Anesthesia for Fetal Surgery

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Disclosure

• Has no relevant financial relationships to disclose.
• Will not be discussing off-label/investigative use(s) of commercial devices.
Fetal Wellbeing

- Fetal heart rate

- Amniocentesis:
  - Lecithin/Sphingomyelin ratio
  - Alpha feto-protein levels

- MRI/Ultrasound
  - Fetal anomalies
MRI
## Top National Fetal Centers

<table>
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<th>Points</th>
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<th>Laser</th>
<th>Heart</th>
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Indications for In-utero Surgery

Fetal conditions amenable to surgical correction:

- Life-threatening conditions
- Non Life-threatening conditions
Life Threatening Conditions

Large thoracic masses

Sacro-coccygeal teratomas
Thoracic space-occupying lesions

- Large lung Masses
  - Congenital pulmonary airway malformations (CPAM)
  - Bronchopulmonary sequestrations (BPS)
- Mediastinal masses
  - Teratomas
Lung Lesions

Congenital pulmonary airway malformation (CPAM)

- Connected to tracheo-bronchial tree
- Majority will shrink
- 10% increase in size during pregnancy
- Rapid increase in size between 22-26 weeks gestation
Management of Lung Masses

Serial ultrasound examination:

• CCAM volume ratio (CVR): tumor volume/head circumference
  
  • CVR < 1.6 = observation
  
  • CVR > 1.6 = risk of fetal hydrops

Fetal MRI for Lung Lesions

Large cystic and solid right lung CCAM with ascites
Pathophysiology of Lung Masses

In utero, expanding lung masses result in compression of:

• Esophagus
• Lung
• Heart & vena cava
Mass Effect of Thoracic Lesions

- Esophagus → Impaired fetal swallowing (Polyhydramnios)
- Lungs → Pulmonary hypoplasia
- Vena cava & heart → Heart failure
- Accumulation of fluid in one or more cavities in fetus: Hydrops fetalis
- Use of maternal steroids has altered management
- In–utero fetal surgery for rapid progression/hydrops
Case Presentation – Lung Mass

• 28 yo G$_2$P$_1$ referred at 22 1/7 weeks for fetus with left lung mass.
  – Initial MRI: large mass, no hydrops.
• Over the next 10 days
  – Echo- mod TR, reversal diastolic flow in ductus venosus
  – Pericardial effusion, 10 mm ascites
Fetal Imaging
Open Fetal Surgery Set-up

- Ultrasound Guidance
- Fetal Fentanyl & Vecuronium IM
- Amniotic Fluid Withdrawn
- Table Tilt Avoids IVC Compression
- Stapled Hysterotomy
- Indomethacin PR
- Continuous Warm Saline Infusion
- Sevoflurane
- B.P. Cuff
- Radial Arterial Catheter
- Pulse Oximeter
- EKG
- O₂
- B.
- Vecuronium IM
Follow-Up

- Hydrops resolved within 10 days
- Lung grew dramatically
Follow-Up

• PROM, PTL, C-section at 32 weeks’
  – Nearly 10 weeks post-op

• Intubated at birth, administered surfactant

• Extubated DOL #2, transferred to Level II DOL #3
Maternal-Fetal Anesthesia

A vital component for the success of these cases
Pre-operative Considerations: In-Utero Surgery

- Healthy mothers (ASA I & II) considered eligible
- Social support and travel restrictions
- Fetus with normal karyotype
- No major associated anomalies
Evaluation and Case Selection

• Presentation at large multi-disciplinary fetal meeting

• All disciplines involved in fetal intervention
  – Alternative options discussed

• Family conference
Family Conference

• Obstetrician (Maternal-Fetal Medicine Specialists)
• Pediatric/Fetal Surgeons
• Anesthesiologists + Fellow
• Cardiologists
• Radiologists
• Neonatologists
• Social Worker
• Fetal Center Nurse Coordinators
Pre-operative Family Conference

• Step-by-step discussion of procedure
• Questions posed & answered
• Patient & family member(s)
  – Team members introduce themselves & explain roles
  – Consent obtained
• Blood ordered:
  – 4 units packed red cells (Mother)
  – 60cc O- blood (Fetus)
Anesthetic Considerations

Pre-operative considerations

• Sequential compression devices
• Anti-emetic/aspiration prophylaxis
• Lumbar epidural placement for post-operative pain management

Intra-operative considerations

• Rapid sequence intubation
• Venous access × 2
• Invasive blood pressure monitoring (arterial line)
Operating Room: Items for Fetus
(On the sterile field)

- Pulse oximeter
- 24 G IV catheters
- Penrose drain (tourniquet)
- Saline flush with extension for attachment to IV catheter
- Resuscitation medications:
  - Three 1 ml syringes each of Epinephrine 1 mcg/kg & 10 mcg/kg
  - Two 1 ml syringes of Calcium gluconate 30 mg/kg

Standard Drugs

- Three 1-cc syringes with 27-G needles for IM administration containing combination of:
  - Vecuronium (0.1 - 0.2 mg/kg)
  - Fentanyl 5 -10 mcg/kg
  - Atropine 20 mcg/kg
- Three syringes of Atropine 20 mcg/kg
- Two 10cc syringes of Albumin
- Two 10cc syringes of Saline

Garcia PJ et al. *Anesthesiology*. 2009
Day of Surgery

Intra-operative Considerations

• Regular anesthetic (Sevoflurane) concentration at beginning of procedure

• Gradually increase anesthetic agent concentration after skin incision

• Prior to uterine incision: 2-3 MAC for uterine relaxation

• Relaxation determined by manual palpation of the uterus
Anesthetic Considerations

Intra-operative considerations

• Continuous spillage of amniotic fluid during surgery
  – Intermittent infusion of warm fluid (Lactated ringers) into uterine cavity
    • Keeps uterus full, prevents expulsion of fetus
    • Thermoneutral environment for fetus
    • Prevents kinking of umbilical cord.
    • Judicious administration of IV fluid to mother (<500cc)
• MgSO₄ administered during closure of uterine incision
Anesthetic Considerations – Fetus

**Intra-operative considerations**

- Monitoring
  - Intraoperative continuous fetal monitoring using Echocardiography (Cardiologist)
  - If possible, pulse oximeter on hand following hysterotomy: 60-70%.

- Time out prior to fetal skin incision
In-utero Surgery: Fetal Considerations

• Anesthesia & analgesia
  – Inhalational agents delivered via umbilical cord
  – Combination intramuscular fetal injection:
    • Fentanyl, Vecuronium & Atropine

• Intravenous access (23-25 week preemie):
  – Lung mass & SCT resection (not for MMC repair)
  – Umbilical cord: large bore venous access (adequate length required)
  – Intra-cardiac administration
Specific Anesthetic Considerations

Lung Mass

- Marked decrease in SVR with removal of mass
- Fluid administration (albumin, lactated ringers solution)
- Recommended before mobilization of mass from thoracic cavity
- Blood transfusion may be required
- Be ready for fetal resuscitation
At Closure of Uterine Incision

- MgSO₄ loading dose (4-6 g) with infusion of 2 g/hour
  - Caution: interaction of MgSO₄ and muscle relaxant
  - Stepwise decrease in concentration of anesthetic agent
  - Alternative: IV anesthesia – Propofol & Remifentanil

- Judicious use of intra-operative crystalloids: 500 ml – 1 Liter
  - Case report: post operative pulmonary edema
At Closure of Uterine Incision

• Incremental dosing of epidural catheter: 0.2% Ropivicaine or 0.25% Marcaine
  – T4-T6 sensory level

• Epidural infusion: opioid with local anesthetic
  – 0.1% Ropivicaine + 10 mcg/ml Fentanyl
In-utero Surgery vs. Cesarean Section

Hysterotomy differs from routine Cesarean section:

• High dose of inhalational agents (2-3 times MAC)

• Uterine relaxation paramount for success

• Vasopressors required for hemodynamic stability

• Hemostatic, absorbable staples used for hysterotomy
Open Fetal Surgery: Post Operative Concerns – Mother

Preterm Labor

- Immediate
- Delayed
- Mean gestational age at delivery: 34+ weeks

Etiology

- Maternal pain: ↑ cortisol
- Fetal pain: ↑ cortisol
- ↑ cortisol → changes in placenta → fetal estrogen & prostaglandin production: ↑ uterine activity
Open Fetal Surgery: Post Op Management

Post-operative pain control

- Second to uterine relaxation in determining success of procedure
- Reduces stress-induced hormonal trigger for preterm labor
- Epidural analgesia preferred (3 - 4 days post op)
  - Reliably prevents stress response
  - High opioid concentration → significant systemic absorption required for fetal analgesia
Sacrococcygeal Teratoma (SCT)

- Most common tumor of newborn
- Incidence: 1 in 40,000
- Female preponderance
- Located anterior to the coccyx
- Prenatal diagnosis
  - 50% mortality
- Postnatal diagnosis
  - 10% mortality
Sacroccocygeal Teratoma – Types

Altman Classification
Mann & Olutoye, Chapter 49.
In Shnider and Levinson’s Anesthesia for Obstetrics
5th Edition
Sacrococcygeal Teratoma

Pathophysiology

- Vascular; large arterio-venous communications
- Lower resistance in tumor “steals” blood from placenta (vascular steal)
- Increased cardiac demand → fetal cardiac hypertrophy & heart failure
- Rupture of tumor and hemorrhage: exsanguination in-utero or during delivery.
Sacroccocygeal Teratoma

Management

• Close prenatal surveillance:
  – Amnioreduction
  – Cyst aspiration

• Development of hydrops:
  – In utero surgical debulking (<28 weeks)
  – EXIT-to-resection (>28 weeks)
Specific Anesthetic Considerations

**Sacrococcygeal Teratoma**

- Marked increase in SVR as mass is resected
- Probably the sickest fetuses for in-utero surgery
- Potential for blood loss requiring transfusion
- Increased third space loss
- Confirm availability of blood for baby in mother’s operating room
Indications for In-utero Surgery: Non-life Threatening Conditions

Myelomeningocele
Myelomeningocele

- Most common open neural tube defect
- May occur anywhere along length of spinal cord (commonly lumbar and sacral region)
- Two hit hypothesis:
  - Abnormal neurulation
  - Exposure of spinal cord to amniotic fluid/trauma
Myelomeningocele (MMC)

- Leakage of cerebrospinal fluid (CSF) →
  - Herniation of hind brain structures
    - Chiari II malformation

- Obstruction → Impaired drainage of CSF with resulting hydrocephalus +/- need for ventriculoperitoneal shunt placement

- Motor dysfunction; neurogenic bladder and bowel
MOMS (Mx of Myelomeningocele Study) Trial

• Pregnant mothers < 26 wks GA randomized:
  – Prenatal repair (in utero repair)
  – Post natal repair
  – Plan to enroll 200 patients

• Primary outcome: Death or need for shunt at 12 months of age

• Secondary outcomes: Neurocognitive development, bladder and motor function @ 30 months
MOMS Trial

• Babies assessed at non-treating center for need for ventriculo-peritoneal shunt

• Trial stopped early due to efficacy of prenatal surgery compared to post natal repair

• 183/200 patients recruited
# MOMS Trial Results

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<th>Pre-natal Repair</th>
<th>Post-natal Repair</th>
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<tr>
<td><strong>Primary Outcomes</strong></td>
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<tr>
<td>Death or need for shunt</td>
<td>68%</td>
<td>98%</td>
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<tr>
<td>Actually got a shunt</td>
<td>40%</td>
<td>82%</td>
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<tr>
<td>Mental development</td>
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<td>Motor function</td>
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<tr>
<td><strong>Secondary Outcomes</strong></td>
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<tr>
<td>Hindbrain herniation at 12</td>
<td>Reversed</td>
<td>Persistent</td>
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<td>months</td>
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<td>Ambulation by 30 months</td>
<td>Improved</td>
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Fetal MMC Pre & Post in-utero repair

- Hindbrain herniation
- Low CSF

- Reversal of hindbrain herniation
- CSF restored
Specific Anesthetic Considerations

Myelomeningocele

- Otherwise healthy fetus with no cardiac dysfunction
- Potential for blood loss very minimal
- Only back exposed so no access to limbs for pulse oximeter or IV access
- Dependent on fetal echocardiography for fetal monitoring
Management of Myelomeningocele

• Revolutionized care of fetuses with Myelomeningocele
• Increased number of centers adopting the proposed surgical approach to treatment
Drawbacks to in Utero Repair

• Premature labor/delivery
• Uterine dehiscence
• Cesarean section for all subsequent pregnancies
Fetoscopic Approach with CO$_2$ Insufflation

Partial amniotic carbon dioxide insufflation (PACI) facilitates fetoscopic interventions in complicated monochorionic twin pregnancies

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$^2$ Department of Cardiology, University Children’s Hospital Münster, Münster, Germany
Fetoscopic Approach

• Investigational Review Board approved study
• Pfannenstiel abdominal incision, Uterus is exteriorized
• Two small (3-4mm) ports in the uterus (no significant uterine incision)
• Intrauterine CO$_2$ insufflation
  – Increases surgical visibility
  – Allows use of monopolar cautery
Anesthetic Management: Fetoscopic Approach

- Same as for open MMC repair
- Extra vigilance with CO$_2$ insufflation
  - Monitor end-tidal CO$_2$
  - Frequent arterial blood gases
Summary

• Identified fetal conditions amenable to open fetal surgery

• Reviewed specific anesthetic considerations depending on fetal lesion

• Highlighted differences in anesthetic approach for fetal surgery and cesarean section
Thank you!

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