Fetal Imaging of Multiple Gestations

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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

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

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

Diamniotic dichorionic (separated) 3-8 d

Diamniotic monochorionic

Diamniotic dichorionic (fused) 0-3 d

Monoamniotic monochorionic 8-13 d

www.babymed.com
<table>
<thead>
<tr>
<th></th>
<th>DiAmniotic</th>
<th>DiAmniotic</th>
<th>DiAmniotic</th>
<th>MonoAmniotic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dichorionic</td>
<td>Dichorionic</td>
<td>MonoChorionic</td>
<td>MonoChorionic</td>
</tr>
<tr>
<td>Separate placentae</td>
<td></td>
<td>Fused placentae</td>
<td>Single placenta</td>
<td>Single placenta</td>
</tr>
<tr>
<td>Frequency:</td>
<td>35%</td>
<td>27%</td>
<td>36%</td>
<td>2%</td>
</tr>
<tr>
<td>Mortality:</td>
<td>13%</td>
<td>11%</td>
<td>32%</td>
<td>44%</td>
</tr>
</tbody>
</table>

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

Dichorionic

Monochorionic

Shetty, A et al
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

Normal vs Abnormal:
- UA
  - RI: 0.70 vs 0.88
- MCA
  - RI: 0.77 vs 0.54
  - MCA/UA RI ratio: 1.1 vs 0.61

IUGR
CHD
TTTS

Courtesy Rick Michelfelder, MD
Umbilical Venous Doppler

Courtesy Rick Michelfelder, MD
Ductus Venosus Doppler

[Diagram of the cardiovascular system with labels such as 'Oxygen saturation of blood', 'High oxygen content', 'Medium oxygen content', 'Poor oxygen content'.]

[Waveform images labeled A, B, C, D, with arrows indicating S and D waves.]

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
<table>
<thead>
<tr>
<th>Measurement</th>
<th>Value</th>
<th>Range</th>
<th>Age</th>
<th>Range</th>
<th>Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC/BPD/FL/HC</td>
<td>755g</td>
<td>110g</td>
<td>24w5d</td>
<td>58.1%</td>
<td></td>
</tr>
<tr>
<td>BPD (Hadlock)</td>
<td>6.07 cm</td>
<td>6.07</td>
<td>avg.</td>
<td>24w5d</td>
<td>58.6%</td>
</tr>
<tr>
<td>OFD (HC)</td>
<td>7.45 cm</td>
<td>7.45</td>
<td>avg.</td>
<td>24w5d</td>
<td>20.3%</td>
</tr>
<tr>
<td>HC (Hadlock)</td>
<td>21.93 cm</td>
<td>21.93</td>
<td>avg.</td>
<td>24w5d</td>
<td>71.6%</td>
</tr>
<tr>
<td>AC (Hadlock)</td>
<td>20.68 cm</td>
<td>20.68</td>
<td>avg.</td>
<td>24w5d</td>
<td>57.2%</td>
</tr>
<tr>
<td>FL (Hadlock)</td>
<td>4.51 cm</td>
<td>4.51</td>
<td>avg.</td>
<td>24w5d</td>
<td>40.8%</td>
</tr>
<tr>
<td>HL (Jeanty)</td>
<td>4.00 cm</td>
<td>4.00</td>
<td>avg.</td>
<td>24w5d</td>
<td>32.1%</td>
</tr>
<tr>
<td>Cereb (Hill)</td>
<td>2.83 cm</td>
<td>2.83</td>
<td>avg.</td>
<td>24w5d</td>
<td>&lt;10.0%</td>
</tr>
<tr>
<td>FL/HC (Hadlock)</td>
<td>21%</td>
<td>19%</td>
<td>avg.</td>
<td>21w0d</td>
<td>&lt;2.0%</td>
</tr>
<tr>
<td>FL/AC</td>
<td>17%</td>
<td>19%</td>
<td>avg.</td>
<td>21w0d</td>
<td>&lt;2.0%</td>
</tr>
<tr>
<td>HC/AC (Campbell)</td>
<td>1.06</td>
<td>1.05 - 1.21</td>
<td>avg.</td>
<td>24w5d</td>
<td>&lt;5.0%</td>
</tr>
</tbody>
</table>
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 11 cm
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

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

MRI Disparate Amniotic Fluid
MRI Disparate Bladders and Growth

Recipient

Donor
MRI Recipient Cardiac
MRI Recipient Lung Lesion (4-5%)

Speculated CPAM

Increased cell proliferation/decreased apoptosis

Vasoactive mediators in TTTS
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

- Neonatal Deaths
- NDI = Neurodevelopmental Impairment
- Death or NDI

Adegbite et al A J Ob Gyn 2004
MRI Cerebral Ischemia/Hemorrhage (5-8%)

- Acute stage not visualized with ultrasound
- Chronic stage
  - Normal head ultrasound
  - Enlarged ventricles
Anatomy of the Placenta
Cord Insertions

Central

Membranous
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

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Z-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RV end-diastolic dimension</td>
<td>- 0.9 ± 0.7</td>
</tr>
<tr>
<td>LV end-diastolic dimension</td>
<td>- 0.5 ± 0.6</td>
</tr>
<tr>
<td>RV free wall thickness</td>
<td>2.8 ± 1.8</td>
</tr>
<tr>
<td>IVS thickness</td>
<td>2.4 ± 1.5</td>
</tr>
<tr>
<td>LV free wall thickness</td>
<td>2.8 ± 1.8</td>
</tr>
</tbody>
</table>

Courtesy Rick Michelfelder, MD
Cincinnati Grading

Polyhydraminos/Oligohydraminos
Urine in bladder of donor twin not visible
Critically abnormal Dopplers*
Mild to moderate TTTS cardiomyopathy**
Moderate to severe TTTS cardiomyopathy**
Ascites or frank hydrops in either donor or recipient
Demise of either fetus

* 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

Evaluation
Ultrasound
Ultra fast MRI
Echocardiogram
Team Meeting

Oligohydramnios
Polyhydramnios

I

Absent Bladder

II

Doppler Changes
Mild Cardiomyopathy

III

Moderate Cardiomyopathy

IIIA

Severe Cardiomyopathy

IIIB

Hydrops
Fetalis

IIIC

IV

Surveillance
Ultrasound
Echocardiogram

Serial
Amnioreduction

Laser
Photocoagulation
Microseptostomy
Amnioreduction

Radiofrequency
Ablation

Progressive Disease

Surveillance
Ultrasound
Echocardiogram

Progressive Disease

Progressive Disease
TTTS Intervention

- Fetoscopic laser photococoagulation
  - 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

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

100% 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!