

3-D printing and holograms to facilitate EXIT airway management planning

Ronald B. George MD FRCPC, Marla Ferschl MD, and Hanmin Lee, MD – Departments of Anesthesia and Perioperative Care & Surgery

Operating on Placental Support: The Ex Utero Intrapartum Treatment Procedure

By George B. Mychaliska, John F. Bealer, Joy L. Graf, Mark A. Rosen, N. Scott Adzick, and Michael R. Harrison
San Francisco, California

● While treating eight fetuses with predictable airway obstruction, the authors developed a systematic approach, the ex utero intrapartum treatment procedure, to secure the airway during delivery. Six patients had their trachea plugged or clipped in utero for treatment of congenital diaphragmatic hernia, and two patients had prenatally diagnosed cystic hygroma of the neck and oropharynx. The ex utero intrapartum treatment procedure was performed by using high doses of inhaled halogenated agents to facilitate uterine relaxation during cesarean section, securing the fetal airway while fetoplacental circulation remained intact, and then dividing the umbilical cord. A variety of procedures were performed during the ex utero intrapartum treatment procedure including bronchoscopy, orotracheal intubation, tracheostomy, tracheostomy with retrograde orotracheal intubation, tracheoplasty, removal of internal tracheal plug, removal of external tracheal clip, central line placement, and instillation of surfactant. There were minimal maternal or fetal complications during the procedure. This approach requires the coordinated efforts of pediatric surgeons, obstetricians, anesthesiologists, sonographers, and neonatologists. The combination of intensive maternal-fetal monitoring, cesarean section with maximal uterine relaxation, and maintenance of intact fetoplacental circulation provides a controlled environment for securing the airway in babies with prenatally diagnosed airway obstruction.

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INDEX WORDS: Airway obstruction, congenital diaphragmatic hernia, cystic hygroma, tracheal occlusion.

AIRWAY OBSTRUCTION at birth is associated with a high morbidity and mortality. We have had to address the clinical problem of airway obstruction because of our treatment of congenital diaphragmatic hernia (CDH) in utero with temporary tracheal occlusion—the PLUG (Plug the Lung Until it Grows) technique. We have used the PLUG to treat fetal diaphragmatic hernia because in utero tracheal occlusion has been shown to induce pulmonary hyperplasia.¹ However, the PLUG procedure required a technique to safely “unplug” the trachea at birth and establish a stable fetal airway. The EXIT (Ex Utero Intrapartum Treatment) procedure relies on maintaining fetoplacental circulation until the fetal airway is secure. As our experience with the EXIT procedure evolved, we established procedural guidelines for this technique and expanded its use to include other cases of prenatally diagnosed airway obstruction.

MATERIALS AND METHODS

The time in gestation when the EXIT procedure should be performed depends on a number of factors. If the fetus and mother are doing well, the procedure should be performed at term. If the fetal condition has

deteriorated, such as the development of hydrops in a fetus with laryngeal atresia, the EXIT procedure must be performed expeditiously. In patients who had undergone an in utero operation, the EXIT procedure was performed when preterm labor could not be controlled.

A multidisciplinary team, including an obstetrician, neonatologist, sonographer, anesthesiologist, and two pediatric surgeons participated in each procedure. In addition to the basic instruments and set-up for a cesarean section, the following items were indispensable for the EXIT procedure: laryngoscope handle with Miller 0 and 00 blades, endotracheal tubes and surfactant adapters ranging in size from 2.5 mm to 4.0 mm, two stylets, a tracheostomy set, a sterile pediatric stethoscope, a 2.5-mm bronchoscope with a 0° lens, and a neonatal pulse oximeter probe.

The mother was positioned with her left side down to avoid aorto-caval compression and hypotension. She underwent rapid sequence induction of anesthesia and tracheal intubation with thiopental (4 to 5 mg/kg) and succinylcholine (1.5 mg/kg). Paralysis was subsequently maintained with vecuronium, and titrated with peripheral nerve stimulation. Deep inhalation anesthesia was achieved with high-dose isoflurane (2% to 3%) in oxygen. Adequate uterine relaxation was achieved in the majority of patients with this anesthetic regimen. Occasionally, a bolus dose of terbutaline (0.25 mg subcutaneously or intravenously [IV]) or nitroglycerin (50 to 100 µg IV) was administered for additional uterine relaxation when the uterus was visibly or palpably contracting. Although the fetus was usually anesthetized during the EXIT procedure from placental transfer of maternally administered anesthesia, paralysis was occasionally required when a fetus was mobile, and was achieved with administration of vecuronium (0.1 mg/kg intramuscularly [IM]). After the airway was secured and the cord divided, the anesthetic regimen was changed to a “balanced anesthetic,” and pitocin was administered in a continuous infusion of crystalloid. The isoflurane was turned off or reduced to a very low level (0.5% to 1.0%) and N₂O (50%) along with intravenous opioids (Fentanyl, 3 to 6 µg/kg, IV, in divided doses), and benzodiazepines (Versed, 1 to 3 mg, IV, in divided doses) were administered. At the end of the procedure, the maternal paralysis was reversed with neostigmine. Maternal monitoring included standard hemodynamic and respiratory monitors.

The maternal laparotomy was performed via a low transverse incision to expose the uterus. Intraoperative sonography was then used to identify the placenta and visualize the fetus. For the open fetal surgery patients, the previously performed hysterotomy site was reopened with a specially designed stapling device loaded with absorbable staples to ensure hemostasis.² For fetuses with a neck mass,

From the Division of Pediatric Surgery, Department of Surgery, The Fetal Treatment Center, and the Departments of Anesthesia and Obstetrics, Gynecology and Reproductive Sciences, University of California, San Francisco, CA.

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Address reprint requests to Michael R. Harrison, MD, The Fetal Treatment Center, University of California, San Francisco, 513 Parnassus Ave, Room 1601-HSW, San Francisco, CA 94143-0570.

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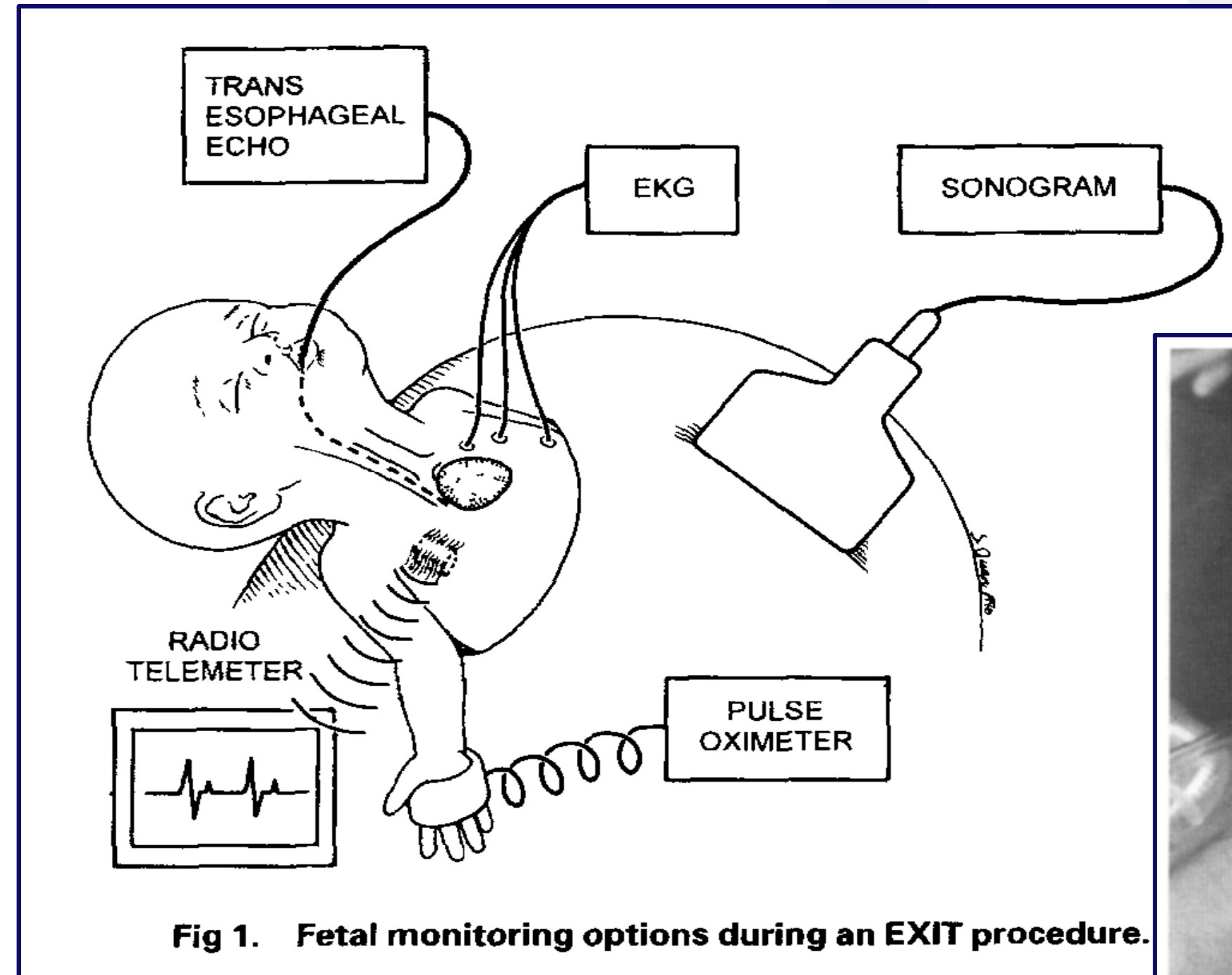


Fig 1. Fetal monitoring options during an EXIT procedure.

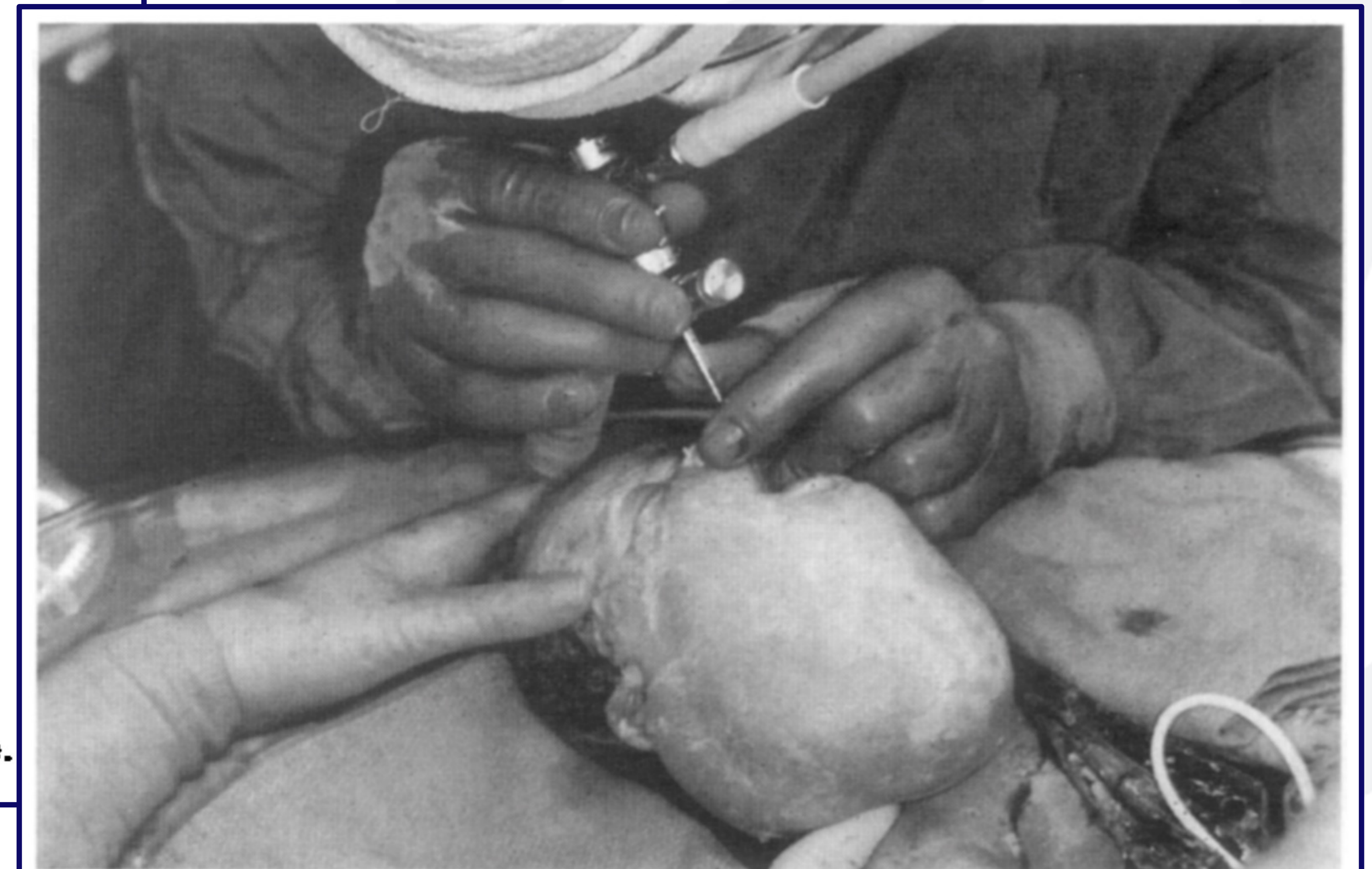


Fig 2. Bronchoscopy performed on a baby with a cystic hygroma during an EXIT procedure.

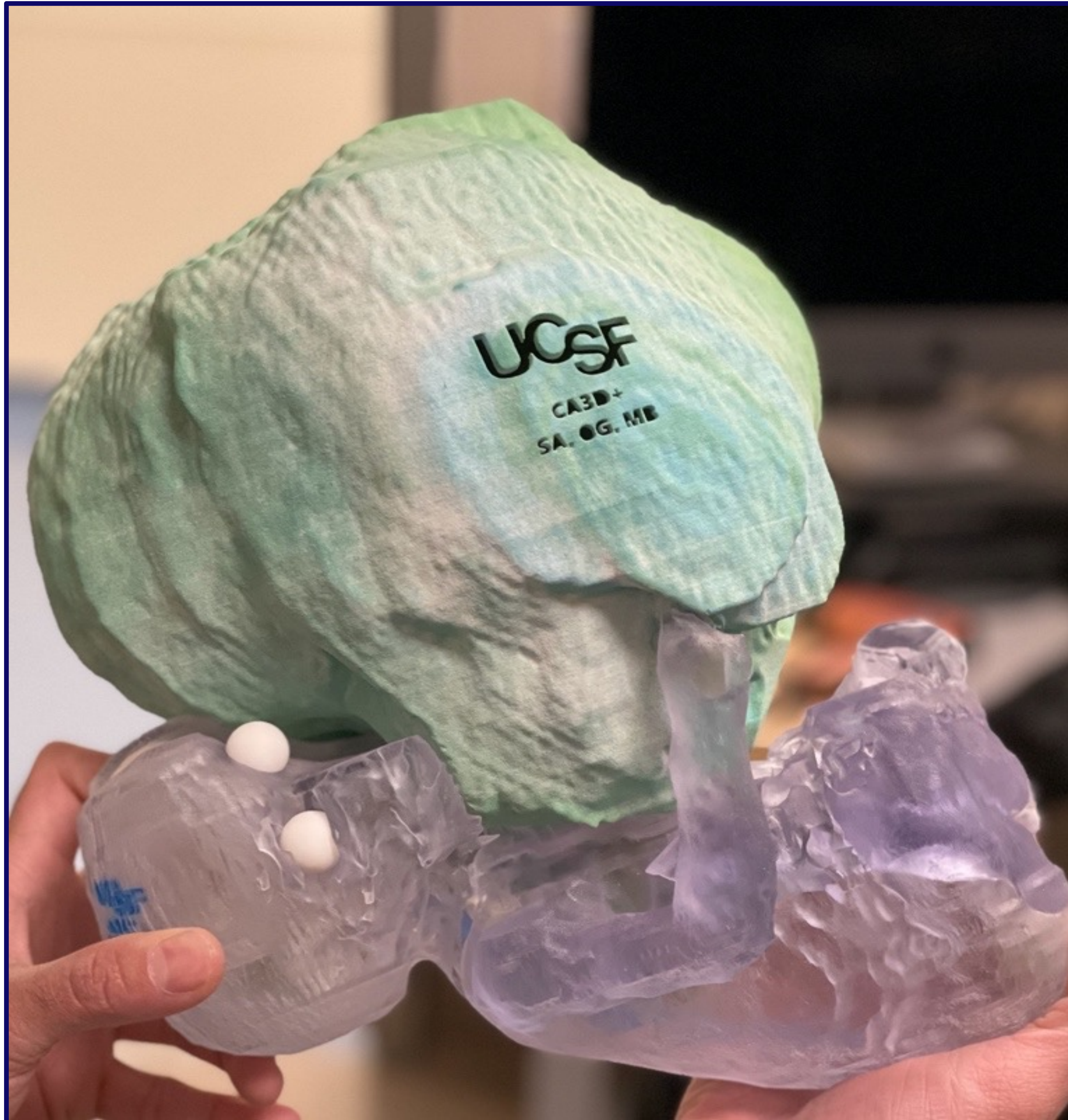
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- ◉ **33-year-old G3P1 – previous cesarean delivery**
- ◉ **Gestational diabetes, obesity, gestational hypertension**
- ◉ **Presented in the second trimester for investigation of polyhydramnios that revealed a large complex fetal neck mass**
- ◉ **Estimated volume = 4000 mL**
- ◉ **UCSF biomedical imaging and printing team constructed a 3-D model of the fetus using MRI images to facilitate surgical planning**

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- ⊙ Thoracic epidural + General anesthesia
- ⊙ High-MAC desflurane -> uterine quiescence
- ⊙ Placental mapping prior to hysterotomy
- ⊙ Cystic drainage prior to delivery
- ⊙ Fetal airway was secured by a pediatric otolaryngologist + rigid bronchoscopy