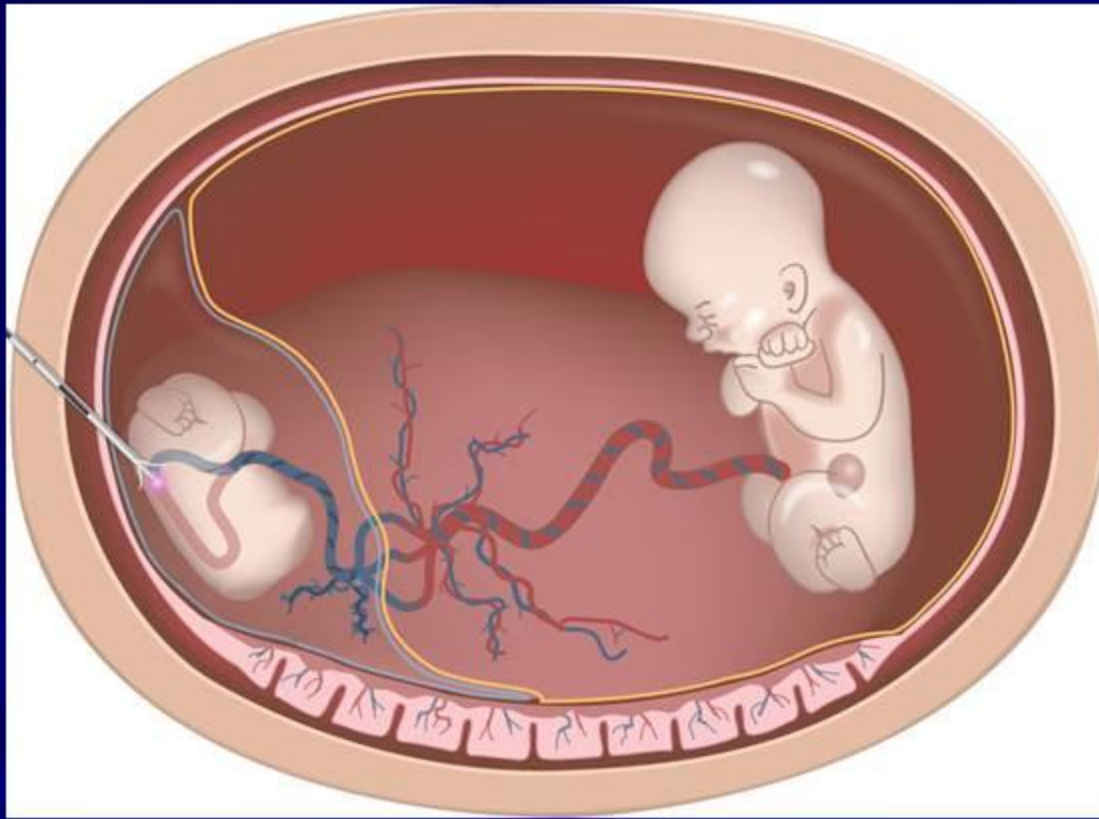


Cord Complications



Interventions

Fetoscopic RFA cord ligation



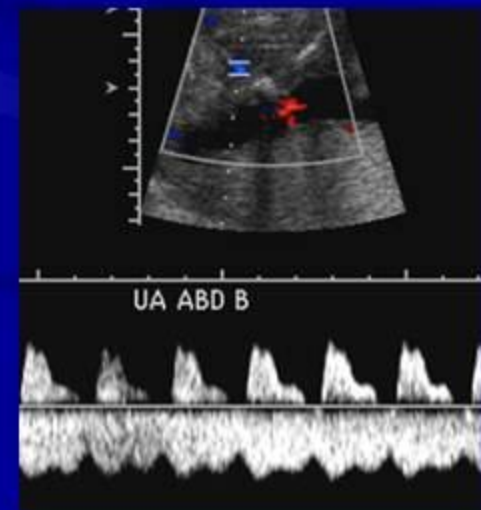
Monoamniotic

- 1% twin
- 2-3% monochorionic
- Intrauterine demise 50-70%
- Prematurity
- Low birth weight
- TTTS less common
 - Cord insertions close
 - Large placental anastomosis

Cord Entanglement

5% CCHMC

- First trimester
 - Fetal movement greatest
- Diagnostic monoamniotic
- Braid or floating knot
- Mechanism for fetal loss
 - Cord compression
 - Absent end diastolic velocities
 - Notch in umbilical artery waveform



Conjoined Twins

<1% CCHMC

- Incomplete anatomic separation
- 1 to 33,000-165,000
- 1% monozygotic
- Female prevalence 75%
- 40% stillbirth
- 35% die first 24 hours



Conclusion Twins

- Imaging is complex
- US with Doppler imperative
- Fetal MR
 - Fetal anatomy
 - Brain ischemia/bleed
 - Brain anomalies
 - Pregnancy anatomy prior to intervention



Thank You!