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Ex-utero intrapartum therapy

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SUMMARY

The ex-utero intrapartum therapy (EXIT) procedure was designed to secure the airway at delivery in fetuses who had undergone tracheal occlusion for severe congenital diaphragmatic hernia. The EXIT was then adapted for deliveries where the airway may be difficult to secure, such as large neck masses or congenital high airway obstruction. Subsequently, use of EXIT has been extended to fetal anomalies where resuscitation may be compromised, including large thoracic masses, severe congenital diaphragmatic hernia, or pulmonary agenesis. The key to EXIT is preservation of uteroplacental blood flow and gas exchange, using inhalational agents to provide uterine relaxation, and maintenance of uterine volume by amnioinfusion and only partial exposure of the fetus. This provides time for procedures such as laryngoscopy, bronchoscopy, vascular access, resection of neck or lung masses, or cannulation for extracorporeal membrane circulation, in order to convert an emergent crisis to a controlled situation.

1. Introduction

The extensive use of prenatal ultrasound has resulted in the increased identification of a number of fetal malformations that have a direct impact on the perinatal management of the fetus and the subsequent outcome. The ex-utero intrapartum therapy (EXIT) procedure was initially described for the reversal of tracheal occlusion at the time of delivery in fetuses with severe congenital diaphragmatic hernia (CDH) that had undergone in-utero tracheal occlusion.[1] The EXIT procedure uses maintenance of uteroplacental blood flow, or placental bypass, to provide time to reverse the tracheal occlusion by removal of the clip, to establish an airway, and to administer surfactant and resuscitative drugs. The additional time provided by the EXIT procedure was subsequently adapted for the delivery of patients where neonatal airway compromise was suspected, including fetal neck masses and fetuses with congenital high airway obstruction (CHAOS).[2,3] The use of the EXIT procedure was then further expanded to include any fetal anomaly where neonatal resuscitation may be compromised, including large thoracic lesions, CDH, unilateral pulmonary agenesis, and cardiac lesions.[4–7] The EXIT procedure provides time to secure the airway, obtain vascular access, administer surfactant and other resuscitation medications, resect cervical or thoracic masses, and for extracorporeal membrane circulation (ECMO) cannulation.[2–7] The time provided by the EXIT procedure converts an emergent crisis into a controlled situation.

2. Prenatal evaluation

In order to identify fetuses that may potential benefit from the use of the EXIT procedure, early and accurate diagnosis is essential. The prenatal evaluation includes high resolution fetal ultrasonography, ultrafast fetal magnetic resonance imaging, fetal echocardiography, and karyotype analysis. In addition, the early involvement of a multidisciplinary team, including pediatric surgeons, high risk obstetricians, radiologists, anesthesiologists, neonatologists, cardiologists, operating room personnel, and social work, are equally important in planning the delivery procedure and facilitating parental understanding of the potential risks and benefits of the proposed procedure.

3. Elements of the EXIT procedure

The EXIT procedure is significantly different from previous reports of intrapartum laryngoscopy or bronchoscopy in which the fetus was delivered either by cesarean section or vaginal delivery and the cord was not clamped.[8,9] In these cases there was no attempt to prevent uterine contraction, and in most of these cases the fetus was removed from the uterus, resulting in uterine contraction, placental separation, and cessation of uteroplacental gas exchange.[10] In the EXIT procedure, high concentrations of inhalational anesthetics and additional tocolytics, if necessary, are used to provide uterine relaxation and preserve placental perfusion. In addition, only the head and upper torso are delivered and amniotic fluid volume is replaced by amnioinfusion; both maneuvers preserve uterine volume, preventing uterine contraction, and

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EXIT Indications

- Suspected airway compromise
  - large neck masses
  - CHAOS
- Resuscitation compromise
  - large thoracic lesions
  - CDH
  - unilateral pulmonary agenesis
  - cardiac lesion

preserve placental blood flow. During the EXIT procedure fetal well-being is continuously monitored by pulse oximetry and echocardiography. Fig. 1 shows an EXIT procedure for a fetus with a large cervical teratoma. Many of the elements of the EXIT are demonstrated. Note that only partial delivery of the fetus is performed to maintain uterine volume. The use of the fetal pulse oximeter is also seen. In this case the fetus is undergoing rigid bronchoscopy to define and establish an airway.

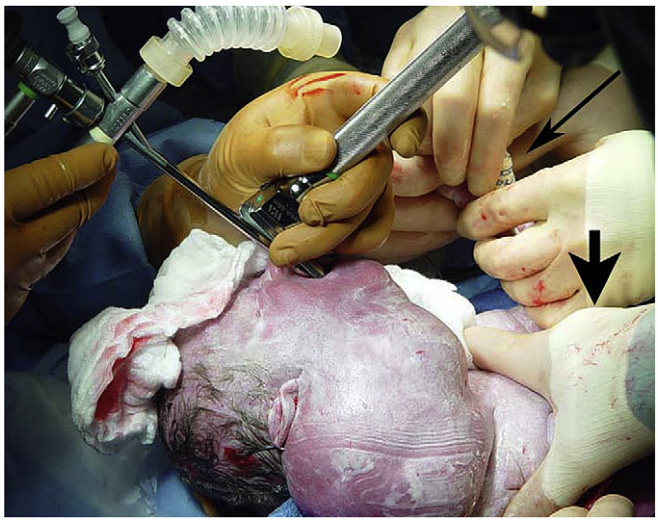

Fig. 1. Ex-utero intrapartum therapy delivery of a fetus with a large cervical teratoma. Rigid bronchoscopy is being performed to identify and secure the airway. The small arrow indicates the pulse oximeter being applied to the hand. The large arrow indicates the partial exposure of the fetus and maintenance of uterine volume.

Key Elements for the EXIT

- Uterine relaxation
  - inhalational agents
  - tocolytic agents
- Maintain uterine volume
  - amnioinfusion
  - partial delivery
- Fetal monitoring
  - pulseoximetry
  - echogardiography
- Maternal monitoring
  - ECG
  - arterial line
  - pulseoximetry
  - end tidal CO_2

The details of the mechanics of the EXIT procedure have been extensively described in the literature.[1–7] In brief, a multidisciplinary team is used and consists of two or three pediatric surgeons, an obstetrician, a neonatologist, an anesthesiologist, and two scrub nurses. The mother is positioned with left uterine displacement to maintain inferior vena cava blood flow, and pneumatic compression boots are applied. Maternal monitoring consists of invasive arterial blood pressure monitoring, continuous electrocardiography and pulse oximetry, and end-tidal CO_2 monitoring. Anesthesia is induced with a rapid sequence technique using thiopental, succinylcholine, and fentanyl given intravenously followed by tracheal intubation. Anesthesia is maintained with desflurane at 0.3–1.9% expired in a balance of oxygen, as measured by end-tidal mass spectrometry. The dose of inhalation agent is titrated to uterine relaxation to preserve uteroplacental circulation and fetal gas exchange.[11] A low transverse maternal laparotomy incision is used to expose the uterus and sterile intraoperative ultrasound is used to map the position of the placenta and to monitor the fetal heart during the procedure. If polyhydramnios is present, amnioreduction is performed to decompress the uterus and avoid underestimation of the proximity of the placental edge to the hysterotomy. Decompression of fetal ascites or large cystic masses may be performed at this time to facilitate manipulation of the fetus. While one assistant stabilizes fetal position, full-thickness uterine stay sutures are placed under ultrasound guidance. A transverse lower uterine segment hysterotomy is performed except when contraindicated because of placental location or concern about the ability to adequately position the fetus. The hysterotomy is then performed using a uterine stapling device to provide hemostasis.[12] The fetal head and upper torso are then delivered through the hysterotomy. To maintain uterine volume, the lower body is left in the uterus and amniotic fluid is maintained using a Level 1 fluid warming device and the infusion of Ringer's lactate. Although the fetus is anesthetized during the EXIT procedure from placental transfer of maternally administered anesthesia, this is supplemented by vecuronium, fentanyl, and atropine administered intramuscularly.

Fetal heart rate and hemoglobin saturation are continuously monitored by a pulse oximeter attached to the fetal hand[13] and by continuous echocardiography. If fetal distress occurs during the case, the position of the umbilical cord, uterine volume, and maternal bleeding are reassessed. In cases where prolonged operative times are expected or where there may be a need for fetal volume loading, as in the case of large thoracic masses, then fetal venous access is obtained with a peripheral intravenous line.

The procedure on the fetus is then initiated. The procedures that can be performed during EXIT range from direct laryngoscopy, rigid bronchoscopy, and even tracheostomy to secure the fetal airway, to resections of neck masses and thoracic masses, to the placement of ECMO cannulas. Following establishment of the airway and if indicated by gestation age, surfactant is administered using a 4 French feeding tube fed through the endotracheal tube or bronchoscope to deliver it to the distal tracheobronchial tree, and ventilation is initiated. Prior to clamping of the umbilical cord and delivery of the baby, communication between the surgical and anesthesia teams is essential to prevent uterine atony and excessive maternal hemorrhage. The inhalational agent is decreased and a Pitocin bolus followed by a continuous infusion is administered and titrated to uterine tone, and the umbilical cord is then clamped and divided and the newborn taken to a separate operating room for further resuscitation, including possible placement on ECMO.