Before They’re Born: Anesthesia for Fetal Surgery

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DISCLOSURE OF CONFLICT OF INTEREST

Farcus

by David Waisglass
Gordon Coulthart

“What conflict of interest?! I work here in my spare time.”
Anesthesia for Fetal Surgery Objectives

• Discuss the history and the current topics in fetal anesthesia.

• Review maternal and fetal physiology as it pertains to anesthesia for fetal surgery.

• Explain the anesthetic concerns and implications for minimally invasive, open midterm and exit fetal procedures.
Pregnancy

- Emotional impact
- Physical changes
- Lifestyle changes
- Financial impact

- 4 million births in US
  Nat. Vital Stats 2010

- 3 percent or 120,000 will have a complex birth defects
  March of Dimes
Fetal Growth From 8 to 40 Weeks
Historical Perspective of Fetal Surgery

- The fetus, up until the last half of the 20th century, was a hidden mystery
- 1960s intraperitoneal blood transfusions to treat erythroblastosis
- 1960s U/S used to monitor fetus
The 1980’s lead the way in fetal surgery
The knowledge and experience gained in the animal labs began to be used in the operating room
Why Fetal Surgery Developed

**Advances made**

Advances in perinatal and neonatal medicine

Improvements in diagnostic and therapeutic technology

Better understanding of the pathophysiology of fetal conditions

Advancements in anesthesia
Future of Fetal Surgery

• Using stem cells or gene therapy to the fetus

• In the future, there may also be a way to combine surgical techniques with stem cell therapy to treat the defect even earlier, which might improve a child's outcome.

• Fetoscopic Endoluminal Tracheal Occlusion

• Fetal surgery will become mainstream treatment

Evolution of a Specialty

“Change is the law of life. And, those who look only to the past or present are certain to miss the future.”

– John F. Kennedy –
Fetal Anesthesia Considerations

- Mother/Family
- Fetus/Baby
- Uterus
- Placenta
- Utero-placental circulation
Who Has Fetal Surgery?

- Mother with a low risk for surgery
  - ASA I or ASA II
  - NOT if pre-eclampsia
  - NOT if ‘mirror’ syndrome
    - Mother’s condition worsens as fetus becomes ill
    - Presents with symptoms similar to PIH
      - Evidenced by maternal tachycardia, proteinuria

You could see their shock and disappointment when all us women got out of the pool with our big bellies and bulging behinds. Serves them right.”
Maternal Anesthetic Considerations

- **Gastrointestinal**
  - Pylorus is displaced
  - Decreased LES tone and increased gastric pressure
  - Gastric acid production is elevated
Maternal Anesthetic Considerations

- **Respiratory changes**
  - Decreased FRC and increased $O_2$ consumption
    - Faster desaturation when apnic
    - Pre-oxygenate
  - Decreased oncotic pressure
  - Mucosal capillary engorgement
  - Higher capillary permeability
    - Airway edema may cause difficult intubation
    - Increased risk of pulmonary edema
Maternal Anesthetic Considerations

- Cardiovascular
  - Decreased preload during supine position
  - Aortocaval compression
  - High C.O state
  - Plasma volume increase more than RBC volume increases
Maternal Anesthetic Considerations

• Neurological
  – Increased sensitivity to muscle relaxants
  – Decreased MAC
  – Increased nerve sensitivity, reduced protein levels and pH changes in CSF
Fetal Anesthetic Considerations

• Cardiovascular
  – Immature cardiac function
    • Heart rate dependent/stiffer heart muscle than adult
    • Susceptible to depression from volatile anesthetics
    • Relies on placenta to compensate for hypovolemia
  – Low circulating blood volume (120-160 ml/kg) at midgestation
  – 2/3rds of the fetal-placental blood volume is in the placenta
Fetal Anesthetic Considerations

• Cardiovascular Cont’d.
  – High vagal tone and low baroreceptor sensitivity causes the fetus to respond to stress with a decrease in heart rate.
  – The fetal cardiovascular system is less able to compensate for hypoxia and hypovolemia than a full-term infant.
  – Less responsive to changes in preload
Fetal Anesthetic Considerations

- **Respiratory System**
  - Function of lungs in utero is the production of amniotic fluid
  - Depends on placenta for oxygenation
    - Normal $\text{PaO}_2 = 21 - 45 \text{ mmHg}$
    - Normal $\text{SpO}_2 = 40 - 70\%$
  - The fetus depends on uteroplacental blood flow and patent umbilical vessels for respiration and the elimination of carbon dioxide
Fetal Anesthetic Considerations

- Neurological
  - Incomplete myelination
    - Decreased MAC
    - Increased sensitivity to muscle relaxants

- Altered coagulation
  - Potential for increased blood loss

- Altered homeostasis
  - Increased risk for hypothermia
Fetal Anesthetic Considerations

Fetal Pain

-Fetus exhibits a circulatory stress response to pain*

-Before thalamic connection exists to the cortex (22-24 weeks), it is doubtful that physiologic or pharmacological responses to noxious stimuli by the fetus involve consciousness.

Fetal Anesthetic Considerations

- Anesthetic goal should be to relieve pain and stress for mother and baby while maintaining hemodynamic stability and ensuring uteroplacental circulation.
Uterine blood flow is directly related to uterine perfusion pressure and inversely related to uterine vascular resistance.

- \( \uparrow \text{UPP} \uparrow \text{UBF} \)
- \( \uparrow \text{UVR} \downarrow \text{UBF} \)

Uterine perfusion pressure = uterine arterial pressure - venous pressure
Uterine blood flow will decrease with:
- Higher uterine tone
- Maternal hypotension or hypertension
- Myometrial vasoconstriction
- Fetal manipulation
- Cord compression
Placental Transfer

- Passive Diffusion (main form: drugs that are lipid soluble, un-ionized and low molecular weight will pass)
- Active transport
- Bulk Flow (negligible)
- Pinocytosis (negligible)
- Inter villous space (negligible)
Utero-Placental Anesthetic Considerations

**DRUGS WHICH DO NOT CROSS THE PLACENTA**

- Glycopyrrolate
- All paralytics
- Insulin
- Heparin

**DRUGS WHICH DO NOT CROSS THE PLACENTA**

- Inhalational agents
- Opiates
- Benzodiazepines
- Ephedrine
- Local anesthetics
- Atropine
- Propofol
- Ketamine
What to remember

- Volatile agents have a direct depressant effects on fetal CVS
- Induction agents and opioids can decrease fetal HR variability but do not lead to fetal morbidity as long as maternal B/P remains stable
- There is no evidence of teratogenicity of anesthetic agents used at clinical concentrations
- The evidence is weak that anesthesia causes neurodegeneration and learning difficulties. These adverse neuro consequences may be attenuated by fetal analgesia and anesthesia
- Pregnant patients have a higher incidence of difficult airway sequela
- Use aggressive blood pressure treatment/ maintain normal ETCO2
- Restrict intravenous fluids to avoid pulmonary edema
- Have a plan for post-op pain and tocolytic therapy

Perioperative Considerations

**GOAL**

- Maintain blood pressure 10% of normal limits
- Mom & fetus warm
- Avoid aortocaval compression
- Avoid uterine contraction
- Provide analgesia for mom and fetus/baby
- Avoid maternal hypercapnia
- Monitor mom and baby
- Maintain viability of baby

**Action**

- Correct amount of crystalloid, use vasoactive drugs
- Warm room, warm irrigation
- Left uterine tilt
- Tocolytic therapy available
- Epidural, GA for mom/ fetal cocktail for baby
- Provide adequate ventilation
- Pulse ox, fetal echo, U/S
- Resuscitation team and drugs available
3 Types of Fetal Surgery

1. Minimally Invasive
   - Twin-Twin Transfusion Syndrome
   - Twin Reversed Arterial Perfusion
   - CDH (Fetoscopic Endoluminal Tracheal Occlusion)
   - Fetal endoscopy and repair of MM
   - Bladder Outlet Obstruction (vesicoamniotic shunt)
   - Amniotic Band Syndrome
3 Types of Fetal Surgery

2. Open Fetal Surgery/Midgestation

- Sacrococcygeal teratoma
- Bladder outlet obstruction
- Myelomeningocele
- Congenital Cystic Adenomatoid Malformation (CCAM)
3 Types of Fetal Surgery

- Large head or neck tumors that require intubation or a trach
- Severe heart or lung problems requiring immediate support with an extra corporeal membrane oxygenation (ECMO)
- Sacrococcygeal teratoma
Anesthesia for Minimally Invasive Fetal Surgery

**Advantages**
- Decreased incidence of post-operative contractions and less risk to mother
- Minimal insult to the uterus while obtaining access to the fetus, no hysterotomy.

**Side effects**
- PROM
- Pre-term delivery
- Septostomy
- IUGR due to placental insufficiency
- Amniotic band
Anesthesia for Fetoscopic Interventions

- Pre-operative considerations for mother:
  - Full history and physical
  - Team meeting with parents
  - Counseling regarding risk
  - Type and screen
  - Terbutaline available
  - Strict IV fluid restriction no longer necessary
Twin-Twin Transfusion Syndrome

- Twin birth rate is 33.2 per 1000 births
- 4 out of 1000 will be monozygotic
- TTTS complicates 10-20% of monozygotic twins
- TTTS occurs due to the shared vascular anastomoses that are uneven
- Shifts can be acute or chronic
- Fetal mortality is 80% if untreated
Anesthesia for Minimally Invasive Fetal Surgery

Twin-Twin Transfusion Syndrome (TTTS)

- There is an uneven sharing of placental blood flow through communicating vessels between the twins, a net fetofetal transfusion occurs from one twin (the donor) to the other (the recipient).
Anesthesia for Minimally Invasive Fetal Surgery
Twin-Twin Transfusion Syndrome (TTTS)

• The donor twin develops: Hypovolemia, Oliguria, Olihydramnios and growth retardation.

• The recipient twin develops: Hypervolemia, Polyuria, Polyhydramnios and signs of circulatory volume overload and hypertensive cardiomyopathy.
Quintero staging system for TTTS

- **Stage I:** Significant difference in amniotic fluid volume in each twin’s sac, no cardiomyopathy
- **Stage II:** Inability to see the donor’s bladder by ultrasound, no cardiomyopathy
- **Stage III:** Abnormal blood flow through the umbilical cord or fetal vessels around the heart can have mild moderate or severe cardiomyopathy in recipient
- **Stage IV:** An abnormal fluid accumulation in more than one body cavity, also known as hydrops, present in one or both twins.
- **Stage V:** The death of one or both twins
Management of Twin-Twin transfusion syndrome

- **Amnioreduction**: improves mothers comfort, improves uteroplacental blood flow and increases length of pregnancy

- **Microseptostomy**: no supporting studies, risk of creating a monoamniotic gestation

- **Fetoscopic laser photocoagulation**: laser selective vessels crossing the intertwin membrane

- **Fetoscopic cord coagulation**: sacrifice one twin arrest the syndrome
Anesthesia for Minimally Invasive Fetal Surgery

Twin-Twin Transfusion Syndrome (TTTS)

- Selective fetoscopic laser photocoagulation
  - Through a fetoscope, a laser is used for the surgical occlusion of superficial communicating vessels.
  - Now considered a standard treatment for severe Twin-Twin Transfusion Syndrome
Short term outcomes

• More than 825* fetal surgical interventions for TTTS, including more than 650 selective fetoscopic laser photocoagulation (SFLP) procedures since 2004 have been performed at CCHMC Fetal Care Center

• 80 percent success rate measured by survival. It is 91 percent for at least one twin’s survival and 69 percent for both twins’ survival.

*Data based on patients cared for by the Fetal Care Center of Cincinnati from Feb. 1, 2004, through March 31, 2013.
Outcomes of treated TTTS

Women deliver later after laser than amnioreduction

78-86% normal neural development

Systolic ventricular function normalizes over the long term


Eurofetus group compared laser to amnioreduction: improved survival of one twin and fewer neurological complications with laser

Anesthetic management for SFLP (selective fetoscopic laser photocoagulation)

- Fetus at midterm
- Recipient with hypertensive cardiomyopathy (procardia)
- Mother polyhydramnios
- Anterior placenta
- Posterior placenta
Epidural Anesthesia

- Nifedipine used to treat hypertensive cardiomyopathy in the fetus.
- Study the effects of preoperative nifedipine on the incidence of maternal hypotension during SFLP under epidural anesthesia.
- Conclusion: Increased intraoperative maternal vasopressor requirements during SFLP under epidural if on nifedipine. No correlation between maternal hypotension and fetal survival.

Ngamprasertwong et al 2013 The Scientific World Journal
Anesthesia for Minimally Invasive Fetal Surgery

Twin Reversed Arterial Perfusion Sequence (TRAP)

- One fetus with a lethal disease
- This threatens the viability of the other fetus
- Occurs 1% monochorionic twins
Anesthesia for Minimally Invasive Fetal Surgery

Twin Reversed Arterial Perfusion Sequence (TRAP)

- The pump twin (normal twin) produces cardiac output for the acardiac fetus and itself
- Eventually, pump twin develops cardiac overload & CHF
- Preterm labor
- Untreated pump twin dies 50-75% of cases
Anesthesia for Minimally Invasive Fetal Surgery  
Twin Reversed Arterial Perfusion Sequence (TRAP)

- This procedure is usually performed at 18 – 25 weeks gestation.
- Ablate cord of twin with fetal demise
- Birth of the live twin and the mummified twin usually occurs near term by spontaneous vaginal delivery

MAC anesthesia
Anesthesia for Minimally Invasive Fetal Surgery

Other Fetoscopic Procedures

- Bladder outlet obstruction: laser used to ablate posterior urethral valves
- Placement of pigtail shunts to decompress fluid-filled spaces
Foreign Body removal
Open Fetal Surgery

Who:
- Fetus who merits intervention
- Mother with low maternal risk
- Mother who is compliant
Open Fetal Surgery

Mother Pre-op Considerations

- Full H&P
  - CXR, EKG, CBC, T&C
  - Team meeting
  - Counseling regarding risk
  - Uncertain outcome
  - Risk uterine atony and hemorrhage
  - Bed rest
  - Obligated C/S for life
  - Team briefing morning of surgery
Open Fetal Surgery

“You can observe a lot just by watching.”
– Yogi Berra –

• Lots of people!
  – Surgeons, anesthesiologists, and OR nurses
  • Second room available
  – Obstetrician, neonatologist, and cardiologist
  – Fetal nurse coordinator, L&D nurse
  – ECMO perfusionist
Open Fetal Surgery
Room Set-up

- Room warm – 80° Fahrenheit
- Type-specific PRBC: for mother, O Neg PRBC for fetus
- Two pulse oximeters
- Epidural for Mom
- A line, 2- IVs for mother
- Fetal drug kit
- IM injection for fetus
  - Epinephrine 10 mcg/kg
  - Atropine 20 mcg/kg
  - Vercuronium 0.2 mg/kg
  - Fentanyl 10 mcg/kg
Open Fetal Surgery

Fetus Pre-op Considerations

- Fetal echocardiography
- Karyotype: normal
- Prior procedures
- Estimated weight of baby
- Complications: pulmonary edema, premature labor, amniotic fluid leak, and fetal demise
Open Fetal Surgery

- Lumbar Epidural
- Rapid sequence induction, NG, foley remi and propofol infusion
- Radial arterial line, second IV
- 6-9% desflurane at uterine exposure
- Restrict IV fluids*

2 MAC for Uterine Relaxation?

- **Goal:** To lower the incidence and severity of CVS depression of the fetus.

- **Use** propofol and remifentanil as a supplement to lower the need for high Desflurane thus decrease CVS depression in the fetus.

- **Chart review:** 18 with high desflurane 18 with supplemental infusion and Desflurane

2 MAC for Uterine Relaxation?

- Findings: Adequate uterine relaxation was achieved with 1.5 Mac of desflurane in the SIVA group compared to 2.5 Mac in the Des group.
- More fetuses in the high desflurane group compared to the SIVA group developed moderate-severe left systolic function.
- 61% of fetuses in high desflurane group received resuscitative interventions compared to 26% in SUVA group.

Open Fetal Surgery

- Significant uterine relaxation
- Nitroglycerin boluses for 20 – 40 mcg if excessive uterine tone
- Desflurane best choice
Open Fetal Surgery

• Maintain uterine relaxation
  – Best monitored by communicating with surgeon
Types of Open Fetal Surgery

- Congenital Cystic Adenomatoid Malformation (CCAM)
  - Begins as cystic lung mass
  - Usually restricted to one lung
  - Restricts growth of surrounding lung tissue
  - Hydrops fetalis develops
Congenital Cystic Adenomatoid

- In experience with 26 cases of open fetal surgery with hydropic CCAM / CPAM, the survival has been 61 percent

- Maternal steroids had been reported to arrest the growth of fetal CCAMs
Types of Open Fetal Surgery

- Sacral Teratoma
  - Most common tumor in newborns
  - Diagnosed before birth, 30–50% mortality
  - Less 32 weeks open

Types of open fetal Surgery
Open Fetal Repair of Myelomeningocele
Open Fetal Repair of Myelomeningocele
Management of Myelomeningocele Study (MOMS)

• Study (2011), compared the effects of fetal surgery at midgestation vs. surgical repair after birth.

• In MOMS, 40 percent of babies who had fetal surgery for myelomeningocele needed a VP shunt, while 82 percent of babies who had surgery after they were born needed a VP shunt.

Management of Myelomeningocele Study (MOMS)

- 42 percent of the children who had fetal surgery were able to walk without crutches by age 2½. Only 21 percent of babies who had surgery after birth were able to walk unassisted at that age.

Open Fetal Surgery

- Ultrasound uterus
- Hysterotomy using stapling device
- Uterus after stapling
Open Fetal Surgery
Fetal Exposure

- Fetal IM cocktail injection to buttocks/arm
- Fetal monitors
  - NL SpO2 = 50 – 70%
  - NL HR = 140 – 180
- Continuous fetal echo
- Fetus returned to the uterus
Open Fetal Surgery

- Resection of pericardial teratoma
Open Fetal Surgery

- Further Resection
Open Fetal Surgery

- Decrease volatile agent
- Remi and propofol
- Magnesium sulfate
  Bolus 4 – 6 gm over 20 min.
  Infusion 2 – 3 gm/hour
- Dose epidural
- Wake mother
Open Fetal Surgery

Post-Operative

- Routine vital signs
- LUD
- Monitor for pulmonary edema
- At the time of delivery: C-section
EXIT Procedure

- EXIT procedure developed from the OOPS (Operation On Placental Support)
- Allows for controlled delivery and intrapartum assessment strategies to treat fetuses with life threatening diseases
EXIT Procedure

- EXIT = EX-utero Intrapartum Treatment
- The EXIT procedure involves a hysterotomy to expose the fetus.
- Fetus still benefits from uteroplacental circulation while an airway or echmo can be established:

EXIT Procedure
This is not your mothers C-section

C–Section
Minimize fetal exposure of anesthetic agents
Maximize uterine tone
No preservation of uterine volume
Regional

Exit procedure
Give anesthetics to fetus
Relax the uterus
Preservation of uterine volume
Regional and General
EXIT Procedure

- Procedures performed on fetus include:
  - Direct laryngoscopy
  - Bronchoscopy
  - Intubation
  - Tracheostomy
  - Tumor Decompression
  - ECMO
EXIT Procedure

- Adequate oxygenation is maintained at all times
- Performed on infants with a low probability of survival with conventional treatment
- Requires complete uterine relaxation thus maternal hemorrhage could result
EXIT Procedure

- Maternal and fetal pre-operative considerations
  - Same as open procedure
EXIT Procedure

- Induction of anesthesia
  - LUD
  - RSI
  - Remi and propofol infusion
  - A-line
  - Two Large Iv's
  - Uterine exposure desflurane 6-9%
  - Decrease propofol
Exit procedure

- Fink et al: remi infusion with combined spinal epidural, phenylephrine infusion, bolus nitroglycerin 50-100mcg followed by 50-100mcg/min infusion (no fetal cocktail)
- Ioscovich et al: remi and nitroglycerine infusion with a general.
- Rosen et al: propofol and nitroglycerin infusion for MH susceptible patient

EXIT Procedure

• Incision

• Dissection
EXIT Procedure

- Uterine exposure
- Stapling uterus
EXIT Procedure

- Baby exposed
EXIT Procedure

- Partial delivery of baby
EXIT Procedure

- Monitor
  - Pulse OX:
  - Echo:
  - IV Placement:

- Monitor
  - Fetal Cocktail IM:
    - Fentanyl 20 mcg/kg
    - Atropine 20 mcg/kg
    - Vecuronium 0.2 mg/kg
EXIT Procedure

• Procedure performed on fetus
  – Laryngoscopy
EXIT Procedure

- Airway Established:
- Cord Clamp:
- Baby Delivered:
EXIT Procedure

- Trach
- Baby in RCNIC
EXIT Procedure

- Pitocin
- Hemabate, Methergine available
- Assess EBL