Anaesthesia for fetal surgery

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1965 - first intrauterine transfusion for hydrops due to Rh incompatibility by A.W. Liley

1974 - fetoscopy to obtain fetal samples by Hobbin

1981 - fetoscopic transfusion by Rodeck

1982 - first open fetal surgery for obstructive uropathy by Dr. Michael Harrison, University of California, San Francisco
What is fetal surgery?

It is application of established surgical techniques to the **unborn baby**
- during gestation
- at the time of delivery

- fetal intervention is reaching **inside the uterus**
- many diseases can now be accurately **diagnosed before birth** by genetic and imaging techniques
- maternal - fetal intervention
- **the safety of the mother**
Contraindication for fetal surgery

- Conditions incompatible with life
- Chromosomal and genetic disorders
- Other associated life threatening abnormalities
- Usually performed between 24-29 weeks gestation

Requires combined expertise of
- Obstetrician
- Anaesthesiologist
- Neonatologist
- Pediatric surgeon
Indications For Fetal Surgery

1. **Anatomic lesions** that interfere with development:

- Bilateral obstructive hydronephrosis or lower urinary tract obstruction
- Obstructive hydrocephalus
- Congenital diaphragmatic hernia (CDH)
- Cardiac anomalies-complete heart block, AS, PS
- Neural tube defects—spina bifida, sacrococcygeal teratoma, myelomeningocele
- Skeletal defects
- Gastrochisis
- Thoracic space occupying lesions
- Giant neck masses
- Tracheal atresia-stenosis
- Congenital cystic pulmonary adenomatoid malformation (CCAM)
- Craniosynostosis
- Cleft lip and palate
- Hydrothorax
Indications For Fetal Surgery

2. **Anomalies associated with twins**

   TTTS - twin-twin transfusion syndrome
   TRAP- twin reverse arterial perfusion

3. **Anomalies of placenta, cord or membranes**

   Amniotic band
   Chorioangioma
Types of fetal surgery

Open fetal surgery

Human Fetal Myelomeningocele Repair
| OPEN SURGERY | Hysterotomy | • CCAM – Lobectomy  
• SCT – Resection  
• MMC – Repair  
• Cervical Teratoma – Resection  
• EXIT  
  Tracheal occlusion  
  Neck tumors  
  CDH (EXIT to ECMO)  
  CCAM (EXIT lobectomy) |
|---|---|---|
| FETENDO | Fetoscopic Surgery | • Balloon Occlusion of Trachea (for CDH)  
• Laser Ablation of Vessels (for TTTS)  
• Cord Ligation/Division  
• Cystoscopic Ablation Valves (Urinary Obstruction)  
• Amniotic Bands Release |
| FIGS | Fetal Image Guided Surgery | • Amnioreduction/Infusion  
• Fetal Blood Sampling  
• RFA Anomalous Twins  
• Vesico/Pleuro Amniotic Shunts  
• Balloon Dilation Aortic Stenosis |
| EXIT procedure | Planned Specialized Delivery | • CHAOS  
• Removal of the CDH Tracheal Occlusion Balloon  
• Pulmonary Sequestration  
• CCAM |

CHAOS - Congenital High Airway Obstruction Syndrome; CCAM - congenital pulmonary airway malformation; CDH - congenital diaphragmatic hernia; STC - sacrococcygeal teratoma; TTTS - Twin to Twin Transfusion Syndrome; RFA - Radio-Frequency Ablation
Open surgery

Most definitive and most invasive
Performed – middle of pregnancy

*Mother anaesthetised by GA*

*Uterus opened similar to LSCS*

Intraoperative sonography – locate the placenta
Incision taken close to the area of interest
Fetal part is exteriorized
Surgical repair of fetus done
Types of fetal surgery

**FETENDO** - Fetal endoscopic surgery or fetoscopy (minimally access fetal surgery - MAFS)
✓ developed in the 1990s

✓ *very small endoscopes*, with very small instruments

✓ the best method of seeing the fetus in real-time is to use both *endoscopic*, and *sonographic*

✓ combination of image-guided manipulation and sonographically - guided manipulation

✓ *percutaneous* or, in some circumstances, *mini-laparotomy*
| OPEN SURGERY | Hysterotomy | • CCAM – Lobectomy  
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The advantages

- *less invasive* than open fetal surgery
- mother's postoperative *recovery is easier*
- *less preterm labor* (not eliminated the problem)
- replaced open fetal surgery
- particularly useful for treating *problems with the placenta*
- useful *for looking inside* the fetus

“yes.... BUT!”

- close pregnancy monitoring and medications to control preterm labor may still be necessary
- requires a skilled team of expert

Uterus irrigated with NS – absorbed to peritoneum through fallopian tubes – *pulmonary oedema* as mother also receives tocolytics
Fetoscopic access to the fetus
During or after the 18th week of pregnancy
Useful for treating placental problems
Technically difficult
Maintains fetal position

- Under LA with infiltration of both skin and peritoneum+/-sedation
- Under epidural, spinal or CSE anaesthesia
- High risk for urgent C-section: CSE preferred
- Sedation required for maternal anxiolysis
Types of fetal surgery

FIGS - Fetal image guided surgery
✓ for amniocentesis
✓ fetal blood sampling
✓ placement of catheter-shunts in the bladder, abdomen, or chest,
✓ radiofrequency ablation to solve problems with anomalous twins
✓ radiofrequency ablation for some fetal cardiac defects the fetus can be treated non-invasively through the mother’s circulation

“yes....BUT!”
✓ not useful for serious structural problems that require surgery
✓ method of manipulating the fetus without either an uterus incision, or an endoscopic view

✓ *percutaneous* or, in some circumstances, *mini-laparotomy*

✓ *MAC*, *under a regional anesthesia*, or even under *local anesthesia*

✓ *the least invasive* of the fetal techniques

✓ *the least problems* for the mother in terms of hospitalization and discomfort

✓ preterm labor is also minimized
Types of fetal surgery

EXIT - Ex-utero intrapartum treatment procedure
Also known as OOPS - operation on placental support
Intervention occurring at the time of delivery
Used in cases where baby’s airway requires surgical intervention
Provide the baby with patent airway that can provide oxygen to the lungs after separation of placenta
Starts as a routine LSCS but under GA with maximum volatile agent (>2 MAC)

Head of the baby is delivered, but placenta is in situ
Baby gets oxygen from placenta via umbilical cord
Considerations during EXIT procedure

- Uterus needs to stay relaxed to permit placental perfusion
- Uterus needs to contract at end to limit bleeding
- Needs hemostatic hysterotomy
- May permit up to 2 hours of ongoing placental perfusion
Challenges before the field of fetal surgery

- Ethical dilemma
- Maternal risk
- Fetal risk
- Maternal anaesthesia
- Fetal anaesthesia
- Post surgical tocolysis
What is the risk to the mother?

- all fetal intervention is the effect on the mother
- varies with the type of fetal procedure

For open surgery risk
- of general anesthesia
- of the abdominal incision
- of the incision in the uterus itself

Fetendo procedures is less because the procedure is less invasive
- the membranes lining the inside of the uterus remains a problem

The risk of FIGS is less than either Fetendo or open fetal surgery.
- without the incision in the maternal abdomen
- entering the uterus
- potential leakage of amniotic fluid
- separation of membranes
- preterm labor
Pre-operative evaluation

Counselling of families:
- Potential fetal benefit
- Maternal risks
- Standard alternatives

Assessment of mother for anaesthesia
- h/o uterine activity
- airway examination
- concurrent medical problems
Assessment of fetus

Detailed USG to rule out other malformations
Fetal echocardiography
Fetal MRI
3D and 4D examination
Detail examination of affected organ system
Amniocentesis
Localisation of placenta and umbilical cord
Volume of amniotic fluid
Consent for caesarean delivery
Maternal blood cross matched
Availability of O-negative
Adequate aspiration prophylaxis- sodium citrate orally and metoclopramide i.v.
Indomethacin rectal suppository for postoperative tocolysis
Epidural catheter- postoperative pain control
Operating room is warmed to 26°C
Local anaesthesia

- 0.5 ml 1% lidocaine
- infiltration of both skin and peritoneum

Field block (TAP, RA)

CSE
Prevention and treatment of preterm labour

Tocolytic agents
✓ beta adrenergic agonists
✓ indomethacin (rectal)
✓ magnesium sulfate
✓ terbutaline (subcutaneous)
✓ Nitroglycerine (20μg/kg/min)

Halogenated agents-halothane, isoflurane, sevoflurane
Vascular stasis during hysterotomy - special stapling device
Postoperative pain control - epidural catheter
Anaesthetic techniques

Maternal sedation and local anaesthesia
Local anaesthesia with foetal paralysis
Regional anaesthesia
General anaesthesia
Maternal sedation and local anaesthesia

Indicated in **percutaneous needle aspirations** or **catheter insertions**
Drug of choice - BZD, narcotics for maternal anxiety

**Disadvantages:**
- increased hypoxia
- unprotected airway; aspiration risk
- presence of foetal movements

Close *monitoring for 3-4 hrs* required
Indicated in fetal umbilical vein blood sampling
For fetal paralysis, NMB given via umbilical vein or intramuscularly into fetal thigh or shoulder (vecuronium 0.1-0.3 mg/kg)

**Advantages:**
Loss of fetal movements for 2-4 hrs without any danger of maternal NMB

**Disadvantages:**
If fetus requires an emergency delivery, NMB will produce paralysed fetus and will require respiratory assistance
Indicated in MAFS (Minimal access fetal surgery)
*Lumbar epidural, spinal or CSE anaesthesia*

**Advantages:**
- excellent analgesia and good muscle relaxation
- avoid GA
- keeps mother awake and alert
- minimal effects on fetal hemodynamics, *uteroplacental* blood flow and uterine activity
Disadvantages:

- hypotension
- lack of fetal anaesthesia
- difficulty manipulating uterus and cord while the fetus may be moving
General anaesthesia

- aspiration prophylaxis - sodium citrate, ranitidine, metoclopramide
- prevention of supine hypotensive syndrome-left lateral tilt
- short acting amnestic
- short acting muscle relaxant-succinylcholine for RSI
- maintenance - 100% O2
- 50% O2 and 50% N2O with low inhalational +++
- maternal and fetal monitoring
✓ uterus opened similar to LSCS
✓ fetal part is exteriorized
✓ special stapling device
✓ surgical repair of fetus
✓ **warmed** Ringer Lactate along with antibiotics infused to replace amniotic fluid
✓ **at the time of closure, i.v. MgSO4 6 gm** over 20 minutes
✓ coughing or straining avoided to maintain integrity of uterine closure
Advantages:
  ✓ profound uterine relaxation
  ✓ allowing uterine manipulation with an immobile anaesthetised fetus

Disadvantages:
  ✓ fetal cardiac depression
  ✓ decreased uteroplacental blood flow
Postsurgical tocolysis

- high risk of preterm labour
- pre-operative: rectal indomethacin
- MgSO4 is tocolytic of choice and maintained for 2-3 days - 3 gm/hr infusion
- adequate maternal analgesia as maternal pain
- epidural analgesia (PCEA) for 24-48 hrs is recommended to prevent uterine contractility
### Fetal monitoring

<table>
<thead>
<tr>
<th>Maternal monitoring</th>
<th>Summary</th>
</tr>
</thead>
</table>
| Pulse oximeter      | ✓ Blood gas, pH, pO2  
| ECG                 | ✓ Blood glucose      
| HR                  | ✓ Electrolytes       
| BP monitoring       | ✓ Fetal Hb from cord blood  
| Capnography         | ✓ Electronic measurements of foetal heart rate, blood pressure and umbilical blood flow  
| Temperature         | ✓ Foetal heart rate cardiotachometer-FHR, temperature  
|                     | ✓ Foetal ECG         
|                     | ✓ Foetal echocardiography  

- Plethysmography and miniature pulse oximetry
- Periodic sonography- quality of foetal cardiac contractility, HR
- Direct uterine palpation - degree of uterine distension
- Irrigating solution is warmed to 37-38°C and monitored
- During fetoscopic placental vessel surgery, fetal i.v. and/or arterial line allows fetal blood sampling, pressure monitoring, administration of blood products, iv fluids and drugs
Fetal anaesthetic considerations

- Fetal organ systems are **immature**
- Fetal **cardiac output** is sensitive to HR changes
- Fetus has high vagal tone and thus response to stress with precipitous **bradycardia**
- Fetal circulatory blood volume is low, hence little intra-operative bleeding can cause **hypovolemia**, so trigger for transfusion is low
- During prolonged surgery, fetus need to be transfused **O-negative blood**
Fetal anaesthetic considerations

- Fetus tend to lose heat much easily from the exposed skin resulting in hypothermia.
- Hypothermia can be minimized by limiting fetal surgical time and use of warm irrigating fluids (37-38°C).
- Immature coagulation system predispose to bleeding and difficulty in hemostasis.
- Autonomic nervous and adrenergic system are immature.
- Placental transfer of anaesthetic agents is a desirable effect of maternal anaesthesia.
Fetal anaesthetic considerations

- Although inhaled anaesthetics rapidly crosses the placenta, fetal levels remain below maternal levels for a prolonged period of time.
- Maternal anaesthesia depresses fetal myocardium and circulation—hypotension, bradycardia, cardiac collapse.
- Maintenance of uteroplacental circulation is vital for successful outcome of the procedure.
- Since uteroplacental flow is influenced by vascular resistance, therefore uterus must remain relaxed.
Fetal anaesthetic considerations

- Kinking of umbilical cord avoided
- Normal **fetal arterial oxygen saturation** is 60-70% and aim is to maintain it above 40%
- Intra-operative **fetal distress** is manifested by **bradycardia**, decreased fetal oxygen saturation and **reduced cardiac output**
- Maternal hyperventilation is avoided as maternal hypocapnia causes **fetal placental vasoconstriction** and fetal hypoxia
Is fetus able to feel pain?
- Not possible to **assess** fetal pain directly
- **Assessed indirectly** by ability of fetus to mount a stress response to noxious stimulus-increased fetal cortisol, beta-endorphins and central sparing hemodynamic changes
- Fetal administration of narcotic inhibits cortisol and beta-endorphin release but does not inhibit central sparing hemodynamic changes
- Fetal stress to **pain starts in 8 weeks gestation age**
What Is Pain?

Pain is a subjective sensory and emotional experience that requires the presence of consciousness to permit recognition of a stimulus as unpleasant.

Is fetus able to feel pain?

Abstract

On the basis of fetal hormonal and hemodynamic responses to pain related stimuli, neuroanatomy and observations of preterm babies, it was concluded that human fetus is able to feel pain after 24 weeks gestation. However it is possible that the fetus may feel pain even before that time. With the development of intrauterine diagnostic and therapeutic procedures, it is crucial to provide fetuses undergoing painful procedures not only with anesthesia but also analgesia. The article presents fetal pain research history and its implications for medicine.
**Table. Anatomical and Functional Development of Nociception and Pain Perception Pathways**

<table>
<thead>
<tr>
<th>Anatomical/Functional Characteristic</th>
<th>Description</th>
<th>Gestational Age, wk</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peripheral cutaneous sensory receptors</td>
<td>Perioral cutaneous sensory receptors</td>
<td>7.5</td>
<td>Humphrey,¹³ 1964</td>
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<tr>
<td></td>
<td>Palmar cutaneous sensory receptors</td>
<td>10-10.5</td>
<td></td>
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<td></td>
<td>Abdominal cutaneous sensory receptors</td>
<td>15</td>
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<tr>
<td>Spinal cord</td>
<td>Spinal reflex arc in response to nonnoxious stimuli</td>
<td>8</td>
<td>Okado and Kojima,¹⁴ 1984</td>
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<tr>
<td></td>
<td>Neurons for nociception in dorsal root ganglion</td>
<td>19</td>
<td>Konstantinidou et al,¹⁵ 1995</td>
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<tr>
<td>Thalamic afferents</td>
<td>Thalamic afferents reach subplate zone</td>
<td>20-22</td>
<td>Kostovic and Rakic,¹⁶ 1990</td>
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<td></td>
<td></td>
<td></td>
<td>Hevner,¹⁷ 2000</td>
</tr>
<tr>
<td></td>
<td>Thalamic afferents reach cortical plate</td>
<td>23-24</td>
<td>Kostovic and Rakic,¹⁸ 1984</td>
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<td></td>
<td></td>
<td></td>
<td>Kostovic and Goldman-Rakic,¹⁹ 1983</td>
</tr>
<tr>
<td>Cortical function*</td>
<td>Somatosensory evoked potentials with distinct, constant components</td>
<td>29</td>
<td>Klimach and Cooke,²⁰ 1988</td>
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<td></td>
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<td>Hrbek et al,²¹ 1973</td>
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<tr>
<td></td>
<td>First electrocardiographic pattern denoting both wakefulness and active sleep</td>
<td>30</td>
<td>Clancy et al,²² 2003</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Torres and Anderson,²³ 1985</td>
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</tbody>
</table>

*Earliest evidence of functional thalamocortical connections required for conscious perception of pain.*
Fetal analgesia

- General anaesthesia (volatile agents) ± fetal i.m injection
- Remifentanil (continuous infusion 0.1μg/kg/min) mo.
- Opioid, Atropine, NMB i.m or into umbilical cord (Fentanyl 10-20μg/kg)
Remifentanil produces improved fetal immobilization with good maternal sedation and only minimal effects on maternal respiration (AnesthAnalg, 2005)

Continuous fentanyl infusion with midazolam provides acceptable maternal analgesia and sedation during fetoscopy (Masui, 2008)